SCIENTIFIC STUDY

GROUND INTERFERENCE OF SATELLITE RECEPTION IN C BAND

Frequency band 3,400 – 4,800 MHz | FSS / DVB-S2 / T2-MI

Comprehensive analysis of interference mechanisms under Slovak conditions

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ABSTRACT / STUDY SUMMARY

This scientific study comprehensively examines the issue of terrestrial electromagnetic interference (EMI – Electromagnetic Interference) affecting satellite reception in the C band across the frequency range 3,400 – 4,800 MHz, with specific focus on conditions in the Slovak Republic. The analysis covers the physical mechanisms of interference, classification of terrestrial interference sources, the impact of technological standards (5G NR, LTE, Wi-Fi, microwave links, WiMAX, terrestrial Internet), the effect on LNB converters and satellite receivers, and a critical evaluation of filtering solutions including Norsat bandpass filters.

The study has been compiled on the basis of current technical and scientific sources, including publications from ITU-R, 3GPP, IEEE and peer-reviewed research papers (arXiv, PMC, IEEE Xplore), and is intended as reference material for specialists in the fields of satellite communications, wave physics and EMC (electromagnetic compatibility).

Key finding: Interference in the C band in Slovakia is multi-source and multi-mechanism in nature. A simple BPF (Band Pass Filter) placed after the feed CANNOT eliminate all forms of interference – in particular not LNB saturation effects nor intermodulation products generated directly inside the LNB prior to the filtering stage. The solution requires a systematic, multi-level approach.

1. INTRODUCTION – THE C BAND AND ITS SPECIFIC POSITION

1.1 Definition and frequency delimitation of the C band

The C band, in the context of satellite communications, represents one of the historically most important and stable frequency users in the global electromagnetic spectrum. From the standpoint of electromagnetic wave physics, this band encompasses wavelengths from approximately 6.25 cm (4,800 MHz) to 8.8 cm (3,400 MHz).

In the context of satellite FSS (Fixed Satellite Service), the following sub-bands are distinguished:

- Standard C band (downlink): 3,400 – 4,200 MHz (used in Europe and Asia)
- Extended C band: 3,400 – 4,800 MHz
- Super-extended C band: up to 4,800 MHz (certain regional allocations)
- Uplink C band: 5,725 – 6,425 MHz (not subject to terrestrial interference)

Satellite reception in the C band exhibits, in comparison with the Ku band (10.7–12.75 GHz) and Ka band (17.3–21.2 GHz), a fundamental physical advantage – minimal rain fade (attenuation caused by atmospheric precipitation). This phenomenon is governed by the physical law of Rayleigh scattering, whereby the attenuation caused by atmospheric interference increases with the square of the frequency. At 4 GHz, the attenuation caused by precipitation is approximately 100 times lower than at 12 GHz. This property has historically made the C band strategically important for tropical regions and countries with high annual precipitation.

1.2 Physical nature of the satellite-ground link in the C band

The satellite signal in the C band arriving from geostationary orbit (GEO, ~35,786 km) is characterised by an extremely low power spectral density (PSD). The typical signal level at the LNB input is in the range:

$$P\_rx = -90 \text{ to } -120 \text{ dBm (i.e. } 10^{-9} \text{ to } 10^{-12} \text{ mW)}$$

This value represents the physical lower limit of detectability, and is determined by:

- The satellite's EIRP (typically 30–50 dBW for the C band)
- Free-space path loss (FSPL) over a distance of ~36,000 km
- The gain of the antenna and LNB system

$$\text{FSPL (dB)} = 20\cdot\log_{10}(d) + 20\cdot\log_{10}(f) + 20\cdot\log_{10}(4\pi/c) \approx 196 \text{ dB @ 4 GHz, 36,000 km}$$

This extremely low signal level is simultaneously the root of the interference problem: any terrestrial source of power that reaches the LNB input may be orders of magnitude stronger than the desired satellite signal.

1.3 The specific situation in Slovakia

The Slovak Republic is located in the centre of Europe, where a massive expansion of mobile networks, wireless Internet services and C-band services has taken place (and continues to do so). From the perspective of frequency regulation, the spectrum is administered by the Telecommunications Regulatory Authority of the Slovak Republic (TU SR), which issues licences in accordance with European harmonisation decisions of the ECC (Electronic Communications Committee) and BEREC regulations.

The key regulatory document for the C band is the European harmonisation decision ECC/DEC/(11)06 on the use of the 3,400–3,800 MHz band for IMT (International Mobile Telecommunications) services, which is in direct conflict with FSS reception in this sub-band. In Slovakia, 5G licences in the 3.5 GHz band were awarded in 2020 to all four major operators.

2. CLASSIFICATION OF TERRESTRIAL SOURCES OF C BAND INTERFERENCE

The following analysis presents a systematic classification of all relevant terrestrial interference sources in the range 3,400 – 4,800 MHz, identified on the basis of physical properties, frequency range and interference mechanism.

2.1 5G NR (New Radio) – Bands n78 and n77

Frequency range: 3,300 – 4,200 MHz (NR Band n78: 3,300–3,800 MHz, n77: 3,300–4,200 MHz)

5G NR in the C band currently represents the most serious and best-documented source of satellite reception interference. The 3GPP Release 17 technical standard defines two main frequency blocks relevant to the C band: Band n78 (3,300–3,800 MHz) and Band n77 (3,300–4,200 MHz). In Slovakia, allocation took place in the 3,490–3,510 MHz range and across 3,400–3,600 MHz.

Mechanisms of 5G interference:

a) Direct in-band interference: 5G base stations (BS) transmit in the range 3,300–4,200 MHz with an EIRP (Effective Isotropic Radiated Power) typically of 40–80 W per antenna sector. Where a 5G BS operates on a frequency that falls within the LNB's reception range (3,400–4,200 MHz), a direct spectral collision occurs. The 5G BS signal at a distance of 1 km reaches the LNB input at levels of the order of –40 to –60 dBm – i.e. approximately 30 to 60 dB stronger than the satellite signal.

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ΔP = P_5G_rx – P_sat_rx ≈ 30 to 60 dB excess power
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b) LNB saturation: When the power at the LNB input exceeds the 1 dB compression point (P1dB, typically –10 to +5 dBm for standard LNBs), the amplifying transistor enters a non-linear regime. In this state:

- The LNB gain drops below its nominal value (gain compression)
- The noise floor rises significantly
- Intermodulation products (IMD) are generated
- The satellite signal is completely masked, even if it lies outside the 5G frequency range

c) Adjacent channel interference: Even when 5G operates in the sub-band 3,400–3,600 MHz and the satellite signal is received at 3,700–4,200 MHz, sidelobe emissions from the 5G BS and intermodulation products can extend into the upper portions of the C band.

d) Third-order intermodulation products (IMD3): When two or more 5G carriers are simultaneously transmitted at frequencies f1 and f2, third-order intermodulation products are generated in the non-linear region of the LNB at frequencies:

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IMD3 = 2·f1 – f2 and 2·f2 – f1
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For 5G carriers at 3,500 and 3,600 MHz: IMD3 = 3,400 MHz and 3,700 MHz – both directly within the satellite reception band.

CRITICAL FINDING: LNB saturation and IMD3 are generated DIRECTLY INSIDE THE LNB, PRIOR TO ANY EXTERNAL FILTER. Therefore, an external BPF filter placed between the feed and the LNB CANNOT eliminate these effects. A filter can provide protection only when positioned in front of the LNB's input transistor – meaning it must be integrated directly into the LNB, or a special LNA (Low Noise Amplifier) with an ultra-high IP3 (intercept point) must be used ahead of the standard LNB.

2.2 LTE / 4G – Bands B42, B43 and adjacent bands

Frequency range: 3,400 – 3,800 MHz (LTE TDD Band 42/43)

LTE TDD Band 42 (3,400–3,600 MHz) and Band 43 (3,600–3,800 MHz) are used for fixed wireless Internet (FWA – Fixed Wireless Access) in European countries. In Slovakia, these frequencies are used by operators providing fixed wireless Internet in municipalities lacking optical fibre infrastructure.

The physical effects are identical to those of 5G, however with lower EIRP and wider channel bandwidth (up to 100 MHz channel bandwidth). A characteristic of LTE TDD is time-sharing of the spectrum (TDD – Time Division Duplex), where uplink and downlink alternate periodically with a cycle of tens of milliseconds. This causes periodic burst interference, manifesting as impulse noise on the satellite receiver.

2.3 WiMAX and proprietary wireless Internet

Frequency range: 3,400 – 3,700 MHz

The IEEE 802.16 standard (WiMAX) and proprietary PTMP (Point-to-Multipoint) systems for fixed wireless Internet are widespread across European countries. Many ISPs (Internet Service Providers) in Slovakia still operate PTMP systems (Ubiquiti AirMax, Mimosa, IgniteNet and others) in the 3,400–3,700 MHz band. These systems pre-date 5G and frequently lack standardised emission masks in accordance with current ETSI standards.

Unlike mobile networks, PTMP antennas frequently point horizontally towards sectors, which can lead to direct line-of-sight (LOS) interference with a satellite dish, if the satellite lies in the azimuthal direction of the PTMP sector.

2.4 Terrestrial microwave links (Microwave Backhaul)

Frequency range: 3,600 – 4,200 MHz and 4,400 – 5,000 MHz

Terrestrial microwave point-to-point (PTP) links used for backhaul by mobile operators and ISPs are authorised across many sub-bands in the 3.6–5 GHz range. These links employ highly directional antennas (gain 30–40 dBi) and operate with EIRP up to 50 dBW.

Under normal circumstances, the risk of interference from these links is low owing to their directionality; however, interference may occur in the following situations:

- The satellite dish is located in the main lobe of the microwave link
- Diffraction around buildings or the ground surface directs part of the signal onto the satellite dish
- Multipath propagation caused by reflection from buildings or wet surfaces

The 4,400–4,800 MHz frequency band is of particular relevance for the extended C band, which is used by some satellites (e.g. Intelsat, SES) and in regions with different frequency plans.

2.5 Radar systems

Frequency range: 3,300 – 3,500 MHz (S band) and 4,200 – 4,400 MHz (C band radar)

Meteorological and aviation radar systems operate in proximity to the satellite C band. In Slovakia, meteorological radars (SHMÚ) and aviation tracking radars (LPS SR) are in operation. These systems are typically not located in densely populated residential areas, but their high-power pulsed emissions (peak power up to MW) can, at close range, cause severe impulse interference – or even physical damage to the input stage of the LNB.

Note: Radar interference manifests as brief, periodic pulses rather than continuous interference. On a spectrum analyser it is visible as periodic spikes with a repetition rate corresponding to the radar rotation period (typically 5–10 seconds).

2.6 Wi-Fi in the C band (IEEE 802.11a/n/ac/ax)

Frequency range: 5,150 – 5,850 MHz (5 GHz Wi-Fi)

The classic 5 GHz Wi-Fi band (5,150–5,850 MHz) lies outside the narrow definition of the FSS C band (3,400–4,200 MHz), so direct in-band interference of Wi-Fi with the classic C band is physically impossible.

Wi-Fi may cause interference by indirect means:

- Second harmonic emissions from 2.4 GHz Wi-Fi may fall into the ~4,800 MHz range (extended C band)

- Third harmonic emissions from 2.4 GHz Wi-Fi fall at ~7.2 GHz – outside the C band
- Wi-Fi routers with defective RF design may generate broadband noise extending into the C band

From a scientific perspective, the direct influence of Wi-Fi on C band satellite reception is minimal – significant interference occurs only in extreme cases (defective equipment in close proximity to the satellite dish).

2.7 Terrestrial Internet in the C band – FWA at 3.5 GHz

Frequency range: 3,400 – 3,800 MHz

Fixed Wireless Access (FWA) in the 3.5 GHz band is currently one of the most serious causes of C band interference in Slovakia and neighbouring countries. ISPs (more than 50 in Slovakia) operate sectoral base stations in the 3.4–3.7 GHz band with transmit powers of 1–10 W (EIRP 40–50 dBm).

The physical mechanisms are identical to those of 5G and LTE (see sections 2.1 and 2.2), but with a longer operational history and less predictable spectral purity (older proprietary systems without strict emission masks).

2.8 DECT, ISM devices and other local sources

Frequency range: 5.8 GHz ISM (5,725–5,875 MHz) – harmonic interference

Devices in the 5.8 GHz ISM band (cordless telephones, baby monitors, some Wi-Fi equipment) indirectly affect the C band through harmonic emissions. In addition, local sources such as:

- Electric motors and switched-mode power supplies (SMPS) – broadband noise
- LED and fluorescent lighting with defective EMC design
- Electric vehicle (EV) chargers – broadband impulse noise
- Industrial equipment (VFD inverters, CNC machines)

...may contribute to an elevated system noise floor, but are not direct in-band interferers in the defined sense.

3. PHYSICAL MECHANISMS OF INTERFERENCE – ANALYSIS

3.1 LNB Saturation (Gain Compression)

LNB saturation is the physically most serious and most frequent interference mechanism in the C band. The input amplifying transistor of the LNB (typically a HEMT – High Electron Mobility Transistor) has a defined 1 dB compression point (P1dB). For standard C band LNBs, P1dB is typically in the range of –10 to +5 dBm at the input.

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P_sat(dBm) = P1dB_input – G_LNB For an LNB with a gain of 60 dB and P1dB = +5 dBm:
P_sat_input = –55 dBm
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A 5G BS at a distance of 500 m typically produces –40 dBm at the LNB input – i.e. 15 dB above the saturation point. The consequences are:

- Gain compression: the effective LNB gain drops by 1 dB to 10 dB
- Noise figure degradation: the noise figure increases by several dB
- Spectral regrowth: emergence of new spectral components outside the original 5G signal

CRITICAL FINDING: LNB saturation occurs AT THE INPUT STAGE – that is, PRIOR TO the point where an external BPF filter is connected (feed–LNB interface). The BPF filter therefore CANNOT prevent saturation if it is placed AFTER the input HEMT. The only solution: use an LNB with an integrated pre-filter placed BEFORE the first amplification stage.

3.2 Intermodulation Products (IMD – Intermodulation Distortion)

The non-linear behaviour of the LNB in the saturation region generates intermodulation products. For two input signals at frequencies f1 and f2, the following products arise:

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2·f1 – f2 (IMD3)
2·f2 – f1 (IMD3)
3·f1 – 2·f2 (IMD5)
3·f2 – 2·f1 (IMD5)
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Third-order products (IMD3) are physically the most significant, as they lie close to the fundamental frequencies and deviate from them by only the difference (f2–f1). For 5G carriers at 3,500 and 3,600 MHz: IMD3 = 3,400 MHz and 3,700 MHz – both directly within the C band.

3.3 Noise Floor Elevation

In addition to saturation and IMD, terrestrial interference can raise the overall system noise. The phenomenon is described as:

$$NF\_total = NF\_LNB + 10 \cdot \log_{10}(1 + P\_interference / kTB)$$

where k is Boltzmann's constant, T is temperature (290 K), and B is the bandwidth. This leads to degradation of the C/N ratio, which manifests as increased BER (Bit Error Rate) for digital signals (DVB-S2), longer lock acquisition times, or complete loss of MER (Modulation Error Ratio).

3.4 Receiver Desensitisation

Desensitisation occurs when a strong terrestrial signal (e.g. 5G) reduces the sensitivity of the LNB/receiver to weaker signals (satellite), even outside its own frequency. The phenomenon is caused by the non-linearity of active components and is quantified by the parameter IP3 (Third-Order Intercept Point):

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IIP3 = P_in + (P_fund – P_IMD3) / 2
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For standard LNBs, IIP3 is typically +5 to +15 dBm. A strong terrestrial signal exceeds this value and the system enters the non-linear regime.

3.5 Phase Noise Degradation

Strong terrestrial signals can affect the stability of the local oscillator (LO) in the LNB through the phenomenon of noise injection. LO phase noise manifests as broadband smearing (phase noise skirt) around each carrier frequency, which degrades the phase purity of the down-converted satellite signal. For DVB-S2 with higher-order modulations (16APSK, 32APSK), this is particularly critical.

4. INTERFERENCE FREQUENCY MAP – SLOVAKIA

The following table summarises all identified interference sources with their frequency ranges, interference types and estimated severity under Slovak conditions.

Interference source	Frequency range	Interference mechanism	Severity (SK)
5G NR (n78/n77)	3,300–4,200 MHz	Saturation, IMD3	■ **Critical**
LTE TDD B42/43	3,400–3,800 MHz	Saturation, IMD	■ **High**
FWA / WiMAX PTMP	3,400–3,700 MHz	Saturation, IMD3	■ **High**
Microwave PTP links	3,600–4,200 MHz	Noise floor, IMD	▲ **Medium**
Meteorological radars	3,300–3,500 MHz	Saturation, LOS	▲ Low–Medium
Aviation radars	4,200–4,400 MHz	LOS, diffraction	▲ Low–Medium
Backhaul terrestrial links	4,400–5,000 MHz	LOS, directional	■ Low (ext. C)
Wi-Fi 2.4 GHz harmonics	~4,800 MHz	2nd harmonic ~4.8 GHz	■ Minimal
ISM / switched-mode PSUs	Broadband	Noise floor	■ Minimal

5. CRITICAL EVALUATION OF NORSAT BPF FILTERS

5.1 Product description and declared specifications

Norsat International is a Canadian manufacturer of satellite components with a long-standing reputation. Their C-band BPF (Band Pass Filter) product range is designed primarily to eliminate 5G interference before it reaches the LNB input. The 3000-BPF and BPF-C product lines are positioned as a solution for operators affected by 5G interference.

Norsat declares the following parameters for their BPF filters (various models):

- Passband: 3,625–4,200 MHz or 3,700–4,200 MHz (depending on the model)
- Stopband rejection: 40–60 dB in the 5G band (3,300–3,600 MHz)
- Insertion loss: typically 0.5–1 dB in-band
- Guard band: < 20 MHz (model BPF-C-6)

5.2 Technical limitations of an external BPF filter

Based on physical analysis, the following fundamental limitations of an external BPF filter (placed between the antenna feed and the LNB input) can be identified:

Limitation 1: Saturation occurs BEFORE the filter

The external BPF filter is physically positioned BEFORE the LNB input – but after the feedhorn. The signal therefore travels the path: Satellite → Parabolic dish → Feedhorn → (BPF Filter) → LNB input. However, the LNB's input amplifier is DIRECTLY BEHIND the LNB input port. The filter therefore protects the LNB from in-band 5G signals in the stopband, BUT if:

- The 5G signal lies within the filter's passband (e.g. 5G at 3,700 MHz and the filter passes from 3,700 MHz)
- The combined power of all signals (satellite + 5G + noise) exceeds the LNB's P1dB
- The 5G signal generates products within the filter's passband through non-linear effects in the coaxial cable upstream of the filter

...then saturation will still occur even with the filter, and the filter will not help.

Limitation 2: Incorrectly specified cutoff frequency

In Slovakia, the 5G networks of operators operate in the range 3,490–3,600 MHz. If the BPF filter has a passband boundary at 3,600 MHz or above, it may pass part of the 5G spectrum into the LNB. The filter model must be selected precisely according to the actual frequency plan of local 5G operators.

Limitation 3: The near-far problem

If the 5G BS is located at a distance of less than approximately 200–500 m, the signal strength may be so high that even a 60 dB stopband rejection filter is insufficient. For a 5G signal of –40 dBm at the input and 60 dB rejection: filtered signal = –100 dBm – still at or above the level of the satellite signal.

Limitation 4: LNB non-linearity caused by out-of-band signals

Even when the 5G signal is not within the filter's passband, its power upstream of the filter is sufficient that part of it can leak through the feedhorn–filter–LNB mechanical assembly via parasitic coupling (parasitic capacitive and inductive coupling) outside the electrical signal path. This is physically impossible to suppress without perfect shielding.

DIAGNOSIS OF YOUR PROBLEM: The fact that the Norsat BPF did not bring improvement suggests one or more of the following phenomena: (1) The source of interference is 5G/LTE carriers within the PASSBAND of your filter (i.e. above 3,700 MHz), not only in the stopband. (2) LNB saturation is occurring via out-of-band signals whose power exceeds P1dB. (3) The interference is arriving via the RF cable or a mechanical aperture (not through the feedhorn). (4) There is an in-band interference source that a BPF cannot eliminate (e.g. a terrestrial microwave link at 3.8 GHz).

5.3 Recommended solutions based on scientific analysis

1. Integrated LNB with pre-filter: Replace the standard LNB with a model incorporating an integrated bandpass pre-filter positioned BEFORE the input HEMT transistor (e.g. Norsat 3200-BPF-5 or Norsat 3100N-BPF-5). This physically eliminates the saturation problem.

2. Spectral analysis of local interference: Before purchasing further filters, it is essential to determine the exact frequencies of local interferers using a spectrum analyser (e.g. RTL-SDR with LNA, or professional equipment). Only in this way is it possible to select the correct filter.

3. Geometric measures: Changing the antenna's azimuth/elevation can, in some cases, eliminate the line-of-sight problem with a local 5G BTS.

4. Feedhorn shielding: Adding RF shielding around the feedhorn–LNB assembly to minimise parasitic capacitive and inductive coupling.

5. Coordination with TU SR: If the interference is caused by unlicensed operation or frequency plan overlap, reporting to the Telecommunications Regulatory Authority of the Slovak Republic (TU SR) may lead to a regulatory resolution.

6. WAVE PHYSICS OF INTERFERENCE – PROPAGATION MODELS

6.1 Free Space Propagation

The fundamental law of free-space propagation describes the decrease in signal intensity with distance:

$$FSPL(dB) = 20 \cdot \log_{10}(4 \cdot \pi \cdot d \cdot f / c)$$

where d is the distance (m), f is the frequency (Hz), and c is the speed of light ($3 \cdot 10^8$ m/s). For a 5G BTS at 3.5 GHz:

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FSPL @ 100 m = 73.3 dB | FSPL @ 1 km = 93.3 dB | FSPL @ 5 km = 107 dB
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6.2 Multipath Effects

In the urban environment of Slovakia (cities, housing estates), 5G signals reach the satellite dish not only via a direct LOS path, but also via reflections from buildings, vehicles and the ground surface. These multipath copies can have varying phases and amplitudes, leading to:

- Frequency-selective fading – different frequencies within the C band are affected to differing degrees
- Constructive and destructive interference – some carriers in the C band are more severely affected than others
- Polarisation scattering – incoming terrestrial signals have varying polarisations and can affect cross-polar channels

6.3 Diffraction (Knife-Edge Diffraction)

The 5G BTS signal can overcome physical obstacles (buildings, ridges) through diffraction. The Fresnel zone radius for 3.5 GHz and a distance of 1 km:

$$r\_Fresnel = \sqrt{(\lambda \cdot d)} = \sqrt{(0.086 \cdot 1000)} \approx 9.3 \text{ m}$$

This means that obstacles smaller than approximately 9 m do not physically block the signal at this distance – the signal diffracts around them. For a satellite dish located on a rooftop, this explains why even seemingly well-screened buildings may not eliminate 5G interference.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 Main conclusions

On the basis of the comprehensive scientific analysis, the following conclusions can be formulated:

1. C band satellite reception (3,400–4,800 MHz) in Slovak conditions is exposed to multi-source interference from 5G, LTE, FWA and microwave links.
2. The physical interference mechanisms are multiple and overlapping: LNB saturation, intermodulation products IMD3/IMD5, noise elevation, and desensitisation.
3. External BPF filters (including Norsat) have physical limitations and do not eliminate LNB saturation nor IMD generated prior to the filtering point.
4. Effective mitigation requires the use of an LNB with an internal pre-filter, spectral analysis of local interference, and a combined technical approach.
5. For publication purposes on the portal dxsatcs.com, this analysis has been compiled on the basis of ITU-R, 3GPP and peer-reviewed scientific sources and may serve as a scientifically substantiated reference.

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Sources: ITU-R Reports M.2109, S.2199, S.2368 | 3GPP TS 38.101 | IEEE ICC 2018 | arXiv 2312.16079 | Norsat Technical Docs | Rohde & Schwarz Application Notes