Achieving Coverage

Planning and site management can make the difference between coverage success and failure

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Every mobile radio system is set up with the objective of providing continuous communications with mobile stations that occupy arbitrary locations in a target zone corresponding to the operator's activities. This objective is frequently not achieved. This article surveys the main problems encountered by every system designer and user. There are often no easy answers and a compromise will have to be reached; the challenge is to find the compromise which results in a commercially useful system

The Mobile Radio Environment

The constraints on system performance arise from the variabilities of propagation, interference from other spectrum users and local effects at the base station when the site is shared with other users and services. The susceptibility of systems is a function of the modulation system and information format adopted —
plain speech, encoded speech or data in different formats. The threshold for effective communication will be different for each combination and a wider choice of options will allow more and adequate low data rate systems to be used in difficult environments. Irrespective of the system chosen, performance will be improved if the environmental constraints are understood and the system design is optimized. The constraints will now be examined in more detail.

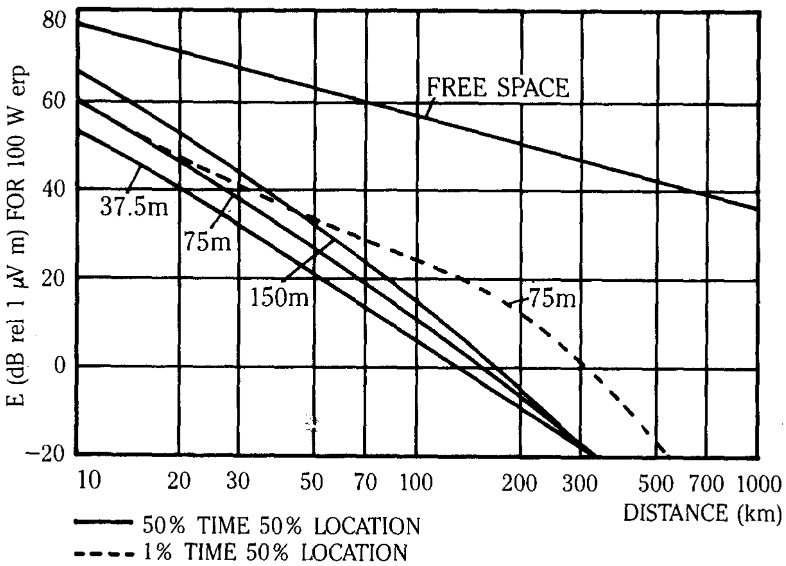

Figure 1.

Propagation

Figure 1 is a standard set of field strength/distance curves for the VHF band. The solid lines indicate median field strength (exceeded at 50% of locations for 50% of time) at a height of 10m above ground level, and separate curves are shown for different effective heights of the transmitting antenna (reference 1).

The curves have several interesting features:

1. Field strength falls between 12 and 15 dB for each doubling of distances except for a region very close to the transmitter.
2. Increasing the height of the transmitting antenna produces a marked increase in field strength at all ranges. Doubling the effective height of the antenna raises field strengths by about 6 dB.

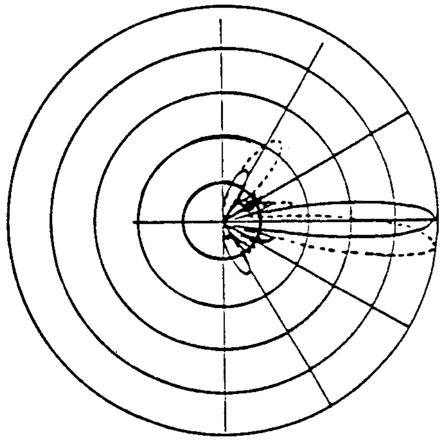
Figure 2.

Superimposed on the smoothly falling field are variations caused by ground topography — sometimes called log-normal shadowing. Much smaller-scale variations, on a scale comparable with the wavelength, are the effects of multipath propagation: signals arriving by direct transmission and by various reflected paths add constructively or destructively to give rise to random variations known as Rayleigh fading.

Interference and other users

The demand for access to the radio frequency spectrum is such that the same frequency channel is allocated to a large number of users whose geographical spacing ensures that mutual interference is reduced to a tolerable level. To achieve solid coverage of a target zone by using a large transmitted power from a high site will simply ensure that a large number of surrounding services receive high signal levels of what, to them, is unwanted interference. A base station receiver on a high site is correspondingly exposed to the signals from mobiles over a much wider area than the intended target zone.

The problem of mutual interference is made worse by the temporal instability of the transmission medium, especially at long ranges. The dashed line on figure I indicates the field strength/distance relationship prevailing for 1% of time—less than I week in a year.

Improving receiver design has reduced the incidence of adjacent-channel interference, but co-channel interference (CCI) can only be managed by good frequency management and system design.

Local Effects At The Base Station

Many base stations are shared by a number of users—often broadcasters or point-to-point link operators as well as mobile radio services. Problems often encountered include:

- Spurious emission by other equipment
- Intermodulation products, often generated as a result of insufficient isolation between systems
- Broadband noise emissions
- Blocking
- Cross modulation

Failure to achieve coverage objectives

The reasons for the failure of a mobile radio system to achieve its objectives are frequently obvious and could have been avoided at the planning stage. Among the commonest problems are:

- Base station incorrectly sited
- Inadequate base-station antenna
- Problems at shared base station
- Failures of frequency re-use
- Unrealistic objectives

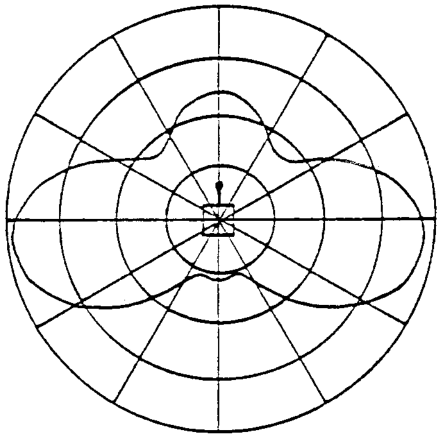

Figure 3.

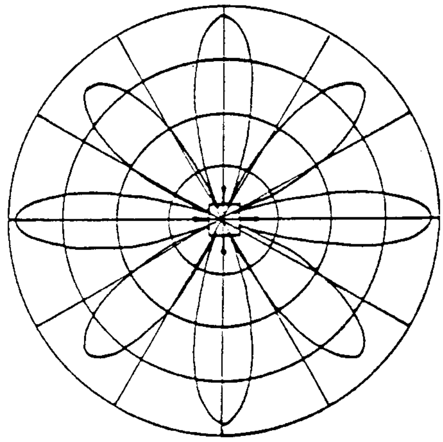

Figure 4.

Base Station Location

The location of the base station is clearly a very major factor in the likely success of a system. Selection should result from a process which considers:

1. Which target zones are essential, which desirable and which optional?
2. Which locations would give access to the essential zone? How do they compare in their likely access to the less essential ones?
3. What existing base stations are at, or near, these locations?
4. How do the locations compare in their co-channel interference

Base stations are often sited on the skyline, resulting in vulnerability to CCI as well as increased planning permission problems. This practice is probably related to the over-use of omnidirectional base station antennas and the expectation that the right location for a base station is in the middle of the area which it serves: it often is not.

Base Station Antennas

The base-station antenna has a major part to play in ensuring coverage of the target zone. In two major respects, current practice in the mobile service often fails to make the best use of available techniques: no use is made of the possibilities for controlling the vertical radiation patterns of high-gain antennas, and side-mounted antennas are often fitted to large structures without sufficient regard to the likely effect on the horizontal radiation pattern which will be obtained.

Figure 2 shows the vertical radiation pattern of a collinear array of four cophased dipoles (full line). The maximum radiation occurs in the horizontal plane and there are deep nulls at angles of depression of 13 and 31 degrees. The dotted curve shows an improved radiation pattern in which the direction of maximum radiation has been depressed to illuminate a point within the required service zone (beam tilt) and the nulls have been filled. A further benefit of beam tilt is that the effective radiated power (erp) in the horizontal direction is reduced, typically by 3 dB, while mean field strength inside the intended service zone is increased.

A commonly encountered problem at base stations is that of obtaining effective omnidirectional coverage from antennas side-mounted on large masts and towers. Figure 3 shows the computed radiation pattern for a vertically polarized dipole stood off a square tower with a 2 m face; even larger nulls appear when dipoles are mounted from the steel cylindrical masts used at some TV stations.

Figure 4 shows an attempt to improve matters by mounting one dipole off each tower face and feeding the dipoles in phase; in this case the configuration has not been successful as unpleasant ripples have appeared in the radiation pattern. A solution employing dipole or slot-fed panels can be much more successful as shown in figure 5.

The radiation patterns of configurations of panels can be computed with accuracy. When simple dipoles are mounted off masts and towers the computed radiation patterns are of variable accuracy owing to the leakage of energy through large open structures. The development of more complex analytical methods is now yielding more accurate results, but requires exact data on the structural configuration of the tower to be entered into the computer member-by-member.

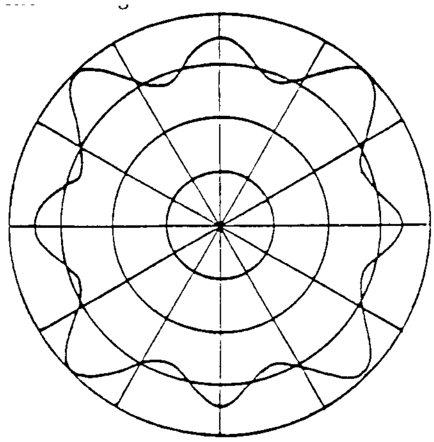

Figure 5.

Shared Base Stations

Some of the problems that can arise have been described above where they were regarded as part of the environment in which the mobile operator must operate. Even 'low power' broadcasting stations may radiate five signals each with an erp of 1-5 kW, giving rise to a wide variety of intermodulation products. Even if these are radiated well below the permitted level of I mW they will severely affect a service sharing the site which uses one of the affected frequencies for reception.

It is often worth considering antennas for the mobile services that have reduced sensitivity in the direction of co-sited services that are producing unwelcome interference.

Beyond this, combinations of filters are often effective, but in the case first described, a change of frequency for the base station receive channel is the only solution.

The avoidance of interfering intermodulation products within single antenna multi-channel systems is the subject of much current work. The last few years have seen a major improvement in the standards of available antenna and filter systems.

A receiving system that is too sensitive may make local effects seem more serious than they really are as the incoming signals which are just masked are at lower level than can reasonably be expected to be protected.

Frequency Re-use

Users of large schemes are often allocated a number of frequencies, some of which will be used in more than one area of the same scheme. Problems arise when the detailed planning of the positions of base stations and the radiation patterns of their antenna fails to recognize the possibilities of co-channel interference; sometimes the requirement for re-use of a channel appears after base stations have been planned and built.

Unrealistic Expectations

Many of the coverage failures that are presented as problems for the antenna engineer relate to systems for which there were no realistic expectations, or where problems were ignored in the hope of saving money. Some such users are lucky: others are not.

There is no substitute for careful planning in the choice of a mobile radio site and the choice of equipment to ensure that the objectives of the service are met. Improvements in current antenna systems and the design of shared installations are possible and are cost effective.