Mitigation of External Interference on an EGSM Network

***Tanveer ul Haq*[1], *Senior Member IEEE, and Asim Iqbal*[2]**

[1]wi-tribe, N-14, F-8 Markaz, Islamabad, Pakistan
[1]haq@ieee.org, [2]its.asimiqbal@gmail.com

Abstract

Wireless Technologies are being used extensively for telecommunication services, thus increasing the demand for frequency spectrum. Regulators are pushed to allocate spectrum efficiently resulting in increased possibility of interference. Interference management becomes a challenge if the same spectrum is allocated to different network operators in neighboring geographic areas. Operators generally use coordinated frequency/PN Offset planning to mitigate such interference. The problem becomes complicated if the adjacent geographic areas fall in different countries. ITU and Regional Regulatory bodies provide guidelines for coordinated spectrum allocations across international borders; however, some scenarios are not addressed. One such problem is faced by an EGSM operator in Pakistan which is facing severe interference from CDMA operators in India. Coordinated frequency/PN Offset planning is not possible in this cross-technology interference scenario. Furthermore, the effect of this interference is only observed on the EGSM side, while CDMA is not impacted. This paper describes the unique interference problem of the EGSM operator in Pakistan and describes a process adopted for analysis and mitigation of this interference.

1. Introduction

Increased frequency spectrum usage for Commercial Wireless Communication, has increased the probability of interference between systems which has to be managed properly for providing the required Quality of Service (QoS) on wireless technologies. This paper reports the analysis and solution of the interference problem of a Pakistani EGSM operator, CMPak. CMPak has been experiencing interference on up to 33 channels of its uplink out of the 38 GSM channels allocated. Analysis indicates that this interference is caused by the downlink of CDMA operators on the Indian side of the Pakistan border. Allocation of the same set of frequencies to two different Wireless Network Operators in adjacent geographical areas can create the problem of co-channel interference. In order to resolve such interference, network operators implement a coordinated frequency plan for TDMA systems, like GSM, or a coordinated PN Offset plan in case of CDMA systems. The problem, however, becomes very complicated if the adjacent operators are using different technologies; for example one is GSM and the other is CDMA. Internationally, GSM and CDMA are allocated non-overlapping frequency bands except for the scenario of EGSM. Allocated frequencies of EGSM and CDMA have a certain overlap. Care is taken by most Telecom Regulators not to allocate the same frequency band to EGSM and CDMA in the same or adjacent geographic areas. This becomes a challenge when adjacent areas fall in different countries and the boundary is the international border. International Telecommunication Union (ITU) and regional regulatory bodies like European Union have adopted certain rules for cross-border frequency allocations to limit interference, however, these recommendations do not cover the specific scenario of overlapping EGSM and CDMA frequencies. It is, therefore, very likely that regulators across borders could assign overlapping frequencies for these two technologies. This is the scenario experienced by CMPak. The frequency band allocated by PTA (Pakistan Telecommunication Authority) to the Uplink of CMPak has been allocated by TRAI (Telecommunication Regulatory Authority of India) to two CDMA Operators (TATA and Reliance). This causes interference between the two systems. The impact of this interference is very severe on the EGSM operator, who sought a solution to this problem. Coordinated Frequency/PN Offset planning or mutually agreed transmit powers and antenna orientations was not a practical option as the CDMA operators were not having much impact because of this interference. A solution was proposed and implemented for CMPak that compromised the RF coverage slightly but significantly improved network performance by mitigating the impact of interference.

2. The Interference Problem

When CMPAK launched its commercial EGSM service network performance in border towns with India, like Lahore, was much below the required Quality of Service (QoS). On analysis it became clear that the Uplink was impacted due to heavy external interference. The source of interference was, however, unknown. In order to identify the source and origin of the interferer a test setup consisting of a spectrum analyzer, a Yagi-Uda Array Antenna and a

978-1-4244-6051-9/11/$26.00 ©2011 IEEE

compass was used. Measurements were taken at different elevated heights. After triangulation it was established that the source of interference was from the eastern Side (across the border in India). Spectrum measurements indicated that there were two distinct frequency ranges of interference as seen in Figure 1. Shape of the interfering signal resembled a CDMA waveform. Some kind of CDMA transmissions from across the Indian border were interfering with CMPak's EGSM system. Frequencies allocated to the Downlink of CMPak and the Uplink of CDMA Operators in India (Reliance and TATA Indicom) are shown in Table 1. CDMA allocated frequencies on the Indian side have an exact overlap with the EGSM frequencies causing two scenarios of interference. EGSM Mobiles (User equipment) on the Pakistani side of the border interfering with the Downlink of CDMA on the Indian side. The likelihood of this interference is minimal because the height of the EGSM Mobile antenna is usually no more than 1.5m; furthermore, the downlink is the stronger link for CDMA. There is enough isolation between the two systems not to cause any degradation of the CDMA downlink. The second scenario of interference is on EGSM Uplink (the weaker link) caused by strong downlink transmissions from the CDMA Base Station Transceiver (BTS) Antennas. BTS antennas are installed at heights of >50m in border rural areas, the antennas are highly directional, and the BTS power is in tens of watts, therefore, the Uplink of EGSM is severely degraded due to interference from CDMA. Practical measurements show that 33 out of the 38 ARFCNs allocated to EGSM on the Pakistan side have severe interference resulting in low Call Setup Rate (CSR), high Call Drop Rate (CDR) and high BER (Bit Error Rate). For CMPak interference has been a major problem that required resolution, whereas, for CDMA operators on the Indian side of the border it is a non-issue.

Table1. EGSM and CDMA Operators Allocated Frequencies

Operator's Name	Interfering Band	Operating Freq. (MHz)	Number of Overlapped Carriers
CMPak (Pakistani EGSM Operator)	Uplink	880.2 - 889.8	ARFCNs 975-1023
Reliance (Indian CDMA Operator)	Downlink	880.455 - 884.15	3 CDMA Carriers - 881.07, 882.3, 883.53 MHz
TATA Indicom (Indian CDMA Operator)	Downlink	884.75 -888.44	3 CDMA Carriers - 885.36, 886.59, 887.82 MHz

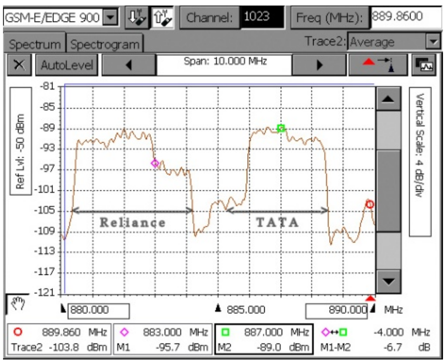


Figure1.Spectrum Analyzer Display

3. Proposed Solution

There are quite a few techniques for mitigation of interference in Cellular Wireless systems including frequency/PN offset coordinated planning, power reduction and power control, and coordinated antenna heights, tilts and azimuths [1], [2], [3-6]. None of these techniques are applicable to the scenario of CMPak. Coordination with operators across the border was a challenge and there was not much incentive for the Indian Regulator or the Indian operators to proactively engage in coordination with CMPak as they were not impacted at all. Therefore, we devised a solution based on actions taken independently by CMPak. The solution relied on utilizing earth's curvature and urban clutter as isolation by carefully reducing antenna heights, increasing antenna tilts and changing the azimuths of the EGSM system. Reduction in antenna heights would compromise the coverage of the system. This tradeoff was acceptable as a DCS system overlay was available in the network, which could be optimized to cover holes. EGSM antenna heights were carefully lowered through a two-step process. First the required height for each BTS was theoretically calculated and then confirmed by spectrum analyzer measurements at appropriate field locations.

4. Interference Mitigation

The interference from a source to a transceiver installed on the curvature of the earth can be estimated by Radar Horizon equation [7-8]. Figure 2 shows the geometry for interference estimation from the source (CDMA transmitter) to the EGSM receiver. The height of transmitter and receiver is given as h_t and h_r respectively. With the extension of h_r and h_t from their tip to center of earth the total length becomes h_t+R_e. Joining the two vertices at the tip of BTS stations gives a triangle with three sides as h_t+R_e, h_r+R_e and D_{RH}. For direct LOS (k=1), the D_{RH} can be derived by splitting the triangle into two right angled triangles whereas D_{RH} will be the sum of D_{RH1} and D_{RH2}. Solving the right angled triangles gives the following equations:

$$D_{RH1} = \sqrt{(Re + ht)^2 - (Re)^2} \quad (1)$$
$$D_{RH2} = \sqrt{(Re + hr)^2 - (Re)^2} \quad (2)$$

Since, Re >>h_t,h_r, so Equations 1 and 2 are reduced to:

$D_{RH1} = \sqrt{2Reht}$, $D_{RH2} = \sqrt{2Rehr}$, $D_{RH} = D_{RH1} + D_{RH2}$

$$D_{RH} \approx \sqrt{2R_e h_t} + \sqrt{2R_e h_r} \quad (3)$$

D_{RH} = Total Radio horizon distance

R_e = Radius of Earth = 6400 km.

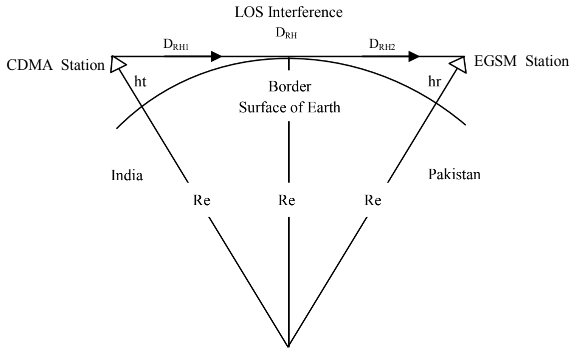


Figure2. LOS (Line of Sight) Mechanism

Assuming a fixed antenna height of 40 and 50m for the CDMA transmitter and a distance of at least 10km from the border, Table 2 gives values of D_{RH} for various heights of the EGSM receive antenna. These are the antenna heights to be used for EGSM BTSs at different distances from the Pakistan-India border for complete isolation from CDMA interference. As we go closer to the border (smaller D_{RH}) antenna heights have to be lower.

4.1 LOS Interference Measurement in Lahore

The heights calculated in Table 2 give a reference height. In order to establish the exact heights for avoiding LOS interference from CDMA BTSs an experiment was performed on a water tank, in the University of the Punjab campus, to measure CDMA signal levels at different heights using YBT250 Interference Tester. The antenna is rotated 360^0 and its azimuth and elevation are varied to get an estimate of the best direction, height and tilt for the EGSM antenna to avoid interference.

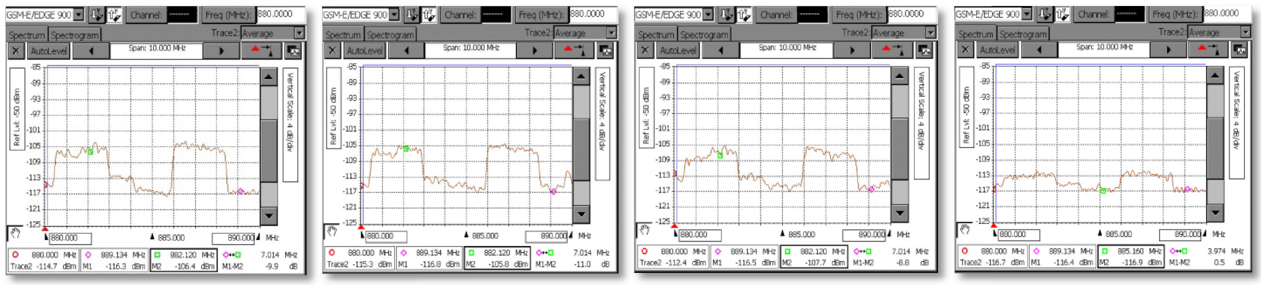
The directional antenna height was lowered gradually starting at 30m while measuring the intereference. Results are shown in Figure 5 (a-d) and Table 3. With the reduction of height from 30m to 21m, only 1dB reduction in interference is observed. As the height is reduced to 18m further 8dB reduction is observed, thus nullifying completely the impact of interference from CDMA transmitters. This is in line with the calculations in Table 2. University of the Punjab is approximately 40Km from the border, therefore, 50Km from the closest CDMA BTS. For this distance receive antenna height (h_r) is 18 meters for LOS. Measurements were also performed by changing the antenna tilts. Antenna tilting did not reduce interference significantly as shown in Figure 5 (b) for 45^o downtilt. The solution of careful antenna adjustments including height, tilt and azimuth was adopted on some of the most affected BTS sites of CMPak. Significant improvements were observed in the performance of the system in terms of CSR, CDR and BER on the uplink. Minor reduction in coverage was filled in by DCS coverage in the same area. Coverage estimation for mobile user from a BTS can be found in [9].

Table2. Calculated values of D_{RH} at R_e = 6400 km

No.	h_r	D_{RH} (ht=50m)	D_{RH} (ht=40m)	No.	h_r	D_{RH} (ht=50m)	D_{RH} (ht=40m)
1.	55 m	52 kms	49 kms	5.	18 m	40 kms	38 kms
2.	45 m	49 kms	46 kms	6.	10 m	36 kms	34 kms
3.	35 m	46 kms	43 kms	7.	8 m	35 kms	32 kms
4.	25 m	43 kms	40 kms	8.	5 m	33 kms	30 kms

Table 3. Interference Tester Measurements

No.	h_r (m)	M1 (dBm)	M2 (dBm)	M1 – M2 (dBm)
1.	30 m	-116.3	-106.4	-9.9
2.	24 m	-116.2	-106.0	-10.2
3.	21 m	-116.5	-107.7	-8.8
4.	18 m	-116.4	-116.9	0.5



(a) h_r = 30 m (b) h_r = 30 m (45° downtilt) (c) h_r = 21 m (d) h_r = 18 m

Figure 5. Spectrum Analyser Interference Measurements with Antenna Height Reduction

5. Conclusion

Performance limiting interference faced by CMPak, a GSM operator in Pakistan was analyzed. The source of interference was identified as two CDMA operators on the Indian side of the border. Co-channel interference was occurring due to similar frequency allocation to the Uplink of EGSM in Pakistan and the Downlink of CDMA in India. This cross-technology interference impacts EGSM only. A carefully planned method of lowering antenna heights and changing antenna tilts/azimuths was adopted to reduce the impact of interference on the system. The coverage gaps generated because of this activity were filled by optimizing the overlapping DCS 1800 system coverage. The results indicated a significantly improved network performance for the EGSM system.

6. Acknowledgements

Authors would like to acknowledge work performed by members of RF Engineering team of CMPak, especially Engr. Abdur Rehman and Engr. Asad Rauf. We also acknowledge Engr. Muzammil Naseer, Engr. Junaid Ahmed and Engr. Asad Raza who did antenna height reduction experiments at University of the Punjab, Lahore.

7. References

1. M. Felegyhazi and J.P Hubaux. Wireless Operators in a Shared Spectrum. In *Proceedings of IEEE International Conference on Computer Communications*, pages 1-11, April 2006.

2. M. Felegyhazi, M. Cagalj, D. Dufour, and J.P Hubaux. Border Games in Cellular Networks," In *Proceedings of IEEE International Conference on Computer Communications*, pages 812-820, May 2007.

3. M. Hayajneh, I. Khalil, and M. Awad. Non-cooperative uplink power control game for CDMA wireless communications systems. *Proc. of IEEE Symposium onComputers and Communication*, pages 587-592, July 2009.

4. U.O Candogan, I. Menache, A. Ozdaglarand, and P.A Parrilo. Near-Optimal Power Control in Wireless Networks: A Potential Game Approach. In *Proceedings of IEEE INFOCOM*, pages 1-9, March 2010.

5. H. Ji and C.Y. Huang. Non-cooperative uplink power control in cellular radio systems. *Wireless Networks (WINET)*, volume 4, number 4, pages 233–240, 1998.

6. T. Alpcan, Fan Xingzhe, T. Basar, M. Arcak, and J.T Wen. Power control for multicell CDMA wireless networks: a team optimization approach. In *Proceedings of Third International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks,* pages 379- 388, April 2005.

7. David Jenn. Lectures Notes on Electromagnetic Wave Propagation.
[Online] (http://faculty.nps.edu/jenn/EO3602/Vol5v1.3.pdf.)

8. D. E. Kerr, Propagation of Short Radio Waves, Radiation Laboratory Series, McGraw-Hill, 1951.

9. K. R. Manoj. Coverage estimation for mobile cellular networks from signal strength measurements. PhD Thesis, Apr. 1999.