INSTRUCTION P2
MEASUREMENTS
AND
TEST PROCEDURES

This Instruction comprises the following four parts

Part 1 Test Procedures (blue)

Part 2 Operating Instructions (green)

Part 3 Test Waveforms (red)

Part 4 Measurement Techniques (no colour)

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AMENDMENT RECORD

Amendment number	Remarks	Amended by	Date
1			
2			
3			
4			
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INSTRUCTION P2

Part 1

TEST PROCEDURES

December 1976

MEASUREMENTS AND TEST PROCEDURES

INTRODUCTION

Instruction P2 contains descriptions of signal-measurement methods which are the preferred test procedures for both maintenance and normal operations.

The descriptions are arranged in groups, in Part 1, according to the following list.

(a) Audio Test Procedures (ATP) **INCOMPLETE**
(b) Digital Test Procedures (DTP) **CONTENTS PAGE ONLY**
(c) General Test Procedures (GTP) **NO CONTENTS OR INSTRUCTIONS**
(d) R.F. Test Procedures (RTP) **INCOMPLETE**
(e) Video Test Procedures (VTP) **INCOMPLETE**

Each Test Procedure is separate and largely self-contained with a title to show which of the listed groups it belongs to and the particular type of measurement it describes; it also carries an identifying number (e.g. ATP1).

Apart from a brief introduction (called **Background**) which describes the purpose of the test, each Test Procedure comprises two main parts.

(1) An explanation which defines the signal parameter to be measured possibly with reference to test-signal illustrations which accompany all relevant Test Procedures.

(2) A description of the preferred test method and (possibly) alternative methods together with:
  (i) a list of the test equipment needed;
  (ii) notes on expected accuracy and precautions to be observed.

In support of (2), above, a Test Procedure is often accompanied by one or more separate Operating Instructions, each explaining the use of an item of BBC coded test apparatus as required for the measurement processes described. These Operating Instructions are usually issued with the Test Procedure and are also assembled in code order as Part 2 of this Instruction.

Assembly of the Instruction will be cumulative, with additional or modified sections issued to take account of:

(a) changes in service requirement
(b) improved measurement techniques
(c) new or redesigned test apparatus.

All items forming the Test Procedures part of this Instruction are concerned with the basic broadcast-signal measurements to be used as standard BBC practice. More detailed information on certain aspects of signal measurement is contained in Part 4; where necessary, reference to these expanded treatments is made in the Test Procedures. The test-signal waveform illustrations relating to (and, where necessary, issued with) the test descriptions form Part 3.

Wherever possible, technical terms used in the Test Procedures are those defined in the relevant British Standard Glossary*. Also, definitions and measurement techniques are generally in accordance with Post Office, EBU and international practice. Standardisation is not complete, however, and care must be taken when testing circuits which do not terminate at both ends on BBC premises, or when making measurements on circuits carrying television signals conforming to systems other than those specified for BBC use.

*Most of the terms used appear in BS 4727 Part 3: Group 04.

LIST OF AUDIO TEST PROCEDURES

This Section of the Instruction will include tests of the audio signal parameters listed below. The identifying numbers of those published to date are shown in **bold type.**

ATP.1
Termination Measurements

Input Impedance — **ATP1.1**
Output Impedance — **ATP1.2**
Input Balance — **ATP1.3**
Output Balance — **ATP1.4**

ATP.2
Gain Measurements

Voltage Gain — **ATP2.1**
Insertion Gain — **ATP2.2**
E.M.F. Gain — **ATP2.3**

ATP.3
Frequency Response Measurements

Amplitude/Frequency Response — **ATP3.1**
Power/Frequency Response — **ATP3.2**
Phase/Frequency Response — **ATP3.3**

ATP.4
Distortion Measurements

Total Harmonic Distortion — ATP4.1
Harmonic Distortion Analysis — ATP4.2
Overload Point — ATP4.3

MISSING

ATP.5
Noise and Crosstalk Measurements

Signal to Noise Ratio (Provisional) — **ATP5.1**
(a) unweighted
(b) weighted
Equivalent Input Noise Level — ATP5.2
(a) unweighted
(b) weighted
Crosstalk — ATP5.3
(a) Linear
(b) Non-linear
(c) Intelligible (listening test)

ATP.6
Machine Measurements

ATP.7
Programme Level Indication

ATP.8
Automatic Gain Control

MISSING

Appendices

ATP.A Earthing Faults and their Correction
ATP.B BBC-designed Signal-isolating Transformers (Repeating Coils)
ATP.C Imperfections in Balanced Output Circuits
ATP.D Studio Line-up and Programme Levels
ATP.E dB Conversion Table
ATP.F Subjective Assessment of Sound and Picture Quality
ATP.G The Use of the dB in BBC Audio Practice

LIST OF DIGITAL TEST PROCEDURES

This section of the Instruction will include tests of the digital-signal parameters listed below. The identifying numbers of those published to date are shown in **bold type.**

MISSING

LIST OF R.F. TEST PROCEDURES

This section of the Instruction will include tests of the radio frequency signal parameters listed below. The identifying numbers of those published to date are shown in **bold type.**

RTP1
Level Measurements

Power Level - C.W./F.M. Signals	— RTP1.1
Power Level - A.M. Signals	— RTP1.2
R.F. Gain	— RTP1.3
Field Strength	— RTP1.4
Definitions	— RTP1.5

MISSING

RTP2
Frequency Measurements

Single Carriers	— RTP2.1
Multiple Carriers	— RTP2.2
Transposers	— RTP2.3

RTP3
Swept Frequency Measurements

Amplitude/Frequency Response	— RTP3.1
Delay/Frequency Response	— RTP3.2
Sideband Analysis	— RTP3.3

RTP4
Impedance Measurements

Return Loss	— RTP4.1
Time Domain Reflectometry	— RTP4.2
LF/MF Impedance Measurements	— RTP4.3
HF Impedance Measurements	— RTP4.4
VHF/UHF Impedance Measurements	— RTP4.5
SHF Impedance Measurements	— RTP4.6

MISSING

RTP5
Intermodulation and Spurious Products

Relative Amplitude Measurements	— **RTP5.1**
3-tone Testing (Television)	— **RTP5.2**
Vision-to-sound Cross-modulation	— RTP5.3
Incidental Phase Modulation	— RTP5.4
Cross-modulation in Stereo-multiplex Systems	— RTP5.5

MISSING

RTP6
Modulation

A.M. Audio	— RTP6.1
A.M. Video	— RTP6.2
F.M.	— RTP6.3
S.S.B.	— RTP6.4

RTP7
Noise

Noise Figure	— RTP7.1
Co-channel Interference	— RTP7.2
Oscillator Noise	— RTP7.3

RTP8
Miscellaneous

Phase Measurements	RTP8.1

MISSING

Appendices

RTP-A	Spectrum Analysers
RTP-B	Tracking Generators
RTP-C	Network Analysers
RTP-D	The Smith Chart
RTP-E	BBC Transmission Bands and Systems
RTP-F	Sideband Analysers
RTP-G	Balanced/Unbalanced Systems
RTP-H	Limiters and Compressors
RTP-I	Measurements in the Presence of Pre- and De-emphasis

MISSING

MISSING

LIST OF VIDEO TEST PROCEDURES

This section of the Instruction will include tests of the video-signal parameters listed below. The identifying numbers of those published to date are shown in **bold type.**

VTP 1
Waveform Amplitude Measurements

Picture Amplitude } Picture/Sync ratio	**VTP1.1**
Sync Amplitude } Picture/Sync ratio	**VTP1.1**
Video Amplitude	**VTP1.1**
Burst Amplitude	**VTP1.1**
Chrominance Amplitude	**VTP1.1**
Gain	– **VTP1.2**

VTP 2
Linear (frequency-dependent) Waveform Distortion Measurements

Luminance k-Rating	– **VTP2.1**
Chrominance-Luminance Gain and Delay Inequalities	– **VTP2.2**
Intermediate Line/Field-Time Distortion (tilt over 4 lines test)	– VTP2.3
Long-time Waveform Distortion (Bump Test)*	– VTP2.4

MISSING

VTP 3
Non-linear (amplitude dependent) Waveform Distortion Measurement

Sync-signal Distortion	– **VTP3.1**
Luminance Non-linearity (Line-time Non-linearity)*	– **VTP3.2**
Differential Gain and Phase	– **VTP3.3**
Chrominance-Luminance Intermod. (Chrominance-Luminance Crosstalk or Chrominance Axis Shift)*	– **VTP3.4**

VTP 4
Signal-to-Noise Measurements

Continuous Random Noise (weighted and unweighted; chrominance and luminance)	– **VTP4.1**
Periodic Noise ('Hum' and 'Patterning')*	– VTP4.2
Inverter Noise	– VTP4.3
Impulsive Noise and Video Crosstalk	– VTP4.4
Moiré	– VTP4.5

VTP 5
Relative Phase and Timing Measurements

Waveform Timings (pulse durations)	– VTP5.1
Colour Subcarrier Phase	– VTP5.2
Pulse Rise Time	– VTP5.3
Jitter	– VTP5.4

VTP 6
Miscellaneous Video Measurements

Amplitude/Frequency and Gain/Frequency Responses	– VTP6.1
Group Delay/Frequency Response	– VTP6.2
Return Loss (Impedance Measurements)	– VTP6.3
Colour Bar Measurements	– VTP6.4
P.C.M. Bit-stream Measurements	– VTP6.5

MISSING

*These alternative descriptions are sometimes used but are not preferred terms.

Appendices

VTP.A	Amplitude Relationships in a Video Signal
VTP.B	The Mean Level, Average Picture Level and D.C. Component of a Television Signal
VTP.C	Practical Examples of the Effect of Impedance Mismatch on Gain Measurement
VTP.D	The Use of Peak Signal and R.M.S. Noise Values in the Expression of Signal-to-Random Noise Ratios
VTP.E	Weighted Random Noise Measurement - Upper Bandwidth Limit for Coded Signals
VTP.F	Subjective Assessment of Sound and Picture Quality

LIST OF AUDIO TEST PROCEDURES

This Section of the Instruction will include tests of the audio signal parameters listed below. The identifying numbers of those published to date are shown in **bold type.**

ATP.1
Termination Measurements

Input Impedance — **ATP1.1**
Output Impedance — **ATP1.2**
Input Balance — **ATP1.3**
Output Balance — **ATP1.4**

ATP.2
Gain Measurements

Voltage Gain — **ATP2.1**
Insertion Gain — **ATP2.2**
E.M.F. Gain — **ATP2.3**

ATP.3
Frequency Response Measurements

Amplitude/Frequency Response — **ATP3.1**
Power/Frequency Response — **ATP3.2**
Phase/Frequency Response — **ATP3.3**

ATP.4
Distortion Measurements

Total Harmonic Distortion — ATP4.1
Harmonic Distortion Analysis — ATP4.2
Overload Point — ATP4.3

MISSING

ATP.5
Noise and Crosstalk Measurements

Signal to Noise Ratio (Provisional) — **ATP5.1**
(a) unweighted
(b) weighted
Equivalent Input Noise Level — ATP5.2
(a) unweighted
(b) weighted
Crosstalk — ATP5.3
(a) Linear
(b) Non-linear
(c) Intelligible (listening test)

ATP.6
Machine Measurements

ATP.7
Programme Level Indication

ATP.8
Automatic Gain Control

MISSING

Appendices
ATP.A Earthing Faults and their Correction
ATP.B BBC-designed Signal-isolating Transformers (Repeating Coils)
ATP.C Imperfections in Balanced Output Circuits
ATP.D Studio Line-up and Programme Levels
ATP.E dB Conversion Table
ATP.F Subjective Assessment of Sound and Picture Quality
ATP.G The Use of the dB in BBC Audio Practice

AUDIO TEST PROCEDURES

TERMINATION MEASUREMENTS

ATP1.1 INPUT IMPEDANCE
ATP1.2 OUTPUT IMPEDANCE
ATP1.3 INPUT BALANCE
ATP1.4 OUTPUT BALANCE

BACKGROUND

A broadcast-signal chain can be thought of as comprising a number of separate circuits or units, interconnected via input and output terminals. Each circuit contributes to the total transmission/distribution process by modifying the signal in some way. Apart from this, a circuit usually causes an incidental modification of the signal because its terminal impedances interact with those of adjoining circuits. Provided that all interconnections are permanently made, the effects of such interactions can be allowed for during installation. But if, as is often necessary in practice, units are required to be interchangeable, these interactions must be considered when making an overall assessment of the performance of the unit. Hence, measurements are made to ensure that circuit parameters (at the input and output terminals) are maintained as specified to give correct operation in both the unit itself and in adjacent units or circuits.

Terminations are generally specified in terms of two characteristics:

(i) impedance

(ii) electrical balance, i.e. the arrangement of the terminal impedance between the signal-connection points with respect to the circuit earth.

The specification of impedance (at a given frequency) gives the modulus in ohms and the value of the phase angle in degrees. The signal level at which terminal impedances are measured should be specified in order to prevent false results being obtained because of noise or non-linearity caused by overload.

The degree of balance in a termination is less easy to measure and quantify. (Unbalanced circuits, i.e. where one of each pair of signal-connection terminals is earthed, obviously do not require such measurement.) For a balanced termination, the properties to be considered are:

(a) its ability to accept and transfer only balanced signals; i.e. those for which the voltage excursions on each of a pair of terminals are **equal and of opposing polarity** relative to a fixed point, usually earth, such that the voltages alternate **symmetrically** about this mid-point of reference. Unbalanced signals have voltage excursions which are not of equal amplitude about the reference, i.e. they are asymmetrical and may even be of only one polarity with respect to the reference. All signals of this type can be considered to comprise two parts: a balanced component as described above, and a **COMMON MODE** component (sometimes known as a LONGITUDINAL signal) for which the voltage excursions are **equal and of the same polarity** relative to the fixed point. Common mode components are rejected by balanced terminations.

(b) Its ability to suppress the effects of interfering electrostatic or magnetic fields. The requirement is that such fields should be able to induce only common-mode signals. If there is appreciable unbalance, spurious symmetrical components may be induced and these would be inseparable from the wanted signal.

The input balance of a unit is quantified by a figure which compares the amplification given to unwanted signals with that given to wanted signals; this is termed the COMMON MODE REJECTION RATIO. Output balance can be the subject of quite complex tests (see Appendix ATP-C), but in BBC practice, a simple symmetrical/asymmetrical signal ratio measurement similar to that made for the common-mode rejection ratio, is considered adequate.

Balanced-input transformers are usually *floating*, i.e. are free of any wired connection to earth. (An exception to this is where the line-side winding centre-tap is used in a phantom d.c. circuit). The absence of an earth connection to the input transformer centre tap is important because, otherwise, the protection given by the transformer screen (against electrostatically-induced common-mode currents) may be nullified. The electrical mid-point in some units, however, is held at earth potential in order to meet a d.c. supply requirement in an active circuit. In this latter instance, overload conditions could obtain if the incoming signal carries a common-mode component of more than a specified limit amplitude.

ASSOCIATED INFORMATION

(normally issued with this Test Procedure)

1. **Operating Instructions (P2, Part 2)** for: EP14/1 A.C. TEST SET
(Technical Instructions are available which deal with the ATM/1 Test Meter and the TS/10 Tone Source).

DEFINITIONS

TERMINAL IMPEDANCE

– is measured between the signal input terminals or the signal output terminals of the unit or circuit under test.

– is a combination of resistance and reactance[1] for which the modulus, indicated by the symbol $|Z|$, is measured and quoted. The reactive component may be negligibly small.

> [1] *The magnitude of the reactive component may be estimated by measuring the modulus at more than one frequency.*

UNBALANCED TERMINATION

– qualifies a type of termination which has two terminals; one being connected via the terminal impedance to the other which is itself connected directly to a circuit earth point.

– has a varying signal voltage on only one terminal, the other being held at earth potential.

BALANCED TERMINATION

– qualifies a type of termination which has two terminals, each being connected via half the terminal impedance to an electrical mid-point or reference.

– is intended to carry signals with voltage excursions on the two terminals which are equal and in antiphase (i.e. they are instantaneously symmetrical)about the mid-point. This reference point may be a circuit centre tap connected to a fixed potential, e.g. earth.

FLOATING TERMINATION (also called EARTH FREE)

– is a balanced termination for which the electrical mid-point is not connected to a fixed potential.

COMMON-MODE INPUT SIGNAL (also called LONGITUDINAL signal)

– is one for which the voltage excursions on each terminal (of a balanced pair) are equal and in the same phase relative to the electrical mid-point.

COMMON-MODE REJECTION RATIO (applicable only to balanced circuits)

– is defined as:

$$\frac{A_n}{A_{cm}}$$

where:

A_n is the normal voltage gain, i.e. the ratio of amplitudes comparing a **symmetrical** signal at the input of a circuit to the corresponding **symmetrical** signal it gives rise to at the output.

A_{cm} can be considered as the common-mode gain, and is the ratio of the amplitude of a **symmetrical** signal at the output to the amplitude of the **common-mode** input signal which caused it.

When A_n and A_{cm} are both measured in dB, the COMMON-MODE REJECTION RATIO (in dB) is given by the difference between the two values.

INPUT BALANCE

– (for both floating and centre-tapped circuits) is, in BBC practice, measured as the COMMON-MODE REJECTION RATIO.

DEFINITIONS (continued)

OUTPUT BALANCE – (for both floating and centre-tapped circuits) is, in BBC practice, measured[2] as the ratio:

$$\frac{V_s}{V_{cm}}$$

where:

V_s is the symmetrical signal voltage at the output terminals across a specified load;

V_{cm} is the common-mode signal voltage measured across an inserted resistance of known value[3] connected between the electrical mid-point of the specified load and the reference point of fixed potential (usually earth).

[2]*As outlined in Appendix ATP-C, the full specification of output balance requires more rigorous measurement than is normal in BBC practice. The test described in ATP1.4 gives a value which is considered sufficiently representative for comparison purposes.*

[3]*This resistance is a practical necessity; in BBC tests, a value of 600 ohms (± 2 per cent) is used.*

NORMAL INPUT/ OUTPUT LEVEL – in this ATP (as in others) the term normal here describes the signal amplitude which exists when the unit or circuit is operated in its usual working condition, i.e. within the limits for which the unit or circuit was designed. A typical test level is 10 dB below the designed maximum.

NOTES ON THE USE OF TEST EQUIPMENT

1. In all the tests specified below, the main test equipment required is:

A.F. signal generator,	e.g. EP14/1 A.C. TEST SET	(or TS/10 TONE SOURCE)
dB meter,	e.g. EP14/1 A.C. TEST SET	(or ATM/1 A.C. TEST METER)
or electronic voltmeter		

2. Signal-isolating transformers (rep coils) are called for in several tests. Brief details of the BBC types available are given in Appendix ATP-B. The R-size transformers (LL/63R and LL216R) have the screen and core connected internally and, for this reason, are not suitable for some tests.

   The replacement types, LL/245/H12 and LL/238/H12, are provided with the same connection but the linking wire is easily accessible and it can be disconnected it required.

3. Generally, test equipment must:
   (a) be capable of operation in balanced circuits (particularly, note that many commercial electronic voltmeters are earth-free but are NOT adequately balanced).
   (b) Be connected by leads having resistance and capacitance giving an impedance which is negligible in relation to other impedance values in the test circuit.

   Note that a standard two-metre P.O. cord has a capacitance between the two conductors of the order of 300 pF. This presents an effective shunt reactance of about 25 kΩ at a frequency of 20 kHz.

4. The dB meters used in BBC practice normally indicate the value (average, r.m.s. or quasi-peak) of the voltage with respect to a sinewave signal of 0.775 volt r.m.s. Hence, dB values for lower levels carry a negative sign which **must be taken into account when making calculations.**

ATP1.1 MEASUREMENT METHODS – INPUT IMPEDANCE, Z_i

A.1 Measurement of Z_i using a fixed resistor of known value in series with the input terminals

Subject to the limitations given below, the result obtained using this method is the value of $|Z_i|$ at the frequency of the applied test signal, irrespective of the proportion of reactance in the measured impedance. This method is not suitable for measuring very large values of Z_i because of errors caused by the loading effect of the meter impedance. As a rough guide, the method can be used for values of Z_i:

(a) up to 200 kΩ provided that the test equipment has an input impedance ≥1 MΩ (such as is generally found in commerical test equipment);

(b) up to 10 kΩ when using BBC test equipment (which generally has an input impedance of the order of 50 kΩ).

Equipment Required

screened signal-isolating transformer (rep coil): NOT types LL63R and LL216R; see Appendix ATP-B

non-inductive resistors: one (R_L) equal to the specified load
one of some known value[4] about $Z_{i/10}$; maximum 5 kΩ.

see **NOTES ON THE USE OF TEST EQUIPMENT**

[4] The test circuit of Fig. 1 shows the signal-isolating transformer with a SEPARATE screen connected to the junction between the series resistor R and the transformer secondary. This connection is necessary to minimise the effect of the screen-to-secondary capacitance which would otherwise act as if it were in parallel with R and thus cause error in the measurement (especially at high audio frequencies).
Other transformer screen capacitances must similarly be taken into account. Errors in the test result are minimised by observing the following restrictions:

(i) the tone source output circuit must be both balanced and earth-free (so that the screen-to-primary-to-earth capacitance has virtually no effect);

(ii) the value of R should not exceed 5 kΩ (so that the screen-to-core capacitive reactance is negligible in comparison).

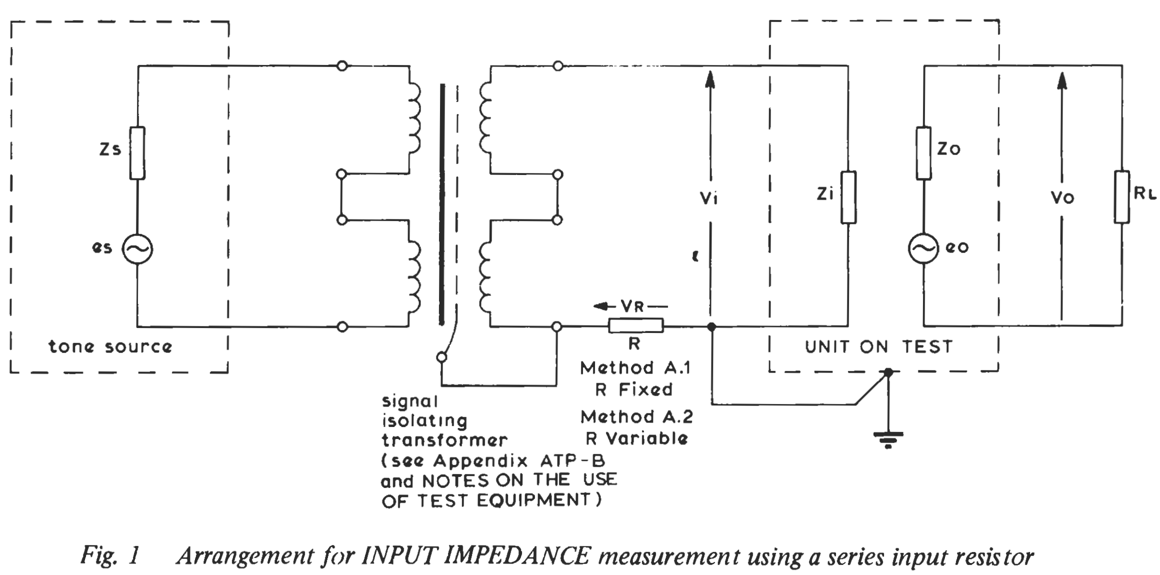


Fig. 1 Arrangement for INPUT IMPEDANCE measurement using a series input resistor

Test Procedure

1. Arrange the circuit as shown in Fig. 1 with **R** of known value (about $Z_i/10$) and R_L equal to the normal load impedance.

2. Apply tone at 1 kHz (or other specified frequencies; see **DEFINITIONS**, note 1) with an input level set to give a normal output measured as V_o.

3. Measure V_i and V_R as shown in Fig. 1. The modulus of the input impedance, $|Z_i|$, is then given by :

$$|Z_i| = \frac{V_i}{V_R} \times R \text{ ohms}$$

A.2 Measurement of $|Z_i|$ using a variable resistance box in series with the input terminals

This alternative method, employing a series resistance, can be used provided that:
(i) the unit/circuit under test has a linear input/output relationship[5], **AND**
(ii) the source of e.m.f. has an impedance which is small compared with the expected value of $|Z_i|$.
The result obtained is exactly equal to $|Z_i|$ ONLY if the circuit/unit under test has a purely resistive input. However, the method may be used where the reactive part of $|Z_i|$ is negligibly small $\not> Z_i/50$ or where a representative value is required for the purposes of comparison.

[5]*The requirement is that a given change of level at the input produces an equal change at the output. Equipment such as compandors and expandors cannot, therefore, be tested using this method.*

Equipment Required
screened signal-isolating transformer (rep coil); see Appendix ATP-B
non-inductive resistor (R_1) equal to the specified load
calibrated resistance box
see **NOTES ON THE USE OF TEST EQUIPMENT**

Test Procedure

1. Arrange the circuit as shown in Fig. 1, with the resistance box, set to zero resistance, in the position of R.

2. Apply tone at 1 kHz (or other specified frequencies; see **DEFINITIONS**, note 1) with an input level set to give a normal output measured as V_o.

3. Increase the value of the resistance box, R, until V_o has fallen by 6 dB, i.e. is reduced to $V_o/2$. The modulus of the input impedance, $|Z_i|$, is then given (approximately) by the value indicated on the resistance box.

ATP1.1 **MEASUREMENT METHODS (continued)**

B. Measurement of Z_i by substitution (normal BBC practice)

Using this method, an accurate value for $|Z_i|$ is obtained ONLY if the reactive component of $|Z_i|$ is negligible. However, if the reactance is sufficiently small ($\not>$ $Z_i/50$), the method may be used to give an approximation for $|Z_i|$; otherwise, it can provide a representative value for the purpose of comparison.

Equipment Required

screened signal-isolating transformer (rep coil); see Appendix ATP-B
calibrated resistance box
non-inductive resistors: one (R_L) equal to the specified load
one (or two) of appropriate value[6] for R_s (or $R_s/2$).

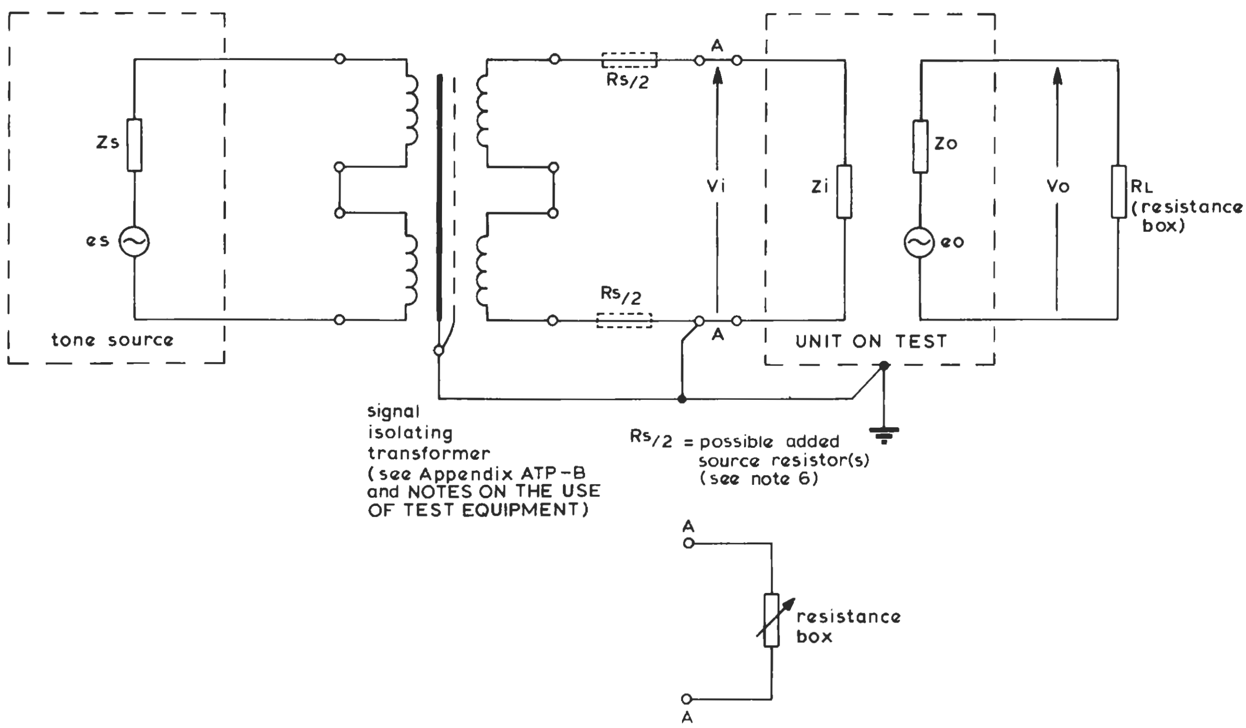


Fig. 2 Arrangement for INPUT IMPEDANCE measurement using the substitution method

[6] The input-circuit series resistor, R_s (or equal resistors, about $R_s/2$, one in each side of a balanced input) is added to give better measurement conditions for tests on high-impedance inputs ($Z_i > 20k\Omega$). A value of $10k\Omega$ is suitable for R_s.

Test Procedure

1. Arrange the circuit as shown in Fig. 2 with the unit/circuit under test connected at points A – **A**. Resistor(s) R_s or $R_s/2$ should be included if required.

2. Apply tone at 1 kHz (or other specified frequencies; see **DEFINITIONS**, note 1) to give a normal output measured as $\mathbf{V_o}$. Measure the input level, $\mathbf{V_i}$.

3. Disconnect the unit from A – A, and connect the resistance box in its place. Apply the same test signal as before and adjust the setting of the resistance box until $\mathbf{V_i}$ is the same as measured in step 2, above.
The modulus of input impedance, Z_i , is then given, approximately, by the value indicated on the resistance box.

ATP1.2 MEASUREMENT METHODS – OUTPUT IMPEDANCE, Z_o

A. Measurement of $|Z_o|$ by matched loading

Note that this method:
(i) is used to measure values of $|Z_o|$ known to be greater than 50 ohms.

(ii) will ONLY give an accurate value of the modulus of the output impedance ($|Z_o|$) if the reactive component is negligible. Where the proportion of reactance is reasonably small, however, the method can be used to obtain an approximate value for $|Z_o|$. Practical impedance values are generally such that the error is less than 10 per cent.

Equipment Required

calibrated resistance box (of adequate dissipation)
see **NOTES ON THE USE OF TEST EQUIPMENT**

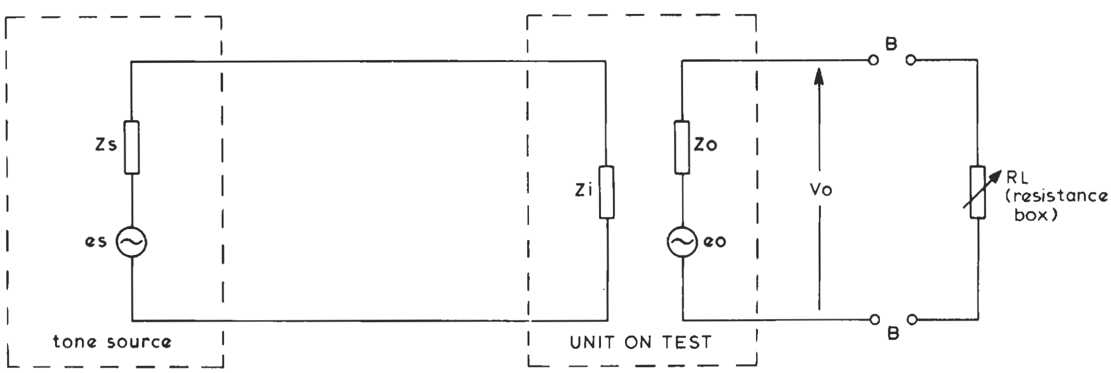


Fig. 3 Arrangement for OUTPUT IMPEDANCE measurement using the matched loading method

Test Procedure

1. Arrange the circuit as shown in Fig. 3 WITHOUT a load connected to points B – B.

2. Apply tone at 1 kHz (or other specified frequencies; see **DEFINITIONS**, note 1) to give a normal output (except if the specified load is equal to or greater than $5Z_o$, when the test should be performed at an output level which is at least 20 dB less than normal). Measure the output as V_o.

3. Connect R_L (resistance box, NOT set to zero ohms) to B–B, and adjust its value until V_o is half the value measured in step 2, i.e. is reduced by 6 dB. Check that the input to the circuit under test (as indicated by e_s in Fig. 3) remains unchanged for steps 2 and 3.
The modulus of the output impedance, $|Z_o|$, is then given approximately by the value indicated on the resistance box.

ATP1.2 **MEASUREMENT METHODS (continued)**

B. Measurement of low values of Z_0 by reverse injection

This method can also be employed to measure the output impedance of a power supplier. The presence of hum, however, may require the use of a selective voltmeter.

Equipment Required

non-inductive resistors: one (R_S) equal to the normal source resistance
one of some known value of about 100 Z_0
two capacitors (possibly; see notes 7 and 8 below)
see **NOTES ON THE USE OF TEST EQUIPMENT**

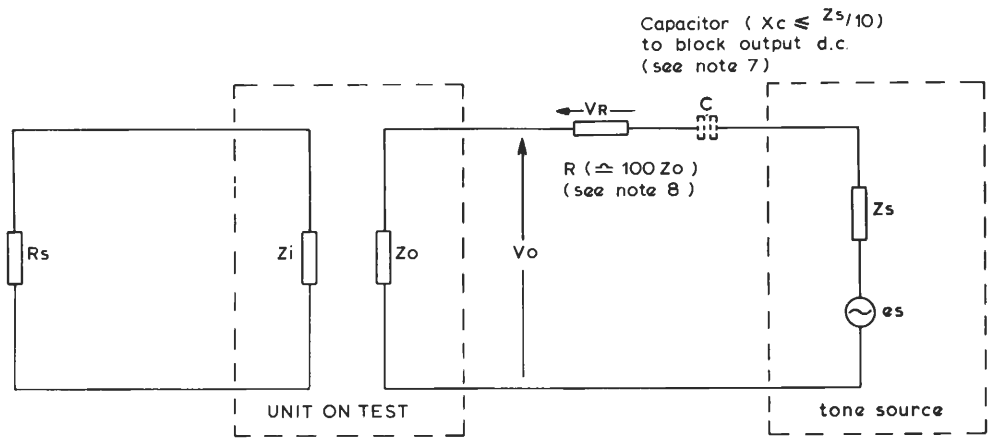


Fig. 4 Arrangement for LOW OUTPUT IMPEDANCE measurement using the method of reverse injection

[7] *If there is d.c. in the output from the unit under test, then the injection circuit must include a series capacitor as shown in Fig. 4.*

[8] *If the unit output contains an appreciable d.c. component, the voltmeter used to measure V_0 must be protected by a series capacitor.*

Test Procedure

1. Arrange the circuit as shown in Fig. 4, with the unit under test powered. Apply tone at 1 kHz (or other specified frequencies; see **DEFINITIONS**; note 1) at a level to give a value of V_0 which is less than the normal unit (a.c.) output by at least 20 dB.

2. Measure V_0 and V_R; see Fig. 4.

3. Calculate:

$$Z_0 = R \times \frac{V_0}{V_R} \text{ ohms}$$

ATP1.3 MEASUREMENT METHOD – INPUT BALANCE (COMMON MODE REJECTION RATIO)

Equipment Required

screened signal-isolating transformer with accurately centre-tapped secondary winding
see Appendix ATP-B
OR
centre-tapped resistor of 600 Ω, half-value matching to be within 0.01 per cent
non-inductive resistor of 600 Ω
non-inductive resistor (R_L) equal to the specified load
see **NOTES ON THE USE OF TEST EQUIPMENT**

The requirement here is to measure Common-mode Rejection Ratios of up to 70 dB. Such measurement can be made either using a signal-isolating transformer in a test-bench circuit or, as an alternative, the tapped resistor arrangement illustrated in Figs. 5(b) and 6(b). However, if resistors are used, the half-value matching tolerance (of ±0.01 per cent) and the necessary screening cannot easily be met using temporary connections. A properly-engineered test unit is virtually essential. The TE1/31 AUDIO TERMINATION TESTER provides the facilities for this and other tests.

Test Procedure

1. Arrange the test circuit as shown in Fig. 5(a) or Fig. 5(b). R_L is the specified load.

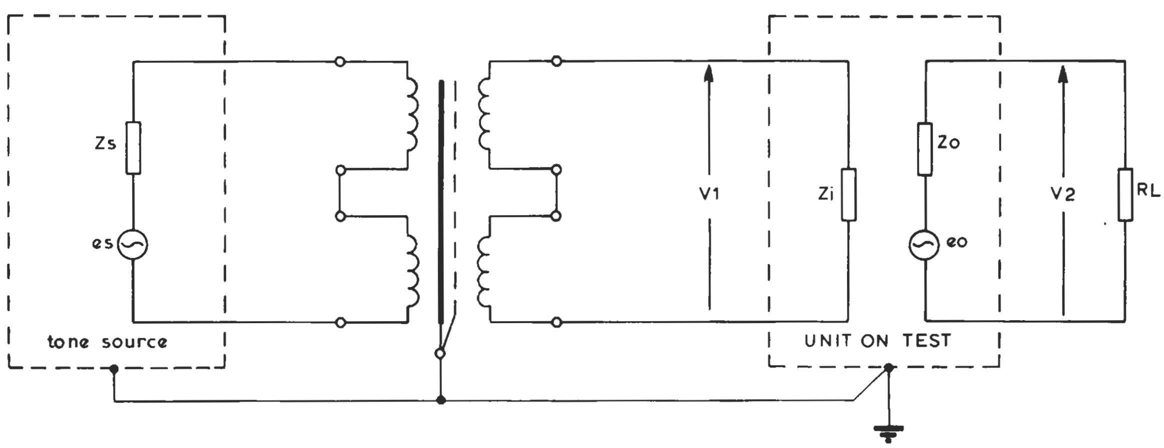


Fig. 5 Arrangement for INPUT BALANCE test; initial measurement
(a) using a signal-isolating transformer

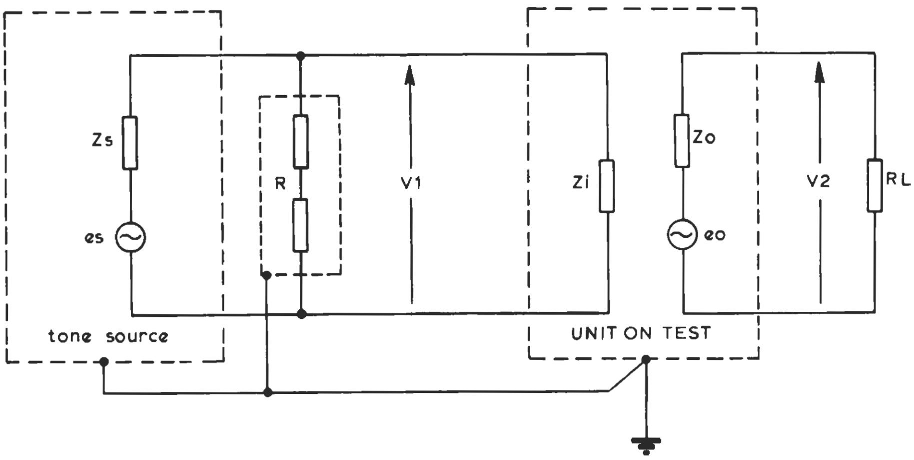


Fig. 5 Arrangement for INPUT BALANCE test; initial measurement
(b) using a centre tapped resistor, R_1.

2. Apply tone at 1 kHz (or other specified frequencies; see **DEFINITIONS**, note 1) at a level, V_1 to give a normal output, V_2. Note the values of these levels.

3. Re-arrange the circuit as shown in Fig. 6(a) or Fig. 6(b), setting the level of injected tone, V_3, so that either:
   (a) (for units with a gain about the same as the expected common-mode rejection ratio) the output level, V_4, equals V_2, OR
   (b) (for low-gain units) V_4 has a lower value which, in practice, is usually determined by the maximum available for the injected level, V_3.

   Note the values of V_3 and V_4. The input balance is then given by:

$$\text{Common-mode Rejection Ratio} = 20 \log \left(\frac{V_2 \times V_3}{V_1 \times V_4} \right) \text{dB}$$

Alternatively, if V_1, V_2, etc are measured directly in dB:

$$\text{Common-mode Rejection Ratio} = (V_2 - V_1) - (V_4 - V_3) \text{ dB}$$
$$= (V_3 - V_1)\text{dB when } V_4 \text{ is made equal to } V_2$$

See item 4 in **NOTES ON THE USE OF TEST EQUIPMENT**

ATP1.3 **MEASUREMENT METHODS (continued)**

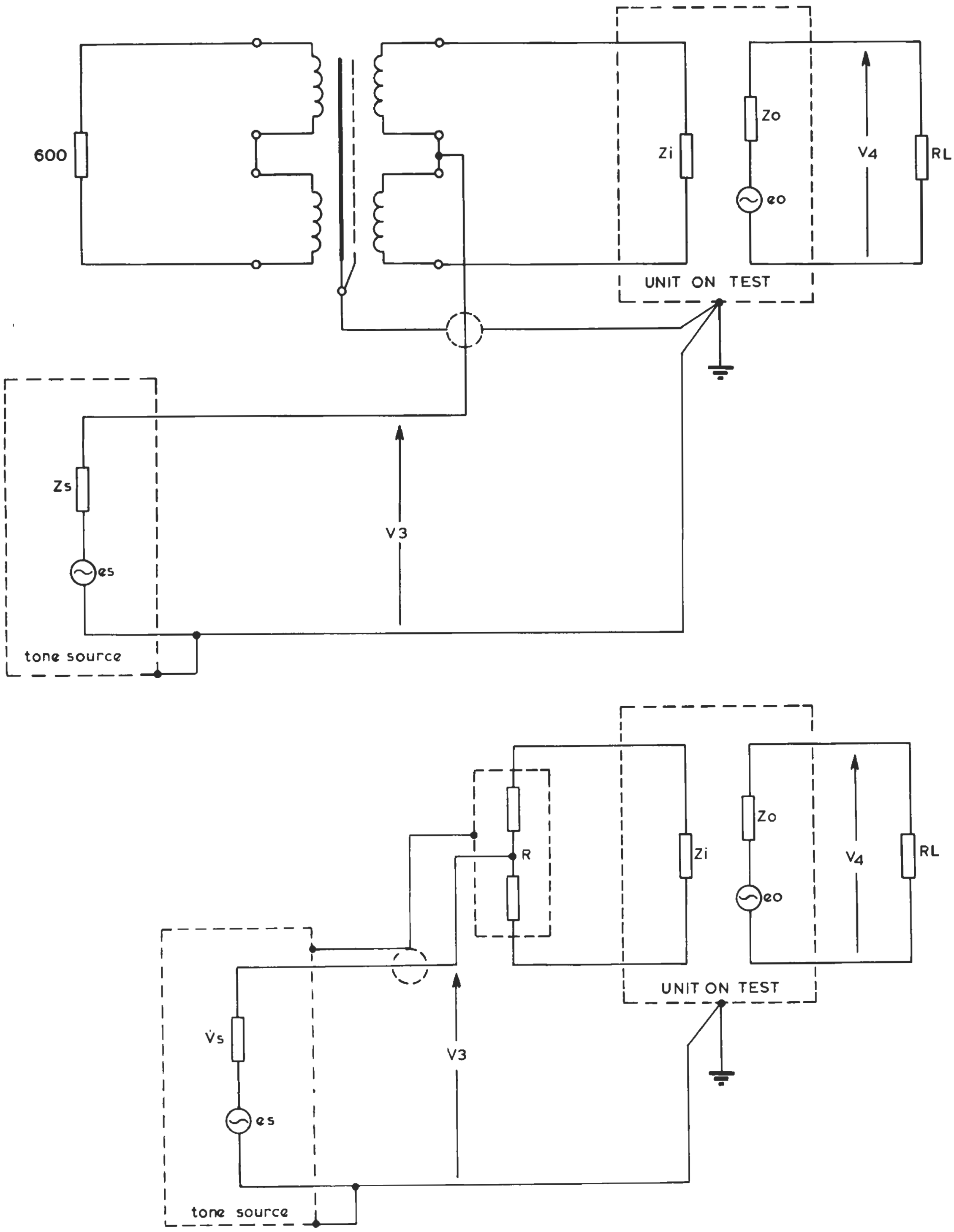


Fig. 6 Arrangement for INPUT BALANCE test; final measurement
(a) using a signal-isolating transformer
(b) using a centre-tapped resistor, R_1.

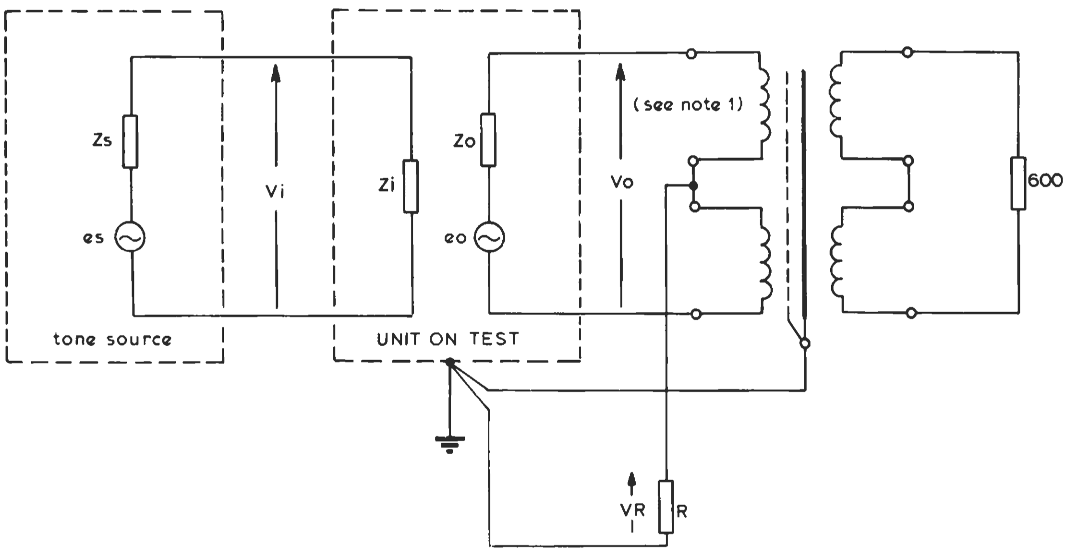
[9] *The transformer screen should be connected to the chassis of the unit under test. This is necessary to prevent any signal potential difference between the transformer and the unit acting as a spurious asymmetrical input via the screen.*

ATP1.4 MEASUREMENT METHOD – OUTPUT BALANCE

Equipment Required

additional equipment as for ATP1.3 except that an extra 600 Ω resistor[10] is required when an isolating transformer is being used

[10]*A termination of 600 Ω (non-inductive) is suggested for the test circuit because the signal isolating transformers recommended in Appendix ATP-B are designed to work into this load, and will do so satisfactorily when fed from any of the values of output impedance likely to be met in practice.*



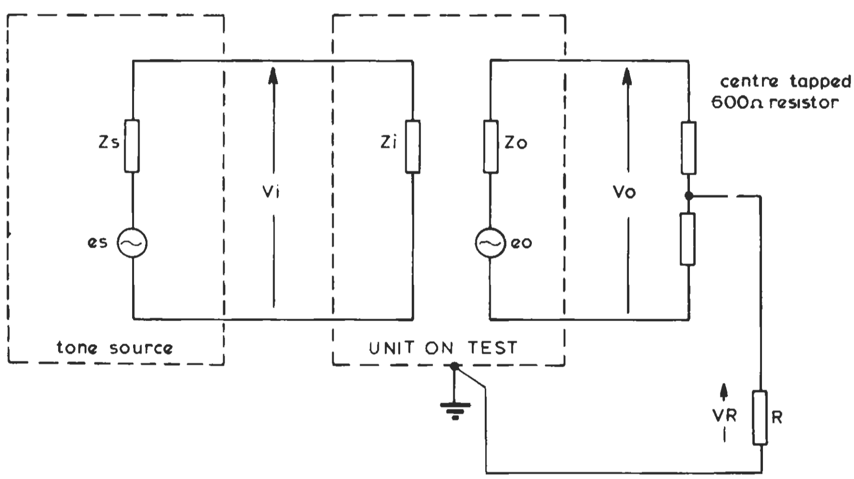


Fig. 7 Arrangement for OUTPUT BALANCE test;
(a) using a signal-isolating transformer
(b) using a centre-tapped resistor

Test Procedure

1. Arrange the circuit as in Fig. 7(a) or Fig. 7(b).

ATP1.4 **MEASUREMENT METHODS (continued)**

2. **Apply** tone at 1 kHz (or other specified frequencies; see **DEFINITIONS**, note 1) at a level, V_i, to give a suitable output, V_o[11]. Note the values of these levels.

[11] *V_o should be set at 0.775 volt (zero level) because:*
(i) most units in the broadcast chain can produce such an output (even those designed for a load other than 600 Ω);
(ii) BBC test equipments such as the EP14/1 can measure levels as low as 0.0775 mV (−80dB) and thus will cover the full range of common-mode rejection figures found in practice.

3. With the same input level (V_i), measure V_R, which is produced by the unbalanced current in the output from the unit under test. Substitute the measured values to give:

$$\text{Output balance} = 20 \log \frac{V_o}{V_R} \text{ dB}$$

or if measured directly in dB:

$$\text{Output balance} = \left(V_o - V_R\right) \text{ dB}$$

AUDIO TEST PROCEDURES

ATP2.1 VOLTAGE
ATP2.2 INSERTION } **GAIN**
ATP2.3 E.M.F.

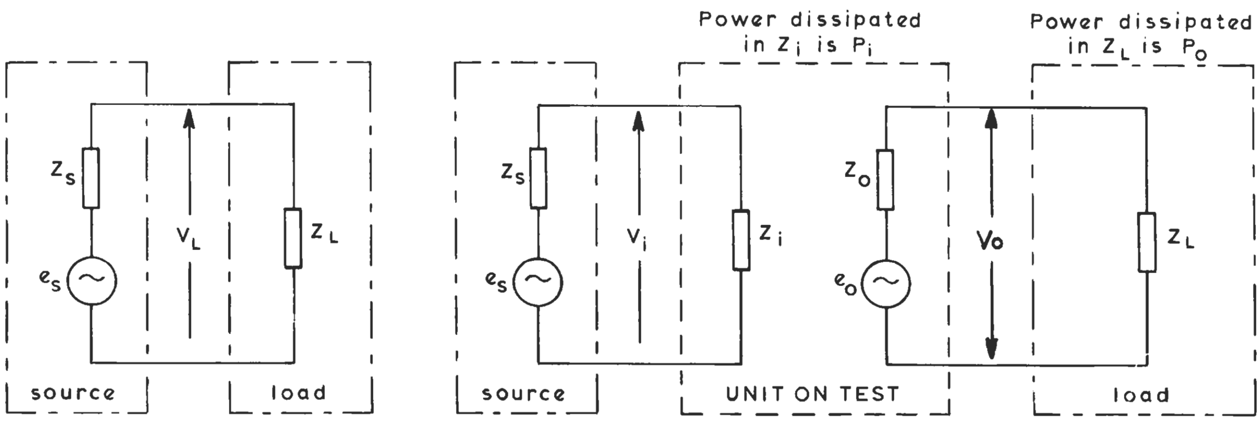
BACKGROUND

The *gain* of a unit is a parameter which quantifies the ability of that unit to change (usually increase) the magnitude of a signal of a specified frequency applied to the input. Strictly, *gain* refers to a power ratio ($= 10 \log \frac{P_{out}}{P_{in}}$ dB), but the figure most commonly measured and quoted for equipment is:

$$\text{VOLTAGE GAIN} = 20 \log \frac{V_o}{V_i} \text{ dB}$$

where V_i and V_o are the input and output voltages; see Fig. 1. Both voltages must be measured in the same terms, e.g. both p-p or both r.m.s. The voltage gain of a unit is numerically equal (in dB) to its power gain if and only if the input and output voltages are measured across identical impedances; i.e. when, in Fig. 1b, $Z_i = Z_L$.

The measurement of voltage gain is the test most often made. This is mainly because it can usually be done without disconnecting the unit under test. Such an in-circuit test not only gives the required gain figure but can also show whether or not the terminal impedances are correct. The in-circuit test results should, however, be regarded with caution. It is possible for an impedance fault to coincide with a gain error so that, although the figure obtained appears acceptable, the actual gain value is wrong (see **ATP1 TERMINATION MEASUREMENTS**).



(a) Fig. 1 Basic circuits illustrating the description of gain (b)

Another characteristic which is often measured is INSERTION GAIN. This expresses the change in the overall gain of a circuit (specifically, the change of E.M.F. Gain; see below) which results when the unit is connected into it. Depending on the particular requirement, connection of the unit may either:

(a) cause an increase in circuit output level for a given input level, or

(b) require a reduced input to provide the same output.

The parameter can be quantified in terms of an output change. Using symbols shown in Figs. 1a and 1b:

$$\text{INSERTION GAIN} = 20 \log \frac{V_o}{V_L} \text{ dB}$$

It is usually easier in practice to employ the alternative sense of change in a test circuit, i.e. the change of input required to keep a constant output is noted as the unit is inserted (or withdrawn).

From Fig. 1a and 1b, it is evident that voltages V_o and V_L used in the expression for insertion gain are measured across the same impedance, and hence the insertion gain is always numerically equal (in dB) to the power gain. It is also possible, in some circumstances, for insertion gain and voltage gain to have the same value. The most obvious instance is when the impedance of the circuit at the insertion point is not altered when the unit is inserted; e.g. in Fig. 1, when $Z_s = Z_i = Z_o = Z_L$.

A third type of gain which may be specified involves the loading effect of the unit input impedance on the source. In BBC practice, this is known as the E.M.F. GAIN; internationally* it is called Overall Voltage Gain. Referring to Fig. 1. the value is given by:

$$\text{E.M.F. GAIN} = 20 \log \frac{V_o}{e_s} \text{ dB}$$

The concept of e.m.f. gain is particularly useful in the measurements of frequency response and of noise factor (see **ATP3** and **ATP5** respectively).

When the input impedance of a unit (Z_i in Fig. 1b) is much larger than the source impedance (Z_s), the e.m.f. gain value is the same as the voltage gain value. If the two impedances are comparable, or if Z_s is larger than Z_i, these gain values will be different and must be obtained by separate measurements.

To avoid possible error, all gain measurements must take into account the various circuit impedances as illustrated in Fig. 1 Quoted figures of gain should always be qualified by a statement of the appropriate values of source and load impedance.

Unless otherwise specified, the gain of a unit is measured using a one kilohertz sinewave input signal. The applied signal should produce an output which is at least 10 dB below the specified maximum for the unit, but must also be of sufficient amplitude so that the measurement is not affected by noise.

ASSOCIATED INFORMATION
(normally issued with this Test Procedure)

1. **Operating Instructions (P2, Part 2)** for : EP14/1 A.C. TEST SET
(Technical Instructions are available which deal with the ATM/1 Test Meter and the TS/10 Tone Source).

* I.E.C. Publication 268, 1969. Part 3.

DEFINITIONS

VOLTAGE GAIN – is the ratio of output voltage to input voltage, usually expressed in dB (decibels).

INSERTION GAIN – is the ratio of the voltages measured across the load fed by a unit, first with and then without the unit in circuit. The ratio is usually expressed in dB.

E.M.F. GAIN – is the ratio of output voltage to source e.m.f., usually expressed in dB.

Because all practical signal sources possess an inherent internal impedance, it is necessary, in order to make a measurement of e.m.f. gain, to create an artificial 'zero impedance source'. This is done by means of a simple network of resistors arranged so that the required voltage – the e.m.f. – appears across a resistor of negligibly low value. This voltage (labelled $e_s^!$ in the drawings) can be measured or calculated; it feeds the input current through a resistor having a value equal to the required source impedance.

VOLTAGE / INSERTION / E.M.F. GAIN – is measured using an a.c. voltmeter which may read either directly in dB or in volts from which:

$$\text{VOLTAGE GAIN} = 20 \log \frac{V_o}{V_i} \text{ dB, or}$$

$$\text{INSERTION GAIN} = 20 \log \frac{V_o}{V_L} \text{ dB, or}$$

$$\text{E.M.F. GAIN} = 20 \log \frac{V_o}{e_s} \text{ dB}$$

where V_i, V_o, V_L and e_s are measured at the appropriate points indicated in Fig. 1.
Note that:

(a) For calculation, the measured voltages must be of the same form (e.g. both r.m.s. values, both peak-to-peak values, etc).

(b) The letters dB are used without suffix because gain is simply a ratio without reference to any other value.

(c) Although the values of terminating impedance do not appear in the gain equations, in practice the gain of a unit is affected by its load (Z_L) and may also be affected by the source impedance (Z_s, or Z_o of the preceding equipment).

NOTES ON THE USE OF TEST EQUIPMENT

1. *Generally, test equipment must:*
   (a) Be capable of operation in balanced circuits (see **ATP1 TERMINATION MEASUREMENTS**). *In this respect, particular care is necessary with some commercial electronic voltmeters.*
   (b) Be connected by leads with impedance which is negligible in relation to the circuit impedances.

2. *The meter or other indicating instrument must have an input impedance which is sufficiently large that it does not cause a significant change in level when it is connected into the circuit at the point of measurement.*

3. *Rep coils act to eliminate common mode components (i.e. longitudinal currents, see ATP.1) which may be present in the output of a tone source. Although the outputs from modern test equipments, such as the EP14/1, are free from significant amounts of common mode current, the presence of small (and otherwise unimportant) attenuator faults can create these currents. To protect against possible measurement error, therefore, it is good practice to include a rep coil in the input circuit as shown in the following diagrams.*

ATP2.1 **MEASUREMENT METHODS – VOLTAGE GAIN**

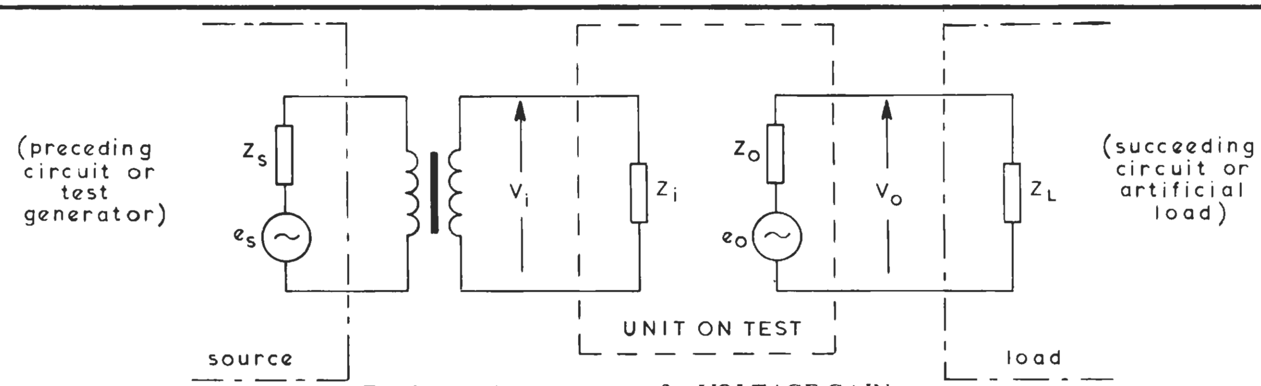


Fig. 2 Basic arrangement for VOLTAGE GAIN test

A. Voltage Gain Test with Unit in Working Position

Equipment Required

Power supplier appropriate to unit specification (see Appendix ATP.A for details of precautions to be observed with regard to earthing connections)
Signal-isolating transformer (Rep coil); see Appendix ATP.B

At input: A.F. signal generator e.g. EP14/1 A.C. TEST SET (or TS/10 TONE SOURCE) or use 1kHz tone

At output: dB meter e.g. EP14/1 A.C. TEST SET (or ATM/1 A.C. TEST METER) or Electronic Voltmeter

Test Procedure (Refer to Fig. 2)

1. On the unit under test:
   (i) Note the settings of all **calibrated** gain controls for comparison with the measured value.
   (ii) Either leave **uncalibrated** controls at the setting used for normal operation or, if the method for subsequent re-setting to this position is known, temporarily set to maximum.

   Maximum setting should be used with caution remembering that damage, or more possibly a change in operating conditions sufficient to cause measurement error, can result from overload in following equipment.

2. Connect the meter across the load circuit and apply the test signal to give the required output level; measure this as $\mathbf{V_o}$.

   Ensure that earthing conditions, particularly in balanced circuits, are not disturbed. See Appendix A at the end of this ATP.

3. Measure $\mathbf{V_i}$. If $\mathbf{V_o}$ and $\mathbf{V_i}$ have been measured in:
   (a) dB – the gain is simply the difference between these measured values;
   (b) volts – the gain is calculated by substituting the measured values in the appropriate expression (see **DEFINITIONS**).

ATP2.1 MEASUREMENT METHODS (continued)

B. Voltage Gain Test with Unit Not in Working Position

Equipment Required

Power supplier appropriate to unit specification (see Appendix ATP.A for details of precautions to be observed with regard to earthing connections)
Signal-isolating transformer (Rep coil); see Appendix ATP.B

At input: A.F. signal generator e.g. EP14/1 A.C. TEST SET (or TS/10 TONE SOURCE) or use 1kHz tone

At output: dB meter e.g. EP14/1 A.C. TEST SET (or ATM/1 A.C. TEST METER) or
Electronic Voltmeter
A non-inductive resistor with a value equal to the specified load and of adequate power rating.

Test Procedure

1. On the unit under test, note the setting of all **calibrated** gain controls for comparison with the measured value. Set all **uncalibrated** gain controls to maximum.

2. Connect the meter across the load, and apply the test signal to give the required output level; measure this as $\mathbf{V_o}$.

   The source and load impedances $\mathbf{Z_s}$ *and* $\mathbf{Z_i}$, *respectively (see Fig. 2) should have values:*
   (a) equal to those for normal working, or
   (b) as otherwise specified

3. Measure $\mathbf{V_i}$. If $\mathbf{V_o}$ and $\mathbf{V_i}$ have been measured in:
   (a) dB – the gain is simply the difference between these measured values:
   (b) volts – the gain is calculated by substituting the measured values in the appropriate expression (see **DEFINITIONS**).

ATP2.2 MEASUREMENT METHOD: INSERTION GAIN

Measurement of Insertion Gain in a Special Test Circuit

Equipment Required

Power supplies appropriate to unit specification (See Appendix ATP-A for details of precautions to be observed with regard to earthing connections).
4-pole change-over arrangement; e.g. switch, jacking system.
Signal-isolating transformer (Rep coil); see Appendix ATP-B

At input: A.F. signal generator e.g. EP14/1 A.C. TEST SET (or TS/10 TONE SOURCE) or use 1kHz tone
Calibrated variable attenuator

At output: dB meter e.g. EP14/1 A.C. TEST SET (or ATM/1 A.C. TEST METER) or
Electronic Voltmeter
A non-inductive resistor with a value equal to the specified load and of adequate power rating.

MEASUREMENT METHODS (continued) ATP2.2

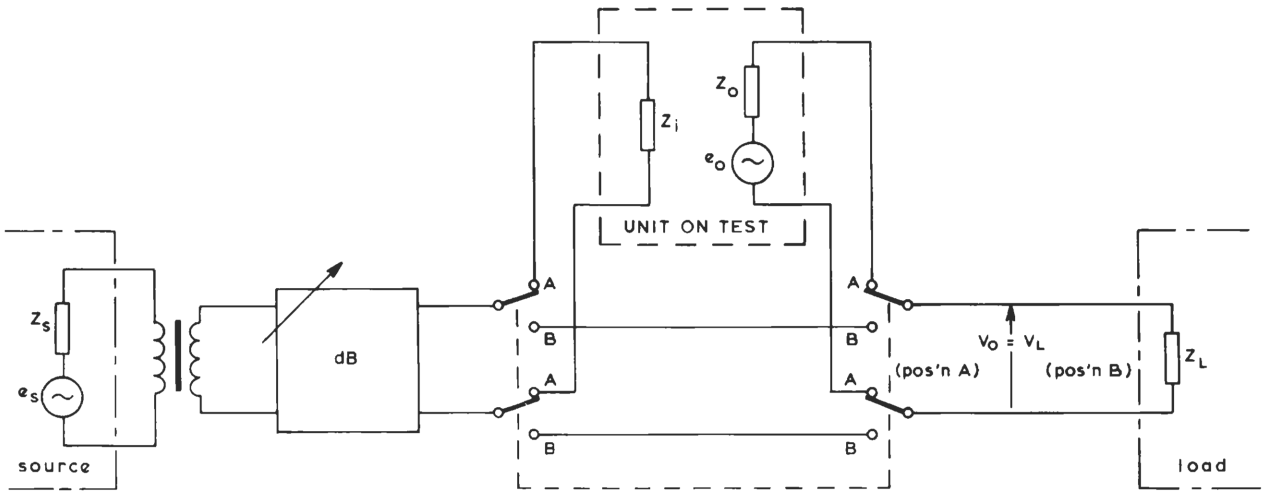


Fig. 3 Basic arrangement for INSERTION GAIN test

Notes:

1. In the test circuit of Fig. 3, Z_S and Z_L have the values specified for the measurement of insertion gain. The characteristic impedance of the attenuator MUST equal Z_S. Generally, for convenience, $Z_S = Z_L = 600$ ohms.

2. The measured value of insertion gain equals that obtained in the working position ONLY if the unit is then operating between impedances which have the same values as those specified for the test.

3. As with voltage gain measurement (see ATP2.1), coincident faults in a unit which cause errors in both gain and terminal impedance can counteract each other so that a satisfactory result is obtained in the test but not in practice. Such faults are rare, and are usually revealed by other tests.

Test Procedure

1. On the unit under test:
   (i) Note the settings of all **calibrated** gain controls for comparison with the measured value.
   (ii) Either leave **uncalibrated** controls at the setting used for normal operation or, if the method for subsequent re-setting to this position is known, temporarily set to maximum.

2. Connect the unit between the source and load circuits. Using the input attenuator, adjust the applied signal to obtain the normal working level V_o, across the load. Note the attenuator setting.

3. Operate the change-over, i.e. disconnect the unit and connect the source and load circuits together. Re-adjust the attenuator to obtain $V_L = V_o$ as before. Note the attenuator setting; the difference between this and the setting noted in step 2 gives the INSERTION GAIN.

ATP2.3 **MEASUREMENT METHOD: E.M.F. GAIN**

Measurement of E.M.F. Gain in Unbalanced-input and Balanced-input Units

Equipment Required

Power supplier appropriate to unit specification (see Appendix ATP.A for details of precautions to be observed with regard to earthing connections)
Signal-isolating transformer (Rep coil); see Appendix ATP.B

At input: A.F. signal generator e.g. EP14/1 A.C. TEST SET (or TS/10 TONE SOURCE) or use 1kHz tone

At output: dB meter e.g. EP14/1 A.C. TEST SET (or ATM/1 A.C. TEST METER) or Electronic Voltmeter
Non-inductive resistors of suitable values for R_1 (or two at $R_{½}$), R_2 (or two at $R_{½}$), R_3 and Z_L as in Figs. 4a and 4b (see notes 1 and 2).

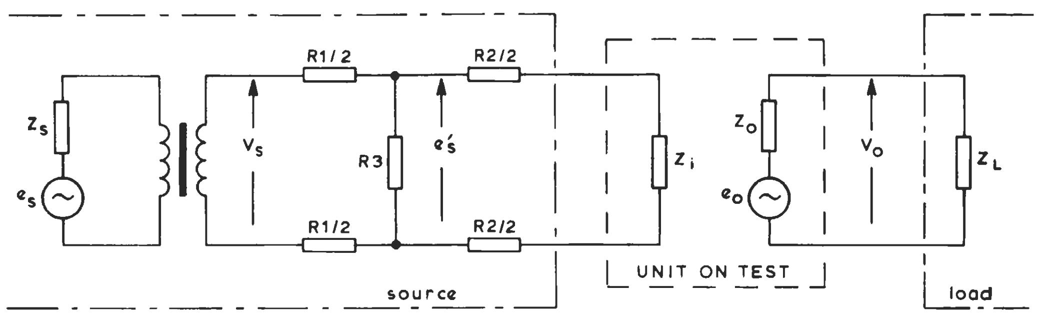


Fig. 4a Basic arrangement for E.M.F. GAIN test; balanced-input units

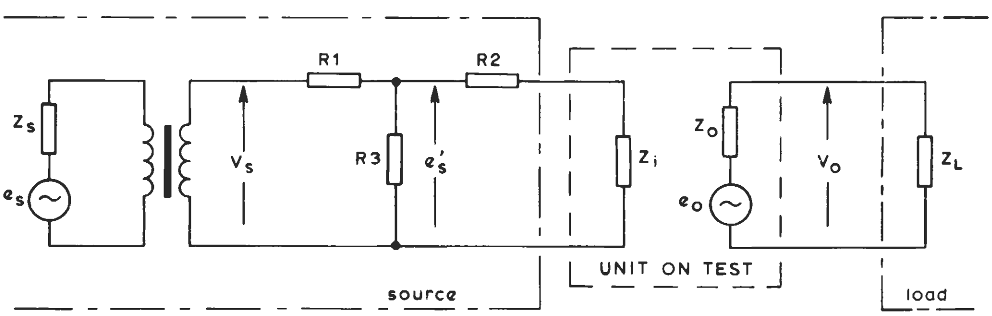


Fig. 4b Basic arrangement for E.M.F. GAIN test; unbalanced-input units

MEASUREMENT METHODS (continued) **ATP2.3**

Notes

1. R_2 and Z_L are the source and load impedances specified for the unit. Ensure that Z_L has a power rating which is adequate for the expected output.

2. R_1 and R_3 values should be known within one percent. R_3 should be about equal to $R_2/100$ so as to present a source impedance within one percent of the specified value.
   The value of R1 is not critical but should be chosen to:
   (a) provide a load within the specified operating range of the tone source and
   (b) give a value for V_s which is appreciably larger, and therefore more easily measured, than that required for e_s'.

3. Zero generator impedance (a requirement implied in the definition of e.m.f. gain) is effectively obtained by measuring V_s at the points shown in Figs. 4a and 4b and deriving e_s' by calculation; see step 3 below. If equipment for measuring low levels is available e.g. an EP14/1 A.C. TEST SET, e_s' can be measured directly.

Test Procedure

1. On the unit under test:
   (i) Note the settings of all **calibrated** gain controls for comparison with the measured value.
   (ii) Either leave **uncalibrated** controls at the setting used for normal operation, or if the method for subsequent re-setting to this position is known, temporarily set to maximum.

2. Connect the meter across the load. Connect the input test circuit as shown in Fig. 4 and set the applied signal level to give an output from the tested unit at approximately 10 dB below the specified maximum. Measure this as V_o.

3. Measure the generator output level as V_s. If V_o and V_s have been measured in:
   (a) dB, then:

$$\frac{V_o}{e_s'} \text{ (the e.m.f. gain)} = V_o - V_s + 20 \log \frac{R_1 + R_3}{R_3} \text{ dB}$$

Be sure to include the negative signs with any measured dB values which are less than zero level when substituting these in the expression.

   (b) volts, then:

$$\frac{V_o}{e_s'} \text{ (the e.m.f. gain)} = 20 \log \frac{V_o}{\dfrac{R_3}{R_3 + R_1} \times V_s} \text{ dB}$$

AUDIO TEST PROCEDURES

FREQUENCY RESPONSE MEASUREMENTS

ATP3.1 AMPLITUDE/FREQUENCY RESPONSE
ATP3.2 POWER/FREQUENCY RESPONSE
ATP3.3 PHASE/FREQUENCY RESPONSE

BACKGROUND

Introduction

The variations with frequency in the input/output (and, for stereo, output A/output B) signal relationships of amplitude, phase and power are important characteristics of a unit or circuit.

Some units are designed so that the variation of a parameter is as small as possible, i.e. the response is substantially constant with frequency within defined limits. In others, one of the characteristics may be arranged to follow a predetermined law, again with specified limits. Units of this second type, particularly those that produce a varying amplitude or phase response, are included in the chain either:

(a) to act as equalisers which compensate for programme circuit deficiencies or which introduce required recording/reproducing characteristics, or

(b) to satisfy a programme requirement; in BBC practice, for example, Response Selection Amplifiers (RSA's) are commonly used to modify the amplitude/frequency response of a microphone circuit output.

The power response of units is generally designed to be independent of frequency. There are exceptions, however, such as those units in which the power output at the ends of the audio band is restricted so as to prevent mechanical damage to a transducer forming the load.

Amplitude/Frequency Response

Of the three responses mentioned, that which compares signal amplitudes at the input and output of a unit is the one most often measured and quoted; it is the gain characteristic of a unit.

As explained elsewhere (see **ATP1 Termination Measurements**), sound broadcasting-signal transmission chains, comprise units connected together in various arrangements of impedance interface. These vary from one extreme, in which the source impedance is negligible compared with the impedance it feeds – the *constant voltage* condition – to the other, where the source impedance is much greater than its load – the *constant current* condition. Between such extremes, the condition of matched impedances (commonly 600 ohms) is often found. These different impedance arrangements affect the way in which amplitude/frequency response measurements are made.

In most instances, a curve showing the variation with frequency of E.M.F. GAIN (see ATP2.3) is taken as the gain characteristic of a unit. This is normally measured as the amplitude response *with constant source e.m.f.* However, the measurement of the inverse condition – change of source e.m.f. for a constant output voltage – is sometimes a practical necessity, e.g. when testing units designed to have a varying response. A further difference in the method of amplitude/frequency response measurement outlined above occurs when testing units operated under true constant-voltage conditions, i.e. where the feeding impedance is negligible compared with the unit input impedance. In such circumstances, the variation of VOLTAGE GAIN (see ATP2.1) is measured and given as the amplitude/frequency response because, here, the voltage gain is equivalent to the e.m.f. gain.

A general principle covering these measurements is that units under test must be operated at an applied signal level such that the output is free from significant distortion. To ensure that this requirement is satisfied, units are usually tested with signal voltages which are at least 10 dB below the maximum specified.

Power/Frequency Response

The power response of a unit or circuit is usually given in terms of the maximum amount of power it can deliver into a stated load at some mid-band frequency and at other frequencies near the upper and lower limits of the spectrum covered by the unit. Sometimes, a curve showing the maximum power available versus frequency is provided. Such a curve is usually derived from the measurement, at appropriate frequencies, of the maximum output voltages developed across a specified load for a specified limiting value of distortion.

Phase/Frequency Response

Phase-response measurements made in practice are of two types:

(a) Tests on individual or cascaded units where the characteristic shows the variation of phase with frequency relating the input and output signals. The input and output connections are both accessible at the test location.

(b) Tests on multi-channel equipment or systems where the characteristic shows the variation with frequency of the difference in phase between the signals at the respective channel outputs when all channel input signals are derived from a common source. The input terminals are not necessarily accessible at the test location.

Usually, phase response measurements are carried out using test equipment specifically designed for the purpose. Although such instruments are generally of commercial manufacture, a phase meter of BBC design (not coded: see page 17) is used in some BBC departments.

A method of phase testing – for use mainly on stereo units or systems – which requires only the measurement of signal level is described in ATP3.3. This is a practical, but less accurate alternative to the use of specialised equipment.

ASSOCIATED INFORMATION

(Normally issued with this Test Procedure)

1. **Operating Instructions (P2, Part 2)** for: EP14/1 A.C. TEST SET
(Technical Instructions are available which deal with the obsolescent ATM/1 Test Meter and TS/10 Tone Source).

DEFINITIONS

AMPLITUDE/FREQUENCY RESPONSE – is the characteristic of a unit or circuit which shows, for a stated bandwidth, the variation with frequency in the ratio:

$$\frac{\text{output voltage}}{\text{applied voltage}}$$

i.e. the variation in gain of the unit or circuit

– is expressed in dB and usually normalised to the value at 1 kHz

– is measured either by means of a direct-reading dB meter or in volts and calculated using:

$$\text{Relative response (at frequency f)} = 20\left[\log\left(\frac{V_o}{V_a}\right)_f - \log\left(\frac{V_o}{V_a}\right)_{1\text{ kHz}}\right] \text{dB}$$

where: V_a is the applied voltage
V_o is the output voltage

Note that:
(a) the letters dB are used without suffix because the gain is simply a ratio without reference to a particular level; see Appendix ATP–G
(b) although terminating impedance values are not involved in the above calculations, they may affect the measurements. Hence, one or both impedances must be specified as a test condition.

AMPLITUDE/FREQUENCY RESPONSE (CONSTANT SOURCE E.M.F.) – shows the variation of **E.M.F. GAIN** with frequency

– is the characteristic relating to conditions where the loading effect of the tested unit input impedance on the feeding circuit is significant

– is the amplitude (gain) characteristic usually quoted

AMPLITUDE/FREQUENCY RESPONSE (CONSTANT APPLIED VOLTAGE) – shows the variation of **VOLTAGE GAIN** with frequency

– is the gain characteristic of a unit when fed from a negligibly low source impedance, i.e. where the loading effect of the tested unit input impedance is not considered to be significant.

POWER/FREQUENCY RESPONSE – is the characteristic of a circuit which shows, for a given bandwidth, the variation with frequency of the maximum available power from a unit or circuit into a specified load for a specified value of Total Harmonic Distortion (THD); see ATP4.1

– is usually determined by measuring across a specified load impedance, at each specified frequency, the output voltage developed for which the THD is at the specified value.

PHASE/FREQUENCY RESPONSE – is the characteristic of a unit which shows the variation of phase with frequency when comparing the waveforms representing either:
(a) the input and output signals of a single unit or system, or
(b) the outputs from a multi-channel unit or system carrying signals derived from a common source.

– is normally measured by applying the voltages being compared in pairs to a phase meter using test (sinewave) signals at a specified level and appropriate frequencies.

DEFINITIONS (continued)

– can be measured, approximately, by simple signal-level comparison using a voltmeter or PPM. This method is particularly suited to phase measurement on multi-channel units or systems, but gives results of a lesser accuracy[1] than can be obtained with a phase meter; also, the result shows only the **magnitude** of the phase difference, **not the sense.**

1 *The accuracy depends on the compared signals being:*
(a) of equal level
(b) free of significant amounts of distortion and noise

NOTES ON THE USE OF TEST EQUIPMENT, SIGNALS AND RESULTS

(Applicable to all ATP3 Test Procedures)

1. Test Equipment and Equipment on Test

(i) In all the following tests, the main items of test equipment required are, unless otherwise stated:

At input: AF signal generator e.g. EP14/1 A.C. TEST SET (or TS/10 TONE SOURCE)

At output: Direct-reading dB meter e.g. EP14/1 A.C. TEST SET (or ATM/1 A.C. TEST METER) or Electronic Voltmeter

Any extra equipment required is listed under a heading: **Additional Test Equipment.**

(ii) Variable controls on equipment under test should be left at the settings used for normal working. The setting of calibrated controls should be noted for reference purposes.

2. Test Signals

The waveform of test signals used for all frequency response measurements is, unless otherwise stated, a sine-wave containing not greater than 0·5 per cent THD, applied at a level as required by the unit specification. For amplitude and phase response measurements, this level is at least 10 dB below the given maximum for the equipment under test.

3. Test Results

Response-measurement results are generally either listed as numerical data corresponding to a number of spot-frequency observations or presented graphically in the form of curves drawn to a vertical (y-axis) linear scale of level (dB), phase (degrees) or power (watts) and a horizontal (x-axis) logarithmic scale of frequency. For equipment known to be free from frequency-localised irregularities, these curves can be constructed from spot-frequency measurements. Some types of equipment, however, such as tape machines, requires a swept-frequency measurement, the result of which appears as a curve drawn automatically by a pen recorder. Manually-plotted response curves should be drawn on standard BBC surrounds DS/L A4 or E339 which, as illustrated in Figs. 1a and 1b, respectively, have logarithmic x-axis scales covering the frequency range 10 Hz to 30 kHz. (E339 has a y-axis scale with major divisions at 1 cm spacing to match the equaliser masks used in the BBC.) Normally, for amplitude/frequency response curves, a y-axis scale of 2 dB per major division is used.

BBC

DS/L A4

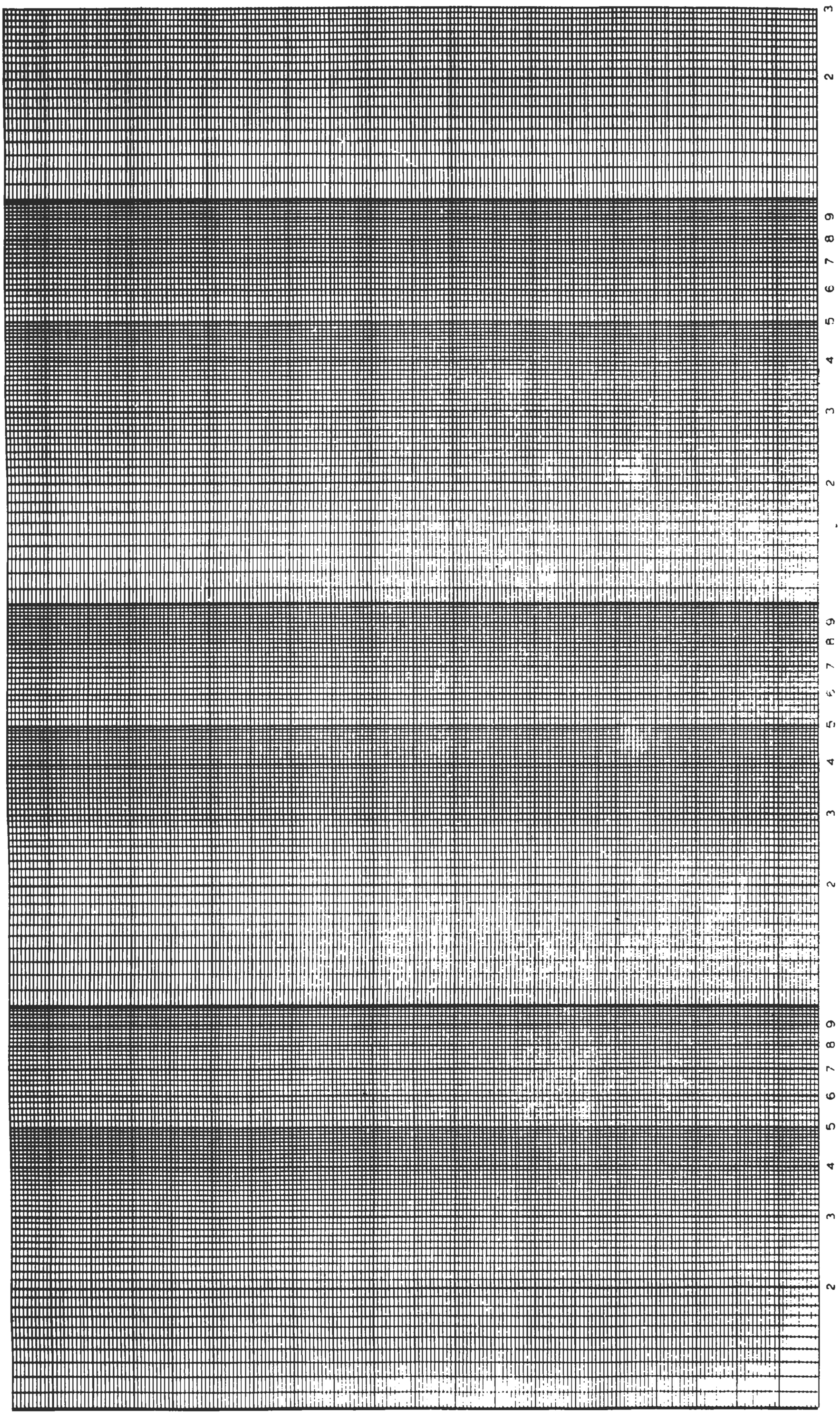


Fig. 1a DS/L A4 logarithmic-frequency/linear-vertical-division scaled paper used in the BBC

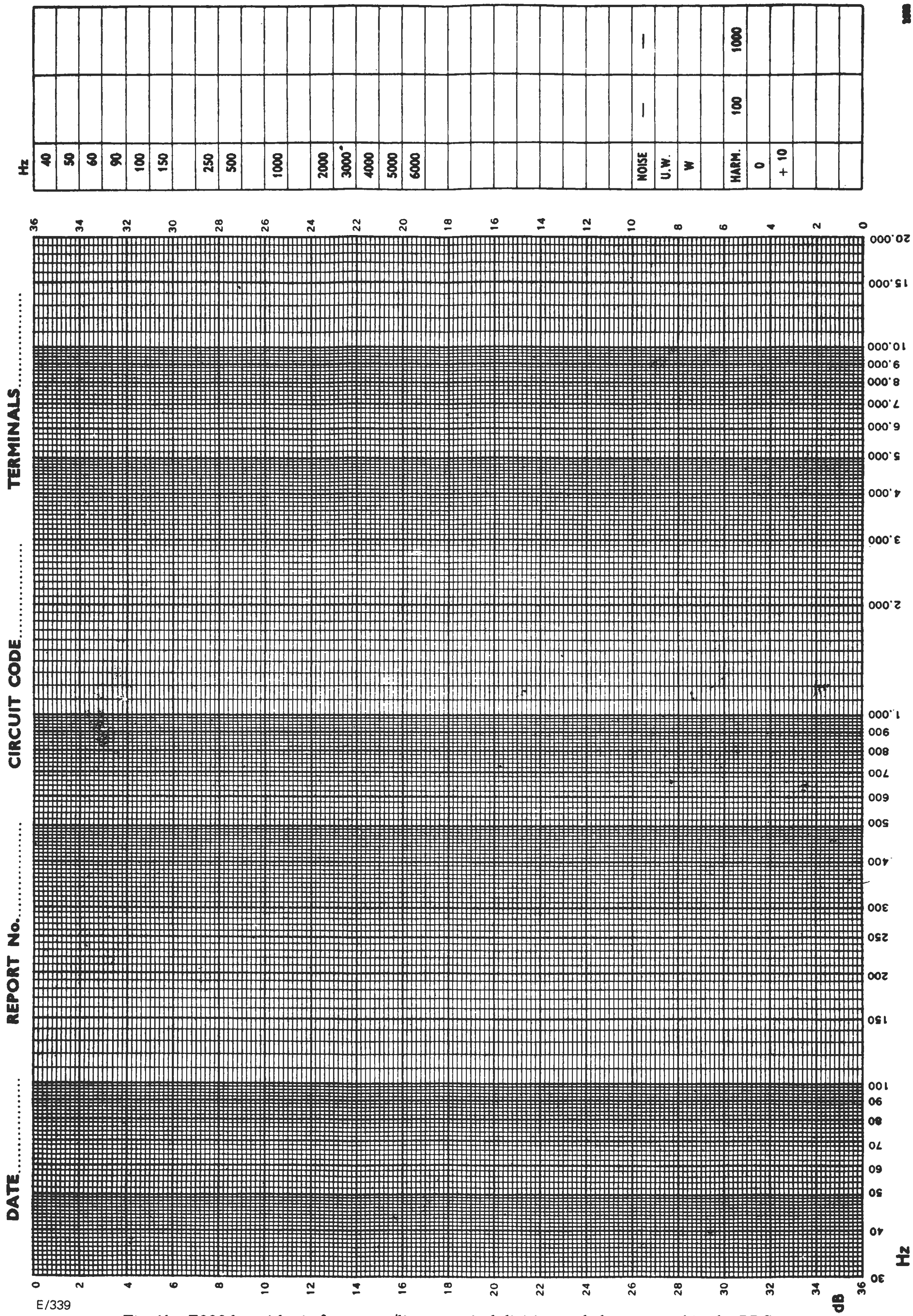


Fig. 1b E339 logarithmic-frequency/linear-vertical-division scaled paper used in the BBC

ATP3.1 MEASUREMENT METHODS: AMPLITUDE/FREQUENCY RESPONSE

General

The Test Procedures given below are divided into two groups as follows:

ATP3.1.1, ATP3.1.2, ATP3.1.3 – Amplitude/Frequency response tests on units which normally work between substantially resistive impedances.

ATP3.1.4, ATP3.1.5 – Amplitude/Frequency response tests on units which normally work with substantially reactive impedances (usually transducers) at either input or output.

ATP3.1 **MEASUREMENT METHODS (continued)**

ATP3.1.1 Amplitude/Frequency response test on unit/circuit normally fed from a source with impedance comparable to the unit input impedance

This test comprises repeated E.M.F. GAIN measurements (as in ATP2.3) at a number of frequencies spaced appropriately to cover all or a specified part of the audio band.

Equipment Required – see **NOTES ON THE USE OF TEST EQUIPMENT, SIGNALS AND RESULTS**

Additional Equipment – see items marked * in the list of Fig. 2 annotations

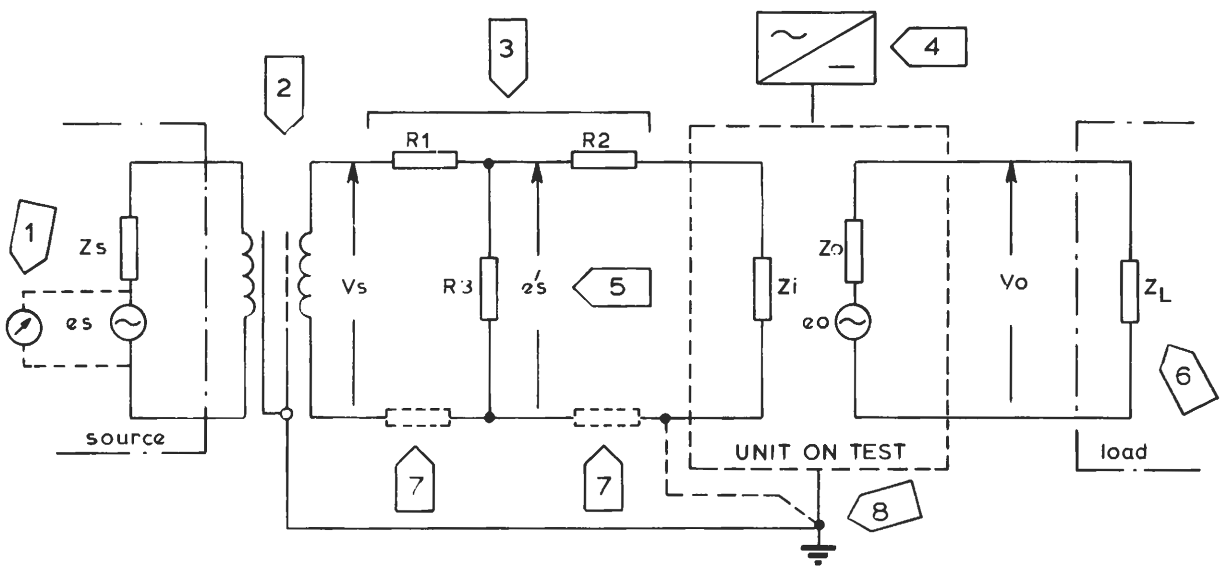


Fig. 2 Basic test circuit for amplitude/frequency response measurement: Source impedance approximately equal to unit input impedance

ATP3.1 **MEASUREMENT METHODS (continued)**

In Fig. 2:

1 Meter which may be contained as an integral part of the signal generator, thus allowing direct measurements of e_s.

2 *Signal-isolating transformer (Rep coil); see Appendix ATP-B

3 *These (non-inductive) resistors should have values such that:
(i) R_2 = the specified source impedance
(ii) $R_3 \leqslant R_2/100$
(iii) R_1 is as small as possible consistent with the total of $(R_1 + R_3)$ being sufficiently large not to adversely affect the performance of the generator

4 *Power supplier appropriate to unit specification (see Appendix ATP-A for details of precautions to be observed with regard to earthing connections)

5 *Constant applied e.m.f.* is the required condition for most amplitude/frequency response tests. It is effected here by measuring e_s (or V_s) at each test frequency and making appropriate adjustments to the input level so that either:
(a) the same value is maintained for e_s (or V_s), or
(b) the same value is maintained for V_o; this is particularly convenient when testing equipment having a designed variation in amplitude response.
The changes in value of the other parameter, V_o or e_s (or V_s) respectively, are measured and recorded as the amplitude response.

6 *Z_L is the load impedance specified for the unit. Ensure that the component (non-inductive resistor) used to represent Z_L has an adequate power rating.

7 When testing balanced-input units, the source circuit should be symmetrical so that half the value of series resistances R_1 (if included) and R_2 is connected in each leg; see ATP1.1.3.

8 When bench-testing units which normally work in an unbalanced-input arrangement, check that the input earth is integrally connected; if it is not, a temporary earth connection must be provided for the test.

Test Procedure

1. Arrange the test circuit as shown in Fig. 2 with the input circuit appropriate to the unit under test.

2. At a mid-band frequency (usually 1 kHz), set the applied signal level so as to obtain an output from the unit which is approximately 10 dB[2] below the specified maximum. Measure this output as V_o and note e_s (or measure V_s).

   [2] *For some low-gain units, it may be impracticable to obtain an output at, or even near, the recommended level. This is not important; a lower level can be used provided it is adequate for the purpose.*

3. At each of the test frequencies (as specified or appropriate), repeat the measurements of Step 2, above. Maintain a constant value for either e_s (or V_s) OR V_o, whichever is appropriate for the unit under test. Record the changes in measured value for the other parameter, i.e. the variation with frequency of V_o OR of e_s (V_s).

4. Plot the recorded values to obtain the required characteristic (see item 3 in **NOTES ON THE USE OF TEST EQUIPMENT, SIGNALS AND RESULTS**).

ATP3.1 MEASUREMENT METHODS (continued)

ATP3.1.2 Amplitude/frequency response test on a unit for which the defined performance is between specified equal impedances (commonly 600 ohms)

This test comprises repeated INSERTION GAIN measurements (as in ATP2.2) at a number of frequencies spaced appropriately to cover all or a specified part of the audio band.

Equipment Required – see **NOTES ON THE USE OF EQUIPMENT, SIGNALS AND RESULTS**

Additional Equipment – see items marked * in the list of Fig. 3 annotations.

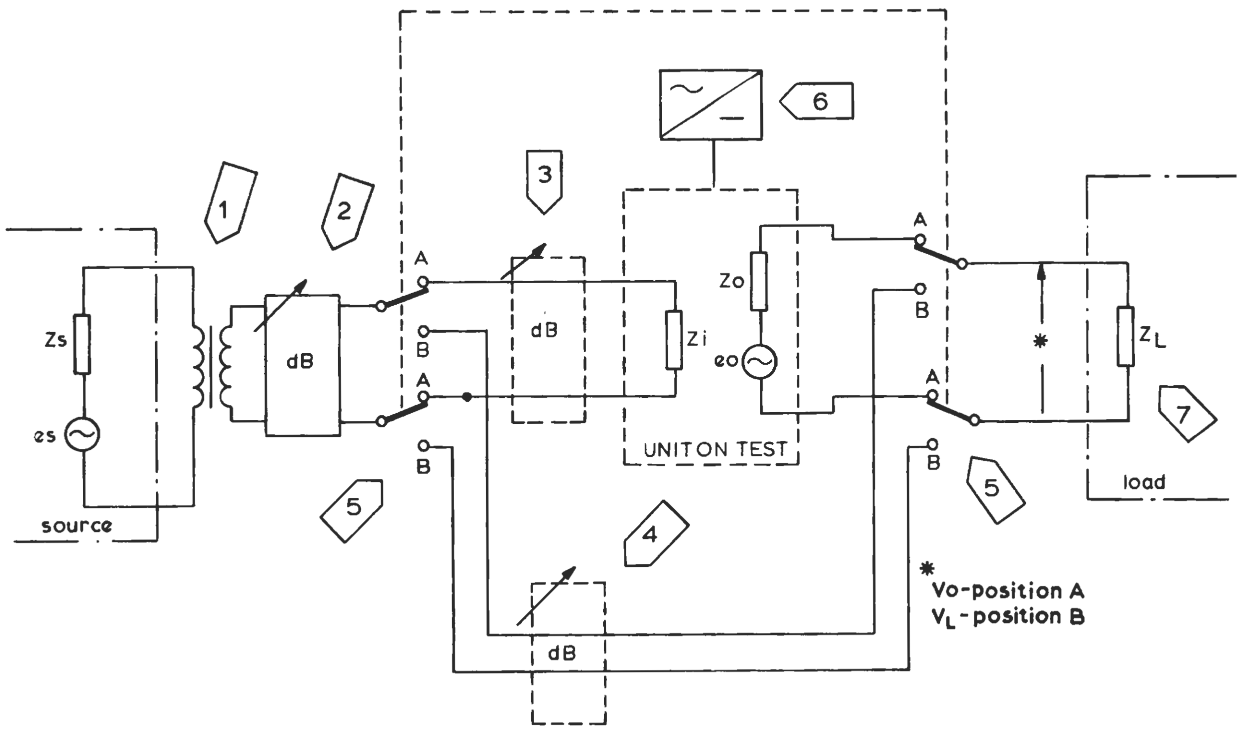


Fig. 3 Basic test circuit for amplitude/frequency response measurement; Unit operating between specified equal impedances

In Fig. 3:

1 *Signal-isolating transformer (Rep coil); see Appendix ATP-B

2 *Calibrated variable attenuator (see also 3 and 4 below). In the test circuit, Z_S and Z_L have the values specified for the unit under test; the characteristic impedance of the attenuator **must** be Z_S (and must also be balanced, if this is a requirement of the unit input circuit)

3 Where the unit under test is known to have an **overall gain** at all frequencies of interest, the attenuator can alternatively be connected here: then follow **Test Procedure (B)**, below.

4 Where the unit under test is known to have an **overall loss** at all frequencies of interest, the attenuator can alternatively be connected here: then follow **Test Procedure (C)**, below.

5 *4-pole changeover arrangement; e.g. switch, jacking system, etc.

6 *Power supplier appropriate to unit specification (see Appendix ATP-A for details of precautions to be observed with regard to earthing connections).

7 *Z_L is the load impedance specified for the unit under test. Ensure that the component (non-inductive resistor) used to represent Z_L has an adequate power rating.

ATP3.1 **MEASUREMENT METHODS (continued)**

Test Procedure (A) – attenuator at circuit position [2> in Fig. 3.

1. Arrange the test circuit as shown in Fig. 3. With the changeover switch in position A and the meter across Z_L, adjust the generator output level (or the attenuator) so that, at a mid-band frequency (usually 1 kHz), the output from the unit under test is at a level approximately 10 dB below the maximum specified. Measure this as V_o; note the attenuator setting for this measured value.

2. Set the changeover switch to position B. Set (or re-adjust) the attenuator to obtain a signal level across Z_L (V_L) which is the same as in Step 1, above, i.e. so that $V_L = V_o$. Note the attenuator setting for this condition; the difference between this and the setting noted in Step 1 is the insertion gain at the measurement frequency. Record the value of this difference.

3. At each of the test frequencies (specified or appropriate), repeat Steps 1 and 2. Plot the recorded differences in attenuation to obtain the insertion gain characteristic (see item 3 in **NOTES ON THE USE OF TEST EQUIPMENT, SIGNALS AND RESULTS**).

Test Procedure (B) – attenuator at circuit position [3> in Fig. 3.

1. Arrange the test circuit as in Fig. 3. With the changeover switch in position B (so that the unit under test is out of circuit) and the meter across Z_L, adjust the generator output level so that, at a mid-band frequency (usually 1 kHz), the level measured as V_L has a value at least 10 dB below the maximum specified for the tested unit.

2. Set the attenuator to a value approximately equal to the gain figure expected (at the test frequency). Set the changeover switch to position A. Re-adjust the attenuator so that the meter reading is the same as in Step 1, i.e. so that $V_o = V_L$. Record the setting of the attenuator; this gives the value of insertion gain at the measurement frequency.

3. At each of the test frequencies (specified or appropriate), repeat Steps 1 and 2. Plot the recorded attanuator settings to obtain the insertion gain characteristic (see item 3 in **NOTES ON THE USE OF TEST EQUIPMENT, SIGNALS AND RESULTS**).

Test Procedure (C) – attenuator at circuit position [4> in Fig. 3.

1. Arrange the test circuit as in Fig. 3. With the changeover switch in position A, adjust the generator output level so that, at a mid-band frequency (usually 1 kHz), the output from the tested unit is at a level approximately 10 dB below the maximum specified for the tested unit. Measure this as V_o.

2. Set the attenuator to a value approximately equal to the loss figure expected (at the test frequency). Set the changeover switch to position B. Re-adjust the attenuator so that the meter reading is the same as in Step 1: i.e. so that $V_L = V_o$. Record the setting of the attenuator; this gives the value of insertion loss at the measurement frequency.

3. At each of the test frequencies (specified or appropriate), repeat Steps 1 and 2. Plot the recorded attenuator settings to obtain the insertion loss characteristic (see item 3 in **NOTES ON THE USE OF TEST EQUIPMENT, SIGNALS AND RESULTS**).

ATP3.1 MEASUREMENT METHODS (continued)

ATP3.1.3 Amplitude/frequency response test on a unit normally fed from a source with impedance much less than that of the unit on test

This test comprises repeated VOLTAGE GAIN measurements (as in ATP2.1) at a number of frequencies spaced appropriately to cover all or a specified part of the audio band.

Equipment Required – see **NOTES ON THE USE OF TEST EQUIPMENT, SIGNALS AND RESULTS**

Additional Equipment – see items marked * in the list of Fig. 4 annotations

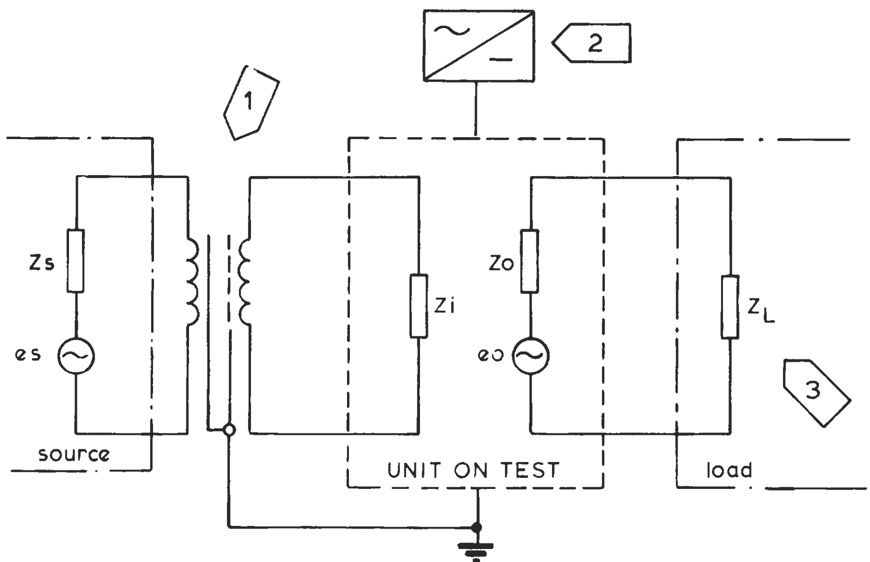


Fig. 4 Basic test circuit for amplitude/frequency response measurement; Source impedance ≪ unit input impedance

In Fig. 4:

1 *Signal-isolating transformer (Rep coil); see Appendix ATP-B

2 *Power supplier appropriate to unit specification (see Appendix ATP-A for details of precautions to be observed with regard to earthing connections)

3 *Z_L is the lead impedance specified for the unit. Ensure that the component (non-inductive resistor) used to represent Z_L has an adequate power rating.

Test Procedure

1. Arrange the test circuit as shown in Fig. 4, with the meter connected across the load circuit (Z_L). At a mid-band frequency (usually 1 kHz), adjust the level of the applied signal (V_i) to give an output from the unit which is approximately 10 dB below the specified maximum. Measure this output at V_o.

2. At each of the test frequencies (as specified or appropriate), repeat the measurement as in Step 1, keeping V_i constant. Record the measured values.

3. Plot the recorded values to obtain the required characteristic (see item 3 in **NOTES ON THE USE OF TEST EQUIPMENT, SIGNALS AND RESULTS**).

ATP3.1 **MEASUREMENT METHODS (continued)**

ATP3.1.4 Amplitude/frequency response test on unit which normally works between a significantly reactive (transducer) source and a resistive load

Note: this test can be used on units having unbalanced or floating (transformer) output circuits. It is **not** suitable for units where the input balance is obtained by means of an active circuit or an earthed centre-tap transformer.

Equipment Required – see **NOTES ON THE USE OF TEST EQUIPMENT, SIGNALS AND RESULTS**

Additional Equipment – see items marked * in the list of Fig. 5 annotations

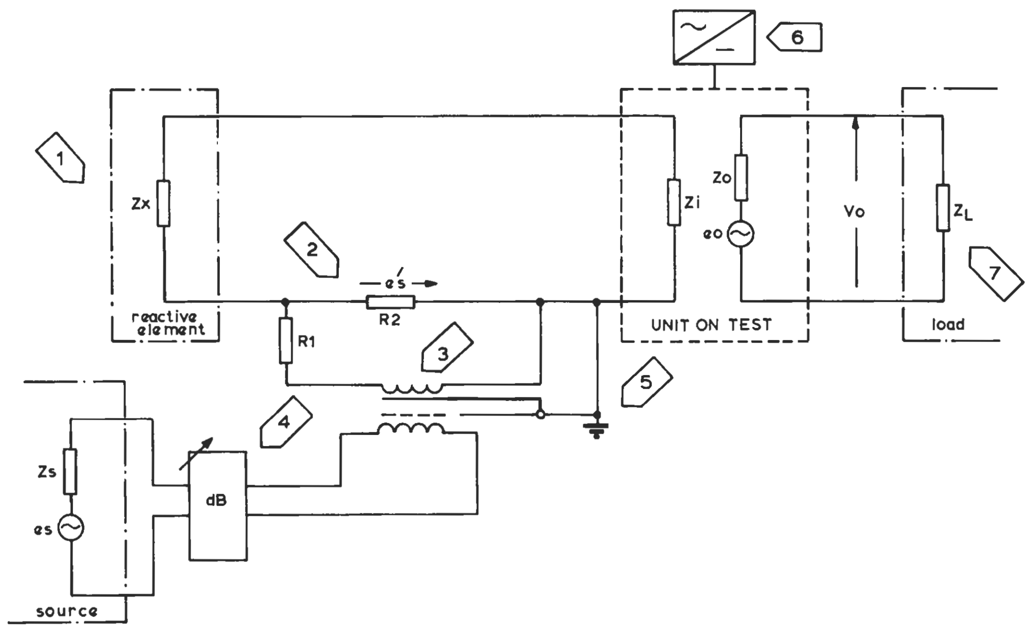


Fig. 5 Basic test circuit for measuring the amplitude/frequency response of equipment normally fed from a reactive (transducer) source

In Fig. 5:

1 *Reactive element having a modulus of impedance Z_X: either the particular component which normally generates the input signal to the unit under test or its direct equivalent.

2 *Non-inductive resistors with values such that:
(i) $R_2 \ll$ minimum value of Z_X – say $Z_{X(min)}/50$
(ii) $(R_1 + R_2)$ is within 50 per cent of the characteristic impedance of the attenuator at 4

3 *Signal-isolating transformer (Rep coil); see Appendix ATP-B.

4 *Variable attenuator – impedance = Z_S

5 This input terminal (i.e. the one directly connected to the series injection resistor, R_2) must be earthed.

6 *Power supplier appropriate to the unit specification (see Appendix ATP-A for details of precautions to be observed with regard to earthing connections).

7 *Z_L is the load impedance specified for the unit. Ensure that the component (non-inductive resistor) used to represent Z_L has an adequate power rating.

Test Procedure

1. Arrange the test circuit as in Fig. 5. At each test frequency (as specified or appropriate), adjust the attenuator so that the unit output, V_0, is at a convenient value which is at least 10 dB below the specified maximum. Measure and record the values of injected voltage, e'_s, required to maintain V_0 constant.

2. Plot the values of e'_s obtained in Step 1. Compare the resulting response curve with the specified characteristic (which may include some degree of equalisation).

ATP3.1	MEASUREMENT METHODS (continued)

ATP3.1.5. Amplitude/frequency response test on a unit which normally delivers a constant-current drive[3] to a significantly reactive (transducer) load

Note: this test can be used on units having unbalanced or floating (transformer) output circuits. It is *not* suitable for units where the output balance is obtained by means of an active circuit or an earthed centre-tap transformer.

Equipment Required – see **NOTES ON THE USE OF TEST EQUIPMENT, SIGNALS AND RESULTS**

Additional Equipment – see items marked * in the list of Fig. 6 annotations.

[3] *The term 'constant-current drive' describes the output of a unit in which, subject to design limitations, the value of current delivered to a load is independent of any variation in the effective impedance of that load.*

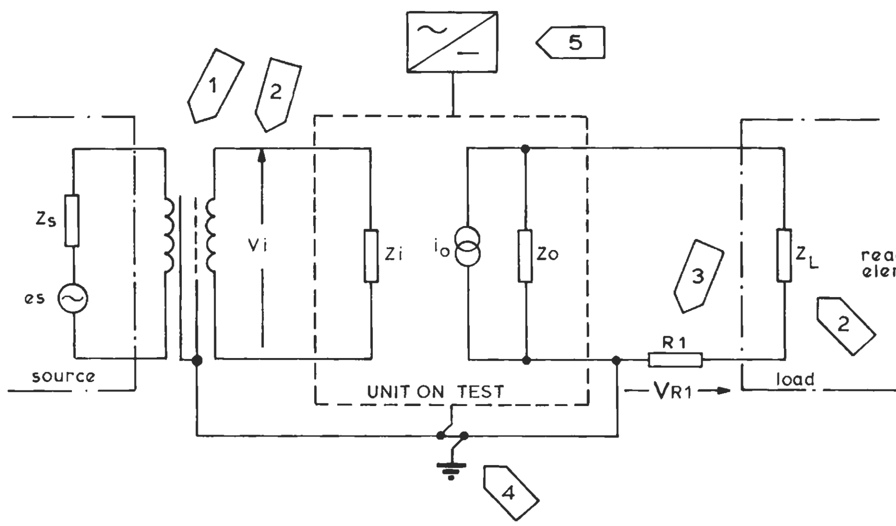


Fig. 6 Basic test circuit for measuring the amplitude/frequency response of equipment normally feeding constant current to a reactive (transducer) load; e.g. a recording head

In Fig. 6:

1 *Signal-isolating transformer (Rep coil); see Appendix ATP-B

2 *Reactive load element having a modulus of impedance Z_L: either the particular component which is normally driven by the output of the unit under test or its direct equivalent.

3 *Non-inductive resistor with a value such that $R_1 \ll$ minimum value of Z_L – say $Z_{L(min)}/50$

4 This output terminal (i.e. the one directly connected to the current-sampling resistor) must be earthed.

5 *Power supplier appropriate to the unit specification (see Appendix ATP-A for details of precautions to be observed with regard to earthing connections).

6 Use the input-circuit configuration of Fig. 2 if:
(a) the value of Z_s is unsuitable for feeding Z_i, and/or
(b) the input condition of 'constant source e.m.f.' is required.

ATP3.1 MEASUREMENT METHODS (continued)

Note: in the **BACKGROUND** description of response tests it is explained that an amplitude characteristic generally shows the variation of voltage gain (in one form or another) with frequency. But, from Fig. 6, item 3, above, and the following **Test Procedure**, it is evident that the voltage values which are measured and plotted are proportional to output **current**. These values are then compared by ratio to the input **voltage**; the resultant therefore has the dimension of an **admittance**, whereas gain figures are normally dimensionless.

Test Procedure

1. Arrange the test circuit as in Fig. 6. At each test frequency (as specified or appropriate), set e_s so that V_{R_1} is maintained at the same value, usually specified. Measure and record the values of V_i.

2. Plot the values of V_i obtained in Step 1. Compare the resulting response curve with the specified characteristic (which may include some degree of equalisation).

ATP3.2 MEASUREMENT METHOD – POWER/FREQUENCY RESPONSE

General

The Test Procedure given below uses the method of AMPLITUDE RESPONSE measurement described in ATP3.1 (particularly ATP3.1.3). The equipment required here therefore includes the items called for in that test together with equipment for measuring total harmonic distortion (THD). This must be used to analyse the unit output signal so that its level can be set at each test frequency to obtain the specified limit amount of distortion.

Remember to observe the operating instructions for the distortion-measuring instrument, particularly in respect of the permitted maximum input level. Note also that such equipment measures the noise and hum components of the tested output as well as the harmonic content.

Test Procedure

1. On the unit under test, if convenient, set all (voltage gain) response controls at the positions indicated for a nominally flat (constant gain/frequency) response.

2. Connect the meter in parallel with the distortion-measuring equipment across the load resistor, Z_L.

   Ensure that earthing conditions, particularly in balanced circuits, are not disturbed (see Appendices ATP-B and ATP-C).

3. At test frequencies spaced appropriately in the band of interest, increase the applied signal level (V_i, in Fig. 4) until the unit output (of level V_o) contains a per-centage of harmonics which equals the specified distortion limit. In each instance, record the value of V_o which obtains when this limit is reached.

   This process may require repeated resetting of the distortion-measuring equipment to account for the (possible) considerable changes in output level, particularly at the ends of the audio band.

4. From the record of changing values of V_o, calculate and plot values of V_o^2/Z_I, i.e. the power delivered to the test load at each test frequency. The resulting curve should have a shape similar to that shown in Fig.7 on page 16.

ATP3.2 **MEASUREMENT METHODS (continued)**

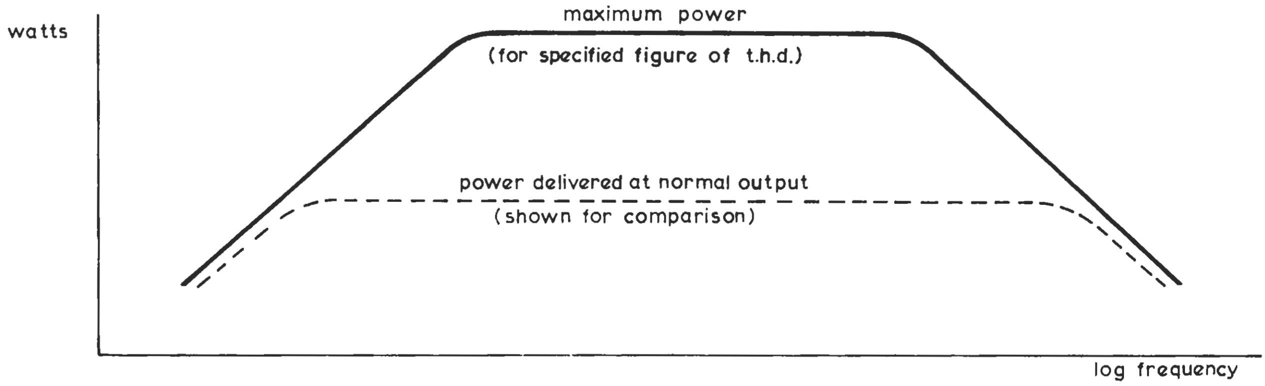


Fig. 7 Idealised response curve showing the maximum power output from a unit into a specified load for a specified value of output-signal distortion (THD)

ATP3.3 **MEASUREMENT METHODS – PHASE/FREQUENCY RESPONSE**

General

The Test Procedures given below are divided into two groups as follows:

ATP3.3.1 – Tests in which sinusoidal signals at the input and output of a single unit are compared so as to measure the phase difference between them. The tests may be repeated at a number of frequencies to show the variation of phase difference over the audio band. For such tests, both the input and the output terminals of the tested equipment must be accessible at the point of measurement.

ATP3.3.2
ATP3.3.3 – Tests in which sinusoidal signals at the outputs of a multi-channel unit or system (the signals originating from a common source) are compared so as to measure their phase difference. Possibly, as for ATP3.3.1, repeated measurements are made to show the variation of phase difference with frequency. Only the channel outputs need be accessible at the point of measurement (provided that suitable control of frequency and level of the common signal fed to the remote inputs can be arranged).

Results of Phase-response Tests

It is important to remember that the concept of phase difference – a statement of the relationship existing between similar waveform points on otherwise identical a.c. signals – is simply a convenient way of quantifying periods of elapsed time which are comparable with the period of one cycle at the signal frequency. Hence, the essential purpose of all phase-response measurements is to determine if, and to what extent, the time taken by a signal to pass through a unit or system is subject to change with frequency. In this context, a further point to note is that where circuit connections or interconnections are such that an arbitrary (and otherwise unimportant) inversion of signal polarity occurs, care must be taken to ensure that this inversion is not misrepresented in any measurement of phase difference as a phase shift of 180 degrees.

ATP3.3 **MEASUREMENT METHODS (continued)**

ATP3.3.1 **Phase/frequency response test comparing signals at the input and output of a unit**

Equipment Required – see **NOTES ON THE USE OF TEST EQUIPMENT, SIGNALS AND RESULTS**

Additional Equipment - see items marked * in the list of Fig. 8 annotations.

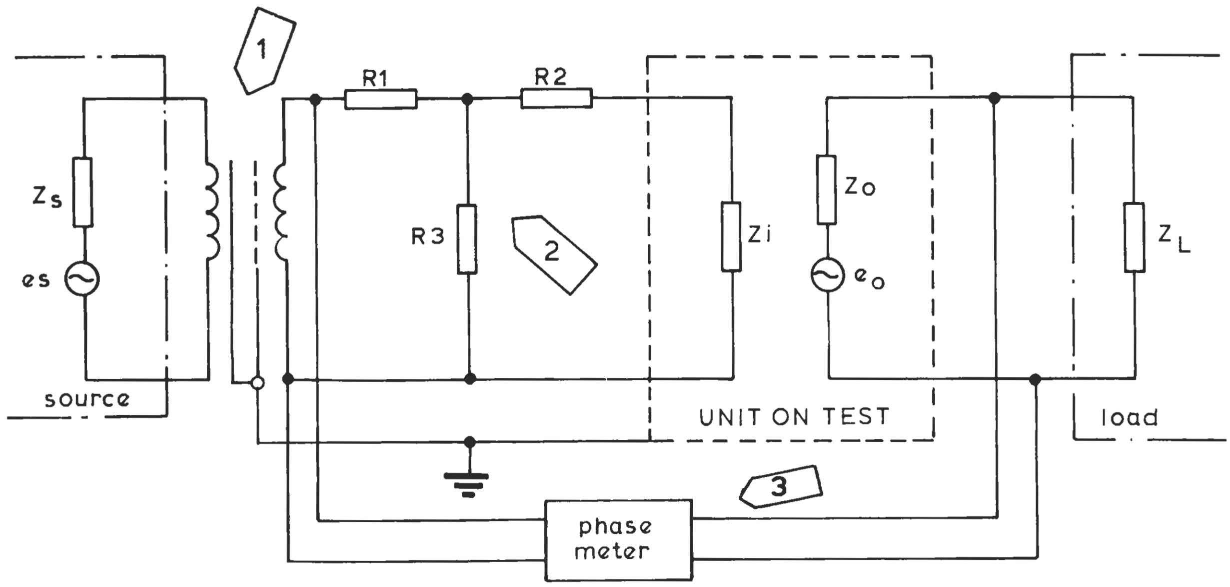


Fig. 8 - Basic circuit showing measurements of phase difference between input and output

In Fig. 8:

1 *Signal-isolating transformer (Rep coil): see Appendix ATP-B

2 *Matching pad required if Z_S is not the value specified for the source impedance and/or if Z_i is appreciably reactive. These (non-inductive resistors) should have values such that:
(i) R_2 = the specified source impedance
(ii) $R_3 \ll R_2/100$
(iii) R_1 – is as low as possible consistent with the total of $R_1 + R_3$ being sufficiently large not to adversely affect the performance of the generator.

3 *Phase meter – of commercial manufacture, e.g. Prosser Type A200
– or BBC Communications Department DIGITAL PHASE DIFFERENCE METER to Drawing Ref. C2041 A2.

Test Procedure

1. Arrange the test circuit as in Fig. 9.

2. Use the phase meter as explained in the appropriate manufacturer's handbook or Operating Instruction to measure the phase difference at the specified (or appropriate) frequencies.

Ensure that the input and output levels are set and maintained at the values consistent with the correct operation of the circuit/unit under test and of the phase meter.

ATP3.3 **MEASUREMENT METHODS (continued)**

ATP3.3.2 Phase/frequency response test comparing signals at the outputs of two channels of a multi-channel unit or system fed with a common input signal

This Test Procedure is virtually the same as ATP3.3.1, above, except that the signals being compared for phase difference are the outputs produced by a multi-channel unit or system. The test signals are derived from a common source and fed to the appropriate channel inputs via a balanced-bridge splitting network as illustrated in Fig. 9. Note that the channel inputs may not be accessible from the output measurement point, e.g. they could be at some geographically-distant location. In this event, the level and frequency of the applied signal must be separately controlled.

Equipment Required – see **NOTES ON THE USE OF TEST EQUIPMENT, SIGNALS AND RESULTS**

Additional Equipment – see items marked * in the list of Fig. 9 annotations.

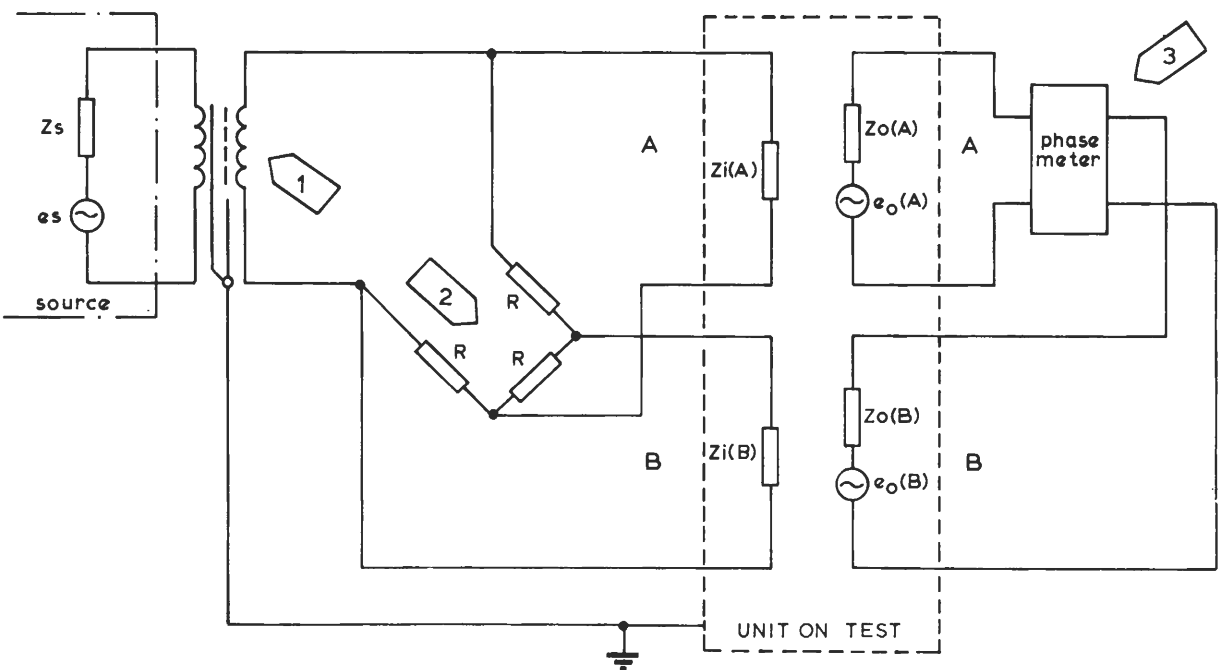


Fig. 9 Basic circuit showing measurement of phase difference between two outputs

In Fig. 9:

[1] *Signal-isolating transformer (Rep coil); see Appendix ATP-B

[2] *Balanced-bridge splitting network ($R = Z_s$). This is required only if the unit/system under test has channel input impedances (Z_i) which vary with frequency, e.g. P.O. lines, equaliser circuits, etc. When Z_i is constant, the source can be connected directly to paralleled channel inputs provided that the generator is able to operate when working into a load of value $Z_i/2$.

[3] *Phase meter – of commercial manufacture, e.g. Prosser Type A200
– or BBC Communications Department DIGITAL PHASE DIFFERENCE METER to Drawing Ref. C2041 A2.

ATP3.3 MEASUREMENT METHODS (continued)

ATP3.3.3 Phase/(Spot) frequency test comparing signals at the outputs of two units or circuits acting as a stereo pair and fed with a common input signal

Equipment Required – see **NOTES ON THE USE OF TEST EQUIPMENT, SIGNALS AND RESULTS**

Additional Equipment – see items marked * in the list of Fig. 10 annotations.

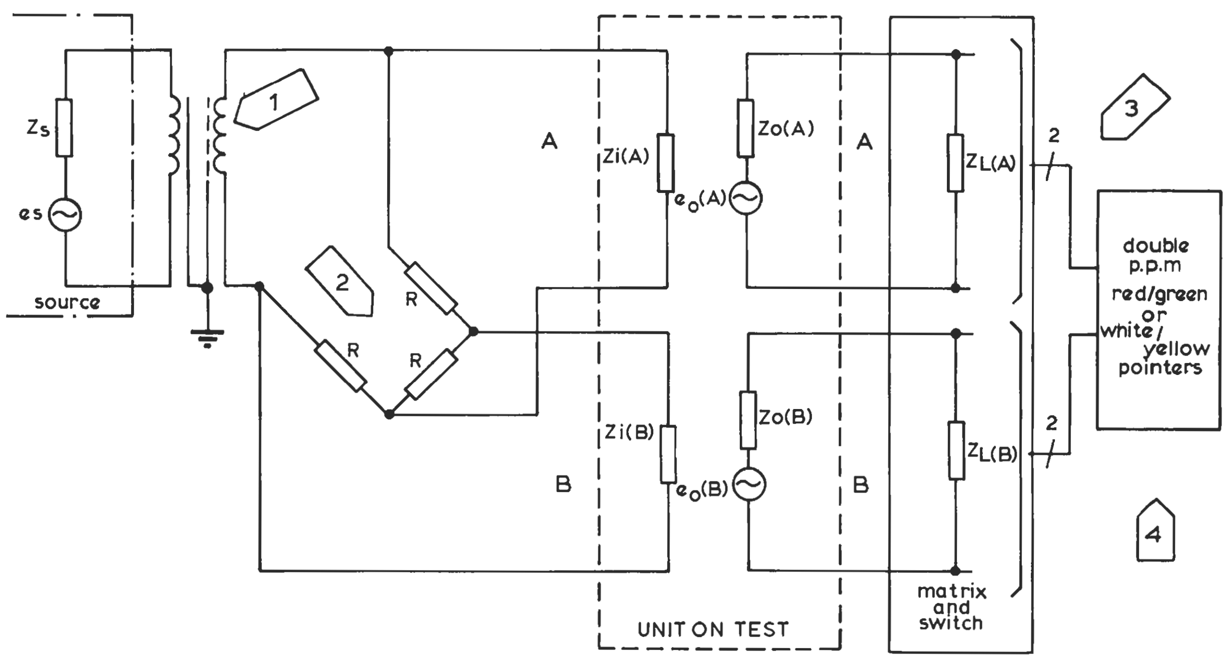


Fig. 10 Basic circuit showing derived signal level measurement in a stereo system to determine the phase difference between channel outputs

In Fig. 10:

1 *Signal-isolating transformer (Rep coil); see Appendix ATP-B

2 *Balanced-bridge splitting network ($R = Z_S$). This is required only if the unit/system under test has channel input impedances which are not constant with frequency, e.g. P.O. lines, equaliser circuits, etc.

3 *Circuit for combining (adding and subtracting) the two channel output signals, and with switching facilities whereby the levels of the derived sum and difference signals or, alternatively, the channel outputs can be checked; e.g. STEREO PPM PANELS PA8/288A and PA8/288B.

4 *Double PPM, e.g. STEREO PEAK PROGRAMME METERS ME12/10A and ME12/10B.

Note: in the equipments exampled above, the twin meter pointers are coloured to show:

	PA8/288A (ME12/10A)		PA8/288B (ME12/10B)	
A-channel signal	– RED	key at normal	– WHITE	key set to **A & B**
B-channel signal	– GREEN		– YELLOW	
M – signal	– RED	key set to **M & S**	– WHITE	key at normal
S – signal	– GREEN		– YELLOW	

ATP3.3 **MEASUREMENT METHODS (continued)**

Test Procedure

According to the convention normally observed in stereo broadcasting/recording practice, the circuits/units separately carrying the two components of the stereo signal are identified as forming (or being connected in) Channel A and Channel B to produce output signals A and B, respectively.
The following instructions are given in terms of tests performed using the STEREO PPM PANELS PA8/288 A & B, or similar equipment.

1. Initially, check the adjustment of the measuring equipment; e.g. for the stereo PPM equipment listed above, the basic line-up procedure is as follows:
   (i) Apply a 1 kHz signal at normal level to the Channel A and Channel B inputs. Set the function change-over switch to **A & B**. Check that the meter pointers (Red and Green, or White and Yellow) both indicate **4**, i.e. that the A and B measurement channels are of equal gain.
   (ii) Switch to **M & S**. Check that the M-signal (Red or White pointer) increases by 3 dB to **4¾** (see Appendix ATP-D) and the S-signal (Green or Yellow pointer) reads below 1 with the **S + 20** button pressed.

2. Apply a signal at a mid-band frequency (usually 1 kHz) and at zero level to the Channel-A and Channel-B inputs of the unit/system under test; feed the outputs to the measuring equipment. If necessary, adjust the gains of the equipment channels so that the output-signal levels are equal.

   e.g. operate the stereo PPM function switch to **A & B**; *if the overall gain of each channel is zero, both pointers will indicate* **4.**

3. Maintaining the same input to Channels A and B, measure the levels of the sum and difference of the A and B output signals, i.e. obtain values for $|A + B|$ and $|A - B|$.

   e.g. operate the stereo PPM function switch to **M & S**; *the M-signal indicated by the Red or White pointer, shows* $(|A + B| - 3)$ *dB and the S-signal, indicated by the Green or Yellow pointer, shows* $(|A - B| - 3)$ *dB.*

4. Determine the difference between the levels of the sum and difference signals, i.e. determine $|A + B| - |A - B|$. From this information, by reference to Table I[4] or otherwise, find the phase difference[5] between the two output signals.

   e.g. on the stereo PPM, note the difference between the two pointers (Red/Green or White/Yellow) giving M – S.

   [4] *Table I gives values of M* $(= |A + B| - 3$ *dB) and S* $(= |A - B| - 3$ *dB) and, on the assumption that the A and B output signals are both zero level (0·775 volt, PPM reading* **4**), *shows how the combination of these values can be used to obtain an approximate value for any difference in phase – from 0 to 180 degrees – between the A and B output signals.*

   [5] *The phase/frequency specification for some units or circuits is given either as a maximum value for the difference signal, S, or as a minimum value of separation between the sum and difference signals, i.e. a minimum for M – S. Such limit figures usually refer to measurements at some specified frequency in the upper part of the audio band (typically, 10 kHz).*

5. Repeat Steps 1 to 4 at other frequencies. (An upper band frequency of 12 kHz is usually specified for phase tests on tape-recording apparatus; different high audio spot frequencies may be chosen for other equipment.)

ATP3.3	MEASUREMENT METHODS (continued)

Caution to be observed when using the method of ATP3.3.3

In phase-characteristic tests on units or systems for which the differences to be measured cover a spread of more than 180 degrees, the method described above must be used with care because errors can occur if the sum and difference signal levels are checked at widely-separated frequencies. This is because the method is effectively based on the measurement of the included angle between two vectors representing the compared sinusoidal signals. The largest possible value of this angle is, of course, 180 degrees; this is therefore the largest angle that can be resolved by the test. Hence, if there is a change in phase difference of more than 180 degrees between two measurement frequencies – a change, say, of (360 – x) degrees (where $x < 180$) – the test result will show only a change of x degrees.

Note to Table 1 (see page 22)

The double PPM readings of derived-signal level separation (M – S) given in these columns are marked with positive and negative signs to indicate the *sense* of the separation. Thus:

(+) means that the Red (or White) pointer is to the **right** of the Green (or Yellow) pointer; the separation figure given is therefore the amount by which the M signal is **greater than** the S signal.

(–) means that the Red (or White) pointer is to the **left** of the Green (or Yellow) pointer; the separation figure given is therefore the amount by which the M signal is **less than** the S signal.

TABLE I

SUM = M = (|A + B| – 3) dB		DIFFERENCE = S = (|A – B| – 3) dB			Separation between M and S = (M – S)			PHASE DIFFERENCE BETWEEN A AND B (degrees)
dB (w.r.t. zero level)	PPM reading Red or White pointer	dB (w.r.t. zero level)	PPM readings Green or Yellow pointer, S + 20 button off	PPM readings Green or Yellow pointer, S + 20 button on	Difference in dB	Pointer separation: Red or White w.r.t. Green or Yellow, S + 20 button off	Pointer separation: Red or White w.r.t. Green or Yellow, S + 20 button on	
+3	4¾	–38	–	–	41	–	–	1
+3	4¾	–32	–	1	35	–	3¾ (+)	2
+3	4¾	–28·6	–	1¾	31·6	–	3 (+)	3
+3	4¾	–26	–	2½	29	–	2¼ (+)	4
+3	4¾	–24	–	3	27	–	1¾ (+)	5
+3	4¾	–22·6	–	≃3¼	25·6	–	≃1½ (+)	6
+3	4¾	–21	–	3¾	24	–	1 (+)	7
+3	4¾	–20	–	4	23	–	¾ (+)	8
+3	4¾	–19	–	4¼	22	–	½ (+)	9
+3	4¾	–18	–	4½	21	–	¼ (+)	10
+3	4¾	–17	–	4¾	20	–	0 (=)	11
+3	4¾	–16·6	–	≃5	19·6	–	≃ ¼ (–)	12
+3	4¾	–16	–	5	19	–	¼ (–)	13
+3	4¾	–15	–	5¼	18	–	½ (–)	14
+3	4¾	–14·7	–	5¼	17·7	–	≃ ½ (–)	15
+3	4¾	–14	–	5½	17	–	¾ (–)	16
+3	4¾	–13·6	–	≃5½	16·6	–	≃ ¾ (–)	17
+2·9	4¾	–13	–	5¾	15·9	–	1 (–)	18
+2·9	4¾	–12·5	1	≃6	15·4	≃3¾ (+)	≃1¼ (–)	19
+2·9	4¾	–12	1	6	14·9	3¾ (+)	1¼ (–)	20
+2·9	4¾	–11	1¼	–	13·9	3½ (+)	–	23
+2·8	4¾	–10	1½	–	12·8	3¼ (+)	–	26
+2·7	4¾	– 9	1¾	–	11·7	3 (+)	–	29
+2·7	4¾	– 8	2	–	10·7	2¾ (+)	–	32
+2·6	≃4¾	– 7	2¼	–	9·6	≃2½ (+)	–	37
+2·5	≃4½	– 6	2½	–	8·5	≃2 (+)	–	41
+2·3	4½	– 5	2¾	–	7·3	1¾ (+)	–	47
+2·1	4½	– 4	3	–	6·1	1½ (+)	–	53
+1·7	≃4½	– 3	3¼	–	4·7	≃1¼ (+)	–	60
+1·4	≃4¼	– 2	3½	–	3·4	≃ ¾ (+)	–	68
+0·8	≃4¼	– 1	3¾	–	1·8	≃ ½ (+)	–	78
0	4	0	4	–	0	0 (=)	–	90
–1·3	≃3¾	+ 1	4¼	–	– 2·3	≃ ½ (–)	–	105
–2·3	≃3½	+ 2	4½	–	– 4·3	≃1 (–)	–	125
–12·2	1	+ 3	4¾	–	–15·3	3¾ (–)	–	177

THE MEASUREMENT OF AUDIO SIGNAL-TO-NOISE RATIO

(PROVISIONAL INSTRUCTION)

Introduction

Since the 10th January 1977, the BBC, the IBA and the Post Office have been using a new audio-weighting network to make measurements of signal-to-noise ratio on audio circuits and equipment. On the same date, the BBC adopted a changed procedure for this measurement so as to conform with the procedures which obtain in the IBA, the Post Office and other broadcasting organisations. The BBC changes were implemented in accordance with the recommendation of a S.E.C. (Sound) Sub-committee as approved by the Designs Co-ordination Committee on 19th June 1975.

This provisional ATP gives a brief background to the changes and sets out the new measuring procedures. It also defines the terms which are to be used to distinguish quoted figures of measurements made using the new procedures and weighting network from those relating to previous measurements.

The New Weighting Network

C.C.I.R. Recommendation 468(78) proposed the use of a noise-weighting network with a loss-frequency characteristic as shown by the full-line in Fig. 1. The new characteristic takes into account the wider circuit bandwidths now in common use. The BBC, the IBA and the Post Office agreed to adopt the new characteristic and bring it into use when all of the organisations concerned had sufficient equipment in service.

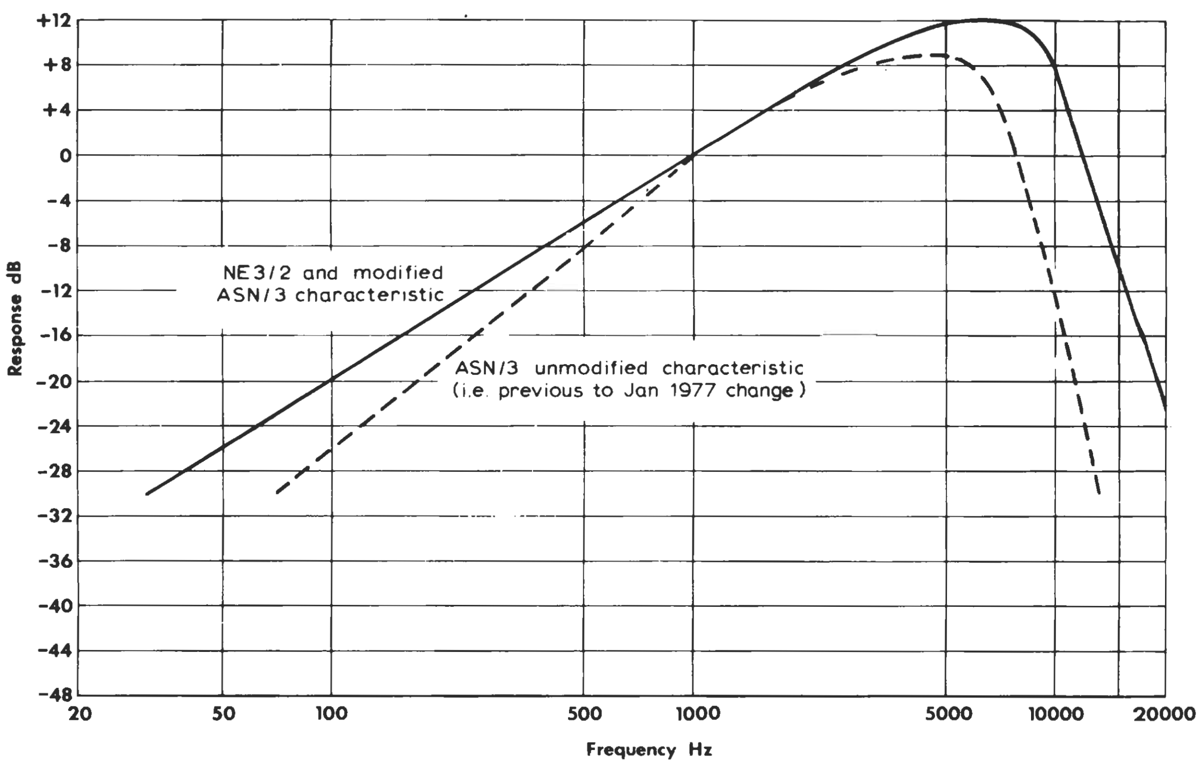


Fig. 1 Response/Frequency Characteristics of NE3/2 and modified ASN/3, ASN/4, NE3/1 Weighting Networks

The effect of the new network has been to alter the measured figures of signal-to-noise ratio; tolerances have therefore been changed to reflect these differences. The exact changes for particular types of equipment have been determined individually. However, a typical result is a reduction in the signal-to-noise ratio of 4 dB. The Post Office have agreed that this is the figure which will be applied to Post Office circuits. It is important to realize that although the new network results in a different figure of signal-to-noise ratio, it does not alter the amount of noise, i.e. the expected circuit performance remains the same.

A network with the response shown by the solid-line in Fig. 1 has been incorporated into the Programme Weighting Network NE3/2 and the A.C. Test Set EP14/1; also, except in some special instances, existing ASN/3, ASN/4 and NE3/1 weighting networks have been suitably modified.

Change of Signal-to-Noise Measurement Procedure

Most measurements on sound circuits are made at points of so-called relative-programme-level. At such a point zero-level tone reads '4' on a standard T.P.M. and programme signals peak to '6', i.e. +8 dB. The difference of 8 dB between zero-level tone and peak-programme is assumed when working with units and equipment or on monophonic circuits. However other circuits use different figures e.g.

stereophonic circuits	11 dB
compressed circuits	20 dB
test tapes	6 to 12 dB

Until January 1977, the signal-to-noise figure applicable to a circuit has been defined as the additional gain required to make the noise signal inherent in that circuit cause a standard T.P.M. to peak to '6'. Since the changeover date, the signal-to-noise ratio has been taken instead as the extra gain required to make the noise on the circuit cause a standard T.P.M. to peak to '4'. As a result of this change, the measured and quoted signal-to-noise figure is reduced to 8 dB.

Apart from bringing BBC noise-measurement practice into line with that of other organisations, the reason for the change is that it reduces the possibility of the measurement error which results from test equipment being overloaded by impulsive noise with high peak-to-mean ratio.

Procedure For Signal-to-Noise Ratio Measurement

The following procedure should always be used.

1. With tone at the specified level and frequency applied to the circuit under test, adjust the calibrated controls on the instrument measuring the circuit output so as to obtain the appropriate constant deflection on a standard T.P.M. (Exceptionally, this preliminary adjustment may be made using a programme signal; then, the controls are set so that the T.P.M. shows maximum programme peaks to '6').
2. Cut the tone (or programme) and correctly terminate the circuit.
3. Adjust the calibrated controls until the noise causes peaks to '4'.
4. Record the difference of control setting between steps 1 and 3. This is the measured signal-to-noise ratio.

The measurement described above may be made either weighted or unweighted. To make a weighted measurement when using a separate noise-weighting unit, connect the unit between the point at which the noise level is required to be measured and the measuring instrument. Adjust the controls as given in step 1. Use the measuring instrument to measure noise as given in steps 2,3 and 4.

For instruments which have the weighting network as an integral part of their circuit the line-up method given in the instrument handbook should be followed and then steps 2, 3 and 4 carried out.

Terminology

The following two abbreviations should, in future, be used throughout the BBC:

(a) dB4 – denotes the unweighted noise measurement peaked to '4' on a standard T.P.M.

(b) dB4w – denotes a weighted noise measurement peaked to '4' on a standard T.P.M.

Overall Difference in Quoted Figures

The effect of the change of weighting network and the alteration of the measurement procedure has been to reduce the weighted signal-to-noise ratio figure quoted for most equipment by a total of 12 dB; of this, 4 dB is due to the change of weighting network and 8 dB is due to the change in measurement procedure.

Further Changes

C.C.I.R. Recommendation 468 (78) also specifies the characteristics of a quasi-peak meter circuit designed to give readings of signal-to-noise ratio which are consistent with the subjective effect of the annoyance caused by all types of noise on a broadcast system. The BBC and the IBA are currently (1979) considering with the Post Office whether or not this circuit should ultimately replace the existing standard TPM for all noise measurements. If it is agreed that replacement is necessary, then the noise-measuring circuits in the EP14/1 A.C. Test Set would have to be modified. (Note that, for continuous random noise, a measured result using the recommended circuit is negligibly different from the result using a standard TPM, whereas there is a considerable difference in the results for some impulsive noise signals). If these instrumental changes were to be carried out, further changes to acceptance limits and nomenclature would follow; it would also no longer be possible, as it is at present, to make measurements of programme volume and noise signals using the same instrument.

APPENDIX ATP.A

EARTHING FAULTS AND THEIR CORRECTION

When a.f. units are interconnected for measurement purposes – either as part of a special test circuit or when remaining in the working position with test connections added to those of the existing installation – the normal earthing arrangements may be disturbed. This may allow spurious voltages to be produced, possibly causing mis-operation of the unit and/or incorrect measurement.

The following diagrams show:

(a) how such voltages may act in typical basic test circuits, and

(b) how the inclusion of a signal-isolating transformer (rep coil) can prevent or reduce these unwanted effects.

The examples given represent worst instances. In practice, not all the sources of interference shown in the illustrations produce voltages or currents of significant magnitude; sometimes, none of them are large enough to cause difficulty. But the possibility of their presence requires that suitable precautions be observed.

1. Reduction of interference in unbalanced circuits

Fig. A1 illustrates the possible sources of interference and the circulating currents produced when an unbalanced circuit has unscreened signal connections and is earthed at several points. Fig. A2 shows the improvement which can be gain by using interconnections and an input signal-isolating transformer.

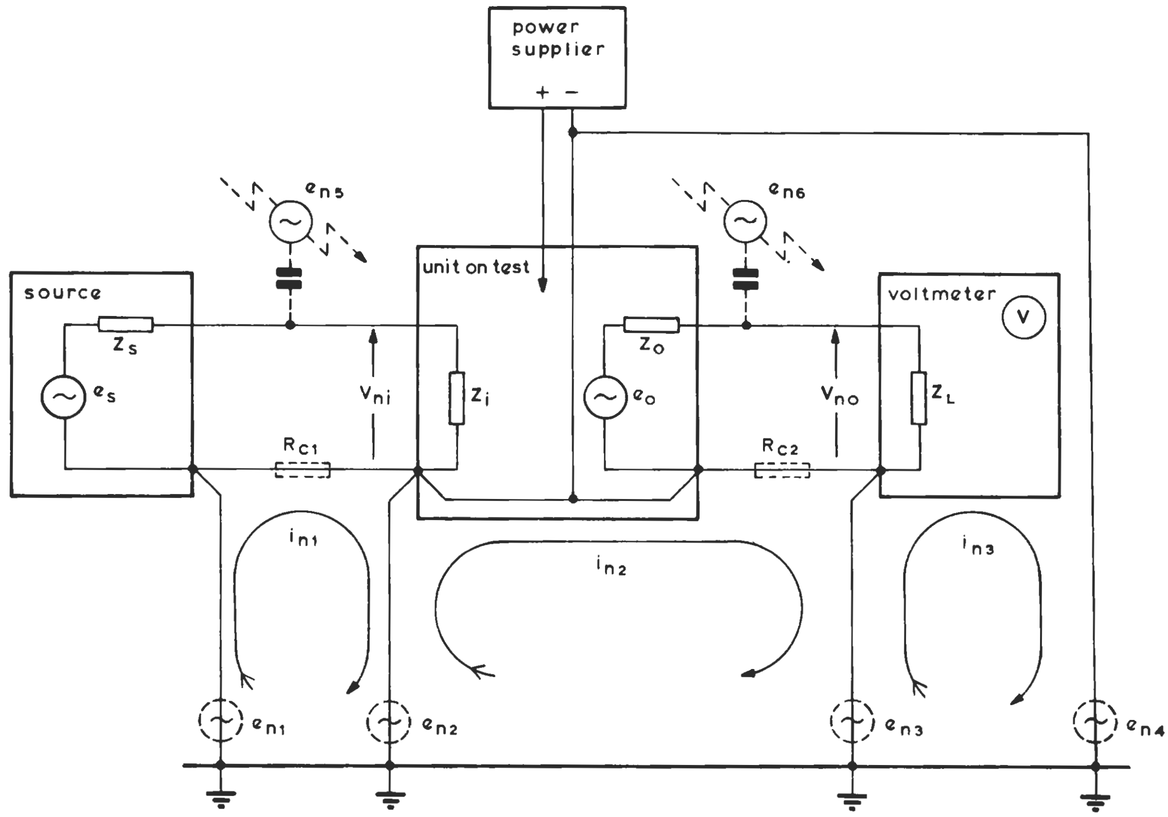


Fig. A1 Noise sources, with resulting interference currents and voltages, in an unbalanced circuit

In Fig. A1:

$e_{n1}, e_{n2}, e_{n3}, e_{n4}$ – are noise e.m.f's caused by separate earth connections following different routes (thus forming 'earth loops').

e_{n5}, e_{n6} – are noise e.m.f's caused by electrostatic fields coupling with exposed (i.e. unscreened) conductors.

i_{n1}, i_{n2}, i_{n3} – are noise currents flowing in signal conductors between the tested circuit, its source and its load. These currents may be produced by:
(a) the (algebraic) sum of various noise e.m.f's – e_{n1}, e_{n2}, etc – and/or
(b) induction from magnetic fields coupling with the earth loops.

R_{c1}, R_{c2} – are the (lumped) resistances of leads carrying the signal to and from the unit under test.

v_{ni}, v_{no} – are, respectively, noise voltages appearing at the input of the unit under test and the input of the voltmeter. They combine the results of the passage of circulating currents through R_{c1}, Z_i and R_{c2}, R_L and voltages directly induced by surrounding fields.

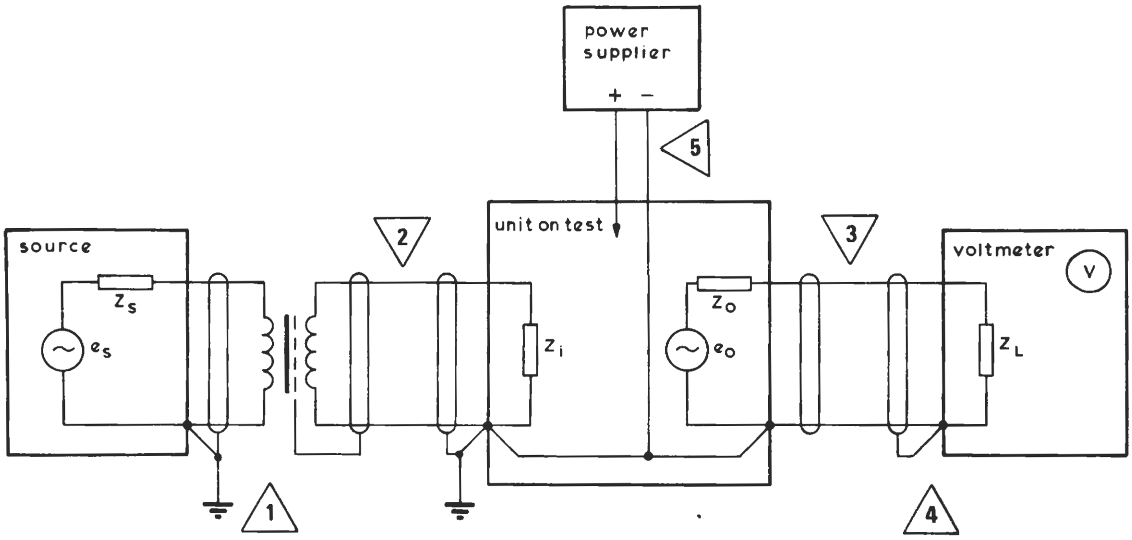


Fig. A2 Reduced effects of interference in an unbalanced unit when this is fed via a signal-isolating transformer and has screened input/output leads.

In Fig. A2:

△1 Source earth and the associated noise e.m.f. e_{n1} is isolated by the transformer which has an electrostatic screen.

△2 Input lead screened from electrostatic fields; conductor and transformer screens are connected to unit earth so that current from e_{n2} (in Fig. A1) cannot flow through conductor/screen capacitance.

△3 Output lead screened from electrostatic fields; screen connected to 'earthy' side of voltmeter.

△4 Voltmeter earthed via screen and 'earthy' output lead from unit.

△5 Power supplier earthed only via unit, i.e. it is free from any separate earth connection.

2. Reduction of interference in balanced circuits

Fig. A3 illustrates interference conditions in a balanced circuit. Fig. A4 shows the partial correction which is possible using screened signal leads and a signal-isolating transformer.

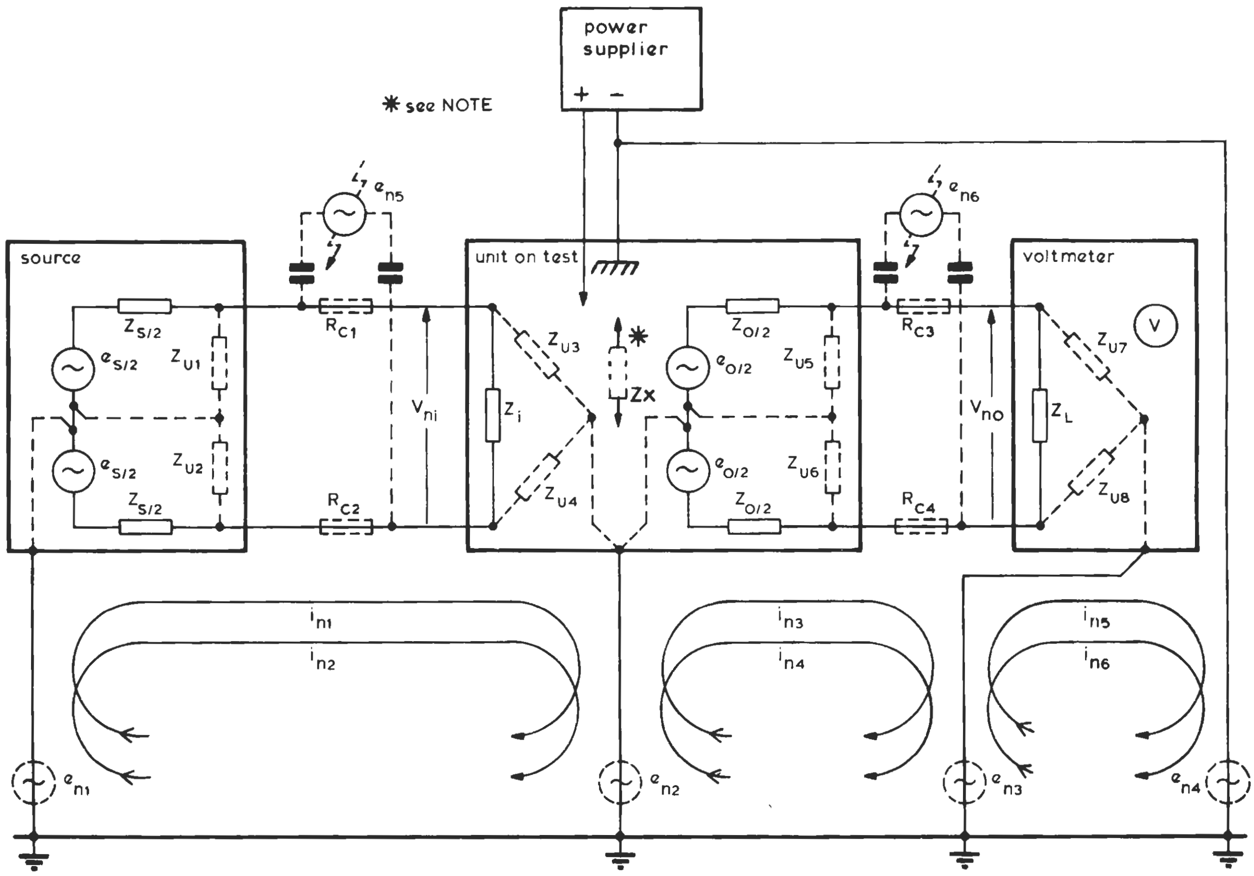


Fig. A3 Noise sources, with resulting interference currents and voltages in a balanced circuit

**NOTE*

An appreciable impedance, shown as Zx, may exist within the unit between the supply common rail and the unit chassis earth. Circulating noise currents may pass through this, and produce a voltage. It is not possible in a simplified diagram such as Fig. A3 to illustrate the points of derivation or application of such a voltage (there may be more than one in each instance). In Fig. A4, a direct connection is drawn here between the common rail and the chassis. This is not intended to indicate a change in circuit arrangement; it simply shows that, with the removal of the separate power supplier earth, circulating currents can no longer flow through any impedance which is present and hence it has no effect.

In Fig. A3:

$e_{n1}, e_{n2}, e_{n3}, e_{n4}$ – are noise e.m.f's caused by separate earth connections following different routes (thus forming 'earth loops').

e_{n5}, e_{n6} – are noise e.m.f's caused by electrostatic fields coupling with exposed (i.e. unscreened) conductors.

$i_{n1}/i_{n2}, i_{n3}/i_{n4}$, – are noise currents flowing in signal conductors between the tested circuit, its source and its load. These currents may be produced by:

(a) the (algebraic) sum of various noise e.m.f's – e_{n1}, e_{n2}, etc – and/or
(b) induction from magnetic fields coupling with the earth loops.

Generally, the noise e.m.f's generate currents which are in COMMON MODE (see **ATP1 TERMINATION MEASUREMENTS***). Hence, the circuit balance should be as accurate as possible in order to minimize the effects of these currents.*

$R_{c1}/R_{c2}, R_{c3}/R_{c4}$ – are the (lumped) resistances of leads carrying the signal to and from the unit under test.

$Z_{u1}/Z_{u2}, Z_{u3}/Z_{u4}$
$Z_{u5}/Z_{u6}, Z_{u7}/Z_{u8}$ – are pairs of impedances representing the effect of unbalance possibly present in the source, the unit under test (input and output circuits) and the measuring voltmeter.

v_{ni}, v_{no} – are, respectively, noise voltages appearing at the input of the unit under test and the input of the voltmeter. They combine the results of the passage of circulating currents through the various resistances and impedances listed above, and voltages directly induced by surrounding fields.

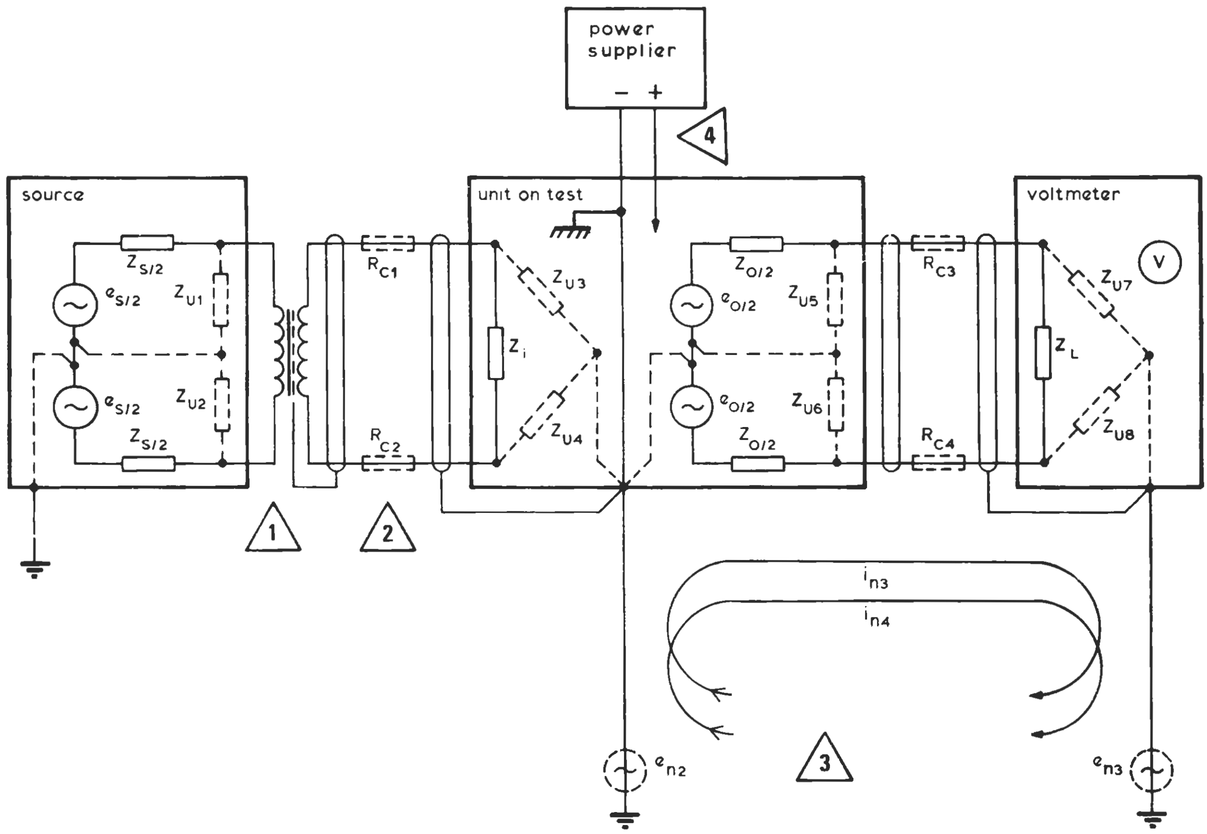


Fig. A4 Reduced effects of interference in a balanced circuit when this is fed via a signal-isolating transformer and has screened input/output leads.

in Fig. A4:

1 Source earth (and the associated noise e.m.f., e_{n1} in Fig. A3) is isolated by the transformer having a high common-mode rejection (see Appendix B) and also an electrostatic screen.

2 Input lead screened from electrostatic fields; conductor and transformer screens are connected to unit earth so that current from e_{n2} cannot flow through conductor/screen capacitance.

3 A proportion of the noise currents circulating at the unit output will remain because of the separate earth on the voltmeter. But if the voltmeter has a well balanced input circuit (i.e. if, in Fig. A4, $Z_{u7} = Z_{u8}$) the interference voltage adding to the output being measured will be negligibly small.

4 Power supplier earthed only via unit, i.e. it is free from any separate earth connection.

APPENDIX ATP.B

BBC-DESIGNED SIGNAL-ISOLATING TRANSFORMERS (REPEATING COILS)

A signal-isolating transformer, otherwise called a repeating (rep) coil, is a component which may be used to carry an audio signal across the junction between two parts of a circuit.
There are two main reasons for using such a transformer:

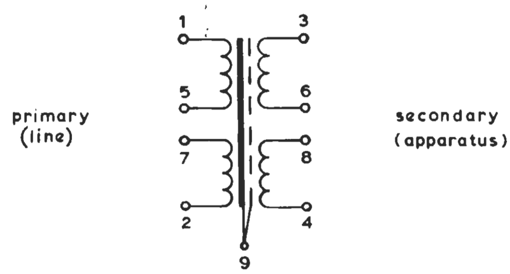
(a) If the circuit is **balanced** on one or both sides of the junction, the transformer acts to preserve the required degree of balance by having one winding (or set of windings) which is symmetrically constructed so that it is balanced in all respects.

(b) If the circuit is **unbalanced** on one or both sides of the junction, an electrostatic screen between the primary and secondary windings of the transformer acts to prevent both the transfer of interfering components caused by noise currents flowing in the 'earthy' lead of the unbalanced circuit or circuits, and spurious coupling of the audio signal itself.

These transformers may have 1:1 primary-to-secondary turns ratio so as to maintain the same source impedance. Alternatively, the turns ratio may be other than 1:1 in order to provide for an impedance change.

There are four signal-isolating transformers of BBC design and manufacture which are recommended for use. Brief details of these are given below.

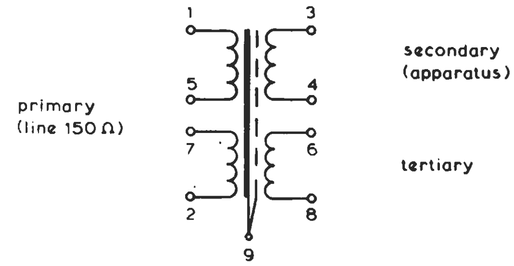
(i) **Type LL/63R (obsolescent) and LL/245/H12 (equivalent)**



1:1 turns ratio for use between 600-ohm impedances.

	LL/63R	LL/245/H12
Winding resistance: Primary = Secondary	30 ohms	9.5 ohms
Inductance: Primary = Secondary	10 H at 30 Hz	10 H at 40 Hz
Leakage inductance (referred to primary)	3 mH	1 mH
Max. signal level (0.3 per cent T.H.D. at 50 Hz)	+20 dB (8 V r.m.s.)	+20 dB (8 V r.m.s.)
Longitudinal balance (Common-mode rejection ratio)	75 dB at 50 Hz 55 dB at 10 kHz	80 dB at 1 kHz 60 dB at 10 kHz
Phantom balance	80 dB at 50 Hz and 1 kHz 70 dB at 10 kHz	80 dB at 1 kHz 60 dB at 10 kHz

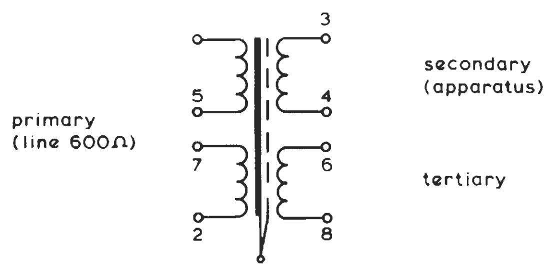
(ii) **Type LL/216R (obsolescent) and LL/238/H12 (equivalent)**



1:2 turns ratio for matching 150 ohms to 600 ohms
(with tertiary winding – 2:1 turns ratio – providing a monitoring feed)

		LL/216R	LL/238/H12
Winding resistance:	Primary	5.5 ohms	7.5 ohms
	Secondary	2.3 ohms	30 ohms
	Tertiary	15.5 ohms	5 ohms
Inductance:	Primary	6.8 H at 50 Hz	6.7 H at 50 Hz
Leakage inductance (referred to primary)		1.1 mH	0.38 mH at 10 kHz
Max. (primary) signal level (0.3 per cent T.H.D. at 50 Hz)		+20 dB (8 V r.m.s.)	+15 dB (4 V r.m.s.)
Longitudinal balance		75 dB at 50 Hz	80 dB at 1 kHz
(Common-mode rejection ratio)		55 dB at 10 kHz	60 dB at 10 kHz
Phantom balance		80 dB at 50 Hz and 1 kHz	80 dB at 1 kHz
		70 dB at 10 kHz	60 dB at 10 kHz

(iii) **Type LL252/H12**



1:1 turns ratio for matching 600 ohms to 600 ohms
(with tertiary winding – 4:1 turns ratio – providing a monitoring feed)

Winding resistance:	Primary	24 ohms †
	Secondary	30 ohms †
	Tertiary	6.5 ohms †
Inductance:	Primary	22 H at 50 Hz †
Leakage inductance (referred to primary)		1.6 mH at 10 kHz †
Max. (primary) signal level (0.3 per cent T.H.D. at 50 Hz)		+20 dB
Longitudinal balance		80 dB at 50 Hz and 1 kHz
(Common-mode rejection ratio)		60 dB at 10 kHz
Phantom balance		80 dB at 1 kHz
		60 dB at 10 kHz

† these are provisional figures and are subject to change.

Note that these rep coils are produced with an electrostatic screen connected to the core. The obsolescent R-size coils are totally enclosed in mu-metal screening cans which makes it difficult to take off the screen-core connection. The modern H12-size coils, however, are only partially enclosed by the magnetic screen with the connections between core and screen being made by a linking wire which is easily accessible.

APPENDIX ATP.C

IMPERFECTIONS IN BALANCED OUTPUT CIRCUITS

In Fig. C1, the three main aspects of balance imperfection in output circuits are illustrated in the form of equivalent circuits. Full lines are used for circuits carrying wanted signals; dotted lines denote sources and paths of unwanted signals produced by interaction.

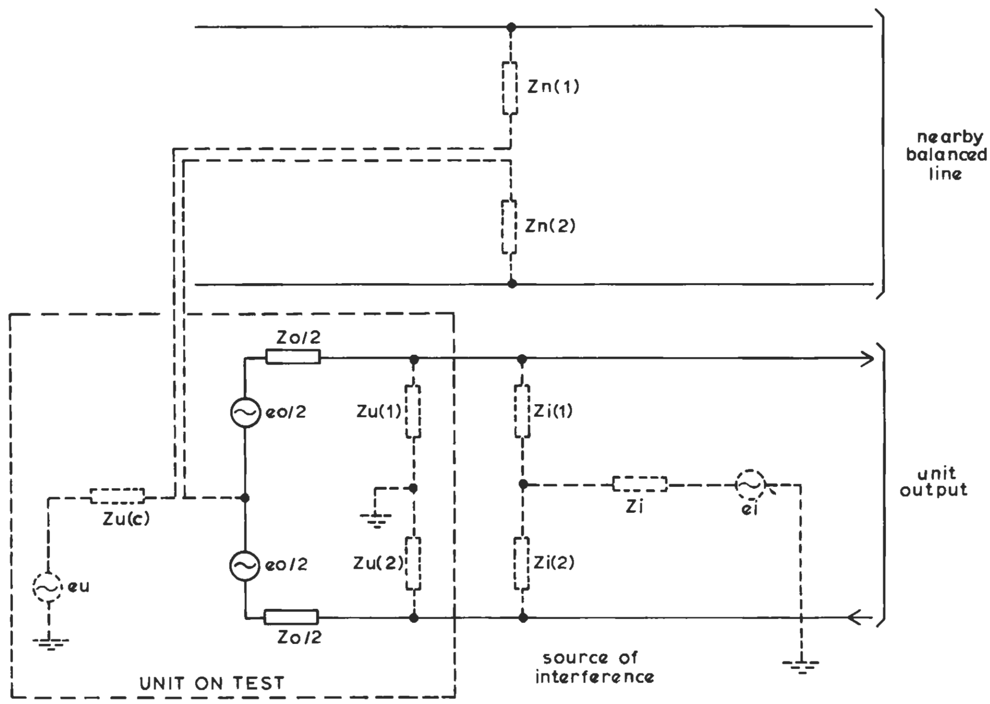


Fig. C1 Balanced output circuit: imperfections

In Fig. C1:-

e_o, Z_o	represent an ideal balanced source which generates the wanted output from the unit/circuit on test; i.e. Z_o is the output impedance of the unit.
e_u, $Z_{u(c)}$	represent the effective source of e.m.f. resulting from unbalance in the unit/circuit output (including the internal impedance of this source)
$Z_{u(1)}$, $Z_{u(2)}$	represent imperfections in output balance of the unit/circuit under test. The degree of unbalance by the amount $Z_{u(1)}$ differs from $Z_{u(2)}$.
$Z_{n(1)}$. $Z_{n(2)}$	represent the coupling (mainly capacitive) which exists between the source of unbalance e.m.f. in the tested unit/circuit and a neighbouring balanced line.
e_i, Z_i	represent a nearby source of interference.
$Z_{i(1)}$, $Z_{i(2)}$	represent the coupling (inductive and capacitive) which exists between e_i, Z_i and the balanced output lines of the unit/circuit under test.

The output balance test normally specified for BBC equipment provides a figure which gives the approximate magnitude of e_u (in Fig. C.1), measured under artificial conditions which are, however, considered sufficiently representative for the purpose of comparison.

The more comprehensive tests specified for internations use* result in a more realistic value for e_u as well as one for its internal impedance, $Z_{u(c)}$. The other two unwanted effects of unbalance illustrated in Fig. C.1, i.e. those resulting from interaction between e_u, $Z_{u(c)}$ and $Z_{n(1,2)}$ and between e_i, Z_i and $Z_{i(1,2)}$, $Z_{u(1,2)}$, are also made the subject of measurement in these documents. These effects are considered to be of second-order importance, however, and are not usually measured in BBC practice.

***I.E.C.** Publication 268-3, Part 3 or **BRITISH STANDARDS INSTITUTION**. BS5428, Part 2: Methods for Specifying and Measuring the Characteristics of Sound Systems Equipment.
C.C.I.T.T. 5th Plenary Assembly, 1972. Vol IV – 1; Rec. 0.121.
C.C.I.T.T. 5th Plenary Assembly, 1972 Vol. III – 3; Question 4/XIV

APPENDIX ATP-D

LINE-UP AND PROGRAMME LEVELS

The existence of two versions of a stereophonically-produced programme can lead to difficulties in monitoring because at some places, where the full-signal is available, the A and B signals can be monitored individually whereas at others the $(A + B)$ signal* only is available. The problems arise because the A and B signals can be either identical or non-identical. When the A and B signals are identical so that $A \equiv B$, the peak level of the $(A + B)$ signal (whether tone or programme) is greater by 6 dB than that of either A or B alone. When the two signals are not identical the peak level of the $(A + B)$ signal can be from 0 to 6 dB greater than that of either A or B alone, depending upon the degree of correlation. For practical purposes the average level of $(A + B)$ is taken to be 3 dB above that of A or B. In the special instances where the source is at an extreme of the stereophonic stage, only the A or the B signal is present and the $(A + B)$ signal therefore is at the same level as that signal. Thus there *can* be differences of up to 6 dB between the levels indicated at the stereophonic and monophonic monitoring points.

A method adopted to minimise the difficulties is to adjust the gain of the outputs so that for identical signals the $(A + B)$ level is 3 dB greater than the level of either A or B alone. This means that for most of the time, with normal programme signals, stereophonic and monophonic monitoring points have substantially the same indications and the total potential discrepancy of 6 dB is thus divided about equally between the stereophonic and monophonic signals. Normal line-up procedure is to use identical signals comprising line-up tone at –3 dBm0 in phase on both channels and this results in the $(A + B)$ output, after adjustment, being at zero level so that observers in non-stereophonic areas need not be aware that the signal is derived from a stereophonic source.

Table 1 gives a summary of the levels for various conditions. Two examples of identical signals are tone applied to the input of both channels in parallel, and exactly central speech. Normal stereophonic material, however, is in general of non-identical form.

TABLE 1

LEVELS MEASURED WITH 3-dB GAIN DIFFERENCE
BETWEEN STEREOPHONIC AND MONOPHONIC OUTPUTS

Nature of Signals	*Level Measured on P.P.M.* (in dBm0; see ATP-G)		
	A	*B*	*A + B*
Identical	zero	zero	+3
	–3	–3	zero
	+5	+5	+8
Non-identical	+8	+8	+8†
	+11	*nil*	+8
	nil	+11	+8

*Although the M signal is theoretically $\frac{1}{2}(A + B)$, the division by two is often ignored. This is especially so in programme control areas where the levels of all the signals can usually be adjusted independently and it is therefore convenient to regard the sum as a simple addition of A and B.

†This level is +8 dBm0 on average, but can vary from +5 to +11 dBm0

Monitoring should, in general, be mainly with respect to the (*A* + *B*) signal because it is important to avoid changes in loudness for listeners to the monophonic version of the programme. This gives rise to some difficulty because, as can be seen from Table 1, a source entirely at one side of the stage can peak to +11 dBm0 without any indication of excess level on the (*A* + *B*) P.P.M. It can be shown‡ that the peak value of the multiplex signal which modulates the transmitter is determined by the peak value of whichever is the larger of the two signals *A* and *B*. A source predominantly to one side may therefore cause operation of limiters which precede the coder and it is thus necessary at the programme control point, to pay particular attention to the *A* and *B* P.P.M. indications when such conditions are likely to occur.

The (*A* – *B*) signal has little practical value in monitoring of programme material but is frequently used as a check of channel balance. Because identical signals should not produce any (*A* – *B*) output, the channels can be balanced by adjusting for a null whilst listening to the (*A* – *B*) signal. This gives a more accurate balance than adjusting for equality by direct measurement

‡See Section 2.2 in Technical Instruction P4: Stereophonic Broadcasting

APPENDIX ATP.E

dB Conversion Tables

Power Ratios

dB	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	1.000	1.023	1.047	1.072	1.096	1.122	1.148	1.175	1.202	1.230
1	1.259	1.288	1.318	1.349	1.380	1.413	1.445	1.479	1.514	1.549
2	1.585	1.622	1.660	1.698	1.738	1.778	1.820	1.862	1.905	1.950
3	1.995	2.042	2.089	2.138	2.188	2.239	2.291	2.344	2.399	2.455
4	2.512	2.570	2.630	2.692	2.754	2.818	2.884	2.951	3.020	3.090
5	3.162	3.236	3.311	3.388	3.467	3.548	3.631	3.715	3.802	3.890
6	3.981	4.074	4.169	4.266	4.365	4.467	4.571	4.677	4.786	4.898
7	5.012	5.129	5.248	5.370	5.495	5.623	5.754	5.888	6.026	6.166
8	6.310	6.457	6.607	6.761	6.918	7.079	7.244	7.413	7.586	7.762
9	7.943	8.128	8.318	8.511	8.710	8.913	9.120	9.333	9.550	9.772
10	10.00	10.23	10.47	10.72	10.96	11.22	11.48	11.75	12.02	12.30
11	12.59	12.88	13.18	13.49	13.80	14.13	14.45	14.79	15.14	15.49
12	15.85	16.22	16.60	16.98	17.38	17.78	18.20	18.62	19.05	19.50
13	19.95	20.42	20.89	21.38	21.88	22.39	22.91	23.44	23.99	24.55
14	25.12	25.70	26.30	26.92	27.54	28.18	28.84	29.51	30.20	30.90
15	31.62	32.36	33.11	33.88	34.67	35.48	36.31	37.15	38.02	38.90
16	39.81	40.74	41.69	42.66	43.65	44.67	45.71	46.77	47.86	48.98
17	50.12	51.29	52.48	53.70	54.95	56.23	57.54	58.88	60.26	61.66
18	63.10	64.57	66.07	67.61	69.18	70.79	72.44	74.13	75.86	77.62
19	79.43	81.28	83.18	85.11	87.10	89.13	91.20	93.33	95.50	97.72

Conversion Table for Large Ratios

dB	ratio	dB	ratio	dB	ratio
20	100.0	40	$10\ 10^3$	60	$1\ 10^6$
22	158.5	42	$16\ 10^3$	70	$1\ 10^7$
24	251.2	44	$25\ 10^3$	80	$1\ 10^8$
26	398.1	46	$40\ 10^3$	90	$1\ 10^9$
28	631.0	48	$63\ 10^3$	100	$1\ 10^{10}$
30	1.10^3	50	$100\ 10^3$		
32	$1.58\ 10^3$	52	$158\ 10^3$		
34	$2.51\ 10^3$	54	$251\ 10^3$		
36	$3.98\ 10^3$	56	$398\ 10^3$		
38	$6.31\ 10^3$	58	$631\ 10^3$		

To convert decibels to nepers – multiply by 0.1151

To convert nepers to decibels – multiply by 8.6860

Voltage or Current Ratios

dB	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	1.000	1.012	1.023	1.035	1.047	1.059	1.072	1.084	1.096	1.109
1	1.122	1.135	1.148	1.161	1.175	1.189	1.202	1.216	1.230	1.245
2	1.259	1.274	1.288	1.303	1.318	1.334	1.349	1.365	1.380	1.396
3	1.413	1.429	1.445	1.462	1.479	1.496	1.514	1.531	1.549	1.567
4	1.585	1.603	1.622	1.641	1.660	1.679	1.698	1.718	1.738	1.758
5	1.778	1.799	1.820	1.841	1.862	1.884	1.905	1.928	1.950	1.972
6	1.995	2.018	2.042	2.065	2.089	2.113	2.138	2.163	2.188	2.213
7	2.239	2.265	2.291	2.317	2.344	2.371	2.399	2.427	2.455	2.483
8	2.512	2.541	2.570	2.600	2.630	2.661	2.692	2.723	2.754	2.786
9	2.818	2.851	2.884	2.917	2.951	2.985	3.020	3.055	3.090	3.126
10	3.162	3.199	3.236	3.273	3.311	3.350	3.388	3.428	3.467	3.508
11	3.548	3.589	3.631	3.673	3.715	3.758	3.802	3.846	3.890	3.936
12	3.981	4.027	4.074	4.121	4.169	4.217	4.266	4.315	4.365	4.416
13	4.467	4.519	4.571	4.624	4.677	4.732	4.786	4.842	4.898	4.955
14	5.012	5.070	5.129	5.188	5.248	5.309	5.370	5.433	5.495	5.559
15	5.623	5.689	5.754	5.821	5.888	5.957	6.026	6.095	6.166	6.237
16	6.310	6.383	6.457	6.531	6.607	6.683	6.761	6.839	6.918	6.998
17	7.079	7.161	7.244	7.328	7.413	7.499	7.586	7.674	7.762	7.852
18	7.943	8.035	8.128	8.222	8.318	8.414	8.511	8.610	8.710	8.810
19	8.913	9.016	9.120	9.226	9.333	9.441	9.550	9.661	9.772	9.886

Conversion Table for Large Ratios

dB	ratio	dB	ratio	dB	ratio
20	10.00	40	100.0	60	$1\ 10^3$
22	12.59	42	125.9	70	$3.2\ 10^3$
24	15.85	44	158.5	80	$1\ 10^4$
26	19.95	46	199.5	90	$3.2\ 10^4$
28	25.12	48	251.2	100	$1\ 10^5$
30	31.62	50	316.2		
32	39.81	52	398.1		
34	50.12	54	501.2		
36	63.10	56	631.0		
38	79.43	58	794.3		

To convert decibels to nepers – multiply by 0.1151

To convert nepers to decibels – multiply by 8.6860

APPENDIX ATP.F

SUBJECTIVE ASSESSMENT OF SOUND AND PICTURE QUALITY

C.C.I.R.5-point scale

The C.C.I.R. recommends that a five-point scale should be used for the subjective assessment of television pictures (Recommendation 500) and also for radio and television sound (Recommendation AE/10). This scale is also used by the C.C.I.T.T. for types of transmission other than telephony (Recommendation N-64). The BBC, in common with other broadcasting authorities throughout the world, has therefore adopted the C.C.I.R. five-point scale in place of the previously used EBU six-point scale. The five-point scale has the following descriptions.

C.C.I.R.5-POINT SCALE

Quality	Grade	Impairment
Excellent	5	Imperceptible
Good	4	Perceptible but not annoying
Fair	3	Slightly annoying
Poor	2	Annoying
Bad	1	Very annoying

All BBC documents using the C.C.I.R. five-point scale should include a reference noting that the five-point scale has been used.

Conversion between C.C.I.R.5-point and EBU 6-point scales

The EBU six-point assessment scale differed from the C.C.I.R. scale not only in having six grades instead of five, but also in that the highest number represented the lowest quality. The EBU six-point scale had the following descriptions:

EBU 6-POINT SCALE

Quality	Grade	Impairment
Excellent	1	Imperceptible
Good	2	Just perceptible
Fairly good	3	Definitely perceptible but not disturbing
Rather poor	4	Somewhat objectionable
Poor	5	Definitely objectionable
Very poor	6	Unusable

If it is necessary to convert from one scale to the other the following approximate expression can be used:

$$A_5 = 5.8 - 0.8A_6$$

Where A_5 = assessment using the C.C.I.R. five-point scale

A_6 = assessment using the EBU six-point scale

Where results have been obtained by conversion, using this equation, it should be stated that such a conversion has been carried out.

APPENDIX ATP.G

THE USE OF THE dB IN BBC AUDIO PRACTICE

INTRODUCTION

Many of the quantities used to define signals in sound (and television) broadcasting can be expressed in terms of the *Bel* - symbol **B** - or, more familiarly, in tenths of this, i.e. in *decibels* - symbol *dB.*

The method of using decibels to quantify signals and other parameters was developed from the idea of *Transmission Units* which was proposed by American engineers in 1924 (see **Note 1** at the end of this Appendix). It is based on the concept of comparing any pair of values by means of the **logarithm of their ratio.**

The two main advantages of doing this are:

(i) many calculations are made simpler because multiplication is replaced by addition;

(ii) the comparision (and statement) of large and small values, particularly the extremes, is easier in the absence of chains of zeros before or after the decimal point.

Beyond this fundamental idea, further benefit can be gained by adding other symbols to the basic dB notation. Letters and/or numbers can be included to show, according to an agreed (standard) terminology, the relevant conditions of reference or measurement relating to a quoted value. The following list gives the dB notations defined and explained in detail in this Appendix.

dB — strictly, shows comparision between two power values, but also commonly used for comparision between two voltage values or two current values (impedances not considered).

dB(mW) — shows comparison between a measured power value and a reference of 1 milliwatt.

dB (0.775V) — shows comparison between a measured voltage value and a reference of 0.775 volt r.m.s.

dBu — an abbreviation for dB (0.775V).

dB4 — a BBC notation for *unweighted* noise measurement made on a PPM or TPM; figure gives either a signal-to-noise ratio or an absolute noise level.

dB4w — a BBC notation for weighted noise measurement made on a PPM or TPM. Weighting to CCIR 468-2; otherwise as for **dB4,** above.

dBr — shows comparison between a measured programme level and a specified reference programme level.

dBm0 — shows comparison between a measured level of line-up tone and a specified line-up level which, in turn, is referred to a specified programme level.

dBq0 — a (signal-to-noise) ratio showing *unweighted* comparison, by means of a quasi-peak meter to CCIR 468-2, between a measured noise voltage and a specified line-up level which, in turn, is referred to a specified programme level as for **dBm0,** above.

dBq0p — a (signal-to-noise) ratio showing *weighted* comparison by means of quasi-peak meter. Weighting to CCIR 468-2; otherwise, as for **dBq0,** above.

dBA — a ratio showing comparison between a sound pressure, measured weighted to IEC 179, characteristic A, and a specified reference pressure.

DEFINITION OF THE dB

The basic definition of the Bel - and, therefore, of the decibel - is given in the IEC publication 27-3 (1974): **Logarithmic quantities and units** (see **Note 2**). The words of this Standard definition effectively lead to the better-known expression relating two values of power, P_1 and P_2, or two values of voltage, V_1 and V_2, which show that:

for relating powers directly: $$N \text{ Bels} = \lg \frac{P_1}{P_2}$$

so that: $$N \text{ dB} = 10 \lg \frac{P_1}{P_2}$$

or, for relating powers by comparison of voltage*: $$N \text{ Bels} = 2 \lg \frac{V_1}{V_2}$$

whence: $$N \text{ dB} = 20 \lg \frac{V_1}{V_2}$$

* *The expression for power comparison by voltage ratio is true only when the voltages are measured across the same impedance or across equal impedances.*

'lg' is recommended (see BSI 1991:1976) as the abbreviation for common logarithms – otherwise written '$\log_{10}$'. Similarly, 'ln' stands for natural logarithms, i.e. '$\log_e$'. See also the definition of neper in ***Note 1.***

USE OF THE dB

From the definitions, it can be seen that the decibel is not a unit but a means of expressing relationships. Thus, because it always gives comparison *by ratio,* a dB (without suffix) is, of itself, dimensionless; it serves only to show, in the form of a number, how one value stands in relation to another - the absolute magnitudes of the compared quantities need not be stated. Hence, in the absence of a suffix, a dB figure simply indicates a gain or a loss taking place in some process of transmission or translation of energy.

In all other instances of its use - where a suffix is included with the letters 'dB' — the size of one quantity is given in terms of the known size of another *of the same type;* like is always compared with like. The quoted figure then has the dimension implied by the suffix which, by separate definition, specifies the reference with which comparison is made.

In practice, three categories of suffix can be identified. These indicate:

(a) **Reference -** the value of the reference quantity, given as an abbreviation comprising letters and numbers, **enclosed in brackets,**† e.g. dB (1mW), dB (1V), etc.. Generally, the value '1' is omitted; thus, where a number is not given, '1' is understood.

† *Nomenclature in accordance with the IEC Standard 27-3 (1974)*

(b) **Qualification of Bandwidth or Weighting** — an identifying letter or number (not in brackets) refers to a standard definition of the bandwidth limits or weighting factor/characteristic. The value of a reference quantity may be stated or inferred in this definition; e.g. dBA, below.

(c) **Method of Measurement** — an identifying letter or number (not in brackets) refers to a standard definition of the type of test equipment, and/or method, to be used in the measurement. The value of a reference quantity may be stated or inferred in this definition; e.g. dBq0, below.

There are two further characteristics of the decibel which make it different from the dimensional units used to quantify electrical parameters.

One difference is that, where a positive or negative sign is included with a dB value, this does not infer a polarity or 'sense'. The signs are interpreted thus:

(a) for a value given in dB only - **without a suffix** - a positive sign implies an increase (a gain) whereas a negative sign is a decrease (a loss);

(b) for a value in dB **with a suffix,** a positive sign means that the quoted value is greater than the reference; a negative value is therefore less.

The second important difference relates to this use of positive and negative signs. It concerns the meaning attached to the value of zero, i.e. 0 dB. In all other means of measurement, zero denotes an absence of the quantity being measured. This is not so for the dB. Consider, again, the basic 'power-comparison' expression:

$$N \text{ dB} = 10 \lg \frac{P_1}{P_2}$$

N is zero when: $\frac{P_1}{P_2} = 1$

i.e. when $P_1 = P_2$

Without further information, this equality shows only that there is neither gain nor loss of power between P_1 and P_2. However, by extension, it leads to the fundamental concept of **reference level:** if P_2 is given an arbitrary (but appropriate) fixed value - i.e. is established as the reference - then all related values such as P_1 can be stated as a number of dB's greater (positive) or less (negative) than the reference or, **for zero dB, equal to it.**

dB NOTATION FOR GENERAL USE IN THE BBC

For Comparison of Power and Voltage

dB — These letters, **without suffix,** indicate the ratio of two values of power, P_1 and P_2, such that:

$$N \text{ dB} = 10 \lg \frac{P_1}{P_2}$$

A quoted positive number, +N dB, shows a **power gain** (where P_1 is greater than P_2); conversely, –N dB shows a **power loss.**

dB — The letters dB without suffix may also be used to indicate the ratio of two values of voltage,‡ V_1 and V_2, such that:

$$N \text{ dB} = 20 \lg \frac{V_1}{V_2}$$

A quoted positive number, +N dB, shows a **voltage amplification** (where V_1 is greater than V_2); conversely, –N dB shows a **voltage attenuation.** Two values of current may be similarly compared.

‡ *According to the original definition, the comparison of voltage by dB should be confined to voltages which are measured across equal impedances. In audio engineering practice, however, such a restriction on usage is not usually necessary because almost all measurements of signal amplitude are in terms of voltage. Hence, circuit impedance values need only be considered if account is to be taken of the power involved in some transmission process.*

For Measurement of Power and Voltage Values

dB (mW) — is the international standard (IEC) notation used to state a measured power level in relation to a reference level of **1 milliwatt.**§

§ *In broadcast engineering practice, the notation 'dBm' is frequently used to signify a power level referred to 1 milliwatt. For audio signals, the use of this notation is now deprecated because it is not in accordance with international recommendation and, even more important, because it is often wrongly applied to voltage values stated relative to 0.775 volt (this is mistakenly done for the reason explained below). Voltage comparison should properly be made using the notation defined immediately below. (The dBm 'power reference' nomenclature is, however, often used particularly for r.f. signal magnitudes.*

— When this reference level of power is dissipated in a resistance of 600 ohms, the value of r.m.s. voltage developed across that resistance is **0.775 volt.** This value has been adopted as the **reference voltage** for use in audio engineering practice (see below).

The resistance value of 600 ohms was taken as a standard because it was, at the time adopted, the most common value of characteristic impedance for transmission lines.

dB (0.775V) — is the international standard (IEC) notation used to state a measured voltage level in relation to a reference level of 0.775 volt r.m.s. - see definition of **dB (mW),** above - **where neither the impedance at the point of measurement nor the impedance associated with the reference are taken into account.** Thus:

$$N \quad dB(0.775V) = 20 \lg \frac{V_x}{0.775V}$$

where V_x is the measured value of r.m.s. voltage giving a relative dB value, N.

Other reference voltages may be used, e.g. 1V, 1mV or 1μV, according to the requirement. The only stipulation here is that **the reference voltage must always be stated as a bracketed suffix** as shown.

dBu — is an abbreviation for dB (0.775V). At present (1980) this notation is used only by UK broadcasting organisations. Here, u simply stands for the number/letter assembly (0.775V); it does not have additional meaning. Therefore, in all respects, the notation dBu serves the same purpose as dB (0.775V).

The abbreviation is accepted for operational ease. The full suffix (0.775V) should always be used in formal documents and elsewhere when there is need for precise statement.

For the Measurement of Noise (BBC use only)

dB4 — denotes the **unweighted** measurement of noise peaking to **4** on a Test Programme Meter (i.e. a TPM; see **Notes 3 and 4**).

As explained in **ATP5.1 The Measurement of Audio Signal-to-Noise,** figures given in terms of dB4 quantify either:

(i) the **Signal-to-Noise Ratio,** which, at a point in a transmission chain, is the result of comparing the separate measurements of a sinewave (line-up) signal and the noise in the absence of any signal, or

(ii) the **Noise Level** which, in equipment test specifications, defines an operating characteristic, and is simply the magnitude of the noise voltage at the point of measurement (usually the output terminals) as indicated by the TPM attenuator settings.

The bandwidth of the measuring circuit should conform with that defined by Fig. 3 in Annex 1 of CCIR Rec 468-2.
At present (1980) ATP5.1 is issued in *Provisional* form only and does not yet cover the subject fully in the manner suggested by this reference. An ATP giving complete treatment will be issued following a final decision on the weighting and meter characteristics to be used in the BBC.

dB4w — denotes the **weighted** measurement of noise peaking to **4** on a TPM. The interpretation to be put on a dB4w figure is the same as for a dB4 figure according to (i) and (ii), above.
The weighting characteristic should conform with that defined by Table 1 and Fig. 1 in CCIR Rec. 468.2.

INTERNATIONAL dB NOTATIONS

The notations defined and described below are the subject of international recommendation. Although these notations have at present (1980) only limited use in BBC engineering practice, they are already used exclusively by some equipment manufacturers and by continental broadcasting organisations. The descriptions given here are intended to help explain the notations in terms which are appropriate to BBC usage.

For Sound Systems Signal Measurements

The signal appearing at any point in a sound broadcast chain will, in general, be either line-up tone or a programme signal. For the purpose of measurement and reference - particularly in terms of dB's - it is important to identify these two types of signal in such a way as to establish, without ambiguity:

(i) how they relate in magnitude to each other, and
(ii) how each relates in magnitude to signals of the same type, especially specified reference signals, appearing at other points in the chain.

Given these relationships, the absolute magnitudes of the signals can be calculated and hence the degree of modulation which the signals will cause at the transmitter can be determined.

In the BBC, the expressions *line-up level* and *programme volume* have been applied to test and programme signals; respectively, the magnitudes of both types of signal often being specified in relation to PPM scale marks. Although *line-up level* is still accepted in connection with test signals, the term *programme volume* is not now used, one reasons being the possibility of confusion with the measurement of volume units on a VU meter. Further, the **1** to **7** PPM scale used in the BBC is not recommended for engineering measurement and specification because this scale is not applicable outside the UK. (See **Note 3**).

International standards organisations - CCIR, CCITT, IEC, etc. - have long been concerned with the need to rationalise the way in which line-up and programme signals at points along a transmission or distribution chain are quantified. Two dB notations - **dBr** and **dBm0** - already exist to serve a similar purpose of rationalisation in respect of telephony signals. The use of these notations for sound broadcast signals has been recommended by the CCIR. * The **dBr** and **dBm0** notations are explained below.

* *Strictly, according to the CCIR recommendation, the notations should be written dBrs and dBm0s, the 's' suffix showing that the values relate to conditions for sound broadcast signals as opposed to those for telephony signals which are always written without the 's'. This would avoid confusion when the two types of signal are shown sharing a common path. However, in BBC usage, this is unlikely to happen. The 's' is therefore usually omitted.*

dBr — denotes the relative magnitude of a programme signal. It quantifies the level of a programme signal at any point in a sound system in relation to a reference programme level. This reference, previously known as **zero programme volume,** is now called **zero relative level** - written, in this notation, **0 dBr** - and is defined as the programme level at a point **where maximum peaks to +8 dB (0.775 V) r.m.s. occur.** In a system, such a point is usually accessible for measurement; if not, it is assumed. A level of this magnitude would be registered on a correctly adjusted PPM by frequent pointer deflections to **6.** In practice, dBr values compared along the transmission path of a system show the designed gain or loss for signals passing through that system.

dBm0 — denotes the relative magnitude of a test or line-up (single-frequency) signal — **NEVER** a programme signal. It quantifies the (power) level of an applied signal, normally a sine wave at 1 kHz, in relation to a reference line-up level — written, in this notation, **0dBm0** -which has a value of **0 dB (0.775 V)** r.m.s. at a **0 dBr** point. In BBC practice, this reference level is established at 8 dB below that of maximum programme signal peaks; thus, maximum programme peaks (considered as short bursts of a sinewave signal) are at a level of +8 dBm0. On a correctly adjusted PPM connected at a 0 dBr point, line-up tone at 0 dBm0 is registered by the pointer held steady at **4.**

The suffix 'm' shows that the quoted value is basically related to a specified signal power level, i.e. 1 mW which, developed in 600 ohms, gives an r.m.s. voltage of 0.775 volt.

Note that most so-called r.m.s. voltage meters correctly show an r.m.s. value ONLY when measuring a signal with a sinusoidal waveform. For the correct r.m.s. voltage measurement of any other waveform, a true r.m.s. reading meter must be used.

The suffix '0' (here and in other dB notations) shows that the quoted figure is an adjusted value such as would be obtained were the measurement made at a point of **zero relative level,** i.e. at a 0 dBr point. The amount by which the given figure is adjusted is therefore the negative of the dBr value carried by the point at which measurement is actually made.

Values stated in accordance with the above definitions may be combined to derive the absolute power level of a signal at a point in a sound system. In audio-signal practice, however, it is normally voltage levels which are measured and quoted; these can similarly be combined, giving:

dB (0.775 V)	=	dBm0	+	dBr
(absolute voltage level of the signal)		(relative test signal level)		(relative programme signal level)

As a demonstration of the way dBm0 and dBr notations are used, some typical transmission/distribution circuit conditions are listed below, giving details of the relationships between line-up and programme signals, including absolute voltage values and equivalent PPM readings.
Irrespective of the dBm0 value of the system line-up signal, the absolute voltage of maximum programme signal peaks (to PPM **6**) will be:

(i) + 8 dB (0.775 V) r.m.s. at a 0 dBr point (this is the dBr value normally found at national/international system-interconnection points);
(ii) + 18 dB (0.775 V) r.m.s. at a +10 dBr point (this is a typical dBr value for a line-feeding amplifier output point);
(iii) – 62 dB (0.775 V) r.m.s. at a –70 dBr point (this is a typical dBr value for a studio mixer microphone channel input point)

At all points in a system (and thus independent of dBr values), maximum programme-signal peaks (to PPM **6**) will be:

(iv) 8 dB above a 0 dBm0 line-up tone which reads steady PPM **4** (this is the normal level for mono system line-up);
(v) 11 dB above a –3 dBm0 line-up tone which reads steady PPM **3 1/4** (this is the normal level for stereo system line-up);
(vi) 20 dB above a –12 dBm0 line-up tone which reads steady PPM **1** (this is the level used on some circuits feeding MF transmitters).

Fig. 1 illustrates the use of the dBr and dBm0 notations by showing the circuit between a studio and a transmitter for a much simplified sound broadcasting chain. In the diagram, note that the annotated signal levels are those which would be registered on a PPM conected to each indicated point ONLY if the meter were preceded by a measuring circuit having an appropriate gain or loss (equal, in fact, to *minus* the dBr value of the point).
Thus, for example, if a PPM were used to inspect the signal level at either of the inputs to the Response Selection Amplifier (RSA), it would have to be preceded by a measuring circuit with an overall GAIN of 20 dB (because these are –20 dBr points). The meter would then show a steady reading of **3 1/4** (i.e. 3 dB below 0 dBm0) if the signal being transmitted were a stereo line-up tone, or maximum peaks to **6** (i.e. 8 dB above 0 dBm0) if it were programme.
Similarly, considering the output of the control room mono-feed amplifier, the PPM readings there would be a steady **4** (i.e. 0 dBm0) for mono line-up tone or maximum peaks to **6** for a programme signal provided that the measuring circuit had an overall LOSS of 10 dB to offset the + 10 dBr value that point carries.

For Sound Systems Noise Measurements

dBq0 — denotes the relative magnitude of a noise signal in a programme circuit as measured **unweighted.**

The suffix '0' has the same meaning here as for dBm0, above. Also the suffix 'q' shows that the stated value is the result of measurement by means of a quasi-peak meter (as specified in Section 2 of CCIR Rec. 468-2), i.e. **it is not an r.m.s. value.** (Note that r.m.s. values of noise are not now quoted for audio circuit measurements but are in general use for acoustic measurements).

As for the measurements giving ***dB4*** *values, the bandwidth of the measuring circuit should conform with that defined in Annex 1 of CCIR Rec. 468-2.*

dBq0p — denotes the relative magnitude of a noise signal in a programme circuit as measured **weighted.** The suffixes '0' and 'p' have the same meaning here as for dBq0, above. Also: The suffix 'q' shows that the stated value is the result of a weighted measurement and specifies the type of weighting as psophometric.

dBA — denotes the level of a sound pressure measured according to the weighting characteristic A (40-phons equal-loudness curve of IEC 179); 1973: **Precision Sound Level Meters.** † The measured sound level is given in dBA as:

$$N \ \ dBA = 20 \ lg \frac{P_n}{P_o}$$

Where: P_n is the measured r.m.s. sound pressure (weighted according to the A characteristic)

P_o is the reference pressure having the value of 2×10^{-5} P_a

P_a (Pascals; given in Newtons/m^2) r.m.s. = 10 dynes/cm^2 r.m.s.

† *Weighting characteristics B (70-phon equal-loudness) and C (100-phon equal-loudness) are also specified in the noted document. These alternatives are rarely used in audio engineering practice.*

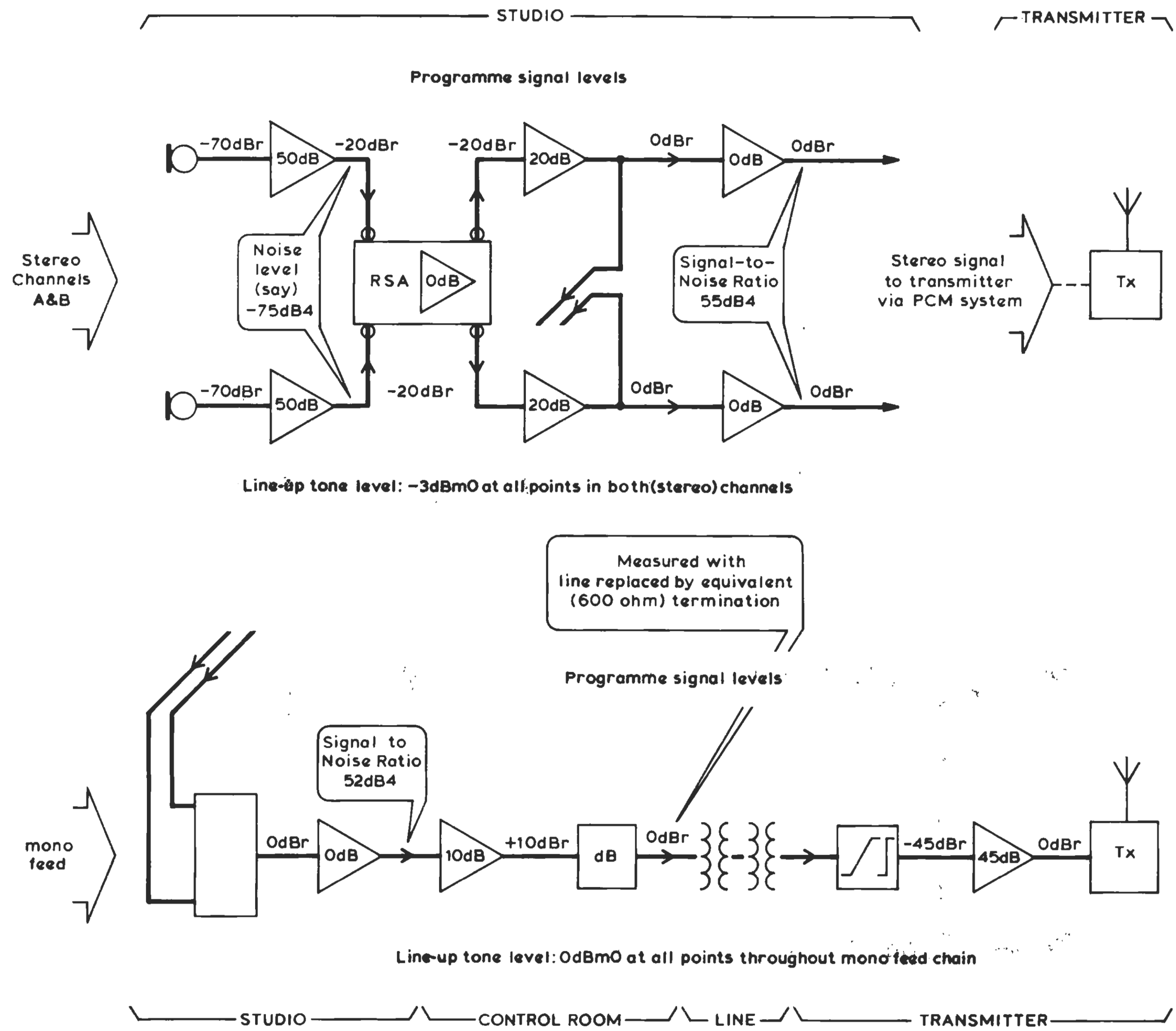


Fig. 1 Simplified distribution circuit showing the use of dBr and dBm0 notations

NOTES

1. Origin of the dB

Until 1924, the transmission qualities of communication (telephone) circuits were quantified by means of comparison with a defined standard. This standard was defined as the performance of a 1-mile length of line of specified construction at a frequency of 800 cycles per second (800 Hz). Hence, the '800 cycle mile', so called, was the criterion against which other circuits were judged. Theory showed that the attenuation of signal current (or voltage) along a line as an exponential function of the distance, x between the compared points whereby:

$$\text{current (or voltage) loss} \sim e^{x}$$

Thus, given that line loss could be expressed in terms of a specified constant raised to a power, it was reasonable to find that the numerical statement of signal-level comparision was based on a system of logarithms, because this made calculations - involving powers of numbers - much easier.
Bell System engineers in America then proposed replacing the 'mile of cable' standard with a new 'Transmission Unit' or T.U. Using this, signal conditions along a line were related in terms of the difference of dissipated power between two points of measurement such that, in the words of the original proposal: ". . . . two amounts of power differ by one transmission unit when that are in the ratio of $10^{0.1}$ . . ." i.e. ". . . . the T.U. is a logarithmic measurement of power ratios and is numerically equal to $\log_{10} 10^{0.1}$."
This proposed system of measurement offered several important advantages over existing methods and quickly gained acceptance. The main benefits were that:

(a) being based on a power ratio, it was independent of frequency and of associated impedance, and
(b) it could be used to express relationships between transmission systems of different types.

At the 4th Plenary Assembly of the C.C.I. in 1927, two types of transmission unit, the Bel and the Neper, were considered and adopted. Both were based on power ratios and expressed in terms of the logarithms of these ratios. For the Bel (and the decibel), the ratios were ordered in the scale of 10, and therefore calculations involved common logarithms; the Neper used the scale of e^2 and the ratios were calculated using natural logarithms. (The latter choice of scale reflected the fact that, if the current or voltage loss along a line is represented by $e^{-\gamma}$ - where γ is the ratio between the measured currents or voltages - then, for a linear transmission system, the power loss is $e^{-2\gamma}$). The two units as originally defined yielded numbers, N, such that:

for Bels: $$N = \lg \frac{P_1}{P_2}$$

and, for Nepers: $$N = \tfrac{1}{2} \ln \frac{P_1}{P_2}$$

If P_1 and P_2 are developed in equal impedances, giving voltages V_1 and V_2, the expression for nepers can be re-written:

$$N = \tfrac{1}{2} \ln \frac{V_1^2}{V_2^2}$$

$$= \ln \frac{V_1}{V_2}$$

The Bel and the Neper then continued in parallel use - with countries showing preference for one or the other -until 1968 when the CCITT finally recognised the dB as the principle means of expressing transmission-signal relationships. The Neper was reserved for scientific purposes, and, since that time, has tended more and more to be used only in theoretical calculations.

2. The definition given in IEC 27, **Letter symbols to be used in electrical technology** - Part 3 is as follows.

'The Bel is the logarithmic reference quantity which for a ratio of two power quantities corresponds to the ratio **10** (10:1) and for a ratio of two field ‡ quantities corresponds to the ratio √ **10** (√ 10:1).'

‡ *A field quantity is a quantity such as voltage, current, sound pressure, etc. for which, in a linear system, the square is proportional to power.*

3. The magnitude of complex-wave signals resulting from the transmission of speech and music (i.e. programme signals) is described in one of two ways according to whether the signal is controlled by reference to measurement made on a Peak Programme Meter (PPM) or a Volume Indicator (usually called a VU meter). Thus, for:

(i) A Peak Programme Meter

The magnitude of a sound programme signal - previously known as the *programme volume* - is now quantified in terms of its **relative level.** This specifies the signal by comparing it with a reference magnitude which is called the **zero relative level** and is defined as that level of signal which causes a correctly-adjusted PPM to show normal maximum peaks of programme to mark **6**.

Correct adjustment requires the meter sensitivity to be such that, for a 1 kHz tone applied at zero level (i.e. at 0.775 volt r.m.s. corresponding to 1 mW in 600 ohms), a steady indication to mark **4** *is obtained.*

(ii) A VU Meter

The magnitude of a programme signal is quantified in terms of volume (VU's) which are expressed as the number of dB above or below a defined steady indication according to the instantaneous reading on a correctly calibrated meter having specified dynamic (ballistic) characteristics.

The line-up and calibration of VU meters is different for different broadcasting authorities. A definition specifying the use of VU meters in Europe has not yet (1980) been ratified and issued.

4. **Test Programme Meter (TPM)**
A (BBC-type) Test Programme Meter is standard PPM - to BS 4297 specification - having an input circuit comprising a calibrated attenuator in series with a high-gain amplifier. In respect of bandwidth and amount of overload 'headroom', the amplifier conforms essentially with the specification given in Annex 1 of CCIR Rec. 468-2.

LIST OF R.F. TEST PROCEDURES

This section of the Instruction will include tests of the radio frequency signal parameters listed below. The identifying numbers of those published to date are shown in **bold type.**

RTP1
Level Measurements

Power Level - C.W./F.M. Signals	— RTP1.1
Power Level - A.M. Signals	— RTP1.2
R.F. Gain	— RTP1.3
Field Strength	— RTP1.4
Definitions	— RTP1.5

MISSING

RTP2
Frequency Measurements

Single Carriers	— RTP2.1
Multiple Carriers	— RTP2.2
Transposers	— RTP2.3

RTP3
Swept Frequency Measurements

Amplitude/Frequency Response	— RTP3.1
Delay/Frequency Response	— RTP3.2
Sideband Analysis	— RTP3.3

RTP4
Impedance Measurements

Return Loss	— RTP4.1
Time Domain Reflectometry	— RTP4.2
LF/MF Impedance Measurements	— RTP4.3
HF Impedance Measurements	— RTP4.4
VHF/UHF Impedance Measurements	— RTP4.5
SHF Impedance Measurements	— RTP4.6

MISSING

RTP5
Intermodulation and Spurious Products

Relative Amplitude Measurements	— RTP5.1
3-tone Testing (Television)	— **RTP5.2**
Vision-to-sound Cross-modulation	— RTP5.3
Incidental Phase Modulation	— RTP5.4
Cross-modulation in Stereo-multiplex Systems	— RTP5.5

MISSING

RTP6
Modulation

A.M. Audio	— RTP6.1
A.M. Video	— RTP6.2
F.M.	— RTP6.3
S.S.B.	— RTP6.4

RTP7
Noise

Noise Figure	— RTP7.1
Co-channel Interference	— RTP7.2
Oscillator Noise	— RTP7.3

RTP8
Miscellaneous

Phase Measurements	RTP8.1

MISSING

Appendices

RTP-A	Spectrum Analysers
RTP-B	Tracking Generators
RTP-C	Network Analysers
RTP-D	The Smith Chart
RTP-E	BBC Transmission Bands and Systems
RTP-F	Sideband Analysers
RTP-G	Balanced/Unbalanced Systems
RTP-H	Limiters and Compressors
RTP-I	Measurements in the Presence of Pre- and De-emphasis

MISSING

MISSING

TECHNICAL INSTRUCTION P2

R.F. TEST PROCEDURES
(PRELIMINARY ISSUE: FEB.1981)

INTERMODULATION
IN
COLOUR TELEVISION
R.F. SYSTEMS
(R.T.P. 5.2)

Technical Instruction P2 has now become so bulky and its distribution so widespread that it is necessary to review its method of presentation.

This preliminary issue of R.T.P. 5.2 is being made available whilst the review is taking place and will be incorporated in any new system resulting from the review.

R.F. TEST PROCEDURES

LEVEL MEASUREMENTS: POWER LEVEL - CW/FM SIGNALS

Introduction
The method used to measure R.F. power is determined by the power level present.
For low power measurements, it is possible to totally absorb the power in a calibrated power measuring instrument.
Where the measuring device is unable to absorb the total power, a known proportion of the power is derived for measurement. This is achieved by the inclusion of a calibrated coupler, probe or attenuator in the circuit. Further calibrated attenuators may be included to reduce the sampled power to a level within the range of the instrument.
To minimise errors, the impedance of the measuring device and associated test items must match the characteristic impedance of the transmission system.
At high powers the test load is cooled by liquid flow and the power calculated from the temperature rise and rate of flow of the coolant.
At the highest power levels the transmitter must remain connected to its aerial. The power may be deduced indirectly as above, or from measurement of the field strength at a known distance from the aerial. Where the feeder impedance is known, a special R.F. Voltmeter can be used to measure the voltage across the feeders and hence the power calculated.
N.B. *Safety Regulations must be strictly observed.

Types of Power Meter
Power meters use either a:

1. Thermistor or
2. Thermocouple or
3. Diode

as the power sensing element to convert r.f. power to a measurable d.c. or low frequency signal.

1. Thermistor Sensors
The thermistors used for r.f. power measurement are semiconductors with a negative temperature coefficient. The fundamental premise of the thermistor power sensor is that the r.f. power absorbed by the thermistor has the same heating effect on the thermistor as d.c. power.
The resistance / power characteristic of a thermistor is non-linear. The characteristics also vary from thermistor to thermistor. Therefore, the technique of using a thermistor as a power sensor is to maintain the thermistor at a constant resistance (which matches the impedance of the system) by means of a d.c. or low frequency bias. As r.f. power is dissipated in the thermistor, the resulting temperature rise causes the thermistor resistance to fall with a consequent decrease in bias current required to maintain the resistance at the same value. The decrease in bias current is displayed on a meter to indicate r.f. power.

2. Thermocouple Sensors
A thermocouple measurement system consists of a power sensor which produces a d.c. output voltage proportional to the power dissipated in it, and a measurement circuit, which measures this d.c. voltage and displays it in units of power. The thermocouple sensor is less sensitive to changes in ambient temperature than the thermistor type of power sensor.
The modern thermocouple sensor employs both thin-film and semiconductor technologies. A thin-film resistor, deposited on the surface of a silicon chip, converts the r.f. energy to heat. The resistor forms a low-reflection termination for the transmission line. It is mainly due to this type of construction that the thermocouple type sensor has the most precisely defined impedance of the power sensing methods. As the resistor converts the r.f. energy into heat, the centre of the chip, which is very thin, gets hotter than the outside edge. Thus there is a thermal gradient across the chip which gives rise to a thermo-electric e.m.f. The cold junction is formed by the outside edge of the silicon chip and the resistor. The hot junction is the resistor-silicon connection to the centre of the chip.

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*Safety Regulations for Engineering Staff; BBC Engineering Division Publication

3. Diode Sensors

There are two main types of diode sensors. One is a simple rectifier circuit whereas the other uses a Schottky diode as the basis of a precision measuring system. A variant of the simple type derives a fixed proportion of the power, by means of an integral directional coupler, which drives a diode detector and meter. An example of this type of power meter is the Thruline (Bird) wattmeter which can be used for measuring forward and reverse power flow.

The system of precision power measurement using a diode sensor is similar to that used with a thermocouple sensor, the only difference being the method used to convert r.f. power into d.c. voltage. Diode and thermocouple power sensors can often be used with the same power meter.

By using diode sensors the range of power measurement can be extended down to 100 pW sensitivity at frequencies of up to 18 GHz with low noise and drift.

The modern precision diode sensor uses a low-barrier Schottky diode which is operated in its square law region (V_{out} proportional to P_{in}) and therefore can be used to measure the power of complex waveforms. The advantage of the Schottky diode over the thermocouple power sensor is that detecting diodes are more effective in converting r.f. to d.c. The diode sensor is less sensitive to changes in ambient temperature than the thermistor type of power sensor.

Sources of Error

(a) Variations in the reading caused by reflections on the transmission line due to mismatched loads.
(b) A mismatch between the power meter and its connecting cable.
(c) Discontinuities caused by the insertion of adaptors, connectors, bends or attenuators causing reflections within the feeder.
(d) The presence of harmonic or spurious components at the output of the r.f. amplifier.
(e) Calibration and directivity of directional coupler and/or attenuator.
(f) Induced RF in power meter leads or circuits.
(g) The accuracy of the power meter:
    (1) Zero set
    (2) Noise
    (3) Drift
    (4) Meter tracking errors
    (5) Circuit non-linearities
    (6) Range-change attenuator inaccuracy
    (7) Meter amplifier gain errors
    (8) ±1 count – digital meter
(h) Errors due to overload damage to components or their use outside the intended frequency range.

Bibliography

1. BBC Engineering Division Publication; Safety Regulations for Engineering Staff.
2. Hewlett Packard, Application Note 64-1; Fundamentals of RF and Microwave Power Measurements.
3. T.C.P.D. Technical Note No.36; Directional Couplers: Principle of Operation.
4. Proc.I.E.E. May 1955; Coupled Transmission Lines as Symmetrical Directional Couplers, G.D. Monteath.

Comparison between types of Power Meter

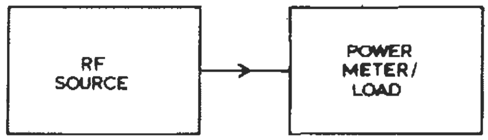
Examples of typical commercial types of meter which are in common use are given in the table below. Limited specifications are given for comparison purposes, *for full specifications see the manufacturers' literature.* See also list of possible sources of error.

Type:	Thermistor	Thermocouple		Diode			
						Absorption	
Model:	Hewlett Packard 432A with 8478B thermistor mount	Hewlett Packard 435A with 8481A sensor	Hewlett Packard 435A with 8482A sensor	Hewlett Packard 435A with 8484A Schottky diode sensor	Bird Thruline Model 43	Bird (Termaline) Model 61	Racal-Dana 9100/02/03
Claimed Accuracy	±0.2% ±0.5 μW †	±1.2% †	±1.2% †	±1.2% †	±5% of FS ¶	±5% of FS ¶	±7.5% of FS ¶
Lower Freq. Limit	10 MHz	10 MHz	100 kHz	10 MHz	2 MHz ‡	30 MHz	1 MHz
Upper Freq. Limit	18 GHz	18 GHz	4.2 GHz	18 GHz	1 GHz ‡	1 GHz	1 GHz
Lower Power Limit (as engraved)	0.2 μW	0.3 μW	0.3 μW	0.1 n W	0.02 W ‡	0.5 W	0.01/0.1/1 W *
Upper Power Limit (without att'n)	10 mW	100 mW	100 mW	10 μW	1 kW ‡	80 W	3/30/100 W *
Max. Cont. Input level		300 mW Av	300 mW Av	200 mW Av	-	80 W	3/30/50 W *
SWR	1.35 30 - 100 MHz 1.10 0.1 - 1 GHz 1.35 1 - 12 GHz	1.18 30 - 50 MHz 1.10 50 MHz - 2 GHz 1.18 2 - 12 GHz	1.6 100 - 300 kHz 1.2 300 kHz - 1 MHz 1.1 1 MHz - 2 GHz	1.4 10 - 30 MHz 1.15 30 MHz - 4 GHz 1.2 4 - 10 GHz	1.05	1.2	<1.2

‡ This meter uses a range of wide-band (2:1) couplers. The figures refer to the lower and upper frequency and power limits of the complete range. The unit does not provide a terminating load.
* These figures refer to the power limits of the 9100/9102/9103 range of meters.
† Practical field accuracy ±(2 to 3%)
¶ Practical field accuracy ±10%

MEASUREMENT METHODS

1. Power Level within Meter Range

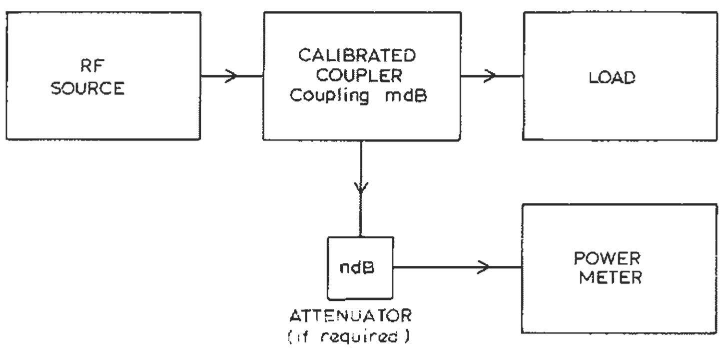


Power Indicated Directly

2. Power Level in excess of Meter Range

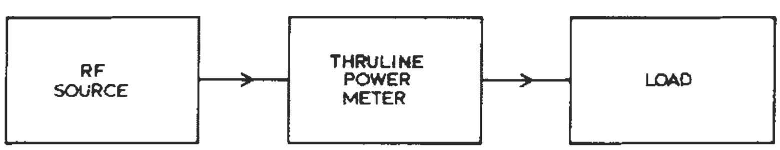
$$\text{Power} = \text{Power Indicated} \times \text{Antilog} \frac{n}{10}$$

3. Power Level in excess of Meter Range



$$\text{Power} = \text{Power Indicated} \times \text{Antilog} \frac{(n + m)}{10}$$

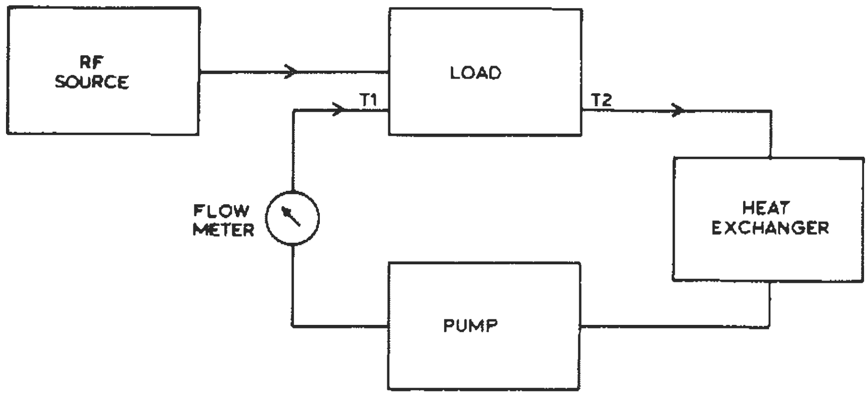
4. Thruline Measurement



Power Indicated Directly

MEASUREMENT METHODS (continued)

5. The Calorimeter



The resistor which forms the test load is cooled by a flow of water or other fluid, surrounding the resistor; the fluid itself can also form part of the test load. The power absorbed by the load is given by:

$$P = 4.187\ m\ C_p\ (\Delta T)$$

where P = power in watts
m = flow, grams per second
C_p = specific heat of the liquid, calories per gram per °C
ΔT = temperature rise in °C ($T_2 - T_1$)

If pure water is used then the power absorbed by the load is given by:

$$P = 0.317\ F\ (\Delta T)$$

where P = power in kilowatts
F = flow, in gallons per minute
ΔT = temperature rise in °C ($T_2 - T_1$)

or

$$P = 0.069\ F\ (\Delta T)$$

where P = power in kilowatts
F = flow of water, litres per minute
ΔT = temperature rise in °C ($T_2 - T_1$)

If a 2:1 mixture of water and glycol is used then the power absorbed by the load is given by:

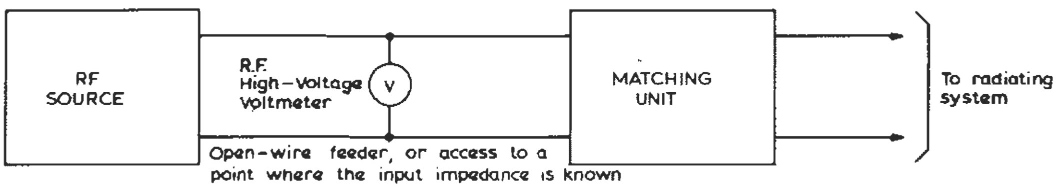
$$P = 0.317 \times 0.95 \times F \times \Delta T$$
$$= 0.3\ F\ \Delta T$$

where P = power in kilowatts
F = flow, gallons per minute
ΔT = temperature rise in °C ($T_2 - T_1$)

MEASUREMENT METHODS (continued)

6. High Power Measurement below 30MHz (Aerial connected)

N.B. *Safety Regulations must be strictly observed before connecting equipment to a feeder or matching system.



$$\text{Power} = \frac{V^2 \text{ r.m.s}}{R_p}$$

where R_p is the value of shunt resistance at the connection point.
It is also given approximately by:

$$\text{Power} = \frac{V^2 \text{ r.m.s.}}{Z_o}$$

where Z_o is the characteristic impedance of the feeder and the S.W.R. is near unity. The accuracy is about 10%.

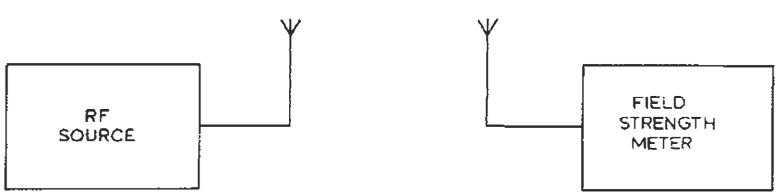
At the upper end of the high frequency spectrum a mismatch due to the connection of the voltmeter could be sufficient to cause a significant error.

7. Field Strength Comparison Method

A change of power level is determined by measuring the change in field strength at a fixed location. The transmitting system and the field strength meter are set up and the effect of any subsequent change in transmitter power output is measured by the corresponding change in field strength. It is assumed that the system is linear and that there is no change in propagation characteristics. To determine the power level of a high power transmitter, determine the field strength at a known point using a low power source, the power output of which has been determined. Substitute the high power transmitter, the power output of which is required, and again measure the field strength

$$\frac{P_1}{P_2} = \left[\frac{E_1}{E_2}\right]^2$$

where E_1 is the field strength measured with transmitter power P_1
E_2 is the field strength measured with transmitter power P_2
With care, measurement accuracies within 5% are possible.



*Safety Regulations for Engineering Staff; BBC Engineering Division Publication

R.F. TEST PROCEDURES

LEVEL MEASUREMENTS: DEFINITIONS

CHARACTERISTIC IMPEDANCE OF A TRANSMISSION LINE – is the impedance that would be presented by a uniform line if it were infinitely long. If any length of the line is terminated in its characteristic impedance, then the energy reaching the termination is absorbed by it and none is reflected back along the line.

COUPLING FACTOR OF A DIRECTIONAL COUPLER – is the ratio, expressed in decibels, of the input power flowing in a matched transmission line to the power from the coupled port.

DIRECTIVITY OF A DIRECTIONAL COUPLER – is the change in coupled power (expressed in decibels) in a matched system when the direction of propagation is reversed.

R.F. POWER DEFINITIONS – Dependent on the class of emission the output power of a radio transmitter is expressed in terms of mean power, carrier power or peak envelope power, as defined below.

MEAN POWER is the power supplied to a test load under specified conditions of modulation, averaged over a time sufficiently long compared with the period of the lowest frequency encountered in the modulation.

CARRIER POWER is the average power supplied to a test load during one r.f. cycle under conditions of no modulation; for each class of emission the condition of no modulation should be specified.

PEAK ENVELOPE POWER is the average power supplied to a test load during one r.f. cycle at the highest crest of the modulation envelope taken under specified conditions of modulation.

RATED OUTPUT OF A TELEVISION TRANSMITTER is defined as being that of the vision transmitter.

OUTPUT POWER OF A VISION TRANSMITTER shall be expressed in terms of **PEAK ENVELOPE POWER**; hence:
for **TRANSMITTERS WITH NEGATIVE MODULATION** the output power is equal to the mean power supplied to the terminal load during one r.f. cycle having an amplitude corresponding to synchronising level.

*These **R.F. POWER DEFINITIONS** are taken from I.E.C. Recommendations* and apply to measurements carried out under specified conditions of modulation (instead of under normal operating conditions) and with the transmitter connected to a test load instead of to an aerial system.*

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*International Electrotechnical Commission, Methods of Measurement for Radio Transmitters.
Publication 244-1, 1968.
Part 1: General Conditions of Measurement of Frequency, Output Power and Power Consumption.
Publication 244-5, 1971.
Part 5: Measurements particular to Transmitters and Transposers for Monochrome and Colour Television.

R.F. TEST PROCEDURES

INTERMODULATION IN COLOUR TELEVISION R.F. SYSTEMS: THREE-TONE TESTING

BACKGROUND

If two r.f. carriers are modulated by television colour video and sound signals respectively to form a single transmission and are then passed through a device with a non-linear transfer characteristic, interaction will occur between them and intermodulation products will result. In normal operation three of these products will be in-band* and two of them may be of significant amplitude, these latter two products occur at frequencies of:

fv ± (fs − fc)

where fv = vision carrier frequency
fs = sound carrier frequency
fc = colour sub-carrier frequency (r.f.)

The third in-band product is usually of much lower amplitude than the other two and occurs at (2fc − fs).

In System I†, fs = fv + 6 MHz and fc = fv + 4.43 MHz; therefore the frequency of those in-band modulation products which may have significant amplitude (greater than -52 dB with respect to peak sync power) will be fv ± 1.57 MHz. Intermodulation distortion will appear as patterning in the demodulated signal and will be particularly visible in large coloured areas. As seen on a monitor, the most susceptible colour is saturated red. The sound modulation tends to break up the patterning and make it less visible and thus the subjective visibility of intermodulation distortion is dependent both on picture content and on the accompanying sound modulation.

It is conventional to measure the intermodulation product (fv + 1.57 MHz) as a carrier and to relate it to the vision carrier amplitude at peak synchronising power. To do this the amplitudes of fv, fs and fc must be defined as specified in BS4478: 1969‡. The defined test signal amplitudes are:

vision carrier	−8 dB	relative to peak sync power
colour sub-carrier	−17 dB	
sound carrier	−7 dB	

The first two of these signals correspond approximately, in video terms, to the luminance and chrominance amplitudes present in the green bar of the so-called 95 per cent colour bar waveform¶. The hue is indeterminate, because subcarrier burst phase is not defined.

The sound carrier amplitude is that which would normally be radiated. The amplitudes of the three signals add up approximately to peak-sync voltage and do not therefore explore the full dynamic range.

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* For the purpose of this test procedure 'in-band' is defined as being within the frequency range (fv − 2) to (fv + 6) MHz.

† CCIR Recommendations and Reports 1978: Vol.XI, Report 624-1

† Specification of Television Standards for 625-line System I Transmissions: published jointly by the BBC and the ITA; 1971

‡ Methods of Measurement of Intermodulation Products in Electronic Valves and Tubes intended for use in Colour Television Transposers.

¶ Technical Instruction P8: Waveforms, page 2.5

Viewer reaction to intermodulation distortion has been analysed* and used to derive a relationship between intermodulation distortion and Q-rating (see VTP-F). The resulting scale, shown Fig. 1, gives the subjective impairment with the intermodulation product for a 100 per-cent colour bar signal which has 50Hz hum modulation on the sound carrier.

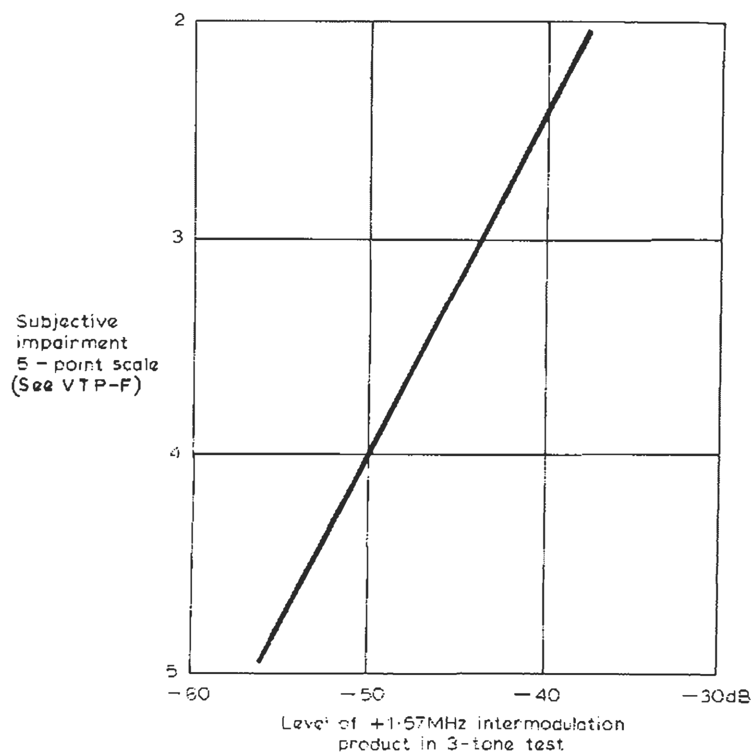

Fig. 1 Suggested Allowable Level of Intermodulation Product for a Given Grading

* See Research Department Report 1974/35

Comparison of Three-tone Test with Related Methods

There are three ways of measuring intermodulation distortion; they are:

1. Three-tone Method
2. Chrominance Bar Method
3. National I.T.S. (B) Method

1. Three-tone Method.

This is the original method. A generator is required, to produce signals corresponding to the three tones at the correct carrier frequencies and amplitudes, and a spectrum analyser is used to measure the intermodulation produced by the device under test.

Advantages – it is accurate and can be done locally, without the aid of a parent transmitter.

Disadvantages – involves an interruption of programme, cannot be easily applied to high-level carrier-modulation systems (because they lack a suitable low-level input point) or to systems requiring a base-band input. It cannot always be applied to tandem chains whilst a.g.c. systems are operating. It does not explore the full dynamic range, i.e. it does not cover the full amplitude of the transmitted signal.

2. Chrominance Bar Method.

Uses a video signal with chrominance and luminance levels which correspond, during the active line period, to the vision and colour sub-carrier amplitudes of the three-tone test. Synchronising and blanking pulses are added to the signal, which can then be used either in the line-repetitive mode or inserted into the field-blanking period. The resulting signal is then used to modulate the transmitter. The sound carrier is produced either by the transmitter drive or by the test modulator in use to drive a transposer.

There are three ways of measuring the intermodulation product, these are (a) using a bandpass filter and a noise meter, (b) using a spectrum analyser and (c) using an oscilloscope to measure the beat pattern amplitude of the demodulated signal.

Advantages – does not necessarily involve interruption of programme. Can be used with high-level carrier-modulation systems. Does explore full dynamic range.

Disadvantages – may give poorer resolution than the three tone test when used for performance comparison. (However, it is more representative of what the viewer sees and is hence, arguably a more suitable test).

3. National I.T.S. (B) Method.

Uses the National Insertion Test Signal (B) which is transmitted on lines 20 and 333 in the field-blanking interval (see VTW.4).

The intermodulation product is measured by viewing the demodulated signal on an oscilloscope and measuring the beat pattern amplitude.

Advantages – simple test equipment requirements and no necessity to interrupt programme. Dependent chains do not require attendance during tests. Can be used with high-level carrier-modulation systems. Does explore full dynamic range.

Disadvantages – it does not meet the requirements of BS4478 for luminance level and it is more prone to error than the Chrominance Bar method.

All three methods have their applications; these are:

(a) ***Three-tone*** for precise measurement of the performance of a constituent part of a chain.
(b) ***Chrominance Bar*** for performance measurements on an operational system.
(c) ***National I.T.S. (B)*** for quick checks in the absence of specialised test equipment.

ASSOCIATED INFORMATION
(normally issued with this Test Procedure)

Operating Instructions (P2, Part 2) for:

1.	EP14M/507	U.H.F. TEST EQUIPMENT
2a.	GE4/546	BAR AND SWEEP GENERATOR (part of PA1M/560 or PA1M/561)
	or	
2b.	GE4M/561	TEST GENERATOR
3a.	ME1/509	FIELD INTERVAL NOISE METER (part of ME1M/508 or EP1M/524)
	or	
3b.	ME3M/502	TV WAVEFORM ANALYSER

DEFINITIONS

CHROMINANCE-LUMINANCE INTERMODULATION – refers to the unwanted change in amplitude of the luminance component of a colour television signal which is caused by the associated chrominance component.

(also called: Chrominance-Luminance Crosstalk and Chrominance Axis Shift) – it can be defined as the change in luminance level expressed as a percentage of the picture amplitude which results from the superimposition of a chrominance component of specified amplitude.

QUADRATURE DISTORTION – is harmonic distortion which is caused by any asymmetry of the two sidebands in a vestigial sideband transmission affecting the shape of the modulation envelope. It may be considered as being due to the appearance of a quadrature component of the modulating signal which adds vectorially to the in-phase component; hence the name quadrature distortion.

Because it is an envelope phenomenon, it is present in signals recovered by envelope demodulation, but it can be eliminated by synchronous demodulation which is able to discriminate between the in-phase and quadrature components.

TRANSPOSER – is a device which accepts a transmission at one frequency and (without demodulation) rebroadcasts it at a different frequency.

MEASUREMENT METHODS

A. Three-tone Method

Equipment Required

A generator to produce the three carriers (corresponding to the three tones) at the correct frequencies and amplitudes. The preferred equipment is:
EP14M/507 U.H.F. TEST EQUIPMENT
(If an EP14M/507 is not available, any suitable generator can be used.)

A spectrum analyser; either of the following can be used:
EP14M/507 U.H.F. TEST EQUIPMENT (and associated oscilloscope)
A commercial spectrum analyser; e.g. HEWLETT PACKARD 180 SERIES

Test Procedure

First make sure that the resolution and bandwidth of the test equipment is adequate (see ***OPERATING INSTRUCTIONS****)*

1.1 Connect the test equipment to the test item as shown in Fig. 2.

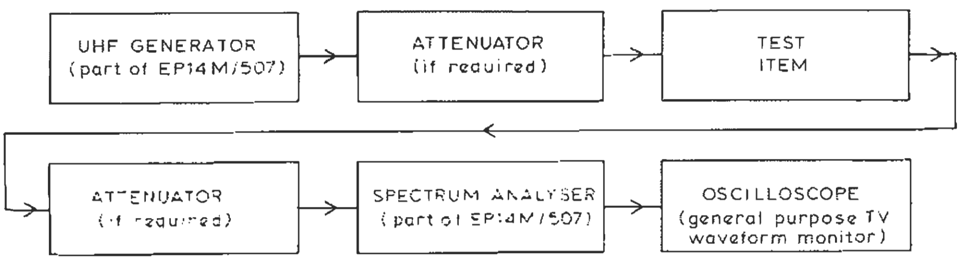

Fig. 2 Connection of Test Equipment to Test Item

1.2 With the system operating normally use a vision carrier signal to calibrate the output of the item under test and obtain a reference level corresponding to peak sync output power (0 dB).

1.3 Check that the u.h.f. generator provides the correct relative levels of the three carrier signals.

BS4478 calls for the levels to be correct at the output of the test item. It is, however, normally sufficient if they are correct at the input, provided that no serious frequency distortion is present.

1.4 Adjust the input attenuator for the correct vision output level from the generator (−8 dB with respect to peak syncs).

MEASUREMENT METHODS (continued)

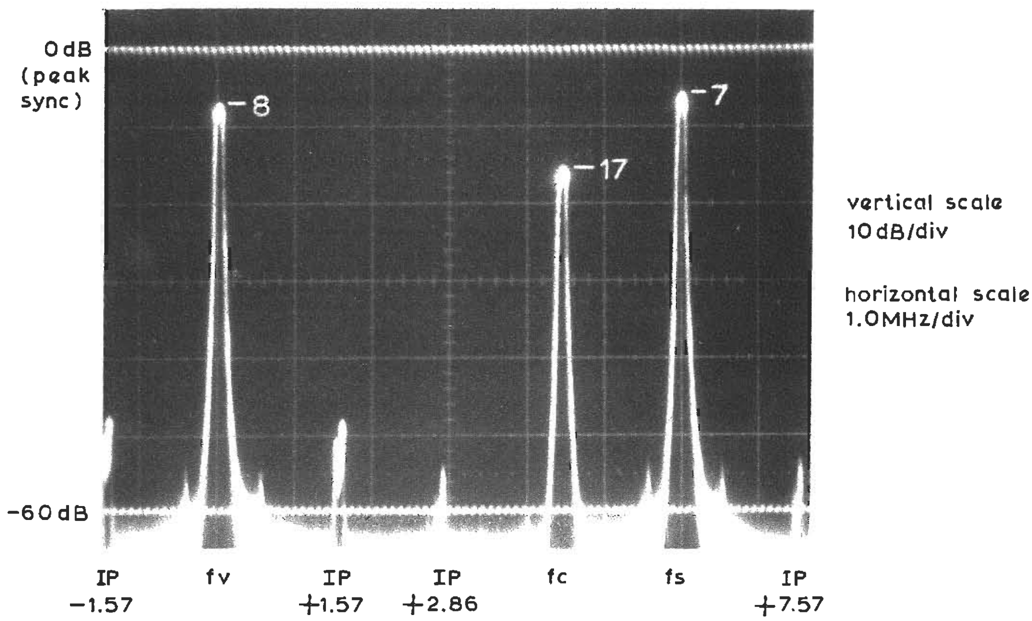

Fig. 3 A typical three-tone display showing an intermodulation product of –48 dB with respect to peak sync power.

Note that although several intermodulation products appear on the display, only those which are spaced 1.57 MHz either side of the vision carrier are both in-band and of significant amplitude.

1.5 Display the spectrum analyser output and measure the amplitude of the intermodulation products (in dB relative to peak sync power); a typical three-tone display is shown in Fig. 3.
Check the amplitude of any intermodulation produced by the test equipment by connecting the spectrum analyser (via the attenuator) to the generator u.h.f. output and adjusting the attenuator for the same display amplitude as before. For the original measurement to be valid any intermodulation produced by the test equipment must be at least 10 dB lower than that produced by the item under test (see Fig. 4).

1.6 Record the measurement method used.
Step 6 is necessary because the three measurement methods used may give slightly different results.

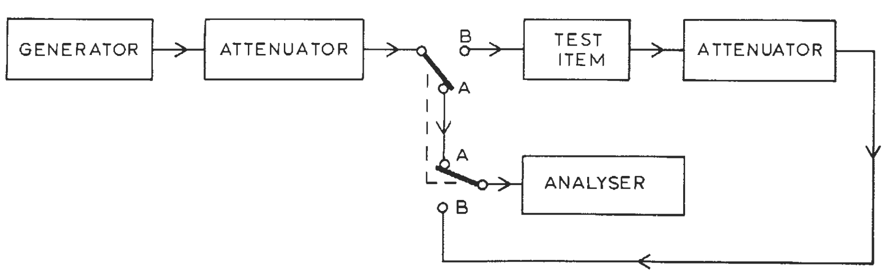

Fig. 4a Connection of Test Equipment to Test Item

MEASUREMENT METHODS (continued)

Correction to intermodulation product levels measured at the output of a test item to take into account intermodulation product levels measured at the input.

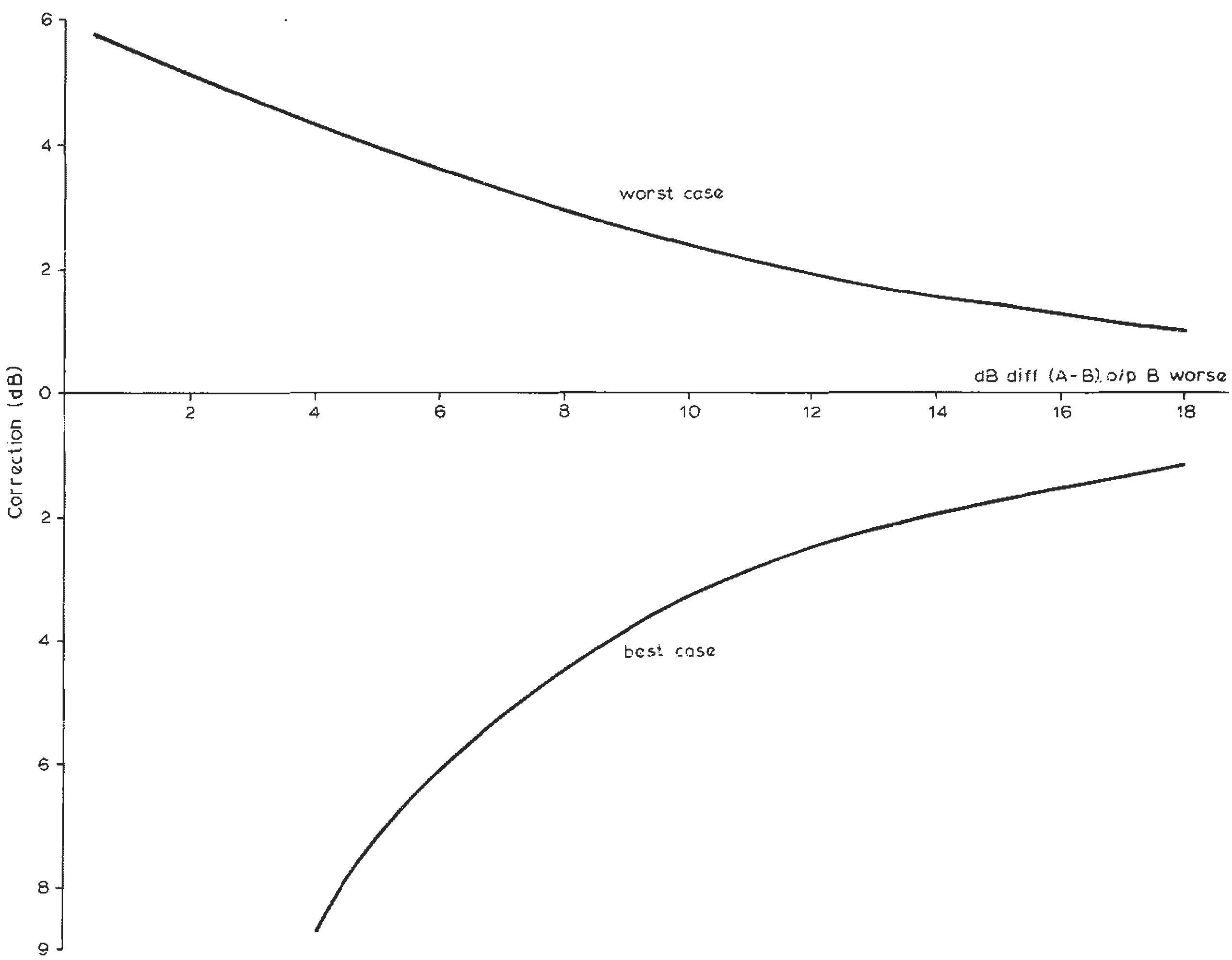

Fig. 4b Graph Showing Correction Necessary

Example: A = −58 dB (intermodulation at input)
B = −50 dB (intermodulation at output)

Difference (A − B) = 8 dB

Worst case +2.8 dB – add this to B
−50 + 2.8 = −47.2 dB due to the test item

Best case −4.5 dB – add this to B
−50 + (−4.5) = −54.5 dB due to the test item

Note: the worst case is the most significant.

MEASUREMENT METHODS (continued)

2. Chrominance Bar Method

Equipment Required

GE4/546 BAR AND SWEEP GENERATOR (part of PA1M/560 or PA1M/561)
or
GE4M/561 TEST GENERATOR (with three-tone facility)

PA1M/560 or	PA1M/561 TEST LINE ERASER/INSERTER	if a field-interval signal only is required.
ME1/509 or ME3M/502	FIELD INTERVAL NOISE METER / TV WAVEFORM ANALYSER	

A Spectrum Analyser (if the signal is line-repetitive)
A Test Modulator (if an R.F. Test Signal is required)
General-purpose TV Waveform Monitor
Demodulator

The modulator, demodulator and spectrum analyser facilities can be supplied by an EP14M/507 U.H.F. Test Equipment.

Test Procedure

2.1 Set the GE4/546 to **SUBCARRIER** (or the GE4M/561 to **3-TONE**); check that the output consists of syncs and 700 mV peak to peak of subcarrier, superimposed on a luminance bar of 450 mV (see Fig. 5).

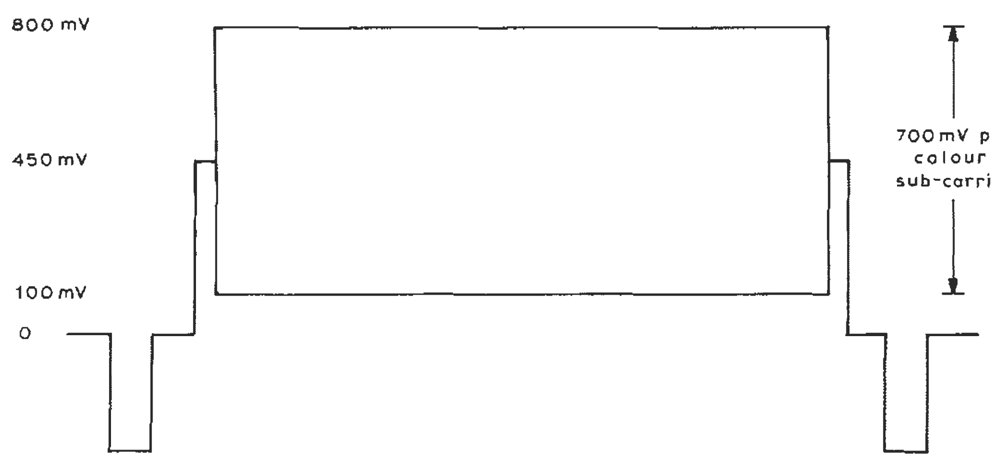

Fig. 5 Chrominance Bar Output of GE4/546

Because of chrominance-to-luminance intermodulation and/or quadrature distortion a demodulated chrominance bar may have its luminance component altered. This is particularly likely if an envelope detector is used. No attempt should be made to compensate for this, beyond checking that the signal is correct at the input to the item under test.

MEASUREMENT METHODS (continued)

2.2 The intermodulation product is measured as the amplitude of the +1.57 MHz component in the demodulated video signal. The product which is 1.57 MHz below the video carrier is removed by the vestigial sideband characteristic of the receiver.

2.3 The various methods of measurement are:

2.3i. If the signal to be measured is inserted in the field-blanking interval, the measurement can be made by using a demodulator and an ME1/509 which is set to the **1.57 MHz** (bandpass) position.
The meter on the ME1/509 measures the equivalent power of the intermodulation component and expresses it relative to picture amplitude. The reading must be corrected (see the ME1/509 **OPERATING INSTRUCTION**) to express it as a power which is relative to peak synchronising power.

Note that the signal is conventionally inserted on lines 21 and 334 of the field blanking interval. Both the PA1/560.561 ERASER/INSERTER and the ME1/509 FIELD INTERVAL NOISE METER or ME3M/502 should be set accordingly.

2.3ii. For a repetitive signal, the measurement can be made using a spectrum analyser in the same way as for a three-tone test (see Method 1). Note that the display will show peak sync level and not −8 dB with respect to peak syncs.

The display is less clear than a three-tone display, because the vision carrier is at full amplitude and because a sideband structure due to synchronising pulses is present. This, typically, limits the measurement to products which are greater than −50 dB.

2.3iii. For a signal which is relatively noise-free at a demodulated measurement point, the intermodulation component can be seen on an oscilloscope as a beat pattern which is superimposed on the subcarrier(see Fig. 6).

$$\text{Intermodulation Product} = 20\,\lg\left[\frac{A}{700}\right] - 17\text{ dB}$$

$$= 20\,\lg\ A\ - 74\text{ dB}$$

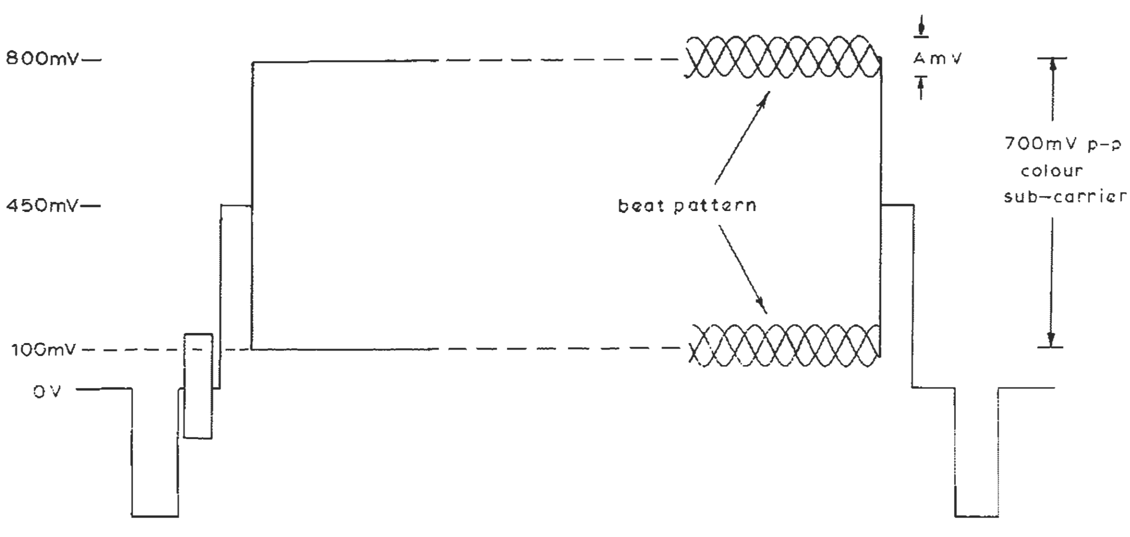

Fig. 6 Showing Intermodulation Product as a Beat Pattern

MEASUREMENT METHODS (continued)

The peak-to-peak amplitude of the beat pattern is measured and expressed in dB's relative to the 700-millivolt picture component of the video signal. −17 dB is then added to the figure obtained, to express it as a power relative to peak synchronising power.

2.4 Record the measurement method used.

Step 4 is necessary because the three measurement methods may give slightly different results.

3. National I.T.S. (Waveform B) Method.

This is similar to the Chrominance Bar method described under 2 but uses instead the chrominance bar which is located on the first half of lines 20 and 333 in the National Insertion Test Signal (B) as shown in Fig. 6. Because the luminance lift of this signal is only 350 mV, instead of the 450 mV provided by Method 2, the test does not meet the requirements of BS4478; however, it does give an indication of performance that is, typically, within 3 dB.

Equipment Required

Grade 1 general-purpose TV waveform monitor
Demodulator

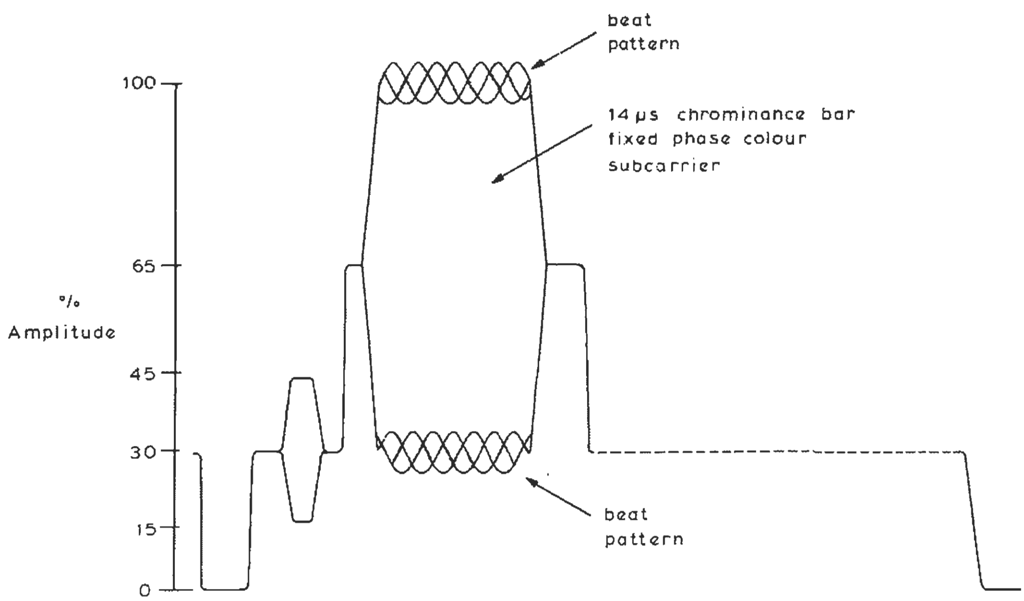

Fig. 7 National Insertion Test Signal (B) (lines 20 and 333) Test Procedure

Test Procedure

3.1 Carry out the Test Procedure as defined in Method 2 (step 2.3iii).

3.2 Record the measurement method used.

Step 2 is necessary because the three measurement methods may give slightly different results.

R.F. TEST PROCEDURES

INTERMODULATION AND SPURIOUS PRODUCTS: VISION-TO-SOUND CROSS-MODULATION

Introduction
In an R.F. system, non-linearity distortions occur when more than one carrier shares a common amplifier. One of these effects is cross-modulation of the sound carrier and is defined as the unwanted amplitude modulation of the sound carrier caused by variations in the level of the vision carrier.
There are two methods of measuring cross-modulation and, since they can produce different results, the method of measurement should be stated.

Measurement of Vision-to-Sound Cross-modulation

1. Steady State Method
Vision-to-Sound Cross-modulation is measured using unmodulated vision and sound carriers. A spectrum analyser is used to measure the change in sound carrier level when the vision carrier is switched off.

Advantages
(a) The method is simple and the results obtained repeatable.

Disadvantages
(a) It is not always possible to switch the vision carrier off and on and measurements can not be made during programme. Also, some systems require the presence of sync pulses to maintain correct operation.
(b) Serious errors can be introduced because this method does not measure cross-modulation at intermediate levels of vision carrier. This is particularly important in systems using pre-correction.
(c) When the vision carrier is switched off and on there may be a change in amplifier gain, due to thermal effects, which can have a time constant of several milliseconds. This is not shown by a dynamic measurement which would give a different result.

2. Dynamic Method
The system is set to deliver normal rated power levels. Modulation is applied to the vision carrier and any corresponding amplitude modulation of the sound carrier is measured.

Advantages
(a) Can be measured without interrupting programme.
(b) Produces a more relevant result than the steady state method.

Disadvantages
(a) When received sound and vision carriers are used as the test signal, any inherent distortion of the test signal will lead to incorrect results. In particular, the vision-to-sound ratio and any cross-modulation of the incoming carriers should be noted.

Bibliography
UHF Test Set Application Notes: Transmitter Group

MEASUREMENT METHODS

1. Steady State Method

Equipment Required

2 UHF CW Generators
Attenuators
Combining pad
Spectrum Analyser

Test Procedure

1.1 Connect the test equipment as shown in Fig.1.

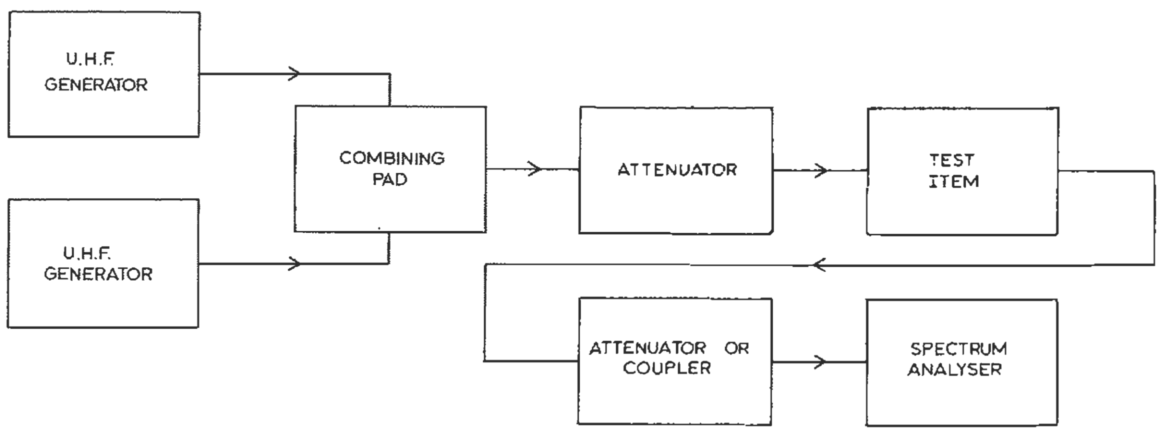

Fig. 1

1.2 The vision and sound carriers should be set to give the rated power levels at the output of the test item. If the signal sources can not be independently varied, it is normally sufficient if the power levels are correct at the input.
1.3 Check that no cross-modulation effects are produced either by interaction between the generators or by non-linear operation of the Spectrum Analyser.
1.4 With the vision carrier switched on, measure the amplitude of the sound carrier.
1.5 Switch off the vision carrier and note the percentage increase in sound carrier level; a decrease should be expressed as a negative percentage.

MEASUREMENT METHODS (continued)

2. *Dynamic Method*

Equipment Required

Video Generator	GE4M/561 etc.
UHF Test Modulator	MD1/502 or MD1/507, EP14M/501, EP14M/507
Spectrum Analyser	Commercial Spectrum Analyser or EP14M/507 (note different procedures)

Test Procedure

2.1 Connect the test equipment as shown in Fig.2.

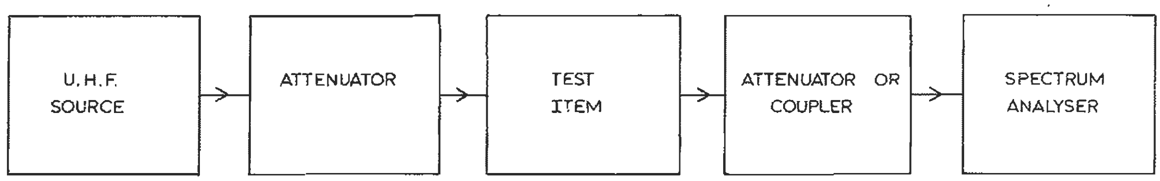

Fig. 2

2.2 Modulate the vision carrier with a composite video waveform* which covers the full video dynamic range, e.g. Sawtooth or 5-step staircase, without chrominance.

2.3 The vision and sound carriers should be set to give the rated power levels at the output of the test item. If the carriers can not be independently varied, set the vision power output to the correct level and note any vision-to-sound ratio error.

2.4 Set the analyser display to Linear Mode+ and display the sound carrier to give a vertical deflection of A divisions, see Fig. 3.

2.5 Set the I.F. bandwidth to at least 100 kHz* and adjust the dispersion, or sweep rate, to give a display similar to those shown in Figs. 3 & 4. These displays are of an amplifier with normal compression. Note that the I.F. bandwidth is insufficient to show full line-sync information.

2.6 Measure the peak-to-peak thickening of the trace, (which is normally absent during the field interval) B divisions, and calculate the vision-to-sound cross-modulation.

$$\text{Cross-modulation} = \frac{B}{A} \times 100\%$$

2.7 If the amplifier includes pre-correction, over-compensation may cause the cross-modulation to appear inverted. B will appear to be negative and this should be noted.

* If a line repetitive video waveform is used, the analyser I.F. bandwidth *must* be set to at least 300 kHz. If the R.F. Test Set is used with a 100 kHz I.F. bandwidth, then the measured cross-modulation must be multiplied by 1.1.

\+ If the analyser is used in the logarithmic mode (preferably 1 dB or 2 dB per vertical division) then the thickness of the trace is the cross-modulation in decibels.

MEASUREMENT METHODS (continued)

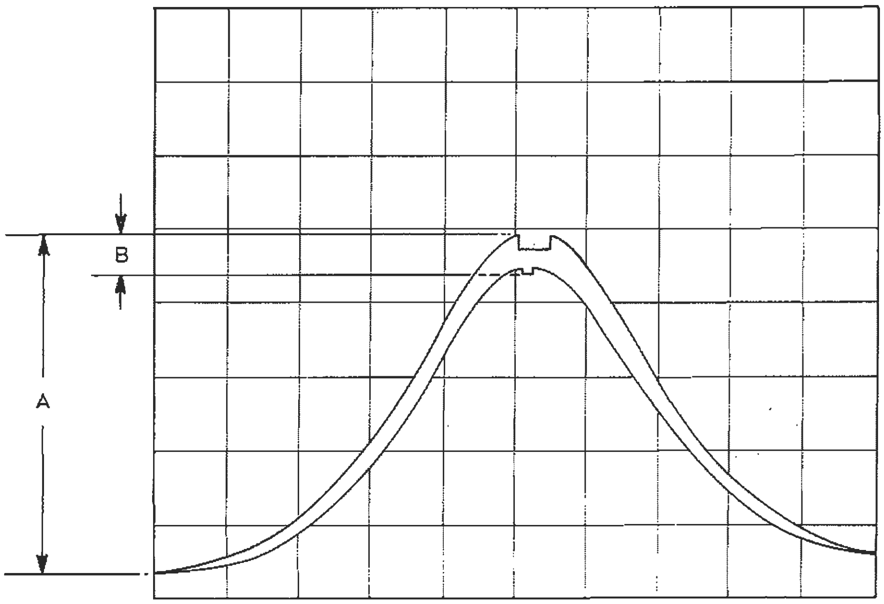

Fig.3 A and B dimensions

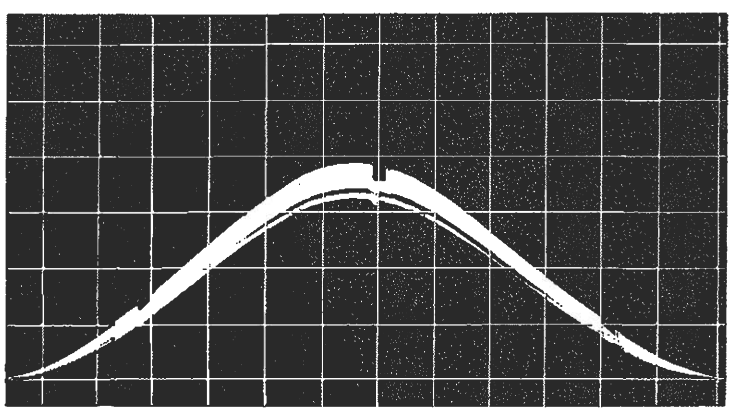

Fig. 4 Typical display showing approximately 15% Vision-to-Sound Cross-modulation

APPENDIX RTP-D

THE SMITH CHART

1. Introduction

The Smith Chart is mainly used for impedance calculations involving transmission lines. It is sometimes referred to as the circle diagram.

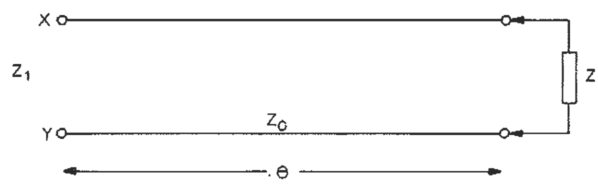

Fig. 1
An Impedance connected to a Lossless Transmission Line

Fig. 1 shows an impedance $Z = R + jX$ connected to a lossless transmission line of characteristic impedance Z_0. The impedance Z_1 at the terminals XY is given by:

$$Z_1 = Z_0 \frac{Z + jZ_0 \tan\theta}{Z_0 + jZ\tan\theta} \qquad (1)$$

where θ is the electrical length of the line.
For a lossless line, Z_0 is a pure resistance. If the impedances Z and Z_1 are divided by Z_0 they are said to be normalised. Equation (1) then becomes:

$$z_1 = \frac{z + j\tan\theta}{1 + jz\tan\theta} \qquad (2)$$

where $z = Z/Z_0$ and $z_1 = Z_1/Z_0$

The Smith Chart provides a convenient way of solving Equation (2); it may be regarded as a two-dimensional slide rule. An example of the chart is illustrated in Fig. 2. Any normalised impedance may be plotted on it, for example the point A represents the normalised impedance $0.32 + j0.68$.
The circumference of the chart has two scales labelled *wavelengths towards generator* and *wavelengths towards load.* These represent the electrical length θ of the transmission line, expressed in terms of its length in wavelengths. For example, 0.25λ corresponds to $\theta = 90°$, although it is represented on the circumference of the chart by a rotation of 180°.
One wavelength in the transmission line is equal to the free-space wavelength only if the line is air-spaced. Otherwise it is shorter, by a factor k called the velocity factor, given in tables of cable data. For a polythene-insulated line, for example, $k = 0.67$; if the free-space wavelength is 30 cm the wavelength inside the cable is only 20 cm.
If the point A in Fig. 2 represents the impedance Z of Fig. 1 (when normalised), then the impedance at the terminals XY of Fig. 1 is found by moving the point A in a clockwise direction (i.e. towards the generator) round the centre of the chart. Thus if the length of the line is 0.1λ ($\theta = 36°$), then A moves to the point B, which indicates that the impedance Z, (when normalised) is equal to $1.58 + j2.06$.
In its most convenient form, the Smith Chart has a transparent overlay which can be rotated. The point A is marked on the overlay, which is then rotated through the required number of wavelengths. The new impedance value can then be read directly.

2. Applications

Some of the many uses of the Smith Chart are described below.

2.1 Effect of a Transmission Line on a Known Impedance

This application was described in Section 1.

2.2 Interpretation of Impedance Measurements

It often happens that an unknown impedance, such as that of an aerial, is measured through a length of transmission line. The unknown impedance can be determined by rotating the measured impedance in an anticlockwise direction, i.e. towards the load.

2.3 Standing-wave Ratio (S.W.R.)

For a given flow of power along a transmission line:

$$\frac{V_{max}^2}{R_{max}} = \frac{V_{min}^2}{R_{min}} \qquad (3)$$

where R_{max} and R_{min} are the resistive impedances at the voltage maxima and minima. It then follows that:

$$\text{S.W.R.} = \frac{V_{max}}{V_{min}} = \left[\frac{R_{max}}{R_{min}}\right]^{1/2} = \left[\frac{r_{max}}{r_{min}}\right]^{1/2} \qquad (4)$$

where r_{max} and r_{min} are the normalised resistances at the voltage maxima and minima. In the example shown in Fig. 2, the points A and B represent complex impedances which, if rotated further, will cross the vertical axis at $4.67 + j0$ and $0.214 + j0$. These values correspond to r_{max} and r_{min} respectively. Since r_{min} is the reciprocal of r_{max}, it follows from Equation (4) that the S.W.R. is equal to 4.67 and that the values at which the circle described by the points A and B cuts the real axis indicate the S.W.R. and its reciprocal.

2.4 Reflection Coefficient

If a transmission line is mismatched, some of the power incident on the termination is reflected and travels back towards the source. The voltage across the termination can be resolved into two components, one corresponding to the incident wave (V_i) and the other corresponding to the reflected wave (V_r). The ratio V_r/V_i is known as the reflection coefficient and denoted by ρ. In general it is complex and is given by:

$$\rho = \frac{z - 1}{z + 1} \qquad (5)$$

where z is the normalised impedance of the termination. The Smith Chart can be used to derive ρ from z, or vice versa, as an alternative to solving Equation (5).

The radial distance of a point from the centre of the Smith Chart is proportional to $|\rho|$. If the point lies at the centre of the chart, the transmission line is matched and $\rho = 0$. On the other hand, if it is situated at the edge of the chart, $|\rho| = 1$ and the line is terminated by a pure reactance. A scale around the circumference of the chart indicates the phase of ρ.

In the example shown in Fig. 2, the distance of the point A from the centre of the chart is 0.64 times the radius, and the radial line through A indicates a phase of 108°. The reflection coefficient at the end of a line terminated by the impedance represented by the point A is therefore $0.64 \angle 108°$. The reverse process is used to determine z from ρ.

A linear scale showing $|\rho|$ on the transparent overlay is a useful addition to the Smith Chart. Alternatively $|\rho|$ may be converted to S.W.R., or vice versa, using one of the following expressions:

$$|\rho| = \frac{S - 1}{S + 1} \quad \text{or} \quad S = \frac{1 + |\rho|}{1 - |\rho|} \qquad (6)$$

where S is the S.W.R. The scale on the real axis of the Smith Chart can then be used to plot the impedance when ρ is given, or to determine ρ for a given impedance.

2.5 Impedance/Admittance Conversion

If the normalised impedances z and z_1 in Equation (2) are replaced by the corresponding normalised admittances, given by $y = 1/z$ and $y_1 = 1/z_1$, the following result is obtained:

$$y_1 = \frac{y + j\tan\theta}{1 + jy\tan\theta} \qquad (7)$$

This equation is of the same form as Equation (2) and the Smith Chart can therefore also be used for normalised admittances.*

If $\theta = 90°$, Equation (2) simplifies to $z_1 = 1/z = y$. Thus the normalised impedance of a load seen through a quarter wavelength of line is equal to its normalised admittance. The admittance of any impedance can be determined by plotting it on a Smith Chart and rotating it through 0.25λ.

2.6 Impedance Matching

The centre of the Smith Chart corresponds to a perfect match. For well-matched impedances an enlargement of the central part of the chart, shown in Fig. 3, gives better accuracy.

One method used for matching is to place a shunt capacitance at a strategic point on the transmission line. This method is illustrated in Fig. 3 where the point A represents the impedance to be matched. It is first converted to normalised admittance by means of a 0.25λ rotation to point B. The next step is to find a point on the line where the normalised conductance is equal to 1.0 and the susceptance is negative, corresponding to parallel inductance. In the example, this is achieved by moving a distance of 0.144λ towards the generator, to the point C. Here the normalised admittance is 1.00 – j0.41 and the addition of a capacitor having a normalised susceptance of j0.41 moves the point to the centre, resulting in a perfect match.

3. The Effect of Attenuation

The transmission line has, so far, been assumed to be lossless. Points revolve around the centre of the chart at constant radius, so that impedance values repeat every half wavelength. Attenuation, however, makes points spiral inwards as the terminals XY of Fig. 1 are approached. If the line were infinitely long the points would spiral to the centre and the impedance at XY would then be equal to Z_0, regardless of the termination.

Attenuation can be taken into account by modifying the standing-wave ratio according to the formula:

$$S_1 = \frac{(S + 1)10^{0.1A} + (S - 1)}{(S + 1)10^{0.1A} - (S - 1)} \qquad (8)$$

where S is the S.W.R. of the termination, S_1 the S.W.R. at the terminals XY of Fig. 1 and A is the total attenuation of the line in dB. Fig. 4 shows the relationship between S and S_1 for attenuations up to 10 dB.

In practice the impedance Z (see Fig. 1) is plotted on the Smith Chart and its S.W.R. (S) is determined by the method described in Section 2.3. The corresponding value of S_1 is then derived from Fig. 4, or Equation (8), and the point is moved radially inwards to the new S.W.R. value. The point is then rotated as before. The opposite procedure applies when impedance measurements are being interpreted because S_1 is now known and it is S which has to be derived from Fig. 4, to enable the point to be moved radially outwards. In all applications, movement towards the load causes the point to spiral outwards, and vice versa.

Bibliography

Smith, P.H., Transmission Line Calculator, Electronics, Vol 12, No. 1 pp 29-31, January 1939.

Hickson, R.A. The Smith Chart, Wireless World, January, February and March 1960. Available as BBC Engineering Division Reprint Article A.110.

Jordan, E.C. and Balmain, K.G., Electromagnetic Waves and Radiating Systems. Prentice Hall 1968 (Section 7.17).

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*The scales of commercially available Smith Charts are usually labelled in terms of normalised resistance and reactance. When used for admittance these scales represent normalised conductance and susceptance. The left-hand half of the chart corresponds to negative susceptance (shunt inductance).

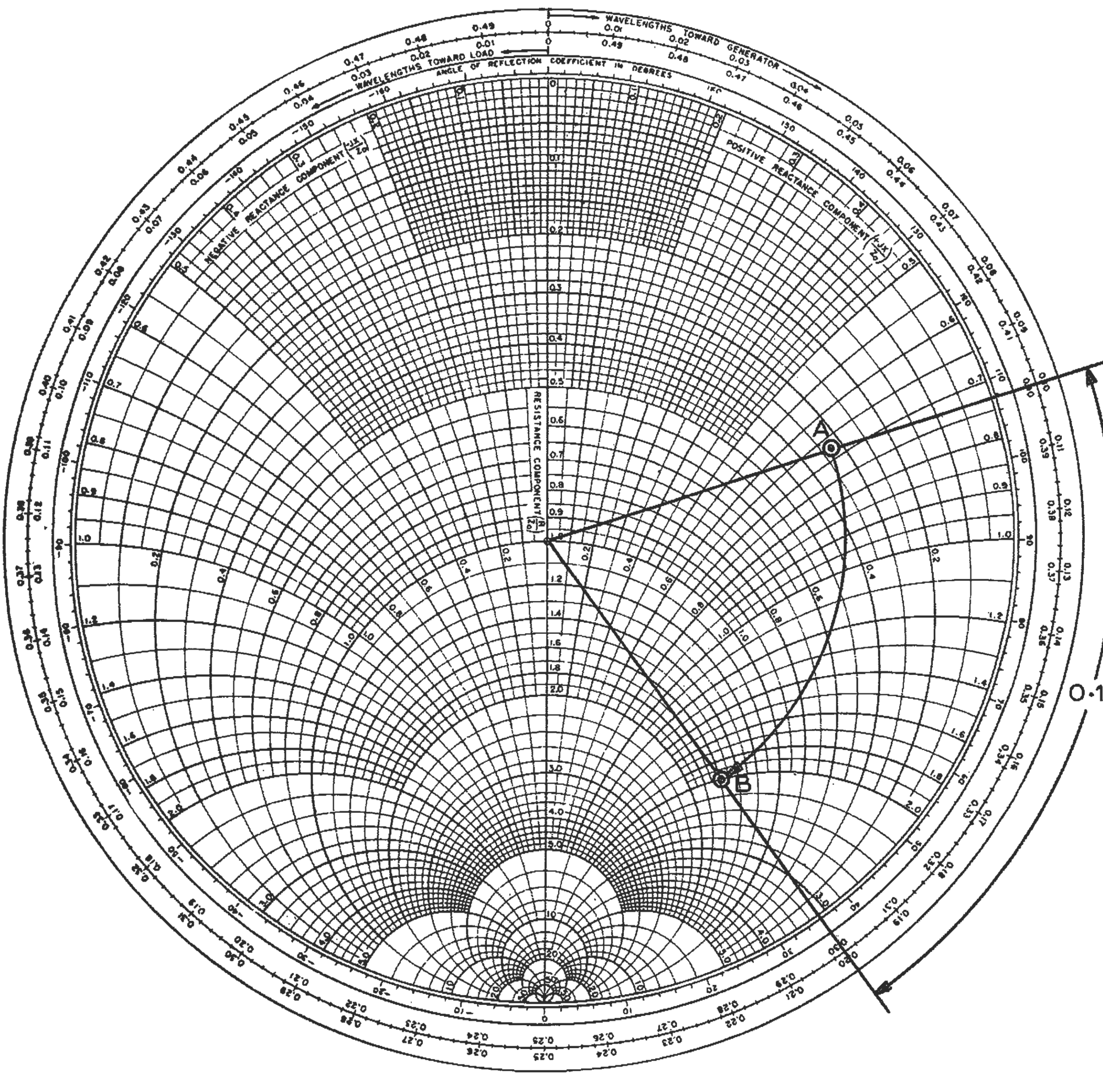


Fig. 2 The Smith Chart

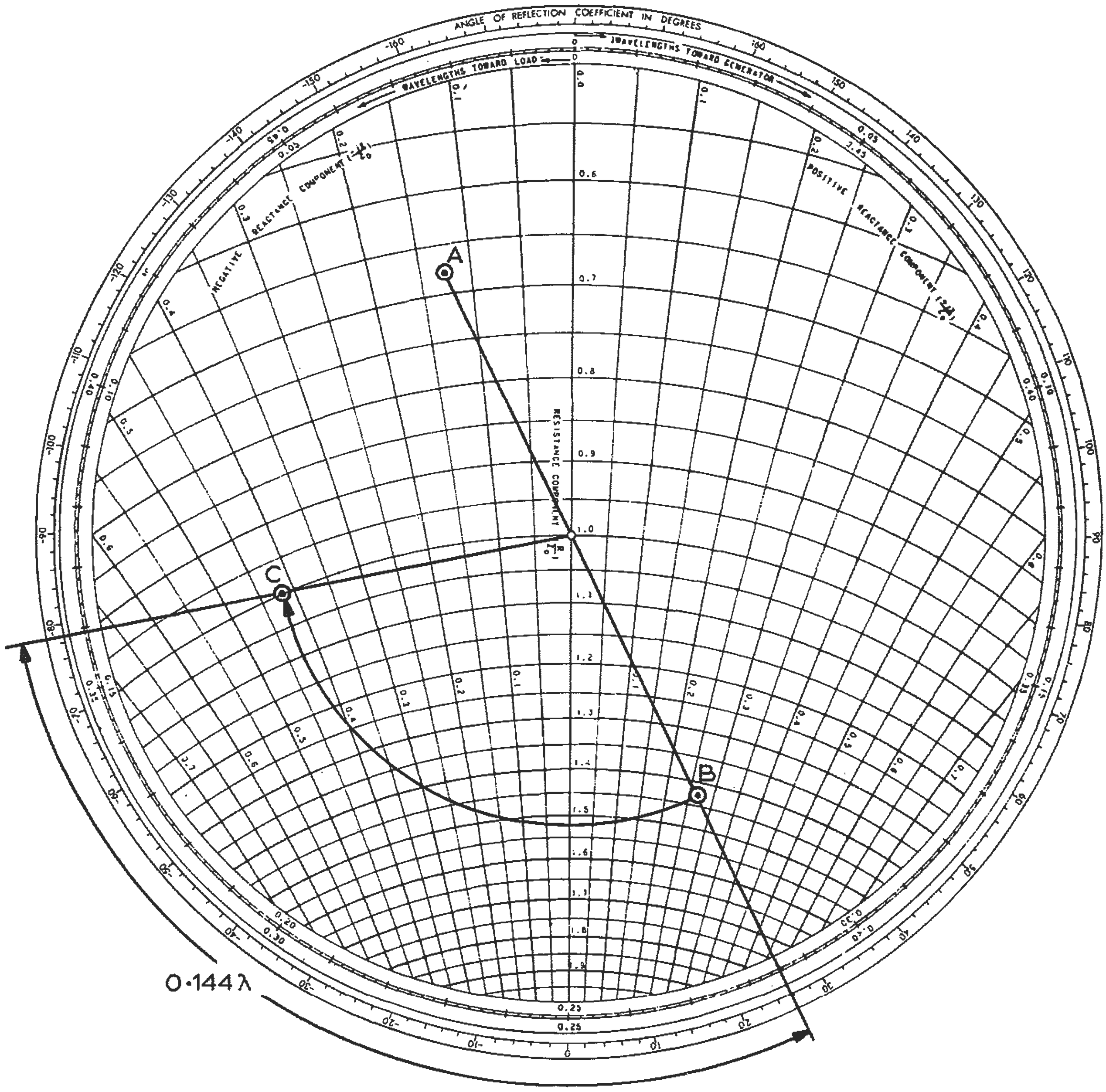


Fig. 3 Impedance Matching with a Smith Chart

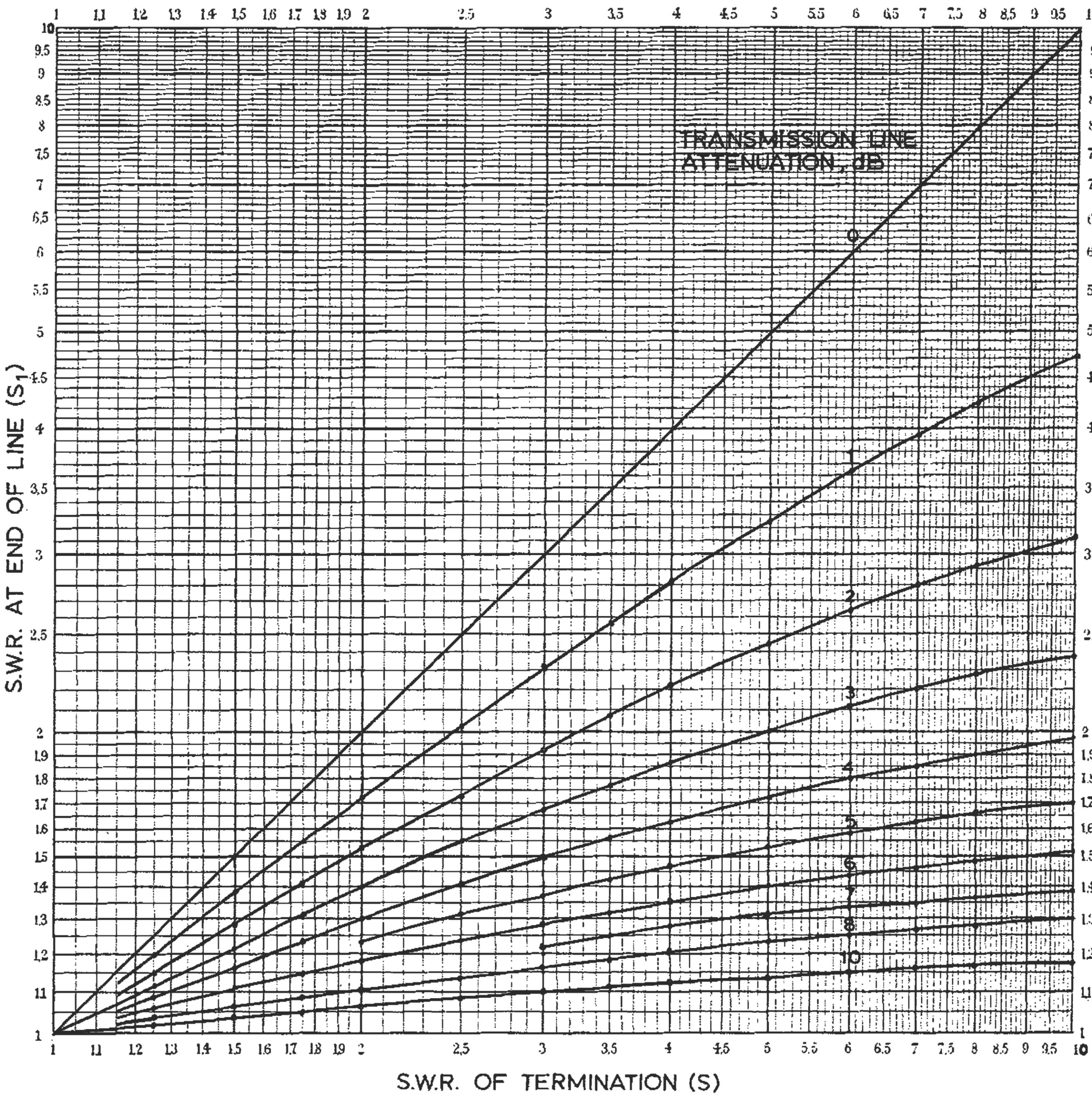


Fig. 4 Effect of Attenuation on S.W.R.

LIST OF VIDEO TEST PROCEDURES

This section of the Instruction will include tests of the video-signal parameters listed below. The identifying numbers of those published to date are shown in **bold type.**

VTP 1
Waveform Amplitude Measurements

Picture Amplitude, Sync Amplitude (Picture/Sync ratio); Video Amplitude; Burst Amplitude; Chrominance Amplitude	–	**VTP1.1**
Gain	–	**VTP1.2**

VTP 2
Linear (frequency-dependent) Waveform Distortion Measurements

Luminance k-Rating	–	**VTP2.1**
Chrominance-Luminance Gain and Delay Inequalities	–	**VTP2.2**
Intermediate Line/Field-Time Distortion (tilt over 4 lines test)	–	VTP2.3
Long-time Waveform Distortion (Bump Test)*	–	VTP2.4

MISSING

VTP 3
Non-linear (amplitude dependent) Waveform Distortion Measurement

Sync-signal Distortion	–	**VTP3.1**
Luminance Non-linearity (Line-time Non-linearity)*	–	**VTP3.2**
Differential Gain and Phase	–	**VTP3.3**
Chrominance-Luminance Intermod. (Chrominance-Luminance Crosstalk or Chrominance Axis Shift)*	–	**VTP3.4**

VTP 4
Signal-to-Noise Measurements

Continuous Random Noise (weighted and unweighted; chrominance and luminance)	–	**VTP4.1**
Periodic Noise ('Hum' and 'Patterning')*	–	VTP4.2
Inverter Noise	–	VTP4.3
Impulsive Noise and Video Crosstalk	–	VTP4.4
Moiré	–	VTP4.5

VTP 5
Relative Phase and Timing Measurements

Waveform Timings (pulse durations)	–	VTP5.1
Colour Subcarrier Phase	–	VTP5.2
Pulse Rise Time	–	VTP5.3
Jitter	–	VTP5.4

VTP 6
Miscellaneous Video Measurements

Amplitude/Frequency and Gain/Frequency Responses	–	VTP6.1
Group Delay/Frequency Response	–	VTP6.2
Return Loss (Impedance Measurements)	–	VTP6.3
Colour Bar Measurements	–	VTP6.4
P.C.M. Bit-stream Measurements	–	VTP6.5

MISSING

*These alternative descriptions are sometimes used but are not preferred terms.

Appendices

VTP.A	Amplitude Relationships in a Video Signal
VTP.B	The Mean Level, Average Picture Level and D.C. Component of a Television Signal
VTP.C	Practical Examples of the Effect of Impedance Mismatch on Gain Measurement
VTP.D	The Use of Peak Signal and R.M.S. Noise Values in the Expression of Signal-to-Random Noise Ratios
VTP.E	Weighted Random Noise Measurement - Upper Bandwidth Limit for Coded Signals
VTP.F	Subjective Assessment of Sound and Picture Quality

VIDEO TEST PROCEDURES

VTP1.1
- **PICTURE AMPLITUDE** } **giving PICTURE/SYNC RATIO**
- **SYNC AMPLITUDE** }
- **VIDEO AMPLITUDE**
- **BURST AMPLITUDE**
- **CHROMINANCE AMPLITUDE**

BACKGROUND

A television signal following the route between an originating source (e.g. a camera) and its ultimate destination, passes through many items of processing or distribution equipment in which the amplitude is intentionally changed by known amounts. It is important that amplitude differences other than the scheduled amounts must be kept to a minimum because the quality of a wanted signal – how much it is distorted or otherwise degraded in usefulness – often changes in proportion to its amplitude and it is both impractical and uneconomic to provide for more than a small range of permissible variation.

Hence, at frequent points throughout a transmission chain, the amplitude of the signal and of its component parts must be checked to ensure that the values are maintained within the specified limits. In general, an analogue television signal carrying programme picture information is not suitable for such measurement and therefore this is normally done using one of the three special test waveforms: Chrominance-Luminance Pulse-and-Bar (preferred) or Insertion Test Signal (I.T.S.)or Colour Bars.

ASSOCIATED INFORMATION

(Normally issued with the Test Procedure).

1. **Video Test Waveforms (P2, Part 3)** VTW.1, 2, 3, 4, 5

2. **Operating Instructions (P2, Part 2)** for: UN1/511 (UN1/511A) SIGNAL MEASURING UNIT
UN1/715 AMPLITUDE MEASURING UNIT
UN2M/504 COLOUR CALIBRATOR
EQ1/520 (EQ1/510) OSCILLOSCOPE EQUALISER

DEFINITIONS – LUMINANCE PARAMETERS

PICTURE AMPLITUDE
– is the voltage difference between blanking and white levels in the luminance component of the signal (composite or non-composite).

– is the principal amplitude parameter, and is the one normally quoted for comparison purposes.

– is measured using the 25-μs luminance bar on a full-field (Chrominance-Luminance) Pulse-and-Bar waveform. This is the preferred test signal, but measurement can also be made, with less accuracy, on the 10-μs bar of an I.T.S., preferably when associated with an active field signal having an average picture level (APL) of near 50 per cent or on the white bar of a Colour Bar signal. The particular points to be used for PICTURE AMPLITUDE measurement are marked A and B in VTW.1, 2 and 3.

The term PICTURE AMPLITUDE is preferred to Video Level because:-
(a) the word video describes the total signal (picture plus syncs);
(b) the word level generally refers to constant voltage values (e.g. blanking level).

STANDARD PICTURE AMPLITUDE
– is 700 mV. Signals of different amplitudes are related to this standard either in dB with respect to it or by percentage. For example: a picture said to be at +2 dB has an amplitude of 1·26 x 700 = 882 mV, i.e. 26 per cent 'high'.

Reference to a 1-volt standard (i.e. to a composite signal of 700 mV picture plus 300 mV syncs) is deprecated because:
(a) a measured composite signal may have a non-standard picture/sync ratio:
(b) sync pulses may not be present at the point of measurement.

SYNC AMPLITUDE
– is the voltage difference between blanking level and the tips of sync pulses.

– is measured using points B′ and C in VTW.1, 2 and 3.
For greatest accuracy, an APL of 50 per cent is required: e.g. as given by a full-field Pulse-and-Bar signal.

STANDARD SYNC AMPLITUDE
– is 300 mV.

PICTURE/SYNC RATIO
– is the percentage ratio of picture component to sync component for a total video signal taken as 100 per cent.

– is measured using points A and B, B' and C and given by:

$$\text{PICTURE SYNC RATIO} = \frac{100}{(A-B)+(B'-C)} \times \frac{(A-B)}{(B'-C)}$$

STANDARD PICTURE/SYNC RATIO
– is 70:30.

VIDEO AMPLITUDE
– is the voltage difference between the tips of sync pulses and white level.

– is measured using points A and C in VTW.1, 2 and 3.
For greatest accuracy, an APL of 50 per cent is required.

STANDARD VIDEO AMPLITUDE
– is 1 volt, comprising:
700 mV picture (STANDARD PICTURE AMPLITUDE)
300 mV syncs (STANDARD SYNC AMPLITUDE)
i.e. 70:30 picture/sync ratio (STANDARD PICTURE/SYNC RATIO)

DEFINITIONS – CHROMINANCE PARAMETERS

BURST AMPLITUDE
– is the peak-to-peak voltage of the subcarrier in the line back-porch periods of a coded signal.

– is measured using points F and G in VTW.1, 2, 3, 4 and 5.

STANDARD BURST AMPLITUDE
– is 300 mV.

CHROMINANCE AMPLITUDE
– cannot be specified for normal colour programme signals and relates only to the peak-to-peak amplitude of the subcarrier component of certain test waveforms.

– is measured using points D and E in VTW.1 and 4.
For greatest accuracy, an APL of 50 per cent is required.

Note: The above definitions refer specifically to UK 625-line (System I) signals. They also apply to other standards with the exception that 525-line signals normally have a picture/sync ratio of 100:40 (for a standard video amplitude of 1 volt = 140 IRE units).

Measurement Methods, see page 4

MEASUREMENT METHODS

A. (Preferred Method) Comparison Measurement

Equipment Required

At input: A source of full-field pulse-and-bar signal; e.g. GE2M/559 CHROMINANCE-LUMINANCE PULSE-AND-BAR GENERATOR. Alternatively, a source of I.T.S. or Colour Bars may be used.

At output: UN1/511 (UN1/511A) SIGNAL MEASURING UNIT
or
UN1/715 AMPLITUDE MEASURING UNIT
with oscilloscope or waveform Monitor[1].

Test Procedure

1. Use the UN1/511[2] (or UN1/715) in the appropriate mode; see Operating Instructions.

B. (Alternative Method) Direct Measurement

Equipment Required

At input: A source of full-field pulse-and-bar signal; e.g. GE2M/559; or use I.T.S. or Colour Bars.

At output: Oscilloscope or Waveform Monitor[1]

Test Procedure

1. Display the signal under test and calculate the appropriate AMPLITUDE from the oscilloscope Y-gain calibration.

Make sure that the test equipment provides the correct termination or does not alter the proper termination if this already exists.
Accuracy depends on the oscilloscope calibration - this is not likely to be better than ±0·2 dB.

NOTES ON TEST SIGNALS AND TEST RESULTS

1. For measurement of chrominance parameters, the oscilloscope response to subcarrier must be known. This can be checked with a signal-calibration unit (e.g. a *UN2M/504 COLOUR CALIBRATOR*) and possibly equalised by means of an *EQ1/520 OSCILLOSCOPE EQUALISER* or similar. If an I.T.S. waveform is used, the oscillo-scope must be able to select and hold a stable display of the appropriate lines.

2. Use only between 75-ohms terminations. Accuracy depends on the *UN1/511* calibration but not on that of the oscilloscope. In each mode, the range of the *UN1/511* is equal to the appropriate *STANDARD AMPLITUDE* ±1 dB.

VIDEO TEST PROCEDURES

VTP1.2 GAIN

BACKGROUND

The gain of a circuit is a parameter which quantifies that property of the circuit which enables it to change the magnitude of a specified input signal. The gain figure can be either positive or negative; when it is negative, it is usually referred to as a *loss*.

Strictly, gain relates to a change of power, comparing the signal power at the input of the circuit (P_{in}) with the power it delivers to an output load (P_{out}). This change is normally stated as a figure in dB, calculated using the expression:

$$\text{Power Gain} = 10 \log \frac{P_{out}}{P_{in}} \text{ dB} \qquad \text{(A)}$$

However, because of practical difficulties in the measurement of power, the figure of gain most often quoted for a circuit is given in terms of the change of signal voltage amplitude which the circuit causes, thus:

$$\text{Voltage Gain} = 20 \log \frac{V_{out}}{V_{in}} \text{ dB} \qquad \text{(B)}$$

In expression (B), the input and output voltages, V_{in} and V_{out}, must be measured in the same units, e.g. both peak-to-peak or both r.m.s. Note also that the values yielded by expressions (A) and (B) are numerically equal if the circuit input impedance equals the load impedance ($Z_i \equiv Z_L$ in Fig. 1).

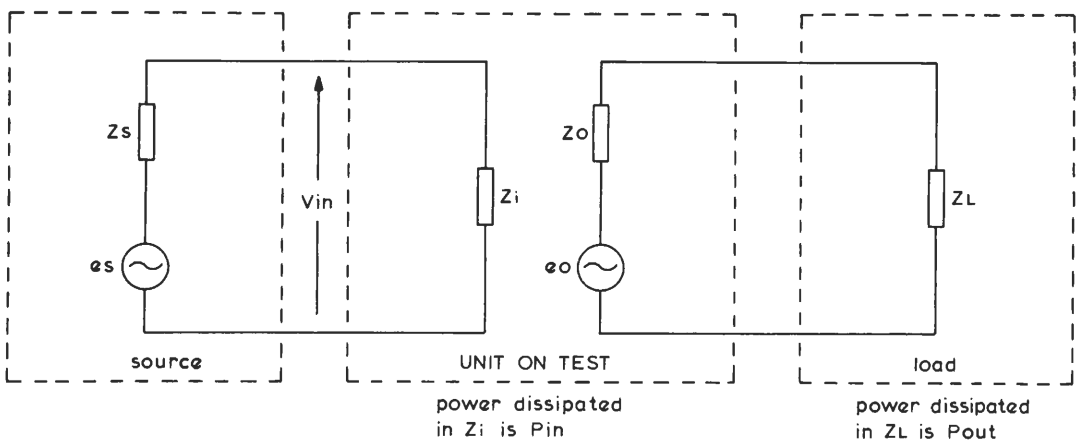


Fig. 1 Circuit illustrating the description of gain

In practice, the impedances involved may not be equal. One method of dealing with this is to express the gain in terms of the change in voltage across Z_L which occurs when the CIRCUIT ON TEST, connected firstly as in Fig. 1, is replaced by a pair of loss-less wires. By comparing the two voltages resulting from this substitution, a parameter known as *Insertion Voltage Gain* is obtained. Thus, referring to Fig. 1:

$$\text{Insertion Voltage Gain} = 20 \log \frac{\text{Volts across } Z_L \text{ with CIRCUIT ON TEST connected between source and load}}{\text{Volts across } Z_L \text{ with source connected directly to load}} \text{ dB} \qquad \text{(C)}$$

It is sufficient to state, without qualification, a result obtained using expression (C) either if:

$$Z_S \equiv Z_i \equiv Z_o \equiv Z_L$$

or, if $$Z_S \equiv Z_o \text{ and } Z_i \equiv Z_L$$

Under these conditions, the resulting figure will equal that obtained from either expression (A) or expression (B); otherwise, it will be different, and it may then be necessary to state the source (Z_S) and load (Z_L) impedances involved in the measurement when the result is quoted.

Generally, in video circuit practice:

(i) signal voltages are given in terms of peak-to-peak amplitude measured between particular points on the waveforms of specified test signals (see **VTP1.1** in **Waveform Amplitude Measurements**).

(ii) the measured gain of a circuit may depend on the composition of the test signal employed, e.g. if a sine wave is used, the gain figure may be different at different frequencies (see VTP6.1 in **Miscellaneous Video Measurements**). A particular instance of this effect occurs when the gain of a circuit at the chrominance sub-carrier frequency is found to be different from that at much lower frequencies. Such a difference is usually expressed in terms of a Chrominance-Luminance Gain Inequality figure (as described and specified in **VTP2.2 Chrominance-Luminance Gain and Delay Inequalities**).

(iii) in the absence of other information, all quotations of video gain are taken to refer to the Insertion Voltage Gain in dB obtained by comparison of PICTURE AMPLITUDES as defined in VTP1.1. This parameter is designated LUMINANCE INSERTION VOLTAGE GAIN.

(iv) the impedance at virtually all video circuit points giving access for gain measurement – unit input/output junctions and circuit interfaces – is 75 ohms; i.e. in Fig. 1 $Z_S \equiv Z_i = Z_o = Z_L = 75$ ohms. Hence,the gain figure obtained in a given instance will be the same irrespective of which expression, A, B or C, is used.

ASSOCIATED INFORMATION

(Normally issued with this Test Procedure)

1. **Video Test Waveforms (P2, Part 3)**: VTW.1, 2, 3

2. **Video Test Procedure VTP1.1 (P2, Part 1)**

3. **Operating Instructions (P2, Part 2)** for: UN1/511 (UN1/511A) SIGNAL MEASURING UNIT
UN1/715 AMPLITUDE MEASURING UNIT
UN2M/504 COLOUR CALIBRATOR
UN2M/509 COLOUR CALIBRATOR
EQ1/520 (EQ1/510) OSCILLOSCOPE EQUALISER

DEFINITIONS

INSERTION VOLTAGE GAIN is the ratio, expressed in dB, comparing voltage amplitudes of:

(i) the signal appearing at the terminated output of the unit on test (V_1 in Fig. 2a) with

(ii) the signal appearing across the same (or equivalent) load but with the unit by-passed (V_2 in Fig. 2b).

Thus:

$$\text{INSERTION VOLTAGE GAIN} = 20 \log \frac{V_1}{V_2} \text{ dB} \qquad \text{(D)}$$

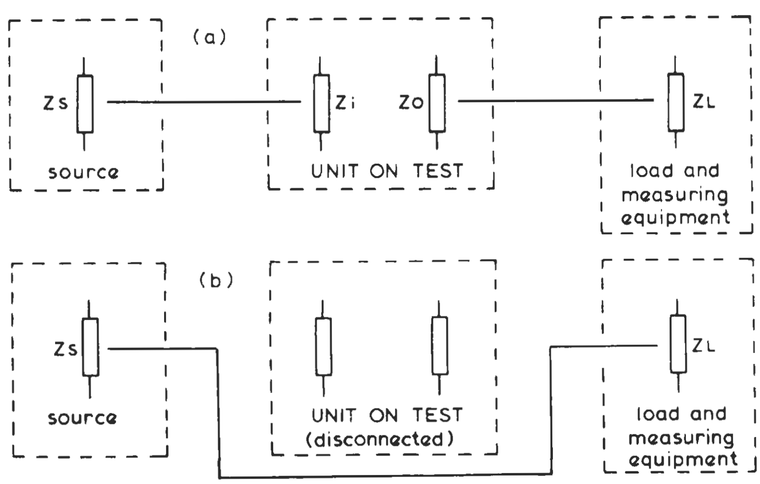


Fig. 2 Diagrams showing interconnections necessary for the measurement of Insertion Voltage Gain

DEFINITIONS (continued)

LUMINANCE INSERTION VOLTAGE GAIN

– is the figure usually quoted as the gain of equipment handling video signals.

– is the ratio of the video signal PICTURE AMPLITUDES, expressed in dB, normally measured under the conditions specified under (i) and (ii) for INSERTION VOLTAGE GAIN.

– is determined by measuring the peak-to-peak voltages on particular test waveforms by means described in Video Test Procedures VTP1.1.

MEASUREMENT METHOD

To obtain the value of LUMINANCE VOLTAGE INSERTION GAIN for a circuit, it is only necessary to make the two measurements of PICTURE AMPLITUDE, as explained under **DEFINITIONS** and illustrated in Fig. 2, at the appropriate termination, circuit junction or test point*. Wherever possible, the measurements should be made using the test signals recommended in Video Test Procedure VTP1.1, specifically:

(a) points A and B on a full-field Pulse-and-Bar signal, see VTW.1 in **VIDEO TEST WAVEFORMS**; this is the preferred waveform;

or (b) points A and B on a National Insertion Test signal (ITS.A; lines 19 and 332), see VTW.3;

or (c) points A and B on a 100.0.100.0 Colour Bar signal, see VTW.2.

*It is essential to remember that, where the two voltage values compared by means of expression (D) are not the result of measurement across the *same* load (with and without the circuit connected to it), the result is the correct value of LUMINANCE INSERTION VOLTAGE GAIN if and only if the load impedances across which these voltages have been measured are identical. (Note that it is the *effective* value of impedance which is considered here, including, if significant, the shunt impedance of the measuring instrument). If the impedances are not identical, the fact should be noted, see Appendix VTP-C.

VIDEO TEST PROCEDURES

VTP2.1 LUMINANCE k-RATING (and 2T PULSE-TO-BAR RATIO)

BACKGROUND

The k-rating system of measurement enables four of the main impairments which affect the luminance component of a television signal to be graded each according to its subjective effect on the displayed picture. The individual grades determined by these measurements can be quoted separately or combined as a 'figure of merit' in an overall k-rating.

The four impairments given k-ratings are all caused by linear distortions, i.e. those which are independent of signal amplitude. For convenience they are further classified by considering three different time scales such that:

(i) short-time – is a duration comparable to that of a picture element
(ii) line time – is a duration comparable to that of a line
(iii) field time – is a duration comparable to that of a field.

The k-ratings, with their abbreviations, are listed below together with the impairments they quantify.

(a) $k_{pulse\text{-}to\text{-}bar}$ ($k_{p\text{-}b}$) – lack or excess of fine detail (a short-time distortion)
(b) k_{pulse} (k_{2T}) – spurious vertical edges and ghost echoes (also a short-time distortion)
(c) k_{bar} (k_b) – smearing/streaking in the horizontal direction (a line-time distortion)
(d) k_{50Hz} – smearing/streaking in the vertical direction (a field-time distortion)

The k-rating measurements are made on an oscilloscope fitted with a special graticule and require particular test waveforms, i.e. those of a Chrominance-Luminance (or monochrome) Pulse-and-Bar signal or similar waveform elements in an Insertion Test Signal (I.T.S.)

ASSOCIATED INFORMATION

(Item 1 is normally issued with the Test Procedure)

1. **Video Test Waveforms (P2, Part 3)**: VTW.1, 2, 3, 4, 5, 6
2. **The Measurement of Linear Distortion in Video Transmission Systems (P2, Part 4)** VMT.1
3. **Measurements Using Insertion Test Signals (P2, Part 4)** VMT.3

DEFINITIONS

The first three k-rating definitions given below refer to measurements made on a line-repetitive (full-field) Pulse-and-Bar test signal using the 2T pulse and the 25-μs bar (see VTW.1). Alternatively, these k-ratings can be derived from measurements on the 2T pulse and 10-μs bar of an I.T.S. (see VTW.2), but the accuracy will probably be less (see VMT.3).

$k_{pulse\text{-}to\text{-}bar}$

– quantifies short-time linear distortion occurring in a video circuit (mainly as the result of a poor h.f. gain response)

– is determined by measuring the percentage difference in amplitude between the 2T pulse and the 25-μs (or 10-μs) bar.
The result is given as:

$$k_{p\text{-}b} = \frac{1}{4} \left| \frac{p-b}{p} \right| \times 100 \text{ per cent}$$

where: p is the base-to-peak pulse amplitude
b is the bar amplitude (between measurement points A, B)

k_{pulse}

– quantifies short-time linear distortion occurring in a video circuit (mainly as the result of a poor h.f. delay response and echoes)

– is determined by measuring, in comparison with percentage limit lines on the k-rating graticule, the distortion of the 2T pulse (including, as part of the distortion, any echoes separated from the 2T pulse itself).

k_{bar}

– quantifies line-time linear distortion occurring in a video circuit

– is determined by measuring the maximum departure in level of the bar top from:
(a) the level at the centre (point A) of the 25-μs bar, or
(b) the level at one end (point H) of the 10-μs I.T.S. bar.
Periods of 0.64 μs at the beginning and end of the bar are neglected in this measurement.
The measured level departure is expressed as a percentage of the total bar amplitude (between measurement points A, B).

k_{50Hz}

– quantifies field-time linear distortion occurring in a video circuit

– is determined by measuring, on the 50-Hz squarewave test signal (see VTW.6), the maximum departure in level along the top of the 10-ms white-line block, neglecting 250 μs at each end, from the level at the centre of the block; k_{50Hz} is then given by expressing an amplitude equal to *half* the measured level departure as a percentage of the total blanking-to-white-level amplitude.

In practice, the k_{50Hz} rating is often considered separately. This is because the distortion it quantifies can be reduced or even removed by clamping. The inclusion (or otherwise) of k_{50Hz} depends on particular knowledge of the test object – e.g. whether or not it contains clamps –and how it normally behaves in the presence of field-time linear distortion.

Overall k-rating

– is a combined 'figure of merit' showing circuit performance in respect of the four types of linear distortion for which individual k-ratings can be specified

– is quoted (in per cent) as the *worst* of the individual k-ratings.

DEFINITIONS (continued)

Pulse-to-Bar Ratio – is an alternative way of stating the amount of distortion otherwise quantified by $k_{p\text{-}b}$.

Because it is not a k-rating, the Pulse-to-Bar Ratio cannot be considered in determining the overall k-rating figure.

– is given as a direct ratio, i.e.

$$\text{Pulse-to-Bar Ratio} = \frac{p}{b} \times 100 \text{ per cent}$$

where p and b are the amplitudes measured as for $k_{p\text{-}b}$.

The above definitions apply specifically to UK 625-line (System I) signals for which the k-rating method of measurement has already been internationally accepted. For other systems a similar method of waveform distortion classification and testing is coming into use. Thus, for:-
SHORT-TIME DISTORTION, two measurements are made – the result of one is the Pulse/Bar Ratio as above; from the other, the 2T pulse lobe amplitudes are expressed as percentages of the pulse amplitude;*
LINE-TIME DISTORTION, the test and result are as for k_{bar} except that the disregarded bar periods are 1 μs instead of 0·64 μs;*
FIELD-TIME DISTORTION, the test is as for k_{50Hz} except that it is the* **total** *measured level departure which is quoted (in per cent) instead of half.*

**Terms as used and defined in C.C.I.R. Rep. 486–1 Geneva 1974.*

MEASUREMENT METHODS

Equipment Required

At input: A source of full-field Pulse-and-Bar signal e.g. a GE2M/559.
Alternatively, a source of I.T.S. can be used.

At output: Oscilloscope or Waveform Monitor fitted with a k-rating graticule.
The preferred graticule is one of the TE1A/507 series, and this form is used in the following illustrations.

The oscilloscope should:

(a) provide the proper termination;

(b) have a good waveform response;

The field and line-time response can be checked with a properly-adjusted Pulse-and-Bar generator. In general, the best response is obtained when the oscilloscope is operated on its most sensitive, d.c.-coupled, range and then fed via a 75-ohm pad.

(c) If necessary, be able to select and hold a stable display of I.T.S. lines for measurement.

A. (Preferred Method) Test for $k_{pulse\text{-}to\text{-}bar}$, k_{pulse} and k_{bar} with Full-field Signal

Test Procedure

(a) for $k_{pulse\text{-}to\text{-}bar}$

a.1 First use the 25-µs bar to set the oscilloscope gain, adjusting it so that signal blanking (waveform point 'B') is at 0% and the bar top centre (point 'A') is on the 100% line (see dotted trace in Fig. A.1).

a.2 With this gain setting, display the 2T pulse and measure its amplitude against the vertical scale.

The figure obtained from this measurement gives the **Pulse-to-Bar Ratio** *directly.*

a.3 Substitute the result of step a.2 for 'p' in:

$$k_{pulse\text{-}to\text{-}bar} = \frac{1}{4}\left|\frac{p-b}{p}\right| \times 100 \text{ per cent}$$

a.4 The figure resulting from steps a.1 to a.3 can alternatively be obtained as follows:

(i) set the oscilloscope gain so that the 2T pulse extends between the 0% and 100% lines in the vertical scale;

(ii) measure the percentage difference between the bar top centre (measurement point 'A') and the 100% line.

From this:

$$k_{p\text{-}b} = \frac{\text{measured percentage difference}}{4}$$

(refer to Fig. B.1)

MEASUREMENT METHODS (continued)

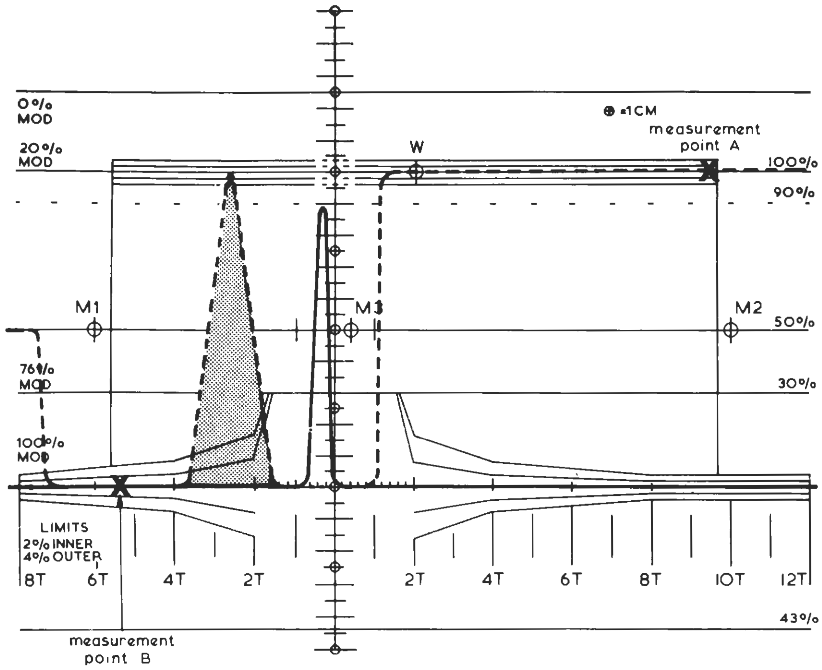


Fig. A.1 Typical measurement of k_{p-b} (k_{p-b} = 3%; P/B = 89%)

MEASUREMENT METHODS (continued)

(b) for k_{pulse}

b.1 Display the 2T pulse so that it extends between 0% and the 100% line and the H.A.D. points are symmetrical with respect to the ±1T markers on the 50% line (see Fig. A.2). The oscilloscope time base must be accurately set so that the sweep rate agrees with the horizontal graticule scale (1T divisions)

The time base may be set by:-

(i) displaying an externally-generated signal, e.g:

(a) an accurate 5 MHz sinewave (1 cycle = 2T);

(b) the incoming 4·433 MHz colour subcarrier (4 cycles = 9·02T);

(ii) displaying a 2T pulse from a local generator and fitting this to the H.A.D. (±1T) graticule marks;

(iii) relying on the oscilloscope time-base calibration (not preferred).

b.2 Estimate the pulse-shape distortion against the 'envelope' lines (as in Fig. A2) and/or measure the echo-pulse amplitude (as in Fig. A.3).

The inner graticule shape-lines (on the TE1A/507) show the limit of 2% k; the outer ones show 4% k; interpolate for greater accuracy.

b.3 Reduce the time-base rate so as to inspect the trace for echoes spaced more than 12T from the main pulse.

The time between the main pulse and any echo should be noted and recorded as possibly useful information.

b.4 The figure for k_{pulse} is taken as the *worst* of the values obtained in b.2 or b.3, above.

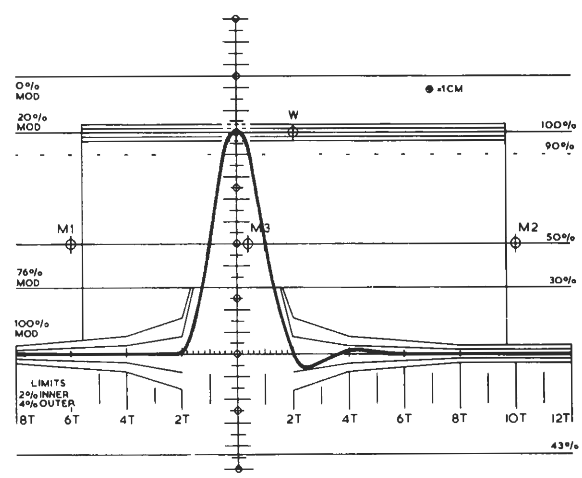


Fig. A.2 Typical measurement of k_{pulse} (overshoot; k_{2T} = 2%)

MEASUREMENT METHODS (continued)

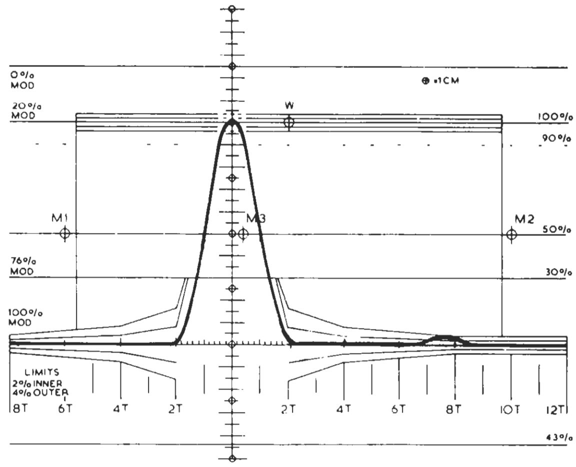


Fig. A.3 Typical measurement of k_{pulse} (echo; k_{2T} = 4%)

(c) for k_{bar}

c.1 Display the 25-μs bar set with respect to the graticule so that the bar top centre (waveform point A) is on W and the leading and trailing edges (half-amplitude points) are on M1 and M2, respectively. (See Fig. A.4)

The spacing of M1 and M2 is such that periods of 0·64 μs at each end of the bar are ignored in the measurement.

• c.2 Measure the maximum departure in level of the bar top from the level at the centre (measurement point 'A'), *over the worst half,* against the 2% and 4% lines above and below 100% (interpolating for greater accuracy). This is k_{bar}.

Values of k_{bar} up to 8% can be measured by first choosing which half of the bar contains the greater level departure and positioning the trace so that the bar centre (waveform point 'A') is on the appropriate 4% line, above or below 100%, whereby the trace can then cross (if necessary) all five graticule lines.

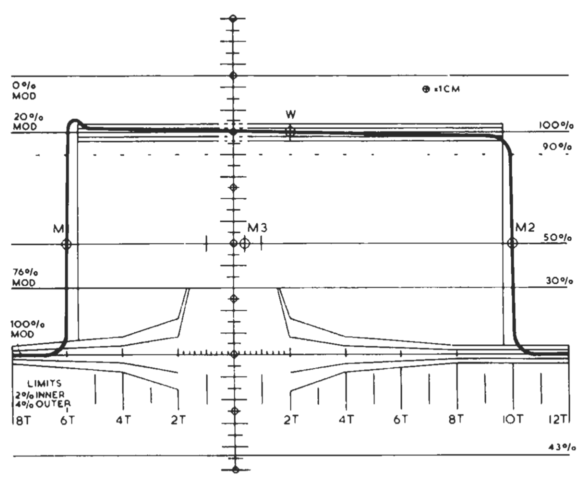


Fig. A.4 Typical measurement of k_{bar} (k_{bar} = 4%)

MEASUREMENT METHODS (continued)

B. (Alternative Method) Tests for $k_{pulse\text{-}to\text{-}bar}$, k_{pulse} and k_{bar} using I.T.S.

Test Procedure

(a) for $k_{pulse\text{-}to\text{-}bar}$

a.1 Display the 10-μs bar, and set the oscilloscope gain so that signal blanking (waveform point B) is at 0% and the bar top (point A) is at 100% (refer to Fig. A.1).

a.2 With this gain setting, display the 2T pulse and measure its amplitude against the vertical scale.

The figure obtained in step a.2 gives the Pulse-to-Bar Ratio directly.

a.3 Substitute the result from step a.2 for 'p' in:

$$k_{pulse\text{-}to\text{-}bar} = \frac{1}{4}\left|\frac{p-b}{p}\right| \text{ x } 100 \text{ per cent}$$

The substitution process can be avoided as explained in **Method A**; *Fig. B.1 shows typical trace settings for this alternative way of deriving*

$$k_{p\text{-}b}\left(= \frac{\text{percentage difference in amplitude}}{4}\right)$$

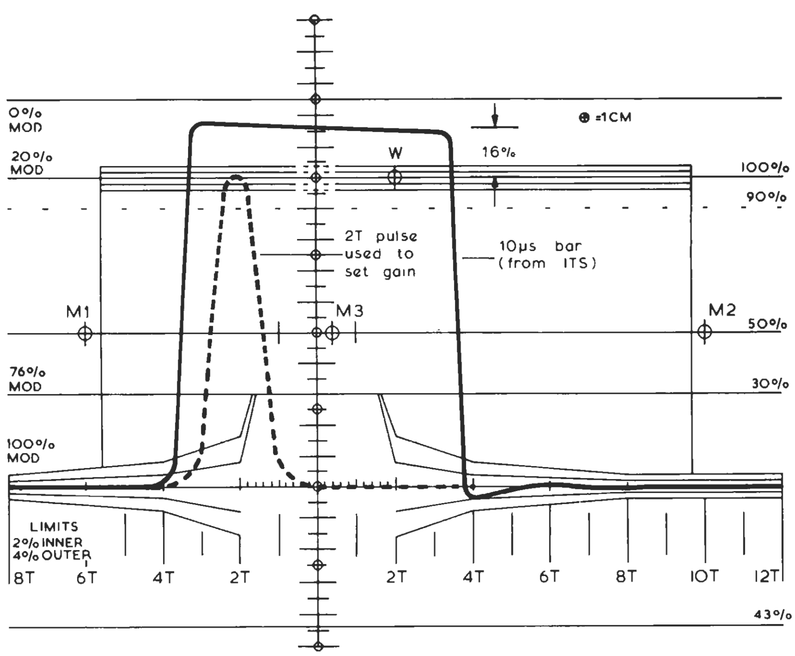


Fig. B.1 Typical measurement of $k_{p\text{-}b}$ using I.T.S. and with 2T pulse (instead of bar) set to 100% ($k_{p\text{-}b}$ = 4%)

MEASUREMENT METHODS (continued)

(b) for k_{pulse}

b.1 and b.2 The procedure to be used here is exactly as described in **Method A** for the k_{pulse} test using a full-field signal.

(c) for k_{bar}

c.1 Display the 10-μs bar (from I.T.S. on lines 19/332) set with respect to the graticule so that the bar top centre (measurement point A) is on 100%, blanking level (measurement point B) is on 0% and the leading and trailing edge half-amplitude points are on M1 and M3 respectively; see Fig. B.2.

The spacing of M1 and M3 is such that periods of about 0·64 μs at each end of the bar are ignored.

c.2 Measure the maximum departure in level of the bar top from that at the trailing-edge (measurement point H) against the 2% and 4% lines above and below 100% (interpolating for greater accuracy). This is k_{bar}.

Because the whole bar top is used, k_{bar} values up to 8% can be measured without modified trace setting (compare with **Method A** *for k_{bar} test).*

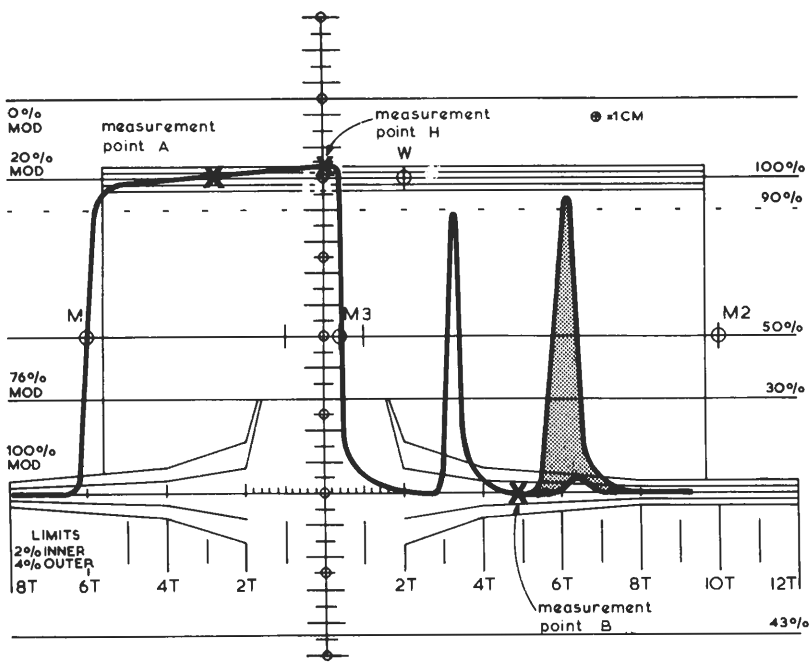


Fig. B.2 Typical measurement of k_{bar} on I.T.S. (k_{bar} = 8%)

MEASUREMENT METHODS (continued)

C. **(Standard Method) Test for k_{50Hz} using 50-Hz Squarewave Signal**

Test Procedure

d.1 Display the 50-Hz squarewave test signal set with respect to the graticule so that the top centre of the white-line block is on W and the bottom centre is on the right-hand 2T mark on 0%; the first white line (leading edge) and the last white line (trailing edge) pass through M1 and M2, respectively. (see Fig. C.1).

Periods of four lines each at the beginning and end of the block are ignored in the measurement.

d.2 Estimate the worst-half slope amplitude against the 2% and 4% lines above and below 100% (interpolating to the nearest 1%). Divide this result by 2 to obtain k_{50Hz}.

Values of k_{50Hz} of up to 4% can be measured by first choosing which half of the block shows the greater slope amplitude and then positioning the trace so that the top centre point is on the appropriate 4% line, above or below 100%, whereby that part of the block envelope being considered can cross all five graticule lines.

Note that the 50-Hz squarewave signal is also used for the Intermediate Line/Field-Time Distortion test which does not result in a k-rating and is therefore described separately (see VTP2.3).

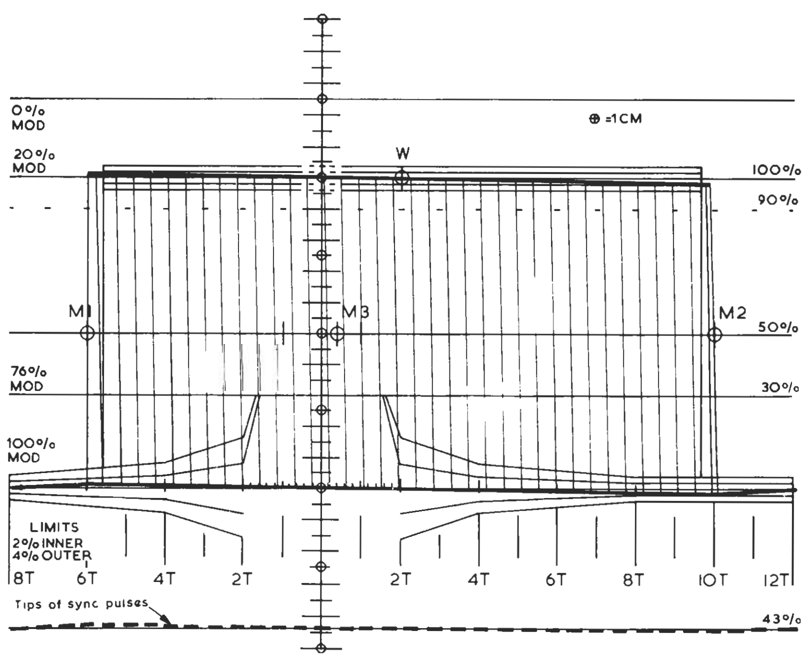


Fig. C.1 Typical measurement of k_{50Hz} ($k_{50Hz} = 1{\cdot}5\%$)

VIDEO TEST PROCEDURES

VTP2.2 CHROMINANCE-LUMINANCE GAIN AND DELAY INEQUALITIES

BACKGROUND

In a transmission chain, the values of gain and delay in processing or distribution equipment may not be the same at all frequencies in the transmitted band. Because a coded television signal carries brightness (luminance) and colour (chrominance) information concentrated at opposite ends of the video band the effect of such differences on the luminance and chrominance components may be sufficient to cause noticeable saturation errors and/or mis-registration in the displayed picture. Tests for gain and delay inequality are therefore made to ensure that the differences are kept within acceptable limits.

The tests are carried out using a Chrominance-Luminance Pulse-and-Bar signal or an Insertion Test Signal (I.T.S.). In both waveforms, the 10-T composite pulse is used to investigate delay inequality. Gain inequality is checked by comparing the relative amplitudes of:

(a) for a full-field pulse-and-bar signal, the 25-μs luminance bar and the 7 μs chrominance minibar or,

(b) for an I.T.S. the 10-μs luminance bar on lines 19/332 and the 14-μs chrominance bar on lines 20/333.

ASSOCIATED INFORMATION

(Items 1 and 2 are normally issued with this Test Procedure.)

1. **Video Test Waveforms (P2, Part 3)** VTW.1, 3, 4

2. **Operating Instructions (P2, Part 2)** for: TE1/513 (TE1L/517, TE1L/552) GAIN, DELAY AND CROSS-TALK TESTER
   TE1/503 COLOUR GAIN AND DELAY TESTER
   UN2M/504 COLOUR CALIBRATOR
   EQ1/520 (or EQ1/510) OSCILLOSCOPE EQUALISER

3. **The Measurement of Linear Distortion in Video Transmission Systems (P2, Part 4)** VMT.1

DEFINITIONS

GAIN INEQUALITY

– is the percentage change, from input to output of a circuit, in the amplitude ratio of the chrominance component to the luminance component, i.e.

$$\text{Gain Inequality} = \left(\frac{\text{Chrominance gain}}{\text{Luminance gain}} - 1\right) \times 100 \text{ per cent}$$

– is measured on the full-field Chrominance-Luminance Pulse-and-Bar test signal (or less accurately on an I.T.S.[1]) using points marked A, B (for the luminance) and D, E (for the Chrominance) in the relevant waveform diagrams VTW.1, 3 and 4.

DELAY INEQUALITY

– is the difference in delay (in nanoseconds) through a circuit for chrominance signals compared with the delay for the lower-frequency luminance signals.

– is measured on the full-field Chrominance-Luminance Pulse-and-Bar test signal (or, with less accuracy, on an I.T.S.[1]) using the 10-T composite pulse, which has a spectrum mainly embracing the frequency regions:

(a) 0-1 MHz, to represent the luminance component, and
(b) 3·4 – 5·4 MHz, to represent the chrominance component.

[1]*For an I.T.S. measurement, the greatest accuracy is obtained when the average picture level (APL) during the active field period is at or near 50 per cent.*

Note. The above definitions refer specifically to UK 625-line (System I) signals. They also apply to other standards except that the half-amplitude duration of the composite pulse is normally 2 μs for 625-line systems whereas it is 1·7 μs for 525-line systems.

MEASUREMENT METHODS – GAIN INEQUALITY TEST

A. (Preferred Method) Gated Measurement

Equipment Required

At input: A source of full-field Chrominance-Luminance Pulse-and-Bar signal e.g. a GE2/559. Alternatively, a source of I.T.S. may be used.

At output: TE1/513 (TE1L/517, TE1L/552) GAIN, DELAY AND CROSSTALK TESTER

The TE1/513 provides direct meter indication of Gain and Delay Inequalities by field-rate/line-rate gated selection of Pulse-and-Bar or National I.T.S. input waveforms. (Alternative gating programmes can be arranged for special test signals, e.g. International I.T.S.)

The ranges and accuracy for Gain Inequality measurement are:

±30%
±10%
± 3%

all within 1% plus 5% of F.S.D.

Test Procedure

1. Use the TE1/513 in the appropriate mode; see Operating Instructions.

B. (Alternative Method) Direct Measurement

Equipment Required

At input: A source of full-field Chrominance-Luminance Pulse-and-Bar signal (e.g. a GE2/559) or use an I.T.S.

At output: Oscilloscope or Waveform Monitor

The oscilloscope h.f. response, particularly at colour subcarrier frequency, is important and should be checked (using for instance, a UN2M/504 COLOUR CALIBRATOR). The oscilloscope may then be equalised by means of an EQ1/520 (or EQ1/510) OSCILLOSCOPE EQUALISER or similar network. If an I.T.S. waveform is used, the oscilloscope must be able to select and hold a stable display of the appropriate lines.

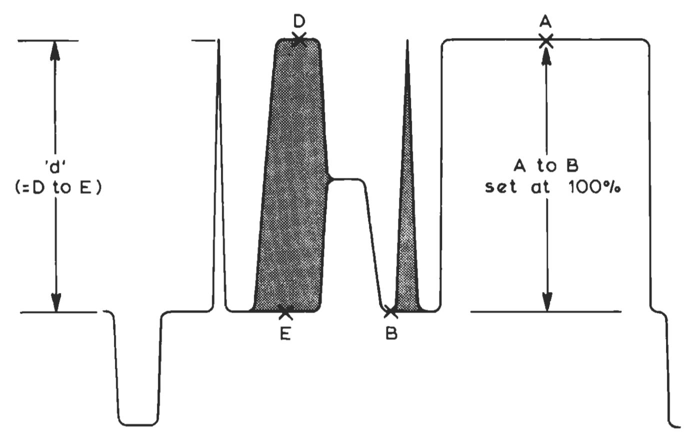
MEASUREMENT METHODS – GAIN INEQUALITY TEST (continued)

B. (Alternative Method) Direct Measurement (continued)

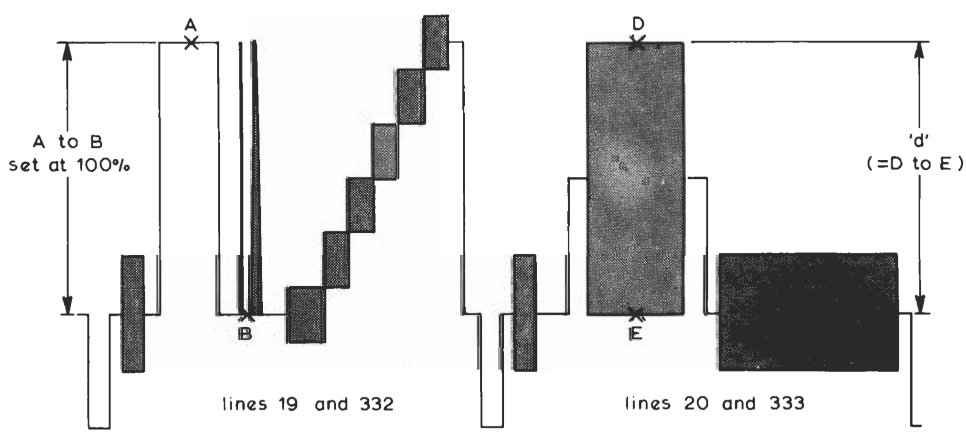
Test Procedure

1. Apply a Chrominance-Luminance Pulse-and-Bar (or I.T.S.) to the circuit under test.
2. Display the circuit output and adjust the oscilloscope Y-gain to give a luminance bar height of 100 per cent (measured between A and B on the relevant Video Test Waveforms; see also Figs. 1a and 1b below.

Make sure that the test equipment either provides the correct terminations or does not alter proper terminations where these already exist.



(a) using Pulse-and-Bar



(b) using I.T.S.

Fig. 1 Waveform Measurement for Gain Inequality Test

3. With this Y-gain setting, measure against the graticule the peak-to-peak chrominance minibar amplitude (i.e. the distance D to E in Fig. 1, shown as 'd').
4. From the above measurements, calculate:

$$\text{Gain Inequality} = \left(\frac{d}{100} - 1\right) \times 100 \text{ per cent}$$

MEASUREMENT METHODS – DELAY INEQUALITY TEST

A. (Preferred Method) Gated Measurement

Equipment Required

At input: A source of full-field Chrominance-Luminance Pulse-and-Bar signal (e.g. a GE2M/559) or use I.T.S.

At output: TE1/513 (TE1L/517, TE1L/552) GAIN, DELAY AND CROSSTALK TESTER.
The ranges and accuracy of the TE1/513 for Delay Inequality measurement are:

±300 ns
±100 ns
± 30 ns
} all within 5 ns plus 5% of F.S.D.

Test Procedure

1. Use the TE1/513 in the appropriate mode; see Operating Instructions.

B. (Alternative Method) Comparison Measurement

Equipment Required

At input: A source of full-field Chrominance-Luminance Pulse-and-Bar signal (e.g. a GE2M/559) or use I.T.S.

At output: TE1/503 COLOUR GAIN AND DELAY TESTER
Oscilloscope or Waveform Monitor

Test Procedure

1. Use the TE1/503 in the appropriate mode; see Operating instructions.

VIDEO TEST PROCEDURES

VTP3.1 SYNC-SIGNAL NON-LINEAR DISTORTION

BACKGROUND

Because the synchronising information in a television signal is carried in the form of pulses – as distinct from the more fragile, analogue-signal form of the picture component – it follows that the sync component can be distorted to a much greater degree before the effect is noticeable on the picture display. Once the limit of acceptable sync distortion is exceeded, however, the resulting picture impairment may be serious.

The term Sync-signal Non-linear Distortion is applied to the errors in sync-pulse waveform amplitude which can occur if the video signal passes through a circuit in which the slope of the transfer characteristic is not constant over the full amplitude range. Specifically, distortion occurs if the mean slope of the characteristic covering the signal excursion below blanking level (the sync-pulse region) differs from the mean slope for excursions above blanking level (the picture-component region). One aspect of this distortion is spurious changes in sync-pulse amplitude. It is the measurement of these changes which is the subject of this Video Test Procedure.

The tests are arranged to take account of the following practical conditions:

(a) When a signal having its blanking level held at a fixed d.c. potential (i.e. a signal in which the d.c. component has been retained; see Appendix VTP-B) is passed through a d.c.-coupled circuit, any change of sync amplitude caused by non-linearity in the circuit transfer characteristic will, in general, be constant and independent of the picture content.

(b) If the signal d.c. component is lost (e.g. as a result of a.c. coupling), the blanking level will vary relative to earth in sympathy with the picture content. Consequently, the transmission circuit requires a linear transfer-characteristic range which is greater (at least 56 per cent more, as illustrated in Appendix VTP-B) than that needed for the maximum peak-to-peak excursion of a standard video signal in which the d.c. component has been retained. When the d.c. component is not present, therefore, it is likely that unwanted changes of sync-pulse amplitude due to non-linearity will be a function of the Average Picture Level (A.P.L.) of the signal.

Separate tests are carried out for A.P.L.-dependent (non-linear) sync distortion. These involve:

(i) The measurement of sync amplitude disturbance which follows **immediately** upon a **sudden** large change of A.P.L. The result is a figure which quantifies the **TRANSIENT-TEST NON-LINEAR SYNC DISTORTION**

(ii) The measurement of sync amplitude disturbance which follows a large change of A.P.L., the measurement being made after sufficient time has elapsed to allow any transient effects to become negligible. The result is a figure which quantifies the **STEADY-STATE (STATIC) NON-LINEAR SYNC DISTORTION.**

It is important to notice that, in practice, the result of the transient test is a figure which necessarily includes the effect of transient and static distortions if these are both present.

The effect on the picture display when Sync-signal Non-linear Distortion occurs following a change in A.P.L. depends on the characteristics of the transmission chain as well as on the rate at which the change takes place. Generally, there will be disturbances to picture stability which may appear as picture rolls or even complete picture break-up. Also, if the chain includes equipment in which syncs are removed and then replaced, the output pulse timing may vary. In this event, variation in sync amplitude could cause random picture movement (i.e. positional modulation; see VTP5.4 Jitter).

Apart from these possible results of sync distortion on the television picture itself, the use of sync pulses to carry the sound component of the programme (sound-in-syncs) places a further restriction on the amount of sync distortion that can be allowed, and increases the need for its measurement.

ASSOCIATED INFORMATION

(Items 1 and 2, below, are normally issued with this Test Procedure)

1. **Video Test Waveforms (P2, Part 3)**

2. **Operating Instructions (P2, Part 2)** for: AM1/505 NON-LINEAR MEASUREMENT PROCESSING AMPLIFIER
   FL1/509B NON-LINEAR MEASUREMENT FILTER
   GE4M/520 NON-LINEARITY TEST SIGNAL GENERATOR
   UN1/511 SIGNAL MEASURING UNIT
   UN1/715 AMPLITUDE MEASURING UNIT

3. **The Measurement of Non-linear Distortion in Video Transmission Systems, (P2, Part 4)** VMT.2

DEFINITIONS

STEADY-STATE (STATIC) NON-LINEAR SYNC DISTORTION

– refers to any long-term departure from the normal amplitude of sync pulses at the output of a unit which has an input video signal containing sync pulses of normal amplitude.

– is specified as whichever is the larger difference in output sync amplitude[1] comparing both:

(a) the sync amplitude for a signal with an A.P.L. of 87.5 per cent (generally) represented by a staircase-plus-3-white-lines test signal and known as the high-A.P.L. signal[2])

AND

(b) the sync amplitude for a signal with an A.P.L. of 12.5 per cent (generally represented by a staircase-plus-3-blanked-lines test signal and known as the low-A.P.L. signal[2])

WITH

(c) the reference[3] sync amplitude determined by calculation from a separate measurement of the tested circuit luminance gain.

The measurements in (a) and (b) above are made after any transient disturbance caused by the A.P.L. change has decayed to a negligible amount.
The larger difference figure found is expressed as a percentage of the reference amplitude to quantify the Steady-State (Static) Non-linear Sync Distortion in the circuit under test.

TRANSIENT-TEST NON-LINEAR SYNC DISTORTION

– refers to the maximum departure from the reference[3] amplitude of sync pulses at the output of a unit or circuit when the average picture level of the input signal is stepped from a high level to a low level or the reverse.

– is specified as whichever is the larger departure of sync pulse amplitude occurring immediately after the transition either from a high-A.P.L. signal (staircase-plus-3-white lines[2]) to a low-A.P.L. signal (staircase-plus-3-blanked-lines[2]) or the reverse. The larger departure figure found is expressed as a percentage of the reference amplitude to quantify the Transient-test Non-linear Sync Distortion in the circuit under test. (See also Note 4, below).

It follows from the above definitions that the figure quantifying the Transient-Test Non-linear Sync Distortion will always be of a magnitude which is either equal to or larger than the comparable Steady-State Distortion figure.

1 Measured between points B' and C see VTW.5.

2 These signals are sometimes termed CCIR white staircase and CCIR black staircase, respectively, and are internationally recommended for sync distortion tests on 625-line transmission circuits.

3 Conventionally, the reference sync amplitude is taken as the result of dividing the relevant Picture Amplitude (defined in VTP1.1 and preferably measured using points A and B on a full-field Pulse-and-Bar test signal; see VTW.1) by the STANDARD PICTURE/SYNC RATIO (70:30).

4 In BBC practice, more stringent tests for sync non-linear distortion are sometimes carried out using a high-A.P.L. signal of 100 per cent A.P.L. (all-lines-white) and a low-A.P.L. signal of 0 per cent A.P.L. (all-lines-black). The test for transient distortion is also called a Bump Test.

The above definitions apply specifically to UK 625-line (System I) video signals. They also apply to other standards with the exception that 525-line system tests are normally carried out using a high-A.P.L. value of 90 per cent (staircase-plus-4-white-lines) and a low-A.P.L. value of 10 per cent (staircase-plus-4-blanked-lines).

DETERMINATION OF REFERENCE SYNC-PULSE AMPLITUDE

This requires the normal measurement of the video signal PICTURE AMPLITUDE.

Equipment Required - see **VTP1.1**

Test Procedure

1. At the input to the circuit, apply a suitable test signal, e.g. a line-repetitive Pulse-and-Bar waveform, of STANDARD VIDEO AMPLITUDE and having a STANDARD PICTURE/SYNC RATIO.

2. At the output of the circuit, measure the PICTURE AMPLITUDE (luminance), using one of the methods described in VTP1.1.

3. Multiply the result obtained in step 2 by a factor which is the inverse of the appropriate picture/sync ratio (i.e. the factor is normally, but not necessarily, 3/7). This product is then taken as the reference amplitude of the sync component of the received signal.

MEASUREMENT METHODS – STEADY-STATE (STATIC) NON-LINEAR SYNC DISTORTION TEST

A (Preferred Method) Comparison Measurement

Equipment Required

At input: A source of standard-amplitude sync pulses, free of sound-in-syncs information, accompanying a picture signal having an A.P.L. which can be switched between low and high values (12.5 per cent and 87.5 per cent); e.g. a GE4M/520 NON-LINEARITY TEST SIGNAL GENERATOR.

At output: UN1/511 SIGNAL MEASURING UNIT or UN1/715 AMPLITUDE MEASURING UNIT } and oscilloscope or waveform monitor
(Optionally, a 3-dB 75-ohm attenuator; see step 5, below).

Test Procedure

1. Apply the high-A.P.L. test signal at standard amplitude to the circuit under test. Ensure that the circuit is properly terminated.

If a GE4M/520 SIGNAL GENERATOR is being used, the control settings should be:

TRIGGER MODE	FREE
TEST W/F	CCIR
AUTO	off (up)
BAR	on (down)
OUTPUT	NORMAL

MEASUREMENT METHODS (continued)

2. Using the UN1/511 or UN1/715 according to the appropriate Operating Instruction, measure the sync amplitude at the output of the circuit. Record the result.

   Use the recommended waveform measurement points (B' and C in VTW.5).

3. Change the input signal to the low-A.P.L. test signal.

   On the GE4M/520, switch **BAR** *off (up)*

4. Again measure the sync amplitude at the output. Determine the difference between each of the amplitude values found (here and in step 2) and the reference amplitude obtained previously. Express whichever is the larger difference as a percentage of the reference amplitude. This is the STEADY-STATE NON-LINEAR SYNC DISTORTION figure for the circuit under test.

5. If required, repeat steps 1 to 4 for a 3-dB increase in applied signal amplitude. (An accurate 3-dB 75-ohm attenuator is then needed to reduce the input to the UN1/511).

   On the GE4M/520, switch **OUTPUT** *to* **+3 dB.**

B. (Alternative Method) Direct Measurement

Equipment Required

At input: As in **Method A**, above (e.g. GE4M/520)

At output: Oscilloscope or waveform monitor

Test Procedure

1. Test the circuit as detailed in steps 1 to 4 (including step 5, if necessary) of **Method A**, above, but measure the output sync amplitude directly on the oscilloscope against the Y-gain calibration.

   In order to minimize the possible effects of oscilloscope non-linearity the display trace should be positioned centrally and have a restricted vertical dimension.

MEASUREMENT METHODS – TRANSIENT-TEST NON-LINEAR SYNC DISTORTION TEST

A. Normal Test (Using the CCIR Staircase Signals)

Equipment Required

At input: A source of standard-amplitude sync pulses, free of sound-in-syncs information accompanying a picture signal the A.P.L. of which can be switched between low and high values (12.5 per cent and 87.5 per cent); e.g. a GE4M/520 NON-LINEARITY TEST SIGNAL GENERATOR.

At output: Long-persistence tube (storage) oscilloscope or normal oscilloscope equipped with a camera, e.g. Polaroid. Shaping/differentiating filter, e.g. FL1/509B NON-LINEARITY MEASUREMENT FILTER. (Optionally, an AM1/505 NON-LINEARITY MEASUREMENT PROCESSING AMPLIFIER, or a similar unit).

Preliminary Calibration of Test Circuit

1. At the measurement location, feed a suitable signal (having a sync-pulse amplitude equal to the reference amplitude as determined previously) from a local source to the shaping/differentiating filter and thence to a correctly-terminated oscilloscope.

   The waveform of this calibration signal is unimportant provided it carries standard sync pulses. A feed of mixed-sync pulses would suffice.

MEASUREMENT METHODS (continued)

2. Adjust the oscilloscope to obtain a trace such as in the example of Fig. 1 (which shows a filtered and differentiated low-A.P.L. signal).

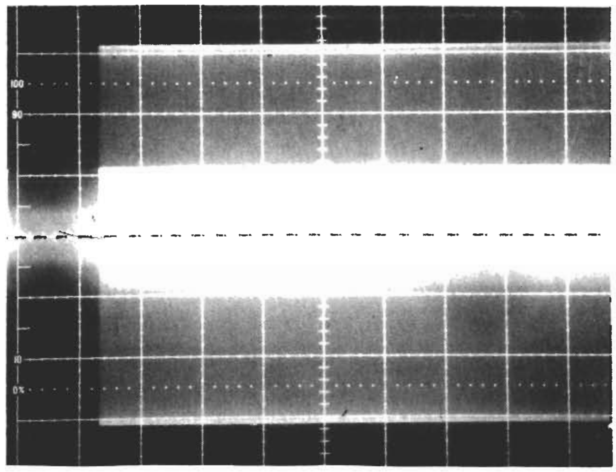


Fig. 1 Calibration display of a low-A.P.L. signal (staircase-plus-3-blanked-lines) through filter FL1/509B

For convenience of measurement, the oscilloscope Y-gain may be set so that the dimension S_d in Fig. 1 between the bright horizontal centre line (the signal at blanking level) and the tips of spikes formed by the differentiated, positive-going sync edges, corresponds to an exact number of graticule divisions. This dimension effectively represents the reference sync amplitude. If S_d is chosen to be 100 or a simple fraction of 100, the following measurement results (percentages of distortion) can be read directly from the scale

Test Procedure (see Fig. 2)

1. At the input to the circuit under test apply the low-A.P.L. test signal, at STANDARD amplitude.

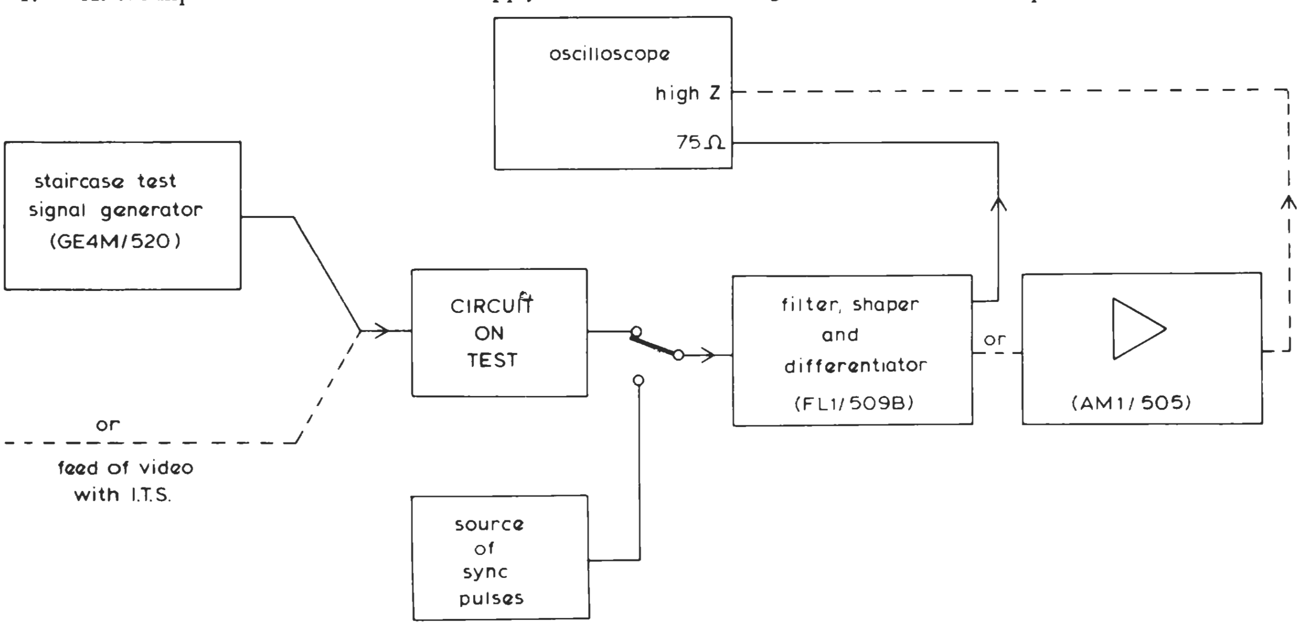


Fig. 2 Basic circuit for calibration and measurement of transient sync distortion

If a GE4M/520 is being used, the control settings are:

TRIGGER MODE	FREE
TEST W/F	CCIR
AUTO	off (up)
BAR	off (up)
OUTPUT	NORMAL

MEASUREMENT METHODS (continued)

2. At the output of the circuit, remove the local signal and connect in its place the incoming test signal.
Ensure that the tested circuit (as well as the filter) is correctly terminated.

3. Change the input signal to one of high A.P.L. (staircase-plus-3-white-lines).
On the GE4M/520, switch **BAR** *on (down)*

At the instant of signal change-over, the change in the received waveform must be inspected in detail – either by using the residual trace on the storage oscilloscope or by means of an oscillogram photograph. A typical example of such a change at the output of a circuit is shown in Fig. 3a; the same change is shown in Fig. 3b after passing through the differentiating/shaping filter (FL1/509B).

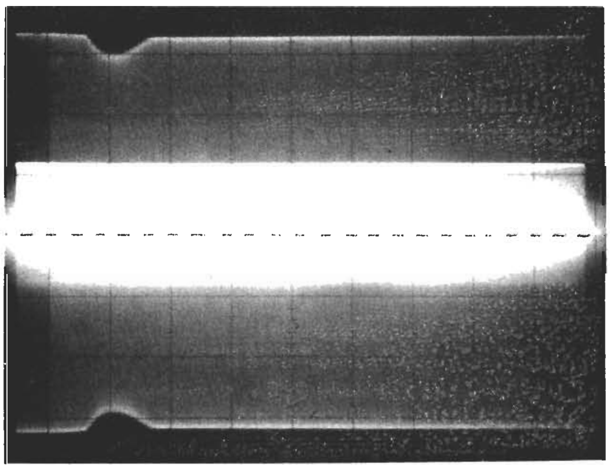


Fig. 3b Input signal transition the same as in Fig. 3a. Output signal filtered by FL1/509B for measurement Note that this trace shows differentiated and shaped sync-pulse edges and is part of a signal of much greater amplitude than appears in the photograph. The bright region across the centre is mainly caused by a photographic effect. It should be ignored.

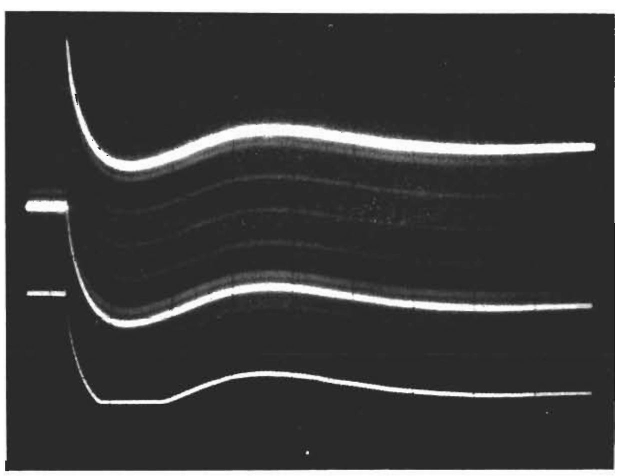


Fig. 3a Example of transient sync distortion (about 12 per cent). The circuit output signal is shown (at a scan rate of about 0.3 sec/cm) for an input-signal change of 12.5 per cent A.P.L. staircase to 87.5 per cent A.P.L. staircase. Note the flattened lower trace line indicating sync crushing.

MEASUREMENT METHODS (continued)

4. Measure the envelope amplitude from the centre line to the point of maximum departure from normal, e.g the dimension *a* in Fig. 3b. Take the difference between *a* and dimension S_d (which represents the reference sync amplitude as previously determined) and express the difference as a per-centage of S_d to give the distortion figure for a low-A.P.L. to high-A.P.L. change. Thus;

$$\text{Distortion} = \frac{|a - S_d|}{S_d} \times 100 \text{ per cent}$$

5. Switch the input signal back to the low-A.P.L. signal

   On the GE4M/520, switch **BAR** *off (up)*

   As in step 3, observe the display change (by 'stored' trace inspection or by means of an oscillogram).

6. Again measure the envelope amplitude at the point of maximum departure from normal and take the difference between this and S_d; similarly, express this difference as a percentage of S_d to obtain the distortion figure for a high-A.P.L. to low-A.P.L. change.

7. The larger of the values found in steps 4 and 6 is quoted as the TRANSIENT-TEST NON-LINEAR SYNC DISTORTION figure relating to the tested circuit.

8. If required, repeat steps 1 to 7 for an input signal amplitude increase of 3 dB

   On the GE4M/520, switch **OUTPUT** *to* **+3 dB.**

VIDEO TEST PROCEDURES

VTP3.2 LUMINANCE NON-LINEARITY

BACKGROUND

When a video signal is displayed on a television screen, the brightness at any point ultimately depends on the level of the luminance component, i.e. on its voltage relative to blanking level. It is important that gradations of brightness between black and white (the grey scale) as seen by the camera tube should result in equivalent gradations on the television display. It follows that the transfer characteristic of equipment in the chain between source and display should be as linear as possible. (Non-linearity may be deliberately introduced for other reasons; see Note 1). The distortion which occurs if the characteristic is not linear over the whole range of normal signal amplitude is called Luminance Non-linearity, and gives an observed effect of incorrect contrast ratio or, in extreme instances, of crushing.

In practical circuits, the use of a.c. coupling aggravates the problem of Luminance Non-linearity because, as the average picture level (A.P.L.) varies, the signal moves up and down the transfer characteristic in such a way that parts of it may encounter non-linear regions. To reveal such defects in operation, tests must be carried out using a signal which can be applied at either a high or a low value of A.P.L.

The effects of Luminance Non-linearity may also depend critically on the overall signal amplitude; hence, circuits are sometimes checked with signals having amplitudes larger than normal. An increase of 3 dB is the usual practice.

The measurements of Luminance Non-linearity described here are used only on those parts of the chain designed to have a linear transfer characteristic. They are not applicable to equipments, usually associated only with the picture source, which introduce a deliberate and controlled amount of transfer-slope curvature known as gamma correction.

ASSOCIATED INFORMATION

(Items 1 and 2 are normally issued with the Test Procedure).

1. **Video Test Waveforms (P2, Part 3)** VTW1, 2, 3, 4, 5, 6.

2. **Operating Instructions (P2, Part 2) for:**
   - AM1/505 NON-LINEARITY MEASUREMENT PROCESSING AMPLIFIER
   - EP1M/523 TELEVISION WAVEFORM ANALYSER
   - FL1/509B NON-LINEARITY MEASUREMENT FILTER
   - GE4M/520 NON-LINEARITY TEST SIGNAL GENERATOR

3. **The Measurement of Non-linear Distortion in Video Transmission Systems (P2, Part 4)** VMT.2.

DEFINITIONS	
LUMINANCE NON-LINEARITY	– refers to the unwanted difference in circuit gain, for a defined small luminance signal step, according to where the step occurs in the blanking-to-white-level range. – is determined, for a given value of A.P.L., by feeding a staircase signal to the circuit under test and checking the output for inequality between riser amplitudes. To simplify this process, the output may be passed through a differentiating and shaping filter to derive a series of pulses each generated by a step riser of the input waveform. Because the input-signal risers are of equal amplitude and duration, the pulses derived at the circuit output should also be of equal amplitude; inequality shows that the circuit gain varies with luminance level. The distortion figure is taken as the difference between the largest and the smallest pulse, expressed as a percentage of the largest pulse. – is measured using a staircase waveform (see **NOTES ON TEST SIGNALS AND TEST RESULTS**) which is part of a video signal produced with either high or low values of A.P.L. The worst result from separate measurements (at high-and-low-A.P.L.) is quoted as the Luminance Non-linearity Distortion.

NOTES ON TEST SIGNALS AND TEST RESULTS

1. In BBC practice (and generally for U.K. 625-line television systems), the test signal has the form shown as VTW5 in **Video Test Waveforms**, i.e. a 5-riser staircase plus subcarrier on every fourth line and the intermediate lines, without subcarrier, either all white (giving an A.P.L. of 87·5 per cent) or all blanked (giving an A.P.L. of 12·5 per cent).

2. Luminance Non-linearity distortion can also be measured using the staircase waveform in a U.K. I.T.S. (see VTW3), but because the A.P.L. cannot then (normally) be controlled and held at the specified values, the test is considered incomplete.
If an I.T.S. signal is used to make a measurement, and the A.P.L. is not controlled, this should be noted against the measurement result.

3. The test signal used in other 625-line systems, particularly those originated by European broadcasting authorities, is similar to that illustrated by VTW5 except that the superimposed subcarrier component is of twice the amplitude shown, i.e. it is 280 mV p-p for a standard picture amplitude of 0·7 volt.

4. The test waveform for 525-line systems is also similar to VTW5 except that the staircase is inserted on every fifth line so that A.P.L. values of 90 per cent (high) and 10 per cent (low) are obtained.

5. Both the recommended 625-line test signal and its alternatives contain a colour subcarrier component. Because it is rejected by the Luminance Non-linearity measurement filter, it can generally be disregarded. If, however, the circuit under test is also affected to an appreciable extent by Chrominance-Luminance Intermodulation (see VTP3.4) then this unwanted component could cause measurement error, and should, if possible, be removed before applying the signal to the circuit.

MEASUREMENT METHODS

Equipment Required

At input: A source of staircase signal (including A.P.L.-control facility), e.g. GE4/520 NON-LINEARITY TEST SIGNAL GENERATOR. Alternatively, an I.T.S. may be used.

At output: A differentiating/shaping filter e.g. FL1/509B NON-LINEARITY MEASUREMENT FILTER* with, if necessary an amplifier e.g. AM1/505 NON-LINEARITY MEASUREMENT PROCESSING AMPLIFIER) or EP1M/523 TELEVISION WAVEFORM ANALYSER.
An oscilloscope or waveform monitor* (if an I.T.S. waveform is to be used, the oscilloscope must be able to hold a stable display of the appropriate television lines, i.e. line-pair 19/332).

**Some waveform monitors have an internal filter which is provided specifically for the measurement of Luminance Non-Linearity distortion.*

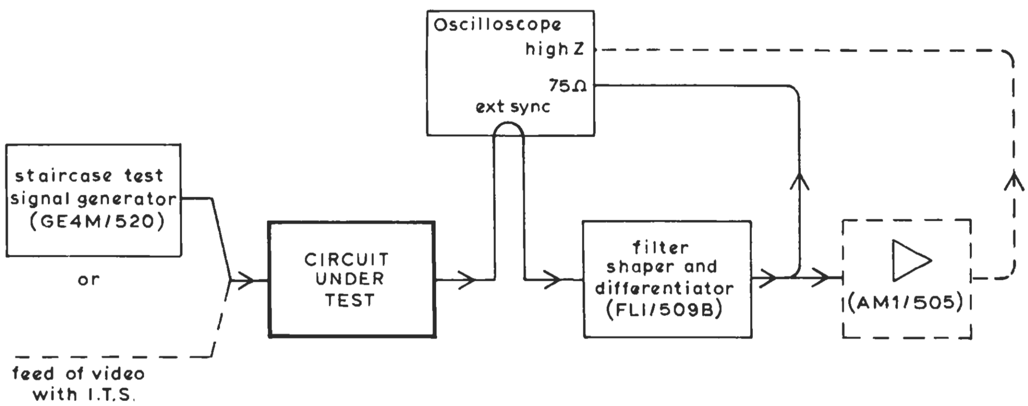


Fig. 1 Basic test circuit for Luminance Non-linearity measurement.
The looped-through trigger feed is only necessary if the input is an I.T.S.; see **NOTES ON TEST SIGNALS AND TEST RESULTS**. *Equipment codes, shown on the diagram are of suggested suitable units.*

Test Procedure

1. Apply the low-A.P.L. test signal (staircase plus three blanked lines) at normal amplitude to the circuit under test.

For the GE4M/520, the control settings are:

TRIGGER MODE	FREE†
TEST W/F	CCIR
AUTO	*off (up)*
BAR	*off (up)*
OUTPUT	NORMAL
SUBCARRIER	OFF

†If the circuit under test requires field syncs for proper operation, set this control to **MIXED** *and supply the GE4M/520 with feeds of mixed-sync and mixed-blanking pulses.*

MEASUREMENT METHODS (continued)

2. Arrange the circuit as shown in Fig. 1. The display obtained should be similar to the example shown in Fig. 2(b).

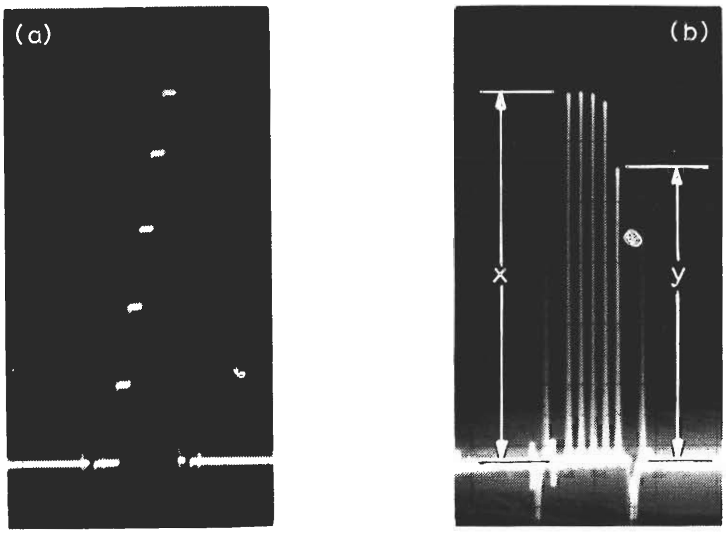


Fig. 2 Typical displays of: (a) staircase signal affected by Luminance Non-linearity – about 20 per cent distortion;
(b) this signal after passing through a shaping/differentiating filter (e.g. FL1/509B)

3. Using the vertical scale on the oscilloscope graticule, measure the difference between the largest (amplitude x in Fig. 2) and the smallest pulse (amplitude y).

4. Calculate: Luminance Non-linearity distortion $= \frac{(x-y)}{x} \times 100$ per cent.

5. Apply the high-A.P.L. test signal (staircase plus three white lines) and repeat steps 3 and 4.

   On the GE4M/520, switch **BAR** *on (down)*

6. The Luminance Non-linearity distortion figure for the tested circuit is taken as the larger of the values calculated in steps 4 and 5.

7. If required, repeat steps 1 – 6 with increased applied signal amplitude.

   On the GE4M/520, switch **OUTPUT** *to* **+3dB**

   If an I.T.S. has been used, and the A.P.L. was not controlled, this should be noted against the measurement result.

VIDEO TEST PROCEDURES

VTP3.3 DIFFERENTIAL GAIN AND DIFFERENTIAL PHASE

BACKGROUND

A coded colour-television signal carries the luminance and the associated chrominance components in time coincidence but separated in frequency so that they are grouped towards opposite ends of the video spectrum. Chrominance information (contained in the colour subcarrier sidebands) occupies the upper part while the luminance signal is mainly in the lower part. One requirement for the transmission and reception of high-quality pictures is that interaction between these separated components must be kept to a minimum; in particular, it is important that circuit parameters affecting the colour subcarrier and its sidebands should show no more than minimal change with luminance level. If the video-circuit transfer characteristics are not linear over the whole range of luminance levels, the chrominance subcarrier-amplitude and/or phase (usually both) may be affected by luminance level with the consequence that, in the displayed picture, colour varies with brightness. The distortions caused by such modulation of chrominance by luminance are termed Differential Gain and Differential Phase.

For PAL and N.T.S.C. coding (but not SECAM) the result of Differential Gain distortion on a displayed signal is that colour saturation changes with brightness. The observed effects of Differentiai Phase distortion also depend on the coding system and, for PAL signals, on the type of decoder used. If a PAL signal with Differential Phase distortion is applied to a delay-line decoder, the subjective result is a reduction in saturation; if the same signal is fed to a simple decoder, the distortion shows up as moving horizontal bands with a pitch of two lines, i.e. the so-called Hanover bars. For N.T.S.C. signals, Differential Phase distortion causes an error in hue.

Just as with other forms of non-linear distortion, Differential Gain and Differential Phase can vary in amount according to the Average Picture Level (A.P.L.) and, therefore, a circuit should be tested with signals having both high and low values of A.P.L. The effects of distortion may also critically depend on the overall signal amplitude, and some circuits are therefore checked with signals having amplitudes larger than normal; an increase of 3 dB is standard practice.

ASSOCIATED INFORMATION

(Items 1 and 2 are normally issued with the Test Procedure)

1. **Video Test Waveforms (P2, Part 3)** VTW1, 2, 3, 4, 5, 6.

2. **Operating Instructions (P2, Part 2)** for: EP1M/523 TELEVISION WAVEFORM ANALYSER
EP1/508 REMOTE SIGNAL ANALYSER

3. **The Measurement of Non-linear Distortion in Video Transmission Systems; (P2, Part 4)** VMT.3.

DEFINITIONS

DIFFERENTIAL GAIN

– refers to unwanted changes in circuit gain at and near colour subcarrier frequency caused by changes in the level of the luminance signal on which the subcarrier is superimposed.

– can also be considered as amplitude modulation of the colour subcarrier by the luminance signal.

– is determined by feeding to the circuit under test a staircase plus constant-amplitude subcarrier signal (see **NOTES ON TEST SIGNALS AND TEST RESULTS**), at high and at low values of A.P.L. The circuit output signal is then checked for variation in subcarrier amplitude. To simplify this process, the output may be filtered to reject the luminance component so that when the staircase signal is displayed on an oscilloscope, it appears as a block of subcarrier having either virtually constant envelope amplitude or stepped differences in amplitude (as shown in Fig. 1) indicating the presence and amount of Differential Gain distortion.

– is specified, for a given value of A.P.L. as whichever is the larger (modulus) difference comparing subcarrier amplitudes:-

(a) at blanking level (x in Fig. 1), with either
(b) the maximum (y), or
(c) the minimum (z).

The chosen difference is then expressed as a percentage of the subcarrier amplitude at blanking level whence, either:

$$\text{Differential Gain distortion} = \frac{y - x}{x} \times 100 \text{ per cent}$$

or

$$\frac{z - x}{x} \times 100 \text{ per cent}$$

When subcarrier amplitudes both larger and smaller than the amplitude at blanking level are present, two results are obtained one of which is negative. The result with the larger modulus is chosen, together with its sign, as the distortion figure (see **NOTES ON TEST SIGNALS AND TEST RESULTS**).

The worst result from the separate measurements at high and low values of A.P.L. is quoted as the Differential Gain distortion for the tested circuit.

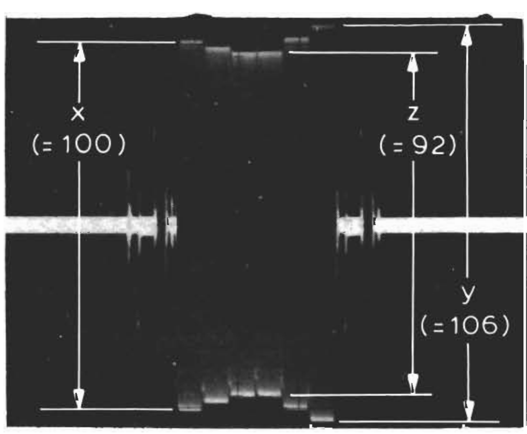


Fig. 1 Typical measurement display showing Differential Gain distortion of about 8 per cent. The test input was a line-duration staircase-with-subcarrier waveform on every fourth line (giving an A.P.L. of 12·5 per cent). The numbers in brackets show relative amplitudes.

DEFINITIONS (continued)

DIFFERENTIAL PHASE

– refers to unwanted changes in circuit phase shift at and near colour subcarrier frequency caused by changes in level of the luminance signal on which the subcarrier is superimposed.

– can also be considered as phase modulation of the colour subcarrier by the luminance signal.

– is determined by feeding the circuit under test with a staircase plus constant-phase constant-amplitude subcarrier signal (see **NOTES ON TEST SIGNALS AND TEST RESULTS**) at high and at low values of A.P.L. The circuit output signal is checked for any variation in subcarrier phase (ignoring changes which correspond with the staircase transients). To simplify this process, the output may be filtered to pass only the subcarrier component which is then demodulated by a phase detector to produce a resultant signal for display on an oscilloscope. If the subcarrier phase has not been disturbed, this resultant has a constant level for the duration of the subcarrier on the staircase; any variation in level (as shown in Figs. 3a and 3b) show that the subcarrier phase has been advanced or retarded or both i.e. that Differential Phase distortion is present.

– is specified, for a given value of A.P.L. as whichever is the larger difference (in degrees) comparing subcarrier phases:-

(a) at blanking level (Φ_x in Fig. 2), with either
(b) that giving maximum phase advance (Φ_y), or
(c) that giving maximum phase retard (Φ_z).

Whence either:-

Differential Phase distortion = $\Phi_y - \Phi_x$ degrees

or

$\Phi_z - \Phi_x$ degrees

Two results are obtained when both advance and retard phase distortions are present (as shown in Fig. 3a). If the negative (retarded) result has the larger modulus, it is chosen as the distortion figure (see **NOTES ON TEST SIGNALS AND TEST RESULTS**) and quoted together with the negative sign.

The sign is directly indicated on some test instruments whereas on others it must be deduced.
The adopted convention is that a signal affected by **positive** *Differential Phase distortion would appear on a conventional vector display having its worst-error-(i.e. maximum difference) phase-vector displaced* **counter-clockwise** *from the blanking-level vector. Fig. 2 (on page 4) illustrates this.*

DEFINITIONS (continued)

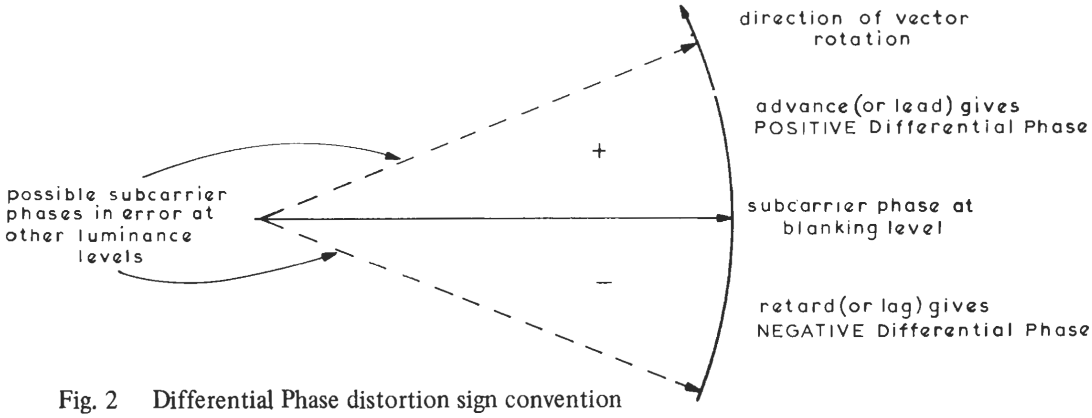
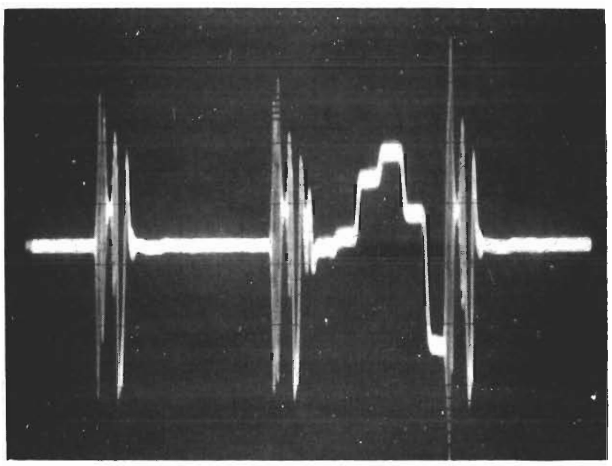
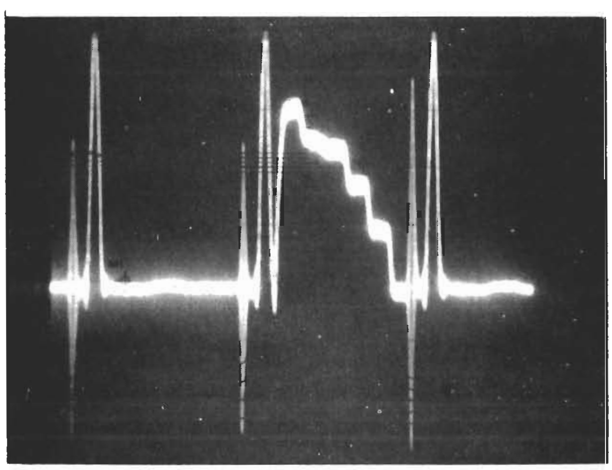


Fig. 2 Differential Phase distortion sign convention

The worst result from the separate measurements at high- and low-A.P.L. is quoted as the Differential Phase distortion figure for the tested circuit.



(a) Comparator output showing both advance and retard phase errors.



(b) Comparator output showing retard phase error only

Fig. 3 Typical Differential Phase distortion measurement displays. (The test input was a line-duration staircase-with-subcarrier with A.P.L. of 12·5 per cent).

NOTES ON TEST SIGNALS AND TEST RESULTS

1. In BBC practice (and generally for U.K. 625-line television systems) the test signal has the form shown as VTW5 in **Video Test Waveforms**, i.e. a 5-riser staircase, with superimposed colour subcarrier, on every fourth line and the intermediate lines, without subcarrier, either all white (giving an A.P.L. of 87·5 per cent) or all blanked (giving an A.P.L. of 12·5 per cent). Differential Gain and Differential Phase distortions can both be measured using the staircase waveform in a U.K. I.T.S. (see VTW3), but because the A.P.L. cannot then normally be controlled, the test are considered incomplete.
   If an I.T.S. is used to make a measurement, and the A.P.L. is not controlled, this should be noted against the measurement result.

2. The test signal in other 625-line systems, particularly those originated by European broadcasting authorities, is similar to that illustrated in VTW5 except that the superimposed subcarrier component is of twice the amplitude shown, i.e. it is 280 mV for a standard picture amplitude of 0·7 volt.

3. The test signal in 525-line systems is also similar to VTW5 except that the staircase is inserted on every fifth line so that A.P.L. values of 90 per cent and 10 per cent are obtained.

4. For broadcasting authorities outside the U.K., it is common practice to quote both negative and positive results for Differential Gain and Differential Phase distortions. If, in any instance, only one distortion figure is obtained from measurement, the other value is stated as zero.

5. The use of digital coding (of the video signal) can lead to difficulty in measurements on staircase waveforms because of quantizing effects. For this reason, Differential Gain and Differential Phase distortion tests are sometimes carried out with a test signal having a sawtooth luminance component (with superimposed colour subcarrier). The test procedures described here will not apply in those instances.

MEASUREMENT METHODS – DIFFERENTIAL GAIN

A. Using a (BBC) Signal Analyser

Equipment Required

At input: A source of staircase-with-subcarrier signal (with A.P.L.-control facility); e.g. GE4M/520 NON-LINEARITY TEST SIGNAL GENERATOR. Alternatively, use I.T.S. on lines 19 and 332 of a television signal (in this instance the A.P.L. cannot normally be controlled).

At output: EP1M/523 TELEVISION WAVEFORM ANALYSER or EP1M/508 REMOTE SIGNAL ANALYSER.

In both these equipments, only the band-pass filter (part of the UN1/541 COLOUR SIGNAL ANALYSER unit) is used in the Differential Gain test.

Oscilloscope or Waveform Monitor (which, if an I.T.S. waveform is to be used, must be able to hold a stable display of the appropriate television lines).

Test Procedure

1. Use the EP1M/523 or EP1M/508 and the oscilloscope as explained in the appropriate Operating Instruction.

MEASUREMENT METHODS – DIFFERENTIAL GAIN (continued)

B. Using a Vectorscope

Equipment Required

At input: As in **Method A**, i.e. a staircase-with-subcarrier generator with variable A.P.L. facility (e.g. GE4M/520); alternatively use an I.T.S.

At output: Vectorscope; the Test Procedure given below refers to Tektronix equipment: Models 520, 521 or 521A.

Test Procedure

1. Apply the test signal to Vectorscope **CH A** at standard amplitude and low A.P.L. (i.e. use a staircase-plus-three-blanked-lines signal).

Steps 2 – 4, following, are used to standardize the vectorscope gain before measuring Differential Gain.

2. On the vectorscope, press buttons:

VECTOR PAL (which illuminates the vector graticule)
CH A (**CH B** or **CH B CAL** must *not* be selected)
FULL FIELD or **VITS 1** for I.T.S. input)
AØ

Note that the **AØ** *button must be pressed to obtain a vector display.*

3. Set the **CHANNEL A GAIN** controls:

switch	to	**MAX GAIN**
thumbwheel	to	**CAL** (indexed position)

Set the **DISPLAY** switch to **BOTH**. The vectorscope display should then be similar to the example shown in Fig. 4. If necessary, adjust **CHANNEL A GAIN** so that the mean vector length is roughly equal to the graticule radius.

blanking-level subcarrier vector

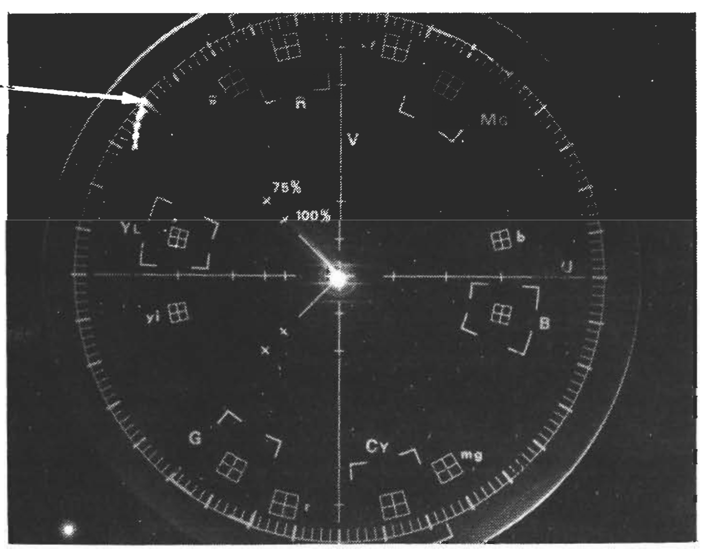


Fig. 4 Calibration display of subcarrier vectors for DIFF. GAIN test; the vectorscope gain is set by making the blanking-level vector length equal to the graticule radius.

MEASUREMENT METHODS – DIFFERENTIAL GAIN (continued)

In Fig. 4 the upper vector traces the path of the spot at the beginning of the staircase and the lower one shows its return after the last (white-level) subcarrier block. Note that inequality of length of the two vectors shows Differential Gain whereas the angular difference between them shows Differential Phase. The mean angular position of the vectors is not important and is set simply for ease of measurement. Check that the vector origin coincides with the graticule centre; if necessary, adjust the **VERT** *and* **HORIZ POSITION CLAMP** *controls (behind the left-hand front cover) to obtain coincidence.*

4a. Press the **DIFF GAIN** button; this changes the graticule illumination. If necessary, adjust the **VERT POSITION** control (behind the right-hand front cover) so that all six demodulated subcarrier blocks can be seen (as shown in Fig. 5). Make particular note of the position of the blanking-level step (the narrowest one on the left) relative to the other steps: it may be the highest, as shown in Fig. 5, but not necessarily so.

4b. Again press the **VECTOR PAL** button. Identify the blanking-level vector (the shortest vector corresponds to the lowest step in the **DIFF GAIN** display; see Fig. 4) and re-adjust **CHANNEL A GAIN** to set its tip on the graticule circle as shown in Fig. 4.

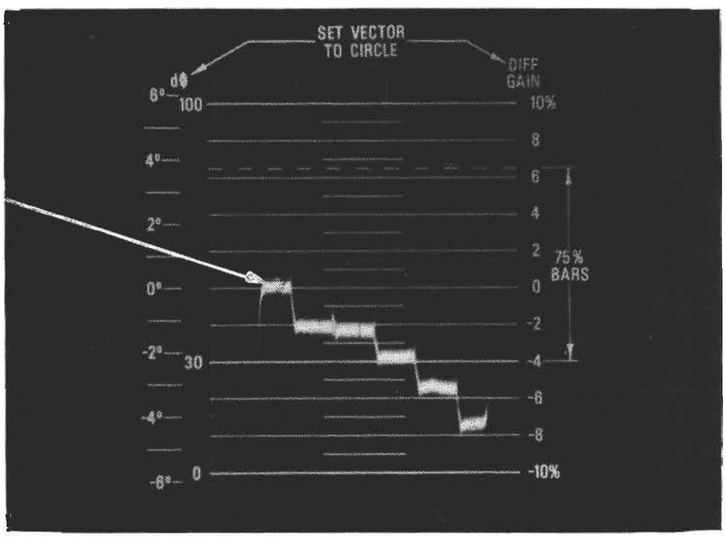


Fig. 5 Measurement display for DIFF. GAIN test; from graticule reading Diff. Gain distortion = −8 per cent.

5. Re-select **DIFF GAIN** and adjust **VERT POSITION** until the blanking level step covers the horizontal graticule **0** line as shown in Fig. 5. Read off the percentage gain difference for the step furthest from the **0** line against the **DIFF GAIN** (right-hand) scale.

6. Repeat the measurement in step 5, for a high-A.P.L. input, i.e. change to a staircase-plus-three-white-lines signal.

7. If required, repeat steps 2 – 6, for an input signal of +3 dB.

If an I.T.S. has been used, and the A.P.L. was not controlled, this should be noted against the measurement result.

MEASUREMENT METHODS – DIFFERENTIAL PHASE

A. Using (BBC) Signal Analyser

Equipment Required

At input: A source of staircase-with-subcarrier signal (including A.P.L.-control facility) e.g. GE4M/520 NON-LINEARITY TEST SIGNAL GENERATOR. Alternatively, use Insertion Test Signal (I.T.S.) on lines 19 and 332 of a television signal.

At output: EP1M/523 TELEVISION WAVEFORM ANALYSER or EP1M/508 REMOTE SIGNAL ANALYSER with Oscilloscope or Waveform Monitor.

Test Procedure

1. Use the EP1M/523 or EP1M/508 with the oscilloscope as explained in the appropriate Operating Instruction.

B. Using a Vectorscope

Equipment Required

At input: As in **Method** A; i.e. a staircase-with-subcarrier generator with variable A.P.L. facility (e.g. GE4/520); or use I.T.S.

At output: Vectorscope; the Test Procedure given below refers to Tektronix equipment: Models 520, 521 or 521A.

Test Procedure

1. Apply the test signal to the vectorscope **CH A** at standard amplitude and low A.P.L. (i.e. use a staircase-plus-three-blanked-lines signal).

2. On the vectorscope:
(left-hand front) press:

CH A (**CH B** or **CH B CAL** must not be selected)
FULL FIELD (or **VITS I** for I.T.S. input)
AΦ

Note that the **AΦ** *button must be pressed to obtain a vector display.*

(right-hand front) press: **DIFF PHASE**

set: **CALIBRATED PHASE** indicator to **0**

3. Set the **CHANNEL A GAIN** controls:

switch	to	**MAX GAIN**
thumbwheel	to	**CAL** (indexed position)

Set the **DISPLAY** switch to **BOTH.**

4. Adjust the **CHANNEL A PHASE** control to bring the horizontal trace lines, representing subcarrier phase at blanking level (Φ_X), into coincidence as shown in Fig. 6.

Alternatively, with **VECTOR PAL** *button pressed, use* **CHANNEL A PHASE** *control to position staircase vector along the (illuminated) graticule* **+U** *axis which corresponds to zero degrees.*

MEASUREMENT METHODS – DIFFERENTIAL PHASE (continued)

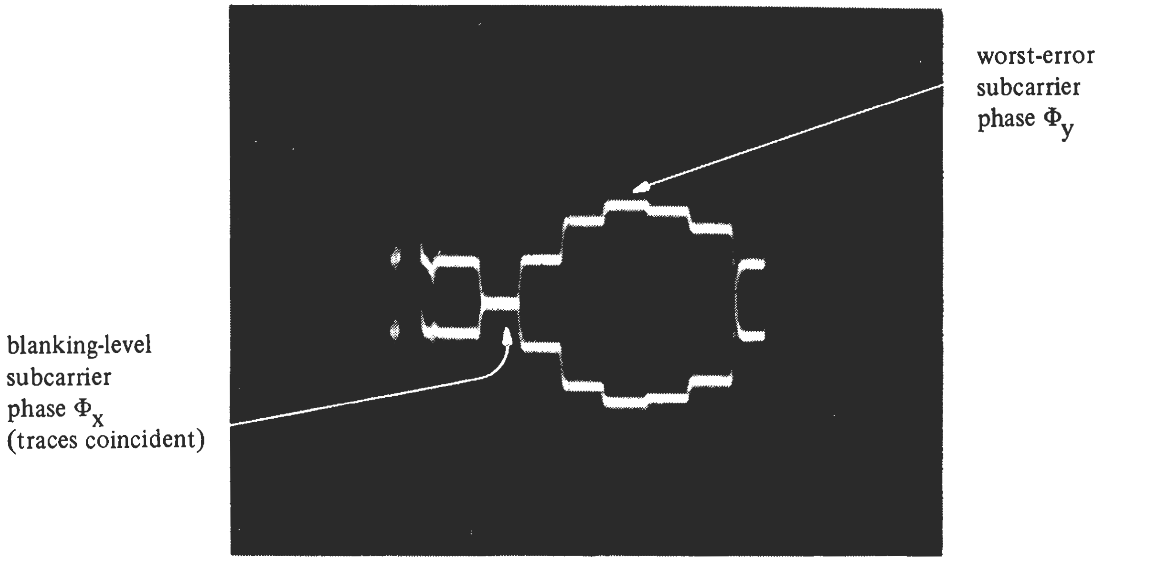


Fig. 6 Set-up display for DIFF PHASE test; blanking-level-subcarrier phase taces coincident.

5. Choose whichever pair of phase trace lines (Φ_y) are most different to the coincident blanking-level pair. Use the **CALIBRATED PHASE** control to bring these into coincidence as shown in Fig. 7. The amount of Differential Phase distortion present is shown in degrees (positive or negative) on the **CALIBRATED PHASE** control indicator. It should be quoted together with the appropriate sign (+ or –), see Fig. 2 in **DEFINITIONS.**

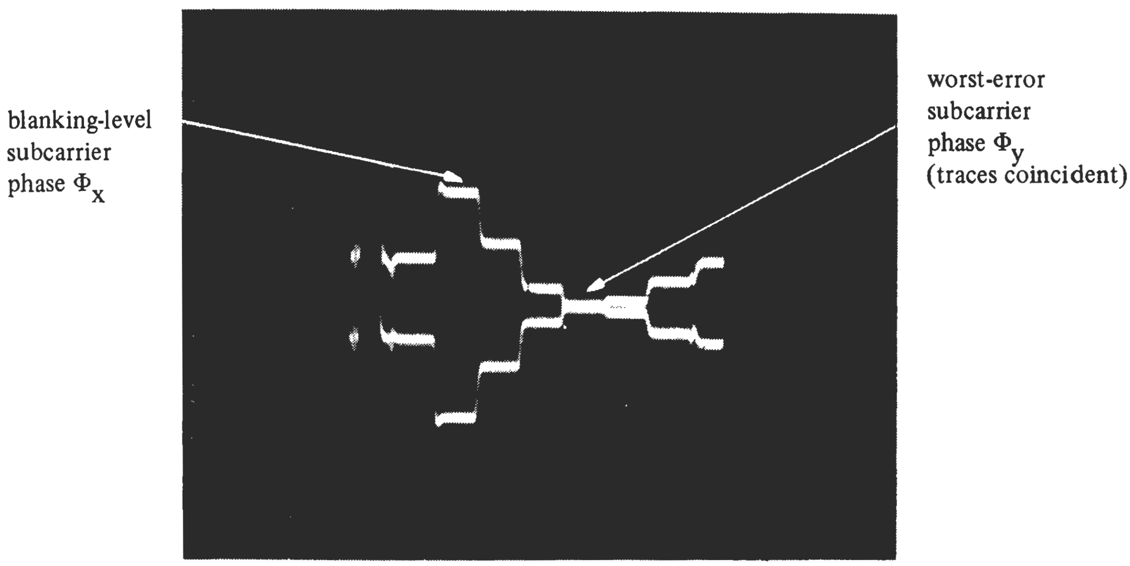


Fig. 7 Measurement display for DIFF PHASE test; worst subcarrier 'phase' traces coincident.

6. Repeat the measurement in step 5 for a high-A.P.L. input, i.e. change to a staircase-plus-three-white-lines signal.

7. If required repeat steps 2 – 6 for an input signal of +3 dB.

If an I.T.S. has been used, and the A.P.L. was not controlled, this should be noted against the measurement result.

VIDEO TEST PROCEDURES

VTP3.4 CHROMINANCE-LUMINANCE INTERMODULATION (also called CHROMINANCE-LUMINANCE CROSSTALK; CHROMINANCE AXIS SHIFT)

BACKGROUND

A coded colour-television signal carries the luminance and associated chrominance components in time coincidence but separated in frequency so that they are grouped towards opposite ends of the video spectrum. Thus, chrominance information (contained in the colour subcarrier sidebands) occupies the upper part while the luminance signal is mainly in the lower part. One requirement for the transmission and reception of high-quality pictures is that interaction between these components must be kept to a minimum; in particular, it is important that the presence of the superimposed colour signal, especially any changes in its amplitude, should have minimal effect on the instantaneous luminance level. Such a condition can only be maintained if the transfer characteristic of circuits handling the signal is substantially linear over the normal range of the coded signal excursion; otherwise, the mean level of the received colour signal may be displaced so that the associated luminance level is effectively raised or lowered with respect to its true value by an amount which varies with chrominance amplitude.

The effect of this distortion on PAL (and N.T.S.C.) signals when displayed on a colour receiver is that the brightness of highly-coloured areas e.g. coloured captions, is wrong, and hence the saturation is effectively increased or decreased according to the sense of the subcarrier mean-level shift of the colour signal. On monochrome receivers, the distortion shows up as grey-scale errors which, again, are most noticable in highly-coloured parts of the original scene.

Fortunately, in practice, the degree of intermodulation of the type discussed here is such that the resulting defects are small enough to be virtually undetectable. However, a possible and often more serious consequence of the distortion is that it can cause difficulty in Chrominance-Luminance Gain Inequality and Luminance Non-linearity tests; see VTP2.2 and VTP3.2. This is because the apparent mean-level shift of chrominance components in the received signal and the resulting spurious change in associated luminance level gives misleading indication of how much inequality or non-linearity is present.

The alternative descriptions, Chrominance-Luminance Crosstalk and Chrominance Axis Shift, are deprecated terms.

ASSOCIATED INFORMATION

(Items 1 and 2 are normally issued with the Test Procedure)

1. **Video Test Waveforms (P2, Part 3)** — VTW.1, 2, 3, 4, 5, 6

2. **Operating Instructions (P2, Part 2)** — TE1/513 (TE1M/517, TE1L/552) GAIN, DELAY AND CROSSTALK TESTER
   TE1/503 COLOUR GAIN AND DELAY TESTER

3. **The Measurement of Non-linear Distortion in Video Transmission Systems; (P2, Part 4)** VMT.2.

DEFINITIONS

CHROMINANCE-LUMINANCE INTERMODULATION (also called:- Chrominance-Luminance Crosstalk; Chrominance Axis Shift)	– refers to the unwanted change in amplitude of the luminance component of a colour television signal which is caused by the associated chrominance component. – can be defined as the change in luminance level expressed as a percentage of the picture amplitude which results from the superimposition of a chrominance component of specified amplitude. – is measured on the line-repetitive Chrominance-Luminance Pulse-and-Bar test signal (VTW1 in **Video Test Waveforms**) using the 7 μs chrominance bar waveform. Alternatively, but with less accuracy, the 14-μs I.T.S. chrominance bar on lines 20/333 of a television signal may be used (see VTW4).

MEASUREMENT METHODS

A. (Preferred Method) Gated (Meter) Measurement

Equipment Required

At input: A source of line-repetitive Chrominance-Luminance Pulse-and-Bar signal (e.g. GE4M/559). Alternatively, use the Insertion Test Signal on lines 20 and 333.

At output: TE1/513 (TE1M/517, TE1L/552) GAIN, DELAY AND CROSSTALK TESTER

The TE1/513 provides direct meter indication of Chrominance-Luminance Intermodulation using either the Chrominance-Luminance Pulse-and-Bar or the (National) I.T.S. waveforms.

The ranges and accuracy for Chrominance-Luminance Intermodulation measurement are:

±30 per cent
±10 per cent
±3 per cent
} *all within 1 per cent +5 per cent of f.s.d.*

Test Procedure

1. Use the TE1/513 (TE1M/517, TE1L/552) in the appropriate mode; see Operating Instruction.

B. (Alternative Method) Filter/Oscilloscope Measurement

Equipment Required

At input: As in **Method A**, e.g. a GE2M/559 generator or use an I.T.S.

At output: Colour-subcarrier band-stop filter (e.g. as contained in TE1/503 COLOUR GAIN AND DELAY TESTER), with
Oscilloscope or Waveform Monitor
OR
Waveform Monitor equipped with suitable luminance (1 MHz) low-pass filter (e.g. Tektronix Types 528, 529 or Hewlett-Packard Type 191A)

If an I.T.S. waveform is being used as the test input, the oscilloscope/waveform monitor must be able to hold a stable display of the appropriate lines.

MEASUREMENT METHODS (continued)

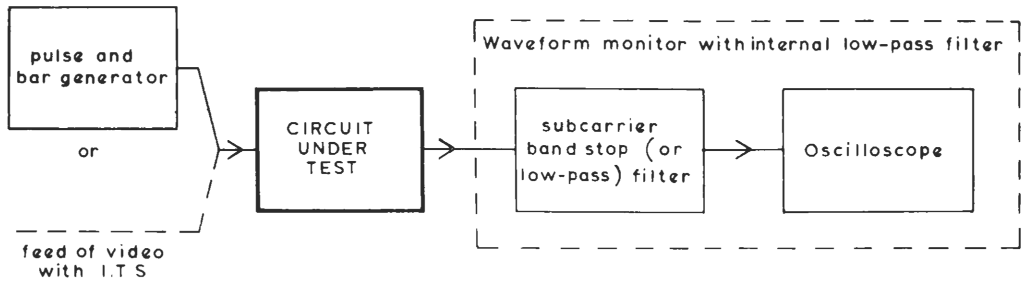


Fig. 1 Test circuit for Chrominance-Luminance Intermodulation measurement (B)

Test Procedure

1. Apply the test signal at normal amplitude to the circuit shown in Fig. 1. The input and output waveforms should be similar to the examples shown in Fig. 2 (for a Pulse-and-Bar input) or Fig. 3 (for an I.T.S. input).

2. Measure the step amplitude (x in the illustrations) and express this as a percentage of the picture amplitude (luminance bar; dimension y). The resulting figure represents the Chrominance-Luminance distortion for the circuit.

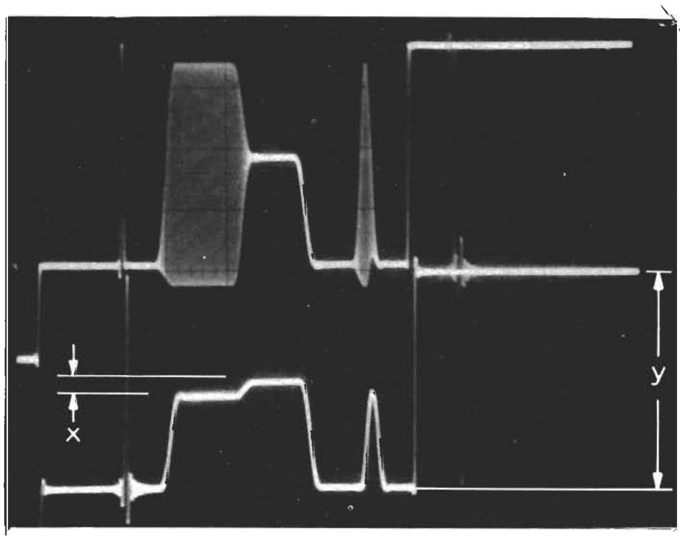


Fig. 2 Typical Chrominance-Luminance Intermodulation measurement displays. Part of one line from a full-field Chrominance-Luminance Pulse-and-Bar test signal showing:
(a) incoming waveform with distortion
(b) filtered signal; note step in remaining luminance pedestal.
Distortion = $x/y \times 100$ per cent.

MEASUREMENT METHODS (continued)

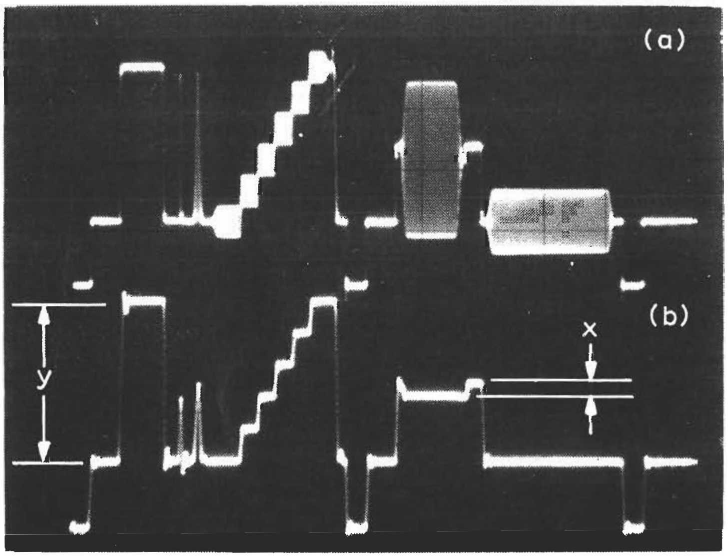


Fig. 3 Typical Chrominance-Luminance Intermodulation measurement displays. The two I.T.S. lines showing:

(a) incoming waveform with distortion; note downward shift of second-line chrominance minibar.

(b) filtered signal showing steps in remaining minibar (luminance) pedestal. Distortion = x/y x 100 per cent.

VIDEO TEST PROCEDURES

VTP4.1 CONTINUOUS RANDOM NOISE

BACKGROUND

When a television signal passes through units or transmission circuits it gains unwanted components of a random nature which are not related to the signal and which may add together in such a way that ultimately they are of sufficient amplitude to impair the displayed picture. Even though the added components give rise to a visual, not an aural, sensation, the interference is commonly called noise. Some of the spurious components form a particular type of noise having an instantaneous magnitude which varies in a completely random manner between zero and a limiting value for the unit or circuit in question. This is termed continuous random noise – often called, simply, random noise.

The word *continuous* in the description qualifies the spectrum of the interfering signal. It shows that, within the limits imposed by the equipment, the noise has components at all frequencies. The qualification of *random* is applied because the instantaneous amplitude of a noise signal cannot be predicted from a knowledge of past excursions and can, in theory, have any value between zero and infinity.

The effect of random noise on a television picture and the amount of impairment it causes depends on two characteristics of the unwanted components. These are:

(i) the magnitude relative to that of the wanted signal
(ii) the energy distribution over the video band.

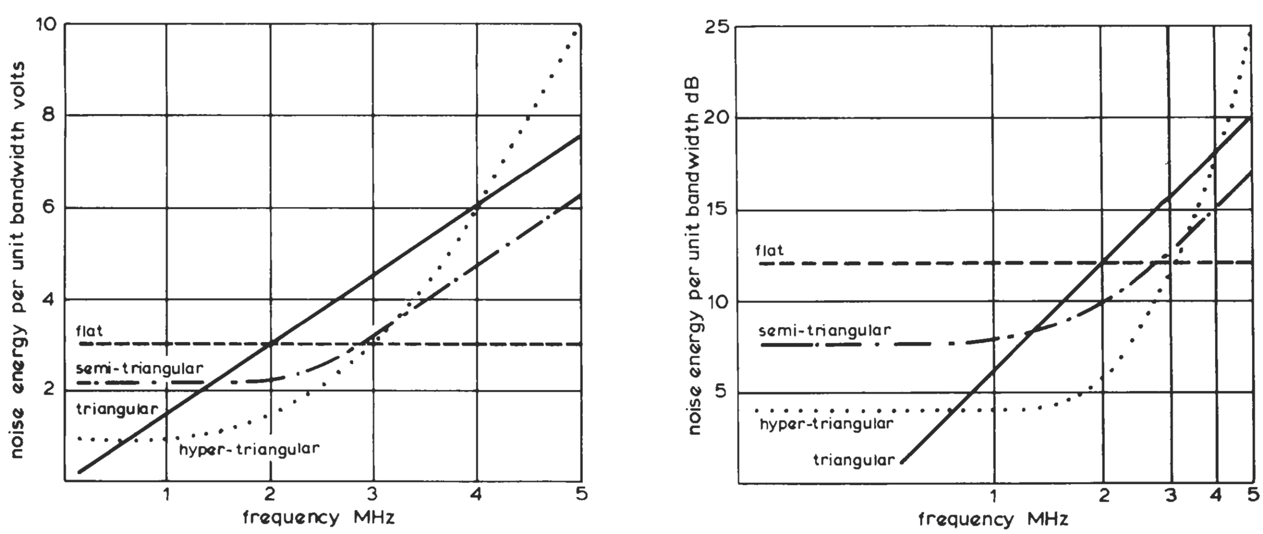
Item (i) is significant because the degree of interference is most easily given a dimension by this comparison; hence, the Signal-to-Random-Noise Ratio is the figure quoted in specifications to express this aspect of equipment performance. Item (ii) is also important because it determines both the way in which noise is classified and how it is measured.

Although, as stated above and by definition, random noise is present to all video frequencies, its energy distribution is not necessarily constant throughout the video band. Two main patterns are of particular interest:

(1) A uniform distribution, where the noise energy per unit bandwidth is constant with frequency. This is called *white* or *flat* noise, and is the type of noise generated by a resistance (thermal noise) or an amplifier with a flat gain-frequency characteristic.

(2) A distribution in which noise energy per unit bandwidth increases at 6 dB per octave, i.e. where the r.m.s. noise voltage (per unit bandwidth) is directly proportional to frequency. This is usually described as *triangular* because of the shape of the noise-voltage/frequency curve which represents it; see Fig. 1. Typically, this is the noise distribution at the output of an f.m. discriminator.

The random noise generated in most items of television-signal transmission equipment has an energy distribution which corresponds with one or other of these curves or a combination of them. A typical combined characteristic is one termed *semi-triangular* or *intermediate* (shown dotted in Fig. 1) which describes, for instance, the noise produced by f.m. microwave signal links in which the discriminator is followed by a video de-emphasis network.



(a) to linear (arbitary) voltage/frequency scales (b) to dB/logarithmic frequency scales

Fig. 1 Energy distribution curves for random noise

Noise distribution patterns other than those described in (1) and (2) or their intermediates are, of course, possible. Consider, for example, the result of cascading equaliser-amplifier combinations to correct for cable losses in direct video transmission links. Here, the noise distribution curve tends to be flat at low frequencies but may have a slope of greater than 6 dB per octave at the upper end of the band. This is called hypertriangular noise, and is represented by the dotted curve in Fig. 1.

The visible effect on a signal of a given amount of noise interference depends on the means of the signal presentation and inspection. On an oscilloscope display, noise components add a random vertical fluctuation to the signal trace in such a way that it appears 'hairy'. The observed result of random noise on a monochrome television picture is that of a constantly-changing, granular structure of differential brightness, sometimes likened to a superimposed snow-storm. In colour television, also, random noise can show up as spurious granular interference in both coloured and grey areas of the picture, the graininess varying in a random manner in hue, saturation and brightness; in fact the appearance is that of a coloured snow-storm.

The subjective effect of noise on a signal is governed by its energy distribution as well as by its relative magnitude. This is because the large particles formed by the low-frequency components of the interfering noise are more easily resolved by the human eye: they are therefore subjectively more annoying than smaller particles due to high frequency components of equal energy. Note that, where noise is added to a coded colour signal, noise components having frequencies in the chrominance band will be decoded as spurious colour information. Further than this, short-duration noise pulses occuring at a rate which is equal or nearly equal to the colour subcarrier frequency (4.433 MHz for PAL, System I) will be transposed by the decoding process and made to appear as large (low-frequency) coloured noise particles with a resulting increase in the subjective annoyance effect.

The specification and measurement of equipment noise performance must be closely related to the signals normally carried, and must also take account of the subjective aspects, outlined above. Hence, the signal-to-random-noise ratio quoted for a given unit or circuit is:

(a) measured between frequency limits which are approximately those of the video band; see Figs. 2a and 2b.

(b) sometimes also measured via weighting networks with responses which simulate the annoyance effect of the noise. In respect of the differing ways in which noise interferes with the chrominance and luminance information in a coded colour-television signal, separate measurements using alternative weighting networks (Figs. 3a and 3b) may be carried out. Two figures are then obtained which together quantify the subjective effect of the interference on a decoded signal display; i.e. both Signal-to-Luminance-Weighted-Random-Noise and Signal-to-Chrominance-Weighted-Random-Noise ratios are quoted.

It is essential to note the distinction between the two types of noise measurement briefly described in (a) and (b) above: the **weighted** measurements (b) give results which are directly related to the subjective effect of the noise on a television picture; they also make it easier to compare the performance of circuits affected by noise with different energy distributions; **unweighted** measurements (a) gives a single signal-to-noise figure which is suitable where comparison is to be made between circuits having similar characteristics – noise energy distribution, etc. – and where the correlation with the subjective effect is not of importance.

At the present time (1979) in the UK, weighted measurements on circuits intended for the transmission of 625-line, PAL System-I, coded signals are made through separate chrominance and luminance weighting networks as stated elsewhere in this Instruction. Internationally, agreement has been reached* on a single, unified† weighting network (see Fig. 4) for use on all international transmission circuits. This unified network may eventually be adopted for use in the UK.

* CCIR Recommendation 567.

† In this context, 'unified' refers to the suitability of the network for noise measurement on all 525-line and 625-line television systems. The only restriction on the use of the network is that the energy distribution curve of the noise being measured should not have a slope which is substantially in excess of 6 dB/octave.

ASSOCIATED INFORMATION
(Normally issued with this Test Procedure)

1. **Video Test Waveforms (P2, Part 3):** VTW 1, 2, 3, 4 and 5
2. **Operating Instructions (P2, Part 2):**

EP1M/524	GAIN, DELAY AND NOISE MEASURING EQUIPMENT
FL4/582P	5.5 MHz LOW-PASS VIDEO NOISE FILTER
FL4/583P	5.0 MHz LOW-PASS VIDEO NOISE FILTER
GE2M/559	CHROMINANCE-LUMINANCE PULSE-AND-BAR GENERATOR
ME1/502	RANDOM NOISE MEASURING SET
ME1M/503	NOISE MEASURING SET
ME1/508	FIELD INTERVAL NOISE MEASURING METER
NE3/503	CHROMINANCE NOISE WEIGHTING UNIT
NE3/504	LUMINANCE NOISE WEIGHTING UNIT
UN1/511	SIGNAL MEASURING UNIT
UN1M/638	GATED NOISE MEASURING UNIT
UN1/715	AMPLITUDE MEASURING UNIT

DEFINITIONS

SIGNAL-TO-UNWEIGHTED RANDOM-NOISE RATIO

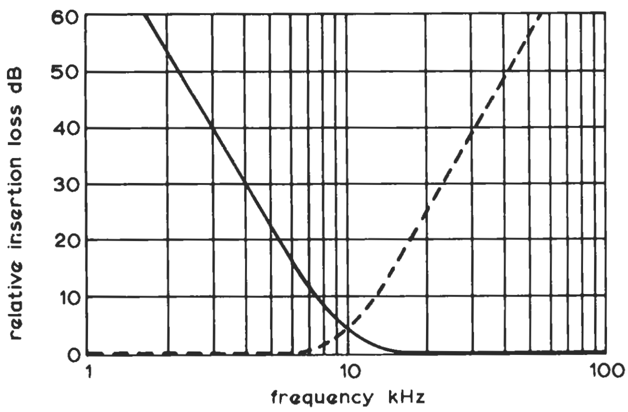
is the ratio in dB of the **PICTURE AMPLITUDE**[1] of the wanted signal normally present at the point of measurement to the r.m.s. amplitude[2] of the unwanted noise compoments contained within a specified frequency band **which should always be quoted.**

[1]*See* **Video Test Procedure VTP1.1**
[2]**Appendix VTP-D** *explains the concept of signal-to-noise measurement in more detail.*

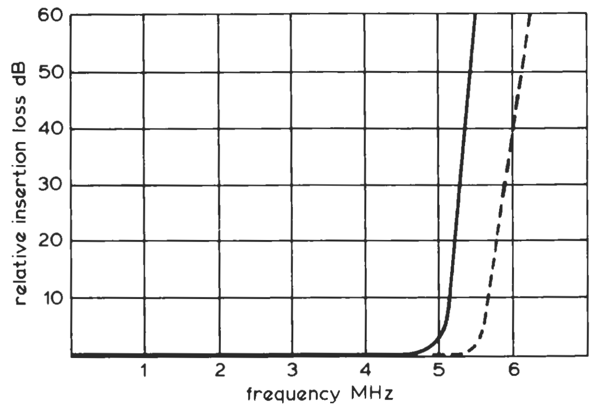
– is generally measured with a direct-reading r.m.s. meter preceded by high-pass and low-pass filters which limit the noise spectrum. For both monochrome and coded colour signals, the upper and lower band limits are 5 MHz and 10 kHz, respectively; see Figs. 2a and 2b (full-line curves), see also **Appendix VTP-E** for more detailed explanation. For uncoded (colour) signals, the upper limit is 5.5 MHz, as shown dotted in Fig. 2b.

The lower band limit is imposed by one half of a splitting network called a junction filter (see Fig. 2a). This divides the video spectrum into two regions loosely termed 'above-line-frequency' and 'below-line-frequency' because the junction frequency, 10 kHz, is nearly the line-frequency of the original 405-line television system. This '3 dB-down' point for both curves is not critical, and has therefore not been changed to suit the 15-kHz value appropriate to 625-line systems.
The main reason for dividing the spectrum in this way is to avoid confusion in measurement if appreciable amounts of a.c. mains hum or other types of low-frequency interference are present in the circuit output being tested. The junction filter low-pass section may subsequently be used for assessment of low-frequency noise.

DEFINITIONS (continued)



(a) Junction filter response; high-pass section used for random-noise measurement (see **Annex 1** to this Test Procedure)



(b) Random-noise measurement filter responses:
full-line – 5.0 MHz low-pass (FL4/583P; for coded signals)
dotted-line – 5.5 MHz low-pass (FL4/582P; for uncoded signals).

Fig. 2 Noise-measurement band-limiting filter characteristics

SIGNAL-TO-WEIGHTED RANDOM-NOISE RATIO

– is the ratio in dB of the PICTURE AMPLITUDE of the wanted signal normally present at the point of measurement to the r.m.s. amplitude of the unwanted noise components contained within a specified frequency band, and measured through a circuit having an amplitude response shaped to a specified weighting characteristic[3].

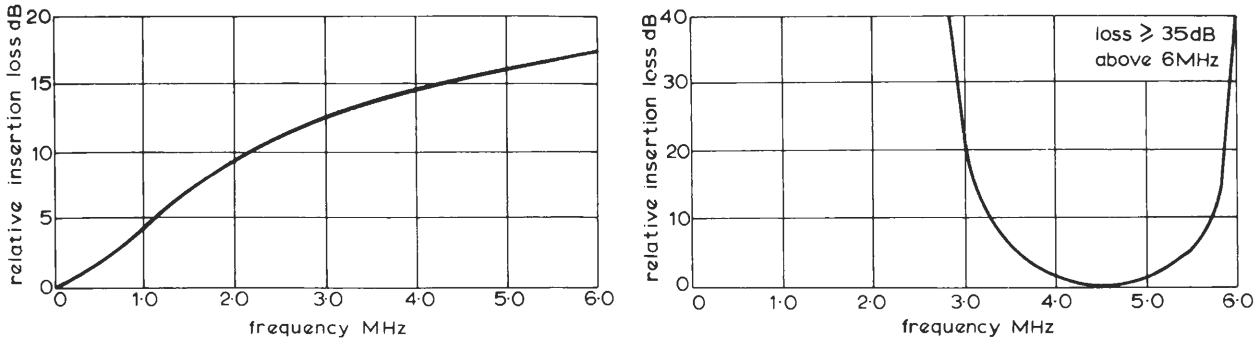
– is measured as for the **SIGNAL-TO-UNWEIGHTED-RANDOM-NOISE RATIO** (see above) but with the measuring circuit modified by inclusion of the appropriate weighting network[3].

[3] *Separate Luminance-Weighted and Chrominance-Weighted measurements are carried out on coded colour signals, using one or other of the networks having the responses shown in Figs. 3a and 3b, respectively. (Fig. 4 shows the C.C.I.R. unified weighting characteristics) Note that the band-limiting low-pass filter (Fig. 2b) is not normally used for Chrominance Weighted noise measurement.*

Note that, when quoting a measured signal-to-noise ratio, **it is important** to state the appropriate conditions of measurement. Specifically, the quoted figure should be accompanied by suitable indication that it is either:

(a) Weighted – Luminance
or (b) Weighted – Chrominance
or (c) Unweighted to a 5.0 MHz upper band limit
or (d) Unweighted to a 5.5 MHz upper band limit

DEFINITIONS (continued)



(a) Luminance weighting (response of NE3/504 switched to '625')

(b) Chrominance weighting (response of NE3/503)

Fig. 3 625-line (System I) noise-measurement weighting characteristic

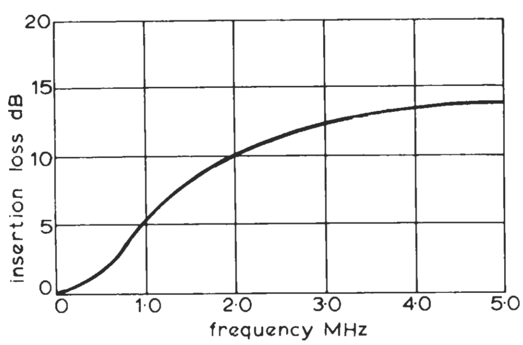


Fig. 4 CCIR unified noise-measurement weighting characteristic (response of NE3/505)

PREPARATION FOR NOISE MEASUREMENT

Measurement of PICTURE AMPLITUDE

The results of all the noise measurements described in this Test Procedure are used to quantify the noise performance of a test object (i.e. a circuit or unit) in terms of a Signal-to-Random-Noise Ratio. At the point where the noise is to be measured, therefore, it is usually necessary first to measure the PICTURE AMPLITUDE of a suitable test signal. This initial check should be carried out using whichever of the methods described in **Test Procedure VTP1.1** is the more suitable considering the succeeding noise measurement. The equipment required in these methods is as follows:

At input: A source of full-field (line-repetitive) pulse-and-bar signal, e.g. GE2M/559 CHROMINANCE-LUMINANCE PULSE-AND-BAR GENERATOR. Alternatively, a source of ITS or Colour Bars may be used.

At output: UN1/511 SIGNAL MEASURING UNIT or UN1/715 AMPLITUDE MEASURING UNIT } for the Preferred Methods
or
Oscilloscope or Waveform Monitor

Signal-to-Random-Noise Ratio Measurement Correction Factor

As explained further in Appendix VTP-D, the signal-to-noise figure quoted as the result of measurement must be based on a value of PICTURE AMPLITUDE which is typical for the video signal normally present. If the PICTURE AMPLITUDE of such signals, and of the test signal used to check the circuit conditions, is other than the STANDARD value of 0.7 volt (which is the reference amplitude assumed to exist for all BBC-designed noise measuring equipment), then the difference in dB must be accounted for in the quoted figure. Thus, for example:

Suppose the received picture amplitude is	–	0.6 V
and the measured noise figure is (i.e. the separation between the noise and an **assumed** STANDARD PICTURE AMPLITUDE of 0.7 volt)	–	52 dB
then, since the measured picture amplitude with respect to the STANDARD is	–	–1.5 dB
the actual Signal-to-Random Noise Ratio to be quoted is	–	50.5 dB

MEASUREMENT METHODS – SIGNAL-TO-RANDOM-NOISE RATIO FOR MONOCHROME AND CODED COLOUR VIDEO SIGNALS

A.1 / A.2 / A.3 } Preferred Methods: Measurement using A Noise Measuring Meter –
- **A.1 Continuous (uninterrupted) Measurement**
- **A.2 Line-rate Gated (all active lines) Measurement**
- **A.3 Field-rate Gated (one line) Measurement**

A.1 Continuous Measurement (in the absence of a video signal)

Equipment Required

At input: Termination (normally, 75 ohms)

At output: ME1/503 NOISE MEASURING METER

Optional: FL4/582P 5.5 MHz LOW-PASS VIDEO NOISE FILTER
or ME1/502 RANDOM NOISE MEASUREMENT SET

Optional: FL4/583P 5.0 MHz LOW-PASS VIDEO NOISE FILTER
or FL4/582P 5.5 MHz LOW-PASS VIDEO NOISE FILTER
NE3/503 CHROMINANCE NOISE WEIGHTING NETWORK
NE3/504 LUMINANCE NOISE WEIGHTING NETWORK (switched to **625**)

MEASUREMENT METHODS (continued)

Test Procedure

1. Carry out **PREPARATION FOR NOISE MEASUREMENT**

2. Disconnect the applied signal and terminate the input of the test object.

3. Use the ME1/503 (or ME1/502) in the appropriate mode; see **Operating Instructions**. Use band-limiting filters and/or weighting networks (integral or additional, as appropriate) according to the type of measurement specified.

4. Apply any correction factor arising from step 1 to the result obtained in step 3.

A.2 (i) Line-rate Gated Measurement (using noise measuring meter and separate gating unit)

Equipment Required

At input: A source of blanked video signal with (or without[4]) sync pulses, having all active line periods at a constant luminance level[5].

At output: ME1/503 NOISE MEASURING METER
UN1M/638 GATED NOISE MEASURING UNIT
Optional: FL4/582P 5.5 MHz LOW-PASS VIDEO NOISE FILTER

[4]*When the video signal being tested is non-composite, gated noise measurement is still possible if a separate feed of sync pulses which is locked to the incoming signal is available for triggering the UN1M/638 gating unit.*

[5]*The active picture periods of the tested video signal can remain at blanking level EXCEPT when a blanking-level clipper is operating between the input of the test object and the point of noise measurement. (The amplitude of the noise could thereby be limited, thus giving an error in the measurement). In such an instance, an alternative input signal must be used, e.g. a 50 per cent pedestal or a line-rate sawtooth.*

Test Procedure

1. Carry out the **PREPARATION FOR NOISE MEASUREMENT**

2. Use the ME1/503 combined with the UN1M/638 in the appropriate mode; see **Operating Instructions**. Use band-limiting filters and/or weighting networks (integral or additional, as appropriate) according to the type of measurement specified.

3. Apply any correction factor arising from step 1 to the result obtained in step 2.

MEASUREMENT METHODS (continued)

A.2 (ii) Line-rate Gated Measurement (using noise measuring meter with integral line-gating facility)

Equipment Required

At input: As for **Method A.2 (i)**, above } see Note 6, below

At output: ME1/502 RANDOM NOISE MEASURING }

Optional: FL4/583P 5.0 MHz LOW-PASS VIDEO NOISE FILTER
or FL4/583P 5.5 MHz LOW-PASS VIDEO NOISE FILTER
NE3/503 CHROMINANCE NOISE WEIGHTING NETWORK
NE3/504 LUMINANCE NOISE WEIGHTING NETWORK (switched to **625)**

[6] *If modified as detailed in Television Service Modification Notice VA7/69 (see* **Annex** *2), the ME1/502 can be used to make gated noise measurement on non-composite video signals in the same way as the ME1/503 and UN1M/638 combination.*
Notes 4 and 5, above then apply.

Test Procedure

1. Carry out the **PREPARATION FOR NOISE MEASUREMENT.**

2. Use the ME1/502 in the appropriate mode; see **Operating Instructions.** Use additional band-limiting filters and/or weighting networks as appropriate according to the type of measurement.

3. Apply any correction factor from step 1 to the result obtained in step 2.

A.3 Field-rate Gated Measurement (one line per field selected)

Equipment Required

At input: A source of video signal which is complete with line and field syncs and which has a noise component present during the so-called quiet lines[7], known to be substantially less than the expected figure; i.e. at least 10 dB below the specified limit for the measured result.

[7] *At present (1978), 625-line video signals distributed in the UK contain two such lines in each field. In BBC practice, these lines are considered to contain insertion test signals designated ITS(N) and ITS(Q) where:*
ITS(N) – on lines 12 and 325 – is intended for video noise measurement*
ITS(Q) - on lines 10 and 323 - is intended for CEEFAX noise measurement

**At some time in the future, it is possible that ITS(N) will be moved to lines 22 and 335 so as to conform with international 625-line-standard practice.*

At output: ME1/508 FIELD INTERVAL NOISE MEASURING METER
(EP1M/524 GAIN, DELAY AND NOISE MEASUREMENT EQUIPMENT)
Note that, in these equipments, luminance weighted and unweighted noise measurements are **band-restricted to an effective upper limit of 5.0 MHz.**

MEASUREMENT METHODS (continued)

Test Procedure

1. Carry out the **PREPARATION FOR NOISE MEASUREMENT**

2. Use the ME1/508 in the appropriate mode; see **Operating Instruction.** Use integral weighting networks as appropriate according to the type of measurement.

3. Apply any correction factor arising from step 1 to the result obtained in step 2.

B.1	**Alternative Methods:**	**in the absence of a video signal**
B.2	**Direct Measurement by**	**in the presence of a test video signal**
B.3	**Oscilloscope Display:**	**in the presence of a (programme) video signal**

B.1 Direct Measurement (in the absence of a video signal)

Equipment Required

At input: Termination (normally 75 ohms)

At output: Oscilloscope
Optional: FL4/583P 5.0 MHz LOW-PASS VIDEO NOISE FILTER
or FL4/582P 5.5 MHz LOW-PASS VIDEO NOISE FILTER
NE3/503 CHROMINANCE NOISE WEIGHTING NETWORK
NE3/504 LUMINANCE NOISE WEIGHTING NETWORK (switched to **625**)

Test Procedure

1. Carry out the **PREPARATION FOR NOISE MEASUREMENT** using an appropriate signal to obtain a value, $\mathbf{V_P}$, for the PICTURE AMPLITUDE.

   If it is not possible to carry out this initial measurement on a video test waveform, then the noise figure obtained as described below will be of use only if:
   (i) the STANDARD PICTURE AMPLITUDE for a video signal normally present at the point of noise measurement is already known, and
   (ii) the object under test is known to have its normal working gain.

2. Disconnect the applied signal (if used). Terminate the input of the object under test.

3. Connect the output of the object under test to the oscilloscope, ensuring that:
   (i) the correct output termination is applied
   (ii) the effective amplitude response of the measuring circuit has the band limits as defined by Fig. 2 (see Note 8). If the weighted noise figure is required, then a suitable weighting network must be included in the measured signal path.

   [8] *If the output from the object under test is known to be free of spurious low-frequency components, particularly those related to the a.c. (mains) supply frequency – the so-called hum components – then the high-pass filter can be omitted from the measuring circuit. To check that such conditions exist, the output should first be inspected using a low (horizontal) scanning rate so that hum can be easily identified Alternatively, if the noise measurement in Step 4, below, is made on an oscilloscope which is triggered from an external source so that the horizontal scan is locked to field rate, then the discrimination against field-synchronous hum components is improved.*

MEASUREMENT METHODS (continued)

4. Using the oscilloscope Y-amplifier calibration and a suitable graticule, measure the quasi[9] peak-to-peak amplitude of the noise from the test object. Let this be V_N volts. Then, combining this result with that found in step 1 (or previously known):

$$\text{Signal-to-(Continuous-Random)-Noise Ratio} = 20 \log \frac{V_P}{V_N} + 17 \text{ dB}$$

(The added 17 dB in this expression is an arbitrary value which represents the difference between the quasi[9] peak-to-peak voltage and the r.m.s. voltage of random noise: see **Appendix VTP-D).**

[9] *The word quasi here means that the measured amplitude is simply* **the maximum amplitude which can be registered by the measuring system** *(as distinct from an actual peak value which, as the* **BACKGROUND** *description of random noise explains, is theoretically infinite). Using an oscilloscope, the most consistent results for random noise measurement are obtained in practice if the horizontal scan rate is very slow or possibly stopped altogether.*

B.2 Direct Measurement (in the presence of a test video signal)

Equipment Required

At input: Source of suitable noise-free test signal, e.g. a constant luminance level on all lines or a line-rate sawtooth.

At output: As **Method B.1** above.

Test Procedure

1. Carry out the **PREPARATION FOR NOISE MEASUREMENT** using an appropriate input signal to obtain a value, V_P, for the PICTURE AMPLITUDE.

2. Replace the input signal with one suitable for noise testing (see above).

3. As step 3 of **Method B.1** to obtain a value for V_N, the quasi[9] peak-to-peak noise voltage.

4. As step 4 of **Method B.1** to obtain the Signal-to-Noise Ratio.

B.3 Direct Measurement (in the presence of a programme video signal)

This method is virtually the same as that described for **Method B.2** except that, here, the oscilloscope is used to inspect the noise affecting a programme video signal as normally distributed/transmitted. To do this, one of the pair of field-blanking-interval lines reserved for noise measurement is selected for gated display.

Equipment Required

At input: A source of video signal which is complete with line and field syncs and which has a noise component present during the so-called quiet lines[7], known to be substantially less then the expected figure; i.e. at least 10 dB below the specified limit for the measured result.

At output: as **Method B.1**, above, but either:
(i) the oscilloscope must be equipped with an integral line-selection facility
OR
(ii) a normal oscilloscope can be used in conjunction with a UN1/702 TRIGGER UNIT (see appropriate Operating Instruction).

MEASUREMENT METHODS (continued)

Test Procedure

1. Carry out the **PREPARATION FOR NOISE MEASUREMENT** as detailed earlier by using the ITS on lines 19 or 332 to obtain a value, V_P volts, for the PICTURE AMPLITUDE.

2. Select for display the noise measurement lines.

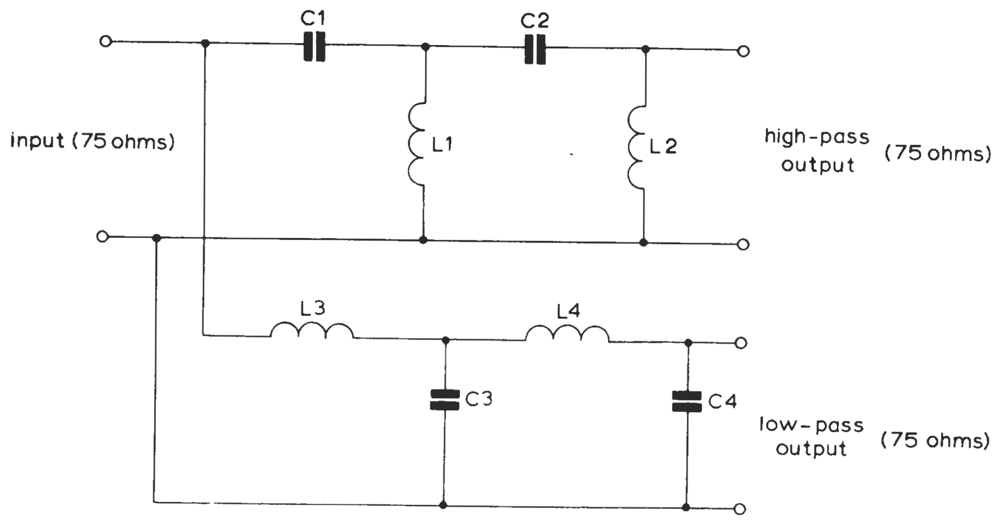
3. As step 3 of **Method B.1** to obtain a value for V_N, the quasi[9] peak-to-peak noise voltage.

   If a chrominance weighting network is being used, a separate feed of the incoming signal must be obtained from a point before the network and applied to the oscilloscope trigger input (or separate unit, if appropriate) so as to operate the field gating circuit.
   Note 8 in **Method B.1** *also applies here.*

4. As step 4 of **Method B.1** to obtain the Signal-to-Noise Ratio.

ANNEX 1 TO VTP4.1

High-pass (junction) filter for random-noise measurement
(See Fig. 2a for the response curve)



Component	Value	Tolerance
C1	139 000	± 5 %
C2	196 000	
C3	335 000	
C4	81 200	
L1	0.757	± 2 %
L2	3.120	
L3	1.830	
L4	1.290	

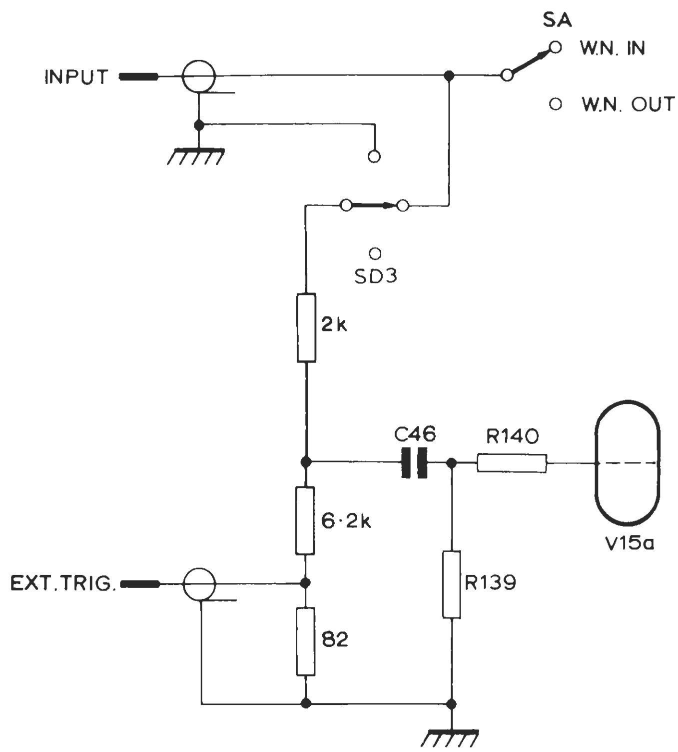
Note 1 – Inductances are given in mH, capacitances in pF.

Note 2 – The Q-factor of each inductor should be equal to, or greater than, 100 at 10 kHz.

ANNEX 2 to VTP4.1

Modification to NOISE MEASURING SET ME1/502

(To enable measurement on a non-composite video signal:
Copy of Television Service Modification Notice V47/69)



Note:
The EXT. TRIG. input connection can be provided either by means of an additional Musa plug on the front panel (this will require a mechanical modification) or via the GATED NOISE O/P plug if the existing output is not normally required and suitable internal reconnection can be permanently made.

Fig. A Detail of Change
(Additional components are underlined; see also Fig. 11 in the Technical Instruction for this equipment)

Reason for Change
To provide an external trigger facility so that the ME1/502 can be used for gated noise measurement on a non-composite video signal.

APPENDIX VTP.A

AMPLITUDE RELATIONSHIPS IN A VIDEO SIGNAL
(gain)

dB relative to STANDARD amplitude	per centage difference from STANDARD amplitude	voltages measured between the appropriate points shown on **Video Test Waveforms VTW1-7**		
dB	%	Picture Amp A – B Volts	Sync Amp B' – C Volts	Video Amp A – C Volts
+6·0	100	1·40	0·60	2·00
+5·0	78	1·24	0·53	1·78
+4·0	58	1·11	0·48	1·58
+3·0	41	0·99	0·42	1·41
+2·5	33	0·93	0·40	1·33
+2·0	26	0·88	0·38	1·26
+1·8	23	0·86	0·37	1·23
+1·6	20	0·84	0·36	1·20
+1·4	18	0·82	0·35	1·18
+1·2	15	0·80	0·34	1·15
+1·0	12	0·78	0·34	1·12
+0·9	11	0·78	0·33	1·11
+0·8	10	0·78	0·33	1·10
+0·7	8	0·76	0·32	1·08
+0·6	7	0·75	0·32	1·07
+0·5	6	0·74	0·32	1·06
+0·4	5	0·73	0·31	1·05
+0·3	4	0·72	0·31	1·04
+0·2	2	0·72	0·31	1·02
+0·1	1	0·71	0·30	1·01
STANDARD VALUE 0	0	0·70	0·30	1·00

The figures of percentage differences have been calculated from the values of Video Amplitude. Due to rounding errors the percentage differences with respect to Picture Amplitude and Sync Amplitude are accurate only to within ±1 and ±2 respectively.

APPENDIX VTP.A

AMPLITUDE RELATIONSHIPS IN A VIDEO SIGNAL
(loss)

dB relative to STANDARD amplitude	per centage difference from STANDARD amplitude	voltages measured between the appropriate points shown on **Video Test Waveforms VTW1-7**		
dB	%	Picture Amp A – B Volts	Sync Amp B' – C Volts	Video Amp A – C Volts
STANDARD VALUE 0	0	0·70	0·30	1·00
–0·1	1	0·69	0·30	0·99
–0·2	2	0·68	0·29	0·98
–0·3	3	0·68	0·29	0·97
–0·4	4	0·67	0·29	0·96
–0·5	6	0·66	0·28	0·94
–0·6	7	0·65	0·28	0·93
–0·7	8	0·65	0·28	0·92
–0·8	9	0·64	0·27	0·91
–0·9	10	0·63	0·27	0·90
–1·0	11	0·62	0·27	0·89
–1·2	13	0·61	0·26	0·87
–1·4	15	0·60	0·26	0·85
–1·6	17	0·58	0·25	0·83
–1·8	19	0·57	0·24	0·81
–2·0	21	0·56	0·23	0·79
–2·5	25	0·52	0·22	0·75
–3·0	29	0·50	0·21	0·71
–4·0	37	0·44	0·19	0·63
–5·0	44	0·40	0·17	0·56
–6·0	50	0·35	0·15	0·50

The figures of percentage differences have been calculated from the values of Video Amplitude. Due to rounding errors the percentage differences with respect to Picture Amplitude and Sync Amplitude are accurate only to within ±1 and ±2 respectively.

APPENDIX VTP-B

THE MEAN LEVEL, AVERAGE PICTURE LEVEL AND D.C. COMPONENT OF A TELEVISION SIGNAL

Basic telelvision signal: positions of blanking and black levels

A composite (625-line-standard) video signal comprises two main parts:

(i) the picture component (see Note 1), which carries all the information necessary to describe the brightness detail (over a period of 1/25th of a second) of the scene being televised. During the transmission of normal (moving picture) signals, the waveform of this component is continuously changing;

(ii) the sync, and blanking, pulse component which is essential for controlling the scanning system of the display device (monitor or receiver) being fed with the signal. This component has a constant waveform.

When these two components are combined to produce what is termed a **composite signal**, their waveforms are added together by being joined along a line (of relatively constant level) which acts as the boundary between the picture and sync parts. This is known as **blanking level.**

In the composite signal the sync component extends from blanking level towards one or other signal polarity, either positive or negative depending on the sense of the signal, with a constant pulse amplitude which is normally 30 per cent of the total (sync tip to white-level) signal excursion. The picture component extends towards whichever is the opposite polarity with an amplitude which varies between a minimum of zero, called **black level**, and a maximum, called **white level.** This component covers an amplitude range which is 70 per cent of the total video signal excursion.

In any television scene, the brightest (or lightest) parts are represented by a picture signal reaching some level – not necessarily the maximum possible – called **picture white**; in the same way, the darkest parts are at a level called **picture black.** If a given scene contains elements of both maximum and minimum brightness, i.e. if the picture component has the maximum and minimum amplitudes, then, for that signal, picture white is at white level and picture black is at black level.

The above explanation implies, correctly, that the waveform of a continuous picture component of minimum amplitude, i.e. a signal corresponding to a completely black scene, is at a constant level which, in a U.K. 625-line composite signal, is normally coincident with blanking level. Because of this, blanking level is often wrongly referred to as black level. These two levels are not necessarily coincident, and in some television systems, a specified difference is maintained between them (see Note 2).

Importance of signal asymmetry: methods of quantifying the changing position of the mean level

From a further consideration of the correspondence between the instantaneous picture-component amplitude and the light and dark detail on the screen, it is evident that the mean amplitude of the picture component will change according to the average apparent brightness of the originating scene. Hence, the corresponding composite video signal is, to a varying degree, asymmetrical; both this asymmetry and the rate at which it varies are characteristics which must be taken into account when the signal is distributed and applied to the display device to re-create the original scene. Because the magnitude of the signal is generally given in terms of voltage, it is, specifically, the varying mean signal voltage which is the important value.

In practice, this mean or average value can be quantified in either of two ways. When it is stated as a voltage – considered relative to a fixed value, usually zero volts – it is termed the **d.c. component** of the signal. Alternatively, it can be referred to the blanking level of the signal itself; it is then called the **Average Picture Level** (A.P.L.) and is expressed as a percentage of the (defined) difference between black level and white level.

Of these two possibilities, Average Picture Level is the parameter which is most easy to use for specification and measurement. This is so because, unlike the d.c. component:

(a) it is completely defined and can be measured solely in relation to the signal it describes, i.e. it does not need an external reference;

(b) it has a value which is unchanged by the form of the signal, i.e. since it relates to the picture component only, the value is independent of the presence or otherwise of sync pulses.

Because of its importance in carrying information concerning the brightness of the original scene, it would seem necessary that the d.c. component of a video signal should be conserved throughout the transmission path. This could be achieved by means of a distribution system which employed only d.c.-coupled circuits. However, such costly provision is not necessary; for both practical and economic reasons, transmission circuits are mostly a.c. coupled, the d.c. component being reconstituted as and when required; e.g. by means of a clamp.

Required signal-transfer amplitude range of a standard signal

Apart from creating the need to reconstitute the d.c. component of the video signal as outlined above, the use of a.c. coupling causes another difficulty; for distortionless transmission the available signal-transfer range for maximum standard (monochrome) signal excursion must be at least 50 per cent greater (see Note 3) than the sync-tip-to-white-level amplitude of the signal being transferred (which is all that would be required in a completely d.c.-coupled system). This is shown in the drawings in the following tables which illustrate the effects of sudden picture-brightness changes on waveforms, voltage excursions and other parameters at various circuit points. The changes illustrated in Table II relate to three simple scenes: a dark (all-black) scene with one point at white level, an overall mid-grey scene and an all-white scene.

Table I gives the relevant d.c. and a.c. voltage values calculated for these three steady-state conditions. Table II shows the effects of instantaneous changes between the scenes which occur at important points in the transmission chain. It should be noted that the critically damp ed response shown at the bottom of Table I relates to a single CR coupling. A circuit including a series of these would exhibit damped oscillation, and there would then be a need for an even greater increase in the signal-transfer range.

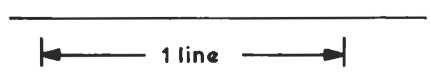
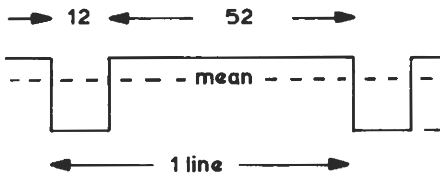
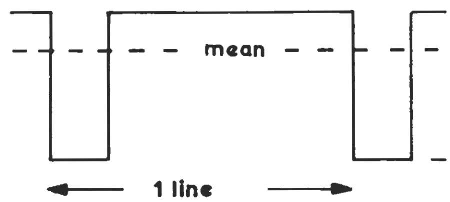
In Table I the figures given are calculated for a field-blanking period of 25 lines, i.e. a duration of 1600 μs.

In Table II, the parameters used are as defined in BS4727; Group 04; 1976, i.e.:
Average Picture Level (APL). The average signal level during active picture scanning time (integrated over a picture period, excluding blanking intervals) expressed with respect to blanking level as a percentage of the difference between blanking and white levels.
D.C. Component. The component of the picture signal or video signal that represents the average luminance of the picture with respect to a given level.

Notes:

1. For simplicity, only a monochrome picture signal is considered here. The explanations given and dimensions used, however, are applicable to the luminance component of any 625-line coded colour signal.
2. In some television standards, the level corresponding to black level (minimum value of picture black) does not coincide with the blanking level; e.g, in the (American) 525/60 system, there is a difference of five per cent (of the blanking-to-white-level amplitude), known as a pedestal, between the blanking and black levels; i.e. black level has a five per cent lift towards white level.
3. The minimum signal-transfer range for an a.c.-coupled monochrome picture signal of standard amplitude is (from Tables I and II) 1.524 volts.
4. For definitions of all text in **bold type** see **VMT-A Glossary of Television Terms** (P2, Part 4).

TABLE I

SCENE MEAN BRIGHTNESS	WAVEFORMS OUTPUT OF BLANKER (duration in μs)	D.C. POTENTIALS in volts w.r.t. blanking level (signal blanked at line and field rate)	LONG TERM (>>20 ms) A.C. MEAN VALUES in volts w.r.t. zero — line only	LONG TERM (>>20 ms) A.C. MEAN VALUES in volts w.r.t. zero — line and field
black		0	0	0
mid-grey		+0·35 +0·26 0	+0·07 0 −0·28	+0·09 0 −0·26
white		+0·7 +0·52 0	+0·13 0 −0·57	+0·18 0 −0·52

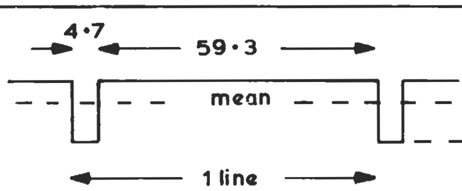
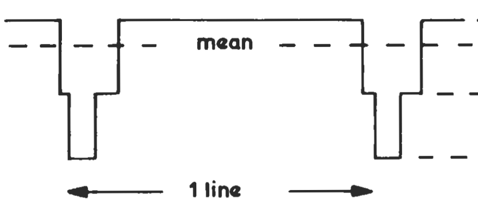
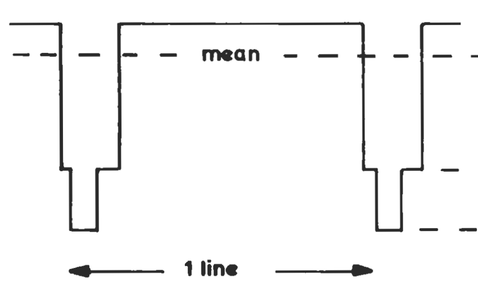
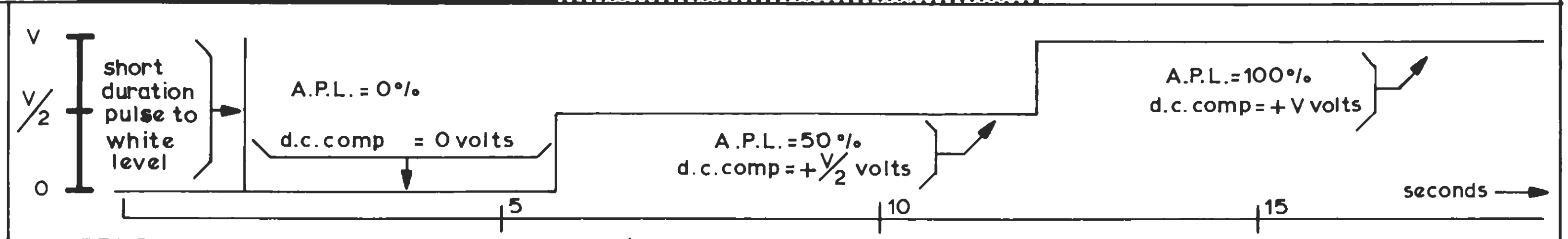
SCENE MEAN BRIGHTNESS	WAVEFORMS OUTPUT OF SYNC ADDER	D.C. POTENTIALS in volts w.r.t. blanking level (signal blanked at line and field rate)	LONG TERM (>>20 ms) A.C. MEAN VALUES in volts w.r.t. zero — line only	LONG TERM (>>20 ms) A.C. MEAN VALUES in volts w.r.t. zero — line and field
black		0 −0·024 −0·3	+0·02 0 −0·28	+0·02 0 −0·28
mid-grey		+0·35 +0·024 0 −0·3	+0·09 0 −0·26 −0·56	+0·11 0 −0·24 −0·538
white		+0·7 +0·5 0 −0·3	+0·153 0 −0·547 −0·847	+0·2 0 −0·5 −0·8

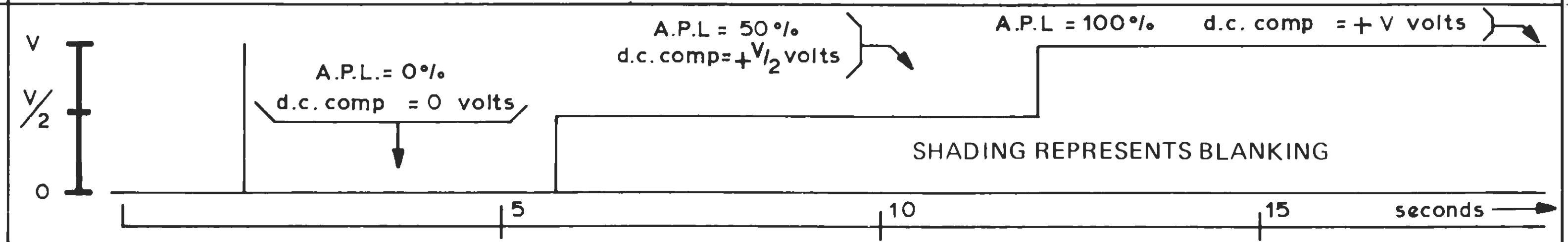
TABLE II

Scene Mean Brightness →	BLACK (with one point of light)	MID-GREY	WHITE

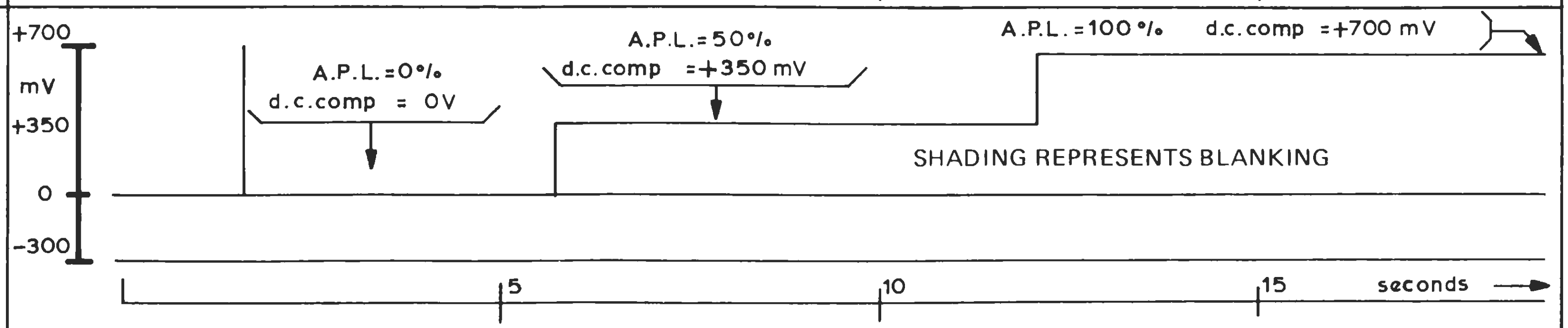
Gamma-corrected output of pick-up tube. Voltage w.r.t. black level of 0 volts for max. (white) level of V volts



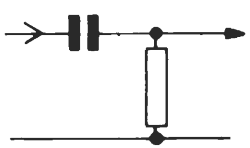
Output of pick-up tube after blanking. Amplitude w.r.t. blanking level of 0 volts for max. (white) level of V volts



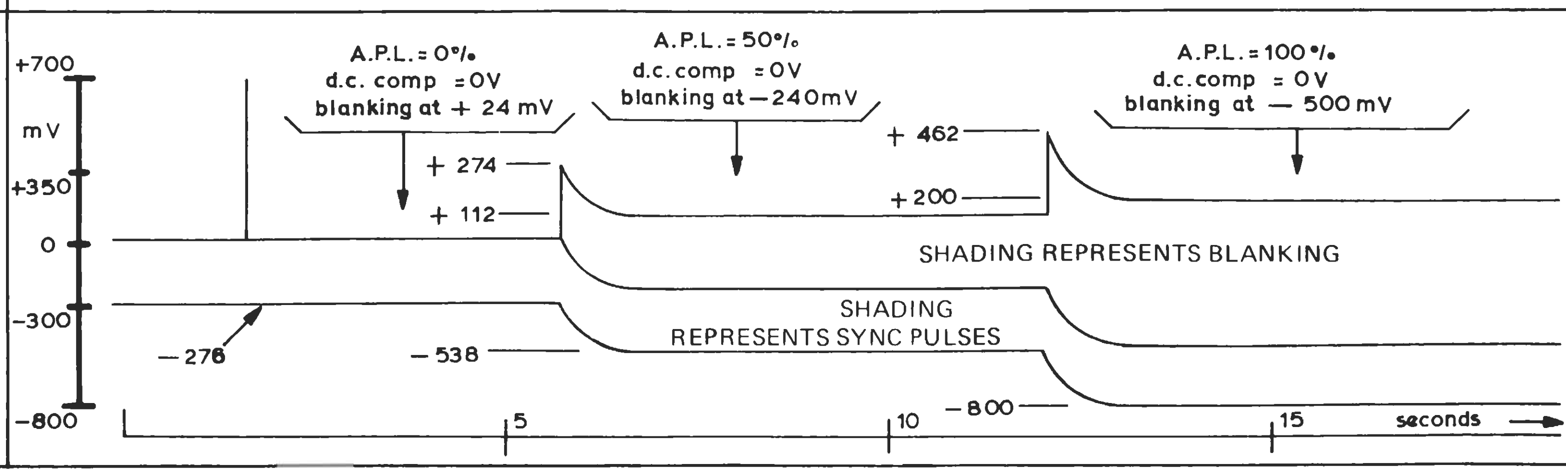
Blanked output of pick-up tube after addition of mixed sync pulses. Amplitude in millivolts w.r.t. blanking level (STANDARD AMPLITUDE signal).



Output after passing through one CR (a.c.) coupling



Amplitude in millivolts w.r.t. blanking level



APPENDIX VTP-C

PRACTICAL EXAMPLES OF THE EFFECT OF IMPEDANCE MISMATCH ON GAIN MEASUREMENT

INTRODUCTION

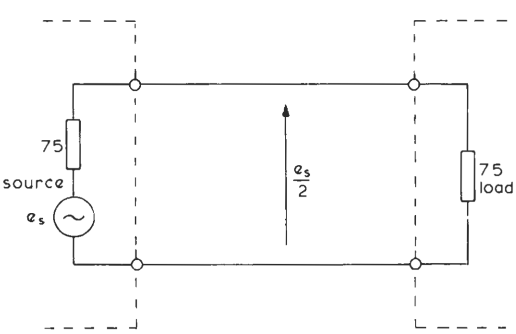
One of the methods which may be used to obtain a figure of Voltage Gain for video circuits, as outlined in VTP1.2, is to measure and compare the input and output voltage of the circuit under test. This is especially convenient for testing circuits where the input and output terminals are not at the same location, e.g. when measuring the gain of a link between two regional centres or of a tie line in a studio centre. However, the method only gives a result in terms of INSERTION VOLTAGE GAIN – the more normally-quoted parameter – under certain specified conditions of impedance matching.

Over and above the particular arrangement of impedance relationships, it is of fundamental importance, when measuring gain by this method, to ensure that the source and load impedances presented to the circuit under test conditions are the same as those which exist under normal working conditions. Failing this, it may be possible to carry out the measurement accepting the incorrect impedance conditions and then compensate for the discrepancy by making a calculation to obtain the correct figure of gain. Measurement and correction by calculation in this way is not recommended, however, because in practice impedance mismatch can result in adverse effects other than simply yielding misleading voltage – and hence gain – figures; for example, an impedance mismatch can cause distortion of the frequency response and reflections. It is better, where possible, to arrange for the correct impedance conditions to exist before making the measurement.

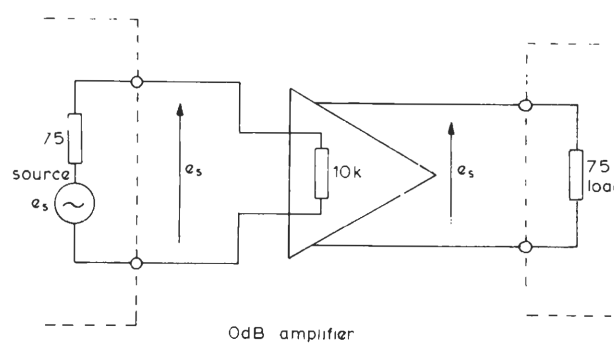
Three typical examples of measurement error caused by impedance mismatching are given below.

(i) **Insertion Gain measurement with mismatched (unterminated) input:**
(Unit on test: 0 dB gain video Distribution Amplifier)

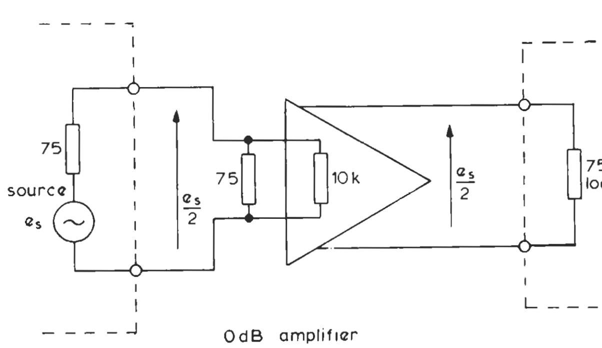
Amplifiers of this type usually have an input impedance of about 10 kilohms, and an output impedance of 75 ohms. They are designed to give a voltage gain of unity when working between 75-ohms source and load impedances *with an added (external) input termination of 75 ohms.* This extra termination should also be provided when measuring the insertion gain of the unit; Fig. 1 shows the measurement error which results if it is not included.



(a) 75 Ω source fed directly to a 75 Ω load



(b) 0 dB gain amplifier inserted between a 75 Ω source and a 75 Ω load but WITHOUT the necessary added input termination.



(c) Showing connection of added 75 ohms input termination

Fig. 1 Example of error caused by absence of required termination

From expression **(d)** in Video Test Procedure **VTP1.2 Gain**:

$$\text{Insertion Gain} = 20 \log \frac{e_s \text{ (from Fig. 1b above)}}{e_{s/2} \text{ (from Fig. 1a above)}}$$

$$= 20 \log 2$$

$$= 6 \text{ dB}$$

When a 75-ohm termination is provided at the unit input, see Fig. 1(c), the input voltage (and hence the output voltage) changes to $e_{s/2}$, so that:

$$\text{Insertion Gain} = 20 \log \frac{e_{s/2}}{e_{s/2}}$$

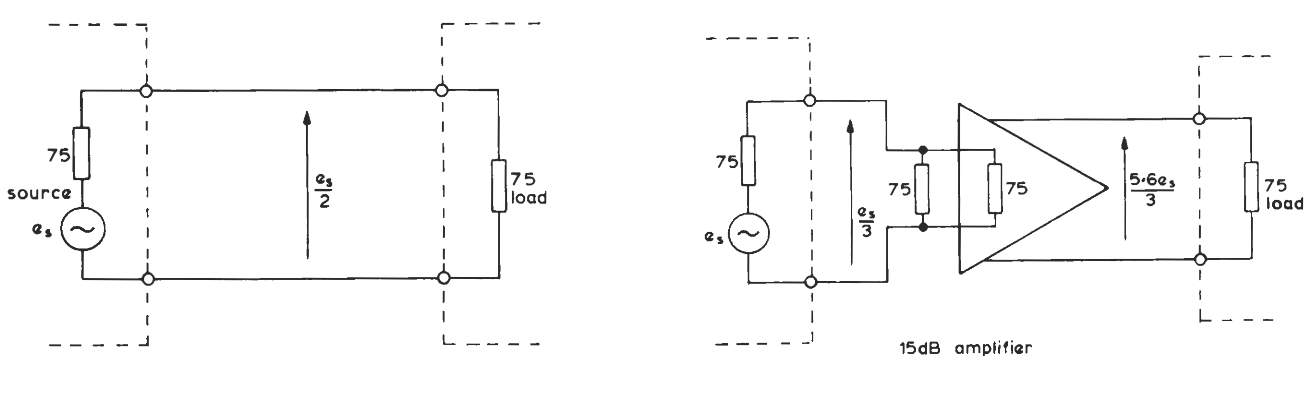
$$= 20 \log 1$$

$$= 0 \text{ dB.}$$

Thus, in the absence of the required matching termination, the gain appears to be 6 dB high;

(ii) Insertion Gain Measurement with mismatched (double terminated) input
(Unit on test: 15 dB gain Video Amplifier

Some types of 15 dB video gain amplifiers used in the BBC have a high-input impedance and some a 75 ohms input impedance; they are all designed to give the same voltage gain of 15 dB (i.e. an amplification factor of 5.6).
The high-input-impedance types require an external 75 ohms to be connected in parallel with the input terminals. If this is done to a 75-ohms-input amplifier, the insertion gain measurement is in error as shown in Fig. 2.



(a) 75 Ω source fed directly to a 75 Ω load

(b) 15-dB-gain, 75 Ω-input amplifier inserted between a 75 Ω source and a 75 Ω load with an UNWANTED 75 Ω input termination.

Fig. 2 Example of error caused by double termination

From Fig. 2:

$$\text{Insertion Gain} = 20 \log \frac{5.6e_s}{3} \Big/ \frac{e_s}{2}$$

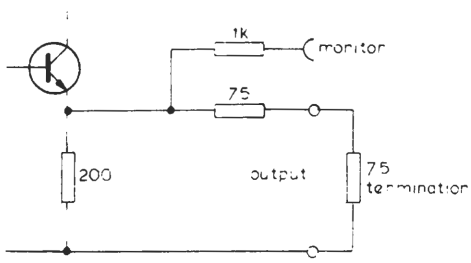
$$= 20 \log 3.73$$

$$= 11.5 \text{ dB.}$$

Thus, with the unwanted extra termination, the gain appears to be 3.5 dB low:

(iii) Measurement of signal amplitude at a medium impedance monitoring point

The third example shows the error in checking signal amplitudes (and thereby gain) which can occur when voltages are measured at a medium-impedance monitoring point. A typical circuit configuration where such errors may occur is an amplifier stage having an emitter follower output (see Fig. 3).



Note: The monitor point is built out to 1 kΩ to prevent measuring equipment from interferring with the output.

Fig. 3 A circuit showing a monitoring point connection

Because of the negative feedback, the effective generator impedance is very low, say 0.1 ohm. The equivalent circuit is shown in Fig. 4.

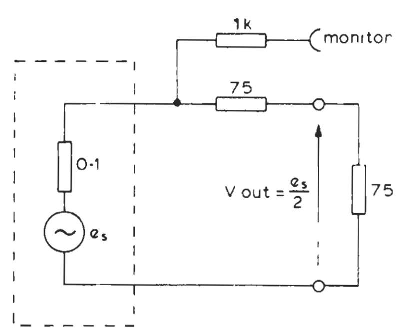


Fig. 4 Equivalent of circuit in Fig. 3.

If the circuit is correctly terminated, the output voltage will be $\frac{e_s}{2}$. If an attempt is made to measure this voltage by means of a high-impedance input – say one megohm – oscilloscope connected to the monitoring point, the result will be as shown in Fig. 5.

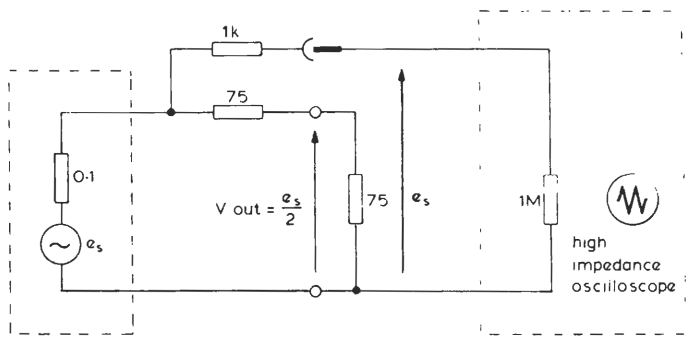


Fig. 5 Measurement at the monitoring point using a high-impedance oscilloscope

There is an error in the measurement of +6 dB.

If the measurement is made in a similar way but with an oscilloscope having an input impedance of 75 ohms, the result will be as shown in Fig. 6.

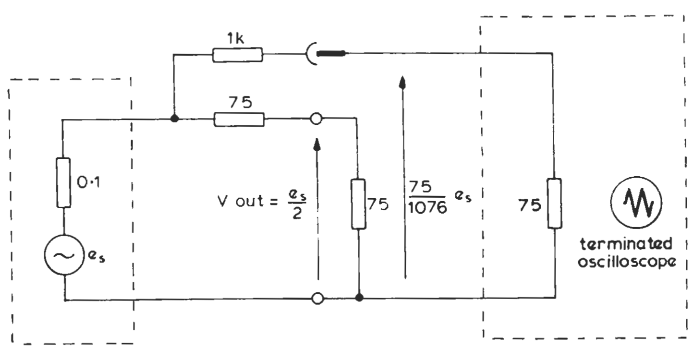


Fig. 6 Measurement using a 75 Ω input oscilloscope

The measurement result is in error by:

$$20 \log \frac{75e_s}{1076} \Big/ \frac{e_s}{2}$$

$$= 20 \log \frac{150}{1076}$$

$$= 17.1 \text{ dB.}$$

In such circumstances, the easiest way to obtain a correct measurement of the output voltage is to ignore the monitor point (which is only provided for inspection) and measure either across the terminated output using a high-impedance oscilloscope or to disconnect the output termination (if this is possible) and feed the output directly to a terminated oscilloscope which will act as the load (of 75 ohms).

APPENDIX VTP-D

THE USE OF PEAK SIGNAL AND R.M.S. NOISE VALUES IN THE EXPRESSION OF SIGNAL-TO-RANDOM-NOISE RATIOS

Because a random-noise interference signal comprises components which are of indefinable amplitude, its magnitude cannot be measured in terms of a peak value. But a noise pulse contains energy which can be measured and used to represent the magnitude. Since power is equivalent to the rate of conversion of energy (from one form to another), if the energy contained in a succession of noise pulses is integrated over a specified period* – by means of a thermocouple meter, for instance – a figure can be obtained which is proportional to the noise power. This is normally given as an r.m.s. voltage.

To obtain a figure for the signal-to-noise ratio, the same terms of measurement must be applied to the *signal* part of the comparison, i.e. its energy content must also be stated as an r.m.s. value.

Consider the output from a television camera – one of the main sources of video signals – before blanking pulses are added. The energy contained in the signal can vary between zero, for continuous black level, up to the maximum of continuous white level. These are, in fact, the limits which define what is called the PICTURE AMPLITUDE of the video signal (see VTP1.1 of **Waveform Amplitude Measurements**).

The picture energy level used as a reference when specifying signal-to-noise ratios must, of course, have a constant value and, for convenience, must be easily repeated. The value chosen is the maximum, i.e. continuous white level, which is +0.7 volt (d.c. with respect to zero volts blanking level) when the picture amplitude has the STANDARD value of 0.7 volt. Note, here, that because continuous white level is specified, the reference picture amplitude has a peak-to-peak value which is also its r.m.s. value.

If, as often happens, the instrument employed to measure the r.m.s. noise is a.c. coupled, it cannot be calibrated directly by using a continuous white-level signal because this is d.c. It must, instead, be referred to an a.c. signal having an equivalent r.m.s. value. Hence, noise measurements made at circuit points where the picture amplitude has the STANDARD value, are calibrated with an a.c. signal of 0.7 volt r.m.s.

Example

Suppose a circuit normally gives an output signal of STANDARD PICTURE AMPLITUDE, i.e. the measured amplitude of the luminance bar in a Chrominance-Luminance Pulse-and-Bar test signal carried by this circuit is 0.7 volt.

Let the random noise measured at the same circuit point in the absence of the test signal be 0.007 volt r.m.s. Then, by definition, for this circuit:

$$\text{Signal-to-Noise Ratio} = \frac{\text{r.m.s. picture amplitude}}{\text{r.m.s. noise amplitude}}$$

$$= 20 \log \frac{0.7}{0.007} \quad \text{(stated in dB)}$$

$$= 40 \text{ dB}$$

Note that, for the reasons already discussed, the numerator here is given an r.m.s. value even though it is measured peak-to-peak.

*The effective time-constant or integrating time recommended for international use is one second. (CCIR Rec. 451-2 for 625-line Systems I signals: Rep. 486-1 otherwise).

For continuous random-noise, an approximate relationship between the r.m.s. and peak-to-peak values can be obtained by statistical calculation: it is generally accepted that the peak-to-peak value (of noise) is greater than the r.m.s. value by about 17 dB. Hence, given the conditions stated above:

$$\text{Signal-to-Noise Ratio} = \frac{\text{p} - \text{p picture amplitude}}{\text{p} - \text{p noise amplitude}}$$

would yield a figure of (40 – 17) dB

= 23 dB

Further calculation shows that this figure relates to an assumed peak-to-peak (random) noise amplitude of 0.05 volt. Note that the numerator in this second ratio has the same numerical value as before, but is here standing as a peak-to-peak value to correspond with the denominator.

APPENDIX VTP-E

WEIGHTED RANDOM NOISE MEASUREMENT – UPPER BANDWIDTH LIMIT FOR CODED SIGNALS

Circuits carrying 625-line-standard (PAL System I) video signals in the United Kingdom require a bandwidth which is, ideally, flat to 5.5 MHz. Thus it might seem that measurements to obtain the signal-to-**unweighted**-noise ratio for such circuits should be made using a low-pass filter with a cut-off at this upper frequency limit. But, according to the definition given in VTP4.1 **CONTINUOUS RANDOM NOISE** and shown by the full-line filter characteristic in Fig. 2b of VTP4.1, the upper limit is set, for historical reasons, at 5.0 MHz. This apparent inconsistency is emphasised by the fact that, to obtain a figure for the signal-to-**weighted**-noise, the networks used for (separate) measurement on the luminance and chrominance channels together cover the whole of the video band up to 5.5 MHz (see VTP4.1, Fig. 3).

In practice, the error incurred by using a 5.0 MHz cut-off filter for unweighted measurement on a 5.5 MHz circuit (instead of the ideal 5.5 MHz rectangular characteristic) is small; typically, it is 0.4 dB for *flat* noise and 1.2 dB for *triangular* noise. It is of interest, here, to note the (unpublished) results of work by the Post Office which suggests that, where the noise distribution is between flat and triangular, unweighted measurement with a band restriction of 5.0 MHz gives a better correlation with the subjective effect than does the 5.5 MHz limit. Where the noise spectrum is steeply-rising, however, as with the so-called super- or hyper-triangular distribution, the error will be greater, and may not be acceptable. One example of such excessive error occurs in noise measurement on the channel amplifiers in cameras; in this instance, an alternative, wider-band filter is usually specified (see the dotted characteristic in Fig. 2b of VTP4.1).

The required video bandwidth varies with the type of television system. Thus the filters and weighting networks used differ accordingly. It is therefore difficult to assess the signal-to-noise ratio which will be obtained when national circuits are connected in tandem to form an international chain. Several attempts have been made to overcome this problem of specification and assessment. The latest compromise proposal concerning measurement of noise affecting coded signals suggests the use of a single weighting characteristic (see VTP4.1, Fig. 4) with the 5.0 MHz low-pass filter of Fig. 2b (full-line characteristic) to give one figure for signal-to-noise that covers both the luminance and chrominance signals, and takes account of the differences between television systems. This unified weighting network might be adopted for use within the U.K. at some time in the future.

APPENDIX VTP.F

SUBJECTIVE ASSESSMENT OF SOUND AND PICTURE QUALITY

C.C.I.R.5-point scale

The C.C.I.R. recommends that a five-point scale should be used for the subjective assessment of television pictures (Recommendation 500) and also for radio and television sound (Recommendation AE/10). This scale is also used by the C.C.I.T.T. for types of transmission other than telephony (Recommendation N-64). The BBC, in common with other broadcasting authorities throughout the world, has therefore adopted the C.C.I.R. five-point scale in place of the previously used EBU six-point scale. The five-point scale has the following descriptions.

C.C.I.R.5-POINT SCALE

Quality	Grade	Impairment
Excellent	5	Imperceptible
Good	4	Perceptible but not annoying
Fair	3	Slightly annoying
Poor	2	Annoying
Bad	1	Very annoying

All BBC documents using the C.C.I.R. five-point scale should include a reference noting that the five-point scale has been used.

Conversion between C.C.I.R.5-point and EBU 6-point scales

The EBU six-point assessment scale differed from the C.C.I.R. scale not only in having six grades instead of five, but also in that the highest number represented the lowest quality. The EBU six-point scale had the following descriptions:

EBU 6-POINT SCALE

Quality	Grade	Impairment
Excellent	1	Imperceptible
Good	2	Just perceptible
Fairly good	3	Definitely perceptible but not disturbing
Rather poor	4	Somewhat objectionable
Poor	5	Definitely objectionable
Very poor	6	Unusable

If it is necessary to convert from one scale to the other the following approximate expression can be used:

$$A_5 = 5.8 - 0.8A_6$$

Where A_5 = assessment using the C.C.I.R. five-point scale

A_6 = assessment using the EBU six-point scale

Where results have been obtained by conversion, using this equation, it should be stated that such a conversion has been carried out.

TECHNICAL PUBLICATIONS SECTION

P2 MEASUREMENTS AND TEST PROCEDURES

Errata (April 1981)

Please amend the following pages as indicated:

1. ATP1.1 - 4, page 12, Fig.7 (a) and (b). Alter designation of resistors R, across which VR is measured, from 'R' to 'R = 600 ohms'.

2. VTW.1, page 2, figure - against possible ident pulse, shown dotted, alter 'see Appendix A' to 'see Appendix B'.

3. VMT.1, page 12, last line of right hand column. Alter '....echo of 3%.' to read '....echo of 4%.'

4. VMT.2, page 10 - formulae at top of R.H. column should be:

$$\text{Differential Gain Distortions} = \frac{y - x}{x} \times 100 \text{ per cent}$$

or

$$= \frac{z - x}{x} \times 100 \text{ per cent}$$