Analysis of the Impact of Radio Frequency Interference from Satellite on Terrestrial Network in Adjacent Channel

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***Abstract*— The rapid expansion of cellular frequency bands has reduced terrestrial network coverage, particularly in areas with low population density or difficult access. Non-Terrestrial Networks (NTNs), which utilize satellites and high-altitude platforms, have emerged as a complementary solution to address these coverage challenges. However, NTNs operating in adjacent frequency bands to terrestrial networks introduce the risk of radio frequency interference. This paper focuses on the interference impact of NTN satellites operating in the NR-NTN band n256 on terrestrial network user equipment (UE) in the adjacent n1 band, under a Downlink (DL) scenario. Interference protection criteria were based on a 5% throughput loss, evaluated using Signal-to-Interference-plus-Noise Ratio (SINR). Simulation results, conducted using SEAMCAT, indicate an average throughput loss of 2.736%, satisfying the interference protection criteria.**

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I. Introduction

With the recent increase in cellular frequency bands, the coverage of terrestrial base stations has been decreasing. As a result, Direct-to-Device (D2D) services, which provide stable network coverage in areas with low population density, disaster-affected regions, and other locations where network provision is challenging, are gaining attention. A Mobile Network Operator (MNO) can provide services through collaboration with a Mobile Virtual Network Operator (MVNO), and 3GPP is currently working on the standardization of Non-Terrestrial Networks (NTN), a technology that utilizes satellites and High Altitude Platforms (HAPs) to deliver network coverage to the ground[1].

However, satellites can cause radio frequency interference to other devices in adjacent bands due to their wide-area signal radiation. In particular, the NR-NTN and IoT-NTN bands standardized by 3GPP can cause frequency interference with other mobile communication devices, as they use existing cellular frequency bands.

In this paper, we analyze the interference impact of an NTN Satellite (SAT) operating in the NR-NTN band n256 on Terrestrial Network (TN) User Equipments (UE) in adjacent band, assuming a Down Link (DL) scenario.

II. Scenario

A. Scenario

In this scenario, it is assumed that the frequency bands of NTN and TN are adjacent. The n256 band for NR-NTN, defined by 3GPP, is adjacent to or overlaps with TN bands such as n1 and n65. Among these, the interference impact of an NTN operating in the n256 band on a TN operating in the n1 band was analyzed[2].

TABLE I. Frequency Band in Scenario

band	UL band	DL band
	NR-NTN	
n256	1980-2010 MHz	2170-2200 MHz
	TN	
n1	1920-1980 MHz	2110-2170 MHz

The NTN provides mobile communication services to UEs outside the coverage of the TN, and the TN network layout was configured as a 3-sector single cell. The scenario figure is shown below.

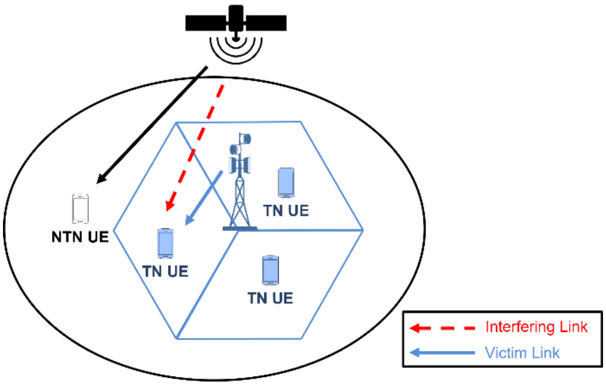

Fig. 1. Interference Scenario between TN ans NTN

It was assumed that the NTN complements the TN, and to account for the computational complexity of the handover point, the protection distance between the TN cell and the NTN UE was set to 400 meters.

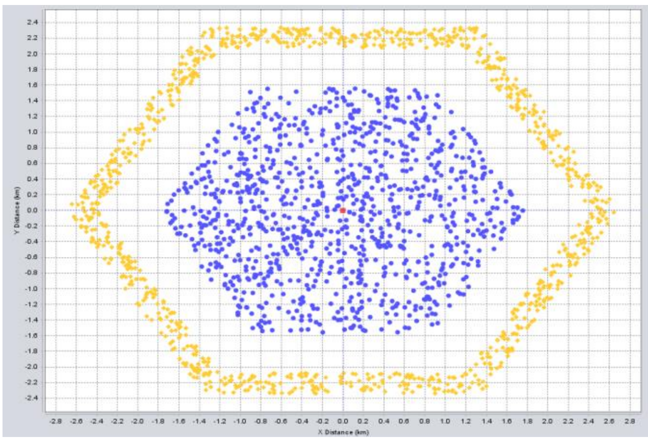

Fig. 2. Protection distance in interference scenario

B. Interference protection criteria

The interference protection criterion was set to a 5% throughput loss, and the throughput loss was calculated based on the Signal to Interference plus Noise Ratio (SINR) of the TN UE. The throughput loss is derived by comparing the throughput that considers Adjacent Channel Interference (ACI) with the throughput that considers only Inter Cell Interference (ICI). The Throughput loss and Throughput are derived by equations (1-3)[3].

$$Throughputloss[bps/HZ] = 1 - \frac{Throughput_{ACI}}{Throughput_{NO\ ACI}} \quad (1)$$

$$Throughput_{ACI}[bps/Hz] = f(SINR_{ACI}) = f\left(\frac{S}{N + I_{ICI} + I_{ACI}}\right) \quad (2)$$

$$Throughput_{NO\ ACI}[bps/Hz] = f(SINR_{ICI}) = f\left(\frac{S}{N + I_{ICI}}\right) \quad (3)$$

SINR is a metric for measuring the signal quality of a UE and is influenced by Noise power (N) and Interference power (I). The throughput is derived by applying the SINR to the Shannon bound (f), as shown in Equations (4-5)[4].

$$Throughput(SINR)[bps/HZ] = log_2(1 + SINR) \quad (4)$$

$$Throughput(SINR)[bps/HZ] = \begin{cases} 0\ for\ SINR \\ \alpha \cdot f(SINR)\ for\ SINR_{MIN} \leq SINR < SINR_{MAX} \\ \alpha \cdot f(SINR_{MAX})\ for\ SINR \geq SINR_{MAX} \end{cases} \quad (5)$$

TABLE II. BASE LINK LEVEL PERFORMACE FOR 5G NR

Parameters	Baseline
α, attenuation	0.6
$SINR_{MIN}$, dB	-10
$SINR_{MAX}$, dB	30

$SINR_{ACI}$ is influenced by the variable Adjacent Channel Interference Ratio (ACIR). The ACIR is calculated using Adjacent Channel Selectivity (ACS) and Adjacent Channel Leakage Ratio (ACLR), which means that the variable ACIR affects the throughput loss. The ACIR is derived by equation (5).

$$ACIR = \frac{1}{\frac{1}{ACLR} + \frac{1}{ACS}} \quad (5)$$

The blocking mask was configured using the ACS of the TN UE, as shown in Figures 3 and 4, and the emission mask was set using the ACLR of the NTN SAT[5].

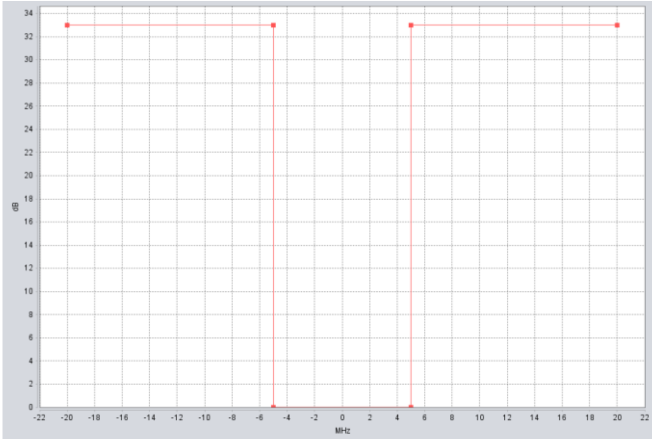

Fig. 3. Blocking mask of TN UE

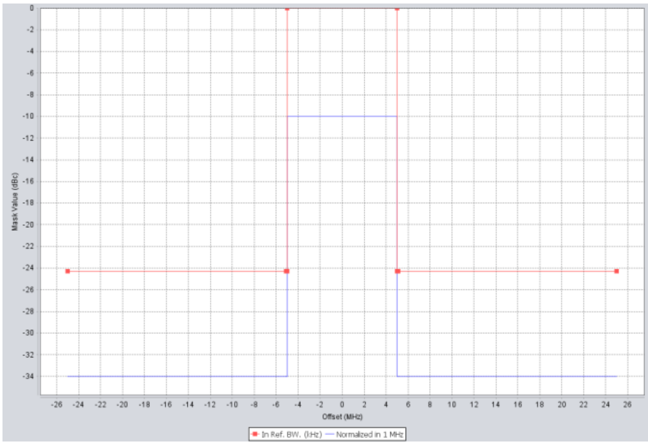

Fig. 4. Emission mask of NTN SAT

The average value of the throughput loss was derived from a total of 10,000 simulations, and the interference analysis simulations were conducted using the Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT), which is based on the Monte Carlo method.

III. PARAMETERS

The study was conducted under the assumption of an urban environment, with the satellite positioned directly above the nadir point.

TABLE III. NTN PARAMETERS

Characteristics	NR Non Terrestrial Network
Satellite altitude	LEO 600 km
Channel bandwidth	10 MHz
Noise figure	4.3 dB
Satellite EIRP density	34 dBW/MHz
Satellite max TX power	43.71 dBm(SCS 15kHz)
Satellite Tx max gain	30 dBi
3dB beamwidth	4.4127 deg
Satellite beam diameter	50 km
The number of active UE	1

TABLE IV. UE PARAMETERS

Characteristics	Handheld
Antenna type	Omni-directional
Rx antenna gain	0 dBi
Noise figure	9 dB
UE height	1.5 m

TABLE V. TN PARAMETERS

Characteristics	NR Terrestrial Network
Channel bandwidth	10 MHz
Network layout	3 sectors
Protection distance	400 m
Link-level performance model	Throughput-SINR mapping
Number of scheduled UE per sector	3
BS Antenna height	25 m
BS noise figure	5 dB
BS max TX power	46 dBm

IV. RESULT

The throughput was derived from a total of 10,000 simulations, and the average values of both no ACI throughput and ACI throughput were calculated. The throughput loss was then determined based on these average values. An average throughput loss of 2.736% was obtained, which does not meet the interference criterion of a 5% throughput loss. This indicates that no significant interference occurred.

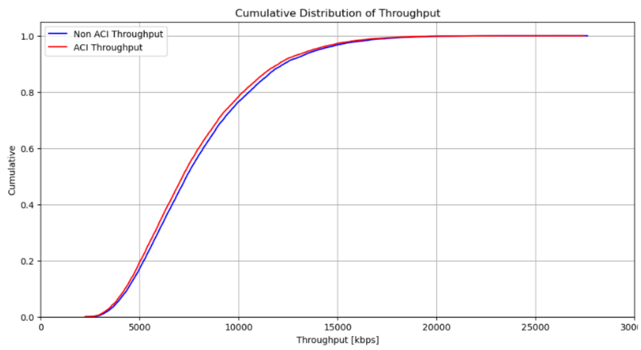

Fig. 5. Throughput between ACI result and no ACI result

V. CONCLUSION

In this paper, the interference analysis was conducted using a simplified scenario. Additionally, the protection distance was arbitrarily set, and the TN network layout was assumed to be a single cell. This cannot be considered a strict interference scenario, and the TN BS antenna did not apply beamforming. In future research, interference analysis will be conducted using a TN BS with an Active Antenna System applied. Additionally, the interference probability for different scan angles will be derived and compared with that of a non-AAS system to evaluate performance.

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REFERENCES

[1] Satellite 2.0: going direct to device, GSMA , March. 2022

[2] Non-Terrestrial Networks (NTN), Joern Krause, 3gpp, May. 2024

[3] 3GPP TR 38.863 v18.3.0. Solutions for NR to support non-terrestrial networks (NTN): Non-terrestrial networks (NTN) related RF and co-existence aspects, 3GPP, September. 2024

[4] 3GPP TR 38.803 v14.4.0. Study on new radio access technology: Radio Frequency (RF) and co-existence aspects, 3GPP, June 2024

[5] 3GPP TS 38.108 v18.3.0. Satellite Access Node radio transmission and reception, 3GPP, June. 2024