REPORT ITU-R M.2110

Sharing studies between radiocommunication services and IMT systems operating in the 450-470 MHz band

(2007)

1 Introduction and Scope

Agenda item 1.4 of the 2007 World Radiocommunication Conference (WRC-07) calls upon the ITU-R "...to consider frequency-related matters for the future development of IMT-2000 and systems beyond IMT-2000 taking into account the results of ITU-R studies in accordance with Resolution **228 (Rev.WRC-03).** Resolution **228 (Rev.WRC-03)** resolves that the ITU-R should undertake among other studies, "...sharing and compatibility studies with services already having allocations in potential spectrum for the future development of IMT-2000 and systems beyond IMT-2000 taking into account the needs of other services." As part of its responsibility to provide the text to the CPM for Agenda item 1.4, Working Party 8F is studying several candidate bands for IMT systems including the 450-470 MHz band.

ITU-R conducted sharing studies related to the candidate bands to determine the suitability of the candidate bands for IMT identification. This Report assesses the feasibility of sharing between IMT systems operating in the 450-470 MHz band and the radiocommunication services having a primary allocation in Section IV of Article 5 of the Radio Regulations – Table of Frequency Allocations (henceforth referred to simply as the Table) in the 450-470 MHz band and in the adjacent 420-450 MHz and 470-480 MHz bands. This study addresses one member of the IMT family, i.e. IMT-2000 CDMA Multi-Carrier (CDMA-MC). For ease of reference, CDMA-MC operating in the 450-470 MHz range is referred to as CDMA450 throughout the document. Further revisions of this Report may include other technologies in the IMT family.

2 Definitions and abbreviations

2.1 Definitions

No new definitions were introduced.

2.2 Abbreviations

ACS	Adjacent channel selectivity
BS	Base station
BPSK	Binary phase shift keying
BW	Bandwidth
CDMA450	CDMA-MC system operating in the 450-470 MHz band
CDMA-MC	CDMA multi-carrier
CPM	Conference Preparatory Meeting
dB	Decibels
DQPSK	Differentially coherent quaternary phase shift keying
DVB-H	Digital video broadcast-handheld

DVB-T	Digital video broadcast-terrestrial
ERP	Effective radiated power
FDR	Frequency dependent rejection ratio
FM	Frequency modulation
FS	Fixed system
GMSK	Gaussian minimum shift keying
IF	Intermediate frequency
kHz	Kilohertz
km	Kilometers
kW	Kilowatt
MCL	Minimum coupling loss
MS	Mobile station
MHz	Megahertz
MW	Megawatts
NMT	Nordic mobile telephone
OFR	Off-frequency rejection
OTR	On-tune rejection
PAMR	Public access mobile radio
PLRS	Position location reporting system
PMR	Private mobile radio
P-MP	Point-to-multipoint
PSK	Phase shift keying
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
Rx	Receiver
TETRA	Terrestrial trunked radio access
WPR	Wind profiler radar

3 Summary

Sharing studies between one member of the IMT family, i.e. IMT-2000 CDMA multi-carrier (CDMA-MC), operating in the 450-470 MHz band and the radiocommunication services having a primary allocation in Section IV of Article 5 of the Radio Regulations (RR) – Table of Frequency allocations in the 450-470 MHz band and in the adjacent 420-450 MHz and 470-480 MHz bands – were conducted. The study evaluated the feasibility of sharing between CDMA450 system and radiolocation services, mobile, fixed, and/or broadcasting services in the above mentioned bands.

The feasibility of certain scenarios is subject to a trade off between technical, regulatory and economical factors. In this Report different points of view have been reflected which correspond to different trade off choices. The views are by no means excluding other points of views. The conclusions below reflect only the studies made in this Report.

The results of the study are summarized in the following tables corresponding to each scenario evaluated.

CDMA450 system interfering with radiolocation systems:

TABLE 1

Results of the study of CDMA450 system interfering with radiolocation systems

Radiolocation system	CDMA450 base station		CDMA450 mobile station	
	Separation distance	Separation distance/filtering	Separation distance	Separation distance/filtering
Ground-based radars (5 MHz Rx. BW)	17.45 km	1 km/50 dB	8.29	1 km/40 dB
Shipborne surveillance radars (2 MHz Rx. BW)	8 km	1 km/30 dB	4	1 km/20 dB
Airborne surveillance radars (1 MHz Rx. BW)	12 km	1 km/20 dB	31.94	1 km/30 dB
PLRS radars (3 MHz Rx. BW)	2 km	1 km/10 dB	< 1 km	No mitigation needed
Wind profiler radars at 3 m (350 kHz Rx. BW)	55 km	1 km/40 dB	3	1 km/10 dB

The results indicate that for most cases sharing between CDMA450 base/mobile stations and the various types of radars when placed in adjacent spectrum is not feasible in the absence of mitigation. The distance between CDMA450 system and radiolocation services can reduce to 1km if CDMA450 operators can provide the amount of isolation specified in the above table. The isolation is typically provided via a filter at the CDMA450 transmitter. If filtering cannot be provided then the use of guard bands and/or other engineering mitigation techniques that provide equivalent isolation needs to be provisioned by the operators of CDMA450 systems for mutual compatibility.

Radiolocation systems interfering with CDMA450 systems:

TABLE 2

Results of the study of radiolocation services interfering with CDMA450 system

Radiolocation system	Radiolocation system antenna height, BW, power, pulse duration	CDMA450 base station		CDMA450 mobile station	
		Separation distance	Separation distance/ filtering	Separation distance	Separation distance/ filtering
Ground based radars	10 m, 1 MW, 0.25 ms	210.49 km	8 km/60 dB	46.4 km	2 km/60 dB
	10 m, 5 MW, 16 ms	285.86 km	12 km/60 dB	77 km	3 km/60 dB
Shipborne surveillance radars	20 m, 2 MW, 0.5 μ s	471.27 km	41 km/60 dB	31.4 km	1 km/60 dB

TABLE 2 (*end*)

Radiolocation system	Radiolocation system antenna height, BW, power, pulse duration	CDMA450 base station		CDMA450 mobile station	
		Separation distance	Separation distance/ filtering	Separation distance	Separation distance/ filtering
Airborne surveillance radars[(1)]	5 000 m, 2 MW, 8 µs	831.48 km	0.8 km/60 dB	41.7 km	1.3 km/30 dB
	5 000 m, 2 MW, 1 µs	125 849 km	125 km/60 dB	50.83 km	1.6 km/30 dB
PLRS radars	10 m, 0.4 W, 824.6 µs	1 km	No mitigation needed	< 1 km	No mitigation needed
	10 m, 125W, 824.6 µs	6.15 km	1 km/ 30 dB	1 km	No mitigation needed
Wind profiler radars	3 m, 16 kW, 6.67 µs	< 1 km	No mitigation needed	< 1 km	No mitigation needed
	3 m, 16 kW, 1.67 µs	< 1 km	No mitigation needed	< 1 km	No mitigation needed

(1) The theoretical distances are greater than the horizon range limits and a consequence of using the free space propagation loss between the airborne radars and CDMA450.

The results indicate that for most cases sharing between CDMA450 base/mobile stations and the various types of radars when placed in adjacent spectrum is not feasible in the absence of mitigation. In particular, large separation distance between CDMA450 and ground, shipborne, or Airborne radars is required. The distance between CDMA450 system and radiolocation services can be reduced to 1 km if CDMA450 operators can provide additional isolation as specified in the above tables. The isolation can typically be provided via a filter at the CDMA450 receiver and/or use of guard bands and other engineering mitigation techniques to enable mutual compatibility.

Fixed and mobile service base stations interfering with CDMA450 base station

TABLE 3

Results of the study of fixed and mobile service base stations interfering with CDMA450 base station

Fixed and mobile systems	CDMA450 base station	
	Separation distance	Separation distance/ filtering
GMSK based fixed system (FS)	53.86 km	1.6 km/70 dB
DQPSK based fixed system (FS) – IF BW = 0.3 MHz	105.45 km	3 km/70 dB
DQPSK based fixed system (FS) – IF BW = 3.14 MHz	116.92 km	3.4 km/70 dB
16-QAM based fixed system (FS)	132.73 km	3.9 km/70 dB
32-QAM based fixed system (FS) – IF BW = 0.15 MHz	63.81 km	1.9 km/70 dB
32-QAM based fixed system (FS) – IF BW = 1.6 MHz	94.43 km	2.8 km/70 dB
Point-to-multipoint systems (P-MP)	71.32 km	2 km/70 dB

TABLE 3 (*end*)

Fixed and mobile systems	**CDMA450 base station**	
	Separation distance	**Separation distance/ filtering**
FM	21.45 km	1 km/60 dB
TETRA	25.6 km	1 km/60 dB
NMT	49.14 km	1 km/70 dB
Trunked land mobile systems – analog FM	43.14 km	1 km/70 dB
Trunked land mobile systems – digital/C4FM	38.6 km	1 km/70 dB
Trunked land mobile systems – digital/BPSK/QPSK/8-PSK/16-QAM	112 km	3 km/70 dB

The results indicate that coexistence between CDMA450 base stations and the various fixed and mobile service base stations may be a challenge even with the use of significant filtering to provide the required attenuation. While the separation distance between the two systems is significantly reduced if a filter at the CDMA450 base station receiver can provide at least 60 dB-70 dB rejection of the unwanted emissions, the value of the separation distance may be large to permit coexistence in a few cases. Other possible mitigation measures are available that could be used to decrease the possibility of harmful interference even further, such as the use of guard bands and/or disabling of one or more CDMA450 carriers.

CDMA450 base station interfering with fixed and mobile systems

TABLE 4

Results of the study of CDMA450 base station interfering with fixed and mobile systems

Fixed and mobile systems	**CDMA450 base station**	
	Separation distance	**Separation distance/ filtering**
GMSK based fixed system (FS)	146.1 km	2.4 km/80 dB
DQPSK based fixed system (FS) – IF BW = 0.3 MHz	212.8 km	3.6 km/80 dB
DQPSK based fixed system (FS) – IF BW = 3.14 MHz	142.9 km	2.3 km/80 dB
16-QAM based fixed system (FS)	219.2 km	3.7 km/80 dB
32-QAM based fixed system (FS) – IF BW = 0.15 MHz	231.7 km	4 km/80 dB
32-QAM based fixed system (FS) – IF BW = 1.6 MHz	203.4 km	3.47 km/80 dB
Point-to-multipoint systems (P-MP)	41 km	1.7 km/60 dB
FM	13 km	1.2 km/40 dB
TETRA	69.8 km	1 km/80 dB
NMT	46.7 km	2 km/60 dB
Trunked land mobile systems – analog FM	61.3 km	1 km/80 dB
Trunked land mobile systems – digital/C4FM	51.2 km	1.2 km/70 dB
Trunked land mobile systems – digital/BPSK/QPSK/8-PSK/16-QAM	175.9 km	3 km/80 dB

The results indicate that coexistence between CDMA450 base stations and the various fixed and mobile service base stations may be a challenge even with the use of significant filtering to provide the required attenuation. While the separation distance between the two systems is significantly reduced if a notch filter at the CDMA450 base stations transmitter can provide at least 60 dB to 80 dB attenuation of the unwanted emissions, the value of the separation distance may be large to permit coexistence in few cases. Other possible mitigation measures are available that could be used to decrease the possibility of harmful interference even further, such as the use of guard bands and/or disabling of one or more CDMA450 carriers.

CDMA450 system interfering with broadcasting systems

TABLE 5

Results of the study of CDMA450 system interfering with broadcasting systems

Broadcasting system	**CDMA450 base station**		**CDMA450 mobile station**	
	Separation distance	**Separation distance/ filtering**	**Separation distance**	**Separation distance/ filtering**
TV	21 km	2 km/40 dB	0.372 km	No mitigation needed
DVB-T	3.76 km	1.3 km/15 dB	0.037 km	No mitigation needed
DVB-H	< 1 km	No mitigation needed	0.003 km	No mitigation needed

The results indicate that CDMA450 base/mobile stations can successfully share adjacent spectrum with the three types of broadcasting systems studied in the Report. For CDMA450 base stations to avoid interfering with TV (analog) and DVB-T, CDMA450 operators need to provide an isolation of 40 dB and 15 dB respectively, to reduce the separation distances to 1 km. No mitigation is needed between CDMA450 mobiles and the three broadcasting systems for mutual compatibility.

Broadcasting systems Interfering with CDMA450 systems

TABLE 6

Results of the study of broadcasting systems interfering with CDMA450 system

Broadcasting system **Typical transmit power**	**CDMA450 base station**		**CDMA450 mobile station**	
	Distance	**Distance/ filtering**	**Distance**	**Distance/ filtering**
2 kW ERP	43.7 km	< 1 km/60 dB	20.3 km	< 1 km/40 dB
15 kW ERP	59.8 km	1.2 km/60 dB	31 km	< 1 km/60 dB
1 MW ERP	92 km	3.9 km/60 dB	49.9 km	< 1 km/60 dB

The results indicate that broadcasting base stations and CDMA450 base/ mobile stations can successfully operate in adjacent spectrum, if the unwanted spurious emissions from the broadcasting base stations can be reduced. Reducing the unwanted emissions by 60 dB will enable successful sharing between the broadcasting base stations and the CDMA450 base/mobile stations.

4 IMT-2000 and IMT-Advanced systems

4.1 Technical characteristics

In terms of establishing a framework for IMT sharing studies in the 450-470 MHz band, guidance was sought from the following ITU-R texts:

– Recommendation ITU-R M.1461 – Procedures for determining the potential for interference between radars operating in the radio determination service and systems in other services.

– Recommendation ITU-R M.1462 – Characteristics of and protection criteria for radars operating in the radiolocation service in the frequency range 420-450 MHz

– Recommendation ITU-R M.1085 – Technical and operational characteristics of wind profile radars for bands in the vicinity of 400 MHz.

– Recommendation ITU-R M.478-5 – Technical characteristics of equipment and principles governing the allocation of frequency channels between 25 and 3 000 MHz for the FM land mobile service.

– Recommendation ITU-R P.1546 – Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz.

– Recomendation ITU-R P.1411 – Propagation data and prediction methods for the planning of short-range outdoor radiocommunication systems and radio local area networks in the frequency range 300 MHz to 100 GHz.

– Report ITU R-M.2039 – Characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses, and

– Doc. 8F/758, § 5.7 – Chairman Report of the 18th Meeting of Working Party 8F.

These texts provided the parametric values that have been used in these sharing studies. These texts also support the use of IMT-2000 parameters for IMT sharing studies.

A further clarification of the IMT-Advanced parametric values for use in sharing studies was defined at the 17th meeting of Working Party 8F and can be found in § 5.7 of the Chairman's Report. The Report states that "Parameters and their values used in sharing and compatibility studies should characterize both the transmission and the reception of radio signals for all the services and systems studied. Parameters used to characterize IMT-2000 systems must be consistent with those given in Report ITU-R M.2039.

The sharing study reported upon here utilizes the parameters for CDMA-MC operations in the 450-470 MHz band that are given, for the most part, in Report ITU-R M.2039. Where there were differences from those given in Report ITU-R M.2039, the values used are consistent with the values of the parameters that are being used in IMT systems that have been deployed and are operating in the 450-470 MHz band around the world. Since a few parameters, such as the adjacent channel selectivity (ACS), transmitter out-of-band and spurious emissions contained in the Report ITU-R M.2039 pertain to the 2 GHz band range, individual technology specifications of IMT-2000 systems were consulted to derive the appropriate values for the 450-470 MHz range. Footnotes are inserted where values were derived directly from these technology specifications.

Table 7 provides the relevant radio parameters corresponding to one member of the IMT-2000 family, i.e. IMT-2000 CDMA multi-carrier (CDMA-MC) The study considers only a macro cell environment, since this represents the most likely deployment of IMT systems and also yields the most stringent sharing scenarios.

TABLE 7

Technical characteristics of the CDMA450 systems

System parameters	Representative values of CDMA450	
	Base station (BS)	**Mobile station (MS)**
Carrier spacing (MHz)	1.23	1.23
Transmitter power (dBm)	43	23
Antenna gain (dBi)	12	2
Cable/transmission line loss (dB)	3	2
Antenna height (m)	30	1.5
Receiver NF (worst-case)	5	9
Receiver thermal noise (dBm)(1)	–108	–104
Receiver reference sensitivity(1) level (dBm)	–117	–104 (for a fully loaded system) –119.6 (for a traffic channel)
Duplex method	FDD	FDD
Protection criteria (dB)	6	6
Macro BS receiver ACS (dB)(2)	72	57
Transmitter spurious emissions(3)		
1st adjacent channel	–45 dBc/30 kHz at 750 kHz to 1.98 MHz	Less stringent of –42 dBc/30 kHz or –54 dBm/1.23 MHz at 885 kHz to 1.98 MHz
2nd adjacent channel	–60 dBc/30 kHz (macro BS) at 1.98 MHz to 4 MHz –36 dBm/1kHz at 4MHz to 6.4 MHz	Less stringent of –54 dBc/ 30 kHz or –54 dBm/ 1.23 MHz at 1.98 MHz to 4 MHz –36 dBm/100 kHz at >4 MHz
3rd adjacent channel	–36 dBm/10 kHz at 6.4 MHz to 16 MHz	
4th adjacent channel	–36 dBm/100 kHz >16 MHz	
CDMA450 carrier allocation(4)	Base station receive	Mobile station receive
First carrier (MHz)	453.35 – 454.6	463.35 – 464.6
Second carrier (MHz)	454.6 – 455.85	464.6 – 465.85
Third carrier allocation (MHz)	455.85 – 457.1	465.85 – 467.1

(1) These values correspond to the CDMA-MC technology operating in the 450-470 MHz band and are derived from the TIA 97/98-E specifications.

(2) ACS values are derived from the receiver sensitivity, target Eb/No specifications, and the single-tone desensitization test specified in the TIA 97/98-E specifications.

(3) The transmitter spurious emission values correspond to the CDMA-MC technology operating in the 450-470 MHz band and are derived from the TIA 97/98-E specifications.

(4) The typical carrier allocation of the CDMA-MC technology operating in the 450-470 MHz band is derived from the band Class 5 (sub-band A) specification of the TIA 97/98-E specifications.

4.2 Protection criteria

The protection criterion for CDMA450 systems used in this study was taken to be an *I*/*N* value of –6 dB, consistent with that specified in Report ITU-R M.2039.

5 Sharing studies between CDMA450 and systems in the radiolocation service

5.1 Allocation in the Table of Frequency allocations

The radiolocation service is allocated on a primary basis in all three ITU Regions in the 430-440 MHz band.

The 420-430 MHz and 440-450 MHz bands are allocated to the radiolocation service on a secondary basis except in Australia, the United States of America, India, Japan and the United Kingdom where they are primary as a result of footnote RR 5.269**,** and in Canada as a result of footnote RR 5.285. Thus an adjacent band study between radiolocation systems and CDMA450 systems was performed to assess the amount of separation distances and/or guard bands needed to enable them to co-exist with each other. The following four cases were evaluated in the sharing study:

a) CDMA450 base station to radar receivers

b) CDMA450 mobile station to radar receivers

c) Radar transmitter to CDMA450 base station

d) Radar transmitter to CDMA450 mobile station.

5.2 Technical characteristics of radiolocation systems

In the 420-450 MHz frequency range, administrations have developed and deployed a variety of mobile and transportable radar systems that operate on land, on ships, and in aircraft.

5.2.1 Ground-based space object tracking radars

Ground radars are used for space object tracking and cataloguing by using very high power (up to 5 MW) transmitter powers and high antenna gains. The radars operate continuously; around the clock and year round. They scan from surveillance “fence” from around 3° up to 60° in elevation, in 120° sectors in azimuth. The radar receivers are very sensitive in order to detect returns from exo-atmospheric and space objects. Because of their specialized function and requisite design characteristics (e.g. very large antenna arrays) these particular ground radars are not numerous, but because of their sensitivity and function they deserve special recognition and protection. Recommendation ITU-R M.1462, contains the nominal technical characteristics of these radars. Table 8 lists the RF parameters of these radars that were used in the sharing study.

5.2.2 Shipborne surveillance radars

Shipborne surveillance radars are also operated in the frequency range 420-450 MHz. They normally operate at sea, though operations in coastal waters as well in naval ports should be expected. As is typical with surveillance radars, the system scans 360° in azimuth, and operations are on a continuous basis. Table 8 lists the RF parameters of these radars that are used in the sharing study and derived from Recommendation ITU-R M.1462.

5.2.3 Airborne surveillance radars

The 420-450 MHz band is an essential band for the operation of airborne radars. These systems operate worldwide, for extended periods (hours to days) in their intended areas of operation. Long-range object detection, acquisition, and tracking are essential functions to sense and control air traffic. Ground-based radars are extremely limited by the radar horizon, and the employment of long-range radars on airborne platforms is an excellent way to extend individual radar's capability. Similar to ground air surveillance radars, airborne radars employ rotating scans in azimuth and scan over a specified range in elevation either by electronically scanning in elevation or by using a relatively wide elevation beam-width. The radar operates during aircraft ascent and descent as well as at operating altitudes; aircraft ceiling altitude is around 12 000 m. Table 8 lists the RF parameters of these radars that were used in the sharing study and derived from Recommendation ITU-R M.1462.

5.2.4 Position location reporting system (PLRS)

Another type of service that operates in the 420-450 MHz range is the PLRS. The nominal technical characteristics of the PLRS were derived from Doc. 7C/239 (22 September 2002) – Compatibility of spaceborne synthetic aperture radars (SAR) with services allocated for operation in the 430-440 MHz band”[1] .

TABLE 8

Technical characteristics of the radiolocation systems

Parameter	**Value**			
	Ground-based space object tracking radars	**Shipborne surveillance radars**	**Airborne surveillance radars**	**PLRS**
Tuning range	420-450 MHz	420-450 MHz	420-450 MHz	425.75-446.75 MHz
Peak RF output power	1-5 MW	2 MW	2 MW	0.4, 3, 20, 125 W
Pulse duration (if simulation is needed, this may be useful)	0.25, 0.5, 1.2, 4, 8, 16 ms	0.5 μs	1, 2, 4, 8 μs	824.6 μs
Duty cycle (average)	25%	Not available	Not available	Not available
Pulse modulation	*Search*: 100-350 kHz linear FM chirp; *Track*: 1 or 5 MHz linear FM chirp	Unmodulated pulses	Unmodulated pulses	Continuous phase modulation
Pulse repetition rate	Up to 41 Hz	Not available	0.1 to 2 kHz	32 Hz (master station); 20 Hz (user unit)
Antenna type	Planar array (22 m diameter)	Parabolic reflector	Yagi element array or planar array	4 element stacked dipole (master station); stacked dipole (Gnd user unit); blade (air user unit)

1 Although, Doc. 7C/239 calls PLRS a radar system, it is a radiodetermination system. PLRS was considered in the study because of the ITU-R texts that refer to them as radar systems. Table 8 below lists the RF parameters of these radars that were used in the sharing study.

TABLE 8 (*end*)

Parameter	Value			
	Ground-based space object tracking radars	**Shipborne surveillance radars**	**Airborne surveillance radars**	**PLRS**
Antenna gain	38.5 dBi	30 dBi (mainlobe); 0 dBi (median sidelobe)	22 dBi	6 dBi (master station); 4 dBi (Gnd user unit); 0 dBi (air user unit)
Antenna scan	3-85° elevation; ±60° azimuth per each of 2 planar arrays for a total of 240° azimuth scan	360° azimuth	±60° el (mechanically positioned or elec-tronically scanned); 360° azimuth at 3-7 rpm	Not applicable
Antenna beamwidth	2.2° elevation; 2.2° azimuth	Not available	6-20° elevation (depending upon scan type); 6° azimuth	43°, 40°, 20°, 90° elevation (manpack, vehicle, master station, plane) 360° azimuth
Antenna height(1)	10 m	20 m	5 000 m	10 m
Polarization	Circular	Circular(2)	Horizontal	Vertical
Receiver noise level	–142 dBW(3)	–136 dBW	–139 dBW(4)	–133 dBW
Receiver bandwidth	1 or 5 MHz (depending on chirp width)	2 MHz	1 MHz	3 MHz
Receiver Protection Threshold	$I/N < -6$ dB	$I/N < -6$ dB	$I/N < -6$ dB	$I/N < -6$ dB
Rise time (t_r)	1 µs	0.1 µs	0.1 µs	0.1 µs

(1) The antenna heights are not contained in Recommendation ITU-R M.1462 and are assumed to be typical values of the corresponding radars.

(2) Assumption.

(3) Value based upon a 450 K receiver noise temperature.

(4) Value based upon a 5 dB receiver noise figure.

5.2.5 Wind profiler radars (WPR)

Another type of radar that operates in the bands immediately below the 450-470 MHz band is the wind profiler radar (WPR). Wind profiler radar is considered as a primary radiolocation service operating between 440-450 MHz band and was therefore addressed in these sharing analyses.

Recommendation ITU-R M.1085 provides the technical and operational characteristics of wind profiler radars in the bands used in this sharing study. In addition, NTIA Report 93-301, NOAA Special Report, "Measurement of wind profiler EMC characteristics" was also consulted for the technical and operational characteristics of the wind profiler radars. Table 9 provides the technical characteristics of the wind profiler radars that were used in the sharing study.

TABLE 9

Technical characteristics of the wind profiler radars	Range of representative values[(1)]
Pulse peak power (kW)	16[(2)]
Average transmitted power (kW)	0.2-2.0
Main beam antenna gain (dBi)	26-34
Beamwidth (degrees)	3-8
Tilt angle (degrees)	12-18
Antenna size (m^2)	30-150
Antenna height (m)	3
Height range[(3)] (km)	0.5-16
Height resolution (m)	150-1 200
Pulse width (μs)	1.67(short), 6.67(long)
Suppression of spurious emissions (dB)	> 60
Receiver IF image frequency rejection (dB)	50
Receiver IF bandwidth (kHz)	350 (low-mode), 120 (hi-mode)
Receiver noise floor[(4)]	–141 dBm/ 350 kHz
Rise time. t_r	0.1 μs
Protection criteria I/N (dB)	–10

(1) Users of this table should exercise caution in using combinations of these values to represent a "typical" or "worst case" profiler. For example, a profiler operating with a peak power of 50 kW while using pulses to yield a height resolution of 150 m would be an unusual system.

(2) Derived from NTIA Report 93-301, NOAA Special Report.

(3) The maximum operating height depends upon the product: (average power) × (antenna effective area).

(4) NTIA Report 93-301 states that the noise floor of wind profiler radars at 404 MHz is –14 1 dBm/350 kHz. It is assumed that wind profiler radars at 449 MHz will also have the same noise floor.

5.3 Protection criteria

Recommendation ITU-R M.1462 provides the protection criteria to be used for the interference assessment of radars. The Recommendation notes that generally a signal from another service resulting in an I/N ratio below –6 dB is permissible by the radar users for signals from the other service having a continuous-wave or noise-like type modulation. An I/N ratio of –6 dB results in a $(I + N)/N$ of 1.26 or approximately 1 dB increase in the radar receiver noise power. This Report used an I/N of –6 dB as the protection criteria for all radars studied except for the wind profiler radars where a more stringent protection criterion of –10 dB, which correlates to less than 0.5 dB of noise floor increase, was used.

5.4 Methodology

An adjacent band study between the radiolocation systems and CDMA-MC operating between 450-470 MHz band was performed to assess the separation distance and/or the size of guard bands needed between the two systems to operate without exceeding the protection criterion of each system. Recommendation ITU-R M.1461 identifies two types of interference mechanisms where radiolocation systems can degrade the performance of other systems. These mechanisms include the front-end overload (or blocking) and the radar emissions coupled through the receiver RF/base band/IF pass band. For the case of radars interfering with the CDMA450 systems, both mechanisms were assessed to determine the amount of separation and/or guard bands needed between the two systems. Equations and sample calculations corresponding to each case are added in the relevant sections of the analyses.

For the case of CDMA450 interfering with the radars the frequency dependent rejection (FDR) analysis was used. FDR is the amount of attenuation offered by an electronic receiver to a transmitted signal. This attenuation is composed of two parts: on-tune rejection (OTR) and off-frequency rejection (OFR).

$$\text{FDR}(\Delta f) = \text{OFR}(\Delta f) + \text{OTR} \tag{1}$$

where:

FDR: rejection provided by a receiver to a transmitted signal as a result of both the limited bandwidth of the receiver with respect to the emission spectrum and the specified detuning (dB)

OTR: rejection provided by a receiver selectivity characteristic to a co-tuned transmitter as a result of an emission spectrum exceeding the receiver bandwidth (dB)

OFR: additional rejection, caused by specified detuning of the receiver with respect to the transmitter (dB)

Δf: tuned transmitter frequency minus the tuned receiver frequency.

FDR, OFR, and OTR are positive numbers.

The study used the FDR program to compute the frequency dependent rejection (FDR) or the frequency-distance relationships between the transmitter and receiver. For example, calculations of the OTR and OFR were made based on the CDMA450 transmitter's spurious emission specifications and the radar receiver's selectivity or blocking specifications.

For the scenarios studied in this section, the level of interference that the receiver can accept is dictated by its performance. In general, minimal impact to the receiver is desired and this can be met only by allowing the interference level from the interfering transmitter to be at a certain level below the receiver's noise floor or sensitivity, i.e. the protection criteria.

The impact is the difference between the interference level referenced at the receiver antenna connector port and the acceptable level dictated by the receiver. This impact is the isolation required between the transmitter and the receiver. If this isolation is negative, then the interference level from the transmitter is within the permissible limits of the receiver, causing minimal-to-no impact on the performance of the receiver. This situation is deemed permissible for the two systems to operate in adjacent spectrum without exceeding each other's protection criterion. If the isolation is positive, then the interference level from the transmitter is above the receiver's acceptable limit, possibly degrading the performance of the receiver. This situation is deemed unacceptable, and the use of mitigation techniques to increase the isolation between the two systems is encouraged to enable compatibility between the two systems operating in adjacent spectrum.

5.5 Propagation models

The propagation models used in this study were derived from Recommendations ITU-R P.1546 and ITU-R P.1411. The field strengths calculated using ITU-R P.1546 in the 450-470 MHz range was done using interpolation, as specified in the Recommendation (see Annex 2). Since, ITU-R P.1546 can only be used for calculating separation distances that are greater than 1 km, a two-slope propagation loss model as specified in Recommendation ITU-R P.1411 was used to calculate distances that are less than 1 km. As the models of the two Recommendations are not aligned at predicting the path loss around 1km, caution should be used when comparing the results obtained by ITU-R P.1411 with those of ITU-R P.1546. For the airborne radars, free space propagation model was used.

5.6 Interference from CDMA450 base station to the radiolocation services

5.6.1 Results

In order to evaluate the potential of interference from CDMA450 base stations to radiolocation systems, three CDMA450 carriers were assumed to be operating in the 450-470 MHz band, with the first, second, and third carriers deployed at 463.35-464.6 MHz, 464.6-465.85 MHz, and 465.85-467.1 MHz respectively. The different radar systems were assumed to be operating in the 440-450 MHz bands with a center frequency of the last radar carrier (radar receive) at 445 MHz. The only exceptions were the PLRS, whose center frequency was at 446.75 MHz, and the wind profiler radars, at 449 MHz. The IF bandwidth of the radars was assumed to equal $1/t$, where t is the pulse duration of the radars, except for the case of WPR. For the WPR, an IF bandwidth of 350 kHz (Hi-mode) was used as specified in NTIA Report 93-301. The CDMA450 transmitter spurious emissions were taken from the technology specifications and are specified in Table 7.

Table 10 below provides the separation distances that are needed between the CDMA450 system and the different types of radars to operate in adjacent bands without exceeding the protection criteria of the radars studied. A sample calculation and the corresponding equation used to derive the results in Table 10 are provided below:

$$\text{Isolation emission (dB)} = \text{BS transmit power} + \text{Transmitter antenna gain} - \text{FDR} + \text{Receiver antenna gain} - (\text{Target noise floor} + \text{Noise rise margin}) \qquad (2)$$

BS transmit power: Effective radiated power of CDMA450 base station (dBm)

Transmitter antenna gain: CDMA450 transmitter antenna gain (dB)

FDR: Frequency dependent rejection (dB)

Receiver antenna gain: Receiver antenna gain (dB)

Target noise floor + Noise rise margin = Level of interfering signal in order to achieve permissible I/N degradation (dBm)

Sample calculation: CDMA450 BS interfering with ground-based radar (5 MHz receiver BW) at 15.85 MHz guard-band:

$$\text{Isolation (dB)} = 155 \text{ dB} = 43 \text{ dBm} + 12 \text{ dBi} - 56.6 + 38.5 \text{ dBi} - (-118 \text{ dBm})$$

Distance (km) is then calculated via ITU-R P.1546. If the distance is less then 1 km, then a two slope propagation model in ITU-R P.1411 is used. For Airborne surveillance radars, the distance is calculated using the free space propagation model.

TABLE 10

CDMA450 base station interfering with radar systems

Radiolocation service	Edge of last radar carrier to 1st CDMA450 carrier Guard band (MHz)	Emission coupling Distance (km)
Ground-based space object tracking radars (5 MHz Rx. BW)	15.85	17.45
Shipborne surveillance radars (2 MHz, Rx BW)	17.35	8
Airborne surveillance radars (1 MHz Rx. BW)	17.85	12
PLRS radars (3 MHz Rx. BW)	15.1	2
Wind profiler radars at 3 m (350 kHz Rx. BW)	13.85	55

The results above indicate that, when placed in adjacent spectrum, CDMA450 base stations and the various radar systems studied can operate without exceeding the protection criteria of the radars, provided that the required separation distances, as indicated in Table 10, can be maintained.

5.6.2 Results with mitigation techniques

In order to reduce the separation distances required between the CDMA450 base stations and radar systems, CDMA450 operators could use a number of mitigation techniques. For example, CDMA450 operators could place a filter at the CDMA450 base station transmitter that would further attenuate or reduce the unwanted emissions that fall into the radar receive bands. It is also possible for the CDMA450 operators to disable the first and second CDMA450 carriers providing additional guard bands of 1.25 MHz and 2.5 MHz, respectively, with the radar systems. The above-mentioned mitigation techniques can be used alone or in combination to reduce the amount of separation distance required between CDMA450 base stations and radar systems. Table 11 provides the separation distances required between the CDMA450 base station and radar systems as a result of placing a filter at the CDMA450 base station transmitter.

A sample calculation and the corresponding equation used to derive the results in Table 11 are provided below:

$$\text{Isolation emission (dB)} = \text{BS transmit power} + \text{Transmitter antenna gain} - \text{FDR} + \text{Receiver antenna gain} - (\text{Target noise floor} + \text{Noise rise margin}) - \text{Additional rejection} \quad (3)$$

BS transmit power: Effective radiated power of CDMA450 base station (dBm)

Transmitter antenna gain: CDMA450 transmitter antenna gain (dB)

FDR: Frequency dependent rejection (dB)

Receiver antenna gain: Receiver antenna gain (dB)

Target noise floor + Noise rise margin = Level of interfering signal in order to achieve permissible I/N degradation (dBm)

Additional rejection (dB): Amount of addition rejection (increments of 10, 20, 30, 40, 50, and 60 dB)

Sample calculation: CDMA450 BS interfering with ground-based radar (5 MHz receiver BW) at 15.85 MHz guard-band with an additional 60 dB rejection

Isolation (dB) = 95 dB = 43 dBm + 12 dBi – 56.6 + 38.5 dBi – (–118 dBm) – 60 dB

Distance (km) is then calculated via ITU-R P.1546. If the distance is less then 1 km, then a two slope propagation model in ITU-R P.1411 is used. For airborne surveillance radars, the distance is calculated using the free space propagation model.

TABLE 11

Distance between CDMA450 base stations and radar systems –
Filtering at CDMA450 base station transmitter

Radiolocation service	Distance (km)					
	Amount of filtering (dB)					
	10	20	30	40	50	60
Ground-based space object tracking radars	10.43	6.15	4	3	1	< 1 km 5.64 (P.1411)
Shipborne surveillance radars	5	3	1	< 1 km 5.63 (P.1411)	< 1 km 1.78 (P.1411)	< 1 km 0.56 (P.1411)
Airborne surveillance radars	3.8	1.2	0.38	0.12	0.04	0.01
PLRS radars	1	< 1 km 5.98 (P.1411)	< 1 km 2.09 (P.1411)	< 1 km 0.66 (P.1411)	< 1 km 0.21 (P.1411)	< 1 km 0.07 (P.1411)
Wind profiler radars at 3 m	30	12	4	1	< 1 km 0.68 (P.1411)	< 1 km 0.27 (P.1411)

5.6.3 Conclusions

The results in Table 11 indicate that CDMA450 base stations and the various radar systems can successfully operate in adjacent spectrum, if CDMA450 operators can adopt additional mitigation techniques to reduce interference from radars. In order to avoid interfering with the radar receivers, the out-of-band emissions of the CDMA450 base station need to be improved/ suppressed. If the CDMA450 base station out-of-band emissions cannot be improved, then the use of guard bands and/or other engineering mitigation techniques that provide the equivalent isolation needs to be provisioned by the operators of CDMA450 systems for mutual compatibility.

The results in Table 11 suggest that by reducing the CDMA450 base stations unwanted emissions by an additional 30 dB the amount of separation needed between CDMA450 and the airborne, shipborne, and PLRS radars is reduced to less than 1 km. For the ground-based and WPR radars, an improvement of 50 dB and 40 dB, respectively, in the CDMA450 base station unwanted emissions is needed to reduce the separation distance to less than 1 km.

5.7 Interference from CDMA450 Mobile Stations to the Radiolocation Services

5.7.1 Results

In order to evaluate the potential for interference from CDMA450 mobile stations into radiolocation services, three CDMA450 carriers were assumed to be operating in the 450-470 MHz band, with the first, second, and third carriers deployed at 453.35-454.6 MHz, 454.6-455.85 MHz, and

455.85-457.1 MHz respectively. As was done for the CDMA450 base station case, the different radar systems were assumed to be operating in the 440-450 MHz band with the center frequency of the last radar carrier (radar receive) at 445 MHz. The only exception was the PLRS, whose center frequency was at 446.75 MHz, and the WPR at 449 MHz.

The analysis considers a single CDMA450 mobile station interfering with a single radiolocation service receiver and as such the results are specific to the scenario assumed in the study. Multiple CDMA450 mobile stations interfering with a single radiolocation service receiver is not studied in the analysis. Caution should be exercised in interpreting the results of the section, as any change in the assumption or scenario may result in different isolation requirements.

Table 12 provides the separation distances that are needed between the CDMA450 mobile stations and the different types of radars to operate in adjacent bands without exceeding the protection criterion of the radars.

TABLE 12

CDMA450 mobile stations interfering with radar systems

Radiolocation service	Edge of last radar carrier to 1st CDMA450 carrier Guard band (MHz)	Emission coupling Distance (km)
Ground-based space object tracking radars (5 MHz Rx. BW)	5.85	8.29
Shipborne surveillance radars	7.35	4
Airborne surveillance radars	7.85	31.94
PLRS radars	5.1	< 1 km 1.42 (P.1411)
Wind profiler radars at 3 m	3.85	3

A sample calculation and the corresponding equation used to derive the results in Table 12 are provided below:

$$\text{Isolation emission (dB)} = \text{MS transmit power} + \text{Transmitter antenna gain} - \text{FDR} + \text{Receiver antenna gain} - (\text{Target noise floor} + \text{Noise rise margin}) \quad (4)$$

MS transmit power: Effective radiated power of CDMA450 mobile station (dBm)

Transmitter antenna gain: CDMA450 transmitter antenna gain (dB)

FDR: Frequency dependent rejection (dB)

Receiver antenna gain: Receiver antenna gain (dB)

Target noise floor + Noise rise margin = Level of interfering signal in order to achieve permissible I/N degradation (dBm)

Sample calculation: CDMA450 mobile interfering with ground-based radar (5 MHz Rx. BW) at 5.85 MHz guard-band:

$$\text{Isolation (dB)} = 141 \text{ dB} = 23 \text{ dBm} + 0 \text{ dBi} - 38.3 + 38.5 \text{ dBi} - (-118 \text{ dBm})$$

Distance (km) is then calculated via ITU-R P.1546. If the distance is less then 1 km, then the two slope propagation model in ITU-R P.1411 is used. For airborne surveillance radars, the distance is calculated using the free space propagation model.

The results above indicate that, when placed in adjacent spectrum, CDMA450 mobile stations and the various radars can operate without exceeding the protection criterion of radars, provided that the required separation distances, as indicated in Table 12, can be maintained. In this scenario, Sharing with the Airborne radars seems to be the most problematic.

5.7.2 Results with mitigation techniques

In order to reduce the separation distances required between the CDMA450 mobile stations and radar systems, CDMA450 operators could use a number of different mitigation techniques. To avoid interference to the radar receivers the unwanted emissions from the CDMA450 mobile stations that fall into the radar receive bands needs to be further reduced. Table 13 provides the separation distances required between the CDMA450 mobile station and radar systems as a result of reducing the unwanted emissions from the CDMA450 mobile stations. If the CDMA450 mobile station out-of-band emissions cannot be improved, then the use of guard bands and/or other engineering mitigation techniques, such as disabling one or more CDMA450 carriers, that provide the equivalent isolation could be provisioned by the CDMA450 operators for mutual compatibility.

TABLE 13

Distance between the CDMA450 mobile stations and radar systems – Filtering at CDMA450 transmitter

Radiolocation service	Distance (km)					
	Amount of filtering (dB)					
	10	20	30	40	50	60
Ground-based space object tracking radars	5.15	3	1.79	< 1 km 1.81 (P.1411)	< 1 km 1.02 (P.1411)	< 1 km 0.57 (P.1411)
Shipborne surveillance radars	2	1	< 1 km 1.28 (P.1411)	< 1 km 0.7 (P.1411)	< 1 km 0.41 (P.1411)	< 1 km 0.14 (P.1411)
Airborne surveillance radars	10	3.2	1	0.32	0.1	0.03
PLRS radars	< 1 km 0.8 (P.1411)	< 1 km 0.45 (P.1411)	< 1 km 0.24 (P.1411)	< 1 km 0.08 (P.1411)	< 1 km 0.02 (P.1411)	< 1 km 0.01 (P.1411)
Wind profiler radars at 3 m	1	< 1 km 0.14 (P.1411)	< 1 km 0.08 (P.1411)	< 1 km 0.05 (P.1411)	< 1 km 0.02 (P.1411)	< 1 km 0.01 (P.1411)

A sample calculation and the corresponding equation used to derive the results in Table 13 are provided below:

$$\text{Isolation emission (dB)} = \text{MS transmit power} + \text{Transmitter antenna gain} - \text{FDR} + \text{Receiver antenna gain} - (\text{Target noise floor} + \text{Noise rise margin}) - \text{Additional rejection} \quad (5)$$

MS transmit power: Effective radiated power of CDMA450 mobile station (dBm)

Transmitter antenna gain: CDMA450 transmitter antenna gain (dB)

FDR: Frequency dependent rejection (dB)

Receiver antenna gain: Receiver antenna gain (dB)

Target noise floor + Noise rise margin = Level of interfering signal in order to achieve permissible I/N degradation (dBm)

Additional rejection (dB) = Amount of addition rejection (increments of 10, 20, 30, 40, 50, and 60 dB)

Sample calculation: CDMA450 mobile interfering with ground-based radar (5 MHz Rx. BW) at 5.85 MHz guard-band with additional 60 dB rejection:

Isolation (dB) = 81 dB = 23 dBm + 0 dBi – 38.3 + 38.5 dBi – (–118 dBm) – 60 dB

Distance (km) is then calculated via ITU-R P.1546. If the distance is less then 1 km, then the two slope propagation model in ITU-R P.1411 is used. For Airborne surveillance radars, the distance is calculated using the free space propagation model.

5.7.3 Conclusions

The results in Table 13 indicate that CDMA450 mobile stations and the various radars can successfully operate in adjacent spectrum, if additional filtering between the two systems can be provided by the CDMA450 operators. In order to avoid interfering with the radars, the out-of-band emissions of the CDMA450 mobile station need to be improved or the use of guard bands and/or appropriate engineering techniques that provide an equivalent isolation would need to be provisioned by CDMA450 operators.

The results in Table 13 suggest that by reducing the CDMA450 mobile stations unwanted emissions to 30 dB the amount of separation needed between CDMA450 and the shipborne, WPR, and airborne radars is reduced to less than 1 km. Similarly, an isolation in the amount of 40 dB is needed between CDMA450 mobile stations and the ground based radarse to enable compatibility. No mitigation is needed to enable compatibility between the CDMA450 mobile stations and the PLRS.

5.8 Interference from radar transmitter to CDMA450 base station

5.8.1 Results

The study of radar interfering into CDMA450 considers the conservative assumption of radars continuously transmitting power, i.e. active 100% or no duty cycle assumed, and transmitting with maximum antenna gain pointing directly to the CDMA450 receivers. Thus the resulting isolation needed to permit permissible operation of radars and CDMA450 in adjacent bands is conservative. Generally, radar systems employ some duty cycles in order to allow time for its own receivers to detect its signal. In such a scenario, the average radar transmit power over long periods of time is less than the peak transmit specifications used in the sharing analyses. Furthermore, the period of time in which the radar is transmitting directly at the CDMA450 receiver may be minimal (unless, for example, the CDMA450 base station receiver is located directly in the line-of-sight path of a radar transmitter). Therefore, the isolation calculated in the following sections is conservative and may decrease as a result of considering the radar duty cycles and/or moving the direction of the antenna gain directly away from the CDMA450 receivers. The only exception is the wind profiler radars that are assumed to be pointing up to the sky and therefore power from the side-lobes is considered when evaluating interference with CDMA450 receivers.

Caution should be exercised in interpreting the results of the section, as any combination of radar transmit power, antenna direction, and pulse duration may result in different isolation requirements.

For the case of radar interference into CDMA450 base stations, the base station receiver was assumed to be tuned to the same three frequency channels that were used in the analysis presented in § 5.7. Likewise the radar operation was assumed to be the same as described in the previous section. The radar transmitter emission masks in the 450-470 MHz band were derived from Recommendation ITU-R SM.1541 – Unwanted emissions in the out-of-band domain.

The radar emission mask in Recommendation ITU-R SM.1541 is similar to the one present in the NTIA Manual of regulations and procedures for federal radio frequency management[2] (§ 5.5, Criteria C), and was used to derive the radar emission masks for all the transmitters except for the wind profiler radars. For the wind profiler radars, NTIA Report 93-301, NOAA Special Report – Measurement of wind profiler EMC characteristics, was used to derive the transmitter emission masks. In evaluating the interference from radars to CDMA450 base stations, combinations of short and long radar pulse duration and transmit power were considered in the study. For airborne interference into CDMA450 receivers, a 20 dB[3] side lobe suppression of the received signal was assumed. Results corresponding to the best case, yielding small separation distances, and the worst case, yielding large separation distances, are presented. The FDR analysis was used to determine the amount of separation needed between the two systems for permissible operation. Table 14 below provides the separation distances that are needed between the radars and the CDMA450 base stations, to operate in adjacent bands without exceeding the protection criterion of CDMA450 systems.

TABLE 14

Radar transmitter interfering with CDMA450 base station

Radiolocation service	Radiolocation service antenna height, BW, power, pulse duration	Edge of last radar carrier to 1st CDMA450 carrier Guard band (MHz)	Emission coupling Distance (km)
Ground-based space object tracking radars	10 m, 1 MW, 0.25 ms	5.85	210.49
	10 m, 5 MW, 16 ms		285.86
Shipborne surveillance radars	20 m, 2 MW, 0.5 µ s	7.35	471.27
Airborne surveillance radars	5 000 m, 2 MW, 8 µs	7.85	831.48
	5 000 m, 2 MW, 1 µs		12,5849
PLRS radars(1)	10 m, 0.4 W, 824.6 µs	5.10	1
	10 m, 125 W, 824.6 µs		6.15
Wind profiler radars	3 m, 16 kW, 6.67 µs	3.85	< 1 km 1 (P.1411)
	3 m, 16 kW, 1.67 µs		< 1 km 1 (P.1411)

(1) The theoretical distances are greater than the horizon range limits and a consequence of using the free space propagation loss between the airborne radars and CDMA450.

2 The NTIA Manual can be downloaded from: http://www.ntia.doc.gov/osmhome/redbook/redbook.html

3 As specified in "cdma2000® Evaluation Methodology - 3GGP2.C.R1002-0 version 1.0 December 10, 2004 (Rev 0, Figure 2.1.1-1)".

Sample calculations and the corresponding equations used to derive the results in Table 14 are provided below:

$$\text{Isolation (dB)= Radar transmit power + Transmitter antenna gain – FDR + Receiver antenna gain – (Target noise floor + Noise rise margin)} \quad (6)$$

Radar transmit power: Transmitted power of radar (dBm)

Transmitter antenna gain: Radar transmitter antenna gain (dB)

FDR: Frequency dependent rejection between radar transmitted and CDMA450 receiver (dB)

Receiver antenna gain: Receiver antenna gain (dBi)

Target noise floor + Noise rise margin = Acceptable level of interfering signal (dBm)

Sample calculations: 5 MW, 16 ms pulse duration Ground radar interfering with CDMA450 base station at 5.85 MHz guard-band:

Isolation (dB) = 208 dB = 97 dBm + 38.5 dBi -53.5 dB + 12 dBi – (-114 dBm)

Distance (km) is then calculated via ITU-R P.1546. If the distance is less then 1 km, the two slope propagation model in ITU-R P.1411 is utilized. For airborne surveillance radars, the distance is calculated using the free space propagation model.

The results indicate that for most cases sharing between CDMA450 base stations and the various types of radars when placed in adjacent spectrum is not feasible in the absence of mitigation. Most notably, compatibility between CDMA450 base stations and the Airborne,shipborne, and Ground based radars seems to be the most problematic. This is due to the very high transmitting powers of the radars and the high levels of unwanted emissions falling into the CDMA450 (mobile transmit) band. In addition, a worst-case analysis, assuming continuous interference from radar systems to CDMA450 systems, i.e. no radar duty cycle, is considered in the study. In order for the two systems to operate in adjacent spectrum without exceeding the protection criterion, additional mitigation techniques would need to be taken into account by the operators of the CDMA450 systems.

5.8.2 Results with mitigation techniques

To reduce the separation distances required between the radars and CDMA450 base stations systems, operators could use a number of different mitigation techniques. For example, appropriate engineering techniques, such as use of guard bands, disabling one or more CDMA450 carriers, antenna engineering, etc. could be employed to provide additional isolation between the two systems. Further it should be noted that this study used very restrictive masks with high out-of-band (OoB) emissions and a relatively flat frequency response. For example, the radar mask starts at 40 dB immediately outside of the measurement bandwidth, has a roll-off of only 20 dB/decade until it reaches 60 dB, and then remains flat at 60 dB (see pages 2-59, Fig. 2 of the NTIA Manual). As indicated in Section 5.8.1, NTIA Report 93-301 was used to derive the emission masks for wind profiler radars (see Figs. 4-2 and 4-3, page 35, Section 4). Note that the actual radar transmitter masks are expected to display much lower OoB emissions and thus perform better than those specified in Recommendation ITU-R SM.1541.

In order to avoid the desensitization of the CDMA450 base station receiver different isolation levels were applied between the two systems to reduce the separation to less than 1 km. Table 15 provides the separation distances required between the radars and CDMA450 base stations as a result of applying different isolation levels between the two systems.

TABLE 15

**Radar transmitter interfering with CDMA450 base station –
Amount of additional isolation needed**

Radiolocation service	Radiolocation service antenna height, BW, power, pulse duration	Distance (km) Amount of additional isolation needed (dB)					
		10	20	30	40	50	60
Ground-based space object tracking radars	10 m, 1 MW, 0.25 ms	147	82.24	40.76	20.7	14.4	8
	10 m, 5 MW, 16 ms	198.5	125.6	66.5	31.4	20	12.4
Shipborne surveillance radars	20 m, 2 MW, 0.5 µs	367.5	285.8	198.5	125.6	77.2	41.4
Airborne surveillance radars	5 000 m, 2 MW, 8 µs	262.9	83.15	26.29	8.3	2.63	0.83
	5 000 m, 2 MW, 1 µs	39,797	12,584.9	3 979.7	1 258.4	397.97	125.85
PLRS radars	10 m, 0.4 W, 824.6 µs	< 1 km 6.87 (P.1411)	< 1 km 2.77 (P.1411)	< 1 km 0.87 (P.1411)	< 1 km 0.28 (P.1411)	< 1 km 0.09 (P.1411)	< 1 km 0.03 (P.1411)
	10 m, 125 W, 824.6 µs	3.14	2	1	< 1 km 4.89 (P.1411)	< 1 km 1.55 (P.1411)	< 1km 0.49 (P.1411)
Wind profiler radars	3 m, 16 kW, 6.67 µs	< 1 km 0.6 (P.1411)	< 1 km 0.2 (P.1411)	< 1 km 0.07 (P.1411)	< 1 km 0.02 (P.1411)	< 1 km 0.01 (P.1411)	< 1 km 0 (P.1411)
	3 m, 16 kW, 1.67 µs	< 1 km 0.59 (P.1411)	< 1 km 0.2 (P.1411)	< 1 km 0.06 (P.1411)	< 1 km 0.02 (P.1411)	< 1 km 0.01 (P.1411)	< 1 km 0 (P.1411)

Sample calculations and the corresponding equations used to derive the results in Table 15 are provided below:

Isolation (dB)= Radar transmit power + Transmitter antenna gain – FDR + Receiver antenna gain – (Target noise floor + Noise rise margin) – Additional rejection (7)

Radar transmit power: Transmitted power of radar (dBm)

Transmitter antenna gain: Radar transmitter antenna gain (dB)

FDR: Frequency dependent rejection between radar transmitter and CDMA450 receiver (dB)

Receiver antenna gain: Receiver antenna gain (dBi)

Target noise floor + Noise rise margin = Acceptable level of interfering signal (dBm)

Additional rejection (dB): Amount of addition rejection (increments of 10, 20, 30, 40, 50, and 60 dB)

Sample calculation: 5 MW, 16 ms ground radar interfering with CDMA450 base station at 5.85 MHz guard-band with additional 60 dB rejection

Isolation Emissions (dB) = 148 dB = 97 dBm + 38.5 dBi – 53.5 dB + 12 dBi – (–114 dBm) – 60 dB

Distance (km) is then calculated via Recommendation ITU-R P.1546. If the distance is less then 1 km, a two slope model in Recommendation ITU-R P.1411 is utilized. For airborne surveillance radars, the distance is calculated via free space propagation.

5.8.3 Conclusion

The results in Tables 15 indicate that operation of CDMA450 base stations and radars in the adjacent bands, is feasible only if appropriate mitigation can be provided by CDMA450 operators. In order to avoid desensitization of the CDMA450 base stations, additional isolation needs to be provided between the two systems. The results in Table 15 suggest that an isolation of greater than 60 dB needs to be provisioned between Ground, Shipborne, and Airborne radars to reduce the separation distance to less than a 1 km while not exceeding the protection criterion of CDMA450 systems. For the PLRS no isolation is needed, except for the case when PLRS are transmitting at 125 W for which an improvement of 30 dB is needed to reduce the distance to less than 1km with CDMA450 base stations. For the WPR no isolation is needed with CDMA450 base stations to permit operation in adjacent bands.

5.9 Interference from radar transmitter to CDMA450 mobile station

5.9.1 Results

For the case of radar interference into CDMA450 mobile stations, the mobile receiver was assumed to be tuned to the three frequency channels used in the analysis given in § 5.6. The analysis, only considered continuous interference from radars to one mobile station. Interference from radars to randomly distributed multiple mobile stations was not studied. The same radar characteristics as described in previous sections likewise were used.

The analysis considers a single radar interfering with a single CDMA450 mobile station receiver and as such the results are specific to the scenario assumed in the study. A single radar system interfering with multiple CDMA450 mobile stations is not studied in the analysis. Caution should be exercised in interpreting the results of the section, as any change in the assumption or scenario may result in different isolation requirements.

Table 16 provides the separation distances that are needed between radars and the CDMA450 mobile stations for a combination of different transmit powers and pulse durations, to operate in adjacent bands without causing harmful interference to each other. For airborne interference into CDMA450 receivers, 20 dB[4] side lobe suppression of the received signal was assumed.

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[4] See footnote 3.

TABLE 16

Radar transmitter interfering with CDMA450 mobile stations

Radiolocation service	Radiolocation service antenna height, BW, power, pulse duration	Edge of last radar carrier to 1st CDMA450 carrier Guard band (MHz)	Emission coupling Distance (km)
Ground-based space object tracking radars	10 m, 1 MW, 0.25 ms	15.85	46.4
	10 m, 5 MW, 16 ms		77.23
Shipborne surveillance radars	20 m, 2 MW, 0.5 μs	17.35	31.4
Airborne surveillance radars	5 000 m, 2 MW, 8 μs	17.85	41.7
	5 000 m, 2 MW, 1 μs		50.83
PLRS radars	10 m, 0.4 W, 824.6 μs	15.10	< 1 km 0.66 (P.1411)
	10 m, 125 W, 824.6 μs		1
Wind profiler radars	3 m, 16 kW, 6.67 μs	13.85	< 1 km 0.12 (P.1411)
	3 m, 16 kW, 1.67 μs		< 1 km 0.1 (P.1411)

Sample calculations and the corresponding equations used to derive the results in Table 16 are provided below:

$$\text{Isolation (dB)} = \text{Radar transmit power} + \text{Transmitter antenna gain} - \text{FDR} + \text{Receiver antenna gain} - (\text{Target noise floor} + \text{Noise rise margin}) \quad (8)$$

Radar transmit power: Transmitted power of radar (dBm)

Transmitter antenna gain: Radar transmitter antenna gain (dBi)

FDR: Frequency dependent rejection between Radar transmitter and CDMA450 receiver (dB)

Receiver antenna gain: Receiver antenna gain (dB)

Target noise floor + Noise rise margin = Acceptable level of interfering signal (dBm)

ACS_GB = Selectivity of the receiver at particular frequency separation (dB)

Sample calculations: 5 MW, 16ms Ground Radar interfering with CDMA40 mobile station at 15.85 MHz guard-band:

Isolation emissions (dB) = 190 dB =97 dBm + 38.5 dBi – 55.3 dB + 0 dBi – (-110 dBm).

To compensate for mobile height below clutter in Recommendation ITU-R P.1546, –9 dB was added to the isolation, therefore, Isolation Emissions (dB) = 181 dB.

Distance (km) is then calculated via Recommendation ITU-R P.1546. If the distance is less then 1 km, a two slope propagation model in Recommendation ITU-R P.1411 is utilized. For Airborne surveillance radars, the distance is calculated using the free space propagation model.

The results indicate that sharing between ground, shipborne, and airborne radars and CDMA450 mobile stations in adjacent spectrum is not feasible in the absence of mitigation. This is because of the very high transmitting powers of the radars and the high levels of unwanted emissions falling into the CDMA450 (base station transmit) band.

In order for the two systems to operate in adjacent spectrum (without exceeding the protection criterion) additional mitigation techniques should be taken into account by CDMA450 operators.

5.9.2 Results with mitigation techniques

Using the same procedures as was done for the case of radar interference into CDMA450 base station receivers, Table 17 provides the separation distances required between the radars and the CDMA450 mobile stations as a result of providing additional isolation between the two systems.

TABLE 17

Radar transmitter interfering with CDMA450 mobile station –
Amount of additional isolation needed

Radiolocation service	Radiolocation service antenna height, BW, power, pulse duration	Distance (km)					
		Amount of additional isolation needed (dB)					
		10	20	30	40	50	60
Ground-based space object tracking radars	10 m, 1 MW, 0.25 ms	25.7	16.5	10.3	6.15	3.14	2
	10 m, 5 MW, 16 ms	40.7	20.7	14.4	8.3	5.15	3
Shipborne surveillance radars	20 m, 2 MW, 0.5 μs	20	12.4	7.3	4.15	2	1
Airborne surveillance radars	5 000 m, 2 MW, 8 μs	13.22	4.1	1.3	0.42	0.13	0.04
	5 000 m, 2 MW, 1 μs	16	152.5	1.6	0.51	0.16	0.05
PLRS radars	10 m, 0.4 W, 824.6 μs	< 1 km 0.37 (P.1411)	< 1 km 0.16 (P.1411)	< 1 km 0.05 (P.1411)	< 1 km 0.02 (P.1411)	< 1 km 0.01 (P.1411)	< 1 km 0.0 (P.1411)
	10 m, 125 W, 824.6 μs	< 1 km 1.56 (P.1411)	< 1 km 0.88 (P.1411)	< 1 km 0.49 (P.1411)	< 1 km 0.28 (P.1411)	< 1 km 0.09 (P.1411)	< 1 km 0.03 (P.1411)
Wind profiler radars	3 m, 16 kW, 6.67 μs	No mitigation needed					
	3 m, 16 kW, 1.67 μs						

Sample calculations and the corresponding equations used to derive the results in Table 17 are provided below:

$$\text{Isolation emission (dB)} = \text{Radar transmit power} + \text{Transmitter antenna gain} - \text{FDR} + \text{Receiver antenna gain} - (\text{Target noise floor} + \text{Noise rise margin}) - \text{Additional rejection} \quad (9)$$

Radar transmit power: Transmitted power of radar (dBm)

Transmitter antenna gain: Radar transmitter antenna gain (dBi)

FDR: Frequency dependent rejection between radar transmitter and CDMA450 receiver (dB)

Receiver antenna gain: Receiver antenna gain (dBi)

Target noise floor + Noise rise margin = Acceptable level of interfering signal (dBm)

Sample calculation: 5 MW, 16 ms ground radar interfering with CDMA450 mobile at 15.85 MHz guard-band with additional 60 dB rejection:

Isolation emissions (dB) = 130 dB = 97 dBm + 38.5 dBi – 55.3 dB + 0 dBi – (–110 dBm) – 60 dB.

To compensate for mobile height below clutter in Recommendation ITU-R P.1546, –9 dB was added to the isolation, therefore, isolation (dB) = 121 dB.

Distance (km) is then calculated via Recommendation ITU-R P.1546. If the distance is less then 1 km, a two slope propagation model in Recommendation ITU-R P.1411 is utilized. For airborne surveillance radars, the distance is calculated using the free space propagation model.

5.9.3 Conclusion

As was the case for radar interference into CDMA450 base stations, the results given in Table 17 indicate that sharing between CDMA450 mobile stations and radars is possible only if appropriate mitigation can be provided between the two systems. In order to avoid desensitization of the CDMA450 mobile stations, isolation in the amount of 60 dB needs to be provisioned between ground and shipborne radars. For airborne radars isolation in the amount of 40 dB is needed. The results in Table 17 further suggest that for PLRS and WPR no mitigation is needed between CDMA450 system to permit operation in adjacent bands.

6 Mobile, fixed, and satellite systems

6.1 Allocation in the Table of Frequency allocations

In all three ITU Regions, the bands 450-470 MHz are allocated on a primary basis to the fixed, mobile (except aeronautical mobile), and satellite services. In this frequency range, administrations have developed a number of mobile and fixed systems. Although there are a number of different fixed systems deployed, the most common systems deployed in the 450-470 MHz bands are the fixed service point-to-multipoint (P-MP) systems, and the analog and digital fixed service (FS) systems. Similarly, the most common mobile service systems deployed in the 450-470 MHz band are the Nordic Mobile Telecommunications (NMT) systems, conventional and trunked land mobile systems, and the private mobile radio (PMR)/public access mobile radio (PAMR) systems. Among the PMR/PAMR systems, the terrestrial trunked radio access (TETRA) and the FM land mobile radio systems are the most widely deployed in the 450-470 MHz frequency band.

Since CDMA450 systems will share the 450-470 MHz bands with other fixed and mobile services that are also primary within the band, a co-channel sharing study was performed between the two types of systems to assess the physical separations needed between the two systems without causing harmful interference to each other. The following two cases are considered in the sharing study:

a) Fixed service base station and mobile service base station to CDMA450 base station

b) CDMA450 base station to fixed service base station and mobile service base station.

The study considers interference from base station to base station, assuming the base station of one system is transmitting in the receiving channel of the base station of the other system. Such a scenario is typically associated with TDD systems or misaligned FDD bandplans. The typically more benign scenario of a common base transmit and mobile transmit band plans is not considered.

The study does not consider the interference at a CDMA450 mobile receiver from a land mobile base transmitting within the CDMA450 channel or vice versa.

6.2 Technical characteristics of fixed systems

6.2.1 Fixed service point-to-multipoint (P-MP) systems

Fixed service point-to-multipoint (P-MP) systems provide voice, video and data signals to geographically distributed communities. These services may be used for entertainment, business, social or community purposes. A typical P-MP distribution service system consists of an omni-directional transmit antenna and instrumentation to combine the output of each transmitter at the transmitting site, a directional receive antenna, down converter and a video receiver at each receive location. The transmit site is generally limited in output power and normally drives an antenna with either an omni directional or a cardioid radiation pattern with gains of 10 to 16 dBi. In some instances, a single transmitter drives pairs of back-to-back cardioid antennas. The received signal is changed by the down converter from the transmission frequency to an unused channel frequency compatible with the video receiver. In the case of multi-channel multipoint distribution services, a narrow-band channel (125 kHz bandwidth) is provided for an audio response to the transmitter site.

Recommendations ITU-R F.755 and ITU-R F.758 provide all of the necessary technical characteristics of the P-MP systems that were used in the sharing study between the P-MP and the CDMA450 systems. Table 18 lists the RF parameters of the P-MP systems:

TABLE 18

Technical characteristics of the P-MP systems

System parameter	Value
Central station (CS) transmitter power (dBm)	53[(1)]
Modulation	16-DPSK
Central station (CS) antenna gain (dBi)	10, omni-directional, Yagi
Out station (OS) antenna (dBi)	Yagi, 10
Operational range (km)	Up to 60
Data rates (kbit/s)	Up to 1.2
Receiver sensitivity (dBm)	–107
Protection ratio (dB)	6

(1) Recommendation ITU-R F.755 – Point-to-multipoint systems in the fixed service, specifies the transmit power of the P-MP systems for the 2 GHz band only. The transmit power of P-MP systems in 2 GHz was assumed to be the same for the systems operating in the 450-470 MHz band.

6.2.2 Analog and digital fixed systems

A number of different analog and digital fixed systems (FS) are deployed in the 450-470 MHz band. These systems use differing modulation schemes ranging from differentially coherent quaternary phase shift keying (DQPSK) to 32-QAM, depending on the type of the radio interface used, to provide basic voice and data services to users.

Recommendation ITU-R F.758 provides all of the necessary technical characteristics of the FS that can be used when considering sharing between the FS and the CDMA450 systems. The various radio system types were identified in the Table 19 by modulation type and system capacity. Table 19 provides the relevant RF parameters of the analog and digital fixed system that were used in the sharing study.

TABLE 19

Technical characteristics of the analog and digital fixed systems

System parameter	Value					
Modulation type	GMSK	DQPSK	DQPSK	16-QAM	32-QAM	32-QAM
Antenna gain (dBi)	12	25	25	25	25	25
Feeder loss (dB)	4.4	2	2	2	2	2
Antenna type	Sectoral	Yagi	Yagi	Yagi	Yagi	Yagi
Max. transmit output power (dBW)	6	7	7	10	0	0
Max. EIRP (dBW)	13.6	30	30	33	23	23
Receiver IF bandwidth (MHz)	0.6	0.3	3.14	3.5	0.15	1.67
Receiver noise figure (dB)	4	5	5	3	3.5	3.5
Receiver thermal noise (dBW)	–146.5	–144	–134	–143	–148.7	–138.3
Receiver protection ratio (dB)	6	6	6	6	6	6

6.3 Technical characteristics of the mobile systems

6.3.1 Private mobile radio (PMR) and public access mobile radio (PAMR) systems

Mobile systems such as the PMR/PAMR, NMT, and conventional and trunked land mobile systems are deployed widely in the 450-470 MHz bands. PMR is part of the land mobile service that is based on the use of simplex, half and full-duplex modes at the terminal in order to provide closed user group communication services. These systems are used primarily to provide voice services and are privately owned and operated. On the other hand, PAMR systems are operator controlled and provide professional communication facilities comparable to those available using PMR networks. Existing PMR/PAMR systems are almost exclusively narrow band systems, including both analog, such as FM land mobile systems and digital systems, such as TETRA.

Administrations around the world have deployed a number of different PMR/PAMR systems in the 450-470 MHz bands. The two most widely deployed PMR/PAMR systems were considered in this sharing study. These include the terrestrial trunked radio access (TETRA) and the FM land mobile radio systems. The technical characteristics of TETRA were derived from Doc. 8A/376, Annex 5 and the ETSI standard (ETSI EN 300 392-2). The technical characteristics of the FM land mobile service were derived from the ECC Report 39 and Recommendation ITU-R M.478.

In addition, the bands between 450 MHz to 470 MHz are often used for conventional and trunked land mobile systems. These bands are also heavily used by public safety agencies, utilities and transportation companies because the propagation characteristics at these frequencies allow large area coverage with little infrastructure. For the sharing study, the technical and operational characteristics of the conventional and trunked land mobile systems operating in the 450-470 MHz band were derived from draft new Recommendation, ITU-R M.1808 as approved by Radiocommunication Study Group 8 (Doc. 8/168(Rev.1)). Due to the wide variety of conventional and trunked land mobile systems and equipment, the Recommendation uses a range of values for the various parameters, along with typical values. This study only considered the values that are considered to be typical of the conventional and trunked land mobile systems.

Tables 20 and 21 contains the relevant parameters of the PMR/PAMR and the conventional and trunked land mobile systems that were used in the sharing study.

6.3.1.2 Nordic Mobile Telecom (NMT) systems

In a few regions of the word, in particular Region 1 and Region 3, NMT systems are deployed to provide basic voice communication services. Since these systems were originally deployed in the 450 MHz range they are also called as NMT450 systems. Some of these systems are still operational today and were thus taken into account in this sharing study. The technical characteristics of the NMT system were derived from the ECC Report 39. Table 20 contains the relevant parameters of the NMT systems that were used in the sharing study. Table 21 contains the relevant parameters of the conventional and trunked land mobile systems that were used in the study.

TABLE 20

Technical characteristics of TETRA, FM land mobile, and NMT systems

System parameter	TETRA		FM land mobile		NMT	
	MS	BS	MS	BS	MS	BS
Channel spacing (kHz)	25	25	12.5	12.5	25	25
Transmit power (dBm)	30	34	37	41	41.8/ 31.8	47
Receiver bandwidth (kHz)	18		8		18	
Antenna height (m)	1.5	30	1.5	30	1.5	30
Antenna gain (dBi)	0	10	0	3	0	10
Receiver sensitivity (dBm)	–103	–106	–104	–104	–107	–109
Receiver protection ratio (dB)	C/I = 19	C/I =19	6	6	8	8

TABLE 21

Technical characteristics of conventional and trunked land mobile systems

Type of emission	Analog		Digital		Digital	
Modulation type	FM		C4FM		BPSK, QPSK, 8-PSK, 16-QAM	
	MS	BS	MS	BS	MS	BS
Channel spacing (kHz)	12.5/25		6.25/12.5		1 250	
Transmit power (W)	1 to 50 (H: 4 V: 40, 50)	5 to 125 (25) (100)	1 to 50 (H: 4 V: 40, 50)	1 to 125 (30) (100)	0.1 to 40 (0.2)	1 to 125 (20)
ERP (dBW)	0 to 20 (H: 0 V: 15, 16)	3 to 27 (20) (26)	0 to 20 (H: 0 V: 15, 16)	3 to 27 (20) (25)	–7 to 20 (–7)	3 to 27 (22)
Receiver IF bandwidth (kHz)	8/12.5		5.5/5.5		1250	

TABLE 21 (*end*)

Type of emission	**Analog**		**Digital**		**Digital**	
Modulation type	**FM**		**C4FM**		**BPSK, QPSK, 8-PSK, 16-QAM**	
	MS	**BS**	**MS**	**BS**	**MS**	**BS**
Antenna height (m) (relative to ground level)	(2)	10 to 150 (60)	(2)	10 to 150 (60)	(1.5)	10 to 150 (30)
Antenna gain (dBi)	–6 to 4 (H: -6 V: 0)	0 to 11 (9)	–6 to 4 (H: -6 V: 0)	0 to 11 (9)	0 to 4 (0)	0 to 15 (12)
Antenna polarization	Vertical	Vertical	Vertical	Vertical	Vertical	Vertical
Receiver sensitivity (dBm)	−115 to −120 (−118)	−115 to −120 (−119)	−115 to −120 (−118)	−115 to −120 (−119)	−115 to −120 (−120)	−115 to −120 (−117)
Total loss (dB)	0 to 1 (H: 0 V: 1)	0 to 9 (3)	0 to 1 (H: 0 V: 1)	0 to 9 (4)	0 to 1 (0)	0 to 9 (3)
Receiver protection ratio (dB)	6	6	6	6	6	6

NOTE 1 – Typical values are shown in parenthesis, “**H:**” represents the value for **h**andheld mobile stations and “**V:**” represents the value for **v**ehicular mobile stations. In some instances, more than one typical value is provided.

NOTE 2 – ERP is equal to the output power (dBW) plus antenna gain (dBd) minus total losses (dB).

6.4 Protection criteria

Recommendations ITU-R M.478, ITU-R M.1767, and ITU-R M.1808 provide the protection criteria to be used for interference assessment. The Recommendations note that generally a signal from another service resulting in an *I*/*N* ratio of below 6 dB is acceptable by the fixed and mobile systems for signals from the other service having a continuous-wave or noise-like type modulation. An *I*/*N* ratio of –6 dB results in a $(I + N)/N$ of 1.26, or approximately 1 dB increase in the receiver noise power. For the NMT systems a value of 8 dB and for the TETRA systems the maximum interference level of –125 dBm (sensitivity of –106 dBm and *C*/*I* of 19 dB) were used as the protection criterion, as specified in their respective standards.

6.5 Methodology

A co-channel sharing study between CDMA450 and fixed and mobile service base stations systems was performed since both systems are primary within the 450-470 MHz band. The deterministic or the minimum coupling loss (MCL) methodology was used to determine the required separation distances needed between the two systems. This approach is used because both the interferer and victim are stationary both in frequency and geographical position (static interference scenario). The MCL method provides a means to address the worst-case scenario, where the antennas of the two systems in consideration are facing each other and have a direct line-of-sight. Interference from multiple fixed and mobile service base station to a single CDMA450 base station was not considered in this study.

6.6 Propagation model

The propagation models used in the study were derived from Recommendations ITU-R P.1546 and ITU-R P.525. Recommendation ITU-R P.525 was used for distances less than 1 km and Recommendation ITU-R P.1546 for distances greater than 1 km. Since Recommendation ITU-R P.1546 does not specify the field strengths and the distances in the 450-470 MHz range, interpolation, as specified in Recommendation ITU-R P.1546, was used to derive the appropriate figures for the 450-470 MHz range. Annex 2 provides the details of the methodology used to interpolate the field strengths and distances in the 450-470 MHz band.

6.7 Interference from fixed service base stations and mobile service base stations to CDMA450 base stations

The protection criterion for CDMA450 systems was derived from Report ITU-R M.2039, which recommends that an *I*/*N* of –6 dB be used as an interference threshold. The minimum path-loss for coexistence between the fixed and mobile service base stations and CDMA450 base station was calculated using formula (10):

$$I = P_T + G_T + G_R - L_T - L_R - L_P \tag{10}$$

where:

I: peak power of the interferer at the interferer's fundamental frequency, at the receiving antenna output or receiver input (dBm)

P_T: peak power of the transmitter (dBm)

G_T: main beam antenna gain of the interferer in the direction of the victim (see Note 1) (dBi)

G_R: receiver antenna gain in the direction of the interfering station (dBi)

L_T: insertion loss in the transmitter (dB)

L_R: insertion loss in the victim receiver (dB)

L_P: propagation path loss between transmitting and receiving antennas (dB).

6.7.1 Results

Table 22 provides the required separation distances needed between the base stations of the two systems to permit them to co-exist without causing harmful interference to each other.

TABLE 22

Fixed and mobile service base station interfering with CDMA450 base station

CDMA450	**Fixed and mobile systems**									
	Analog and digital fixed systems (FS)						**P-MP**	**FM**	**TETRA**	**NMT**
	GMSK	**DQPSK**	**DQPSK**	**16-QAM**	**32-QAM**	**32-QAM**				
Distance (km)	53.86	105.45	116.92	132.73	63.81	94.43	71.32	21.45	25.59	49.14

CDMA450	**Fixed and mobile systems**		
	The conventional and trunked land mobile systems		
	Analogue/FM	**Digital/C4FM**	**Digital/BPSK, QPSK, 8-PSK, 16-QAM**
Distance (km)	43.14	38.59	112.04

The results in Table 22 indicate that it is not feasible for the CDMA450 base station and the fixed and mobile services base stations to co-exist without providing additional isolation between the two systems. Large separation distances are required between the two systems because of the very high transmit power of the interfering systems, such as 63 dBm (or 33 dBW) of FS systems using the16-QAM modulation and 53 dBm of the P-MP systems. The exact amount of isolation needed between the two systems is dependent on the actual frequency, the number of carriers deployed, the type of antennas, the transmitter power, and the filter attenuation of the fixed and mobile transmitters

6.7.2 Results with mitigation techniques

In order to reduce the separation distances required between the two types of systems, operators could use a number of different mitigation techniques. One such technique is to place a filter in front of the victim receiver, i.e. at the CDMA450 base station. Table 23 provides the separation distances between the two systems as a result of using the above mentioned mitigation technique.

TABLE 23

Fixed and mobile service base station interfering with CDMA450 base station – Improvement in CDMA450 receive filter

CDMA450	Fixed and mobile systems									
	Analog and digital fixed systems (FS)						P-MP	FM	TETRA	NMT
	GMSK	DQPSK	DQPSK	16-QAM	32-QAM	32-QAM				
Distance at 10 dB (km)	32.61	63.84	70.79	80.36	38.63	57.17	43.18	12.98	15.49	29.75
Distance at 20 dB (km)	19.74	38.65	42.86	48.66	23.39	34.61	26.15	7.86	9.38	18.01
Distance at 30 dB (km)	11.95	23.40	25.95	29.46	14.16	20.96	15.83	4.76	5.68	10.91
Distance at 40 dB (km)	7.24	14.17	15.71	17.84	8.57	12.69	9.58	2.88	3.44	6.60
Distance at 50 dB (km)	4.38	8.58	9.51	10.80	5.19	7.68	5.80	1.74	2.08	4.00
Distance at 60 dB (km)	2.65	5.19	5.76	6.54	3.14	4.65	3.51	1.06	1.26	2.42
Distance at 70 dB (km)	1.61	3.14	3.49	3.96	1.90	2.82	2.13	0.64	0.76	1.47

CDMA450	Fixed and mobile systems		
	The conventional and trunked land mobile systems		
	Analogue/FM	Digital/C4FM	Digital/BPSK, QPSK, 8-PSK, 16-QAM
Distance at 10 dB (km)	26.12	23.37	67.83
Distance at 20 dB (km)	15.81	14.15	41.07
Distance at 30 dB (km)	9.57	8.57	24.87
Distance at 40 dB (km)	5.80	5.19	15.05
Distance at 50 dB (km)	3.51	3.14	9.11
Distance at 60 dB (km)	2.12	1.90	5.52
Distance at 70 dB (km)	1.29	1.15	3.34

6.7.3 Conclusion

The results in Table 23 indicate that coexistence between CDMA450 base stations and the various fixed and mobile service base stations may be a challenge even with the use of significant filtering to provide the required attenuation. While the separation distance between the two systems is significantly reduced if a filter at the CDMA450 base station receiver can provide at least 60 dB or 70 dB rejection of the unwanted emissions falling into its receive band, the value of the separation distance may be too large to permit coexistence in some cases. Other possible mitigation measures are available that could be used to decrease the possibility of harmful interference even further, such as the use of guard bands.

6.8 Interference from CDMA450 base stations to fixed service base station and mobile service base station

The protection criteria for the various fixed and mobile service base stations are contained in Tables 19 and 20. In most cases the I/N of –6 dB was used except for NMT for which a value of –8 dB was used and TETRA for which an interference level of –125 dBm was used as interference thresholds. The minimum path-loss for coexistence between CDMA450 base stations and the various fixed and mobile service base stations can be calculated using equation (10).

6.8.1 Results

Table 24 provides the separation distances needed between the base stations of the two systems to co-exist without causing harmful interference to each other.

TABLE 24

CDMA450 base station interfering with fixed service base station and mobile service base station

CDMA450	Fixed and mobile systems									
	Analog and digital fixed systems (FS)						P-MP	FM	TETRA	NMT
	GMSK	DQPSK	DQPSK	16-QAM	32-QAM	32-QAM				
Distance (km)	146.19	212.88	142.90	219.23	231.71	203.47	41.07	12.98	69.81	46.73

CDMA450	Fixed and mobile systems		
	The conventional and trunked land mobile systems		
	Analogue/FM	Digital/C4FM	Digital/BPSK, QPSK, 8-PSK, 16-QAM
Distance (km)	61.32	51.28	175.90

The results in Table 24 indicate that it is not feasible for the CDMA450 base station and the various fixed and mobile service base stations to co-exist without providing additional isolation between the two systems. Large separation distances between the two systems are required because the victim systems are very sensitive to interference and do not provide enough rejection of the unwanted emissions falling into their receive bands.

6.8.2 Results with mitigation techniques

In order to reduce the separation distances required between the two systems, operators could use a number of different mitigation techniques. One such technique is to use a notch filter at the transmitting station, i.e. at the CDMA450 base station. Table 25 provides the separation distances between the two systems as a result of using the above mentioned mitigation technique.

TABLE 25

CDMA450 base station interfering with fixed service and mobile service base stations – Improvement in transmit Notch filter of CDMA450 base stations

CDMA450	Fixed and mobile systems									
	Analog and digital fixed systems (FS)						P-MP	FM	TETRA	NMT
	GMSK	DQPSK	DQPSK	16-QAM	32-QAM	32-QAM				
Distance at 10 dB (km)	85.49	126.04	84.73	129.83	137.19	119.88	22.96	5. 68	40.68	27.18
Distance at 20 dB (km)	51.53	76.53	50.87	79.05	82.98	73.15	14.47	3.56	24.13	15.67
Distance at 30 dB (km)	31.44	46.25	30.42	47.56	49.43	44. 61	8. 22	2.28	14.89	9.87
Distance at 40 dB (km)	19.14	28.10	18.70	29.06	30.74	26.84	5.02	1.24	8.88	5.78
Distance at 50 dB (km)	11.49	16.92	11.23	17.44	18.45	16.15	2.94	0.66	5.28	3.40
Distance at 60 dB (km)	6.90	10.19	6.74	10.50	11.11	9.72	1.72	0.34	3.14	2.03
Distance at 80 dB (km)	2.44	3.64	2.38	3.76	3.98	3.47	0.54	0.13	1.06	0.64

CDMA450	Fixed and mobile systems		
	The conventional and trunked land mobile systems		
	Analogue/FM	Digital/C4FM	Digital/BPSK, QPSK, 8-PSK, 16-QAM
Distance at 10 dB (km)	36.02	29.85	104.37
Distance at 20 dB (km)	21.24	17.09	62.73
Distance at 30 dB (km)	12.10	10.08	37.91
Distance at 40 dB (km)	7. 02	5.67	22.15
Distance at 50 dB (km)	3.87	3.54	12.89
Distance at 60 dB (km)	2.79	2.16	7.49
Distance at 70 dB (km)	1.70	1.29	4.97
Distance at 80 dB (km)	1.05	0.81	3.09

Another possible mitigation technique that can be employed is frequency separation between the two systems. The CDMA450 base stations unwanted emissions are reduced by 45 dBc/30 kHz, 60 dBc/30 kHz, and 79 dBc/30 kHz (or –36 dBm/100 kHz) at frequency separations of 0.125 MHz, 1.355 MHz, and 3.375 MHz respectively from the carrier edge of the CDMA450 system. According to the results in Table 25, this would imply that using a guard band of 3.375 MHz alone between the two systems would enable the two systems to co-exist without the need to provide any physical separation between the two systems.

6.8.3 Conclusions

The results in the Table 25 indicate that coexistence between CDMA450 base stations and the various fixed and mobile service base stations may be a challenge even with the use of significant filtering to provide the required attenuation. While the separation distance between the two systems is significantly reduced if a notch filter at the CDMA450 base stations transmitter can provide at least 60 dB or 80 dB attenuation of the unwanted emissions falling into the receive band of fixed and mobile base stations, the value of the separation distance may be too large to permit coexistence in many cases. If filtering by the CDMA450 base stations cannot be provided, a frequency separation or guard band of 3.375 MHz could enable the two systems to co-exist without causing harmful interference to each other. This guard band could be totally in the IMT sub-band, or it could be shared between both applications or it could be totally in the land mobile sub-band. In the last case, this will leave only a pair of 1.625 + 1.625 MHz for the fixed and mobile services. This mitigation could be used in non-congested areas where fixed and land mobile services are not heavily used and where it is possible to displace those services to a sub-band.

6.9 Satellite services

The 450-470 MHz band is allocated in part to the mobile-satellite service (Earth-to-space) and the meteorological satellite service (space-to-Earth) by virtue of identification in Section IV of RR Article 5 (Table of Frequency allocations, henceforth referred to simply as the Table) and to the Earth exploration-satellite service through footnote 5.289 to the Table. As discussed in the sections below, in all instances involving satellite allocations, footnotes to the Table in the 450-470 MHz band obviate the need to undertake sharing studies between systems operating within a terrestrial fixed or mobile primary allocation and systems involving satellite operations except in the case of the meteorological satellite service operating between 460-470 MHz in Afghanistan, Azerbaijan, Belarus, China, the Russian Federation, Japan, Mongolia, Uzbekistan, Kyrgyzstan, Slovakia, Tajikistan, Turkmenistan and Ukraine.

6.9.1 Mobile-satellite service

The mobile-satellite service (Earth-to-space) is allocated on a primary basis in Region 2 in the Table in the frequency range 455-456 MHz and 459-460 MHz. In Canada, the United States, Mexico and Panama, the band 454-455 MHz is also allocated to the mobile-satellite service (Earth-to-space) on a primary basis by virtue of footnote 5.286D. In Cape Verde, Indonesia, Nepal, Nigeria and Papua New Guinea, the bands 454-456 MHz and 459-460 MHz are allocated to the mobile-satellite (Earth-to-space) service on a primary basis by virtue of footnote 5.286E. Footnote 5.209 limits the use of the bands 454-456 MHz and 459-460 MHz by the mobile-satellite service to non-geostationary-satellite systems.

However, footnote 5.286B states that stations operating in the mobile-satellite service in the frequency bands 454-456 MHz and 459-460 MHz shall not cause harmful interference to, or claim protection from, stations of the fixed or mobile services operating in accordance with the Table. Furthermore, footnote 5.286C states that stations operating in the mobile-satellite service, shall not constrain the development and use of the fixed and mobile services operating in accordance with the Table. It is assumed in this study that any CDMA450 system will operate under a fixed, or more likely, a mobile primary allocation in the 450-470 MHz band. Thus sharing between CDMA450 and the mobile-satellite service in the 450-460 MHz range is not an issue as the mobile-satellite service cannot cause harmful interference to, nor claim protection from, any CDMA450 system.

6.9.2 Meteorological-satellite service

The meteorological-satellite service (space-to-Earth) is allocated on a secondary basis worldwide in the Table in the frequency range 460-470 MHz. In Afghanistan, Azerbaijan, Belarus, China, the Russian Federation, Japan, Mongolia, Uzbekistan, Kyrgyzstan, Slovakia, Tajikistan, Turkmenistan and Ukraine, the allocation of the band 460-470 MHz to the meteorological-satellite service (space-to-Earth) is a primary allocation by virtue of footnote 5.290. Again using the argument that any CDMA450 system will operate under a fixed, or more likely, a mobile primary allocation in the 450-470 MHz band, sharing studies are not required between CDMA450 systems and the meteorological-satellite service (space-to-Earth) except perhaps for the countries indicated in footnote 5.290.

In an attempt to determine the likelihood that the countries listed in footnote 5.290 are in fact using, or planning to use, the 460-470 MHz band for meteorological-satellite services (space-to-Earth), the ITU-R Space Networks Systems Database (http://www.itu.int/sns/) was queried. Of the countries listed in footnote 5.290, only Japan and Russia had listings in the Space Networks Systems Database indicating intention to use the 460-470 MHz band for meteorological-satellite services (space-to-Earth). In all cases the indicated frequencies of use were limited to the 468-469 MHz band.

6.9.3 Earth exploration-satellite service

As stated in footnote 5.289 to the Table, the Earth exploration-satellite service, other than the meteorological-satellite service, may be used for space-to-Earth transmissions on a global basis in the 460-470 MHz subject to not causing harmful interference to stations operating in accordance with the Table. Again referring to the argument that any CDMA450 system will operate under a fixed, or more likely, a mobile primary allocation in the 450-470 MHz band, Earth exploration-satellite services cannot cause harmful interference to CDMA450 systems. Furthermore, in accord with footnote 5.43A because the Earth exploration-satellite service may operate subject to not causing harmful interference to CDMA450 systems operating under a fixed or a mobile primary allocation, the Earth exploration-satellite service cannot claim protection from harmful interference caused by CDMA450 systems operating under a fixed or a mobile primary allocation. Thus it is not necessary to conduct studies between CDMA450 systems and the Earth exploration-satellite service.

6.9.4 Conclusions

The 450-470 MHz band contains allocations to the mobile-satellite, meteorological-satellite and Earth exploration-satellite services. It is also noted that meteorological-satellite service (space to the earth) is being operated in Japan and is continuously used for the alert system against natural disaster. Taking account of the results of the investigation of the allocations in the Table of Frequency allocations, the footnotes to the Table, the information contained within the ITU-R Space Networks Systems Database, and the situation mentioned for the case of Japan, it is considered that there might be no need to undertake sharing studies between CDMA450 systems operating within a terrestrial fixed or mobile primary allocation and systems involving satellite operations at the moment.

7 Broadcasting service

7.1 Allocation in the table of frequency allocations

The 470-490 MHz, 470-608/ 614-890 MHz, and 470-890 MHz bands are allocated to the broadcasting service on a primary basis in Regions 1, 2, and 3 respectively[5].

Since CDMA450 systems will operate in the 450-470 MHz bands an adjacent channel study between CDMA450 and the various broadcasting systems was performed to assess the amount of separation needed between them to operate without causing harmful interference to each other. The following three general cases were studied:

a) CDMA450 base station to the broadcasting service.

b) CDMA450 mobile station to the broadcasting service.

c) Broadcasting service base station to CDMA450 mobile station and base station.

7.2 Technical characteristics of broadcasting service

7.2.1 TV systems

The typical characteristics of TV systems can be found in the Recommendations ITU-R SM.851 and ITU-R BT.1368. Table 26 lists the typical RF TV parameters that were used in the sharing study.

TABLE 26

Typical technical characteristics of analog TV systems

System parameter	Values
Transmitter power ERP (dBW)	41.76 (15kW) to 60 (1MW)
Analog channel bandwidth (MHz)	8 (PAL or SECAM), 6 (NTSC)
Modulation	QPSK
Antenna gain (dBi)	15
TV receiver antenna height (m)	10
TV transmit antenna height (m)	300
Receiver sensitivity (dB(μV/m))	53
Protection ratio for continuous interference (dB)	58

7.2.2 Digital video broadcasting (DVB)-terrestrial/ DVB-T systems

The typical characteristics of the DVB-T systems were derived from ETSI TR 101 190 V1.1.1. Table 27 lists the typical RF parameters of the DVB-T systems that were used in the sharing study.

[5] See RR 5.149 5.291A 5.294 5.296 5.300 5.302 5.304 5.306 5.311 5.312 5.314 5.315 5.316 5.319 5.321 5.322 5.319 5.323 5.319 5.323 5.292 5.293 5.297 5.293 5.309 5.311 5.291 5.298 5.149 5.305 5.306 5.307 5.317A 5.149 5.305 5.306 5.307 5.311 5.320.

TABLE 27

Typical technical characteristics of the DVB-T systems

System parameter	Values
Transmitter power ERP (dBW)	33, 41.76 or 60
Channel bandwidth (MHz)	8
Modulation	QPSK, 16-QAM, 64-QAM
Antenna gain (dBi)	13
Receiver antenna height (m)	10
Transmitter antenna height (m)	300
Receiver sensitivity (dB(μV/m))	53
Protection ratio for continuous interference (dB)	26

7.2.3 Digital video broadcasting (DVB)-handheld/ DVB-H

The typical characteristics of the DVB-H systems were derived from ETSI TR 102 377 V1.2.1. Table 28 provides the typical RF parameters of the DVB-H systems that were used in the sharing study.

TABLE 28

Typical technical characteristics of the DVB-H systems

System parameter	Values
Transmitter power ERP (dBW)	33, 41.76 or 60
Channel bandwidth (MHz)	8
Modulation	QPSK, 16-QAM
Antenna gain (dBi)	13
Mobile antenna height (m)	1.5
Transmitter antenna height (m)	300
Receiver sensitivity (dB(μV/m))	76
Protection ratio for continuous interference (dB)	26

7.3 Protection criteria

Recommendation ITU-R SM.851 provides the minimum field strength values to be protected at 10 m above ground level for the broadcasting service (television) and the wanted field strength values from which they are derived. Similarly, the ETSI standards for DVB-T and DVB-H provide the required field strengths needed by the two systems to be protected from harmful interference. Table 29 provides these field strengths.

TABLE 29

Field strength values of the broadcasting systems

Broadcasting system	Field strength value	
Analog television	Field strength to be protected (dB(µV/m)) at edge of coverage area (50% of time, 90% of locations)	53[(1)]
	Wanted field strength (dB(µV/m)) at edge of coverage area (50% of time, 50% of locations) from Recommendation ITU-R BT.417	65
DVB-T	Field strength to be protected (dB(µV/m)) at a *C*/*I* of 20 dB at 500 MHz with 95% coverage	53
DVB-H	Field strength to be protected (dB(µV/m)) at a *C*/*I* of 20dB at 500 MHz with 99% coverage	76

(1) A more restricted value of 53 dB µV/m is used in the sharing study. However, a value of 65 µV/m is used in North America.

Table 30 provides the required necessary protection ratios that were this sharing study.

TABLE 30

Protection ratios of the broadcasting systems

Broadcasting system	Protection ratio	
TV	Tropospheric interference	50 dB
	Continuous interference	50 dB + 8 dB (58 dB)
DVB-T	One CDMA carrier/channel	10 dB
	Three CDMA carrier/channel[(1)]	18 dB
DVB-H	One CDMA carrier/channel	10 dB
	Three CDMA carrier/channel[(2)]	18 dB

(1) Since the out-of-band emissions from a typical IMT system deployment in the 450-470 MHz will cover the complete TV channel, a value of 18 dB is used in the sharing study.

(2) DVB-H protection ratio values are assumed to be the same as the DVB-T values.

7.4 Methodology

Since the CDMA450 systems and the various broadcasting systems operate in adjacent bands, an adjacent channel study was performed between the two systems. The study estimated the amount of unwanted spurious emissions falling within the receiver of the victim system. The protection criterion of the different services, as specified in § 7.3, was then used to calculate the amount of "tolerable" interference by the victim system. The difference between the unwanted spurious emissions and the tolerable interference levels provided a minimum path loss budget, which with the aid of the appropriate path loss models (see § 7.5) provided the minimum separation distance that is needed between the interfering and victim systems to operate without causing harmful interference to each other.

7.5 Propagation model

Recommendation ITU-R P.1546 was used to estimate the propagation loss and quantify the attenuation due to the path loss. Graphs pertaining to the land-path and representing field strength values for 10% of the time was used in the study. Where applicable, the graphs were interpolated, as specified in the ITU-R P.1546, to adjust for antenna height, operational frequency, and distance.

In some cases, the calculated separation distance was less than 1 km, and the results are simply documented as "< 1 km". This is because the path loss model specified in the Recommendation ITU-R P.1546 can only be used for calculating separation distances that are greater than 1 km. For results that were less than 1km there will be minimal interference between the broadcasting and the CDMA450 systems because their base station antennas are likely to be separated by a distance greater than 1 km.

For emissions from the mobile handsets, separation distances predicted from ITU-R P.1546 are usually less than 1 km, so instead of using ITU-R P.1546, a two-slope propagation loss model, as specified in Recommendation ITU-R P.1411, was used. As the models of the two Recommendations are not aligned at predicting the path loss around 1km, caution should be used when comparing the results obtained by ITU-R P.1411 with those of ITU-R P.1546.

7.6 Interference from CDMA450 base station to the broadcasting service

7.6.1 Results

In evaluating the potential of interference from CDMA450 base station to the broadcasting systems, three CDMA450 carriers were assumed to be operating in the 450-470 MHz band with the third carrier deployed at 465.85-467.1 MHz. The first 8 MHz channel of the TV, DVB-T, and DVB-H systems was assumed to be deployed at 470-478 MHz. Table 31 provides the separation distances that are needed between the CDMA450 base station transmitting on 465.85-467.1 MHz and the broadcasting systems to permit them to operate without causing harmful interference to each other.

TABLE 31

CDMA450 Base station interfering with broadcasting service

CDMA450	Broadcasting service		
	TV	DVB-T	DVB-H
Distance (km) – ITU-R P.1546	21.01	3.76	< 1 km 2.058 (ITU-R P.1411)

The results above indicate that sharing between the CDMA450 base stations and the DVB-T and DVB-H broadcasting systems is feasible even without providing any additional mitigation between the two systems. For the case of TV, additional mitigation needs to be provided to enable to two systems to operate in adjacent spectrum.

7.6.2 Results with mitigation techniques

In order to reduce the separation distances required between the CDMA450 base stations and the broadcasting systems, operators could use a number of different mitigation techniques. One such technique is to place a filter in front of the CDMA450 base station that will further reduce the amount of unwanted emission falling into the receive bands of the broadcasting systems. Table 32 provides the amount of separation needed between the two systems as a result of using the above mentioned mitigation technique. Even though, as suggested by the results in § 7.6.1, no mitigation is needed between the CDMA450 base stations and the DVB-T and DVB-H systems the Table below provides the distances corresponding to the DVB-T/H systems as a result of applying filtering.

TABLE 32

CDMA450 base station interfering with broadcasting service – Improvement in CDMA450 base station transmitter mask

CDMA450 with filters	**Broadcasting service**		
	TV	**DVB-T**	**DVB-H**
Distance at 10 dB (km)	12.76	1.91	< 1 km 0.706 (ITU-R P.1411)
Distance at 15 dB (km)	9.91	1.34	< 1 km 0.397 (ITU-R P.1411)
Distance at 20 dB (km)	7.62	< 1 km	< 1 km 0.223 (ITU-R P.1411)
Distance at 25 dB (km)	5.76	< 1 km	< 1 km 0.125 (ITU-R P.1411)
Distance at 30 dB (km)	4.26	< 1 km	< 1 km 0.071 (ITU-R P.1411)
Distance at 35 dB (km)	3.09	< 1 km	< 1 km 0.040 (ITU-R P.1411)
Distance at 40 dB (km)	2.20	< 1 km	< 1 km 0.022 (ITU-R P.1411)

In addition to using filters as a means to provide the necessary mitigation, several other techniques in combination with filtering could be used. Table 33 provides the separation distances required between CDMA450 base stations and TV systems, as a result of using some additional mitigation techniques along with filtering.

TABLE 33

CDMA450 base station interfering with broadcasting service – Applying mitigation

Type of mitigation technique applied	Distance (km) and amount of filtering (dB)						
	10	**15**	**20**	**25**	**30**	**35**	**40**
Two CDMA450 active carriers. The first carrier now at 464.6-465.85 MHz. First TV channel at 470-478 MHz, resulting in a guard band of 5.4 MHz	11.17	8.63	6.58	4.93	3.60	2.58	1.82
Three CDMA450 active carriers and the first TV channel deployed at 478-486 MHz, resulting in a guard band of 10.9 MHz	7.88	5.98	4.43	3.22	2.30	1.62	1.13
Three CDMA450 active carriers and the first TV channel deployed at 486-494 MHz, resulting in a guard band of 18.9 MHz	5.07	3.72	2.67	1.89	1.32	< 1 km	< 1 km
CDMA450 antenna gain reduced to 7.5 dBi (10 dB down from typical value). First TV channel at 470-478 MHz	10.17	7.83	5.93	4.40	3.19	2.27	1.6

7.6.3 Conclusions

The results above indicate that CDMA450 base stations and TV can successfully operate in adjacent spectrum if the appropriate mitigation techniques can be applied between the two systems. By using filters as a means to provide attenuation, the separation distances between CDMA450 base stations and the TV systems can be reduced significantly. Additionally, using any of the mitigation techniques specified in Table 33 will also enable sharing between CDMA450 base stations and the TV systems by reducing the separation distances needed by the two systems. Operators of the two systems could also use filtering jointly with the mitigation techniques mentioned in Table 33 to further reduce the distances between CDMA450 base station and TV systems. As was shown in § 7.6.1 sharing between CDMA450 base stations and DVB-T/H is feasible without the use of any mitigation techniques.

7.7 Interference from CDMA450 mobile stations to the broadcasting service

7.7.1 Results

The potential for interference from CDMA450 mobile stations into the broadcasting systems was evaluated assuming direct main-beam coupling, yielding a worst-case analysis. Three CDMA450 carriers were assumed to be operating in the 450-470 MHz band with the third carrier deployed at 455.85-457.1 MHz. The first 8 MHz channel of the TV, DVB-T, and DVB-H broadcasting systems was deployed at 470-478 MHz. Since a 13 MHz natural separation exists between the mobile transmit band and the first adjacent broadcast system channel, the potential of CDMA450 mobile interfering with the broadcast system is reduced significantly. To quantify the amount of separation needed, Recommendation ITU-R P.1546 was used which results in separation distances between the two systems of less than 1 km. Therefore, the two-slope propagation model as specified in Recommendation ITU-R P.1411 was used in this case. In addition, CDMA450 mobile stations were assumed to be complying with the stringent spurious emission level of <-76 dBm/MHz or –106 dBW/MHz, as specified in the CDMA450 technology standards. Table 34 provides the separation distances that are needed between the CDMA450 mobile stations and the broadcasting systems to operate in adjacent spectrum without causing harmful interference to the broadcast system.

TABLE 34

CDMA450 mobile station interfering with broadcasting systems

CDMA450	**Broadcasting service**		
	TV	**DVB-T**	**DVB-H**
Distance (km) – ITU-R P.1411	0.372	0.037	0.003

The results in the Table 34 indicate that small separation distances are needed between the CDMA450 mobile stations and the broadcasting systems to enable them to operate in adjacent bands without causing harmful interference.

7.7.2 Results with mitigation techniques

Filters could be placed at the transmitter of the CDMA450 mobile stations that would reduce the amount of unwanted emissions falling into the broadcasting bands. Table 35 provides the distances needed between the two systems as a result of using the above mentioned mitigation technique.

TABLE 35

CDMA450 mobile station interfering with broadcasting systems – Improvement in CDMA450 mobile station masks

CDMA450 with filters	**Broadcasting service**		
	TV	**DVB-T**	**DVB-H**
Distance at 10 dB (km) – (ITU-R P.1411)	0.209	0.012	0.001
Distance at 15 dB (km) – (ITU-R P.1411)	0.157	0.007	<0.001
Distance at 20 dB (km) – (ITU-R P.1411)	0.118	0.004	<0.001
Distance at 25 dB (km) – (ITU-R P.1411)	0.082	0.002	<0.001
Distance at 30 dB (km) – (ITU-R P.1411)	0.046	0.001	<0.001
Distance at 35 dB (km) – (ITU-R P.1411)	0.026	0.001	<0.001
Distance at 40 dB (km) – (ITU-R P.1411)	0.015	<0.001	<0.001

7.7.3 Conclusion

As expected, the results above indicate that CDMA450 mobile stations and broadcasting systems can successfully operate in adjacent spectrum, if filters that would reduce the unwanted emissions from the CDMA450 mobile stations can be provisioned. Filtering in the amount of 10 dB to 20 dB will enable successful sharing between CDMA450 mobile stations and the broadcasting systems. Other possible mitigation technique, such as the use of a guard band or frequency separation between the two systems could also be used. Using guard bands alone would obviate the need to use filtering at the transmitter of the CDMA450 mobile stations because of the small separation distances needed without the use of filtering, as shown in Table 34.

7.8 Interference from broadcasting service base station to CDMA450 mobile station and base station

7.8.1 Results

To evaluate the potential of interference from broadcasting system base stations to CDMA450 mobile and base stations the following was assumed. The victim CDMA450 carrier, corresponding to the mobile transmit, was deployed at 455.85-457.1 MHz and the corresponding base station transmit carrier, was deployed at 465.85-467.1 MHz. Additionally, the first 8 MHz channel of the broadcasting system was deployed at 470-478 MHz. The Broadcasting systems were assumed to be transmitting at powers of 2 kW ERP, 15 kW ERP and a high power of 1 MW ERP. In the study, the broadcasting systems were assumed to comply with the spurious emissions specified in Recommendation ITU-R SM.329. ITU-R SM.329 specifies a flat spurious emission mask 20 MHz from the center frequency of the broadcasting system, i.e. at 474 MHz.

A high broadcasting system power emission of 1 MW ERP amounts to an unwanted power level of 12 mW/100 kHz falling outside of the 20 MHz from the center of the first broadcasting channel. Using a typical 15 dBi antenna gain, 12 mW/100 kHz amounts to an interfering power of 3.8 W falling into the CDMA450 mobile transmit band. For the emissions falling into the base transmit band the same unwanted power level, i.e. 3.8 W, is assumed to be present. These assumptions give a very conservative analysis of the amount of separation needed between the broadcasting system and the CDMA450 mobile and base station systems. To quantify the amount of separation distances needed between the two systems, Recommendation ITU-R P.1546 is used. Even though a 13 MHz of natural separation exists between the mobile transmit band and the first adjacent broadcast band, large separation distances are needed between the two systems. This is due to the very high transmitting power of the broadcasting systems and the high level of spurious emission power (3.8 W) falling into the CDMA450 mobile transmit band. For the same reasons, large separation distances between the base stations of the broadcasting and CDMA450 base station systems are needed. Table 36 shows the amount of separation distances needed between the broadcasting stations and the CDMA450 mobile and base stations.

TABLE 36

Broadcasting system interfering with CDMA450 mobile and base stations

Broadcasting system Typical transmit power (ERP)	Distance (km)	
	CDMA450 mobile station	CDMA450 base station
2 kW	20.36	43.77
15 kW	31.21	59.79
1 MW	49.91	92.12

As expected, the separation distances between the broadcasting systems and CDMA450 systems are quite large. This is due to the very high transmit powers of the broadcasting stations and a high level of broadcast spurious emission falling into the mobile transmit and receive bands. The results suggest that in order to reduce the amount of separation needed between the broadcasting and CDMA450 mobile and base systems the unwanted spurious emissions of the broadcasting systems need to be reduced.

7.8.2 Results – with mitigation techniques

Mitigation in the form of filters placed at the broadcasting base station systems that reduce the amount of unwanted spurious emissions falling into the CDMA450 mobile transmit and receive bands is applied. Note that the amount of reduction applied is to the emission masks specified in ITU-R SM.329. Table 37 provides the amount of separation distance needed between the two systems, as a result of applying the above-mentioned technique. Care should be taken in applying the results of the Table to the actual systems deployed, as these systems might already be complying with very strict emission masks and thus may not require any mitigation.

TABLE 37

Broadcasting system interfering with CDMA450 mobile and base stations results with mitigation

Broadcasting system Typical transmit power (ERP)	Distance (km)		Amount of reduction to ITU-R SM.329 unwanted emissions (dB)
	CDMA450 mobile station	CDMA450 base station	
2 kW	10.66	29.11	10
15 kW	19.01	41.78	
1 MW	34.05	64.17	
2 kW	4.67	17.33	20
15 kW	9.7	27.47	
1 MW	21.22	45.09	
2 kW	1.89	8.57	30
15 kW	4.18	16.07	
1 MW	11.31	30.19	
2 kW	< 1 km	3.64	40
15 kW	1.67	7.75	
1 MW	5	18.17	
2 kW	< 1 km	< 1 km	60
15 kW	< 1 km	1.28	
1 MW	< 1 km	3.91	

7.8.3 Conclusion

The results in the Table 37 indicate that broadcasting base stations and CDMA450 mobile and base stations can successfully operate in adjacent spectrum, if the unwanted spurious emissions from the broadcasting base stations can be reduced. Reducing the unwanted emissions by 60 dB will enable successful sharing between the broadcasting base stations and the CDMA450 mobile and base stations. In addition to lowering the spurious emissions, several other mitigation methods such as reducing the transmit antenna gains, avoiding main beams of the two antennas (above or below the main lobe), adding a guard band between the two systems could be used to further lower the separation distances required between the two systems.