CEPT ECC
Electronic Communications Committee

ECC Report 369

Technical Feasibility and Implications of Increasing Power for Private Mobile Radio in the 446.0-446.2 MHz Frequency Band

approved 30 January 2026

0 EXECUTIVE SUMMARY

This Report presents a comprehensive technical assessment, evaluating the feasibility and implications of increasing the maximum effective radiated power (*e.r.p.*) for PMR 446 equipment from 500 mW to 1 W, while maintaining the requirement for integral antennas. The study encompasses capacity[1] evaluations, simulation modelling, and empirical monitoring data.

In this Report, there are studies for in-band compatibility between existing PMR 446 equipment operating at 500 mW and proposed high-power variants operating at 1 W, including analysis of potential interference scenarios in co-channel configurations. These studies evaluate whether mixed operation can be supported without reducing the spectrum availability or increasing harmful interference beyond acceptable thresholds.

The following elements are considered:

- Technical Parameters: Existing and proposed transmitter and receiver specifications for analogue and digital PMR 446 devices are outlined. Parameters include modulation types (FM and 4 FSK), channel separations (6.25 kHz and 12.5 kHz), receiver sensitivity, co-channel rejection, adjacent channel selectivity, and emission constraints. Equipment categories A–D are differentiated by antenna type and placement;
- Coverage and Range Assessment: Using SEAMCAT v5.5.0, simulation scenarios demonstrated that increasing *e.r.p.* from 0.5 W to 1 W extends coverage by up to ~48% in rural environments. Propagation modelling was based on the extended Okumura-Hata model for urban, suburban, and rural settings;
- Minimum Coupling Loss (MCL): MCL calculations indicate that a 3 dB increase in *e.r.p.* results in a proportional increase in required separation distance between terminals to maintain coexistence, with estimated increases ranging from 1.2x to 1.4x, depending on the environment. This worst-case analysis corresponds to a user capacity reduction of approximately 33-50%.
- Interference Analysis:
  - Study 1 (Single Interferer): A first Monte Carlo analysis indicated that, to maintain a constant interference probability of 5%, doubling *e.r.p.* requires an expansion of the interference area by 50% which is equivalent to a capacity reduction around 33%;
  - Study 2 (Multiple Interferers): Mixed scenarios involving standard and high-power terminals showed that user density and capacity degrade as the proportion of high-power devices increases. In the worst case (100% 1 W interferers), capacity loss reaches ~30%.
- User Density and Coexistence: Analytical modelling determined user group densities (user groups/km²) for different mixes of terminal power and device types. Digital systems with narrower 6.25 kHz channels demonstrated higher spectral efficiency under equal conditions. However, interference effects intensified with higher power, particularly in low-loss rural environments;
- Empirical Monitoring: National monitoring campaigns in France, the Netherlands and Romania assessed actual channel occupancy within the 446.0-446.2 MHz band. Measurement results are showing an occupancy much below 50%;
- Capacity Trade-Offs: While increasing *e.r.p.* enhances link reliability and extends communication range, especially in remote or high-interference environments, it concurrently reduces the maximum number of concurrently operable terminals due to increased interference footprint. In hybrid-use cases (e.g. 50% standard, 50% high power), average capacity degradation is estimated at 18%.

Although there is a trade-off between coverage gains and capacity reduction shown in the studies, current usage of the band indicates that the 446.0-446.2 MHz band has sufficient headroom to support higher power (1 W *e.r.p.*) PMR 446 operations and that there is no need for advanced spectrum management techniques like power control, or automatic avoidance mechanism/channel sensing.

[1] In this Report, capacity of PMR 446 is evaluated by the number of users per channel and per square kilometre.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
BER	Bit Error Rate
CEPT	European Conference of Postal and Telecommunications Administrations
Ch.sep	Channel separation
DTM	Digital Terrain Model
ECC	Electronic Communications Committee
ERC	European Radiocommunications Committee
ETSI	European Telecommunications Standards Institute
ETSI EN	ETSI Harmonised Standards
ETSI TS	ETSI Technical Specifications
HP-A	High power analogue PMR 446 equipment
HP-D	High power digital PMR 446 equipment
MCL	Minimum Coupling Loss
PMR	Private Mobile Radio
PTT	Push-to-Talk
RBw	Receiver Bandwidth
Rx	Receiver
SENS	Sensitivity
SINAD	Signal-to-Noise and Distortion ratio
SP-A	Standard power analogue PMR 446 equipment
SP-D	Standard power digital PMR 446 equipment
SRD	Short Range Devices
SNR	Signal-To-Noise Ratio
Tx	Transmitter
VOX	Voice activation exchange

1 INTRODUCTION

The PMR 446 band is a license-exempt communication service in the 446.0-446.2 MHz frequency range, harmonised within the European Conference of Postal and Telecommunications Administrations (CEPT) for Private Mobile Radio (PMR) applications. It is widely used for short-range, peer-to-peer communication in both analogue and digital formats, with applications spanning personal, recreational and ad-hoc use cases.

PMR 446 operates under the regulatory framework of ECC Decision (15)05 [1], which was first adopted in 2015 and amended in 2018. This decision defines the technical and operational conditions for PMR 446 equipment, including a maximum effective radiated power (*e.r.p.*) of 500 mW *e.r.p.* and the requirement for an integral antenna. These constraints aim to ensure efficient spectrum utilization, interoperability and compatibility across CEPT countries while maintaining the licence-exempt status of PMR 446 devices.

A requirement for longer communication range using PMR 446 was recently identified due to the increasing diversity of user environments. PMR 446 use ranges from densely populated urban areas to sparsely populated rural regions, which have different spectrum access requirements and initiated a reassessment of PMR 446 technical parameters.

To address these challenges, discussions within SRD/MG and WG FM considered the possibility of increasing the *e.r.p.* limit to 1 W while retaining the integral antenna requirement.

This Report presents the results of comprehensive technical studies evaluating the impact of increasing the PMR 446 power limit. This Report includes:

- Technical Parameters: A comprehensive identification of transmitter and receiver characteristics, frequency arrangements, and signal protection thresholds;
- Capacity Assessment: A study on how higher-power devices impact overall spectrum capacity and coexistence with existing PMR 446 systems;
- Simulation Scenarios: SEAMCAT-based modelling to assess coexistence, interference and coverage performance in urban, suburban, and rural environments;
- Impact on Ecosystem: An evaluation of potential effects on the PMR 446 ecosystem, considering user density, interference, and the coexistence of devices with differing power levels.

This Report provides a technical foundation for updating ECC Decision (15)05 [1], ensuring that PMR 446 remains a relevant, and effective communication tool for a wide range of users, while balancing the need for regulatory stability and spectrum efficiency.

2 DEFINITIONS

Term	Definition
Adjacent Channel Selectivity	The receiver's ability to reject signals on adjacent channels while maintaining sensitivity to the intended channel.
BER (Bit Error Rate)	A performance metric for digital communication systems, representing the ratio of bit errors to the total number of transmitted bits. Typical BER for PMR 446 is 10^-2.
Channel Separation/Spacing	The offset between two adjacent carrier frequencies. Analogue systems use 12.5 kHz spacing, while digital systems may use 6.25 kHz or 12.5 kHz spacing.
Co-Channel Rejection	The ability of a receiver to suppress interference from another transmitter operating on the same frequency, measured as the required carrier-to-interference ratio (C/I).
Effective Radiated Power (*e.r.p.*)	The power radiated by the antenna of a transmitter, as referenced to an isotropic radiator. For PMR 446, the current maximum allowed *e.r.p.* is 500 mW, with proposals for 1 W.
Integral Antenna	An antenna permanently attached to the PMR 446 device, designed as an inseparable part of the equipment to ensure minimal interference and consistent performance.
Push-to-Talk (PTT)	A method of transmitting voice communications where the user activates a button to enable the transmitter. PMR 446 includes PTT with a timeout for prolonged use.
Short Range Devices (SRD)	Devices operating under a general authorisation regime on a non-interference non-protected basis. PMR 446 is an example of an SRD in the 446 MHz band.
SINAD (Signal-to-Noise and Distortion Ratio)	A measure of signal quality, expressed in decibels (dB), which indicates the ratio of signal strength to the sum of noise and distortion. Used to evaluate receiver sensitivity.
Voice Activation Exchange (VOX)	An automated method for initiating voice transmission without manual button activation, based on detecting audio input, commonly used in PMR 446 for hands-free operation.

3 PMR 446 TECHNICAL PARAMETERS

PMR 446 is intended to operate on collective frequencies shared by many users on an uncoordinated basis. The equipment is hand portable (no base station or repeater use) and uses integral antennas only in order to maximise sharing and minimise interference. PMR 446 equipment operates in short range peer-to-peer mode and cannot be used neither as a part of infrastructure network nor as a repeater.

3.1 FREQUENCY RANGE AND CHANNEL PLAN

The 446.0-446.2 MHz frequency band is harmonised within CEPT for Private Mobile Radio (PMR) 446, serving both analogue and digital systems.

3.1.1 Analogue PMR 446

Analogue PMR 446 systems have a channel plan structured around 12.5 kHz channel spacing. The lowest carrier frequency for analogue systems is set at 446.00625 MHz. Analogue systems use frequency modulation (FM) and support 122 private codes, enhancing privacy and limiting interference among users in shared environments.

3.1.2 Digital PMR 446

Digital PMR 446 systems have a more flexible channel plan, supporting both 6.25 kHz and 12.5 kHz channel spacing to increase capacity and accommodate varied operational needs.

For 6.25 kHz channel spacing, the lowest carrier frequency is 446.003125 MHz, enabling a greater number of channels within the same spectrum range. For 12.5 kHz channel spacing, the lowest carrier frequency is 446.00625 MHz.

Digital systems use advanced modulation schemes such as 4 FSK, enabling higher data rates and robust performance. They support 16 colour codes to facilitate secure and distinct user communications.

3.1.3 Operational Characteristics

PMR 446 equipment operates exclusively in simplex mode, without the use of repeaters or base stations. The mandatory use of integral antennas ensures consistent performance, reduced interference potential. The band supports a maximum effective radiated power (*e.r.p.*) of 500 mW, with ongoing studies evaluating the impact of increasing the limit to 1 W to enhance coverage and reliability.

3.1.4 Summary of Frequency range and Channel Plan

Table 1: Summary of Frequency range and Channel Plan

Channel Type	Channel Spacing	Lowest Carrier Frequency	Number of Channels
Analogue PMR 446	12.5 kHz	446.00625 MHz	Up to 16
Digital PMR 446	6.25 kHz	446.003125 MHz	Up to 32
Digital PMR 446	12.5 kHz	446.00625 MHz	Up to 16

ChNo	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
6.25 kHz raster	446.003125	446.009375	446.015625	446.021875	446.028125	446.034375	446.040625	446.046875	446.053125	446.059375	446.065625	446.071875	446.078125	446.084375	446.090625	446.096875	446.103125	446.109375	446.115625	446.121875	446.128125	446.134375	446.140625	446.146875	446.153125	446.159375	446.165625	446.171875	446.178125	446.184375	446.190625	446.196875
12.6 kHz raster	446.00625		446.01875		446.03125		446.04375		446.05625		446.06875		446.08125		446.09375		446.10625		446.11875		446.13125		446.14375		446.15625		446.16875		446.18125		446.19375	
ChNo	1		2		3		4		5		6		7		8		9		10		11		12		13		14		15		16	

Figure 1: PMR 446 channel arrangement in the frequency band 446.0-446.2 MHz

3.2 PARAMETERS OF EXISTING PMR 446 TERMINALS

This section provides an overview of the technical and operational characteristics of existing PMR 446 terminals, focusing on their design, performance metrics, and regulatory compliance. These parameters establish the baseline for evaluating the impact of proposed changes, such as increased power limits or antenna modifications, on the PMR 446 ecosystem.

3.2.1 Transmitter Parameters

The transmitter (Tx) specifications of PMR 446 terminals define their signal emission capabilities and spectral behaviour.

The following characteristics are extracted from ETSI documents, particularly ETSI EN 303 405 v.1.1.1 [2].

Table 2: Tx parameters

Parameter	Value	Source
Frequency band	446.0-446.2	ECC Decision (15)05 [1]
Channel separation / spacing	6.25 kHz – 32 channels 12.5 kHz – 16 channels	ETSI EN 303 405 v.1.1.1, chapter 7.1.3 [2]
Operation	Simplex handheld	
Modulation	4 FSK - for digital FM - for analogue	ETSI TS 102 490 [4]; ETSI TS 102 361-1 [5], ETSI EN 300 296 [6]
Private codes	Analogue – 122 codes Digital 16 channel codes	ETSI TS 103 236 [8] ETSI TS 102 490 [4]
Effective radiated power (*e.r.p.*)	500 mW	ETSI EN 303 405 v.1.1.1, chapter 7.2.3 [2]
Antenna Height	1.5 m	
Adjacent channel power	max ({60.0 dB below the transmitter carrier power, RBw 100 Hz}, 0.20µW)	ETSI EN 303 405 v.1.1.1, chapter 7.4.3 [2]
Alternate channel power	max ({70.0 dB below the carrier power, RBw 100 Hz}, 0.20µW)	ETSI EN 303 405 v.1.1.1, chapter 7.4.3 [2]
Unwanted emissions in the spurious domain	See Table 3	ETSI EN 303 405 v.1.1.1, chapter 7.5.3 [2]
Maximum Tx time	< 180 s	ETSI EN 303 405 v.1.1.1, chapter 7.7.3 [2]

Table 3: Unwanted emissions in the spurious domain [2]

Frequency offset from carrier	Value (dBm)	RBW (kHz)
250% of the Ch.sep – 100 kHz	-36	1kHz
100-500 kHz	-36	10 kHz
500 kHz – 5 MHz	-36	100 kHz

3.2.2 Receiver Parameters

Receiver (Rx) characteristics of PMR 446 terminals maintain sensitivity and selectivity while mitigating interference from other users or external sources.

Table 4: Rx parameters

Parameter	Value	Source
Frequency band	446.0-446.2	ECC Decision (15)05 [1]
Channel separation / spacing	6.25 kHz – 32 channels 12.5 kHz – 16 channels	ETSI EN 303 405 v.1.1.1, chapter 7.1.3 [2]
Operation	simplex handheld	
Modulation	4 FSK- for digital FM - for analogue	ETSI TS 102 490 [4], ETSI TS 102 361-1 [5], ETSI EN 300 296 [6]
Private codes	Analogue – 122 codes Digital 16 channel codes	ETSI TS 103 236 [8] ETSI TS 102 490 [4]
Antenna Height	1.5 m	
Average usable sensitivity analogue	Category A and D: ≤ 31.5 dB uV/m for SINAD ratio of 20 dB (note 1) Category B and C: ≤ 26.5 dB uV/m for SINAD ratio of 20 dB (note 1)	ETSI EN 303 405 v.1.1.1, chapter 8.1.3.1 [2]
Average usable sensitivity digital	≤ 26 dB uV/m (4800 bits/s) for BER 10-2 ≤ 29 dB uV/m (9600 bits/s) for BER 10-2	ETSI EN 303 405 v.1.1.1, chapter 8.1.3.2 [2]
Co-channel rejection	In the range 0 to 12 dB (Ch.sep. 12.5 kHz - analogue and digital). In the range 0 to 15 dB (Ch.sep. 6.25 kHz - digital, 4800 bits per second).	ETSI EN 303 405 v.1.1.1, chapter 8.3.3 [2]
Adjacent channel selectivity	60 dB for Ch.sep. 12.5 kHz 50 dB for Ch.sep. 6.25 kHz	ETSI EN 303 405 v.1.1.1, chapter 8.4 [2]

Parameter	Value	Source
Spurious response rejection	70 dB	ETSI EN 303 405 v.1.1.1, chapter 8.5 [2]
Co-Channel protection requirement C/N+I	In the range 0 to 12 dB (for Ch.sep. 12.5 kHz) In the range 0 to 15 dB (for Ch.sep. 6.25 kHz)	ETSI EN 303 405 v.1.1.1, chapter 8.3 [2]
Note 1: Category A: equipment having an integral antenna fully within the case. Category B: equipment having an extractable or fixed integral antenna, with an antenna length not exceeding 20 cm external to the case. Category C: equipment having an extractable or fixed integral antenna, with an antenna length exceeding 20 cm external to the case. Category D: equipment not covered by category A, B or C.		

As defined in ECC Decision (15)05 [1], all analogue and digital PMR 446 radio equipment should have reception capability and equipment having Push-To-Talk (PTT) functionality capable of being latched 'on' should apply a 180 seconds maximum transmitter time-out; equipment having no Push-To-Talk (PTT) functionality should apply a 180 seconds maximum transmitter time-out and VOX (Voice activation exchange) control.

3.2.3 Operational Characteristics

PMR 446 terminals are designed with strict operational constraints to ensure simplicity, efficiency, and minimal interference:

- Power Output: Transmitter power is limited to 500 mW *e.r.p.*, supporting short-range communications;
- Antenna Design: Devices must use integral antennas, ensuring uniformity and preventing modifications that could lead to interference or regulatory breaches;
- Peer-to-Peer Operation: All devices operate in simplex mode, without repeaters or base stations, to simplify deployment and maintain compatibility across environments;
- Robustness: Both analogue and digital devices incorporate features like private codes (e.g. 122 for analogue and 16 colour codes for digital) to reduce unwanted interactions among users.

3.2.4 Emission and Interference Control

- Unwanted Emissions: Devices must comply with strict emission limits in both adjacent channels and the spurious domain;
- Time-out Mechanisms: A transmission time-out feature limits Tx operation to 180 seconds, preventing prolonged emissions that could disrupt the ecosystem;
- Interference Mitigation: Receiver selectivity ensures resilience to interference from adjacent and alternate channels, enabling coexistence in crowded spectrum environments.

3.3 PARAMETERS OF PMR 446 TERMINALS WITH INCREASED *E.R.P.* UNDER CONSIDERATION

This section outlines the proposed parameters for PMR 446 terminals operating with an increased effective radiated power (*e.r.p.*) of up to 1 W.

3.3.1 Transmitter Parameters

The increased *e.r.p.* introduces changes in the transmitter characteristics to accommodate the higher power output and ensure compliance with regulatory limits. Transmitter parameters of the PMR 446 equipment with increased power remains the same as for the PMR 446 equipment with standard power as shown in section 3.2.1. with the exception that the *e.r.p.* of the equipment is 1 W.

3.3.2 Receiver Parameters

The increased *e.r.p.* impacts receiver design to ensure compatibility and resilience in mixed-power environments (500 mW and 1 W devices). Receiver parameters of the PMR 446 equipment with increased power remains the same as for the PMR 446 equipment with standard power as shown in section 3.2.2.

3.3.3 Use Case Scenarios

The increased *e.r.p.* could be beneficial for scenarios such as:

- Ad hoc communications: Enhanced range and reliability in zones where cellular networks are unavailable;
- Remote Applications: Improved performance in rural or remote locations with sparse user density;
- High-Interference Environments: Improved signal robustness in industrial or urban areas with high noise levels.

The increased *e.r.p.* may have potential negative effects for scenarios such as:

- Urban areas with many users, where higher *e.r.p.* increasing interference to other users on the same channel, may restricts channel re-use.

4 CAPACITY ASSESMENT OF PMR 446

WG FM indicated that it would be of particular interest to show how the overall capacity of PMR 446 in an observed area may change depending on partial use of PMR 446 equipment with increased power. This section presents methodology of calculating overall capacity of PMR 446 and how to estimate capacity loss.

The capacity of PMR 446 systems is influenced by technical parameters, environmental factors, and the operational characteristics of user devices. This section presents a methodology to calculate the capacity, focusing on the effects of the proposed increase in effective radiated power (*e.r.p.*) from 500 mW to 1 W and its impact on spectrum utilisation, interference levels, and overall system performance.

The proposed methodology, combining worst-case MCL calculations and SEAMCAT statistical analysis, provides a comprehensive framework for evaluating PMR 446 capacity under increased *e.r.p.* scenarios. While higher power offers significant benefits in terms of range and reliability, careful consideration of interference management and coexistence strategies is essential to maintain the integrity of the PMR 446 ecosystem.

4.1 PMR 446 TERMINALS COVERAGE AND RANGE

Increasing power of the PMR 446 equipment results in increasing of the communication range between user terminals and increase in the coverage area of the PMR 446 system.

To analyse and quantify effect of the power increase simulations using SEAMCAT Tool were performed. For the studies official version v.5.5.0. of the SEAMCAT tool was used in ECC Report 252 [9] and Online SEAMCAT Handbook, Edition 4, [10].

4.1.1 Simulation Scenario

Simulation scenario for estimating the PMR 446 terminals coverage range is illustrated in Figure 2:

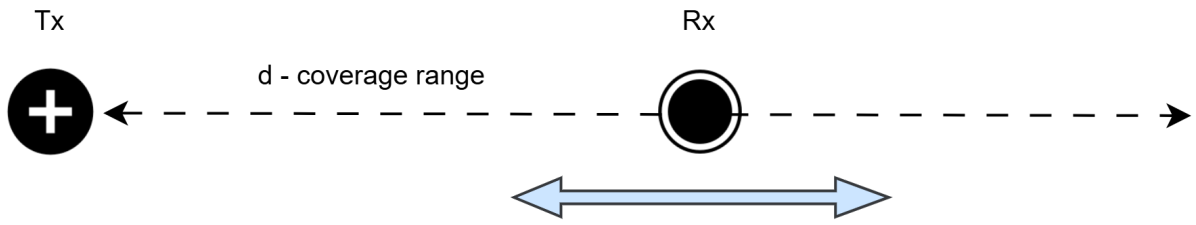


Figure 2: Coverage range simulation scenario

For each simulation run the distance between the PMR 446 transmitter and receiver was set to fixed coverage range and simulation is run for 200.000 events which was sufficient to establish results stability. Multiple successive simulations have been done with changing the distance between 0 km and 2 km.

4.1.1.1 Analysed systems

Simulations were performed on four categories of Standard power analogue PMR 446 systems and one category digital equipment as defined in section 3.2.2 and in ETSI EN 303 405 [2]. For the PMR 446 equipment with increased power an increased effective radiated power (*e.r.p.*) of 1 W was used.

Categories of the analogue equipment have been grouped in two groups: categories A and D; categories B and C. Analogue PMR 446 equipment in the same group have same transmission and reception characteristics. Digital PMR 446 equipment have only one category in specifications, and the sensitivity level used in simulation is one specified for 4800 bits/s and BER 10-2. Transmitter characteristics of the standard power analogue and digital PMR 446 systems are given in Table 2 and receiver characteristics are given in Table 4.

For the PMR 446 equipment with the increased power the same categories as for the standard power equipment was used with exemption of the higher *e.r.p.* of 1 W. Transmitter characteristics of the higher power analogue and digital PMR 446 systems are given in section 3.3.1 and receiver characteristics are given in section 3.3.2.

Summary of the PMR 446 equipment types for coverage analysis is given in Table 5.

Table 5: PMR 446 equipment types analysed

System ID	Characteristics (*e.r.p.*, ch.sep)	Description
SP-A PMR 446 (A and D)	500 mW, 12.5 kHz	Class A and D standard power analogue PMR 446 equipment
SP-A PMR 446 (B and C)	500 mW, 12.5 kHz	Class B and C standard power analogue PMR 446 equipment
SP-D PMR 446	500 mW, 6.25 kHz	Standard power digital PMR 446 equipment
HP-A PMR 446 (A and D)	1 W, 12.5 kHz	Class A and D high power analogue PMR 446 equipment
HP-A PMR 446 (B and C)	1 W, 12.5 kHz	Class B and C high power analogue PMR 446 equipment
HP-D PMR 446	1 W, 6.25 kHz	High power digital PMR 446 equipment

4.1.1.2 Propagation model

Propagation model Extended Okumura-Hata "Field strength and its variability in VHF and UHF land-mobile radio service" [11], "Empirical Formula for Propagation Loss in Land Mobile Radio Services" [12] and COST Action 231 “Digital mobile radio towards future generation systems: Final Report”, [13] for urban, suburban and rural areas with variations was used for simulating environments settings for urban, suburban and rural. The digital elevation model or other site-specific characteristics have not been considered in this analysis.

4.1.1.3 Coverage criteria

For the coverage range estimation, it was assumed that PMR 446 system is a noise limited network where 95% of the connections should receive signal above receiver sensitivity (P_Rx ≥ Rx Sens). It has to be noted that coverage range of interference limited network could be smaller.

4.1.2 Results of range and coverage analysis

Results of the simulation determining coverage range of the PMR 446 systems with different characteristics are shown in Table 6. Coverage range varies for different system types and category of environment. Lowest distance for coverage is for the standard power analogue PMR 446 system of categories A and D in the urban environment and equals to 0.0901 km. Highest coverage range is obtained for the standard power digital PMR 446 system in the rural environment and equals to 0.9863 km.

Increase of *e.r.p.* transmitter power of the PMR 446 equipment from 0.5 W to the 1 W results in increasing of the coverage range as indicated from the results of the simulations presented in Table 6.

Table 6: Coverage range of standard power and high power PMR 446 equipment

System ID	Characteristics	Environment		
		Urban	Suburban	Rural
	e.r.p.; ch.sep.	Coverage range (km)		
SP-A PMR 446 (B and C)	500 mW, 12.5 kHz	0.095	0.132	0.965
SP-A PMR 446 (A and D)	500 mW, 12.5 kHz	0.090	0.098	0.691
SP-D PMR 446	500 mW, 6.25 kHz	0.096	0.133	0.986
HP-A PMR 446 (B and C)	1 W, 12.5 kHz	0.098	0.155	1.166
HP-A PMR 446 (A and D)	1 W, 12.5 kHz	0.093	0.112	0.840
HP-D PMR 446	1 W, 6.25 kHz	0.099	0.160	1.200

To quantify the impact of increasing the power of the PMR 446 equipment to the system coverage area, the percentage increase of the coverage area is calculated and presented in Table 7. Coverage area percentage increase considers ratio of the coverage area of high-power variant of the system and of the coverage area of the standard power variant of the system. It can be seen from the table that the coverage area increase is in the range from 6.7% for the analogue system of categories B and C in the urban environment to 47.97% for the digital PMR system in the rural environment.

Table 7: Coverage area percentage increase of the high power with respect to standard power PMR 446 system

Standard Power System	High Power System	Environment		
		Urban	Suburban	Rural
		Coverage area increase (%)		
SP-A PMR 446 (B and C)	HP-A PMR 446 (B and C)	6.70	38.26	46.08
SP-A PMR 446 (A and D)	HP-A PMR 446 (A and D)	6.73	29.42	47.57
SP-D PMR 446	HP-D PMR 446	6.94	44.84	47.98

Graphical illustration of coverage area for the analogue PMR 446 with standard power and high power are shown in Figure 3 and Figure 4, while coverage area for the digital PMR 446 with standard power and high power are shown in Figure 5 and Figure 6. Figures are generated by simulation in SEAMCAT where transmitter position is in the centre at coordinate (0,0) and receivers' positions are illustrated by different points. In Figure 3, Figure 4, Figure 5 and Figure 6 represent distance in km while received power is expressed in dBm and shown in different colours.

From the analysis, it can be concluded that the increase of the power of the PMR 446 equipment has impact to the increase of the system coverage range and coverage area. Coverage area increase is significant in the suburban and the rural environments (37.5% in average for the suburban and 47.2% in average for the rural environment) and is more modest in the urban environment (6.7% in average for the urban environment).

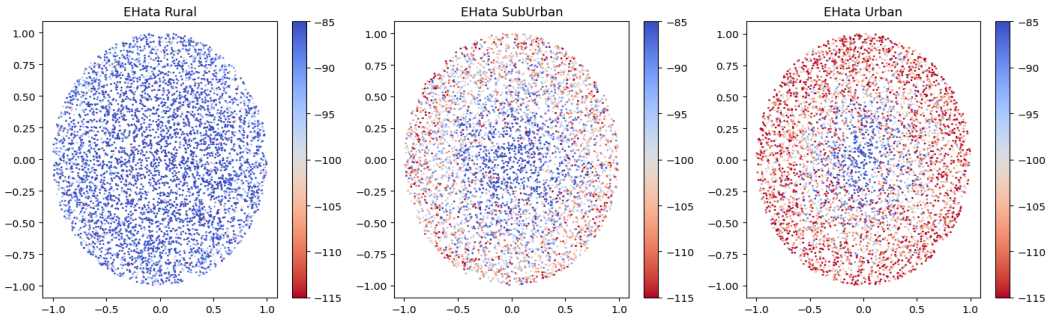


Figure 3: Standard power analogue PMR 446 coverage (rural, suburban and urban area)

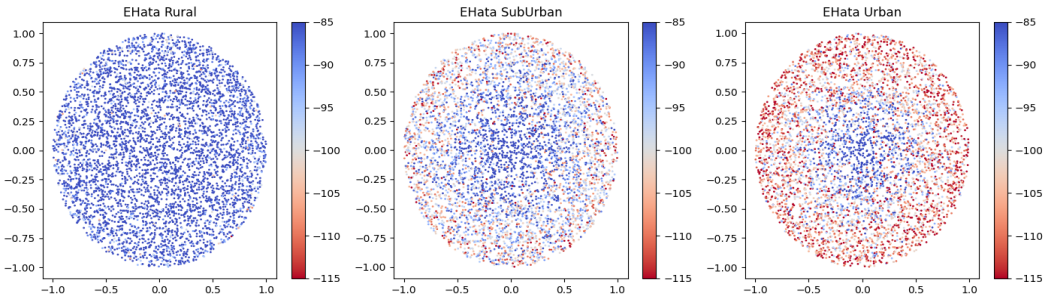


Figure 4: Higher power analogue PMR 446 coverage (rural, suburban and urban area)

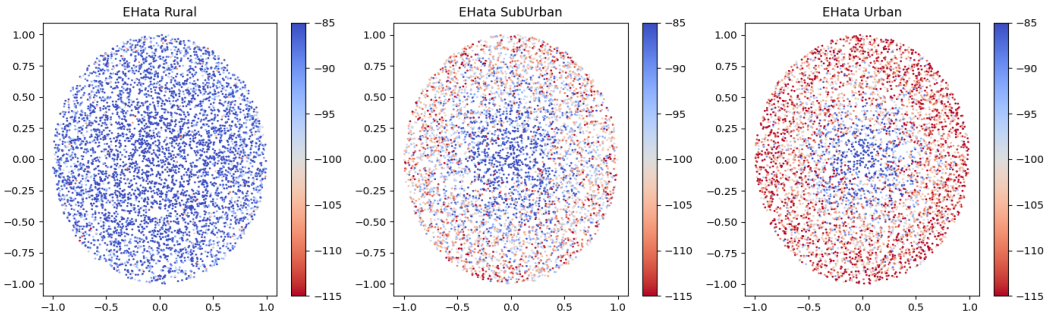


Figure 5: Standard power digital PMR 446 coverage (rural, suburban and urban area)

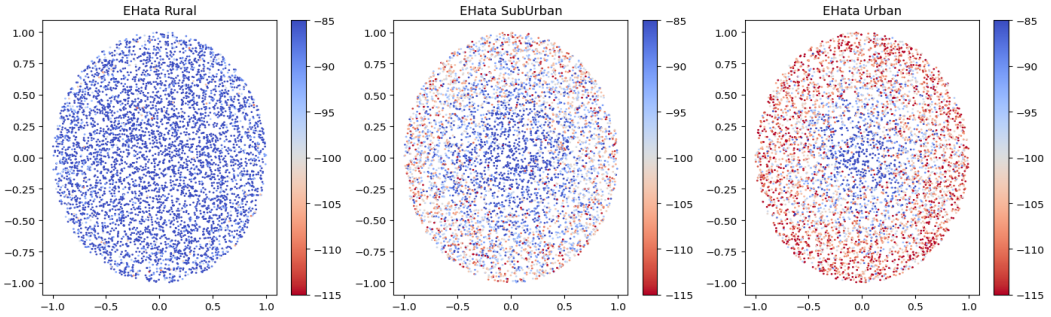


Figure 6: Higher power digital PMR 446 coverage (rural, suburban and urban area)

4.2 WORST-CASE MCL CALCULATION

The Worst-Case Minimum Coupling Loss (MCL) is calculated to estimate the minimum separation distance required to avoid interference between two terminals. This approach ensures reliable communication under adverse conditions.

ETSI EN 303 405 v.1.1.1 [2] provide ranges for several characteristics and no values for noise figure or antenna gain which are necessary to the analysis. Therefore, some parameters are assumed, and others are selected to be consistent with the maximum sensitivity level of ETSI EN 303 405 v.1.1.1.

Table 8: Selected parameters

Parameter	Source
k (J/K)	1.38065E-23
T (K)	290
B (Hz)	12.5E3
Noise figure (dB)	10
C/N	12
Minimum received power (dBW)	-141
Antenna Gain (dBd)	-6
Antenna Gain (dBi)	-3.85
Antenna aperture (dB m2)	-18.3
Minimum received pfd (dB(W/m2))	-122.7
Sensitivity (dBµV/m)	23.1
Sensitivity (dBm)	-111

The maximum pathloss to achieve communication between two terminals can be expressed with the following equation:

$$L_{max} = P_{tx} + G_{tx} + G_{rx} - P_{rx\,min} \quad \text{(dB)} \quad (1)$$

With the parameters of Table 8, L_{max} = 136.3 dB for existing terminals and 139.3 dB for terminals with increase *e.r.p.* of 1 W.

Table 9 and Table 10 present separation distance between two terminals at 1.5 m, calculated with Extended Okumura-Hata propagation model, using the SEAMCAT propagation model test tool.

Table 9: Distance (km) for a 136.3 dB path loss with Extended Okumura-Hata

Propagation model	Rural	Suburban	Urban
Extended Okumura-Hata	3.159	0.997	0.580

Table 10: Distance (km) for a 139.3 dB path loss with Extended Okumura-Hata

Propagation model	Rural	Suburban	Urban
Extended Okumura-Hata	3.843	1.213	0.706

The minimum pathloss to avoid interference between two terminals using the same frequency can be expressed with the following equation:

$$L_{min} = P_{tx} + G_{tx} + G_{rx} - P_{rx\,min} + PR \quad \text{(dB)} \quad (2)$$

With the parameters above, L_{min} = 148.3 dB for existing terminals and 151.3 dB for terminals with increase *e.r.p.* of 1 W.

Table 11: Distance (km) for a 148.3 dB path loss with Extended Okumura-Hata

Propagation model	Rural	Suburban	Urban
Extended Okumura-Hata	6.921	2.185	1.271

Table 12: Distance (km) for a 151.3 dB path loss with Extended Okumura-Hata

Propagation model	Rural	Suburban	Urban
Extended Okumura-Hata	8.421	2.658	1.546

A simplified MCL calculation shows that, depending on the environment and the propagation model used, a 3 dB *e.r.p.* increase of PMR 446 terminals may raise the separation distance to avoid interference between co-channel terminals by a ratio between 1.2 and 1.4, and that the number of users in any given area may be reduced by a ratio between 1.5 and 2, corresponding to a loss of capacity of, respectively, 33% and 50%.

4.3 STUDY 1 - STATISTICAL ANALYSIS WITH SEAMCAT OF SINGLE INTERFERER

The Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT) is used to simulate and analyse the consequence of an *e.r.p.* increase of PMR 446 equipment to 1W, on the user density per square kilometre per channel.

In this study, only one channel is used and the number of users is fixed (one interfering equipment, one victim equipment). The surface where the victim is randomly placed is adjusted to keep a 5% probability of interference.

4.3.1 Simulation scenario

A victim receiver $(x_v,\ y_v)$ is located at a random distance from another terminal, so that the wanted signal is above the sensitivity level. An unwanted terminal $(x_i,\ y_i)$ is then randomly placed in a square area of size d (x_i in the range x_v to $x_v + d$, and y_i in the range $y_v\ to\ y_v + d$). d is adjusted to reach a 5% probability of interference. The evaluation of the size of the area is repeated for urban, suburban and rural environments.

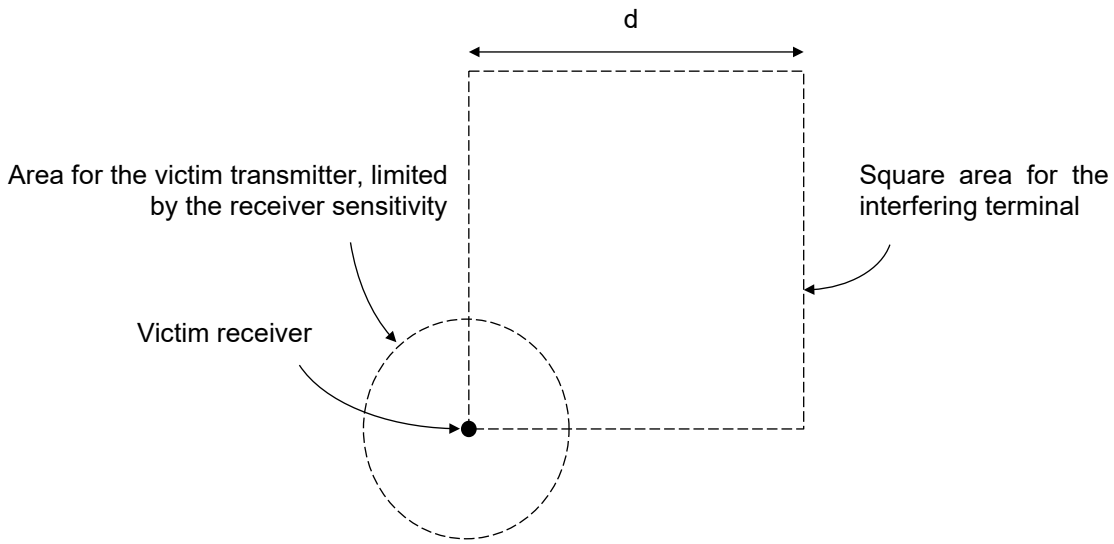


Figure 7: Simulation scenario

The interference criterion is:

$$\frac{C}{N+I} \leq PR \qquad (3)$$

where:

- $C \geq sensitivity\ level$

4.3.2 Simulation results

Table 13: Size of the area for a 5% probability of interference between two terminals

Terminal *e.r.p.* (W)	Rural	Suburban	Urban
0.5	17.46 km	5.52 km	3.2 km
1	21.35 km	6.78 km	3.94 km
d1W/d0.5W	1.22	1.23	1.23
(d1W/d0.5W)2	1.50	1.51	1.52

4.3.3 Findings of SEAMCAT Study 1

In this scenario, to compensate for an *e.r.p.* increase of 3 dB while keeping the same probability of interference between two terminals, the surface of the area has to be increased by a ratio around 1.5.

Hence, an *e.r.p.* increase of 3 dB may reduce the number of terminals per square kilometre by a ratio of around 1.5, corresponding to a loss of capacity of 33%. This ratio may be pessimistic, considering that a mixture of 0.5 W and 1 W terminals may coexist.

4.4 STUDY 2 - STATISTICAL ANALYSIS WITH SEAMCAT OF MULTIPLE INTERFERERS

This section show results of the analysis of the simulation scenario which evaluates impact of the multiple interfering PMR 446 equipment on the single PMR 446 victim equipment. Different interfering PMR 446

equipment have been simulated as interferers and victims composing different mix of the high power and standard power equipment in the interference pool.

To analyse and quantify effect of the power increase simulations using SEAMCAT Tool was performed. For the studies official version v.5.5.0 of the SEAMCAT tool was used in ECC Report 252 [9] and Online SEAMCAT Handbook, Edition 4, [10].

Simulation results present separation distance needed between the interfering system links and victim equipment links, achieved user density per square kilometre per channel, density of PMR 446 user groups in 446.0-446.2 MHz frequency band and how the overall capacity of PMR 446 in the analysed area changes depending on the scenario.

4.4.1 Simulation Scenario

Simulation scenario with multiple interferers is illustrated in Figure 8.

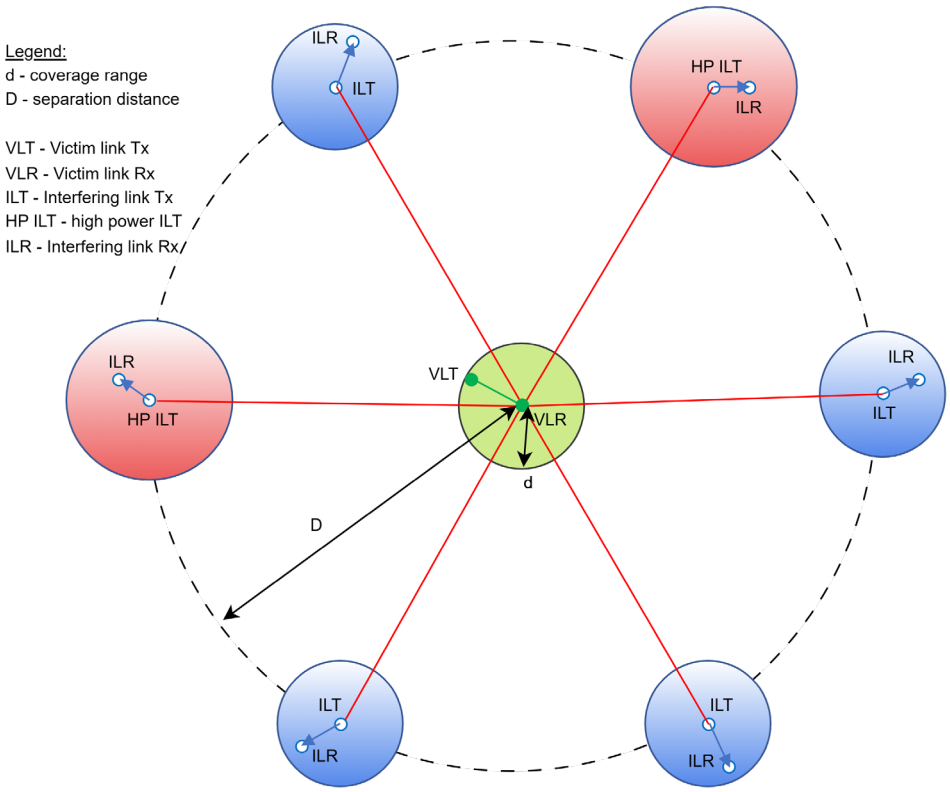


Figure 8: Simulation scenario of one tier of interferers (illustration of four standard power and two high power interferers)

Victim is a standard power PMR 446 device surrounded with one tier of interfering PMR 446 equipment at an equal distance. Interfering PMR 446 in different simulation runs vary in different ratios of standard power and high power to evaluate how different mix of PMR 446 equipment power types would influence victim system performance.

For each simulation run the distance between the victim PMR 446 system receiver and multiple interfering PMR 446 system transmitters was set to the fixed separation distance. For the coverage range of the PMR 446 system distances from the analysis in section 4.1.2 and given in Table 6 were used. Each individual simulation was run for 400000 to 700000 events which was sufficient to establish the results stability.

Multiple successive simulations have been done with varying the separation distance between interfering and victim systems in the range from minimal to maximal (typically in the range from 0 km to 20 km). For each of the Victim system type and mix of the high power and standard power simulations were run to determine the

minimal separation distance satisfying the interference criteria of 5% probability of interference. In total 63 simulation scenario types have been investigated which were varied for different separation distances. Process of running simulations for this analysis can be illustrated with multiple loops as shown in the Figure 9.

For Victim system in the Range (SP PMR-A A & D, SP PMR-A B & C, SP PMR-D) {
For simulation propagation environment in the Range (Urban, Suburban, Rural) {
For the Interfering system mix in the Range (from 0 SP – 6 HP to 6 SP – 0 HP) {
For the separation distance d in the Range (min – MAX km) {

- Do SEAMCAT simulation run for N events
- Extract simulation results
- Compare probability of interference to the interference criteria
- Store Optimal separation distance

} } } }

Figure 9: Pseudocode for multiple sets of the SEAMCAT simulations for the PMR 446 scenario

4.4.1.1 Analysed systems

Simulations were performed on four categories of Standard power analogue PMR 446 systems and one category digital equipment as defined in section 3.2.2 and in ETSI EN 303 405 [2]. For the PMR 446 equipment with increased power an increased effective radiated power (*e.r.p.*) of 1 W was used.

Categories of the analogue equipment have been grouped in two groups: categories A and D; categories B and C. Analogue PMR 446 equipment in the same group have same transmission and reception characteristics. Digital PMR 446 equipment have only one category in specifications, and the sensitivity levels specified for 4800 bits/s and BER 10-2 was used in the study. Transmitter characteristics of the standard power analogue and digital PMR 446 systems are given in Table 2 and receiver characteristics are given in Table 4 in section 3.2.

For the PMR 446 equipment with the increased power the same categories as for the standard power equipment was used with the increased *e.r.p.* of 1 W. Transmitter characteristics of the higher power analogue and digital PMR 446 systems are given in section 3.3.1 and receiver characteristics are given in section 3.3.2. Summary of the PMR 446 equipment types for co-channel interference analysis is given in Table 14.

Table 14: PMR 446 equipment types analysed

System ID	Characteristics (*e.r.p.*, ch.sep)	Description
SP-A PMR 446 (A and D)	500 mW, 12.5 kHz	Class A and D standard power analogue PMR 446 equipment
SP-A PMR 446 (B and C)	500 mW, 12.5 kHz	Class B and C standard power analogue PMR 446 equipment
SP-D PMR 446	500 mW, 6.25 kHz	Standard power digital PMR 446 equipment
HP-A PMR 446 (A and D)	1 W, 12.5 kHz	Class A and D high power analogue PMR 446 equipment
HP-A PMR 446 (B and C)	1 W, 12.5 kHz	Class B and C high power analogue PMR 446 equipment
HP-D PMR 446	1 W, 6.25 kHz	High power digital PMR 446 equipment

4.4.1.2 Propagation model

Propagation model Extended Okumura-Hata "Field strength and its variability in VHF and UHF land-mobile radio service" [11], "Empirical Formula for Propagation Loss in Land Mobile Radio Services" [12] and COST

Action 231 “Digital mobile radio towards future generation systems: Final Report”, [13] for urban, suburban and rural areas variations was used for simulation environments settings for urban, suburban and rural. The digital elevation model or other site-specific characteristics have not been considered in this analysis.

4.4.1.3 Objective criteria

Objective is set in a way that the received signal at the victim PMR 446 receiver is greater or equal than receiver sensitivity (P_Rx ≥ Rx Sens) and that C/(N+I) is greater or equal to co-channel rejection (C/(N+I) ≥ PR) required by the victim PMR 446 system. Receiver sensitivity and co-channel rejection are taken from Table 4 in section 3.2.2. Simulations were run until minimal separation distance is found which satisfies objective criteria.

4.4.2 Results

4.4.2.1 Separation distance

Separation distance shows minimal distance needed between standard power PMR 446 receiver and PMR 446 interfering systems in the first tier. Simulation scenarios evaluate different ratio of high power and standard power interferers for co-channel interference scenario. All interfering systems are considered active throughout the simulation, thus not considering activity factor.

The separation distance increases with the increase the ratio of high-power interfering transmitters in relation to standard power interfering transmitters. Distances are lowest in the case all standard power interferers of class A and D in urban environment and equals to 0.66 km. Highest separation distance is obtained in the case all high-power interferers in rural environment and equals to 17.8 km. In the case when 50% of the interferers are standard power and 50% of the interferers are high power the separation distance increases in average by 11% (in the range 10.1-12.0%) comparing to separation distance for only standard power interferers. In the case when all the interferers are high power the separation distance increases in average by 21.5% (in the range 19.8-22.8%) comparing to separation distance for standard power interferers. The distances are smaller in the urban environment because of higher transmission loss comparing to sub urban and rural environment where separation distances are much higher.

Table 15 shows separation distances for Analogue standard power PMR 446 equipment of Class A and D as the victim system.

Table 15: Minimal separation distance between PMR 446 Victim (SP-A PMR 446 A and D) and mix of SP and HP PMR 446 Interferers

Interfering Systems Composition (Standard and High Power)	Environment		
	Urban	Suburban	Rural
	Separation distance (km)		
0.0% SP - 100.0% HP	0.8111	1.3386	10.9750
16.7% SP - 83.3% HP	0.7925	1.2954	10.7271
33.3% SP - 66.7% HP	0.7631	1.2699	10.4292
50.0% SP - 50.0% HP	0.7408	1.2283	10.0552
66.7% SP - 33.3% HP	0.7161	1.1910	9.7788
83.3% SP - 16.7% HP	0.6958	1.1391	9.3893
100.0% SP - 0.0% HP	0.6653	1.0898	9.0312
Note: Victim system link is SP-A PMR 446 (A and D); Interference system links are SP-A PMR 446 (A and D) and HP-A PMR 446 (A and D)			

Table 16 shows separation distances for Analogue standard power PMR 446 equipment of Class B and C as victim system.

Table 16: Minimal separation distance between PMR 446 Victim (SP-A PMR 446 B and C) and mix of SP and HP PMR 446 Interferers

Interfering Systems Composition (Standard and High Power)	Environment		
	Urban	Suburban	Rural
	Separation distance (km)		
0.0% SP - 100.0% HP	1.0601	2.7785	14.3368
16.7% SP - 83.3% HP	1.0334	2.7154	14.0195
33.3% SP - 66.7% HP	1.0055	2.6566	13.5625
50.0% SP - 50.0% HP	0.9734	2.5571	13.2074
66.7% SP - 33.3% HP	0.9414	2.4834	12.7743
83.3% SP - 16.7% HP	0.9094	2.3888	12.2932
100.0% SP - 0.0% HP	0.8745	2.2945	11.8212
Note: Victim system link is SP-A PMR 446 (B and C); Interference system links are SP-A PMR 446 (B and C) and HP-A PMR 446 (B and C)			

Table 17 shows separation distances for digital standard power PMR 446 equipment as victim system.

Table 17: Minimal separation distance between PMR 446 Victim (SP-D PMR 446) and mix of SP and HP PMR 446 Interferers (SP-D PMR 446 and HP-D PMR 446)

Interfering Systems Composition (Standard and High Power)	Environment		
	Urban	Suburban	Rural
	Separation distance (km)		
0.0% SP - 100.0% HP	1.3199	3.4777	17.8303
16.7% SP - 83.3% HP	1.2821	3.3940	17.3762
33.3% SP - 66.7% HP	1.2573	3.2847	16.8950
50.0% SP - 50.0% HP	1.2069	3.1918	16.3638
66.7% SP - 33.3% HP	1.1833	3.0761	15.8336
83.3% SP - 16.7% HP	1.1257	2.9634	15.2860
100.0% SP - 0.0% HP	1.0818	2.8985	14.6069
Note: Victim system link is SP-D PMR 446; Interference system links are SP-D PMR 446 and HP-D PMR 446			

It can be observed that separation distance for Analogue PMR 446 of Class A and D is lowest, separation distance for Analogue PMR 446 of Class B and C in the middle range and separation distance for digital PMR 446 is higher than other two. The cause of this trend can be explained by different level of sensitivity and co-channel rejection ratio for different systems resulting in different level of allowed interference for different system types.

Analogue PMR 446 of Class A and D has higher sensitivity filed strength (less sensitive) than Analogue PMR 446 of Class B and C (lower sensitivity filed strength) with same co-channel rejection ratio allowing Class A

and D equipment to withheld higher interference level without being disturbed. Analogue PMR 446 of Class B and C has same sensitivity filed strength as Digital PMR 446 equipment but has smaller co-channel rejection ratio allowing Class B and C equipment to withheld higher interference level then digital without being disturbed.

4.4.2.2 Achievable PMR 446 user density

User density shows number of concurrent PMR 446 users which can be active per 1 km^2 per 1 channel without suffering and causing interference to each other. For the calculation of User density, for the number of users it is assumed one pair of users where there are two active terminals in each PMR 446 systems and that there are 7 co-channel systems in the system layout. For the surface area the separation distance and system coverage range are taken into consideration.

Obtained user densities vary in the range from 0.012 Users / (km^2 x channel) in the rural environment and all high-power interferers to 7.75 Users / (km^2 x channel) in the urban environment and standard power interferers. The achievable user densities in the urban environment are higher because of higher transmission loss comparing to sub urban and rural environment where user densities are lower. The achievable user density reduces with the increase the number of high-power interfering transmitters in relation to standard power interfering transmitters. In the case when 50% of the interferers are standard power and 50% of the interferers are high power the achievable user density reduces in average by 18% comparing to density for standard power interferers. In the case when all the interferers are high power the achievable user density reduces in average by 31% comparing to density for standard power interferers.

Detailed results for the Analogue standard power PMR 446 equipment (Class A and D), Analogue standard power PMR 446 equipment (Class B and C) and Digital standard power PMR 446 equipment as victim and various mix of standard and high-power interferers are shown in the following tables.

Table 18: PMR 446 user density for PMR 446 Victim (SP-A PMR 446 A and D) and mix of SP and HP PMR 446 Interferers

Interfering Systems Composition (Standard and High Power)	Environment		
	Urban	Suburban	Rural
	PMR 446 User Density (Users / km^2 x ch)		
0.0% SP - 100.0% HP	5.4514	2.1175	0.0319
16.7% SP - 83.3% HP	5.6818	2.2497	0.0333
33.3% SP - 66.7% HP	6.0792	2.3334	0.0351
50.0% SP - 50.0% HP	6.4089	2.4806	0.0375
66.7% SP - 33.3% HP	6.8065	2.6246	0.0395
83.3% SP - 16.7% HP	7.1602	2.8467	0.0426
100.0% SP - 0.0% HP	7.7487	3.0849	0.0457
Note: Victim system link is SP-A PMR 446 (A and D); Interference system links are SP-A PMR 446 (A and D) and HP-A PMR 446 (A and D)			

Table 19: PMR 446 user density for PMR 446 Victim (SP-A PMR 446 Band C) and mix of SP and HP PMR 446 Interferers

Interfering Systems Composition (Standard and High Power)	Environment		
	Urban	Suburban	Rural
	PMR 446 User Density (Users / km^2 x ch)		
0.0% SP - 100.0% HP	3.3201	0.5178	0.0185
16.7% SP - 83.3% HP	3.4784	0.5409	0.0193
33.3% SP - 66.7% HP	3.6564	0.5637	0.0205
50.0% SP - 50.0% HP	3.8791	0.6058	0.0216
66.7% SP - 33.3% HP	4.1213	0.6402	0.0229
83.3% SP - 16.7% HP	4.3874	0.6887	0.0246
100.0% SP - 0.0% HP	4.7080	0.7427	0.0264
Note: Victim system link is SP-A PMR 446 (B and C); Interference system links are SP-A PMR 446 (B and C) and HP-A PMR 446 (B and C)			

Table 20: PMR 446 user density for PMR 446 Victim (SP-D PMR 446) and mix of SP and HP PMR 446 Interferers (SP-D PMR 446 and HP-D PMR 446)

Interfering Systems Composition (Standard and High Power)	Environment		
	Urban	Suburban	Rural
	PMR 446 User Density (Users / km^2 x ch)		
0.0% SP - 100.0% HP	2.2135	0.3367	0.0123
16.7% SP - 83.3% HP	2.3364	0.3528	0.0129
33.3% SP - 66.7% HP	2.4227	0.3755	0.0136
50.0% SP - 50.0% HP	2.6135	0.3966	0.0144
66.7% SP - 33.3% HP	2.7102	0.4255	0.0154
83.3% SP - 16.7% HP	2.9712	0.4567	0.0164
100.0% SP - 0.0% HP	3.1962	0.4763	0.0178
Note: Victim system link is SP-D PMR 446; Interference system links are SP-D PMR 446 and HP-D PMR 446			

4.4.2.3 User group density in PMR Spectrum

This section of the results analyses how many independent PMR 446 groups of users per km^2 can fit in the whole frequency spectrum available to PMR-446 equipment (446.0-446.2 MHz). For analogue systems 12.5 kHz channels are assumed, while for the digital systems 6.25 kHz channel raster is assumed giving total of 32 channels in the observed frequency band.

One user group can consist of pairs of users, small group of users or large group of users which are using resource channel together. To avoid transmission conflicts in user group it is assumed that only one user transmits in the observed time, while other terminals corresponding in the same group are in the listen mode. Number of users of the user group does not impact the presented results and in order to get total number of

individual users the numbers presented in the tables needs to be multiplied by average size of user group in the analysed area.

The user group density per km^2 varies from 0.25 to 61.99 for Class A and D analogue equipment, from 0.15 to 37.66 for Class B and C analogue equipment, and from 0.20 to 51.14 for the digital PMR 446 equipment.

Table 21 shows user group density of Analogue PMR 446 systems of Class A and D in 446.0-446.2 MHz frequency band considering channel separation of 12.5 kHz.

Table 21: User group density in 446.0–446.2 MHz frequency band for - PMR 446 Victim (SP-A PMR 446 A and D) and mix of SP and HP PMR 446 Interferers

Interfering Systems Composition (Standard and High Power)	Environment		
	Urban	Suburban	Rural
	User group density in PMR spectrum (User groups / km^2)		
0.0% SP - 100.0% HP	43.6112	16.9401	0.2554
16.7% SP - 83.3% HP	45.4547	17.9977	0.2665
33.3% SP - 66.7% HP	48.6334	18.6675	0.2807
50.0% SP - 50.0% HP	51.2712	19.8448	0.3003
66.7% SP - 33.3% HP	54.4522	20.9971	0.3162
83.3% SP - 16.7% HP	57.2815	22.7738	0.3407
100.0% SP - 0.0% HP	61.9896	24.6795	0.3659
Note: Victim system link is SP-A PMR 446 (A and D); Interference system links are SP-A PMR 446 (B and C) and HP-A PMR 446 (A and D)			

Table 22 shows the user group density of Analogue PMR 446 systems of Class B and C in 446.0-446.2 MHz frequency band considering channel separation of 12.5 kHz.

Table 22: User group density in 446.0-446.2 MHz frequency band for - PMR 446 Victim (SP-A PMR 446 B and C) and mix of SP and HP PMR 446 Interferers

Interfering Systems Composition (Standard and High Power)	Environment		
	Urban	Suburban	Rural
	User group density in PMR spectrum (User groups / km^2)		
0.0% SP - 100.0% HP	26.5605	4.1427	0.1483
16.7% SP - 83.3% HP	27.8269	4.3268	0.1546
33.3% SP - 66.7% HP	29.2509	4.5096	0.1643
50.0% SP - 50.0% HP	31.0329	4.8466	0.1726
66.7% SP - 33.3% HP	32.9701	5.1212	0.1835
83.3% SP - 16.7% HP	35.0993	5.5093	0.1968
100.0% SP - 0.0% HP	37.6641	5.9412	0.2114
Note: Victim system link is SP-A PMR 446 (B and C); Interference system links are SP-A PMR 446 (B and C) and HP-A PMR 446 (B and C)			

Table 23 shows the user group density of Digital PMR 446 systems in 446.0-446.2 MHz frequency band considering channel separation of 6.25 kHz.

Table 23: User group density in 446.0-446.2 MHz frequency band for - PMR 446 Victim (SP-D PMR 446) and mix of SP and HP PMR 446 Interferers (SP-D PMR 446 and HP-D PMR 446)

Interfering Systems Composition (Standard and High Power)	Environment		
	Urban	Suburban	Rural
	User group density in PMR spectrum (User groups / km^2)		
0.0% SP - 100.0% HP	35.4159	5.3875	0.1969
16.7% SP - 83.3% HP	37.3831	5.6442	0.2066
33.3% SP - 66.7% HP	38.7627	6.0080	0.2178
50.0% SP - 50.0% HP	41.8162	6.3459	0.2311
66.7% SP - 33.3% HP	43.3640	6.8074	0.2458
83.3% SP - 16.7% HP	47.5398	7.3075	0.2623
100.0% SP - 0.0% HP	51.1388	7.6210	0.2854
Note: Victim system link is SP-D PMR 446; Interference system links are SP-D PMR 446 and HP-D PMR 446			

4.4.2.4 Impact of introducing high power PMR terminals on the overall capacity

Overall capacity of the PMR 446 system in this section is estimated based on the achievable PMR 446 user density per unit area. Achievable user density of inference scenarios with all standard power terminals as victim and interferes are taken as a reference capacity. In the tables bellow the percentage decrease of the overall capacity is calculated with respect to the reference scenario with all standard power terminals as a victim.

Table 24 shows the overall capacity decrease of Analogue PMR 446 systems of Class A and D for various combination of standard power and high power PMR 446 equipment.

Table 24: Overall capacity decrease percentage for - PMR 446 Victim (SP-A PMR 446 A and D) and mix of SP and HP PMR 446 Interferers

Interfering Systems Composition (Standard and High Power)	Environment		
	Urban	Suburban	Rural
	Capacity decrease (%)		
0.0% SP - 100.0% HP	-29.65	-31.36	-30.20
16.7% SP - 83.3% HP	-26.67	-27.07	-27.18
33.3% SP - 66.7% HP	-21.55	-24.36	-23.27
50.0% SP - 50.0% HP	-17.29	-19.59	-17.91
66.7% SP - 33.3% HP	-12.16	-14.92	-13.59
83.3% SP - 16.7% HP	-7.60	-7.72	-6.88
100.0% SP - 0.0% HP	0.00	0.00	0.00
Note: Victim system link is SP-A PMR 446 (B and C); Interference system links are SP-A PMR 446 (A and D) and HP-A PMR 446 (A and D)			

Table 25 shows the overall capacity decrease of Analogue PMR 446 systems of Class B and C for various combination of standard power and high power PMR 446 equipment.

Table 25: Overall capacity decrease percentage for - PMR 446 Victim (SP-A PMR 446 B and C) and mix of SP and HP PMR 446 Interferers

Interfering Systems Composition (Standard and High Power)	Environment		
	Urban	Suburban	Rural
	Capacity decrease (%)		
0.0% SP - 100.0% HP	-29.48	-30.27	-29.82
16.7% SP - 83.3% HP	-26.12	-27.17	-26.86
33.3% SP - 66.7% HP	-22.34	-24.10	-22.25
50.0% SP - 50.0% HP	-17.61	-18.42	-18.36
66.7% SP - 33.3% HP	-12.46	-13.80	-13.21
83.3% SP - 16.7% HP	-6.81	-7.27	-6.89
100.0% SP - 0.0% HP	0.00	0.00	0.00
Note: Victim system link is SP-A PMR 446 (B and C); Interference system links are SP-A PMR 446 (B and C) and HP-A PMR 446 (B and C)			

Table 26 shows the overall capacity decrease of Digital PMR 446 systems for various combination of standard power and high power PMR 446 equipment.

Table 26: Overall capacity decrease percentage for - PMR 446 Victim (SP-D PMR 446) and mix of SP and HP PMR 446 Interferers (SP-D PMR 446 and HP-D PMR 446)

Interfering Systems Composition (Standard and High Power)	Environment		
	Urban	Suburban	Rural
	Capacity decrease (%)		
0.0% SP - 100.0% HP	-30.75	-29.31	-31.01
16.7% SP - 83.3% HP	-26.90	-25.94	-27.59
33.3% SP - 66.7% HP	-24.20	-21.16	-23.69
50.0% SP - 50.0% HP	-18.23	-16.73	-19.01
66.7% SP - 33.3% HP	-15.20	-10.68	-13.88
83.3% SP - 16.7% HP	-7.04	-4.11	-8.07
100.0% SP - 0.0% HP	0.00	0.00	0.00
Note: Victim system link is SP-D PMR 446; Interference system links are SP-D PMR 446 and HP-D PMR 446			

Obtained overall capacity varies from 0% for all standard power terminals to -31.4% for scenario with all high-power terminals as interferers. Overall capacity decrease varies depending on the type of the PMR 446 equipment and type of environment. It is interesting to observe that there is not much difference on the capacity loss with respect the type of the PMR 446 equipment and type of environment. The main impact on the overall

capacity loss is by the ratio between standard power and high-power terminals in the interference pool. With the introduction of more high-power terminals the overall capacity decreases. In the case when 50% of the interferers are standard power and 50% of the interferers are high power the overall capacity loss is in average -18.13% comparing to scenarios with all standard power interferers in the pool. In the case when all the interferers are high power the overall capacity loss is in average by -30.2% comparing to scenarios with all standard power interferers in the pool. The capacity decrease is summarised in Table 27.

Table 27: Summary of the overall capacity decrease percentage for PMR 446 equipment

Interfering Systems Composition (Standard and High Power)	Average	Min.	Max.
	Capacity decrease (%)		
0.0% SP - 100.0% HP	-30.20	-31.36	-29.31
16.7% SP - 83.3% HP	-26.83	-27.59	-25.94
33.3% SP - 66.7% HP	-22.99	-24.36	-21.16
50.0% SP - 50.0% HP	-18.13	-19.59	-16.73
66.7% SP - 33.3% HP	-13.32	-15.20	-10.68
83.3% SP - 16.7% HP	-6.93	-8.07	-4.11
100.0% SP - 0.0% HP	0.00	0.00	0.00

4.4.2.5 Sensitivity analysis

To evaluate sensitivity of the obtained results, the analysis of the set of simulation for the Analogue PMR 446 system of Class A and D as victim in the rural environment was evaluated. The graph shows dependence of probability of interference with respect to the separation distance in kilometres. As mentioned above, the objective was set to obtain 5% of probability of interference, while having signal above receiver sensitivity. Different colours show different ratio of high power and standard power interferers for co-channel interference scenario. Individual dots show result of one simulation run, while lines show estimated linear trendline for the evaluated cases.

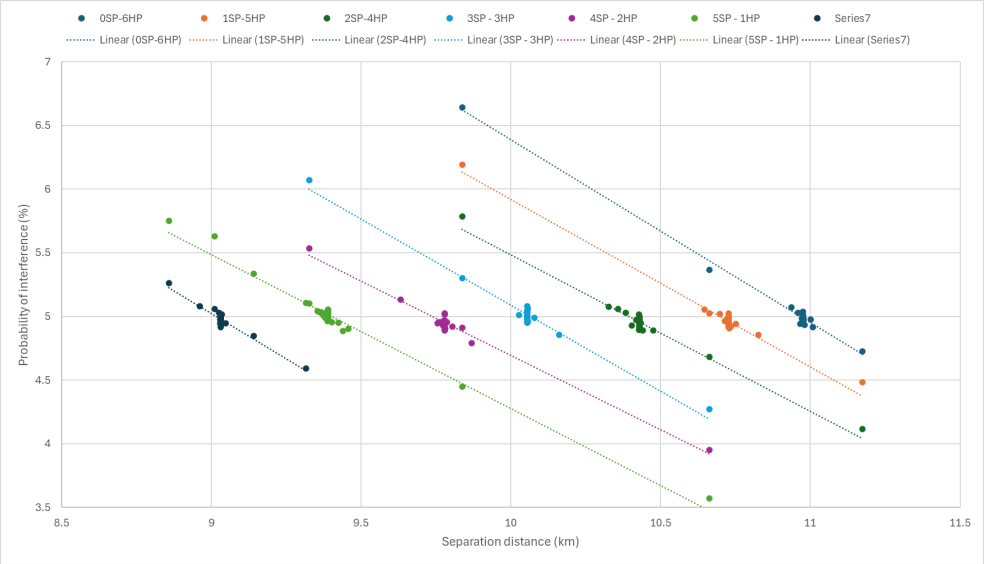


Figure 10: Sensitivity analysis of simulation runs for the Analogue PMR 446 system of Class A and D as victim in the rural environment

5 MONITORING OF THE USAGE OF THE BAND

5.1 MONITORING CAMPAIGN IN FRANCE

Between January and April 2025, some monitoring stations were used in France to evaluate usage of the band 446-446.2 MHz. This campaign consisted in three steps:

1 Monitoring at a threshold T_u 5 dB above the noise level of the monitoring stations

2 On field evaluation of the range of a monitoring station

3 Monitoring at a threshold T_a 20 to 35 dB above the noise level of the monitoring stations

The objective of the first step was to capture usage of the band on the largest possible area (well above $200\ km^2$), using a low threshold T_u.

The second step was necessary to set a revised threshold level T_a for the third step.

The purpose of the third step was to evaluate the availability of free channels in the band from the viewpoint of a PMR 446 equipment, compensating for the height of the monitoring antennas and for the dominant and unobstructed position of the stations.

The revised threshold was set after an on-field assessment of the range of a monitoring station, showing that PMR 446 equipment up to 30 km from the station could be seen by it. Such a great distance was possible due to the geographically dominant position of the station and its antenna height.

In practice, it can hardly be considered that terminals distant from 3 km would interfere with each other. Therefore, it was decided that the threshold for step 3 would be raised to 20 dB above the noise level, to compensate for the favourable positions of the monitoring stations. Another offset would be used to align the sensitivity levels of different monitoring stations. The station used in step 2 having the worst sensitivity of them all, in the end, thresholds for step 3 were set in the range 20 to 35 dB above noise level, depending on the monitoring station considered.



Figure 11: Monitoring station of Cordemais

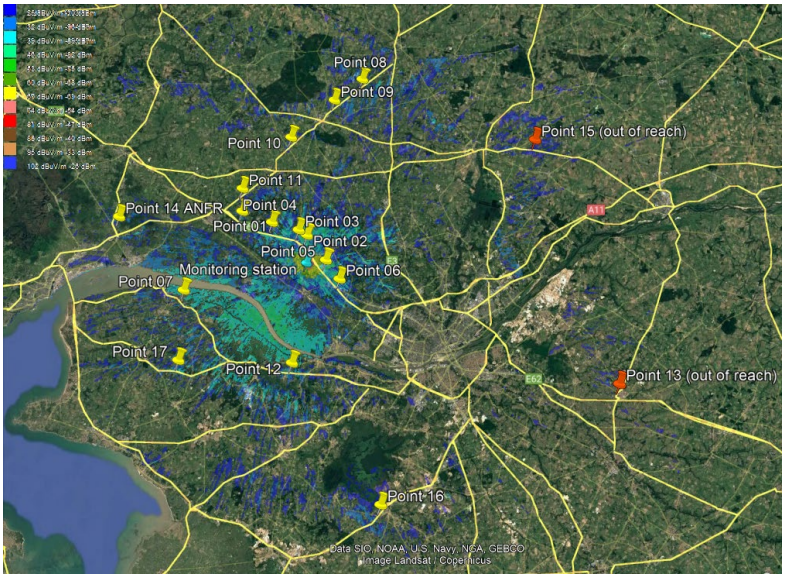


Figure 12: Reverse coverage using Recommendation ITU-R P.452-18 and points where a 0.5 W *e.r.p.* PMR 446 equipment was visible from the monitoring station

5.1.1 Stations used

Five monitoring stations were used in this campaign.

Stations of Cordemais, Monthyon and Saint-André-La-Côte are located in rural areas at a distance between 10 to 15 km from the nearest urban areas (respectively Nantes, Paris and Lyon).

Stations of Melun and Tournefeuille are located inside urban areas (respectively Melun and Toulouse).



Figure 13: Monitoring stations

5.1.2 Monitoring parameters

Occupancy is the percentage of time, where a threshold is exceeded. In this campaign, occupancy is evaluated for periods of 5 minutes, on channels of 6.25 kHz.

Two thresholds are used:

- a first threshold T_u for assessing usage of the band over a large area (well above $200\ km^2$), at 5 dB above the noise floor of the monitoring stations;
- a compensated threshold T_a for the assessment of occupied channels from the viewpoint of a PMR 446 equipment, at 20 to 35 dB above the noise floor of the monitoring stations.

Two sets of data are provided:

- a histogram of occupancy for about a week, providing percentages of occupancy over periods of 5 minutes, for each 6.25 kHz channels in the band 446-446.2 MHz;
- a count of used channels, for the longest period of observation available, by periods of 5 minutes.

When assessing usage with a low threshold, occupancy equal or below 3% (9 seconds on a period of 5 minutes) are discarded to avoid temporary increase of the noise floor that can affect all channels at the same time.

When evaluating availability of channels, as seen by a PMR 446 equipment, using the compensated threshold T_a, a channel with an occupancy above 0% is considered to be occupied.

5.1.3 Monitoring results

5.1.3.1 Cordemais

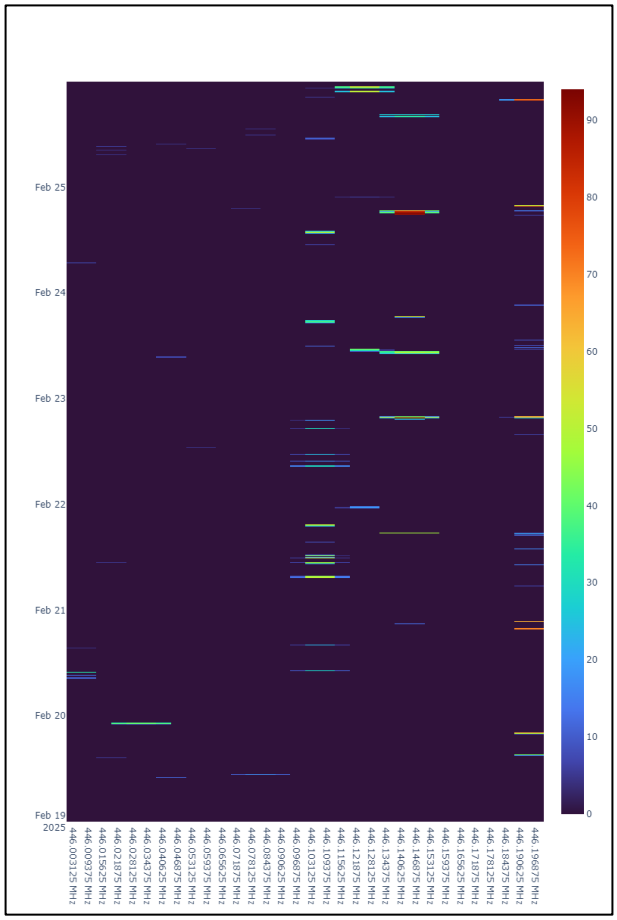


Figure 14: Percentage of occupancy by steps of 5 minutes as seen by the monitoring station

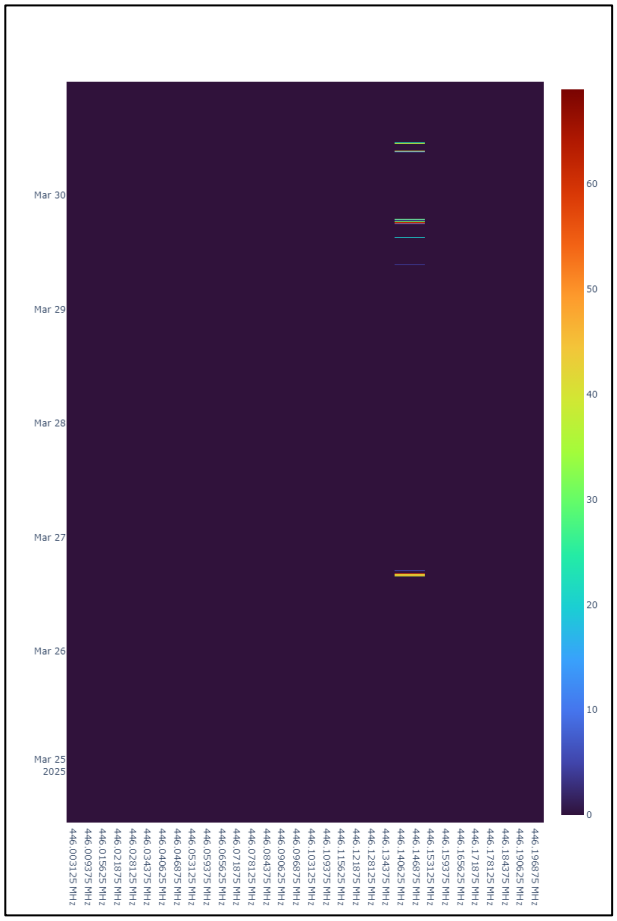


Figure 15: Percentage of occupancy by steps of 5 minutes as seen by a PMR 446 equipment

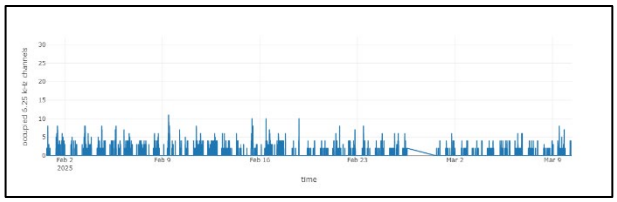


Figure 16: Number of used channels as seen by the monitoring station

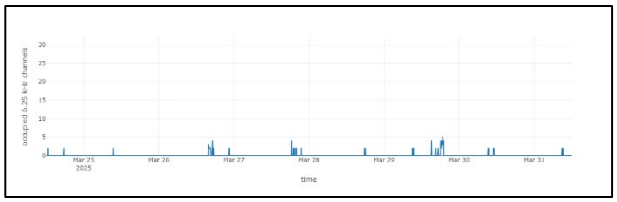


Figure 17: Number of occupied channels as seen by a PMR 446 equipment

The station was not available for some days towards the end of February.

Evaluated over a large geographical perimeter for several weeks, usage of the band is similar from one week to the next.

Occupancy of the band, evaluated from the perspective of a PMR 446 equipment, peaks at about the equivalent of 5 channels of 6.25 kHz.

5.1.3.2 Melun

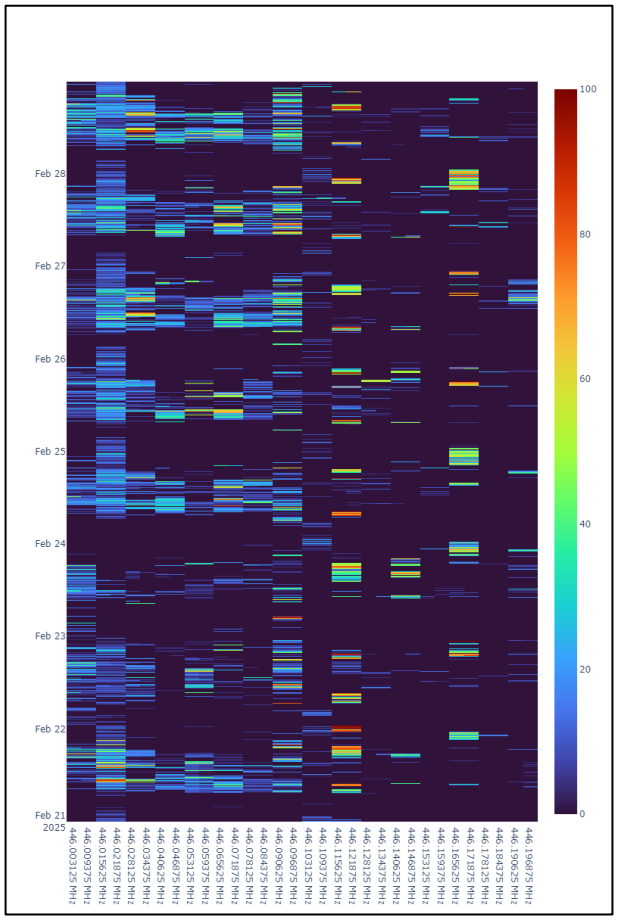


Figure 18: Percentage of occupancy by steps of 5 minutes as seen by the monitoring station

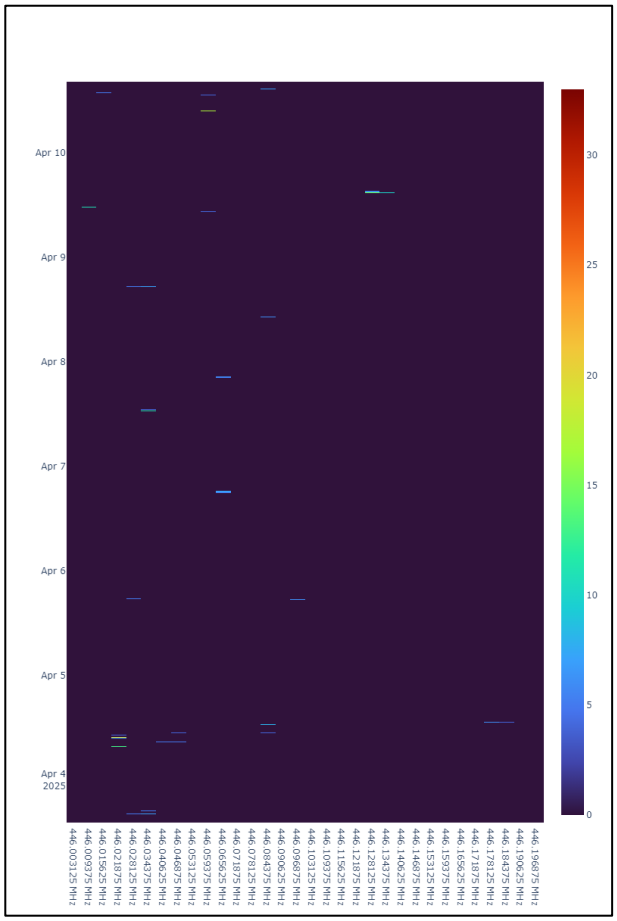


Figure 19: Percentage of occupancy by steps of 5 minutes as seen by a PMR 446 equipment

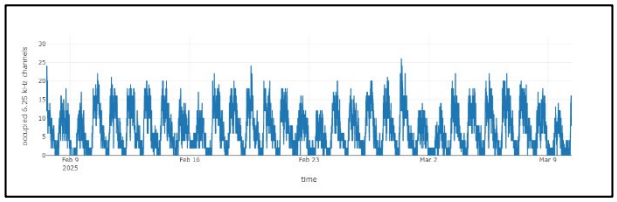


Figure 20: Number of used channels as seen by the monitoring station

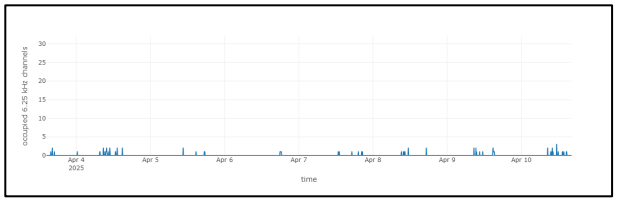


Figure 21: Number of occupied channels as seen by a PMR 446 equipment

Evaluated over a large geographical perimeter for several weeks, usage of the band is similar from one week to the next.

Usage is higher on weekdays, compared to weekends.

5.1.3.3 Monthyon

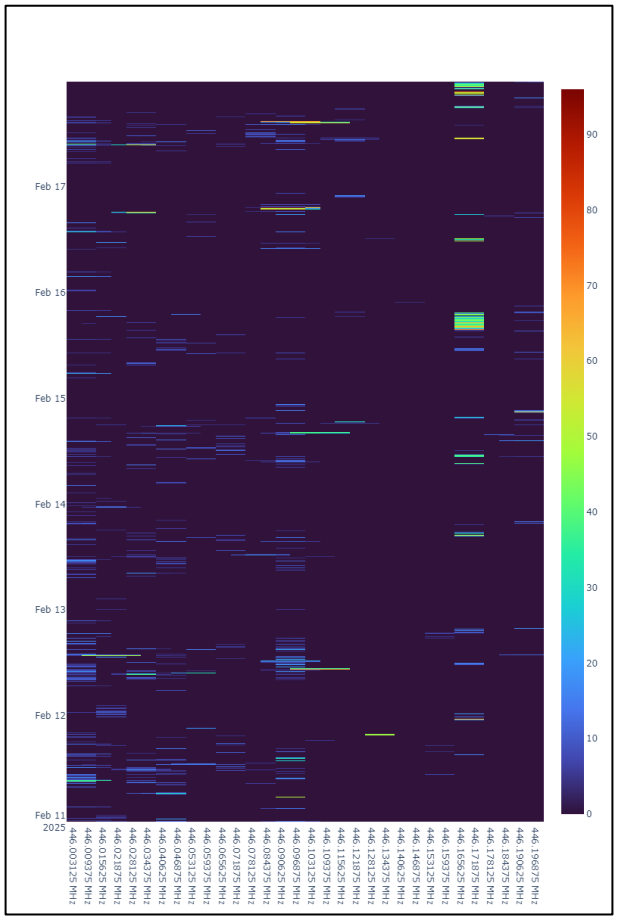


Figure 22: Percentage of occupancy by steps of 5 minutes as seen by the monitoring station

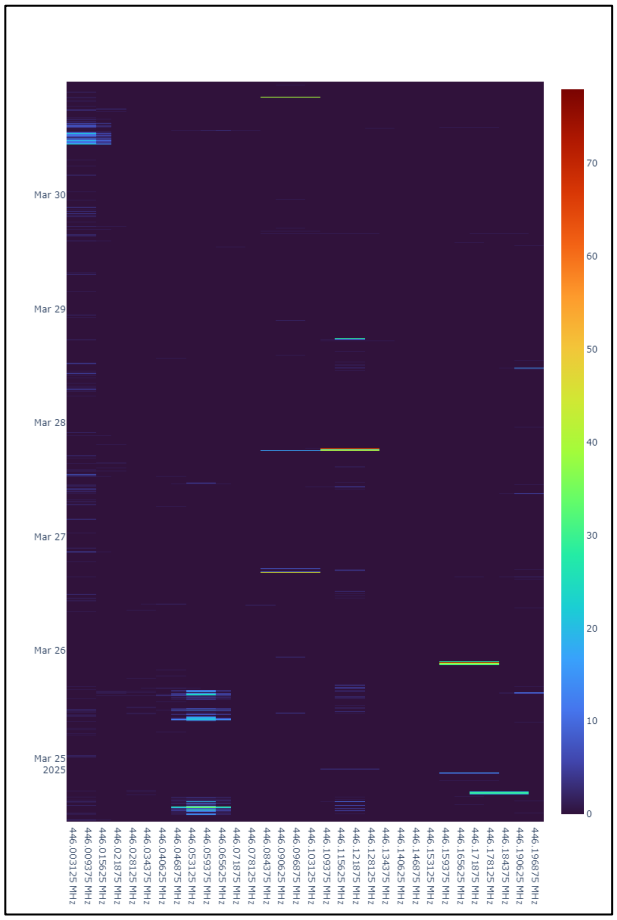


Figure 23: Percentage of occupancy by steps of 5 minutes as seen by a PMR 446 equipment

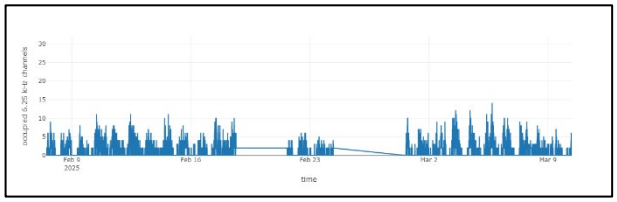


Figure 24: Number of used channels as seen by the monitoring station

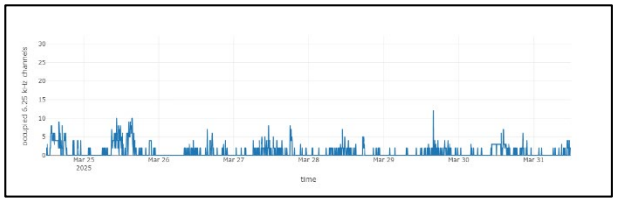


Figure 25: Number of occupied channels as seen by a PMR 446 equipment

The monitoring station wasn't available for several days in the second half of February.

Occupancy, as seen by a PMR 446 equipment, peaks at the equivalent of 12 channels of 6.25 kHz.

5.1.3.4 Saint-André-La-Côte

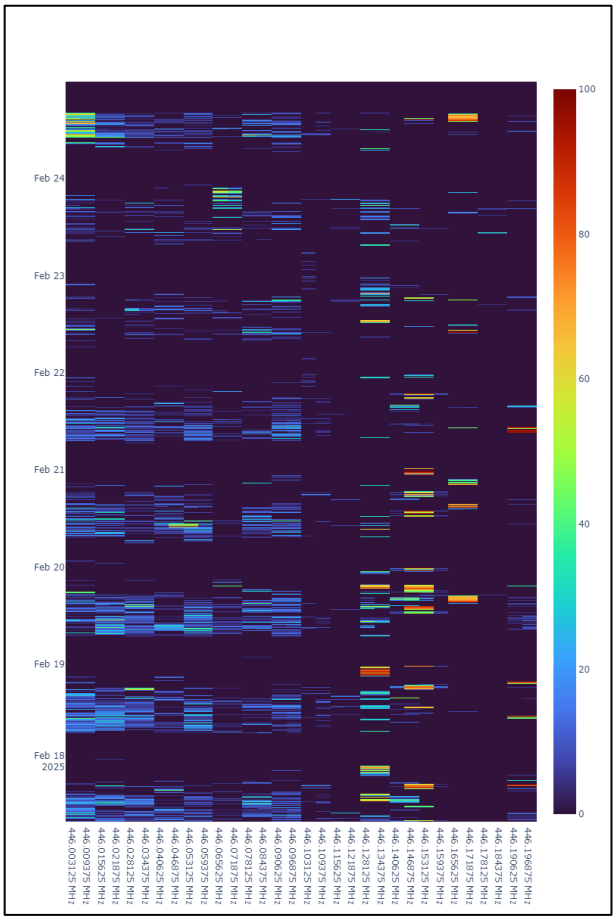


Figure 26: Percentage of occupancy by steps of 5 minutes

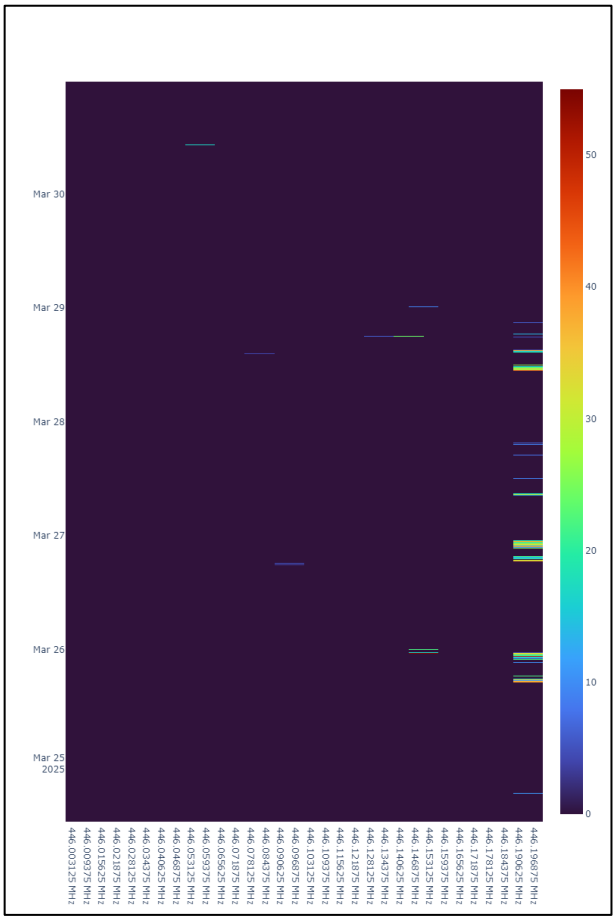


Figure 27: Percentage of occupancy by steps of 5 minutes as seen by a PMR 446 equipment

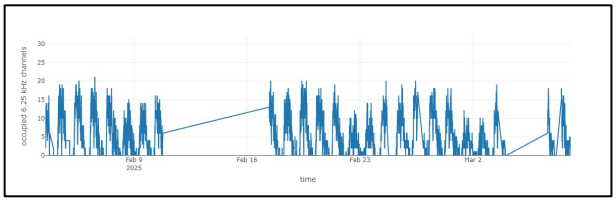


Figure 28: Number of used channels as seen by the monitoring station

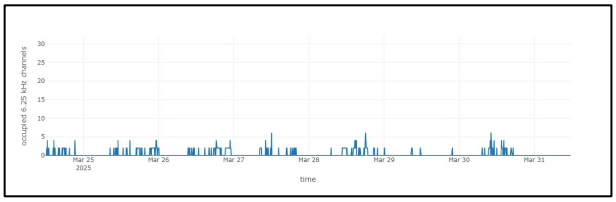


Figure 29: Number of occupied channels as seen by a PMR 446 equipment

The station wasn't available over the entire period of observation.

The occupancy of the band, evaluated from the perspective of a PMR 446 equipment, peaks at the equivalent of 6 channels of 6.25 kHz.

5.1.3.5 Tournefeuille

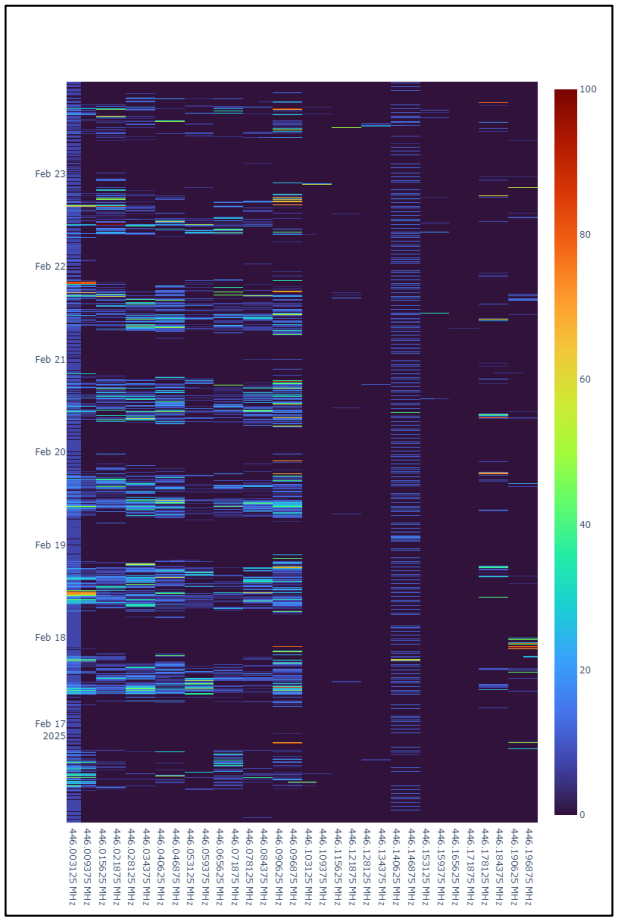


Figure 30: Percentage of occupancy by steps of 5 minutes

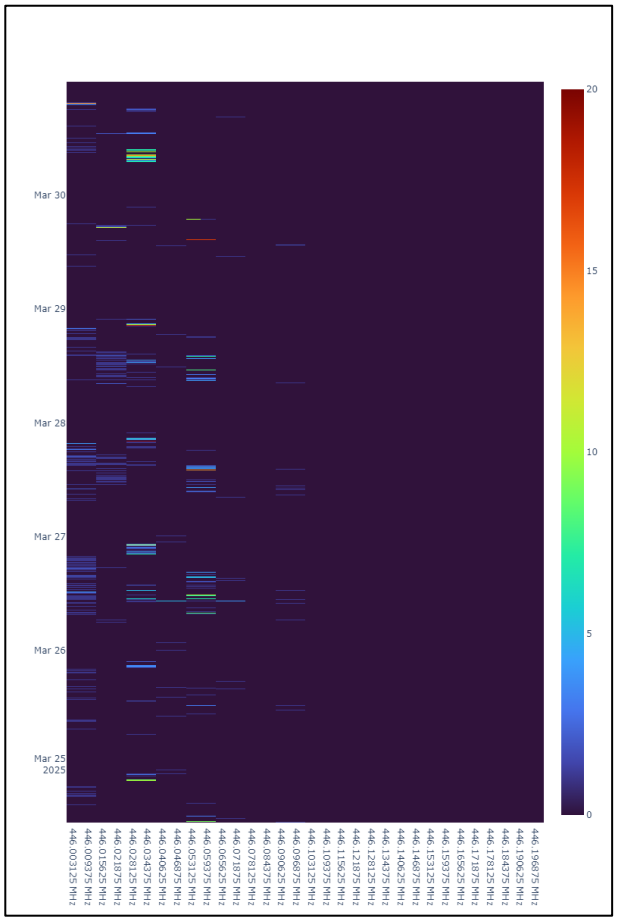


Figure 31: Percentage of occupancy by steps of 5 minutes as seen by a PMR 446 equipment

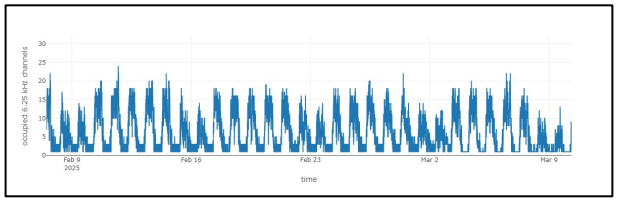


Figure 32: Number of used channels as seen by the monitoring station

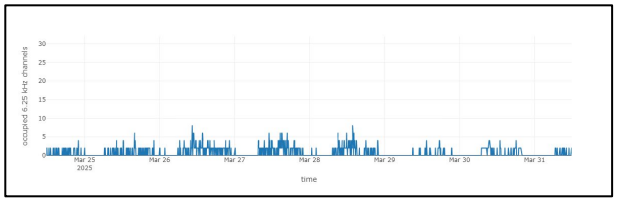


Figure 33: Number of occupied channels as seen by a PMR 446 equipment

Occupancy of the band, evaluated from the perspective of a PMR 446 equipment, peaks at the equivalent of 8 channels of 6.25 kHz.

5.1.4 Observations

Over large areas, from the viewpoint of monitoring stations, usage of the band is similar from one week to the next. Usage of the band is more important on weekdays compare to weekends.

PMR 446 equipment sees a maximum of twelve 6.25 kHz occupied channels in its vicinity, corresponding to 37.5% of the 32 channels available in the band 446-446.2 MHz.

5.2 MONITORING CAMPAIGN IN THE NETHERLANDS

As part of the master study of one of the colleagues of the Dutch administration and subsequent development of a new monitoring principle a short monitoring activity was performed in the PMR 466 band in one city (Deventer) in the Netherlands.

The monitoring setup consisted of a PlutoSDR software defined radio and a Raspberry Pi with software written in python. As antenna a commercial omnidirectional antenna (Diamond V-2000) at the rooftop of a low residential building in an urban environment was used.

The software [14] used processes the data per 12.5 kHz channel and calculates the percentage occupancy for each hour. This is done by Fast Fourier Transform (FFT) processing the data in such a way that a high channel separation is achieved. The noise level and detection threshold are dynamic and assure that only real traffic, in this case PMR 446 is captured.

During the activity is became clear that mainly the lower 8 analogue channels are occupied with a maximum occupancy of 40% in extreme cases. A clear day night pattern can be observed. Amongst the observed usage was a fast-food restaurant, a swimming pool and several baby monitors. Figure 34 and Figure 35are two from a large set of observations but typical for what has been observed for a whole month.

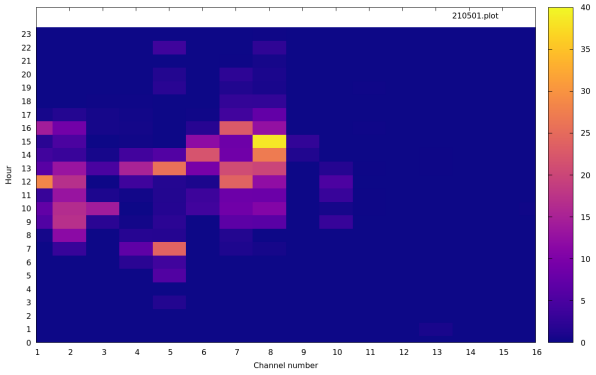


Figure 34: 1 May 2021 (Saturday)

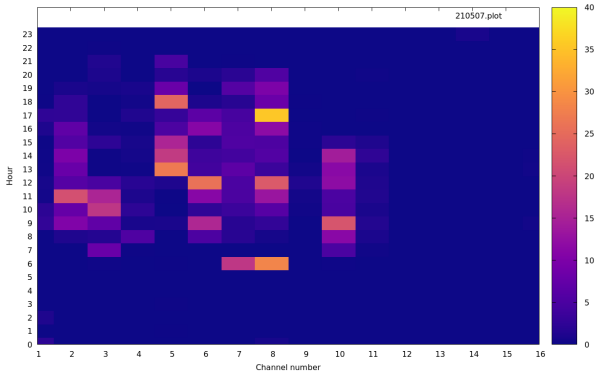


Figure 35: 7 May 2021 (Friday)

5.3 MONITORING CAMPAIGN IN ROMANIA

In January and May 2025, in Romania were conducted monitoring activities to evaluate usage of the band 446-446.2 MHz. These monitoring activities consisted of two sets of measurements:

1 The first set of measurements were performed in January 2025, between 17.01.2025 and 27.01.2025;

2 The second set of measurements were performed in May 2025, between 14.05.2025 and 23.05.2025.

The objective of the first set of measurements was to capture the usage of the PMR 446 band, using two receivers installed in urban areas, in two municipalities with a population greater than 200,000 inhabitants. The objective of the second set of measurements was to investigate the channel occupancy patterns in less granular detail.

5.3.1 Stations used

Two monitoring stations were used for the two sets of monitoring measurements.

Stations” Iași” and ”Galați” are installed in the centre of the two county seat municipalities. These monitoring stations were proposed for these measurements in order to best reflect the use of the band in urban areas where there is a higher density of PMR 446 stations.



Figure 36 : Monitoring station IAȘI



Figure 37: Monitoring station GALAȚI

The receiver used in both stations is N6841A - RF Sensor from Keysight, equipped with one of the following antennas: AOR - DA3200 and KEYSIGHT - N6850A. All the receivers and antennas are installed at sufficient heights to get out of clutter and to have good visibility to the coverage area (Hant > 35 meters).

5.3.2 Monitoring parameters

In Romania the usage of the PMR 446 band is regulated by the "RO-IR SRD-12 TECHNICAL REGULATION for the radio interface concerning PMR 446 private mobile radio communications devices" - https://www.ancom.ro/en/uploads/links_files/RO_IR_SRD_12_Dispozitive_PMR 446_v4_en.pdf. According to this document, it is possible to use PMR 446 equipment in the following frequencies (depending on the channelling):

Frequency	6.25 kHz channeling	12.5 kHz channeling	Frequency	6.25 kHz channeling	12.5 kHz channeling
446,000000			446,100000		
446,003125	X		446,103125	X	
446,006250		X	446,106250		X
446,009375	X		446,109375	X	
446,012500			446,112500		
446,015625	X		446,115625	X	
446,018750		X	446,118750		X
446,021875	X		446,121875	X	
446,025000			446,125000		
446,028125	X		446,128125	X	
446,031250		X	446,131250		X
446,034375	X		446,134375	X	
446,037500			446,137500		
446,040625	X		446,140625	X	
446,043750		X	446,143750		X
446,046875	X		446,146875	X	
446,050000			446,150000		
446,053125	X		446,153125	X	
446,056250		X	446,156250		X
446,059375	X		446,159375	X	
446,062500			446,162500		
446,065625	X		446,165625	X	
446,068750		X	446,168750		X
446,071875	X		446,171875	X	
446,075000			446,175000		
446,078125	X		446,178125	X	
446,081250		X	446,181250		X
446,084375	X		446,184375	X	
446,087500			446,187500		
446,090625	X		446,190625	X	
446,093750		X	446,193750		X
446,096875	X		446,196875	X	
446,100000			446,200000		

Figure 38: PMR 446 channelling in Romania

In all missions sent to the receivers the band 446-446.2 MHz was set with RMS averaging of 64 traces in order to average the noise and the possible peaks of unwanted signals. The total sweeping time resulted was 75 ms, in order to observe also the smallest transmission times.

In the first set of measurements, no channelisation was used with the purpose to find the real TX frequency of the PMR stations (observing TX offset) and also to find the real usage of 6.25 kHz and 12.5 kHz channels. In the second set of measurements, the monitoring task included a channelling of 3.125 kHz for the results to be "centred" in the middle of the possible channels 6.25 kHz and 12.5 kHz channels.

For both sets of measurement the occupancy was computed for observation times of 1 minute, also for the purpose of a higher degree of precision.

The thresholds used to determine occupancy were:

- Monitoring station ”Iași” - threshold = -117 dBm for DANL of -125 dBm;
- Monitoring station ”Galați” - threshold = -114 dBm for DANL of -123 dBm.

The results are provided as:

- Waterfall diagrams for minimum, maximum and average received levels
- Waterfall diagrams with percentages of occupancy over periods of 1 minute for the total observation time
- Histograms of intercepts and occupancy for the total observation time

5.3.3 Monitoring results

5.3.3.1 Iași - 17.01.2025 to 27.01.2025

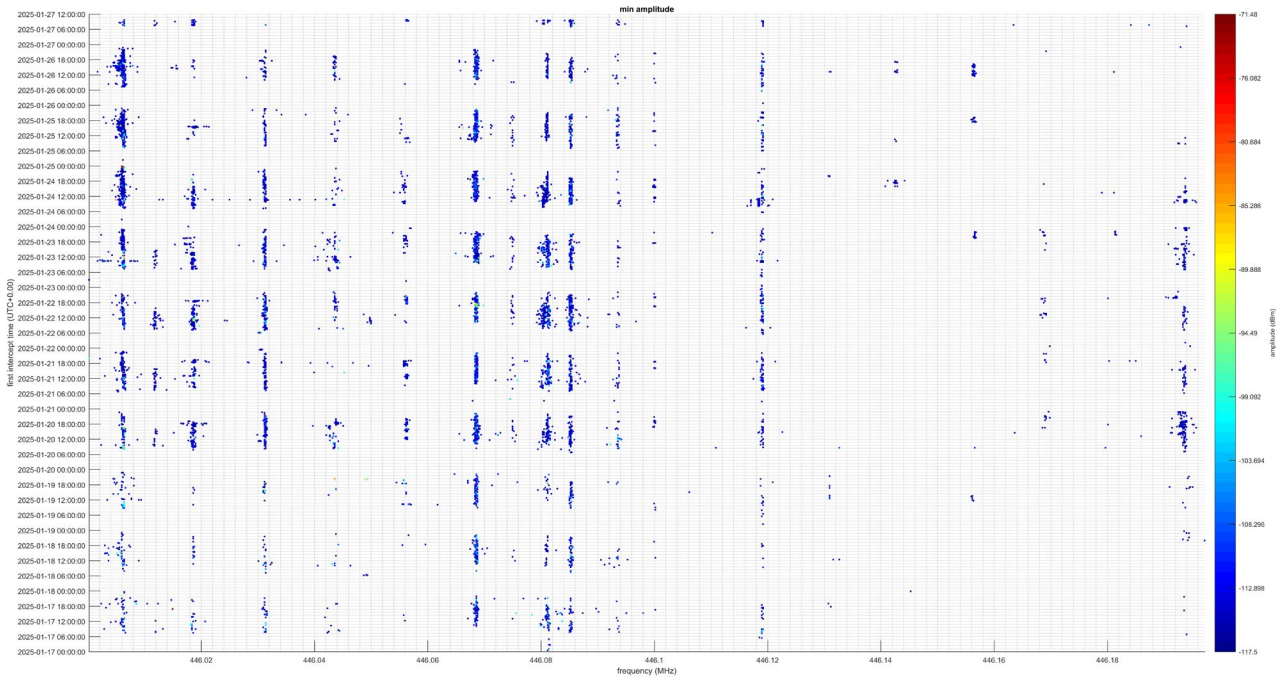


Figure 39: Minimum amplitude received at Iași - 17.01.2025 to 27.01.2025

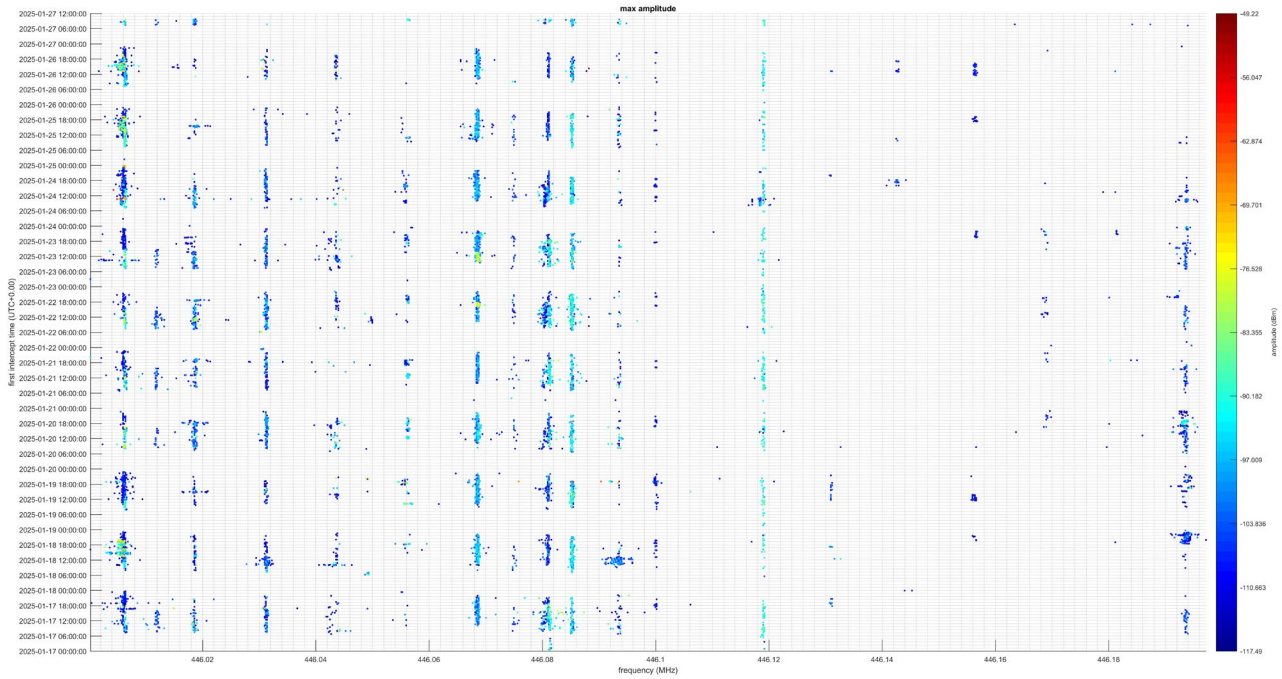


Figure 40: Maximum amplitude received at Iași - 17.01.2025 to 27.01.2025

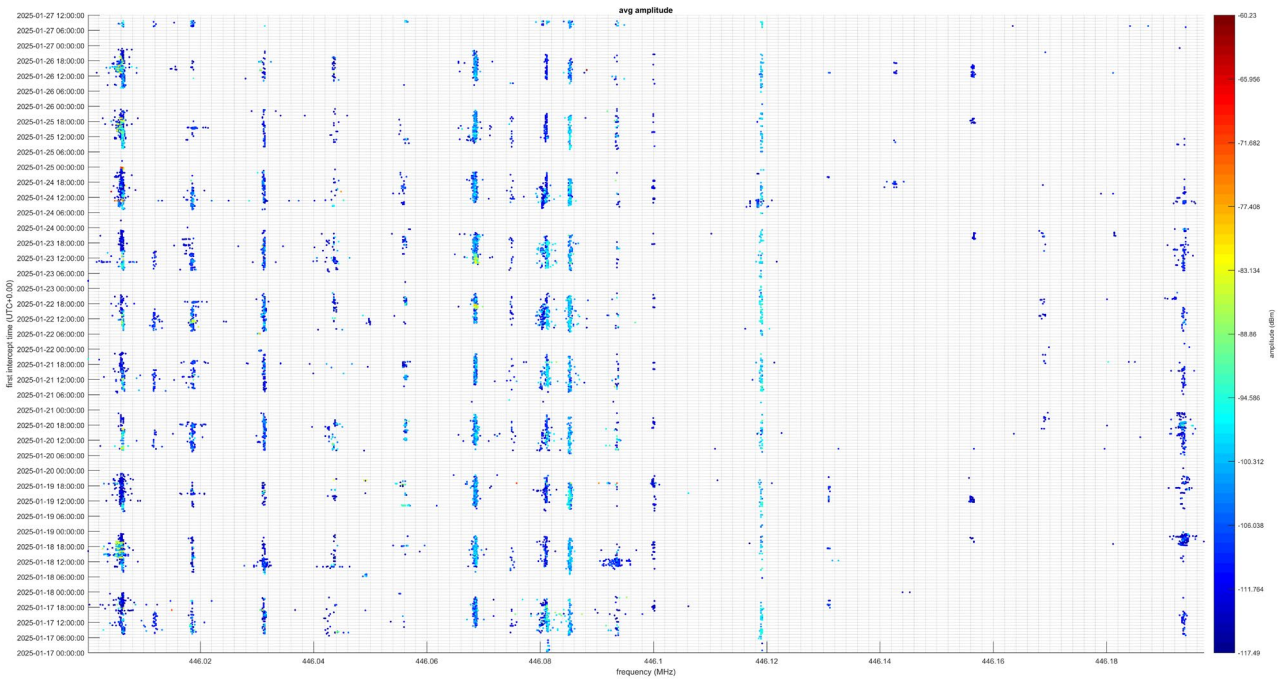


Figure 41: Average amplitude received at Iași - 17.01.2025 to 27.01.2025

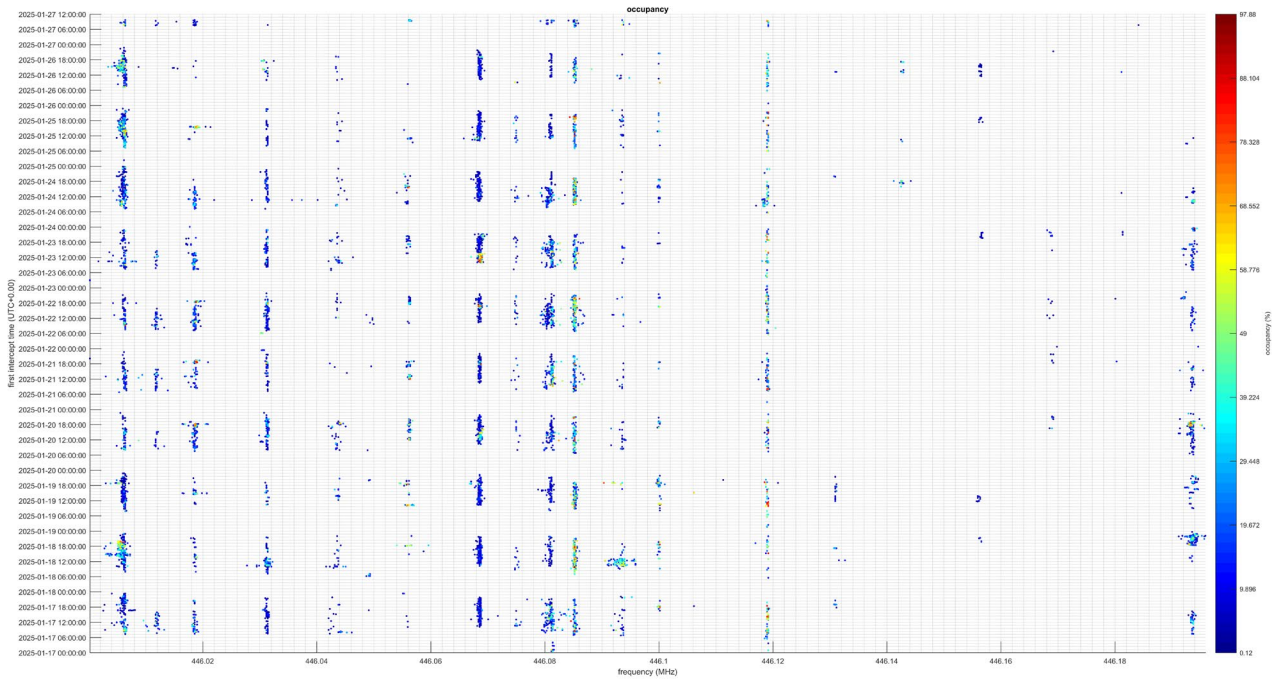


Figure 42: Occupancy per 1 minute at Iași - 17.01.2025 to 27.01.2025

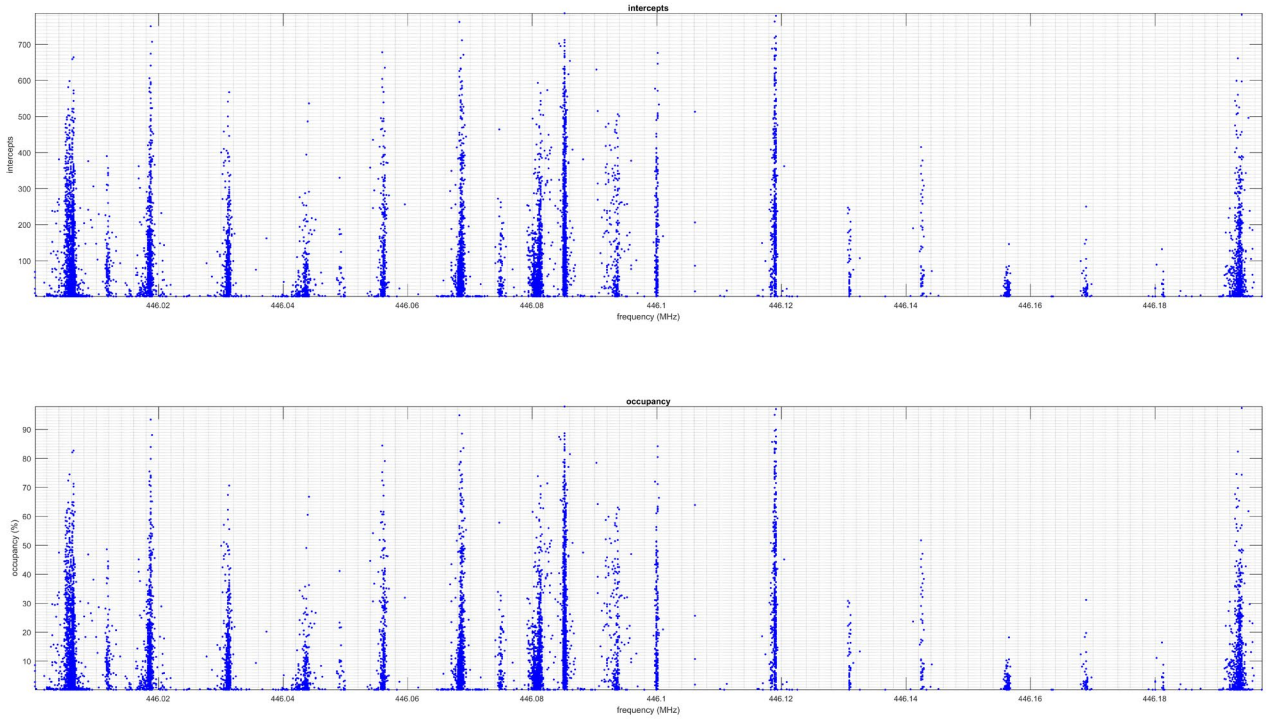


Figure 43: Histogram of number of intercepts and occupancy per 1 minute received at Iași - 17.01.2025 to 27.01.2025

5.3.3.2 Iași - 14.05.2025 to 23.05.2025

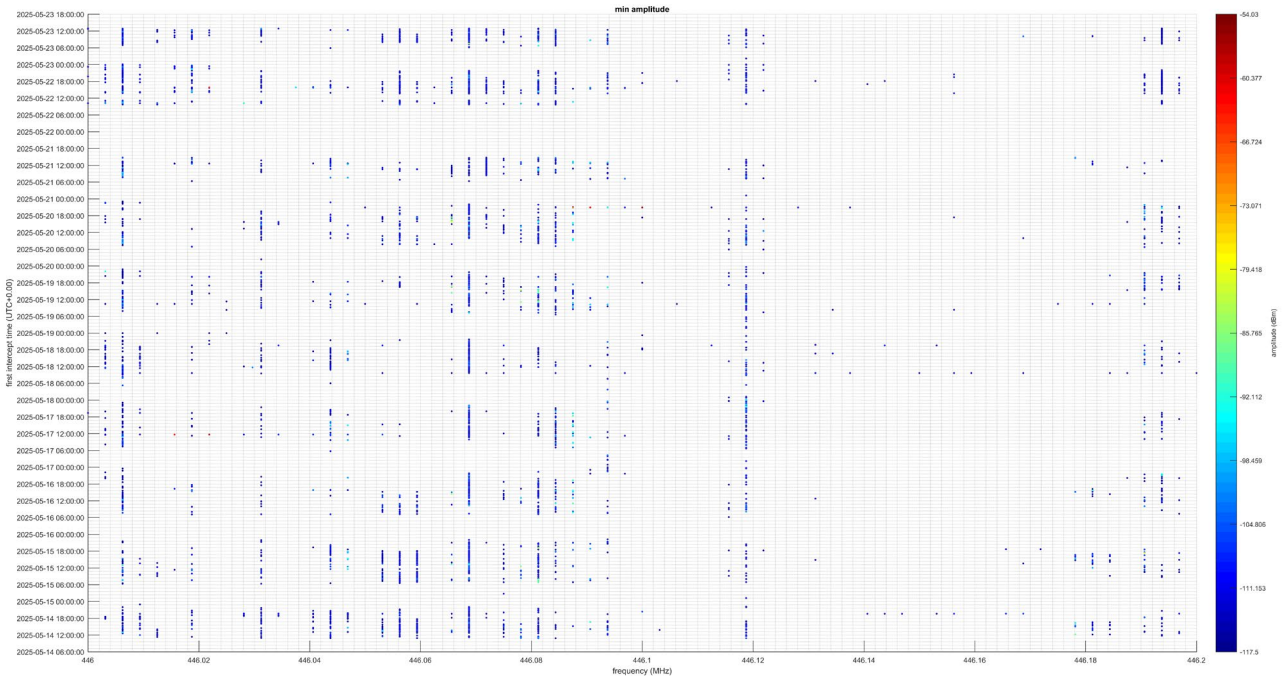


Figure 44: Minimum amplitude received at Iași - 14.05.2025 to 23.05.2025

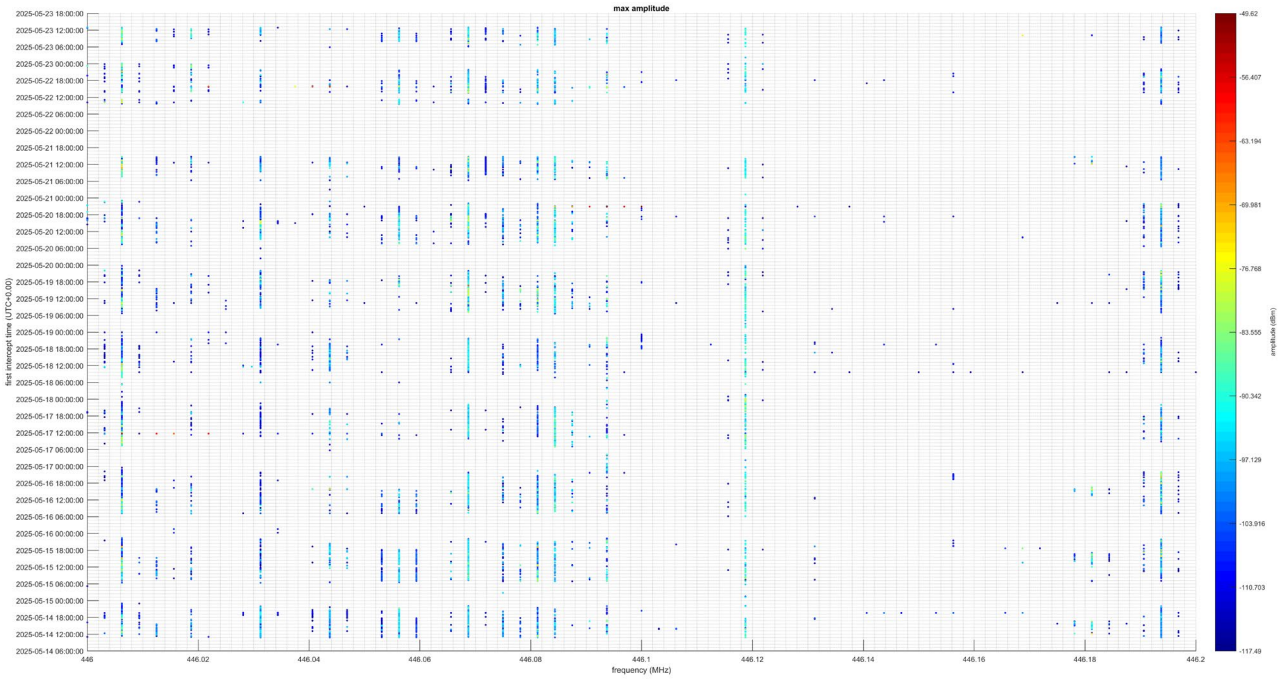


Figure 45: Maximum amplitude received at Iași - 14.05.2025 to 23.05.2025

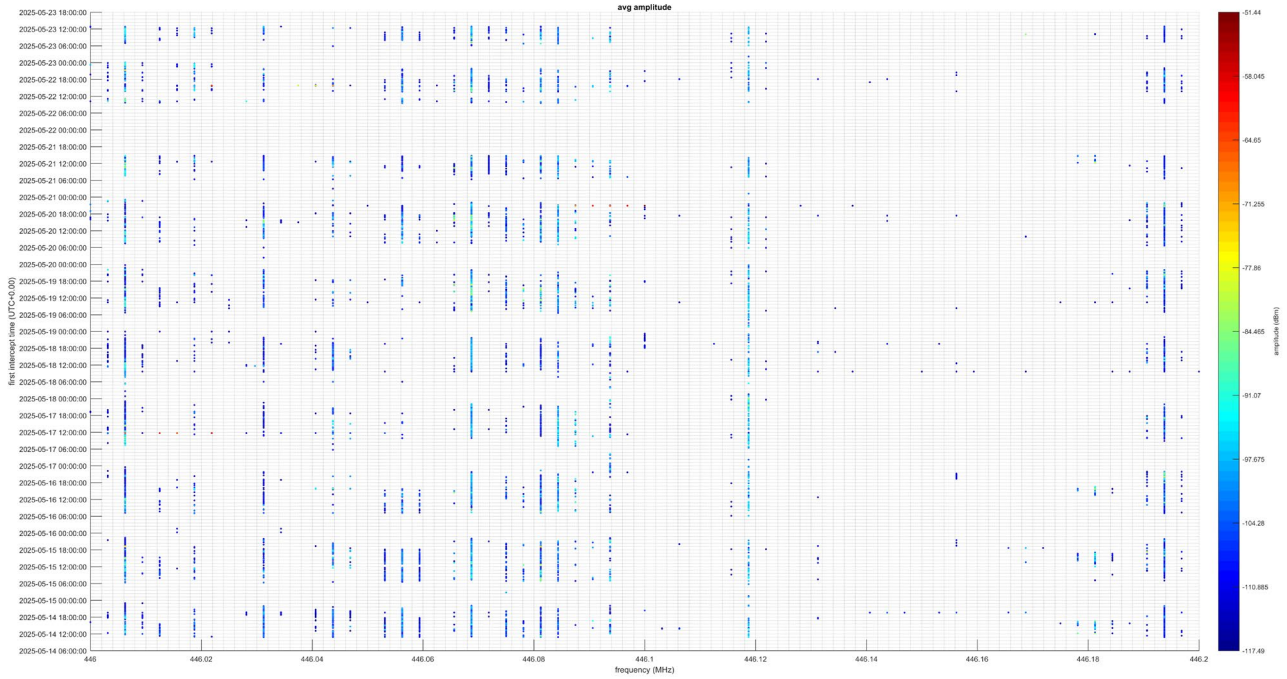


Figure 46: Average amplitude received at Iași - 14.05.2025 to 23.05.2025

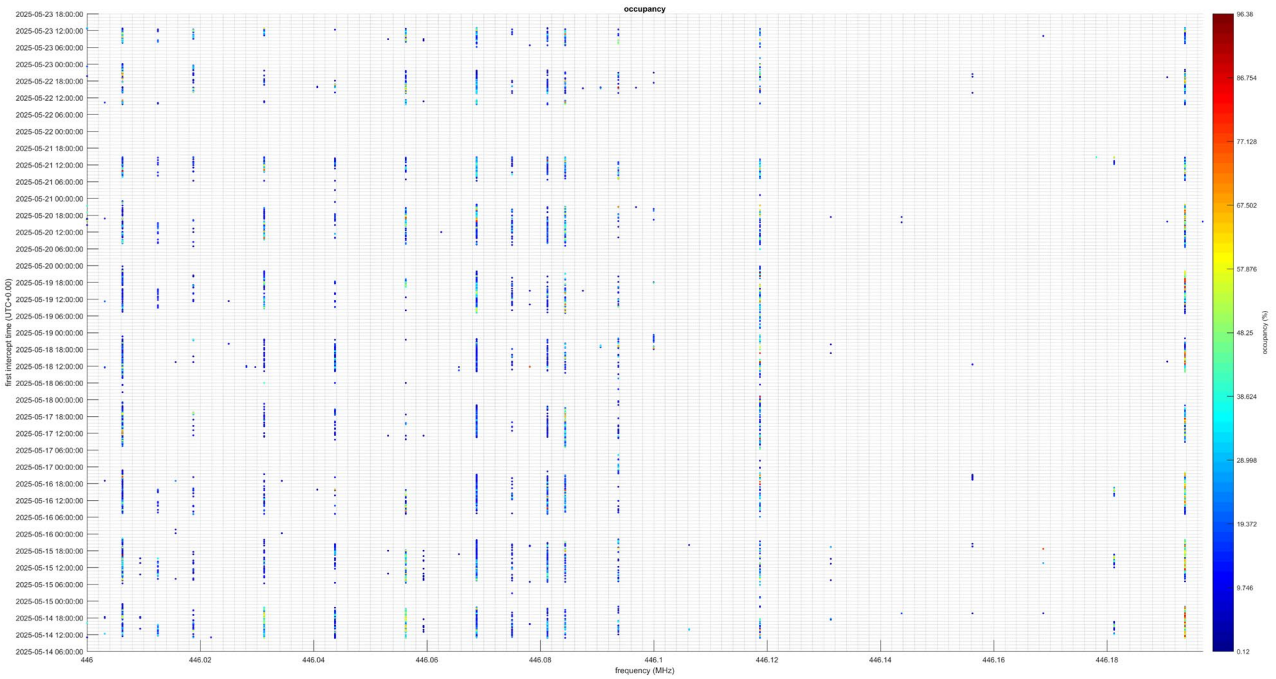


Figure 47: Occupancy per 1 minute at Iași - 14.05.2025 to 23.05.2025

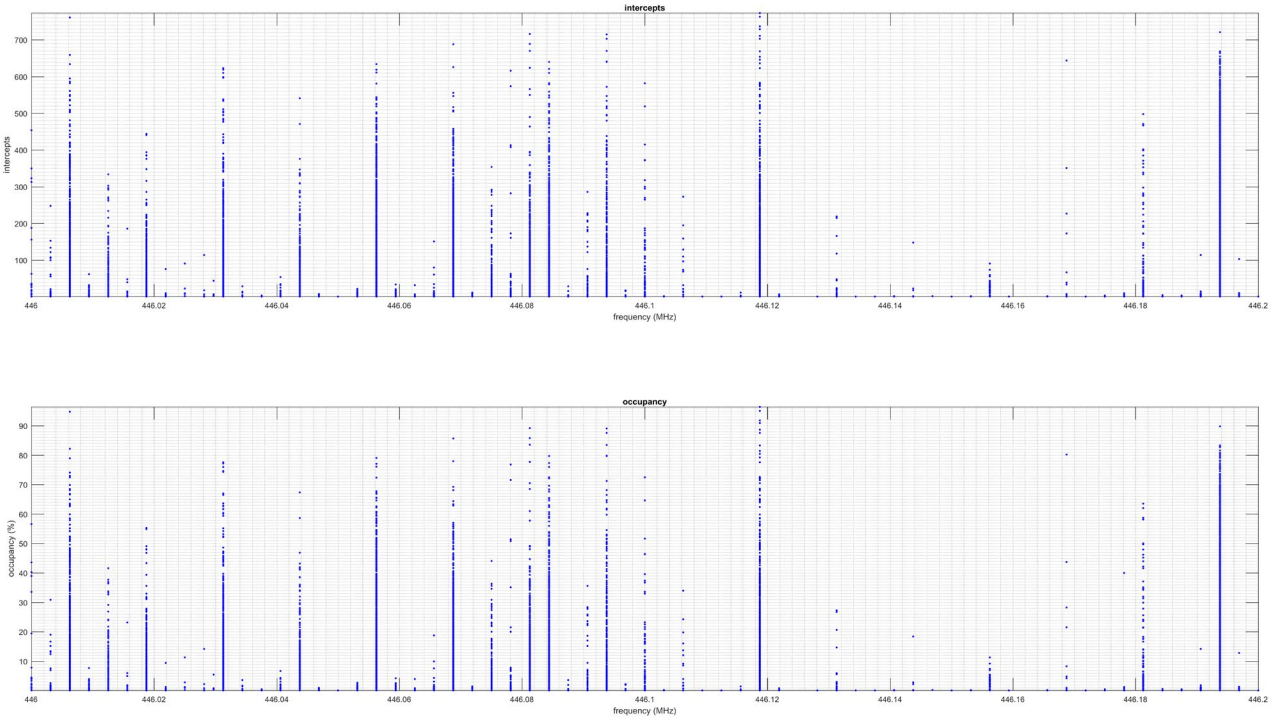


Figure 48: Histogram of number of intercepts and occupancy per 1 minute received at Iași - 14.05.2025 to 23.05.2025

5.3.3.3 Galați - 17.01.2025 to 27.01.2025

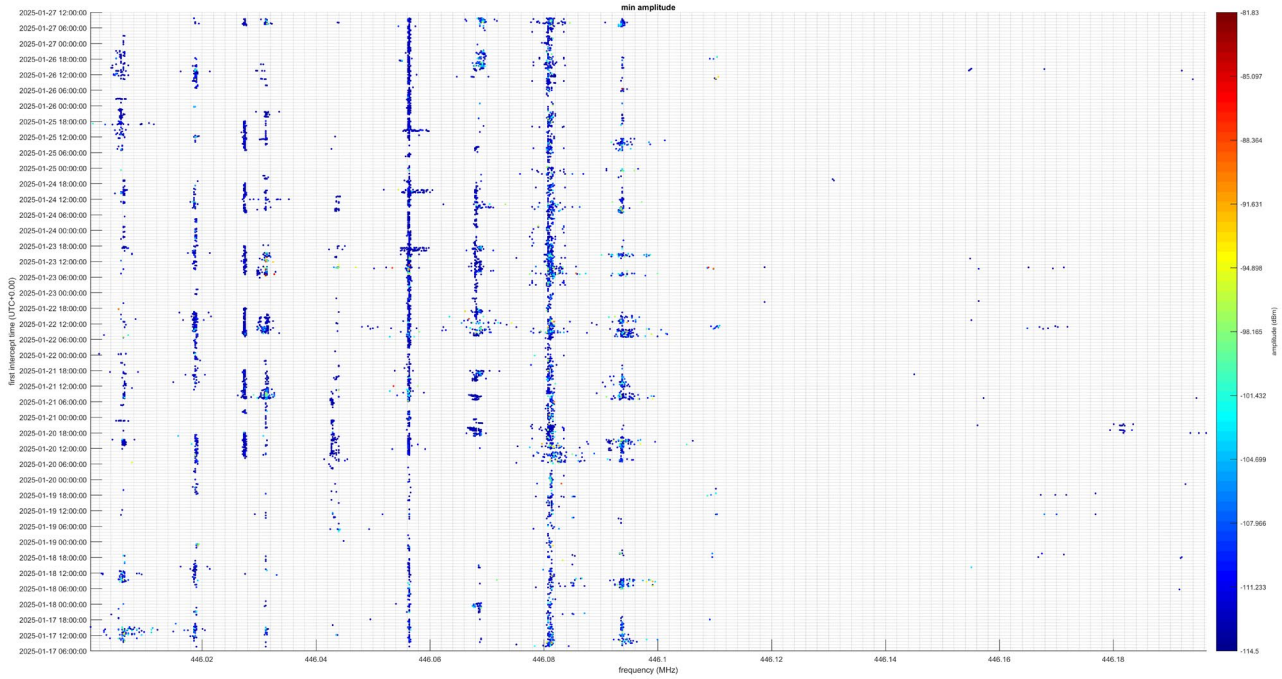


Figure 49: Minimum amplitude received at Galați - 17.01.2025 to 27.01.2025

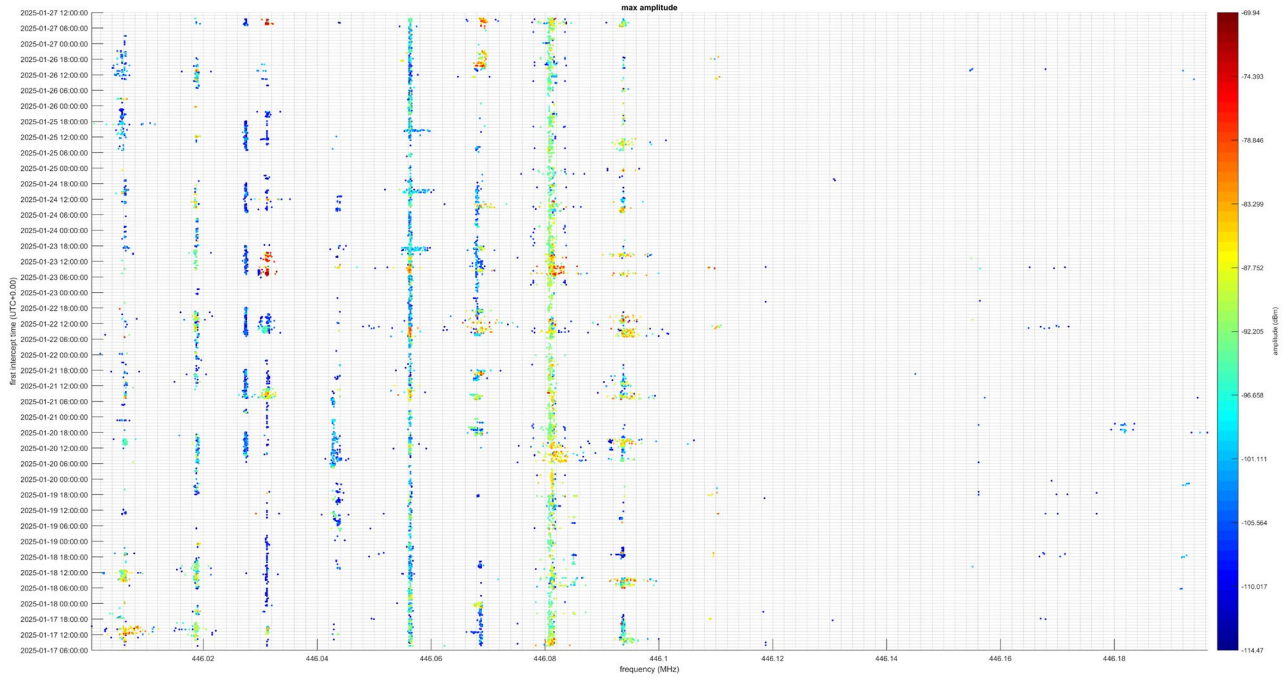


Figure 50: Maximum amplitude received at Galați - 17.01.2025 to 27.01.2025

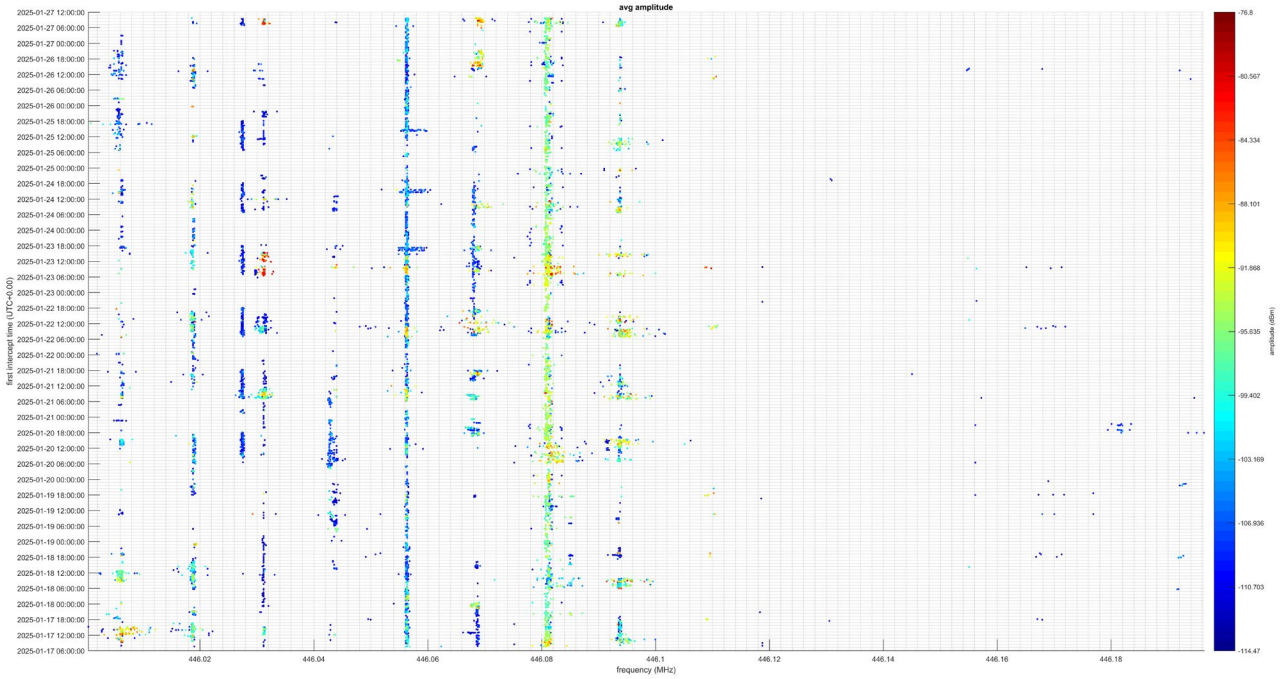


Figure 51: Average amplitude received at Galați - 17.01.2025 to 27.01.2025

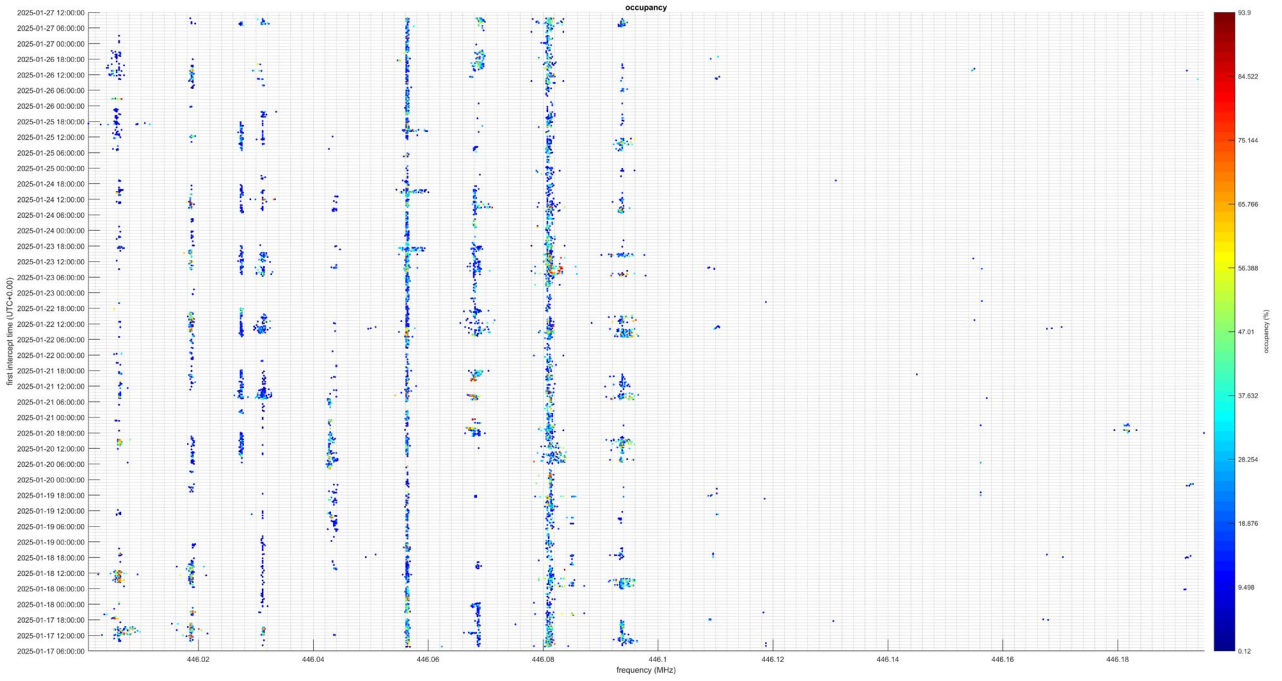


Figure 52: Occupancy per 1 minute at Galați - 17.01.2025 to 27.01.2025

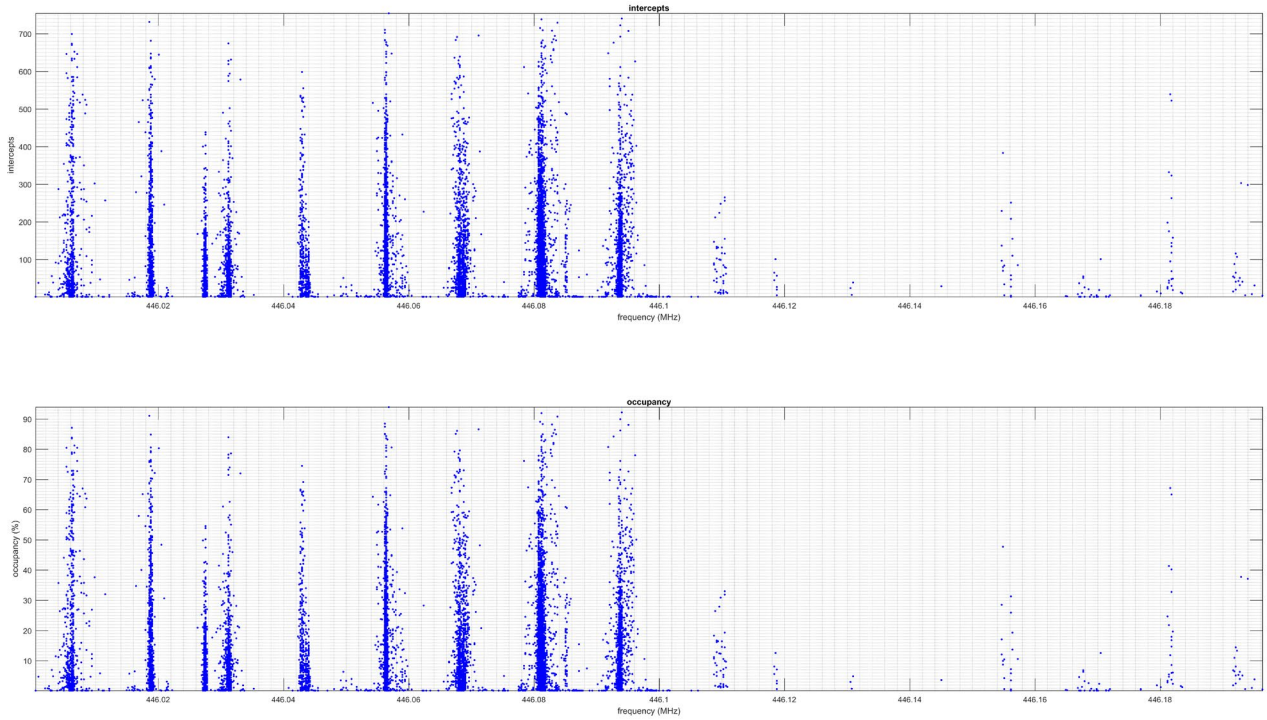


Figure 53: Histogram of number of intercepts and occupancy per 1 minute received at Galați - 17.01.2025 to 27.01.2025

5.3.3.4 Galati - 14.05.2025 to 23.05.2025

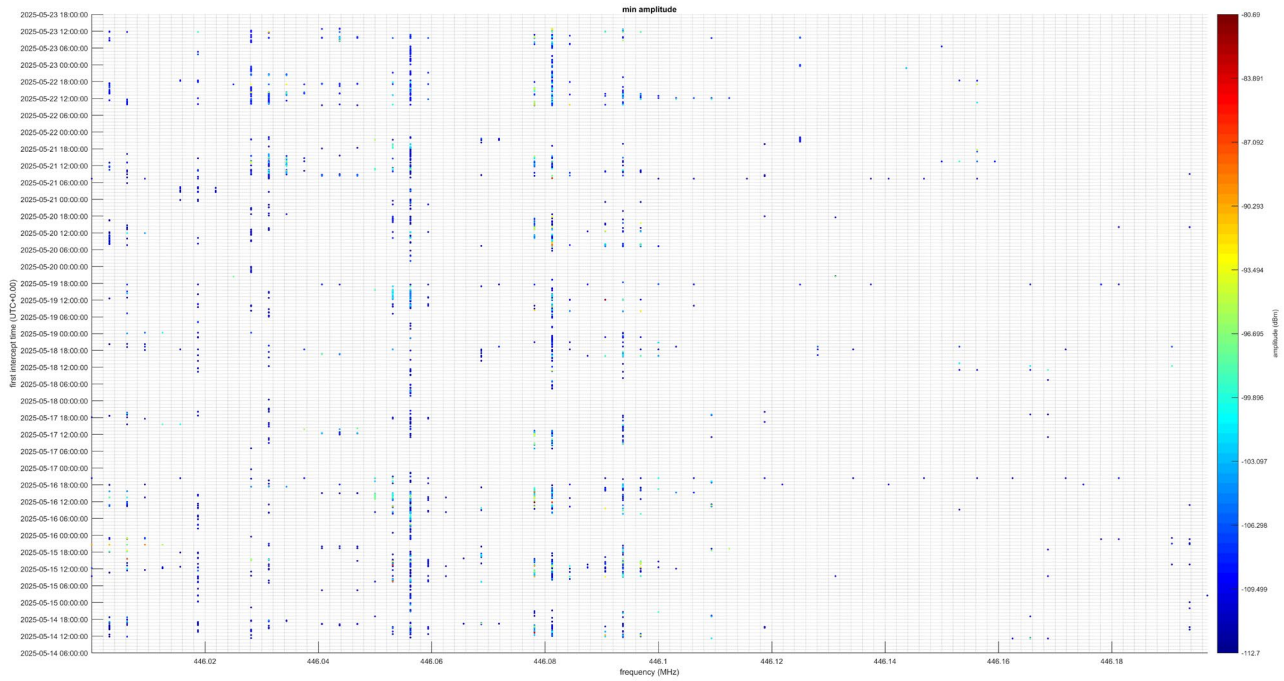


Figure 54: Minimum amplitude received at Galați - 14.05.2025 to 23.05.2025

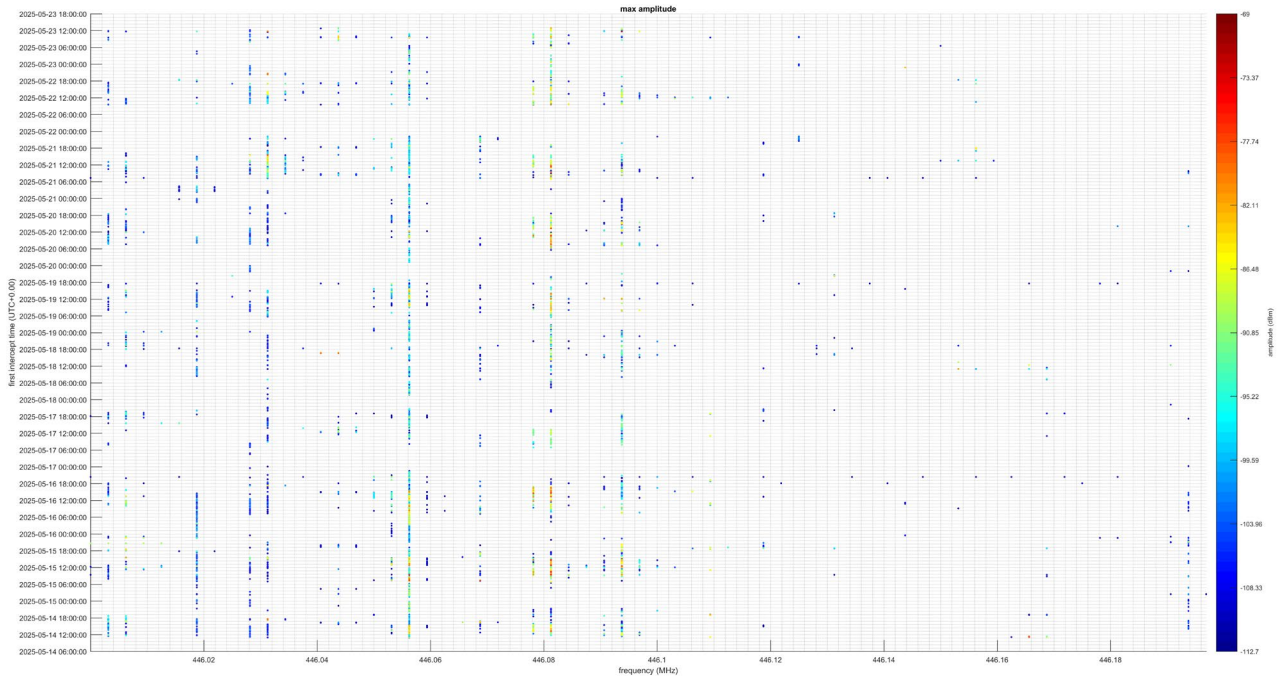


Figure 55: Maximum amplitude received at Galați - 14.05.2025 to 23.05.2025

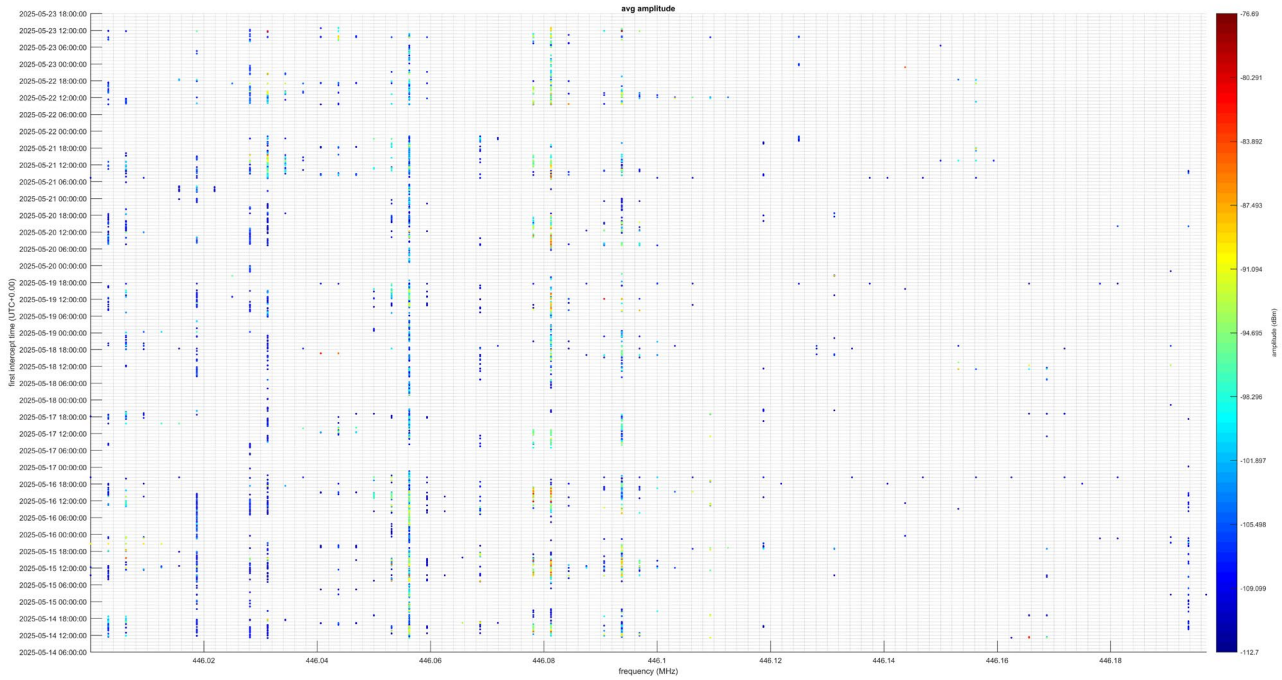


Figure 56: Maximum amplitude received at Galați - 14.05.2025 to 23.05.2025

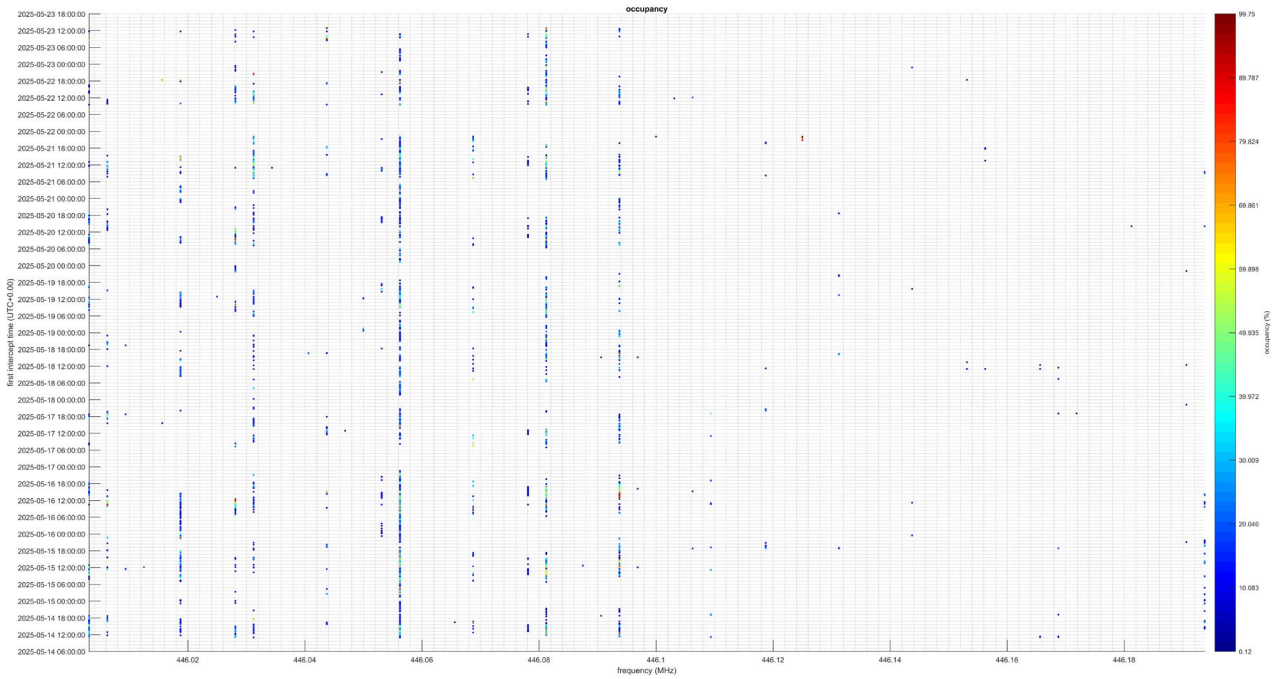


Figure 57: Occupancy per 1 minute at Galați - 14.05.2025 to 23.05.2025

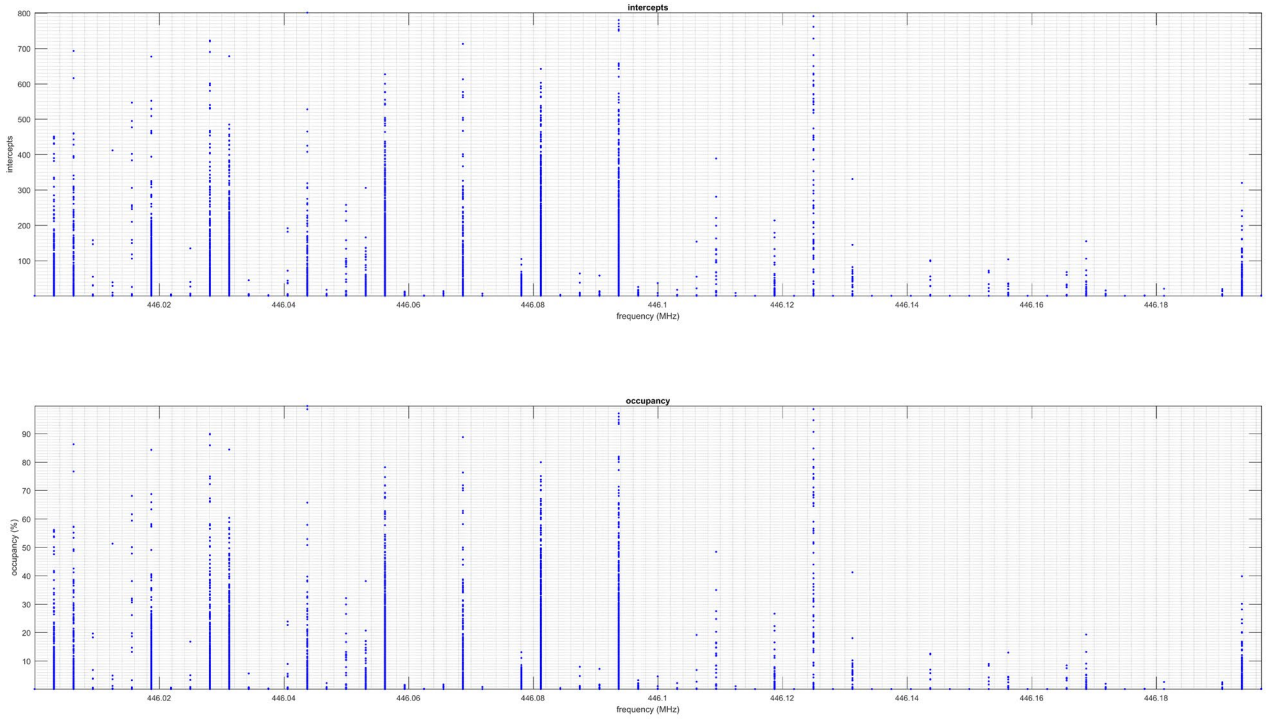


Figure 58: Histogram of number of intercepts and occupancy per 1 minute received at Galați - 14.05.2025 to 23.05.2025

5.3.4 Observations

Throughout the entire monitoring period, the number of samples far exceeds the recommended number of minimum 38,047 independent samples from the ITU-R SM.1880-2 - Recommendation for Spectrum occupancy measurements and evaluation. In the first set of measurements, the starting time of recording was 2025-01-17 09:32 and the ending time was 2025-01-27 11:43, which totals 10 days, 02 hours and 11 minutes. The total numbers of seconds were 871,860 which multiplied with 75 ms per sweep equals 11,624,800 sweeps (samples).

Due to the fact that in the second monitoring period, the monitoring stations "channelised" the emissions, we can see that the energies received from the 12.5 kHz channel transmitters were also integrated into the adjacent 6.25 kHz channels, with a smaller received level and occupancy, due to the emission band used by the transmitters.

It can also be seen in the graphs from the first set of measurements that the central frequency of the PMR stations is not centred, there is also an offset compared to the central frequencies corresponding to the regulated channels, that reaches values of ±1.5 kHz from the nominal channel TX frequency, as is Figure 59.

As a result, the final occupancy results are computed just from the first sets of measurements and only for the 12.5 kHz channels.

The highest received level for Iași monitoring station was -49 dBm, with a SNR of 76 dB, and for the Galați monitoring station, the highest received level was -68dBm, with a SNR of 55 dB.

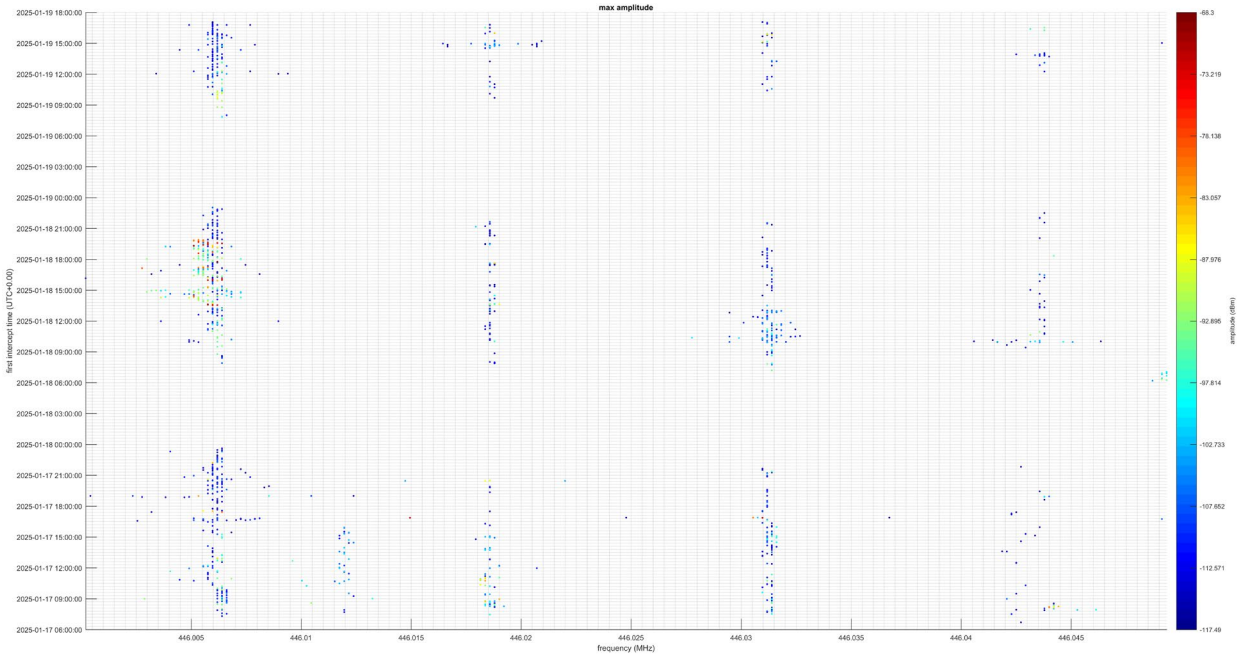


Figure 59: Maximum received level for 446.000-446.050 subband of PMR 446 for 30 hours of monitoring

The final occupancies per channel were computed by summing all the numbers of intercepts per minute and by dividing these sums by the total numbers of sweeps.

Table 28: Occupancy values determined for the PMR 446 band measured with monitoring stations Iași and Galați

Channel No.	Frequency	Occupancy for Iași	Occupancy for Galați
1	446.006250 MHz	1.974%	0.808%
2	446.018750 MHz	0.855%	1.067%
3	446.031250 MHz	0.536%	1.022%
4	446.043750 MHz	0.148%	0.456%
5	446.056250 MHz	0.388%	2.952%
6	446.068750 MHz	1.331%	1.239%
7	446.081250 MHz	2.825%	3.593%
8	446.093750 MHz	0.511%	1.298%
9	446.106250 MHz	0.146%	0.032%
10	446.118750 MHz	1.062%	0.003%
11	446.131250 MHz	0.038%	0.001%
12	446.143750 MHz	0.057%	0.000%
13	446.156250 MHz	0.021%	0.018%
14	446.168750 MHz	0.014%	0.003%
15	446.181250 MHz	0.005%	0.029%
16	446.193750 MHz	0.611%	0.012%

At both monitoring stations the most used channels are 1 to 8, with similar occupancy patterns, with very low values for channels 9-16.

6 CONCLUSIONS

6.1 COVERAGE

Increasing power of the PMR 446 equipment results in increasing of the communication range between user terminals and increase in the coverage area of the PMR 446 system. Coverage range varies for different system types and category of environment. Lowest coverage range is for the standard power analogue PMR 446 system of categories A and D in the urban environment and equals to 0.0901 km. Highest coverage range is obtained for the standard power digital PMR 446 system in the rural environment and equals to 0.9863 km. Coverage area increase is significant in the suburban and the rural environments (37.5% in average for the suburban and 47.2% in average for the rural environment) and is more modest in the urban environment (6.8% in average for the urban environment).

Table 29: Average coverage area increase of the high power with respect to standard power PMR 446 system

Standard Power System	High Power System	Environment		
		Urban	Suburban	Rural
		Average coverage area increase (%)		
SP-A PMR 446	HP-A PMR 446	6.79	37.50	47.20

6.2 SEPARATION DISTANCE

The separation distance increases with the increase of the ratio of high-power interfering transmitters in relation to standard power interfering transmitters. Distance are lowest in the case all standard power interferers of class A and D in urban environment and equal to 0.66 km. Highest separation distance is obtained in the case all high-power interferers in rural environment and equals to 17.8 km. In the case when 50% of the interferers are standard power and 50% of the interferers are high power the separation distance increases in average by 11% (in the range 10.1-12.0%) comparing to separation distance for only standard power interferers. In the case when all the interferers are high power the separation distance increases in average by 21.5% (in the range 19.8-22.8%) comparing to separation distance for standard power interferers.

6.3 USER DENSITIES

Obtained user densities vary in the range from 0.013 Users / (km^2 x channel) in the rural environment and all high-power interferers to 7.75 Users / (km^2 x channel) in the urban environment and standard power interferers. In the case when 50% of the interferers are standard power and 50% of the interferers are high power the achievable user density reduces in average by 18% comparing to density for standard power interferers. In the case when all the interferers are high power the achievable user density reduces in average by 31% comparing to density for standard power interferers.

6.4 USER GROUP DENSITY

User group density presents number of independent PMR 446 groups of users per km^2 can fit in the whole frequency spectrum available to PMR-446 equipment (446.0–446.2 MHz). For analogue systems 12.5 kHz channels are assumed, while for the digital systems 6.25 kHz channel raster is assumed giving total of 32 channels in the observed frequency band. The user group density per km^2 varies from 0.25 to 61.99 for Class A and D analogue equipment, from 0.15 to 37.66 for Class B and C analogue equipment, and from 0.20 to 51.14 for the digital PMR 446 equipment.

6.5 OVERALL CAPACITY

Impact of introducing of high-power terminals to overall capacity varies from 0% for all standard power terminals to -31.4% loss for scenario with all high-power terminals as interferers. The main impact on the overall capacity loss is by the ratio between standard power and high-power terminals in the interference pool. With the introduction of more high-power terminals the overall capacity decreases. In the case when 50% of the interferers are standard power and 50% of the interferers are high power the overall capacity loss is in average -18.13% comparing to scenarios with all standard power interferers in the pool. In the case when all the interferers are high power the overall capacity loss is in average by -30.2% comparing to scenarios with all standard power interferers in the pool. The capacity decrease is summarised in Table 18.

Table 30: Summary of the overall capacity decrease percentage for PMR 446 equipment

Interfering Systems Composition (Standard and High Power)	Average	Min	Max
	Capacity decrease (%)		
0.0% SP - 100.0% HP	-30.20	-31.36	-29.31
16.7% SP - 83.3% HP	-26.83	-27.59	-25.94
33.3% SP - 66.7% HP	-22.99	-24.36	-21.16
50.0% SP - 50.0% HP	-18.13	-19.59	-16.73
66.7% SP - 33.3% HP	-13.32	-15.20	-10.68
83.3% SP - 16.7% HP	-6.93	-8.07	-4.11
100.0% SP - 0.0% HP	0.00	0.00	0.00

6.6 FINAL RESULTS

Studies performed using SEAMCAT and MCL methodologies confirm that increasing the effective radiated power (*e.r.p.*) from 500 mW to 1 W in PMR 446 devices results in:

- Coverage increases ranging from approximately 6.8% in urban, 37.5% in suburban, and up to 47.98% in rural environments, depending on device category and modulation type;
- The maximum communication range in rural terrain increases from approximately 0.986 km (standard digital) to 1.2 km (high-power digital), under noise-limited conditions assuming 95% service reliability;
- For analogue equipment, similar increases are noted, with significant range extension particularly in open-field or low-interference scenarios.

From a capacity standpoint, simulations indicate the following impacts:

- Overall user capacity decreases by up to 31.4% when all terminals operate at 1 W. This corresponds to reduced spatial reuse and increased mutual interference, especially in dense environments;
- In a mixed deployment (50% standard / 50% high-power devices), the average system-wide capacity reduction is approximately 18.13%, consistent across multiple simulation scenarios and environments;
- User density, defined as the number of concurrent PMR 446 users per square kilometres per channel, drops from a peak of 7.75 Users/km²/ch (urban, standard power) to 5.45 Users/km²/ch (urban, all high power), and from 0.0457 Users/km²/ch to 0.0319 Users/km²/ch in rural scenarios.

Interference zone expansion was also quantified:

- The required separation distance to maintain 5% interference probability increases by an average of 21.5% for high-power interferers;

- Worst-case distances increase from 0.66 km to 0.81 km (urban) and from 9.03 km to 10.97 km (rural) depending on the class of equipment and environmental losses.

Monitoring campaigns conducted in France, the Netherlands and Romania corroborate simulation data:

- Average band occupancy was much below 50%, even in urban deployments;
- Most digital channels (6.25 kHz spacing) remained unused;
- No evidence of band saturation was recorded; some analogue channels showed transient peaks up to 40% occupancy linked to commercial or public service use (e.g. restaurants, pools, baby monitors).

6.7 OVERALL CONCLUSION

Although there is a trade-off between coverage gains and capacity reduction shown in the studies, current usage of the band indicates that the 446.0-446.2 MHz band has sufficient headroom to support higher power PMR 446 operations and that there is no need for advanced spectrum management technics like power control, or automatic avoidance mechanism/channel sensing.

ANNEX 1: LIST OF REFERENCES

[1] ECC Decision (15)05: "The harmonised frequency range 446.0-446.2 MHz, technical characteristics, exemption from individual licensing and free carriage and use of analogue and digital PMR 446 applications", amended March 2018

[2] ETSI EN 303 405 (V1.1.1, 2017-05): "Land Mobile Service; Analogue and Digital PMR 446 Equipment; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU"

[3] ETSI TS 103 236 (V1.1.1, 2014-01): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Continuous Tone Controlled Signalling System (CTCSS) and Digitally Coded Squelch Signalling (DCSS) system"

[4] ETSI TS 102 490 (V1.9.1, 2016-08): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Peer-to-Peer Digital Private Mobile Radio using FDMA with a channel spacing of 6,25 kHz with *e.r.p.* of up to 500 mW"

[5] ETSI TS 102 361-1 (v2.6.1, 2023-05): "Electromagnetic compatibility and Radio spectrum Matters (ERM); Digital Mobile Radio (DMR) Systems; Part 1: DMR Air Interface (AI) protocol"

[6] ETSI EN 300 296 (V2.1.1, 2016-03): "Land Mobile Service; Radio equipment using integral antennas intended primarily for analogue speech; Harmonised Standard covering the essential requirements of article 3.2 of the Directive 2014/53/EU"

[7] ERC Report 052: "Methodology for the assessment of PMR systems in terms of spectrum efficiency, operation and implementation", approved December 1997

[8] ETSI TS 103 236 (V1.1.1, 2014-01): " Electromagnetic compatibility and Radio spectrum Matters (ERM); Continuous Tone Controlled Signalling System (CTCSS) and Digitally Coded Squelch Signalling (DCSS) system"

[9] ECC Report 252: "SEAMCAT Handbook Edition 2", approved April 2016

[10] "Online SEAMCAT Handbook, Edition 4", revised February 2025, https://ecowiki.atlassian.net/wiki/spaces/SH/overview?homepageId=491522

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[12] Hata, M. (August 1980): "Empirical Formula for Propagation Loss in Land Mobile Radio Services". IEEE Transactions on Vehicular Technology. VT-29 (3): 317–25. doi:10.1109/T-VT.1980.23859. S2CID 40015949

[13] European Commission: Directorate-General for the Information Society and Media, COST Action 231 – Digital mobile radio towards future generation systems: Final Report, Publications Office, 1999

[14] https://pe1rik.wordpress.com/2021/06/26/observations-using-specmon2/ and https://github.com/sdrwaverunner/specmon