Impact of Ultra Wide Band (UWB) on Macrocell Downlink of DCS-1800 and GSM-900 Systems

Bazil TAHA-AHMED, Miguel CALVO-RAMÓN, Leandro de HARO-ARIET

Departamento Sistemas, Señales y Radiocomunicaciones, ETSI Telecomunicación, Universidad Politécnica de Madrid, Ciudad Universitaria, Madrid, 28040, Spain

bazil@gr.ssr.upm.es

Abstract. The effect of UWB interference on the DCS-1800 and GSM-900 downlink is studied for different UWB power density. For high UWB power density (-70 dBm/MHz), the effect of UWB signals is very high when the distance between UWB transmitter and DCS-1800 receiver is less than 1 m. For low UWB power density (-100 dBm/MHz), the effect of the UWB signals is quasi null even if the distance between the UWB transmitter and the DCS-1800 receiver is 0.5 m. It is found that the spectrum mask proposed by the FCC for indoor application (-53 dBm/MHz in the DCS-1800 band and -41 dBm/MHz in the GSM-900 band) is very high to be tolerated by the two mobile systems and we have to propose another spectrum mask with lower UWB power density.

Keywords
UWB, DCS-1800, GSM-900.

1. Introduction

The Federal Communications Commission (FCC) agreed in February 2002 to allocate 7.5 GHz of spectrum for unlicensed use of ultra-wideband (UWB) devices for communication applications in the 3.1–10.6 GHz frequency band, the move represented a victory in a long hard-fought battle that dated back decades. With its origins in the 1960s, when it was called time-domain electromagnetics, UWB came to be known for the operation of sending and receiving extremely short bursts of RF energy. With its outstanding ability for applications that require precision distance or positioning measurements, as well as high-speed wireless connectivity, the largest spectrum allocation ever granted by the FCC is unique because it overlaps other services in the same frequency of operation. Previous spectrum allocations for unlicensed use, such as the Unlicensed National Information Infrastructure (UNII) band have opened up bandwidth dedicated to unlicensed devices based on the assumption that “operation is subject to the following two conditions:

1. This device may not cause harmful interference;
2. This device must accept any interference received, incl. interference that may cause undesired operation.

(1) Harmful interference is defined as interference that seriously degrades, obstructs or repeatedly interrupts a radio communication service.

(2) This means that devices using unlicensed spectrum must be designed to coexist in an uncontrolled environment.

Devices utilizing UWB spectrum operate according to similar rules, but they are subject to more stringent requirements because UWB spectrum underlays other existing licensed and unlicensed spectrum allocations. In order to optimize spectrum use and reduce interference to existing services, the FCC’s regulations are very conservative and require very low emitted power.

UWB has a number of advantages which make it attractive for consumer communications applications. In particular, UWB systems

- have potentially low complexity and low cost;
- have noise-like signal characteristics;
- are resistant to severe multipath and jamming;
- have very good time domain resolution.

DCS-1800 is a Digital Communications System based on GSM, working on a radio frequency of 1800 MHz. Also known as GSM-1800 or PCN, this digital network operates in Europe and Asia Pacific. The DCS-1800 band provides for a DCS uplink in the range 1710-1785 MHz, a DCS downlink in the range 1805-1880 MHz.

The GSM 900 band provides for a GSM uplink in the range 890-915 MHz, a GSM downlink in the range 935-960 MHz. The GSM 900 band is used in all countries (more than 168 countries across the globe) in which GSM networks are found, except for United States.

Hamalainen et al. studied the coexistence of the UWB system with GSM900, UMTS/WCDMA, and GPS [1], and evaluated the level of the interference caused by different UWB signal to the three up mentioned systems. Also they evaluated the performance degradation of UWB systems in the presence of narrow bandwidth interference and pulsed jamming. They have given the bit error rate (BER) of the above mentioned systems for different pulse length.

Hamalainen et al. investigated the coexistence of the UWB system with IEEE802.11a and UMTS in Modified
2. Effect of UWB Interference on the DCS-1800 and GSM-900 Downlink Performance

The DCS-1800 and the GSM-900 downlink link-budget used in this section has an elements shown in Table 1.

To account for UWB, an extra source of interference is added linearly to the GSM and DCS system interference. The interference power is calculated by assuming the UWB source to be at different distances from DCS or GSM receiver (the mobile station). Therefore, the interference power generated by a device UWB, IUWB, is given by (in dBm):

\[ I_{UWB} = P_{UWB} - L_{UWB}(d) + G_{Ant} . \]  

where \( P_{UWB} \) is the UWB EIRP in dBm in the GSM or the DCS band, \( L_{UWB}(d) \) is the path-loss between the UWB device and the GSM or the DCS receiver which varies with the separation distance \( d \) in m, and \( G_{Ant} \) is the DCS antenna gain.

Non of the above mentioned works studied the effect of the UWB interference on the urban macrocell range. The aim of this work is to investigate the effect of UWB on DCS-1800 and GSM-900 on the urban macrocell downlink performance (range).

The rest of the paper is organized as follows. Section 2 presents the methodology for studying the effect of the UWB interference on the DCS-1800 and GSM-900 downlink performance is presented. In section 3 different results are given. Finally, section 4 addresses the conclusions.

### Tab. 1. The DCS-1800 and GSM-900 macrocell downlink budget.

<table>
<thead>
<tr>
<th>A</th>
<th>Max. link transmit power</th>
<th>dBm</th>
<th>40 dBm</th>
</tr>
</thead>
<tbody>
<tr>
<td>B</td>
<td>Transmitter gains</td>
<td>dB</td>
<td>18 dB</td>
</tr>
<tr>
<td>C</td>
<td>Transmitter local losses</td>
<td>dB</td>
<td>2 dB</td>
</tr>
<tr>
<td>D</td>
<td>Transmitter EIRP</td>
<td>dB</td>
<td>A+B+C= 56 dBm</td>
</tr>
<tr>
<td>E</td>
<td>Receiver noise figure</td>
<td>dB</td>
<td>8</td>
</tr>
<tr>
<td>F</td>
<td>SNR, dB</td>
<td>dB</td>
<td>10</td>
</tr>
<tr>
<td>G</td>
<td>Receiver sensitivity</td>
<td>dBm</td>
<td>-174+53+E+F = -103 dBm</td>
</tr>
<tr>
<td>H</td>
<td>Indoor loss</td>
<td>dB</td>
<td>10 dB</td>
</tr>
<tr>
<td>I</td>
<td>Maximum path loss</td>
<td>dB</td>
<td>D-G-H= 149 dB</td>
</tr>
<tr>
<td>J</td>
<td>Log normal fade margin</td>
<td>dB</td>
<td>8</td>
</tr>
<tr>
<td>K</td>
<td>Compensated Path-loss</td>
<td>dB</td>
<td>I-J= 141 dB</td>
</tr>
</tbody>
</table>

Given that UWB devices are typically low power, short range devices, then the line-of-sight path-loss model is often most appropriate. Effect of UWB interference is to reduce the DCS-1800 and the GSM-900 macrocell range.

The UWB signal propagation loss in dB at a distance \( d \) is given by [3]:

\[ L_{UWB}(d) = a + 20 \log_{10}(d) , \]

where \( a \) is given by:

\[ a = 20 \log_{10}\left(\frac{4 \pi}{\lambda}\right) , \]

where \( \lambda \) is the wave length. The UWB signal propagation loss in dB at the DCS-1800 band is calculated as:

\[ L_{UWB}(d) \approx 37.7 + 20 \log_{10}(d) . \]

To calculate the DCS-1800 macrocell initial range \( R_{DCS,o} \) we have used the following relation:

\[ L_{DCS}(dB) = 135 + 35 \log_{10}(R_{DCS,o}) . \]

Thus,

\[ 10 s \log_{10}(R_{DCS,o}) = L_{DCS}(dB) - 135 , \]

where \( s \) is the DCS-1800 signal propagation exponent assumed to be 3.5. \( L_{DCS} \) depends on the SNR of the DCS-1800 signal, i.e., lower is the noise, higher is the accepted compensated propagation loss. Thus we can rewrite (6) as

\[ 10 s \log_{10}(R_{DCS,o}) = k - S - 135 , \]
where \( k \) is constant, and \( S \) is the DCS-1800 receiver sensitivity. When the total noise power consists from the DCS-1800 system noise \( I_{DCS} \) only, then:

\[
10 \log_{10} R_{DCS,o} = k - S - 135, \tag{8}
\]

where \( R_{DCS,o} \) is the DCS-1800 initial range.

With the existence of the UWB noise \( (I_{UWB}) \), the DCS receiver sensitivity will increase. Thus

\[
10 \log_{10} R_{DCS} = k - S - N - 135, \tag{10}
\]

where \( R_{DCS} \) is the DCS new range when the UWB affects the DCS system and \( N \) is the DCS receiver sensitivity increment (dB):

\[
R_{DCS}^N = 10^{N/10}, \tag{11}
\]

\[
R_{DCS,o}^N = 10^{N/10} R_{DCS,o}^{N/10}, \tag{12}
\]

\[
\left( \frac{R_{DCS}}{R_{DCS,o}} \right)^N = 10^{N/10} \tag{13}
\]

\[
\left( \frac{R_{DCS}}{R_{DCS,o}} \right)^N = 1/10^{N/10} = 10^{-N/10}, \tag{14}
\]

\[
R_{DCS} = R_{DCS,o} \left( 10^{-N/10} \right)^N = R_{DCS,o} \sqrt[10]{10^{-N/10}}, \tag{15}
\]

We can notice that \( 10^{N/10} \) is the DCS receiver sensitivity increment in natural number, given by:

\[
\frac{N}{10} = \frac{I_{DCS} + I_{UWB}}{I_{DCS}}. \tag{16}
\]

Thus, the macrocell range \( R_{DCS} \) with the existence of the UWB interference is given as:

\[
R_{DCS} = R_{DCS,o} \sqrt[10]{\frac{I_{DCS}}{I_{DCS} + I_{UWB}}}. \tag{17}
\]

The UWB signal propagation loss in dB at the GSM-900 band is calculated as:

\[
L_{UWB}(d) \approx 32 + 20 \log_{10} (R_{UWB} \ d). \tag{18}
\]

The macrocell range \( R_{GSM} \) with the existence of the UWB interference is given as:

\[
R_{GSM} = R_{GSM,o} \sqrt[10]{\frac{I_{GSM}}{I_{GSM} + I_{UWB}}}, \tag{19}
\]

where \( R_{GSM,o} \) is the GSM-900 urban macrocell initial range without the UWB interference, \( s \) is the GSM-900 signal propagation exponent assumed to be 3.5. The GSM-900 macrocell initial range \( R_{GSM,o} \) has been calculated using the following relation:

\[
L_{GSM}(dB) \approx 129 + 35 \log_{10} (R_{GSM,o}). \tag{20}
\]

3. Results

Firstly, we study the case of DCS-1800 service where SNR (Signal to Noise Ratio) of 10 dB is required. The initial DCS-1800 receiver sensitivity is -103 dBm. To calculate the receiver sensitivity increment we use (4) to calculate the UWB signal propagation loss. Then the UWB noise is calculated using (1) assuming that the UWB transmitting antenna gain is 0 dB, the DCS receiving antenna gain is 0 dB and that the DCS noise bandwidth is 200 kHz.

![Fig. 1. DCS-1800 SNR as a function of DCS-1800 macrocellular range for 3 different distances between the UWB transmitter and the DCS-1800 receiver for \( P_{UWB} = -70 \text{dBm/MHz} \).](image)

Fig. 1 shows the downlink SNR as a function of the DCS-1800 macrocellular range for three different distances (0.5 m, 1 m and 2 m) between the UWB transmitter and the DCS-1800 mobile when UWB power density is -70 dBm/MHz. It can be noticed that the DCS-1800 new macrocell range (in the presence of the UWB interference) is 972 m, 1219 m and 1351 m for distances of 0.5 m, 1 m and 2 m respectively.

![Fig. 2. DCS-1800 SNR as a function of the DCS-1800 macrocellular range for three different distances between the UWB transmitter and the DCS-1800 mobile when UWB power density is -90 dBm/MHz.](image)

Fig. 2 shows the downlink SNR as a function of the DCS-1800 macrocell ranges for three different distances (0.5 m, 1 m and 2 m) between the UWB transmitter and the DCS-1800 mobile when UWB power density is -90 dBm/MHz. It can be noticed that the DCS-1800 new macrocell range (in the presence of the UWB interference) is 1402 m, 1410 m and 1412 m for distances of 0.5 m, 1 m and 2 m respectively.

Table 2 gives the new DCS-1800 macrocell range for different UWB power density as a function of the distance between the UWB transmitter and the DCS-1800 mobile. It can be noticed that the effect of UWB interference is high for a power density of -50 dBm/MHz and distance of 2 m.
At an UWB power density of -90 dBm/MHz or less, the effect of the UWB interference is quasi null (macrocell range reduction < 1%). Also it can be noticed that, the uncontaminated DCS-1800 system has macrocell range of 1412 m.

Next we study the case of GSM-900 service where SNR (Signal to Noise Ratio) of 10 dB is required. The initial GSM-900 receiver sensitivity is also -103 dBm. We assume that the UWB transmitting antenna gain is 0 dB, the GSM receiving antenna gain is 0 dB and that the GSM noise bandwidth is 200 KHz. Fig. 3 shows the downlink SNR as a function of the GSM-900 macrocell ranges for three different distances (0.5 m, 1 m and 2 m) between the UWB transmitter and the GSM-900 mobile when the UWB power density is -70 dBm/MHz. It can be noticed that the GSM-900 new macrocell range (in the presence of the UWB interference) is 1055 m, 1463 m and 1823 m for distances of 0.5 m, 1 m and 2 m respectively.

Table 3 gives the new GSM-900 macrocell range for different UWB power density as a function of the distance between the UWB transmitter and the GSM-900 mobile. It can be noticed that the effect of UWB interference is high for a power density of -70 dBm/MHz and distance of 2 m. At UWB power density of -95 dBm/MHz or less, the effect of the UWB interference is quasi null (macrocell range reduction < 1%).

From the above given results we can conclude that the spectrum mask proposed by the FCC for indoor application (-53 dBm/MHz in the DCS-1800 band and -41 dBm/MHz in the GSM-900 band) is very high to be tolerated by the two mobile systems and we have to have another spectrum mask with lower UWB power density.
the DCS-1800 receiver is less than 1 m. For low UWB power density (-100 dBm per MHz) or less, the effect of the UWB signals is very low even when the distance between the UWB transmitter and the DCS-1800 receiver is less than 1 m.

**References**


**About Authors...**

Bazil TAHA-AHMED was born in Mosul, Iraq, in 1960. He received the B.Sc. and M.Sc. degrees in telecommunication engineering from the University of Mosul, in 1982 and 1985, respectively. He got the Ph. D degree in telecommunications engineering from the Polytechnic University of Madrid in 2003. From 1985 to 1998, he was teaching at the Electrical Engineering Department at Mosul University.

Bazil has published more than 30 scientific journal and conference papers in the area of the electromagnetic propagation and CDMA systems, particularly the CDMA capacity. His research interests includes CDMA capacity and E. M. Wave propagation in micro-cellular and macro-cellular environments.

Miguel CALVO-RAMON was born in Pueyo de Jaca, Huesca, Spain on June 10, 1949. He got the Ingeniero de Telecomunicación degree from the Escuela Técnica Superior de Ingenieros de Telecomunicación of the Universidad Politécnica de Madrid in 1974 and the Doctor Ingeniero de Telecomunicación degree from the same University in 1979.

He works as Professor in the Señales Sistemas y Radiocomunicaciones (Signals, Systems and Radiocommunications) department where he obtained the Catedrático (Full Professor) position in 1986.

Leandro de HARO-ARIET was born in Barcelona, Spain, on May 17, 1962. He got the Ingeniero de Telecomunicación degree in 1986 and the Doctor Ingeniero de Telecomunicación degree (Apto cum laude) in 1992 both from the Escuela Técnica Superior de Ingenieros de Telecomunicación of the Universidad Politécnica de Madrid (Dept. of Señales, Sistemas y Radiocomunicaciones).

Since 1990 he develops his professional career in the E.T.S. Ingenieros de Telecomunicación of the Universidad Politécnica de Madrid (Dept. of "Señales, Sistemas y Radiocomunicaciones") as Assistant Professor on the Signal Theory and Communications area.
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