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

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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

Saleh-Valenzuela Channel [2]. The UWB system performance has been studied in the presence of multiband interference. Interference sources considered are IEEE802.11a and UMTS which are operating simultaneously with their maximum system bandwidths. The system under consideration is single band and single user UWB link operating at data rate of 100 Mbps without error correction coding. They have given the bit error rate (BER) of the UWB system for different types of modulation (direct sequence and time hopping).

Guiliano et al. studied the interference between the UMTS and the UWB system [3]. They have used the free space propagation model to calculate the UWB signal propagation loss. They have concluded that, a carrier frequency of 3.5 is the minimum allowable value for UWB device transmitting at 100Mb/S in order to avoid harmful interference between UMTS and UWB. In [4], Hamalainen et al. investigated the effect of in band interference power caused by different kinds of UWB signal at UMTS/WCDMA uplink and downlink frequency bands. UWB frequency spectra have been produced by using several types of narrow pulse waveforms. They have concluded that one can reduce interfering UWB power by using different waveforms and pulse widths to avoid UMTS frequencies without any additional filtering. In [5], Hamalainen et al. studied the effect of the in band interference power caused by three different kinds of UWB signal on GPS L1 and GSM-900 uplink band. UWB frequency spectra have been generated by using several types of narrow pulse waveforms all base on Gaussian pulse. In-band interference power has been calculated over the IF bandwidth of the two victim receiver as a function of the UWB pulse width. Also the signal attenuation with distance has been presented.

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.

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):

$$I_{UWB} = P_{UWB} - L_{UWB}(d) + G_{Ant} \ . \tag{1}$$

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 GSM or the DCS antenna gain.

A	Max. link transmit power	dBm	40 dBm
B	Transmitter gains	dB	18 dB
C	Transmitter local losses	dB	2 dB
D	Transmitter EIRP	dB	A+B-C= 56 dBm
E	Receiver noise figure	dB	8
F	SNR $_{req}$	dB	10
G	Receiver sensitivity	dBm	-174+53+E+F = = -103 dBm
H	Indoor loss	dB	10 dB
I	Maximum path loss	dB	D-G-H = 149 dB
J	Log normal fade margin	dB	8 dB
K	Compensated Path-loss	dB	I-J = 141 dB

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

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]:

$$L_{UWB}(d) \approx a + 20\log_{10}(d) \ , \tag{2}$$

where a is given by:

$$a = 20\ \log_{10}\left(\frac{4\pi}{\lambda}\right) , \tag{3}$$

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

$$L_{UWB}(d) \approx 37.7 + 20\log_{10}(d) \ . \tag{4}$$

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

$$L_{DCS}(dB) \approx 135 + 35\ \log_{10}(R_{km}) \ . \tag{5}$$

Thus,

$$10\ s\ \log_{10}(R_{km}) = L_{DCS}(dB) - 135 \ , \tag{6}$$

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

$$10\ s\ \log_{10}(R_{km}) = k - S - 135 \ , \tag{7}$$

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:

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

where $R_{DCS,o}$ is the DCS-1800 initial range

$$R^s_{DCS,o} = 10^{\frac{k-S-135}{10}} \,. \tag{9}$$

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

$$10\, s \log_{10} R_{DCS} = k - S - N - 135 \,, \tag{10}$$

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

$$R^s_{DCS} = 10^{\frac{k-S-N-135}{10}} \,, \tag{11}$$

$$\frac{R^s_{DCS,o}}{R^s_{DCS}} = 10^{\frac{k-S-135}{10} - \frac{k-S-N-135}{10}} = 10^{\frac{N}{10}} \,, \tag{12}$$

$$\left(\frac{R_{DCS,o}}{R_{DCS}}\right)^s = 10^{\frac{N}{10}} \,, \tag{13}$$

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

$$R_{DCS} = R_{DCS,o} \left(10^{-N/10}\right)^{-s} = R_{DCS,o} \sqrt[\frac{1}{s}]{10^{\frac{-N}{10}}} \,. \tag{15}$$

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

$$10^{\frac{N}{10}} = \frac{I_{DCS} + I_{UWB}}{I_{DCS}} \,. \tag{16}$$

Thus, the macrocell range RDCS with the existence of the UWB interference is given as:

$$R_{DCS} = R_{DCS,o} \sqrt[\frac{1}{s}]{\frac{I_{DCS}}{(I_{DCS} + I_{UWB})}} \,. \tag{17}$$

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

$$L_{UWB}(d) \approx 32 + 20 \log_{10}(d) \,. \tag{18}$$

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

$$R_{GSM} = R_{GSM,o} \sqrt[\frac{1}{s}]{\frac{I_{GSM}}{(I_{GSM} + I_{UWB})}} \,, \tag{19}$$

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:

$$L_{GSM}(dB) \approx 129 + 35 \log_{10}(R_{km}) \,. \tag{20}$$

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.

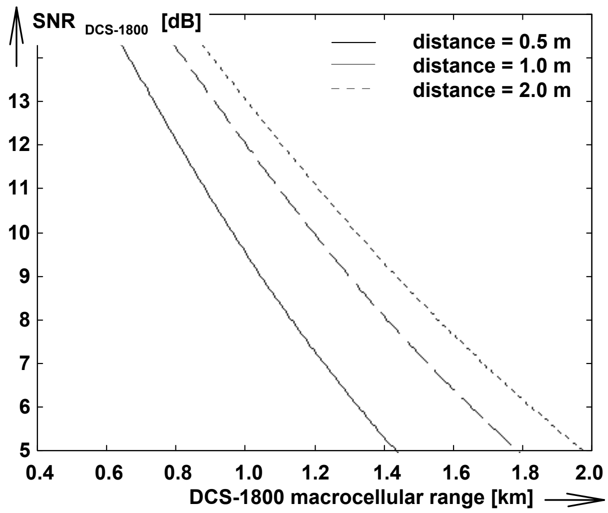

Fig. 1. DCS-1800 SNR as a function of DCS-1800 macrocellular range for 3 different distances between the UWB transmitter and the DCS-1800 receiver for P_{UWB} = -70 dBm/MHz.

Fig. 1 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 -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 resp.

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 the 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.

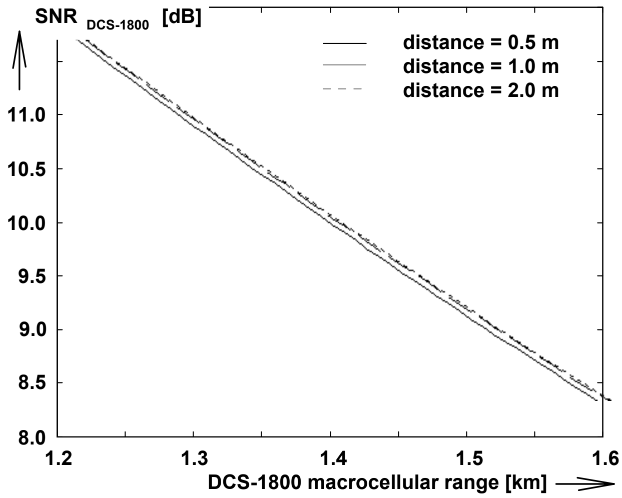

Fig. 2. DCS-1800 SNR as a function of DCS-1800 macrocellular range for 3 different distances between the UWB transmitter and DCS-1800 receiver when P_{UWB} = -90 dBm/MHz.

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.

UWB power density [dBm/MHz]	DCS range at the distance= 0.5 m	DCS range at the distance = 1.0 m	DCS range at the distance = 2.0 m
-50	285	422	620
-55	395	582	834
-60	545	787	1065
-65	742	1019	1250
-70	972	1219	1351
-75	1184	1336	1392
-80	1319	1386	1406
-90	1402	1410	1412
-100	1411	1412	1412

Tab. 2. DCS-1800 macrocellular range vs. UWB power density.

Fig. 4 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 UWB power density is -100 dBm/MHz. It can be noticed that the GSM-900 new macrocell range (in the presence of the UWB interference) is 2090 m, 2094 m and 2095 m for distances of 0.5 m, 1 m and 2 m resp. The GSM-900 system has an original macrocell range of 2096 m.

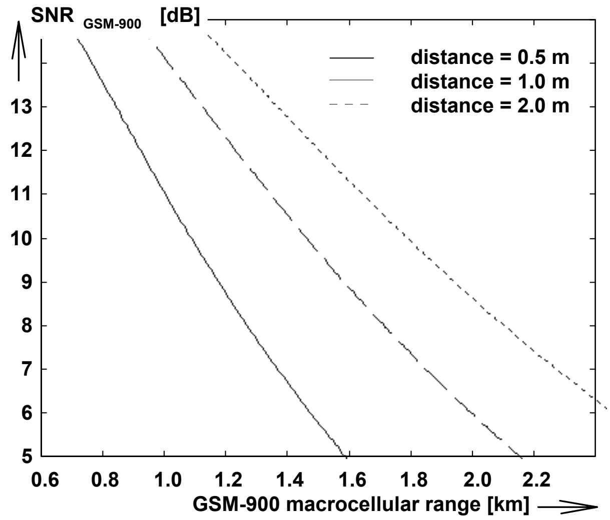

Fig. 3. GSM-900 SNR as a function of GSM-900 macrocellular range for 3 different distances between the UWB transmitter and the GSM-900 receiver when P_{UWB} = -70 dBm/MHz.

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%).

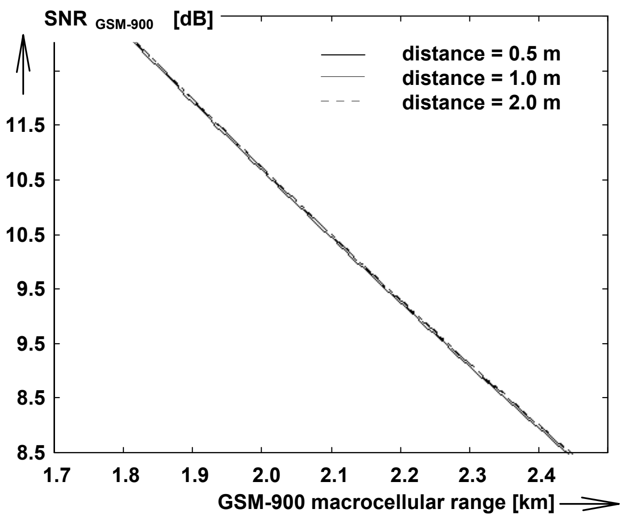

Fig. 4. GSM-900 SNR as a function of GSM-900 macrocellular range for 3 different distances between the UWB transmitter and the GSM-900 receiver when P_{UWB} = -100 dBm/MHz.

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.

UWB power density [dBm/MHz]	GSM range at the distance = 0.5 m	GSM range at the distance = 1.0 m	GSM range at the distance = 2.0 m
-70	1055	1463	1823
-80	1718	1966	2060
-85	1937	2051	2084
-90	2039	2081	2092
-95	2077	2091	2095
-100	2090	2094	2095

Tab. 2. GSM-900 macrocellular range vs. UWB power density.

Fig. 5 shows the FCC indoor and our recommended radiation mask for indoor applications resulting from this work. For a frequency greater than or equal to 3.1 GHz, the two masks have the same values of the UWB accepted power density. For frequencies less than 3.1 GHz, our recommended mask has always an accepted UWB power density lower than the UWB power density given by the FCC recommendations.

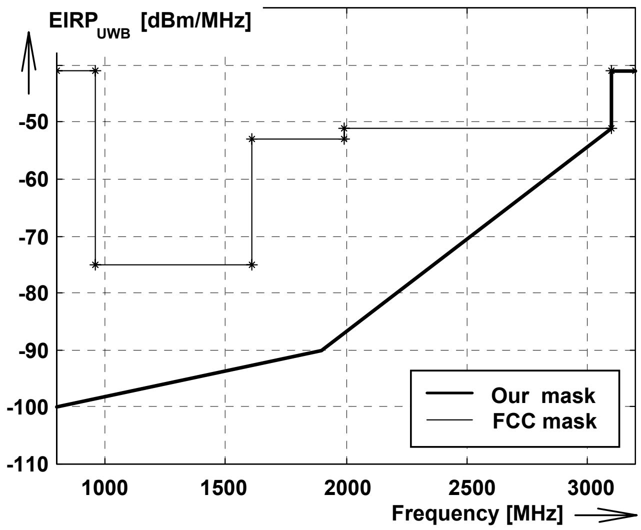

Fig. 5. The FCC and our recommended radiation masks.

4. Conclusions

We have studied the effect of the UWB transmitters on the DCS-1800 and GSM-900 downlink for different UWB power density. For a high UWB power density, the effect of the UWB signals is very high when the distance between the UWB transmitter and 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.

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