# Evaluation of 5G Coexistence and Interference Signals in the C-Band Satellite Earth Station

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***Abstract*—ixed Satellite Services (FSS) used to be alone at the C-Band spectrum in most countries. Since the deployment of 5G in many countries (i.e., 3.3 - 3.6GHz), FSS is not the exclusive system in the C-Band anymore. In order to minimize the detrimental interference for the FSS to allowable levels, regional exclusion zones of maximum radiated power in 5G base stations (BS) are proposed and evaluated.ixed Satellite Services (FSS) used to be alone at the C-Band spectrum in most countries. Since the deployment of 5G in many countries (i.e., 3.3 - 3.6GHz), FSS is not the exclusive system in the C-Band anymore. In order to minimize the detrimental interference for the FSS to allowable levels, regional exclusion zones of maximum radiated power in 5G base stations (BS) are proposed and evaluated.F In this paper, a measurement campaign has been carried out, and an analysis of the interference has been studied. A filtering model, namely Filter to Remove Broadband Interference 5G (FIREBRING), is proposed and analyzed concerning the carrier-to-noise ratio (C/N). Moreover, this paper focuses on the evaluation of the 5G interference into the FSS. The proposed solution deployed an Low-Noise Block (LNB) with a band frequency of 3.7 to 4.2GHz to test the satellite down-conversion signal at the receiver. The paper offered a complete analysis of the 5G signal, taking into account the implications of out-of-band emissions, potentially LNB saturation into FSS receiver, and the repercussions of the deployment of the 5G BS active antenna systems. With the LNB and down-converter in place, it can be found that the signal interference between 1.450GHz and 1.550GHz, is nearly 18dB.**

***Index Terms*—5G Base station (BS), C-Band FSS, 5G Interference signals, and Carrier-to-noise ratio (C/N).**

This work was supported by the BIDANET: Parametric Big Data Analytics over Wireless Networks (UPM.RMC.800-3/3/1/GPB/2021/9696300, Vot No.: 9696300) and IGNITE - Interference Modeling for 5G and FSS Coexistence at mmWave with Climate Change Considerations in the Tropical Region (FRGS/1/2021/TK0/UPM/01/1) for the financial assistance in the measurement campaign. In addition, this work was partly funded by Projects "IRENE (PID2020-115323RB-C33) (MINECO/AEI/FEDER, UE), and MFOC, Madrid Flight on Chip - Innovation Cooperative Projects Comunidad of Madrid - HUBS 2018/ Madrid Flight on Chip."

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## I. Introduction

In recent years, a wide range of applications and diversification of mobile internet applications of intelligent terminals prompted global mobile data services into high-speed growth mode [1]. The worldwide mobile instead of 4G industry is led by the 5G mobile communication network of the industry sector of the fifth generation [2]. The frequency spectrum is important for the future growth of the 5G [3]. The 2016 fifth-generation (5G) spectrum policy, which included the United States, the European Union, South Korea, Japan, and other essential nations and organizations, drove demand for this 5G sector. The next significant breakthrough in mobile broadband is projected to be 5G mobile networks. Peak download speeds of up to 20 gigabits per second will allow for specialized jobs such as remote precision medicine, linked autos, virtual and augmented reality, and many Internets of things (IoT) applications [4]. As 5G allows IoT applications such as health care, education, energy, and transportation [4], it is critical provided applications performing as planned each time. Some significant countries also proposed a commercial schedule and carried out pre-technical tests, paving the foundation for the 2018-2020, 5G commercial [5]. Wireless 5G technology provides the incredible data speeds of multi Gbps, extremely low latency, better protection, large network capacity, enhanced availability, and more continuous experience design for more users [6]. Improved efficiency and higher performance enable new user information and link new industry [7]. 5G Mobile Networks offers a range of applications requiring extremely high data transmission, excellent dependability, and incredibly low latency [8].

The global regulators are immediately attempting to assign additional spectrum bands above 6GHz, and new technology to address the difficulties of these mmWave frequencies has been developed [9]. Besides, several frequency bands below than 6 GHz may be suitable for a potential 5G wireless service. The mobile network's 3.4 to 3.8 GHz range of frequency is offered standardized wireless services in the European Union (EU) digital communications operations. In reality, the most advanced installations are based on a band below the 6-GHz [10]. In addition, the "European Postal and Telecommunications Conference (CEPT)" has set standardized technical requirements to assure continuous spectrum use [11]. However, until the summer of 2018, Japan sets the 5G use standard for roughly "3.6 to 4.2 and 4.4 to 4.9 GHz". The South Korean Ministry of Science and ICT proposed a bandwidth for a 5G wireless spectrum of 280 MHz in the

This article has been accepted for publication in IEEE Transactions on Vehicular Technology. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TVT.2022.3158344



3.42 to 3.7 GHz [12]. In the next few years, the data traffic is estimated to grow annually by 45% for terrestrial wireless broadband services to 10 times by 2023 [13]. Hong Kong has a major allocation to the "fixed-satellite service, (FSS) the frequency band 3.4 to 4.2GHz," also termed as the C-Band, in the space-to-earth direction [13]. Once the frequency bands for satellite and 5G have been revised worldwide, in the following, some of the propagation models used for the analysis and the interference management will be summarized. Starting by the ITU-R 452 propagation model [14] , was the possibility of spectrum sharing techniques in their first contribution. Furthermore, the other purpose is the effect of clutter loss in urban area propagation, which was unrealistic with the field test measurement due to the heights of the buildings. Their proposal to add clutter loss in the model was accepted and resulted in a new model version. Their field test was conducted using three techniques of interference mitigation, use of "Multiple-Input Multiple-Output (MIMO)," disabling of the sector, and Dynamic Spectrum Access Allocation (DSA) [15], [16]. The beamforming of MIMO has provided 15dB in reducing interference. And it has also been found that oscillator fluctuation will reduce this improvement [17].

The sector disabling technique also substantially reduced interference around 7 dB when the entire sector facing the earth station is disabled and about 8dB reduction in interference when not the entire sector is disabled in the middle region of the sector facing the earth station. Also, the DSA was investigated and found promising through the use of Transmit Power Control (TPC), but it did not take the feasibility of deployment between the two systems. Likewise, (AsiaSat) is one of Asia's heavy C-Band satellite operators. They published several papers and studies relating to the issue of coexistence [18]. Their most recent commercial innovation is the 5G rejection Bandpass filter, which ensures the coexistence of the adjacent spectrum and protects the LNB to avoid saturation. In addition, this rejects signal between 3.4-3.6 GHz, 5G into the C-Band frequencies, which usually are in the LNB, and a lack of action is performed to remove it from a saturation of the LNB. The drawback in LNB filters is the significantly stronger filters; a more significant insertion loss is caused if rejected. The loss of insertion leads to a more significant temperature of the noise, an acute problem. One of these stated that the signal above 61 dB could be rejected within 3.4 to 3.6GHz, and the insertion loss will be less than 0.4 dB at the 3.7 to 4.2GHz whereas, these will be three-year guarantee frequency. Their experiment set with a 5G base station (BS) with a fully loaded beam launched with a "Bandpass filter (BPF)," 100m from the "Fixed satellite service (FSS) antenna" [19].

Their report said that the earth station runs periodically and suppresses the interference substantially. By the end of 2020, the existing state is to be adopted and promoted by 5G. Malaysia also published a system frequency 5G use candidate frequency "3 to 5GHz," that is set clear the frequency "3.3 to 3.4GHz" as an operating band of 5G System, in general limiting indoors usage, "3.4 to 3.6 and 4.8 to 5GHz" [20]. The C-Band frequency for FSS, satellite to an earth station, is "3.4 to 3.7GHz," is the expanded C-Band, with "3.7 to 4.2GHz." Malaysia has declared it to the "ITU," according to the corresponding data. The drawn-out of C-Band 3.4 to 3.7 GHz is included in several satellite networks. Also, if the 5G networks operate in the same frequency band as the FSS, it will introduce the 5G interference with the FSS, which is permitted to operate within "3.4 to 3.7GHz" and for FSS operating rang frequency "3.4 to 3.6GHz" [21], [22]. The FSS system's sophistication, based on the national spectrum of 3.4 to 4.2GHz, potentially leads to a detrimental effect, for instance, interference with the projected 5G network and thus a challenge to the coexistence [23]. That can be shown as an undesirable signal at 5G stations and mobile communication, interfering with others [24]. The paper contributions are the following:

- 5G measurement campaign in Malaysia, whereas prior work by other researchers were based on IMT models.
- The exclusion zones definitions based on practical environment.
- The RF and IF signals spectrum was measured to indicate the possible interference problem caused by the deployment of 5G BS adjacent and co-channel to the FSS.
- The Filter to Remove Broadband Interference 5G (FIREBRING) filtering model is proposed and examined using the carrier-to-noise ratio (C/N).
- The performance evaluation is based on quality signal on the Television network using a 5G network reflection coefficient.
- Acceptable solutions are proposed to prevent 5G NR interference with the FSS, and their successes are accurately compared with other literature reports.
- The use of an LNB with a band frequency of 3.7GHz to 4.2GHz to test the satellite down-conversion signal at the receiver is suggested and analyzed to improve performance.

Effective technical solutions are suggested, and their achievements are correctly compared with the other literature reports to mitigate 5G NR interference with the FSS [25]. The rest of the paper has the following structure: Section II discusses the measurement of the reception system for satellite earth stations. Section III includes a step-by-step technique for examining the interference model between both the 5G Network and the FSS station in existence. Section IV has also discussed and validated using the LNB filter with a suggested 5G (FIREBRING) model result. Moreover, we propose to model adjacent co-channel interference between a 5G-BS and an FSS satellite receiver on the same frequency channel for a better understanding and insight of the interference, and also for easing the design of solutions. Indeed, an exclusion zone has been envisaged and defined to that end as a new concept. Furthermore, the distances between 5G-BS and FSS used are significant for the wireless communications system. The reason for this is that adjacent co-channel interference can significantly impact wireless performance if the appropriate exclusion zone is not addressed. We developed a solution and assessment models based on the measurements. The paper summarizes the results and therefore shows the possible solutions to the above problems.

## II. The Satellite Earth Station Receiving System

To enhance service quality, especially in Malaysia, the determination and quantification of these needs are crucial. In addition, testing was carried out in template locations whose climatic features are significantly different from others in Malaysia using the present models for satellite propagation. This divergence considers conventional models of transmission inapplicable and useless, particularly to tropical environments [26]. Additionally, advancements in satellite communication technology have led to considerable increases in applications and services requiring fixed and mobile satellite terminals to demand great quality channels in tropical regions. During both situations, thorough signal quality analysis is required because of the lack of substantial investigation concerning correct performance assessment, tests, and analyses in tropical satellite communication locations [27]. Moreover, the C-Band downlink of FSS usually uses the 3.7 to 4.2GHz frequency band, and the extended C-Band is 3.4 to 3.7GHz. Therefore, the complete C-Band frequency range is 3.7 to 4.2GHz, which is the core frequency band of Malaysia's satellite broadcasting and television business, and it happens to be used under the state's authorization. As it can be seen, there is a partial overlap with the 5G frequency bands. The rapid deployment of 5G BS will inevitably affect radio and television satellite signals' regular reception and seriously threaten radio and television broadcasting safety. The findings of this paper are intended to give some insight on the crucial impact of future deployments of 5G systems in FSS receivers operating in the C-Band for spectrum controllers and other associated stakeholders. Also, it proposes solutions and examines various strategies that may be used to assist the coexistence of both systems, 5G and FSS, such as switching off important transmitters or reducing their transmit power [28], [29].

To avoid existing and potential 5G development interfering with C-Band networks, this article analyzes 5G signal interference to FSS, conducts specific technique experiments, and discusses techniques to eliminate interference and coexist in harmony. In addition, notices about a low carrier-to-noise ratio appeared immediately on C-Band satellite receivers. The receiving link was not observed to have weak connections throughout the investigation. The size of the antenna used in the facility is measured using a spectrum analyzer, and there are many different types of high-frequency heads. Each satellite broadcasting and television receiving station can adjust its satellite receiving equipment to the existing situations to reduce future interference from the 5G signal. The activity of radio and television safety broadcasts is carried out more compacted and effective [22], [30], [31]. The structure of a typical satellite earth station receiving system is shown in Fig. 1, which usually includes satellite receiving antennas, feeds, low-noise frequency conversion amplifiers, high-frequency heads, connecting cables, satellite receivers, and other equipment. The C-Band receiving antennas of broadcasting and TV satellites mainly use parabolic antennas. The parabolic antenna's main lobe is narrow, the side lobe is low, and the gain is high. This antenna is passive, and the primary antenna's function is to concentrate the electromagnetic wave reflections of satellite signals from the air into single point. The signal is initially amplified. The feed is set at the focal point of the parabolic antenna to receive satellite signals, as shown in Table I. The horn transmits the electromagnetic wave energy concentrated to the focus to the low noise frequency conversion amplifier. The tuner is also denoted as a low-noise frequency conversion amplifier. Its function is to amplify the radio frequency signal output by the satellite antenna feed and convert it into an L-band signal that the satellite receiver can receive. The frequency range is generally 950 - 1450 MHz. Correct the quality of satellite signal reception is crucial. In the satellite earth station receiving system, the signal level and signal modulation error are commonly used [32]. Technical parameters such as Modulation Error Ratio (MER). This is also a critical indicator to characterize the signal link. Generally, the satellite receiver level is not lower than $45dB\mu V$, and MER is not lower than 10dB can achieve standard decoding.

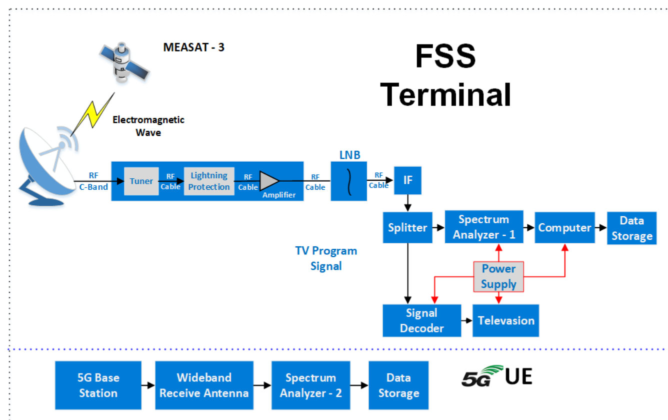


Figure 1: Satellite earth station receiving system diagram.

Table I: Frequency Bands Filed for MEASAT-3 Satellite Network

| **MEASAT Network Parameters** | **Uplink Frequency (GHz)** | **Downlink Frequency (GHz)** | **Type of Services** |
|---|---|---|---|
| MEASAT-3A | 5.925 - 6.725 | 3.4 - 4.2 | Fixed Satellite |
| EIRP | | | 41 (Global beam) 45 (Asia beam). |
| Traveling-Wave Tube Amplifier(TWTA) Power. | | | 65 Watts |
| Transponder Bandwidth. | | | 24 x 36 MHz |
| Channel Polarization. | | | Linear |

As in other frequency bands, the same motivation can be applied to C-Band satellite transmissions, which use the frequency range 3.4 to 4.2GHz, share some of the same purposes. Low Noise Amplifiers (LNAs), also known as Low Noise Blocks (LNB), are designed to amplify very weak signals from satellites to ensure that the receiver is sensitive across the whole frequency range. Satellite receivers can be damaged in two ways, causing them to lose their ability to receive satellite signals:

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- Co-channel interference can occur when emissions on the same desired frequency as the receiver are powerful enough or when emissions anywhere within the LNB passband are strong enough to overload the LNB. These situations degenerate into non-linear effects and reduction in performance at the receiver.
- 5G transmissions may use frequencies ranging from 3.3 to 4.2 GHz, depending on the band selected; 3GPP Band n78 covers the frequency range 3.3 to 3.8GHz and is the most commonly considered for wide-area mobile services. In contrast, 3GPP Band n77, which extends the frequency range up to 4.2GHz and is partially used in Malaysia for mobile services, is being considered in a few countries for low-power campus type networks and is partially used in Malaysia for mobile services.

However, the targeted transmissions use the appropriate frequency ranges, and the transmitters simultaneously generate out-of-band emissions, which are undesirable consequences of digital transmission systems and occupy the spectrum on either side of the intended transmission. As a result, there are two aspects of a 5G signal that may cause satellite reception interference:

- The frequency on which the 5G transmitter operates and the intended transmission. As a result, there is a model of possible interference mechanisms between the two systems. Four possible outcomes must be considered to assess whether a 5G broadcast will interfere with the satellite reception.
- Signal thresholds, separation distances, guard bands, appropriate mitigation, and other factors could be included. Mitigation against 5G transmission interference may be included in satellite receivers' design.
- The interference impact and limited frequency resources must be minimized by field tests and simulations that examine the impacts based on the probability of sharing between radio systems operating in co-channel and adjacent channels interference. An investigation of the coexistence of 5G-BS and FSS-ES [33].

## III. Interference Model

The 5G BS mainly has co-channel interference, design frequency interference, and saturation interference to satellite earth stations. The degree of interference depends on the location, elevation angle, and the received 5G BS aggregate interference power factors. In the 3.4 to 3.6GHz frequency band, the 5G BS will interfere with the satellite earth station same downlink carrier frequency. That is the most significant interference from the 5G BS to the C-Band satellite earth station, and it is the focus of this article: the interference in the 3.6 - 4.2GHz from 5G BS to satellite reception jointly with the results of a measurement campaign. The measurements were carried out and being measurements in the date of December 19, 2020, at MAEPS SERDANG, Universiti Putra Malaysia, (UPM) and gives a solution, which has general reference significance for the situation where satellite reception is affected by 5G interference in various places.

### A. 5G Interference Model

Interference was caused by the coexistence of 5G-BS and FSS with distance 110 m. Furthermore, the C-Band communications several research mentioned like [33], [34], has been seriously affected. The C-Band signal received by cable and digital TV's front-end satellite earth station was severely distorted. Moreover, to eliminate interference, disaster response measures include restarting broadcasting as fast as possible and subsequently switching the impacted C-Band satellite signal to a backup device. The C-Band frequency source, is automatically switched to broadcast, and the frequency with a single satellite source is automatically changed to an off-site satellite source for broadcast. To avoid 5G signals to interfere with C-Band satellite received signals, we investigated the resistance of the 5G interference technique by installing filters and replacing narrowband tuners on satellite earth stations' dishes to check if a harmonious coexistence of 5G and C-Band signals could be obtained. However, the deployment of the 5G BS next to a located C-Band receiver and the spectrum will undoubtedly cause interference with the existing receiver signal, which avoids the use of the 5G BS. This is the main reason for the increasing demand for coexistence between 5G BS and FSS in the C-Band. To maintain distance or isolate the satellite earth station, the 5G BS and the FSS use interference to enhance the isolation of the satellite signal and the 5G interference signal to mitigate interference.

Moreover, to reduce interference, use spatial attenuation or medium isolation, employ the antenna directivity. Adjusting the maximum radiation direction and lowering angle of the 5G BS and the direction of the peak amplitude of the receiving antenna of the base station improves the isolation of the satellite signal from the 5G interference signal and reduces interference. Power control technique can also be considered to help mitigate the interference increasing the satellite's downlink signal strength reduces the transmission power of the 5G-BS [35] and increases the signal-to-noise ratio of the satellite signal and the 5G interference signal. In addition, Radio Frequency (RF) devices are designed to restrain and reduce interference that installs a filter or replaces the narrowband tuner to reduce the amplitude of the 5G interference signal and the nonlinear distortion caused by the tuner's interference signal of the same frequency.

### B. Interference Measurement

In Malaysia, the FSS mostly uses C-Band at 5.15 GHz for uplink and 3.7 to 4.2 GHz for the downlink. Currently, the mainstream radio frequency spectrum for 5G applications is 3 to 6GHz after the 5G spectrum allocation plan was finalize. In terms of frequency, 3.4 to 3.5 GHz has 100 MHz, and 3.5 to 3.6 GHz, has a total of 100 MHz. These two frequencies happen to be in the broadband tuner 3.4 GHz. Within the receiving range of 4.2 GHz, the downlink frequency range of FSS and the frequency spectrum of 5G-BS overlap between 3.4 and 3.6 GHz. The overlapping part in Fig. 2 easily distorts the signal reception performance of the satellite earth station. The C-Band with optical fiber signal source automatically switched to the optical fiber source for broadcasting; the single satellite signal source program manually switched to the remote satellite signal source. When the front-end satellite signal is interfered with, all the signal programs in the C-Band experienced a mosaic-like view.

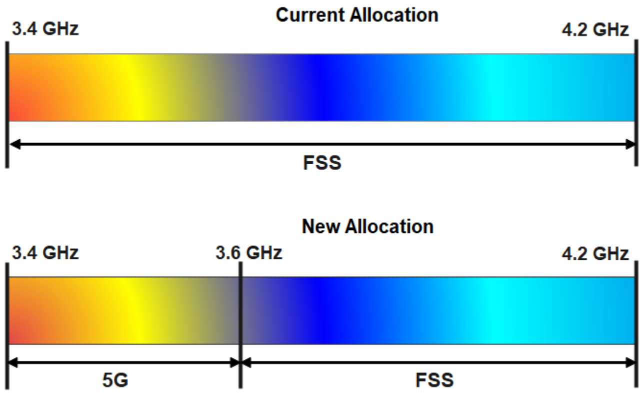


Figure 2: Proposed frequency arrangements for C- Band in Malaysia.

Table II: FSS Receive Antenna

| **Parameters** | **Values** | **Symbol** |
|---|---|---|
| | **Eurostar Single C-Band LNB** | |
| Input Frequency | 3.4 - 4.2 | GHz |
| L.O. Frequency | 5150 (±500 @25) | MHz |
| Output Frequency | 950 1750 | MHz |
| L.O. Stability | ±1.5 : (-40 - +70) | MHz |
| Conversion Gain | >65 | dB |
| Cross Polar Isolation | 20 | dB(min) |
| Image Rejection | 45 | dB(min) |
| VSWR | 2.0:1 | (max) |
| | **Type Splitter (CATV Antenna Diplexer** | |
| Frequency range | 5 - 2150 | MHz |
| DC power passing | 24 | vDC |
| | 500 | mA (max) |
| | **Filter type (AsiaSat – C-Band Bandpass Filter )** | |
| Interference Rejection-BPF | 5 - 2150 | MHz |
| Frequency range | 24 | vDC |
| | **Type of Spectrum Analyzer "Rohde and Schwarz Spectrum Rider FPH Handheld Spectrum Analyzer"** | |
| Frequency range | 5 kHz to 6 | GHz |

In order to avoid the interference of 5G signals on C-Band satellite reception signal programs, we have carried out engineering practices of installing filters and replacing narrowband tuners on satellite earth stations, exploring the idea behind this is to reduce the interference generated by the 5G yet maintain the 5G and FSS transmissions. Since 5G-BS are currently testing, the carrier transmission is interactive signals. During signal interaction, the transmit power of BS will increase to varying degrees, and 5G BS will continue to increasing in the future. Therefore, we need to give the system a higher significant power margin. Further, the 5G interference signal to the satellite receive antenna is attenuated in such cases depending on the 5G signal center frequency is 3.5GHz and the wavelength is 8.6cm, therefore the metal mesh's width is recommended to be within 2cm, and the metal shielding mesh is grounded. According to the ground's situation, the back of the satellite antenna is the 5G BS on the parking area with a height 25m that interferes most with, and its height is

Table III: QRC's Wideband Antenna

| **Parameters** | **Values** | **Symbol** |
|---|---|---|
| | **Cellular** | |
| Frequency | 350 - 6000 | MHz |
| Peak Gain | 8 | dBi |
| Impedance | 50 | Ohm Ω |
| Radiation Pattern | Omni | Omni |
| Polarization | 8 | dBi |
| Transmit Power | 50 | Watts |
| Cable Type | 240 | LMR |
| | **Separate GPS Antenna** | |
| Frequency | 1575.42 | MHz |
| Peak Gain | 26 | dBi |
| Input Voltage | 3 - 5 | Volts |
| Connector | SMA | n/a |
| | **Mechanical Dimensions** | |
| Height | Diameter | |
| 5.22 | 7.72 | inches |
| | **Environmental** | |
| Temperature Range | -40 to 85 | $^\circ C$ |

much higher than our satellite antenna. In Fig. 3 all the values and parameters can be seen. After the shielding mesh is set up, the isolation of 5G signals can be enhanced by 8 dB to 12 dB, which further reduces the interference of 5G signals and improves the system's safety. Furthermore, Tables II and III shows the specifications of the FSS receive antenna and 5G NR receive antenna.

## IV. Measurements and Discussion

All C-Band signal frequencies fluctuate when the front-end satellite signal is disturbed during 5G interference to the Satellite earth station, as shown in the results of spectrum analysis measurement. The signal spectrum after the monitoring spectrometer records the high-frequency head down-conversion is shown in Fig. 4. This paper also used different frequencies in current measurements, including 3.4 to 3.6GHz. According to the measurement result, the peak between 3.4 to 3.6GHz coincides with the frequency of the interference signal.

### *A. Broadband tuner with a Filter*

The C-Band satellite signal system reception is expected once the high-frequency broadband head of the satellite earth station is fitted with a narrowband filter. Fig. 5 depicts a spectrum analyzer, which is used to collect the enhanced. The spectrogram shows that installing a filter may suppress the out-of-band 5G interference signal to some extent, and the intensity of the 5G interference signal is about 10dBμV. The main problem with installing a narrowband filter on the existing splitters are: 1) There is insertion loss in the filter; 2) The filter is heavy, and the weight on the feed support rod is too large; 3) 5G signals may still be introduced from the surface gap between the filter and the tuner [36].

However, aluminum foil can be used to wrap the surface, and other techniques to avoid 5G signals from interference into the splitters. The disadvantage is that the southern summer temperature is too high, which may affect the splitters' performance and even pose security risks; 4) the surface gap between the filter and the splitters may leak, causing problems with the splitters' regular operation.

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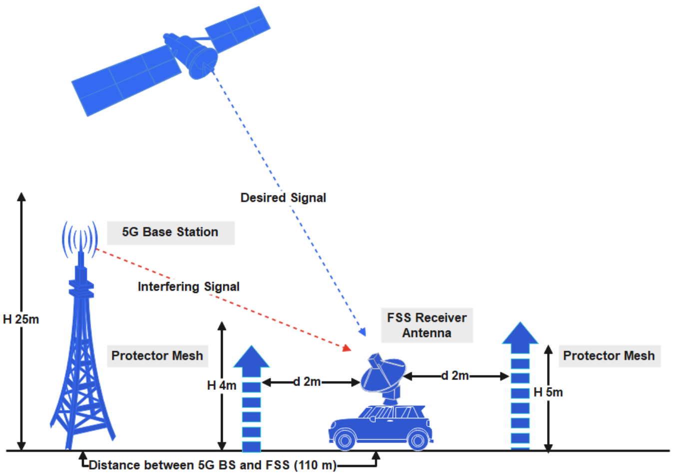


(a) schematic design


(b) on-site photo

Figure 3: The FSS receiving antenna metal shielding mesh with a 5G BS.

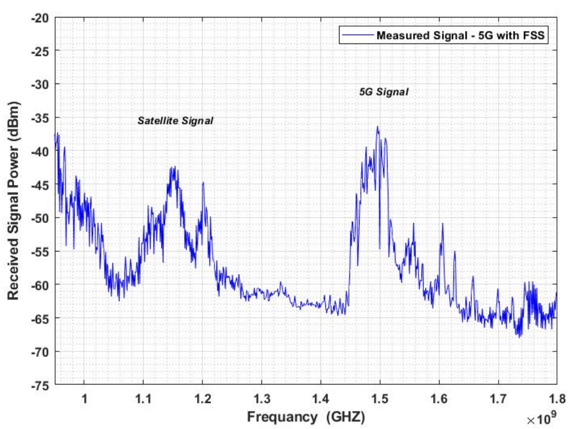


Figure 4: C-Band satellite signal.

## B. Narrowband high-frequency head

In order to avoid 5G interference, the satellite earth station was replaced with a narrowband tuner. Furthermore, the C-Band satellite received signal acceptance is normal, and Fig. 6 shows the spectrum analyzer to capture the signal spectrum.

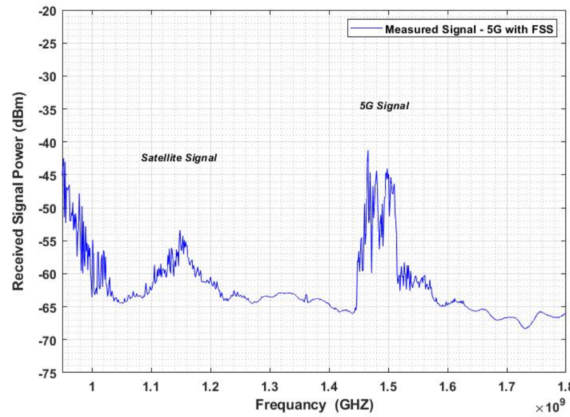


Figure 5: **After installing a narrowband filter**, the spectrum of the C-Band satellite signal is disturbed.

Moreover, the spectrum analyzer shown in Fig. 6 is often used to collect the enhanced signal spectrum. As shown in Fig. 6, replacing it with a narrowband tuner suppresses the 5G interference signal level by around $20dB_{\mu}V$, which is better than the filter, and the narrowband tuner is light, requiring less weight on the feed support rod, enabling the measured uncomplicated to implement.

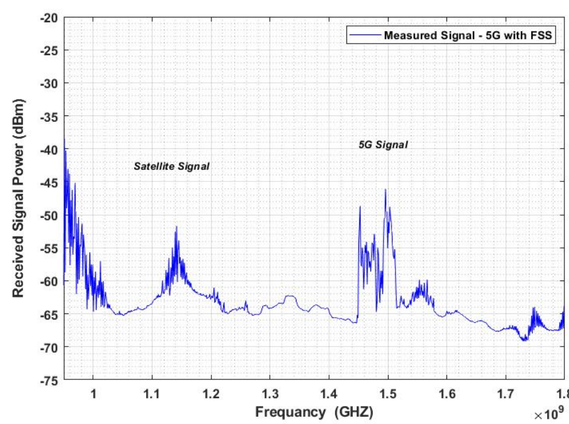


Figure 6: **After replacing a narrowband filter**, the spectrum of the C-Band satellite signal is still disturbed.

## C. Impact of resistance interference method of measures on Satellite receiving System

The deployment of narrowband filters and narrowband splitters has no significant impact on the transmission indicators of the satellite earth station receiving system in the presence of 5G interference. The satellite receiver is fully functional in terms of transmitting and decoding. The C-Band satellite signal reception is expected, completely in compliance with radio and television transmission requirements, even in the face of a 5G BS approximately 110 m, planar distance. Moreover, in Table IV, wideband tuner, narrowband filter, and narrowband tuner can typically transmit and decode satellite signals without 5G interference level $>45dB_{\mu}V, MER<10dB$.

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Whereas the use of a wideband high-frequency head cannot normally transmit and decode satellite signals in the case of 5G interference level $>45dB_{\mu}V, MER<10dB$. As a result of existing radio and television based on satellite earth station reception problems, using a narrowband filter and a narrowband high-frequency head, satellite signals can be transmitted and decoded generally in the case of 5G interference level $>45dB_{\mu}V, MER<10dB$.

Table IV: Comparison of level, MER index, and satellite reception decoding

| Measurement Parameters | | | | | |
|---|---|---|---|---|---|
| 5G interference | | | 5G interference | | |
| $dB_{\mu}V, dB$ value | MER dB | Decoded normally | $dB_{\mu}V, dB$ value | MER dB | Decoded normally |
| **Broadband high-frequency head LNB** | | | | | |
| 59.88 | Unable to read data | mosaics | 59.73 | 17.9 | normal |
| **Narrowband Filter** | | | | | |
| 59.45 | 18.6 | normal | 59.87 | 18.8 | normal |
| **Narrowband Tuner** | | | | | |
| 59.06 | 18.3 | normal | 59.05 | 18.7 | normal |

Additionally, this paper shows how 5G BS interact with satellite earth stations, focusing on the narrowband filter and narrowband tuner equipment used by C-Band FSS to counteract 5G interference signals and their engineering methods.

### D. 5G interference signal

The satellite vertical polarization downlink spectrum of the satellite MEASAT-3A, has been swept, and the result is shown in Fig. 6. It is known that the local oscillator frequency of LNB is 5.150 GHz, the downlink frequency of C-Band satellite is usually 3.625 GHz to 4.2GHz, and the down-conversion frequency of LNB is 950MHz to 1.525GHz. The 5G frequency allocation by the operator are 3.4GHz to 3.5GHz, and the frequency resources obtained by Malaysian Communications and Multimedia Commission, (MCMC) are 3.5 GHz to 3.6 GHz. The two frequencies are relatively close to the C-Band satellite signal. When the signal passes through the LNB, the down-conversion frequencies are 1.450 GHz to 1.550 GHz, respectively. Fig. 7 shows that in the frequency spectrum after LNB down-conversion, there are many signals outside 1.525 GHz, which are within the frequency range where 5G frequency is down-converted by LNB, so it is suspected that the interference is caused by 5G signal.

For further testing, we contacted the operators after closing the 5G BS around our station, the C-Band satellite receivers returned to normal, and the carrier-to-noise ratio increased by nearly 3dB. The frequency spectrum is shown in Fig. 8. It can be seen from Fig. 7 that after the 5G BS is turned off, the interference signal entering the LNB disappears, and the system returns to normal. It can be determined that the 5G signal caused the interference of the C-Band satellite reception.

### E. Analysis of 5G interference signal

Once the impact of 5G signal interference has been shown, it is necessary to analyze the impact of FSS interference on the 5G signal, which is divided into two categories: The first category is the in-band impact of satellite signals. The C-Band satellite downlink frequency is usually 3.525 GHz to 4.2 GHz. If the 5G signal, especially the 5G signal of MCMC, is around 3.6 GHz if the out-of-band attenuation is not done well, it will overlap with the C-Band satellite signal around 3.6 GHz, resulting in a decrease in the received carrier-to-noise ratio cannot even receive. The second category is the out-of-band influence of satellite signals. That is, the spectrum of satellite signals and 5G signals does not overlap. In particular, 5G signals from 3.4 to 3.5 GHz can enter the passband of LNB from 3.4 to 4.2GHz, and the intensity is more significant than the LNB. The power is pushed to the saturation state, which causes the LNB to produce a more nonlinear distortion. This nonlinear distortion will cause a series of problems such as increased in-band noise, intermodulation interference, and spread of the received signal spectrum, and may even cause damage to the LNB. That is the situation encountered in this article. When the 5G interference signal appears, the power of the satellite downlink signal is almost not weakened, but the carrier-to-noise ratio drops. The following focuses on the analysis of this out-of-band 5G signal interference. The out-

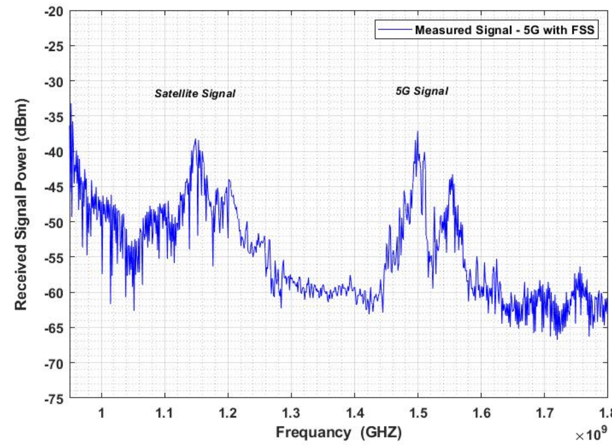


Figure 7: The satellite signal **after interference**.

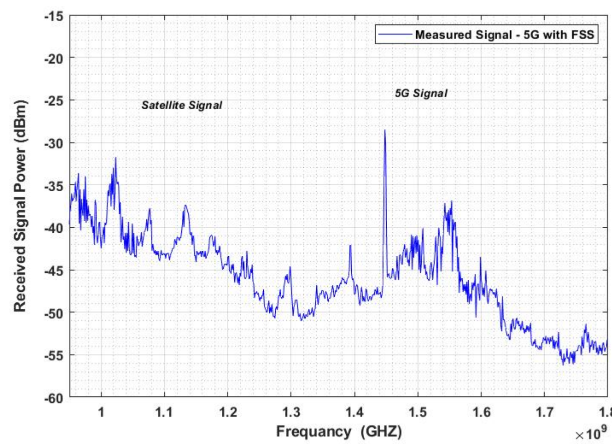


Figure 8: Satellite signal spectrum **after the 5G base station has been switched off**.

of-band influence of 5G signals is mainly to cause saturation distortion of LNB. Therefore, we need to pay attention to how much input power the LNB will produce saturation distortion. Usually, the input power of this intensity is called Input P1, dB. According to the information, the output P1dB of the 3.4 to 4.2GHz, passband LNB used is -9dBm, and the gain is 62dB, then the Input P1 dB is about -43dBm, that is, if the 5G interference signal enters the LNB, if it is higher than -53dBm, the LNB will be directly pushed to saturation distortion state. Next, use the equipment's to focus on measuring the strength of the 5G interference signal near the satellite receiving antenna. With the cooperation of Telecom Malaysia, the 5G signal near the satellite receiving antenna was tested, taking the strongest 5G signal as an example, as shown in Fig. 9.

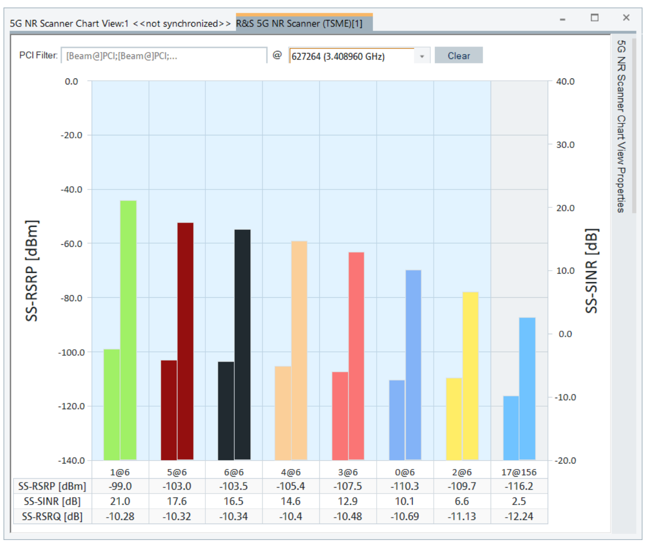


Figure 9: The receiving beam analysis of 5G BS.

The Reference Signal Received Power (RSRP) in Fig. 9 represents the 5G network and the receiving quality of the reference signal. At the same time, the RSRQ signal represents the wireless signal's intensity. The SINR is the power ratio of the signal to the additive interference noise. The physical cell code is the area to which the telecommunication base station belongs. It can be seen that the 5G signal of telecommunications can be received near the satellite receiving antenna. Under this test beam, the strength of the 5G signal is -99dBm. More than one beam of an antenna of a base station can reach the receiving point, and there may be one base station working around the receiving point.

The situation encountered in this article is that one 5G BS is working in the surrounding area. Therefore, the valid 5G signal is the sum of the beam intensities of the multiple antennas of the 5G BS pointing to the receiving location, which is greater than the intensity of a single beam. If we consider using 5G mobile phones in the future, when the 5G mobile phone signals contact the base station, the power of its beam transmission will increase again. Fig. 10 is the result of the frequency sweep of a base station with a test antenna near the satellite receiving antenna. From Fig. 9, we can see that around 3.4 GHz, the maximum signal has reached -55dBm at some point. Such as, considering that 5G signals can enter the side lobes of the parabolic satellite receiving antenna, the satellite receiving antenna has a different amplification effect, so the 5G signal reaching the LNB can reach -53dBm or more after amplification, which exceeds the saturation distortion point Input P1dB of the LNB, which will cause the LNB Nonlinear distortion.

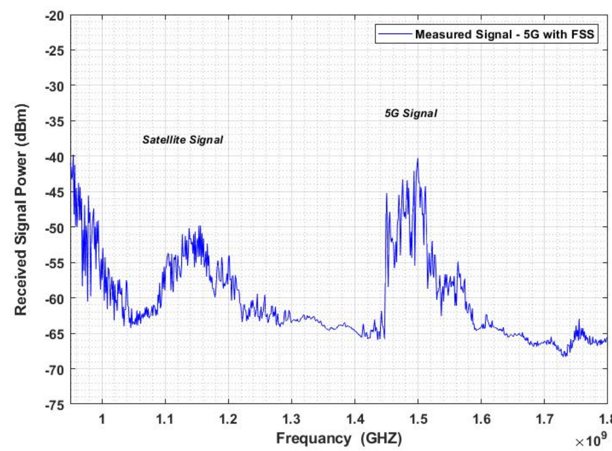


Figure 10: The receiving signal spectrum of 5G BS.

## V. The Proposed Solution Model: Filter to Remove Broadband Interference 5G (FIREBRING)

In order to solve the 5G interference, first, we need to contact the operator to test and solve them jointly. The operator's base station usually has power ranging from 20W-200W, and the best distance from the satellite receiving antenna of the broadcasting and television is more than 200m. Besides, adjusting the base station's transmission power is necessary according to the degree of interference. In addition to coordinating with operators, we need to do some countermeasures. According to the plan, we have divided the implementation into two steps: The first step is to replace the LNB at the receiver station and install a filter. From the previous test on the 5G signal of telecommunications, it can be seen that the signal near 3.4 GHz is relatively strong. The 5G signal near 3.4GHz will access the LNB if the initial LNB with a frequency range of 3.4 to 4.2GHz is used, which will directly cause the LNB to enter a saturated state and produce nonlinear distortion, causing the carrier-to-noise ratio of the satellite signal to decrease, and the satellite signal cannot be demodulated. As a result, we replaced the current LNB with a frequency band of 3.7 to 4.2GHz for testing. Before and after replacing the LNB, the satellite down-conversion signal reception spectrum is shown in Fig. 5. After replacing the narrowband LNB, it can be found that the frequency points corresponding to the 5G interference, whereas the 5G signal attenuation between 1.450GHz and 1.550GHz is nearly 18dB.

The satellite's signal strength remains unchanged, and the improved carrier-to-noise ratio allows regular reception, as shown in Fig. 11. It can be seen from Fig. 11 that there are still some residual 5G signals near 3.4 - 3.6GHz. It is likely that the 5G residual signals still exist due to insufficient

This article has been accepted for publication in IEEE Transactions on Vehicular Technology. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TVT.2022.3158344



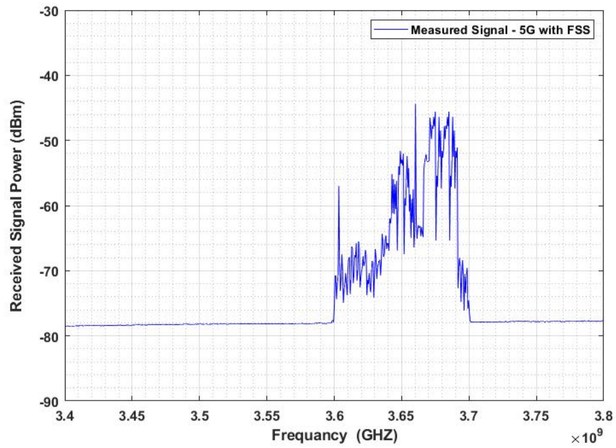


Figure 11: The down-conversion signal of 3.4 to 4.2 GHz passband LNB **Before replacement the LNB**.

sideband attenuation of the narrowband LNB. When the signal suddenly becomes more significant, it enters the LNB after being amplified by the satellite antenna. It may still cause the LNB to saturate and produce nonlinear distortion. Further analysis from Fig. 12 shows that the 5G interference signal from 3.4GHz to 3.5GHz is about -60dBm and the 5G signal can interfere the side lobe of the satellite antenna. (According to engineering experience, it can also increase the gain by about 10dB). If the new LNB is for the 3.4 to 3.7GHz, the signal is attenuated by 18dB, and the 5G interference signal from 3.4 to 3.5GHz is about -70dBm before entering the mixer of the new LNB. At this time, the valuable satellite signal is -60dBm after being amplified by the LNB, and the gain of the LNB is about -60dB, then the satellite signal is about -80dBm before entering the working unit of the new LNB. According to this estimate, before the LNB performs signal processing, the valid signal is about -50dB lower than the noise signal.

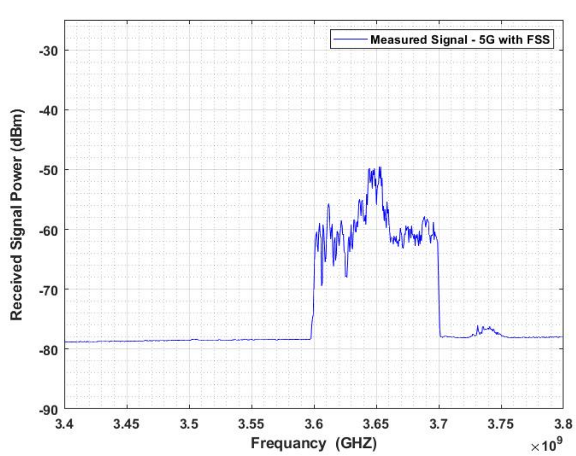


Figure 12: The down-conversion signal of 3.4 to 4.2 GHz passband LNB **After replacement the LNB** .

This demodulation effect is undesirable due to a little extra noise is added as small as possible as part of the

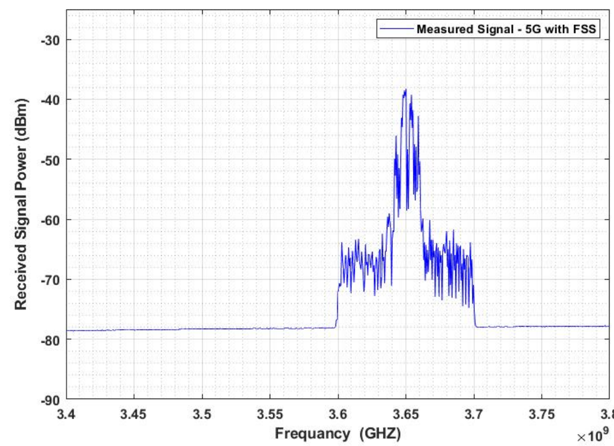


Figure 13: The down-conversion signal of 3.4 to 4.2GHz passband LNB **after replacing the LNB and adding a filter**.

Table V: Interference Signal From 5G To FSS

| **Measured** | **No 5G interference** | **There is 5G interference that has not been dealt with** | **Replace narrowband LNB with 5G interference** | **If there is 5G interference, replace the narrowband LNB and add a filter** |
|---|---|---|---|---|
| Satellite signal strength (dBm) | -52.1 | -52.6 | -52.9 | -53.4 |
| Carrier-to-noise ratio C/N (dB) | 9.7 | 7.9 | 8.7 | 9.5 |
| Received signal effect | The image and sound are both clear and very well | It cannot be demodulated at all | Occasionally there are mosaics in the image, and the sound is attenuated | The image and sound are clear and smooth |

amplification process. In the second step, based on replacing the narrowband LNB, a band-pass filter is installed to make the attenuation edge of the 5G signal steeper and further increase the attenuation of the 5G interference signal. The filter specifications are as follows, 3.7 to 4.2GHz the passband range in-band insertion loss of 3.7 to 4.2GHz lower than 0.4dB, out of band isolation is less than 3.5GHz it is most significant than -61dB, 3.5 to 3.6GHz is -60dB, and 4.4 to 4.8GHz also, most considerable than 55dB. After adding this filter, test its satellite down-conversion frequency spectrum, as shown in Fig. 13. It can be seen that the peak corresponding to 5G interference, that is, 1.450GHz to the signal between the 1.550GHz, has further attenuation, and the out-of-band signal becomes steeper. Before the filter is added, the 5G interference signal from 3.4-3.5 GHz is about -70dBm before entering the mixer of the new LNB. After the filter is added, it will bring about 60dB attenuation. Before entering the mixer of the new LNB, there is about -130dBm. The satellite signal is about -120dBm before entering the working unit of the new LNB, and the valuable satellite signal is 10dB higher than the 5G interference signal. It can be seen from the detected spectrogram that the 5G signal on the right side of Mark1 is attenuated by nearly 10dB. The carrier-to-noise ratio has also been further improved. Under the same test environment, take the receiving parameters received by a C-Band satellite receiver as an example for specific analysis, as shown in Table V, after replacing the narrowband LNB and installing a filter, the 5G interference signal. The attenuation amplitude is considerable. As a result, the satellite signal's carrier-to-noise ratio improves. Thus, the signal source's protection level improves. Moreover, Table VI also shows the types of analyses, the recommended solution, and the variety of interferers, the distance of protection, and the advanced solution.

Table VI: Comparison between proposed solution and other existing methods

| Interference Signal | Type of Analysis | Projected Solution | Achieved Results | References |
|---|---|---|---|---|
| LTE Signal 3400 - 3600 MHz | Ordinal Analytical | Commercial Filter | 50 m | [37] |
| 5G Signal 3400 - 3600 MHz | Ordinal Analytical | Commercial Filter | 100 m | [22] |
| 5G Signal 3.8 GHz | Ordinal Analytical | n/a | 15 km | [38] |
| TD-LTE/5G in frequency 2.0 GHz | Experimental and Ordinal Analytical | n/a | n/a | [39] |
| Coexistence of 5G system with fixed satellite 3.8GHz | Ordinal Analytical | Interference Analysis | 5, 10 & 15Km | [40] |
| Measurements of 5G NR at 3.55 GHz | Experimental and Ordinal Analytical | New RF filter and increasing LNBF p1dB | 111m | [28] |
| Real 5G NR at 3.5 GHz | Experimental | Increased LNB P1dB with new Radio-frequency filter | 110m | The Proposed Solution Model (FIRE-BRING) |

## VI. Conclusion

This paper performed a measurement evaluation of 5G signal interference onto the FSS system at Malaysia Agro Exposition Park Serdang (MAEPS), which is located near University Putra Malaysia (UPM). The paper proposed a filtering mechanism called FIREBRING to alleviate the 5G interference problem considering practical installation and testing. Depending on the level of interference, the transmission power of a base station must be adjusted. The power of the operator's base station typically ranges from 20W to 200W, the exclusion zone more clearly, indicating specifically exclusion zone, because we claim as one of the contributions. The ideal distance from the satellite receiving antenna of broadcasting and television is more significant when it is longer than 200m. Countermeasures techniques and collaborate with operators to resolve the issue, which is the main contribution of this FIREBRING: The first step is installing a filter and replacing the satellite receiving LNB. The second step is to install a band-pass filter after replacing the narrowband LNB. 3.7 to 4.2GHz passband range in-band insertion loss is less than 0.4dB, out of band isolation is less than 3.5GHz it is most significant than -61dB, 3.5 to 3.6 GHz is -60dB, and 4.4 to 4.8 GHz is likewise most significant than -55dB. It can potentially solve the problem of satellite reception being interrupted by 5G signals, especially in close areas. Specifically, the 5G BS transmits away from the satellite receiving antenna, causing the carrier-to-noise ratio of the satellite receiving signal to drop at approximately -65dBm and is 50m. A metal protective net can be installed around the satellite antenna to protect the surrounding area and reduce potential interference signals for future work.

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This article has been accepted for publication in IEEE Transactions on Vehicular Technology. This is the author's version which has not been fully edited and content may change prior to final publication. Citation information: DOI 10.1109/TVT.2022.3158344



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