ICAO

INTERNATIONAL CIVIL AVIATION ORGANIZATION

A UN SPECIALIZED AGENCY

ICAO WRC-27 Preparatory Workshop

Agenda item AI 1.13:
Direct Satellite Connectivity for IMT

Impact on ATC radar

ICAO

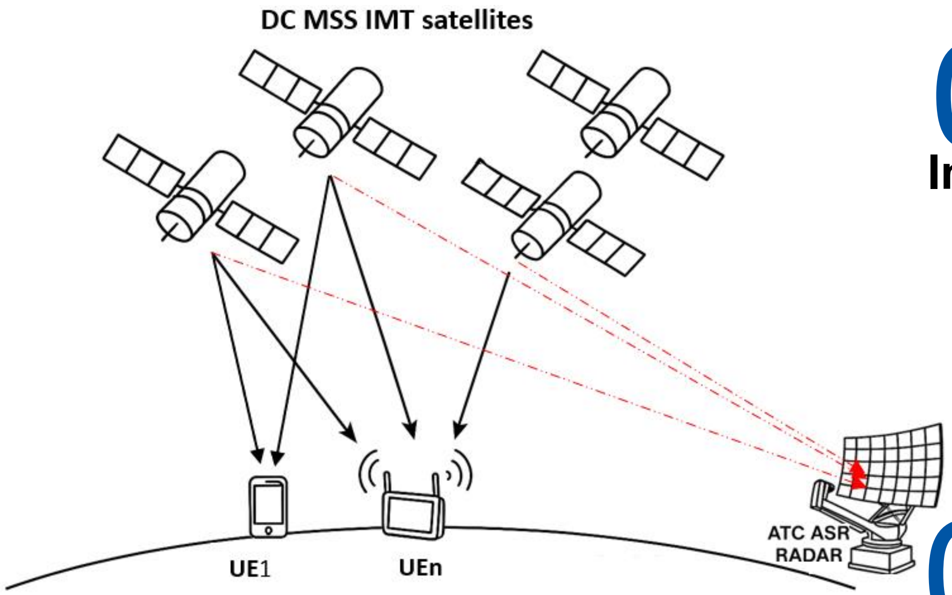
Workshop on ITU World Radiocommunication Conference 2027
(WRC-27 Workshop)
Paris, France, 06-07 October 2025

Abed Ferr
Senior Systems Engineer\
Spectrum Management.
NAV CANADA

Presentation Overview

01
Background

02
Impact on ATC radar



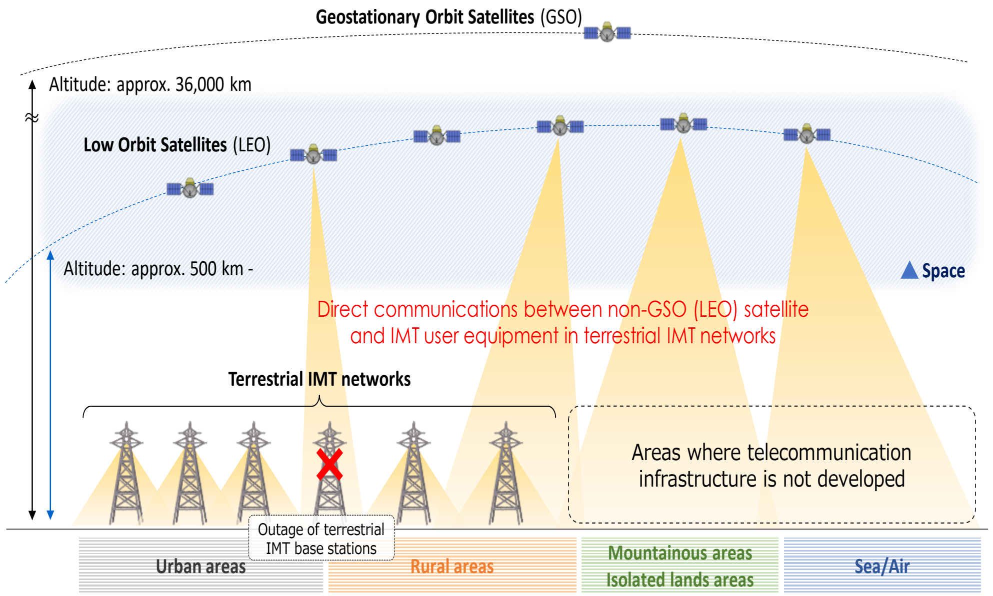
03
ICAO Position

04
Conclusion

Resolution 253 (WRC-23).

resolves to invite the ITU Radiocommunication Sector to complete in time for the 2027 world radiocommunication conference

1 studies on possible allocations to the MSS in the frequency range between 694/698 MHz and 2.7 GHz, taking into account the IMT frequency arrangements addressed in the most recent version of Recommendation ITU R M.1036;



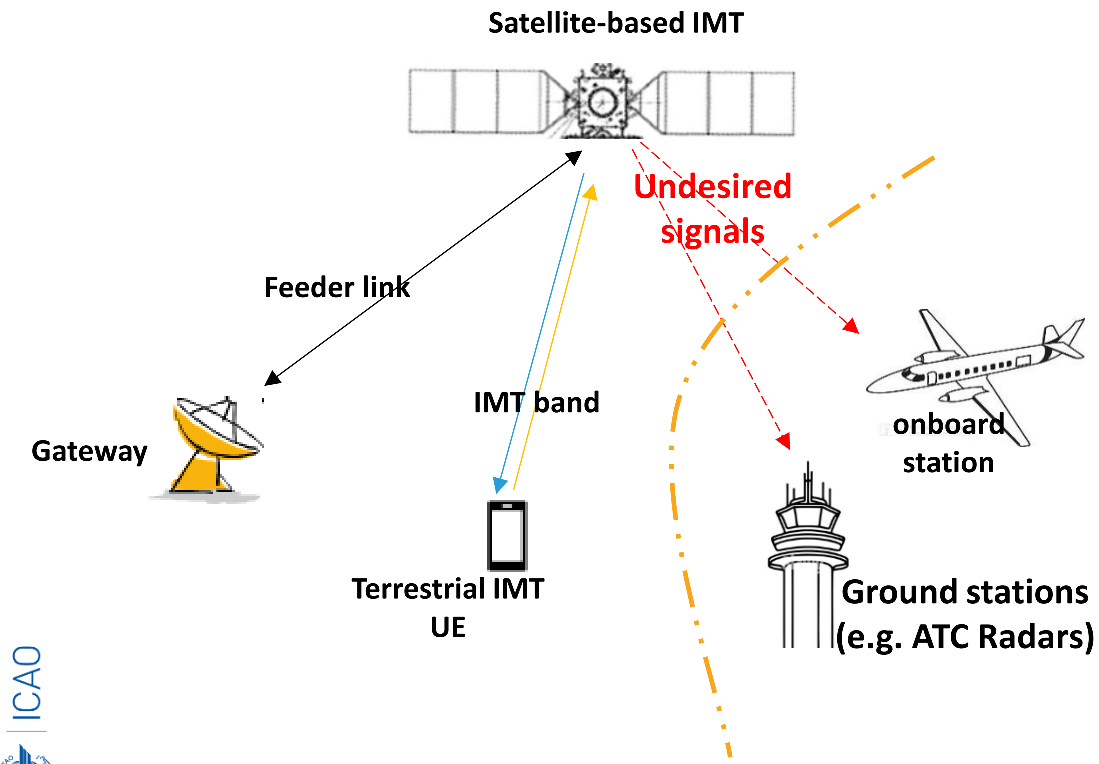
Potential impact on aviation

Mobile station transmitter (MHz)	Base station transmitter (MHz)	ICAO spectrum	ICAO use
698-748	753-803		
698-716	716-746		
776-798	746-768		
832-862	791-821		
880-915	925-960		
		960 – 1 164	(ACAS), automatic dependent surveillance – broadcast (ADS-B), (DME), (LDACS), multilateration (MLAT) (SSR) & (UAT)
		1 164 – 1 215	Distance Measuring Equipment (DME) & global navigation satellite systems (GNSS)
		1 215 – 1 300	Global navigation satellite systems (GNSS) & primary surveillance radar
		960 – 1 164	(ACAS), automatic dependent surveillance – broadcast (ADS-B), (DME), (LDACS), multilateration (MLAT) (SSR) & (UAT)
1 427-1 470	1 475-1 518		
		1 525 – 1 559	Satellite communication
		1 559 – 1 626.5	Global navigation satellite systems (GNSS)
		1 610 – 1 626.5	Satellite communication
		1 626.5 –1 660.5	Satellite communication
1 920-1 980	2 110-2 170		
1 710-1 785	1 805-1 880		
1 850-1 920	1 930-2 000		
1 710-1 780	2 110-2 180		
2 000-2 020	2 180-2 200		
2010-2025	1880-1920		
2 305-2 320	2 345-2 360		
2 500-2 570	2 620-2 690		
		2 700 – 2 900	Primary surveillance and weather radar

- BS total spectrum : 630 MHz; Mobile total spectrum : 593 MHz
  => BS + Mobile spectrum: 1 223 MHz
- **Report ITU-R M.2077-0:** Shortfall of spectrum for the satellite component of IMT and systems beyond IMT-2000 of > 144 MHz (s-E) and > 19 MHz (E-s).

Potential impact on aviation

Interference scenario from the envisaged IMT MSS systems into the incumbent aeronautical systems



- ❑ Undesired signals may impact aeronautical systems in out-of-band, or spurious emissions (Rec. ITU-R SM.328-11, Rec. ITU-R SM.329-13).
- ❑ Studies is limited to the impact of satellite operations in the space-to-Earth direction.
- ❑ The user equipment (UE) would remain the same and regulatory changes to the terrestrial component of IMT are out of scope of the agenda item.
- ❑ Space stations would be a complementary service to existing IMT terrestrial operations, any regulatory considerations for the MSS could be considered on a secondary basis.

ICAO

Compatibility study of MSS (s-E) in 2 620-2 690 MHz and ARNS systems in 2 700-2 900 MHz

Characteristics of DC MSS IMT systems in the frequency band 2 500-2 690 MHz

Two representative constellations in the 2500–2690 MHz band, in North America, have been identified as potential providers of DC MSS/IMT services. (*Document 4C/356-E: Annex 7 to Working Party 4C Chair's Report)*

Below is the characteristics of constellation 2:

MSS (s-E)	Constellation 2
Altitude (km)	340
Inclination (deg)	53
# Planes	48
Sats per plane	110
RAAN spacing (deg)	7.5
Typical bandwidth (MHz)	5 MHz
Polarization	RHCP
PFD on ground per sat (dBW/m^2/MHz)	–82.5
Total number of sats	5 280

Source: Table A5.1.2-1 of document 4C/356-E.

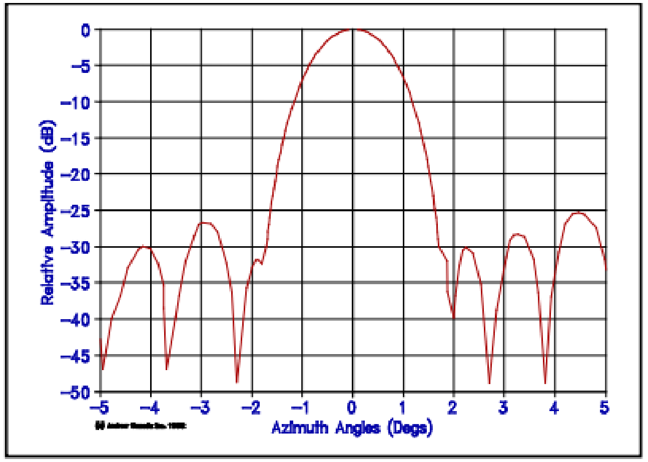
Power spectral density at ground (in-band) : PFD ≈ −82.5 dBW/m²/MHz per satellite.

- This PFD is necessary to achieve satisfactory performance for consumer IMT user terminals (Cellphones).
- The received PFD peaks at the center of the beam and gradually decreases, producing lower levels (–82.5 dBW/m²/MHz) towards the edges of the cell. (typically, 3–6 dB variation from center to edge).
- Co-visibility of multiple satellites is possible; for UE, k* is typically limited to 1–3, though more may simultaneously illuminate an ATC radar main beam.

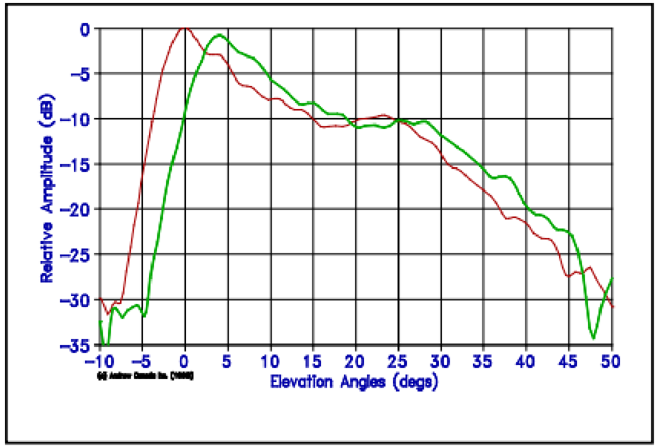
* K is the aggregation factor related number of satellites : K=10 Log (k)

ICAO

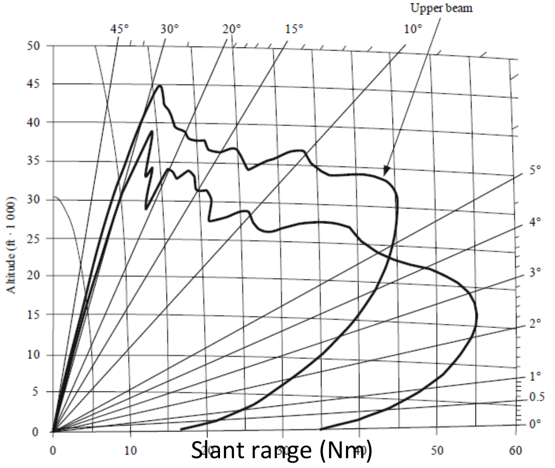
Characteristics and protection criteria of ARNS radar systems in the frequency band 2 700-2 900 MHz



Typical Low Beam Azimuth Pattern at 2.8 GHz for ASR-11



Typical Low/High Beam Elevation Pattern at 2.8 GHz for ASR-11



High and low beams coverage patterns

- **Azimuth**: The antenna **rotates continuously through 360°**, scanning horizontally, at 12 RPM (5 sec per rotation).
- **Elevation**:
  - the radar uses a dual-beam elevation pattern:
    - A low beam pointed at approximately 0.9° elevation.
    - A high beam pointed at approximately 7° elevation .

This dual-beam configuration helps detect aircraft at both low altitudes near the airport and higher altitudes farther out, balancing ground clutter rejection with long-range detection.

- Table 1 of **Rec. ITU-R M.1464-2** contains technical characteristics of representative aeronautical radionavigation radars deployed in the frequency band 2 700-2 900 MHz.
- Document 4C/356-E “WD on Sharing and compatibility studies under WRC-27 AI 1.13” selects (03) ATC radars for sharing study.

ATC radar victim model (what the satellite “spills” into)

- Radar noise power (per MHz): N= –114 dBm + 10 log BIF (MHz) + NF *(Rec. ITU-R M.1461)*
- Protection: $I_{max} = N_{1MHz} - |I/N|$ *(Rec. ITU-R M.1461)*

Parameter	Symbol	Unit	F1		F2		C
Pulse width type			SP	LP	SP	LP	SP/LP
Frequency	f	GHz	2.7	2.7	2.7	2.7	2.7
Bandwidth	BIF	MHz	1.2	1.8	1.2	1.6	1.1
Noise figure	NF	dB	6	6	6	6	3.3
Total radar receiver noise	Ntot	dBW	-137.21	-135.45	-137.21	-135.96	-140.29
Noise spectral density per MHz	N1MHz	dBW/MHz	-138	-138	-138	-138	-140.7
Interfere to Noise	I/N	dB	-6	-6	-6	-6	-6
Maximum permissible interference	Imax	dBW/MHz	**-144**	**-144**	**-144**	**-144**	**-146.7**

Rec. ITU-R M.1464-2

- Radar F1 → short-to-medium range, terminal ATC radar (about 40–60 NM range and up to ~30 000 ft)
  Radar F2 → long-range, en-route ATC . (often 200+ NM, altitudes up to 100 000 ft in spec).
  Radar C → for terminal air traffic control.
- Short Pulse (SP): 0.5–1.5 ms, high resolution to distinguish aircraft that are close in distance.
  Long Pulse (LP): 10–50 ms, greater detection range.

Interference at the radar RF port

$$I = PT + GT + GR – LT – LR – LP – FDRIF$$ (Rec. ITU-R M.1461)

FDRIF= 0dB. AOOBE components lie within the receiver's IF passband, the IF selectivity provides no additional suppression.

This equation can be generalized to account for radar-specific parameters and adjacent-band OOBE, since the PFD (for DC MSS/IMT) is presently defined only for the in-band IMT frequency.

$$I\ [dBW/MHz] = PFD\ [dBW/m2/MHz] + 10\log_{10}(\lambda^2/4\pi)\ [dB] – AOOBE(\Delta f) + Grx\ [dBi] – Lrad – L\ feed – Lmisc – Lpol$$

Parameter	Designation	Unit	Radar F1		Radar F2		Radar C
Pulse duration type			SP	LP	SP	LP	SP/LP
Power Flux Density	PFD	dBW/m2/MHz	-82.5	-82.5	-82.5	-82.5	-82.5
Wavelength	λ	m	0.111	0.111	0.111	0.111	0.111
Antenna aperture gain factor	m2	dB	-30.1	-30.1	-30.1	-30.1	-30.1
Adjacent OOBE	AOOBE	dB	50	50	50	50	50
Antenna main-beam gain	Gpeak	dBi	41	41	46	46	34
Antenna main-beam gain @ -1°	G	dBi	38	38	43	43	31
Loss feeder	Lfeed	dB	1.3	1.3	1.3	1.3	1.3
Loss radome	Lradome	dB	1	1	1	1	1
Polarization-mismatch loss linear	Lpol-Lin	dB	3	3	3	3	3
Polarization-mismatch loss Circular	**Lpol-circ**	**dB**	**0**	**0**	**0**	**0**	**0**
Polarization-mismatch loss Circular, opposite direction	**Lpol-circ-Opp**	**dB**	**20**	**20**	**20**	**20**	**20**
mismatch loss	Lmisc	dB	1.2	1.2	1.2	1.2	1.2

- Typical pointing angle = 1° => Antenna main-beam gain at -1° is 3dB less at the horizon.

ICAO

Results/ Interpretations 1/2

Case of Polarization-mismatch loss Circular, same direction

Parameter	Designation	unit	F1		F2		C
Pulse width type			SP	LP	SP	LP	
Maximum permissible interference	Imax	dBW/MHz	-144	-144	-144	-144	-146.7
Interference at the radar RF port (mainbeam Gain)	IRF	dBW/MHz	-126.9	-126.9	-121.9	-121.9	-133.9
Marge		dB	-17.1	-17.1	-22.1	-22.1	-12.8

- Both the satellite and radar antennas employ Right-Hand Circular Polarization (RHCP)
- The interference level at the radar receiver input exceeds the allowable threshold

Case of polarization-mismatch loss Circular, opposite direction

Parameter	Designation	unit	F1		F2		C
Pulse width type			SP	LP	SP	LP	
Maximum permissible interference	Imax	dBW/MHz	-144	-144	-144	-144	-146.7
Interference at the radar RF port (mainbeam Gain)	IRF	dBW/MHz	-146.9	-146.9	-141.9	-141.9	-153.9
Marge		dB	2.9	2.9	-2.1	-2.1	7.2

- 20 dB for cross-polarization isolation RHCP/ LHCP
- The cross-polarization significantly reduces the interference on Radars F1 and C From DC MSS IMT.

Case of aggregation over K co-visible satellites

Parameter	Designation	unit	F1		F2		C
Pulse width type			SP	LP	SP	LP	
Maximum permissible interference	Imax	dBW/MHz	-148	-148	-148	-148	-150.7
Interference at the radar RF port (mainbeam Gain)	IRF	dBW/MHz	-142.1	-146.9	-141.9	-141.9	-153.9
Marge (I/N=-10dB. Cross Circ Opp Polar)		dB	-5.9	-1.1	-6.1	-6.1	3.2

- Aggregation factor K: 10Log10 k. for k=3 => K=4.771 dB, the DC MSS IMT ground power will increase by 4.771 dB.
- In this case, Rec. ITU-R M.1464-2 recommends I/N protection criterion should be –10 dB.

Worst-case aggregate interference at radar input

Parameter	Designation	unit	F1		F2		C
Pulse width type			SP	LP	SP	LP	
Maximum permissible interference	Imax	dBW/MHz	-148	-148	-148	-148	-150.7
Interference at the radar RF port (mainbeam Gain)	IRF	dBW/MHz	-122.1	-122.1	-117.1	-117.1	-129.1
Margin (I/N=-10dB. Cross Circ Opp Polar)		dB	-25.9	-25.9	-30.9	-30.9	-21.6

- No cross-polar isolation; performance criterion I/N ≤ –10 dB
- The radar cannot tolerate the aggregated interference levels at the receiver of about 22–31 dB higher than permissible.

ICAO

Results/ Interpretations, cont. 2/2

- Radars switch linear from/to circular polarization to improve clutter rejection (e.g., ground clutter, rain clutter)

  - **Circular polarization** → robust in rain/multipath, useful for clutter suppression and target discrimination.
  - **Linear polarization** → simple, efficient, and good for general detection.

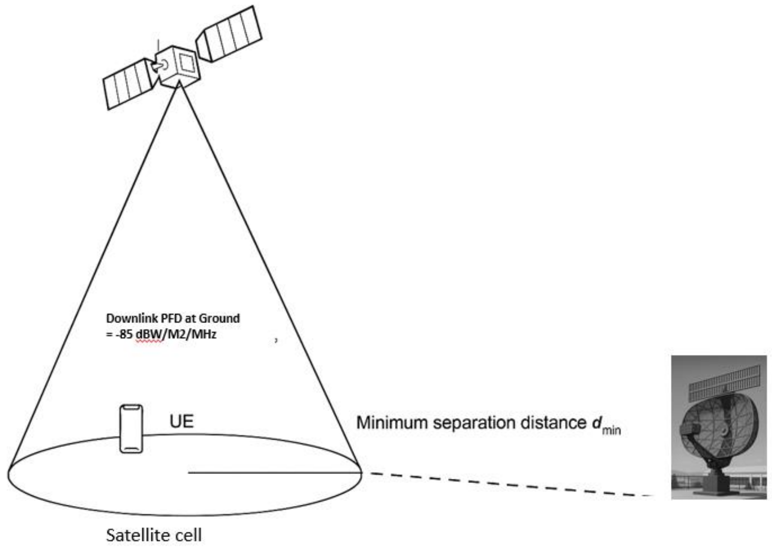
  Enforcing opposite polarization limits Radar performance !

- Tighter AOOBE / transmitter filters. Applying 60–70 dB is realistic , **but not enough**.

- Geographic power restrictions for radar service volume.

Sufficient distance is required to bring the interference down to acceptable levels, highlighting the necessity of geographic power restrictions or exclusion zones around radar sites.

To avoid harmful interference to ATC radar, IMT DC-MSS transmitters must support geographic power control necessary to protect radar areas.



ICAO

ICAO position

Ensure that the results of this agenda item for bands adjacent to aeronautical systems (694–2700 MHz):

- Do not reduce the protection of civil aviation systems operating in this frequency range.
- Do not impose additional regulatory or technical constraints on civil aviation systems operating in this range.

Special emphasis on protecting:

- Multiple civil aviation systems operating within 694–2700 MHz.
- Primary surveillance radars adjacent to the upper end of 694–2700 MHz.
- Weather radars adjacent to the upper end of 694–2700 MHz.

Conclusion

Coexistence between DC MSS/IMT (2500–2690 MHz) and ATC radar (2700–2900 MHz) is feasible provided studies and deployments:

- account for aggregate interference from multiple satellites/beams covering a radar;
- meet the agreed I/N protection criterion (e.g., ≤ –10 dB).
- apply adequate adjacent-band out-of-band-emission (OOBE) limits; and
- implement geographic (location-based) power control to MSS satellite station, within protection zones;

Excel sheet calculations.

Radar noise power and allowable interference							
			F1		F2		C
			SP	LP	SP	LP	SP/LP
Frequency	f	GHz	2.7	2.7	2.7	2.7	2.7
Bandwitdh	BIF	MHz	1.2	1.8	1.2	1.6	1.1
Noise figure	NF	dB	6	6	6	6	3.3
Total radar receiver noise	Ntot	dBW	-137.21	-135.45	-137.21	-135.96	-140.29
Noise spectral density per MHz	N1MHz	dBW/MHz	-138	-138	-138	-138	-140.7
Interfer to Noise	I/N	dB	-10	-10	-10	-10	-10
Maximum permissible interference	Imax	dBW/MHz	-148	-148	-148	-148	-150.7
Interference at the radar RF port							
Power Flux Density	PFD	dBW/m2/MHz	-82.5	-82.5	-82.5	-82.5	-82.5
Wavelength	λ	m	0.111	0.111	0.111	0.111	0.111
Antenna aperture gain factor	m2	dB	-30.1	-30.1	-30.1	-30.1	-30.1
Adjacent OOBE	AOOBE	dB	50	50	50	50	50
Antenna main-beam gain	dBi	dBi	41	41	46	46	34
Antenna main-beam gain @ -3°	G at -3°	dBi	38	38	43	43	31
Loss feeder	Lfeed		1.3	1.3	1.3	1.3	1.3
Loss radome	Lradome		1	1	1	1	1
Polarization-mismatch loss linear	Lpol-Lin	dB	3	3	3	3	3
Polarization-mismatch loss Circular, same direction	**Lpol-circ**	**dB**	**0**	**0**	**0**	**0**	**0**
Polarization-mismatch loss Circular, opposite direction	**Lpol-circ-Opp**	**dB**	**20**	**20**	**20**	**20**	**20**
Mismatch loss	Lmisc	dB	1.2	1.2	1.2	1.2	1.2
Interference at the radar RF port (mainbeam Gain)	IRF	dBW/MHz	-122.1	-122.1	-117.1	-117.1	-129.1
Aggregation factor	K	dB	4.771	4.771	4.771	4.771	4.771

Parameter	**Designation**	**unit**	**F1**		**F2**		**C**
Pulse width type			SP	LP	SP	LP	
Maximum permissible interference	Imax	dBW/MHz	-148	-148	-148	-148	-150.7
Interference at the radar RF port (mainbeam Gain)	IRF	dBW/MHz	-122.1	-122.1	-117.1	-117.1	-129.1
Margin		dB	-25.9	-25.9	-30.9	-30.9	-21.6

ICAO

Thank You

ICAO