Analysis of Adjacent Channel Interference between Terrestrial and Non-Terrestrial 5G Networks Over 28 GHz Millimeter-wave Band

Dércio M. Mathe, Daniel da S. Souza and Bruno M. Pinheiro

***Abstract*—This letter assesses the interference between terrestrial 5G network (TN-5G) and non-terrestrial 5G network (NTN-5G) operating in millimeter wave Ka-band. Specifically, the impact that NTN-5G causes on the TN-5G system in the 28 GHz band is analyzed. Simulations using the Monte-Carlo method are performed to obtain the interference power in the victim system for different guard bands. Also, experiments using laboratory equipment are performed to analyze the block error rate (BLER) and Throughput of the user equipment (UE) under different interference power levels. The results showed that interference from NTN-5G may impact the TN-5G, depending on the adopted guard band. Ideally, guard bands above 100 and 180 MHz are recommended for TN-5G operating with 50 and 100 MHz bandwidths, respectively. On the other hand, experiments showed that UE performance can be severely degraded by interference power above -108 dBm. Then, it is concluded that TN and NTN 5G can coexist since the appropriate guard bands are considered, depending mainly on the bandwidth of the victim system.**

***Index Terms*—5G, NTN, Interference, Coexistence, mmWave.**

I. Introduction

Currently, mobile communications networks are in the fifth generation, which has been introduced through Release 15 of the 3rd Generation Partnership Project (3GPP) [1] as a successor to Long Term Evolution (LTE) technology, 4G. According to [2], it is expected that the fifth-generation (5G) will become the dominant mobile access technology and reach around 5.6 billion subscriptions in 2029, thus making up 60 percent of all mobile subscriptions globally. The first deployment of 5G networks, which are currently the most prevalent, follows the non-standalone (NSA) architecture, as presented in release 15 of the 3GPP standardization [1]. These deployments allowed a smooth transition from 4G to 5G since the newly deployed 5G network uses the legacy infrastructure of 4G cells as anchors and also accesses its core network, the Evolved Packet Core (EPC), i.e., all the control plane of the 5G-NSA architecture is carried out via 4G network. Therefore, secondary 5G cells serve as a data pipe to increase transmission rates of the end user through enhanced Mobile Broadband (eMBB). However, in a standalone (SA) deployment, in which 5G has its core network, the 5G Core (5GC), it provides services and applications such as Ultra-reliable low-latency communication (URLLC) for low-latency and high-reliability applications, e.g., autonomous vehicles driving, and medical surgeries, in which delays and losing data packets may be harmful. Also, 5G-SA provides massive Machine-Type Communications (mMTC) for massive Internet of Things and low-cost devices with lower data rates [3], [4].

Generally, mobile technologies are based on terrestrial network transmission systems operating on the Earth's surface. As with predecessor technologies, conventional TN-5G provides services to the users through an access network composed of several terrestrial base stations connected to the core network through a high-capacity transport network, backhaul. Currently, TN-5G networks are primarily implemented in the sub-6GHz frequency bands, also called frequency range 1 (FR1) [5]. However, to exploit larger bandwidths and achieve higher data rates, TN-5G can be deployed in bands over 24 GHz, which are also known as frequency range 2 (FR2) [5], [6]. On the other hand, NTN-5G networks have been presented on 3GPP release 17 [7] and are based on communication systems operating beyond the Earth's surface, e.g., satellite systems, aiming to provide massive coverage, including remote locations where TN infrastructure is unavailable. However, although the standardization establishes specific frequency bands for TN and NTN-5G, the coexistence between these technologies in FR2 may become a concern since some of the allocated bands share the same frequency spectrum, and interference scenarios may occur.

The coexistence between TN and NTN-5G systems has been studied before. In [8], the authors studied the performance of integrated terrestrial/non-terrestrial networks when operating on the same frequency channel in S-band. Two co-existence scenarios in which the TN users receive interference from the NTN downlink and uplink have been analyzed. Reported results showed that, depending on adopted network parameters, some co-existence scenarios may outperform others regarding the probability of coverage and data rates. Also, the authors showed that a minimum isolation distance is required between TN and NTN to minimize the effect of interference.

The study in [9] presents the Coordinated Dynamic Spectrum Sharing (C-DSS) between TN and NTN-5G. This work develops and simulates an algorithm that aims to provide the system with the necessary resources while prioritizing TN and considering the peculiarities of NTN frequency reuse. The results achieved in this work show that the proposed C-DSS enables the deployment of NTN on a shared frequency spectrum while causing minimal disturbance to primary TN. The paper in [10] provides a comprehensive overview of interference sources in LEO Satellite-Integrated Terrestrial Networks (LITNs), categorizing them into Inter-Beam Interference (IBI), Inter-Satellite Interference (ISI), and LEO Satellite-Terrestrial Infrastructure Interference (LTI). It discusses the limitations of traditional interference mitigation techniques when applied

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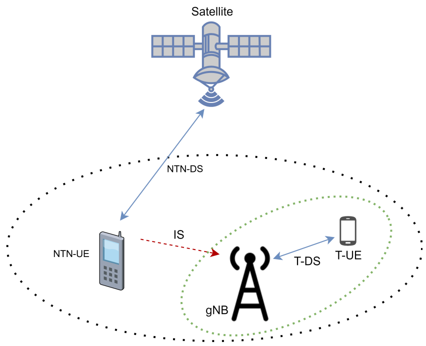

Fig. 1. Interference scenario between terrestrial and non-terrestrial 5G.

to the dynamic and complex characteristics of LITNs and emphasizes the need for advanced solutions to maximize spectral efficiency and network reliability in these hybrid networks. In [11], a framework is presented for integrating NTN with TN to improve coverage and reliability for 6G IoT applications. It utilizes Non-Orthogonal Multiple Access (NOMA), Automatic Repeat Request (ARQ), and cooperative communications to enhance data offloading. The main contribution is the offline Packets Repair and Recovery (PRR) technique, which uses wired connections for bidirectional cooperation to reduce multi-user interference and improve signal quality.

Finally, in [12], the coexistence of terrestrial and non-terrestrial networks on adjacent channels is analyzed through simulations under the 2 GHz frequency band. Based on the results, the authors concluded that terrestrial and non-terrestrial 5G can coexist on adjacent channels with a relaxed Adjacent Channel Interference Ratio (ACIR).

Unlike the aforementioned works, this letter presents a study on interference between TN and NTN-5G systems operating in the millimeter wave band. The main contribution of this work is that, in addition to analyzing the interference between TN and NTN 5G, through Monte-Carlo simulations, the impact of interference is analyzed at the end-user level through lab experiments using commercially available smartphones. To the best of our knowledge, this form of analysis has not been reported in the literature. Also, through the obtained results, this work provides benchmark values, which operators and regulatory entities can use to propose network deployment methods that ensure coexistence between TN and NTN-5G systems over the millimeter wave context.

II. Analysis Scenario

The analysis scenario presented in this paper consists of two 5G networks, terrestrial and non-terrestrial, operating in the same geographic region, as illustrated in Fig. 1.

In this scenario, NTN-5G transmits and receives desired signals (NTN-DS) through the satellite to/from the receiver (NTN-UE) within the NTN system's coverage radius. Also, within the coverage area of NTN-5G, a smaller coverage radius is located in the TN-5G system. This system is composed of a 5G TN base station (gNB) transmitting and receiving terrestrial desired signals (T-DS) from/to the end-user (T-UE). It can also have an inter-satellite link (IS) between NTN-UE and the TN-5G system. Fig. 1 shows that terrestrial and non-terrestrial network receivers are susceptible to interference. For example, the downlink signal generated by the gNB may interfere with the NTN-UE, and the signal transmitted by the satellite can interfere with the T-UE. Furthermore, the uplink signals generated by the NTN-UE can interfere with the T-UE and vice versa. This interference can impact the performance of both systems.

III. Analysis Methodology

The methodology adopted in this paper consists of analyzing the performance of terrestrial 5G under external interference from non-terrestrial 5G. First, the power of the interference signal generated by the NTN interfering system in the adjacent channel is calculated through Monte-Carlo simulations since both systems operate in the same frequency range,i.e., between 27.50 GHz and 28.35 GHz. Note that this frequency range corresponds to the terrestrial Time Division Duplexing (TDD) n261 5G band, with up to 400 MHz bandwidth. The same frequency range is also allocated to the uplink of n510 NTN-5G, with up to 400 MHz bandwidth [13]. Monte-Carlo simulations have been conducted using the powerful Spectrum Engineering Advanced Monte Carlo Analysis tool (SEAMCAT) [14], which calculates the interference probability (P_i) through (1).

$$P_i = 1 - \frac{\frac{DS}{\sum_{j=1}^{J} IS_j} > \frac{C}{I} | DS > S}{P(DS > S)}, \quad (1)$$

where, DS is the victim system desired signal strength, $\frac{C}{I}$ is the carrier to interference ratio [14], and S represents the victim system receiver sensitivity. IS_j is the j^{th} interference signal, i.e., the number of active interferers, given by (2).

$$IS = EM_{ilt}(f_{ilt} - f_{vlr}) + G_{ilt}^{PC} - max(PL_{ilt-vlr} - G_a), \quad (2)$$

where $EM_{ilt}(f_{ilt} - f_{vlr})$ is the relative emission mask between the interference link transmitter (ilt) and victim link receiver (vlt), which is a function of $\Delta f = (f_{ilt}, f_{vlr})$. G_{ilt}^{PC} is the power control gain for the ilt with the power control function, $PL_{ilt-vlr}$ is the path loss between the interfering link transmitter and the victim link receiver. G_a is the gain of ilt antenna in the direction of the vlr antenna and, vice-versa, given by $G_a = G_{ilt-vlr} + G_{vlr-ilt}$. More details on the mathematical modeling of the Monte-Carlo method and IS calculation can be found in [14].

Then, the simulated interference power is used as input in the laboratory equipment, and its impact is analyzed through experiments. The metrics considered in this analysis are block error rate (BLER) and Throughput (THP) performance, which are directly measured on the user's equipment. Then, measured BLER and THP values are compared with the performance targets of 10% and 95% (5% THP loss), respectively [12]. Therefore, in the case of BLER, as the UE performance remains below 10%, it is considered good, and vice-versa. On the other hand, when the UE THP remains above 95%, it is considered good. Otherwise, UE performance is considered degraded. A summary of the parameters used in this analysis is presented in Tab. I.

TABLE I
CONFIGURATION PARAMETERS

Parameter	Value
TN Transmission band	n261 [15]
Number of simulated TN cells	1
TN base station height	22m [14]
TN UE height	1.5m [14]
NTN Transmission band	n510 [15]
Victim system bandwidth	50 MHz and 100 MHz
Coverage radius of victim system	200m [16]
Number of active interferes (J)	1
Distance victim and interferer	50m
Guard band	10 MHz to 180 MHz
Victim system transmit power	33 dBm [14]
Victim system desired power	-70 dBm [14]
NTN satellite altitude	600 *km* (LEO) [17]
$\frac{C}{I}$	19dB [14]
Receiver Sensitivity (S)	-107 dBm [14]
Interfering link propagation model	ITU-R P.525 Free space [14]

IV. Measurement setup

The measurement setup used in this analysis is shown in Fig. 2. Since the terrestrial 5G system follows NSA deployment, the measurement setup is composed of the following: 1) LTE test station to generate LTE anchor cell, which is responsible for transferring the control plane signaling messages between the UE and the emulated network; 2) NR test station to emulate the 5G secondary cell groups (SCG), responsible for carrying user plane data and performs carrier aggregation (CA); 3) A control PC, used to control the measurement equipment through a graphical user interface (GUI); 4) RF anechoic chamber provides an Over-the-air (OTA) environment.

5) FR2 up-converters are connected to the NR test station for shifting the NR carrier frequency from intermediate frequency to mmWave range; 6) the device under test, a flagship commercial Smartphone supporting mmWave 5G technology with the Qualcomm Snapdragon 8 Gen 3 SM8750-AB chipset and, 7) the UE position controller, used to rotate the UE over both the elevation and azimuthal planes, emulating different receiving positions. In our measurement, the UE was positioned at a 90-degree angle in front of the NR-FR2 antennas. Due to the limitations of lab equipment, which do not allow testing multiple mobile devices, the performance measurement was performed for a single UE. Furthermore, the tests were performed in a highly controlled environment, e.g., it was not feasible to test user mobility scenarios.

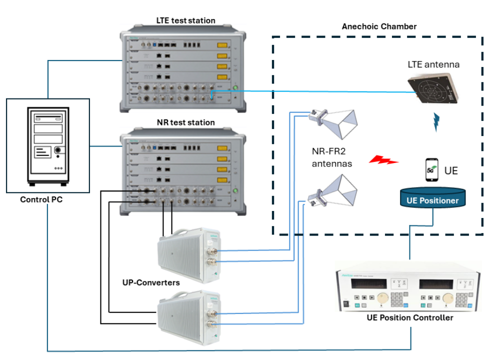

Fig. 2. Measurement setup for terrestrial mmWave 5G.

V. Results and discussion

This section presents the performance analysis results of TN-5G under adjacent channel interference of NTN-5G.

A. Simulation

Fig. 3 shows the simulation result of the interference power received by the victim TN-5G system as a function of the guard band variation. Guard bands from 10 MHz to 100 MHz have been analyzed previously under coexistence scenarios between satellite earth stations and 5G base stations [18]. However, with guard bands of up to 80 MHz, our experiments showed higher interference, depending on the analyzed scenario, and in this work, we extend the guard band analysis to 180 MHz.

Generally, this result attests that the interference power received by TN-5G tends to be higher for smaller guard bands. When the victim TN-5G operates with 50 MHz bandwidth, the calculated interference power is around -79 dBm for a guard band of 10 MHz. When increasing the guard band, the interference power tends to decrease; e.g., for the 60 MHz and 80 MHz guard bands, the interference power decreases to -84 dBm and -107 dBm, respectively.

On the other hand, when the victim system operates with 100 MHz bandwidth, the interference power tends to be higher, i.e., for a 10 MHz guard band, the received interference power is around -76 dBm. As in the previous case, the interference power decreases when the guard band increases. In the 60 MHz and 90 MHz guard bands, the interference power decreases to -80 dBm and -86 dBm, respectively. Note that, in cases of 80 MHz and 90 MHz guard bands, the interference power received by the TN-5G operating with 50 MHz and 100 MHz bandwidth may differ by around 20 dB. Finally, for guard bands above 100 MHz, the interference power remains below -104 dBm.

B. Measurement

Through laboratory measurements, the experimental result is presented in Figs. 4 and 5. These results were obtained for a victim system operating with 50 MHz and 100 MHz

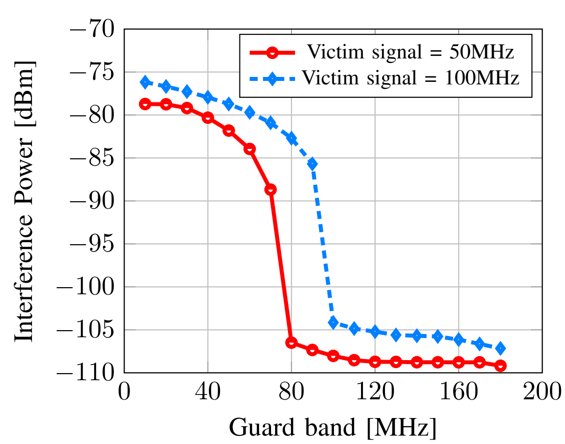

Fig. 3. Simulated interference power in victim system vs guard band.

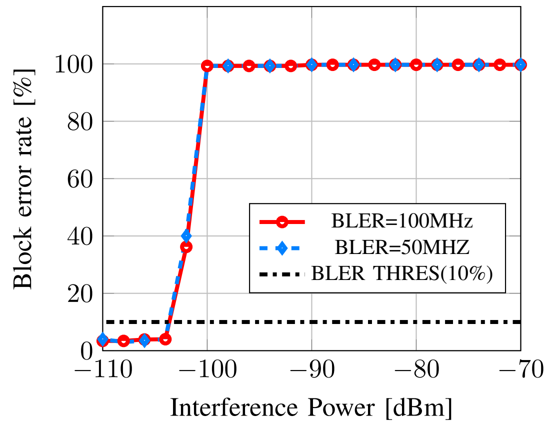

Fig. 4. Measured BLER vs received interference power.

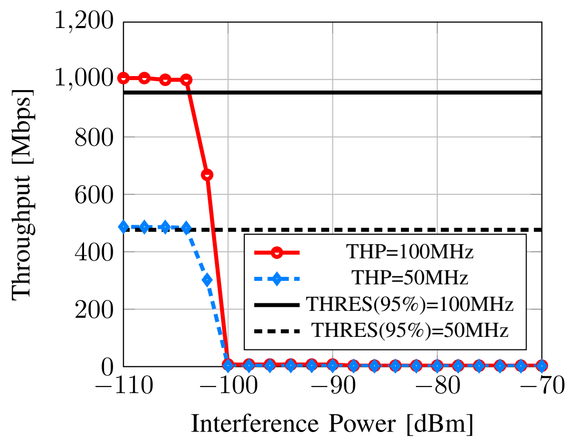

Fig. 5. Measured Throughput vs received interference power.

bandwidth. Fig. 4 shows the block error rate (BLER) results for the TN-5G victim system. The analyzed interference power is according to the range obtained through simulations in subsection V-A, i.e., it varies between -110 dBm and -75 dBm. The measurement results show that BLER presents similar relative values in both cases, i.e., for the victim system operating at 50 MHz and 100 MHz.

This is due to the level of interference power received by the victim system is proportionally greater the greater the bandwidth and vice versa, as shown in Fig. 3. Thus, for the range of interfering signal power varying between -110 dBm and -108 dBm, BLER reaches approximately 4%, remaining below the threshold (THRES) value of 10%. Then, BLER values tend to increase as the power of the NTN-5G interfering signal increases. Thus, when the interfering signal varies between -108 dBm and -102 dBm, the BLER value increases gradually and reaches approximately 16% and 50%, exceeding the threshold of 10%, i.e., the victim TN-5G performance is degraded. Additionally, when the power of the interfering signal is above -100 dBm, reported BLER remains 99%.

On the other hand, Fig. 5 shows the THP of the victim TN-5G UE. As in the previous case, the interference power range also varies between -110 dBm and -75 dBm. However, different from the previous result, in both cases, i.e., victim system bandwidth of 50 MHz and 100MHz, respectively, UE THP tends to decrease as the power of the NTN-5G interfering signal increases, thus attesting that THP is inversely proportional to BLER. When the interference power remains below -108 dBm, THP reaches its maximum value of 490 Mbps and 1005 Mbps for the victim system operating with 50 MHz and 100 MHz, respectively. However, the reported values remain above the performance thresholds of 476.5 Mbps and 954.7 Mbps for the victim system operating with 50 MHz and 100 MHz, respectively. Then, as the interference power increases to -102 dBm, THP starts decreasing gradually to 668 Mbps and 302 Mbps, for 50 MHz and 100 MHz, and, in both cases, THP remains below the threshold, i.e., the victim system is experiencing a significant impact of the adjacent channel interference, with the performance decreasing by 33% and 38%, respectively. When the interference power reaches -100 dBm, THP drops abruptly to 7.23 Mbps and 3 Mbps, respectively, and the victim system performance decreases by 99%, i.e., the interference power severely impacts it. This trend remains for interference power greater than -100 dBm, for which the measured THP on the victim system is almost zero in both cases, which, in practice, means a total loss of UE performance due to the interference signal.

VI. Conclusion and Future Works

This letter presents a study on interference between TN-5G and NTN-5G systems operating in millimeter-wave Ka-band. First, the paper calculates the interference in adjacent channels through Monte-Carlo simulations. Then, the impact of the interference on UE is analyzed through laboratory experiments. The simulation results showed that the interference from NTN-5G may severely impact the TN-5G, depending on the power of the interfering signal and the separation guard bands between the systems. Ideally, guard bands above 100 MHz and 180 MHz are recommended for TN systems operating with 50 MHz and 100 MHz bandwidth, respectively, since the interference power will remain below -108 dBm. On the other hand, laboratory experiments showed that the performance of the UE can be severely degraded, causing an abrupt increase in BLER and decreasing throughput when the power of interfering signals from the NTN-5G remains above -108 dBm. Thus, this attests to the high sensitivity of 5G systems operating in mmWaves. So, with the achieved results, we concluded that it is possible that TN-5G and NTN-5G systems coexist over the 28 GHz band since the appropriate guard bands are considered, i.e., depending mainly on the bandwidth of the victim system.

For future works, we are investigating more complex interference scenarios involving multiple NTN interferences, aiming to reach a detailed and more realistic analysis of both constructive and destructive interference effects on the victim system performance. Furthermore, we plan to evaluate and compare the performance of alternative interference mitigation strategies, such as filter design, power control, and beamforming, aiming to identify the optimal solutions for NTN/TN-5G coexistence.

REFERENCES

[1] 3GPP, "5g; procedures for the 5g system," Tech. Rep TS 23.502, v15.2.0 Release 15, Jun. 2018.

[2] Ericsson, "Ericsson mobility report," https://www.ericsson.com/49ed78/assets/local/reports-papers/mobility-report/documents/2024/ericsson-mobility-report-june-2024.pdf, Jun. 2024.

[3] P. Popovski, K. F. Trillingsgaard, O. Simeone, and G. Durisi, "5g wireless network slicing for embb, urllc, and mmtc: A communication-theoretic view," *IEEE Access*, vol. 6, pp. 55 765–55 779, 2018, doi: 10.1109/ACCESS.2018.2872781.

[4] R. Kumar, D. Sinwar, and V. Singh, "Qos aware resource allocation for coexistence mechanisms between embb and urllc: Issues, challenges, and future directions in 5g," *Computer Communications*, vol. 213, pp. 208–235, 2024, doi: 10.1016/j.comcom.2023.10.024.

[5] R. Dilli, "Analysis of 5g wireless systems in fr1 and fr2 frequency bands," *2nd International Conference on Innovative Mechanisms for Industry Applications (ICIMIA)*, pp. 767–772, 2020, doi: 10.1109/ICIMIA48430.2020.9074973.

[6] C. Hausl, J. Emmert, M. Mielke, B. Mehlhorn, and C. Rowell, "Mobile network testing of 5g nr fr1 and fr2 networks: Challenges and solutions," *16th European conference on antennas and propagation (EuCAP)*, pp. 1–5, 2022, doi: 10.23919/EuCAP53622.2022.9769635.

[7] 3GPP, "5g; nr; nr and ng-ran overall description; stage-2," Tech. Rep TS 38.300 version 17.1.0 Release 17, Aug. 2022.

[8] N. Okati, A. N. Barreto, L. U. Garcia, and J. Wigard, "Co-existence of terrestrial and non-terrestrial networks in s-band," *arXiv preprint arXiv:2401.08453*, 2024.

[9] H. Martikainen, M. Majamaa, and J. Puttonen, "Coordinated dynamic spectrum sharing between terrestrial and non-terrestrial networks in 5g and beyond," *IEEE 24th International Symposium on a World of Wireless, Mobile and Multimedia Networks (WoWMoM)*, pp. 419–424, 2023, doi: 10.1109/WoWMoM57956.2023.00074.

[10] N. Heydarishahreza, T. Han, and N. Ansari, "Spectrum sharing and interference management for 6g leo satellite-terrestrial network integration," *IEEE Communications Surveys & Tutorials*, 2024, doi: 10.1109/COMST.2024.3507019.

[11] A. Ahmed, A. Al-Dweik, Y. Iraqi, and E. Damiani, "Integrated terrestrial-wired and leo satellite with offline bidirectional cooperation for 6g iot networks," *IEEE Internet of Things Journal*, vol. 11, no. 9, pp. 15 767–15 782, doi: 10.1109/JIOT.2023.3 349 144, 2024.

[12] L. Sormunen, H. Martikainen, J. Puttonen, and D. Panaitopol, "Co-existence of terrestrial and non-terrestrial networks on adjacent frequency bands," *11th Advanced Satellite Multimedia Systems Conference and the 17th Signal Processing for Space Communications Workshop (ASMS/SPSC)*, pp. 1–6, 2022, doi: 10.1109/ASMS/SPSC55670.2022.9914774.

[13] H. Shahid, C. Amatetti, R. Campana, S. Tong, D. Panaitopol, A. Vanelli-Coralli, A. Mohamed, C. Zhang, E. Khalifa, E. Medeiros *et al.*, "Emerging advancements in 6g ntn radio access technologies: An overview," *Joint European Conference on Networks and Communications & 6G Summit (EuCNC/6G Summit)*, pp. 593–598, 2024, doi: 10.1109/EuCNC/6GSummit60053.2024.10597037.

[14] S. ECC, "Ecc report 252. seamcat handbook," https://docdb.cept.org/download/5b8f9726-04a6/ECCRep252.pdf, 2016.

[15] 3GPP, "5g; nr; user equipment (ue) radio transmission and reception; part 2: Range 2 standalone," Tech. Rep 38.101-2 version 17.6.0 Release 17, Aug. 2022.

[16] K. Arunruangsirilert, P. Wongprasert, and J. Katto, "Performance analysis of 5g fr2 (mmwave) downlink 256qam on commercial 5g networks," *arXiv preprint arXiv:2502.03416*, 2025.

[17] 3GPP, "Study on narrow-band internet of things (nb-iot) / enhanced machine type communication (emtc) support for non-terrestrial networks (ntn)," Tech. Rep 36.763 V0.0.2 Release 17, 2021.

[18] S. Liu, Y. Wei, and S.-H. Hwang, "Guard band protection for coexistence of 5g base stations and satellite earth stations," *ICT Express*, vol. 9, no. 6, pp. 1103–1109, 2023, doi:https://doi.org/10.1016/j.icte.2023.03.005.