Radiocommunication Study Groups

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Annex 31 to Joint Task Group 4-5-6-7 Chairman's Report

WORKING DOCUMENT TOWARD A PRELIMINARY DRAFT NEW REPORT ITU-R M.[RADAR2900]

Studies on the impact of IMT use on radar systems in the frequency band 2 900-3 100 MHz

1 Overall consideration of results of studies

The attachments to this document represent submissions to JTG 4-5-6-7, and have not been reviewed in detail or agreed.

Several studies have been carried out with respect to the frequency band 2 900-3 100 MHz. All of the studies show, based on the parameters provided by [the relevant working parties/ITU-R], that within the same geographical area co-frequency operation of mobile broadband systems and radar is not feasible. As a result, globally harmonised usage of the 2 900-3 100 MHz frequency band or a portion thereof by the mobile service for the implementation of IMT may not be possible.

Local circumstances, such as; ubiquity of radar deployments and additional mitigation are, when taken together, the single most critical factor as to whether IMT can operate in particular geographic areas. The attachments to this document make no conclusion as to the complexity, practicability or achievability of the applied mitigations as discussed. Those decisions would have to be made at a national level under the current regulatory framework.

Based on the same parameters provided by the relevant working parties, compatibility also cannot be achieved in the same geographic area when operations including frequency offset are considered (i.e., when the occupied bandwidth of the IMT signal and the occupied bandwidth of the radar do not overlap). However several studies presented showed that compatibility may be achievable subject to a frequency offset and geographic separation if certain mitigation techniques can be implemented including the modification of mobile and radar parameters from those provided by the relevant expert groups within the ITU. This might offer possibilities for the introduction mobile services into the 2 900-3 100 MHz frequency band, with due consideration of the future deployment of radar. It should be noted that those mitigation techniques have not at this point been determined as practical by the expert working parties.

The size of the frequency offset and geographical separation depends on the mitigation technique assumptions made in the studies and the acceptability of those assumptions to an administration and its neighbouring administrations (i.e., those within several hundred kilometres, where no mitigation whatsoever, is employed). Coordination of IMT stations with the neighbouring administrations shall ensure protection of radars operating co-frequency and/or on adjacent frequencies to the proposed IMT stations.

It should also be noted that all of the studies which concluded it is feasible to introduce IMT systems in the 2 900-3 100 MHz frequency band require modification of the IMT and radar equipment. Such studies also suggest segmentation in accordance with Recommendation ITU-R SM.1132 which may involve replanning radar systems as necessary to remove radars from a portion of the band to provide sufficient spectrum to accommodate the IMT channel plus the frequency offset. Any consideration of radar replanning must take into account that some administrations make use of radars that operate across the band between 2 700-3 100 MHz.

Attachment 1: “Co-existence of mobile broadband systems and radars in the frequency band 2 900-3 100 MHz”

Attachment 2: “Sharing between IMT-Advanced and radiodetermination systems in the band 2 900-3 100 MHz“

Attachment 3: “Studies on the impact of IMT interference on radar systems with pulse compression operating in the frequency range 2 700-3 100 MHz”

ATTACHMENT 1

Co-existence of mobile broadband systems and radars in the frequency band 2 900-3 100 MHz

1 Introduction

This initial study investigates, based on the relevant ITU-R Recommendations where necessary supplemented by other freely available data, the potential for introducing mobile broadband systems, with respect to WRC-15 agenda item 1.1, into the frequency bands 2 900–3 100 MHz

This update includes maritime radar analysis using the Recommendation ITU-R P.452 propagation model.

2 Background

The frequency band 2 900-3 100 MHz is allocated on a primary basis to the radiolocation and radionavigation service on a primary basis and is used various radar systems. RR No. **5.426** limits aeronautical radionavigation use, in this band, to ground based.

3 References/Study Work

The technical characteristics under consideration are taken from ITU-R Recommendations:

- Recommendation ITU-R SM.329-10 – Unwanted emissions in the spurious domain.
- Recommendation ITU-R M.1460 Technical and operational characteristics and protection criteria of radiodetermination radars in the 2 900-3 100 MHz band.
- Recommendation ITU-R M.1461-1 – Procedures for determining the potential for interference between radars operating in the radiodetermination service and systems in other services.
- Recommendation ITU-R M.1464-1 – Characteristics of radiolocation radars, and characteristics and protection criteria for sharing studies for aeronautical radionavigation and meteorological radars in the radiodetermination service operating in the frequency band 2 700-2 900 MHz.
- Recommendation ITU-R SM.1541-4 – Unwanted emissions in the out-of band domain.
- Recommendation ITU-R M.1849 – Technical and operational aspects of ground-based meteorological radars.
- Recommendation ITU-R M.1851 – Mathematical models for radiodetermination radar systems antenna patterns for use in interference analyses.
- Recommendation ITU-R P.452-14 - Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz

Characteristics of the mobile broadband systems are based on those for IMT systems operating in the frequency range 2 500-2 690 MHz as contained in:

- Recommendation ITU-R SM.329-10 – Unwanted emissions in the spurious domain.
- Recommendation ITU-R SM.1541-4 – Unwanted emissions in the out-of band domain.
- Recommendation ITU-R F.1336-2 – Reference radiation patterns of omnidirectional, sectorial and other antennas in point-to-multipoint systems for use in sharing studies in the frequency range from 1 GHz to about 70 GHz.
- Report ITU-R M.2039-2 – Characteristics of terrestrial IMT-2000 systems for frequency sharing/interference analyses.

4 Technical characteristics

Radar

The frequency band 2 900-3 100 MHz is used by different types of radars evenly accommodated in the whole band. Characteristics of those radars may be found in Recommendations ITU-R M.1460 and ITU-R M.1464. Tables 1 to 4 below show extracted from those Recommendations technical characteristics of aeronautical radionavigation radars and meteorological radars. Table 2 presents technical characteristics of government[1] radiolocation radars reflected in the above Recommendations ITU-R. Tables 3 and 4 contain technical characteristics of ship-borne and land-based radiolocation radars as extracted from Recommendation ITU-R M.1460. The above mentioned technical characteristics were used for calculations.

TABLE 1

Technical characteristic of aeronautical radionavigation radars and meteorological radars operating in the frequency band 2 700-3 100 MHz (as described in Recommendation ITU-R M.1464)

	Aeronautical radionavigation radars					**Meteorological radars**	
Type	**Radar A**	**Radar B**	**Radar C**	**Radar E**	**Radar F**	**Radar G M.1849 Radar-1**	**Radar H M.1849 Radar-2**
Operation frequency range, MHz	2 700 - 3 100					2 700-3 000	2 700-2 900
Receiver gain, Grec, dBi	33.5	33.5	34	34.3	33.5	45.7	38.0
Receiver noise figure, NF, dB	4	4	3.3	2.1	2.0	2.1	9
Receiver pass band, ΔF, kHz	5 000	653	15 000	1 200	4 000	630	500
Protection criterion, I/N, dB	-10						

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[1] The term government is used here and throughout the document. However it should be recognised that a number of the ITU-R Recommendations referenced in the documented studies, use an alternative term to indicate government use.

TABLE 2

Technical characteristic of generic military radiolocation radars operating in the frequency band 2 700-3 400 MHz (as described in Recommendation ITU-R M.1464)

Type	**Radar I**	**Radar J**
Operation frequency range, MHz	2 700-3 100	2 700-3 100
Receiver gain, Grec, dBi	33.5	40
Receiver noise figure, NF, dB	2	1.5
Receiver pass band, ΔF, kHz	3 500	10 000
Protection criterion, I/N, dB	-6	

TABLE 3

Technical characteristics of ship-borne radiolocation radars and land-based radiolocation radars operating in the frequency band 2 900-3 100 MHz (as described in Recommendation ITU-R M.1460)

	Ship-borne radiolocation radars	**Land-based radiolocation radars**		
Type	**Radar No. 1**	**Radar No. 4**	**Radar No. 5**	**Radar No. 6**
Operation frequency range, MHz	2 910-3 100.5	2 905-3 080	2 901.5-3 098.4	2 900-3 100
Receiver gain, Grec, dBi	37	41	38	36.7
Receiver noise figure, NF, dB	–	–	–	–
Receiver noise temperature, Tn, K	–	–	–	–
Receiver pass band ΔF, kHz	500	350	1 600	1 100
Noise level, dBm	–109	–116	–105	–105
Protection criterion, I/N,	–6			

Radar details from the latest revision of Recommendation ITU-R M.1460:

TABLE 4

Characteristics of shipborne radiolocation radars operating in the frequency band 2 900-3 100 MHz

Characteristics	**Units**	**Radar No. 3**	**Radar No 3A**	**Radar No. 3B**
Overall tuning range	MHz	2 910-3 100.5	2 900-3 100	2900- 3100
Antenna gain	dBi	37	40	27.5
Antenna beamwidths	degrees	Azimuth: 1.9 Elevation: 2.25	Azimuth: 1.1 to 5.0	2 in Azimuth 26.5 in Elevation
Rx IF bandwidth	MHz	Long-range: 0.080 High-angle: 0.174 High-data-rate and MTI: 0.348	10-30	15, 0.3, and 0.045

Mobile broadband systems

[The third JTG 4-5-6-7 meeting discussed technical characteristics of IMT systems in different frequency bands. Those characteristics compiled by WP 5D were presented in Document 4-5-6-7/236. The document was used for preparing Annex 2 to JTG 4-5-6-7 Chairman's Report (Document 4-5-6-7/242) which contained technical and operational characteristics presented by relevant ITU-R Working Parties for using in studies related to feasibility of compatibility and frequency sharing. *Note cannot be referred to in this manner in a DNR*]

We note that Recommendation ITU-R M.1580-4 and 3GPP TS 36.104 contain emission limits for certain frequency ranges that are substantially below the generic spurious emissions limit of -30 dBm/MHz. It is likely that a similar reduction would be feasible for the 2 700-2 900 MHz frequency band, which would improve coexistence.

It should be noted that in case of parameters having a range of values, 'typical' values should be used in sharing studies, where applicable.

TABLE 5

IMT-Advanced specification-related parameters

		IMT-Advanced			
	Duplex mode	**FDD**		**TDD**	
No.	Parameter	Base station	Mobile station	Base station	Mobile station
1	Channel bandwidth (MHz)(1)	1.4, 3, 5, 10, 15 and 20		1.4, 3, 5, 10, 15 and 20	
2	Signal bandwidth (MHZ)(1)	1.08, 2.7, 4.5, 9, 13.5 and 18		1.08, 2.7, 4.5, 9, 13.5 and 18	
3	Transmitter characteristics				
3.3	Power dynamic Range (dB)	(2)	63(18)	(2)	63(18)
	Polarization discrimination (dB)	3(19)	0	3(19)	0
3.4	Spectral mask	(3) (17)	(4) (17)	(3) (17)	(4) (17)
3.5	ACLR	(5)(17)	(6)(17)	(5)(17)	(6) (17)
3.6	Maximum output power	(7)	(8)	(7)	(8)
3.7	Spurious emissions	(15), (17)	(16), (17)	(15), (17)	(16), (17)
4	Receiver characteristics				
4.1	Noise Figure	5 dB	9 dB	5 dB	9 dB
4.2	Sensitivity	(9)	(10)	(9)	(10)
4.3	Blocking response	(11)	(12)	(11)	(12)
4.4	ACS	(13)	(14)	(13)	(14)

Notes to the table

(1) See 3GPP Document TS 36.101 v.11.2.0, §5.6. Signal bandwidth in MHz corresponds to "Transmission bandwidth configuration*0.180".

(2) See 3GPP Document TS 36.104 v.11.2.0, § 6.3.2.1.

(3) See 3GPP Document: TS 36 104 v 11.2.0, § 6.6.3.

(4) See 3GPP Document: TS 36 101 v 11.2.0, § 6.6.2.1, 6.6.2.1A, 6.6.2.2 and 6.6.2.2A describe UE spectrum emissions masks for different channel bandwidths. In case multiple UEs are transmitting simultaneously on the same carrier they will share the available radio blocks. As the actual transmission bandwidth is thus decreased the unwanted emissions performance might be improved. This may be taken into account during sharing analysis when measurements or detailed models are available.

(5) See 3GPP Document TS 36.104 v.11.2.0, § 6.6.2.

(6) See 3GPP Document TS 36.101 v.11.2.0, § 6.6.2.3.

(7) See 3GPP Document TS 36.104 v.11.2.0, § 6.2.

(8) See 3GPP Document TS 36.101 v.11.2.0, § 6.2.

(9) See 3GPP Document TS 36.104 v.11.2.0, § 7.2.

(10) See 3GPP Document TS 36.101 v.11.2.0, § 7.3.

(11) See 3GPP Document TS 36.104 v.11.2.0, § 7.6.

(12) See 3GPP Document TS 36.101 v.11.2.0, § 7.6 and § 7.7.

(13) See 3GPP Document TS 36.104 v.11.2.0, § 7.5.

(14) See 3GPP Document TS 36.101 v.11.2.0, § 7.5.

(15) See 3GPP Document TS 36.104 v.11.2.0, § 6.6.4.

(16) See 3GPP Document TS 36.101 v.11.2.0, § 6.6.3.

(17) These unwanted emission limits are the upper limits from SDO specifications for laboratory testing with maximum transmitting power. It is assumed that when the in-band transmitting power is reduced by x dB through power control, the unwanted emission levels would be reduced by x dB in consequence in the coexistence simulations.

(18) See 3GPP Document TS 36.101 v.11.2.0, § 6.3.

(19) Typically base stations today use cross-polarized antennas (two sets of dipoles slanted at ±45° against the horizontal plane), usually transmitting on one of the two polarisation paths (either +45° or −45° for a given frequency) whilst receiving on both paths (to achieve polarisation diversity). Such signals provide an isolation of 3 dB against both horizontally and vertically polarized signals (e.g. DVB-T signals) due to cross-polarisation discrimination.

TABLE 6

Deployment-related parameters for bands between 1 and 3 GHz

	Macro rural	**Macro suburban**	**Macro urban**	**Small cell outdoor / Micro urban**	**Small cell indoor / Indoor urban**
Base station characteristics / Cell structure					
Cell radius / Deployment density (for bands between 1 and 2 GHz)	> 3 km (typical figure to be used in sharing studies 5 km)	0.5-3 km (typical figure to be used in sharing studies 1 km)	0.25-1 km (typical figure to be used in sharing studies 0.5 km)	1-3 per urban macro cell[2] <1 per suburban macro site	depending on indoor coverage/ capacity demand
Cell radius / Deployment density (for bands between 2 and 3 GHz)	> 2 km (typical figure to be used in sharing studies 4 km)	0.4-2.5 km (typical figure to be used in sharing studies 0.8 km)	0.2-0.8 km (typical figure to be used in sharing studies 0.4 km)	1-3 per urban macro cell[4] <1 per suburban macro site	depending on indoor coverage/ capacity demand
Antenna height	30 m	30 m (1-2 GHz) 25 m (2-3 GHz)	25 m (1-2 GHz) 20 m 2-3 GHz)	6 m	3 m
Sectorization	3-sectors	3-sectors	3-sectors	single sector	single sector
Downtilt	3 degrees	6 degrees	10 degrees	n.a.	n.a.
Frequency reuse[3]	1	1	1	1	1
Antenna pattern	Recommendation ITU-R F.1336 Annex 10 (see "Antenna Pattern" section) $k_a = 0.7$ $k_p = 0.7$ $k_h = 0.7$ $k_v = 0.3$ Horizontal 3 dB beamwidth: 65 degrees Vertical 3 dB beamwidth: determined from the horizontal beamwidth by equations in Recommendation ITU-R F.1336. Vertical beamwidths of actual antennas may also be used when available.			Recommendation ITU-R F.1336 omni	
Antenna polarization	linear / +- 45 degrees	linear / +- 45 degrees	linear / +- 45 degrees	linear	Linear
Indoor base station deployment	n.a.	n.a.	n.a.	n.a.	100 %
Indoor base station penetration loss	n.a.	n.a.	n.a.	n.a.	20 dB (horizontal) P.1238, Table 3 (vertical)
Below rooftop base station antenna deployment	0 %	0 %	30 % (1-2 GHz) 50 % (2-3 GHz)	100 %	n.a.
Feeder loss	3 dB	3 dB	3 dB	n.a	n.a

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[2] Outdoor small cells would typically be deployed in very limited areas in order to provide local capacity enhancement. Within these areas, the outdoor small cells would not need to provide contiguous coverage since there would typically be an overlaying macro network present.

[3] If the IMT network consists of three cell layers – macro cells, small outdoor cells and small indoor cells – they will not all use the same carrier. Two layers may use the same carrier, although separate carriers in the same or different bands are also possible.

	Macro rural	**Macro suburban**	**Macro urban**	**Small cell outdoor / Micro urban**	**Small cell indoor / Indoor urban**
Base station characteristics / Cell structure					
Maximum base station output power (5/10/20 MHz)	43/46/46 dBm	43/46/46 dBm	43/46/46 dBm	35 dBm	24 dBm
Maximum base station antenna gain	18 dBi	16 dBi	16 dBi	5 dBi	0 dBi
Maximum base station output power (e.i.r.p.)	58/61/61 dBm	56/59/59 dBm	56/59/59 dBm	40 dBm	24 dBm
Average base station activity	50 %	50 %	50%	50 %	50 %
Average base station power/sector	55/58/58 dBm	53/56/56 dBm	53/56/56 dBm	37 dBm	21 dBm

3.2.3 User equipment characteristics

User terminal characteristics	**Macro rural environment**	**Macro suburban environment**	**Macro urban environment**	**Small cell outdoor/micro urban environment**	**Small cell indoor/indoor urban environment**
Indoor user terminal usage	50 %	70 %	70 %	70 %	100%
Indoor user terminal penetration loss	15 dB	20 dB	20 dB	20 dB	20 dB
User terminal density in active mode	0.17 / 5MHz/km^2	2.16 / 5MHz/km^2	3 / 5MHz/km^2	3 / 5MHz/km^2	Depending on indoor coverage/ capacity demand
Maximum user terminal output power	23 dBm	23 dBm	23 dBm	23 dBm	23 dBm
Average user terminal output power[4]	2 dBm	–9 dBm	–9 dBm	9 dBm	–9 dBm
Typical antenna gain for user terminals	–3 dBi	–3 dBi	–3 dBi	–3 dBi	–3 dBi
Body loss –	4 dB	4 dB	4 dB	4 dB	4 dB

5 Analysis

Editorial note: The following single interferer/victim scenarios for both **co and adjacent channel** situations are proposed to be studied:

- – mobile base station impact on radar;
- – mobile user equipment impact on radar;
- – radar impact on mobile base station;

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[4] According to JTG5-6/180 Annex 2 (except for small cell indoor scenario, which was not covered in that document).

– radar impact on mobile user equipment.

The applied protection criteria and radar parameters, if not specified in section 3, and other assumptions should be contained in the sections containing the specific sections.

Main body: Assumption, methodology and summary of results,

Shown in Tables 1 – 3 characteristics of radar receivers were used for estimating an acceptable interference level at radar receiver front end. The acceptable interference level was calculated using the following equation:

$$I_{acc} = \left(I/N\right)_{acc} + kT_N \Delta F \, ,$$

where:

I_{acc} - acceptable level of noise at receiver front end, dBW;

$\left(I/N\right)_{acc}$ - acceptable interference-to-noise ratio, dB;

k - Boltzmann constant;

$T_N = 293(10^{\frac{NF}{10}} - 1)$ - receiver noise temperature, K;

NF – receiver noise figure, dB;

ΔF - receiver passband, Hz.

The obtained value of acceptable noise level was used for estimating acceptable interference field strength based on the following equation:

The evaluation of the field strength, E_{acc}, is necessary because propagation model Recommendation ITU-R P.1546 requires it. It is recommend that E_{acc} Equation may be replaced with NTIA TM 10-469 Equation 21 or Equation 40 of Recommendation ITU-R P.1546-5.

$$E_{acc} = I_{acc} - G_{rec} - 10\lg(\lambda^2 / 960\pi^2) + 120 \, ,$$

where:

E_{acc} - acceptable level of interference field strength, dB(μV/m);

G_{rec} - radar antenna gain in a receiving mode, dB;

λ - operation wavelength, m.

Estimated values of acceptable interference power and associated values of maximum admitted interference field strength for the radar types under consideration are shown in Tables 7 - 9.

TABLE 7

Estimates of separation distances for radars operating in the frequency band 2 700-3 100 MHz without accounting tropospheric scattering

	Radar A	**Radar B**	**Radar C**	**Radar E**	**Radar F**	**Radar GM.1849 Radar-1**	**Radar H M.1849 Radar-2**
Receiver noise temperature, Tn, K	438	438	330	180	170	180	2014
Receiver thermal noise, dBW	–135	–144	–132	–145	–140	–148	–139
Acceptable interference power, dBW	–145	–154	–142	–155	–150	–158	–149
Acceptable interference field strength, dB(μV/m)	–5.9	–14.7	–2.8	–16.7	–11.0	–30.9	–13.7

	Radar A	**Radar B**	**Radar C**	**Radar E**	**Radar F**	**Radar GM.1849 Radar-1**	**Radar H M.1849 Radar-2**
	Separation distances						
Interference bandwidth, MHz	5; 10						
$e.i.r.p._{eff}$, dBW	25.0	16.2	25.0	18.8	24.0	16.0	15.0
Land path, km	193	193	165	231	227	[>324]	[172]*
Sea path, km	572	572	534	631	624	[>773]	[545]*
Interference bandwidth, MHz	20						
$e.i.r.p._{eff}$, dBW	22.0	13.1	22.0	15.8	21.0	13.0	12.0
Land path, km	165	165	139	204	203	[>299]	[144]*
Sea path, km	526	523	506	589	586	[>728]	[509]*

[Note *: The separation distances for Radars G and H have not been confirmed at this time and need further evaluation]

TABLE 8

Estimates of separation distances for radars operating in the frequency band 2 700-3 100 MHz without accounting tropospheric scattering

	Radar I	**Radar J**
Receiver noise temperature, Tn, K	170	120
Receiver thermal noise, dBW	–141	–138
Acceptable interference power, dBW	–147	–144
Acceptable interference field strength, dB(μV/m)	–7.5	–11.0
	Separation distances	
Interference bandwidth, MHz	5	
$e.i.r.p._{eff}$, dBW	23.5	25.0
Land path, km	194	236
Sea path, km	572	637
Interference bandwidth, MHz	10	
$e.i.r.p._{eff}$, dBW	23.4	28.0
Land path, km	193	262
Sea path, km	572	678
Interference bandwidth, MHz	20	
$e.i.r.p._{eff}$, dBW	20.4	25.0
Land path, km	165	236
Sea path, km	534	637

TABLE 9

Estimates of separation distances for radars operating in the frequency band 2 700-3 100 MHz without accounting tropospheric scattering

	Radar No. 1	**Radar No. 4**	**Radar No. 5**	**Radar No. 6**
Receiver thermal noise, dBW	–139	–140	–135	–135
Acceptable interference power, dBW	–145	–146	–141	–141
Acceptable interference field strength, dB(μV/m)	–9.2	–14.2	–6.2	–4.9
	Separation distances			
Interference bandwidth, MHz	5; 10			
$e.i.r.p._{eff}$, dBW	15.0	13.5	20.1	18.4
Land path, km	168	164	151	123
Sea path, km	500	532	513	478
Interference bandwidth, MHz	20			
$e.i.r.p._{eff}$ $EIRP_{eff}$, dBW	12.0	10.4	17.0	15.4
Land path, km	108	135	122	99
Sea path, km	454	493	480	435

The technical characteristics of IMT stations presented in Table 4 were used for estimating the minimum separation distances for protection of radar receivers from interference caused by base stations of potential IMT systems. The separation distances for the radars were estimated in relation to IMT systems operating with signals of 5 MHz, 10 MHz and 20 MHz bandwidth.

Therewith it was taken into consideration that in most cases operational receiver passband of considered radars was narrower as compared with IMT base station frequency band. Therefore interference estimation used an effective IMT station e.i.r.p. value calculated on the basis of the following equation:

$$e.i.r.p._{eff} = P_{trans\,IMT} + G_{trans\,IMT} + 10\lg\left(\Delta F_{RLS} / \Delta F_{IMT}\right),$$

where:

$e.i.r.p._{eff}$ - effective interference e.i.r.p., dBW;

$P_{trans\,IMT}$ - IMT transmitter output power, dBW;

$G_{trans\,IMT}$ - IMT transmitter gain, dB;

ΔF_{RLS} - radar receiver operational passband, MHz;

ΔF_{IMT} - IMT transmitter operational bandwidth, MHz.

Estimated values for effective interference e.i.r.p. in the bandwidth of 5 MHz, 10 MHz and 20 MHz are shown in Tables 7-9.

Estimation of interference to ground-based radar receivers used a radiowave propagation model reflected in Recommendation ITU-R P.1546. The required separation distances were estimated for 10% of time and for 50% of locations for land and sea radio paths. The estimation assumed that ground radar antenna height was 10 metres. The results of separation distance estimation are shown in Tables 7-9.

Note that Recommendation ITU-R P.1546 "Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz" recommends that the procedures given in Annexes 1 to 8 should be used for point-to-area prediction of field strength for the broadcasting, land mobile, maritime mobile and certain fixed services (e.g. those employing point-to-multipoint (P-MP) systems) in the frequency range 30 MHz to 3 000 MHz and for the distance range one kilometre to 1 000 kilometres. Recommendation ITU-R P.1546 is used to give guidance to engineers in the planning of terrestrial radiocommunication services in the VHF and UHF bands. Recommendation ITU-R P.1546 may not be valid for frequencies above 3 000 MHz.

Also note that Recommendation ITU-R P.1546 is intended for area problems, such as broadcasting and mobile, where the receiver locations may not be fixed, or may be unknown, while Recommendation ITU-R P.452 is intended for point-to point problems such as interference into a Radar station where the receiver location is known.

The results obtained show that the required separation distance related to interference of 5 MHz and 10 MHz bandwidth would vary from 123 to 324 kilometres for a land path and from 478 to 773 kilometres for a sea path. The values for interference of 20 MHz bandwidth would be less but even in that case the minimum separation distance would be 99 kilometres for a land path and 435 kilometres for a sea path.

It is worth mentioning that the separation distances shown in Tables 7-9 were estimated without accounting for tropospheric scattering therefore they would not provide a complete protection for radar systems from the interference concerned. Tables 10 - 12 below reflect the separation distance estimates accounting the tropospheric scattering.

TABLE 10

Estimates of separation distances for radars operating in the frequency band 2 700-3 100 MHz accounting tropospheric scattering

	Radar A	**Radar B**	**Radar C**	**Radar E**	**Radar F**	**Radar G M.1849 Radar-1**	**Radar H M.1849 Radar-2**
Receiver noise temperature, Tn, K	438	438	330	180	170	180	2014
Receiver thermal noise, dBW	–135	–144	–132	–145	–140	–148	–139
Acceptable interference power, dBW	–145	–154	–142	–155	–150	–158	–149
Acceptable interference field strength, dB(μV/m)	–5.9	–14.7	–2.8	–16.7	–11.0	–30.9	–13.7
	Separation distances						
Interference bandwidth, MHz	5; 10						

	Radar A	**Radar B**	**Radar C**	**Radar E**	**Radar F**	**Radar G M.1849 Radar-1**	**Radar H M.1849 Radar-2**
$e.i.r.p._{eff}$, dBW	25.0	16.2	25.0	18.8	24.0	16.0	15.0
Land path, km	257	256	227	303	298	[415]	[234]*
Sea path, km	582	582	542	642	635	[783]	[550]*
Interference bandwidth, MHz	20						
$e.i.r.p._{eff}$, dBW	22.0	13.1	22.0	15.8	21.0	13.0	12.0
Land path, km	228	228	200	273	268	[385]	[209]*
Sea path, km	544	535	508	604	596	[754]	[518]*

[Note *: The separation distances for Radars G and H have not been confirmed at this time and need further evaluation]

TABLE 11

Estimates of separation distances for radars operating in the frequency band 2 700-3 100 MHz accounting tropospheric scattering

	Radar I	**Radar J**
Receiver thermal noise, dBW	170	120
Acceptable interference power, dBW	–141	–138
Acceptable interference field strength, dB(µV/m)	–147	–144
Receiver thermal noise, dBW	–7.5	–11.0
	Separation distances	
Interference band width, MHz	5	
$e.i.r.p._{eff}$, dBW	23.5	25.0
Land path, km	258	308
Sea path, km	583	648
Interference band width, MHz	10	
$e.i.r.p._{eff}$, dBW	23.4	28.0
Land path, km	257	339
Sea path, km	582	687
Interference band width, MHz	20	
$e.i.r.p._{eff}$, dBW	20.4	25.0
Land path, km	228	308
Sea path, km	544	648

TABLE 12

Estimates of separation distances for radars operating in the frequency band 2 700-3 100 MHz accounting tropospheric scattering

	Radar No. 1	**Radar No. 4**	**Radar No. 5**	**Radar No. 6**
Receiver thermal noise, dBW	–139	–140	–135	–135
Acceptable interference power, dBW	–145	–146	–141	–141
Acceptable interference field strength, dB(µV/m)	–9.2	–14.2	–6.2	–4.9
	Separation distances			
Interference bandwidth, MHz	5; 10			
$e.i.r.p._{eff}$, dBW	15.0	13.5	20.1	18.4
Land path, km	195	227	214	187
Sea path, km	500	542	524	488
Interference bandwidth, MHz	20			
$e.i.r.p._{eff}$, dBW	12.0	10.4	17.0	15.4
Land path, km	169	198	186	162
Sea path, km	464	504	488	454

Analysis of data presented in Tables 8 – 10 shows that accounting for the tropospheric scattering results in significant increasing of the required separation distances. As for interference of 5 MHz and 10 MHz bandwidth the required separation distance would be from 187 to 415 kilometres for a land radio path and from 488 to 783 kilometres for a sea path. For interference of 20 MHz bandwidth the values of separation distances would be reduced. However in that case the required separation distance would be of 162 kilometres for a land radio path and of 754 kilometres for a sea path.

The results shown in Tables 10 - 12 were obtained assuming a cold sea radio path. Consideration of a warm sea radio path would result in ever increased separation distances.

The above presented results were obtained assuming single-source interference effect on a radar receiver. But since the beam width of radar antenna patterns features a finite value the pattern main lobe could be affected by emissions from several IMT interferers located at different distances from the radar receiver considered.

[Annexes with detailed study] Additional Results obtained using Recommendation ITU-R P.452

The modelling parameters for Recommendation ITU-R P.452 propagation model are as follows:

- The path loss will be calculated using Recommendation ITU-R P.452.
- The model predicts signal levels exceeded for a given percentage of time, the assessment will use a set time percentage of 0.1%, 1%, 10% and 20%.
- Predictions are based on the terrain profile and clutter along the path. In this case one kilometre terrain data resolution is used.

The analysis was conducted for maritime Radar 3B located in the Gulf of Mexico USA. The one kilometre resolution terrain profile in this area is typical of low rolling hills and flat environment. The results are shown in the following figures A to P. In the figures, the areas in orange indicate that the radar protection criteria, I/N= -6 dB, is exceeded. The results are obtained from only one base station using either 5 MHz or 20 MHz transmitter bandwidths. The results of aggregate multiple base stations and or mobile stations was not considered in this study.

Summary of results using Recommendation ITU-R P.452

The results show that large separation distances in the order of 72 kilometres to 450 kilometres are required to prevent interference from one macro suburban or one macro ruler base stations into maritime radar depending on the probability value that is used in Recommendation ITU-R P.452. Therefore, it is concluded that co-frequency sharing between the two applications is not possible in areas close to navigation routes and bodies of water where maritime radars operate. In addition this frequency band is heavily used by IMO navigation radars worldwide. Note that in this analysis, the radar antenna gain was reduced by 3 dB to account for having the antenna pattern 3 dB level intersect the ground.

FIGURE 1

5 MHz macro suburban base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=0.1%

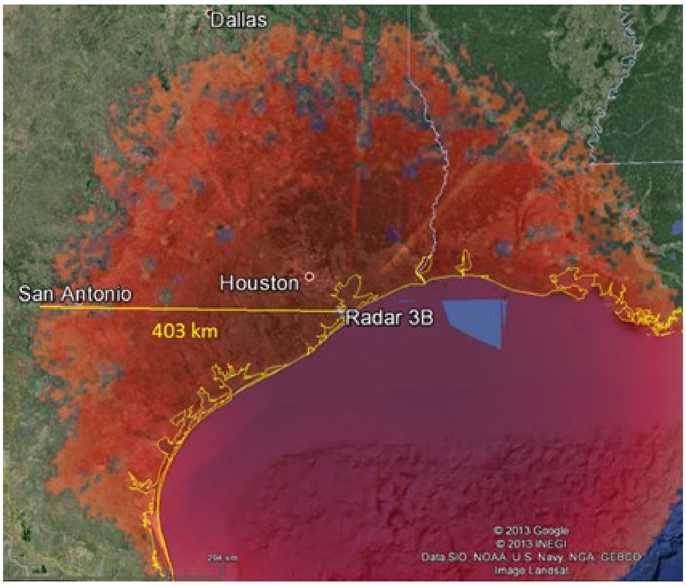


FIGURE 2

5 MHz macro suburban base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=1.0%

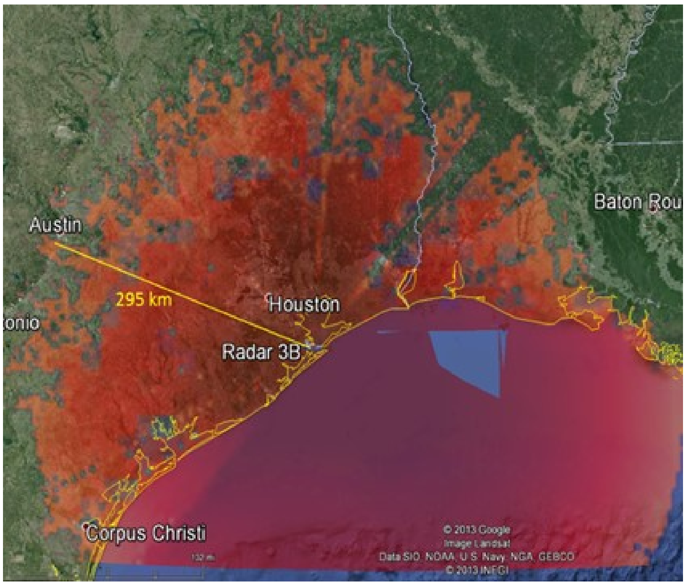


FIGURE 3

5 MHz macro suburban base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=10.0%

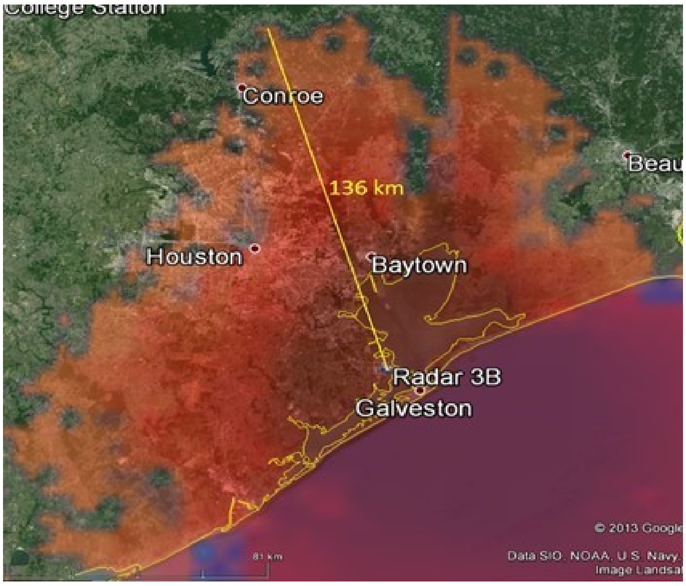


FIGURE 4

5 MHz macro suburban base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=20.0%

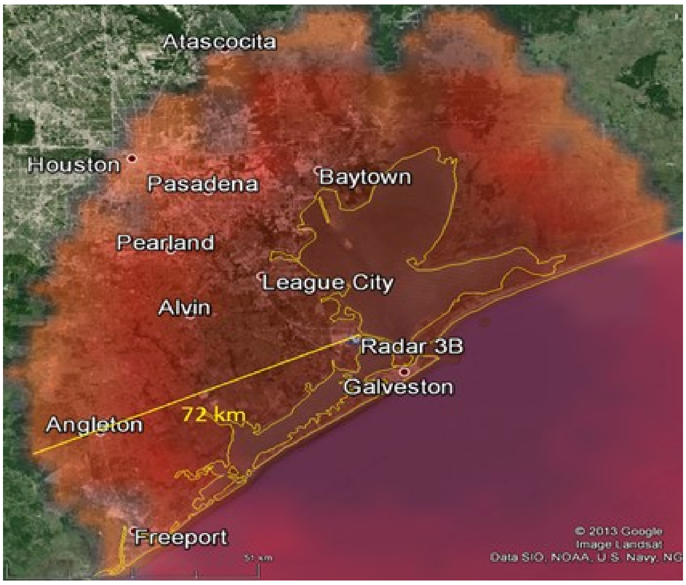


FIGURE 5

5 MHz macro rural base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=0.10%

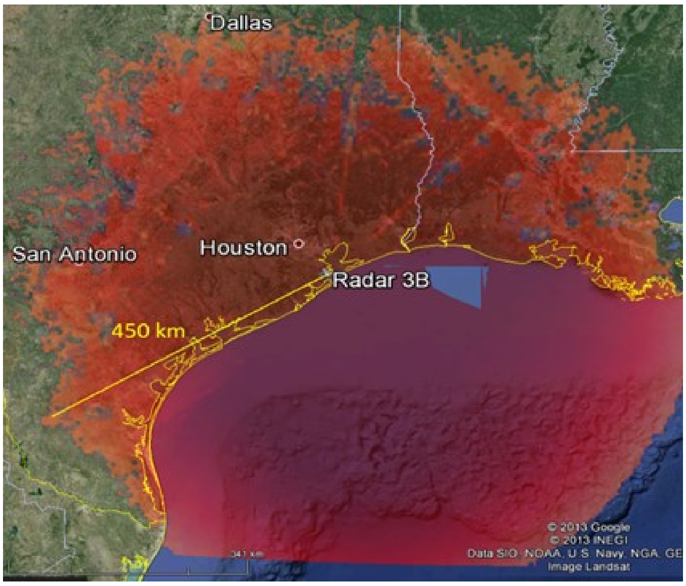


FIGURE 6

5 MHz macro rural base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=1.0%

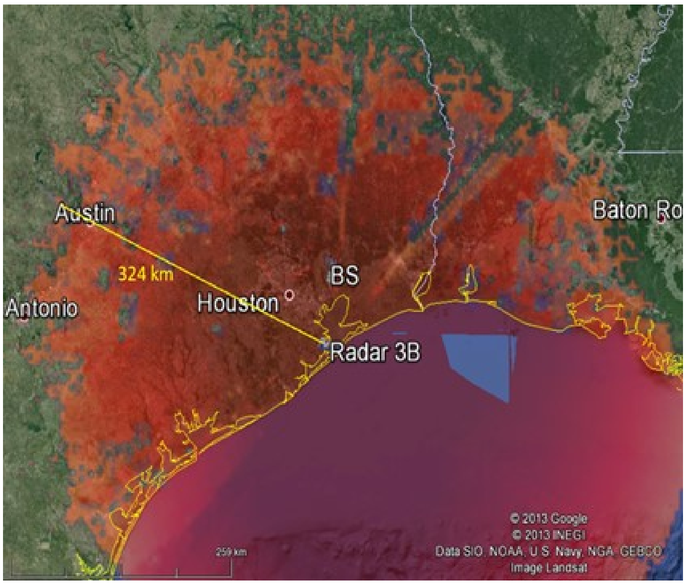


FIGURE 7

5 MHz macro rural base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=10.0%

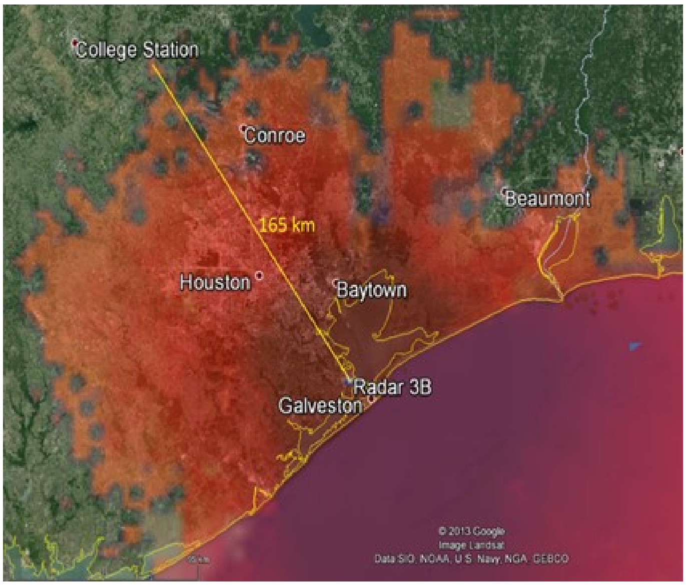


FIGURE 8

5 MHz macro rural base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=20.0%

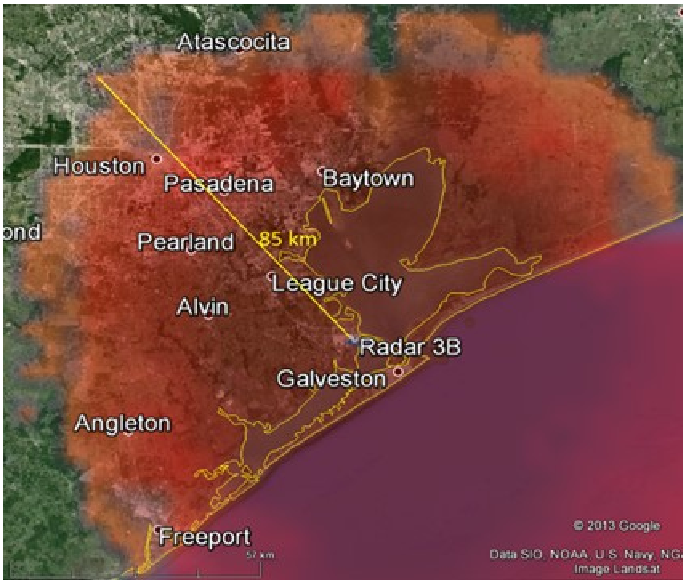


FIGURE 9

20 MHz macro suburban base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=0.10%

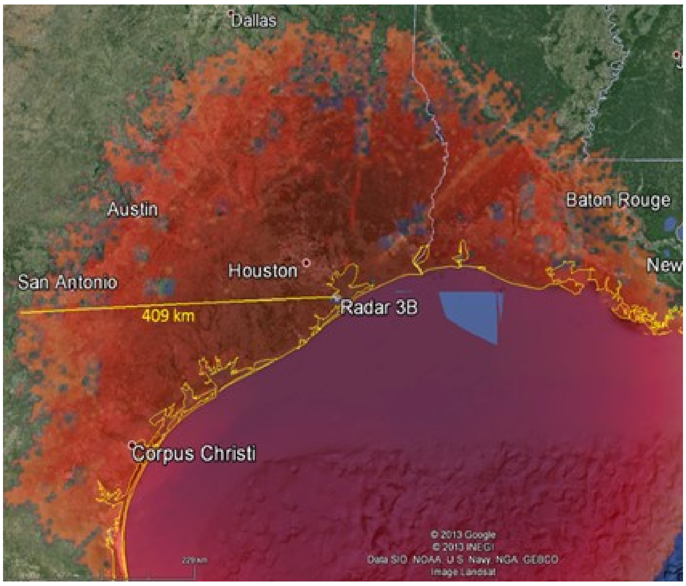


FIGURE 10

20 MHz macro suburban base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=1.0%

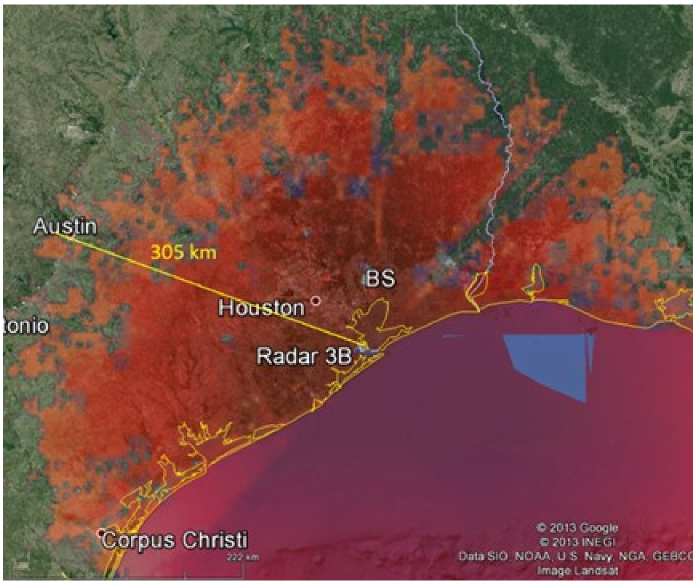


FIGURE 11

20 MHz macro suburban base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=10.0%

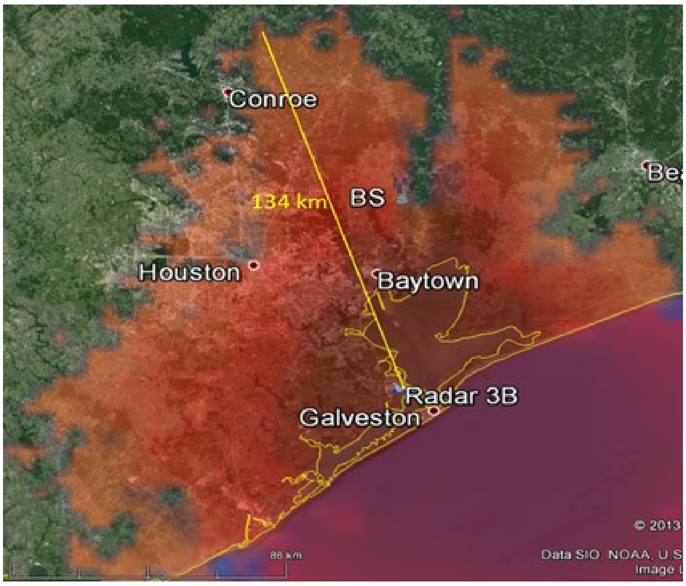


FIGURE 12

20 MHz macro suburban base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=20.0%

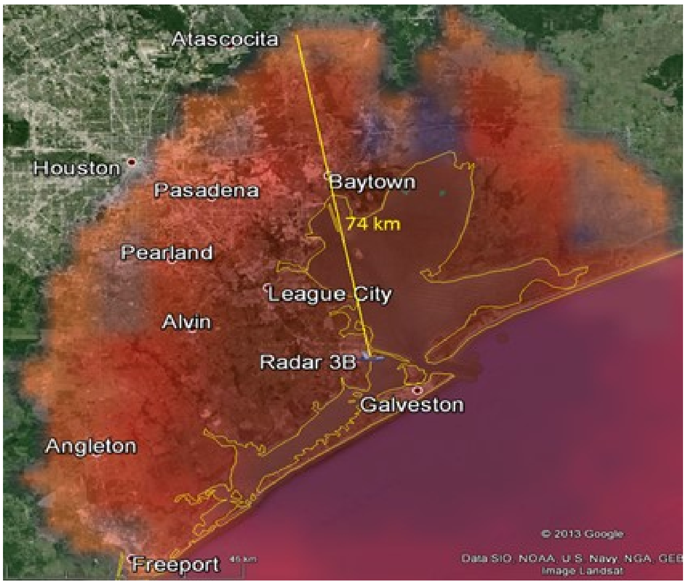


FIGURE 13

20 MHz macro rural base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=0.10%

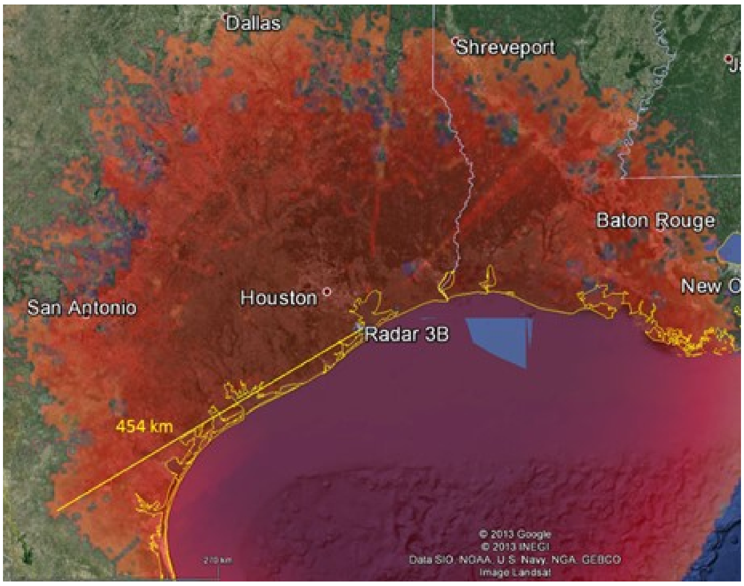


FIGURE 14

20 MHz macro rural base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=1.0%

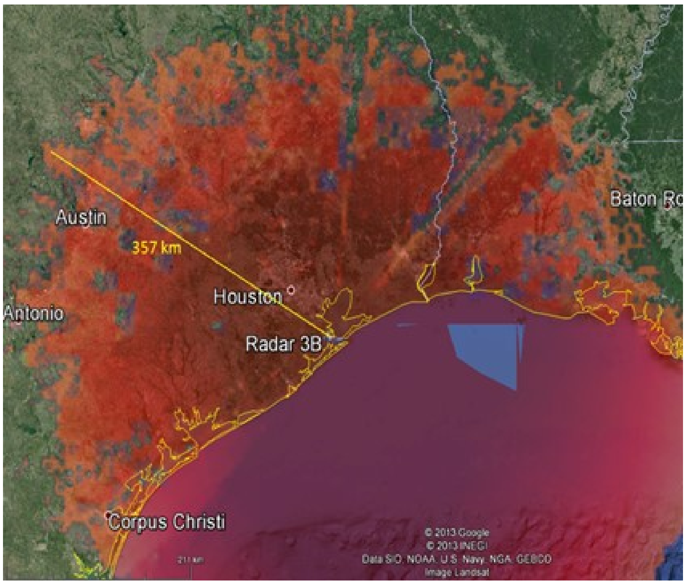


FIGURE 15

20 MHz macro rural base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=10.0%

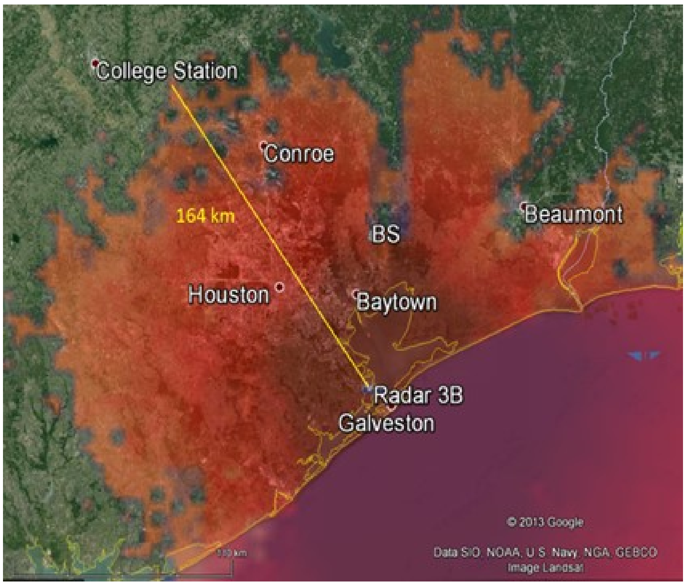


FIGURE 16

20 MHz macro rural base station interfering with maritime Radar 3B, Recommendation ITU-R P.452 P=20.0%

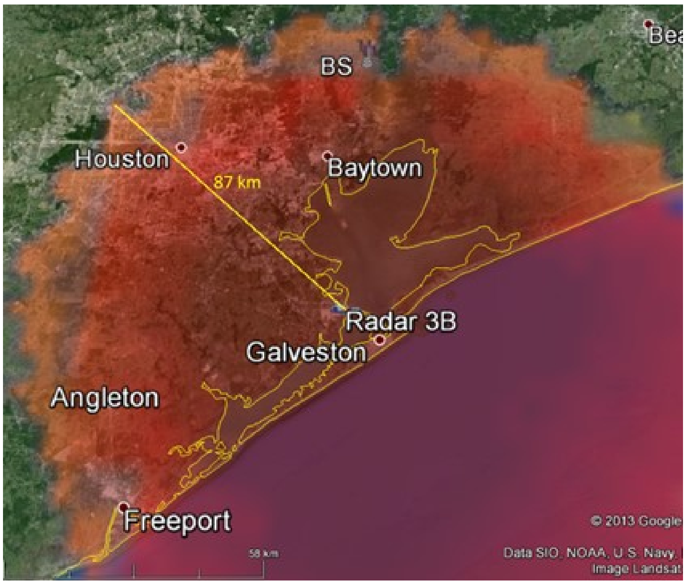


TABLE 13

Summary of estimates of separation distances for radars operating in the frequency band 2 700-3 100 MHz employing Recommendation ITU-R P.452

ITU-R P.452 Probability (%)	Base Station Bandwidth (MHz)	Suburban Base Station Separation Distance to Protect Maritime Radar (km)	Rural Base Station Separation Distance to Protect Maritime Radar (km)
0.1	5	405	450
1.0		295	324
10.0		136	165
20.0		72	85
0.1	20	409	454
1.0		305	357
10.0		134	164
20.0		74	87

6 Conclusion

Analysis of the obtained results shows that providing protection for radars operating in the frequency bands 2 900-3 100 MHz may require large separation distances. Considering the global nature of radiolocation service allocations a conclusion could be drawn that sharing between IMT stations and the mentioned radars in the frequency bands 2 900-3 100 MHz would be difficult and challenging to implement

Based on the above it is proposed to exclude the frequency bands 2 900-3 100 MHz from consideration as a candidate for satisfying WRC-15 agenda item 1.1.

ATTACHMENT 2

Sharing between IMT-Advanced and radiodetermination systems in the band 2 900-3 100 MHz

1 Introduction

The World Radio Conference 2015 agenda item 1.1 seeks to identify additional spectrum for the mobile service to meet the forecast increase in capacity demand for mobile broadband systems to 2020 and beyond. One of the frequency bands of interest is the 2 700-3 100 MHz band, which is currently allocated to Radionavigation and radiolocation services.

In some countries, there is minimal usage of the band 2 700-3 100 MHz by radiodetermination services - prompting administrations to explore opportunities for other services such as wireless broadband systems including IMT to better exploit the band (or some portion of it) toward further facilitating national economic growth and development.

[A contribution (Document 4-5-6-7/130) to a previous meeting of JTG 4-5-6-7 illustrated the opportunities for segmentation of the band 2 700-3 100 MHz, based on studies submitted to ITU-R Working Party 5B (Document 5B/101) and included in the Chairman's Report (see Document 5B/167 Annex 29) that demonstrated the potential for improved usage efficiency throughout this band. *Note Cannot be referred to in this manner in a DNR*]. See the Annex attached for illustration of several alternative structural options.

This [contribution builds] on preliminary studies [(Document 4-5-6-7/277)] submitted [to the last meeting of JTG 4-5-6-7] and presents more detailed technical sharing studies that investigate the minimum necessary frequency and geographic separation necessary to protect ship-borne maritime and coastal surveillance radars and from unacceptable interference caused by emissions of IMT-Advanced fixed and mobile stations.

The more detailed studies reported in this contribution have focused on modelling adjacent-channel operating scenarios to illustrate the potential of alternative approaches:

i) local segmentation of the band (per Recommendation ITU-R SM.1132) to accommodate IMT-Advanced systems in one segment and incumbent systems in an adjacent segment; or

ii) co-ordinated sharing of the band by IMT-Advanced systems and existing incumbent systems, through a combination of frequency and geographic separation.

In particular, it is highlighted that only IMT *downlink* usage of the band 2 900-3 100 MHz is envisaged in this study. Therefore, only IMT base-station interference to radars is considered.

The results of these studies also suggest a possible basis for initiating cross-border co-ordination discussions enabling administrations to ensure both sufficient protection of incumbent systems and efficient usage of the radiofrequency spectrum resources.

2 Background

In Article **5** of the International Radio Regulations (RRs), the frequency band 2 900-3 100 MHz is currently allocated to the radiolocation and radionavigation services (RLS and RNS) for maritime radar applications, as well as ground-based aeronautical radars under RR No. **5.426**.

[The technical characteristics for the RLS, RNS and IMT systems were derived from the ***Compilation of Material maintained by the Joint Task Group 4-5-6-7 Working Groups***, Annex 2 to the JTG 4-5-6-7 Chairman's Report of the 3rd Meeting (Document 4-5-6-7/242). *Note cannot be referred to in this manner in a DNR.*]

In addition, reference was also made to relevant ITU-R Recommendations, including:

- Recommendation ITU-R SM.329-10 – Unwanted emissions in the spurious domain.
- Recommendation ITU-R M.1460-1 – Technical and operational characteristics and protection criteria of radiodetermination radars in the 2 900-3 100 MHz band.
- Recommendation ITU-R M.1461-1 – Procedures for determining the potential for interference between radars operating in the radiodetermination service and systems in other services.
- Recommendation ITU-R SM.1541-4 – Unwanted emissions in the out-of band domain.
- Recommendation ITU-R M.1851, – Mathematical models for radiodetermination radar systems antenna patterns for use in interference analyses.

Where parameter values were not available in the above reference sources, supplementary references highlighted by previous contributions were also consulted, including:

- Ofcom Report AY4051, – The Report of an Investigation into the Characteristics, Operation and Protection Requirements of Civil Aeronautical and Civil Maritime Radar Systems.

Similar to other studies, and to explore the sensitivity of results to potential performance improvement of certain parameters, additional sensitivity analysis is undertaken using selectively adjusted parameter values as noted in the results.

The radio propagation environments were modelled in accordance with [the recent liaison advice from Working Parties 3K and 3M (Document 4-5-6-7/141) along with *Note cannot refer in this manner in a DNR*] relevant ITU-R documents and Recommendations:

- Revision 1 to ITU-R Document 3/39 – concerning recent modifications to Recommendation ITU-R P.1546.
- Recommendation ITU-R P.452-12 – Prediction procedure for the evaluation of microwave interference between stations on the surface of the Earth at frequencies above about 0.7 GHz.
- Recommendation ITU-R P.525-2 – Calculation of free-space attenuation.

3 Technical characteristics

Recommendation ITU-R M.1460 identifies Radar Nos. 2 and 3 as representative of contemporary ship-borne radiolocation radars, and Radar Nos. 5 and 6 as representative of modern land-based radiolocation radars. While Radars 2 and 3 are similar, Radar 2 operates at higher peak power. Further, while Radars 5 and 6 are similar in performance, Radar 5 has slightly wider emission bandwidth. Annex 3 to Recommendation ITU-R M.1460 also provides a brief summary of ship-borne radionavigation radars. Therefore, the following technical characteristics have been assumed for radar systems in these studies:

TABLE 1

Radar systems technical characteristics

Parameter	Units	RLS System 2	RLS System 5	Ship-borne RNS
Receiver				
Noise figure	dB	[*4*]	[*4*]	5
RF bandwidth	MHz	200	200	-
IF bandwidth	MHz	0.35	1.6	2.5/6/28
Target I/N	dB	-6	-6	-8
Min sensitivity	dBm	-109	-105	[*105*]
Antenna				
Pattern type	-	Vertical step-scan	Vertical step-scan	Rotational sweep
Polarisation	-	Horizontal	Vertical	[*horizontal*]
Boresight Gain	dBi	38.5	Tx: 34.5 Rx: 38	28/26
Azimuth beamwidth	degrees	1.5	1.1	4.0/1.0
Vertical beamwidth*	degrees	-	-	30
1st side-lobe suppression	dB	25	25	32
Nominal height (AGL/ASL)	m	[*15*]	[*15*]	[*15*]

Values shown in […] are assumptions due to absence of specification data.

*NOTE: For low-elevation (<3° above horizon) beam pointing, the vertical illumination patterns are assumed to be similar to the cosecant^2 patterns defined in Recommendation ITU-R M.1851 “Mathematical models for radiodetermination radar systems antenna patterns for use in interference analyses”.

As noted above, [previous contributions to the JTG 4-5-6-7] in relation to the 2 900-3 100 MHz band have proposed that only IMT downlink usage of this band is envisaged, based on the potential for rationalisation and consolidation of existing radiodetermination services in the broader 2 700-3 100 MHz band. Thus, this contribution only investigates the potential for IMT base-station emissions impacting on radar receivers – and the following technical characteristics have been assumed for IMT-Advanced base-stations:

TABLE 2

IMT-Advanced technical characteristics

Parameter	Units	Base Station
Antenna Type	-	65° sector
Antenna Gain	dBi	Rural: 18 Suburban: 16 Urban: 16
Feeder Loss	dB	3
Antenna elevation	m (AGL)	Rural: 30 Suburban: 25 Urban: 20
Cell radius	km	Rural: 4 Suburban: 0.8 Urban: 0.4
Antenna down-tilt	degrees	Rural: 3 Suburban: 6 Urban: 10
Typical body loss	dB	-
User terminal density (in active mode)	Users/5MHz/km^2	-
Transmitter *		
Maximum Tx Power	dBm	43
Dynamic Power Control	-	No
Max Tx EIRP	dBm	58
Channel bandwidth	MHz	10
Average activity factor	%	50

* Applicable to the case of 10 MHz IMT-Advanced channel.

The out-of-band (OOB) and spurious emission characteristics of IMT base-station transmitters are based on the maximum mask specified in the 3GPP technical specification series 36 (TS 36). Commercial IMT products typically offer significantly better performance[5] than 3GPP requirements – noting that earliest practical date of launch of IMT services in this band is unlikely before end-2017. However, for the purposes of studies reported in this contribution, the following out-of-band (OOB) and spurious emission mask for IMT user devices is assumed:

---

[5] Recent (2012) vendor contributions to CEPT have already indicated considerably better OOB and spurious emissions performance by IMT equipment than is currently specified by 3GPP TS 36.104.

TABLE 3

IMT base-station OOB and spurious emission limits

Parameter	Units	Value	Notes
IMT Base-stations – for 5, 10, 15 and 20 MHz channel bandwidths (3GPP TS 36.104)			
OOB emissions	dBm/MHz	-15	Category B - for frequency separation of up to 10 MHz from channel edge above and below operating band
Spurious emissions	dBm/MHz	-30	Category B – except for OOB emission region noted above, in the range 1-12.75 GHz

4 Analysis

As noted above, the studies reported in this contribution have focused on *adjacent channel* sharing, in support of administrations considering to review the efficiency of current usage of the band 2 700-3 100 MHz by radiodetermination services in their own country. While the deployment of radar systems may be widespread in some countries, other countries have deployed few such systems (or none, in some cases) in this band – and, in the latter case, administrations are exploring the possibility for greater utilisation of the band 2 700-3 100 MHz (in particular, by IMT-Advanced systems) in an effort to facilitate further national economic growth and development.

4.1 Approach

As noted above, only the impact of IMT downlink emissions on radar receivers is evaluated in this contribution, reflecting the proposed FDD structure shown in the Annex.

Two modes of interference should be evaluated to fully assess impact on a radar system:

- in-band interference to the radar – due to out-of-band and spurious emissions of IMT base-station transmitter falling within the radar receiver IF bandwidths; and
- out-of-band interference to the radar – due to high-level emissions within the assigned IMT channel from a nearby base-station transmitter which saturates the radar receiver causing input gain compression.

No information is available in relation to radar receiver selectivity performance, so evaluation of the second mode is subject to various assumptions concerning likely radar performance.

4.1.1 In-band interference to the radar

Since IMT base stations are stationary, evaluation of the downlink scenario is achieved using a relatively simple three-stage minimum coupling loss approach:

1) Calculate the maximum allowable interfering level at the radar, based on the radar technical characteristics and minimum I/N protection criteria:

$$P_{int} = -174 + NF + I/N + 10 \log_{10} 10^6 \text{ dBm / MHz}$$

where:

P_{int} = received power spectral density;

NF = noise figure;

I/N = protection ratio.

2) Calculate the minimum coupling loss (MCL) required to protect the radar, by considering IMT base-station emissions in the direction of the radar, taking account of spectral offset (guard-band):

$$P_{IMT} = \Delta_{OOB} + G_{IMT}$$

$$MCL = P_{IMT} – Pint + G_{radar} - L_{feed}$$

Where:

P_{IMT}= IMT base-station out-of-band spectral density;

Δ_{OOB}= IMT base-station Tx out-of-band power spectral density (for relevant guard-band offset);

G_{IMT}= IMT base-station antenna gain;

G_{radar}= radar receiver antenna gain;

L_{feed}= radar receiver feeder loss.

3) Finally, calculate the required minimum separation distance, using relevant propagation loss models – and two alternative models are relevant:

- **Recommendation ITU-R P.1546-5** (09/2013) - A point-to-area propagation model, as recommended by WP-3K and WP-3M, which provides an estimate of field strength – and including relevant adjustments for: operating frequency of around 2 800 MHz; land path; field strength exceeded for 1%, 10% and 50% of time[6]; transmitter height above ground; radar height above ground; and smooth earth scenario; and
- **Recommendation ITU-R P.525-2** (1994) – The free-space propagation model providing an estimate of field strength for either point-to-area or point-to-point propagation scenarios, in the absence of clutter and obstacles. This model could be applicable to cases involving elevated stations with clear line-of-sight between them.

4.2 Assumptions

4.2.1 Propagation environment

Since the relevant radar stations are either located near the coast, or on-board shipping vessels, then the following assumptions are made:

- for radiolocation systems: suburban or rural environment – and may include non-urban clutter;
- for radionavigation systems: partly over land and partly over-water environment – equal portions of the path are assumed.

4.2.2 Guard-band

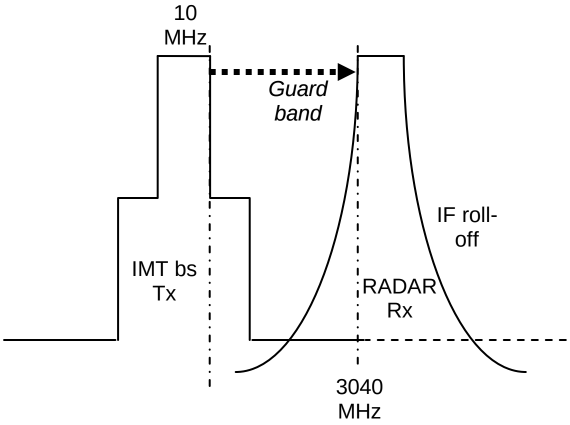
The guard-band is taken to be the frequency separation between the respective 3 dB-bandwidth boundaries of the radar and IMT carrier:

---

[6] [Per advice of chairmen of WP-3K and WP-3M, noted in Document 4-5-6-7/393 Annex 2: '*for short distance scenarios, particularly with low antenna heights, the time variability of path loss is unlikely to be an important factor in interference estimation, so mean path loss values might also be used*' Note cannot be referred to in this manner in a DNR.]

FIGURE 1

Illustration of assumed guard-band scenarios



A nominal radar channel lower-boundary value of 3 040 MHz is assumed for the purposes of these studies, although this is merely to derive realistic propagation losses and does not materially affect the resulting suggested minimum separation distances.

4.3 Analysis

The analysis initially determines the minimum required separation distance based on a minimum guard-band of 10 MHz between upper IMT channel edge and the lower edge of the radar channel. Subsequent sensitivity analyses could potentially explore the implications of variation of certain parameter values along with various mitigation measures.

To evaluate in-band interference to radar systems from IMT base-station transmitters:

Radar receiver characteristics	**Units**		**RLS System 2**	**RLS System 5**	**Ship-borne RNS**
Thermal noise	dBm/Hz	A	-174	-174	-174
Noise figure	dB	B	4	4	5
Noise floor	dBm/MHz	C =a+b+10log1e6	-100	-100	-99
I/N objective	dB	D	-6	-6	-6
Maximum Interference power	dBm/MHz	E = c+d	-106	-106	-105
Radar antenna gain	dBi	F	38.5	38	28
Feeder loss	dB	G	2	2	2
Maximum allowable interference incident on radar antenna	*dBm/MHz*	*H = e-f+g*	*-142.5*	*-142.0*	*-131*
IMT base-station transmitter characteristics					
Guard-band	MHz	J	10	10	10
IMT Transmitter OOB level	dBm/MHz	K	-30	-30	-30
IMT base-station antenna gain ** no down-tilt is assumed*	dBi	L – suburban L – rural	16 18	16 18	16 18
IMT base-station feeder loss	dB	M	3	3	3
Polarisation loss	dB	N	3	0	3
Minimum coupling loss objective	dB	P = k+l-h-m-n	122.5 124.5	125.5 127.5	111 113
Minimum separation distance by model					
Rec. ITU-R P.1546	km	Q =d1546(P)	5.4 6.0	6.3 6.9	2.9 3.2
Rec. ITU-R P.525	km	R =d525(P)	10.6 13.3	15.0 18.9	2.9 3.6

Notably, if the IMT base-station antennas are deliberately oriented to face directly away from the radar stations, taking advantage of 40-50 dB front-to-back ratios, the larger separation distances will further reduce to around 2 km.

To evaluate out-of-band interference to radar systems from IMT base-station transmitters, consideration of the radar selectivity performance at specific spectral offsets is required. As this information was not readily available, evaluation of out-of-band interference to maritime radar stations was unable to be completed.

These results suggest that protection of coastal maritime and ship-borne radar systems could be feasible with a minimum 10 MHz guard-band offset – provided that a minimum station separation distance of several kilometres is also maintained. If additional performance information associated with maritime radar systems (eg. Receiver selectivity and 1 dB compression point) were to become available, then further studies could be undertaken to confirm the absence of any out-of-band degradation to radar receivers. However, it would seem reasonable to assume that if incident emissions from IMT base-station transmitter is maintained below the I/N = -6 dB threshold, and that base-station antennas were required to be oriented to avoid illuminating the radar site, then out-of-band interference may be comfortably avoided.

5 Conclusions

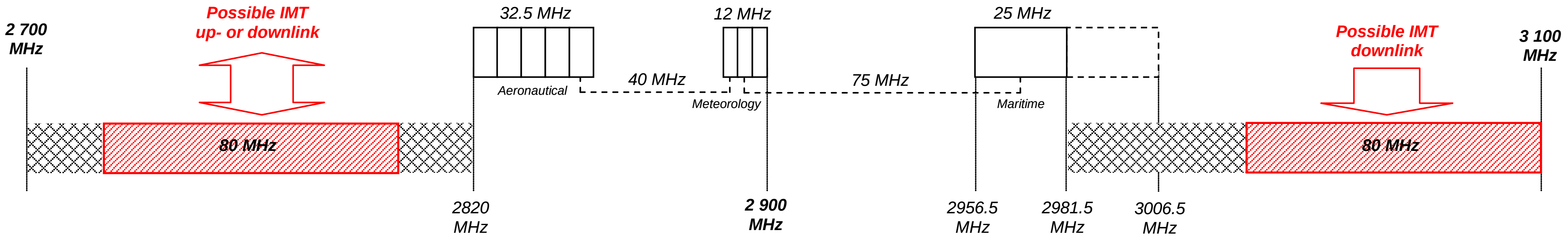
Results of these MCL studies of the co-existence of IMT base-stations with coastal maritime and ship-borne radar systems in the band 2 900-3 100 MHz suggest that sharing is likely to be feasible – provided that a minimum 10 MHz guard-band offset is maintained between respective IMT and radar station frequency assignments, IMT base-station antennas are oriented away from the radar sites, and a minimum physical separation distance of around 2 km is imposed. Noting that the band is assumed to be used for IMT downlink only, then no risk to IMT base-station receivers is anticipated.

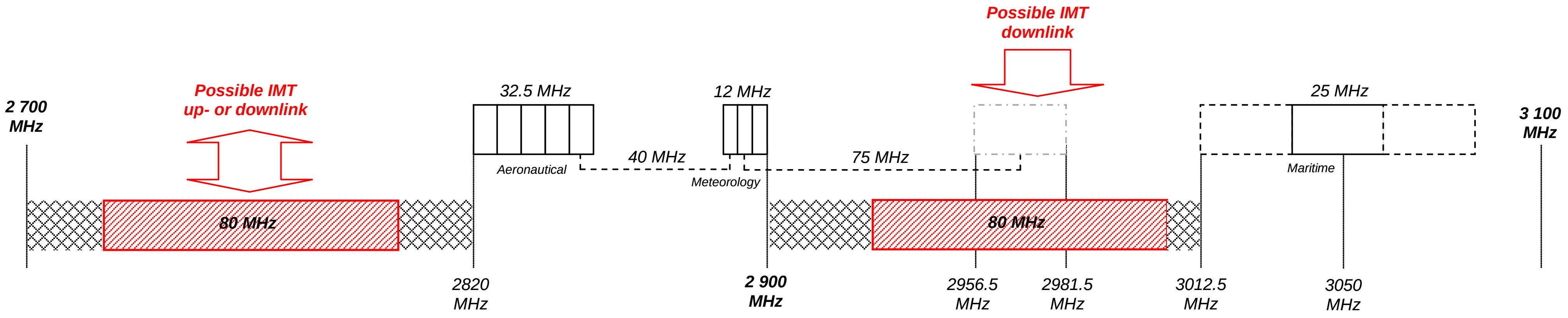
While there may be perceived risk to IMT user equipment (UE) receivers, the low-elevation (1.5 metres AGL) and generally cluttered surrounding environment surrounding them – along with the higher elevation and minimal emissions below the horizontal – is anticipated to minimise impact to UE receivers.

[*Text considered as a note:* The working document on sharing/compatibility studies of IMT systems and radiolocation systems in the frequency band 2 900-3 100 MHz (Attachment 5 to Annex 6 of Document 4-5-6-7/393) contains relevant studies contributed to JTG 4-5-6-7. Telstra proposes that the above updated study report and conclusions be inserted under section 5.1 in Attachment 5 of the working document in Annex 6 of Document 4-5-6-7/393.]

ANNEX

Possible alternate arrangements for rationalising and consolidating use of the band 2 700-3 100 MHz





ATTACHMENT 3

Studies on the impact of IMT interference on radar systems with pulse compression operating in the frequency range 2 700-3 100 MHz

1 Introduction

In accordance with Resolution **233 (WRC-12)**, WRC-15 agenda item 1.1 seeks to allocate additional spectrum to the mobile service and to identify additional frequency bands for IMT in order to meet the expected increased demand for mobile broadband. The frequency bands 2 700-2 900 MHz and 2 900-3 100 MHz are under consideration [by JTG 4-5-6-7] as potential candidate bands for IMT. These frequency bands are currently allocated to the aeronautical radionavigation and radiolocation; and radiolocation and radionavigation services respectively. These frequency bands are used extensively by air traffic control, meteorological and government radar applications.

The attached study investigates the impact of IMT interference with I/N = -6 dB on the performance of a shipborne radar utilising pulse compression in the frequency range 2 700-3 100 MHz.

2 Proposal

[*Text considered as a note:* Working document towards a preliminary draft new Report ITU-R M.[RADAR2700] (Attachment 4 to Annex 6 of Document 4-5-6-7/393) and working document towards a preliminary draft new Report ITU-R M.[RADAR2900] (Attachment 5 to Annex 6 of Document 4-5-6-7/393) contain studies on the compatibility of mobile broadband systems and radars in the frequency bands 2 700-2 900 MHz and 2 900-3 100 MHz.

Australia proposes to incorporate the study given in the Annex to this contribution into appropriate sections of the working documents ITU-R M.[RADAR2700] and ITU-R M.[RADAR2900].]

Annex: 1

ANNEX TO ATTACHMENT 3

Studies on the impact of IMT interference on radar systems with pulse compression operating in the frequency range 2 700–3 100 MHz

1 Background

Radar systems which use pulse compression have their intermediate frequency (IF) bandwidth matched to the compressed pulse and act as a matched filter to maximise signal-to-noise ratio. Pulse compression filters may be partially matched to and hence increase the effect of interference which might otherwise be considered "noise-like" over longer integration times. In that case, an interference signal, which is 6 dB below the noise floor, can lead to degradation of the radar performance in excess of the 1 dB reduction in signal-to-noise ratio that would otherwise be expected. The probability of detection performance of radar system M from the working document towards a preliminary draft revision of Recommendation ITU-R M.1464-1 [(Annex 16 to Document 5B/475)[7]] in the presence of an IMT signal is examined below.

2 Assumptions

The following radar characteristics are assumed:

Characteristics	**Radar M**[8]
Tuning range, MHz	2 700-3 400
Receiver gain, Grec, dBi	40
Receiver noise figure, NF, dB	1.5
Receiver pass band, ΔF, kHz	10 000
Pulse repetition frequency, kHz	10
Pulse width, μs	20
Antenna azimuth beamwidth , Degrees	2
Antenna horizontal scan rate, degrees/s	80
Chirp Bandwidth, MHz	2

A pulse repetition frequency (PRF) of 10 kHz is used, which is the highest in the given range. A duty cycle of 20% is used, which is the highest in the given range. This defines the pulse width to be 20 μs. Assuming 2 degrees of azimuth beamwidth, and 80 degrees/s azimuth scan rate, the length of the coherence processing intervals (CPIs) is set to 25 ms. A linear frequency modulation waveform with chirp bandwidth of 2 MHz is used.

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[7] [The working document towards preliminary draft revision of Recommendation ITU-R M.1460-1 (Annex 15 to Document 5B/475) has the same radar as Radar 3B in Table 1.]

[8] The radar characteristics are given in the form of ranges of value in the Recommendation ITU-R M.1464. The exact values used in the study are shown in the table.

IMT interference is simulated using an LTE signal generated according to 3GPP LTE Release 8 specifications. Fully loaded LTE frames with 25 resource blocks (5 MHz channel bandwidth) with FDD duplexing, QPSK modulation, single transmission antenna, and single receiving antenna are used. The interference power level at the radar receiver is set to 6 dB below the noise floor.

For comparison, Gaussian interference 6 dB below the receiver noise floor is also applied in order to show that interference caused by LTE signals differ from typical Gaussian interference.

Note that interfering signals can be co-channel or adjacent channel to the radar receiver.

3 Methodology

Simulated radar received data consisting of receiver noise, interference, and a non-fluctuating target is passed through standard radar signal processing steps. These steps include matched-filtered pulse compression, Doppler processing, and constant false alarm rate (CFAR) detection. The probability of detection curves against signal-to-noise ratios are shown in Figure 1. The false alarm rate is set at 10^{-4} for all the cases.

In the ‘average’ case, the target was injected with a random range and velocity, thus it has an equal likelihood of appearing in any range-Doppler cell. In the ‘worst’ case, the target was injected with particular range and velocity parameters such that it will appear in the range-Doppler cell where highest CFAR noise estimate was found, thus has less probability of detection.

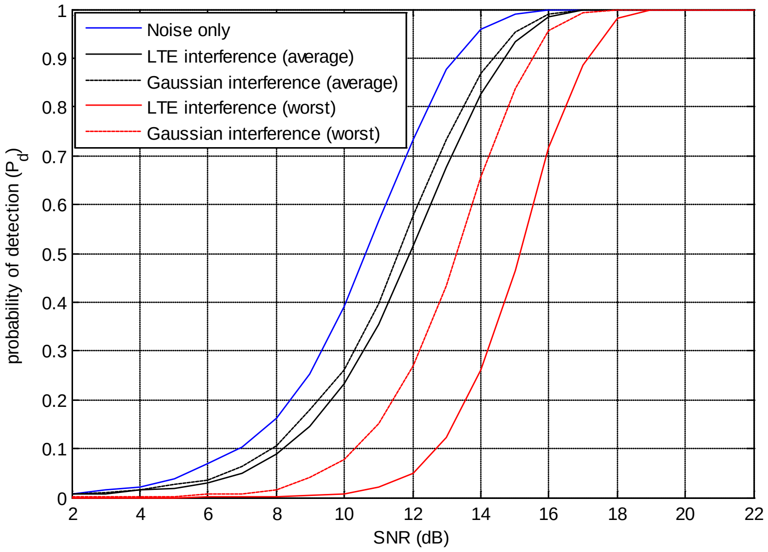
4 Results

The results show a significant reduction in radar detection performance in the presence of IMT interference. To achieve the same detection probability of 0.5 compared to the noise only case, an additional target SNR of 1.3 dB is required in the ‘average’ case, and in the ‘worst’ case additional target SNR of 4.5 dB is required.

Results also indicate that IMT signals cannot be treated as typical Gaussian interference, and the impact of IMT interference on the radar is worse than simply an increased noise floor. As expected, in the ‘average’ case the reduction in signal-to-noise ratio in the presence of Gaussian interference is 1 dB when I/N = -6 dB. In the ‘worst’ case, Gaussian interference degrades signal-to-noise ratio by 2.7 dB. However, as stated above, radar detection performance is significantly further degraded in the presence of IMT interference at the same interference power level.

FIGURE 1

Probability of detection of a non-fluctuating target at presence of LTE interference and Gaussian interference. False alarm rate is set at 10^{-4}



A summary of the results is shown in Table 1 for both interference types, and compared with the noise only case.

TABLE 1

Required SNR to achieve probability of detection = 0.5

	I/N = -∞ dB (noise only)	**I/N = -6 dB (‘average’ case)**	**I/N = -6 dB (‘worst’ case)**
IMT interference	10.6 dB	11.9 dB	15.1 dB
Gaussian interference	10.6 dB	11.6 dB	13.3 dB

5 Discussion

The protection criteria of I/N = -6 dB is often used to in interference studies as being equivalent to a 1 dB reduction in signal-to-noise ratio. However, as shown above, the impact of IMT interfering signals on radar performance can be significantly greater in systems which use pulse compression. These systems have their IF bandwidth matched to the compressed pulse and act as a matched filter for minimum S/N degradation. Pulse compression filters may be partially matched to and hence increase the effect of IMT interference. In some cases, the recommended *I/N* protection criteria of -6 dB may not be adequate and further studies or compatibility measurements may be necessary to assess the interference in terms of the operational impact on the radar’s performance.

6 Conclusions

Administrations considering deployment of IMT systems in the frequency range 2 700-3 100 MHz should be aware that an interference margin greater than the level recommended in relevant ITU-R Recommendations may be necessary, to minimise the impact of IMT interference on radar systems.