

Analysis of frequency sharing between mobile systems and radiolocation radars in VHF band

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Abstract— This paper provides the study results of separation distance for land mobile station from the space surveillance radar operating in VHF band using methodology given in Recommendation ITU-R M.1461. Recommendation ITU-R P.1546 model is used for calculation of propagation losses and time rate of 1% is applied. In this sharing study, protection criteria based on the interference-to-noise ratio are applied, $I/N = -6$ dB for general land mobile stations, and $I/N = -10$ dB for applications with greater protection requirements, such as public protection and disaster relief (PPDR).

Keywords— Radiolocation service, aerospace surveillance radar, mobile service, frequency sharing, VHF, WRC-12 agenda item 1.14

I. INTRODUCTION

Radiowaves in the VHF (3-30 MHz) band propagate well through the ionosphere, thus various space object detection applications including remote space sensing and asteroid detection as well as defining the position of natural and artificial Earth satellites are enable from terrestrial-based radiolocation radars in this frequency band. Considering the effective and economical aspects, VHF bands are appropriate for implementation of these new radiolocation radars.

As the number of space objects including artificial debris is increased, needs for development of new applications in radiolocation service (radars) are also growing to be used for aerospace surveillance and tracking the launch and movement of spacecrafts.

Current requirements for radiolocation radars used for space-object detection from terrestrial locations are based on 2 MHz bandwidth in portion of the VHF band. Recently 154-156 MHz frequency band are under consideration for frequency allocation of radiolocation service and in this band fixed service and mobile service are allocated on primary basis.

It is important to ensure radiolocation radars can be operated compatibly with the existing primary services already allocated. Therefore, sharing studies between radiolocation radars and land mobile systems are conducted and calculation results of separation distance are provided in this paper.

II. SYSTEM CHARACTERISTICS

Following sections contain the technical characteristics for radiolocation system and land mobile system operating in 154-156 MHz frequency bands that will be used in the sharing analysis. System characteristics and protection ratios used in this paper are referred by latest versions of ITU-R Recommendations and relevant standards.

A. Radiolocation System

Recommendation ITU-R M.1802[1] contains technical characteristics and protection criteria for radiolocation radars in the 154-156 MHz frequency band. A modification to the table of the system characteristics for radiolocation radars operating in VHF band was made at the ITU-R WP 5B November 2009 meeting. The modified system characteristics for radar A and radar B operating in 154-156 MHz band are used in the sharing analysis for this paper and the characteristics are shown in Table 1 below.

Table 1. System Characteristics of Radiolocation Radars

Characteristics	Radar A	Radar B
Frequency band (MHz)	154-156	154-156
Output pulse power (min/max) (dBW)	27/46	40/46
Mean output power (min/max) (dBW)	22/41	35/41
Polarization	Linear	Linear
Pulse duration (μ s)	13 000	3 200
Duty cycle	0.322	0.322
Modulation type	Pulse	pulse
Altitude above the ground level (m)	19	19
Maximum antenna gain (dB)		
– transmitter	25	25
– receiver	30	30
Maximum antenna gain on the horizon (dB)	9	9
Operational receiver passband (kHz)	0.132	625
3 dB bandwidth (kHz)	0.132	625
I/N protection ratio (dB)	-6	-6

B. Land Mobile System

Technical characteristics and characteristics and the protection criteria to be used in sharing studies involving land mobile systems(LMS) in the VHF band shall be taken from table of the Recommendation ITU-R M.1808[2].

Table 2 and Table 3 below list the technical characteristics of base station and mobile station of the land mobile service operating the VHF band.

Table 2. System Characteristics of LMS Base Stations

Characteristics	Analog	Digital
Frequency (MHz)	138-174	138-174
Channel BW (kHz)	12.5/15/25/30	6.25/7.5/12.5/15
Modulation type	FM	C4FM
Type of operation	Simplex/duplex	Duplex
Noise figure (dB)	6 to 12 (7)	6 to 12 (7)
IF filter BW (kHz)	8/11/12.5/16	5.5/5.5/5.5/5.5
Antenna gain (dBd)	0 to 9 (6)	0 to 9 (8)
Antenna height (m)	10 to 150 (60)	10 to 150 (65)
Radiation pattern	Omni	Omni
Antenna polarization	Vertical	Vertical

Table 3. System Characteristics of LMS Mobile Stations

Characteristics	Analog	Digital
Frequency (MHz)	138-174	138-174
Channel BW (kHz)	12.5/15/25/30	6.25/7.5/12.5/15
Modulation type	FM	C4FM
Type of operation	Simplex/duplex	Duplex
Noise figure (dB)	6 to 12 (7)	6 to 12 (7)
IF filter BW (kHz)	8/11/12.5/16	5.5/5.5/5.5/5.5
Antenna gain (dBd)	-10 to 4 (H: -10, V: 0)	-10 to 4 (H: -10, V: 0)
Antenna height (m)	(2)	(2)
Radiation pattern	Omni	Omni
Polarization	Vertical	Vertical

III. SHARING ANALYSIS METHODOLOGY

A. Scenario and Assumptions

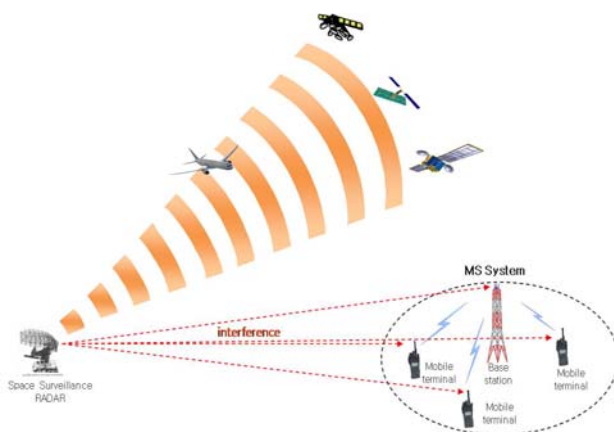


Figure 1. Sharing analysis scenario

In sharing analysis it is assumed that a radiolocation system causes interference to a base station and a mobile station receiver of land mobile service. The analysis assumptions are as follows:

- Antenna coupling : side lobe of radiolocation radar and main lobe of receiver for land mobile system(maximum antenna gain on the horizon (dB) of radar is adapted).
- Simulation frequency : 155 MHz
- Antenna height of the radiolocation system: 19 m
- Antenna height of the victim receiver :
 - Base station : 60 m for analog and 65 m for digital
 - Mobile station : 2 m for analog and digital.
- Path losse model : Recommendation ITU-R P.1546[3] "Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3 000 MHz"
 - Propagation path: land path, suburban area
 - Percentage of time is 1%.

B. Protection Criteria of Land Mobile System

When the protection criteria are given in the term of the interference-to-noise ratio, the interference threshold level, I_T (dBm) can be calculated by following equation.

$$I_T = I/N + N \quad (1)$$

Where, I/N is required interference-to-noise ratio at the detector input (IF output) necessary to maintain acceptable performance criteria (dB). N is receiver inherent noise level (dBm) and can be calculated from IF bandwidth B_{IF} (kHz), noise figure NF (dB) and noise temperature T (K) of receiver using Equation (2).

$$\begin{aligned} N &= -144 \text{ dBm} + 10 \log B_{IF} + NF \\ &= -168.6 \text{ dBm} + 10 \log B_{IF} + 10 \log T \end{aligned} \quad (2)$$

Interference threshold level I_T (dBm) can be converted to electric field strength E_T (dBμV/m) using following equation.

$$E_T = I_T - G_R + 20 \log f + 77.2 \quad (3)$$

Where, f is frequency (MHz) and G_R is antenna gain (dBi) of a receiver. Calculation results of interference threshold level in term of electric field strength for base station and mobile station in the 154-156 MHz band are listed in Table 4 and Table 5 below.

Table 4. Protection Criteria for LMS Base Station

System	Analog	Digital
f (MHz)	155	
B_{IF} (kHz)	12.5	5.5
G_R (dBi)	8.1	10.1
NF (dB)	7.0	7.0
Protection Criteria E_T (dBμV/m)		
$I/N = -6$ (dB)	-19.3	-24.7
$I/N = -10$ (dB)	-23.3	-28.7

Table 5. Protection Criteria for LMS Mobile Station

System	Analog	Digital
f (MHz)	155	
B_{IF} (kHz)	12.5	5.5
G_R (dBi)	2.1	2.1
NF (dB)	7.0	7.0
Protection Criteria E_T (dBμV/m)		
$I/N = -6$ (dB)	-13.2	-16.7
$I/N = -10$ (dB)	-17.2	-20.7

C. Calculation of Received Field Strength

Recommendation ITU-R M.1461[4] “Procedures for determining the potential for interference between radars operating in the radiodetermination service and systems in other services” is used as a methodology of the procedure for determining the potential for interference between radars operating in the radiodetermination service and systems in other services.

Procedure of determining whether radar transmitter emission interference is likely when radars operate within particular distances of other stations and are separated in frequency by certain amounts, is provided in the section 2.2 of Annex 1 of Recommendation ITU-R M.1461. Received peak power of the radar pulses at the victim receiver input can be calculated as follow.

$$I = P_T + G_T + G_R - L_T - L_R - L_P - FDR_{IF} \quad (4)$$

Where,

I (dBm) : peak power of the radar pulses at the receiver

P_T (dBm) : peak power of the radar transmitter

G_T (dBi) : main beam antenna gain of the radar

L_T (dB) : insertion loss in the radar station transmitter

L_R (dB) : insertion loss in the victim receiver

L_P (dB) : propagation path loss between transmitter and receiver

FDR_{IF} (dB) : frequency-dependent rejection produced by the receiver IF selectivity curve on an unwanted transmitter emission spectra.

Propagation curves in Recommendation ITU-R P.1546[3], which is used as a propagation loss model in this simulation, represent received electric field strength values in (dB μ V/m) for 1 kW effective radiated power (ERP). 1kW ERP is equal to 62.1 dBm equivalently isotropic rated power (EIRP). Therefore, propagation path loss L_P (dB) can be calculated from $E_{P.1546}$, field strength (dB μ V/m) for 1 kW ERP in Recommendation ITU-R P.1546, using following equation.

$$L_P = 139.3 - E_{P.1546} + 20 \log f \quad (5)$$

Using Equation (3), (4) and (5), electric field strength E (dB μ V/m) can be calculated from $E_{P.1546}$ using Equation (6). Here, L_T and L_R are assumed to be zero.

$$E = E_{P.1546} + P_T + G_T - 62.1 - FDR_{IF} \quad (6)$$

The FDR value to be used in the Equation (4) and (6) can be determined as follow from Recommendation ITU-R SM.337[5]. The FDR can be divided into two terms, the on-tune rejection (OTR) and the off-frequency rejection (OFR), the additional rejection which results from off-tuning the radar and the receiver.

$$FDR_{IF}(\Delta f) = OTR + OFR(\Delta f) \quad (7)$$

For CW and phase-coded pulsed signals, the OTR factor is given as follows. Here, B_R is 3 dB bandwidth (Hz) of receiver and B_T is 3 dB bandwidth (Hz) of transmitter.

$$OTR = 0 \quad \text{for } B_R \geq B_T \quad (8)$$

$$OTR = 20 \log (B_R/B_T) \quad \text{for } B_R < B_T \quad (9)$$

As the Δf , frequency difference between transmitting frequency and receiving frequency is zero, $OFR(\Delta f)$ value is assumed to be zero. Calculation results of frequency dependent rejection are given in Table 6.

Table 6. FDR Values

Characteristics		Analog	Digital
Radar A	B_T (kHz)	0.132	
	B_R (kHz)	12.5	5.5
	FDR (dB)	0.0	0.0
Radar B	B_T (kHz)	625.0	
	B_R (kHz)	12.5	5.5
	FDR (dB)	16.99	20.56

IV. CALCULATION RESULTS

For several cases, interference levels at the input of land mobile receiver from radiolocation transmitter are calculated using Equation (6) in Chapter 3.

- Bandwidth : Narrow bandwidth radar system (Radar A) and wide bandwidth radar system (Radar B)
- Base station and mobile station of land mobile service
- Modulation : Analog(12.5 kHz channel bandwidth) and digital system(5.5 kHz channel bandwidth) of land mobile service
- Protection Criteria : $I/N = -6$ (dB) for general case and $I/N = -10$ (dB) for special case such as PPDR(Public Safety and Disaster Relief).

Plots of the electric field strength curves for base station of land mobile service are shown in Figure 2 to Figure 5.

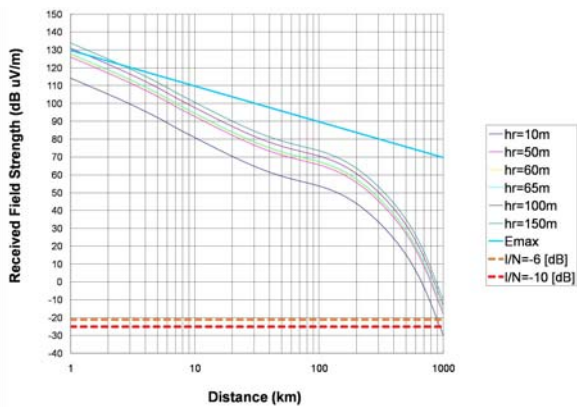


Figure 2. Result for analog base station from Radar A

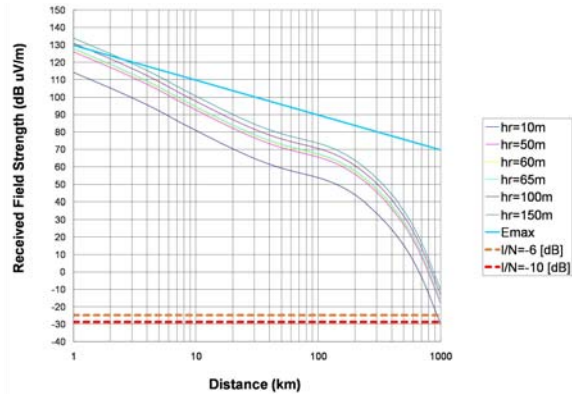


Figure 3. Result for digital base station from Radar A

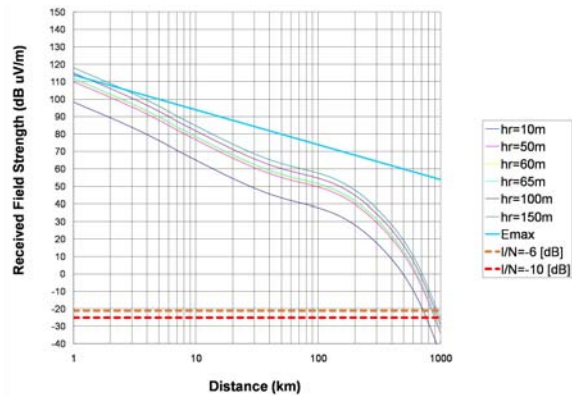


Figure 4. Result for analog base station from Radar B

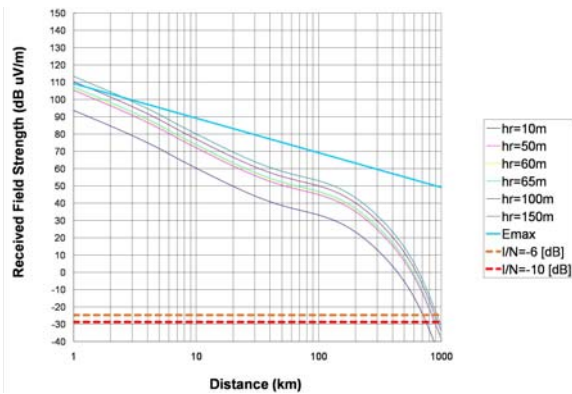


Figure 5. Result for digital base station from Radar B

Curves for mobile station of land mobile service are shown in Figure 6 to Figure 9.

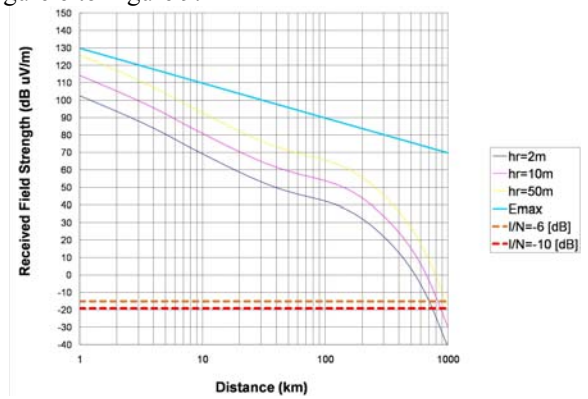


Figure 6. Result for analog mobile station from Radar A

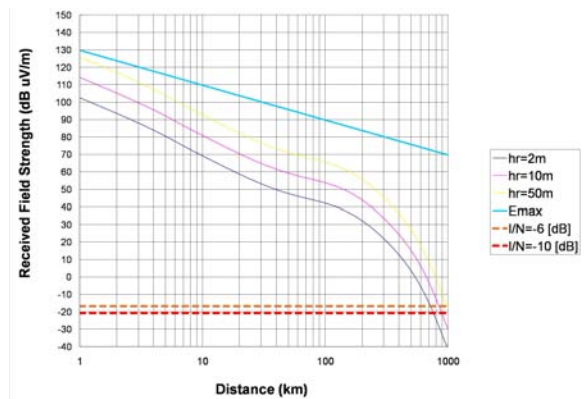


Figure 7. Result for digital mobile station from Radar A

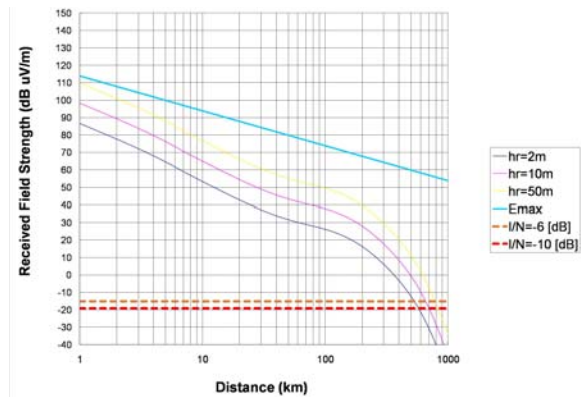


Figure 8. Result for analog mobile station from Radar B

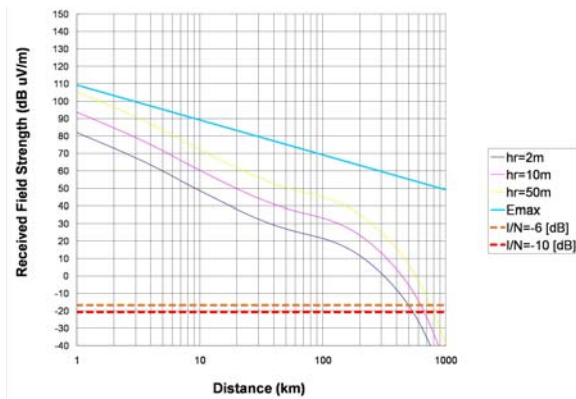


Figure 9. Result for digital mobile station from Radar B

Separation distances of land mobile system from radiolocation system for each case are figured out through comparing the electric field strength and the required protection criteria for land mobile service in Table 4 and Table 5.

Required separation distances of land mobile system are summarized in Table 8 and Table 9 for narrowband and wideband. The assessment can be made regarding the separation distances that are required to ensure sharing between the radiolocation system and the land mobile system.

Table 7. Separation distance of land mobile system from Radar A

Station	Modulation	Separation Distance (km)	
		$I/N = -6$	$I/N = -10$
Base	Analog	> 1 000	> 1 000
	Digital	> 1 000	> 1 000
Mobile	Analog	703	745
	Digital	720	762

Table 8. Separation distance of land mobile system from Radar B

Station	Modulation	Separation Distance (km)	
		$I/N = -6$	$I/N = -10$
Base	Analog	861	906
	Digital	856	901
Mobile	Analog	531	575
	Digital	497	542

V. CONCLUSIONS

In this paper, sharing study between radiolocation service and land mobile service is conducted based on the methodology introduced in Recommendation ITU-R M.1461. For the calculation of path losses Recommendation ITU-R P.1546 propagation model is applied and propagation path of land and time rate of 1% are assumed. Summary of the sharing studies are as follows.

The required protection distances for base station are

- for the narrowband radar
 - $I/N = -6$ (dB): more than 1 000 km
 - $I/N = -10$ (dB): more than 1 000 km
- for the wideband radar
 - $I/N = -6$ (dB): from 856 km to 861 km
 - $I/N = -10$ (dB): from 901 km to 906 km.

The required protection distances for mobile station are

- for the narrowband radar
 - $I/N = -6$ (dB): from 703 km to 720 km
 - $I/N = -10$ (dB): from 745 km to 762 km
- for the wideband radar
 - $I/N = -6$ (dB): from 497 km to 531 km
 - $I/N = -10$ (dB): from 542 km to 575 km.

Study results for mobile station indicates shorter separation distances than those for base station, because the height of the mobile station is lower than that of base station. If the cross polarization effect is considered as the interference mitigation techniques, the required separation distance would be reduced. However, it would be difficult to achieve the cross polarization effects for mobile stations. Moreover if the propagation path of sea is considered, separation distance would be increased due to propagation characteristics.

REFERENCES

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