

Interference analysis between Maritime ESIM and 5G system in the 28GHz band

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Abstract— This paper evaluates the interference effects on the fifth generation (5G) wireless system from maritime earth stations in motion (ESIM) using the adjacent frequency band. We established the interference analysis scenario and analytic methodology considering real environment. And Monte-Carlo(MC) simulations is performed to evaluate interference effects on the 5G base station by a maritime ESIM in terms of average bitrate loss. As a result, we suggest the appropriate protection distance between 5G and the maritime ESIM to protect 5G system from interference due to the maritime ESIM transmission. Our result can be used to propose technical criteria for frequency sharing between two systems.

Keywords— 5G, Maritime ESIM, adjacent band interference, Monte-Carlo

I. INTRODUCTION

5th generation mobile network, 5G, are the next generation communication providing more than 1Gb per second faster speeds for various applications [1]. World Radiocommunication Conference (WRC)-15 identified the several millimeter wave (mmW) bands as a possible band for 5G wireless service

South Korea recently auctioned 5G frequency for 3.5 GHz, 28 GHz band and operators will launch the next-generation mobile technology in early 2019. In the 28 GHz range, which can support the very highest-speed services but offers poor coverage, three operators secured 800 MHz [2] of 26.5-28.9 GHz band.

WRC-15 decided to clarify that Earth Stations in Motion (ESIMs) can communicate with geostationary (GSO) FSS space stations using the 19.7-20.2 GHz (space-to-Earth) and 29.5-30.0 GHz (Earth-to-space) Ka-band radio frequency spectrum [3].

The ESIMs are one of the most latest satellite technology which can be used on ships, land vehicles and aircraft. They provided multiple spot beam coverage with high-power and also high-precision tracking capabilities with small size terminals using Ka band[4].

26.5-28.9 GHz band for South Korea's 5G service and 29.5-30.0 GHz band considering the earth stations in motion (ESIM) service are located in adjacent band. Therefore, the compatibility studies need to protect 5G mobile service from ESIM operating with geostationary FSS networks operating in the 29.5-30.0 GHz frequency band.

In the [5], the co-channel interference results from land vehicles ESIM to receiving Fixed Service station in 27.5-29.5

GHz frequency band considering the antenna pointing error was assessed.

The interference effect from maritime ESIM in 29.5-30.0 GHz to receiving 5G mobile service in 27.5-29.5 GHz frequency band was evaluated using the Minimum Coupling Loss (MCL) method in [6].

In this paper, we discuss interference effect on 5G mobile service in 26.5-28.9 GHz frequency band from maritime ESIM in 29.5-30.0 GHz. The scenario of maritime ESIM-into-5G base station only is considered because interference to the base stations is more serious than that to the user equipment. The adjacent band interference effect from maritime ESIM uplink to 5G base stations is analyzed via Monte-Carlo simulation based on beamforming model [7]. We provided a protection distance which is required between 5G system and a maritime ESIM to satisfy the acceptable interference criteria.

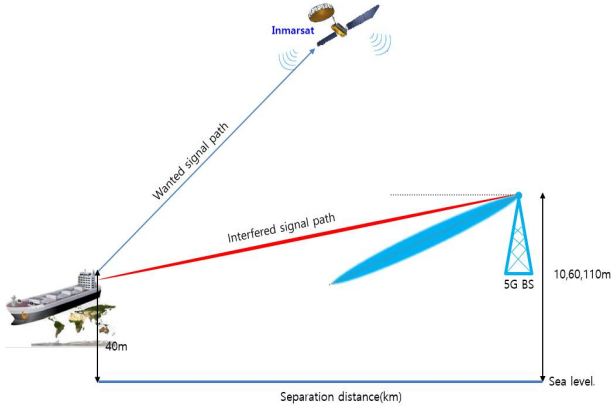
This paper is organized as follow. We discuss the interference scenario and analysis methodology for compatibility of maritime ESIM with 5G at 28 GHz band in section II. In section III, we described simulation parameters and evaluation results and in section VI, we draw conclusions.

II. INTERFERENCE SCENARIO AND ANALYSIS METHOD

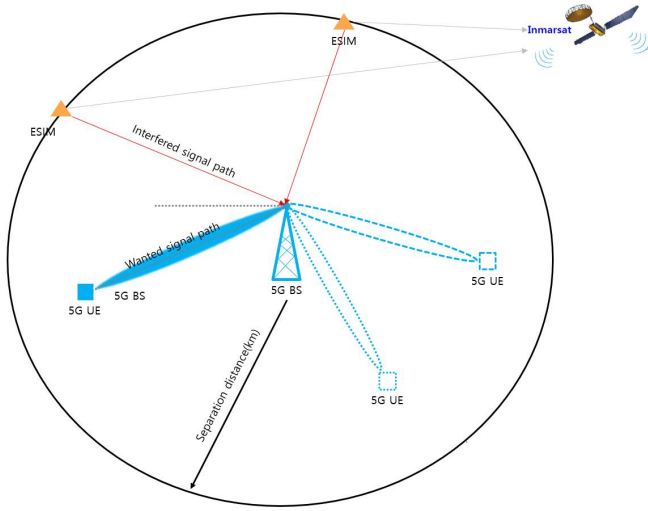
A. Scenario

There are two scenarios of interference, maritime ESIM – into-5G base station and maritime ESIM-into-5G user equipment. We focus only the scenario which maritime ESIM transmitting interferes into the 5G base station receiving, because ESIM-into-5G base station is more serious impact than ESIM-into-5G user equipment.

Figure 1 shows the scenario for interference analysis maritime ESIM into 5G system and describe a Monte Carlo evaluation of interference impact of maritime ESIM on the 5G base station. Maritime ESIM can be located randomly with uniform probability at the separation distance from 5G base station and connected to the fixed satellites for ESIM service.



(a) maritime ESIM and 5G system on vertical plane



(b) maritime ESIM and 5G system on azimuth plane

Figure 1. Interference scenario of maritime ESIM into 5G system

B. Analysis method

Figure 2 describes the proposed method to assess the interference effect into 5G base station based on the [7].

First, the parameters for 5G system and ESIM are specified including transmitting powers, antenna patterns, antenna pointing, antenna height, propagation model, separation distance etc. The next step generates 5G deployment which characterized by the random location between simulation radius and protection distance relative to the ESIM for current snapshot. And then UEs are randomly located within the sector, calculate the path loss with all BS and connect UEs to each BS with having the minimum path loss. The UE power control algorithm is specified in [8] and is applied with following parameters.

$$CL_{x-ile} = 88 + 10 \cdot \log_{10}(200 / X) \quad (1)$$

where X is uplink transmission bandwidth (MHz), the balancing factor for UEs(γ) is 1.

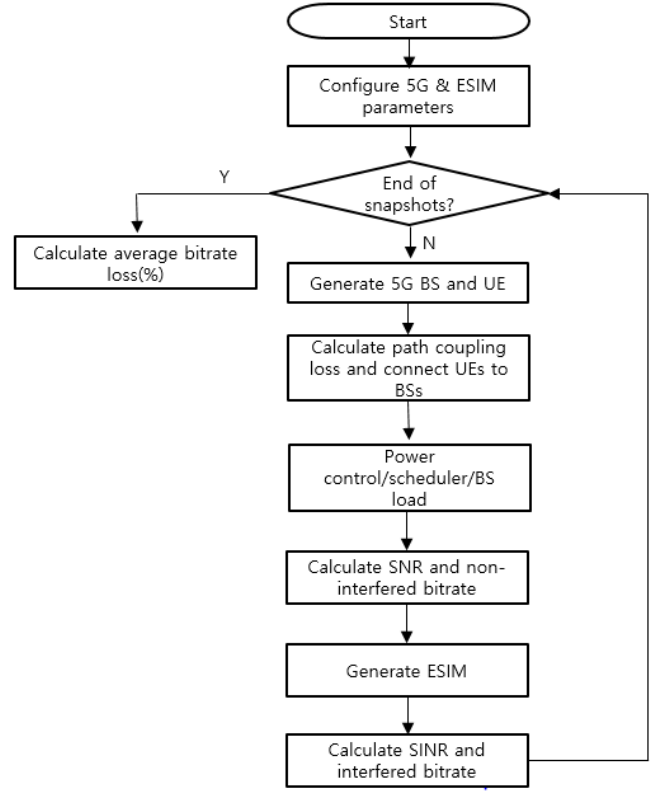


Figure 2. Interference analysis methodology from a maritime ESIM on 5G system

The bitrate can be approximated based on calculated SNIR as following [9]

$$Bitrate(SNIR), bps / Hz = \begin{cases} 0 & \text{for } SNIR \leq SNIR_{min} \\ \alpha \cdot S(SNIR) & \text{for } SNIR_{min} \leq SNIR \leq SNIR_{max} \\ \alpha \cdot S(SNIR_{max}) & \text{for } SNIR \geq SNIR_{max} \end{cases}$$

(2)

where $S(SNIR)$ is Shannon bound and it presents $S(SNIR) = \log_2(1 + SNIR)$ bps/Hz; α is attenuation factor representing implementing losses; $SNIR_{min}$ is minimum $SNIR$; $SNIR_{max}$ is maximum $SNIR$. The parameters α , $SNIR_{min}$ and $SNIR_{max}$ may be chosen to represent different link conditions and the value in [9] used.

The beamforming antenna gain between 5G BSs and UEs are given by [6,8].

$$G_{5G}(\theta_{BS}, \varphi_{BS}) = A_E(\theta_{BS}, \varphi_{BS}) + 10 \log_{10} \left(\left| \sum_{m=1}^{N_H} \sum_{n=1}^{N_V} w_{i,n,m} \cdot v_{n,m} \right|^2 \right)$$

(3)

Where $A_E(\theta, \varphi)$ is antenna element gain of the elevation and azimuth plane; the super position vector $v_{n,m}$ and the weighting $w_{i,n,m}$ are given by [7,9].

The average bitrate loss of 5G uplink due to ESIM interference signal is defined as follows:

$$\text{Average bitrate loss}(\%) = (1 - \frac{\text{interfered bitrate}}{\text{non_interfered bitrate}}) \times 100\% \quad (4)$$

where the non_interfered bitrate of the 5G is the calculated bitrate without the ESIM interference signal. And the interfered bitrate of the 5G is the bitrate along the ESIM interference signal.

III. INTERFERENCE ANALYSIS

A. Simulation parameter

Table I and II provide simulation parameters for the 5G BS/UE and ESIM, respectively. We performed 5000 snapshots and the 5G base stations beam is pointing to connected UE and a downtilt of 10° in elevation is assumed.

TABLE 1. PARAMETERS FOR 5G

Parameter	Value	
	Base station	User Equipment
Center frequency(MHz)	28800	
Channel bandwidth(MHz)	200	
Cell radius(m)	150	
Cell layout	1 cell (omni)	
Total Tx power (dBm)	-	23
Total antenna element	64(8×8)	4(2×2)
Antenna pattern	ITU-R M.2101	
Element gain(dBi)	5	
H/V 3dB beamwidth($^\circ$)	65	90
H/V front-of-back ratio(dB)	30	25
Antenna height above ground level(m)	10	1.5
Ground height above mean sea level	0, 50, 100	
H/V element spacing	$\lambda/2$	
Ohmic loss(dB)	3	
ACLR	27.5	
ACS	23.5	
Simultaneous UEs per BS	1	
Antenna tilt($^\circ$)	10	
Noise figure(dB)	10	-
Propagation model	P.452-16	

Figure 3 show the composite antenna pattern used in the simulation. The path loss between 5G BS and UE is calculated using Recommendation ITU-R P. 452-16 [12] and the percentage of time in the P.452-16 is constant of 50%. The path loss between 5G BS and maritime ESIM is calculated using Recommendation ITU-R P. 525-3 [13].

The antenna height of the 5G BS is assumed 10m above ground level and the mean sea level of 0m, 50m and 100m are considered.

TABLE 2. PARAMETERS FOR MARITIME ESIM

Parameter	Value		
Center frequency(MHz)	29500		
Spectrum mask[10]	Frequency band	EIRP limit	Measurement bandwidth
	1.0 GHz to 2.0 GHz	53 dBpW	1 MHz
	2.0 GHz to 3.4 GHz	59 dBpW	1 MHz
	3.4 GHz to 10.7 GHz	65 dBpW	1 MHz
	10.7 GHz to 21.2 GHz	71 dBpW	1 MHz
	21.2 GHz to 27.35 GHz	77 dBpW	1 MHz
	27.35 GHz to 27.50 GHz	85 dBpW	1 MHz
	27.50 GHz to 30.00 GHz	85 dBpW	1 MHz
	30.00 GHz to 31.00 GHz	85 dBpW	1 MHz
	31.00 GHz to 31.15 GHz	85 dBpW	1 MHz
31.15 GHz to 60.0 GHz	77 dBpW	1 MHz	
ESIM antenna height(m)	40		
ESIM EIRP[11]	Angle θ °	Maximum e.i.r.p. per 40kHz ρ	
	$2^{\circ} \leq \theta \leq 7^{\circ}$ °	$(19 - 25 \log \theta)$ dB(W/40 kHz) ρ	
	$7^{\circ} < \theta \leq 9.2^{\circ}$ °	-2 dB(W/40 kHz) ρ	
	$9.2^{\circ} < \theta \leq 48^{\circ}$ °	$(22 - 25 \log \theta)$ dB(W/40 kHz) ρ	
	$48^{\circ} < \theta \leq 180^{\circ}$ °	-10 dB(W/40 kHz) ρ	
Elevation angle(°)	5°, 10°, 20°		

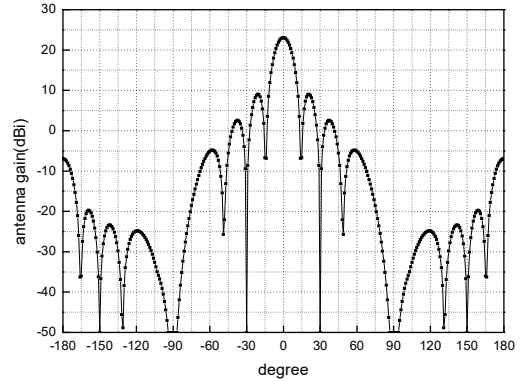


Figure 3. 5G BS composite antenna pattern_azimuth.

B. Simulation results

Figure 4 shows average bitrate loss of 5G base station versus separation distance. It show the result for various elevation angles of 5° , 10° and 20° assumed the antenna height of the 5G BS is 10m above ground level and the mean sea level of 50m. The results show that if the elevation angle of the maritime ESIM is smaller, average bitrate loss has larger value.

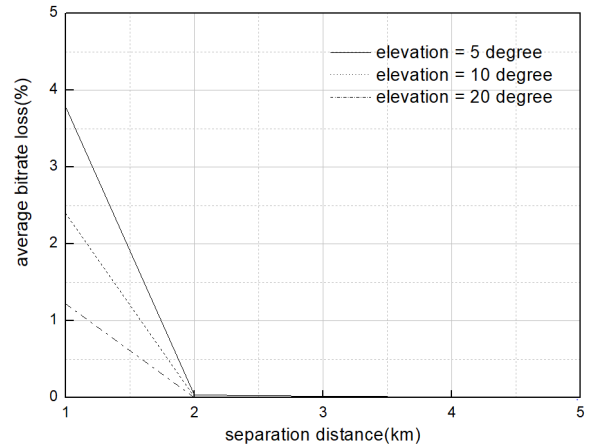


Figure 4. Result I - average bitrate loss vs Separation distance.

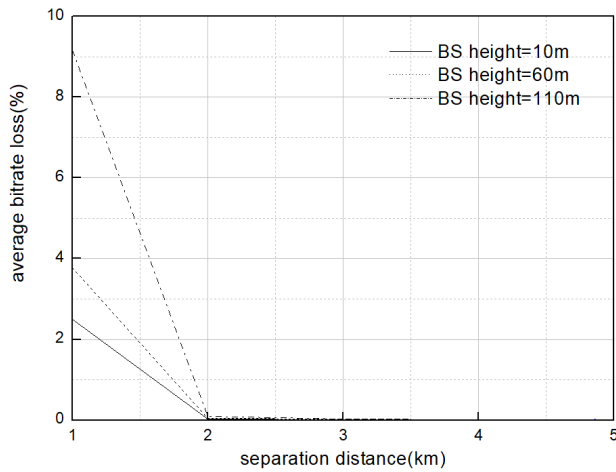


Figure 5. Result II - average bitrate loss vs Separation distance.

We assumed 5% average bitrate loss as the interference protection criterion and the results of all elevation angle with BS height of 60m considered satisfy given the 5% interference protection criterion target for the separation distance of 1km.

Figure 5 presents average bitrate loss of 5G base station versus separation distance for the various base station antenna height with the elevation angle of 5° for the maritime ESIM. The results show that if the antenna height of the 5G BS is higher, average bitrate loss has higher value. The protection distance is more than 1.5km to satisfy less than 5% average bitrate loss.

IV. CONCLUSIONS

An analysis of interference scenarios between 5G and maritime ESIM in the 28 GHz band was performed in this paper. Only the scenario of maritime ESIM into 5G base station of adjacent band interference was considered. Monte-Carlo simulation considering 5G's beamforming model was performed and ITU-R P. 525 model was used to calculate the propagation loss between 5G BS and maritime ESIM.

From the result, we confirmed that a protection distance more than at least 1.5km is required to satisfy interference protection criterion of the 5G base station with various

parameter for maritime ESIM. And the required separations can be varied to 5G system deployments and the maritime ESIM characteristics like as elevation angle or antenna pattern.

Our results can be useful for technical criteria of frequency sharing between 5G system and maritime ESIM in the 28 GHz band.

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