



**Federation of Communication Services (FCS)**

**FCS 1331 Code of Practice for Business Radio Site  
Engineering**

***For the installation of radio transmitters, associated receivers  
and their ancillary equipment in base station sites, for use in  
the Business Radio Sector***

**DRAFT –December 2008**

**For public consultation**

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## Foreword

This FCS UK Code of Practice is based on MPT 1331, "Code of Practice for Radio Site Engineering", which was a voluntary code of practice for use by radio base-station planners and installers in the Business Radio Sector and has been updated to FCS 1331 taking due account of technology advances

The FCS 1331 Code of Practice defines appropriate procedures and techniques that can be used to establish efficient radio-base station radio system designs and equipment installations taking due account of good practice within the industry whilst being fully compatible with essential regulatory and quality requirements.

This Code of Practice is intended for use in the Business Radio Sector and may be developed at a later date to cover other types of radio site installations; it is presented as a multi-part document:

- Part 1:** Addresses Common Requirements for all types of installation and is the base of this FCS Code of Practice; it can also be used as a generic stand-alone document,
- Part 2:** Addresses SOHO (Small Office-Home Office) installations, which are essentially 'off the shelf' items that can purchased as a package and their installation is advised by the manufacturer(s). The SOHO package is a special case that requires minimal engineering skill and knowledge and is equivalent to installing a domestic television receiver and its associated antenna.
- Part 3:** And its sub-sections relates to specific professional Business Radio technologies, it provides detailed information on specific Business Radio technologies and identifies any requirements that are associated with the specific technology.

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## Definitions



# PART 1

## Common Requirements (Generic Option)

# 1 Introduction

- (1) This section of the Code of Practice provides basic information for a generic radio base-station site and identifies the necessary skills required of the design, installation and commissioning team. All aspects are considered including the base skills such the preparation of cables, the fitting of connectors, earth bonding and other safety related aspects.
- (2) Part 1 of this document can be used as a Generic Option if required, to facilitate new products and innovation. It is intended to be applicable to all scales of installation from single-user on-site systems through to wide-area installations on shared sites. Consequently, the definitions of terms are “Generic” in nature and may require a certain amount of interpretation to fit a specific requirement. A Radio Site may range from the corner of an office to a large communal site on a hilltop. Only the scale of the facility changes; the basic requirement remains the same.

## 2 Radio base-station Design considerations

(3) Radio base-station design, installation and commissioning are addressed under the following headings:-

- Specification and Design procedure
- Procurement practice
- Installation requirements
- Setting-up equipment/system
- Switch-on and initial testing
- Radio Interference considerations
- Final commissioning and customer handover
- Field operation
- Routine maintenance requirements
- Modification and updating of system/equipment
- De-commissioning equipment/system
- End-of-life scenario, disposal of equipment
- Site Records
- Health and Safety considerations

### 2.1 Specification and Design Procedure

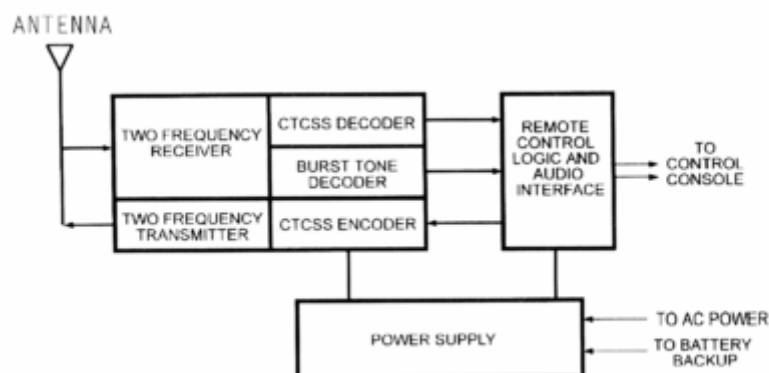
(4) The radio base-station site design and installation must meet the user's expectations, thus the requirements must be fully understood and interpreted in the design taking due account of the propagation parameters of the radio frequencies to be used, together with any regulatory restrictions imposed such as the maximum antenna heights, radiated power levels.

(5) Whilst individual requirements may vary in scale, be they for larger sites or smaller on-site installations the fundamentals to the choice of radio sites may be summarised as follows:

- examination of user requirements, service area, frequency, licence power limits, modes of operation;
- inspection of service area to identify preferred locations for sites;
- search for existing sites in the preferred areas;
- analyse suitability of existing sites and the feasibility of site sharing;
- ease of site access for on-going maintenance.
- take due account the likelihood of local sources of interference such as electrical motors, fluorescent lighting, etc.
- formulate proposals for new sites only where necessary

- (6) The choice of site will probably be a compromise between the radio coverage requirements, technical and economic considerations or planning constraints imposed by the landowner and/or Local Authority. It is frequently an iterative process that has to be repeated to produce the optimum choice of sites.
- (7) Where compromises are necessary it is essential that the user is given the opportunity to consider what effect any coverage irregularities will have on the planned service area
- (8) A basic design for a radio base-station site will consist of the following elements, although the scale may vary. For instance, a radio site with protective enclosure may be a hill top site with a security fence around it or the corner of a store room in an industrial building:
- Physical equipment/facilities
    - Radio site with protective enclosure
    - Supporting structure with lightning protection
    - Equipment room
    - Electrical (mains) power supply
    - Auxiliary power supply equipment and/or batteries
    - Power cable connections as required
    - Sundry electrical facilities such as a switch box
    - Telephony lines and termination equipment if required
    - Cable containment as required
  - Radio Equipment/System
    - Antenna system
    - Antenna coupler equipment
    - Base-station transmitter(s)
    - Base station receiver(s)
    - Sundry RF cable connections as required
    - Operators console

**Basic base station elements used in a remote-controlled installation- Selective calling options such as CTCSS are optional.** 



## 2.2 Procurement practice

- (9) Equipment compliant with the agreed design should be procured from reputable manufacturers on the basis of a procurement specification. Consideration of the equipment suppliers' ability to provide adequate on-going support should be an essential ingredient in the procurement process
- (10) The procurement specification can refer to (for example) an ETSI standard to define the equipment's technical characteristics, which will also provide an assurance that the equipment is compliant with the regulatory requirements of current legislation such as the R&TTE Directive.
- (11) The procurement specification should be part of the contract between the parties and ideally the supplier will have the relevant Quality Assurance credentials, so that the equipment can be delivered directly to the site if required.

## 2.3 Installation requirements

### 2.3.1 Mast/Tower

- (12) The installation of the supporting structure, be it a wall bracket, mast or tower is to be carried out to the specifications required by the Local Authority and should include all the basic earthing and lightning protection required. The structural integrity of the supporting structure must be established by a competent person as required by the Law; the analysis must include the loads imposed by each antenna system.

### 2.3.2 Equipment room

- (13) Fundamental requirements for equipment rooms on radio sites:
  - security against vandalism and casual attack by intruders, alarm systems should be fitted as required;
  - cables in and out of the equipment room must be protected so that they cannot be easily damaged;
  - the equipment room should be divided to allow access to individual parties if required by the site owner;
  - A separate area is provided for the common services facility, e.g. mains power supply, filter multi-couplers and incoming feeder cable assemblies;
  - cooling, heating and lighting be provided of a standard suitable for the environmental requirements of the site;
  - Sufficient space within the enclosure to allow for reasonable expansion.

## 2.4 Equipment configurations

- (14) Fundamental rules that should apply wherever possible:
  - filter couplers and associated signal distribution systems should be located in a separate area whenever possible;
  - when batteries or emergency supplies are involved, they should be housed in a separate cubicle
  - and ventilated to the outside atmosphere, to ensure that no explosive gases or corrosive fumes are present within the equipment room;

- each frequency band will have its own cable feed and associated harness and all the equipment in that band should be placed in adjacent racks and convenient to the cable tray;
- It is advisable to keep receivers and transmitters as far apart as possible and this can be arranged in separate racks within the frequency band and its associated area.

## 2.5 Lightning effects and protection

(15) Many radio sites are prone to lightning strikes due to their exposed locations and the physical size of antenna support structures. Practical considerations include:

- Connections to site earthing systems (where corrosion may be unavoidable) should be made by means of a sacrificial anode of a material compatible with the structure being earthed.
- All underground clamps on site earthing arrangements should be suitably protected by the use of non-reactive, non-setting pastes and tapes.
- Where the tape may be subject to chemical attack, when in close proximity to concrete, for instance, it should be protected by the use of non-reactive paste or with some other appropriate method.
- Protected test points should be included if appropriate and sacrificial earth lugs should be clearly marked and easily accessible for periodic inspection and replacement if necessary.

## 2.6 Earthing of external antenna support structures

(16) A structure will generally act as its own lightning conductor and will therefore not require a conducting tape from the apex to its base. However, it is recommended that additional bonding be used to ensure that "side strikes" and/or high transient voltages in adjacent conductors be minimized. A lightning finial may be required to extend the zone of protection to protect equipment mounted on top of the structure. The finial should extend to at least 1m above the highest equipment.

(17) Replacement of sacrificial anodes should be part of the maintenance programme.

## 2.7 Earthing of external antennas, feeders and associated plant

(18) All antenna feeders should be bonded to the supporting structure at the upper and lower ends and earthed at the point of entry into the building. Fast acting gas filled surge arrestors can be used on some systems and may provide additional equipment protection, providing that Voltage Standing Wave Ratio (VSWR) degradation is acceptable. In the case of radiating cables or RF cables in tunnels, the outer conductor is usually earthed at the point of entry into equipment rooms.

(19) There may be different practices between authorities regarding how earthing at intermediate points should be arranged. In general any metallic structures in tunnels should be earthed to a common point to avoid the possibility of electrocution. Buildings may require lightning conductor terminals (finials) where they are not within the zone of another protected structure.

## 2.8 Electrical power supplies

(20) Radio sites will normally have the AC Supply provided by the local Electricity Supply Company. It is essential to arrange adequate 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.

- (21) In many instances standby power supplies will be required and this should be based on the requirements of the service. There are an increasing number of sites where DC supplies, usually in the form of 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.

## 2.9 Setting-up equipment/system

- (22) When the equipment has been physically installed, and the antennas mounted on the mast a number of routine checks should be made prior to initial switch-on of the system, if appropriate a dummy load may replace the antenna system for the initial testing of the transmitter to ensure that no spurious signals are generated by the installation.

- (23) Initial checks should cover:

- antenna system
- power supply and back-up
- transmitter(s)
- receiver(s)

### 2.9.1 Antenna system

Antenna Isolators:

Communal sites require isolators to be fitted; the site owner may provide a multi-coupler system. The losses in the system should be ascertained in order to calculate the effective radiated power stated on the licence.

Antenna feeder:

In order to calculate the effective radiated power (ERP), the feeder loss is required. This is normally calculated based on the manufacturer's data and the approximate feeder length.

Antenna type:

The type of antenna should be checked as it affects the ERP; any gain of the antenna over a dipole should be noted. On common base station (CBS) systems, the type of antenna employed at a fixed mobile installation will be stated on the licence schedule.

Direction of antenna main beam

The direction of the antenna main beam (Azimuth) is stated on the licence when an omni-directional antenna is not used. These details should be confirmed and Ofcom notified if the direction needs to be altered. For example, using a yagi antenna, the approximate Azimuth can be obtained by looking along the length of the antenna from the mounting position and taking a compass reading, or comparing the direction with known features on a map. If it is found that the antenna azimuth as noted on the licence is significantly different to the one required then Ofcom should be notified immediately. The frequency assignment will have been calculated using the

licence azimuth and unless the difference is minor then the correct azimuth should not be used without the agreement of Ofcom. The installer's professional judgement should be used in this case.

**Caution:** If a compass reading is taken, care should be taken to ensure that local metalwork does not affect the reading.

#### Antenna Mounting

Local metalwork may also unavoidably affect the radiation pattern of the antenna. This can be limited by using the manufacturer's recommendations for mounting. Whilst this does not affect the antenna azimuth, it may affect the direction of maximum radiation; the antenna may have a "squint", which is not taken into account by Ofcom.

#### Antenna height:

The height of the antenna above ground level, in metres, and should be checked against the licence. Details of the height of the structure should be available from the site operator or owner.

## 2.10 Switch-on and initial testing

### 2.10.1 Transmit and receiver carrier frequency

- (24) The transmitter and the receiver should be checked to ensure that they are operating within tolerance of the carrier frequency stated on the licence. For multi-channel equipment, all channels should be checked if crystals are used to generate the carrier frequency. When a frequency synthesiser is used then only one channel needs to be checked.
- (25) For base stations only those frequencies authorised for the particular site shall be operational. Where possible, it is recommended that the mobile is checked with the network or system, to ensure that the mobile will function correctly with the wanted system.

### 2.10.2 Transmitter Radiated Power (erp)

- (26) The transmitter's ERP should be checked against the value stated in the licence.
- (27) To calculate the ERP (dBW) use the following formula:

$$ERP = P_T - L_f - L_i + G_A$$

Where:

ERP	= Effective Radiated Power (dBW)
P <sub>T</sub>	= Transmitter output power dB relative to 1 Watt (dBW)
L <sub>f</sub>	= Feeder losses including Connectors (dB)
L <sub>i</sub>	= Loss for filters or isolators (dB)
G <sub>A</sub>	= Antenna gain relative to a dipole (dBd)

## 2.11 Radio Interference considerations

- (28) An 'intermodulation check' should always be carried out when a multi-channel system is installed on a site, to ensure the compatibility of the new system channels with each other as a group and with the existing channel environment into which the system is to be installed.
- (29) An intermodulation checking program will provide a calculation of the mixing products caused when multiple transmitters are operational in close proximity, up to the fifth order. It is important to determine, in advance, that none of these products create a significant signal level on (or very close to) any receiver channel in use on the site. (See 2.12.12: "Calculation of intermodulation products at radio sites", below)
- (30) It is strongly recommended that new channels issued as groups (by any regulatory authority or other source) should always be independently checked by the system supplier before being accepted by the user or licence holder.
- (31) The suppliers of Aerial Combining equipment can often provide much useful advice in this specialist area.

### 2.11.1 Interference Generation

- (32) Interference due to intermodulation generally occurs when at least two transmitters close to the receiving antenna produce very strong signals in the receiver. The two signals form intermodulation products at non-linearities, such as transistors or other semiconductors in the receiver (e.g. in the mixer). Intermodulation can also occur at non-linearities in the supporting structure: the famous "Rusty Bolt" effect. This is less common, however, but underlines the need to ensure the structure is well maintained.
- (33) Unwanted signals are produced which may interfere with the wanted frequencies of the system. Intermodulation signals are also produced when two or more transmitters operate in close proximity to one another. In this case, the transmitter not only transmits its own signal but also receives the signals from the other transmitters.
- (34) From both signals, the transmitter generates and re-transmits mixture products which can interfere with the wanted frequencies. A multitude of IM products are produced in multi-channel systems. Proper frequency selection therefore requires careful planning.

### 2.11.2 Generation of unwanted products within receiver systems

- (35) Three main sources of radiated products are capable of disturbing the receiver equipment on the same site or on another in close proximity:
- Broadband noise and spurious products of transmitters;
  - Intermodulation products between several source frequencies;
  - Intermodulation products caused by external effects.
- (36) The apparent nature of the disturbance may be:
- 1) Unwanted received signals which do not result from transmissions on that frequency by the intended user or any other operator sharing the frequency. The signals may or may not contain modulation although in many cases they are distorted by the intermodulation process and they may contain a composite of the modulation from several sources; or

- 2) An increased level of noise, which degrades the useable sensitivity of receivers.
- (37) Disturbances of type 1) may be identified with relative ease since the unwanted signals are heard in between wanted transmissions or they are of sufficient magnitude that wanted signals are occasionally obliterated.
- (38) Disturbances of type 2) are more insidious since they cannot be heard by the user. The effect causes a degradation of receiver sensitivity and a reduction in effective range. The operator may not notice the change or he may mistakenly blame his equipment and/or installer.

### **2.11.3 Intermodulation and blocking effects within receiver systems**

- (39) These problems are usually a result of large signals at the input of a receiving system that cause non-linearity. There are four different sources:
- Intermodulation between received signals;
  - Saturation of receiver front end;
  - Inadequate receiver selectivity;
  - Receiver spurious responses.
- (40) The operational parameters for receivers are well defined in existing standards provided by the European Telecommunications Standards Institute ( ETSI, <<http://www.etsi.org/>> ) – used in the Land Mobile Service (LMS), the effect of receiver distribution amplifiers must also be considered in addition as these amplifiers often operate in a hostile RF environment on densely utilized radio sites. (Note: ETSI standards may be downloaded free of charge from the ETSI web-site)
- (41) There is a need to define two bandwidths in the receiving system:
- The bandwidth of the receiver when aligned on the allocated channel; and
  - The bandwidth of the receiver's front-end system, and if this is the pre-selector filter of the receiver's RF amplifier or the input filter of a receiver distribution system.
- (42) Intermodulation between received signals;  
The reception of high level signals within the bandwidth of the first RF filter, is the worst case of intermodulation in a receiver system. On a communal site, a high performance pre-selector filter is generally placed at the antenna input to the distribution amplifier to define the operational frequency band.
- (43) For angle modulation systems, receiver intermodulation performance is defined in the ETSI standard EN 300 086 as a ratio between an on-frequency wanted test signal of -107 dBm and two off-frequency unwanted signals at 70 dB above this level displaced to cause a third order intermodulation product on the wanted channel.
- (44) Under these conditions an audio output approximately equivalent to a 7 dB RF carrier to interference ratio (C/I) at the receiver input must be obtained. This definition accepts that in the presence of the off-frequency signals, the receiver sensitivity required by standards may be degraded by 3 dB.
- (45) The practical result of this definition is that for unwanted input signals at third order related frequencies, the receiver which just meets intermodulation standards experiences a 3 dB sensitivity degradation when the unwanted signals exceed -107

+ 70 = -37 dBm. This requires that there is a minimum isolation from other 20 Watt (+ 43 dBm) transmitters of 80 dB.

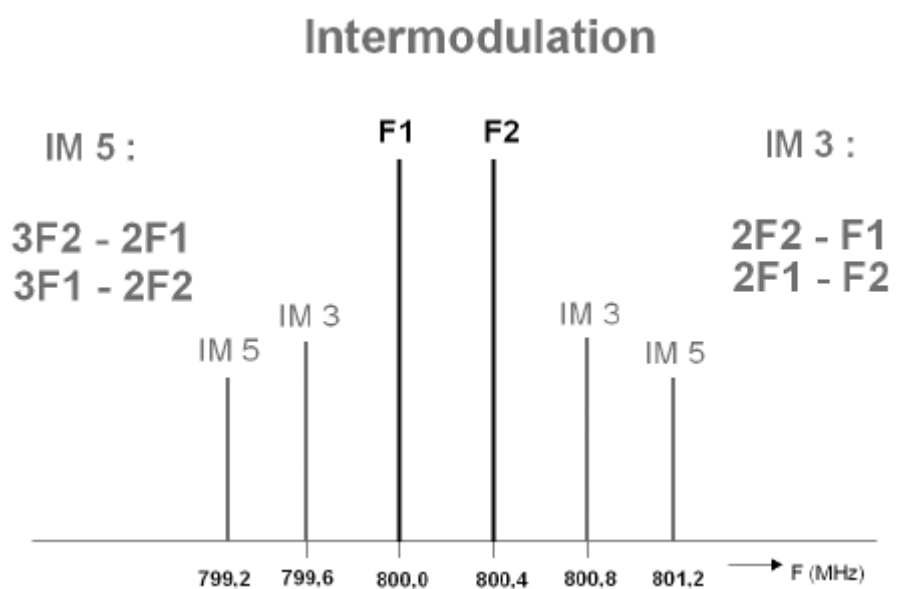
- (46) In the case of receivers that exceed the minimum sensitivity required by standards, the degradation caused by intermodulation may be much higher.
- (47) The design aim in receiver distribution systems should always be that the performance is limited by the performance of the receivers themselves rather than the distribution amplifier.
- (48) Fulfilling the above criteria should ensure that intermodulation problems do not originate in the site receiver system but will not stop intermodulation occurring in the neighbouring transmitters. Careful frequency planning and radio site engineering should minimize transmitter intermodulation effects.
- (49) Saturation of receiver front end;  
Very high level received signals in the receiver's front end active devices reduce their gain resulting in receiver sensitivity degradation.
- (50) Existing standards define this as the blocking performance and acceptable limits are defined in the same way as for intermodulation which means that the limit stated corresponds to a received signal of -23 dBm or an isolation of at least 66 dB between source and receiver (these figures assume a +43 dBm source).
- (51) This problem is independent of frequency, but care should be taken to identify all critical signals within the response of the receiver system's front end filters using appropriate monitoring techniques.
- (52) Selectivity of the receiver;  
This parameter defines the ability of a receiver to reject signals at unwanted frequencies. The selectivity figure not only depends on the characteristic of the intermediate frequency filter but also on the spectral performance of the local oscillator.
- (53) The existing ETSI standards define a two-signal method of measurement taking all these problems into account by looking at sensitivity degradation. The limits refer also to a wanted signal of - 07 dBm and are 60 dB above for the worst case (12.50 kHz channel spacing). This means that great care should be taken with the frequency planning to avoid having signal levels higher than - 47 dBm on adjacent channels in this case and -37 dBm in close frequency proximity (up to 5 x channel spacing).
- (54) These problems show the importance of having adequate isolation between equipment and radio sites. The design aim is to preserve the quality of service from the radio site by eliminating, or at least minimising, receiver disturbance.
- (55) Spurious response of the receiver;  
All receivers use frequency conversion. The result of this process, added to the RF filtering response and to the possible spurious signals of the local oscillators used, may be the source of other spurious responses at the RF input, resulting from the complex mixing of signals.
- (56) The ETSI standards give well-defined methods of measurement for these spurious responses and the calculation of frequencies at which they can occur (including duplex mode) by taking into account all local oscillator sources.

- (57) The limits considered are referred to a -107 dBm wanted signal and 70 dB above. They are identical to intermodulation limits and the same comments should apply regarding suitable response of all RF filters.

## 2.12 Calculation of intermodulation products at radio sites

- (58) Intermodulation products are generated as indicated in the diagram below, which uses two frequencies: 800.00 MHz and 800.40 MHz, as an example.

**Table 2-1: An Illustration of Intermodulation Products**



- (59) A number of software products are available to facilitate the calculation of possible IM products using the specific radio site frequencies. In addition to commercial offerings there are a number of 'free' products that can be downloaded and used on a computer to calculate possible IM products. Two sources of IM Calculation tools are given below:

### TCS Consultants Inc.

- <<http://www.tcstx.com/software/intermod/intermodulation.htm>> (Free to use)

- (60) TCS Consultants provides intermodulation calculation software for the analysis and calculation of intermodulation products generated by multiple transmitters on the same radio structure. This free tool is used to calculate interference from co-located transmitters that generate harmonics that may be in the same frequency as a receiver on the same site. It will calculate virtually any range of frequencies (00,000.00001 MHz to 99,999.99999 MHz).

### RF GlobalNet – Intermodulation – (Free to use)

Calculation of Intermodulation Products up to 5th Order. Uploaded by Fritz Dellsperger.

<<http://www.rfglobalnet.com/Downloads/Detail.aspx?docid=8b3b7cb7-b579-11d4-8c77-009027de0829>>

### RF GlobalNet – Mixer Intermod Spreadsheet – (Free to use)

This tool calculates mixer intermodulation products up to 5th order and displays graph in amplitude vs. frequency. Use the amplitude level as a guide instead of absolute spec. The tool is a Microsoft Excel 97 spreadsheet containing macros.

<http://www.rfglobalnet.com/Downloads/Detail.aspx?docid=8b3b7e56-b579-11d4-8c77-009027de0829>>

### **2.13 Generation of unwanted products by transmitters**

- (61) All practical transmitters generate unwanted outputs generally described as spurious emissions. A spurious emission is defined as:

*The emission of a signal on a frequency, or frequencies, which is outside the necessary bandwidth of the wanted transmission, the level of which may be reduced without affecting the integrity of the transmitted information. Spurious emissions include harmonic emissions, parasitic emissions, intermodulation products and frequency conversion products but exclude out-of-band emissions.*

- (62) An out-of-band emission, which is excluded from the above definition, is defined as:

*The emission of a signal on a frequency, or frequencies, immediately outside the necessary bandwidth of the wanted transmission, which results from the modulation process, but excludes spurious emissions.*

- (63) Both spurious emissions and out-of-band emissions may occur at a discrete frequency or be broadband noise occupying a significant bandwidth. Harmonics of the wanted carrier frequency are commonly occurring spurious emissions and may occur at the harmonic frequencies  $2f_c$ ,  $3f_c$ ,  $4f_c$ , where  $f_c$  is the fundamental carrier frequency.
- (64) At radio sites where several transmitters and receivers are co-located with associated antennas in close proximity, it is necessary to analyse the spurious and out-of-band emissions in relation to the receivers' operating frequencies to see what additional measures are necessary to avoid degradation of the receivers' performance.
- (65) The minimum isolation required between transmitters and receivers on the same radio site is calculated by relating the transmitters' spurious and out-of-band emissions with the useable sensitivity and noise floor of the receivers.
- (66) Attention is drawn to ITU-R Recommendation SM.329-10 [16] giving full details of methods of measurement of spurious and out-of-band emissions and the different categories of permitted levels for several different classes of radio communications equipment

### **2.14 Final commissioning and customer handover**

- (67) Commissioning of the completed radio system and handing it over to the user/operator is the culmination of the installation process. A commissioning schedule together with any necessary formal certification documents should be identified in the supply contract and thus need to be agreed before the radio station can be handed over to the user/operator.
- (68) The commissioning schedule will be required to demonstrate to the user's satisfaction that the radio station is fully functional and specifically that it meets the user's needs in so far as they are specified in the supply contract. In addition any regulatory commitments that need to be complied with, specifically those defined in the radio licence, should form part of the schedule.

- (69) The satisfactory demonstration that the radio station together with any related remote facilities complies with the user's aspirations, identified via the supply contract needs to be formally recorded as part of the documentation chain and a formal handover notice be prepared and signed by both parties.

## **2.15 Field operation**

- (70) The field operation and the ongoing maintenance of the radio site may form part of the original supply contract or it may be a separate supply contract with the same or an alternative contractor.

- (71) In either case it is in the contractor's interest that the radio site performs in accordance with its specification and is essentially fault free. In the event that faults occur during any warranty period then the contractor should use their best endeavours to rectify the faults at the earliest opportunity. Faults that manifest themselves in outsourced equipments or services should be addressed with equal vigour.

## **2.16 Routine maintenance requirements**

- (72) Successful field maintenance relies to a great extent on skill of the maintenance technician - a combination of training, competence and common sense, leading to:

*A SATISFIED CUSTOMER  
WITH A SAFE AND EFFICIENT RADIO SYSTEM*

### **2.16.1 Antennas and feeders:**

- (73) Inspection should be undertaken in accordance with an agreed maintenance (normally annual) schedule:
- antenna elements should be inspected for signs of corrosion. Where pitting of the surface metal is evident replacement is recommended;
  - plastic encapsulation forming antenna terminations or balun networks are liable to degradation and splitting subsequently admitting water and should, therefore, be examined in detail for hairline cracks;
  - feeder trays and securing cleats should be checked for tightness and earthing straps must be checked for electrical integrity. Cables should be inspected for physical damage which can be caused by in-experienced riggers climbing on existing cable trays;
  - far field performance for antennas on a site should be measured every 2 to 3 years and compared to gain and radiation pattern measurements recorded at installation. Any antenna showing substantial deviation should then be further examined to deduce the cause.

### **2.16.2 Mast/Tower**

- (74) At annual intervals the structural installation should be inspected for condition, protection against rust, tension in guy assemblies and general deterioration of the surface. If defects are found, they should be recorded and corrective action taken. Adjustable screws or tensioners for a guy system should be greased and protected, corrosion should be removed and the cleaned surface provided with a protective coating.

NOTE: In particular, earth bonding, lugs, straps or connections must remain free from corrosion.

## **2.17 Modification and updating of system/equipment**

- (75) It is probable that during the life of any radio site that the services offered and hence the equipment it contains will be replaced or updated. In many cases more modern equipments will be physically smaller and consume less power, but where the functionality of the site is extended e.g. with the provision of additional services – more physical space, additional mast height to accommodate new antennas and other new support services may be required.
- (76) The maintenance of a radio site and the replacement/updating of defective equipment can be treated as part of an overall maintenance schedule.
- (77) The updating of a radio site to offer additional or alternative services should be treated as a 'new' build compliant with the user/operator's updated requirements. Note also that the regulatory provisions, including those from a Local Authority may have changed and some site features may have to be updated to be compliant with later legislation.

## **2.18 Decommissioning equipment/system**

- (78) The de-commissioning of a radio site will require that the equipment, cables, antenna mounting equipment or structures that it contains is removed and disposed of in accordance with safe working practice. In the current climate the need for radio sites is increasing and hence it is probable that the site will be re-used by another operator.
- (79) In the event that the site is required to be returned to a 'green' state then the Local Authority should be consulted to determine if there are any specific requirements that need to be complied with.

## **2.19 End-of-life scenario, disposal of equipment**

- (80) The Waste Electrical and Electronic Equipment (WEEE) Directive requires the correct disposal procedures be adopted for all electrical and electronic waste material.

## **2.20 Site Records**

- (81) Site information should be kept centrally, and displayed in a useful form on site, where appropriate, and where security considerations allow. A common practice is to maintain a master outline of each structure, referring to detailed drawings of mounting arrangements, feeder routes and other relevant information.
- (82) On multiple user sites, records should be kept of each user with contact details for both the owner and maintenance contractor for the equipment.
- (83) Physical information should include:
- antenna types;
  - feeder lengths and types;
  - connector types and sex;
  - distribution harness details;
  - details of mounting hardware.
- (84) Electrical information established at systems commissioning provides a useful reference for the diagnosis of later problems.
- (85) Data recorded for each antenna system should include:

- VSWR, insulation and attenuation of feeder cable for the appropriate frequency band;
- VSWR measurements on complete antenna systems, bench measurements of power division networks for the appropriate frequency band;
- power output of each transmitter at the transmitter output port;
- calculated effective radiated power of each transmitter.

## 2.21 Health and Safety considerations

- (86) The safety of the working environment on, and in the vicinity of radio sites must always remain of high importance to site operators and engineers. Health and safety issues in EC countries must comply with the Low Voltage Directive 73/23/EEC [26], this legislation has been introduced for the protection of employers, employees and the public.

### 2.21.1 Physical safety

- (87) In most cases common sense is the best guide to the physical safety on radio sites.
- (88) A working policy should be in force for all staff, especially those engaged on work external to the equipment room. In many cases the wearing of a hard hat is a legal requirement when work is undertaken on the antenna support structure and the dangers of falling objects makes their use essential.
- (89) Only qualified personnel should be allowed to climb the antenna support structures. They should have had training on all aspects of climbing procedures, particularly the emergency procedures pertaining to these activities.
- (90) A consideration that is sometimes overlooked is the danger of falling ice in colder climates during winter months. 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.
- (91) Inside the equipment room care should be taken to ensure that sharp projections are avoided and that the common walkways remain clear and unhindered. This is particularly important when additional services are added and equipment rooms become crowded.
- (92) Where lead acid battery power supplies are installed the first aid aspect of acid splashes must be considered and in particular the requirement for eye wash solution in first aid cabinets.
- (93) High power devices commonly found on radio sites often contain beryllium, usually in the form of an oxide. Beryllium is a toxic substance the inhalation of Beryllium dust can cause inflammation of the nose, throat and chest. If a beryllium device is broken then the utmost care should be taken in removing the fragments and dust from the site. It is recommended that professional advice be obtained in all cases before removal of the substance is attempted.

### 2.21.2 Electrical safety

- (94) Accidents that are related to the electrical installation are amongst the most common occurrences. The design and construction of the electrical installation has already been amply illustrated in the present document, but emphasis should be placed on the importance of electrical safety and correct earthing procedures on radio sites. The minimum requirement as far as the user is concerned is the use of

Residual Current Devices (RCD). In particular, it is desirable that anyone who regularly works in a radio site environment should be aware of the procedures for the first aid treatment of personnel suffering electric shock

### **2.21.3 Fire hazards**

- (95) The requirements for the prevention and extinguishing of fires are governed by legislation; in particular the storage of paper, cardboard boxes, paint and other inflammable goods is not desirable. The number and type of extinguishers that are required at a site should be decided in consultation with the appropriate fire authority.

### **2.21.4 RF Exposure Guidelines**

- (96) Radio sites need to be designed and operated to limit the exposure of both the General Public and Workers to RF emissions. At positions where people are exposed to the radio waves from base station antennas, the level of exposure is much more constant over the whole body than when they are exposed to a mobile phone. Under these circumstances, the basic restriction in the ICNIRP guidelines is that placed on SAR averaged over the entire body mass. ICNIRP specifies that this should not exceed 0.4 W/kg for workers or 0.08 W/kg for the general public.
- (97) Whole-body SAR is not very easy to measure practically; consequently ICNIRP gives a reference level for the power density below which the SAR restriction would be complied with. These reference levels vary with frequency and range from 2 W m<sup>-2</sup> to 10 W m<sup>-2</sup> for the general public over the radiofrequency range 10 MHz to 300 GHz.
- (98) The reference level is 4.5 W m<sup>-2</sup> in the 900 MHz GSM frequency band and 9 W m<sup>-2</sup> in the GSM1800 frequency band. This is not because a lower limit is set for operators using the GSM900 band since the underpinning basic restriction is the same for both frequency bands. The different reference levels arise because the body tends to interact more strongly with radio waves at 900 MHz than at 1800 MHz meaning that a lower reference level has to be set. The reference level in the 2000 MHz 3G base station band is 10 W m<sup>-2</sup>.
- (99) When considering exposure in the context of the ICNIRP guidelines, it is important to recognise that the guidelines are intended to limit total exposure to radio waves from all sources and not just that part of exposure arising from a particular base station.

## 3 Required Installation Skills

- (100) The skill set required by the design installation and commissioning teams is addressed under the following headings:

**Antenna mast build and erection practice**  
**RF antenna build and installation practice**

### 3.1 Antenna mast build and erection practice

- (101) The terms "mast" and "tower" are often used interchangeably. However in engineering terms, a tower is a self-supporting or cantilevered structure, while a mast is held up by stays or guys. Masts tend to be cheaper to build, but they require an extended area surrounding them to accommodate stay blocks.

#### 3.1.1 Steel lattice

- (102) The steel lattice is the most widespread form of construction. It provides great strength, low wind resistance and economy in the use of materials. Such structures are usually triangular or square in cross-section.

#### 3.1.2 Tubular steel/Poles

- (103) Masts can be constructed out of steel tubes. Shorter masts may consist of a self-supporting or guyed wooden pole, similar to a telegraph pole. Sometimes self-supporting tubular galvanized steel poles are used; these may be termed monopoles.

#### 3.1.3 Reinforced concrete

- (104) Reinforced concrete towers are relatively expensive but provide a high degree of mechanical rigidity in strong winds. This can be important when antennas with narrow beamwidths are used, such as microwave point-to-point links, and when the structure is to be occupied.

#### 3.1.4 Buildings

- (105) It is possible to install antenna systems on the roofs or walls of buildings. This is common practice in urban areas.

#### 3.1.5 Telescopic, pump-up masts

- (106) The telescopic mast can be erected quickly, and are mostly used in setting up temporary sites or for survey work.
- (107) Telescopic masts consist of two or more concentric sections and come in two principal types:
- (108) Pump-up masts are often used on vehicles and are raised to their full height pneumatically or hydraulically. They are usually only strong enough to support fairly small antennas.
- (109) Telescopic lattice masts are raised by means of a winch, they cater for greater heights and loads than the pump-up mast type. When retracted, the assembly can be lowered to a horizontal position, which enables antennas to be fitted and adjusted at ground level before winching the mast up.

#### 3.1.6 Economic and aesthetic considerations

- (110) In recent times there has been a lot of opposition to the building of masts and towers. Much of this opposition is on aesthetic grounds. Ugly, over-engineered

structures instil a feeling of dread in susceptible people and this may manifest itself as an irrational fear of “Radiation” or, indeed, the attribution of symptoms that may, or may not, be real to the proximity of the structure.

- (111) The cost of a mast or tower is roughly proportional to the square of its height.
- (112) A guyed mast is cheaper to build than a self-supporting tower of equivalent height.
- (113) A guyed mast needs additional land to accommodate the guys, and is thus best suited to rural locations where land is relatively cheap. A tower will fit into a much smaller plot.
- (114) A steel lattice tower is cheaper to build than a concrete tower of equivalent height.
- (115) Two small towers may be less intrusive, visually, than one big one; especially if they look identical.
- (116) Towers look less ugly if they and the antennas mounted on them appear symmetrical.

### **3.1.7 Access for riggers**

- (117) Because masts, towers and the antennas mounted on them require maintenance, access to the whole of the structure is necessary. Small structures are typically accessed with a ladder. Larger structures, which tend to require more frequent maintenance, may have stairs and sometimes a lift.

### **3.1.8 Aircraft warning lamps**

- (118) Taller structures will need to be equipped with lamps, usually red, to warn pilots of the structure's existence. In the past, under-run filament lamps were used to maximise the bulb life. Nowadays such lamps tend to use LED arrays.

## **3.2 RF antenna build and installation practice**

- (119) Antennas and their mounting hardware should be procured from a reputable supplier, in accordance with the radio system design. Antennas to be installed onto or removed from the mast/tower structure require the consent of the site manager and should be mounted using commercially available hardware.
- (120) Cable runs must be secured to the cable tray/ladder, using the appropriate hardware, cables are not to be run on the mast/tower legs.
- (121) Modification of any antenna configurations including the ‘swapping’ of radio systems versus antenna in multiple radio/antenna installations, should not be undertaken without the prior consent from the site manager, and any other responsible party.

## **3.3 Electrical (mains power) switchboard, cable routing and connection practice**

- (122) Multiple use residential buildings may require that **BS 7671:2001 - Requirements for Electrical Installations**, apply if shared by an equipment installation
- (123) Detached buildings not normally used by people, such as buildings containing fixed plant or machinery intermittently used by people only to maintain or inspect that plant or machinery, are exempt.

### 3.4 Auxiliary power supply connection practice

- (124) Auxiliary power can be supplied by a battery system or a generator that is activated when there is a mains failure. These are considered to be specialist items and an appropriate supplier needs to be identified, if an auxiliary power supply is required.

### 3.5 RF Cable Routing, Marking and Connection practice

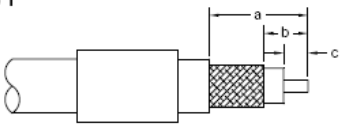
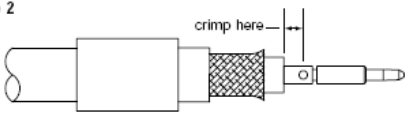
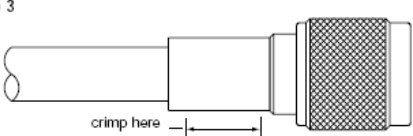
#### 3.5.1 RF Cables, Routing and Marking

- (125) All RF transmission cables are to be routed neatly, and secured in the provided overhead cable trays. Excess cable is not to be coiled up in the cable tray, nor is a coil to be strapped to the bottom of the tray.
- (126) All RF cables, from the mast/tower to the building, must be terminated on equipment of proper impedance, or if not connected to equipment then the cables are to be attached to a termination load of proper impedance.
- (127) All transmission lines will be identified with a colour code sequence assigned by the site manager, for example, red-green-yellow. 1) The feeder end at the antenna is to have the colour code applied to it next to the connector (outside of any protective covering applied to the connector), 2) outside the building wall at the feeder entry point, 3) inside the building wall at the building entry point and 4) on the jumper cable at the point of entry into the equipment rack or cabinet. ZCZC

#### 3.5.2 RF Connectors

- (128) RF cables require that the correct termination procedures are applied to the connectors to ensure that the characteristic impedance of the line and environmental protection is maintained.
- (129) A typical procedure for a type N connector is given below. More details can be found at: <<http://www.amphenorlf.com/products/AssemblyInstructions/typen.pdf>>

#### Sample assembly instructions for Type “N” Plug

- Step 1**
- 
- Step 1** Strip cable jacket, braid, and dielectric to dimensions shown. All cuts are to be sharp and square. **Important:** Do not nick braid, dielectric, and center conductor. Tinning of center conductor is not necessary if contact is to be crimped. For solder method, tin center conductor avoiding excessive heat.
- Step 2**
- 
- Step 2** Slide outer ferrule onto cable as shown. Flare slightly end of cable braid as shown to facilitate insertion of inner ferrule. **Important:** Do not comb out braid. Place contact on cable center conductor so it butts against cable dielectric. Center conductor should be visible through inspection hole in contact. Crimp or solder contact in place as follows:  
**Crimp Method:** Use Die Set Cavity for contact indicated in table above. **Solder Method:** Soft solder contact to cable center conductor. Do not get any solder on outside surface of contact. Avoid excessive heat to prevent swelling of dielectric.
- Step 3**
- 
- Step 3** Install cable assembly into body assembly so inner ferrule portion slides under braid. Push cable assembly forward until contact snaps into place in insulator. Slide outer ferrule over braid and up against connector body. Crimp outer ferrule using Die Set Cavity specified in table above.

Amphenol Number	Connector Type	Cable RG-/U	Strip Dimensions, inches (mm)			Hex Crimp Data			
			a	b	c	Cavity for Contact	Cavity for Outer Ferrule	Die Set for Tool 227-944#	CTL Series Tool No.
82-332	N Plug	9, 214	.531(13.5)	.234(6.0)	.140(3.5)	.100(2.5)	.429(10.9)	227-1221-25	CTL-3
82-340	N Plug	8, 213	.531(13.5)	.234(6.0)	.141(3.6)	.100(2.5)	.429(10.9)	227-1221-25	CTL-3
82-340-1052	N Plug	B9913, 9914	.539(13.7)	.250(6.4)	.158(4.0)	.116(2.9)	.429(10.9)	227-1221-63	CTL-11
82-340-1054	N Plug	LMR 400	.539(13.7)	.250(6.4)	.157(4.0)	.116(2.9)	.429(10.9)	227-1221-63	CTL-11
82-4425	N Plug	9, 214, 225, 393	.687(17.4)	.281(7.1)	.187(4.7)	.100(2.5)	.429(10.9)	227-1221-25	CTL-3
82-4425-1003	N Plug	9, 214, 225, 393	.687(17.4)	.281(7.1)	.187(4.7)	.100(2.5)	.429(10.9)	227-1221-25	CTL-3
82-4426	N Plug	8, 213	.687(17.4)	.281(7.1)	.187(4.7)	.100(2.5)	.429(10.9)	227-1221-25	CTL-3
82-4426-11RFX	N Plug	8, 213, 214 EthCables	.630(16.0)	.303(7.7)	.157(4.0)	.100(2.5)	.429(10.9)	227-1221-25	CTL-3
82-4426-1001	N Plug	Ethernet Cables	.687(17.4)	.281(7.1)	.187(4.7)	.100(2.5)	.429(10.9)	227-1221-25	CTL-3
82-4426-1002	N Plug	Ethernet Cables	.687(17.4)	.281(7.1)	.187(4.7)	.100(2.5)	.429(10.9)	227-1221-25	CTL-3
82-4427	N Plug	142, 400	.687(17.4)	.281(7.1)	.187(4.7)	.100(2.5)	.213(5.4)	227-1221-57	CTL-3
82-4427-1006	N Plug	142, 142B, 400	.600(15.2)	.275(7.0)	.140(3.5)	.100(2.5)	.213(5.4)	227-1221-57	CTL-3

### 3.6 Earth bonding for electrical and RF safety practice

(130) All racks / cabinets will be secured electrically to the earth-ground provided in the building. This is to be accomplished using heavy copper braid, or a minimum of 4 stranded copper conductors. If insulated, standard electrical grounding codes require it to be solid green or green with yellow stripe(s).

### 3.7 Telephony interface connection practice

(131) Local telephony practice needs to be observed, the local preferred supplier needs to be contacted; a direct telephony link is not permitted in some cases.

### 3.8 RF interference troubleshooting

(132) RF troubleshooting is a specialist activity that requires the skill to identify the cause of any RF interference, such as 'modulation products' and to effect a cure. In many complex radio installations complex filters may be required to achieve the necessary isolation. A small number of specialist filter manufacturers can provide a bespoke service and it is recommended that one of these Companies is contacted.

### 3.9 Ventilation and air conditioning equipment knowledge

(133) Air conditioning and ventilation equipment is essential in larger installations to minimise the rise in the local ambient temperature. The designer needs to undertake an assessment of the maximum level of heat (energy) that can be generated and contact a specialist supplier to design and install the necessary equipment taking due account of the ventilation unit's power needs, if an auxiliary power supply is required.

## **PART 2 SOHO – Installations**

- (134) **SOHO** installations are the equivalent to flat-pack furniture, they comprise a single base station and a small number of mobile units which may be hand held or vehicle installed. There has been a considerable growth in de-regulated radio products, many of which fall into this category. These radio products are frequently supplied as bubble packs and are available to the public through the High Street retailers.

## 4 Radio Products

### 4.1 PMR 446

- (135) PMR 446 the PMR (Private Mobile Radio) service is an example of a hand-held only product that uses the frequency band 446.0 - 446.1 MHz. There are eight 12.5 kHz simplex frequencies which can be used anywhere in the United Kingdom.
- (136) PMR 446 is a short range voice only communication system, which provides a basic but effective radio service for both business and non business users, and is ideal for providing communication over short distances; such as within office buildings, factories and building sites. Only speech transmissions can be made.
- (137) The PMR 446 service is licence exempt, so users do not require a licence to use PMR 446 radios, which must be hand portable, have an integral antenna, and a maximum ERP of 500 mW and be compliant with EN 300 296, the use of CTCSS, DCS and/or selective calling is recommended.

### 4.2 CB Radio

- (138) CB (Citizen's Band) radio equipment also comes into this category of radio equipment and from December 2006 CB Radio joined [PMR446](#) radio under the licence exempt category. CB Radio is not limited to a hand-held service and operates 40 channels in the 27 MHz band. A basic CB installation will consist of a Base Station transceiver powered from the domestic mains supply feeding an external antenna which is mounted on a building or mast c.f a Band I television antenna installation.



## **PART 3 – Business Radio Sector Technologies**

# 1 Private Mobile Radio (PMR) Systems

- (139) The most common use of private mobile radio (PMR) is to provide two way communications between a fixed site and a number of mobile units. PMR systems operate in specifically allocated parts of the Very High Frequency (VHF) and Ultra High Frequency (UHF) bands. Each frequency band may be divided into a number of separate channels spaced at 5 kHz, 6.25 kHz, 12.5 kHz, 20 kHz or 25 kHz.
- (140) Most mobile radio services use Frequency Modulation (FM). In some cases Phase Modulation (PM) or FM with pre-emphasis is used to improve the received signal to noise ratio. Amplitude Modulation (AM) is used in some of the VHF bands. An increasing number of modern mobile radio networks use digital modulation such as Phase Shift Keying (PSK) or Frequency Shift Keying (FSK). Single sideband or linear modulation techniques using narrow band channels may be introduced, with the aim of improving spectrum efficiency.
- (141) Most PMR systems use two frequency channels. The base station transmits on one of these frequencies and the mobile stations in the same system transmit on the other frequency. This is known as two frequency simplex, or semi duplex operation. With the addition of suitable control apparatus, the base station transmitter may be operated in a full duplex, or repeater, mode. In this way communication may be established between mobile or portable users within range of the base station who may not otherwise be able to communicate directly between themselves. The repeater facility may be under the control of an operator.
- (142) Most users operate a single base station with a few mobiles. Some private networks have many base stations and may have several thousand mobile units. These larger systems use various techniques to provide near contiguous coverage of large areas. These techniques include scanning mobiles, quasi-synchronous operation of all base station transmitters with receiver voting and more recently trunked radio systems. Other systems may use a single frequency with or without base stations for applications such as site security.
- (143) Shared PMR channels are used by several licensees, each with their own base station. In highly populated areas the coverage area of many channels can overlap each other such that several simultaneous transmissions can occur, with resulting interference. The use of access tone signalling systems can minimize the problem but does not offer a complete solution.

## 1.1 Basic PMR

- (144) A basic PMR installation requires frequency assignment and a licence from Ofcom. Specialist suppliers will undertake this task and provide the User with the 'bubble pack' containing all of the radio equipment required and licence ready for installation in an analogous way to the CB Radio equipment.
- (145) The base station equipment will be powered from a domestic mains socket feeding an external antenna mounted on a building or mast as indicated above. The complete installation will include a microphone and may include an uninterruptible power supply, and an external loudspeaker
- (146) All of the equipment can be purchased directly from many specialist suppliers who will set up and test the equipment prior to delivery.

## 1.2 Common Base Station Systems

- (147) Common Base Station (CBS) systems are offered to subscribers by operators or service providers. CBS operators provide wide area coverage using a single or

many radio channels from one or several base stations. Some networks can be built in a complex configuration in order to provide a good service and use coverage techniques such as simulcast, multi-channel configuration with sites linked by leased lines and voting systems. In some cases, networks can be dedicated to specific types of use, e.g. security, funds transportation, building or park keepers. Different user groups have to share a system. Sharing needs a signalling protocol based on audio tones or digital signalling resulting from the needs of users of the networks.

### 1.3 MPT1327 PMR Systems

- (148) A trunked version of the Private Mobile Radio (PMR) concept that is defined under the standard MPT 1327 (MPT1327) is widely used and provides significant advantages over the simpler single station systems that are in use. MPT1327 enables stations to communicate over wider areas as well as having additional facilities. In view of the very high cost of setting up trunked networks, they are normally run by large leasing companies or consortia that provide a service to a large number of users. In view of the wider areas covered by these networks and the greater complexity, equipment has to be standardised so that suppliers can manufacture in higher volumes and thereby reduce costs to acceptable levels. Most trunked radio systems follow the MPT1327 format.
- (149) To implement trunked PMR a network of stations is set up. These stations are linked generally using land lines, although optical fibres and point to point radio are also used. In this way the different base stations are able to communicate with each other.
- (150) In order to be able to carry the audio information and also run the variety of organisational tasks that are needed the system requires different types of channel to be available. These are the control channels of which there is one in each direction for each base station or Trunking System Controller (TSC).
- (151) A number of different control channels are used so that adjacent base stations do not interfere with one another, and the mobile stations scan the different channels to locate the strongest control channel signal. In addition to this there are the traffic channels. The specification supports up to 1024 different traffic channels to be used. In this way a base station can support a large number of different mobile stations that are communicating at the same time. However for small systems with only a few channels, the control channel may also act as a non-dedicated traffic channel.
- (152) The control channels use signalling at 1200 bits per second with fast Frequency Shift Keying (FFSK) subcarrier modulation. It is designed for use by two-frequency half duplex mobile radio units and a full duplex TSC.
- (153) For successful operation it is essential that the system knows where the mobiles are located so that calls can be routed through to them. This is achieved by base stations polling the mobile stations using the control channel.
- (154) To make an outgoing call the mobile transmits a request to the base station as requested in the control channel data stream from the base station. The mobile transmits its own code along with that of the destination of the call, either another mobile or a control office. The control software and circuitry within the base station and the central control processing area for the network sets up the network so that a channel is allocated for the audio (the traffic channel). It also sets up the switching in the network to route the call to the required destination.

- (155) To enable the mobile station to receive a call, it is paged via the incoming control channel data stream to indicate that there is an incoming call. Channels are allocated and switching set up to provide the correct routing for the call.
- (156) There is no method to "handover" the mobile from one base station to the next if it moves out of range of the base station through which a call is being made. In this way the system is not a form of cellular telephone. It is therefore necessary for the mobile station to remain within the service area of the base station through which any calls are being made.
- (157) The control channel signalling structure has to be defined so that all mobiles know what to expect and what data is being sent. Signalling on the forward control channel is nominally continuous with each slot comprising 64 bit code words. The first type is the Control Channel System Codeword (CSCC). This identifies the system to the mobile radio units and also provides synchronisation for the following address codeword. As mentioned the second type of word is the address codeword. It is the first codeword of any message and it defines the nature of the message. It is possible to send data over the control channel. When this occurs, both the CSCC and the address codewords are displaced with the data appended to the address codeword. The mobile radio unit data structure is somewhat simpler. It consists fundamentally of synchronism bits followed by the address codeword.
- (158) There are a number of different types of control channel messages that can be sent by the base station to the mobiles:
- (159) Aloha messages -- Sent by the base station to invite and mobile stations to access the system.
- (160) Requests -- Sent by radio units to request a call to be set up.
- (161) "Ahoy" messages -- Sent by the base station to demand a response from a particular radio unit. This may be sent to request the radio unit to send his unique identifier to ensure it should be taking traffic through the base station.
- (162) Acknowledgements -- These are sent by both the base stations and the mobile radio units to acknowledge the data sent.
- (163) Go to channel messages -- These messages instruct a particular mobile radio unit to move to the allocated traffic channel.
- (164) Single address messages -- These are sent only by the mobile radio units. Short data messages -- These may be sent by either the base station or the mobile radio unit.
- (165) Miscellaneous messages -- Sent by the base station for control applications.
- (166) One of the problems encountered by mobile signalling systems is that of clashes when two or more mobile radio units try to transmit at the same time on the control channel. This factor is recognised by the system and is overcome by a random access protocol that is employed. This operates by the base station transmitting a synchronization message inviting the mobile radio units to send their random access message. The message from the base station contains a parameter that indicates the number of timeslots that are available for access. The mobile radio unit will randomly select a slot in which to transmit its request but if a message is already in progress then it will send its access message in the next available slot. If this is not successful then it will wait until the process is initiated again.

- (167) Although the data is transmitted as digital information, the audio or voice channels for the system are analogue, employing FM. However some work has been carried out to develop completely digital systems.
- (168) The main competing systems are by Motorola, by Ericsson (EDACS) and Johnson (LTR). These systems have not gained widespread acceptance outside the USA.

#### 1.4 Digital PMR Systems

- (169) Many complete systems are known under their commercial designation. These are dedicated to different users such as mobile data, police systems and taxi networks. They can be operated on a local, regional, national or European coverage, using one or many frequencies. The protocols can be proprietary or public. The digital systems can use different types of modulation, direct via the normal audio circuitry for a rate of signalling not higher than 2.4 kbit/s and direct frequency modulation for higher data rates (>4.8 kbit/s) or other modulation techniques for data rates up to 36 kbits/s.
- (170) The most current modulation methods are:
- Minimum Shift Keying (MSK);
  - Frequency Shift Keying (FSK);
  - BiPolar Shift Keying (BPSK);
  - Gaussian Minimum Shift Keying (GMSK);
  - Gaussian Frequency Shift Keying (GFSK);
  - FM 2 or 4 levels;
  - $\pi/4$  QPSK (Quadrature Phase Shift Keying).
- (171) The access to the channels can be by Frequency Division Multiple Access (FDMA) or Time Division Multiple Access (TDMA) methods.
- (172) The general objectives of a spectrum efficient digital land mobile system, for despatch in either private or public systems, are to provide:
- systems that offer a higher spectrum efficiency, thereby accommodating more users within limited spectrum resources than analogue systems;
  - a higher average level of voice quality over the network and enciphered speech for privacy;
  - users with a wide range of services and facilities, both voice and non-voice, that are compatible with those offered by the public fixed networks;
  - users with a variety of applications to satisfy their requirements, ranging from handheld stations to vehicle mounted stations, with voice and data interfaces;
  - mobiles and infrastructure equipment which use state of art technology to provide savings in weight, power consumption and cost.
- (173) The basic services offered by a digital dispatch traffic system can be divided into three types: teleservices, bearer services and supplementary services. These systems, as opposed to public radiotelephones, use a fast call set up time and a short call re-establishment time. Some categories of users, emergency and police services for example, need complex networks where the users apply different mode operations such as:

- network mode where the mobile is within the coverage and control of the infrastructure (including trunking mode and open channel mode);
- direct mode where the mobile directly communicates with the other terminal in or outside the network coverage;
- repeater mode where the mobile communicates with the other terminal through a repeater.

#### **1.4.1 Digital PMR – TETRA**

- (174) **Terrestrial Trunked Radio (TETRA)** is a digital Private Mobile Radio (PMR) and Public Access Mobile Radio (PAMR) technology for police, ambulance and fire services, security services, utilities, military, public access, fleet management, transport services, closed user groups, factory site services, mining, etc.
- (175) With support of the European Commission and the ETSI members, the TETRA standard has been developed over a number of years by the co-operation of manufacturers, users, operators and other experts, with emphasis on ensuring the standard will support the needs of emergency services throughout Europe and beyond. The standard builds upon the lessons and techniques of previous analogue Trunked radio systems and the successful development of GSM during the 1980s. The work started in 1990 and the first standards were ready in 1995.
- (176) TETRA offers fast call set-up time, addressing the critical needs of many user segments, excellent group communication support, Direct mode operation between radios, packet data and circuit data transfer services, frequency economy and excellent security features. TETRA uses Time Division Multiple Access (TDMA) technology with 4 user channels on one radio carrier and 25 kHz spacing between carriers. This makes it inherently efficient in the way that it uses the frequency spectrum. For emergency systems in Europe the frequency bands 380-383 MHz and 390-393 MHz have been allocated for use by a single harmonized digital land mobile systems by the ERC Decision (96)01. Additionally, whole or appropriate parts of the bands 383-395 MHz and 393-395 MHz can be utilized should the bandwidth be required.
- (177) For civil systems in Europe the frequency bands 410-430 MHz, 870-876 MHz / 915-921 MHz, 450-470 MHz, 385-390 MHz / 395-399,9 MHz, have been allocated for TETRA by the ERC Decision (96)04.
- (178) TETRA trunking facility provides a pooling of all radio channels which are then allocated on demand to individual users, in both voice and data modes. By the provision of national and multi-national networks, national and international roaming can be supported, the user being in constant seamless communications with his colleagues. TETRA supports point-to-point, and point-to-multipoint communications both by the use of the TETRA infrastructure and by the use of Direct Mode without infrastructure.

#### **1.4.2 Digital PMR – TETRAPOL**

- (179) TETRAPOL is an all-digital frequency division multiple access (FDMA) PMR technology that uses a 12.5 kHz narrow-band channel with GMSK modulation. It was originally developed for the French Gendarmerie Military Police under the code name of "RUBIS", to provide secure digital radio communications.
- (180) It differs from the TETRA technology which implements a time division multiple access (TDMA) technology in 25 kHz channels with pi/4 DQPSK.
- (181) The TETRAPOL FDMA technology is well suited to PMR requirements:-

- The radio coverage from each base station is comparable to 12.5 kHz analogue PMR
- The progressive installation of digital capabilities by re-using the 12.5 kHz analogue assigned channels is feasible
- The ability to simulcast and offer a live mode function allows contact without using the base station infrastructure
- TETRAPOL has now been migrated to an all IP (Internet Protocol) based network.

## **1.5 Project MESA**

(182) Project MESA is a cooperative process between ETSI and TIA (USA) that is developing new standards for mobile broadband technologies and services. These platforms are intended to serve the needs of the world's public protection, public safety, disaster relief and peacekeeping agencies or organizations.

## **1.6 Paging**

- On-site
- Wide-area Public and Private
- Local Communications



## Appendix A - European Legislation.

**Directive 1999/5/EC**

of the European Parliament and the Council of 9th March 1999 on radio equipment and telecommunications terminal equipment and the mutual recognition of their conformity (R&TTE Directive).

**Council Directive 89/336/EEC**

of 3 May 1989 on the approximation of the laws of Member States relating to electromagnetic compatibility.

**Council Directive 73/23/EEC**

of 19 February 1973 on the harmonization of the laws of Member States relating to electrical equipment designed for use within certain voltage limits.

**Directive 2004/40/EC**

of the European Parliament and of the Council of 29 April 2004 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (18th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)

**Directive 2002/96/EC**

of the European Parliament and of the Council of 27 January 2003 on Waste Electrical and Electronic Equipment (WEEE)



## Appendix B– Standards and Codes of Practice.

**MPT 1331:**

Code of Practice for Radio Site Engineering –  
Radiocommunications Agency – DTI – Code of Practice only -  
non-mandatory standard - *Reprinted 1996*.

**ETSI EG 200 053 V1.5.1 (2004-06):**

"Radio site engineering for radio equipment and systems".

**ETSI TR 101 870 (V1.1.1):**

"Fixed radio transmitter sites; Exposure to non-ionising  
electromagnetic fields; Guidelines for working conditions".

**ETSI EN 301 489-1:**

"ElectroMagnetic Compatibility (EMC) standard for radio  
equipment and services; Part 1: Common technical  
requirements".

**ICNIRP guidelines:**

"Guidelines for limiting exposure to time-varying electric,  
magnetic and electromagnetic fields (up to 300 GHz)".  
Health Physics, April 1998, vol. 74, n 4, p. 494-522.

**BS 7671:2001:**

Requirements for Electrical Installations

**Council Recommendation 1999/519/EC:**

of 12 July 1999 on the limitation of exposure of the general  
public to electromagnetic fields (0 Hz to 300 GHz).



## Appendix C – Bibliography

Standards and Guidelines for Communications Sites

Published by Motorola and known as the 'R56 Manual' or 'Fixed Equipment Installation Instruction Manual'. Available in two formats: Printed - 6881089E50 or CD-ROM - 9880384V83



## Appendix D – Spectrum licences

Ofcom licence products available from December 2008 can be found at [www.ofcom.org.uk](http://www.ofcom.org.uk).

