LAND MOBILE RADIO SYSTEMS

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Chapter 1
Introduction to mobile radio

R.J. Holbeche

1.1 INTRODUCTION

This book is concerned with the techniques and practices of Civil Land Mobile Radio Communications, generally known simply as Mobile Radio, and regarded merely as the technology of Police and taxi radios. However, the scientific complexity and commercial significance of this important area of activity is considerable, and whereas the commercial significance of this important area of activity is considerable, and whereas the commercial significance of mobile radio is a consideration for companies and governments it is with a view to enhancing the technological and scientific understanding and appreciation of the subject that this book has been prepared by acknowledged experts in the field.

1.2 POLICE AND TAXI RADIOS

Mobile radio is of course concerned with both Polic and taxi radios, identifying samples of two of the major groups of users with significantly different requirements. The public safety, i.e. the Police, Fire and Ambulance authorities have a specific requirement to operate within well defined boundaries the geographic area of which will generally be in excess of that which can be covered by a single base station installation. They will therefore require a multisite scheme to achieve coverage. Also, due to the urgency of their business and the number of users involved, opration on more than one channel is, in addition, a most likely requirement. Rapid access to the Police National Computer (P.N.C.) and a possible requirement for location and status information will also generate a requirement for high speed reliable data communication. Therefore the multisite, multichannel, possibly computer controlled, speech and data communication system will be substantially different from the radio scheme required by the small taxi firms who is most likely to operate over a much smaller area and one that can be covered by a single base station. However, the need for urgency of communication is no less significant than the police authority who, unlike the taxi driver, do not have to survive in a ruthless atmosphere of commercial competition.

The communication requirement for the country vet who will need the facility for efficient and reliable message handling, who unlike the taxi driver does his work away from his vehicle will again be quite different from, say, the ail company senior executive for whom immediate access to the international telephone system may be his most important requirement.

Historically mobile radio equipment has been vehicle mounted. However, because the actual need has generally been to talk to the man and not his vehicle a wide range of portable equipment has emerged. Technological advances in semiconductor devices which due to their small size and modest power requirements are particularly suitable for portable equipment, has led to truly portable radio telephones and pagers. A pager is a small body-worn receiver which can convey a simple message to the user in the form of an alerting tone, a short recorded message or a line of text displayed on the pager itself. These compact, sophisticated equipments embody a large number of significant technological advances over the early vehicle mounted sets with thermionic valves and rotary convertors that were produced in the late 1940's.

1.3 HISTORICALLY

Immediately after World War II, during which radio communication technology advanced dramatically it became possible to produce vehicle mounted radio transmitters and receivers to operate in the VHF band of frequencies which could be used to satisfy the need for improved communications in the police and fire services. At that time the licensing authority which was the Post Office made available a number of channels for private and business use. The very first of those licences were for a fleet of tugs in the Tyne and Wear rivers and Camtax radio taxis in Cambridge both of which were equipped by Pye Telecommunications in 1947.

These early valve equipments were bulky and inefficient, and were vehicle mounted by sheer necessity. A major part of the early technical development of mobile radio did no more than effectively exploit the advances in device technology of the day. Thermionic valves became smaller and more efficient eventually to be replaced entirely by germanium and then silicon transistors. Each quantum improvement in devices producing a smaller, more efficient and often more attractive radio.

This eventual widespread and cost effective availability of reliable transistors combined with the very slow but steady development of battery technology enabled truly portable rather than transportable personal radio telephones to be developed.

The advent of the digital integrated circuit, apparently ideal to produce frequency synthesisers and essential for handling data transmission did not immediately produce a new range of sophisticated equipments as might have been expected. It ook many years and the development of the microprocessor to achieve the next significant advance in mobile radio equipment design. A present day mobile radio will consist of a radio transmitter and receiver, a frequency synthesiser, a data modem and a microprocessor. So that, in theory at least, the radio can perform any desired function to control the system as required. These intelligent radios are necessary in all the various cellular systems.

1.4 RADIO SCHEMES

A basic mobile radio scheme will include a fixed, or base, station, transmitter and receiver located either in a tall building or on a hill top which is connected back to the radio operator, sited usually in an office, either by a dedicated telephone line or often by a pair of low power radio transmitters and receivers connected to highly directional aerials. These radio link equipments were introduced when spectrum was available largely on the grounds of cost, convenience and reliability. They were operated not only on different frequencies but in a different band of frequencies from the base station to reduce the probability of interference.

There are a number of potential sources of interference in mobile radio systems. The most obvious will be when two base stations have been allocated the same frequency but are insufficiently spaced apart so that a mobile radio will experience cochannel interference in its service area. In areas of low mobile radio usage the problem is clearly avoidable, however, in areas of substantial usage the problem becomes largely unavoidable. Intelligent and informed frequency planning, which in practice is a most difficult task, is vitally important to achieve optimum satisfactory performance from a large number of mobile radio schemes operating in the same area.

The output spectrum of any transmitter will contain frequencies other than the main transmit frequency and likewise all radio receivers will respond to frequencies other than that for which they were intended to operate. As the numerical values of these spurious emission and spurious responses will be dependent on the equipment types, avoidance of this problem is beyond the reasonable capability of the planners and when interference occurs can only sensibly be tackled by the equipment users and suppliers.

However, by far the most serious problem of interference in spectrally congested areas is caused by electrical nonlinearity. This occurs principally in the output stages of transmitters and the input stages of receivers although even rusty bolts on transmitter aerial masts can be culprits. Potentially the problem starts when more than one transmitter operates in a band and increases very rapidly when additional transmitters are installed.

In areas of considerable spectral utilisation it is nonlinearity that is the limiting factor on communication and although this happened many years ago with H.F. communication and was partially resolved by adopting an alternative modulation method it appears that this route is unlikely to be followed by V.H.F. and U.H.F. mobile radio.

The problem can be alleviated somewhat by careful frequency planning because the resulting inter-modulation products produced by the nonlinearity can be calculated with reasonable reliability.

1.5 COVERAGE

Initially all radio schemes consisted of a base station transmitter and receiver located on a convenient hill top and a number of mobiles or portables that could clearly only maintain communication in a invariably irregular but reasonably well defined service area. As the radio coverage area from a convenient hill top and the county boundary for a police force, for example, are invariably different, area coverage techniques were developed to extend and tailor the service area by using additional base station sites although still the total service area for any radio scheme rarely exceeds the size of a county.

Much later, as equipment prices reduced and the cost benefit of mobile radio increased dramatically due to the escallation in fuel and vehicle costs, the benefits to be obtained attracted a far wider range of users whose coverage requirements exceeded the defined boundaries of the public safety authorities. Enterprising organisations, calling themselves message handlers, introduced efficient radio schemes combined with a highly professional secretarial service on a virtually national basis.

As the list of mobile radio users expanded rapidly the need was clearly established for a truly national facility when any one could have in his vehicle, or even his pocket, a telephone instrument at least as convenient as the one in his home or on his desk, and preferably more reliable.

The techniques necessary to realise this facility have been embodied in a system which has become known as cellular radio and will eventually satisfy a substantial proportion of the national mobile radio need.

It is interesting to make a comparison between the development of mobile radio systems and the development of the land telephone system, and just as the requirement for private dedicated landlines remains then so will the requirement for private dedicated radio telephone systems.

Chapter 2

Radio wave propagation

J.D. Parsons

2.1. INTRODUCTION

Electromagnetic waves are usually launched into space by energising a suitable antenna. At frequencies below 1 GHz the antenna normally consists of a wire or wires of a suitable length coupled to the transmitter via a suitable transmission line. At these frequencies it is relatively easy to design an assembly of wire radiators which form an array, and beam the radiation in a particular direction. For distances large in comparison with the wavelength and the dimensions of the array, the field strength in free space decreases inversely with the distance, and a plot of the field vs angle is known as the radiation pattern of the antenna.

We can design an antenna to have a radiation pattern which is not omnidirectional, and it is convenient to have a figure of merit to quantify the ability of the antenna to concentrate the radiated energy in a particular direction.

The directivity D of an antenna is defined as

$$D = \frac{\text{Power density at a distance d in the direction of maximum radiation}}{\text{mean power density at distance d}}$$

This is a measure of the extent to which the power density in the direction of maximum radiation exceeds the average power density at the same distance.

The directivity involves knowing the power actually transmitted by the aerial, and this differs from the power supplied at the aerial terminals by the losses in the antenna itself. From the system designers point it is more convenient to work in terms of this quantity and a power gain G is defined as

$$G = \frac{\text{Power density at a distance d in the direction of maximum radiation}}{P_T/4\pi d^2}$$

P_T = power supplied to the antenna

(Note: $G/_D$ is the efficiency of the antenna).

So, given P_T and G it is possible to calculate the power density at any point in the far field that lies in the direction of maximum radiation. A knowledge of the radiation pattern is necessary to determine fields at other points.

The power gain is unity for an isotropic antenna, i.e. one which radiates uniformly in all directions, and so an alternative definition of power gain is therefore the ratio of power density in the direction of maximum radiation to that for an isotropic aerial radiating the same power. We can calculate the power gain of an array by integrating the outward power flow from the array and relating it to the mean power flux. For example, the power gain of a $\lambda/2$ dipole is 1.64 (2.15 dB) in a direction normal to the dipole, and is the same whether the antenna is used for transmission or reception.

The concept of effective area is useful in considering receiving antennas. If an antenna is placed in the field of an electromagnetic wave the received power available at its terminals is the effective area x power per unit area carried by the wave, i.e. P = AW.

It can be shown (see Ref.1, Chap.11) that the effective area of an antenna and its power gain are related by

$$A = \frac{\lambda^2 G}{4\pi}$$

If we consider two antennas separated by a distance d in free space, then if the transmitting antenna has a gain G_T the power density at a distance d is

$$\frac{P_T G_T}{4\pi d^2}$$

So the power available at the receiving antenna, which has an effective area A is

$$P_R = \frac{P_T G_T}{4\pi d^2} A$$

$$= \frac{P_T G_T}{4\pi d^2} \frac{\lambda^2 G_R}{4\pi}$$

So that

$$\frac{P_R}{P_T} = G_T G_R \left(\frac{\lambda}{4\pi d}\right)^2$$

The propagation loss is usually expressed in dB and from this equation we can write

$$L = 10 \log_{10} P_R/P_T$$

$$= 10 \log G_T + 10 \log G_R - 20 \log f - 20 \log d + K$$

and for unity gain antennas we can define a "basic transmission loss" L_b as