HF ENGINEERS' INTRODUCTION TO TELEVISION

RF TECHNIQUES & MEASUREMENTS

Module RF3: Spectrum Analysers

1 Introduction

It will be remembered that spectrum analysers display signal amplitude on a vertical axis against a horizontal frequency scale. The concept was introduced in section 5 of module RF2 (RF Test Set) and various limitations of the built in analyser due to compromises within the Test Set were identified. It will be seen in this module that a dedicated spectrum analyser is more versatile, enabling a wider range of measurements to be made.

This module briefly describes the extra characteristics of dedicated analysers and the use of UHF analysers in the routine maintenance of TV transposers. It was written around Hewlett Packard (HP) analysers with RF units 8553B (0 - 110 MHz) or 8558B (0 - 1500 MHz) and Takeda Riken (TR) model TR4122B (0 - 1500 MHz), although it can not go into detail due to this variety of makes and models.

The tracking oscillator (generator) was covered in section 6 of module RF2 (RF Test Set). HP spectrum analyser have a tracking oscillator as an accessory, whilst Takeda Riken include it as standard equipment. Again, because of this variety, it is not possible to cover the use of either in this module.

BOLD TYPE is used in this module to indicate equipment controls, legends or new concepts.

2 Facilities

The general requirements for UHF analysers are similar irrespective of make or model.

2.1 Frequency range

The frequencies of interest in the UHF band lie between 470 and 850 MHz (channels 21 to 68). A general purpose spectrum analyser covering this range will usually be tunable from a nominal 100 kHz up to at least 1000 MHz (1 GHz).

2.2 Frequency resolution

Frequency resolution is the ability of the analyser to distinguish between two adjacent carriers - the closer carrier frequencies are, the better the resolution required to separate them. Resolution is a function of analyser IF bandwidth, horizontal sweep speed and scan width (width of the frequency band to be examined). These are variable over wide ranges for maximum flexibility, and best resolution is achieved with the narrowest IF bandwidth.

2.3 Amplitude Measurement

A spectrum analyser displays signal amplitudes on either LOGARITHMIC or LINEAR scales. The log scale can be either 10 dB/DIV for displaying signals of widely differing amplitudes, or 2 dB/DIV for a more accurate measurement but restricted range. The display can also be switched to LINEAR for analogue measurements, such as modulation depth.

A simplified block diagram of a typical spectrum analyser is shown in fig (i).

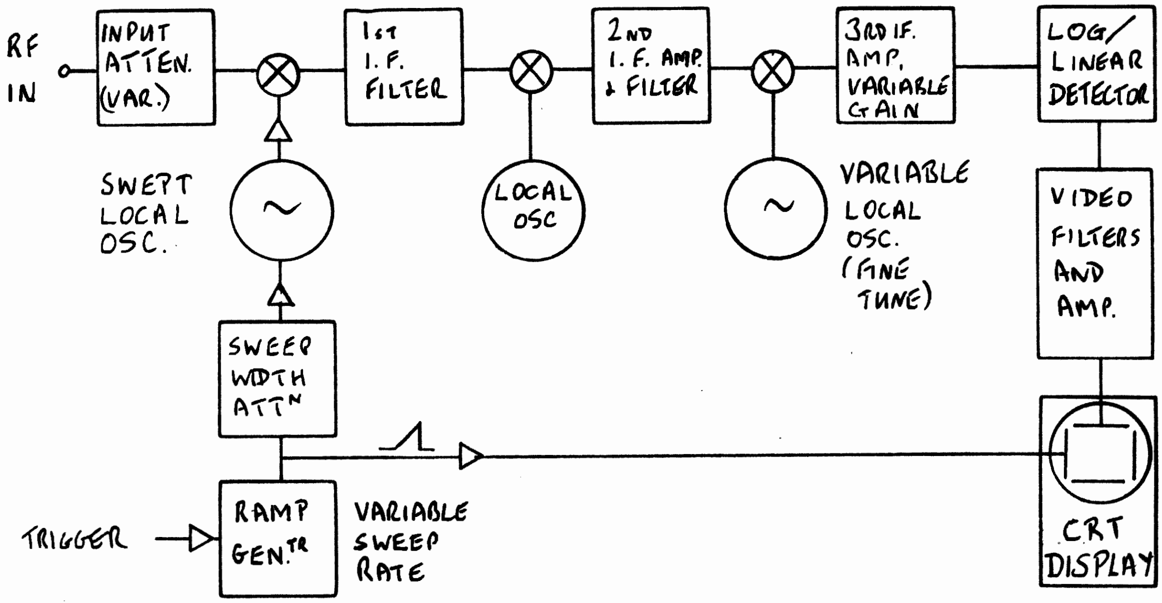

fig (i)

Frequency resolution and amplitude measurement characteristics of the analyser will now be examined in more detail since they are likely to be less familiar concepts than frequency range.

3 Frequency resolution

When the analyser local oscillator is swept across the frequency spectrum, the input to the IF amplifier will vary each time a carrier is encountered. If a narrow IF bandwidth and a fast sweep speed are selected then the IF amplifier will not have time to respond fully to the signal. This results in the displayed signal amplitude being reduced and some analysers indicate this source of error with a light on the front panel. The HP 8558B uses a mechanical arrangement to interlock the FREQ SPAN and RESOLUTION BandWidth knobs so that they are always on the OPTIMUM setting. The TIME/DIV control has a setting where the sweep speed is varied automatically.

As stated in 2.2 above, there are three variables which determine the analyser frequency resolution:

IF bandwidth
Horizontal sweep speed
Scan width

3.1 IF Bandwidth

Sweep speed can be measured by the time taken for one traverse of the screen. Consider a SWEEP RATE of 1 mS and a SCAN WIDTH setting of 1 MHz/DIV. Assuming 10 horizontal divisions, this gives a scan width of 10 MHz, so the rate of change of frequency is

10 MHz/2 mS = 5 MHz/mS

In this example an IF bandwidth of 100 kHz will be found sufficient, but 10 kHz too narrow.

3.2 Sweep Rate

In the above example, if the SWEEP RATE is increased to 0.5 mS then the rate of frequency change becomes

10 MHz/0.5 mS = 20 MHz/mS

and 100 kHz bandwidth is no longer wide enough.

3.3 Scan Width

For the original SWEEP RATE of 2 mS but a new SCAN WIDTH of 10 MHz, the rate of frequency change is

100 MHz/2 mS = 50 MHz/mS

and again an IF bandwidth of 100 kHz causes the apparent amplitude of the signal to be reduced, but a bandwidth of 300 kHz is adequate.

4 Vertical Display Scaling

The vertical scaling may be switched between LOGARITHMIC or LINEAR. The log scale is usually calibrated 10 dB per vertical division and is switchable to 2 or 1 dB/DIVISION. Check this on your analyser.

4.1 Advantage of Log Scales

Consider the analyser with the vertical scale set to log, 10 dB/DIV. Assuming 8 divisions betwen top and bottom of the screen, (check on your instrument) this will give a theoretical maximum resolution of 80 dB. This is a power ratio of 100,000,000:1 with the advantage that two carrier levels equivalent to 10 kw and 0.1 mW can be displayed on the same scale. The disadvantage is that it is difficult to differentiate betwen power levels closer than about 1 dB, and so the 2 or 1 dB/DIV setting is provided.

4.2 Log Display Measurements

Absolute measurements are made relative to the top graticule line, usually called the REFERENCE LEVEL. The REFERENCE LEVEL can be compared to the FSD of a multimeter whose range is changed by altering calibrated controls.

The reference level calibration can be checked by using an internal marker of specified amplitude.

Measurements can be taken in two ways:

(a) Using the calibrated graticule to measure a signal level by comparison with the REFERENCE LEVEL.

(b) Using the calibrated controls to alter the analyser sensitivity until the signal reaches the top of the screen. This in effect makes the REFERENCE LEVEL the same as the signal level.

Spectrum analysers have at least two switched, calibrated level controls. One is an RF attenuator prior to the first mixer, the second an IF gain control called SENSITIVITY or REFERENCE LEVEL. The latter often has an associated variable control, the overall sensitivity of the analyser depending on all controls. If the combination gives a REFERENCE LEVEL of 0 dBm (1 mW into 50 ohm), then applying signals of (say) 0 and -10 dBm to the analyser will produce responses peaking to the reference and one division below it, (see figure ii).

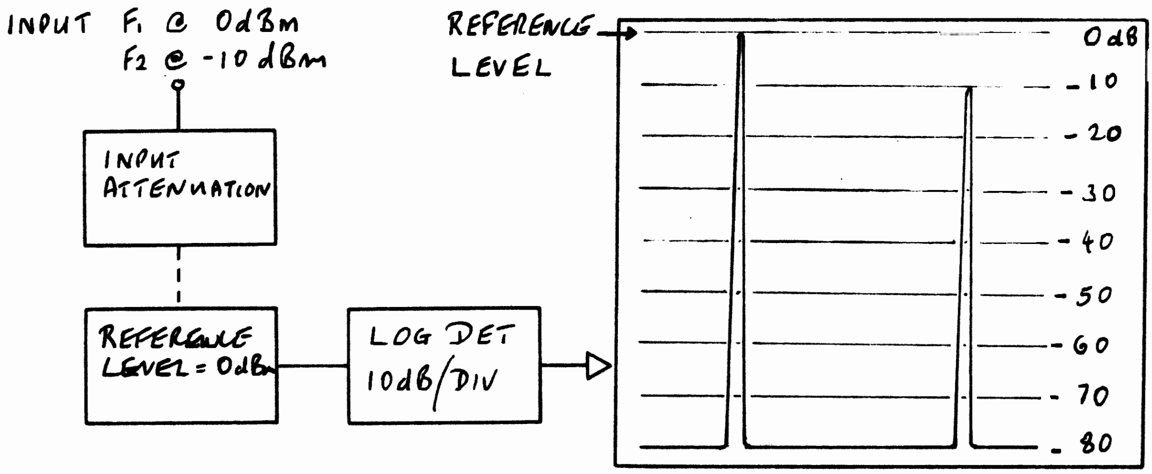

fig (ii)

Since there are two level controls, it might be thought that any combination of settings capable of producing the wanted reference level could be used. In practice, maximum RF attenuation and maximum IF gain will give a noisy display and make low level signals unreadable. Conversley, high level signals with minimum RF attenuation and minimum IF gain could drive the mixer into non-linearity. An overloaded mixer will produce effects which are not always easy to spot:

(a) The height of the displayed signal will not be proportional to the amplitude of the input signal (GAIN COMPRESSION). This is detected by increasing the RF input attenuation by 10 dB and noting that the displayed signal only falls by a lesser amount (say 5 dB).

(b) Spurious mixing products will be seen on the screen. In this instance, increasing the RF input attenuation will result in a 10 dB drop in wanted signals but a larger drop (say 20 dB) of the spurii.

As a guide, Hewlett Packard suggest that the optimum signal level at the first mixer should be -40 dBm. Hence if the signal applied to the analyser is -10 dBm, the RF input attenuator would be set to 30 dB to give -40 dBm at the mixer.

4.3 Linear Display

When the analyser is switched to LINEAR, signals are displayed on the screen in analogue form. That is, if the signal power is halved then the display amplitude drops by 50%. Contrast this with the logarithmic display set to 10 dB/DIV. where the same drop in level would be less than 7%. The range of displayable signal levels in the linear mode is about 1,000:1 - again, compare this to the 100,000,000:1 in the log mode.

4.4 Linear Display Measurement

Absolute measurements are made with respect to the bottom of the graticule, the height of the display being directly proportional to the signal amplitude. The internal marker can be used for calibration on one range. As an example, a marker level of -30 dBm will give a voltage level of 7.1 mV. Note that the same calibrated IF controls used for log measurements are also used for linear work, and may have two sets of calibrations for this purpose.

4.5 Measurement Summary

To summarise, use the 10 dB/DIV log range for examining widely differing signal levels and the 2 dB/DIV range for more accurate comparisons. Use the linear range for analogue displays.

5 Calibration Checks

This section is a practical one for which you will need a spectrum analyser.

Calibration is needed for both signal amplitude and frequency. All analysers incorporate a CW marker of fixed amplitude and frequency to cater for this, and some also have a variable frequency marker.

If recalibration is found to be necessary, please consult the analyser handbook.

Set the analyser controls as follows:

Scan Width, Freq Span or Dispersion	10 MHz/DIV
Frequency Sweep	Centre or Per Division
(Scan) Time/Division	1 mS
Scan mode (if fitted)	auto/internal
Trigger	Auto or Free Run
Tuning Stabiliser (where fitted)	off
Resolution Bandwidth	Widest bandwidth
Vertical mode	10 dB/div
Reference level	0 dBm
Base line clipper	off
Video filter	off

5.1 Logarithmic Calibration Check

This section covers calibration checks of the logarithmic display. The method is to first check that the trace lines up with the bottom of the graticule and then that the marker reaches the reference level.

(a) Switch to LINEAR and turn the IF gain to minimum (to reduce effect of noise). Confirm that the trace is aligned with the base line, then return to 10 dB/div.

(b) Connect the MARKER directly to the analyser input and set the RF attenuation to 0 dB. Adjust the IF gain to make the REFERENCE LEVEL equal the marker level, (commonly -30 dBm).

(c) Tune the analyser to display the marker in the centre of the screen.

(d) Reduce the SCAN WIDTH to, say, 100 kHz/DIV whilst keeping the marker centralised. Adjust the IF BANDWIDTH to 100 kHz.

(e) A frequency marker should now be seen in the centre of the screen. Confirm that it touches the reference level (+/- 0.5 dB), thus checking the absolute calibration. Check the logarithmic calibration by increasing the RF attenuation in 10 dB steps and noting that the marker drops in 10 dB steps. Note that the marker height can be restored by increasing the IF gain at the penalty of increasing the noise level.

(f) Switch to 1 or 2 dB/DIV. The marker should still be on the REFERENCE line (+/- 0.5 dB nominal).

This completes the calibration check of the logarithmic display.

5.2 Linear Calibration Check

The only analyser which is calibrated in the LINEAR mode is the HP 8553B. The checks may be carried out on other analysers to gain familiarity with their controls.

(a) Switch to LINEAR and turn the IF gain to minimum (to reduce effect of noise). Confirm that the trace is aligned with the base line, then return to 10 dB/div.

(b) Determine the marker voltage amplitude, (7.1 mV for a power level of -30 dBm). Adjust the IF gain to set the vertical scaling to the appropriate level, (1 mV/DIV in the above example). Connect the MARKER directly to the analyser input and set the RF attenuation to 0 dB.

(c) Select a TIME/DIV of 1 mS, SCAN WIDTH of 100 kHz and 100 kHz RESOLUTION.

(d) Switch to LINEAR and (HP 8553B only) measure the amplitude of the marker. It should be 7.1 divisions in this example.

That completes the calibration check of the linear display of a Hewlett Packard analyser.

5.3 Frequency Calibration Check

The main function of spectrum analysers is not to measure frequencies, but amplitudes. As such, a frequency measuring accuracy of only +/- 10% can be expected.

There are two references associated with frequency measurement. The first is zero frequency and is always available since it is a function of the analyser. The second is the internal marker, which has to be plugged up when required. These two references are used to check the SCAN WIDTH calibration. The marker is then used by itself to check the accuracy of any analyser frequency indicator.

(a) Set the analyser controls as listed at the begining of section 5 and disconnect any input. If neccessary, adjust the X SHIFT to centre the horizontal trace on the screen.

(b) The analyser scan can be switched to start at either the left or centre of the screen. Depending on model, the switch is marked START (or 0 or 0-100 MHz) and CENTRE (or PER/DIV). Switch to CENTRE (or PER DIV) and tune the analyser until the frequency indication is zero. The zero frequency marker should now be in the middle of the screen. Switch the scan to START and confirm that the zero marker coincides with the extreme left hand line of the graticule. Any frequency indicator should read zero in both cases.

(c) Connect the marker to the analyser input and select the appropriate REFERENCE LEVEL.

(d) Adjust the SCAN WIDTH until the marker is as far to the right of the screen as possible. For example, a marker frequency of 100 MHz and a graticule with 10 horizontal divisions requires a scan width of 10 Mhz/DIV if the horizontal calibration is correct. The calibration of a variable marker (if fitted) can now be checked by using it to measure the frequency of the fixed marker.

The SCAN WIDTH calibration has now been checked. The final step is to check the absolute frequency calibration of the analyser.

(f) Switch the scan to CENTRE (or PER DIV) and adjust the tuning until the marker is on the centre line. The frequency indication should now display the marker frequency.

All the calibration checks on the analyser have now been completed.

6 Logarithmic Measurements

Sections 6 and 7 use the spectrum analyser to carry out the Transmitter Group RF Performance Check on a low power TV relay station. A copy of the form needed for these tests, with typical values, is shown in appendix i. The appropriate module paragraph number also appears on this sheet. The performance limit for individual stations will be found at the relay site.

Unless stated otherwise, the peak sync vision signal is to be measured or used as a reference.

6.1 Equipment

Spectrum analyser covering UHF band (HP 8558B or TR 4122B)
UHF transposer fed from local transmitter or Test Set.

Set the analyser controls as follows:

Scan Width, Freq Span or Dispersion	Maximum MHz/DIV
Frequency Sweep	Centre or Per Division
(Scan) Time/Division	1 mS
Scan mode (if fitted)	auto/internal
Trigger	Auto or Free Run
Tuning	Zero Frequency
Tuning Stabiliser (where fitted)	off
Resolution Bandwidth	Widest bandwidth
Vertical mode	10 dB/div
Reference level	0 dBm
Base line clipper	off
Video filter	off

The practical section begins with the precautions to be taken when connecting external signals to an analyser.

6.2 Precautions

The spectrum analyser has to measure signal amplitudes over a wide dynamic range, so the input circuit must be sensitive. The analyser input circuit must also present the correct impedance throughout the frequency spectrum. Hence the input circuitry is the most vulnerable part of the device, and there is a very real risk of an overload burning out the variable input attenuator. Specialist test gear is needed for repair and recalibration so it is normally done by the manufacturer or his agent, which is expensive. The obvious way to avoid disaster is not to feed too much power into the analyser!

The following is good practice to avoid damage and maintain accuracy:

(a) Before connecting anything to the analyser input, estimate the maximum power which the test item could deliver in the worst case. This includes power of unwanted signals since the analyser input is aperiodic.

Should the slightest doubt about levels exist, use a power meter to check because it will show the total RMS power over the band. If this power only approaches the limit quoted in the handbook or on the front panel, then reduce the applied signal level by using an external attenuator or directional coupler.

(b) Use a 10 dB attenuator on the input of the analyser. If an error is made, the attenuator may burn out but will be less expensive to replace than the analyser. A fixed attenuator also improves the match and so maintains accuracy.

6.3 Absolute Level Measurement

This measurement is made by selecting a suitable REFERENCE LEVEL, applying the signal and reading the amplitude off the graticule. This is illustrated in fig (iii).

(a) The analyser switched to START, widest SCAN WIDTH and broadest IF BANDWIDTH will give a panoramic view of the whole frequency spectrum so that it will be immediately obvious if, despite all precautions, an overload does occur.

(b) Estimate the level of the signal to be measured, using the figures in appendix (i) as a guide. Hence decide the size of attenuator needed external to the analyser. Set the REFERENCE LEVEL appropriate to the signal level on the external attenuator output.

(c) Connect the signal to the analyser and confirm that nothing goes above the reference level. Switch the scan to CENTRE and tune the analyser to centralise the wanted signal.

(d) Progressively adjust the SCAN WIDTH to 1 MHz/DIV, keeping the signal centralised. It is vital for accurate measurement that calibration is not lost, as mentioned in section 3 earlier.

(e) Note on the graticule how far down the signal is from the reference level. Subtracting this figure from the reference level gives the signal level in dBm APPLIED TO THE ANALYSER INPUT. The value of the external attenuator must be added to this measurement. See figure (iii).

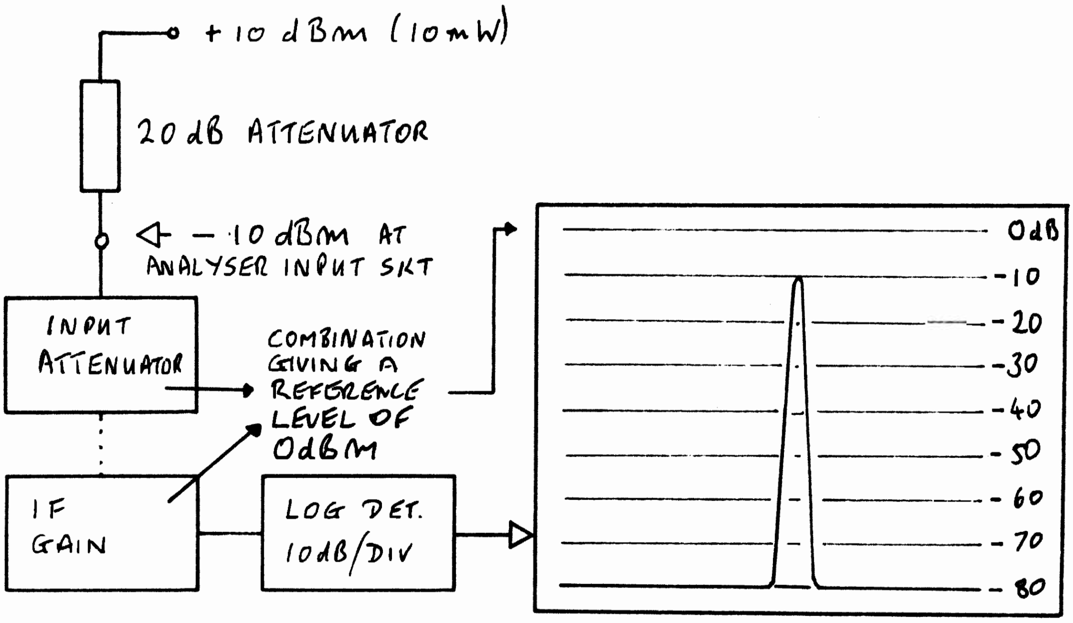

fig (iii)

6.4 Sound to Vision Ratio

The sound to vision ratio is a relative level measurement. The peak sync vision carrier is taken as reference and the sound compared to it. The actual amplitude of the two signals is unimportant as it is their difference which is required. This difference should be 7 dB, so the 2 dB/DIV scale may be used for greater accuracy.

(a) Switch the analyser to START, widest SCAN WIDTH and broadest IF BANDWIDTH. Tune to zero frequency. This will give a panoramic view of the whole frequency spectrum so that it will be immediately obvious if, despite all precautions, an overload does occur.

(b) Estimate the level of the transposer signal to be measured, using the figures in appendix (i) as a guide. Hence decide the size of attenuator needed external to the analyser. Set the REFERENCE LEVEL appropriate to the signal level (on the external attenuator output).

(c) Connect the transposer output monitor to the analyser and confirm that nothing goes above the reference level. Switch the scan to CENTRE and tune the analyser to centralise the wanted signal.

(d) Adjust the RF ATTENUATOR and IF GAIN (including FINE) until the peak syncs touch the REFERENCE line.

(e) Progressively adjust the SCAN WIDTH to 2 MHz/DIV whilst keeping the vision signal centralised. Ensure that calibration is not lost (section 3 above).

(f) Switch to 1 or 2 dB/DIV and repeat (d) if neccessary. Adjust the analyser tuning until the sound carrier is on the centre line and read off the difference in dB between the REFERENCE line (vision peak sync) and sound carrier; this is the sound/vision ratio.

6.5 Chrominance to Luminance Ratio Measurement.

This is another example of relative measurement. The 10 dB/DIV scale has to be used since 17 dB is the normal chrominance/luminance ratio, equivalent to a 100% chrom/lum on the Insertion Test Signal (see module TV2).

(a) Switch to 10 dB/DIV and proceed as for 6.4 (a) to (e). Repeat (d) if neccessary.

(b) Adjust the analyser tuning until the chrominance sub carrier (vision carrier + 4.43 MHz) is on the centre line.

Measuring the amplitude of the chrominance takes practice, since the signal only peaks once per frame when the Insertion Test Signal is present. Read off the difference in dB between the vision peak sync and the chrominance sub carrier; this is the chrominance/luminance ratio which should be 17 dB.

Repeat the measurement by switching the analyser SWEEP RATE to MANUAL and using the MANUAL SWEEP to tune across the spectrum and peak the chrominance signal. This method takes longer but gives a steady spot which is easier to read and so is more accurate.

6.6 Intermodulation Product Measurement

This is another relative level measurement but using a test generator. The analyser is connected to monitor the output of the transposer whilst it is being fed with a three-tone test signal. The resulting intermodulation products are then measured.

The three tone method of testing requires either the RF Test Set or a three tone test Generator. If neccessary, refer to BBC Technical Information volume 3 section 5 and module RF2, section 8. (In practice, if the RF Test Set were available, then it would be used instead of the analyser for the test).

Measurements are made relative to peak sync power, NOT to the level of vision carrier produced by the test generator. This is 8 dB lower than peak syncs to simulate average programme. The transposer AGC circuits operate on vision carrier peak syncs and since these are not present, the transposer must be switched to MANUAL gain control. The gain is then set to deliver the rated output with normal signal applied.

The level of +/-1.57 MHz intermodulation products should be better than -52 dB relative to peak sync power, so the 10 dB/DIV scale is used.

The entry "others" on the performance sheet refers to unwanted signals worse (greater) than the intermodulation products already measured.

(a) Switch to 10 dB/DIV and proceed as for 6.4 (a) to (e).

(b) Confirm that the peak syncs are still on the reference line. Switch the transposer from AGC to MANUAL, adjusting the MANUAL GAIN to keep the peak syncs on the REFERENCE LINE.

(c) Switch the test generator to single tone (vision carrier). Attenuate the output to the level normally applied to the transposer, (previously measured in 6.3). Apply this test signal to the transposer input, adjusting the level until the single tone touches the reference line. Minor adjustment may be made using the transposer MANUAL GAIN. The transposer should now be transmitting this single tone at the rated output power.

(d) Switch the generator to three tones and the analyser RESOLUTION BANDWIDTH to 100 kHz, checking that the analyser calibration is maintained. Measure the level of the resulting intermodulation products.

6.7 Spurious Emission Measurement

This is a relative level measurement using the normal TV transmission. Because the level of spurii should be better than -52 dB relative to peak sync power, the 10 dB/DIV scale is used.

(a) Proceed as for 6.4 (a) to (e).

(b) Confirm that the peak syncs are still on the reference line, then measure the spurious frequencies relative to this line. The entry "others" on the performance sheet refers to unwanted signals greater than the +12/-6 MHz already measured.

7 Linear Measurements

Section 7 completes the RF Performance Test by describing how to use the analyser in the linear mode to measure crosstalk between the sound and vision carriers and display a demodulated television waveform. The equipment is listed in 6.1.

7.1 Vision-on-Sound Cross Modulation

The analyser is tuned to the sound carrier and switched to LINEAR. The sound carrier amplitude is equated to 100% and any cross modulation of vision signal on the sound carrier can then be expressed as a percentage. See BBC Technical Information Volume 3, RF Test Procedures, section 5 if required.

(a) Set the analyser controls as listed at the start of section 5 and tune in the signal as described in 6.4 (a) to (c).

(b) Reduce the RESOLUTION BandWidth to 100 kHz to eliminate the effects of the colour sidebands.

Progressively adjust the SCAN WIDTH to zero, peaking the signal with the TUNE control. The tuning STABILISER (if fitted) can now be switched on.

(c) Switch the analyser to linear and readjust the FINE and coarse IF gain controls to make the sound carrier 100% (i.e. 5 divisions). The analyser should now be displaying a horizontal line with the only disturbance being due to sound programme. In practice, non linearity within the transposer will cause vision-sound cross modulation and a small amplitude vision signal will be seen superimposed on the sound carrier.

Measure the peak amplitude of this vision signal and express it as a percentage of the sound signal.

7.2 Modulation Depth Measurements

The analyser is tuned to the vision carrier and set to display the TV waveform. Modulation depth, as described in module RF2 section 3.5, can then be read. See fig (iv).

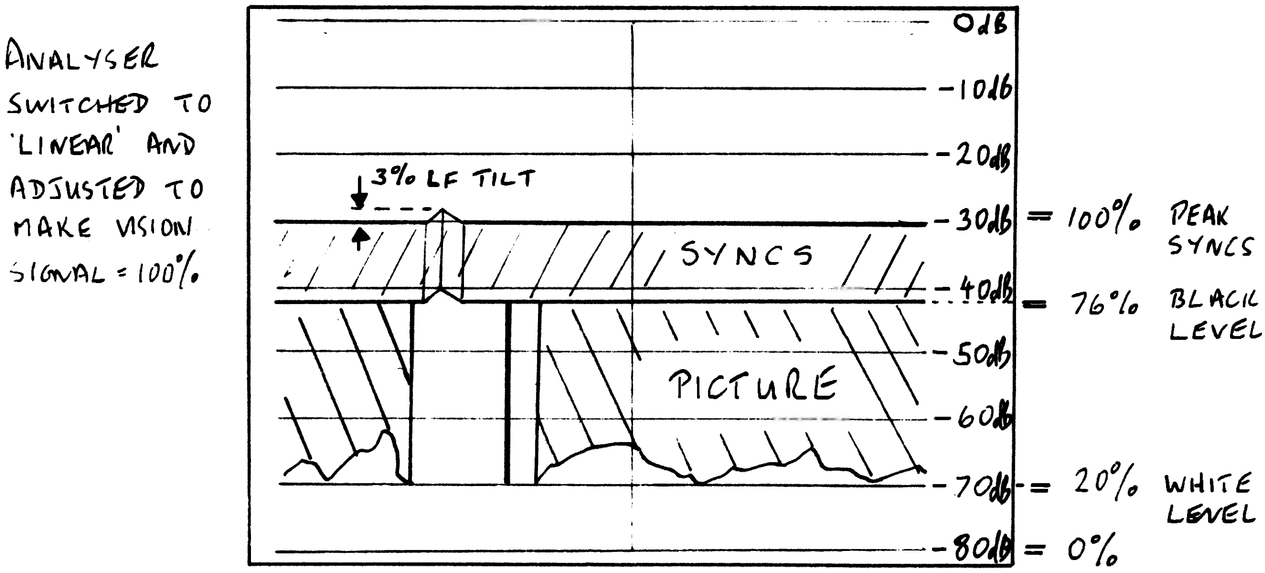

fig (iv)

(a) Tune in the signal as described in 6.4 (a) to (c).

(b) Progressively reduce the SCAN WIDTH to zero whilst peaking the vision signal with the TUNE control. The tuning STABILISER (if fitted) can now be switched on.

(c) Switch the analyser to linear and readjust the FINE and coarse IF gain controls to make the vision signal 100%. The analyser should now be displaying a TV waveform, syncs uppermost, fig (iv) overleaf.

(d) The vision signal blanking level can now be measured. The peak white level can be measured as the ITS bar drifts past. LINE trigger (50 Hz supply) can be tried to slow this drift down.

7.3 Field Distortion

Transposer AGC systems can introduce an LF distortion onto the vision waveform. This defect can be measured as a percentage of the total vision signal.

(a) Tune in the signal as described in 7.2 (a) to (c).

(b) Measure any LF distortion as a percentage of the vision signal, fig (iv). LINE trigger (50 Hz supply) can be tried to slow the waveform down.

8 Conclusion

This module has aimed to show the use of a spectrum analyser in routine performance testing. It has emphasized that the analyser is a vulnerable instrument and must always be treated with care. The analyser is a versatile device and this module has only scratched the surface of the many uses to which it is capable of being put.

When you have completed this module to your own satisfaction, please fill in & return the slips overleaf.

I would welcome any comments you care to make about the module, but please write them on a separate piece of paper.

Appendix (i)

Extract of Transmitter Group RF Performance Test sheet with typical figures in the BBC-1 Main section. The module paragraph numbers are also given, where applicable.

TRANSMITTER GROUP. UHF RELAY STATIONS: R F PERFORMANCE TESTS

STATION .... DATE ....

		BBC 1 Main	BBC 1 Reserve	Paragraph Number
LPT Oscillator frequency error (Hz)	Input			–
	Output			–
Transposer I/P signal level		-30dBm		6.3
Transposer AGC range				–
3 Tone I/P's	- 1.57	-50dB		6.6
	+ 1.57	-50dB		6.6
	others			6.6
Spurii outputs with normal radiation	- 6	-57dB		6.7
	+ 12	-57dB		6.7
	others			6.7

	I/C	Outgoing Main	Outgoing Reserve	Paragraph Number
Sound to vision Pk sync ratio		7.0dB		6.4
Chrome Relative to Pk Sync		-17dB		6.5
Vision on sound 'X' mod.		5%		7.1
Mod depth to black level(%)		76%		7.2
Mod depth to VITs Bar (%)		20%		7.2
Field distortion (%)		3%		7.3

	BBC 1 Main	BBC 1 Reserve	Paragraph Number
Measured on output feeder probe the relative service powers	+1.0dBm		6.3
Return loss	-30dBm		6.3

From: Date:

SUBJECT: TV TRAINING, MODULE RF3 (Spectrum Analyser)

To: John Barker, TV Training Coordinator, Skelton.

I have completed the above module to my own satisfaction & am now ready to receive the next one.

....

From: Date:

SUBJECT: TV TRAINING, MODULE RF3 (Spectrum Analyser)

To: STM Daventry / Rampisham / Skelton / Woofferton *

I have completed the above module to my own satisfaction & am now ready to receive the next one.

(* Delete as applicable)