Commission E: Electromagnetic Noise and Interference

(e) Scientific basis of noise and interference control

# Electromagnetic Interference Compatibility for Mobile Communication System

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## Abstract

Electromagnetic interference with one another in space, in time and frequency and therefore the effect of EMI assumes importance. Therefore it is essential that various systems (or parts of system) coexist in the electromagnetic environment. This requires the desired signal to be separated from the interference and noise in power level and/or in frequency. Elementary EMC analysis can be applied which is based on determining the median value of the field intensity. However one needs to go for advanced EMC analysis, which relies upon the probability distribution of the RF signal-to-interference (S/I) ratio and signal-to-noise (S/N) and is aimed at calculating the probability of satisfactory communication. The mobile networks are supposed to contain typical base station with enhanced transmitted power and elevated antennas as well as simple mobile station. From EMC point of view, there are no direct indications against cell-size reduction. Local growth of system's compatibility can be achieved by splitting of cells. With cell size reduction, data traffic increases rapidly however with excessive reduction hand-off accompanied by conversation breaks will be too frequent. All these aspects of EMC for mobile communication are presented.

## 1.1 Introduction

The interference in radio environment is a cause of interference which could be due to the objects belonging to the system under consideration (Intera- system interference) or objects belonging to other radio systems (Inter – system interference) or objects not belonging to any radio system(natural or man-made noise). It is therefore essential that various systems (or part of system) co exist in the electromagnetic environment. Thus radio communication systems have to be externally or internally compatible if the reception of the transmitted signal is to be satisfactory. In

most cases the desired electric field must dominate all the undesired fields since they may fluctuate randomly.

Elementary EMC analysis can be applied which is based on determining the median value of the field intensity. However, one needs to go for advanced EMC analysis, which relies upon the probability distribution of the RF signal-to-interference (S/I) ratio and signal to noise (S/N) and is aimed at calculating the probability of satisfactory communication. It would be sufficient, if we could determine the electric field intensities of the desired and undesired signals in order to assess the existence and magnitude of resulting output interference.

The interference and compatibility of mobile communication system involves the array of fixed station sites usually approximated by a regular lattice model. The service zones of the stations are based on the non-overlapping polygonal cells. Within a regular lattice each complete cluster contains the same set of frequency channels. In actual design the displacement of fix station cannot follow the regular lattice model. The available interval is then a measure of lattice deformability. Adjacent channels also create interference and they cannot be avoided. The mobile networks are supposed to contain typical base station with enhanced transmitted power and elevated antennas as well as simple mobile station. The rule of power density matching is an important parameter in cellular networks.

Communication network analyses are valid for large system with frequency reuse. Internal compatibility in the cellular system can be ensured by satisfying the co-channel and adjacent channel criteria. With a fixed total allocation of channel, local overloads in the cellular system can be expected even in UHF (800-900 MHz). Local growth of systems compatibility can be achieved by splitting of cells. With cell size reduction, data traffic increases rapidly. However with excessive reduction hand-off accompanied by conversation breaks will be too frequent. All these aspects of EMC for mobile communication are discussed.

## 1.2 Mobile Communication Network

The basic type of mobile network is the point to area structure and is extensively used in two-way mobile radio communication. We assume that many-fixed station are spread over a larger system territory where it becomes necessary to reuse frequency channels. radio communication network.

By analyzing the radio links, field strength Es can be given by the formula

$$Es = \frac{4\Pi\sqrt{30}}{\lambda} \sqrt{KTBFRs/Grws}$$

Rs is the prescribed output quality

Likewise the bit error rate of the keyed signals (ASK, FSK, PSK) in the presence of noise has also been analyzed.This can be given by the relation;

Mean bit error rate Qbe = ½exp(-½ r) and this is transformed into

ln(1/2 Qbe) = ½ r and is taken as a output quality measure given by:

R = ln(1/2 Qbe) with w = ½

With this analysis we get important network parameter termed the action radii.

They are applicable to two cooperating station and for a given transmitter are defined with respect to a given receiver with antenna. First of all we consider the service radius ds which gives the communication range. This is the smallest distance from a transmitter where the median field intensity decreases to a level where we can get a minimum usable signal at the receiver input. Another action radius di is necessary for EMC analysis of the radio networks. It arises due to the transmitter – receiver pair which is disturbed by another transmitter. The array of fixed station is usually represented by latest model with regular geometry. Regular lattice is composed of elementary cells around each fixed station. Adjacent cells with non repeated frequency channels constitute a cluster of cells. Two geometrical parameters are of interest:

a. Lattice Modulus M which represents the closest spacing between adjacent fixed stations
b. The coordination distance dc which gives the closest spacing between co channel fixed station.

The area (zone) covered by radio transmitter communicating with a receiver is ultimately limited by the inevitable noise in the receiver and its environment. It is usual to relate ds, the radius of service zone, to the minimum usable signal min Pr, at the receiver input. Two interpretation of the min Pr are possible.

1. If the environmental noise is negligible, the minimum usable signal equals the receiver sensitivity Prs given by

   Prs = (KTBF/Ws) Rs

   The obvious coverage criterion Pr >= Prs

2. If however the environment noise characteristics by the noise figure Fe is present, the coverage criterion contains the minimum usable signal.

$$Pr >= min\ Pr = Prs \frac{F + Fe}{F}$$

In terms of the received field strength median values at the receiving antenna

$$Es = \frac{4\Pi\sqrt{30}}{\lambda} \sqrt{KTBFRs/Grws}$$

We have Er >= min Er(min Pr)

The coverage area should ensure adequate level of separation between the desired incoming signal and the environmental and receiver noise.

## 1.3 Internal Compatibility in the Lattice Structure

The point to area communication network is characterized by its spatial, spectral and function properties. From the structural concept the fixed station is usually characterized by regular lattice model which is essentially based on the non-overlapping polygonal cells. Interference is the major limiting factor in the performance of the cellular radio systems. Interference on control channel leads to missed and blocked calls due to errors in the digital signaling. Interference is more severe in urban areas, due to the greater RF noise floor and large number of base stations and mobiles. Two major types of system generated cellular interference are co-channel interference and adjacent channel interference. Unlike thermal noise which can be overcome increasing the signal-to-noise ratio (SNR), co-channel interference cannot be controlled by simply increasing the carrier power of a transmitter. To reduce co-channel interference, cells must be physically separated by a minimum distance to provide sufficient isolation due to propagation.

Now if R is the radius of the cell and D is the distance between the centers of the nearest co-channel cells, and if we increase the ratio D/R, the spatial separation between co-channel cells relative to the coverage distance of a cell is increased.

Thus interference can be reduced because of the isolation of RF energy from the co-channel cell.the parameter Q related to the cluster size is related by a relation for hexagonal geometry as

$$Q = D/R = \sqrt{3N};$$ where Q =co-channel reuse ratio.

A small value of Q will provide larger capacity since cluster size N is small, whereas a larger value of Q improves the transmission quality. This is due to the smaller level of co-channel interference. A tradeoff is usually made in cellular design.

The signal to interference ratio S/I or SIR for a mobile receiver is expressed as:

$$\frac{S}{I} = \frac{S}{i_o \sum_{I=1} I_i}$$ interfering co-channel cell base station

where S = desired signal power

Ii =interference power caused by the ith

Knowing the signal level of co-channel cells,S/I ratio is determined. When the transmitted power of each base station is equal and path loss exponent is the same throughout the coverage area S/I for a mobile can be express

$$\frac{S}{I} = \frac{R^{-n}}{i_o \sum_{I=1} (Di)^{-n}}$$

where Di is the distance of the ith interferer from the mobile.

If all the interfering base stations are equidistant from the desired base station and if this distance is equal to the distance D between cell centers. Then

$$S/I = (D/R)^n / i_o = (\sqrt{3N})^n / i_o$$

S/I relates to the cluster size N which in turn determine the overall capacity of system. Io is the number of co-channel interfering cells.

For a cellular system which uses FM and 30 kHz channels, sufficient voice control is obtained when S/I is greater than or equal to 18db.This indicates that the cluster size should be at least 6.49 assuming a path loss exponent n = 4. Thus a minimum cluster size of 7 is required to meet the S/I of 18db.The analysis is based on the hexagonal cell geometry where all interfering cells are equidistant from the base station. For a seven-cluster cell, with mobile unit at the cell boundary, the mobile is at distance D-R from the two nearest co-channel interfering cells and exactly D+R/2. D. D-R/2 and D+R from the other interfering cells. Assuming n = 4, the signal to interference ratio for the worst case is approximated as:

$$\frac{S}{I} = \frac{R^{-4}}{2(D-R)^{-4} + 2(D+R)^{-4} + 2D^{-4}}$$

In terms of co-channel reuse ratio Q, the above equation can be written as:

$$\frac{S}{I} = \frac{1}{2(Q-1)^{-4} + 2(Q+1)^{-4} + 2Q^{-4}}$$

For N = 7.The co-channel reuse ratio Q is 4.6 and the worst-case S/I is approximated as 49.56 (17db), whereas the exact solution yields 17.8db. Therefore to design cellular system for performance in worst case, the N should be increased to the next largest size and using equation

$$N = i^2 + ij + j\,2$$

where i and j are non-negative integers and is found to be 12 (i=j =2). This shows a decrease in the capacity, 12-cell reuse offer a spectrum utilization of 1/7. In practice the capacity reduction of 7/12 would not be tolerable to accommodate for the worst-case situation. However such situation rarely occurs.

Another factor that influence the mobile communication system is the adjacent co-channel interference which results from the imperfect receiver filter that allows nearby frequencies to leak into the pass band. The separation between adjacent channels at the base station may not be sufficient to keep the adjacent channel interference level within tolerable limits; Thus, if a close in mobile is 20 times as close to be base station as another mobile, the signal-to-interference ratio at the base station for weak mobile is approximately

$$\frac{S}{I} = (20)^n$$

For a path loss exponent n= 4: this ratio is equal to –52 dB. Assuming that the I.F. filter of the base station receiver has a slope of 20 dB/octave, then the adjacent interferer has to be displaced by at least six times the passband bandwidth from the center of the receiver frequency pass band to achieve 52 dB attenuation. Thus to obtain 0 dB SIR from a close-in-adjacent channel user, separation of approximately six channel bandwidth is required. Thus tight base station filters are needed when close-in and distant users share the same cell. Co-channel interference in a cellular system can also be decreased by replacing a single omnidirectional antenna, at the base station by several directional antennas, each radiating within specified sector. By using directional Antennas, a given cell will receive interference and transmit with only a fraction of the available co-channel cells. A cell is normally positioned into three $120^0$ sectors or six$60^0$ sectors. It has been

observed that in S/I with $120^0$ sectoring, the minimum S/I of 18 dB can be easily obtained with 7 cell reuse as compared to 12 cell reuse for worst condition in the unsectored case.

## 1.4 Conclusion and Discussion

Cellular public radio telephony networks are perhaps the most advanced and sophisticated terrestrial communication system. Enormous technological effort has gone to solve the spatial and spectral problems of the electromagnetic compatibility. Communication network analyze have shown that results are varied for any large system with frequency re-use. Internal compatibility in the cellular system have been ensured by satisfying the co-channel and adjacent channel criteria. With a fixed total allocation of the channels, local overloads in the cellular system can be expected even in the UHF (800 – 900 MHz) band. Then the local growth of a system's capabilities can be achieved by *splitting* of cells. Hereby, hexagonal cells are usually supposed to be split into 3 contiguous rhombi. Directional ($120^0$) antenna will illuminate each rhombus-sector from one corner – the former cell site. It has been proved that networks with directional sectoral cells are spectrally more efficient than networks with omnidirectional hexagonal ones. Thus, a further increase of traffic can be attained, again without violating the frequency allocation. Of course, with the new pattern of sectoral sublattice, local modification of the coordination-distance formula is necessary, but relevant EMC criteria remain unchanged.

Mobile stations are usually authorized to function over the entire large territory of the system composed of many small cells. When a vehicle in motion crosses a cell boundary, its radio station has to be automatically *switched* to another channel, even during conversation. For this purpose, the central processing and switching office has to informed about the station's position ( accurately to within one cell) ; the best choice of the next cell; and the moment of crossing the cell border. If necessary, a conversation hand-off to another channel take place.

Remote *location* and the *hand-off* are automatically performed by the central office. This is surely the most advanced technique in the whole domain of terrestrial radio-communication. It should be noted that no new EMC problems are directly created by the locating of mobiles and by the hand-off switching of conversations.

With cell-size reduction, the data traffic increases rapidly and finally absorbs an excessively large portion of the central processor's capacity. The conversation quality is also impaired due to short breaks during hand-offs. With an excessive reduction of the cell-size, hand-offs accompanied by

conversation breaks would b too frequent. These are the most difficult technical problem of the small-cell systems. The technological issues of cellular radio communication systems appear to be approaching acceptable solutions. Although EMC problems increase in size and complexity, their solutions depend on fixed principles.

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