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Assessing 5G Interference on C-Band TV Signals: An Experimental Study in Nigeria

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Abstract: *The deployment of 5G services in the C-band frequency range has raised concerns about potential interference to existing TV broadcasting services. This study investigates the impact of 5G interference on C-band TV signals in Nigeria. An experimental setup was designed to act out the coexistence of 5G and C-band TV services. The results show that 5G signals can cause significant interference with C-band TV signals, leading to degraded image quality. However, the use of low-cost planar RF filters and improving the LNBF P1dB can significantly reduce the required protection distance between 5G base stations and C-band TV receivers. The findings of this study have important implications for the deployment of 5G services in Nigeria and other countries using C-band for TV broadcasting.*

Keywords*: 5G, C-Band, coexistence, TV broadcasting, interference, Nigeria*

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I. INTRODUCTION

The global deployment of fifth-generation (5G) wireless networks is gaining pace, and Nigeria is at the forefront, launching 5G services in key urban areas. However, concerns have been raised about the potential interference between 5G signals and existing C-band television broadcasts. The coexistence of 5G and TV signals can lead to interference, which can degrade TV signal quality. Investigating the effects of 5G interference on TV signals is essential.

Extensive research has been conducted on the impact of 5G interference on TV signals. For instance, a study by [1] revealed that 5G signals can cause substantial interference with TV signals, particularly in the C-band. Furthermore, research by [2] showed that 5G interference can lead to errors in TV signal reception, especially in areas with high 5G signal strength. These findings highlight the potential for 5G interference to compromise TV signal quality.

Numerous mitigation techniques have been proposed to reduce 5G interference on TV signals. A study by [3] found that filtering and shielding techniques can be effective in reducing 5G interference on TV signals. Another study [4]establishes that antenna design optimization and beamforming can also be effective in mitigating 5G interference on TV signals.

The impact of 5G interference on TV signals has been extensively studied globally. However, experimental studies are needed in Nigeria to investigate the specific effects of 5G interference on TV signals in the country. Notably, while several studies have addressed this issue in developed countries, there is a dearth of research on the impact of 5G on C-band TV signals in Nigeria. Nigeria's unique socio-economic, environmental, and technological context necessitates a local study to investigate the potential impact of 5G on C-band TV signals. The country's tropical climate, dense population, and diverse broadcasting infrastructure may affect signal propagation and interference patterns, which could differ significantly from those observed in developed countries. There is a significant knowledge gap in understanding the potential impact of 5G on C-band TV signals in Nigeria. Local studies are needed to provide insights into the technical, economic, and social implications of 5G deployment on existing broadcasting services. This study aims to bridge this knowledge gap by investigating the potential interference between 5G signals and C-band TV broadcasts in Nigeria.The study's objectives are threefold: (1) to investigate the impact of 5G interference on TV signals, (2) to identify effective mitigation techniques, and (3) to provide recommendations for broadcasters, telecom operators, and regulatory bodies.

II. RELATED WORK

Previous studies have extensively examined the theoretical analysis of co-channel and adjacent channel interference between TVRO (Television Receive Only) and 5G systems [1-11]. Research has focused on co-existence strategies, including TVRO LNB (Low Noise Blocker) plus filters and waveguide filters [4, 5]. Performance analyses have been conducted to assess the impact of 5G power levels on TV channel quality signals [4, 7]. Additionally, deterministic analysis of propagation models has been explored [5, 7]. A study by [2] investigated co-channel interference from 5G systems to Fixed Satellite Service (FSS) downlinks in the 3.8 GHz band, proposing sharing conditions to safeguard FSS Earth Stations (ES) from interference. Another study [8] examined interference from 5G cellular systems operating below the 6 GHz band, considering out-of-band emissions, LNB saturation, and Active Antenna Systems (AAS) deployment.

Building on existing research [4], this study investigates potential solutions to mitigate interference, including LNBs with built-in filters and waveguide filters. A feasibility study [1] assessed the coexistence of IMT-2020 and FSS systems in the extended-C band, analyzing potential interference using deterministic calculations. Results showed that co-channel scenarios require significant separation distances, while adjacent channel scenarios allow for coexistence with smaller protection distances and guard bands.

III. MATERIALS AND METHODS

In the coexistence scenario, the 5G transmitter acts as an interferer on the C-Band TV signal reception. To simulate the desired DVB-S2 signal, a Rohde & Schwarz SMW200A signal generator was utilized. The C-Band TV signal was received using a log-periodic antenna, which was connected to a Tandberg TT1260 set-top box. The set-top box converted the digital signal to an analog signal, as most television sets in Nigeria currently utilize analogue technology. The output was then fed to a 52" LCD Samsung television set.

Figure 1 illustrates the essential test setup for evaluating the impact of 5G on C-Band TV reception. A field study was conducted at six locations: NTA Headquarters Area 11, Garki, Abuja, Lagos, Kano, Ibadan, Benin, and Port Harcourt. These sites were selected because they represent areas where 5G and C-Band TV services coexist.

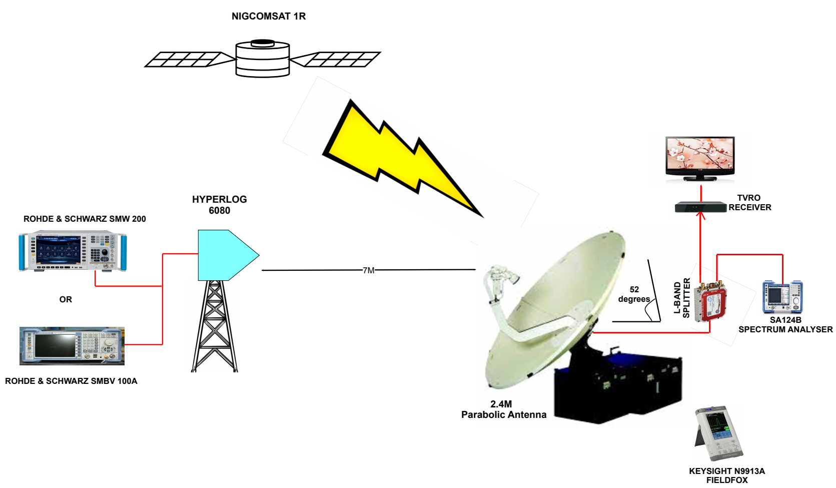

Figure 1: Influence of 5G on C-Band TV reception

Rohde & Schwarz signal generators, SMW 200 and SMBV 100A, were utilized to create a 100 MHz-bandwidth 5G waveform at 3550 MHz, which was radiated by the antenna using vertical polarization. The RF signals were generated in accordance with the 3GPP TS 38.141-1 and 3GPP TS 38.141-2 base station conformance testing standards [12, 13]. A distance of 8 meters was maintained between the 5G signal generator and the Fixed Satellite Service (FSS) receiver to ensure a suitable dynamic range for interference evaluation and to guarantee far-field conditions.

For reception, a Television Receive Only (TVRO) system was installed at 90° 2' 48" N latitude and 70° 29' 52" E longitude. The system consisted of a 2.4m C-Band parabolic antenna with a 65 dB-gain Low Noise

Block Frequency Converter (LNBF). The TV system was tuned to the NigComSat-1R satellite, located at 42.5° E orbital position, to receive satellite transponder signals.

The L-Band signal received from the LNBF was split into two separate paths using a 1:2 splitter. One path connected directly to the Tandberg TT1260 Satellite receiver, with output fed to a 52" Samsung TV. The other path connected to the SA 124B Spectrum Analyzer, allowing observation and evaluation of the 5G interference signal at different power levels.

Field measurements were conducted by first measuring the intermediate frequency (IF) at the L-Band, after LNBF down-conversion, without the 5G signal present. Readings were taken and recorded using the SA 124B Spectrum Analyzer. Next, the Vector Signal Generator was switched on at various frequencies within the extended C-band, and signal reception quality records were taken. The 5G transmitted power was varied at 0 dBm, 3 dBm, 6 dBm, 9 dBm, 12 dBm, 15 dBm, and 18 dBm to determine the maximum power level that would not harm C-Band TV reception.

The presence of a 5G signal was observed on the spectrum analyzer, showing variations in transmitted power. The impact on TV display images was recorded, along with visual displays on the 52" Samsung TV.

Three major measurement scenarios were carried out:

1. Co-Channel Interference (CCI) Measurement

The C-Band TV receiver, SA 124B, 5G Signal Generator, antennas, and cables were set up and configured. The C-Band TV set was tuned to the desired frequency (3.7-4.2 GHz), while the 5G Signal Generator was set to the same frequency as the C-Band DVB-S2 (Co-Channel). The signal strength of the C-Band TV signal reception was recorded in dBm. Then, the 5G signal was introduced, and the resulting signal strength was recorded in dBm. The Carrier to Interference (C/I) ratio was measured, and CCI was calculated. This process was repeated, varying the 5G signal power and frequency to assess CCI under different conditions.

2. Adjacent Channel Interference (ACI) Measurement

In Nigeria, the adjacent channels for 5G and C-Band TVRO are defined as follows: 5G Frequency band: 3.5 GHz (n78), Channel Bandwidth: 5 MHz, 10 MHz, 15 MHz, 20 MHz, and 50 MHz, and Adjacent channels: 3.5 MHz (n78): 3410 MHz – 3600 MHz = Channel 1 – 20, C-Band TVRO frequency band: 3.7 GHz - 4.2 GHz, and Channel Bandwidth: 27 MHz, 36 MHz, and 54 MHz

- Adjacent Channels: 3.7 GHz - 4.0 GHz = Channel 1 - 10 (27 MHz each) and 4.0 GHz - 4.2 GHz = Channel 11 - 15 (36 MHz each)

The strength of the C-Band DVB-S2 signal (desired signal) was recorded in the absence of 5G interference. Then, the strength of the 5G signal (Adjacent Channel Signal) on the adjacent channel was recorded. The Adjacent Channel Interference (ACI) ratio was computed by subtracting the adjacent channel signal strength from the desired signal strength.

3. Varying Distances and Angles Measurement

Data collection was carried out by recording: Signal Strength, Interference Power, Carrier to Interference (C/I) ratio for each scenario, and Bit Error Rate (BER) was measured for each scenario

IV. RESULT AND DISCUSSION

The impact of the 5G New Radio (NR) spectrum on the TV receiver is evident, particularly at 1.65 GHz, which was down-converted from 3550 MHz. This resulted in significant interference to the TV receiver. Notably, the measured interference levels exceeded acceptable thresholds in certain areas.

Figure 2 illustrates the TV images at various power levels:

Figure 2(a) shows a clear image without distortion or saturation at -49 dBm channel power.

Figure 2(b) exhibits interference from the 5G system at power levels above -47 dBm, affecting the NTA signal at 3720 MHz.

Figure 2(c) displays a degraded image at -40 dBm, where the IF signal misrepresentation and overload resulted in a poor-quality image. As expected, this degradation worsened at higher power levels.

a. TV signal without distortion (-49dBm)

b. TV signal without distortion (-47dBm)

c. TV signal Distorted and Saturated (-40dBm)

Figure 2: Displays TV Images for Different Power Levels

For the 5G and TV coexistence analysis, the minimum protection distance is a critical parameter. It represents the minimum separation required between Fixed Satellite Service (FSS) TV receivers and 5G base stations to prevent performance degradation, characterized by image distortion in analog channels and blocking in digital channels.

The study revealed that interference levels varied significantly depending on factors such as: Increased distance resulted in decreased interference, Variations in terrain affected the interference levels, and the angle of elevation played a crucial role, with higher angles resulting in reduced interference impact.

These findings emphasize the importance of careful planning and optimization of 5G base station deployments to ensure harmonious coexistence with TV services. Figure 3 shows the co-channel interference level while figure 4 illustrates adjacent channel interference level

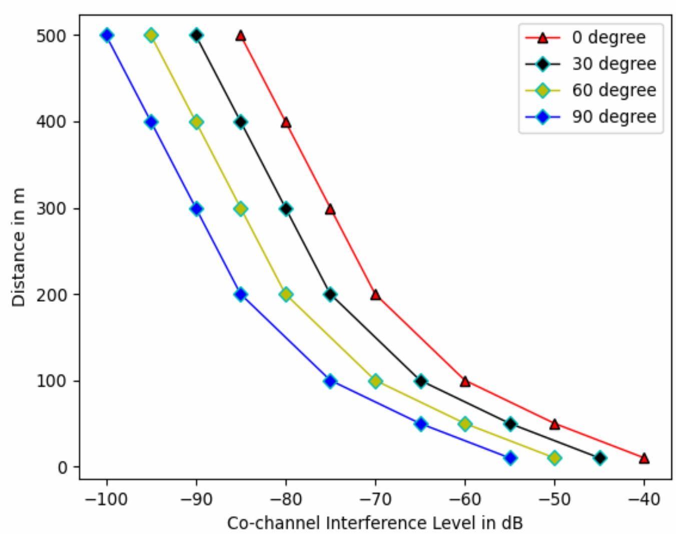

Figure 3.Co-Channel Interference Level

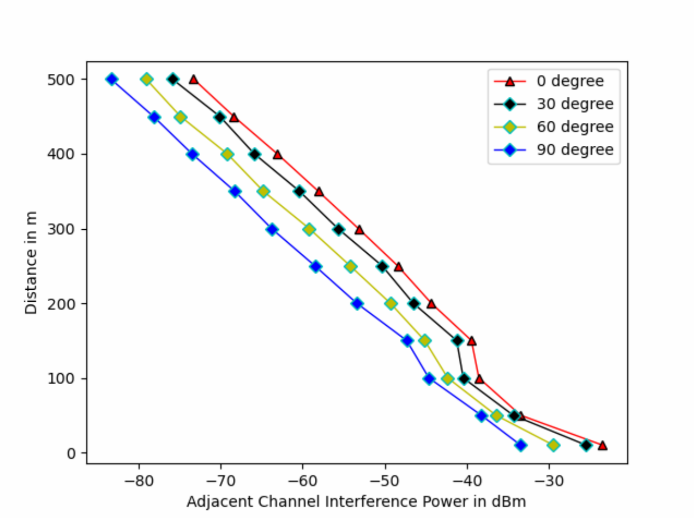

Figure 4. Adjacent Channel Interference Level

The 5G signal, operating on an adjacent channel, had a lower signal level compared to the C-Band DVB-S2 TV signal. However, its proximity to the TV frequency band still caused significant interference. To mitigate this interference, the study recommends: maintaining a minimum distance of 300 metres between the 5G base station and C-Band TV reception and adjusting the elevation angle to 60° or higher to reduce interference power.

Furthermore, the investigators propose a cost-effective solution to minimize 5G interference in TV signals. As illustrated in Figure 3, they suggest inserting low-cost planar RF filters with low insertion loss before the Low Noise Amplifier (LNA) stage of the Low Noise Block Frequency Converter (LNBF). This filter would effectively block 5G interference, ensuring uninterrupted TV reception.

Figure 5 : Integration of Planar RF Filter to Reception

Table 1 summarizes the protection distance calculations for a 5G base station with an Effective Isotropic Radiated Power (EIRP) of 75 dBm.

The results show that the proposed filter significantly reduces the required separation distance between the 5G base station and C-band TV signals from 12.05 km to 663.6 m. Furthermore, improving the Low Noise Block Frequency Converter (LNBF) P1dB (referred to as "Proposed solution 2" in Table 1) can alleviate TV signal saturation, allowing for a further reduction in protection distance. The calculated enhanced protection distance is only 110 m, making 5G deployment viable in the C-band. This enables harmonious coexistence between 5G and DVB-S2 systems without mutual interference.

Table 1: Evaluation of the protection distance including an RF filter before the LNBF First amplification stage.

LNBF	RF Filter	LNBF P 1dB	Protection distance
Commercial	No	-60 dBm	12.05km
Proposed solution 1	Yes	-60 dBm	672.6 m
Proposed solution 2	Yes	-45 dBm	110 m

Table 2: Field Measurement results for LNBS &Filters

Measurement number test	LNB	Receiving Filter	BER	C/N dB	Picture
1		No	> 1 E – 1	1.8	Black screen
2		3.7 Filter	1.60 E-04	15	Good
3		3.625 Filter	> 1E – 1	15.2	Mosaic & black screen
4		No	>1E-1	4.9	Mosaic & black screen
5		3.625 filter	9.72E-03	11.7	Good

Measurement results 1 and 4 of table 2 show that a TV operating in the frequency range of 3700 – 4200 MHz and equipped with a LNB of 3400 -4200 MHz is vulnerable to the saturation interference of the 5G system in adjacent frequency bands. Measurement results 2 and 5 show that by installing a filter to front end of the LNB, the two systems will be compatible with each other under the isolation distance of about 50 m. From measurement results 2 and 3 we can see that different filter performance (suppression capability and cutoff frequency) are required in different interference scenarios. Measurement results 3 and 5 show that the direction of the main lobe of massive MIMO antenna (determined by the distribution of 5G terminals) significantly affects the level of interference. The two systems became compatible with each other when the direction of the main lobe pointed to a terminal deployed 50 m away from the earth station (measurement result 5).

The experimental results demonstrated interference problems and even image cancellation, due to the installation of 5G base stations close to television user homes. Two efficient strategies have been proposed for minimizing the saturation and distortion problems and addressing the coexistence between 5G and TV reception. The first approach relies on adding low-cost planar RF filters with low insertion loss before the LNBF first amplification stage. Furthermore, increasing the TV reception LNBF1dB compression point by 15 dB might further lessen the protection distance to only 110 m. The findings of this study acquiesce with [4] and [8].

V. CONCLUSION

This experimental study investigated the impact of 5G interference on C-band TV signals in Nigeria. The results showed that 5G signals can cause significant interference to C-band TV signals, leading to degraded image quality and potential service disruption. However, the study also demonstrated that the use of low-cost planar RF filters and improving the LNBF P1dB can significantly reduce the required protection distance between 5G base stations and C-band TV receivers. These findings have important implications for the deployment of 5G services in Nigeria and other countries using C-band for TV broadcasting.

VI. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are made:

1. The Nigerian Communications Commission (NCC) should establish a regulatory framework to ensure that 5G deployments do not interfere with C-band TV signals.
2. TV broadcasters and operators should install low-cost planar RF filters at their receiving stations to mitigate 5G interference.
3. Manufacturers should improve the P1dB of LNBFs to reduce the impact of 5G interference on C-band TV signals.
5. The public should be educated on the potential impact of 5G interference on C-band TV signals and the measures being taken to mitigate it.

FUTURE RESEARCH DIRECTIONS

1. Other techniques, such as antenna redesign and signal processing algorithms, should be investigated to mitigate 5G interference on C-band TV signals.
2. Large-scale measurements should be conducted to characterize the impact of 5G interference on C-band TV signals in different environments and scenarios.
3. Models should be developed to predict the coexistence of 5G and C-band TV services in different scenarios.

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