Interference Mitigation using Adaptive Beamforming with RLS Algorithm for Coexistence between 5G and Fixed Satellite Services in C-Band

C B Muhammad¹ and K Anwar²

¹,²The Center for Advanced Wireless Technologies (AdWiTech), Telkom University, Jl. Telekomunikasi No. 1, Terusan Buah Batu, Bandung, Indonesia

Abstract. Smart antenna system is one of the most suitable techniques making the sharing between incumbent Fixed Satellite Services (FSS) and the Fifth Telecommunication Generation (5G) possible, because adaptive beamforming can make null the beam towards the FSS earth station. This paper proposes the use of Recursive Least Square (RLS) algorithm for adaptive beamforming in 5G Base Station (BS) having a null beam toward FSS earth station. We perform a computer simulation to evaluate the proposed RLS algorithm and compare the result in terms of separation distance between FSS earth station and 5G BS with and without RLS algorithm. The results confirmed that the RLS algorithm for adaptive beamforming makes the coexistence between 5G and FSS possible indicated by the significant reduction of separation distance between FSS earth station and 5G BS leading to the minimum interference of 5G BS to the FSS earth station.

1. Introduction

The radio frequency (RF) spectrum is a limited natural resource and currently growing on demand, of which the amount of availability is not increasing. The strategic and substantial value of limited natural resource for the national and international interest is on the interests of the increase of effectiveness, productivity, the quality of life and prosperity of the community.

While the wireless data traffic demand is increasing every year [1], the available spectrum is still not enough to meet the demand of the data traffic. This situation occurs because the growth of available spectrum does not match with the growth of the data traffic. Meanwhile, the emerging wireless technology, called the fifth telecommunication generation (5G), wireless network has arrived. The technology aims to meet and implement some new services such as three-dimensional (3D) entertainment, Car-to-X communication [2][3], and high definition augmented reality video streams application such as gaming entertainment, and industry revolution 4.0 factories requiring a broad range of bandwidth-hungry services [4]. It is also predicted that by 2020 around 50 billion internet of thing (IoT) devices will serve the community [5].

The demand of communication of wireless depends heavily on the spectral efficiency and bandwidth as stated by the Shannon capacity. Almost all technologies using wireless spectrum are operating in 300 MHz to 3 GHz band [6]. Since the technology of physical layer has already touched Shannon capacity [7], the remaining unexplored option in this case is the system bandwidth. Therefore, the key enabler of 5G wireless networks is left on exploration of high frequency mm Wave band starting from 3 GHz until 300 GHz.

Global System for Mobile Communications Association (GSMA) stated that 5G needs spectrum within three key frequency ranges, namely (i) sub-1 GHz, (ii) 1-6 GHz, and (iii) above 6 GHz. The
System Model

We consider as system model of coexistence between 5G and FSS as illustrated in Figure 1. Before we apply the adaptive beamforming, we evaluate the impact when the C-band is used by two wireless services, i.e., FSS and 5G, simultaneously. First, we use margin calculation using a method acknowledged by International Telecommunication Union (ITU) as C/I method. We use C/I calculation for interference assessment in space services according to the parameters from ITU. The result of margin (M) calculation is used to indicate whether the interference received by the 5G is acceptable or not. If the margin M below zero or negative, the two services cause harmful interference to each other. If the margin M is zero or positive, the two services do not cause harmful interference. The margin M is calculated as

\[ M = \frac{C}{I} - \frac{C}{I_{\text{required}}} \]  

where \( \frac{C}{I} \) is carrier to Interference (dB) and \( \frac{C}{I_{\text{required}}} \) is single-entry interference protection criteria.

First, we must calculate \( \frac{C}{I_{\text{required}}} \). To calculate this variable, we must find \( \frac{C}{N} \) of the satellite.

On the other hand, the current use of the C-band varies between countries, which are mainly used for fixed satellite services (space-to-earth) [12]. The Fixed Satellite Services (FSS) applications in the 3.4-4.2 GHz range are, for example, wide diameter earth station serving as a teleport carrying feeder links to and from satellite space stations, Telemetry Tracking and Command (TTC) stations used for communication between satellite and the ground system, Very Small Aperture Antenna (VSAT) used primarily for business such as banking, Automatic Teller Machine (ATM) or other payment technologies that require high availability including military and government applications, Direct-to-Home (DTH) and Television Receive-only (TVRO) [9].

Spectrum sharing means that the use of the same frequency band by different systems or services. The use of the same frequency band needs to coexist without causing any harmful interference to the other devices in different services. The possible way to sharing between different services is through well-defined limitations and technical requirements to enable sharing capabilities [13].

To achieve sharing between FSS and 5G, we propose a smart antenna technology for 5G systems based on adaptive beamforming. Smart antenna technologies are best suited with an overall system approach. A smart antenna is an array of antenna elements connected to a digital signal processor combining individual antenna elements and signal processing algorithms. It is the most effectively leading innovation for maximum coverage, more capacity, and improved quality. Its system forms narrower beam toward Signal of Interest (SOI) and nulls toward interfering signal or Signal Not of Interest (SNOI) with adaptive beamforming techniques [10].

Adaptive beamforming techniques actively dynamic reshape the array pattern to optimize some characteristics of the received signal. In the proposed smart antenna, the adaptive beamforming can minimize interference of 5G signal to the FSS earth station, such that the FSS is free from the harmful interference. The output of the array is the weighted sum of the transmitted signals having gain patterns and the thermal noise from receivers. In adaptive systems, the weights are iteratively determined based on the array output [11].

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However, in this paper we only calculate $C/N$ downlink because the frequency used in coexistence scheme is in FSS downlink.

We calculate $C/N$ downlink is

$$
C/N = P_{\text{Sat Max}} + G(\theta)_{\text{TX Sat}} + G_{\text{RX Es Max}} - FSL_{\text{Downlink}} - (k + T_{\text{ES}} + B) \ (dB).
$$

The specification of the satellite space services, ground services, 5G BS and 5G User Equipment (UE) provided in Table 1.

| Parameter                     | Value  |
|-------------------------------|--------|
| Diameter Satellite Antenna    | 4 meter|
| Diameter ES Antenna           | 1.2 meter|
| Power Satellite Antenna       | 10 dBW |
| Free Space Loss               | 194.58 dB |
| Noise                         | -114.79 dB |

Table 1. Satellite space and ground service specification.

| Parameter       | Value  |
|-----------------|--------|
| BS Power        | 24 dBm |
| Gain Tx BS      | 20 dB  |
| Gain UE         | -69 dB |
| Noise           | -114.79 dB |

Table 2. 5G BS and UE specification.

After calculating $C/N$, we calculate the $C/I_{\text{required}}$ from $C/N$. To calculate $C/I_{\text{required}}$, we use the methodologies shown by Table 2 in Section B3 of Rules of Procedures (RoP) and ITU-R S.741-2.

| Interfering Wanted | TV/FM or Other | Digital | Analogue (Other than TV/FM) |
|--------------------|----------------|---------|-----------------------------|
| TV/FM              | $C/N + 14 \ (dB)$ |         |                             |
| Digital            |                 | $C/N + 12.2 \ (dB)$  |
| Analogue (other than TV/FM) | $11.4 + 2*\log(BW)$ (dB) | $C/N + 12.2 \ (dB)$ |
| Other              | $11.4 + 2*\log(BW)$ (dB) | $C/N + 14 \ (dB)$ |
With $BW_W$ is necessary bandwidth of wanted carrier in MHz and $BW_{eqi}$ is an equivalent bandwidth of interfering carrier in MHz. Because the interfering signal is 5G BS and the wanted signal is FSS that uses digital services, therefore we choose $C/N + 12.2$ (dB).

After calculating $C/I_{required}$, we calculate $C/I$ of the system, where the carrier is based on the wanted signal which is FSS earth station and the interference signal which is 5G BS in C-Band spectrum. Finally, we can calculate $C/I$ as follow

$$C = P_{Sat Max} + G(\theta)_{TX Sat} + G_{RX ES Max} - FSL_{Sat Downlink}, \quad (3)$$

$$I = P_{5G Max} + G(\theta)_{TX BS} + G_{RX UE Max} - FSL_{5G Downlink}, \quad (4)$$

$$C/I = C - I. \quad (5)$$

After $C/I$ and $C/I_{required}$ is calculated, we calculate the margin $M$ as

$$M = C/I - C/I_{required}. \quad (6)$$

The margin $M$ determines whether the specification of these two services in coexistence scenario produce harmful interference or not, especially the harmful interference from 5G BS to the FSS earth station. This margin is related to the distance between aperture antenna, off-axis angle of the earth station impacted by harmful interference from 5G BS and the height of the 5G BS antenna. After we obtain the margin, we can evaluate whether the beamforming technique in the coexistence scenario between FSS earth station and 5G BS in the C-band is helpful or not.

3. The Proposed Adaptive Beamforming

The adaptive beamforming techniques adjust the array pattern to change some characteristics of the transmit signal having a null direction to the FSS earth station. Figure 1 shows the mechanism of the coexistence between 5G and FSS, where $D$ is separation distance between 5G BS to FSS earth station.

![Figure 1. Desired and interfering signal in adaptive beamforming mechanism.](image-url)
There are two signals in the Figure 1, the first one is desired signal and the second one is interfering signal. FSS is the incumbent services in the C-band spectrum, while the 5G is the newcomer in this band. Therefore, we consider to protect the FSS leading to classify that the interfering signal is the signal from 5G BS, while the desired signal is the signal from FSS earth station signal.

![Figure 2. The proposed model of smart antenna.](image)

The performance evaluations using a series of computer simulations. Our results are plotted in Figure 3, where the X-axis is margin in dB and Y-axis is the distance between aperture in meters. Figure 3 shows that the separation distance between aperture antenna FSS earth station and 5G BS is in 900 meter or below.
It indicates that the coexistence cannot occur because the margin is negative or below zero. Based in Figure 3, the coexistence between FSS earth station and 5G BS is possible if the distance between aperture antenna is 900 meter and above.

Our calculation for the coexistence using beamforming is shown in Figure 4 with the X-axis being the margin (dB) over distance between aperture (m). We set the distance between 5G BS and FSS earth station at around 100 meter.

The coexistence is acceptable if the height of the 5G BS is 900 meter or above. Otherwise, the height of 5G BS should be lower than 900 meter indicated by the potential interference.

In Figure 5, the adaptive beamforming using the RLS algorithm is nulling the beam towards interference which is to FSS earth station. We simulate two FSS earth station and one UE as a target as shown in Figure 5. The result of RLS algorithm successfully null the beam towards FSS earth station.
producing an array factor of around -40 dB. For the UE communications, the RLS algorithm can create beam towards the target that produce an array factor around 0 dB. As we can observe from Figure 5, there is still beam produced although no UE or desired signal is existing.

In the Figure 6, we increase the target signal from one UE to three UE. The result is RLS algorithm can sustain for nulling the beam towards FSS earth station. There is decrease performance to produce the beam towards the three UE. We can see in the Figure 7 that there are no peak in target user (20, 40 and 90 degree).

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**Figure 5.** Array Factor for one desired signal and two interference signal.

**Figure 6.** Array Factor for three desired signal and two interference signal.
Figure 7 shows the result of distance calculation after beamforming having null beam toward the FSS earth station, where 100 m is possible for a distance between 5G BS and FSS earth station from originally 900 m prior to the use of beamforming. The 5G BS Effective Isotropic Radiated Power (EIRP) is around 20 dBm to gain 100 meter distance with the objective to avoid harmful interference to the FSS earth station.

Figure 7. Margin (dB) over distance between station (m) after beamforming.

5. Conclusions

In this paper, we have proposed the use of RLS algorithm to make the coexistence between 5G BS and FSS earth station possible without giving harmful interference to the FSS earth station. We have made a series of computer simulations to evaluate the performances of the proposed adaptive beamforming. The results confirmed that the use of adaptive beamforming using RLS algorithm can reduce the distance between FSS earth station and 5G BS from 900 m to around 100 m for the acceptable interference. The proposed RLS algorithm helps nulling the beam effectively, while keeping the target signal of 5G UE high and reliable. The proposed design is expected to provide contribution to the development of technology for coexistence between 5G and FSS.

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