Radio Sensor Detection of Interference to Satellite Earth Station in Frequency Spectrum Sharing

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***Abstract*—In recent years, the growing demand for wireless communications has led to the depletion of frequency resources. Frequency sharing technology is attracting attention as a solution to this problem. Dynamic frequency sharing is a mechanism whereby one frequency band is used by multiple systems in different time and space. Beyond5G is considering sharing the millimeter wave band with satellite communications, and if it becomes clear that this frequency resource can also be allocated and used for mobile communications systems, expectations for frequency sharing will increase. The expectation for frequency sharing will increase when it becomes clear that this frequency resource can be allocated and used for mobile communication systems. In the dynamic frequency sharing, the first priority is to protect existing systems that have already been issued radio station licenses. Technology is needed to ensure that radio waves emitted by the secondary system do not interfere with primary systems, and among these is sensing technology to detect interference from the secondary system. When the secondary system's interference is detected by this technology, the administrator of the secondary system is notified and the transmission of the secondary system is stopped. Assuming that the new space exploration satellite communication is used for the primary system and the 5G system is used for the secondary system, the application of radio sensors to deep space exploration satellite communication is assumed.**

In this paper, focusing on the sensing technology of interference detection, we assume dynamic frequency sharing between space exploration communications and ground systems, and propose a radio sensor to detect interference from the ground system to the satellite exploration ground station.

***Index Terms*—spectrum sharing, frequency sharing, satellite communication, wireless communication, secondary system**

I. INTRODUCTION

Frequency sharing with satellite communications is being considered for Beyond5G [1]. In this paper, we propose a radio sensor to detect interference from ground systems to satellite ground stations, assuming frequency sharing between space exploration satellite communications and ground systems.

II. TRENDS IN FREQUENCY SHARING BETWEEN SATELLITE COMMUNICATIONS AND TERRESTRIAL SYSTEMS

Frequency sharing between different systems is being actively studied [1] [2]. Frequency sharing methods can be broadly classified into database type and sensing type. TableI shows the characteristics of each type. In the database type, the primary system registers usage information in a database and performs interference calculations based on that information, and the secondary system uses the time- and space-available resources. In particular, when satellite communication is the primary system, satellite movements and positions are planned and interference calculations are easy. However, detailed operational information must be registered from the primary system to the secondary system or database. On the other hand, when the secondary system is a mobile station, the accumulated interference caused by multiple radio stations radiating simultaneously increases the interference power. Therefore, depending on the number of radio stations assumed in the interference calculation, there is a concern that unexpected interference may occur and that frequency resources may be used less efficiently due to excessive radio frequency outages.

On the other hand, the sensing type deploys radio sensors that specialize in observing the received electric field strength of spatially emitted radio waves over an area to observe or accurately predict interference to the protected object. In the U.S. CBRS, sensors are installed in coastal areas and used for secondary system control because they are shared with naval radars and it is impossible to know operational information [2]. Furthermore, it was decided to share the communication frequency with the National Oceanic and Atmospheric Administration's (NOAA) meteorological satellites, but NOAA required sensing protection due to the possibility of cumulative interference [1]. A prototype frequency monitoring system has been implemented and verified accordingly [3].

III. DETECTION OF INTERFERENCE TO SATELLITE EXPLORATION GROUND BASE STATIONS BY RADIO WAVE SENSOR

In this paper, assuming frequency sharing between satellite ground stations and ground systems, radio sensors are deployed to detect interference from ground systems (mobile terminals, UAVs, etc.) to the satellite ground stations.

When using radio sensors for detection, it is necessary to capture the noise level interference in the protected object. In particular, satellite communications often use high-gain antennas, and if a sensor is installed at the same location as the protected object, it is necessary to install a sensor of equal or greater gain. On the other hand, by installing multiple sensors at a distance from the protected object and designing them so that the path loss ensures that they fall below the

TABLE I
FEATURES OF DATABASE TYPE AND SENSING TYPE

	Database type	Sensing type
Application Examples	2.3GHz FPU (Japan)	CBRS(USA) , NOAA Satellites(USA)
Primary System Burden	× : Need to provide detailed information	◎ : Minimum
Costs	◎ : Database construction and maintenance	× : Sensor Installation and maintenance
Primary System Protection	△ : Insufficient response to unforeseen interference such as cumulative interference	◎ : Certain to capture actual interference
Secondary System	△ : Control by interference calculation	○ : Control upon detection of interference
When secondary systems increase	△ : Increased interference calculations	○ : Almost no change

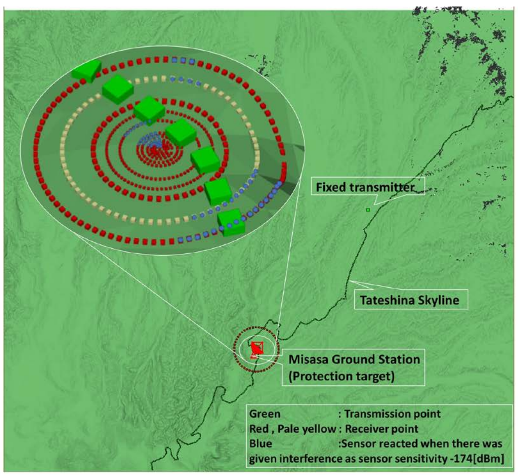

Fig. 1. Protected object and Tateshina skyline, sensor placement

noise level, the detection sensitivity of the sensors can be reduced. However, the power fluctuates due to shadowing caused by the presence of obstructions around the satellite station. To ensure reliable detection, spatial diversity is used to improve detection accuracy by assuming the simultaneous use of multiple radio sensors. In this study, the relationship between sensor sensitivity, the distance between the sensor and the protected object, and the number of required sensors is evaluated by ray-tracing simulation.

IV. SIMULATION OVERVIEW

Wireless InSite was used to analyze the radio propagation status of about 16[km] $\times$ 17[km] around the JAXA Misasa Deep Space Station in Saku City, Nagano Prefecture, Japan, as the protection target. The protected area, transmission points, and sensor locations are shown in Fig.1. The red icon shows the protected area, Misasa ground station, and the dark green line shows the Tateshina skyline. The transmitter is assumed to move along the Tateshina skyline, which passes near the protection target, and to account for accumulated interference,

TABLE II
SIMULATION PARAMETERS

	Transmitter	Protection target	Sensors
Transmission power	23[dBm]	-	-
Allowable Interference Power	-	-173 [dBm/100MHz]	-
Transceive point interval	50[m]	-	5〜100[m]
Height above ground	2[m]（Fixed transmitter only 100[m]）		
Center frequency	32[GHz]		
Frequency Bandwidth	100[MHz]		
Reflections Transmissions Diffractions	6[times] 1[time] 2[times]		

TABLE III
CONCENTRIC SENSOR ARRANGEMENT

Radius from protected target [m]	Sensor-to-sensor spacing [m]	Number of sensors per circle [pieces]
5	5	6
6	5	7
8	5	10
10	5	12
14	5	17
20	5	25
25	5	31
45	5	56
60	5	75
75	10	47
110	10	69
140	10	87
750	100	47

an additional transmitter assuming a UAV is fixed at a single point 100[m] above the target, where the interference by itself is less than the noise of the protection target. The sensors were placed at unequal intervals within a radius of 5 m to 750 m, centered on the protected object, in a total of 13 concentric circles. The output power of the transmitter was always constant, and the directivity of the protected object was not considered, and omni-directional antennas were assumed for both the transmitting point and the protected object.

The Tateshina skyline is moved one transmitting point at a time from the top right to the bottom left of Fig.1, and the interference power to the protected object and sensor is calculated at all points on the Tateshina skyline to determine the presence or absence of interference and the detection status of the sensor throughout the entire Tateshina skyline. At this time, there are always two transmission points because the fixed transmitter is also transmitting. This interference calculation is performed by varying the sensor sensitivity from -180[dBm] to -108[dBm] to evaluate the relationship between the number of sensors and the radius required for detection.

V. SIMULATION RESULTS

Simulation parameters are shown in Tables II and III.

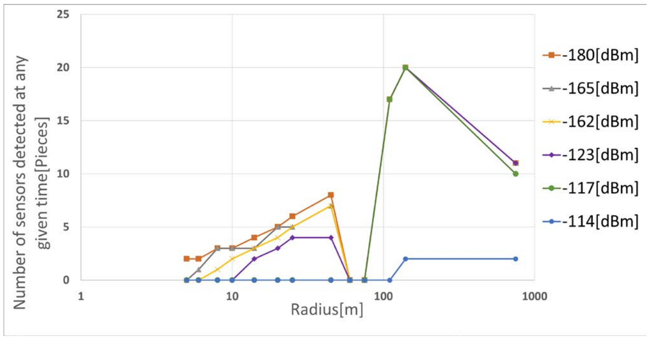

Fig. 2. Number of sensors that always detected when there was interference

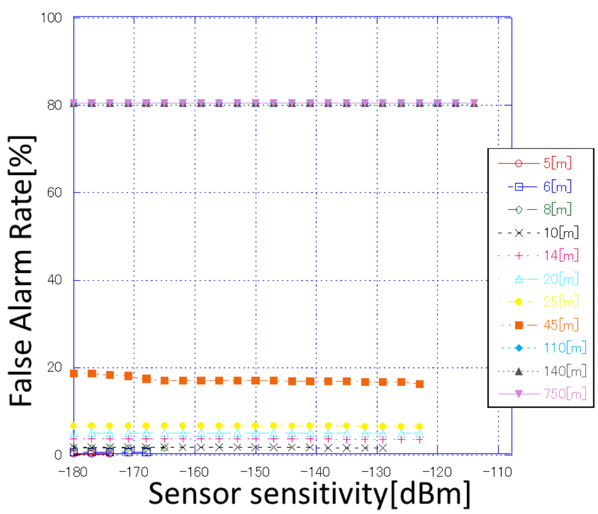

Fig. 3. Variation of false alarm rate with sensor sensitivity

If any one of the sensors responds when the protected target is interfered with, it was found that only one sensor is needed, regardless of the sensor sensitivity.

Fig. 2 shows a graph summarizing the number of sensors that always respond when the protected target is interfered with. The number of sensors decreases as the sensor sensitivity is decreased, but by increasing the radius, two or more sensors can always be detected. As an example, the blue dots in Fig. 1 show the sensor positions that always responded when the protected target received interference at a sensor sensitivity of -174[dBm].

Next, false alarms, in which the sensor reacts even if the protected object is not subject to interference, are evaluated. The false alarm rate was defined as the percentage of false alarms among all transmission points on the Tateshina skyline. Fig. 3 shows the change in the false alarm rate depending on sensor sensitivity. The false alarm rate is based on the assumption that there is no interference because the data is limited to the case where two or more sensors responded when interference occurred. Fig. 3 shows that the false alarm rate increases to about 80% as the radius increases, but when the radius is reduced to 10[m], the false alarm rate decreases to about 1.56% at a sensor sensitivity of -129[dBm].

The above results show that it is possible to reliably detect interference to the protected object while also suppressing false alarms and improving accuracy through spatial diversity by utilizing multiple sensors.

Acknowledgment

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References

[1] CSMAC (2013). Final report: Working group 1 – 1695–1710 MHz Meteorological-Satellite. Tech. rep., Commerce Spectrum Management Advisory Committee. (“WG-1 Report”)

[2] Ryo SAWAI ”Current status and its future advanced solutions of database control & management in dynamic spectrum sharing/access techn”, IEICE Technical Report SR2020-46(2020-11) , 2020 , p152-158

[3] P. Amirshahi , P. Ransom, S.Grippando, and I. Navarro ,“Comparison of Centralized and Distributed Spectrum Monitoring Methods for Enabling Spectrum Sharing Between Weather Satellites and Terrestrial Networks”, DySPAN , Dec.2019