

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 μ s	831.48 km	0.8 km/60 dB	41.7 km	1.3 km/30 dB
	5 000 m, 2 MW, 1 μ s	125 849 km	125 km/60 dB	50.83 km	1.6 km/30 dB
PLRS radars	10 m, 0.4 W, 824.6 μ s	1 km	No mitigation needed	< 1 km	No mitigation needed
	10 m, 125W, 824.6 μ s	6.15 km	1 km/ 30 dB	1 km	No mitigation needed
Wind profiler radars	3 m, 16 kW, 6.67 μ s	< 1 km	No mitigation needed	< 1 km	No mitigation needed
	3 m, 16 kW, 1.67 μ s	< 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.
- Recommendation 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⁾		
1 st 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
2 nd adjacent channel	−60 dBc/30 kHz (macro BS) at 1.98 MHz to 4 MHz	Less stringent of −54 dBc/30 kHz or −54 dBm/1.23 MHz at 1.98 MHz to 4 MHz
3 rd adjacent channel	−36 dBm/1kHz at 4MHz to 6.4 MHz	−36 dBm/100 kHz at >4 MHz
4 th adjacent channel	−36 dBm/10 kHz at 6.4 MHz to 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 band¹.

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	<i>Search</i> : 100-350 kHz linear FM chirp; <i>Track</i> : 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 electronically 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 −141 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).

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

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:

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

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 than 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.