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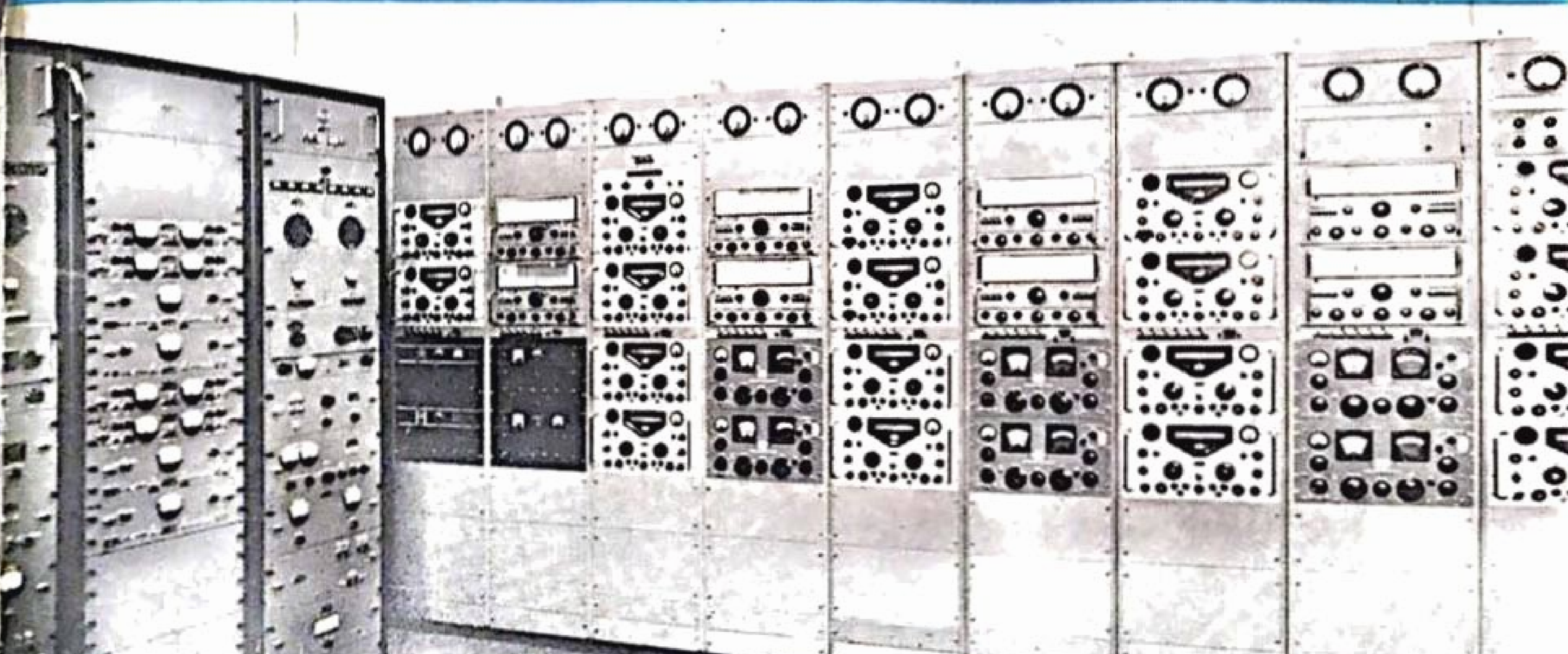

Monitoring and Relaying of Short-wave Broadcast Signals

The cover illustration shows the Control Room at BBC Tatsfield Receiving Station. Opposite is a bank of a.m. double-sideband receivers and on the left a diversity pair of single-sideband receivers.

ENGINEERING TRAINING SUPPLEMENT

No. 13

MONITORING AND RELAYING OF SHORT-WAVE BROADCAST SIGNALS

by

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BRITISH BROADCASTING CORPORATION

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PREFACE

The successful relaying or monitoring of short-wave signals requires specialised equipment and aerials. In addition the staff responsible for operating the equipment must be skilled in its use, familiar with the hazards of short-wave propagation and experienced in the identification of signals.

This book is intended to provide basic information on the equipment, aerials, propagation, signal identification and other subjects required in work at a receiving station.

CONTENTS

REQUIREMENTS OF A BROADCAST RELAY AND MONITORING SERVICE

Introduction

Most broadcasting organisations, at some time or another, wish to relay programmes from a distant source, or themselves have distant transmitting stations from which they want to relay their own programmes. A good example of the latter is the BBC Atlantic Relay Station, which receives World Service, African and South American programmes from the United Kingdom and re-transmits them to the appropriate areas.

The success of such a relay is as dependent on the receiving equipment as on the transmitting apparatus and the purpose of this booklet is to describe the problems of receiving short-wave signals and the methods which can be employed to obtain the best quality of signal pick-up with least noise and interference.

Because any relay operation can usually carry out a vital monitoring function to provide valuable information to the engineers responsible for selecting the transmitter frequencies, the requirements of monitoring are also examined; these include observations on, and technical assessment of:—

- (a) the authority's own overseas broadcasts
- (b) identification of interference and its source
- (c) general investigation of the r.f. spectrum with a view to its maximum exploitation
- (d) monitoring the broadcasts of other organisations who are prepared to provide reception data on the authority's own broadcasts
- (e) providing information adding to the store of knowledge on propagation conditions, so increasing the accuracy of predictions of the best frequencies to be used for transmitting to a given area, at a given time of day, season of the year and period of the sunspot cycle.

Relaying of Broadcast Radio Signals

Relaying may involve a long-period broadcast, such as World Service extending over some hours or a short news bulletin. It may be a music programme requiring high quality or a news item accompanied by noise and interference and, at times, almost unintelligible but nevertheless urgently required because of its topical value.

The greatest attention and care must be taken to achieve the best result even though the standard may, because of transmission and propagation defects, be well below that of the studio control line link. Transmitter faults, interference, fading, static, etc. should be looked for and a quick change made to a better signal when there are two or more outputs radiating the same programme. The number of receivers available should be adequate to allow a pair operating in diversity to be tuned to each transmission; diversity linking is essential to reduce the effect of fading. Aerials are generally selected to give highest signal strength but in the presence of interference it may be worth while using an aerial which provides a null on the unwanted signal even though it is off-beam to the wanted signal. Restriction of receiver bandwidth is not necessarily the best device for eliminating heterodynes because the resulting audio quality may be poor and, when programme other than speech is relayed, it may be hardly worth listening to.

Changeover from one receiver output to another is carried out by a cross-fade, the period of mix being generally made as short as possible especially when the particular programme is being received from two different transmitting sites and may have different time delays because different lengths of line are used to feed the transmitters. The problem can be solved if the cross-fade is made only during a programme pause. Preliminary tests should be made to ensure that the outputs of the two sets of receivers are in audio phase. Reverse phase is normally indicated by poor and thin quality when the two signal outputs are mixed together.

Signals interfering with the relay can be so varied in character that only experience with the equipment will indicate the best way of dealing with them. A relatively strong heterodyne at a frequency of about 1 kHz and carrier beats between 3 and 7 per second are perhaps the most severe forms of interference: high or very low-frequency heterodynes can generally either be eliminated or reduced to tolerable limits. Adjacent-channel interference may be lessened by the use of more selective receiving equipment though slight de-tuning of a double side-band (d.s.b.) receiver away from the offending channel may suffice if there is no alternative.

Constant monitoring is essential, not only of the signal being relayed but also of the standby channels. The tuning of all receivers should be checked from time to time and the equipment should preferably be switched on all the time even when not relaying. Receivers fitted with wavechange switches or turrets are susceptible to contact troubles and only conscientious attention to detail by the operator can ensure that all the hazards are prevented from causing serious deterioration of quality.

Monitoring of Broadcast Radio Signals

Observations on Outgoing Signals

Staff operating relay stations should be familiar with the Radio Regulations book issued by the International Telecommunications Union. This indicates the use of the frequency spectrum by various services, the technical

characteristics and the classification of transmissions together with information on frequency tolerance and allowable [illegible] of spurious emissions.

There may be difficulties due to the monitoring station itself being in the skip zone of many of the transmissions, though directional aerials and high-sensitivity receiving equipment generally permit the majority of the outgoing broadcasts to be heard possibly by back scatter. The points to be looked for are whether the transmission is clear of faults, is modulated with the correct opening announcement or time signal, and whether the correct material is being broadcast. The same programme radiated from two or more transmitting centres may provide a means of comparison if fault conditions are suspected.

Subjective assessment of the quality and overall merit of a short-wave signal by experienced amateurs in the receiving area can be a very useful supplement to measurement and assessments made by the organisation's own monitoring system. The BBC receives considerable help from reception reports of enthusiasts within the service area of its transmissions.

Identification of Interference and its Source

Interference may be caused by another broadcast in the same channel or an adjacent channel but the language of the interfering broadcast may indicate the probable area from which it emanates and confirmation may be obtained by direction-finding techniques.

The transmitting site itself may be causing interference due to cross-modulation between transmitter outputs; harmonics of a transmission may be of sufficient magnitude to cause interference. Intermodulation frequencies (e.g. sum and difference frequencies of short-wave transmissions from the same site) can fall within the short-wave band and cause objectionable interference. Whenever these are noted they should be reported so that action can be taken.

Investigation of the R.F. Spectrum

The growth of short-wave broadcasting throughout the world has been such that the limited frequency spectrum allocated for this purpose is hardly adequate to contain the transmissions now being carried. Band-scanning equipment is now available for automatically recording an up-to-date picture of band occupancy. The charts are scaled in frequency and time, the presence of a transmission being indicated by a line parallel to the horizontal time axis or by a band when interference is present. The chart cannot indicate the identity of the recorded signals and this has to be obtained from observation or documentation.

Monitoring Other Organisation's Broadcasts

The monitoring of other broadcasts follows the same lines as those of the authority's own broadcasts and the information supplied consists of an assessment of signal strength, details of any interference observed and an estimate of the overall merit of the broadcast. The date, time, type of receiver and the gain and directional characteristics of the aerial should all be noted. Other details such as fading, atmospheric noise, modulation depth, etc. are normally assessed only if a special test transmission requiring maximum information has been made.

Information Adding to Knowledge on Propagation

The data can be supplied in the form of reports covering a 24-hour (or less) period over a given path. A comparatively simple system of observation reporting is described in Chapter 9 and once experience of the ratings system has been acquired, close correlation is generally achieved between observers. Back-scatter observations may be obtained by pulse-modulating a short-wave transmitter and observing the forward pulse and the pulse reflected back from the first earth-reflection point and possibly from subsequent earth-reflection points.

PROPAGATION

Introduction

Many articles and text books have been written about propagation of radio signals through the ionosphere and in this handbook reference will be made only to those aspects which materially affect the work of relaying and monitoring. For a relaying operator to be fully effective his knowledge of propagation must lead him to anticipate ionospheric change so that he ensures that relaying can continue even under adverse conditions. Thus he should know when propagation of a particular frequency is likely to fail and have receivers tuned to an alternative frequency in a band which he believes will continue to propagate. During severe ionospheric disturbances all propagation may cease for a time but a relay may sometimes be continued longer if the operator has familiarised himself with the vagaries of storms.

We can summarise the basic features of short-wave propagation in the following way. Communication at such frequencies is achieved by waves which strike the ionosphere* at an oblique angle and are reflected back to earth to cover the target area. The waves may be reflected at the earth and reach other receiving areas after successive bounces from the ionosphere. However in certain areas for example between the transmitter and the first earth-reflection point the transmission may be very difficult to receive; this is a so-called skip zone.

For satisfactory short-wave communication the frequency must be chosen with care. If it is too high the waves penetrate the ionosphere and are lost in space; if it is too low the waves are attenuated by absorption before reaching the ionosphere. Best results are achieved by using the highest frequency which does not penetrate the ionosphere and the value of this, the maximum usable frequency (m.u.f.) depends on the degree of ionisation of the gas forming the ionosphere. This in turn depends on the extent to which the ionosphere over the chosen path is illuminated by the sun. M.u.f.s thus vary according to the time of day and the time of year.

Any changes in the degree of ionisation of the reflecting layers can affect long-distance reception and such changes can be produced by increased radiation from the sun, e.g. from blemishes on its surface such as sunspots and invisible areas called M regions. As seen from the earth, the sun takes 27 days to rotate on its axis and some effects on reception particularly those due to long-lived M regions tend to have a 27-day periodicity. Moreover the incidence of sunspots follows an 11-year cycle; this in turn causes an 11-year periodicity in short-wave reception conditions.

*Ionised layers of rarefied gases in the upper atmosphere (50 miles upwards).

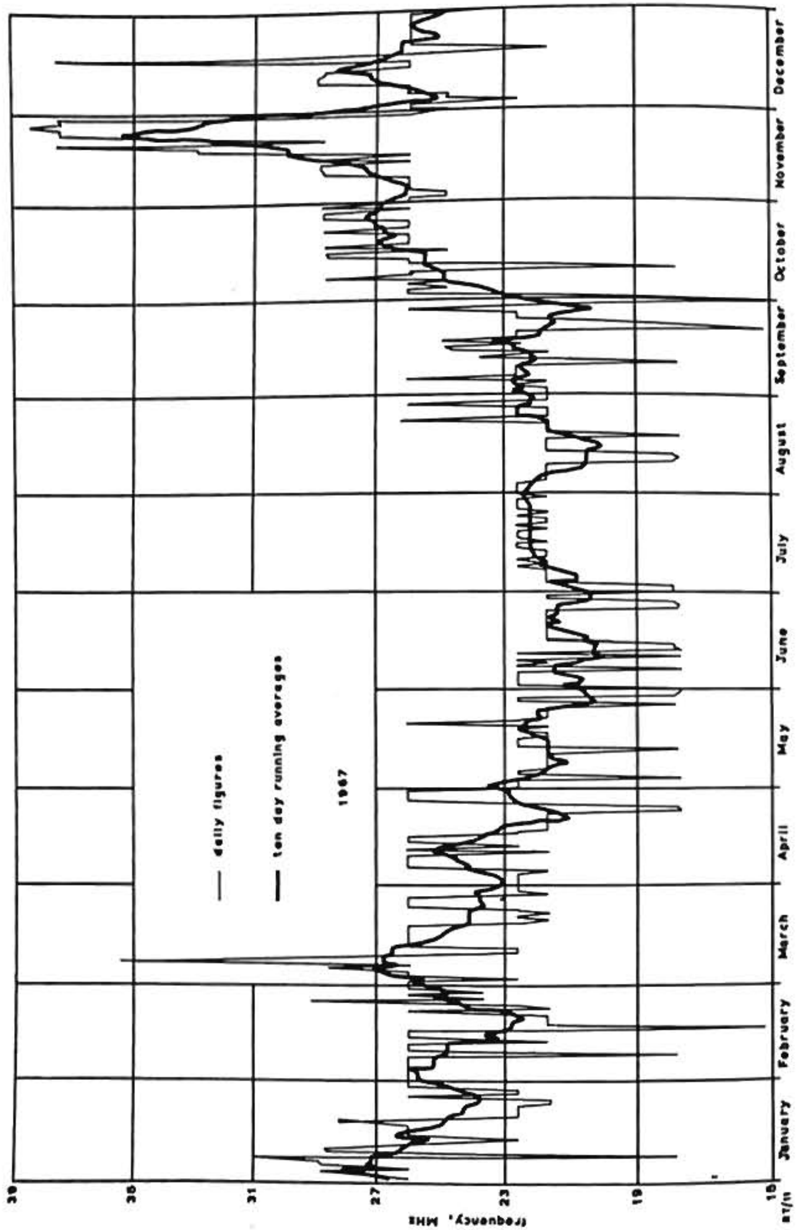


Fig. 1 Highest-received-frequency plots with the ten-day running averages superposed.

Highest Received Frequency and Propagation Forecasts

The highest received frequency (h.r.f.) represents the operational maximum usable frequency (m.u.f.) over a given path and is derived from observations carried out on signals which are known to be broadcast daily, together with information concerning the power and type of aerial used. These observations are made at two-hourly intervals during the 24 hours and after weighting has been applied to take into account the differences in location of the transmitter, the equivalent radiated power (e.r.p.) from the aerial and the beam azimuth angle, plots are made of the highest received frequency for each observation. An example of recorded h.r.f. over the North Atlantic path from America to Tatsfield is shown in Fig. 1. Observations are generally made on broadcasting stations but other services may be included providing their siting is on the same Great Circle path. Information of this kind has been collected for many years to give record of diurnal, seasonal and sunspot propagational changes. The late afternoon daily maximum h.r.f. when smoothed to a 10-day running average gives the black line curve in Fig. 1 and shows the periodic variation of about 27 days.

The data from the daily h.r.f. observations is averaged over four 6-hour periods (0000-0600 G.M.T. 0600-1200 G.M.T., etc.) and the results are graded in accordance with the scale used by the U.S. Institute of Telecommunications, Sciences and Aeronomy (I.T.S.A.). The I.T.S.A. scale has 9 gradations from 1 (signal useless) to 9 (signal excellent); normal propagation conditions are recorded as 7, 8 being reserved for above normal and 9 for unusually good conditions. Thus the coding I.T.S.A. 7777 for a given day represents a good average signal throughout the four 6-hour periods, whilst I.T.S.A. 7643 would indicate a deterioration from 0600 G.M.T. reaching storm conditions by mid-afternoon. This data is made immediately available at Tatsfield and those engaged in relaying will take action by re-tuning to frequencies in other bands to guard against further deterioration, the onset of which could be quite sudden. If the programme to be relayed by Tatsfield becomes available via other stations sited on a more southerly Great Circle path, some receivers would be re-tuned and aerials selected for these transmissions which will tend to be less affected by the storm.

Radio propagation forecasts are transmitted at 5-minute intervals in International morse code in the service provided by the National Bureau of Standards on each of the Standard Frequency Transmissions (S.F.T.) of station WWV at Boulder, Colorado; they refer to the North Atlantic radio propagation paths such as Washington to London, the times of issue being 0500, 1200, 1700 and 2300 G.M.T. The code employs a letter and a digit, as shown in the table below, the letter denoting the broad classification and the digit the position in the classification of the forecast for the next 6 hours.

02, 08, 14, 20. 1/11 – 30/4

01 07 13 19 1/5 – 31/10

NOT RELATED

Disturbed (W)	*Unsettled (U)*	*Normal (N)*
1. Useless	5. Fair	6. Fair to good
2. Very poor		7. Good
3. Poor		8. Very good
4. Poor to fair		9. Excellent

Short-wave propagation is affected whenever the ionisation density in the ionosphere is seriously disturbed. There are two main types of disturbance classified as *Sudden Ionospheric Disturbances* (s.i.d.), and *Ionospheric Storms*; both have a solar origin and are generally much more prevalent during years of high sunspot activity.

Sudden Ionospheric Disturbances

The cause of sudden ionospheric disturbances is thought to be outbursts of X-ray radiation from solar flares. This radiation which travels at the speed of light takes about 8 minutes to travel from the sun to earth and it greatly increases the electron density in the D-layer about 50 miles above earth's surface. It is in the D-layer that the greatest absorption of short-wave transmissions takes place and the result is a considerable increase in absorption of short-wave frequencies, the lowest frequencies being most affected and at times completely disappearing within a few seconds. The effect is progressively less at the higher short-wave frequencies though in severe cases all bands up to 17 or even 21 MHz may provide no communication path and signals at 26 MHz be weakened to such an extent that they are unusable. The complete short-wave fadeout is generally short-lived and after a short while the higher frequency signals are gradually restored to normal, the improvement being continued on each band in turn until the lowest frequency band is back to normal. S.I.D.s are generally of short duration rarely exceeding 1 hour. Fig. 2 is a record of one of the worst s.i.d.s. This started at 0847 G.M.T. on 1st June 1960 and nearly 5 hours elapsed before propagation returned to normal. Fig. 3 gives examples of more typical s.i.d.s when three occurred on the same day. A short-wave fadeout due to an s.i.d. can occur only when the propagation path is partially or wholly in daylight and there appears to be no seasonal variation in the frequency of occurrence. However there is a marked correlation between sunspot cycle variation and the incidence of s.i.d.s which occur most frequently during Sunspot Maximum years.

Ionospheric Storms

An ionospheric storm is thought to be due to outbursts of electrified

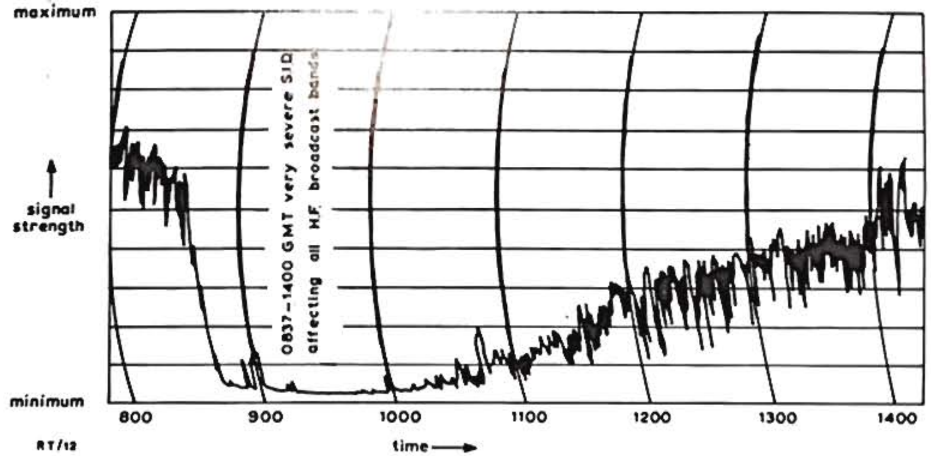


Fig. 2 The longest recorded example of a sudden ionospheric disturbance

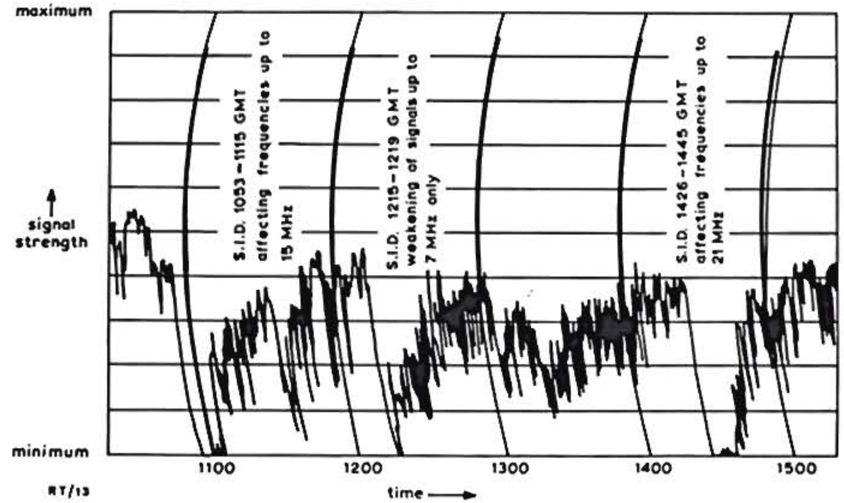


Fig. 3 A series of three sudden ionospheric disturbances recorded on the same day

corpuscles from the sun, these outbursts taking from 1 to 2 days to reach the earth. An s.i.d. occasionally precedes an ionospheric storm by about 1 to 2 days. The effect of these corpuscles on the ionosphere is to decrease the ionisation density of the reflecting layers so that transmissions which are normally reflected back to earth tend to escape into outer space. The corpuscles tend to affect the upper ionospheric layers to a greater extent than the lower; the higher frequency short-wave signals are affected first. Ionospheric storms may last for periods varying from a few hours to many days and they may vary considerably in intensity. They have a seasonal variation with incidence least in summer and there is a solar cycle variation, their incidence being greatest 2 to 3 years after Sunspot Maximum. There is also a geographical variation, paths passing near or through the auroral zones being most affected. This is because the streams of solar corpuscles are deflected by the earth's magnetic field towards these zones. Hence easterly reception paths from North America to the U.K. and westerly transmission paths from the U.K. to North America, which both pass close to the northern auroral zone are more frequently and severely affected by ionospheric storms.

The size, complexity and position of spots on the sun's surface can sometimes give warning of a future ionospheric storm.* The approach of a storm may be heralded by an enhancement of signals followed, within a few hours, by an appreciable decrease in field strength sometimes accompanied by flutter fading. When the spots (or spot) are in the central region of the sun's visible surface, the probability of an ionospheric storm is increased. This is because the stream of corpuscles faces the earth and is thus more likely to affect the earth's ionosphere. Ionospheric storms can also be caused by emissions from long-lived sources on the sun, which have not yet been visually identified, the so-called 'M' regions. These can give recurrent ionospheric storms at intervals of about 27 days, this being the synodic period of the sun's axial rotation with respect to earth. This recurrent phenomenon is most prevalent in years following sunspot maximum.

The BBC External Services broadcast ionospheric storm warnings based on observations made at Tatsfield, on receipt from Tatsfield of one of the following code words whose meanings are listed below:

Westdown – propagation from the U.K. to Canada and Western U.S.A. reduced.

Westout – propagation from the U.K. to the whole of North America reduced.

*Under no circumstances should the sun be viewed with the naked eye: if the image from a telescope aligned on the sun is focused on to a paper screen, major sunspots can be made visible.

Eastdown – propagation from U.K. in all Easterly directions seriously reduced.

Westnormal – propagation of all U.K. transmissions Westward back to normal.

Eastnormal – propagation of all U.K. transmissions Eastwards back to normal.

S.I.D. – sudden ionospheric disturbance.

The sudden ionospheric disturbance indicates a complete fadeout of short-wave transmissions operating over daylight or partial daylight paths. As this effect which is often called a short-wave fadeout is normally of short duration no code is sent to indicate restored conditions.

Flutter Fading

Flutter fading chiefly occurs at Equinoctial periods during the period following on sunset and preceding sunrise. It mainly affects those signals which are reflected by the ionosphere in low magnetic dip latitudes (i.e. near the magnetic equator). Automatic gain control is less effective against this type of fading which may be so rapid and selective over the modulation band that radiated speech may become almost unintelligible and music be completely degraded. Sometimes reception is improved by switching out the automatic gain control.

Flutter fading can also be met on auroral paths when it may presage an ionospheric storm.

3

RECEIVERS

If a signal is to be relayed, reception must necessarily be consistent and to achieve this the receiver must have high sensitivity, good frequency stability, low noise factor, and adequate selectivity. Attention must also be paid to the aerial system and it may be necessary to spend more money on this than on the receiver. In this chapter the general principles of the various types of superheterodyne receiver available for relaying are discussed, starting from simple single-frequency-change equipment.

Superheterodyne Receiver

The single-frequency-change superheterodyne receiver has remained substantially unchanged in circuit arrangement over the past 40 years though there have been improvements in performance. Such receivers have been almost entirely superseded by the double-frequency-change type for communication purposes but the design of the single-frequency-change receiver merits attention because the basic principles apply in the modern receiver. The block diagram in Fig. 4 shows that it typically consisted of two radio-frequency stages, a mixer valve with separate oscillator, two or more intermediate-frequency stages, diode detector and automatic gain control, noise limiting, beat-frequency oscillator and audio amplification.

Coverage of the entire short-wave band from 1·5 to 30 MHz was provided and the medium-wave or long-wave band, or both, were often included. Wavechanging was accomplished either by rotary switches or the use of a turret. Switching was generally preferred because it required less maintenance than the turret, which was expensive to produce, heavy to manipulate and often gave rise to intermittent contact troubles. Tuning was achieved by multiple-gang capacitors in conjunction with trimming devices in each coil assembly and this provided good tracking in each frequency range. Coil design aimed at stability of inductance by reducing deformation due to temperature change and, for the same reason, a strong die-cast metal chassis was employed to reduce twisting and bending.

Each section was screened, particular attention being paid to the oscillator unit. Sensitivity was of the order of 1 to 2 μV for a signal-to-noise ratio of 10 dB. The noise factor of this type of receiver was often between 3·5 and 5 dB. Switchable selectivity generally provided total bandwidths at 6-dB points of 15, 11, 9 and 6 kHz for broadcast relay purposes and narrower bandwidths were generally available for monitoring and for telegraphic reception.

The h.t. supply to the oscillator valve was stabilised and a frequency change

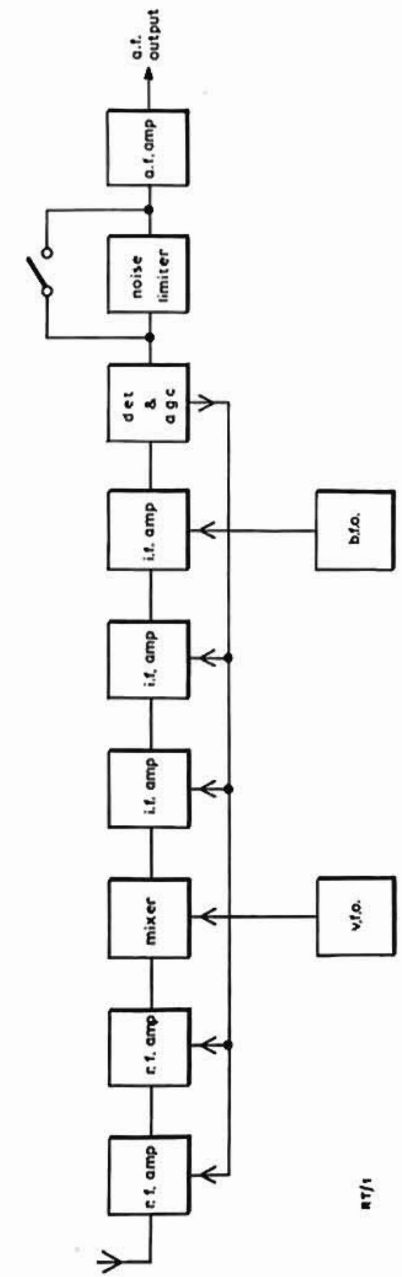


Fig. 4 Block diagram of single-frequency-change superheterodyne receiver

not exceeding 200 parts in 1 million after the receiver had been switched on for an hour could be realised. The oscillator frequency was normally higher than the signal frequency by the value of the intermediate frequency which, for British receivers, was usually 465 kHz and for American receivers 456 kHz. The 2- or 3-stage i.f. amplifier was transformer-coupled, and switched selectivity was achieved by varying the mutual inductance between the two tuned circuits of each transformer. Very narrow bandwidths were obtained by the use of a crystal filter and phasing control in an i.f. stage which enabled a very narrow band of modulation frequencies to be accepted. A double-diode valve which demodulated the signal and provided the automatic-gain-control voltage was followed by a two-stage audio amplifier with a separate output for feeding to line. The variable-mu valves chosen for the r.f. and i.f. stages provided reasonable signal-handling characteristics and usually were, to some degree or other, controlled by the automatic-gain-control voltage which, if delayed* and amplified could maintain the audio-frequency output within about 3 dB for 90-dB input change as shown in Fig. 5.

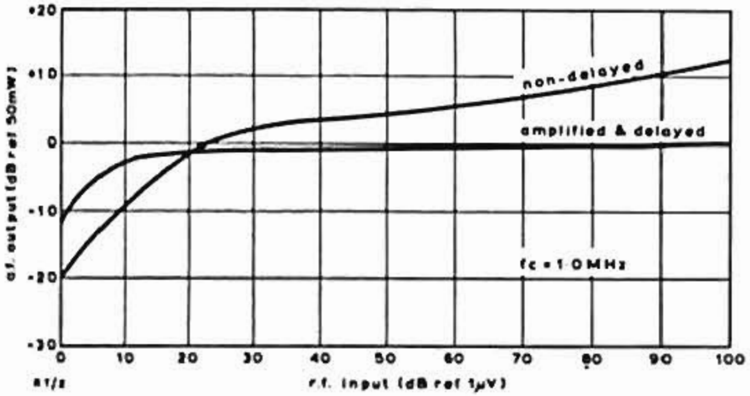


Fig. 5 Input-output characteristics for non-delayed and delayed automatic gain control

A b.f.o. (beat-frequency oscillator) enabled c.w. signals to be heterodyned, and diversity operation was achieved by paralleling the detector and automatic-gain-control voltages of two receivers supplied from different aerials.

Double Frequency Changing

The next development in communication receivers design was the adoption of double or triple frequency-changing, a high intermediate frequency being

*In delayed a.g.c. there is no automatic control of gain until the signal at the a.g.c. source exceeds a certain predetermined value. Thus there is no control on very weak signals and the sensitivity of the receiver is not limited as with undelayed a.g.c.

used first to provide good image rejection. This was followed by a lower-frequency second i.f. stage to achieve adequate selectivity against adjacent channel signals. These advantages were not achieved without cost: the additional mixer stages and associated oscillators tended to contribute noise and increased screening problems. Costs were increased and the design of the equipment was rendered more difficult by problems introduced by the use of two oscillators.

Improvements in Tuning Systems

When a receiver is used for monitoring, search or relaying purposes it is essential that the tuning scale should be marked in frequency and that the frequency calibration should not drift. The oscillator is the stage which controls these features and, unless it is crystal-controlled or operating at a low frequency, temperature and humidity changes may cause serious frequency drift from the original calibration.

There is normally a change in tuning immediately after a receiver has been switched on and this is more marked at the higher than at lower radio frequencies. In receiving stations, however, warm-up tuning drift is not a serious problem because receivers are normally left switched on for the whole of the period during which they are likely to be required which may amount to 24 hours per day.

Clearly the problem can be overcome by using a crystal-controlled oscillator with a drift of perhaps 1 in 10^6 or better, or by using some form of automatic tuning correction. The crystal-controlled oscillator has the disadvantage of operating at a fixed frequency and requires as many crystals as there are signals to be received. Unfortunately the requirements of a relaying service are such that a great many frequency channels are normally involved: diurnal and seasonal propagational changes and possibly interference prevent a given transmission operating continuously at a fixed frequency. Easy removal and insertion of crystals must be provided, and thermal control will not normally be acceptable because of the inevitable delay due to the warm-up period. Because of the different conditions in communication as distinct from broadcasting, multi-channel crystal-controlled receivers can be used for the former.

One way of obtaining variable tuning with good stability is to employ a highly-stable (e.g. crystal-controlled) oscillator and an i.f. amplifier with variable tuning. If the i.f. amplifier is designed to have a tuning range of 1 MHz, by switching the oscillator frequency in 1-MHz steps, the receiver frequency range can be extended as desired. Only a limited number of crystals (one for each of the fixed oscillator frequencies) is required.

A development of this system which reduced the number of crystals was achieved in about 1950 by Wadley who pioneered a triple superheterodyne

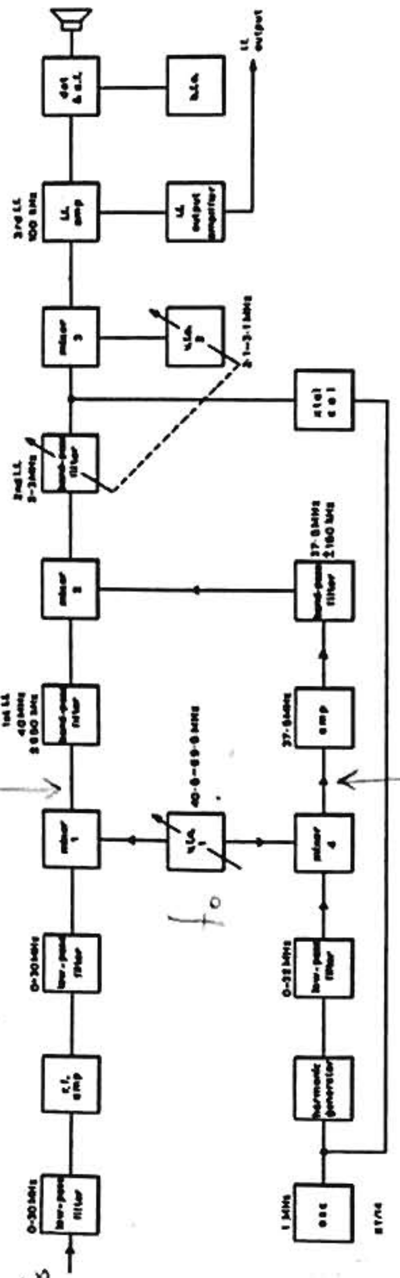


Fig. 6 Block diagram illustrating the principle of the Wadley receiver

system employing a form of partial crystal-control associated with the first oscillator. A tuning error not exceeding about 1 kHz at 15 MHz was achieved by this method which was incorporated by Racal in their RA17 communications receivers.

The Wadley principle is illustrated in the block diagram of Fig. 6. The r.f. amplifier stages use low-pass filters cutting off at 30 MHz to feed into the first mixer which uses an oscillator covering the range 40·5 to 69·5 MHz. The output from this first mixer is passed to a band-pass filter with a centre frequency of 40 MHz and a bandwidth of ± 650 kHz. The output of this band-pass filter feeds into the second mixer. A 1-MHz crystal oscillator output is connected to a harmonic generator feeding a low-pass filter with a cut-off at 32 MHz, and the first 32 harmonics of this crystal are coupled to a mixer together with the output from the first oscillator. The difference-frequency output from this is fed to another band-pass filter tuned to 37·5 MHz with a bandwidth of ± 150 kHz. This is then amplified and fed to the second mixer, the output from which goes to the third mixer through a band-pass filter covering the range 2 to 3 MHz.

The effect of this double frequency-change, using the first oscillator and a combination frequency of the first oscillator with the crystal oscillator, is to produce an output which is independent of the frequency drift or small frequency variations of the first oscillator. This may be seen as follows:–

Let f_s = incoming-signal frequency,
f_o = first-oscillator frequency,
f_1 = crystal-oscillator frequency
and n = number of harmonics of f_1.

The frequency of the output from the first mixer M1

$$= (f_o - f_s)$$

The frequency of the output from the harmonic mixer M4

$$= (f_o - nf_1)$$

Hence the frequency of the output from the second mixer M2

$$= (f_o - f_s) - (f_o - nf_1)$$
$$= nf_1 - f_s$$

which has no term in f_o and is therefore independent of any small variation of f_o.

In practice there are some restrictions on the value of f_o because it must be such that, when combined with nf_1, it will pass through the 37·5 MHz ± 150 kHz filter. In fact the tuning control of the first oscillator is calibrated in MHz from 0 to 29, and uncritical setting close to these markings will produce, from the output of the second mixer, i.f. outputs corresponding to receiver input frequencies within the range from X to (X+1) MHz where X is the frequency as indicated on the dial of the first oscillator. The band-pass filter following the second mixer is tunable over the range 2 to 3 MHz and this, in association with the second variable oscillator, which covers a range from 2·1 to 3·1 MHz, allows any frequency over the incoming signal frequency range of X to (X+1) to be selected. The dial of the second variable oscillator is marked in kHz so that a direct reading of the frequency in MHz and kHz is obtained, accurate to the degree of frequency drift in this oscillator ± the very small drift due to the crystal oscillator. The second i.f. filter is made tunable in order to improve channel selectivity and to give protection against cross-modulation and it is ganged to the tuning control of the second variable oscillator.

Diversity Operation

The variations in amplitude of a short-wave signal caused by ionospheric changes are appreciably reduced by applying a.g.c. to a receiver, but a system employing only one receiver is not normally adequate for relay purposes. A further improvement can be realised if diversity reception (see page 43) is employed. In space-diversity reception the outputs of two or more separate receivers fed from separate and spaced aerial systems are combined, and in its simplest form the a.g.c. systems and a.f. outputs of two receivers are paralleled.

The disadvantage of this simple system is that the receiver giving the weakest output can contribute a noise quota to the output, and improved operation is obtained by eliminating the receiver providing the weaker signal. An electronic switch operated from the a.g.c. voltage may be arranged to open a gate and provide an output from the receiver giving the larger a.g.c. voltage, i.e. greater carrier input. Fig. 7 illustrates the method which in effect

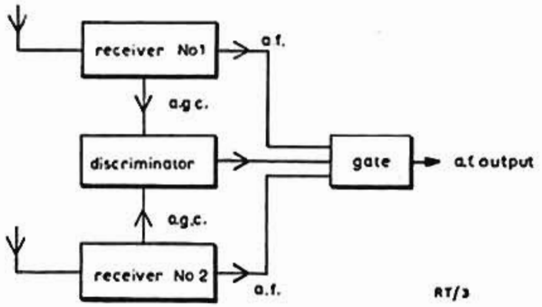


Fig. 7 Block diagram illustrating switched diversity operation

converts the system to a single aerial-receiver unit making use of the better of the two available input signals. Transient clicks due to the switch operation must be avoided and this can generally be achieved by allowing a brief period (about 0·3 s) of mixing both outputs. The r.f. and a.f. gains of the two receivers must be equalised and noticeable differences in bandwidth and a.f. response must be avoided.

S.S.B. and I.S.B. Reception

The need to conserve frequency spectrum usage in the short-wave broadcast band has resulted in the development of single-sideband (s.s.b.) transmission for point-to-point communication. The independent sideband system (i.s.b.) radiates two separately-modulated sidebands, one on either side of the carrier so that two different programmes can be relayed simultaneously using a single primary transmitter. However because of the small frequency separation between low-frequency components of the a.f. signals care in filter design is necessary to separate one programme from the other at the receiver. To make best use of the available r.f. power output from a transmitter the power should be concentrated in the sidebands: thus the carrier is either suppressed or reduced to a value lower than in d.s.b. transmission. For linear detection the carrier must be present at an adequate level at the detector of a receiver and this can be obtained either by selectively amplifying the partially-suppressed carrier in the received transmission or by use of a carrier-reinsertion oscillator of very high stability (usually crystal-controlled). Both methods result in an elaborate receiver design which is necessarily expensive.

The BBC relay stations have for some time been supplied with receivers equally suitable for receiving d.s.b. and s.s.b. signals. Interference on a d.s.b. transmission may be confined to one of the sidebands and can thus be eliminated by selecting the interference-free sideband. Until recently the BBC has supplied its relay stations entirely from normal broadcast transmissions but the large increase in the number of short-wave broadcasting stations is making it difficult to ensure that relay feeds are free from interference. Experiments have been carried out with s.s.b. programme links on a point-to-point basis, and this method of feeding BBC relay stations is likely to increase.

Although expensive equipment is necessary for high-quality s.s.b. reception it is possible to obtain intelligible results from an s.s.b. signal with a d.s.b. receiver by using the b.f.o. as a carrier reinsertion oscillator and this method is sometimes used by amateurs. For broadcast quality however the reinsertion oscillator frequency must be within a few Hz of the carrier frequency and this degree of stability must be maintained. Such high stability cannot be obtained from a normal d.s.b. receiver. S.S.B. receivers to give broadcast

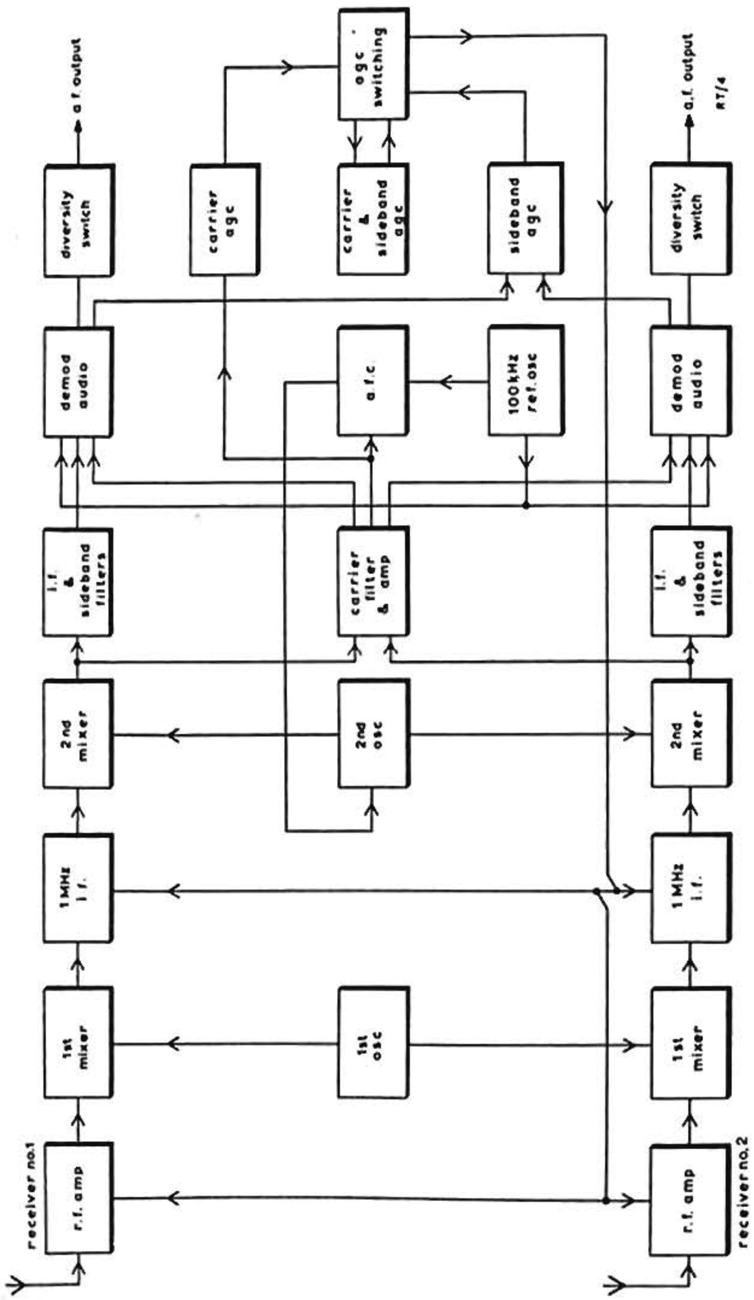


Fig. 8 Block diagram illustrating a typical single sideband diversity pair

quality require selective amplification of the carrier, a very rapid fall-off in the sideband filter near carrier frequency and a highly-stable local oscillator. These receivers also require a special type of detector because the envelope of an s.s.b. waveform is not a true copy of the modulating waveform. If an envelope detector were used a very large carrier amplitude would be necessary to reduce distortion to an acceptable level. For detection in s.s.b. receivers it is common practice to use a so-called product detector, e.g. a balanced modulator. By modulating the received signal with the output of a local oscillator operating at the carrier frequency we can obtain the sideband information directly.

Fig. 8 gives the block diagram of two s.s.b. receivers operating in diversity and using common local oscillators. The 100-kHz oscillator is the carrier-reinsertion oscillator: its output is compared with the i.f. corresponding to the carrier frequency of the received signal and any difference gives rise to an a.f.c. signal applied to the second oscillator. Automatic gain control is applied to the r.f. and first i.f. amplifier and can be derived from the carrier level or the sideband level. For broadcasting relaying, control from the carrier is preferred and a.g.c. derived from the sidebands is normally only used in communication equipment.

4

AERIALS AND EARTHS

General

The basic requirement of an aerial is to produce a wanted signal with as large an amplitude as possible compared with noise and interfering signals. Thus practical aerials are frequently highly directional and are sited at some distance from the receiver building although for some purposes, e.g. frequency measurement where high quality is not required from the receiver simpler aerials can be used.

Programmes for relay normally come from specific directions and the aerial system must be designed to give maximum pick-up from the required direction so that a broadcasting service is maintained over a very wide range of ionospheric conditions. Unlike point-to-point communications services, broadcasting normally provides no immediate contact between transmitter and relay engineer and a change in the original transmitting frequency to suit exceptional ionospheric conditions is not feasible unless it is planned in advance.

The whole of the short-wave band cannot be covered satisfactorily by one aerial and at least two, covering for example 6 to 12 MHz and 12 to 26 MHz, are usually provided to prevent serious reduction in receiving aerial efficiency at the extremes of the range. No aerial is ideal in terms of frequency coverage, gain and directivity but the rhombic is the most popular for point-to-point services. Other wide-band aerials used for short-wave reception are the inverted-V, log-periodic and the h.f. Beverage. Resonant aerials are used for special purposes. As a general rule the BBC employs rhombic aerials for reception, and when land area is limited the smaller rhombic (suitable for the 12 to 26 MHz range) is erected inside the larger one (covering 6 to 12 MHz).

The inverted-V and the bi-square are easily-erected aerials, which can be useful additions at relay bases for receiving signals from directions other than those for which aerials already exist.

Receiving Aerials

Rhombic

This aerial consists of four conductors (legs) arranged in the form of a rhombus in the horizontal plane as shown in Fig. 9. Each leg is usually about 4λ in length at the midband or design frequency and the aerial then gives about 14 dB gain compared with a simple dipole, maximum response being to signals in line with the major axis and in the direction of the feeder to the receiver. The angle required between the legs is dependent on leg length and

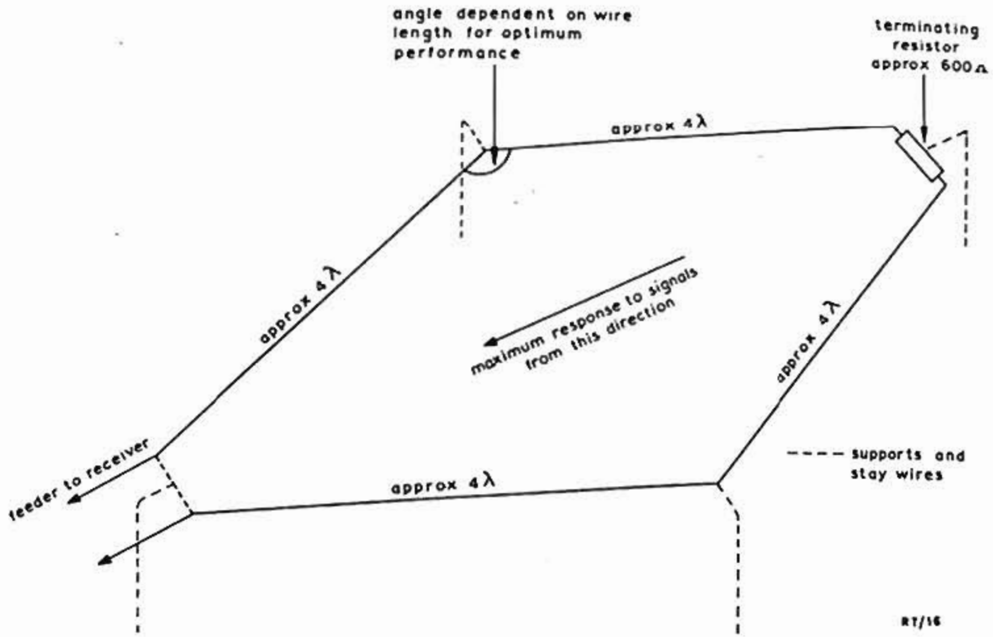


Fig. 9 Rhombic aerial

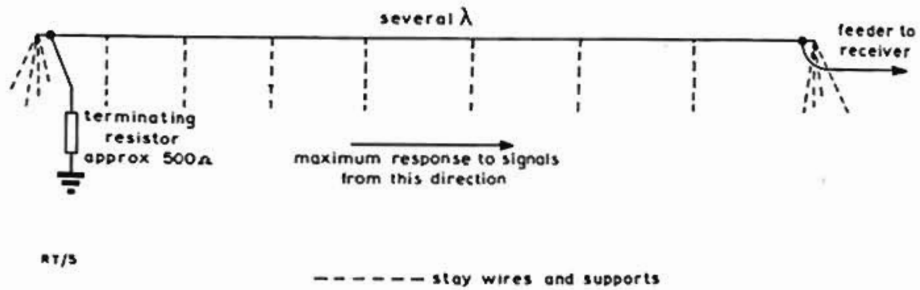


Fig. 10 Beverage aerial

provided the optimum value is used, the aerial can be satisfactorily used over a frequency range of 2:1.

The height of the aerial plane above the ground is important because this determines the vertical angle of the aerial.

H.F. Beverage

The Beverage aerial was originally conceived as a medium-wave aerial but can also be used on short waves. It is very simple, consisting of a heavy-gauge wire suspended above ground at a level of about 8 feet. Wooden poles surmounted by suitable insulators are placed at convenient intervals to minimise sag. The aerial is extended for several wavelengths at the lowest frequency it is desired to receive from the receiver end in the direction of the desired bearing. It is terminated at its far end in a matching resistance (about 500Ω) and under these conditions has a good front-to-back ratio, little pick-up from signals off-bearing and a forward gain up to 12 dB.

Bi-square

The bi-square aerial (Fig. 11) is, in effect, a dipole system, cross-connected at the base and folded back to form a square, each side of which is λ/2 long at the mid-band frequency. The two squares are separated by about λ/8. It is suspended from a triatic at its insulated far-ends. The sides are strained out

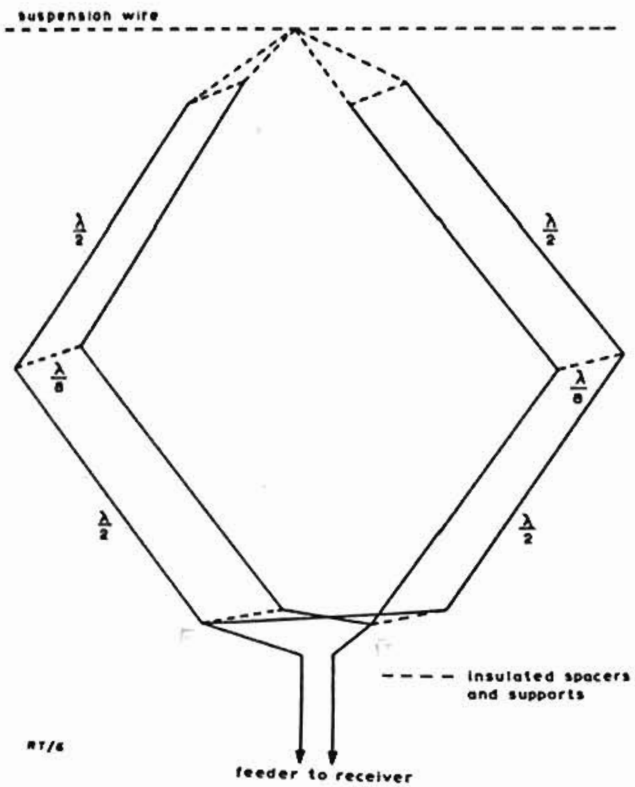


Fig. 11 Bi-square aerial

and anchored at right angles to the desired direction. A change of bearing can be made by rotating the aerial and re-anchoring at right angles to the new desired direction. This aerial has a bi-directional characteristic but where front-to-back ratio is more important than ease of rotation a reflector may be used. A further improvement in front-to-back ratio may be obtained by using a director in addition to a reflector.

Inverted-V

The inverted-V aerial (Fig. 12) gives maximum pick-up from signals arriving from the direction of its terminating resistance (about 400Ω). The direction of maximum pick-up can be reversed by exchanging the terminating resistance and receiver feeder transformer (i.e. by using two feeders, one from each end of the aerial) and reception from four directions can be achieved if two inverted-V aerials are supported from the same point. The inverted-V operates satisfactorily over a frequency range of 3:1, e.g. from 9 to 26 MHz and a typical forward gain at mid-band is 12 dB compared with a half-wave dipole.

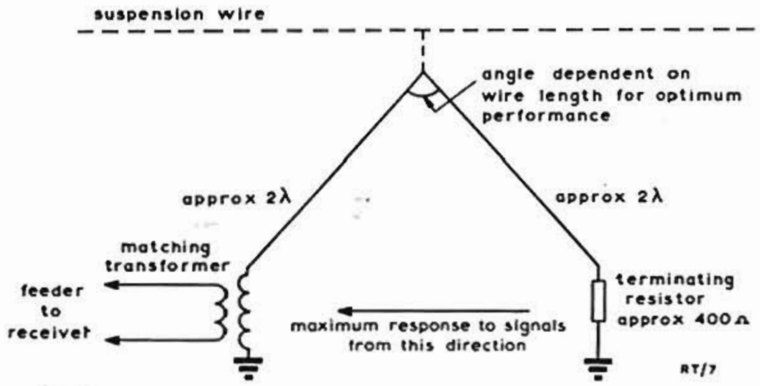
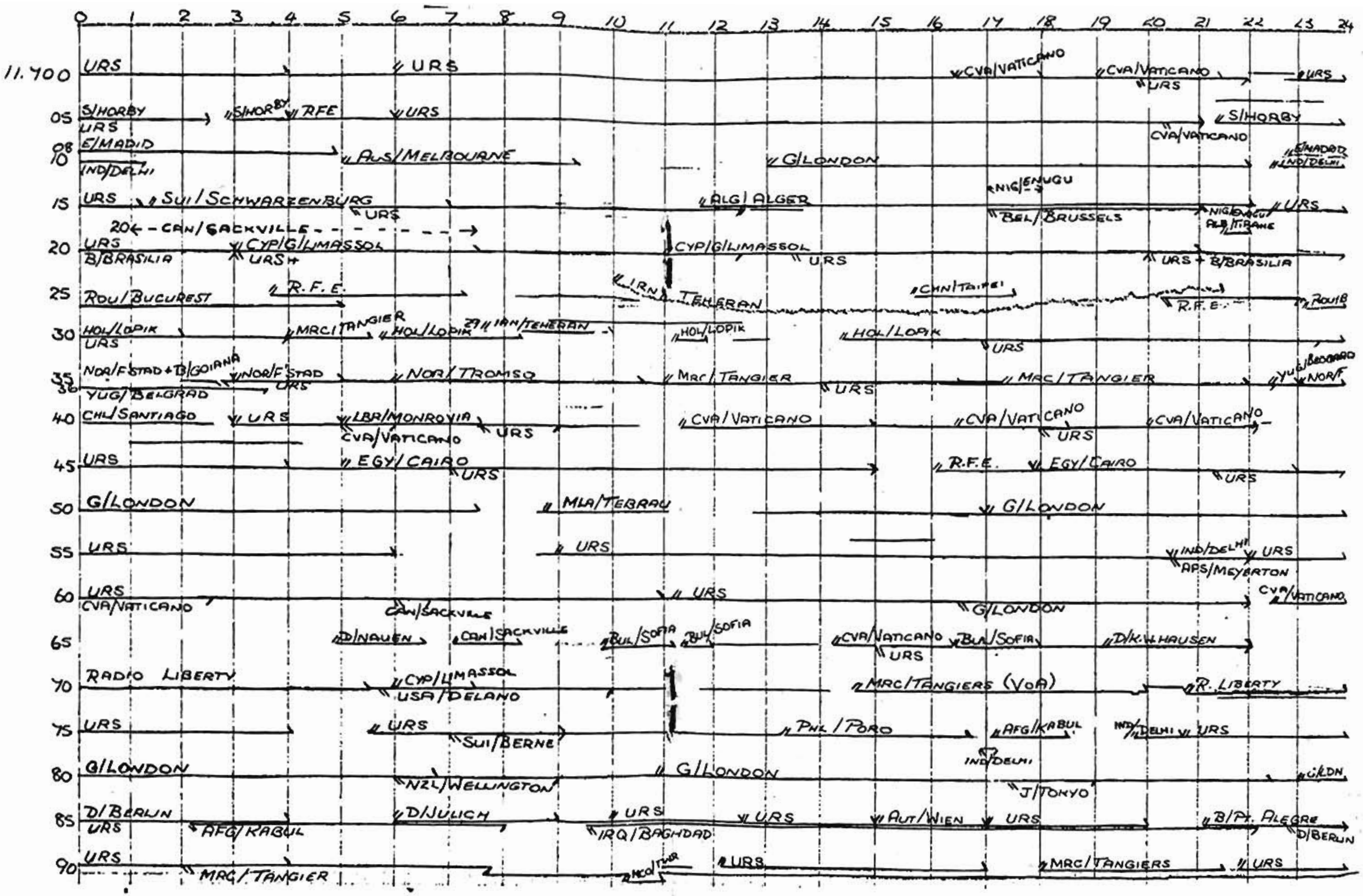


Fig. 12 Inverted-V aerial

Feeders and Terminating Connections

The terminating connections and feeder from aerial to receiver building are important and require some attention to details. Although the terminating resistors and matching transformers are shown on the diagrams directly connected to the aerial, this is often inconvenient in practice and it is possible to have, for example, the matching transformer near the ground and connected to the aerial by transmission line. If open-wire transmission lines are used they must be carefully balanced to avoid undesired signal pick up. In temperate zones aerials are rarely struck by lightning but precautions against this are necessary in areas where lightning is more likely, e.g. in equatorial regions.



24th June 1967.

Fig. 13 Reproduction of part of a band-scanning chart (See page 37)

Weather-proof screening boxes should be used for the connections and transformers.

Coaxial cable is normally used to connect the aerial to the receiver building because its losses are less than for other types of screened cable; semi-air-spaced cables are available with an attenuation of about 2 dB per 100 ft at 100 MHz falling to less than 1 dB per 100 ft at 10 MHz. Cables with a suitable protective coating should be laid on a level bed of sand in a trench. A protective covering of tiles should be placed over the cable and the trench filled in with earth. Buried cables should be at least 18 in below the surface of the ground to avoid accidental damage, e.g. by ploughing. The cable should preferably be ordered in one length because joints are likely to be a source of trouble in time. Where joints must be made in the cable the manufacturer's installation instructions should be carefully followed if troubles are to be avoided. It is not generally realised that ordinary PVC-sheathed coaxial cable may be buried in the ground for temporary use to give a life of a year or more—sufficient to determine whether an experimental aerial is satisfactory—after which a more durable cable can be installed.

Earthing

Most short-wave aerials are balanced and do not require an earth connection, nor does the aerial end of a coaxial feeder. For unbalanced systems, however, an r.f. earth must have an impedance low compared with that of the associated circuit. For this reason a number of buried plates or wires connected in parallel are often used. However at high radio frequencies earth connections for aerial systems do not normally require such elaborate arrangements unless the ground conductivity is very poor. For normal values of conductivity a single 4-ft copper earth spike with a very heavy-gauge lead is adequate.

At the receiver building a low-impedance earth connection is essential if only for safety reasons. Typically this is achieved by means of a series of copper plates say 3 ft by 4 ft buried at least 4 ft under the ground around the building and connected to a 1-inch copper tape around the inside of the building just above floor level. Connections between the tape and the plates should be by conductor comparable to the tape and all joins below ground level should be welded or brazed to prevent electrolytic corrosion. For instance the d.c. resistance between one plate and all the others connected together should ideally be less than 1 ohm.

5

ANCILLARY EQUIPMENT

Aerial Switching

It is frequently necessary at a receiving station to connect a number of receivers to one aerial and also to switch receivers rapidly from one aerial to another. Paralleling receivers on to one aerial, if correct matching is to be preserved, necessarily results in loss of signal and for this reason aerial distribution amplifiers are required.

For convenience these amplifiers must be effectively aperiodic and typically they have zero insertion loss between the input and each of the multiple outputs and can cope with a total signal input up to 1V without serious intermodulation effects. An advantage of designing for zero insertion loss is that in an emergency receivers can be connected directly to an aerial without adjustment of gain.

The outputs of the distribution amplifiers can be terminated on a patching panel but if the system is to cater for more than three or four aerials and perhaps twenty or more receivers, the panel will become congested by flexible connections and trouble may arise from poor contacts or because the operator accidently removes a wanted cord. If direct switching is used instead of patch cords and is centred at or near the distribution amplifier equipment, an array of control knobs will result and the same operational faults may occur as with the patch-panel. Conversely if the switches are located near each receiver of a large multi-aerial complex, the resulting number of cables can be embarrassing and may prove uneconomic to install.

A more elegant solution is to use r.f. relays at the distribution point with the control extended to the individual receiver and this arrangement is normally preferred in any large installation because only one coaxial cable is required to each receiver and the relays can be operated via a multi-core cable from a small row of switches located near each receiver thus giving the operator complete access to the aerial system.

Audio-frequency Control

In relay work it is normal for two or more receivers or diversity systems to be receiving the same programme and facilities are required for listening to and fading from one to the other so that the best quality signal available is sent to line. Thus the outputs from the receivers should be at a standard level to permit cross fading without changes in volume. Low- and high-pass filters giving cut-off frequencies of 120 Hz, 3·5 and 4·5 kHz should be available together with a frequency-response weighting network providing variations of lift and cut of treble and bass up to 12 dB. The output is passed via amplifiers to line and transmitter or distribution centre and a side-chain provides volume-measuring facilities, e.g. a peak-programme-meter and monitoring, i.e. listening facilities.

Another type of filter which is useful is a notch filter of variable frequency designed to eliminate heterodyne interference. It is difficult to design a passive network of variable frequency with a satisfactory performance and active filters are more usual. A typical commercial design has a coverage of the whole a.f. range with rejection of up to 50 dB and with zero insertion loss except, of course, at the rejection frequency. The circuit usually comprises a high-gain amplifier with the frequency-selective network as a coupling element and overall feedback to sharpen the notch. Notch filters may be cascaded if more than one heterodyne note is to be rejected.

Ionospheric variations and interference may require quick attention by the relay operator and the design of the audio control desk should be such as to facilitate any switching that may be required.

Monitoring Equipment

Frequency Measurement

For frequency measurement and for most other monitoring work the receiver need not have a wide bandwidth but cross modulation must be low because very weak signals may need to be monitored. It is essential to provide ready access through the aerial-amplifier distribution to the maximum number of arrays giving world coverage and also to a simple vertical aerial of the type likely to be used by an ordinary listener.

Measurement of carrier frequency is occasionally required to check transmitter-drive stability or to provide accurate information when registering a complaint of interference. The method of determining the frequency of an incoming carrier is to compare it against that of a standard frequency obtained from an accurate source. The equipment required for this is usually a variable-frequency source of high accuracy such as frequency synthesiser which is locked to a stable standard-frequency oscillator and may be adjusted to synchronisation with the unknown frequency. The general principles of one type of frequency synthesiser are dealt with in BBC Technical Instruction T1.

Field-Strength Measurement

Field-strength measurement is valuable for assessing the worth of a received signal. A comparison method is employed, and one form of the apparatus comprises a tunable receiver with a meter to measure the input carrier voltage, a loop aerial and a signal generator with an attenuator against whose output the received signal is compared. In this method the field strength is calculated from the measured voltage, the attenuator setting and the

dimensions of the loop. It is commonly expressed in dB relative to 1μV/m. A calibrated vertical aerial may be used in place of the loop aerial.

The equipment must be located at a site clear of other aerials and metal structures which would either screen or enhance the wanted signal. As far as possible the loop aerial should be mounted well above building wiring and other conductors. In h.f. work the signal is normally fading and an assessment of the mean value must be quoted: a chart recorder is commonly connected to the receiver to determine the fading pattern.

Band-Scanning Equipment

Planned usage of the short-wave broadcasting bands requires continuous watch on the extent to which the channels are exploited. Automatic apparatus is available which periodically records the presence of discrete frequencies in a chosen band on a paper chart. For the broadcast bands experience shows that a chart width embracing 100 kHz provides the best resolution with a spacing of about ½-in between signals at 5-kHz separation but if required the frequency sweep can be restricted to a few kHz to show modulation and other details of signals.

The scanner is connected by a cardan shaft through gearing to the receiver tuning control, the gears being adjusted to cover a sweep of the desired 100 kHz. Simultaneously, the stylus travels horizontally across the chart, the process taking 40 seconds, during which any carrier through which the receiver is tuned, is marked by operation of the stylus. In the next 20 seconds the receiver and stylus return to the zero position, the latter being blanked off so that no marking occurs. During repeated excursions, the chart is continuously moved down vertically, so that the following series of marks builds up to a vertical line in the form of very short dashes until either the signal fades out or goes off the air as indicated in the reproduction of part of a chart given in Fig. 13 (pages 32 and 33).

A clear record is obtained by restricting the receiver bandwidth by a crystal filter (−3 dB at 50 Hz) connected to the receiver i.f. output which after rectification operates the stylus on each transmission. The time calibration of the chart is obtained from a clock-operated relay which gives a continuous line at hourly intervals.*

Measurement of Back-Scatter

Measurement of back-scatter of transmitted energy from a first ground reflection point is a satisfactory means of determining propagation conditions

*At Tatsfield the 9-in wide chart is run for 24 hours and is then approximately 13-in long. The hour marks are timed in GMT, the frequency scale is inscribed together with the date and station name at the bottom and all identifications are marked in the body of the chart adjacent to the carrier marking. Finally, it is photo-copied and distributed.

over a single-hop transmission path. The BBC uses a pulsed frequency shift method. To prevent interference with programme the pulsing is carried out during the unmodulated period or the period when interval signals are being transmitted immediately before the commencement of the normal programme. The phase change introduces a carrier frequency change in multiples of 2·5 kHz for 1 to 2 milliseconds at a repetition rate of 1 to 10 per second.

With this method the receiving site must be sufficiently distant from the transmitter to avoid over-loading by the ground-wave signal and the receiver is operated in a highly-selective mode to accept only the frequency-shifted carrier. A c.r.t. display of the forward and return pulses gives an indication of the ionospheric conditions at the point of first reflection. The height of the layer or layers is determined by the time spacing between the ground-wave signal and the returned pulse. An example of a back-scatter observation is shown in Fig. 14 which indicates return pulses from distances of approximately 3,000 and 3,600 km.

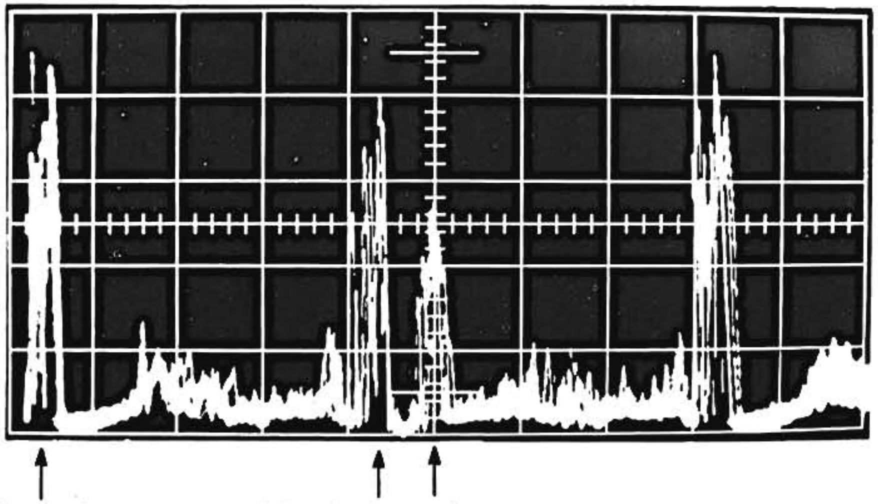


Fig. 14 An example of back-scatter pulses obtained on a 25-MHz signal radiated from Daventry and received at Tatsfield at 1545 GMT. Two return pulses are displayed representing distances of 3000 and 3600 km.

6

OPERATIONAL TECHNIQUES

The operational techniques needed for replaying or monitoring are not difficult to acquire though attainment of a high degree of skill and success calls for patience, a keen interest in short-wave listening, a knowledge of propagation and a good ear for recognising foreign languages. Some knowledge of the Morse Code is an advantage in verifying certain types of interference and notes should be made of any unusual features which may be observed.

Layout of Equipment

The layout of relaying and monitoring apparatus is extremely important; controls in constant use should be readily accessible without stretching and be sensibly grouped. The curved or angled crescent-shaped console is to be preferred with the desk top at the right height for the sitting operator and sufficient in area to allow log books and other documents to be readily at hand and easy to write up. Lighting must be arranged so that no appreciable glare is reflected from panels, glass-covered tuning dials, plated escutcheons or other parts. Lighting pendants sited immediately above and behind the operator's head tend to produce heat leading to headache and fatigue. Natural lighting should come from one side of the operator who should be protected from direct sunshine.

Receiving equipment with the appropriate switching for aerials and diversity is normally mounted on bays arranged in an L or U formation around the control desk which should be situated centrally leaving sufficient room for easy access to all receivers from the desk. Low- or medium-frequency adaptors should be mounted as required on the bays. Normally two pairs of receivers operating in diversity with a second and third pair as spares will be required for each relay frequency. The schedule will probably follow a well-defined pattern with two or more programmes continuing for long periods, and certain receivers, or bays of receivers, should be allocated to a particular network so that at a change of shift the incoming operators know immediately where the receivers for each programme are located.

The siting of the wide-band amplifier and distribution system for the aerial inputs is largely dictated by the entry point of the underground feeders and the method of switching adopted; if U-links are used the apparatus must be near the receivers but if relays are preferred the whole of the equipment may be located anywhere convenient. Similarly the audio amplifiers, mains units, monitoring, switching and line test equipment may be placed in any convenient position within easy reach of the desk. The control desk may need to be sufficiently large to accommodate two sitting positions placed fairly close together but all the variable controls should be operable by one man without leaving his seat. Thus if up to six programmes are being relayed simultaneously one engineer might take complete responsibility for the relays with his assistant answering telephone calls, logging and monitoring.

An alternative and more satisfactory method of dealing with many simultaneous relays is to allocate one engineer to what might be called the radio-frequency work (i.e. aerial selection, receiver tuning, diversity switching and general alignment) and the second engineer to presentation (i.e. audio switching and control to line.) This allows maximum attention to be given to the main aspects of relaying, i.e. the presentation of the best signal through optimum apparatus performance and the immediate change to alternative sources when faults or programming demand. A technical assistant would complete the team to take telephone enquiries, maintain logs and share the monitoring duties.

Input switching or a patch-cord system needing attention from time to time should be placed to one side of the control desk but the main body of the desk should include means of selecting programme sources, switching of filters, level control, presentation units for adjusting audio frequency response and an easily-seen programme meter for each chain. The output switching unit must allow any programme chain to be connected to any line, or number of lines, but be latched to prevent the switching of two programmes to a single line. Some means of indicating which receiver is in use (e.g. a lamp) is desirable and every facility should be incorporated to make the whole system as fault-free as possible. The front of the desk should preferably face the receivers and give the shortest walking distance to them.

Maximum window space should be available on the wall having minimal apparatus and any opening sashes should be arranged to provide good ventilation in hot weather. High top-lights or a lantern roof may be the only solution and precautions must be taken to prevent draughts or direct sunshine affecting the equipment. Fairly high-level fluorescent lighting provides the best shadow-free illumination and the inclusion of two or three metal-filament lamp fittings will overcome the objection to flicker often noted after working for long periods–particularly at night–under fluorescent lighting.

Choice of Frequency to be used

A given programme is often transmitted on a number of channels some of which may be off-beam to the relay site but nevertheless may be usable in certain circumstances so that a choice of frequency has to be exercised. The decision must be left to the duty engineer although log books will offer guidance when the commitment is a daily one. If, for example, the programme is radiated on three or four channels it is probable that these will be

distributed over as many bands. The highest frequency, if propagating well, will give the best noise-free signal but it will be more liable to propagational changes. A stand-by diversity-pair of receivers should be tuned to the next lower channel with a third pair on the next band.

An engineer with a good knowledge of ionospheric conditions will know approximately the time of day when a particular broadcast band in use from a given area will tend to fail and he will have stand-by receivers tuned to more suitable scheduled channels. It is not unusual to find a period when, within a time interval of thirty to sixty minutes, it may be necessary to change over three different bands in sequence and adequate preparations must be made beforehand. When it is known that a given programme is transmitted from more than one site stand-by receivers should be tuned to a transmission from the alternative site; this means that the relay can continue even if the mains power supply or a Post Office line to one site fails.

Interference may make a channel quite unusable for relaying when using a double-sideband receiver but if only one sideband is affected s.s.b. operation can permit the selection of the interference-free sideband. Heterodynes may be eliminated by the use of notch or heterodyne filters though at some loss of quality.

Choice of Aerial

An aerial beamed in the direction of the transmitter will of course be a first choice with a second on the same or a nearby bearing as an alternative. The same aerial may be used via the wide-band distribution system to feed standby receivers but the equipment is usually so designed that the feed is taken through different amplifiers and power units to guard against mains unit or amplifier failure. It must be remembered that aerials have side-lobes, some providing a fair degree of gain, and if strong signals are present in the direction of the side-lobes interference can arise. Another array, not exactly on beam, may be better if a side-lobe null is in the direction of the unwanted signal. Much depends on the strength of the signal to be relayed for some decrease in aerial gain can be tolerated if the signal is strong. When difficulties of this nature occur it is good practice to assess the merits of almost any array by listening because it sometimes happens that a particular aerial–though theoretically less suitable–is in practice better.

Any change in the behaviour of an aerial should be investigated immediately and not dismissed as a difference in propagation because terminations are liable to damage. If, for example, the forward-end terminating resistor of a rhombic aerial is broken it may not seriously affect reception from a forward direction but would almost certainly appreciably reduce the front-to-back ratio and increase the impedance variation over the band. After any period of high wind or electrical storm, aerial systems should always be tested for faults of this kind.

The gain of the aerial distribution system (which should be about unity) should be checked daily prior to the commencement of the relaying schedule. A convenient method is to connect a standard signal generator or the output from a local oscillator tuned to a suitable frequency at any acceptable output level, direct to the receiver with automatic gain control switched off and the r.f. control adjusted to give a mid-scale reading on the S-meter. The outputs of all available amplifiers are then connected to the receiver and the signal generator is connected to each amplifier input in turn. Any appreciable fall in the S-meter reading indicates a fault condition.

Tuning Methods

The tuning of a receiver is not such a simple task as would at first appear and skill in tuning can minimise background noise, adjacent channel break-through and audio distortion. Harmonic distortion tends to increase rapidly when a receiver is off-tuned and is affected by the bandwidth control. A given degree of off-tuning which may produce little increase in distortion when the bandwidth is wide may cause serious distortion when the receiver is switched to a narrower band.

Most communication receivers use a small capacitor (labelled aerial trimmer) across the input coil for individually tuning the first resonant circuit of the receiver. Its effect increases as the received frequency increases and on the high-frequency bands few if any signals may be audible until the trimmer is adjusted approximately to its optimum value. With a.g.c. applied and the time constant switch set to *fast*, the aerial trimmer should be carefully adjusted to give maximum output of noise; the required signal is then tuned in after which tuning and aerial trimmer controls are sequentially adjusted for maximum signal output. Rocking the controls through the position giving maximum S-meter reading will finally establish the correct position. If optimum aural output is obtained with the S-meter reading well away from what appears to be the correct point, it is probable that the metering circuits or even the entire receiver needs realignment.

Precise tuning is only possible with a.g.c. switched off and r.f. gain adjusted to a convenient level. Under these conditions, the tuning meter clearly indicates the centre point of a double-humped response (characteristic of the wideband selectivity position) or the very sharp tuning point which occurs when bandwidth is narrow. If a.g.c. is not switched off, the tuning appears to be very much broader and precise tuning is more difficult.

When the selectivity switch is set to a narrow bandwidth, readjustment of the aerial trimmer as well as the main tuning should be tried. Trimmer and main tuning adjustment may be very critical in attempts to pick up a weak signal with a strong signal adjacent or near to the weak channel because the selectivity of the r.f. stages offers little discrimination in this situation.

Use of Specialised Controls

Some of the controls of a communications receiver may be independent of each other, e.g. crystal calibrator, a.f. gain, beat-frequency oscillator and automatic gain control: others are interdependent. The effect of a change of selectivity on aerial trimmer and main tuning controls has already been mentioned. The introduction of a crystal filter with very narrow bandwidth can cause serious difficulties, and most careful adjustment of both phasing control and tuning is required to achieve satisfactory performance. Control of r.f. and i.f. gain may be separately adjustable and on weak signals best signal-to-noise ratio is obtained by adjustment of i.f. gain with r.f. gain maximum. Strong signals will require control of both to prevent overload and intermodulation.

Modern receivers using wide-band input technique are almost always fitted with front-end or aerial attenuation in automatic or manual form and a combined r.f.-i.f. gain control is a modern tendency. An aerial attenuator is a considerable advantage for the reception of signals which are too large to be accommodated on the curved characteristics of the r.f. valves or transistors. When intermodulation is present, sufficient aerial attenuation should be inserted to reduce it to negligible proportions. Excessive attenuation leads to a reduction in the wanted signal and therefore less satisfactory performance on fading.

Diversity Reception

Short-wave signals from the same transmitter received over two or more different propagation paths in general differ in phase and intensity and mutually interfere to cause fading. If the signals from these paths are combined in a suitable manner the overall fading may be appreciably reduced. These paths are typically those terminating at two receiving aerials. Such a system of diversity reception is known as *space diversity*. An improvement in fading characteristic can also be achieved by combining signals having different frequencies or different polarisation, and these systems are known as *frequency* and *polarisation diversity*. The most commonly used system is space diversity with aerials spaced several wavelengths apart so that a fair-sized land area is required. Maximum diversity (minimum fading after signals are combined) between two aerials is achieved with a spacing of between 4 and 10 wavelengths.

Frequency diversity requires two or more co-sited transmitters radiating the same programme on different frequencies either in the same broadcast band or in adjacent bands where propagation conditions are expected to be similar. Co-siting is necessary to preserve identical time relationships between the modulation of each transmitter.

Polarisation diversity depends upon the differential fading of waves arriving horizontally- and vertically-polarised. Though radio waves may start off horizontally-polarised from the transmitting aerial, the polarisation is changed during passage through the ionosphere and the wave arrives at the receiving aerial eliptically- or circularly-polarised with vertical as well as horizontal components. The fading pattern of the two components is usually different and diversity combining reduces the fading. Other methods are available, notably the Musa system used by the British Post Office employing steerable aerials; the system is suitable only for revenue-earning communications systems because it is complex and expensive to install.

The reduction in fading due to operating two receivers in diversity is shown in Figs. 15(a) and 15(b). Fig. 15(a) shows the fading pattern for a single receiver. It would be possible to combine three receivers in diversity, but the improvement in the fading characteristic shown in Fig. 15(c), is not sufficient to warrant the additional complication and cost. Receivers operating in diversity must be of the same type and have similar operating characteristics. The simplest method of combining two receivers in diversity is to parallel the automatic-gain-control voltages and the detector outputs. The alignment of the two receivers calls for careful tuning of the individual units to the desired channel. Only a.f. gain control is used, the r.f. and i.f. gains being left at maximum. Any tone controls should be out of circuit or set for maximum

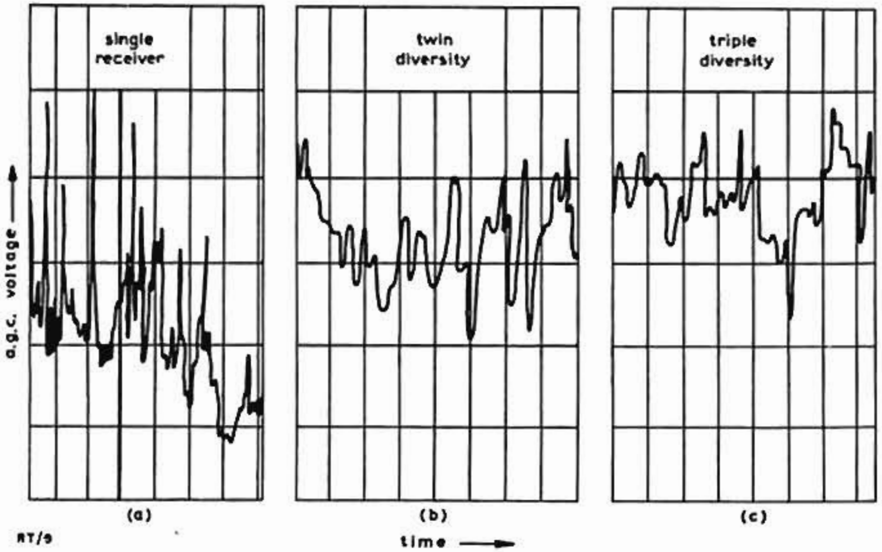


Fig. 15 A.g.c voltage in a single receiver, a twin and a triple diversity system indicating the stabilising effect on fading

flatness of response. An examination of the S-meters indicates whether the fading patterns are dissimilar and, if not, a re-selection of aerials may be necessary. The a.g.c. lines are connected together via a centre-zero microammeter which indicates to the operator the receiver making the greater contribution. When the outputs of the two receivers are combined at the audio-frequency stages it is desirable that the audio-frequency gains of each should be equal. It is, of course, also desirable that the r.f. and i.f. gains of the two receivers should be approximately equal though if they are fed from two aerials of different gains it will probably be necessary to increase the gain of the receiver fed from the lower-gain aerial. When signals are strong and fading is shallow and infrequent it may be worthwhile to arrange the diversity so that one receiver only is contributing the signal for most of the time, the second unit being mainly used to compensate at times of deeper fading.

In some s.s.b./i.s.b. diversity systems automatic gain control is applied to the audio-frequency as well as r.f. stages.

Checking Spurious Emissions

I.T.U. Radio Regulations indicate the permitted limits of radiation for harmonics and other spurious signals but, with the advent of high-power transmissions, even the permitted limits may cause interference as well as representing a waste of power. It is, therefore, the responsibility of a monitoring station to look for, identify, measure and report to the transmitting authority any harmonic or spurious radiation which routine observation would indicate as abnormal, whether or not the actual limit is exceeded. As a rule exceptional care is taken at transmitter sites to reduce harmonic radiation to negligible proportions, otherwise serious interference to television and Civil and Military aircraft communications may be caused within an appreciable radius from the transmitting site. Nevertheless observations should be made from time to time on all transmissions to check that the intensity of harmonics is normal and any weak unidentified signal just above noise level should be suspected as a possible harmonic. The first requisite in such investigations is to prove that the receiving equipment and aerial is not contributing, and this involves searching for the supposed harmonic on other types of receiver and aerial.

Parasitic frequencies may be produced in the transmitter circuits continuously or only when modulation is applied. They can be produced by undesirable coupling between the drive circuits of different transmitters when the drives are generated from a central point. Generally the parasitics are twinned and symmetrically disposed in relation to the fundamental carrier frequency and may even fall within the normal sideband spectrum. Once the twin parasitic frequencies have been determined, the fundamental carrier frequency is half the sum of these two frequencies. Both frequencies may not always be detectable; one of them may be obscured by another transmission in the same channel or it may be suppressed by aerial or receiver selectivity. A modulation-triggered parasite tends to appear as an intermittent gritty noise sometimes spread over a wide frequency range and devoid of carrier. If the transmitter cannot immediately be taken out of service, a temporary palliative is to reduce modulation level at the transmitter.

Intermodulation normally occurs due to interaction between transmitters on the same site. It may be caused by power fed from one transmitter into another, the non-linearity in the output stages generating the intermodulation frequency or it may be due to power fed from one feeder or aerial into another, which has a poor-conductivity connection in some part of its circuit. Re-routing or the use of other feeder lines or aerial may eliminate the trouble. Sometimes it is operationally necessary to fire one aerial array through another and this may lead to intermodulation. When this occurs the best solution is to schedule one of the transmissions from another site.

Yet another form of parasitic may appear as frequency modulation sidebands disposed symmetrically on either side of the fundamental. The effect may be missed except by very experienced engineers because the frequency variation will be audible on an a.m. receiver only when the tuning is adjusted so that the parasitic falls on the skirts of the i.f. selectivity characteristics of the receiver. This somewhat rare fault has always been traced to interaction between the field of a high-power short-wave transmitter and a drive circuit to another transmitter causing phase modulation in some part of the drive circuit. This, in turn, appears as a frequency variation of the final carrier at the modulation rate of a high-power transmitter field.

There is no evidence to show that intermodulation occurs on short-waves during propagation through the ionosphere though ionospheric cross-modulation is well known as a phenomenon affecting long and medium-wave broadcasts.

Use of S.S.B. and I.S.B. Facilities

A d.s.b. signal may have serious heterodyne and sideband splash interference on one sideband from the signal on an adjacent channel. Such interference can be rejected and a satisfactory audio signal obtained from a receiver if s.s.b. operation is employed; hence a signal unusable for a relay purpose with d.s.b. transmission may be satisfactory if the correct sideband is offered to an s.s.b. receiver. An i.s.b. unit can deal with two programmes simultaneously if these are carried one in the upper and one in the lower sideband.

Signal fading can be reduced by employing automatic gain control at the receiver and, when selective fading occurs, i.s.b. or s.s.b. can have advantages over normal d.s.b. reception. This is particularly true when there is

appreciable fading of the carrier frequency. The reconstitution of the carrier in the s.s.b. or i.s.b. systems appreciably reduces variations of the carrier due to fading and less distortion results. Distortion due to selective fading of frequencies in the same sideband is not reduced by s.s.b. operation.

The automatic gain control in the s.s.b. or i.s.b. receiver may be obtained from the low level carrier or from the sidebands. The larger of these two voltages is used for automatic gain control. The time constants of the a.g.c. circuits are so arranged that automatic gain control increases comparatively quickly but decreases slowly. If automatic gain control decreases quickly the gain of the receiver might rise between syllables of speech causing noise level to be adversely affected.

Automatic frequency control of the receiver oscillator is generally used in s.s.b./i.s.b. systems to ensure correctness of tuning within 1 or 2 Hz of the received carrier. The a.f.c. tracks slow deviations of frequency faithfully and sudden excursions up to about ±50 Hz are followed by searching; variations greater than this require manual assistance. The a.f.c. unit can be switched out if a powerful adjacent channel threatens to capture the tuning during fading of the wanted signal. The block diagram of Fig. 8 gives an example of a.f.c.; the amplified final i.f. carrier is compared in frequency against a 100-kHz crystal-controlled local oscillator and any error is used to operate the a.f.c. system controlling the second oscillator and bring the receiver tuning into correct alignment.

7

IDENTIFICATION OF SIGNALS

The identification of a station is often just the first stage of a procedure that requires knowledge of its location, its controlling organisation and the probable target area. Announcements, language, interval signals, local clock chimes, time of operation, type of programme, directional bearing of the signal, field strength and frequency stability all require careful observation and analysis.

Announcements and Languages

The large number of languages used in short-wave broadcasting would be beyond the understanding of one person but consistent listening to world-wide broadcasts from known countries, many radiating similar versions of the current world news, affords an excellent opportunity to acquire the ability to recognise through sound and intonation the language being used. The expression and intonation of an unrecognised language should be compared with other broadcasts of languages which sound similar and consideration should also be given to the possibility that a dialect is being used. When uncertainty exists a recording should be made and played back to someone who might be expected to recognise the language. Knowledge of the normal occupancy of the band and of the programming of many of the broadcasting organisations using it is a valuable aid in language recognition.

Interval Signals

Interval signals or particular tunes are often used by broadcasting authorities to herald the start of the transmission or programme; typical examples being the use of Bow Bells, the Greenwich Time Signal and Big Ben prior to BBC news bulletins, the Canadian National Anthem by Sackville, the Kremlin Bells by Moscow or the Kookaburra by Melbourne. Eastern European stations frequently use the first few bars of a well-known melody generally written by an eminent local composer and details of these are given in World Radio and T.V. Handbook (O. Lund-Johansen, Denmark). It is important for a relay and monitoring engineer to commit these to memory as they can be a great help in identification. A tape recording comprising many of the interval signals heard in Western Europe and some of the melodies used to preface certain regular programmes has been made and is available at all BBC relay and monitoring stations.

Timing

The timing of broadcasts can often be a useful guide; thus the commencement and closure of a transmission within the normal working day of the country probably indicates that it is intended for home consumption. If, however, the programme consists of short duration items accompanied by changes of field strength indicating that the aerial beam direction is being changed, it is almost certainly an external service. Local clock chimes will narrow the choice by fixing a time zone and they often precede an announcement or news bulletin. Operators should familiarise themselves with the time differences existing between major countries, not forgetting that Summer Time operates in some and not in others. A time check and an approximate indication of bearing of the transmission, obtained by comparing the field strength received on a number of directional aerials, may be sufficient to give a clue to the country of origin, confirmation being obtained from the language intonation.

The commencement of all broadcasts tends to follow a fixed pattern, with radiation of tone for alignment purposes followed by an interval signal, possibly a time check and announcement and finally the programme. The frequency of the alignment tone can vary from organisation to organisation; thus the BBC uses 1 kHz, Western Germany 900 Hz, whilst others use 440 Hz (the musical pitch for A above Middle C). The close-down of a transmission is equally important because of the possibility of clock-chimes and announcements being radiated.

Programme Content

The type of programme may yield evidence of the nationality of the organisation operating the transmission as well as the intended zone of reception. Home Service programmes can generally be recognised by the parochial nature of the news, the World coverage being small. Programmes for the country's nationals abroad will be recognised as being a blend of domestic and world news, with commentaries in the national language. A typical example is the BBC World Service. Frequent news bulletins in many languages almost exclusively concerned with world events are nearly always part of an external broadcasting system.

The U.S.S.R. broadcasts a number of different services designed for home consumption. These programmes are heard on many frequencies with normal conditions of modulation but the same material is sometimes used in an over-modulated and heavily-distorted form as a counter-broadcast to overlay other transmissions directed to Russia from a foreign country. The over-modulation may quite frequently be accompanied by parasitic radiation. Another form of counter-broadcast which can be difficult to identify is a popular phrase of music continuously repeated through the period of the programme it is intended to jam.

Simultaneous Broadcasts

When a programme whose source is unknown is sufficiently intelligible for its pattern to be followed and a guess made at the language, a search for other identical programmes on different frequencies may help in identification. A second receiver should be tuned to known stations operating services of the same language and if one of these is carrying an identical programme it may be assumed that both originate from the same source though not necessarily from co-sited transmitters. It may be a relay in which case the quality of the unknown programme may not be as good as that of the known. Technical aids will be needed to determine its location though listening at times of programme change for the insertion of local or regional announcements can help in reaching a conclusion. Location can be difficult if the known and unknown programme sites are in line with the monitoring station because then direction finding does not help. Paris and Brazzaville are examples of this ambiguity from Tatsfield. The two transmitters radiate simultaneously in time and programme, and both can produce comparable signals at Tatsfield.

If a simultaneous broadcast cannot be found but the programme pattern can be established, a search of programme schedules issued by the various countries may show details which conform closely to that of the unknown station.

Aerials, Fading and Operating Expertise

The strengths of the signals picked up by various directional aerials can be helpful in indicating the approximate bearing of a transmission. If few aerials are available a simple form of direction finder can be constructed using a loop aerial. A number of such aerials will be required since each has only a limited frequency coverage. To achieve reasonable accuracy the loop aerial must be well removed from metal windows, equipment bays, etc.

The type of fading experienced is another means of determining location; little fading with a high noise level is indicative of a nearby low-powered broadcast whereas appreciable fading suggests a more distant location. Flutter fading if not affecting most other signals may mean that the unknown broadcast is propagating over a very northerly great circle path or, if it occurs near sunset, over a path crossing the equator. Care must be taken to avoid reaching conclusions on short-term intermittent evidence and sustained observation is essential. Measurement of frequency and the stability of a carrier can provide useful information if associated with a knowledge of the operating expertise in the different organisations. Poor operating is evidenced by failure to change from the last scheduled frequency or starting the programme some kHz off the correct frequency and following this by slow adjustment to the scheduled channel.

Documentation

Frequency lists of h.f. broadcasting stations are generally readily available, the best example being the I.T.U. Tentative H.F. Plan issued four times per annum. This official list which indicates the time occupancy of each transmission is based on applications for high-frequency allocations made by broadcast administrations. Since it is produced and distributed before the plan comes into action it cannot be fully up-to-date and in fact the inevitable delay in any publication means that complete accuracy cannot be guaranteed.

Band-scan charts are used by the BBC to give an up-to-date picture of band occupancy and the full h.f. broadcast spectrum is examined within about fourteen days of the start of the new plan. Each chart as it is completed is distributed by Tatsfield and the information is not more than three or four days old at posting. Subsequent issues contain details made available by other monitoring sources and finally all bands are scanned a second or third time to check any changes that may have occurred. From information available on the usage of the bands in the form of proposed, past and current operation, and from clues provided by listening it is generally possible to identify even the most unexpected transmission.

8

INTERFERENCE

Introduction

Interference may occur from any of the following causes:–

1. Incorrect transmitter carrier frequency setting.
2. Harmonic radiation.
3. Parasitic emissions at other than the carrier frequency due to self-oscillation in some part of the transmitter circuit.
4. Inter-modulation–the algebraic sum or difference of carrier frequencies or harmonics of two or more transmissions originating from a common site. Such inter-modulation signals can also be generated in the receiver itself.
5. Cross-modulation occurring between two or more transmitters co-sited but radiating different programmes; this may occur at the receiving site when signal strengths there are large.
6. Induction by line or a.f. circuits.
7. Generation of input carrier frequency harmonics in or near the receiving equipment.
8. Radiations from local receivers.
9. Cross-modulation in the ionosphere; this is known to occur only in the long- and medium-frequency bands.

Some forms of interference may occur at transmitter or receiving sites; and it is essential to absolve the receiving equipment before initiating a complaint. Interference in the h.f. spectrum noted by a monitoring or relay station does not necessarily mean that action needs to be taken. It will be necessary only if it is judged that the interference will be serious in the intended service area, because reasonable sharing of channels is essential in order that the greatest number of transmissions may operate in the limited frequency spectrum allocated to broadcasting. Interference occurs not only due to lack of negotiation but also to non-compliance with regulations, lack of knowledge of the occupancy of the channel, inability to control carrier frequency precisely, faulty operation of the equipment and because errors of judgment occur when attempting to operate on existing occupied channels. Difficulties arise when stations move channels to avoid interference and cause interference to other users by adopting a frequency which may be clear only for a limited period of time. Hence the need for continuous observation of a channel before transferring to it.

Reduction of Interference by reducing bandwidth or detuning

Interference with reception may be decreased by reducing bandwidth or

detuning. Narrow bandwidth impairs quality by decreasing the amplitude of the higher audio frequencies of the modulation but it can cope with interference on both sidebands. Quality is less affected by detuning if not carried too far, and it generally gives the impression of treble lift; detuning is effective only when the interference is on one side of the carrier. The degree of detuning should not be more than is necessary to reduce the interference to an acceptable value. A better solution is to change to s.s.b. operation.

Bandwidth control and interference

The selectivity of a communication receiver is generally quoted in terms of total bandwidth of the i.f. circuits and is therefore twice the modulation frequency range; thus, a bandwidth of 6 kHz means that modulation frequencies above 3 kHz are severely attenuated. This point needs stressing because it has sometimes been found that relay operators have assumed that the selectivity markings represent the modulation range accepted and by not listening critically to the output they have relayed a signal so restricted in modulation range as to be of doubtful intelligibility. The aim of the relay operator should be to use the minimum selectivity consistent with low interference and he should always start his initial preparation at maximum bandwidth and reduce bandwidth in the light of prevailing conditions. If interference elimination leads to too narrow bandwidth and low intelligibility of signal, a search should be made for the same programme on another frequency; failing this recourse should be made to s.s.b. operation.

The following table gives bandwidths more suitable for broadcasting and the conditions governing their use:–

Bandwidth at 6-dB points	*Conditions of Use*
15 kHz	Strong wanted signal, clear of adjacent channel interference.
9·5 kHz	Weak interference from 5 kHz separate adjacent channel.
8 kHz	Adjacent channel stronger, resulting quality fair.
7·5 kHz	Increasing interference from adjacent channel, resultant quality reasonable.
6 kHz	Minimum relayable quality.

The bandwidths available in communication receivers are limited in respect of 'voice' reception but a modified i.f. strip may provide bandwidths of 3, 5, 7, 9 and 13 kHz which, at first sight, would appear adequate for broadcast reception. It must be stressed however, that such figures are the full bandwidth and with d.s.b. transmission the actual aural spectrum covered is only half these values: it is apparent therefore that only the last three are really usable. In the presence of interference from a 5-kHz adjacent channel, the 9-kHz bandwidth effectively reduces the heterodyne and if modulation is low, the wanted signal should be reasonably clear although restricted in a.f. response. Opening the i.f. bandwidth to 13 kHz improves the frequency range of the audio output and admits the 5-kHz heterodyne but by carefully tuning an audio-frequency variable notch filter, giving an attenuation of about 30 dB with skirts ±300 Hz wide, the heterodyne can be removed, providing the frequency remains stable. If sideband chatter is obstrusive, a slight cutting of treble frequencies by adjustment of a variable correction unit (VCU) or by the insertion of a low-pass filter with a cut off at 5 kHz may be sufficient. Thus the extension of the a.f. spectrum and the elimination of interference may be accomplished by judicious use of available equipment as opposed to closing bandwidth.

The marking of the selectivity setting in bandwidths is not necessarily an accurate indication of the aural effect on the signal; thus a selectivity curve with a slow fall-off at the skirts (see the dotted curve 1 in Fig. 16) is much less satisfactory than the full-line curve 2 with the rapid fall-off outside the band. For example an adjacent channel heterodyne at 5-kHz is attenuated 60 dB by curve 2, which represents minimum relayable quality but only 30 dB by curve 1 and, to obtain the same degree of 5-kHz heterodyne

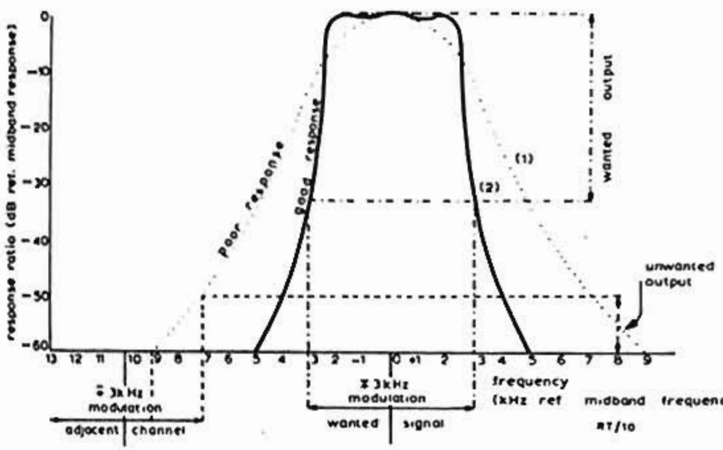


Fig. 16 A good (curve 2) and poor (curve 1) i.f. response in relation to interfering signals

rejection, receiver 1 (curve 1) must be set to a much narrower bandwidth than receiver 2 (curve 2). Response of receiver 1 could, of course, be improved by inserting in the a.f. stages a low-pass filter with sharp cut-off at about 4 kHz.

Any reduction in bandwidth tends to upset the balance of audio response by attenuating the higher frequencies and causing woolly reproduction. This may be made more acceptable to the ear if balance is partially restored by cutting the bass frequencies and accentuating the treble by a variable correction unit.

It is fortunate that under normal relaying conditions the required broadcast is generally beamed towards the receiving point, whereas the adjacent channels may not be so directed and their signals strengths are correspondingly lower. The receiving aerial itself can have directional characteristics which may further reduce adjacent channel interference.

Noise on the signal usually appears as a hiss which may or may not be irritating. It is preferable to reduce hiss by slight reduction in the a.f. treble response to a point where a reasonable balance has been achieved between good intelligibility and slight hiss, rather than to reduce i.f. bandwidth. A reduction in bandwidth may remove the hiss but it does so at the expense of overall aural merit of the signal.

Directional Aerials

The signal presented to the receiver input should be kept reasonably high in order to obtain a satisfactory signal-to-noise ratio and directional aerials improve the signal level over a restricted range of bearing. The aim should not be maximum wanted signal but rather minimum unwanted signal. If an interfering signal is on approximately the same bearing as the wanted no advantage can be gained from bearing alone but some benefit may accrue if the two signals arrive at different angles and the vertical directional diagram of the aerial has a minimum at the angle of arrival of the unwanted signal.

It may also be found that there is a difference of polarisation between the two signals and the aerial should be selected to favour the polarisation of the wanted signal. Outputs from aerials operating on roughly the bearing of the wanted signal should be compared and the one giving greatest wanted-to-unwanted ratio should be used provided adequate wanted signal strength is obtained. Every possible aerial combination should be tried before it is decided that no improvement is possible.

Interference Due to Electrical Storms

The discharge of static electricity exemplified in extreme form by the lightning flash can produce considerable interference in a receiver, even when strong signals are being received, if the electrical storm is local. This effect is a function of the tuning frequency and the higher this is the less is the interference from the discharge, i.e. short-wave reception is less affected than medium-wave. The effect of this static interference may be reduced by means of a limiter. This has to be carefully controlled otherwise audio quality suffers. It may be found that static is more troublesome on some aerials than others, e.g. a vertical wire with pointed end can attract a discharge during electrical storm conditions and lightning protectors themselves can increase static noise. Gas-discharge tubes are sometimes used as lightning protectors but they may remain conductive for so long a period that a part of the desired signal is cut out and the effect is very noticeable.

Impulsive Interference (Man-Made)

Man-made noise generated locally or conveyed close to the site may put a monitoring station out of action for accepting signals of very low field strength (about 1 μV/m). Power lines and machinery are the usual sources; the former may produce appreciably more noise during dry weather when the insulators become dirty. In wet weather a cracked insulator may provide a high-noise-level leakage path which is very difficult to trace. The metal filament in an electric lamp produces a good deal of noise when the filament breaks and the two ends maintain brushing contact. Little change in illumination may be noticeable but the noise ceases when the current is switched off and the two ends collapse. Power surges caused when machinery is switched on or off are a common source of noise; other sources of noise may be cars, farm tractors, electric fences, pulsynetic clocks, etc.

The solution to the problem is to have the receiving site in a comparatively isolated position well away from power lines, housing and factories. The incoming power lines to the relay or monitoring building should incorporate radio frequency filters and be carried in metal conduit inside the building. There must also be an adequate earthing system.

Locally-Generated Radio-Frequency Interference

Non-linearities in the receiving aerial and r.f. circuits may generate harmonics and inter-modulation as well as cross-modulation products. A comparatively strong received signal operating on a frequency far removed from the tuning frequency of the receiver may produce a response by harmonic generation at a bad joint in the aerial or a wire close to the aerial. The bad joint is, in effect, a metal-oxide rectifier, and metal masts, guy wires, triatics, guttering or roof drainage pipes may be the cause (hence the term 'drain-pipe effect').

Wires used for aerials, triatics, guys, etc. should be installed in continuous lengths, joints being avoided as far as possible:any joints should be lapped, hard soldered and then protected by suitable covering against the weather. All

earthing joints should be similarly treated, any copper strip being riveted and soldered. If the source of interference is outside the buildings, weather conditions exercise some control and the effect may disappear during and after rain.

Wideband aerial amplifiers and the r.f. and i.f. stages of receivers may be overloaded by unwanted signals. Attenuators, filters or rejection circuits should be available to control this. Such interference may occur irregularly corresponding to times of good propagation. A near-by transmitter may produce such signals due to a faulty transmitting aerial reflector system changing the radiation pattern and increasing the signal in the direction of the receiving location.

The production of spurious frequencies by intermodulation may occur in like manner because any system which produces harmonics can also produce intermodulation products (sum and difference frequencies) from two carrier frequencies. The signal strengths at the receiving station are seldom large enough to cause serious intermodulation and such products are usually produced at the transmitting site by co-sited transmitters.

An inherent drawback of the superheterodyne receiver is that it can produce interference whistles due to intermodulation between harmonics of the local oscillator and unwanted carriers giving signals which fall within the i.f. band. The most serious is image interference when the oscillator (fo) combines with an unwanted signal (fu) such that fu – fo = fi the intermediate frequency. The oscillator frequency is normally higher than the signal frequency so that the image frequency is higher than the oscillator frequency. The term image arises because the unwanted signal is as much above the oscillator frequency as the wanted signal is below it. Discrimination against image signals is provided only by the r.f. circuits preceding the frequency changer but, if the selectivity of these is good at a frequency 2fi away from the wanted signal frequency, no difficulties should arise unless the aerial trimmer setting is incorrect and is favouring the unwanted frequency. The aerial trimmer adjustment can play an important part in reducing image interference and it should be fully exploited for this purpose.

Other unwanted signal frequencies which may produce whistles are those spaced fi above or below harmonic frequencies of the local oscillator. Receiver-generated whistles are characterised by change in pitch when the tuning is varied whereas externally-generated whistles do not change in pitch. The beat frequency oscillator (b.f.o.) provides a means of checking whether a received signal is an image or not. After a known signal has been tuned in and the b.f.o. tuning adjusted for zero beat, the main tuning is altered slightly in a given direction and the direction of the b.f.o. tuning necessary to restore zero beat is noted. If the same procedure is followed with an image signal it will be found that the b.f.o. tuning has to be turned in the opposite direction to restore zero beat.

Cross-modulation can be produced by the drain-pipe effect at transmitter or receiver but it is normally caused by overload in an r.f. stage of the receiver leading to non-linear amplification in valve or transistor. A strong unwanted signal within the comparatively wide pass-band of the r.f. circuits can transfer its modulation to the wanted carrier. The problem can be overcome by inserting before the first amplifying stage a notch filter making the unwanted signal comparable with or less than the wanted signal; when the wanted signal is large enough the interference may sometimes be reduced to small proportions by inserting attenuation between aerial and receiver. Sometimes a change of aerial will effect a cure.

Wherever a number of receivers are operated in close proximity the possibility of mutual interference exists, mainly from their internal oscillators though occasionally i.f. harmonics from one receiver have found their way into another; stringent precautions must be taken to prevent this. All screening covers must be kept in place and cover screws reinserted and tightened after routine maintenance. Thorough bonding of all metal work, aerial, feeder screens, etc. should be carried out and it is good practice to disconnect the aerial whenever a receiver is unused for an appreciable time because the oscillator radiation is generally via the aerial connection.

9

RECEPTION REPORTS

Form of the Report

Though reports must be concise and in telegraphic language when they have to be cabled, they must, nevertheless, contain sufficient information to be accurately interpretable to the recipient. The following items are essential:–

1. Date and time, G.M.T. preferably, or if local mean time (L.M.T.) clearly marked as such.
2. Service involved and carrier frequency. If means are not available for frequency measurement, the nearest known station should be quoted.
3. The observations: signal strength, interference, modulation, fading, noise and overall merit.

If field-strength measuring apparatus is not available, estimation of signal strength is subjective and dependent on the skill of the reporter; interpretation requires some knowledge of his capabilities. Enthusiastic short-wave listeners often provide reliable and accurate assessments, especially when an S-meter is available, though here errors may creep in due to a change in receiver gain over the wavebands or with time. If a standard signal generator is available, the source of error can be removed by re-calibration at regular intervals. Even so, the results can only be comparative and unless the characteristics of the aerial are known the answer cannot be given in μV/m. In the absence of a signal generator, the receiver-generated noise can be used to give an idea of receiver gain variation with time. With the receiver input short-circuited, automatic gain control off and maximum r.f. and i.f. gain settings, a noise reading can probably be obtained at the a.f. output; a regular check will show any reduction in this output thus indicating a loss of gain in the receiver. The problem of getting a large enough noise reading may arise at the higher frequency bands where gain and noise output tend to fall.

Coding System

In order to facilitate quick appraisal and extraction of information (perhaps by non-technical clerks), reporting codes have been developed. The most comprehensive Internationally agreed one is SINPFEMO, the letters standing for:–

S – signal strength
I – interference
N – noise
P – propagation disturbance
F – frequency of fading

E – modulation quality
M – modulation depth
O – overall merit.

Each of the items is given five grades of quality ranging from 5 which is the best possible to 1 which is the poorest. The interpretation of these gradings for the various letters is tabulated below.

	S.E.O.	I.N.P.	F.	M.
5	Excellent	Nil	Nil	Maximum
4	Good	Slight	Slow	Good
3	Fair	Moderate	Moderate	Fair
2	Poor	Severe	Fast	Poor
1	Very poor, barely audible, unusable	Extreme	Very Fast	Nil, continuous over modulation

A shortened version of this code uses the terms corresponding to SINPO, and this has been compressed further by the BBC to SIO and the gradings 4 to 2. This represents a contraction of information to the minimum required by transmitter scheduling engineers for assessing the technical quality of the broadcast and taking remedial action when signals are for some reason or another unsatisfactory. On long-distance short-wave transmission grade 5, representing a quality equivalent to that of the line feed to the transmitter, is not often obtained and grade 1 (barely audible) is of little interest because grade 2 already indicates a poor signal of doubtful broadcast value. Subjective judgment is involved when the gradings themselves are reduced in number. The degree of subjectivity in a reporter's assessment can be estimated and allowed for if he is asked to send a tape recording of the signal heard with his report. The type of any interference present and the identity of the station emitting it should, if possible, be given on the form.

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