Preliminary RFI measurements in LOFAR frequency range at Yebes Observatory

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1 Introduction

This report shows the preliminary measurements of the RFI spectrum at Yebes Observatory in the Low Frequency Array (LOFAR) telescope frequency bands: 30 - 80 MHz and 110 - 240 MHz.

These bands have been measured in order to evaluate, from the RFI viewpoint, the feasibility of the installation of a LOFAR station in Yebes Observatory.

The band 87.5 - 108 MHz has been discarded in this report because it is allocated to FM radio broadcasting.

Firstly, the measurement setup will be described together with the instrumentation used for that purpose. Secondly, the measured spectrum will be shown in terms of electric field intensity, E [dB ($\mu\frac{V}{m}$)].

2 Measurement setup

The measurements were performed during the 22^{th} and 23^{th} of January 2018. Part of the equipment used for these measurements was placed on top of the roof of the new laboratory building (Figure 1), where the horizon is fairly clear.

The instrumentation used consists of the following elements:

- Wideband (25 - 1300 MHz) Discone Antenna (2 dBi gain) mounted on a mast, model D130J from Diamond Antenna (see appendix A for details).
- 20 - 3000 MHz pre-amplifier, model MiniCircuits ZX60-3018G+ (see appendix B for details).
- 1 MHz - 20 GHz spectrum analyzer from Keysight Technologies, model N9344C.
- RG-58 Coaxial cable.
- 8 - 1024 MHz USB and Ethernet controlled RF synthesizer from Holzworth Instrumentation, model HS1001B.
- 10 MHz - 67 GHz PNA network analyzer from Keysight, model N5277A.

Data analysis took place at the laboratory (located on the first floor of the building), so the antenna signal went down from the roof of the building to this place along the coaxial cable. To improve sensitivity and compensate for cable losses, a pre-amplifier was installed at the antenna output.

The gain curve of the pre-amplifier was obtained by fitting the measured data in the vector network analyzer to an 8 degree polynomial.

The coaxial cable losses were characterized. To do that, the synthesizer was configured in frequency sweeping mode between 1 - 250 MHz at -29 dBm and installed on the roof of the building at the input of the coaxial cable. Measuring the signal received with the spectrum analyzer and taking the difference between

Figure 1: Discone Antenna location

input and output level, the coaxial cable losses were characterized and taken into account in the computations of RFI incident E-field, together with the gain of the pre-amplifier.

Figures 2 and 3 shows the gain of the pre-amplifier and coaxial cable losses, respectively, in frequency range of 30 - 240 MHz.

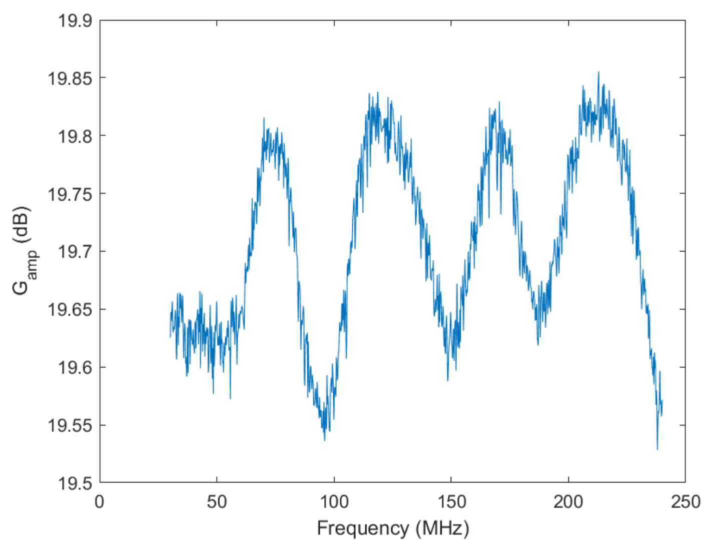


Figure 2: Gain (dB) of the pre-amplifier in the range 30 - 240 MHz.

In order to convert the power measured by the spectrum analyzer to incident electric field intensity on the antenna, the antenna factor was computed from the antenna gain data and the gain of the set pre-amplifier plus coaxial cable from the antenna to the spectrum analyzer.

The incident electric field on the antenna is given by the following equation:

$$E[dB(\mu \frac{V}{m})] = AF[dB(\frac{1}{m})] + V[dB(\mu V)] \quad (1)$$

where E is the incident electric field, AF is the antenna factor and V is the voltage measured across antenna terminals.

The voltage V, can be expressed as:

$$V[dB(\mu V)] = 107 + P[dBm] = 107 + P_m[dBm] - G_{amp}[dB] + L_{cab}[dB] \quad (2)$$

where P_m is the measured power by the spectrum analyzer, G_{amp} is the gain of the pre-amplifier and L_{cab} refers to coaxial cable losses.

The value of AF is computed as follows:

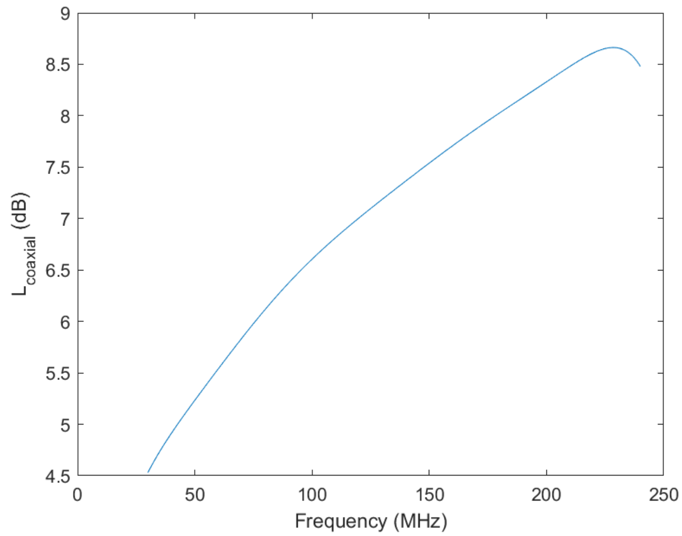


Figure 3: Coaxial cable losses (dB) in the range 30 - 240 MHz.

$$AF[dB(\frac{1}{m})] = 20 \cdot log(f[MHz]) - G_{ant}[dBi] - 29.77 \tag{3}$$

where where f is the frequency in MHz and G_{ant} is the gain of the antenna in dBi units.

3 Results

In this section, the spectrum in the bands 30 - 80 MHz and 110 - 240 MHz is given in calibrated units of intensity of electric field (Figures 4 and 5) to show the existing RFI signals in the band of interest for LOFAR telescopes.

Also several figures (6 - 23) will show with more detail (10 MHz subband width) the same in dBm units. This measurements have been taken with a software define radio. Its purpose is to analyze the kind of information that this RFI signal has by means of decoding the data when it is possible. The kind of subband is also indicated depending on the purpose for which the spectrum is defined.

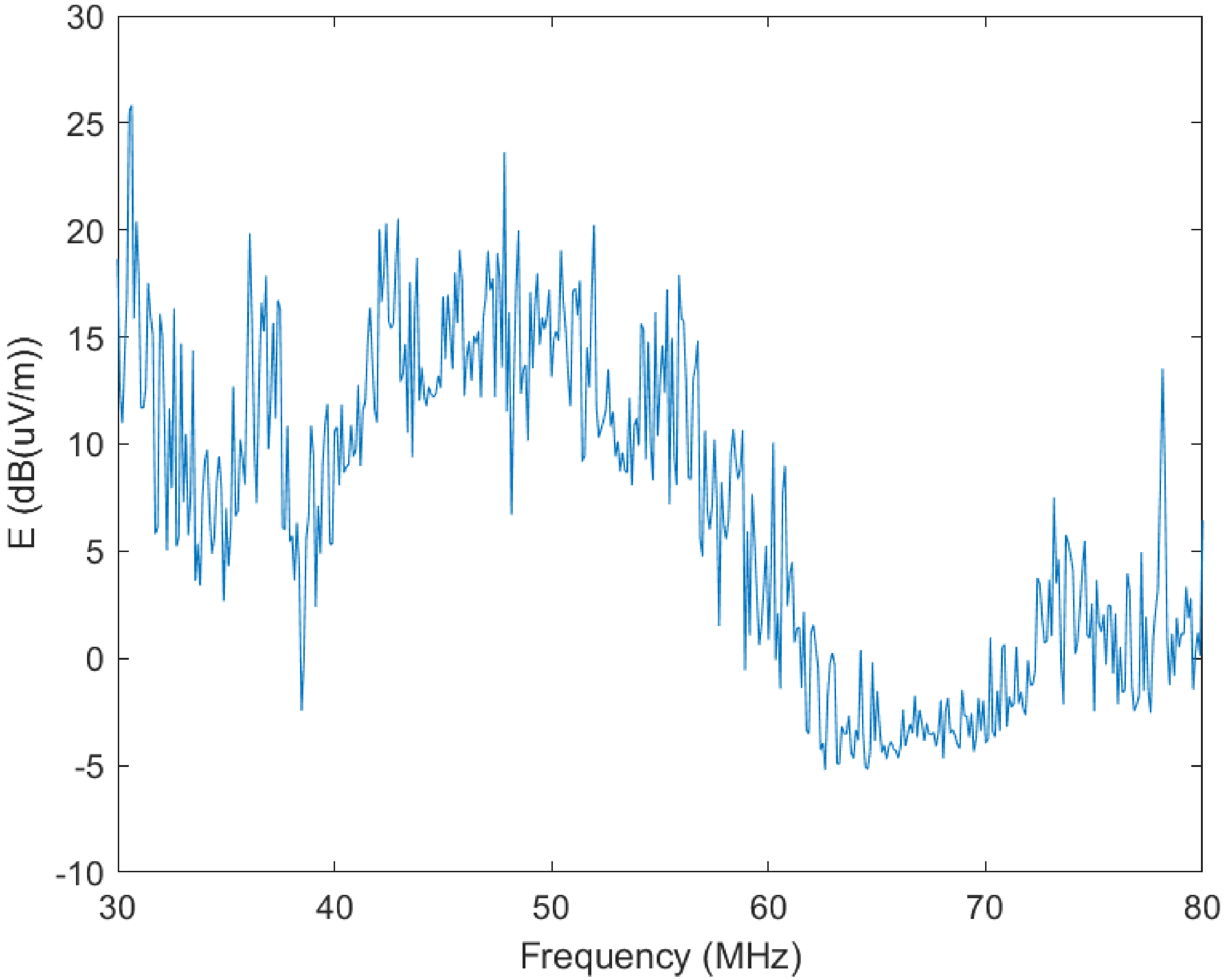


Figure 4: Electric field intensity in the range 30 - 80 MHz.

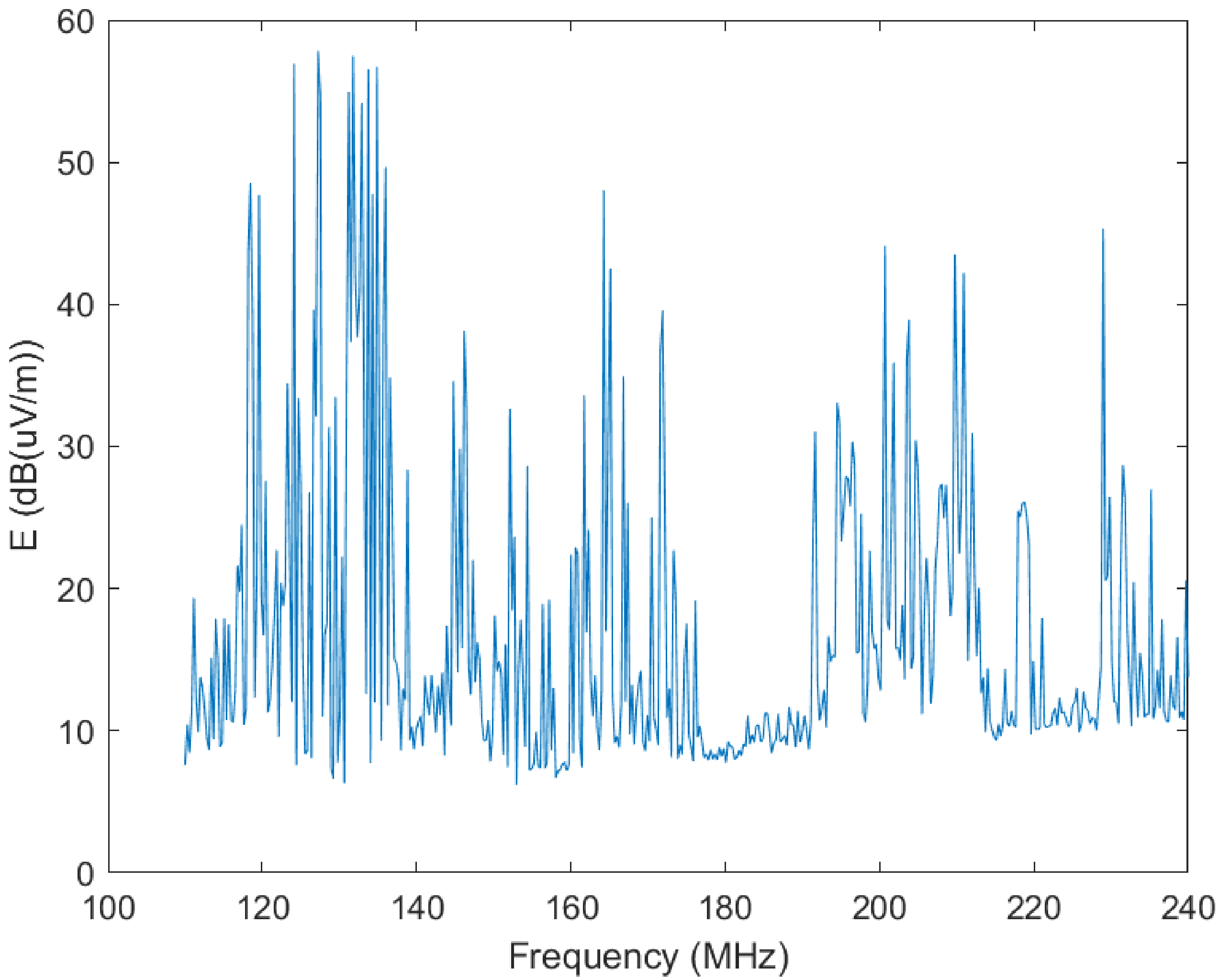


Figure 5: Electric field intensity in the range 110-240 MHz.

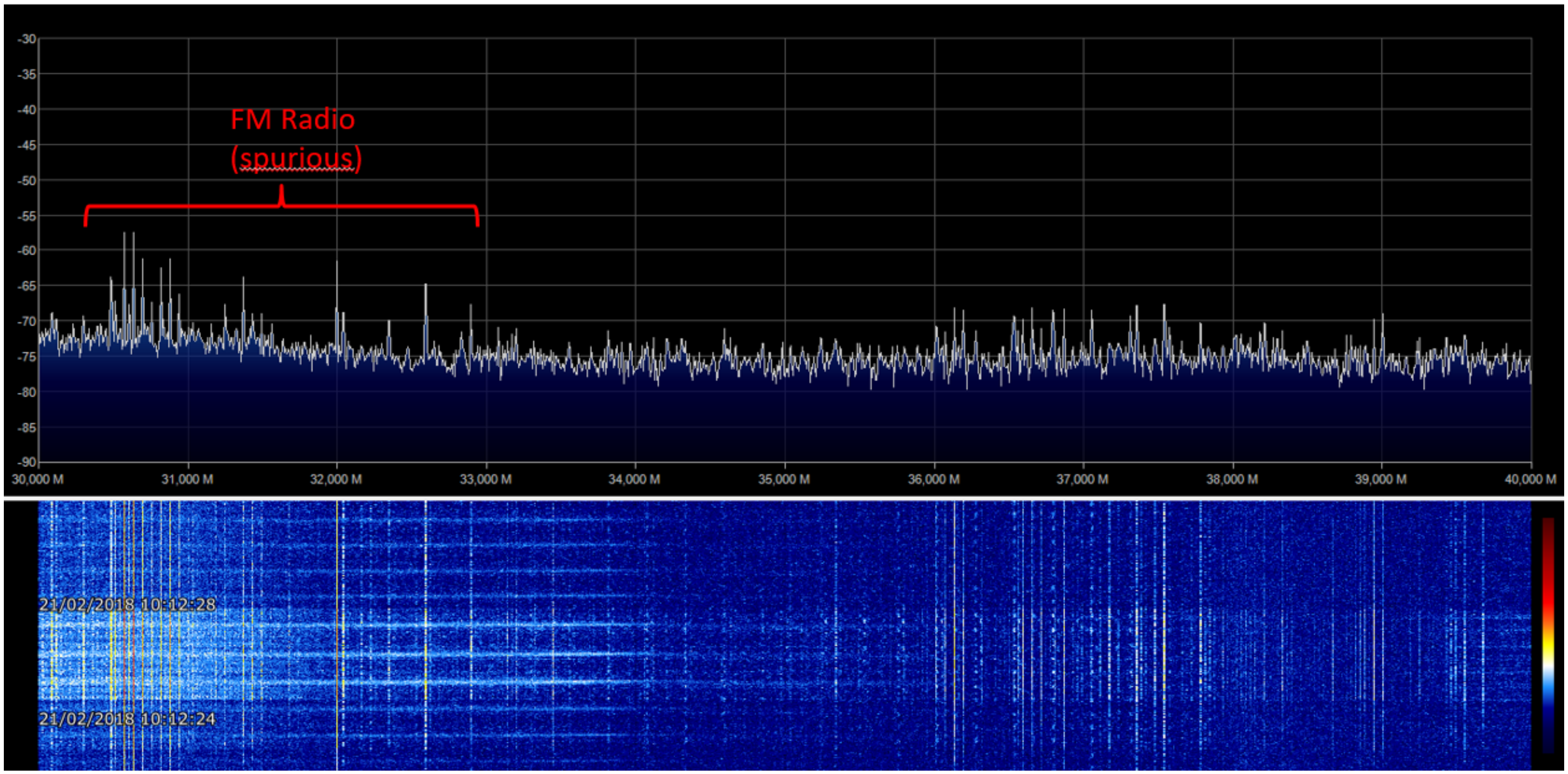


Figure 6: RFI spectrum in frequency range 30-40 MHz.

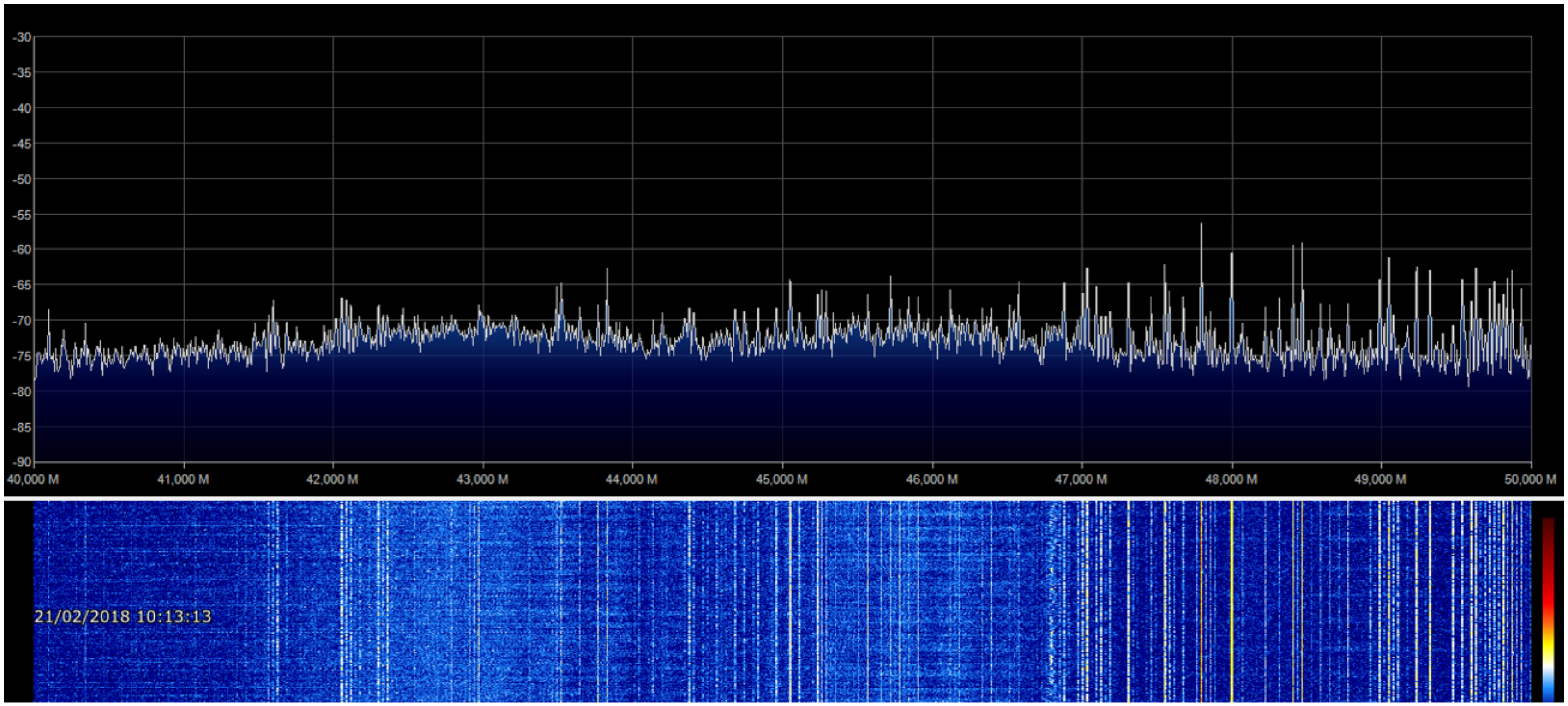


Figure 7: RFI spectrum in frequency range 40-50 MHz.

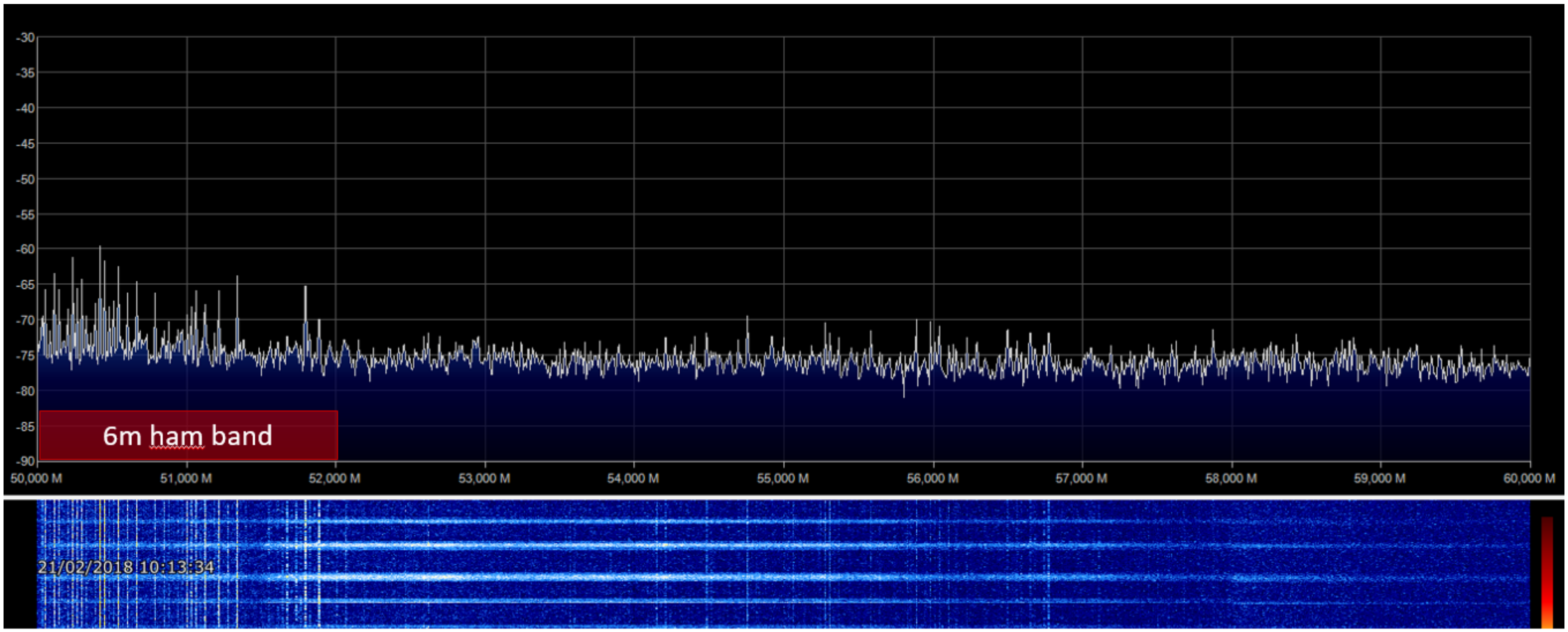


Figure 8: RFI spectrum in frequency range 50-60 MHz.

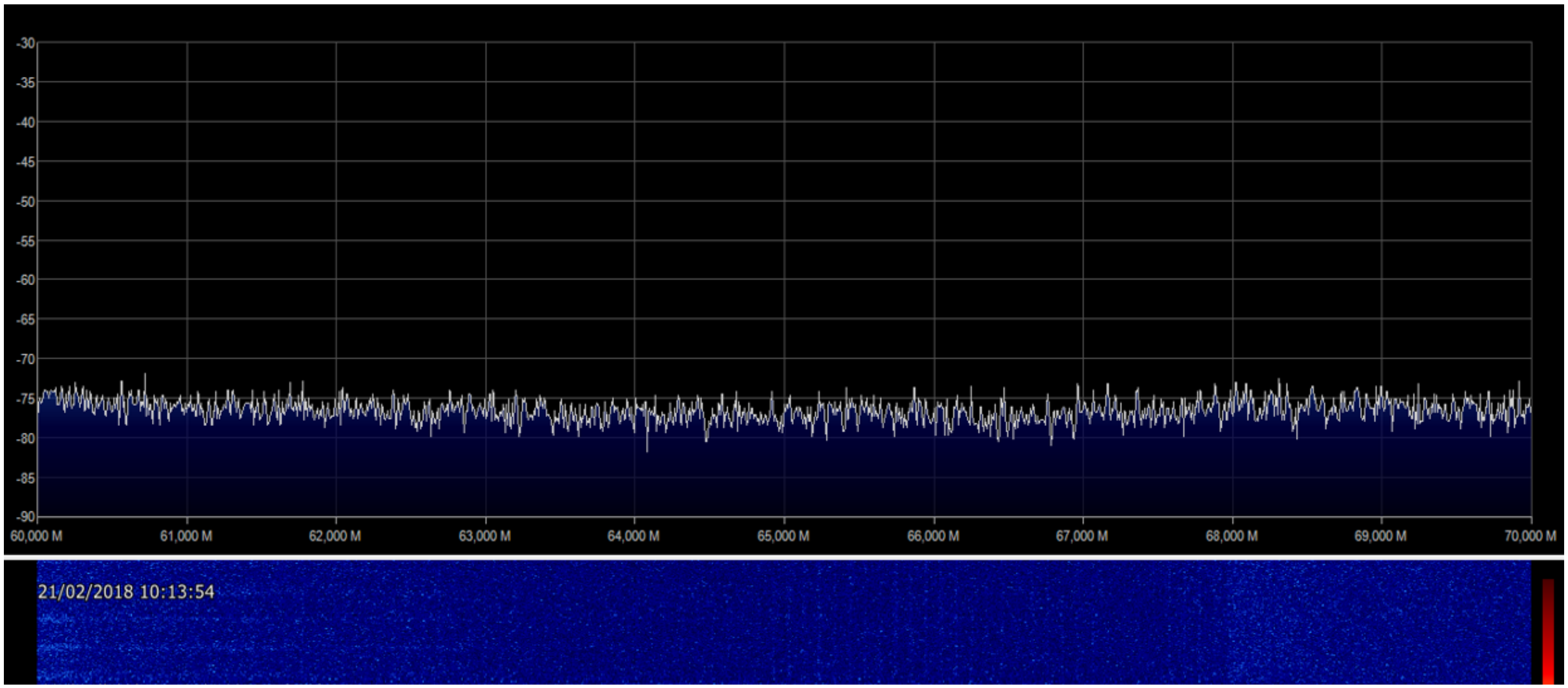


Figure 9: RFI spectrum in frequency range 60-70 MHz.

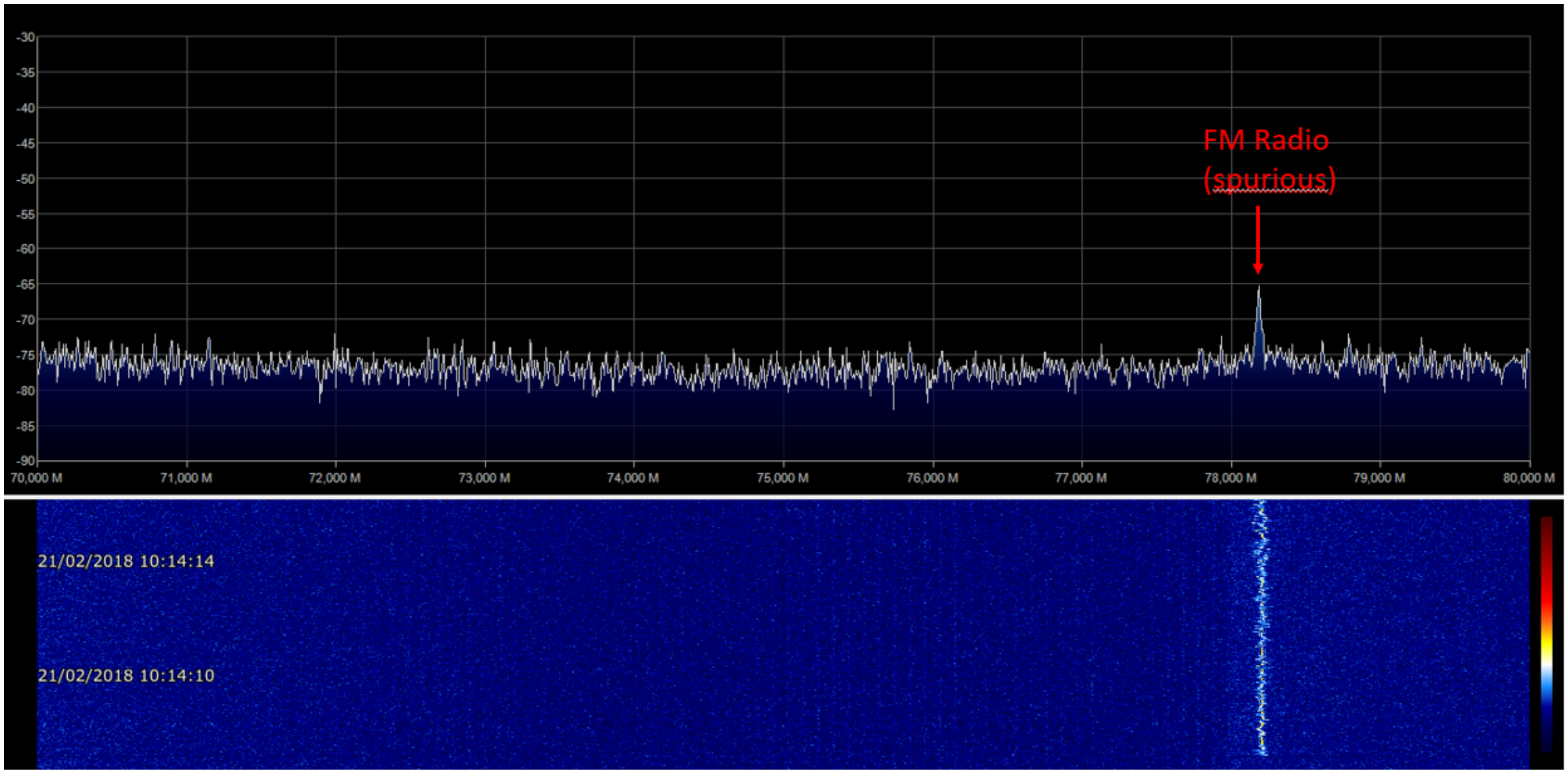


Figure 10: RFI spectrum in frequency range 70-80 MHz.

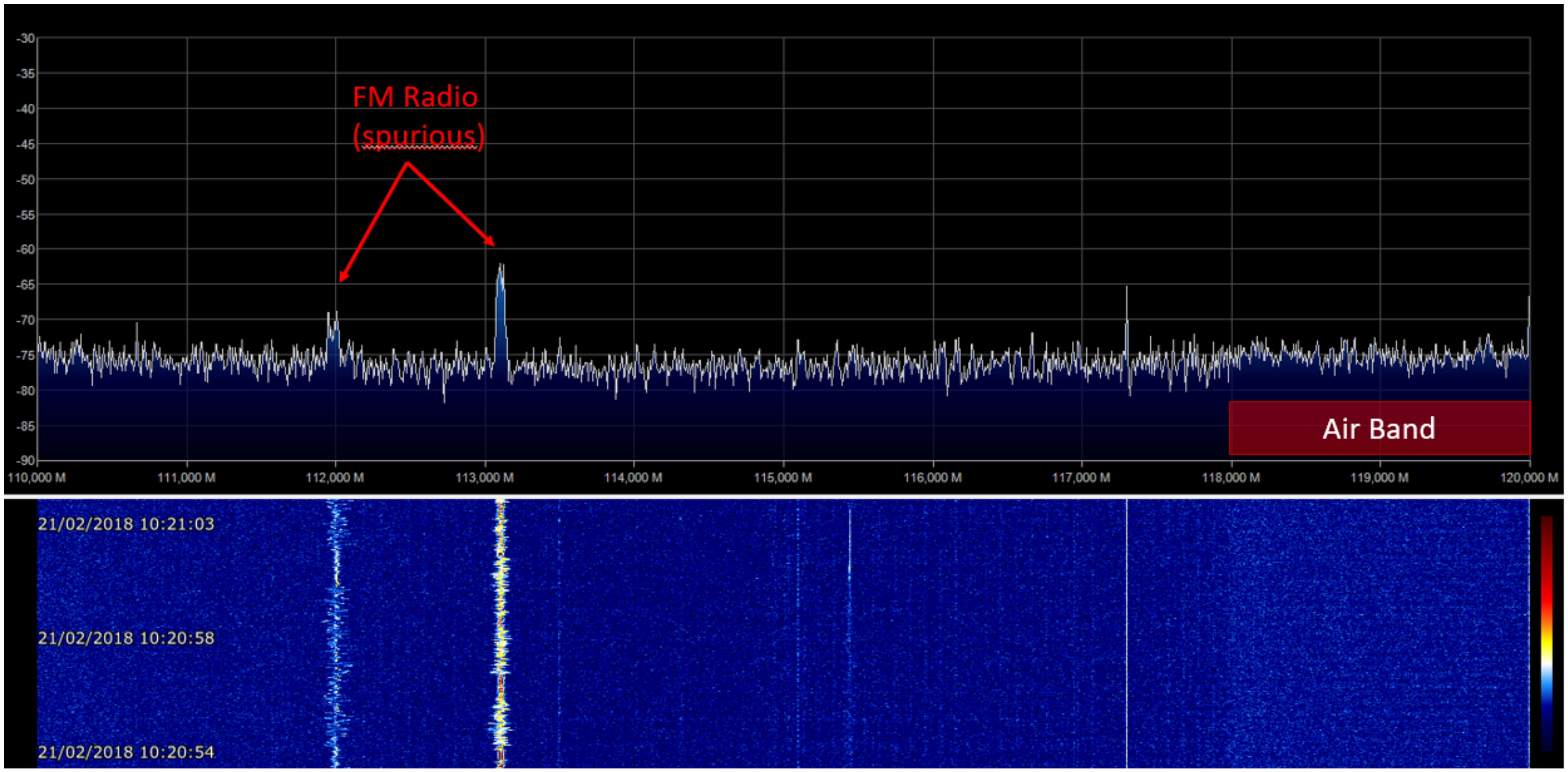


Figure 11: RFI spectrum in frequency range 110-120 MHz.

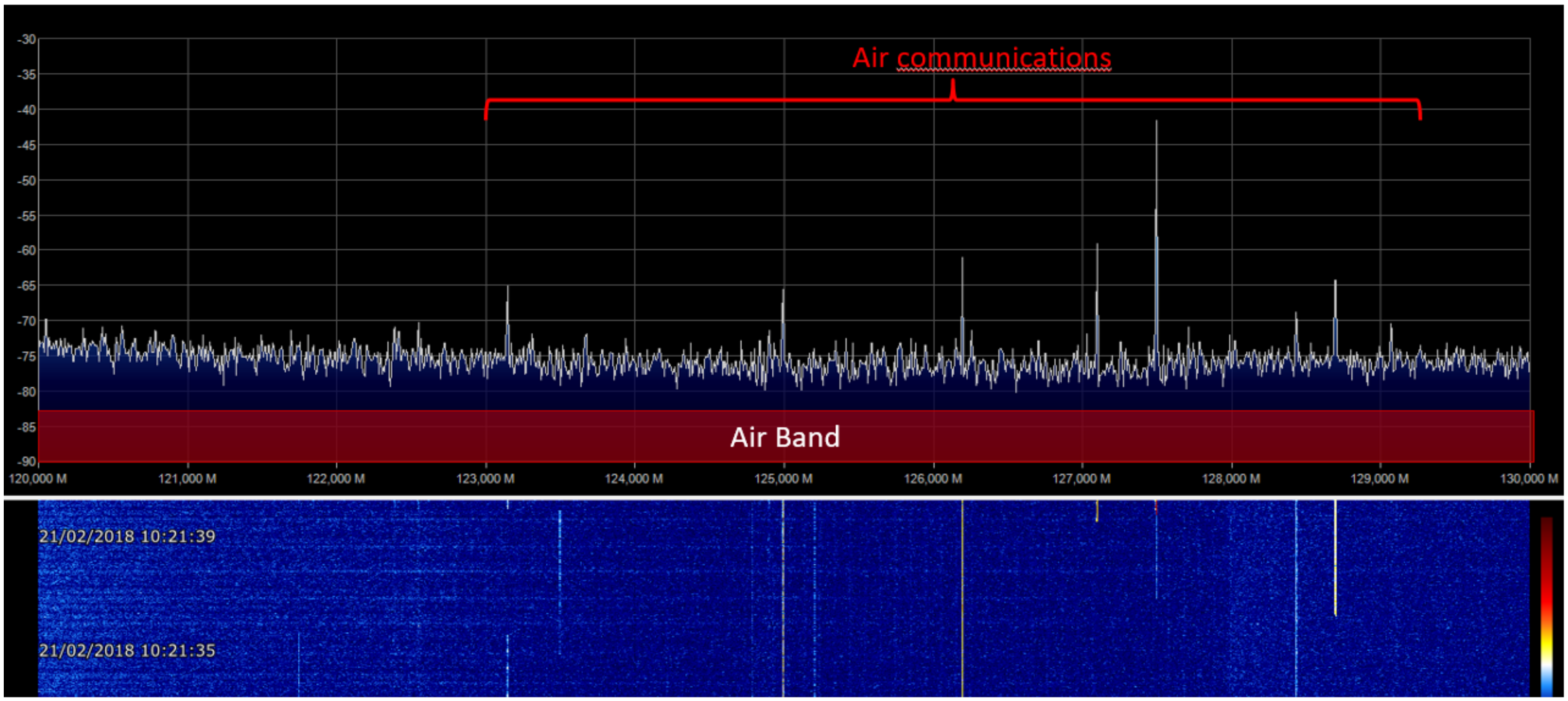


Figure 12: RFI spectrum in frequency range 120-130 MHz.

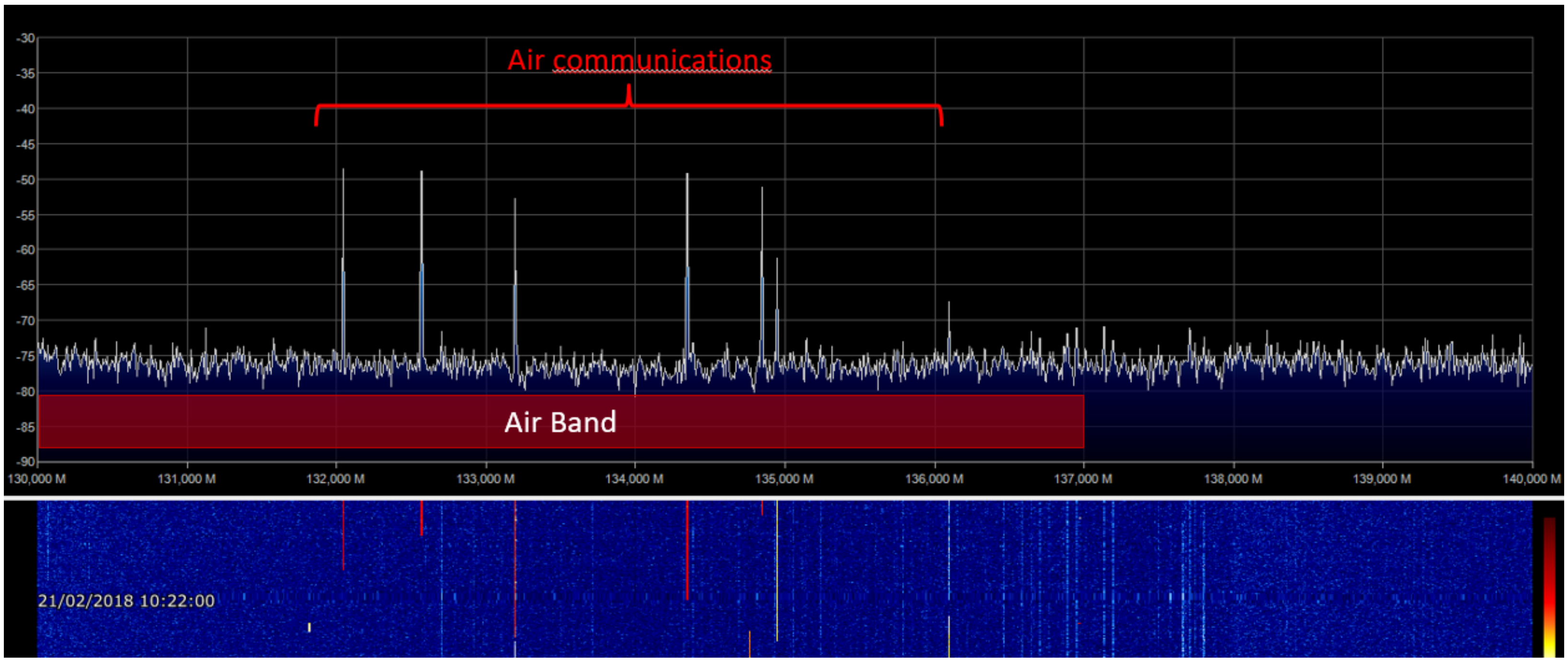


Figure 13: RFI spectrum in frequency range 130-140 MHz.

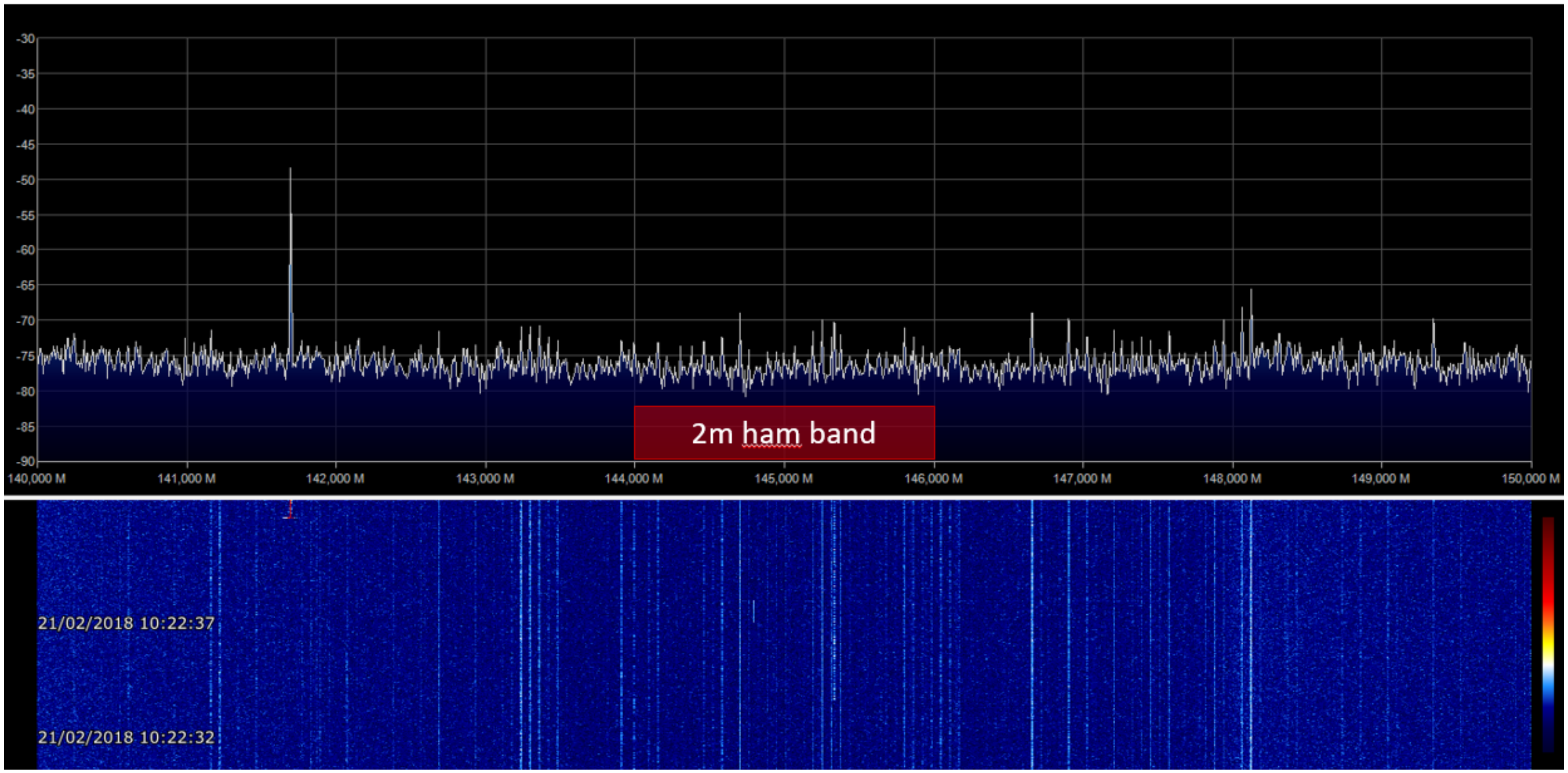


Figure 14: RFI spectrum in frequency range 140-150 MHz.

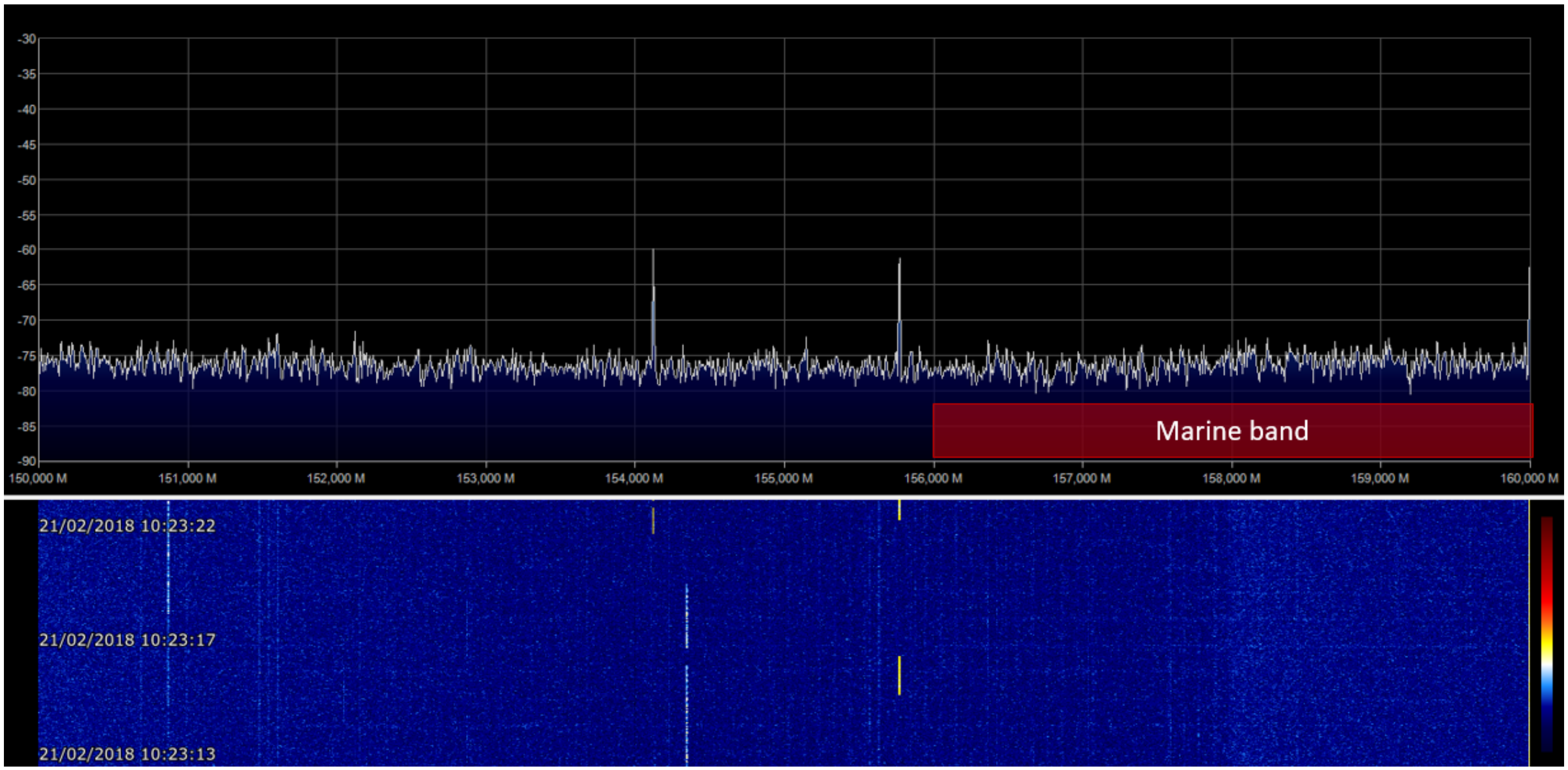


Figure 15: RFI spectrum in frequency range 150-160 MHz.

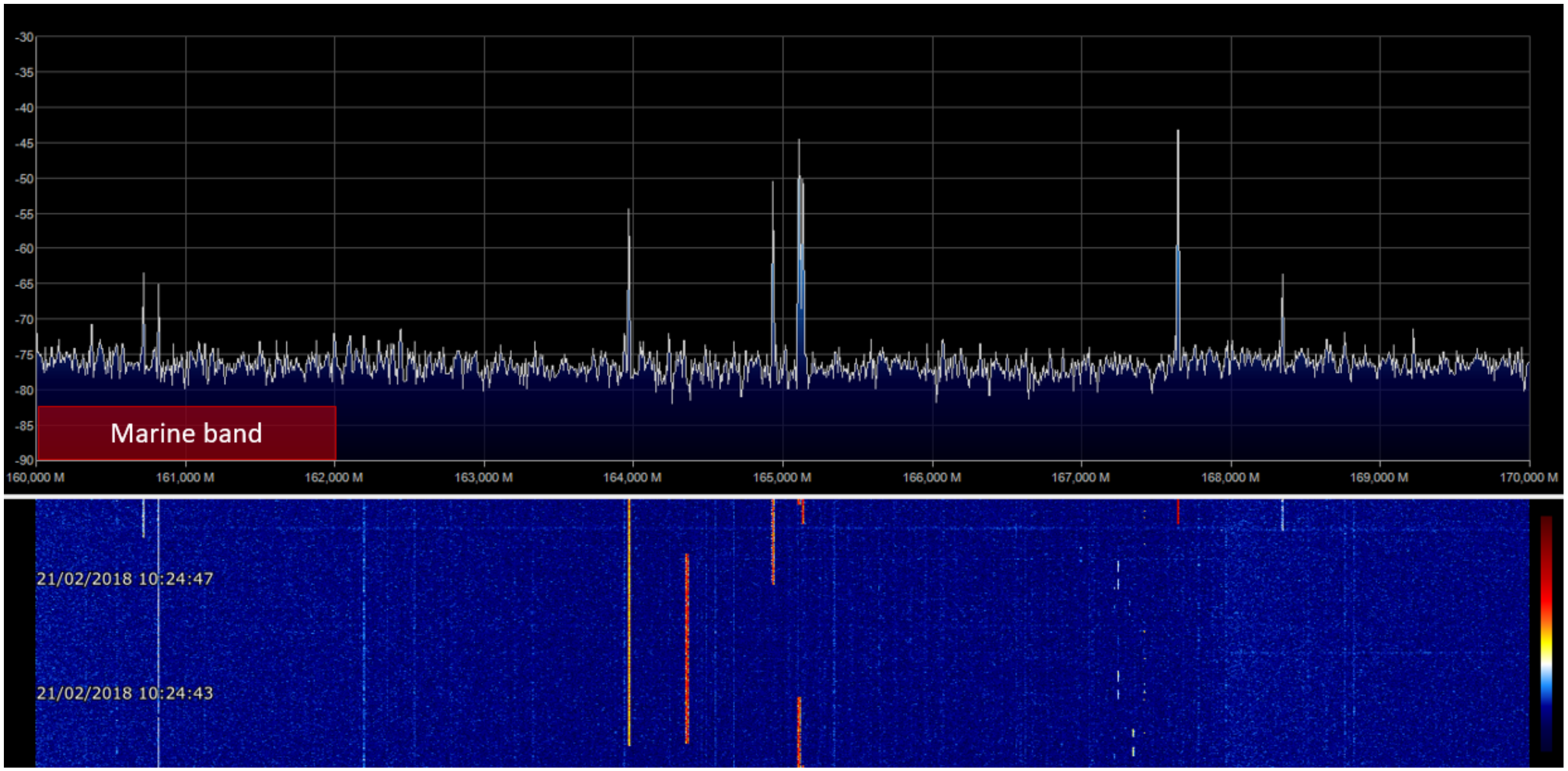


Figure 16: RFI spectrum in frequency range 160-170 MHz.

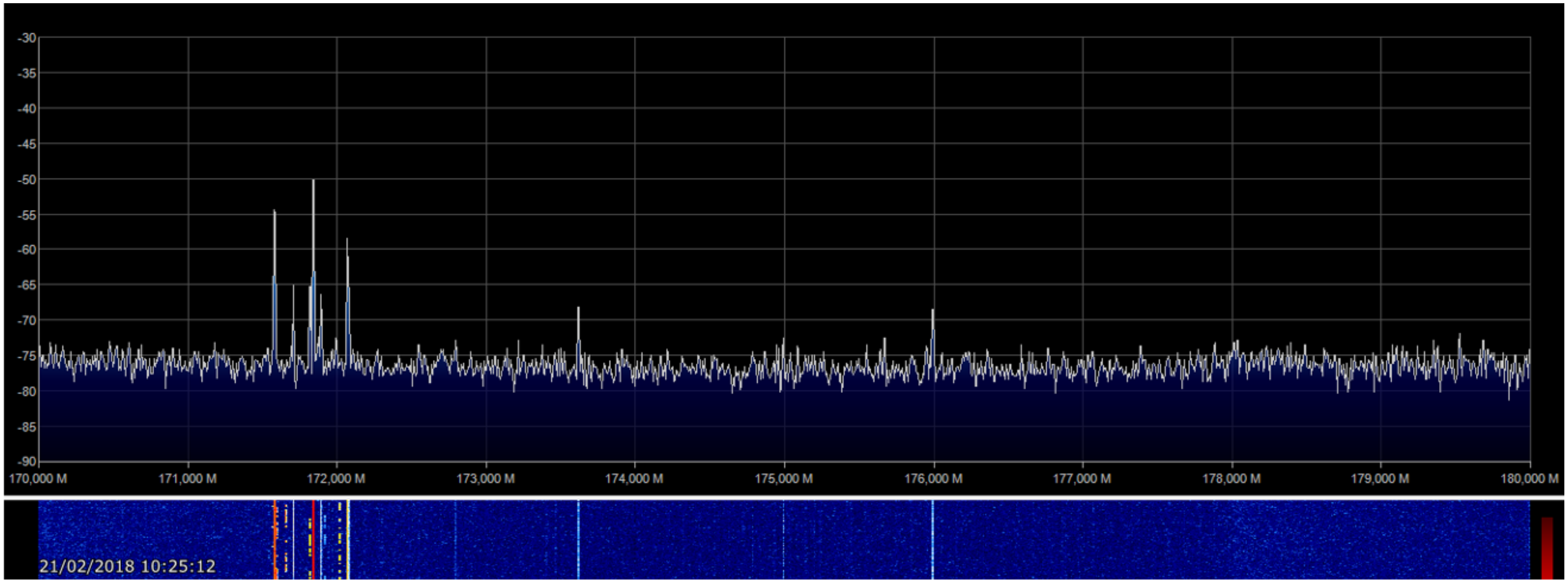


Figure 17: RFI spectrum in frequency range 170-180 MHz.

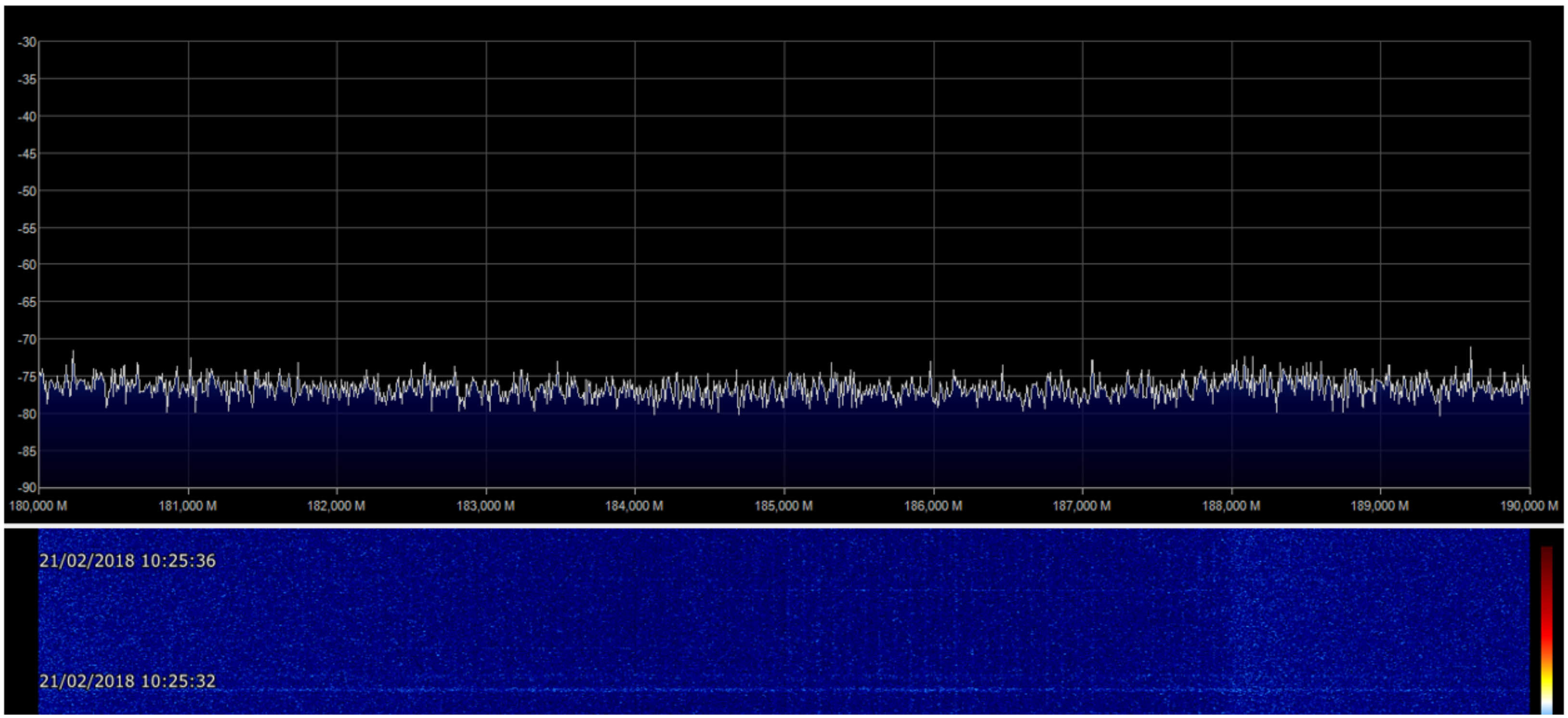


Figure 18: RFI spectrum in frequency range 180-190 MHz.

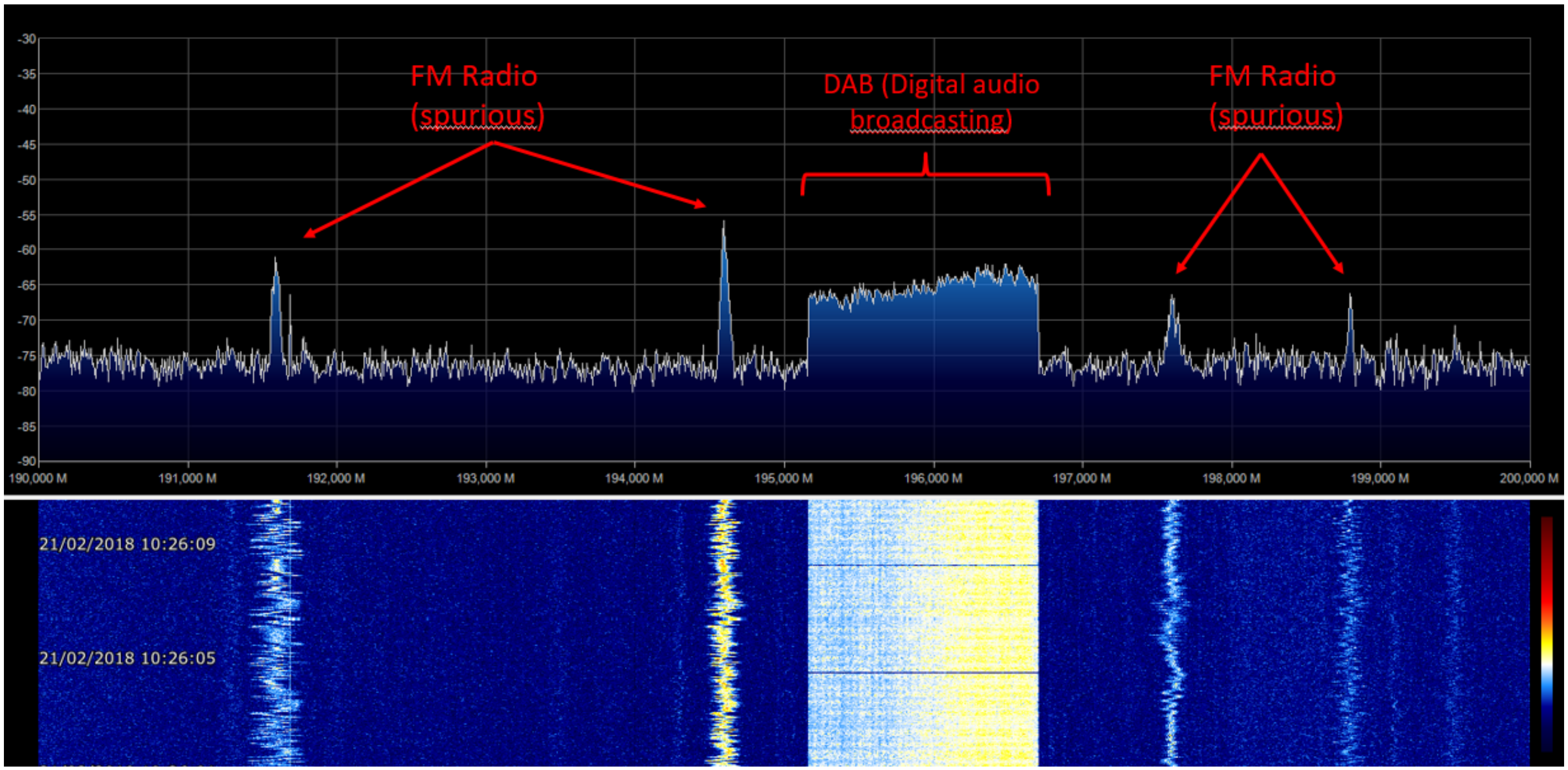


Figure 19: RFI spectrum in frequency range 190-200 MHz.

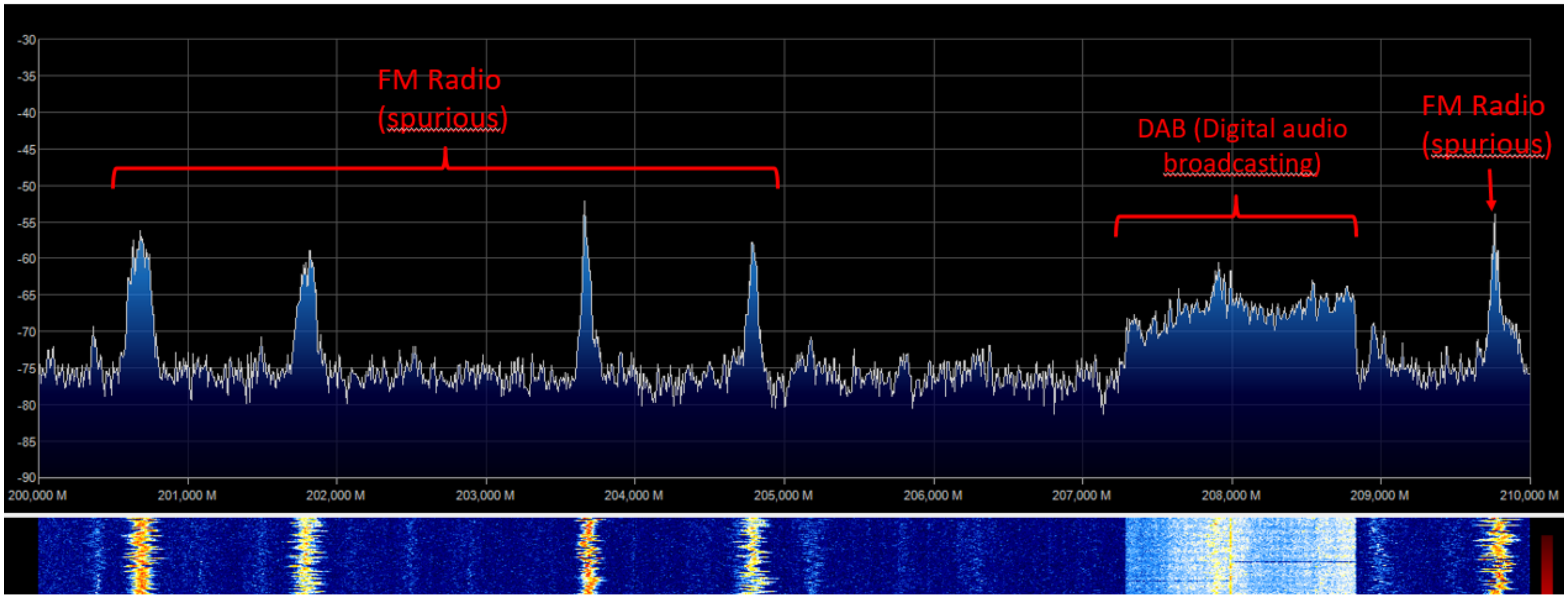


Figure 20: RFI spectrum in frequency range 200-210 MHz.

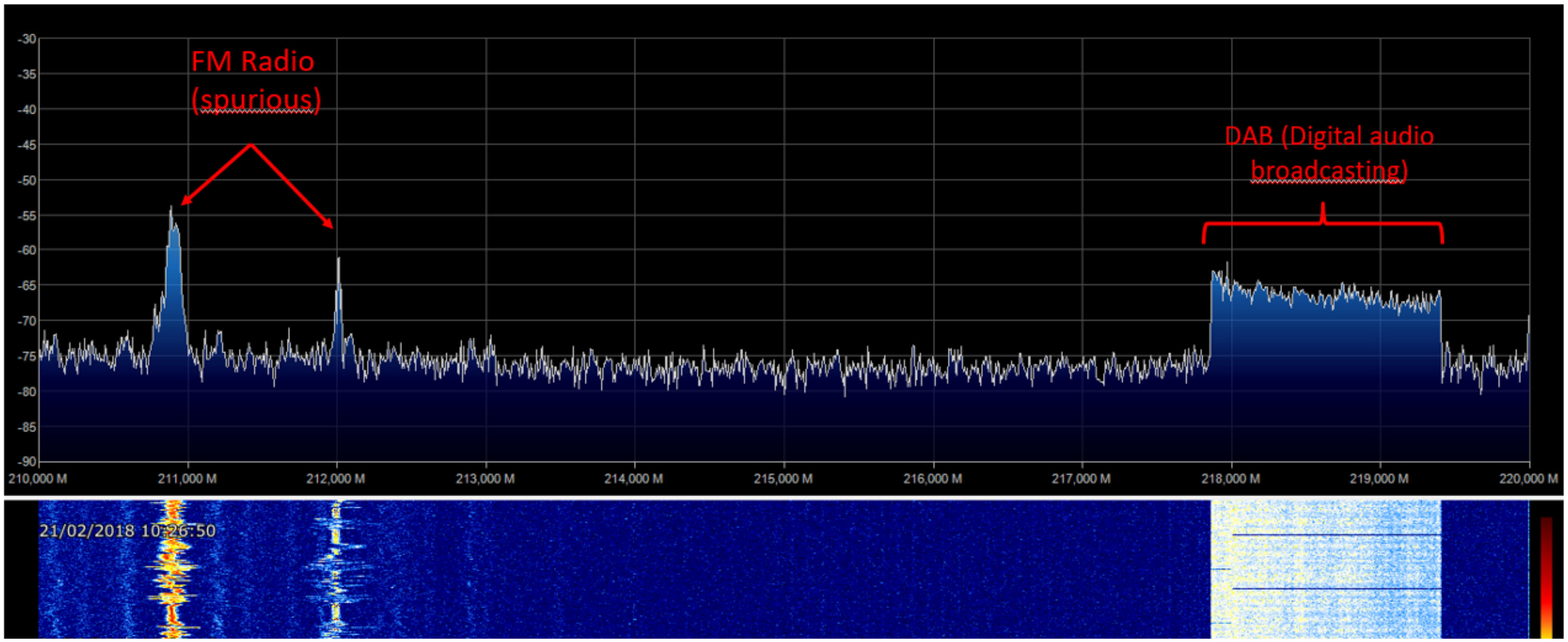


Figure 21: RFI spectrum in frequency range 210-220 MHz.

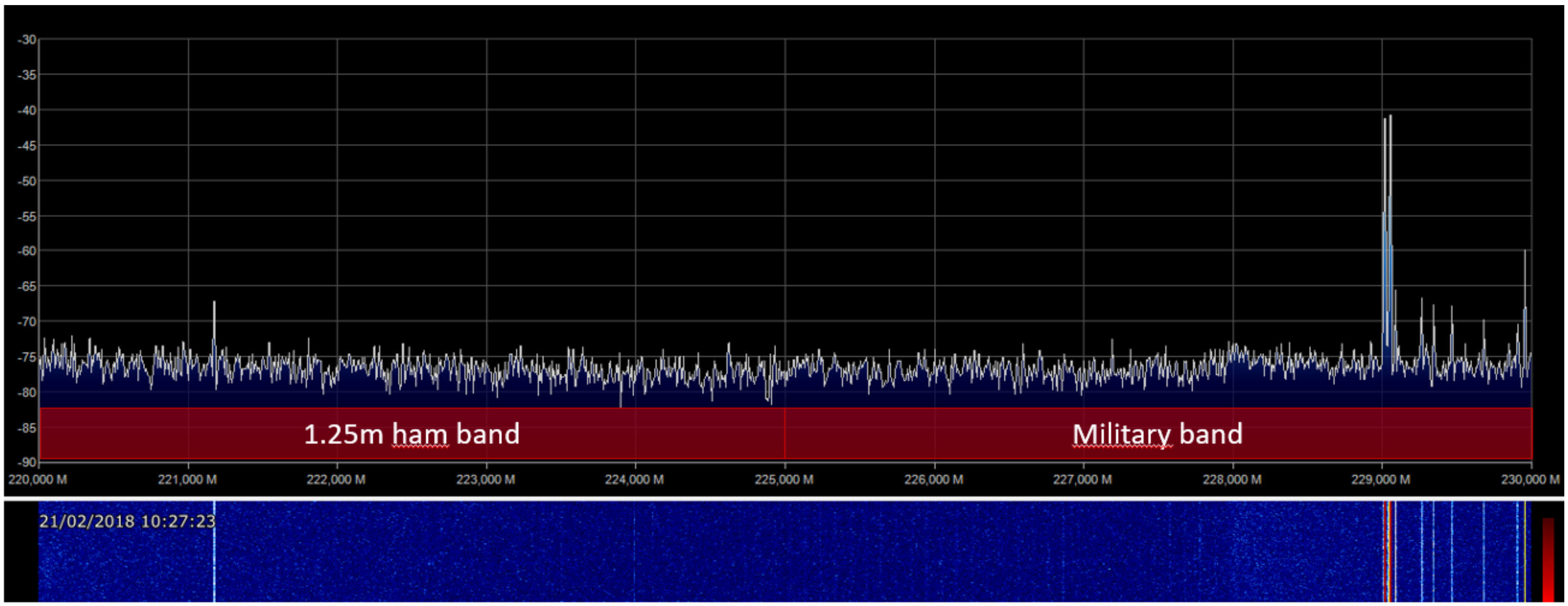


Figure 22: RFI spectrum in frequency range 220-230 MHz.

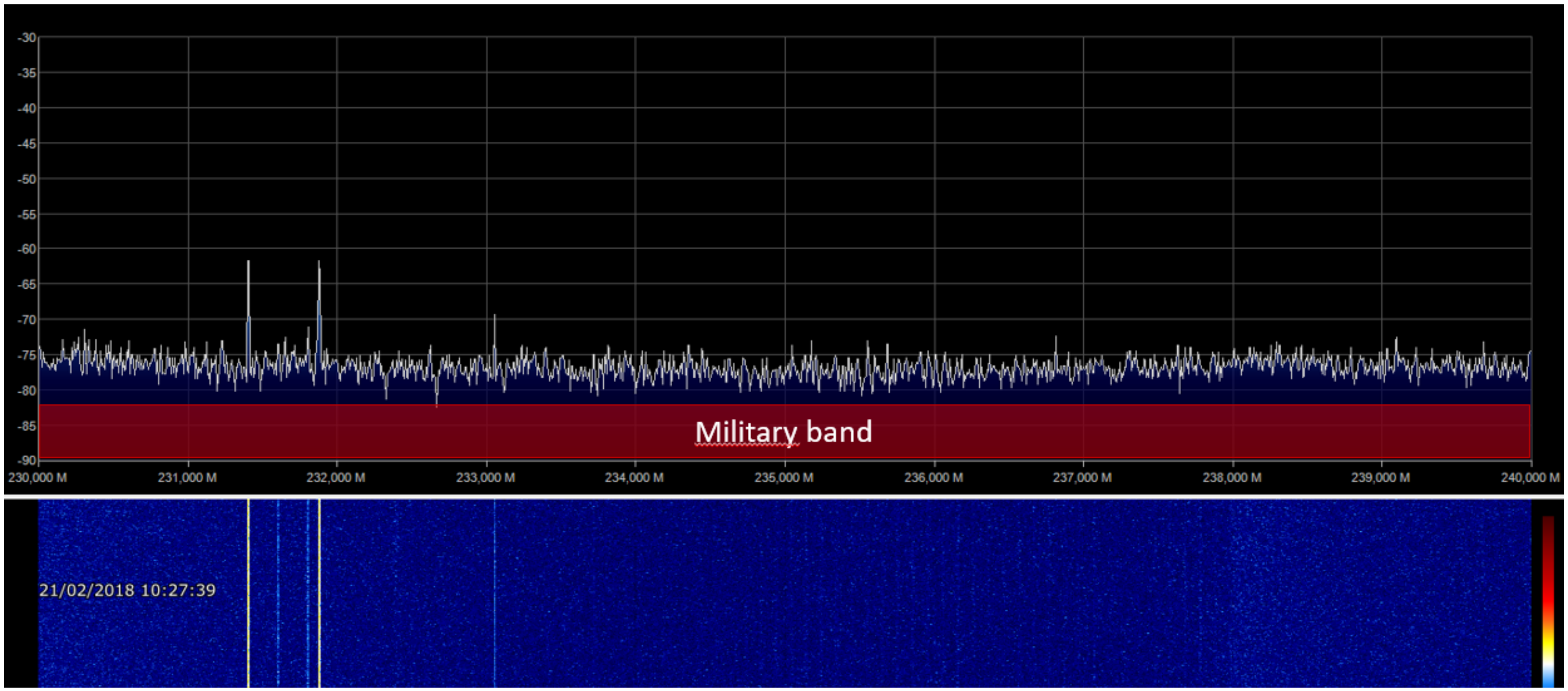


Figure 23: RFI spectrum in frequency range 230-240 MHz.

4 Conclusion

Decoding the signals, it is shown that several radio FM signal transmission are found out of the FM radio band (80-110 MHz). They could be seconds harmonics from the main ones. Also, in the air band (118-137 MHz) several air communication between the pilot and control tower are found. Yebes is located 60 km from Barajas airport and 40 km from military airbase of Torrejon, so it is logical to find this RFI signals in the spectrum.

As this title indicates, these measurements are preliminary. In the following ones, the observation period will be grater in order to evaluate its continuity along the time.

A Antenna specifications

D130J Super Discone Antenna

Special Features:

- Ultra-wideband design 25 to 1300 MHz receive, 50-1300 MHz transmit (6m tunable for transmit)
- Compact and lightweight design enables antenna to be installed on balcony railing at an apartment or condominium
- Ideal for 2m, 1-1/4m, 70cm, 33cm and 23cm amateur bands
- Excellent "shop" antenna for testing various transmitters on a single coax
- Can be made further compact and lightweight by removing the top loading coil if 25-50 MHz reception is not required

Specifications:

Bands:	25-1300 MHz
Gain dBi:	2 (nominal)
Max Power Rating:	144 MHz up: 200 watts 6m: 20 watts FM, 50 watts PEP
Height:	5.6'
Weight:	2.2 Lbs.
Connector:	UHF
Element Phasing:	Wideband Discone

Remarks: Adjustable 50-54 MHz. Also available with Type-N connector.

B Amplifier specifications

Connectorized

Amplifier

ZX60-3018G+

50Ω 20 MHz to 3 GHz

CASE STYLE: GC957

Connectors	Model
SMA	ZX60-3018G-S+

+RoHS Compliant
The +Suffix identifies RoHS Compliance. See our web site for RoHS Compliance methodologies and qualifications

Features
- Wide bandwidth, 20 MHz to 3 GHz
- Low noise figure, 2.7 dB typ.
- Output power up to 12.8 dBm typ.
- Protected by US patent 6,790,049

Applications
- Buffer amplifier
- Cellular
- PCS
- Lab
- Instrumentation
- Test equipment

Electrical Specifications at T_{AMB} = 25°C

MODEL NO.	FREQ. (GHz)	DC VOLTAGE @ Pin V+ (V)	GAIN over frequency in GHz Typ (dB)					MAXIMUM POWER (dBm) Output (1 dB Comp.) Typ.		DYNAMIC RANGE		VSWR (:1) Typ.		ACTIVE DIRECTIVITY (dB) Isolation-Gain	DC OPERATING CURRENT @ Pin V+ (mA)	
	f_L - f_U		0.1	1.0	2.0	3.0	Min.at 2 GHz	f_L	f_U	NF (dB) Typ.	IP3 (dBm) Typ.	In	Out	Typ.	Typ.	Max.
ZX60-3018G+	0.02 - 3	12.0	22.8	21.9	20.3	18.8	18.0	12.8	10.2	2.7	25.0	1.3	1.4	2-6	34	45

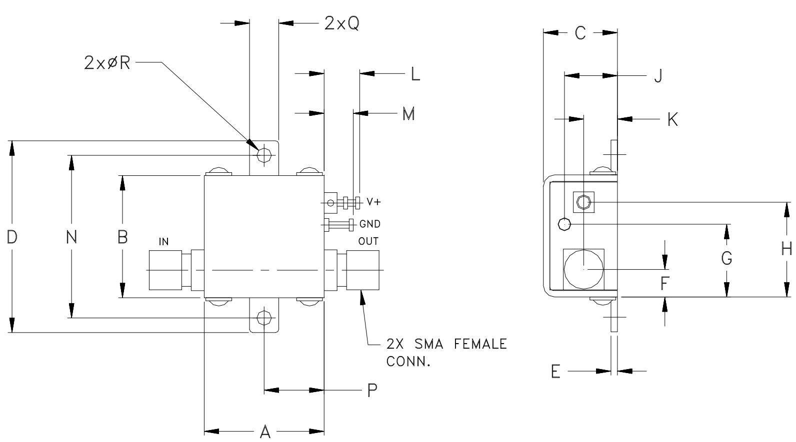
Maximum Ratings

Operating Temperature	-45°C to 85°C case
Storage Temperature	-55°C to 100°C
DC Voltage	12.5V
Input Power(no Damage)	13dBm
Power	0.7W

Permanent damage may occur if any of these limits are exceeded.

NOTE: When soldering the DC connections, caution must be used to avoid overheating the DC terminals. See Application Note AN-40-10 .

Outline Drawing

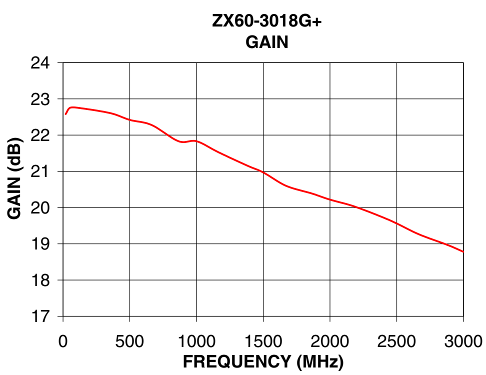


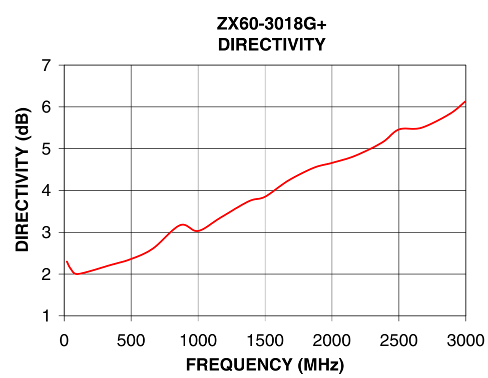
Outline Dimensions (inch / mm)

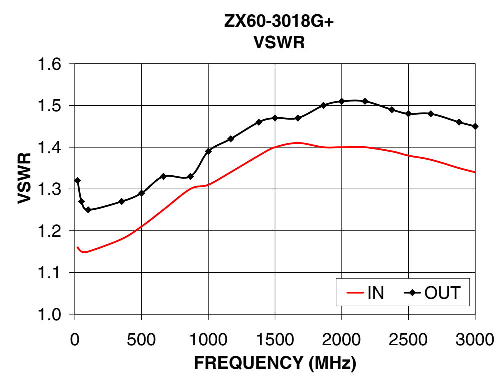
A	B	C	D	E	F	G	H	J	K	L	M	N	P	Q	R	WT.
.74	.75	.46	1.18	.04	.17	.45	.59	.33	.21	.22	.18	1.00	.37	.18	.106	GRAM
18.80	19.05	11.68	29.97	1.02	4.32	11.43	14.99	8.38	5.33	5.59	4.57	25.40	9.40	4.57	2.69	23.0

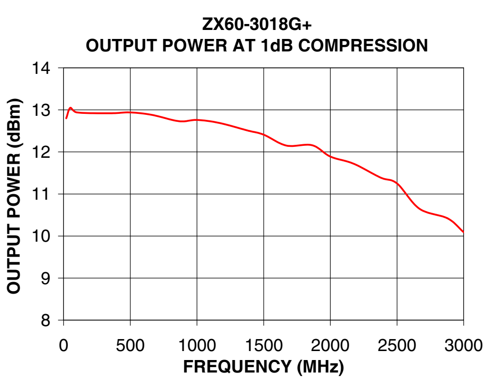
Typical Performance Data & Curves at 25°C ZX60-3018G+

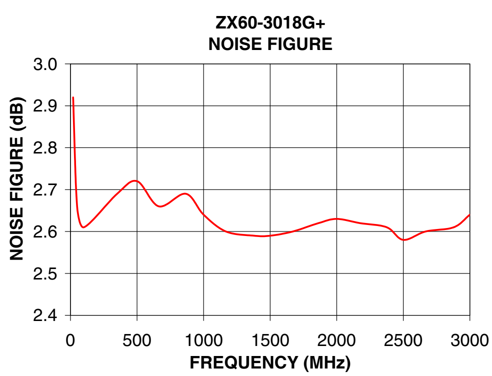
FREQUENCY (MHz)	GAIN (dB)	DIRECTIVITY (dB)	VSWR IN (:1)	VSWR OUT (:1)	POWER OUT @1dB COMPRESSION (dBm)	IP3 (dBm)	NF (dB)
20	22.58	2.30	1.16	1.32	12.80	25.61	2.92
50	22.75	2.12	1.15	1.27	13.05	25.87	2.66
100	22.76	2.00	1.15	1.25	12.94	25.89	2.61
351	22.61	2.22	1.18	1.27	12.92	25.39	2.69
500	22.42	2.36	1.21	1.29	12.94	25.26	2.72
663	22.28	2.61	1.25	1.33	12.88	25.39	2.66
866	21.83	3.17	1.30	1.33	12.73	25.67	2.69
1000	21.83	3.03	1.31	1.39	12.76	25.66	2.64
1168	21.52	3.35	1.34	1.42	12.69	25.66	2.60
1378	21.16	3.74	1.38	1.46	12.51	25.64	2.59
1500	20.97	3.85	1.40	1.47	12.41	25.45	2.59
1671	20.60	4.23	1.41	1.47	12.15	25.80	2.60
1863	20.39	4.54	1.40	1.50	12.16	25.64	2.62
2000	20.22	4.66	1.40	1.51	11.89	25.08	2.63
2174	20.04	4.83	1.40	1.51	11.72	24.67	2.62
2376	19.76	5.15	1.39	1.49	11.39	23.90	2.61
2500	19.56	5.46	1.38	1.48	11.25	23.54	2.58
2668	19.26	5.50	1.37	1.48	10.65	22.94	2.60
2879	18.97	5.83	1.35	1.46	10.42	22.62	2.61
3000	18.78	6.14	1.34	1.45	10.09	22.36	2.64

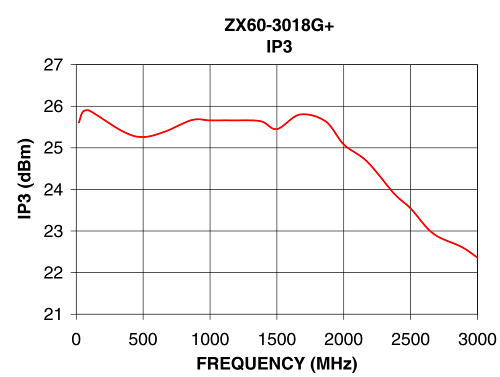












Notes
A. Performance and quality attributes and conditions not expressly stated in this specification document are intended to be excluded and do not form a part of this specification document.
B. Electrical specifications and performance data contained in this specification document are based on Mini-Circuit's applicable established test performance criteria and measurement instructions.
C. The parts covered by this specification document are subject to Mini-Circuits standard limited warranty and terms and conditions (collectively, "Standard Terms"); Purchasers of this part are entitled to the rights and benefits contained therein. For a full statement of the Standard Terms and the exclusive rights and remedies thereunder, please visit Mini-Circuits' website at www.minicircuits.com/MCLStore/terms.jsp