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Co and Adjacent Channel Interference Evaluation in GSM and UMTS Cellular Networks

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Abstract: Interference is the major limiting factor when evaluating the performance of cellular radio systems. Sources of interference could be another mobile at the same cell, a call in progress in a neighboring cell or other base stations operating in the same frequency band. Interference on voice channels causes cross talk due to an undesired transmission. On control channels, interference leads to missed and blocked calls due to errors in the digital signaling. Interference is more severe in urban areas, due to the large number of base stations and mobiles. Interference has been recognized as a major bottleneck when looking for increasing capacity and is often responsible for dropped calls. The two major types of system-generated cellular interference are co-channel interference and adjacent channel interference. Even though interfering signals are often generated within the cellular system, they are difficult to control in practice (due to random propagation effects). Even more difficult to control this interference caused out-of-band users, which arises without warning due to front end overload of subscriber equipment or intermittent inter-modulation products. In practice, the transmitters from competing cellular carriers are often a significant source of out-of-band interference, since competitors often locate their base stations in close proximity to one another in order to provide comparable coverage to customers. This paper presents study of co and adjacent channel interferences in second and third generations of cellular radio systems.

Keywords: Frequency Reuse; Co-Channel Interference; Adjacent Channel Interference; Evaluation.

I. INTRODUCTION

GSM, commonly known as the second Mobile Network Generation (2G), was the famous standard for mobile networks. Early eighteens decade, a group was formed by the European Telecommunications Standards Institute (ETSI) to develop a digital mobile communication system [1]. This standard has introduced digital technology transmission processing approaches. This system has retained both carriers' frequencies (900 MHz, 1800 MHz) in Europe and (850 MHz, 1900 MHz) for the US [2].

It uses a circuit-switching mode and combines both TDMA and FDMA access techniques. Carriers are time divided as done in Time multiplexing scheme. This allows, different users of a single radio frequency channel, being allocated different time slots. Any slot will then be allocated to a particular user. So, users are able to use the same radio frequency channel without mutual interference [3].

In 3G radio mobile networks, the parameters of UMTS are, spectrum allocation for uplink is 1710-1785 MHz and for downlink is 1805-1880 MHz, the bandwidth is 5 MHz and the multiple access scheme used is Code Division Multiple Access (CDMA). The CDMA mobile phones and Base Stations (BS) use minimum amount of power to communicate with each other. They use accurate power control to reduce users' transmission power. By decreasing a user's transmission power, the mobile phone has added battery life, increased talk time, and smaller batteries [4].

Resources optimization in mobile networks depends on two essential characteristics of the radio waves that are the attenuation as a function of distance, and the frequency reuse mechanism. This enables radio communications systems to cover large areas, and serve very high traffic densities [5].

Reuse of resources is limited by Interference (I) and Noise (N). However, the most restrictive constraints of the mobile system capacity are the interference caused by transmission at the same frequency (co-channel interference) and issue on neighboring frequencies (adjacent channel interference) [6].

This paper mainly describes an evaluation procedure for the co and adjacent channel interferences in GSM and UMTS systems with the consideration of regular hexagonal cellular network.

The rest of this paper is organized as follows. The frequency reuse technique will be described in section II. Sections III and IV present respectively the co-channel and adjacent channel interference in GSM and UMTS cellular networks. Simulation results are described in section V. Finally, in section VI, we conclude the paper

II. FREQUENCY REUSE AND INTERFERENCE TYPES

Cellular radio systems such as GSM and UMTS rely on an intelligent allocation and reuse of channels throughout a coverage region. Each cellular base station is allocated a group of radio channels to be used within a small geographic area called a cell. Base stations in adjacent cells are assigned channel groups which contain completely different channels than neighboring cells.

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By limiting the coverage area to within the boundaries of a cell, the same group of channels may be used to cover different cells that are separated by distances large enough to keep interference levels within tolerable limits [7].
Frequency reuse, or, frequency planning, is a technique of reusing frequencies and channels within a communication system to improve capacity and spectral efficiency. Frequency reuse is one of the fundamental concepts on which commercial wireless systems are based that involve the partitioning of an RF radiating area into cells. The increased capacity in a commercial wireless network, compared with a network with a single transmitter, comes from the fact that the same radio frequency can be reused in a different area for a completely different transmission. Frequency reuse in mobile cellular systems means that frequencies allocated to the service are reused in a regular pattern of cells, each covered by one base station.
The repeating regular pattern of cells is called cluster. Since each cell is designed to use radio frequencies only within its boundaries, the same frequencies can be reused in other cells not far away without interference, in another cluster. These are called co-channel cells. The reuse of frequencies enables a cellular system to handle a huge number of calls with a limited number of channels.
In Mobile networks, the number of subscribers has quickly grown. This has given issue to a great dangerous drawback trying to overcome the offered mobility advantage. Networks suffer from a coverage constraint having lead operators to a frequency reuse technique [8].

III. CO-CHANNEL INTERFERENCE EVALUATION IN GSM AND UMTS CELLULAR NETWORKS

A. In cell center

Frequency reuse implies that in a given coverage area there is several cells that could use the same set of frequencies. The interference between signals from this cell is called co-channel interference.
When the size of each cell is approximately the same and the base stations transmit the same power, the co-channel interference ratio is independent of the transmitted power and depends on the radius of the cell (R) and the distance between centers of the nearest co-channel cells (D).By increasing the D/R ratio, the spatial separation between co-channel cells relative to the coverage distance of a cell is increased. Thus, interference is reduced from improved isolation of RF energy from the co-channel cell. The parameter Q, called the co-channel reuse ratio, is related to the cluster size. For a hexagonal geometry [9]:

$$Q = D/R = \sqrt{3N} \qquad (1)$$

Let N be the number of co-channel interfering cells, then, the co-channel interference power for a mobile receiver can be expressed as [9]:

$$I = \sum_{i=1}^{N} I_i \qquad (2)$$

Where I_i is the interference power caused by the ith interfering co-channel cell base station
And the signal-to-interference ratio S/I for the same mobile are given with the following expression [9]:

$$S/I = S/\sum_{i=1}^{N} I_i \qquad (3)$$

Where, S is the desired signal power from the desired base station.
Propagation measurements in a mobile radio channel show that the average received signal strength at any point decays as a power law of the distance of separation between a transmitter and receiver. The average received power P_r at a distance d from the transmitting antenna is approximated by [9]:

$$P_r = P_0(d/d_0)^{-\alpha} \qquad (4)$$

Where P_0 is the power received at a close-in reference point in the far field region of the antenna at a small distance d0 from the transmitting antenna and α is the path loss exponent. This latter parameter is typically ranged between two and four in cellular systems [10].
If D_i is the distance of the ith interferer from the mobile, the received power at a given mobile due to the ith interfering cell will be proportional to $(D_i)^{-\alpha}$. Then, when the transmit power of each base station is equal and the path loss exponent is the same throughout the coverage area, S/I for a mobile can be approximated as [9]:

$$S/I = R^{-\alpha}/\sum_{i=1}^{N}(Di)^{-\alpha} \qquad (5)$$

In this paper we consider only the first layer of interfering cells, all the interfering base stations are equidistant from the desired base station and this distance is equal to the distance D between cell centers as represented by the following figure.

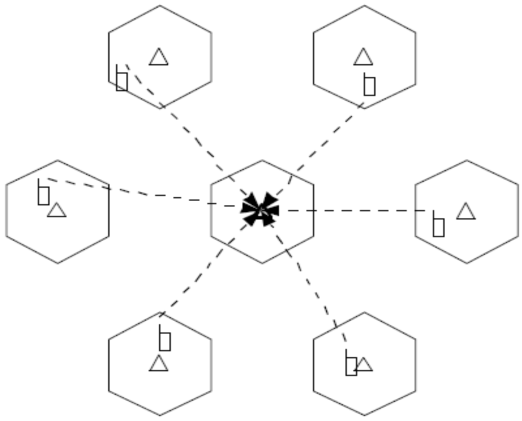

Fig.1Co-Channel Interference for user in cell center [11]

So, equation 5 simplifies to :

$$S/I = R^{-\alpha}/\sum_{i=1}^{N}(D)^{-\alpha} = (D/R)^{\alpha}/N = (\sqrt{3N})^{\alpha}/N \qquad (6)$$

B. In boundary cell

Using an exact cell geometry layout, it can be shown for a seven-cell cluster, with the mobile unit at the cell boundary, the mobile is a distance D-R from the two nearest co-channel interfering cells and is exactly D from

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the two other co-channel cells and D+R from the other interfering cells in the first tier, as shown rigorously in the following figure:

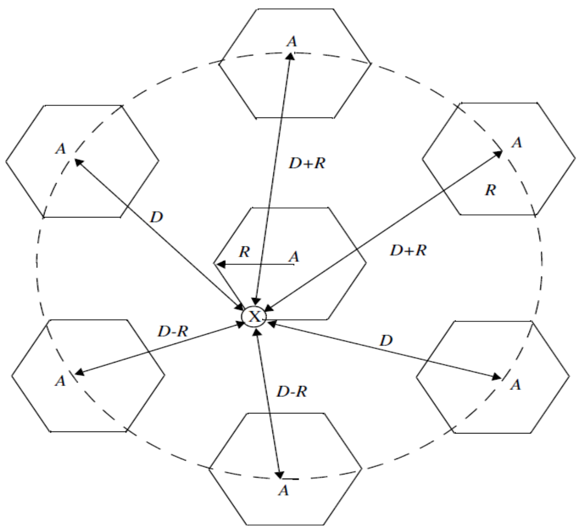

Fig. 2 Co-channel interference for user in boundary cell [12]

The signal-to-interference ratio in the worst case can be approximated as [9]:

$$S/I = R^{-\alpha}/[2(D-R)^{-\alpha}+2D^{-\alpha}+2(D+R)^{-\alpha}] \qquad (7)$$

Equation 7 can be rewritten in terms of the co-channel reuse ratio Q, as:

$$S/I = 1/[2(Q-1)^{-\alpha}+2Q^{-\alpha}+2(Q+1)^{-\alpha}] \qquad (8)$$

IV. ADJACENT CHANNEL INTERFERENCE EVALUATION IN GSM AND UMTS CELLULAR NETWORKS

Adjacent channel interference (ACI) is interference between links that communicate geographically close to each other using neighbouring frequency bands. Adjacent channel interference results also from imperfect receiver filters [13].

Our study looks at downlink adjacent channel interference. Thus, the two adjacent channel interference instances are considered, Base Station $\longrightarrow$ Mobile Station (BS $\rightarrow$ MS) and Mobile Station $\longrightarrow$ Mobile Station (MS $\longrightarrow$ MS).

To explore the impact of adjacent channel interference in the downlink, we need to determine firstly the Interference power from a single adjacent channel Base Station (I_{BS}) and secondly the interference power from a single Mobile Station in one adjacent channel cell at a victim mobile station (I_{MS}). These interferences powers are given by the following equations respectively [14]:

$$I_{BS} = (P_{BS}.U_{BS}) / pl_{BS\text{-}MS} \qquad (9)$$

Where P_{BS} is the adjacent channel BS transmission power, U_{BS} is the number of users served by this BS, and $pl_{BS\text{-}MS}$, is the pathloss between the adjacent channel BS and the victim MS.

$$I_{MS} = P_{MS} / pl_{MS\text{-}MS} \qquad (10)$$

Where PMS is the adjacent channel MS transmission power and plMS-MS, is the path loss between the adjacent channel MS and the victim MS.

If we note IB the interference power from all adjacent channels base stations and IM the interference power from all mobile stations in adjacent channel cells then the total adjacent channel interference power (IT) in downlink results in [14]:

$$I_T = I_B + I_M \qquad (11)$$

V. SIMULATION RESULTS

The results of simulation are shown graphically using Matlab. The table 1 summarizes the simulation parameters used in the study of co and adjacent channel interference in cellular systems GSM and UMTS.

TABLE I SIMULATION PARAMETERS

Parameter	**Value**
BS transmission power	46 dBm
MS transmission power	24 dBm
Number of active users in interfering adjacent cell	From 10 to 30 users
Bandwidth (GSM)	200 KHz
Bandwidth (UMTS)	5 MHz

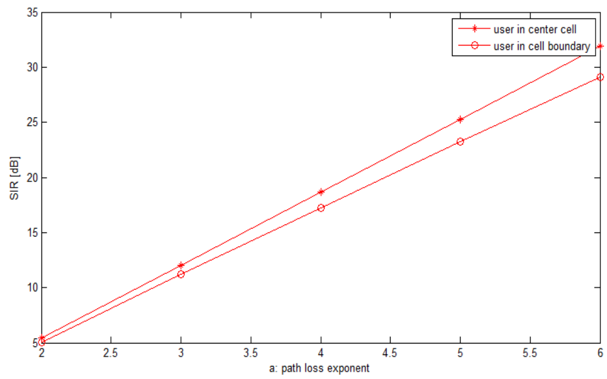

Fig. 3 Signal to Co-channel Interference Ratio's variation

This figure shows that Signal to Co-channel Interference Ratio's mobile user is less important for a user located in the cell boundary than another user situed in the cell center in the different environment types.

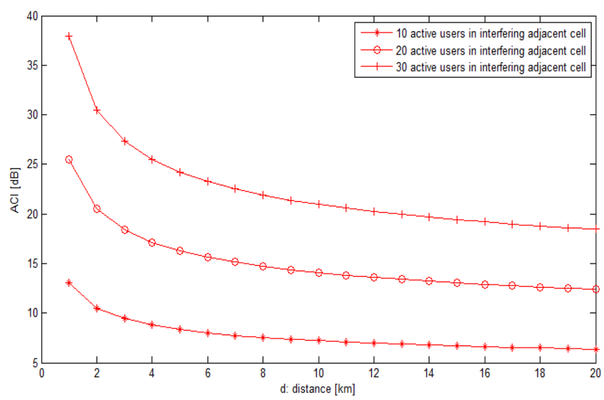

Fig. 4 Adjacent Channel Interference power depending on the number of active users in interfering adjacent cell

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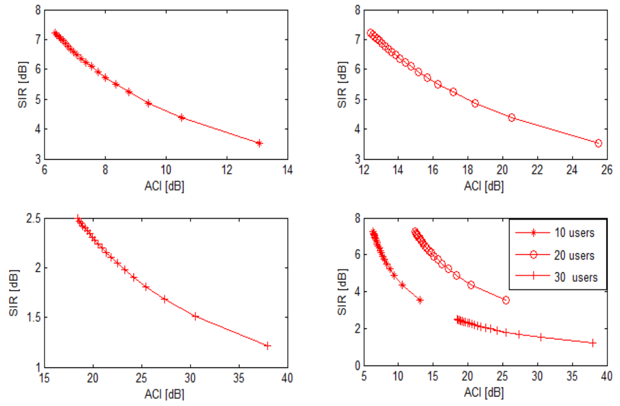

Fig. 5 Signal to Adjacent Channel Interference

Figures 4 and 5 present respectively the variation of adjacent channel interference power according to the distance between interfering equipment (BS or MS) and interfered equipment (MS) and according to the number of active users in interfering adjacent cell and the variation of the Signal to Adjacent Channel Interference according to the adjacent channel interference power measured and obtained in figure 4.

It is concluded that the adjacent channel interference power increased if the number of active users in interfering adjacent cell is increased and the distance between aggressor and victim of interference is decreased and vice versa.

VI. CONCLUSION

The fundamental principle of cellular systems is that a limited radio bandwidth has the potential to support a large number of users by means of frequency reuse. Two limiting factors relating to frequency reuse are co-channel interference and adjacent channel interference. This paper presented complete calculations of co-channel and adjacent channel interference in GSM and UMTS cellular standards.

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BIOGRAPHIES

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