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FYLDE

MPT 1331

**Code Of Practice
For Radio Site Engineering**

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Foreword

The growth of radio services has resulted in an increase in the number of radio sites required and in the number of users sharing their facilities.

The radio frequency spectrum is a finite natural resource for which there are many competing demands, therefore radio systems must be designed so that individual systems are very efficient and operate with minimum interference to other systems.

The aesthetic impact of radio structures provides an increasing constraint on the development of further radio sites. It is essential therefore to obtain the support of the community with regard to environmental issues, consequently it is necessary to demonstrate that the optimum use will be made of the proposed installation.

In granting planning permission for a radio structure local authorities expect radio system users to operate the maximum number of systems from existing structures before giving consideration to an application for another structure in the same area.

This code of practice has been prepared to assist radio system designers to obtain the optimum use of radio sites and the radio spectrum.

The engineering problems encountered on sites should be dealt with in relation to the site as a whole and with the interests of all site users in mind, and not simply in relation to a single user.

Definition of a Communal Site

A communal site is a location at which there is more than one fixed transmitter.

Fixed Site Configurations

1. Single user - single fixed station

Only one radio frequency carrier can be radiated at any one time; the fixed station equipment is only required to meet the limit specified for intermodulation attenuation. All other limits in the relevant MPT specifications should be met.

2. Multiple fixed stations

At all communal sites equipment installed on the site must meet the limits as specified in the relevant MPT specifications.

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1 Scope of the code

This code provides guidance for engineers concerned with the design, specification, installation, operation and maintenance of radio systems. It is particularly directed towards systems working in the VHF and UHF bands where co-sited operation of many different users equipment has become common.

The code examines the objectives of good design and the effects of common deficiencies. It provides recommendations designed to ensure that users avoid interactions which result in mutual interference, spectrum contamination, or danger to personnel or equipment. References and appendices are provided for further reading by engineers who are new to the field or are encountering the problems which are described for the first time.

This code also includes information relating to the safety precautions required when dealing with non-ionising radiation.

A bibliography at the end of this document gives relevant information on:

- 1 relevant British Standards:
- 2 health and safety;
- 3 Department of Trade and Industry radio equipment specifications:
- 4 CCIR and CCITT Recommendations.

The contents of this document have been arranged to identify the source of the problems found on radio sites and recommendations are made for the control of these problems.

2 System design objectives

Radio equipment for the mobile and fixed services is built to specifications which are directed to ensure the efficient use of the radio spectrum. One set of parameters control emitted bandwidth and the level of out of band radiation which will cause interference to other users; they establish suitable transmitter power or effective radiated power (erp) limits and will specify the receiver sensitivity and limits to the levels of spurious emission from receivers. Another set of parameters define conditions which make a system less susceptible to interference by others; they include receiver selectivity, dynamic range and blocking characteristics. Good installation design ensures that as far as possible the performance of a complete installation preserves the professional characteristics of the components, laying down the intended field strength in the designated area, avoiding the radiation of spurious emissions and preserving the sensitivity of receivers.

The objectives are as follows

- (a) to obtain the coverage required from the chosen site in a precise and well defined manner;
- (b) to cause minimal spectrum pollution to other users on adjacent sites;
- (c) to cause minimal interference to other co-sited users;
- (d) to operate the system with the erp and optimum spectral efficiency compatible with providing the required service;
- (e) to minimise the effects of lightning.

To fulfil the requirements of all relevant legislation and recommendations, the above criteria should be met for the whole of the working life of the installation and should allow for future expansion. The quality of service is largely dependant on the planning of the system and considerable guidance on the topic of protection ratios is given in Appendix 1.

Preventive maintenance and repairs will be required to ensure that the installation continues to meet the performance criteria described; good engineering design will allow these activities to be carried out safely and with minimum loss of service, (see Appendix 2).

3 System deficiencies

3.1 Generation of unwanted products

There are three main sources of radiated products, and these are defined as follows:

- (1) the noise and spurious products generated within transmitters; these occupy a broad bandwidth on both sides of the carrier frequency (see Appendices 3 and 4);
- (2) intermodulation products caused by mixing of two or more source frequencies which produce well defined and often high level signals. These are normally caused by transmitters coupling into an adjacent transmitter output stage, due to inadequate isolation between the two transmitters (see Appendices 3, 4 and 5);
- (3) intermodulation products caused by non-linear effects on the mast and antenna hardware (see Appendices 3, 4 and 5).

3.2 Intermodulation, cross modulation and blocking effects in receiver systems.

Problems are usually caused by large signals at the input of the receiving system causing non-linearity. Examples are provided in Appendix 3.

The specifications for receivers are well defined in existing documents; distribution amplifier may be called upon to operate in a more hostile environment on densely utilised site and require a mandatory specification.

3.3 Degradation of antenna performance

It is important to appreciate that the performance of an antenna is very dependent on the environment in which it is mounted. This is particularly true of many antenna types commonly used in the VHF and UHF bands. The data quoted by manufacturers will generally relate to parameters measured on a test-range in which the antenna is erected clear of all obstructions, using the optimum mounting arrangement. Such an environment will not normally apply at a typical user's installation, and inferior performance may result unless particular care is taken.

Appendix 6 shows a number of common configurations and indicates their relative merits.

3.3.1 Radiation pattern

As a general rule, the less directional the radiation pattern of an antenna, the greater the influence the mounting environment has on the pattern.

Highly directional antennas such as paraboloidal dishes and antennas with large mesh reflectors have high front/back ratio and may be regarded as largely independent of what lies behind them. Antennas of moderate front/back ratio such as yagis must be mounted with their rear elements at least one wavelength from the supporting tower if optimum performance is to be achieved.

Nominally omnidirectional antennas (dipoles, stacked dipole and collinear arrays) will only achieve genuine omnidirectional performance when mounted on top of the supporting structure. When side mounted, large currents flow in the supporting structure, causing distortion of the omnidirectional pattern and the probability of intermodulation product radiation due to non-linear joints between structure members or mast sections. In practice omnidirectional azimuth patterns can be obtained only by side mounting several antennas (usually 3 or 4) firing in equispaced radial directions; radiation patterns may be most accurately predicted when the individual units of the antenna have a large front/back ratio. As such antennas are very expensive, their use is most attractive when a number of services can be multiplexed onto a single broadband antenna system.

3.3.2 Gain

The modification of the radiation pattern of an antenna, referred to above (3.3.1), also implies a change in its directivity and hence its gain. In general an antenna will lose forward gain when mounted too close to the supporting tower; side and rear lobes will be increased. These changes result in reduced forward range and reduced protection against co-channel interference.

3.3.3 Cross-polar performance

The cross-polar performance of base station antennas for the mobile service has in the past been non-critical, as all stations used vertical polarisation. An important change has taken place with the opening of services in Band III (174-225 MHz) to the mobile radio service in the UK as polarisation protection is an important parameter in ensuring low interference levels caused to (and by) continuing overseas television transmissions in that band. Similar consideration will also apply in Band 1(41.5-67 MHz).

In bands used for fixed services the cross-polar protection provided by link antennas is an important factor in frequency planning and management; the geographical separation between stations using the same frequency can be reduced when orthogonal polarisation is used. The cross-polar discrimination (CPD) achieved by a practical antenna under test range conditions will lie between 20 dB, for a simple yagi or dipole of orthodox construction, and 40 dB, for a paraboloidal reflector illuminated by a well designed feed horn. The significance of the path to CPD must be considered.

Two commonly seen faults degrade the CPD of an installed antenna:

- 1 If an antenna is installed in such a position that currents are induced into members of the supporting structure, these currents, flowing in arbitrary directions, will couple energy from the plane in which it was radiated into the orthogonal plane. This is a particular hazard for installations of yagi and similar antennas of moderate or low directivity.
- 2 Failure to erect antennas with the plane of polarisation aligned exactly in the Required direction produces a field component in the orthogonal plane. The CPD of an ideal linearly polarised antenna falls as misalignment increases, as shown in Appendix 7.

3.3.4 VSWR

There are two major causes of increased VSWR when an antenna system is mounted for use. In the VHF band, where antennas of low or moderate directivity are used, the proximity of structural or mounting components will change the antenna VSWR; this change will be of most significance when a very low antenna VSWR is needed. Above VHF (where more directive antennas are generally used) the chief cause of degradation is reflection from connectors and from discontinuities in the line itself.

It should be noted that the attenuation of the antenna feeder has the effect of reducing the VSWR seen by the transmitter, and for critical installations a reflection budget should be drawn up as indicated typically in Appendix B.

The budget may be used to determine the worst-case VSWR which may occur with specified components, or to determine the component limits when the overall system performance is already determined. The cable reflection coefficients quoted are typical; the reflection caused by the terminations and any adaptors which are used must be included. See Appendix 9 for the method of calculation of the system reflection performance.

3.4 Corrosion and climatic effects

The materials which are used in the construction of antennas and their support structures are prone to corrosion. The UK environment combines wet and humid conditions with mild temperatures: industrial pollutants and coastal conditions accelerate corrosion in many locations. With one of the windiest climates in the world, ice and snow, and the incidence of ultra-violet radiation to degrade paints and plastics, UK designers of outdoor installations must understand the problems which can arise and recognise the practices which have proved adequate to overcome them.

Deterioration will take the following forms:

- 1 Corrosion of metallic components, causing structural weakening of antenna elements and mountings. Corrosion will be accelerated at bi-metallic contacts and will give rise to non-linear conduction with consequent generation of intermodulation products. A rise in contact resistance at connections will increase ohmic losses and reduce antenna gain.
2. Water ingress into insulating materials will cause changes in permittivity (giving rise to VSWR changes) and will increase dielectric losses, especially if the water is polluted or has run off metallic components.
- 3 Water ingress into feeders and connectors produces mismatch and increases loss.
- 4 Wind-induced vibration causes antenna elements to break by fatigue failure and accelerates corrosion at element clamps.
- 5 Snow and ice cause temporary increases in VSWR and losses of gain and polarisation purity. These effects will become permanent if the weight or wind load is large enough to cause permanent distortion. Freezing splits components into which water

has penetrated. Falling ice can cause damage, distorting elements or even breaking off complete antennas.

- 6 Wind-induced vibration and falling ice cause damage to badly mounted feeders. Damage is often in the form of complete annular cracks in the outer conductor of corrugated semi-flexible cables; these produce intermittent faults with high VSWR and severe non-linearity.

The problems listed above result not only in a degraded service for the user of the antenna and feeder concerned, but by loss of directivity, polarisation discrimination and linearity may result in problems for other users, whether co-sited or not.

The management of these problems lies in the care with which an installation is designed, carried out and maintained.

4 Radio site selection criteria

Performance criteria can be classified as follows:

- a) location chosen by propagation analysis;
- b) availability of capacity on existing sites;
- c) electromagnetic compatibility with existing installations;
- d) environmental and planning considerations.

4.1 Location chosen by propagation analysis

A search for existing sites should be undertaken; consultations with site operators should produce propagation information concerning existing sites.

If a new site is considered necessary, a propagation study based on an initial theoretical analysis backed up by a physical survey may be required. Computer predictions are available from a number of sources, and these are based on the Ordnance Survey grid. A number of commercial organisations offer these services. Propagation predictions are essentially statistical by nature and are subject to wide local variations.

4.2 Availability of capacity on existing sites

When a suitable site has been located there are several options available to the new user and these are as follows:

- a) to share an information channel on an existing system;
- b) to share a frequency division filter system on an existing antenna;
- c) to share the accommodation and install his own antenna on the structure;

- d) to provide his own equipment accommodation and antenna and share space for the antenna on the structure;
- e) in the eventuality that neither the structure or accommodation are suitable for the new facility, a complete redevelopment may be required.

There may be structural loading implications introduced by the proposals listed above, and these are discussed in Section 5.4.4 of this document.

4.3 Electromagnetic compatibility with existing installations

It is necessary to establish whether a compatible background noise level is available at the frequencies under consideration for the proposed installation. The overriding consideration is whether signals emanating from existing installations will adversely affect the proposed installation. Contributing factors that will form the basis of a decision are as follows:

4.3.1 Ambient noise levels

It is recognised that any ambient noise measurement is only an approximate indication, since it is strictly applicable to the antenna employed and the noise conditions at the time. The ambient noise level particularly at urban sites in the lower VHF bands, has a major influence on system range and performance.

Precipitation static noise, caused by the exchange of static charges between raindrops and the antenna system, is a significant source of noise at frequencies below 150 MHz. It may be controlled by the fitting of insulating shrouds to antenna elements (see Appendix 10).

Ambient noise includes atmospheric, sky noise and man made electrical noise. In general this is beyond control of the site operator (see Appendix 11).

On a remote green field site it may be possible to operate receivers in the VHF band at levels below - 107 dBm (2 μ V emf). However in a more realistic situation the minimum usable signal will be typically -104 dBm (2.8 μ V emf).

4.3.2 Interference generated on site

The examination and control of unwanted products are considered in Section 5 of this code of practice.

4.3.3 Technical responsibility of the site operator

It is essential that the site operator is able to quantify any unwanted products which give rise to unreasonable degradation of service to co-sited installations.

Some solutions to the problems arising from unwanted products are offered in Section 5. There is a need for further procedures to control the lack of coordination that often exists between the site operator, the users and the licensing authority.

4.4 Environmental and planning considerations

Radio sites are prominent features of the landscape. It is therefore understandable that many Planning Authorities are paying particular attention to applications for both new sites and redevelopment of existing sites. There are also organisations and individuals who will raise objections to any application. These objections will be more numerous where the site is in a National Park, Area of Outstanding Natural Beauty or Area of High Landscape Value.

It is important that these aspects are carefully considered at the planning stage of any new site. Whilst the site should have sufficient capacity for the foreseeable requirements, it should create the minimum impact on the environment. For example:

- relocating the site a small distance without changing its performance may dramatically reduce its impact;
- the careful choice of antennas together with their arrangement in a symmetrical form, subject to a satisfactory performance, or a reduction in their numbers by the use of combiners will provide a better appearance;
- an alternative type of support structure may present a more acceptable profile;
- varying materials, styles and colours for construction of equipment buildings may result in a more acceptable appearance;
- landscaping of the compound with the addition of trees and shrubs will improve the visual impact of the site.

Helpful advice can usually be obtained from the Local Council's Planning Authority.

Applications prepared without due consideration of the foregoing factors may result in a refusal.

NOTE: An existing mandate DOE Circular 16/85, makes specific recommendations that sites shall be shared wherever possible, and that new applications must take sharing into consideration.

5 Recommendations

5.1 Control of unwanted products

The **origins** of unwanted products are related to mixing processes that take place in any non-linear component of the complete system. (See Appendices 3, 4 and 5). The simple guidelines of increasing the isolation between the components of the mixing process will result in the reduction of the intermodulation product level.

5.1.1 The ferrite circulator

The ferrite circulator is a practical component which can be utilised to provide directional isolation at the output stage of the transmitter.

A ferrite circulator has directional properties that typically result in additional isolation of between 20 and 40 dB. The isolation parameter has to be considered in conjunction with the insertion loss and bandwidth, all parameters being considered in the system design.

For isolation in excess of 40 dB, a dual circulator version may be fitted.

The third port of the ferrite circulator is terminated in a matched load, the power rating of which is intended to withstand the maximum return power that is envisaged in the worst fault condition that can arise on the system.

5.1.2 The cavity resonator

The cavity resonator is a bandpass circuit, having a centre resonance frequency related to its physical dimensions. The unloaded Q of such a device depends on its physical volume, and at VHF it ranges between 2000 and 10,000. The loaded Q is normally arranged to be between 500 and 1500 according to the insertion loss and isolation required (see Appendix 12 for details).

A system using a cavity resonator gives protection to co-sited receivers by reducing the radiation of wide-band noise.

Cavity resonators may be connected together to provide additional isolation when used to combine several transmitters to a single antenna.

When used in conjunction with ferrite isolators, cavity resonators provide the necessary isolation to combine several transmitters into a single antenna configuration. This system employs several cavity resonators coupled together with a precisely dimensioned cable harness, to allow single antenna working with insertion losses of typically 2 dB with a relative frequency separation of 1%. With high performance cavities the separation can be reduced to 0.25%, and still give isolations greater than 20 dB. When used in conjunction with a ferrite isolator it is typically possible to attain 50 dB isolation between adjacent transmitters when coupled to a single antenna (see Appendix 14 for details).

5.1.3 The spectrum dividing filter

When the outputs of several transmitters are to be considered as a combined signal it is convenient that each antenna shall have the frequency spectrum coupled to it defined by a filter having a comparatively broad, flat topped response. This enables any transmitter to be operated within the specified band without excessive filter insertion loss, and ensures the attenuation of signals outside the defined frequency band.

This system defines the band edges, controls spurious emissions, and is therefore given the title "spectrum dividing filter".

The spectrum dividing filters can be coupled together by means of a precisely dimensioned cable harness to other similar filters, to provide duplex and combiner facilities for multiple bands to a single antenna system. (See Appendix 13 for further details).

5.2 Control of intermodulation, cross modulation and blocking in effects receiver systems

5.2.1 Filter protection

A common source of receiver problems is that incoming signals outside the band of interest arrive at the receiver front end at an amplitude which can cause blocking, inter-modulation and distortion of the wanted signals. This situation is mostly likely to occur when the receiver is connected to an antenna which may be in close proximity to other antennas on a communal site. An improvement in this situation can be obtained by positioning the receiver antenna well away from any other installation and in particular from other transmit antennas. On shared sites this is often not possible.

An alternative procedure is to connect bandpass filters between the antenna and the receiver input. These filters need to have the necessary shape factor to limit the bandwidth to that which is required for the receiver system.

A single small cavity resonator providing 20 dB isolation at the offending frequency will often provide a solution to receiver interference problems but, in those cases where the interfering signal is closer than 1% of the centre frequency of resonance to the wanted signal then multiple section filters or large cavity resonators may be required. The typical responses for such filters are given in the Appendices (see Appendix 13).

5.2.2 Receiver distribution networks

There are many instances where many receiver systems in the same frequency band are required to be installed at the same radio site. It may therefore be appropriate to fit a receiver distribution network comprising one antenna input feeding a suitable bandpass filter, followed by a low noise amplifier which then distributes its output, usually by a passive network, to the receivers in that band.

The low noise amplifier is carefully chosen to have a very good signal to noise performance to minimise degradation of the overall system signal to noise performance whilst feeding up to typically 16 receivers in the same band. The amplifier needs also to be chosen for large signal handling capability together with an inherent protection against damage by transient impulse voltages. The use of a high quality semiconductor device operated at a small fraction of its rated dissipation will meet these requirements and provide a MTBF typically in excess of 100,000 hours. It is essential to appreciate that the design objectives for the receiver distribution network will determine the failure rate of the subsequent systems involved.

It should be noted that overloading of a receiver distribution network could affect many other users on the same system.

The power supply associated with such amplifiers can operate either from mains supply or batteries which are becoming increasingly common on remote hilltop sites. Again it must be stressed that the reliability of the supply is essential for the maintenance of the service and it is usual to provide back-up in the event of mains failure. (See Appendix 15 for further details of distribution amplifiers).

5.2.3 On site interference

A common problem caused by mobile transmitters is being able to come within a very short distance of the receiving site, e.g. 25 metres, in which case signals typically in excess of +10 dBm can arrive at the receiver within the wanted frequency band; this is a source of non-linearity. On a communal site where there is a multiplicity of users, it is likely there will be several potential users in the same band able to visit the site using their mobile transmitters. This problem can be avoided by strict discipline on this topic or a complete ban on the use of mobile transmitters on the site.

A further cause of interference on base station receivers can be distant mobiles using their transmitters when on elevated locations or during conditions of enhanced propagation.

These problems can be minimised by co-operation with the distant user, the use of signalling systems, the choice of site and assignment of frequencies in association with the appropriate authority.

5.3 Control of antenna system performance

5.3.1 Choice of antenna type

The principle which governs the choice and siting of transmitting antennas is that only the minimum necessary ERP must be radiated in each desired azimuth direction.

Omnidirectional antennas should be used only when necessary for the service requirements. The simplest examples of this class of antenna are top-mounted end-fed and coaxial dipoles, monopoles and collinear arrays. When omnidirectional characteristics are required of a side mounted array, a number of antenna elements must be placed around the supporting structures.

There are many satisfactory types of directional antennas; common examples are yagi arrays, corner reflector antennas and panel antennas.

Many antennas in common use fall between the omnidirectional and directional types described. They include simple dipoles side mounted from support structures. Many of these antennas have ill-defined radiation pattern performance and are likely to give rise to radiation of intermodulation product frequencies originating from currents excited in the supporting structure. Their use is not recommended for multi-frequency applications.

5.3.2 Antenna specification

The following parameters must all be specified when procuring or selecting antennas.

Electrical

- 1 Gain: Specified either in dB relative to an isotropic radiator (dBi) or a half-wave dipole (dBd).
- 2 VSWR : Specify the maximum value compatible with the system being considered.
- 3 Radiation pattern: Specify the beamwidth in the azimuth and elevation planes, together with any necessary restrictions on side or rearlobe levels.

- 4 Balance ratio: This parameter defines the effectiveness of the balun fitted to balanced driven elements and consequently the acceptable level of currents on the outside surface of the feeder cable. A value of 20 dB should be considered as a minimum.
- 5 Input power: For combined transmitter outputs specify both the mean and effective peak powers.

6 Intermodulation performance : The following specifications are desirable:

for single frequency transmit and receiving applications: - 100 dBc

for multiple frequency transmission: - 130 dBc

for multiple frequency transmission and reception on a single antenna; -143 dBc

the more severe specification will be met using all-welded construction and exceptional care in the encapsulation of antenna terminal arrangement.

- 7 Bandwidth: Specify the frequency band over which the antenna is to be used, over which all the parameters specified must be met. The practice of regarding the VSWR bandwidth as indicating the usable frequency band is unsound.

Mechanical

- 1 Structural design of antennas and supports must comply with BS CP3 ChV Part 2; BS CP1 18 and BS 449.
- 2 Electrolytic contact potentials between dissimilar metals must be less than 0.25V even for encapsulated assemblies.
- 3 Conformity to a chosen environmental test specification (see BS2011).

5.3.3 Location of antennas

When determining the mounting positions for antennas each antenna must be mounted in a manner which does not impair its performance (see Appendix 6). The spacing between antennas must be chosen to provide sufficient isolation to allow system intermodulation product targets to be met.

5.3.4 Cables and connectors

Semi-flexible cables with corrugated copper outer and conductors are in widespread use for long feeders. Recommended connector interfaces include types N', 'HN', 'C', and 'IEC' flanges. The use of low-performance connectors such as type 'UHF' is deprecated. All connectors must be fitted in conformity with manufacturers' instructions to ensure proper sealing and electrical uniformity. A flexible tail must be used to connect a semi-rigid feeder to an antenna.

5.4 Control of corrosion and climatic effects

5.4.1 Standards

It should be recognised that corrosion and climatic effects cannot be eliminated; however, the effects can normally be contained by careful design and selection of materials, high quality manufacturing, high standards of installation and a maintenance programme planned for the life of an installation. Detailed information is found in BS 5493 and BS PD 5484.

Maintenance on the basis of remedial action only is a dangerous practice. For further guidance see Section 5.6.

5.4.2 Dissimilar metals

Structure design must take particular account of corrosion between dissimilar metals: electrolytic contact potentials between metals in contact in outdoor exposure must be less than 0.25 volt, and in indoor situations should be less than 0.5 volt.

Connections to site earthing systems (where corrosion may be unavoidable) should be made by means of a sacrificial earth lug of a material compatible with the structure being earthed. Replacement of sacrificial lugs should be part of the site maintenance programme.

5.4.3 Protective coatings

Steel structures should be protective coated to BS 729, with screwed fasteners spun galvanised to BS 4190. Aluminium structures should be anodised to BS 1615. It should be noted that anodising on aluminium is likely to insulate the components and thus produce difficulties in terms of earthing and conductivity of the structure.

The cutting or drilling of protective coated items should not be permitted during installation.

On the occasions when cutting or drilling is unavoidable, consideration should be given to possible structural weakening, and the affected areas must be treated with a recommended protective coating.

The painting of structures should be considered as an essential part of the post installation programme. A well defined schedule of time scale and of the exact process should form part of the design of the structure and must be implemented rigorously.

In the case of a galvanised structure there will be a recommended period after which a paint process should be applied.

For structures of other materials requiring protective treatment, BS CP 118 indicates the recommended processes.

5.4.4 Wind loading

The design of antenna support structures should be in accordance with 88 CP 3 Ch V Part 2, BS CP 118 and BS 449 and should take into account the wind loading of all the components on the structure,

e.g. antennas, feeders and associated hardware.

Twist and tilt limitations for parabolic antennas may also have a bearing on design or reinforcement.

The design or selection of a suitable support must be by qualified structural engineers.

The design of new structures should where possible take into account the probability of future development.

5.4.5 Wind vibration

All antennas, mounting steelwork, feeders and ancillary equipment should be securely clamped to protect feeders and other semi flexible items from damage by vibration throughout the projected life of the installation.

Manufacturers' recommended feeder clamp spacings should be observed, with particular attention to exposed areas and transitions from antenna to tower, tower to gantries and gantries into buildings; feeders should not be laid loose on gantries. Where necessary additional protection should be provided.

5.4.6 Icing

The structure design and site layout should take into account the icing which could reasonably be expected to occur on structures and antennas in a particular location and the danger of falling ice in relation to personnel and damage to buildings, equipment, antennas and feeders.

5.4.7 Sealing

Feeder and cable entries, external cable or feeder termination's, and earth connections to feeders on towers or gantries should be suitably sealed or protected against the ingress of moisture using non setting pastes, self amalgamating tapes, neoprene paints as appropriate and in accordance with manufacturers instructions. Particular attention should be paid to shedding of surface water.

The use of PVC boots or drip covers is not recommended; self amalgamating tape, and non setting sealant methods are preferred. (See Section 5.6.3).

All underground clamps on site earthing arrangements should be suitably protected by the use of non reactive non setting pastes and tapes.

5.4.8 Ultraviolet degradation

Products liable to degradation by ultraviolet light should not be used in external situations where there is an acceptable alternative. Where the life of an item is known to be limited, its periodic replacement should be included in the site maintenance programme. Replacement only on failure is not generally acceptable.

5.5 Choice of site

For a proposed service, the ideal site is one that is located in the service area with a position for installation of a suitable antenna system. A high building or existing structure may suffice if the final antenna height that can be provided is above the mean height of physical obstructions in the service area. In an urban environment it may be extremely difficult to provide a clear path for the required radiation pattern and usually a compromise has to be reached.

If there are no suitable locations fulfilling the basic parameters, it will then be necessary to construct a purpose built mast or tower to provide the necessary service. In every case a careful search should be made for all other existing users who may have an additional interest in extending their own systems. When a new structure is proposed, a large number of new users may wish to share the facility.

It is essential that all these potential users are taken into account in the initial planning as there have been many cases in the past where a multitude of structures have been erected in close proximity due to lack of early consultation.

Wherever possible, the location of a radio structure should be determined by the isolation from any other radio transmission activity, and should preferably be a minimum distance of 500 metres from a busy road. This is to minimise the possibility of mobiles operating close to the site, for reasons which are discussed elsewhere in this document (see section 5.2.3), and to avoid radiated vehicle noise. Care should be taken to avoid close proximity to sources of industrial and domestic electrical noise.

In the event that no suitable location having sufficient height is available in the service area, it may be necessary to utilise an existing site on the fringe of the service area, in which case directional antennas may be required. In these circumstances it is essential from the outset that the user is given the opportunity to consider the effects on his service that will be caused by the irregularity in the service area.

There are many existing installations in which the service area is not in accordance with the users requirements; this may have been caused by lack of appreciation of user requirements and the propagation parameters or the use of an unsuitable site for economic or planning reasons. The fundamentals to the choice of radio site are:-

- (a) research into the service requirements,
- (b) careful examination of the service area,
- (c) determined attempts to co-locate with existing users.

If when these points have been investigated a new site has to be found, then its location should be subject to extensive investigation (See section 4).

5.6 Installation and maintenance

5.6.1 Orientation of support structure and antennas

Orientation should be based on True North, although it may be preferred that a statement of magnetic bearing, deviation and date is also kept on records. A clear method for referring to the legs and faces of the structure should be observed.

5.6.2 Data logging

The efficient administration of complex radio sites relies on precise details of physical facilities, users and emissions. Information should be kept centrally, and displayed in a useful form on site.

(a) Physical information should include:

antenna types,
feeder lengths and types,
connector types and sex,
distribution harness details,
details of mounting hardware.

A common practice is to maintain a master outline for each structure, referring to detailed drawings of mounting arrangements, feeder routes and other information.

(b) Electrical information established at systems commissioning provides a useful reference for the diagnosis of later problems. Data recorded for each antenna system should include:

VSWR, insulation and attenuation of feeder cables

VSWR measurements on complete antenna Systems, bench measurements of power division networks.

5.6.3 Feeder identification, terminations, earthing and sealing

Feeder cables should be uniquely and permanently identified at each end, and at the point of exit from the structure. More frequent identification may be advisable when cables are buried in a duct.

Connectors and earthing kits should be fitted in accordance with manufacturers' instructions. Connector fitting should be carried out in dry surroundings wherever possible, feeders should be lifted in accordance with manufacturers' recommendations, with connectors already fitted to their upper ends and suitably protected from water ingress. Earthing of feeders should follow the recommendations of section 5.6.7.

On completion, connectors should be wrapped with polyisobutylene (PIB) self-amalgamating tape and over-wrapped with a carefully applied layer of petroleum jelly impregnated waterproof tape. Where PVC covers are provided for connectors, they should be removed and the connectors taped as described.

5.6.4 Structural integrity

The structural integrity of the mast or tower must be established by a competent structural engineer, the analysis must include the loads imposed by each antenna system.

Structural components must be designed to comply with BS 449 (or BS CP118), steel components being hot-dip galvanised to BS 729 with threads spun galvanised to BS 4190. All nuts should be provided with spring washers or other means of locking.

5.6.5 Working arrangements

Operations at site must follow safe working practice. Only one user or contractor must work on the structure at any time and arrangements for lifting equipment past working antennas must be agreed with the Site Manager. Attention is drawn to section 6 (Health and Safety).

5.6.6 Equipment room installation

5.6.6.1 Environment

Consideration should be given to ensuring that the equipment room should be kept at an ambient condition which never allows the temperature to fall below the dew point and which keeps within the specified temperature range of the equipment, or at an acceptable working temperature for personnel.

It may be necessary to provide heating, ventilation or cooling to achieve this condition.

Precautions may be necessary to exclude pests and vermin from the equipment room.

5.6.6.2 Choice of cables

It is recommended that wherever possible, solid, semi-rigid or double-screened cables shall be used for all radio frequency connections. This is to ensure maximum screening between adjacent cables and feeders and to reduce coupling between equipments.

The use of single screened cable, e.g. UR67, UR43, RG58 should be avoided wherever possible and in particular, in cable runs where several of these conductors are brought close together.

5.6.6.3 Choice of connector

Wherever possible, high quality connectors should be used, typically type N, preferably with a silver-plated finish. Use of such connectors produces maximum screening effect and gives the best radio frequency connection between the various components of the system.

5.6.6.5 Cable routes

The direct and shortest route is always the best for minimum radiation and minimum insertion loss. However it is important that transmitter cables and receiver cables should be installed as far apart as possible. It is advisable that when they cross they should cross at right angles. Cable trays carrying transmitter cables should not be directly connected to receiver path cable trays and it is best if cables are insulated from each other at all times. It is normal to use cables with insulated outer jackets and the only points at which earth straps and earth bonding should be employed are those specifically chosen for the purpose.

5.6.6.5 Earth connections

There should be a careful plan designed at the outset of the station design in order to provide the best earthing procedures and to minimise earth loop currents. This should be achieved by taking the outer casings of the cables by a large section copper strap to a central earth bonding point and the size of the conductor should increase as each branch path is added. The final conductor should go directly to the earth system. For a radio site a single copper spike is insufficient for the station earth as its impedance is likely to be too high.

5.6.6.6 Electrical supplies

The majority of sites will have AC power provided by the local Electricity Supply Authority. It is essential to arrange sufficiently large capacity for future expansion, and wherever possible a sub-division of the input circuits should be provided separately for each user function. This ensures that individual fuses or trips protecting sub-sections of the site installation cannot interrupt the supply of other users.

In many instances, standby power supplies will be required and this should be based on the requirement of the service.

There are an increasing number of sites where DC supplies, in the form of large capacity batteries, are used to power equipment, and these batteries are charged continuously by means of 'float charge' systems. This has the dual advantage of automatic standby and "no-break" characteristics.

5.6.7 Antenna feeder systems

5.6.7.1 Incoming cables from the mast

It is often convenient to break down very large feeder cables to a more convenient size and there is a tendency to put connectors just inside the equipment room when reducing the main incoming feeder to a more manageable size. It is best, however, to take the main feeder as close as possible to the equipment to which it is to be connected before having a break in its outer conductor.

The only exception to this rule is to provide an earth connection for lightning conductor purposes and this should be carried out by means of an external clamp on the outer copper conductor and this should be taken via the most direct route (as outlined in section 5.7.5).

Incoming feeders must not be interconnected by a "patch panel", traditionally used in the past. The "patch panel" is a source of earth current coupling and intermodulation and should be avoided.

5.6.7.2 Antenna distribution networks

In the case of a filter system, combining network, or receiver distribution network, it is important that the cables are treated very carefully and that the distribution network should be mounted away from the transmitters and receivers whenever possible. Ideally the filter or distribution network should be mounted on the wall adjacent to the antenna incoming feeders and the transmitter section shall be connected as far away from the receiver section as possible. The interconnecting cables between various sections of the filter network should also be treated as in section 5.6.6.4

5.6.7.3 Use of dissimilar metals

It should be carefully noted that wherever possible all metals used in contact with each other shall be in the yellow metal series, i.e. copper, brass, silver, nickel, or possibly even gold. The iron and steel part of the metals table should be avoided at all times as their oxides form non-linear junctions and can cause intermodulation.

The ideal combinations are silver/brass to copper using nickel plated nuts and bolts.

5.6.7.4 Inspection for moisture

In cases where the mast is exposed and there is a possibility of moisture gathering at the outer jacket of the copper case of the incoming cables, it is wise to remove the outer insulating jacket at a point well inside the equipment room where it can be inspected for traces of moisture forming.

It is essential that between the incoming cable glands and the earth strap assembly an easily visible section of the outer copper jacket is available for routine inspection.

5.7 Lightning protection

5.7.1 Effects and responsibilities

Radio sites can be particularly prone to lightning strikes by virtue of their normally exposed locations and the presence of relatively tall antenna support structures.

The effects of strikes on a site could comprise any or all of the following:-

- a Death or injury to personnel.
- b Damage to equipment, or loss of service.
- c Damage to buildings and structures
- d Loss or corruption of stored data.

It is not possible to provide and guarantee complete protection from these dangers; however they can be considerably reduced by careful attention to earthing, protection devices and the layout of the site itself.

Understandably site owners and users will be concerned with the protection of equipment to maintain the integrity of Systems. However this concern must go alongside the prime consideration which is the safety of personnel.

Site owners and site users have a responsibility for safety under current Health and Safety legislation.

This section (5.7) provides some guidelines for designers of radio systems but is not in itself a complete guide.

Reference should also be made to various relevant publications, some of which are listed in the Bibliography. Where any site owner or site user is in doubt about the protection requirements for a particular location, the appropriate authority should be consulted.

5.7.2 Protection arrangements

The aims of any protection arrangements should be to provide a suitable path to earth for the lightning current, to ensure adequate bonding between structures, all metalwork on the site and the site common earthing system in order to reduce the side flashing, and to attempt to prevent the entry of flashes or surges into buildings.

The resistance to earth should be kept to a minimum and a value of less than 10 ohms is recommended. The important feature is that the system should ideally be equipotential across the whole site.

Reference should generally be made to the Code of Practice for the Protection of Structures Against Lightning BS 6651:1985.

Certain authorities and service providers have their own particular practices which may have to be followed where applicable.

Arrangements will vary considerably from very simple sites to complicated sites with a multiplicity of buildings, antenna support structures and associated plant, and may involve integration with existing systems. Such systems may require upgrading.

5.7.3 Lightning conductors

Down conductors, bonding interconnections, earth rings and radial tapes should be of uninsulated solid copper tape of minimum cross section 25 x 3 mm with all connection clamps and supports protected by non reactive paste or tape (aluminium conductors may be acceptable)

Where the tape may be subject to chemical attack, e.g. when in close proximity to concrete, it should be protected by the use of non reactive paste or similar.

Protected test points should be included if appropriate and sacrificial earth lugs should be clearly marked and easily accessible for periodical inspection and replacement if necessary.

5.7.4 Earthing of antenna support structures

A structure will generally act as its own lightning conductor and will not therefore require a conducting tape from the apex to its base. A lightning finial may be required to extend the zone of protection to protect equipment mounted on the top of the structure. The finial should extend to about 2.5 metres above the highest equipment.

Ground mounted support structures should be connected at their base to an earth ring arrangement (or equivalent) via sacrificial earth lugs. Towers may require a connection from each leg.

An earth ring may consist of copper tape with driver earth electrodes or radial tapes round the base of the structure as close to it as possible, buried to a depth of approximately 0.6 metre where solid conditions allow.

The earth rings should be connected to the main building earth by the most direct route, buried as appropriate.

Roof mounted structures should be connected to the main building earth by the most direct route using sacrificial lugs and copper tapes as appropriate.

Mast guy wires should be directly bonded at their lowest point to a suitable earth electrode or connected to the site earth by the most direct route.

5.7.5 Earthing of feeders

All antenna feeders should be bonded to the tower at the upper and lower ends and earthed at the point of entry into the building (see Appendix 18). Weatherproof earthing kits are available from antenna manufacturers.

Fast acting gas filled surge arrestors can be used on some systems and may provide additional equipment protection, providing that VSWR degradation is acceptable.

5.7.6 Earthing of associated plant

All gantries, fuel tanks, above and below ground pipes, fences and other metalwork within 3 metres of the support structure or building should be bonded to the earthing system by the most direct route using copper tape, buried where appropriate. This should include any reinforcing rods in foundations which are not already bonded to earth.

5.7.7 Earthing of buildings

An earth ring ideally should surround the building and be connected to the individual earths associated with the feeder entry, antenna support structure, building lightning conductor, equipment room, mains supply and other facilities. Each connection should be made by the most direct route to minimise interaction between the different earthing functions.

The earth ring should consist of copper tape with electrodes or radial tapes buried to a depth of 0.6 metre and at a distance from the building preferably not exceeding 1.0 metre.

Building may require lightning air terminals (finials) where they are not within the zone of another protected structure.

6 Health and Safety

With the increasing use of single antenna arrays to radiate the combined output of several transmitters, radio site operators must assess the physiological hazard presented by the radio frequency energy radiated from their antennas. It is the responsibility of the site operator to ensure that antenna systems and access arrangements do not expose personnel to hazards. Everyone who is allowed access to the antenna structure must be properly informed of all necessary precautions.

The current UK limit for continuous exposure is a power density of $10\text{mW}/\text{cm}^2$ (100 WIm^2). The limit is currently under review and may well be reduced, especially for frequencies in the range 70 - 250 MHz. As an example, it is unsafe to work continuously within 1 metre of a dipole radiating 500W. Even at stations radiating only 250W from a dipole mounted on a small guyed mast, it may be unsafe to climb past the antenna unless power is reduced or removed.

For further guidance the reader is referred to:

- 1 "Safety Precautions Relating to Intense Radio Frequency Radiation". HMSO 1960 (ISBN 011 340576 6). This is the present standard which is currently under review.
- 2 "Proposals for the Health Protection of Workers & Members of the Public against the Dangers of Extra Low Frequency, Radio Frequency and Microwave Radiations: A Consultative Document", National Radiological Protection 1982, ISBN 085951185 5). This document sets out proposals for future standards.

Appendices

1	Protection ratios and minimum field strengths
2	System availability
3	Interference due to intermodulation products
4	Sources of unwanted signals
5	Intermodulation interference
6	Common antenna configurations
7	Achieved cross polar discrimination
8	Calculation procedure for a system reflection coefficient budget
9	Formulae for calculation of system reflections
10	Control of precipitation noise
11	Noise power on typical radio sites
12	Parameters of cavity resonators
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15	Characteristics of distribution amplifiers
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PROTECTION RATIOS AND MINIMUM FIELD STRENGTHS

REQUIRED IN THE MOBILE SERVICES *

(Question I /8)

(1966-1970-1974-1978-1982-1986)

I. VHF and UHF land and maritime mobile services**1 - 1 Protection ratios based on internal noise and distortion in the receiver**

The World Administrative Radio Conference, Geneva, 1979, defined the protection ratio as the minimum value of the wanted-to-unwanted signal ratio, usually expressed in decibels, at the receiver input determined under specified conditions such that a specified reception quality of the wanted signal is achieved at the receiver output (*RR No. 164*). For further information on the definition see Report 525. This ratio may have different values, according to the type of service desired.

However, in the absence of information submitted to Study Group 8 on subjective measurements made in the VHF and UHF land and maritime mobile services, several administrations submitted the results of laboratory measurements, using appropriate test signals, of the degradation of the signal-to-noise ratio of the wanted test signal, when a co-channel interfering signal is superimposed on the latter. A degradation of the initial signal-to-noise ratio of 20 dB to a signal-to-noise + interference ratio of 14 dB is taken as the criterion. For some systems this grade of service is acceptable.

In the tests described by the various administrations, the frequency deviations are 70% or 60% of the maximum specified frequency deviations, and for amplitude modulation the modulation percentages are 70% or 60%, for both wanted and unwanted signals. From a study of the documents submitted, it may be deduced that the slight differences in measurement conditions and in the characteristics of the receivers used in the different tests, may result in differences in the measured receiver protection ratios, of up to about ± 3 dB.

One administration performed tests to determine the protection ratio for the case where the wanted narrowband G3E signal is interfered by a direct-printing F2B signal (see Recommendation 476) [CCIR. 1978-82]. The e.m.f. of the wanted signal at the receiver input was 2 μ V. In these tests the level of the interfering co-channel F2B signal was so adjusted that the subjective effect on the wanted signal was the same as that of an interfering co-channel narrowband G3E signal attenuated by the protection ratio of 8 dB laid down in Table I for this case. The peak frequency deviations used for the F2B signal were ± 1 , ± 3 and ± 5 kHz respectively. The sub-carrier was 1500 Hz and the frequency shift 170 Hz. 12 dB was found to be a suitable representative value for the protection ratio and is therefore included in Table 1.

Although the ability of the receiver to receive the wanted signal is dependent on the passband characteristics of the receiver, the frequency difference between the co-channel wanted and unwanted signals, the frequency deviation, etc., the receiver protection ratios in Table I may be used as the basis for the calculation of system protection ratios for mobile systems for a minimum grade of service. Additional protection should be provided to allow for the effects of multipath propagation, man-made noise, terrain irregularities, and in the case of very closely spaced assignments, adjacent-channel interference (see Report 319).

When using frequency modulation, "capture effect" is enhanced as the frequency deviation of the wanted signal is increased: therefore, a wideband F3E, G3 E system requires less protection than a narrowband F3E, G3F system for the same type of interfering source.

If a higher grade of service is required, a higher protection ratio should be adopted, particularly in the case of amplitude-modulated wanted emissions.

1.2 Man-made noise

Man-made noise degrades the performance of a mobile system. To maintain a desired grade of service in the presence of man-made noise, it is necessary to increase the level of the field strength of the wanted signal. Motor vehicles have been shown, by measurements [US Advisory Committee, 1967], to be the primary source of man-made noise for frequencies above 30 MHz. Other noise sources are fewer in number and usually radiate from fixed locations.

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Table 1 - Typical receiver protection ratios, for use in
Calculating system protection ratios

Wanted emission (Note 1)	Unwanted emission (Note 1)	Receiver protection ratio (dB)
Wideband F3E, G3E	Wideband F3E, G3E	See Report 319
Narrowband F3E, G3E	Narrowband F3E, G3E	See Report 319
Wideband F3E, G3E	A3E	8
Narrowband F3E, G3E	A3E	10
Narrowband F3E, G3E	Direct printing F2B	12
A3E	Wideband F3E, G3E	8 - 17 (Note 2)
A3E	Narrowband F3E, G3E	8 - 17 (Note 2)
A3E	A3E	17

Note 1. - Wideband F3E, G3E Systems normally employ frequency deviations with a maximum value in the range ± 12 to ± 15 kHz.

The narrowband F3E, G3E systems considered here normally employ frequency deviations with maximum values of either ± 4 or ± 5 kHz.

The value of the F2B case is with a peak frequency deviation of ± 5 kHz. Frequency deviations of ± 3 and ± 1 kHz do not significantly decrease this value.

Note 2. - The receiver protection ratio may vary within the range shown dependent upon the difference in frequency between the carriers of the wanted and unwanted emissions and the frequency deviation of the unwanted emission. In general, it will tend towards the higher figure as the frequency deviation of the unwanted emission decreases.

For convenience in evaluating the degradation of performance of a base receiver, the following classifications of noise sources are provided:

- high noise locations - traffic density of 100 vehicles/km² at any given instant of time:
- moderate noise locations - traffic density of 10 vehicles/km² at any given instant of time:
- low noise locations - traffic density of 1 vehicle/km² at any given instant of time:
- concentrated noise sources (hot spots): noise radiated from individual sources or closely spaced multiple sources which are usually located within 500 m of the receiving antenna, such as a high concentration of vehicles, manufacturing plants and defective power transmission lines.

Noise data for base stations at high, moderate and low noise locations are presented by a noise amplitude distribution (NAD) (the number of pulses per second equal to or greater than the value shown as ordinate) and are illustrated in Fig. 1. The amplitude (A) (in dB(μ V/MHz)) of noise pulses at a rate of 10 pps (pulse-per-second) is expressed as follows:

$$A = C + 10 \log V - 28 \log f$$

where,

C : constant (tentative value: 106 dB μ V / M Hz)

V : traffic density vehicles/km²

f : channel frequency, MHz.

Noise data for hot spots can also be presented in the form of a noise amplitude distribution. However, due to a wide variety of noise sources, it is not yet practical to provide a classified list.

The constant C is a function of the electrical noise suppression applied to vehicles and may also vary according to the relative proportion of goods and passenger vehicles if the level of suppression is not the same for both categories. A tentative value of 106 dB(μ V/MHz) is shown and this may be revised as more information becomes available.

APPENDIX 1

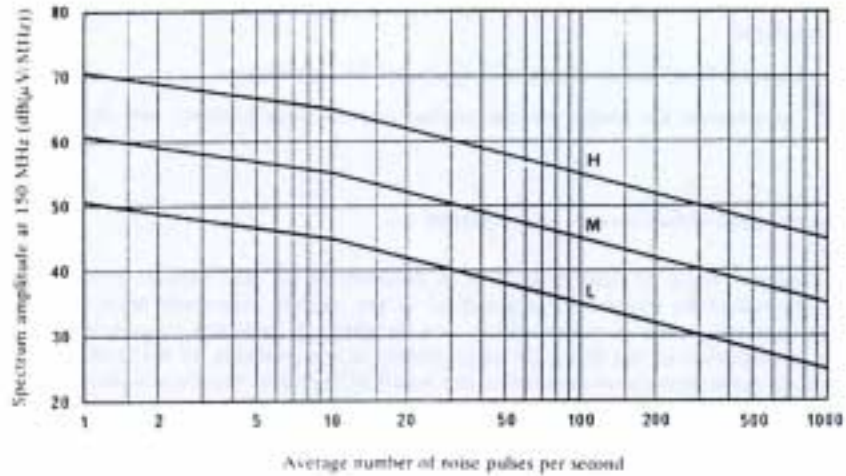


FIGURE 1 - Noise amplitude distribution at base station (150 MHz)

For frequencies other than 150MHz, raise or lower curves H,M and L
In accordance with the formula below

$$A = C + 10 \log V - 28 \log f$$

Where A=dB (μ V/MHz) at 10pps

Curve H: high noise location ($V=100$)

Curve M: Moderate noise location ($V = 10$)

Curve L: low noise location ($V=1$)

1.3 Noise Amplitude Distribution (NAD)) determination of degradation

1.3.1 *Definitions*

1.3.1.1 Noise amplitude distribution

A presentation of impulsive noise data in terms of its basic parameters of spectrum amplitude and impulse rate.

1.3.1.2 Spectrum amplitude

The vector sum of the voltages produced by an impulse in a given bandwidth, divided by the bandwidth.

1.3.1.3 *Impulse rate*

The number of impulses that exceed a given spectrum amplitude in a given period of time.

1.3.1.4 Impulsive-noise tolerance

The spectrum amplitude of impulses at a given pulse-repetition frequency at which the receiver, with an input signal applied at specific levels, produces standard signal-to-noise ratios at the output terminals.

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1.3.2 Determination of degradation

Degradation of receivers can be determined as follows:

- 1.3.2.1 measure the impulsive noise tolerance of the receiving equipment in accordance with applicable IEC standards:
- 1.3.2.2 measure NAD in accordance with applicable IEC standards:
- 1.3.2.3 Superimpose the graphs for the receiver impulse noise tolerance and the NAD.

1.4 Minimum values of field strength to be protected

The minimum values of field strength to be protected in the land mobile service at frequencies above 30 MHz are determined by internal noise generated in the receiver, man-made noise usually in the form of radiation from ignition Systems of motor vehicles and the effects of multipath propagation to and from moving vehicles. Some information on the effects of traffic density is now available. In the maritime mobile service, the level of man-made noise depends on the number and nature of high level sources of noise on the ship.

A convenient measure of the threshold of performance for narrowband receivers is a specified value of

$$\frac{S+ N+ D}{N+ D}$$

ratio, the conventionally accepted value being 12 dB (see Recommendation 331).

This defines the minimum usable field strength for any particular installation, in the absence of man-made noise.

The sensitivity of typical receivers is such that an input signal of 0.7 μ V e.m.f. (assuming a receiver input impedance of 50 Ω) would result in a 12 dB

$$\frac{S+ N+ D}{N+ D}$$

ratio at the output. A mobile service is characterised by large variations of field strength as a function

of location and time. These variations may be represented by a log-normal distribution for which standard deviations of 8 dB at VHF and 10 dB at UHF are appropriate for terrain irregularities of 50 m (see Recommendation 370). To determine the minimum value of median field strength to be protected, it is necessary to specify the percentage of time for which the minimum usable field strength should be exceeded for different grades of service. For land mobile radiotelephony, a high grade of service would require that the value be exceeded for 99% of the time, but, for a lower (or normal) grade of service, for 90% of the time.

The minimum values of field strength to be protected can be determined subjectively, taking into account man-made noise and multipath propagation. Ignition systems of motor vehicles are usually the most prevalent source of man-made noise. Field strength cancellations due to multipath propagation produce an annoyance somewhat similar to that created by ignition systems. When a mobile unit is in motion, both of these annoyances occur at the same time. Only the effects of receiver noise and man-made noise remain when the mobile unit is stationary. The separation of motor vehicles is generally less with slow-moving or stationary traffic and under these circumstances, particularly at the lower frequencies, the degradation experienced in a stationary mobile unit is greater than when it is in motion.

Figures 3 and 4 can be used to determine the combined degradation effects of man-made noise and multipath propagation for the case of vehicles in motion. These figures are based on subjective testing under traffic conditions commonly experienced by most mobile vehicles [FCC, 1973]. Specifically, these traffic conditions are the following: in motion while in a low noise area, in motion in traffic surrounded by other vehicles and stationary surrounded by other stationary or moving vehicles.

The tendency for the curves of Figs. 3 and 4 to merge at the higher frequencies is due to the almost constant multipath degradation effect with frequency and the fact that the degradation effect of man-made noise decreases with frequency.

Degradation is defined as the increase of level necessary in the desired input signal to maintain the receiving signal at the degree of quality obtainable when affected by receiver noise only.

APPENDIX 1

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Definitions of signal are as follows:

Grade	Interfering effect:
5	Almost Nil] Speech understandable,
4	Noticeable] but with increasing
3	Annoying] effort as the grade
2	Very Annoying] decreases
1	so bad that the presence of speech is barely discernible

Some information on field strengths can be derived from Recommendation 370. Additional information can be found in the document of the CCI R, [1966-69], and in the article of Okumura *et al.* [1968].

Information on protection ratios and minimum field strengths may also be found in the "Special Agreement between the Administrations of Belgium, the Netherlands, and the Federal Republic of Germany relating to the use of metric and decimetric waves for fixed and mobile services in border areas, Brussels, 1963", and in the Final Acts of the Special Regional Conference, Geneva, 1960. Similar information may be found in the Agreement between the Telecommunications Administrations of Austria, the Federal Republic of Germany, Italy and Switzerland, Vienna, 1969.

The document of the CCIR [1963-66]. deals with the above questions for signal-to-noise ratios of 30 dB and 40 dB at the receiver output.

Until values based on man-made noise and multipath effects are available, the calculated values of minimum and median values of field strength shown in Fig. 2 may be used for hand-portable stations.

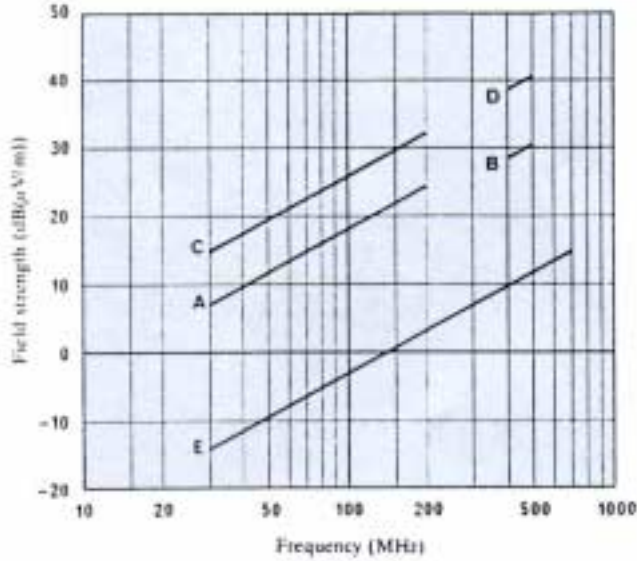


FIGURE 2 - Minimum usable and median field strengths for typical hand-portable stations (based on minimum usable input of $0.7\mu V$ e.m.f., in the absence of man-made noise)

Characteristics assumed: antenna gain {
 {A and C: - 9dB
 {B and D: - 6dB

A, B: median, normal grade
 C, D: median, high grade
 E: minimum usable field strength (dipole antenna)

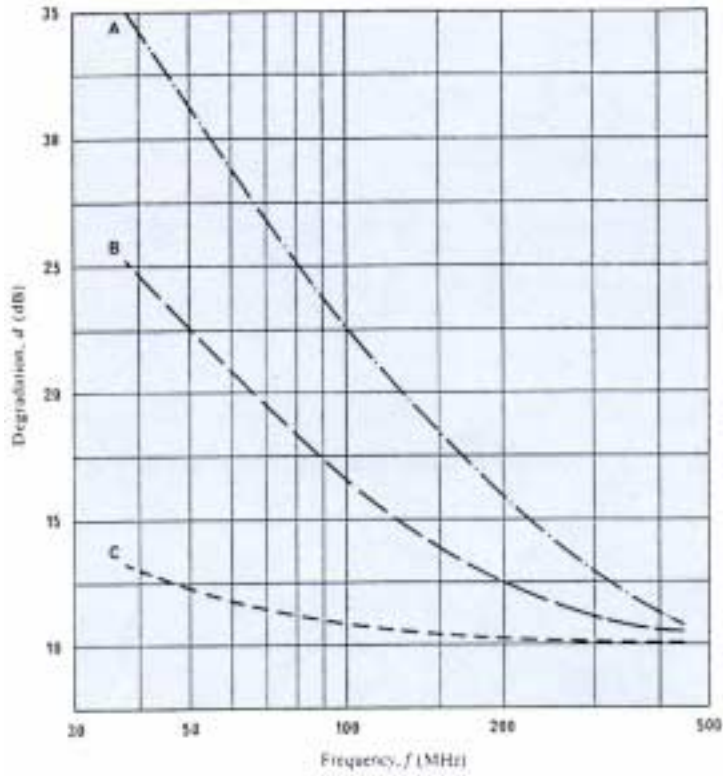


Figure 3 - Variation of degradation of mobile reception and minimum values of field strength
 To be protected for signal quality grade 4 and receiver sensitivity of $0.7 \mu V_e.m.f.$
 Field Strength $+ -41 + d + 20 \log f \quad dB(\mu V/m)$

- A: mobile vehicle stationary within a high noise area
- B: mobile vehicle in motion within a high noise area
- C: mobile vehicle in motion within a low noise area

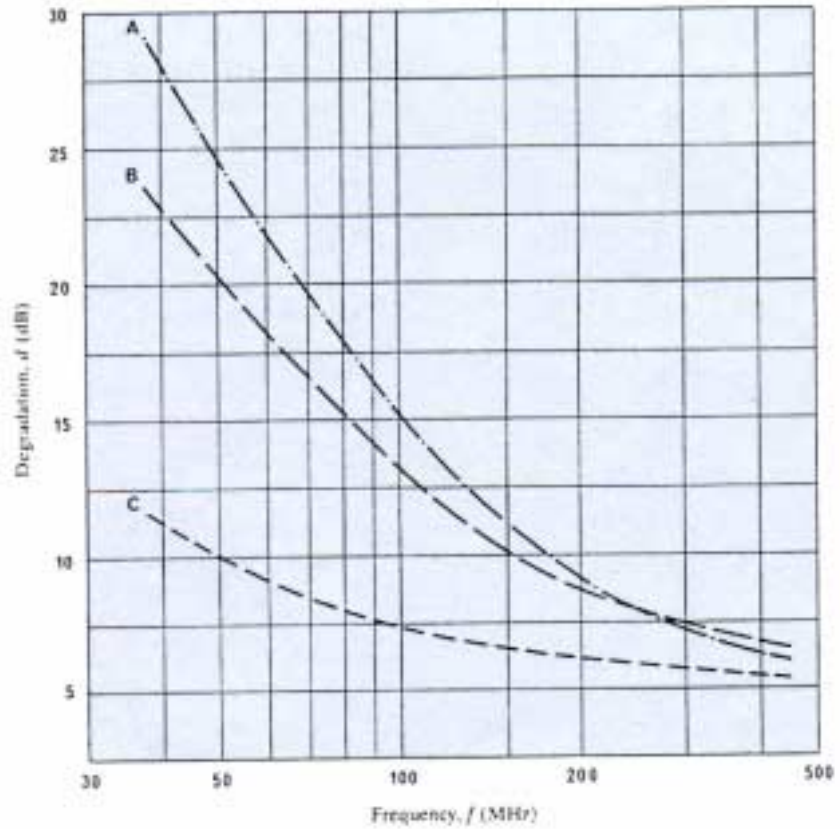


FIGURE 4 - Variation of degradation of mobile reception and minimum values of field strength To be protected for signal quality grade 3 and receiver sensitivity Of 0.7 μV e.m.f.

$$\text{Field strength} = -41 + d + 20 \log f \quad \text{dB}(\mu V/m)$$

- A: mobile vehicle stationary within a high noise area
- B: mobile vehicle in motion within a high noise area
- C: mobile vehicle in motion within a low noise area

- This information is abstracted from CCIR Report 358-5

APPENDIX 2

SYSTEM AVAILABILITY

The cost and practicability of any communications system depend on the proportion of time for which the communications channel must be available, ie deliver the required signal with at least the minimum specified ratio of signal to noise. Factors which contribute to communications channel failure include:

- Propagation Variability
- Co-channel interference
- Icing or wind deflection of antennas
- Radio equipment failure
- Down time required for equipment servicing
- Loss of supply
- Failure of signal input equipment
- Unavailability of a multi-access channel

The reduction of down time due to each of these causes usually costs money and the most economic system requires a careful balance of these factors. Where long breaks in service (typical of site inaccessibility and antenna icing or power loss in winter) are not acceptable, reserve equipment, alternative routing or other costly measures may be needed.

The service life over which the system availability is required to meet its objective must be defined.

System Type	Median Field Strength dB μ V/m	Typical Availability % time
Private mobile radio		88
Private multi user mobile		92
Trunked mobile		99
Fixed links	Define as required by system and grade of service necessary	

Site operators should agree basic rules for loss-of-service with their site users, for example:

- 1 Longest permissible outage without notice
- 2 Longest permissible outage with 7 days notice
- 3 Signal reduction (dB) acceptable (with 7 days notice) which allows minimum essential facility.
This parameter may also be subdivided by time of day or week.

APPENDIX 3

REPORT 739-1

INTERFERENCE DUE TO INTERMODULATION PRODUCTS IN THE LAND MOBILE SERVICE BETWEEN 25 AND 1000 MHz *

(Study Programme 7C/8)

(1978 - 1986)

1. Introduction

Intermodulation causes a degradation to radio services when:

- Unwanted emissions are generated in transmitters:
- Unwanted emissions are generated in non-linear elements external to the transmitters:
Or
- In-band intermodulation products are generated in the radio-frequency stages of receivers.

These cases occur with varying probability and varying severity. They may be reduced by equipment design or careful choice of channels, but solutions of the latter type to one case intermodulation may increase another.

2. Transmitters

The last active stage of a transmitter is usually an amplifier. The current in this stage will be repeatedly swept from zero amplitude to a maximum and the impedance of the output active device is liable to contain a small amount of non-linearity.

If any other signal from another emission is also present at the output of this stage the non-linearity will give rise to a number of products having frequencies with specific frequency relationships to the frequency of both the wanted and unwanted signals. These products are called intermodulation products, and their frequencies may be expressed as

$$f_I = C_1 \cdot f_1 + C^2 \cdot f^2 + \dots + C^n \cdot f^n$$

where the sum $|C_1| + |C^2| + \dots + |C^n|$ is the order of the product.

The odd-order intermodulation products may be relatively close in frequency to the wanted signal frequency and thus coupled via the output circuit to the antenna with minimal attention.

In order to be able to calculate the effects of these products, it is necessary to establish certain terms.

Coupling loss. A_i

The coupling loss, A_i , in dB, is the ratio of the power emitted from one transmitter to the power level of that emission at the output of another transmitter which may produce the unwanted intermodulation product.

Typical values for the coupling loss on a common site are of the order of 30 dB.

Intermodulation conversion loss. A_i

The intermodulation conversion loss A_i , in dB is the ratio of power levels of the interfering signal from an external source and the intermodulation product, both measured at the output of the transmitter.

Without any special precautions, typical values for semi-conductor transmitters are to be found in the range of 5 to 20 dB and for the valve transmitters, in the range of 10 to 30dB, in respect of the 3rd order product ($2f_1 - f_2$)

The overall loss between a transmitter providing the unwanted emission giving rise to the intermodulation product and a receiver operating at the frequency of the product is:

$$A = .4, + A_i + A_p$$

Where A_p , in dB, is the propagation loss of the intermodulation product between the relevant transmitter output and the receiver input.

* this information is abstracted from CCIR Report 739

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Note that the power level of the transmitter in which the intermodulation is produced is not included in the formula but this level may have an effect on the value of the intermodulation conversion loss A_i .

Example

Signal frequency of transmitter producing intermodulation product:	f_1
Signal frequency of transmitter whose emission is coupled into transmitter (f_2):	f^2
Power level of transmitter (f^2):	-10 dBW
Assumed coupling loss A_i	30 dB
Assumed conversion loss A_c :	15 dB
Assumed receiver threshold signal level:	-150 dBW

Overall path loss is equal to 10 dBW - (-150 dBW) = 160 dB.
 If $A_{i,c} + A_i = 45$ dB, then the required value of A_p is 115 dB

Figure 1 gives an example of propagation path losses at 100 MHz and, under free space conditions' a very large distance is required between the "product producing" transmitter and the receiver. If the receiver is a mobile station, this distance is considerably reduced. It may be concluded therefore that 2-frequency operation provides - better conditions for the reduction of the effects of inter-transmitter intermodulation if the base receive frequency band is remote from the transmit frequency band.

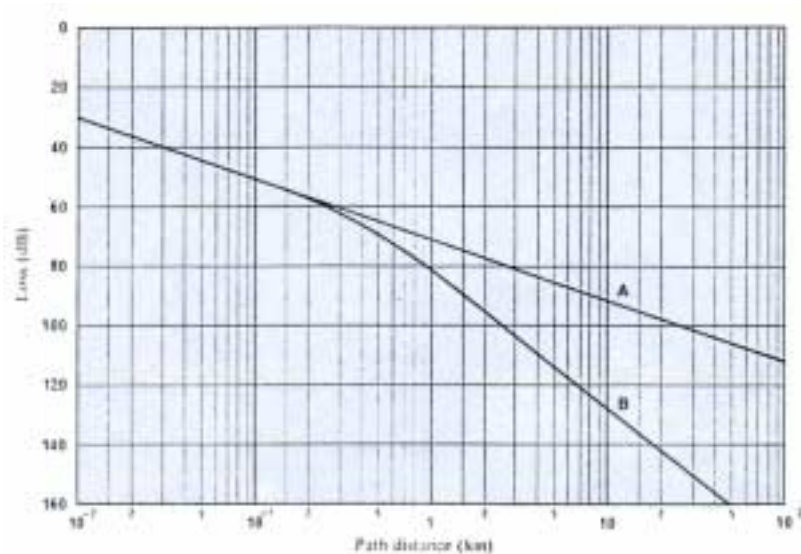


FIGURE 1- Short range path loss at 100 MHz (dipoles assumed)

Curves A: free space

B: Recommendation 370-3: $h_1=37.5$ m, $h_2=2$ m

The intermodulation caused by two or more mobile transmitters will be worse when the mobiles are closest together and when the desired signal originates at a mobile at the edge of the service area, an event which is associated with some (perhaps small) probability. The mobile being interfered with will be received at its base as a signal of widely varying level (due to fades and shadows) which will be independent of the 1M interference. These wide and independent variations can allow the 1M to reach harmful values for periods of time, even when its average value is much less than that of the signal.

3. External non-linear elements

On most sites, external non-linear elements will be at junctions in masts, feeders, and other antenna which are closely coupled to the radiating elements of nearby transmitters.

It would be useful to determine conversion losses for masts etc., of various qualities in terms of the isotropic loss between transmitters and the masts, etc. It would then be possible to establish specific values a good engineering practice.

4 Receivers

.An intermodulation response is a response at the output of a receiver from an in-band signal generated in the RF stages of the receiver. This in-band signal is generated by the presence of two (or more) high-level signal in a non-linear section of the RF stages. As with transmitters, the two (or more) unwanted signals must have specific frequencies such that the intermodulation product lies within the frequency band accepted by the receiver

This receiver characteristic is normally recorded as a single measurement with the level of the unwanted signals equal and is given as a single ratio which is:

the ratio of the level of these two equal signals

to

- the apparent level of the intermodulation product at the input to the receiver.

It is possible, however, to cause a similar product level when the unwanted signals are not equal.

Figure 2 gives examples (3 theoretical and 1 measured) of the overall third order intermodulation characteristic of receivers. It shows that intermodulation may easily be a problem

- when one of the unwanted signals is not excessively high. Such curves can be used to calculate other intermodulation product levels when the unwanted signals do not have values equal to those plotted.

For a product with a frequency relationship of the form $(2f_1 - f_2)$, the level will be proportional to the level of the signal at frequency f_2 , but will vary as the square of the level of the signal f_1 i.e. the product will have an amplitude of the form $k \cdot V_1^2 \cdot V_2$, where V_1 , V_2 are the amplitudes of the signals at frequencies f_1 and f_2 respectively.

When a mobile receiver is used in a multi-channel system it will be subject to an intermodulation response due to many equally spaced high level signals. The following relationship has been suggested by the People' Republic of China to relate the maximum permissible signal level with the intermodulation response rejection ratio of the receiver [CCIR, 1982-86a]:

$$E_s + 3E_M \geq 3E_{max} + B + k(n,p)$$

Where

E_s : wanted signal level (dB) above sensitivity:

E_{1max} : maximum interference signal level (dB) above sensitivity:

E_M : receiver's third-order intermodulation rejection ratio (dB) (for two signals):

B : RF protection ratio (dB)

$k(n.p)$: a constant dependent on the number of channels n and channel sequence p .
The derivation of this formula and the calculation of $k(n.p)$ are given in Annex 1

Reduction of intermodulation product levels in transmitters

5.1 Intermodulation conversion loss

It is obvious that a reduction of the non-linearity, particularly of the odd-numbered orders, will improve the overall performance and increase the value of the intermodulation conversion loss A_1 .

From the example in § 2. it is evident that a considerable improvement is necessary before the relevant path loss reduces to manageable values.

5.2 Coupling loss

The coupling loss can obviously be increased by increasing the distance between the relevant transmitter but it may not always be possible to do so effectively at a particular site.

Ferrite isolators could be used in the output circuits of the transmitter in which the product is generated but present production units do not provide much more than 25 dB additional loss and the use of multiple units is inhibited by the inherent non-linearity of the isolators themselves. To suppress undesirable products, filters may be required after such isolators. These isolators are equally effective irrespective of the frequency spacing between f_1 and f_2 .

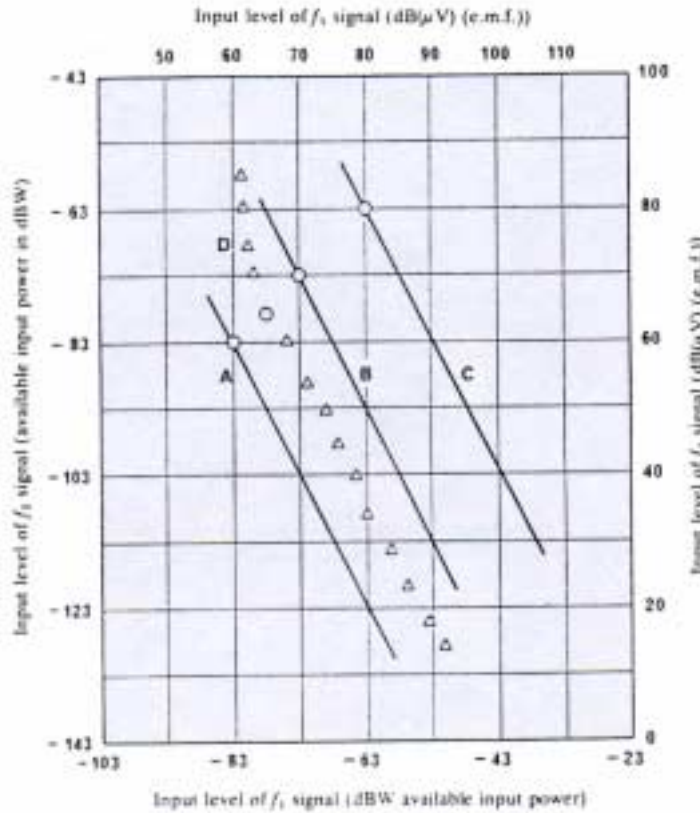


FIGURE 2 - Receiver intermodulation characteristic

Levels of unwanted input signals which together produce a constant product level.

Curves A,B and C: derived characteristics based on a single recorded value of the receiver's third order intermodulation characteristic, i.e. for $(2f_1 - f_2)$.

Curves A: based on a single value, with both input levels at a level of 60dB(μ V) (e.m.f. to 50 ohms).

B: based on a single value, with both input levels at a level of 70dB(μ V) (e.m.f. to 50 ohms).

C: based on a single value, with both input levels at a level of 80dB(μ V) (e.m.f. to 50 ohms).

D: measured values for a receiver for which the specified criterion is achieved with equal input signal levels of 65.5 dB(μ V) (e.m.f. to 50 ohms).

Cavity Filters can also be used and examples of their theoretical responses are given in Fig. 3. They may be used in cascade or in more complex series-parallel combinations but in all cases, their performance is dependent on the frequency spacing between f_1 and f_2 . They have the advantage that they will also attenuate the product level at the input to the antenna or transmission line and thus increase A1.

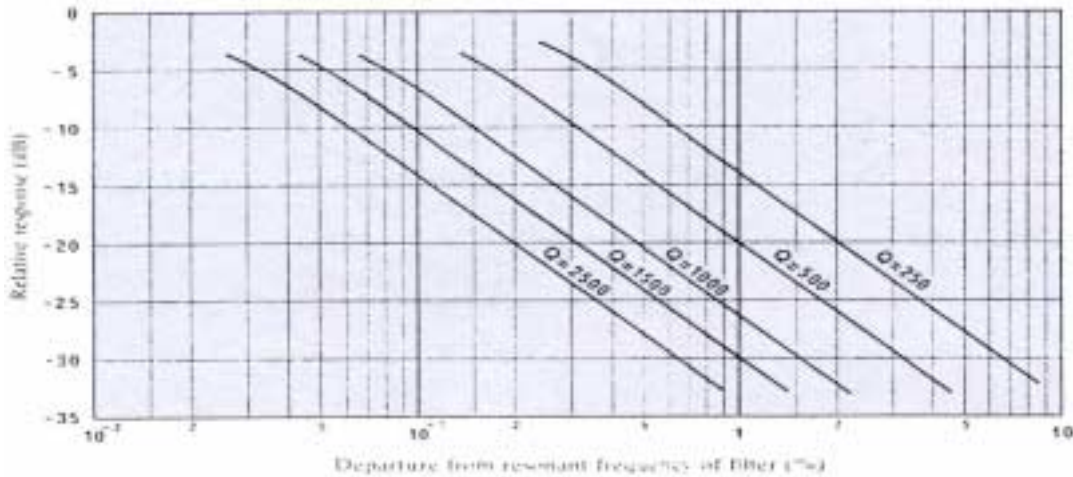


FIGURE 3 - Theoretical response of cavity band-pass filters

For values of loaded Q of 250-2500.

Note. - The unloaded Q should be at least 5 times the loaded Q and preferably 10 times

An economic and efficient filter is the coaxial cavity resonator, either in its pure quarter-wavelength form or with varying degrees of modification to reduce the overall tenth and improve the value of the loaded Q. The resonator should be robust, simple to tune, highly efficient in terms of transmission loss, and provide a high degree of isolation at the required frequencies. Resonators for use with transmitters should have a low temperature coefficient and good thermal conductivity. So that their performance is not affected by changes in ambient temperature or through being heated by transmission losses. Temperature compensation can be employed to maintain the length of the centre conductors. Physical robustness is necessary to avoid changes in technical parameters from being caused by mechanical shock or deformation. The physical and mechanical design should also prevent the formation of electrical discharges or corona. Adjustable telescopic centre conductor assemblies permit a variation of resonant frequency of, typically, $\pm 1.5\%$ of the centre frequency.

Reliable and economical resonators can be manufactured from high-conductivity aluminium for the larger units, and silver-plated copper or brass for smaller units. Practical limitations of mechanical engineering govern the upper limits of Q obtainable with a cavity resonator. As the diameter is increased, the value of the unloaded Q is increased, but the sensitivity of tuning and the temperature coefficient become more critical. Practical and satisfactory resonators with a power handling capacity of up to 250 W can, however, be made for the band 150-170MHz, for example, having an unloaded Q as large as 18 000, with a diameter of 0.58 m. and length 0.63m, giving 35 dB discrimination at a frequency 1% removed from the resonant frequency.

It is not usual to employ cavity resonators for values of Q_0 below about 1000, since there are more satisfactory techniques, e.g. helical resonators, which can be coupled together to form smaller but relatively efficient filter units. Tables I and II give the choice of types of filter and their relative costs.

TABLE I *Relative sizes and costs of resonators (150-174 MHz)*

1	2	3	4	5	6
<i>Reference</i>	Q_0	QL	<i>Attenuation at 1% F_0 (dB)</i>	<i>Diameter (m)</i>	<i>Relative cost of practical resonators</i>
A	920	100	7	0.03	1.0
B	2300	250	14	0.07	1.7
C	4600	500	20	0.14	2.8
D	6900	750	24	0.21	3.3
E	9200	1000	26	0.29	3.9
F	11700	1250	28	0.37	4.6
G	13800	1500	30	0.46	5.3
H	16100	1750	32	0.53	6.8
1	18400	2000	35	0.58	7.1

TABLE II - *Relative costs of practical resonators for other frequencies*

Resonant Frequency (MHZ)	Cavity height (m)	Unloaded Q					
		920	2300	4600	6900	9200	13800
50- 60	1.55	*	*	8.7	12.0	14.7	+
60- 80	1.15	*	*	5.5	7.3	10.6	14.9
95- 110	0.85	*	3.3	4.1	5.2	6.4	10.7
120- 150	0.68	*	2.6	3.3	4.2	5.0	8.9
150- 174	0.63	1.0	1.7	2.8	3.3	3.9	5.3
160- 180	0.52	0.9	1.5	2.4	2.9	3.4	4.6
400- 500	0.24	0.8	1.0	1.5	2.0	2.2	3.0

Note. - Items not tabulated are identified as follows:

*Helical resonator superior

+Single cavity large and somewhat uneconomic.

Compared with the total cost of the radio equipment at a base station, cavity resonator filters are an economical and efficient means of reducing spurious emissions and preventing or minimizing interference.

5.3 Identification of the source of an intermodulation product

The frequency of the third order intermodulation resulting from the interaction of two transmitters may be expressed as either $2f_1 - f_2$ or $2f_2 - f_1$.

If the product is $2f_1 - f_2$, the mixing is occurring within or close to the transmitter operating on f_1 .

Conversely, if the product is $2f_2 - f_1$, the mixing is occurring within or close to the transmitter operating on f_2

In the case of FM or PM emissions, the deviation caused by modulation is doubled when a second harmonic is generated. So if the modulation on one of the intermodulation products appears to be excessive, this modulation is probably transferred from the f_1 signal of a $2f_1 - f_2$ mixing.

APPENDIX 3

Rep. 739-I

6. Reduction of intermodulation products in receivers

As with transmitters, a reduction in the non-linearity of a receiver will improve the performance.

Attenuation at the input of the receiver may be used to reduce the level of an intermodulation product. The levels of these products are related to the levels of the signals that produce them, in such a way that the attenuation (in dB) of each "nTH" order product will, in most cases, be n times the attenuation (in dB) of the wanted signal.

For example, a 3 dB attenuator will reduce a third order product by 9 dB while reducing the wanted signal by 3 dB. This may also be used as a test device to prove that the intermodulation product is being generated in the receiver.

Cavity filters can be used, either as rejection filters to f_1 and/or f_2 or as band-pass filters to the wanted signal. Again the effectiveness of these filters depends on the frequency spacings involved.

7. Reduction of intermodulation interference by frequency arrangements

The frequencies to be used can be arranged so that no receiver on the product frequency is required to operate in an area where the unwanted signals may produce an intermodulation product of sufficient level to disturb the service. If this level is at the maximum sensitivity level of the receiver; it will mean receivers cannot be used for distances up to 2 km from the sites of the base station operating at f_1 and f_2 . This applies even when the f_1 and f_2 stations are

separated by several kilometres and thus implies that the base station on the product channel must be sited outside the service area of stations operating on f_1 and f_2 . This leads to very poor use of the frequency spectrum.

In systems that operate a number of frequency channels, most cases of harmful base transmitter and mobile receiver intermodulation within the system can be alleviated by the choice of even channel sets at the base stations. This means that the channels of each base station are evenly distributed at a constant frequency separation. In a service area the intermodulation products within the band used will in that case coincide with channels of the set, and the ratio of the desired signal to the intermodulation product in a mobile receiver is independent of the distance and propagation characteristics.

8. Reduction of intermodulation interference by other arrangements

If continuous tone signalling is used, the receiver will operate only in the presence of this signalling tone and it is then necessary only to ensure that the wanted signal on the product channel exceeds the level of an unwanted product off f_1 and f_2 by an amount in excess of the required protection ratio. This can be best assured by siting the product channel base transmitter at the same, or near to, the site of stations operating on f_1 and f_2 .

Under these conditions, the need for filters or other devices in the transmitter or receiver is reduced.

APPENDIX 4

Rep. 1019 REPORT 1019

SOURCES OF UNWANTED SIGNALS IN MULTIPLE BASE STATION SITES IN THE LAND MOBILE SERVICE *

(Question 7-2/8)

(1986)

I. Introduction

The greatly increased use of land mobile services has resulted in a dramatic increase in the number of base stations on any one site, particularly on those sites strategically placed to serve large built-up areas. This has led to instances of severe interference due to unwanted signals being generated at the site. This Report is not intended to examine every possible type of interference but rather to indicate the more commonly occurring sources. It should be particularly noted that transmitters of other services may be involved.

2. Simple frequency relationships

As land mobile frequency bands are used throughout the VHF/UHF spectrum there may be harmonic relationships between frequencies in the various bands. The equipment cabinet, the power supply cabling and land-line cabling can contribute to the level of these unwanted harmonic signals.

Other interfering signals can be caused by simple mixes either in transmitter output stages or at the antenna mast. As an example, if the signal from a VHF broadcasting transmitter at 93 MHz mixes with a signal of the mobile service at 170.5 MHz, a difference signal of 77.5 MHz can be produced. This can cause a problem if it is a receive frequency of the mobile service.

3. Complex frequency relationships

3.1 Generation of intermediate Frequency and/or its derivatives

Interference can be caused in a receiver where signals are received from two transmitters whose frequencies are separated by an amount equal to the IF, or a submultiple of the IF, of the receiver.

3.2 Generation of transmit/receive (Tx/Rx) difference frequency

This problem arises on Sites where there are several base stations having "repeater" or "talk-through" facilities, i.e. the transmitters and receivers are in use simultaneously. If the Tx/Rx spacing is constant (D), an incoming signal from a mobile station will produce in the base station transmitter output stage a difference frequency, D . Any other base station transmitter may now mix with D to produce its own receiver frequency in the same band.

4. Intermodulation products

4.1 Generated external to the site

Under this heading, products arise from stations on adjacent sites, and, in particular, the third order product i.e. $2f_1 - f_2$, which is prevalent in large built-up areas. In some instances significant intermodulation products up to and including the seventh order have been noted and in exceptional cases the interference has been traced to the nineteenth order.

4.2 Intermodulation products generated on-site by non-linear junctions on the mast

More study is required to verify the mechanisms and levels of such interference, which certainly exists in the land mobile bands. However, at lower radiated powers, the significance of these products is reduced, compared with other forms of non-linearity, e.g. § 4.1 and 4.3.

4.3 Intermodulation products generated on-Site by non-linearity in components of the system

Junctions between dissimilar metals cause non-linearity, and therefore intermodulation products, when subjected to radio frequency currents, and recent work has highlighted such products up to the eleventh order at VHF caused by connectors, cables and dissimilar junctions in what might be regarded as otherwise innocuous components.

For the long-term development of the land mobile radio industry, it may be necessary to define the non-linearity of passive components in the system.

5 Transmitter noise

Until quite recently, most transmitters on base station sites had valve output stages, which fortuitously were not a major contributor to the noise spectrum compared with the more modern solid-state output stages.

With a valve output stage, the unwanted noise is generally narrow-band, having frequencies which are multiples of the crystal oscillator frequency or a combination derived from the multipliers. However, in the case of solid-state output stages the noise is generally wideband and higher in level.

Figures 1, 2 and 3 give the graphical results of measurements made in the United Kingdom of noise from VHF transmitters with thermionic valve output stages and with solid-state output stages for the VHF "high band" (150-170 MHz) and VHF "low band" (71.5-87.9 MHz).

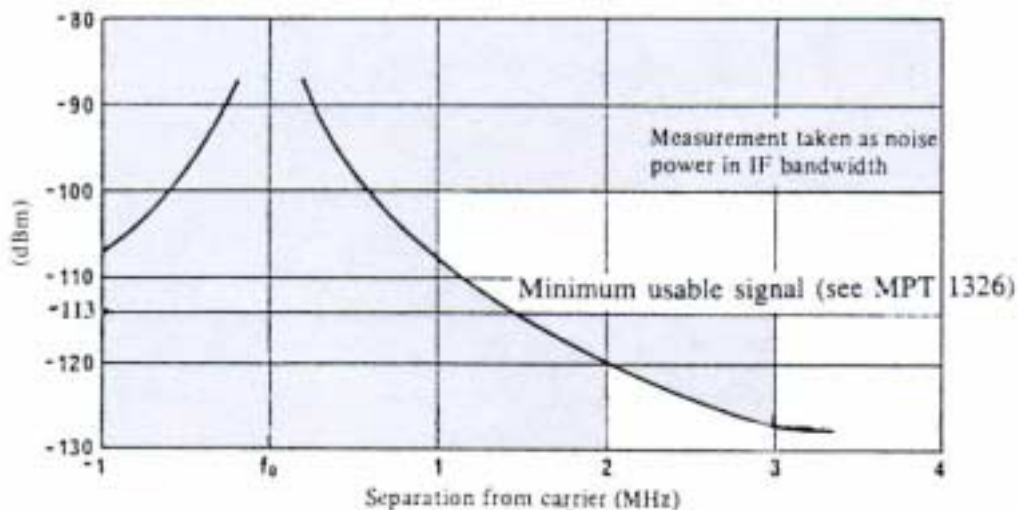


FIGURE 1 – Typical transmitter noise VHF high band (150-170 MHz): thermionic output stage

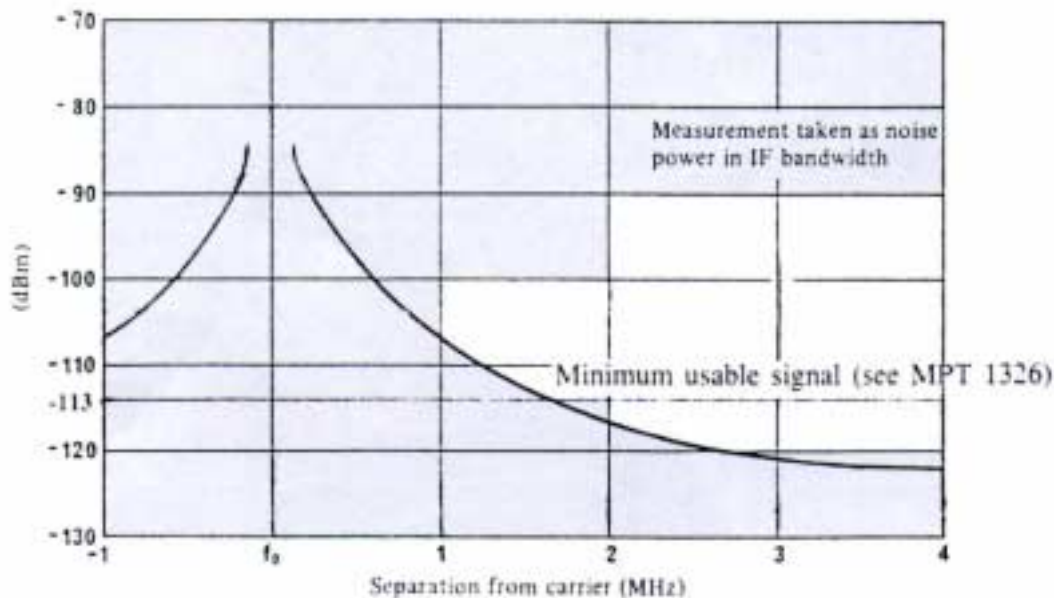


FIGURE 2 – Typical transmitter noise VHF high band (150-170 MHz): solid-state output stage

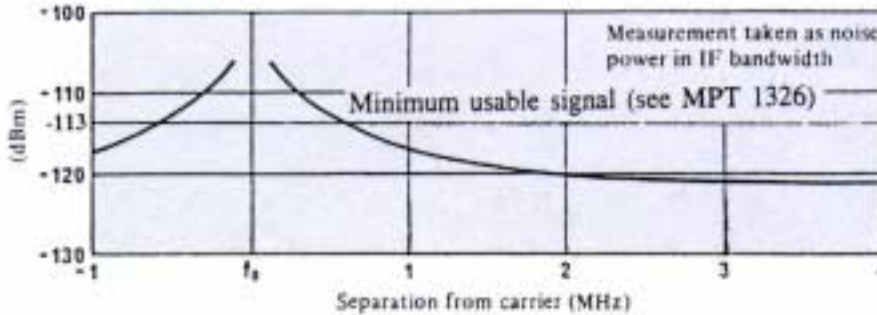


FIGURE 3 – Typical transmitter noise VHF low band (71.5-87.9 MHz): solid-state output stage

6. External electrical noise

Apart from ignition noise, there are the well-known sources of radio interference, which continue to proliferate, particularly from industrial users, i.e. RF heating, microwave ovens, X-ray and medical equipments. These normally provide a broad spectrum of noise which tends to vary in frequency.

Screening or suppression of the interfering equipment normally reduces the problem to an acceptable level.

There is however, a new family of sources, namely computers and computer peripherals, which are currently causing problems with broadband noise over the VHF spectrum.

7. Summary

There are instances where the present engineering practices in multiple transmitter sites have allowed the generation of excessive unwanted signals. With the increased use of land mobile radio it is desirable to perfect techniques to reduce interference effects in the future. There is a need for better site engineering in order to establish "quiet" base station sites for trunking networks and cellular radio.

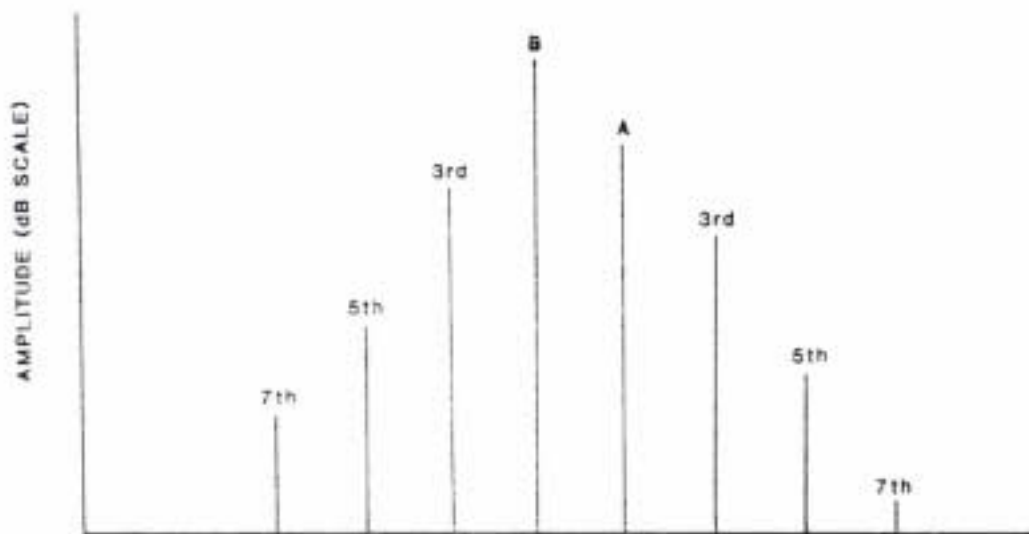
The following should be considered:

- spurious emissions from transmitters;
- filtering of transmitter outputs to reduce spurious emissions and noise at frequencies near the carrier;
- use of directive isolators in transmitter output stages;
- additional filtering to provide protection at adjacent frequency bands;
- non-linear effects at all points in the system.

APPENDIX 5

INTERMODULATION INTERFERENCE

At the Output of a transmitter of frequency B, the level of the interfering signal due to a transmitter on frequency A will be attenuated by the isolation between the transmitters. In this case the amplitudes of the intermodulation products of the same order will not be equal. (Appendix 3 refers, CIIR REPORT 739-I).



INTERMODULATION SPECTRUM

(at the output of transmitter frequency B, interfering signal frequency A)

APPENDIX 5

4A+3B=7fa+ Δf		A+3B=8fa+2Δf		5A+4B=9fa+ Δf	
4B+3A = 7fa - Δf		5B+3A=8fa-2Δf		5B+4A=9fa+ Δf	
*4A-3B=fa+7Δf	7th Order	5A-3B=2fa+8Δf	8th Order	*5A-4B=fa+9Δf	9th Order
*4B-3A=fa-7Δf		5B-3A=2fa-8Δf		*5B~4A=fa-9Δf	
5A+2B=7fa+3Δf	(Oty 12)	6A+2B=8fa+4Δf	(Otv 15)	6A+3B=9fa+3Δf	(Oty 16)
5B+2A=7fa-3Δf		6B+2A=8fa-4Δf		6B=3A=9fa-3Δf	
5A-2B=3fa+7Δf		6A-2B=4fa+8Δf		6A-3B=3fa+9Δf	
5B-2A=3fa-7Δf		6B-2A=4fa-8Δf		6B-3A=3fa-9Δf	
6A+B=7fa+5Δf		7A+B=8fa+6Δf		7A+2B=9fa+5Δf	
6B+A=7fa+5Δf		7B+A=8fa-6Δf		7B+2A=9fa-5Δf	
6A-B=5fa+7Δf		7A-B=6fa+8Δf		7A-2B=5fa+9Δf	
6B-A=5fa-7Δf		7B-A=6fa-8Δf		7B-2A=5fa~9Δf	
		4A+4B=8fa		8A+B=9fa+7Δf	
		4A-4B=8fa+8Δf		8B+A=9fa-7Δf	
		4B-4A=8fa-8Δf		8A+B=7fa+9Δf	
				8B-A=7fa-9Δf	

* Inband

INTERMODULATION PRODUCTS

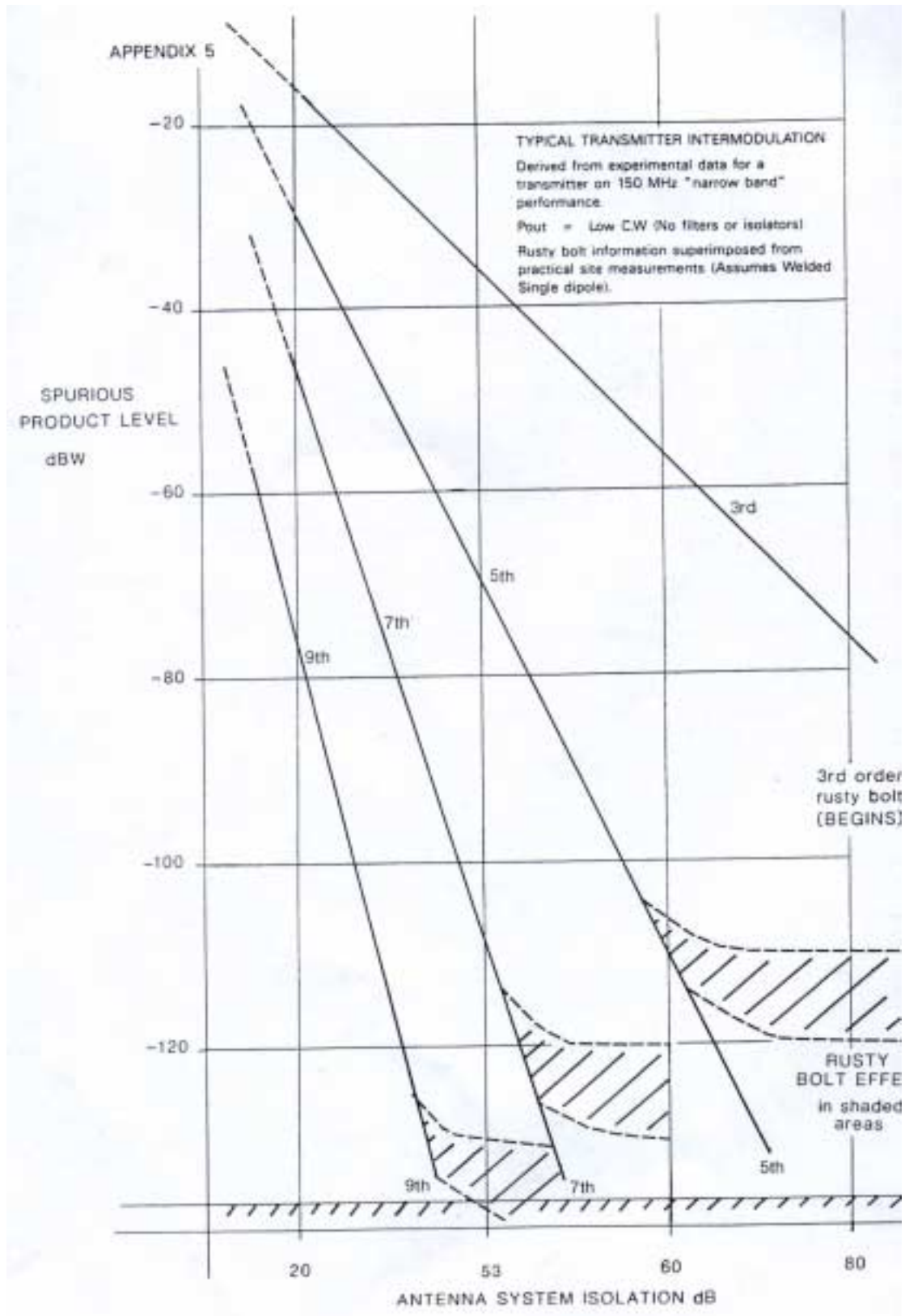
Intermodulation between frequencies of channels allocated in a bandwidth B Hz will be spread over the spectrum from DC to n times the highest frequency used (where n is the order of the non-linearity producing the intermodulation). Of particular interest are those products which fall back within and around the band B. This group will extend over a range of n x B Hz. the distribution within this being dependent on the initial distribution within B. In addition the modulation of the generating carriers will cause each individual product to be spread over n times the occupied bandwidth.

For example if the band B were 2MHz wide from 154 to 156 MHz then 9th order intermodulation products would extend from 146 to 164 MHz and each product would cover a band of 72 KHz if the occupied bandwidth is taken as ± 4 KHz.

The number of such products is given in table 5.1

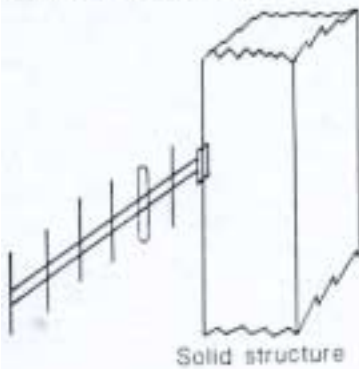
Table 5.1 - Number of Intermodulation Products

Non-linearity Order number	3 rd	5 th	7 th	9 th
Number of channels				
2	2	2	2	2
3	9	15	21	27
4	24	64	124	204
5	50	200	525	1095
6	90	510	1770	4626
7	147	1127		



COMMON ANTENNA CONFIGURATIONS

GOOD PERFORMANCE



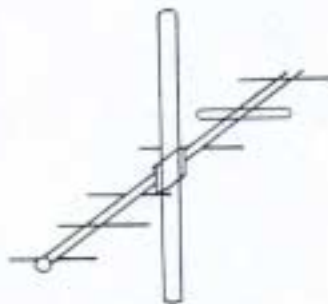
Solid structure



Triangular metal mast

ADVANTAGES

- a) Little gain or pattern change
- b) Good cross-polar performance
- c) Good intermodulation performance



Pole mounted

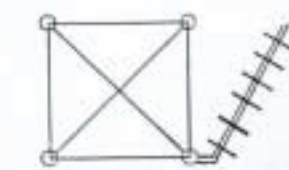
ADVANTAGES

- a) Acceptable gain loss
- b) Small loss of cross-polar performance
- c) Small degradation of intermodulation level

ACCEPTABLE PERFORMANCE



Pole mounted



Square section mast

DISADVANTAGES

- a) Loss of gain and directivity
- b) Dubious cross-polar performance

APPENDIX 7

ACHIEVED CROSS POLAR DISCRIMINATION (CPD) FOR ANTENNAS MOUNTED AT AN ANGLE TO A PRECISE HORIZONTAL AND VERTICAL FRAME OF AXES

Angle of plane of polarisation from nominal (degrees)	Achieved CPD for various test range values (dB)			
	Ideal Antenna	40	30	20
0 (Correctly aligned)	∞	40	30	20
0.1°	55	38.6	29.6	19.6
0.5°	41	34.6	27.9	19.3
1°	35	31.2	26.1	18.6
2°	29	27.0	23.5	17.4
5°	21	20.2	18.5	14.5

The table indicates the CPD which is achieved between an antenna mounted with its polarisation plane exactly horizontal and vertical, and an antenna mounted with a small angular error. As an example two antennas providing 40 dB CPD when correctly mounted provide a CPD of 27 dB if mounted with an alignment error of 20.

The table emphasises the importance of accurate mounting; the achievement of a CPD of 30dB or more requires especial care at frequencies at which the antenna elements are small or inaccessible. In such cases it is necessary to optimise cross polar performance by electrical measurements.

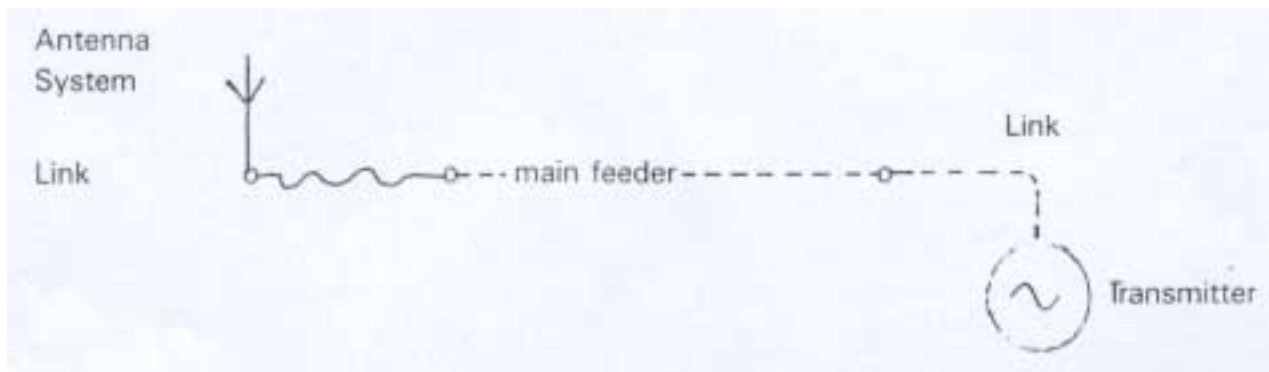
APPENDIX 8

CALCULATION PROCEDURE FOR A SYSTEM REFLECTION COEFFICIENT BUDGET

	Component Of System	Typical Figures		
		VSWR	Reflection Coefficient	Return Losses
A (from manufacturer's data)	Antenna	1.3	0.13	
B (from cable data)	Flexible link feeders		0.07	
C (= A + B)	Reflection coefficient At top of main feeder		0.20	
D (from C)	Return loss at top of main feeder			14dB
E (from cable data)	Main feeder attenuation			
F (= D + 2E)	Return loss at bottom of main feeder			20dB
G (from F)	Reflection coefficient at bottom of main feeder		0.10	
H (from cable data)	Link to transmitter		0.07	
J = G + H	Condition at transmitter	1.4	0.17	

The cable reflection coefficients quoted are typical; the reflection caused by the terminations and any adaptors which are used must be included.

See Appendix 9 for formulae and method of calculation



APPENDIX 9

ANTENNAS AND FEEDERS: CALCULATION OF SYSTEM REFLECTION PERFORMANCE

When several components are connected together in series, the reflected waves caused by each discontinuity travel back from the discontinuity towards the system input. In general the reflection from each discontinuity will arrive at the system input with a phase which has a random relationship to other reflections, but in the worst case all these reflections will add in phase. This will almost certainly occur in a broadband system over some part of the operating band.

To convert from VSWR (U) to voltage reflection coefficient ($p v$),

$$p v = \frac{\sigma - 1}{\sigma + 1}$$

and conversely

$$\sigma = \frac{1 + p v}{1 - p v}$$

Note that $p v$ is always less than 1 for a passive system; when $p v$ is expressed as a percentage it must first be rewritten in standard form, eg 7% = 0.07.

Return loss is expressed in dB and is given by

$$LR = -20 \log_{10} (p v)$$

-LR

$$\text{or } p v = 10^{\frac{-LR}{20}}$$

The return loss measured at the input end of a cable is always greater than that at the load end owing to the attenuation of the cable. The input VSWR is correspondingly lower than that of the load alone. For a cable with an attenuation of 2dB, the input return loss (L_{in}) is related to the return loss at the load (L_e) by

$$L_{in} = L_e + 2$$

It should be noted that cable manufacturers generally guarantee the input VSWR which will be achieved from an installed cable with both connectors fitted. Now allowance can be made in calculation for the attenuation of the cable in respect of this figure, as it is only guaranteed as the figure which will be measured at the cable input. In practice longer cables are more likely to suffer discontinuities along their length, but the increased attenuation inherent in longer cables limits the degradation of input VSWR caused by distributed discontinuities.

APPENDIX 9

For this reason, very long large diameter cables with very low loss present the greatest VSWR problems to the cable manufacturer and to their installers. The discontinuity represented by any defect becomes more significant with increasing frequency and great care must be taken when handling, bending, clamping and terminating cables for UHF and SHF use.

When choosing cables for the UHF band (900 MHz, 1.5 GHz etc) it should be remembered that coaxial cables have an upper frequency limit above which operation becomes uncertain due to overmoding. This may be approximately found by the relationship.

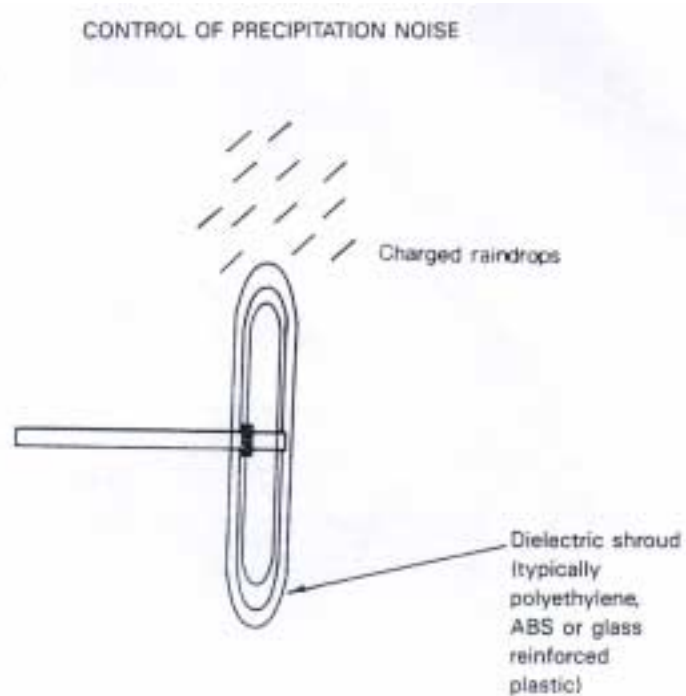
$$\lambda_c = \pi v_r (d_o + d_i)/2$$

Where d_o is the diameter of the outer conductor
 d_i is the diameter of the inner conductor
 v_r is the velocity ratio

For these frequency bands the intended operating frequency should always be quoted when ordering cables or connectors.

APPENDIX 10

CONTROL OF PRECIPITATION NOISE

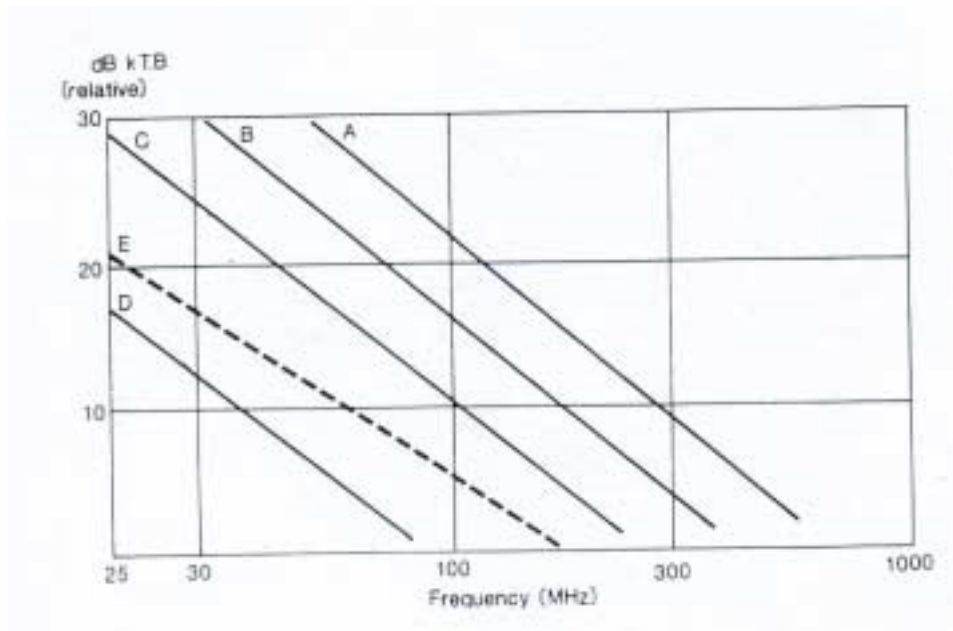


Raindrops which fall in highly convective conditions (not only during thunderstorms) often carry electrostatic charges which inject noise impulses when the drops which fall on a shrouded element will exchange charge with the film of water wetting the shroud; this process radiates some noise energy but the noise power coupled into the antenna is much reduced.

Shrouds typically provide between 25mm and 50mm radial clearance between the antenna element and the wetted surface. They are often fitted only to the dipole element of Yagi antennas.

APPENDIX 11

NOISE POWER ON TYPICAL RADIO SITES



Mean values of man-made noise for a short vertical lossless grounded monopole antenna

Environmental category:

- A: Business
- B: residential
- C: rural
- D: quiet rural
- E: galactic

The above graphs have been taken from CCIR Report 258-4, and have been expanded from 25 to 1000MHz for ease of reference to the Land Mobile Services.

APPENDIX 12

PARAMETERS OF CAVITY RESONATORS

- 1 The resonant frequency is normally proportional to the length of the centre conductor, which approximates to a quarter wavelength.
- 2 The insertion loss is determined by the coupling factor between the input and output coupling structures, and is related to Q.
- 3 The bandwidth of the cavity is directly related to Q as shown below.

Q_0 is the unloaded Q of the resonator.

Q_L is the loaded Q of the resonator.

The relationships between these parameters are as follows:

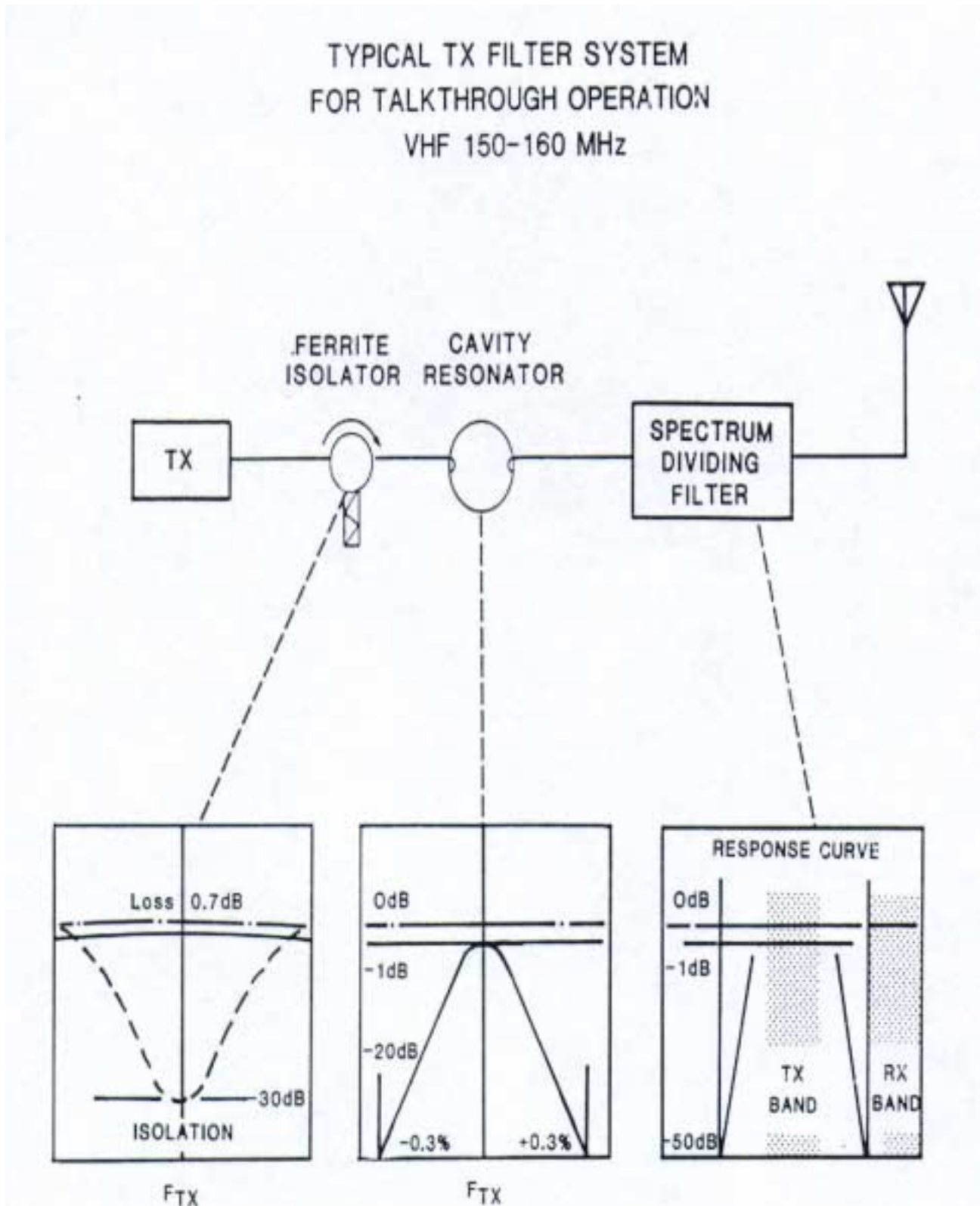
$$Q_L = \frac{F}{\Delta F}$$

Where F = Centre frequency of resonance
 ΔF = 3 dB bandwidth

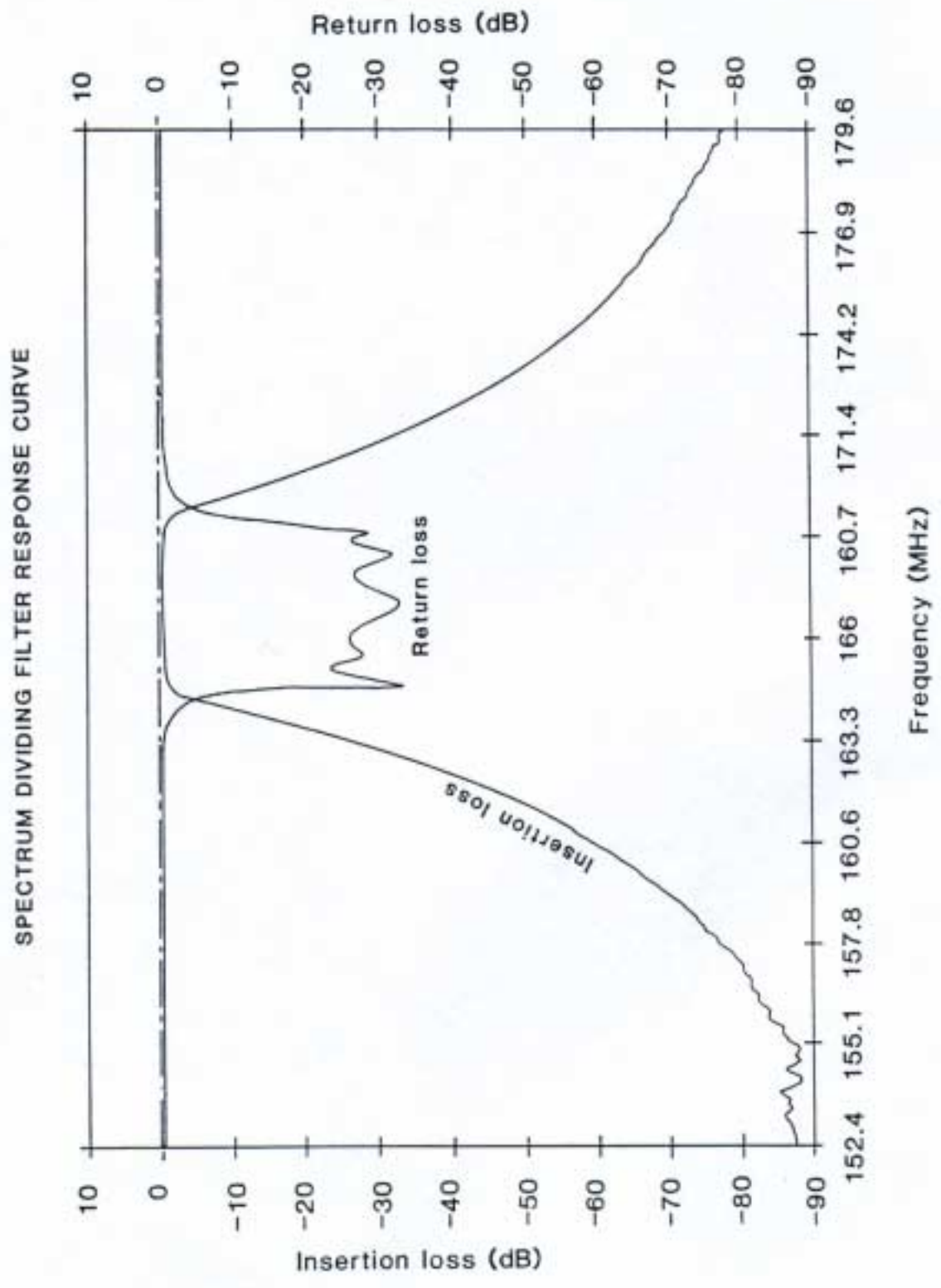
$$\text{Insertion Loss: (dB)} = 20 \log_{10} (1 + \frac{Q_0}{Q_L})$$

APPENDIX 13

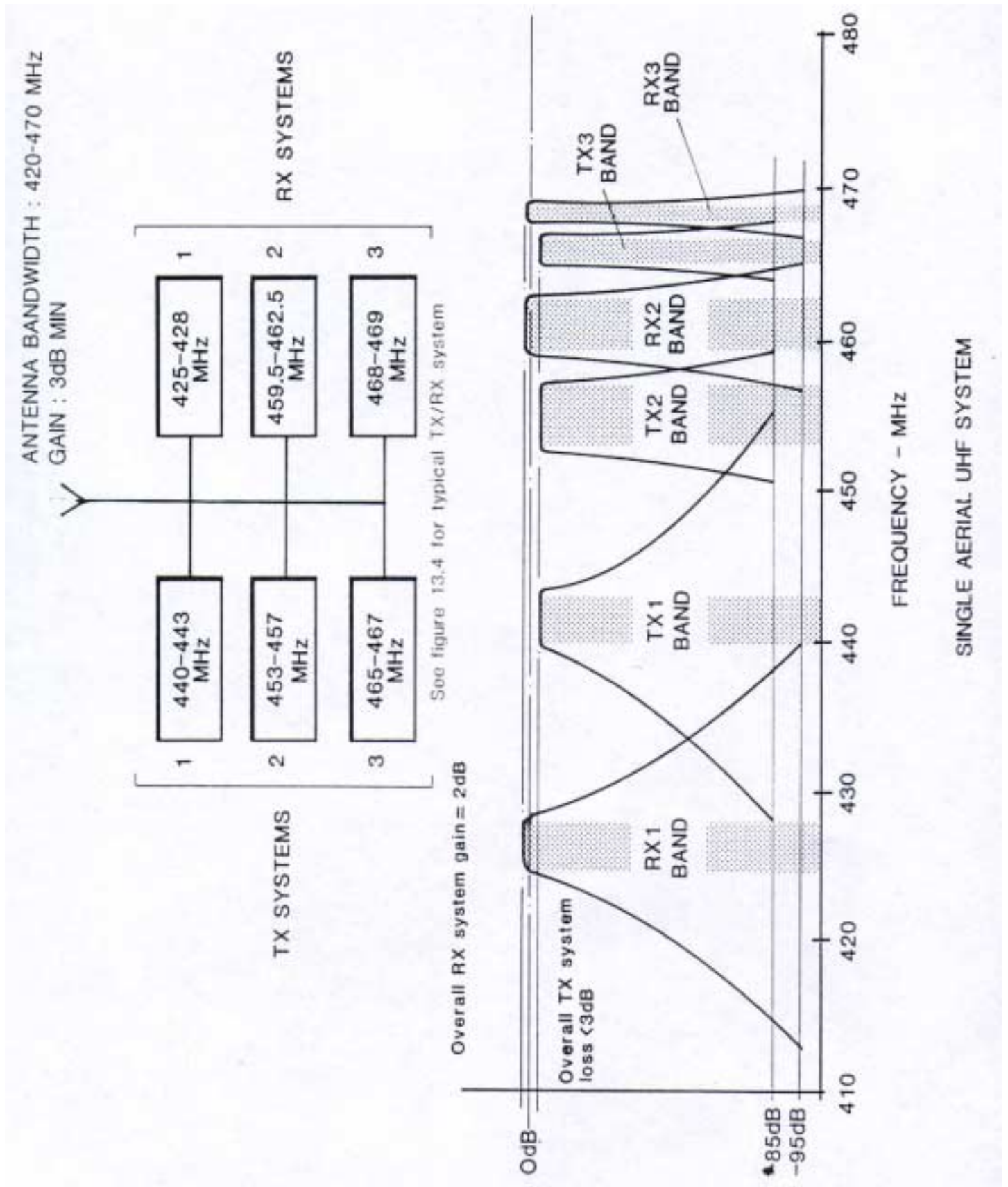
Typical filter System



Spectrum dividing filter response curve



Single Aerial UHF system



Typical Sub-band TX/RX system

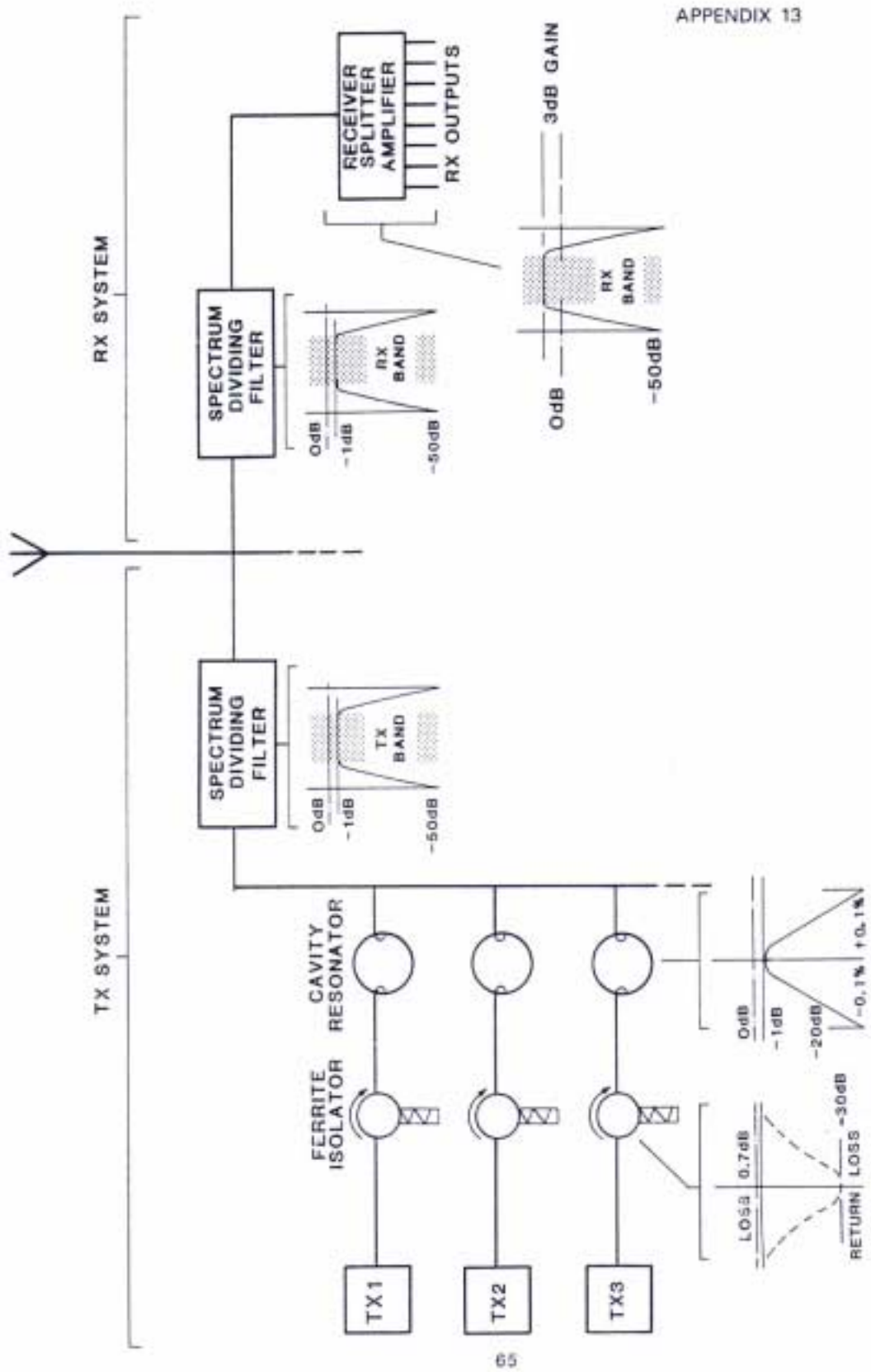
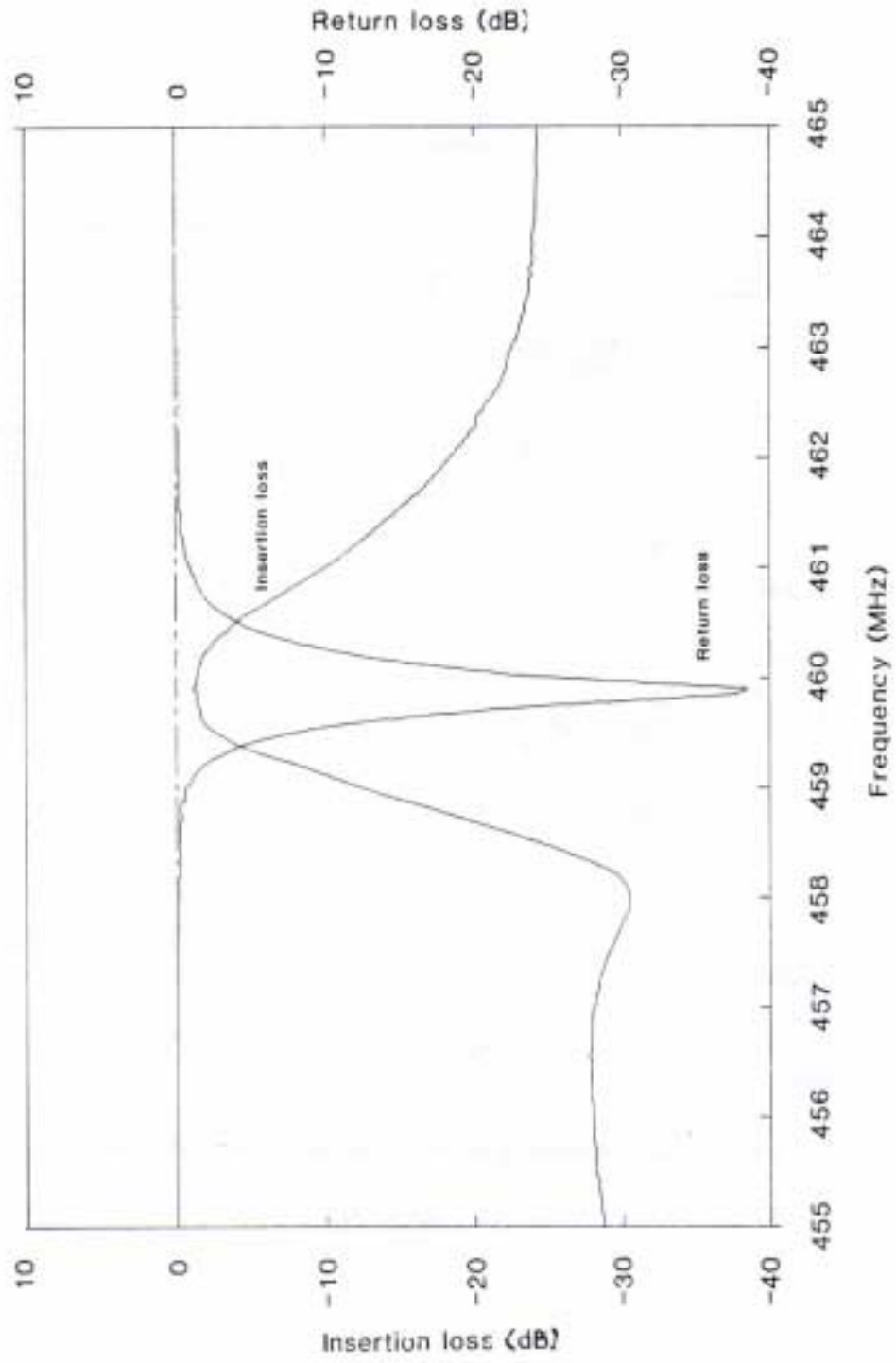
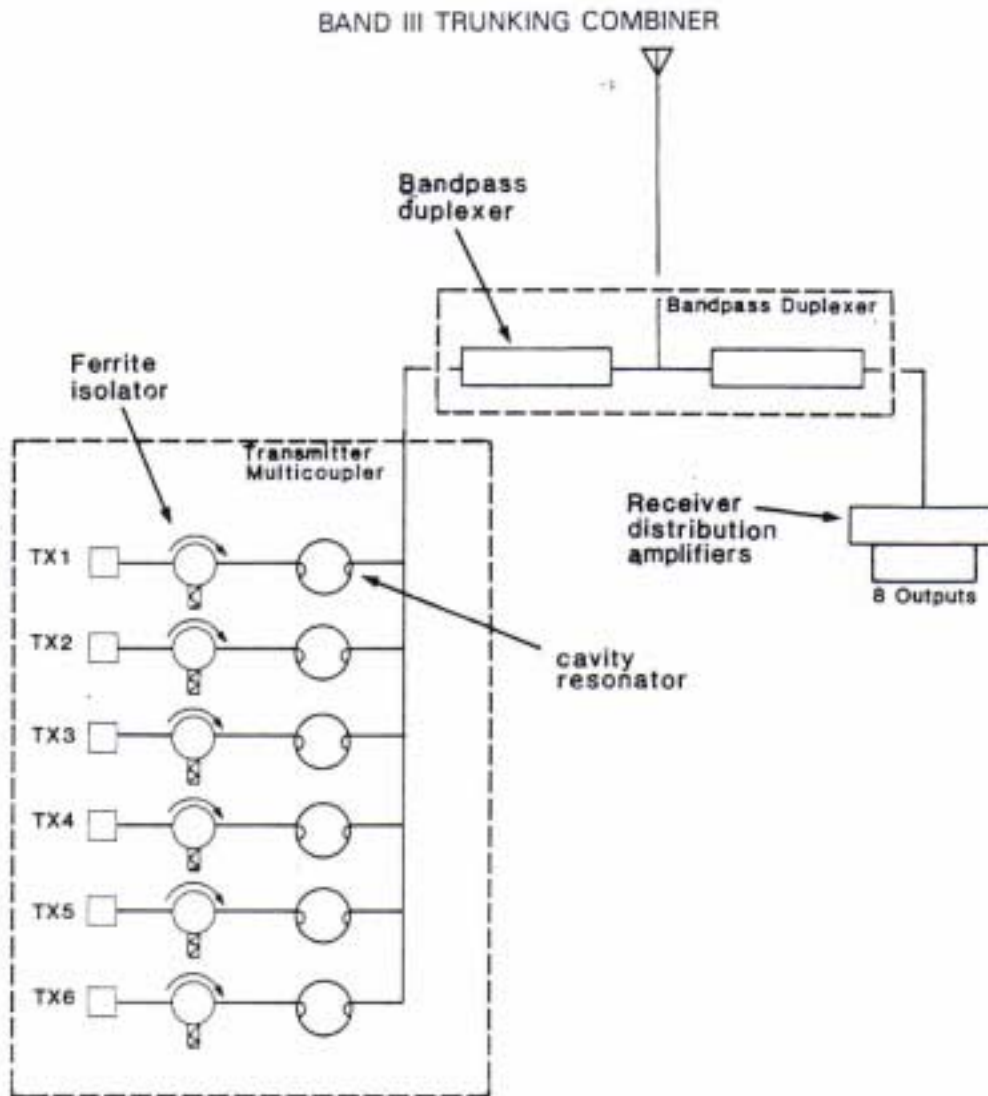


Figure 13.4
TYPICAL SUB-BAND TX/RX SYSTEM AS SHOWN IN FIGURE 13.3

Figure 13.5 SPECTRUM DIVIDING FILTER RESPONSE CURVE





This system is designed to allow single antenna working for a multi-channel trunking installation.

The equipment is configured such that it can operate over various bandwidths (range 1 – 10MHz).

The system can accommodate up to 16 channels in VHF Band III or UHF.

Figure 14.1

NOTES:

APPENDIX 14

BAND III TX/RX TRUNKING COMBINER

This system is designed to allow single antenna working for a multi-channel trunking installation

The equipment is configured such that it can operate over various bandwidths (1-10 MHz range)

The system can accommodate up to 16 channels in VHF Band III or UHF. The following specification relates to an 8 channel combiner.

TX PATH

Insertion Loss: (from input to antenna port):	Typically 2.8dB
TX to TX Isolation:	>55dB
Minimum Frequency Spacing between Transmitters:	120KHz
Input VSWR:	Better than 1.1:1 (Return Loss 26dB)
Output VSWR:	Better than 1.2:1 (Return Loss 21dB)
Power Handling (each channel):	60 watts (17dBW)(100 watt version available)
5th Order Intermodulation (For 17 dBW Inputs):	Better than - 154dBBW
TX to RX Isolation:	>90dB
Number of channels;	5, 8, 10, or 16

RX PATH

Overall Gain:	+dB (can be adjusted up to 6dB)
Input VSWR:	Better than 1.2:1 (Return Loss 21dB)
Output VSWR:	better than 1.2:1 (Return Loss 21dB)
RX to TX Isolation:	>90dB
Noise Figure:	5dB typical
Third Order Intercept:	+25dBm typical
RX to RX Isolation:	25dB typical

CHARACTERISTICS OF DISTRIBUTION AMPLIFIERS

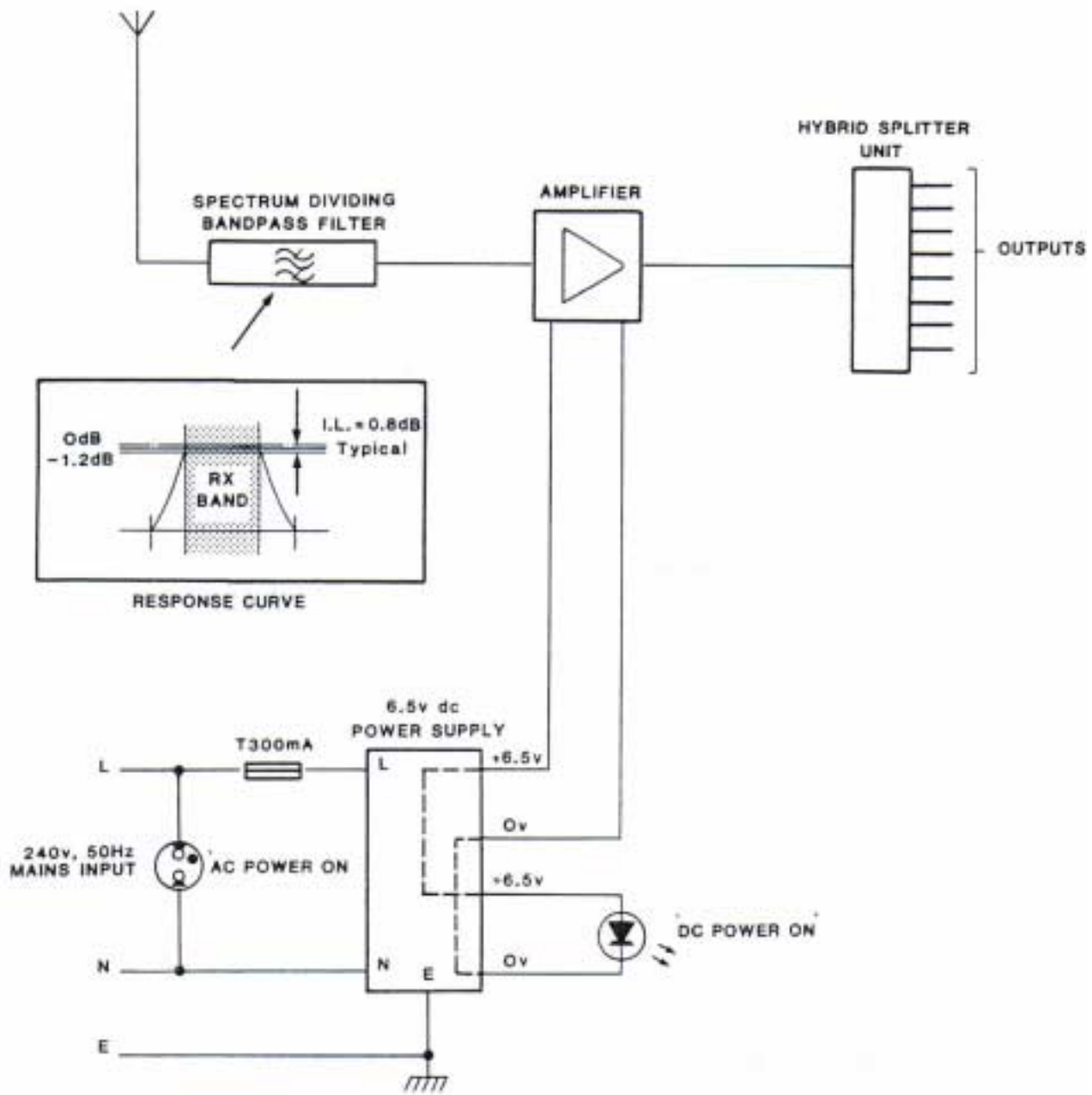


Figure 15.1 Receiver distribution amplifier system

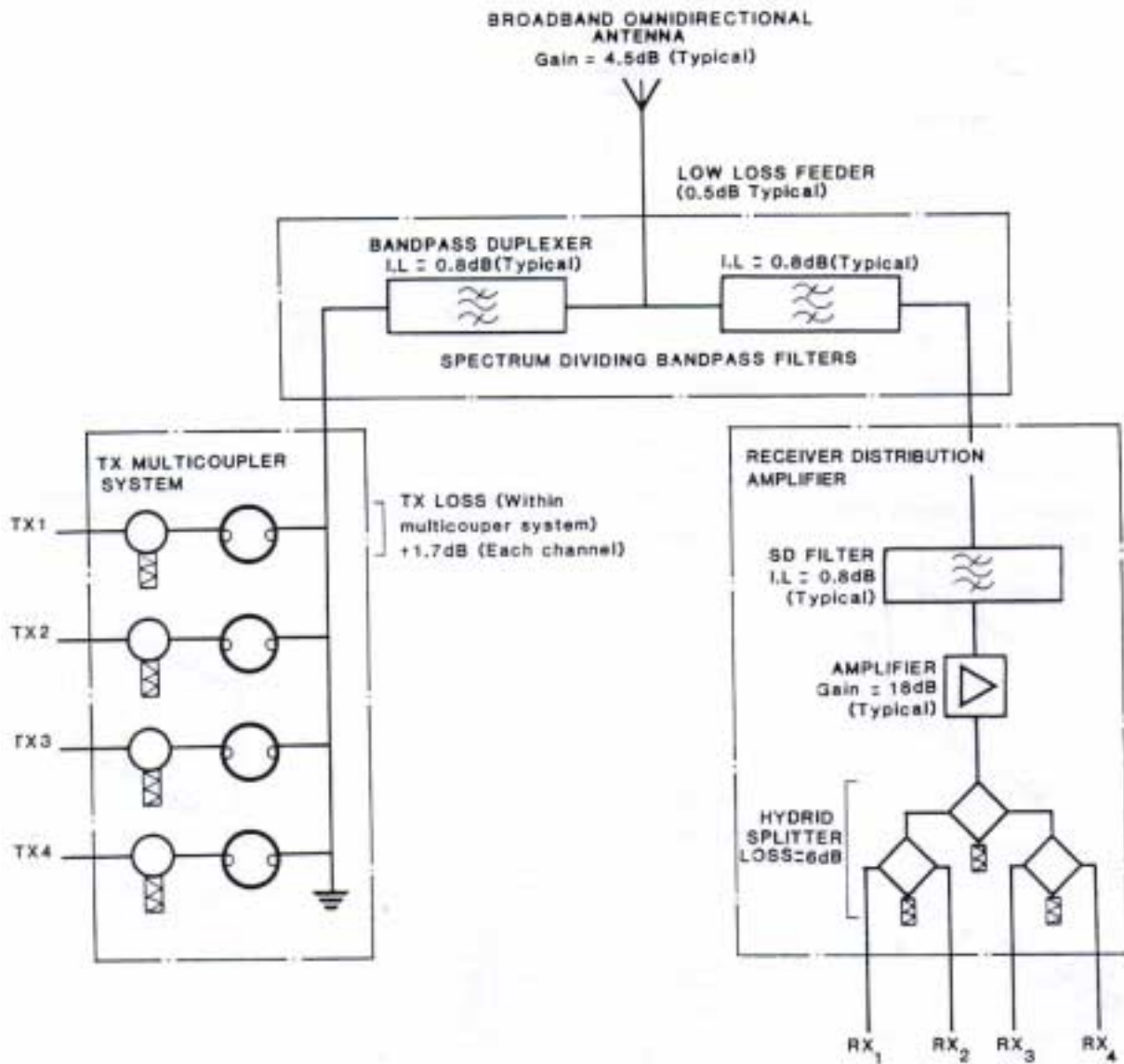
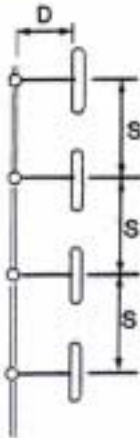


Figure 15.2 Receiver distribution amplifier in a 4 way multicoupler system

STACKING AND BAYING DATA

Side-mounted Dipoles
Stacking Data

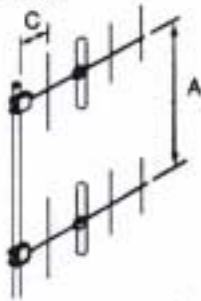


Frequency MHz	Dimensions (in metres)	
	D	S
35	0.9	3.4
80	0.75	2.7
100	0.6	2.4
125	0.5	1.8
140	0.4	1.7
180	0.4	1.4
400	0.14	0.63
430	0.133	0.48
460	0.127	0.43

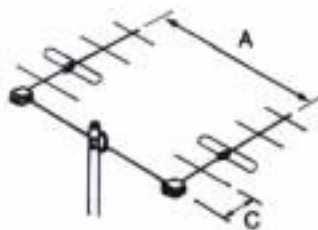
NOTES:

- 1 When antennas are stacked, correct phasing is essential. The installer must ensure that all dipoles are mounted on the same side of the booms when erected.
- 2 Dimensions "D" above is a minimum figure for a 51mm diameter mast. The required polar diagram will determine the actual spacing used. For general purposes, a spacing of $\lambda/4$ is recommended. These points refer also to the installation of a single VHF/UHF antenna.

Yagi Antennas
Stacking and Baying Data
E-PLANE

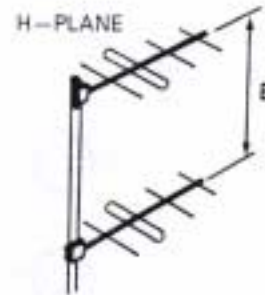


VERTICALLY POLARISED
(STACKED)

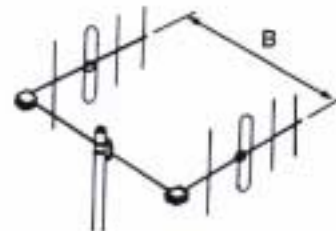


HORIZONTALLY POLARISED
(BAYING)

NUMBER OF ELEMENTS	D M	Frequency (MHz)				
		80	120	160	400	460
2	A	2.3m	1.5m	1.2m		
	B	3.1	2.0m	1.5m		
3	A	3.0m	2.0 m	1.1m		
	B	3.3m	2.6 m	1.9m		
4	A	3.8m	2.2 m	1.7m		
	B	4.0m	3.4 m	2.3m		
6	A		3.2 m	2.3m		
	B		2.9 m	2.6m		
8	A			2.8m		
	B			3.0m		
9	A				0.7 m	0.6
	B				0.7 m	0.6 m
12	A				1.1 m	1.0 m
	B				1.1 m	1.0 m
ALL TYPES	C	0.4m	0.25m	0.2m	0.08m	0.06m

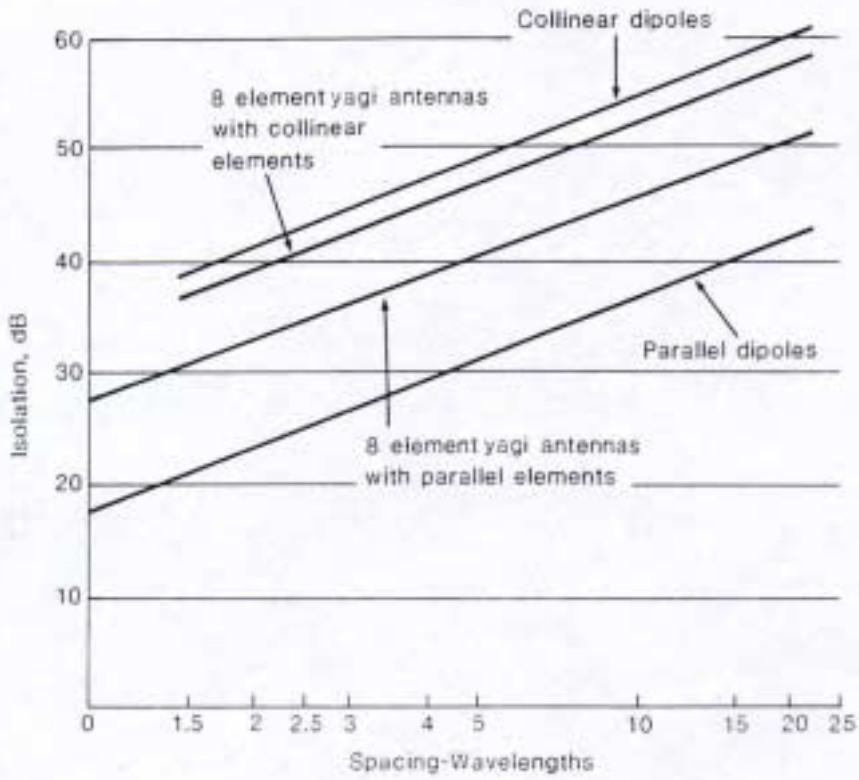


HORIZONTALLY POLARISED
(STACKED)

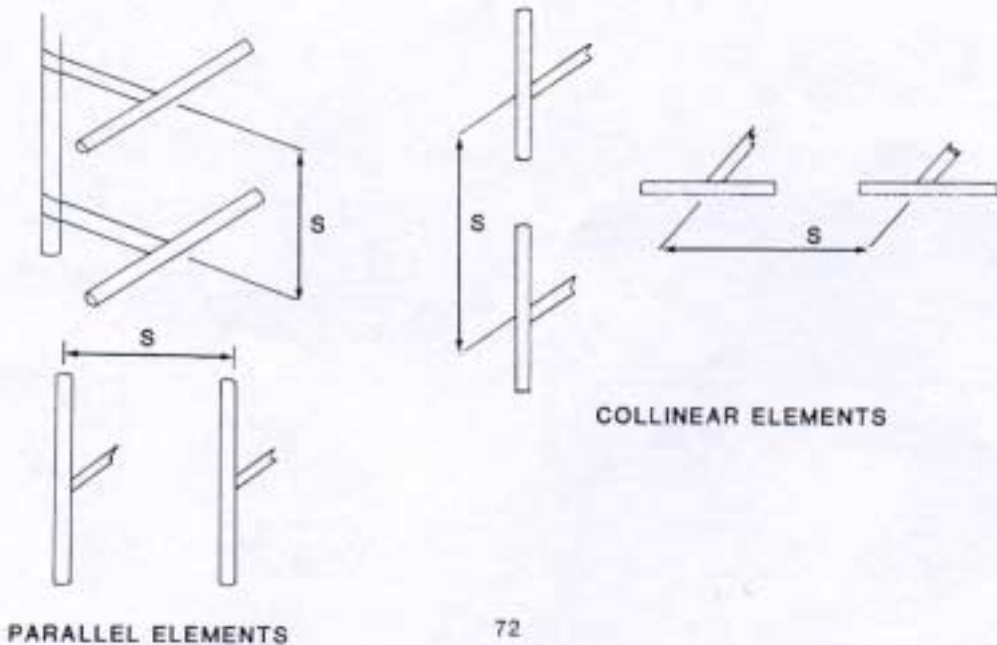


VERTICALLY POLARISED
(BAYED)

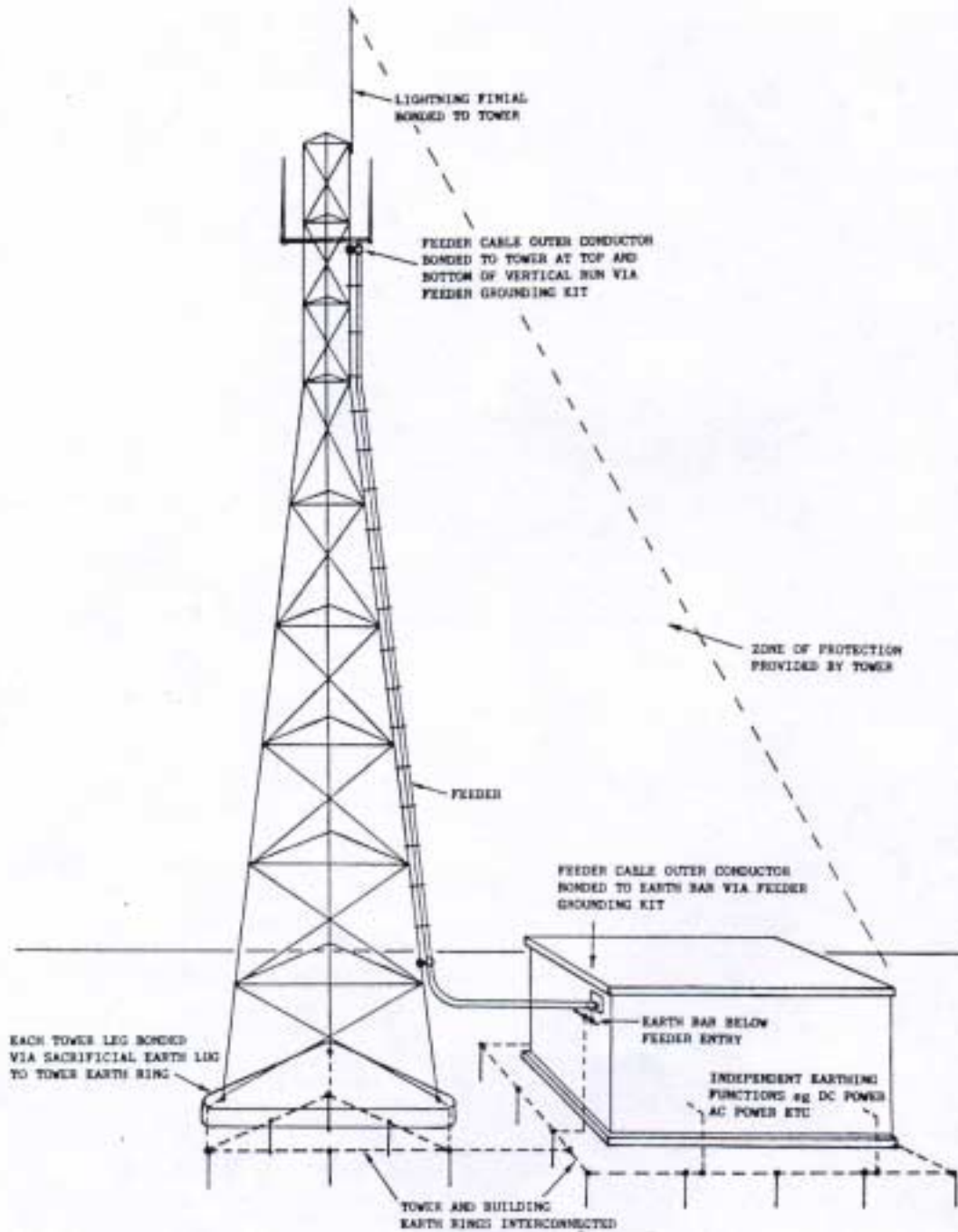
ISOLATION BETWEEN ANTENNAS



Typical isolation between antennas



TYPICAL EXAMPLE OF GOOD EARTHING PRACTICE



BIBLIOGRAPHY

- BS CP3 Ch. V Part 2: 1972 Wind loads
- BS CP118: 1969 The structural use of aluminium
- BS 449: The use of structural steel in buildings
- BS 729: Hot dip galvanised coatings on iron and steel articles
- BS PD 6484: 1974 (1984) Commentary on corrosion at bimetallic contacts and its alleviation
- BS 5293: 1977 Code of practice for protective coating of iron and steel structures against corrosion
- BS 1615: 1972 Anodic oxidation coatings on aluminium
- BS 4190: 1967 ISO metric black hexagon bolts, screws and nuts
- BS 2011: Basic environmental testing procedures
- BS 6651: 1985 Code of practice for the protection of structures against lighting
- Earthing of Telecommunications Installations - International Telecommunication Union, General ISBN 92- 61 - 0031 -x CCITT, 1976
- MPT 1326 Performance specification for angle modulated VHF and UHF equipment for use at fixed and mobile stations in the Private Mobile Radio Service
- CCIR Report 358 - 5 Protection ratios and minimum field strengths required in the Mobile Services
- CCIR Report 1019 Sources of unwanted signals in multiple base station sites in the Land Mobile Service
- CCIR Report 258 - 4 man made radio noise
- Safety Precautions Relating to Intense Radio Frequency Radiation HMSO 1960 (ISBN 0 11 340576 6)
- Proposals for the health Protection Of workers & Members of the Public against the Dangers of Extra Low Frequency Radio Frequency And Microwave Radiations: A constructive Document National Radiological Protection 1982 (ISBN 085951 185 5)

Annex I To MPT 1331 Case Studies

The following cases contained in this section are typical examples of interference cases which could have been prevented if the guidelines contained in this code had been followed.

If interference occurs, then a logical sequence of steps should be followed to identify the cause of the problem:

- a Check that the receiver front end is not being overloaded; a notch filter tuned to the interfering signal installed at the antenna input to the receiver will normally solve an overload problem.
- b Check that mixing is not taking place in the front end of the receiver; if the unwanted received signals are within 1% of the wanted frequency then follow step "a", however, normally a bandpass filter installed at the antenna input to the receiver will solve this problem.
- c If the interference is not generated in the receiver, then the direction of the interference can be traced by using an antenna, with directional properties, connected to a receiver with signal level indication.
- d When interference has been traced back to a site, and the signals causing the intermodulation component have been identified, it will be necessary to determine where the mix is occurring.
- e DO NOT tamper with any equipment on site unless the owners prior permission has been obtained. If it is necessary to disconnect the antenna feeder from the transmitter output, ensure that the transmitter cannot be keyed.
- f It should be noted that when making measurements with sensitive measuring instruments, particularly when tracing intermodulation products (IMP) in the transmitter output, that appropriate precautions are taken. [Such as stop or notch filters, attenuators or directional couplers to protect the input stages of sensitive equipment.]
- g Mixing can occur in a transmitter output stage, due to the carrier frequency mixing with another signal being fed back via the antennafeeder. This problem can normally be solved by fitting an isolator or bandpass filter in the antenna feeder close to the transmitter output.
- h If interference is still present then mixing is most likely taking place either on the transmitter or receiver mast structure. It may be possible to overcome the problem by increasing the horizontal or preferably the vertical separation between the antenna on the existing mast.

Alternatively if the radiating source on the mast can be located, it may be possible to carry out the necessary maintenance.
- i In extreme cases it may be necessary for one of the users to change sites, to overcome the interference problems.

Case 18 is included as a reminder, that the cause of the problem may be in the users own equipment, therefore it should be ensured that the equipment is regularly maintained.

Case 1

A high power 150 MHz band transmitter was causing interference to a Cosited 160 MHz marine band receiver by desensitising the receiver and causing blocking. The transmitter already had an isolator and bandpass filter fitted to the output antenna feeder. The problem was solved by inserting a bandpass cavity resonator into the antenna feeder to the marine receiver.

Case 2

Interference was being received on a Police VHF base station receiver. It was suspected that a high power BT Radiophone transmitter, located approximately 500 metres away, was overloading the front end of the receiver. A bandpass filter was inserted into the antenna feeder of the receiver, and although the level of interference was reduced, a significant signal level was still present.

Further tests showed that the RF signal from the BT transmitter was getting into the output stage of the Police transmitter, Co sited with the receiver. The mix between the two carriers produced a resultant product on the Police receive frequency. An additional band pass filter was inserted in the output feeder of the Police transmitter. The interference problem was solved by placing bandpass filters in both the Police transmitter and receiver antenna feeders.

Case 3

Interference was being received on several base station receivers, located on a communal site. During tests at the site, it was noted that the interference ceased when one particular co-sited transmitter was keyed. The transmitter used a semiconductor output stage, which was still active even when the drive had been removed, ie the transmitter was in the standby mode. The problem was caused when co-sited transmitters were keyed, causing the output stage of the offending transmitter to go unstable and radiate spurious noise.

By installing a bandpass filter and isolator at the output of the transmitter the problem was solved.

Case 4

Interference was being caused to a 141 MHz fm base station receiver from a co-sited 138 MHz am base station transmitter.

It was suspected that the 138 MHz transmitter was overloading the fm receiver. An additional bandpass cavity filter was installed in series with the existing high-Q bandpass filter which is normally fitted to the receiver input, but produced no improvement. A Notch filter tuned to the interfering carrier was then tried in the receiver, again no improvement was noted.

A spectrum analyser was used to observe the transmitted spectrum, which showed a number of low level spurious signals, one of them falling directly onto the fm channel. By fitting a bandpass filter at the transmitter output and retaining the single bandpass cavity at the receiver, the interference was cured.

Case 5

Co-channel interference was being caused to a Police base station receiver which was located near to a communal base station site approximately 500 metres away, with some 10 pwr transmitters on site. None of the transmitters had filters or isolators fitted to their outputs, therefore a large number of intermodulation products were being generated over a wide band. The problem was solved by fitting isolators and filters to the outputs of the offending transmitters.

Case 6

Co-channel interference was received on a 141 MHz band base station receiver.

The source of the interference was traced to a spurious signal being radiated from a 145 MHz amateur band repeater. The repeater transmitter used a local oscillator with a times 36 multiplying stage to obtain the required carrier frequency. A spurious signal, which was due to the 35th harmonic of the local oscillator, was being radiated.

The problem was solved by inserting an additional bandpass filter at the transmitter output.

Case 7

A high band VHF transmitter was set up at the repair depot before being reinstalled on site. The transmitter when installed on the communal site was connected to the antenna via a high-Q filter. When the transmitter was keyed high level spurious signals were emitted causing interference to other co-sited systems. The problem was solved by retuning the transmitter rf stages to match the filter system.

NOTE: A transmitter should be set up in the workshop into an accurate 50 ohm dummy load.

Case 8

Radio 3 programmes from a VHF FNI Broadcast transmitter were received on a Police base station receiver.

Inter modulation products were generated in the structure of the mast on which the Police antennas were mounted, due to the high powered broadcast transmitter.

This problem was solved by removing the receiving antenna to a position above the mast structure using a vertically stacked dipole on a 3 metre pole. This succeeded in removing the receiving antenna away from the field of interference caused by the mast structure.

Case 9

Interference was received on a British Gas base station receiver operating on 106 MHz. Co-sited was a 4 kilowatt Local radio broadcast transmitter, on 96 MHz and also an AA transmitter on 86.525 MHz band. No 3rd order intermodulation products were detected from the Broadcast transmitter, however, by using a loop antenna connected to an analyser the intermodulation product was traced to the Broadcast antenna. The antenna was checked but no fault could be found.

Some reduction in level was obtained by changing the B.Gas Colinear antenna for two dipoles. Additional reduction was obtained by siting the antennas further down the mast, ie increasing the vertical separation.

Case 10

An on air third order intermodulation product was traced to a communal site. The two transmitters were identified, which already had isolators and filters fitted to their outputs. On further investigation the interference was traced to a receiver antenna which was radiating the antenna intermodulation product. When the antenna feeder was disconnected from the associated receiver, the interference disappeared. To solve the problem a band pass filter was installed at the input to the receiver.

Case 11

British Telecom were experiencing on site problems from their Radiophone and paging transmitters which were causing breakthrough on the radiophone receivers. After a considerable amount of work on the site, breakthrough was still being experienced. The problem was eventually solved by replacing the existing feeders with double screen cables and using high quality connectors.

Case 12

An on air interference signal was traced to a communal site. The actual source, however could not easily be identified, therefore with the owners permission equipment was switched off to try and eliminate the source. With all known equipment off, the interference was still present. The source was traced to the system master crystal oscillator, which was still running.

Following modification to the equipment by the manufacturer, the interference was eliminated.

Case 13

A high band user was complaining of interference on his channel: the system (system A) was using free running talk through. The frequency separation between the transmit and receive on a high band channel is 4.8 MHz. A nearby transmitter (system B) operating on a channel 2.4 MHz above system A produced an on air third order 1PM which fell on the receive frequency of system A. Due to the 1PM system A would remain on whilst system B was transmitting even when the mobiles of system A ceased transmitting.

Case 14

An on air IMP was traced to a communal site. Work had recently taken place at the site on the mast and in the equipment room. The problem was traced to an intermodulation product which was being picked up by a feeder cable and radiated from the attached antenna. The feeder cable and antenna were no longer being used at the site. When the feeder cable and antenna were removed the problem was resolved. It should be noted that all unwanted equipment should be removed from mast structures and equipment rooms.

Case 15

A fire brigade base station receiver was receiving Radio 3 programmes. The co-channel interference was traced to a nearby communal base station site. The medium wave transmission was being picked up on the antenna feeder, which provided a path to the power amplifier stage of a pmr transmitter where the mixing occurred. The broadcast transmitter was several kilometres from the communal site. The problem was solved by earthing the antenna feeder, the cable ducts and equipment racks.

Case 16

Use of multiple common base stations on a communal site exhibits the same problem as any talk through stations, that is the generation of transmitter/receiver difference frequencies.

A classic case is that of two VHF high band talk through base stations having standard Tx/Rx spacing (ie 4.8 MHz) in an urban environment where the mobiles of one system have regular access within 500 metres of the communal site, the transmitter not being fitted with an isolator. The level of the received mobile frequency can be in the order of several millivolts, and mixing with its own transmitter produces a different frequency equal to the Tx/Rx spacing. If now the second base station is keyed, its own receiver will be disturbed by the resultant of the mix from the first base station, and so will any subsequent VHF high band transmitters keyed on the site.

In many cases of this type the disturbance to the mobiles of the second system is that of an extremely over-modulated signal carrying the modulation of the first base station.

The solution to this problem would be the fitting of suitable ferrite isolators and/or bandpass filters to the offending transmitters.

Case 17

There have been numerous cases of moisture within antennas and feeder cables causing a deterioration of transmission characteristics. In extreme cases severe corrosion takes place at the lower connector of the feeder run, where the moisture gathers behind the connector. The source of the problems are numerous, the main points of entry being:

- a the drain holes in antennas and antenna structures
- b the connectors and interfaces
- c cracks and orifices in the outer casing of the antenna feeder cables

Due to atmospheric changes in temperature and pressure there is a tendency for feeder systems to "breathe" and in extreme wind conditions, "VENTURI effect" may be produced sucking moisture into the system.

The solution to these problems are mainly inspection and maintenance, since complete abandonment of drain holes in antennas can lead to other problems due to ingress of water in the upper part of the antenna, and excessive use of sealants and wrapping of connector assemblies can produce adverse effects of a secondary nature.

It is possible to provide "dnp loops" and examination points within the equipment room by removing a short section of the outer casing of the feeder cable. This provides a means of detecting any moisture that may be trapped between the outer coaxial tube and the casing.

The real solution is to provide annual inspection and regular maintenance of the system.

Case 18

Interference was being caused to a 141 MHz base station receiver whenever a co-sited 139 MHz base station transmitter was keyed.

A bandpass filter was fitted to the receiver, which reduced the level of interference. However, the wanted signal was still unworkable, even at this reduced level of interference. As a result of using a spectrum analyser it was found that the receiver front end was oscillating at around 140 MHz. When the 139 MHz transmitter was keyed, mixing occurred to produce a 3rd order IMP which fell on to the receiver channel. The receiver was modified to prevent the front end oscillation and the interference problem was cured.



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