Frequency Coordination Between UMTS and GSM Systems at 900 MHz

Vieri Vanghi, Mustafa Saglam, and Jiang Jindi
QUALCOMM Incorporated
5775 Morehouse Drive, San Diego, CA 92121
E-mail: vvanghi@qualcomm.com, msaglam@qualcomm.com
Huawei Technologies Co., LTD
Huawei Industrial Base, Bantian Longgang Shenzhen, 518129 P.R.China
Email:jjdi@huawei.com

Abstract – UTRA-FDD requirements for operation in the 900 MHz band have been recently standardized in 3GPP paving the way for refarming of GSM spectrum to UMTS. UMTS900 networks will have to co-exist with GSM900 networks for some time. 3GPP [1] has studied co-existence issues and has concluded that GSM900 and UMTS900 can co-exist in both coordinated and un-coordinated deployments in which the UMTS900 carrier is allocated 5 MHz in addition to a guard-band equal to 1 GSM channel (200 KHz) on each side. However, in some deployments the operator may not have sufficient available GSM spectrum to allow the GSM traffic to be offloaded from the spectrum allocated to UMTS900 to the remaining GSM spectrum. Hence of interest is to assess system performance under much more stringent spectrum clearing assumptions. Here we characterize transmitter and receiver performance based on lab tests conducted on commercial equipment, both UMTS900 and GSM900 terminals and base stations. From such measurements we assess the impact of mutual interference, GSM MS with UMTS NodeB and UMTS UE with GSM BTS, on receiver performance as a function of frequency offset and coupling loss between interfering transmitter and offended receiver. We show that the limiting factor is the interference caused by the GSM MS to the UMTS Node B, and that as little as 4.2 MHz of GSM spectrum can be cleared and allocated to one UMTS carrier with satisfactory system performance.

1 Introduction

UMTS900 combines the benefits of WCDMA with better propagation advantage at lower carrier frequency. UMTS900 offers CAPEX gains (less number of NodeBs) in rural morphologies and better in building penetration in urban morphologies compared to UMTS2100. UMTS900 and GSM900 are expected to co-exist in Band VIII. The deployments can be in coordinated or uncoordinated mode. Coordinated operation requires one-to-one overlay of UMTS900 NodeBs with GSM900 BTSs. The locations of two technologies' sites are non-collocated in uncoordinated operation. [1] and [6] recommend conservative carrier to carrier separation: 2.6 MHz for coordinated operation, 2.8 MHz for uncoordinated operation.

This paper studies the required guard band between UMTS900 and GSM900 in coordinated and uncoordinated operation using lab test measurements with commercial GSM BTS, UMTS NodeB and dual mode handset. Section 2 describes the transmitter and receiver characteristics and explains the calculation of adjacent channel interference rejection (ACIR) using the sensitivity degradation measurements in the lab. Section 3 presents how the sensitivity of victim receiver is degraded based in the interferer strength and coupling loss between the interferer and the victim. Mutual interference between GSM MS and UMTS Node B and mutual interference between UMTS UE and GSM BTS are studied. Conclusions are summarized in Section 4.

2 Transmitter and Receiver Characteristics

Mobile station and base station receivers can tolerate only a certain level of adjacent channel interference without suffering significant performance degradation. The proximity in frequency and space with which UMTS and GSM channels can be located depend mainly on the network design, and on the transmitter/receiver design. In particular, of interest are the out-of-band emissions (OOBE) of the transmitter and the adjacent channel selectivity of the receiver. The transmit spectrum is affected by the baseband FIR filters, up conversion to the desired carrier frequency and amplification. The amplifier non-linearity causes inter-modulation effects, resulting in the transmit signal energy to spill into the adjacent channels. At the receiver, filtering is used to selectively suppress out-of-band interference. Typically, SAW filters are used at the first stage of filtering because they introduce negligible amount of distortion. Following stages of filtering with good close-in properties further suppress residual interference before it can make its way into the AGC and then into the ADC of the receiver.

Transmit and receive filters on the uplink (mobile station interfering with base station) and downlink (base station interfering with mobile station) determine the system adjacent channel interference rejection (ACIR), defined in [3] as the ratio of the total power transmitted from a source (base or mobile station) to the total interference power affecting a victim receiver, resulting from both transmitter and receiver imperfections. In [1], the ACIR is computed as

$$ACIR = \frac{1}{\frac{1}{ACLR} + \frac{1}{ACS}} \quad (1).$$

where ACLR stands for adjacent channel leakage ratio [4], and ACS for adjacent channel selectivity [5]. The ACLR is the ratio of power in the adjacent channel to the power in the assigned channel. The ACS is the ratio of the receive filter attenuation on the assigned channel frequency to the receive filter attenuation on the adjacent channels.

Now notice that Eq.(1) represents only a crude approximation, as ACLR and ACS give only partial information on transmitter OOBE and receiver frequency response. Hereafter we then seek an accurate method to estimate system ACIR based on lab measurements conducted on commercial UMTS900 and GSM900 base stations and terminals.

2.1 ACIR Estimation

The ACIR can also be seen as the attenuation L that the adjacent channel interference at frequency offset Δf undergoes while making its way through the receiver filter chain. $L(\Delta f)$ can then be estimated by measuring the sensitivity loss caused by an adjacent channel interfering signal of know power level. Consider a receiver with noise figure F. The sensitivity of such receiver can be measured as the required signal power S received at the antenna connector that results in a certain performance, say a bit error rate (BER) equal to 0.1%. We can introduce a known amount of adjacent channel interference J at the receiver antenna connector and measure the effect of receiver sensitivity, which is now S^*. We then have that

$$\frac{S}{N_o W \cdot F} = \frac{S^*}{N_o W \cdot F + \dfrac{J}{L(\Delta f)}} \quad (2),$$

Where $N_o W$ is the thermal noise power in the receiver bandwidth W. Solving for $L(\Delta f)$ in dB we obtain

$$L(\Delta f) = 10 Log\left(\frac{J}{N_o W \cdot F}\right) - 10 Log\left(\frac{S^*}{S} - 1\right) \quad (3).$$

The following commercial equipment was used: Huawei UMTS900 NodeB, GSM900 BTS, and QUALCOMM dual-mode test mobile TM6280. For the downlink, measurements were taken on several different terminals to account for handset component variability. Results are summarized in the tables below.

Table 1 UMTS NodeB sensitivity loss due to adjacent channel GMSK interference

Δf	2.8 MHz	2.6 MHz	2.4 MHz	2.2 MHz
$\frac{S^*}{S}$ dB	J [dBm]			
10	-23	-23	-53	-61

Table 2 UMTS UE sensitivity loss due to adjacent channel GMSK interference

Δf	2.8 MHz	2.4 MHz	2.3 MHz	2.2 MHz
$\frac{S^*}{S}$ dB	J [dBm]			
10	-27	-46	-55	-65

Table 3 GSM BTS sensitivity loss due to adjacent channel WCDMA interference

Δf	2.8 MHz	2.6MHz	2.4 MHz	2.2 MHz
$\frac{S^*}{S}$ dB	J [dBm]			
3	-43	-43.7	-69.1	-93.3

Table 4 GSM MS sensitivity loss due to adjacent channel WCDMA interference

Δf	2.8 MHz	2.4 MHz	2.3 MHz	2.2 MHz
$\frac{S^*}{S}$ dB	J [dBm]			
4	-37	-51	-70	-80

One can notice that both NodeB and UE under test exceeded by several dB the minimum narrow band blocking performance requirements set forth in [4] and [5]. For example, in [5] the UMTS NodeB suffers a sensitivity degradation of 6 dB (useful signal level increases from -121 to -115 dBm) in the presence of a GMSK interfering signal at -47 dBm and 2.8 MHz frequency offset. However from Table 1 one can notice that in same conditions the interference level at the UMTS NodeB is -23 dBm, thus exceeding by 24 dB the minimum performance specification. Similarly, it can be seen that the UMTS UE exceeds by 29 dB the narrow band blocking requirements in [4].

Using Eq.(3) one can then estimate uplink and downlink ACIR. The GSM MS, UMTS UE, GSM BTS and UMTS NodeB receiver noise figures are 9 dB, 8 dB, 3dB and 2.1dB, respectively. Results are plotted in Figure 1.

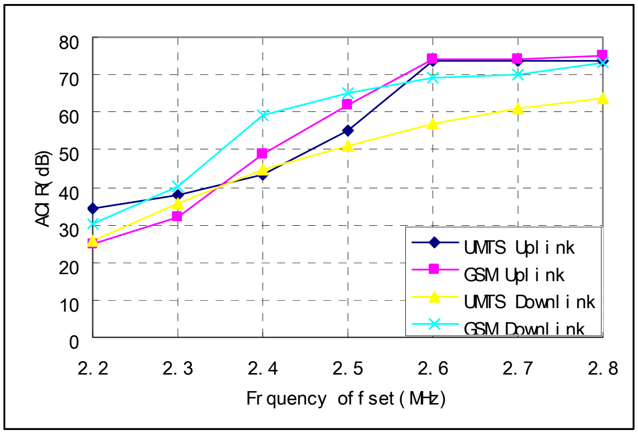

Figure 1 Estimated ACIR

Now that the ACIR is known, we can investigate impact of adjacent channel interference on system performance.

3 Mutual Interference and Noise Figure Degradation

In [1] and [2], network capacity loss is estimated as a function of ACIR by means of computer simulations. In addition to the impact on capacity, it is also of interest to assess impact of adjacent channel interference on the quality of service of individual users. With that in mind, we now estimate the receiver noise figure degradation of a receiver due to an adjacent channel interferer transmitting at power P_{Tx} and frequency offset Δf. Let L_p be the coupling loss between transmitter and receiver. The receiver noise floor will increase by an amount proportional to the interferer transmit power, and inversely proportional to the coupling loss and the ACIR. This is represented by the left hand side of Eq.(4). Rearranging terms we obtain the expression within brackets in Eq.(4) which represents the receiver effective noise figure F^*.

$$N_0W\cdot F+\frac{P_{Tx}}{L_p\cdot L(\Delta f)}= \\ =N_0W\left(F+\frac{P_{Tx}}{N_0W\cdot L_p\cdot L(\Delta f)}\right)=N_0W\cdot F^* \quad (4).$$

The receiver noise figure degradation is then

$$\frac{F^*}{F}=1+\frac{P_{Tx}}{N_0W\cdot F\cdot L_p\cdot L(\Delta f)} \quad (5).$$

Noise figure degradation is equivalent to sensitivity degradation, so sensitivity degradation is also equal to:

$$\frac{S^*}{S}=1+\frac{P_{Tx}}{N_0W\cdot F\cdot L_p\cdot L(\Delta f)} \quad (6).$$

Numerical results obtained by applying Eq.(5)-(6) to the scenarios of interest are presented hereafter.

In downlink, we use max allowed sensitivity degradation to evaluate if the actual sensitivity degradation is acceptable. We can get the max allowed sensitivity degradation is:

$$\left.\frac{S^*}{S}\right|_{AllowedMax}=\frac{P'_{Tx}}{L_p\cdot S}. \quad (7)$$

where P'_{Tx} is the transmitting power of BTS or NodeB of victim system. It can be assumed that downlink coverage is not impacted if the sensitivity degradation is less than $\frac{P'_{Tx}}{L_p\cdot S}$, but downlink capacity is degraded. One shall remember that the max allowed sensitivity degradation defined in Eq (7) is rough estimation and doesn't consider the head room for power control.

3.1 Mutual Interference between GSM MS and UMTS NodeB

We now consider the mutual interference between GSM MS and UMTS NodeB. We consider two operation modes: Coordinated operation and uncoordinated operation. Uncoordinated operation, here, assumes site layout of GSM sites at the cell edge of UMTS sites as defined in [1].

1、 Coordinated Operation

In this scenario, the minimum TX power of GSM MS is 5dBm and the maximum power is 33dBm because of power control. MS TX power is determined by coupling loss between NodeB and MS. MS transmitting power is: $P_{Tx}=Min(Max(5dBm,L_p+S),33dBm)$, where L_p is the coupling loss and S is the sensitivity of GSM BTS. The NodeB sensitivity degradation in different coupling loss is shown in Figure 2. We can find that UMTS NodeB noise floor will increase about 1.7 dB when coupling loss is equal to 80dB and frequency offset is 2.2 MHz, which will result in increase UE transmit power and impact UL coverage. In scenarios where coverage is not a limiting factor, 2.2MHz offset can give satisfactory performance. If frequency offset is 2.4MHz, the sensitivity degradation is less than 0.2dB when coupling loss is 80dB. So the interference to UMTS Node B is negligible when frequency offset is 2.4 MHz.

Here, it is assumed GSM MS transmits at all eight time slots. In practice, a user occupies only one slot. The effective interference to UMTS Node B is decreased by 9 dB in this case and the UMTS900 sensitivity degradation is only 0.2 dB at 2.2 MHz offset.

We assume NodeB transmit at full power, i.e. 43dBm when consider UMTS NodeB interference GSM MS. GSM MS sensitivity degradation and the allowed sensitivity degradation are showed in Figure 3. We can find that GSM MS allowed sensitivity degradation is always larger than actual sensitivity degradation about 20 dB. The delta is large enough to cover the power control head room in downlink. So, the NodeB interference to GSM MS can be tolerated in coordinated operation when frequency offset is 2.2MHz.

2、 Uncoordinated Operation

In uncoordinated operation, we assume the worst case scenario in which GSM MS and UMTS NodeB transmit at full power, i.e., 33 dBm and 43 dBm, respectively. Sensitivity degradation vs. coupling loss is shown in Figure 4 and Figure 5. The minimum coupling loss (MCL) between UMTS NodeB and GSM MS is assumed to be 80dB.

From Figure 4, we can find that the sensitivity degradation of UMTS NodeB is less than 0.2dB, which is obviously acceptable, when coupling loss is 80 dB and frequency offset is 2.6 MHz.

We can find from Figure 5 that the GSM MS allowed max sensitivity degradation is always larger than the actual sensitivity degradation. The max allowed sensitivity degradation is calculated by assuming maximum coupling loss of 120 dB. So GSM MS can tolerate the adjacent inference from UMTS NodeB in uncoordinated operation scenario when frequency offset is 2.6 MHz.

3.2 Mutual interference between UMTS UE and GSM BTS

Similar to GSM MS-UMTS NodeB mutual interference case, two operation modes are considered: Coordinated operation and uncoordinated operation.

1、 Coordinated Operation

The minimum TX power of UMTS UE is -50dBm and the maximum power is 21dBm. UMTS UE TX power is determined by coupling loss between GSM BTS and UMTS UE. UMTS UE transmitting power is: $P_{Tx} = Min(Max(-50dBm, L_p + S), 21)$, where L_p is the coupling loss and S is the sensitivity of UMTS Node B. The GSM BTS sensitivity degradation for different coupling loss values is in Figure 2. We can find from Figure 2 that there is no interference impact from UMTS UE to GSM uplink with 2.2 MHz frequency offset.

Maximum GSM BTS power, i.e. 43dBm, is assumed when assessing the impact of GSM BTS interference to UMTS UE. Figure 3 shows the max allowed sensitivity degradation and the actual UMTS UE sensitivity degradation. As can be seen in Figure 3, the max allowed sensitivity degradation is always larger than the actual value by around 25 dB. . The delta is large enough to cover the power control head room in downlink. So it can be concluded that the interference from GSM BTS to UMTS UE doesn't impact the UMTS quality in coordinated operation when frequency offset is 2.2MHz.

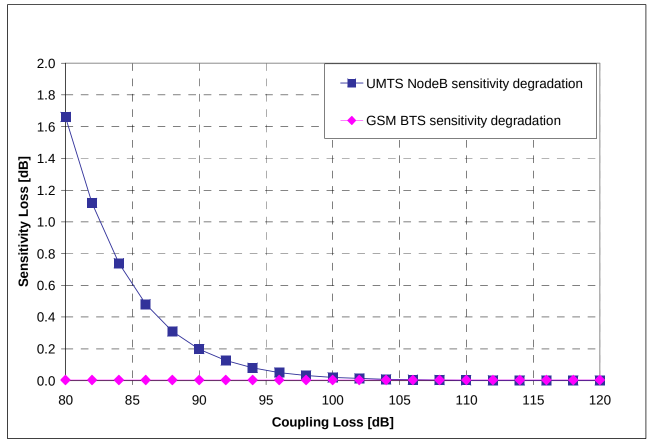

Figure 2 UMTS NodeB and GSM BTS sensitivity degradation vs. coupling loss in coordinated operation (Frequency offset 2.2MHz)

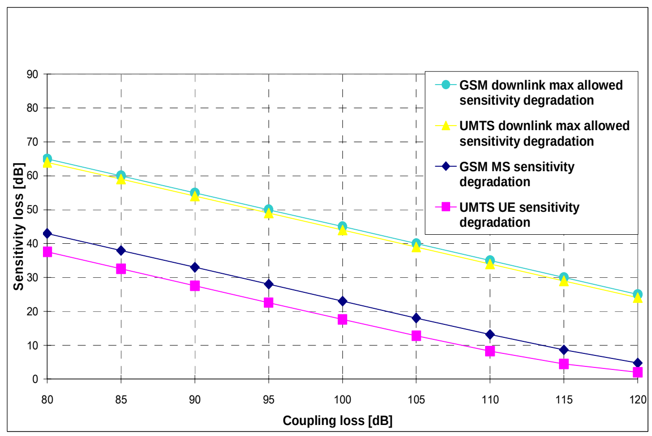

Figure 3 UMTS UE and GSM MS sensitivity degradation vs. coupling loss in coordinated operation (Frequency offset 2.2MHz)

2、 Uncoordinated Operation

In uncoordinated operation, we assume the worst case scenario in which UMTS UE and GSM BTS transmit at full power, i.e., 21 dBm and 43 dBm, respectively. The MCL between GSM BTS and UMTS UE is 80dB and the sensitivity degradation vs. coupling loss is showed in Figure 4 and Figure 5.

From Figure 4, we can find GSM BTS noise floor will increase less than 0.2dB due to the interference from UMTS UE. This is evidently negligible.

We can also find from Figure 5 that the UMTS UE allowed max sensitivity degradation is always larger than UMTS UE actual sensitivity degradation. Maximum coupling loss of 120 dB is assumed when calculating allowed max sensitivity degradation. So UMTS UE can tolerate the adjacent channel inference from GSM BTS in uncoordinated operation scenario at 2.6 MHz frequency offset.

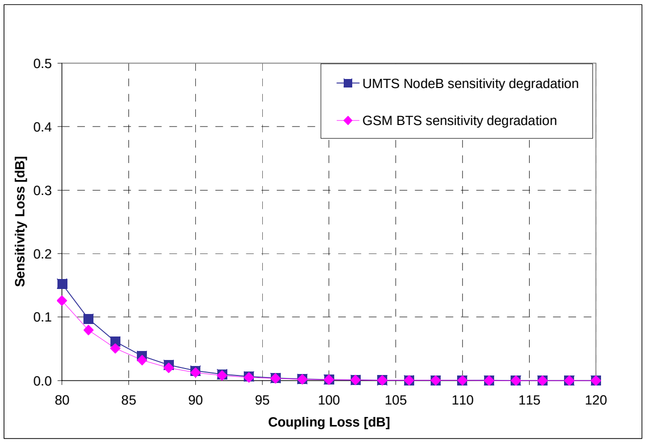

Figure 4 UMTS NodeB and GSM BTS sensitivity degradation vs. coupling loss in uncoordinated operation (Frequency offset 2.6MHz)

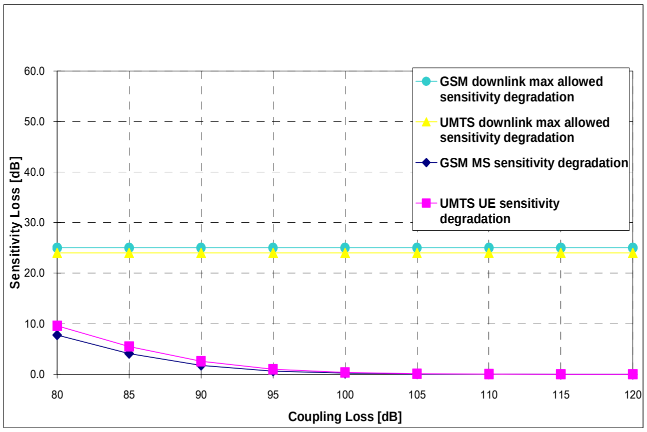

Figure 5 UMTS UE and GSM MS noise degradation vs coupling loss in coordinated operation (Frequency offset 2.6MHz)

4 Conclusions

Findings can be summarized in Table 5.

Table 5 Sensitivity Degradation Summary

Frequency Offset	2.2MHz	2.6MHz
Scenario	Coordinated	Uncoordinated
UMTS NodeB NF Degradation	≤1.7 dB	≤0.2 dB
GSM BTS NF Degradation	0dB	≤0.1
UMTS UE NF Degradation	Less than max allowed by ~25dB	Less than max allowed
GSM BTS NF Degradation	Less than max allowed by ~20dB	Less than max allowed

From [1],we can find the average UMTS uplink capacity loss less than 5% when frequency offset is 2.2MHz （ACIR=34.5dB）and downlink capacity loss less than 1.5%(ACIR=25.5dB) in rural area with cell range of 5000 m in coordinated operation. The UMTS capacity loss and GSM outage degradation are all less than 1% when frequency offset is 2.6MHz (all ACIR larger than 55dB from Figure 1) in uncoordinated operation.

From above description, we can get the following conclusion:

- In coordinated deployment，2.2MHz frequency offset from UMTS center can be satisfied for requirement when the operator can tolerate slight capacity and coverage loss (i.e. UMTS900 carrier is allocated 4.2 MHz).
- In coordinated deployment, when the operator has enough frequency resource or cannot tolerate about 1.7dB UMTS uplink sensitivity degradation and about 5% UMTS uplink capacity loss, 2.4MHz carrier separation is needed (i.e. UMTS900 carrier is allocated 4.6 MHz).
- In uncoordinated deployment，2.6MHz frequency offset satisfies the capacity and coverage requirements (i.e. UMTS900 carrier is allocated 5.0 MHz).

5 References

[1] 3GPP TR25.816, “UMTS900 Work Item Technical report”, 2005.

[2] S. Soliman, C. Weathley, “Frequency Coordination Between CDMA and Non-CDMA Systems”, xxxx

[3] 3GPP TR25.942, “Radio Frequency System Scenarios”

[4] 3GPP TS25.101, “UE Radio Transmission and reception”

[5] 3GPP TS25.104, “Base Station Radio Transmission and reception”

[6] ECC/CEPT, ‘Compatibility Study for UMTS Operating Within the GSM 900 and GSM 1800 Frequency Bands’