CHAPTER 1. INTRODUCTION

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A few years ago mobile radio communication was seen largely as a specialists area much to the preserve of PTTs and a few equipment suppliers. In general it was regarded as being some what peripheral to the wider background of developing communications. However, during the past decade the whole perspective has changed dramatically. In the 1970s, mobile radio was a minority activity in communications, based on relatively unsophisticated technology. The 1980s, has been the emergence of new technology of analog cellular systems [18],[48]. With competitive networks, new value added services and vastly improved equipment design, there is now a far wider appreciation of the tremendous potential of the mobile communication industry.

Perhaps the real catalyst has been the explosive growth of demand - from security, institutional and public sector from commercial and industrial user and from ordinary consumers. The simple realization of mobile communications, by definition provides a dimension beyond the confines of fixed services to homes, offices and industrial plants etc. In Western Europe, for example, the total mobile communication business is expanded by over 40% a year. It is predicted that, by the late 1990s, world
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will have resulted in the majority of population in Europe and North America being dependent on radio communication. This is not just a European phenomenon, new networks and services are being launched world wide - in the Far East, Latin America, the middle East and the USA. In Japan extensive use is made of mobile radio for business and commercial purposes [38]. In Scandanavian, where a fully automatic mobile system has existed for many years, the demand for the service has far exceeded the expectations. In UK mobile radio usage continues to expand at a rate of 10% per year.

The technological developments that have occurred in this field, notably cellular mobile telephone [11],[36],[63] offer new and effective approaches to meet the needs for mobile communication. The improvements in public services and productivity that can be gained through effective mobile communication systems and services apply to both industrialised and developing countries. It is now recognised as one of the most efficient ways to increase effectiveness, reduce operating cost and preserve energy.

The growth in mobile radio communication has been so rapid that the existing radio frequency spectrum to meet the increasing demand of spectrum is now of a primary concern to every nation.
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1.1 STATEMENT OF PROBLEM

A mobile radio communication system is required to operate over areas too large to be economically covered by a single base station. The requirement, therefore, exists for some kind of area coverage technique using number of base stations. However, when a number of base stations are used to provide total area coverage, it is desirable to reuse the radio frequency channels in order to optimally utilize the radio spectrum.

An ideal mobile radio communication system would operate within a limited assigned frequency band and would serve an almost unlimited number of users in unlimited areas with excellent speech quality.

Thus the major problem facing the radio communication field is the limitation of the available radio frequency spectrum to provide wide area coverage.

SPECTRUM EFFICIENCY

The major approaches to achieve the ideal frequency planning are:

* Single-side band (SSB), which divides the allocated frequency band into maximum number of channels.
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* Cellular, which reuses the allocated frequency band in different geographic locations [45].
* Spread spectrum, frequency hopped, which generates many codes over a wide frequency band [20].

A comparison of channels per square mile and spectrum efficiency of single side band and cellular systems for equivalent voice quality and a given transmitted power, shows:

The cellular system permits larger cells with less separation between co-channel cells, whereas a SSB system requires smaller cells with greater separation between co-channel cells.

The existing 30 KHz FM cellular system is about as spectrally efficient as the hypothetical 3-KHz SSB system and much more efficient than either of the 5 KHz or 7.5 KHz SSB systems.

The frequency hopping scheme in FDMA and spread spectrum technique in TDMA is also being proposed for use in mobile radios. Comparing the relative spectral efficiency of a frequency hopping DPSK modulated system with a 30 KHz cellular system, it is seen that the spectral efficiency of both the systems are the same.
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TOTAL AREA COVERAGE

As far as area coverage is concerned an ideal coverage of 100 percent would require the transmitted power to be very high to illuminate weak spots with sufficient reception. However, it is usually not practical to cover 100 percent of the area. Therefore, system designers usually try to cover 90 percent of an area in flat terrain and 75 percent of an area in a hilly terrain with a voice quality between good and excellent in the served area.

The most sophisticated technique in current use for area coverage is a cellular scheme.

The cellular approach makes the most efficient use of spectrum to provide optimum area coverage and is one of the most advanced of its kind in the world. This approach to spectral efficiency is essential if the rapidly increasing demand for mobile service is to be met without requiring enormous allocations from dwindling frequency resources.

1.1.1 CELLULAR APPROACH

In a cellular approach the system is realised as a network of contiguous cells [113],[41]. The area to be covered is
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divided into a number of cells in a regular fashion. Each cell is served by a base station, which covers the area upto and into that of adjacent cells without leaving any gap. The size of the cell is determined by the number of users expected to operate in that area. In cities, for example, cells may have 2 Kms. radius across while in less densely populated rural areas the cell radius may be as large as 30 kms.

A special rule governs the frequency assignment. The total allocated frequency band is divided into number of channels of equal width. A set of these interleaved channels is then assigned to a base station. Care is taken that adjacent radio base stations operate on different set of channels, while the non-adjacent radio base stations use the same set of radio frequency channels simultaneously. The entire set of these frequencies is then repeated to provide wide area coverage. The effective traffic handling capacity can be further increased by using dynamic channel assignment technique [6],[31].

Thus the frequency reuse concept enables optimum utilisation of scarce radio spectrum. It permits the system to meet the important objectives of serving a very
large number of users in a large area, while using a relatively small spectrum.

PROBLEM OF FREQUENCY REUSE
Frequency reuse refers to the use of radio channels on the same carrier frequency to cover different areas which are separated from one another by sufficient distance. Frequency reuse is the core concept of the cellular mobile radio communication system. In this, users in different geographic locations may simultaneously use the same frequency channel. The frequency reuse system can drastically increase the spectrum efficiency but if the system is not properly designed serious interferences may occur.

The type of interferences which occur are co-channel interference and adjacent channel interference.

Co-channel interference is more critical than the adjacent channel interference. Co-channel interference is handled by selecting a geographical reuse pattern for frequencies which ensure that the same channel is not used in adjacent cells. Whereas the adjacent channel interference can be controlled by better filter design.
The other requirement of providing high quality service would require the system designer to reduce the overall noise in the system.

It is well understood that the noise in a FM system can be reduced by increasing the bandwidth. The wider the channel bandwidth the lower is the required level of transmitted power.

However, in order to efficiently use the spectrum, a system designer is interested to reduce the channel bandwidth. But to maintain voice quality when channel bandwidth is reduced, it is necessary to increase the signal-to-noise ratio in order to improve the reception. This requires a higher transmitter power.

But every time the power is increased, interference problems are created. For point-to-point radio links, these problems are manageable because no frequency reuse is involved. This is not the case, however, for a frequency reuse radio communication system for wide area coverage, such as a cellular radio. As the number of cells increase in a given area, interference may appear in one of the several forms: co-channel, adjacent-channel, or multi-channel at co-locations: thus the
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probability of its occurrence increases. Interferences may also result from received power-level differences.

Thus geographic location of cells is an important factor in the application of the frequency reuse concept in mobile cellular technology.

To gain maximum advantage of frequency reuse, the planning of cells must be carefully considered. Since the interferences, co-channel and adjacent channel occur within the system, they can be controlled by a careful system design.

1.1.2 CHALLENGE TO FIND AN OPTIMUM SOLUTION

Since the radio frequency spectrum is finite in mobile radio systems, the most significant challenge is to use the radio frequency spectrum as efficiently as possible.

The minimum distance which allows the same frequency to be re-used will depend on many factors, such as the number of co-channel cells in the vicinity of the centre cell, the type of geographic terrain contour, the antenna height, and the transmitted power at each cell site.

The frequency reuse distance D can be determined from:

\[ D = \sqrt{3N.R} \]
Where $N$ is the frequency re-use pattern and $R$ is the cell radius. In a practical system, the choice of number of cells per cluster is governed by co-channel interference considerations. As the number of cells per cluster increases, the relative separation between co-channel cells obviously increases, and consequently poor signal to interference conditions become progressively less probable. Thus, theoretically a larger value of $N$ is desired. However, when the total number of channels is fixed, for a too larger value of $N$, the number of channels assigned to each of $N$ cells become small, which results in spectrum inefficiency. So in order to improve spectrum utilization it is desired to maximize the frequency reuse, in order to bring the cells using same frequencies as close together as possible. This suggests aiming at smaller value of $N$. But there are constraints which restricts a designer from reducing the value of $N$.

Thus, the challenge is to obtain the smallest number $N$ which can still meet the system performance requirements. This involves estimating co-channel and adjacent channel interference and selecting the minimum frequency reuse distance $D$ and the service radius $R$, to reduce these interferences.
1.2 ORGANISATION OF THESIS

The most important task in system planning is the prediction of path loss. This is to ensure adequate signal strength in areas where a mobile is required to operate. Indeed, it is crucial for efficient use of allocated frequency band and for the success of a system based on cellular concept, which rely heavily on frequency reuse. Accurate prediction of path loss is necessary, so as to be able to predict the minimum power of transmission required from a given base station at a given frequency in order to provide an acceptable quality of coverage over a pre-determined service area.

Chapter 2 deals with path loss prediction and median signal strength variation. The various models which can be used for prediction of path loss for different terrain conditions are described in section 2.1 and section 2.2. The received mean signal strength is constant only over a small area and varies slowly as the mobile moves. Super imposed on this slow fading is fast fading caused due to multi-path propagation in the vicinity of mobile. A quantitative measure of the signal variability is essential, to estimate the percentage of area that has an adequate signal strength or the likelihood of interference
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from a distant transmitter. This is described in details in section 2.3 of this chapter, followed by an empirical relation for calculating the correction, which must be applied to the median path loss when location probability other than 50% is desired. The later part of this chapter describes the method for prediction of path loss for beyond line of sight conditions.

Chapter 3 is devoted to the analysis of interferences common to a mobile radio communication system. In order to make the most efficient use of the radio frequency spectrum, it is necessary to repeat frequency assignments as closely as possible without producing unreasonable interference. The interferences which occur and are required to be taken care off in system design can be categorised as co-channel interference and adjacent channel interference. This aspect has been dealt in details in this chapter. A worst case of co-channel interference for multiple interfering sources is considered and a relationship for co-channel reduction factor is derived. The relationship defines the minimum distance requirement between any two cells using the same frequency. The effect of next channel and neighbouring channel interference on the system design based on
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The frequency reuse concept is also considered. The results pertaining to these interferences are analysed to describe the approaches that can be adopted to reduce their influence.

Chapter 4 deals with signal/interference requirements for satisfactory communication. To achieve reliable communication between a base station and a mobile within the desired service area, we require, firstly an acceptable signal level. A computer programme to calculate received signal level for given system parameters is described. The programme is modified to enable calculation of received signal level for desired probability of satisfactory communication. Signal to interference requirements for a network planning are considered. The RF protection ratios required for total area coverage and avoidance of co-channel and adjacent channel interference are defined. These requirements ensure coverage and internal compatibility of the communication system. A cellular approach for total area coverage is also discussed.

Chapter 5 describes the network design for coverage of a large area with limited number of frequency channels. It
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deals with development of a computer algorithm to
calculate service radius as affected by propagation and
interference radii as affected by protection ratios. The
cell parameters are related to the RF protection ratios
and empirical formulas for finding optimum value of these
parameters are derived. The results are extended to
define the optimum cell parameters which satisfy the
interference and coverage criterion.

A summary of the work done has been given in Chapter 6. A
brief guide for further work which might lead to
interesting results is also given.