BS-to-BS INTERFERENCE OF WCDMA AND PCS 1900 (IS-95)

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Abstract: Coexistence of different cellular communication systems that share the same frequency band is becoming one of the most challenging issues. It is important to understand the risk of interference between systems when planning in such environments. In this paper, potential interference problems between WCDMA (UMTS/IMT-2000) and PCS1900 (IS-95) systems are studied. The scope of this paper is to study the impact of IS-95 base-station to WCDMA base-station interference. The results show the required distance separation to limit the interference. The calculations are based on certain assumptions, chosen as realistic as possible.

Keywords: WCDMA, PCS1900, BS-to-BS, and Interference

1. Introduction

Collectively, GSM, TDMA (IS-136), and CDMA (IS-95) are referred to as second generation, or 2G systems. The most mature of the digital cellular standards, GSM is available in North America as PCS1900 (one of the three "PCS" standards) [1]. The fact that it operates at a different frequency than GSM in Europe is irrelevant to the end user. PCS protocols include CDMA, TDMA, and GSM. CDMA is predominantly used in the U.S. (e.g., Verizon Wireless and Sprint PCS), Canada, and South Korea. CDMA is also expected to be popular in emerging markets in mainland China. According to guidelines set by the Federal Communications Commission (FCC), mobile phones may send signal at 800 MHz and/or 1900 MHz in the U.S. Other countries allow mobile phone frequencies at 900 MHz and 1800 MHz.

The WCDMA (UMTS/IMT-2000), third Generation (3G) technology, is intended to revolutionize the capabilities of mobile communications. The 3G systems are expected to integrate all present and future services into one system. In order to utilize multimedia applications sufficiently and to optimize spectrum resources, both circuit switching and packet switching type traffic are assumed. High data rates up to 2Mbps will open the possibility of transmitting information in a various type of media such as voice, pictures, video clips, sound tracks and software applications [2],[3].

The ITU Radiocommunication Assembly has recommended (WRC-95) that the frequency bands 1.885-2.025 GHz and 2.110-2.200 GHz are intended for use in UMTS/IMT-2000 on a worldwide basis. In Europe, the European Radiocommunications Committee (ERC) has assigned the frequency bands 1.900 – 1.980 GHz, 2.010 – 2.025 GHz and 2.110 – 2.170 GHz to terrestrial UMTS applications. The spectrum allocation in the Asian Pacific region will be similar to those in Europe. Therefore, similar operator scenarios will appear, as in Europe. In contrast, PCS services led to a split into licenses of 2 x 15 MHz and 2 x 5 MHz up to 1990 MHz in North America.

In some countries, the possibility of using PCS1900 and WCDMA in the same region is currently assessed. Therefore, coexistence of both mobile radio systems may cause interference resulting in performance degradation. The scope of this paper is to describe the coexistence interference issues and, specifically, present study focuses on base-station (BS) to base-station (BS) interference. The calculations are based on certain assumptions, chosen as realistic as possible.

2. PCS 1900 (IS-95) System

The IS-95 standard was adopted by TIA in July 1993, and an upbanded version of the standard to operate at 1.9GHz was subsequently submitted to the JTC (Joint Technical Committee). The JTC established seven Technical Adhoc Groups (TAGs) in March 1994, one for each selected air interface proposal. The TAGs drafts the specifications document for the respective air interface technologies and conducted validation and verification to ensure consistency with the criteria established by the JTC. This was followed by balloting on each of the standards. After the balloting process, four of the proposed standards were adopted as ANSI standards: IS-136-based PCS, IS-95-based PCS, GSM1900 (based on GSM), and personal access communication system (PACS) [2].

The PCS 1900 spectrum in the U.S. and Canada is allocated as shown below:

Table 1 Frequency band of PCS1900

Transmit/Receive Frequency Band (MHz)		
	Uplink	Downlink
A	1850-1865	1930-1945
D	1865-1870	1945-1950
B	1870-1885	1950-1965
E	1885-1890	1965-1870
F	1890-1895	1970-1975
C	1895-1910	1975-1990

For IS-95 power control system, accurate control of input levels to base receiver needed to obtain optimum (sufficient) C/I and C/N. Only terminals serviced by the cell can be controlled. Therefore need for soft handover. Power control is mainly needed for uplink. In downlink the propagation loss is the same for all signals from own base.

Power control at the terminals can be divided into two parts as following:

a) Open-loop regulation keeps the local average of C to optimum value. Distance dependence and shadow fading are fully correlated uplink/downlink. The terminal is informed about the power of the pilot channel transmitted from base. The terminal can compute suitable output power by measuring the received level of pilot.

b) Closed-loop regulation needed to compensate for multi-path fading. The base sends up/down power commands to each terminal about 1000 times per second.

3. WCDMA System

WCDMA is intended for wideband multimedia services and support for bit rates of at least 384 kbit/s with good coverage and full mobility. Up to 2 Mb/s can be supported with one 5 MHz carrier with local coverage. One of the most important characteristics of WCDMA is the fact that power is the common shared resource. This makes WCDMA very flexible in handling mixed services and services with variable bit-rate demands. The access scheme of WCDMA is Direct-Sequence Code Division Multiple Access (The name "direct sequence CDMA " means that a code sequence is directly used to modulate the transmitted radio signal) with information spread over approximately 5 MHz bandwidth. The basic chip rate is 3.84 Mcps which leads to a carrier spacing of around 5MHz. There is a flexible carrier spacing in order to allow for different carrier spacing dependent on the actual need for separation.

WCDMA is adopted as the technology for UMTS public, wide-area service, in the paired bands (1920 - 1980 MHz (uplink), 2110 - 2170 MHz (downlink)). A Time Division Duplex (TDD) mode is adopted for private, indoor services (1900-1920 MHz and 2010 - 2025 MHz). The TDD mode is considered to be a complement to WCDMA to boost the capacity in local areas. The WCDMA system is required to operate in the following frequency bands specified in Table 2 [4]. The nominal carrier spacing is 5 MHz and the chip rate is 3.84 Mcps. The carrier can be adjusted in steps of 200 kHz.

Table 2 Frequency band of WCDMA

Uplink	1920 – 1980 MHz
Downlink	2110 – 2170 MHz
Carrier spacing	5 MHz (nominal)
Duplex distance	190 MHz
Chip rate	3.84 Mcps

4. Coexistence of IS-95 BS and WCDMA BS: Impact of IS-95 BS to WCDMA BS

The PCS1900 (IS-95) downlink band 1930 – 1990 MHz is adjacent to blocks of the UMTS/IMT-2000 (WCDMA) uplink band 1920 – 1980 MHz. Therefore, coexistence of both mobile radio systems may cause interference resulting in performance degradation.

Fig. 1 below illustrates the scenario, with a distance d between the base stations of the two systems. The IS-95 base station transmits the power P_{Tx}, which is the total power for the pilot channel, broadcast channel and a number of traffic channels. The WCDMA base station receives the power P_{Rx} from one of its associated mobiles, plus the interference I from the IS-95 base station. The interference I is the transmitted out-of-band emission P_{OOB} from the IS-95 base station minus the path loss L between the base stations [5].

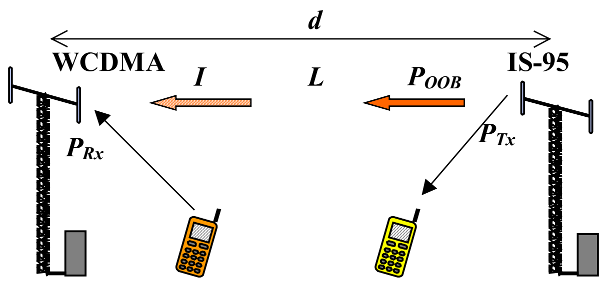

Fig. 1 Coexistence of IS-95 BS and WCDMA BS: Impact of IS-95 BS to WCDMA BS interference

For IS-95 parameters, the following parameters were used in the scenario [5]:

Maximum total Tx power	P_{Tx} = 43 dBm
Transmit antenna gain:	G_{IS95} = 20 dBi
Tx bandwidth	W = 1.23 MHz

Out of band emissions at a frequency offset of more than 2.3 MHz (corresponding to 1 MHz guard band to WCDMA uplink) is allowed to be -13 dBm/MHz according to the IS-95 specification. This gives at the transmit antenna connector P_{OOB} = -7 dBm in 3.84 MHz.

For WCDMA parameters, the level of noise floor in the WCDMA BS is about –103 dBm, assuming a noise figure of 5 dB. For this study, we assume that the system operates at 60% of maximum capacity and the remaining 40% is for noise protection to have a balance between coverage. This implies an increase of the total interference level of 4 dB compared to noise only, i.e. the total interference level is –99 dBm. It is also assumed a 3 dB degradation in performance (30% reduced cell size). The interference level from IS-95 will then also be –99 dBm [5].

IS-95 interference level:	I = -99 dBm
Receive antenna gain:	G_{WCDMA} = 20 dBi
Receive bandwidth:	W = 3.84 MHz

For path loss analysis, the path attenuation strongly depends on the specific site assumptions for the base stations. For high mount antennas (above roof-top) in a line-of-sight formation, the free space propagation model may be used for even large distances. Experiences from field trials have shown that under this assumption the free space model is valid for 10 km distance separation and more. Therefore we can use as minimum path loss model the free space propagation model which for 1.9 GHz can be written as [5]:

Model 1: $L = 20 \log(d) + 38.4 \text{ dB} - G_{IS95} - G_{WCDMA}$ (distance d in meters) (1)

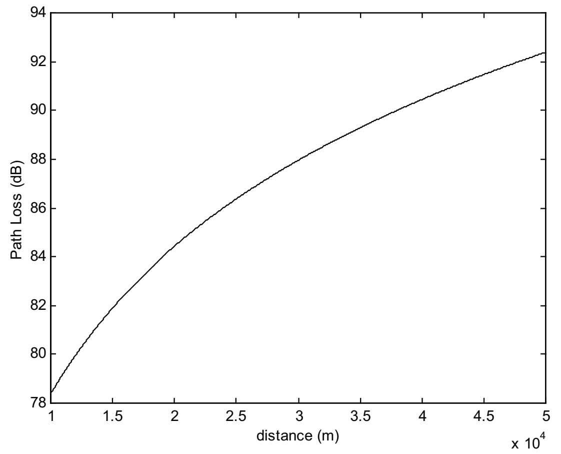

Fig. 2 Path loss for high mount antennas (above roof-top) in a line-of-sight

However, for urban areas with base antennas below the roof-top having no line-of-sight, the attenuation is significantly higher. In order to assess a lower boundary for the required distance separation we assume free space propagation below 10m and a 4th power law for higher distances. This leads to the following model [5]:

Model 2: $L = 20 \log(d) + 38.4 \text{ dB} - G_{IS95} - G_{WCDMA}$ for d<10m (2a)

$L = 40 \log(d) + 18.4 \text{ dB} - G_{IS95} - G_{WCDMA}$ for d>10m (2b)

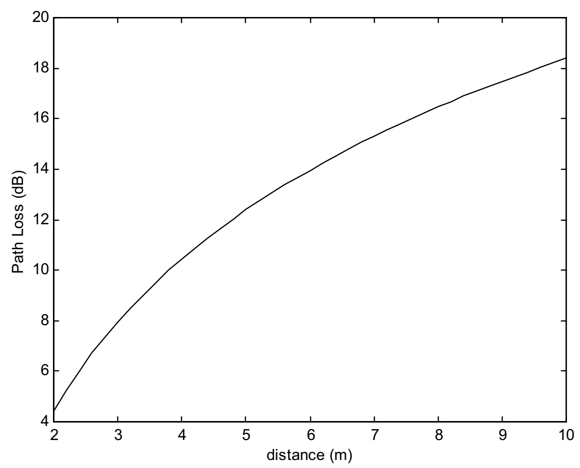

Fig. 3 Path loss for urban areas with base antennas below the roof-top having no line-of-sight for d<10m

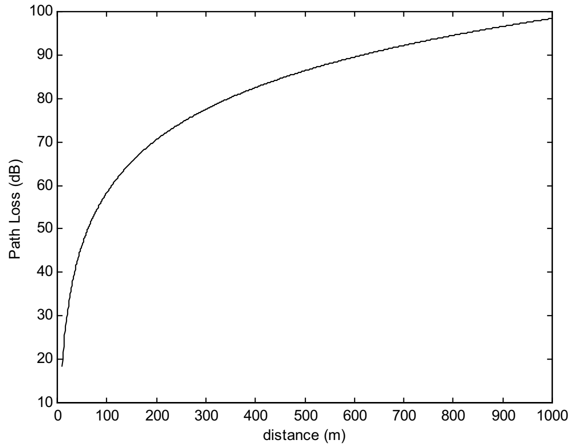

Fig. 4 Path loss for urban areas with base antennas below the roof-top having no line-of-sight for d>10m

Now, the required distance separation can be calculated for the two propagation models and two assumptions on the relative directions of the antenna main beams. For this study, the face-to-face assumption means that the maximum gains of both antennas need to be taken into account, such that the total adds up to 40 dB.

Now, it can be concluded that the path loss is given by [5]:

$$L = P_{OOB} - I \quad (3)$$

From the information above, one can get L = –7+99 = 92 dB. From Figs. 2-4, for L > 92 dB, the separated distance between WCDMA BS and PCS1900 BS can be specified as following:

Model 1	d > 48 km
Model 2	d > 700 m

From the calculation results above, in case of line-of-sight (Model 1), the required distance becomes unrealistically high which is not practical in the real situation. It is clear that the line-of-sight assumption is most likely no longer valid at a distance of 48 km.

On the other hand, this calculation shows basically, that both systems can practically only co-exist in adjacent bands if there is no line-of-sight (Model 2) between two base stations. A minimum distance of at least 700 m is required to avoid BS-to-BS interference. For most environments the required distance will be significantly higher. However, for urban areas, it is possible in very dense population area that cellular engineers need to design the distance between base stations greater than 700 m. In next section, BS-to-BS interference is studied by using the path-loss Walfisch-Ikegami model of urban environment.

5. Very Dense Urban Environment: Case study

For small cells in an urban environment the cell range is typically less than 1 km. In that case the Okumura-Hata algorithm is not valid. The Walfisch-Ikegami model gives a better approximation for the cell radius in urban environments. In order to obtain a simple expression that can be used for cell radius estimations, the specific parameters in Table 3 are used:

Table 3 Parameter setting for estimating urban cell sizes with the Walfisch-Ikegami model [6]

Parameter	Default value
h_m	1.5 (m)
b	40 (m)
H	18 (m)
w	20 (m)
f	1900 (MHz)

Note: h_m = mobile antenna height
b = distance between building (center-to-center)
H = height of building
w = distance between building (edge-to-edge)

The path loss formula can now be expressed as [6]:

$$L = 155.3 + 38 \log d - 18 \log (hb - 17) - G_{IS95} - G_{WCDMA} \quad (4)$$

Eq.(4) is only valid for base antenna heights above 18 m.

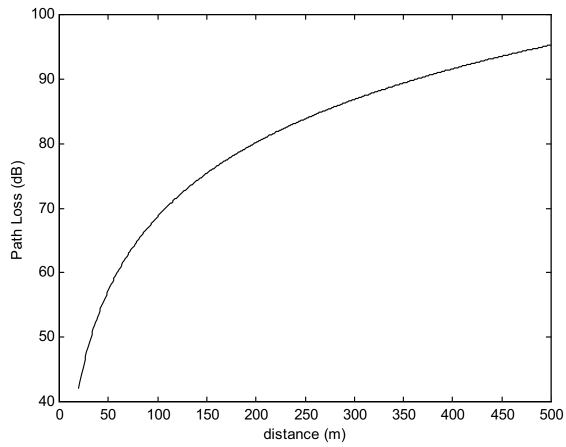

Fig. 5 Walfisch-Ikegami path loss for small cells in a very urban environment

For this specific case, the calculation result in Fig. 5 indicates that, in very dense building and population area, the required distance separation to limit the interference should be greater than 350m.

6. Conclusion

Allocating PCS1900 (IS-95) systems adjacent to UMTS/IMT-2000 (WCDMA) systems is an important problem for cell site design. This paper describes the coexistence interference issues, which may occur when operating WCDMA (UMTS/IMT-2000) system with PCS 1900 (IS-95) system within the same geographical area. Specifically, present study focuses on base-station (BS) to base-station (BS) interference. Minimum separation distances in several cases to limit the impact of IS-95 base-station to WCDMA base-station interference are recommended in this paper.

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