A new incumbent protection method based on three-dimensional beamforming for dynamic spectrum access

Keita Onose¹, a) Hiroto Kuriki¹, Ryota Kimura¹, and Ryo Sawai¹
¹ Sony Corporation, 1-7-1 Konan Minato-ku, Tokyo, 108-0075 Japan
a) Keita.Onose@sony.com

Abstract: In this letter, we propose a new incumbent protection method that considers three-dimensional (3D) aspects of 5G beamforming characteristics in dynamic spectrum access (DSA). We show some computer simulation results in which fixed wireless access (FWA)-based primary system (PS) and 5G-based secondary system (SS) were assumed to be deployed in a 26 GHz band. The results show that the proposed method can increase allowable transmission power of the SS by considering the 3D beamforming aspects, and that PS and SS height deployment information can additionally bring benefits to the proposed method in terms of the allowable transmission power in DSA.

Keywords: dynamic spectrum access, incumbent protection, spectrum management/access system, beamforming, transmission power control

Classification: Wireless Communication Technologies

References

[1] M.M. Sohul, M. Yao, T. Yang, and J.H. Reed, “Spectrum access system for the citizen broadband radio service,” IEEE Commun. Mag., vol. 53, no. 7, pp. 18–25, July 2015. DOI: 10.1109/MCOM.2015.7158261

[2] K. Yamazaki, et al., “A proposal of dynamic spectrum sharing architecture between different radio services and 5G system,” IEICE Technical Report, vol. 119, no. 449, pp. 41–46, March 2020 (in Japanese).

[3] “Frequency reorganization action plan (FY2020 second revision),” Ministry of Internal Affairs and Communications (MIC), Tokyo, Japan, https://www.soumu.go.jp/main_content/000704672.pdf, Nov. 2020 (in Japanese).

[4] Wireless Innovation Forum, “Requirements for commercial operation in the U.S. 3550-3700 MHz citizens broadband radio service band,” WINNF-TS-0112 Version V1.9.0, Dec. 2019.

[5] ITU-R, “Liaison statement to Task Group 5/1 - Spectrum needs and characteristics for the terrestrial component of IMT in the frequency range between 24.25 GHz and 86 GHz,” Feb. 2017.

[6] 3GPP, “TR 38.901 Study on channel model for frequencies from 0.5 to 100 GHz,” Jan. 2020.
1 Introduction

Dynamic spectrum access (DSA) technology has attracted much attention as one of core technologies to solve a spectrum/frequency resource shortage problem for the 5G/Beyond-5G evolution. DSA allows unused spectrum resources that are primarily allocated to existing wireless systems (Hereinafter referred to as primary systems (PSs)) to be used by different wireless systems (Hereinafter referred to as secondary systems (SSs)) in a secondary use manner. The SSs have to coexist with the PSs in the same spectrum resources without causing harmful interference. In DSA, spectrum management systems, also known as interference coordination systems, spectrum access systems, geolocation databases, and so on, have been introduced to control such coexistence and interference coordination. Those network entities and their relevant legislation, standardization, and proof of concept activities have been conducted worldwide [1].

In Japan, the Ministry of Internal Affairs and Communications (MIC) has formulated an action plan for frequency reorganization [2, 3]. In the plan, the MIC aims at DSA for the 5G systems in a 26 GHz band, which is primarily assigned to fixed wireless access (FWA). However, since the SS is based on 4G Long Term Evolution (LTE) in the existing studies and standardizations of DSA, the conventional interference coordination methods, also called as incumbent protection methods, have never considered any kind of the 5G New Radio (NR) features which are used in the 5G-based SSs. For instance, beamforming is a major 5G feature, but is not taken into account in the conventional incumbent protection methods [4].

To explore a more advanced DSA towards the 5G era, we propose a new incumbent protection method in this letter. The proposed method considers three-dimensional (3D) aspects of the 5G NR beamforming characteristics. We show some computer simulation results in which FWA-based PS and 5G-based SS were assumed to be deployed in a 26 GHz band. The results show that the proposed method can increase allowable transmission power of the SS by using the 3D beamforming aspects in DSA.

2 Incumbent protection method

2.1 System model of DSA [4]

In DSA, a spectrum management system communicates with an SS base station (SSBS) to obtain operational parameters of the SSBS such as 3D position information, upper limit of transmission powers, and antenna configurations. The spectrum management system also obtains operational parameters from PS directly or via other network entities such as a database managed by government or a public institution. The operational parameters of the PS also include 3D positions, moving areas, acceptable interference power thresholds, antenna configurations, operating dates and times, and so on. Then the spectrum management system conducts the incumbent protection and dynamically determines radio parameters of the SSBS, e.g. allowable transmission powers and frequency channels, by using the operational parameters and radio propagation models, so as not to cause harmful interference from the SS to the PS.
2.2 Problem of conventional method

In protecting a target PS station (PSS) from harmful interference, a conventional method attempts to find a single allowable transmission power for all beam patterns of an SSBS so that an interference power from the SSBS to the PSS is less than a certain threshold [4]. This single allowable transmission power assumes the worst-case interference to the PS and may be a very small value. That is, the conventional method is difficult to provide a sufficient coverage and signal quality even with using beamforming.

2.3 Proposed method

To ensure both incumbent protection and beamforming enhancement even when the SSBS is based on 5G NR, our proposed method aims at two things: (a) to calculate allowable transmission power per beam pattern per radio station, and (b) to increase allowable transmission powers of beam patterns which will not cause any harmful interference to the PS.

Figure 1 illustrates a geolocation model for calculating an allowable transmission power with a beam pattern in the proposed method. For simplicity, let us assume one PSS, one SSBS, and one secondary system user equipment (SSUE). A total $K$ beam patterns are available at the SSBS. The SSBS selects a beam pattern whose peak gain is in the direction of the SSUE. $\theta_{ZoD}$ and $\phi_{AoD}$ represent zenith and azimuth angles of departure (ZoD and AoD) from the SSBS to the SSUE. $\theta_{PS}$ and $\phi_{PS}$ represent ZoD and AoD from the SSBS to the PSS. $\theta_{SS}$ and $\phi_{SS}$ represent zenith and azimuth angles of arrival (ZoA and AoA) at the PSS from the SSBS. When the SSBS uses the selected beam pattern, an interference power to the PSS $I$ (dBm) can be expressed as follows:

$$ I = P_{SS} + G_{SS}(\theta_{ZoD}, \phi_{AoD}, \theta_{PS}, \phi_{PS}) - L_{SS\rightarrow PS} + G_{PS}(\theta_{SS}, \phi_{SS}). \quad (1) $$

where $P_{SS}$ (dBm) and $L_{SS\rightarrow PS}$ (dB) are a transmission power of the SSBS and a propagation loss from the SSBS to the PSS, respectively. Also, $G_{SS}(\theta_{ZoD}, \phi_{AoD}, \theta_{PS}, \phi_{PS})$ (dB) is the selected beam pattern’s gain of the SSBS in the direction of $\theta_{PS}$ and $\phi_{PS}$, and it’s peak gain is in the direction of $\theta_{ZoD}$ and $\phi_{AoD}$. Similarly, $G_{PS}(\theta_{SS}, \phi_{SS})$ (dB) is an antenna gain of the PSS in the direction of $\theta_{SS}$ and $\phi_{SS}$.

![Fig. 1. Geolocation model for the proposed method.](image-url)
To keep the interference to the PSS below an acceptable interference power $I_{\text{Threshold}}$ (dBm), the allowable transmission power of the SSBS’s selected beam pattern $P_{SS}$ can be finally calculated as follows:

$$P_{SS} = I_{\text{Threshold}} - G_{SS}(\theta_{\text{AoD}}, \phi_{\text{AoD}}, \theta_{PS}, \phi_{PS}) + L_{SS\rightarrow PS} - G_{PS}(\theta_{SS}, \phi_{SS}). \quad (2)$$

### 3 Performance evaluation

#### 3.1 Simulation parameters

In our simulations, we considered an FWA radio station as PSS, and a 5G small cell base station as SSBS, respectively, in a 26 GHz frequency band. For the PSS, a center frequency was 26.5 GHz, a bandwidth was 58.5 MHz, an Rx antenna gain was 6.5 dBi, and an acceptable/allowable interference power was $-96.8$ dBm [5]. For the SSBS, a center frequency was 26.5 GHz, a bandwidth was 100 MHz, and an upper limit of transmission power was $5 \text{ dBm/MHz}$ [5]. We assumed that the SSBS was equipped with 16 (4$\times$4), 64 (8$\times$8), and 256 (16$\times$16) element antenna arrays, in which an element spacing was set to a half wavelength and each element gain was 5 dBi. The beam patterns of the SSBS were calculated using a formula given in 3GPP TR38.901 [6, Section 7.3] for both azimuth and zenith angles. The beam pattern moves every 1 degree in a range of $-60$ to 60 degrees horizontally and 30 to 150 degrees vertically. The radio propagation model is free-space path loss model. A distance between the PSS and the SSBS $d$ was 100 meters. The PSS’s height $h_{PS}$ was set to 18, 32 and 46 meters. The SSBS’s height $h_{SS}$ was set to 6 meters. That is, the PSS and SSBS were deployed at different height levels each other. We also considered availability of the height information, which affected the assumed zenith direction from the SSBS to the PSS $\theta_{PS}$ in (1) and (2). When the height information was available, $\theta_{PS}$ was set to $\tan^{-1}[d/(h_{PS}-h_{SS})]$. Otherwise, $\theta_{PS}$ was fixed to 90 degrees, which means that PSS and SSBS were assumed to be deployed at the same height. The azimuth direction from the SSBS to the PSS $\phi_{PS}$ was set to 0.

#### 3.2 Comparison of allowable transmission power

Figure 2 compares the allowable transmission powers of the SSBS calculated by the conventional and proposed methods with the different numbers of antenna elements and the height of the PSS was set to 18m. In Figs. 2(a), 2(c), and 2(e), the SSBS was assumed to transmit its radio waves in the azimuth angle from $-60$ to 60 degrees while the zenith angle was fixed to the PSS. In both the conventional and proposed methods, their own worst-case allowable transmission powers appeared at the azimuth direction equivalent to $\phi_{PS}$ to protect the PSS from the SSBS interference. In the conventional method, the worst-case allowable transmission power was also applied to all beam patterns in common. Therefore, the conventional method resulted in constant and very low transmission powers regardless of $\phi_{\text{AoD}}$. Moreover, the conventional method could not improve the allowable transmission powers even by using the height information of the PSS and SSBS. In terms of the numbers of the antenna elements, the conventional method resulted in lower allowable transmission powers when the number was large, because of the higher peak beam gain and the worst-case calculation. On the other hand, the proposed method dramatically increased the allowable transmission powers, e.g. by up to 60 dB in Fig 2(e), thanks...
to the per-beam-pattern calculation. The proposed method brought this advantage particularly in the azimuth angle ranges far from 0 degree (i.e. $\phi_{PS}$). Additionally, by utilizing the height information, it further improved the allowable transmission power, e.g. by up to 15 dB in Fig 2(e). Furthermore, when the number of the antenna elements became large, the proposed method increased the allowable transmission powers in contrast to the conventional one. This result implies that the gain of the per-beam-pattern calculation is promising more in the 5G-based SSs with massive MIMO (multiple input multiple output) antenna configurations.

In Figs. 2(b), 2(d), and 2(f), the SSBS was assumed to transmit its radio waves in the zenith angles from 30 to 150 degrees while the azimuth angle was fixed to the PSS. Similarly to Figs. 2(a), 2(c), 2(e), both the conventional and proposed methods showed their own worst-case allowable transmission powers at the zenith direction equivalent to $\theta_{PS}$. And also, the conventional method could not gain the

Fig. 2. Comparison of the allowable transmission powers at SSBS with the different numbers of antenna elements.
allowable transmission powers in the zenith angles. Note that the proposed method also resulted in very low allowable transmission powers which were equal to those of the conventional method when the height information was unavailable. On the other hand, the proposed method improved the allowable transmission powers by utilizing the height information. It means that the height information is useful to avoid the worst-case incumbent protection and to gain the benefits of the SSs’ beamforming in both the azimuth and zenith angles.

Figure 3 compare the allowable transmission powers of the SS calculated by the conventional and proposed methods with the different heights of the PSS. The number of antenna elements was set to 256 (16×16). The proposed method improved the allowable transmission powers by utilizing the height information particularly when the height of the PSS was higher, or when the height differences between the PSS and SSBS was larger. Figure 3 implies that the proposed method has an advantage in practical situations in the 26 GHz band because FWA stations would be typically deployed at very high locations like roofs of buildings.

4 Conclusion

In this letter, we proposed an advanced incumbent protection method considering the SS’s beamforming capabilities. The simulation results show that the proposed method can increase the allowable transmission power of the SS. It implies that the proposed method can make use of the benefits of the beamforming in improving network coverages and signal qualities of the SS in DSA.
Acknowledgments

This research is supported by the Ministry of Internal Affairs and Communications in Japan (JPJ000254).