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Electromagnetic Environment Assessment for Future VHF Meteorological and Mobile Satellite Communications: From Spectrum Supervision to Informed Policy Making

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Abstract

The radio spectrum is a scarce natural resource and a public asset that needs to be effectively, efficiently and rationally managed and used to deliver the finest societal value possible. Innovative satellite applications have struggled to find deployment opportunities below 1 GHz. Supervision has been playing a key role in the overall spectrum management process, ensuring that in-force regulations are consequent and resolving operational challenges on the field, but it may also deliver unique intelligence about the actual status of spectrum use for improved policy, planning and regulation making. In this contribution we develop metrics and deliver results concerning the VHF spectrum use by meteorological- and mobile-satellite services.

1. Introduction

Understanding the electromagnetic environment a radio equipment is supposed to operate in is essential for equipment manufacturers, operators and regulators. This understanding enables the design of robust and cost-efficient technological solutions by manufacturers, and it promotes the delivery of quality services by operators [1]. As for regulators, the appropriate radio spectrum supervision is the gateway for accessing the electromagnetic environment, enabling them to monitor the equipment deployments and services delivery, to control and mitigate interference scenarios, ensuring safe operations, and, in case of non-compliances, to act consequently in line with applicable regulations and legislation [2]. Furthermore, it may well serve the compass for future realistic policy and regulation making.

The radio spectrum is a scarce natural resource that needs to be effectively, efficiently and rationally managed and used to deliver the finest societal value possible. In particular, spectrum in bands below 1 GHz offers ideal characteristics for innovative satellite connectivity solutions in the domain of *internet of things* (IoT) and *machine-to-machine* (M2M), and it has been highly procured in recent years for these applications [3-4]. Its availability, however, is understood to be rather limited, driving the need for alternative regulatory solutions to unlock innovation. The deployment of satellite networks not subject to radio protection, in particular, challenges the existing regulatory processes, as well as the spectrum sharing and compatibility feasibility with incumbent services, particularly with terrestrial services and devices. Exercising effective spectrum supervision is paramount to ensure the due protection of incumbent services. In a past contribution, the supervision of satellite networks for law enforcement purposes has been addressed [5].

In this contribution we address the spectrum needs and challenges in deploying satellite downlinks in VHF by assessing the electromagnetic environment and the spectrum use by meteorological- (MetSat) and mobile-satellite services (MSS), aiming to deliver, based on the established conditions, intelligence for improved policy and regulation making, guiding and supporting the design and deployment of future systems, while ensuring the most effective, efficient and rational use of spectrum resources.

2. Regulatory framework and frequency assignment plan

The 137-138 MHz portion of the VHF band is fragmented in four pieces. Downlinks of Metsat, space operation and space research services have primary frequency allocations across the entire 137-138 MHz band, whereas the MSS have primary frequency allocations in the 137-137.025 MHz and 137.175-137.825 MHz pieces of the band [6]. The 137-138 MHz band is shared with terrestrial services allocated on a secondary basis and it's used by several satellite networks in both MetSat and MSS, which an excerpt is laid down in Table 1 [7-9].

Table 1. Some of the frequency assignments of satellite networks in the 137-138 MHz band.

Satellite Network	Radio Serv.	Initial Freq. (MHz)	Final Freq. (MHz)	Bandwidth (kHz)
NOAA-15	MetSat	137.6010	137.6390	38
		137.3270	137.3730	46
NOAA-18	MetSat	137.8935	137.9315	38
		137.3270	137.3730	46
NOAA-19	MetSat	137.0810	137.1190	38
		137,7470	137,7930	46
ORBCOMM	MSS	137.2375	137.2625	25
		137.4475	137.4725	25
		137.5350	137.5850	50
		137.6500	137.6750	25
		137.7000	137.7250	25
		137.7250	137.7500	25
		137.7875	137.8125	25
Meteor	MetSat	137.8250	137.9750	150

Table 1 lists some of the satellite networks, and respective emissions, that have been identified, but not all of them.

3. Spectrum supervision campaign

For this study, the spectrum monitoring and control station located in Santa Comba, north of Portugal, has been used. This station is equipped with a standard R&S ESMD receiver and R&S HK014 omnidirectional antenna. For the span of 1 MHz, the resolution of the receiver is 625 Hz. The measurements are integrated over the period of 1s so to sample the entire 137-138 MHz band at every second. These values are then recorded daily for appropriate pre-processing.

The data pre-processing aims at checking data validity and consistency and removing effects that otherwise could bias the results. A summary of the spectrum supervision campaign, with an overall availability after pre-processing of 94 %, is in Table 2.

Table 2. Spectrum supervision campaign overview.

Measurement Date	Measurement Period	Data availability (after pre-processing)
01/02/25	00:00:00 - 23:59:59	98 %
02/02/25	00:00:00 - 23:59:59	100 %
03/02/25	00:00:00 - 23:59:59	90 %
04/02/25	00:00:00 - 23:59:59	100 %
08/02/25	00:00:00 - 23:59:59	100 %
09/02/25	00:00:00 - 23:59:59	100 %
10/02/25	00:00:00 - 23:59:59	90 %
11/02/25	00:00:00 - 16:59:59	71 %

4. Data processing and spectrum indicators

We treat the measured data in a systematic fashion to derive several indicators describing the spectrum use status and emissions properties, as presented in Table 3.

Table 3. Indicators and metrics to describe spectrum use status and emissions properties.

Indicator	Description	Metric
Received signal level (dBµV)	Tridimensional distribution of signal level (measured at each instant and at each frequency)	- Total complementary cumulative distribution function
Band occupancy (%)	Fraction of the band that is occupied at a given instant	- Total complementary cumulative distribution function
Emission bandwidth (kHz)	Perceived bandwidth of an emission	- Total complementary cumulative distribution function
Emission duration (s)	Perceived duration of an emission	- Total complementary cumulative distribution function - Mean value - Maximum value
Occupancy (%)	Fraction of time a frequency is occupied	- Mean value - Maximum value

The receiving system sensitivity is estimated to be around -25 dBµV (see Figure 1), and emissions are detected based on their received signal level. A given frequency is considered "occupied" if it presents a signal level greater than -18 dBµV. Data below such detection threshold are ignored. An emission is then a cluster of contiguously occupied frequencies over time. Therefore, low power spectral density emissions, potentially falling under the detection threshold, are not identified or accounted. Considering the measured time and the receiver resolution, we found the probability of an emission taking place to be about 1.2 %.

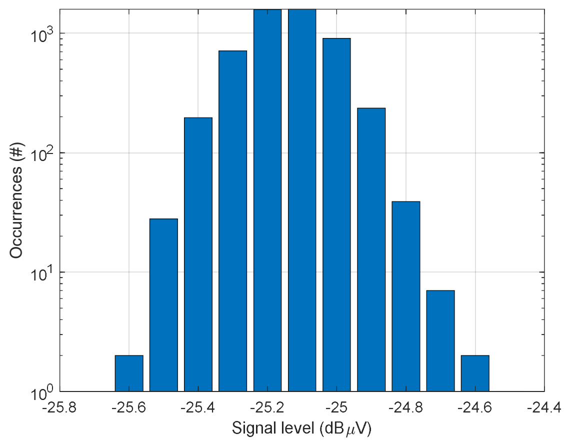

Figure 1. Distribution of noise signal level.

5. Spectrum supervision results

Figure 2 presents the distribution of signal level as measured, where it is possible to observe that less than 1 % of the emissions present a signal level above 0 dBµV when an emission is detected.

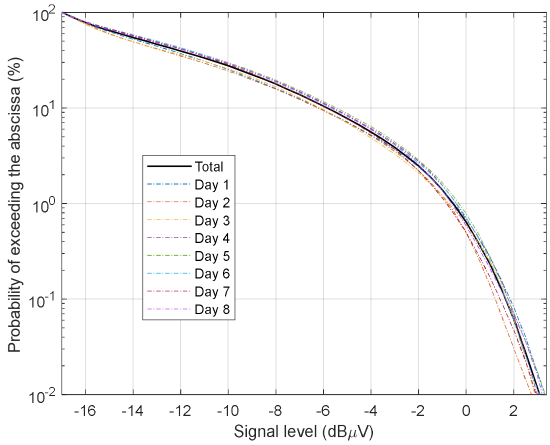

Figure 2. Distribution of the received signal level.

The band occupancy, presented in Figure 3, is relatively low, exceeding 10 % in 0.4 % of the time there are emissions.

Figure 4 and Figure 5 present the distributions of the emissions bandwdith and duration, respectively.

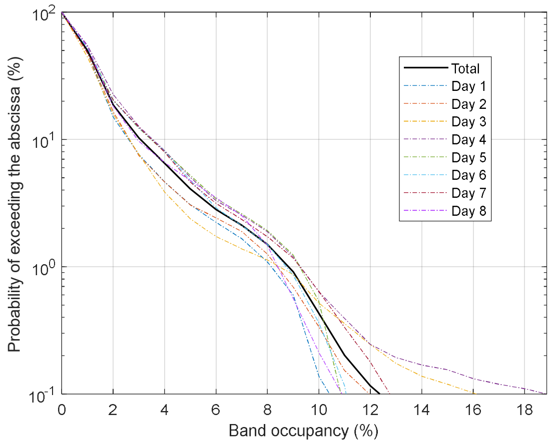

Figure 3. Distribution of the band occupancy.

In analysing these results we need to bear in mind that some emissions, barely crossing the detection threshold, may be perceived as multiple very narrow-band emissions of short duration. On the other hand, multiple interfering emissions may be perceived as a single emission. The satellite orbit, signal transmission dynamics (duty-cycle, activity factor), modulation nature and schemes, propagation losses and antenna pointing are some aspects determining the received signal characteristics and dynamics.

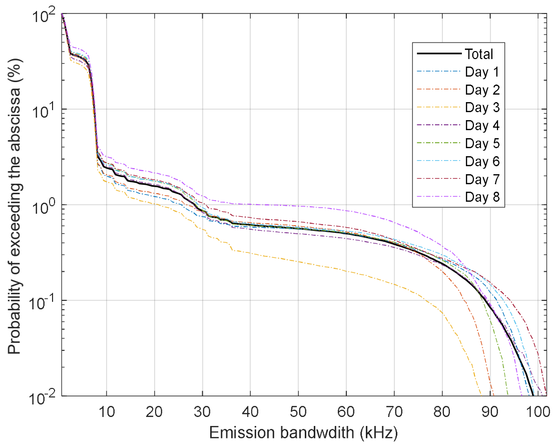

Figure 4. Distribution of the emissions bandwdith.

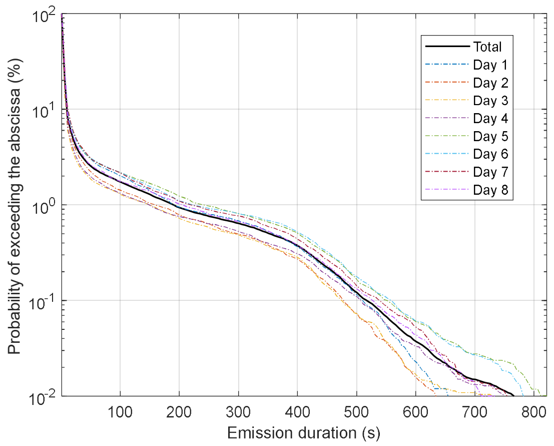

Figure 5. Distribution of the emissions duration.

Figure 6 illustrates these effects. It is possible to observe that, over time, there will be signal interruptions which will be perceived as several emissions. Similarly, several emissions will be perceived when emissions like those of NOAA satellites cut across the spectrum. As we see on ground, emissions rarely present a bandwidth wider than 90 kHz or a duration longer than 10 minutes.

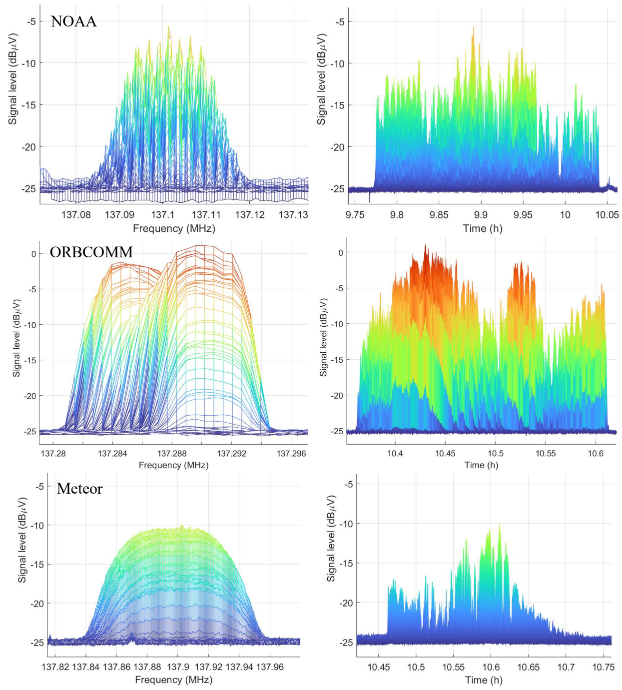

Figure 6. Emissions of satellites on 13/02/25: NOAA-19 (on top), ORBCOMM (on the middle) and Meteor (on the bottom).

Figure 7 depicts the average and maximum duration a frequency is occupied. The first reaches as much as 50 seconds, whereas the second reaches almost 15 minutes for ORBCOM satellites. These figures are 10 seconds and 10 minutes, respectively, for NOAA satellites, and 7 seconds and 7.5 minutes, respectively, for Meteor satellites.

Finally, the occupancy of the different frequencies across the 137-138 MHz band is depicted in Figure 8. It is possible to observe that a maximum occupancy of about 20 % is reached by ORBCOMM satellites. Some out-of-band emissions from the lower adjacent band are also observable which, on some occasions, may limit the quality of service delivered by networks in the lower portion of the band. The identified emissions fit in with less than 50 % of the band.

6. Conclusions

The 137-138 MHz band is populated by emissions presenting relatively low power, narrow bandwidth and short duration. Based on its frequency assignment plan, the 137-138 MHz band may be perceived as very occupied. In reality, based on the established conditions and observed supervision results, the band seems to be significantly underused. In fact, should all observed emissions occur at the same time, they would fit in less than 50 % of the band but, because they don't occur simultaneously, the band occupancy rarely exceeds 20%. Furthermore, no observed emission occupies its band more than about 20% of the time.

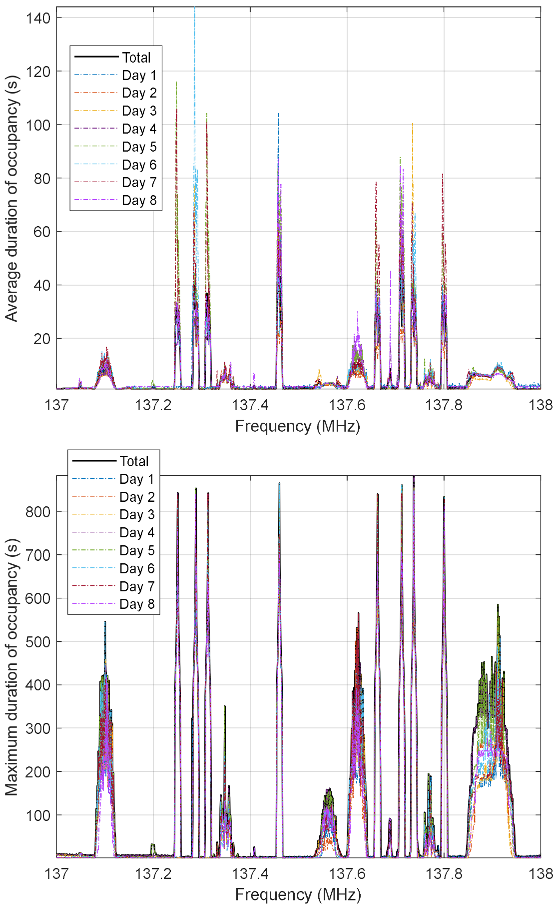

Figure 7. Duration of emissions: average (on top) and maximum (on bottom).

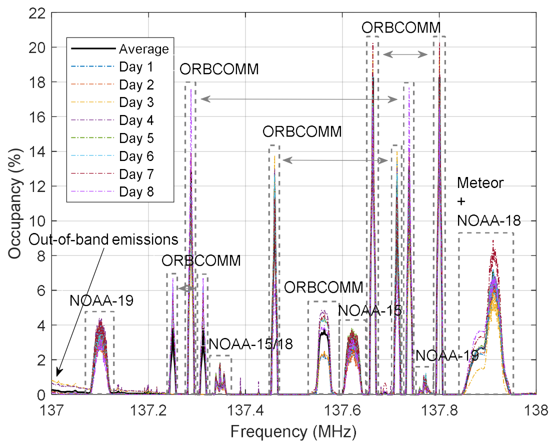

Figure 8. Occupancy of frequencies in the 137-138 MHz.

As we observe, each frequency is uniquely assigned to a satellite system, with the exception being the Meteor and NOAA satellite systems sharing the upper part of the band. Despite that, their joint occupancy still lags behind some ORBCOMM satellite systems. Overall, there is significant potential for improving the future band planning and for accommodating further satellite networks to ensure a more effective, efficient and rational use of spectrum resources.

7. References

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