Interference Management for the Coexistence of DTTV and LTE Systems within the Proposed Digital Dividend Band in Nigeria

B. I. Bakare, V. E. Idigo, and S. U. Nnebe

Abstract — This paper seeks to present the Interference Management for the Coexistence of DTTV and LTE Systems within the proposed digital dividend band in Nigeria. The study focused on LTE Down-link (DL) signal from the nearest cell site interfering with the Digital Terrestrial Television (DTTV) fixed outdoor receiving antenna in Port Harcourt, Nigeria. The qualitative signal analysis of the DTTV systems is essential as DTTV system cannot start to operate in the newly formed frequency band without the evaluation of the possible harmful influence of the coexisting systems. This research work investigated the Compatibility of the two systems and the Probability of interference of Channel 17 (490MHz) and Channel 51 (693MHz) when DTTV and LTE systems coexist within the proposed Digital Dividend band. A test-bed approach method was adopted for the generation of the required simulation data. Star Time transmitting Station in Port Harcourt and Smile LTE 4G Communication LTE Base Station (eNBs) Network also in Port Harcourt were adopted as the Victim Link Transmitter (VLT) and Interfering Link Transmitter (ILT) respectively. Data was obtained, analyzed, and evaluated. It was observed from the simulation result that the probability of interference is a function of the separation distance between ILT and VLR. The Compatibility analysis result shows that the resulting C/I is above the protection criteria (19dB), that is there’s a minimal rate of interference. Hence, the interference issue can be managed when the two systems coexist in 700MHz band. It was also established that DTTV channel 51 suffers more interference when compared with DTTV channel 17 for the same separation distance. The study recommended the minimum protection distance approach (Interference Avoidance method) as the interference management techniques when DTTV and LTE systems coexist in the proposed digital dividend (700MHz) band in Nigeria.

Keywords — Cellular Network; Communication; Digital Terrestrial Television (DTTV); Interfering Link Transmitter (ILT); Long Term Evolution (LTE); Victim Link Transmitter (VLT).

I. INTRODUCTION

The migration from Analogue Television (ATV) to Digital Terrestrial Television (DTTV) released a wide range of frequency band (689MHz-806MHz) called Digital dividen[1]. The Digital dividend (DD) can be made available for commercial usage and it can be utilized by mobile telecommunication operators to expand their services in providing higher capacity and ensuring more access to multimedia resources due to the propagation characteristics of the digital dividend, it is also considered as an attractive alternative for the allocation of mobile broadband services (MBS) such as Long Term Evolution (LTE).

Nigeria had missed two deadlines (June 17, 2015, and June 17, 2017) of Digital Switchover (DSO) [2]. In 2016, Nigeria launched the pilot phase of the Federal government's digital transmission project to transit from analogue broadcasting to digital broadcasting. Presently, Nigeria is in a phase called longer Simulcast, which is the simultaneous transmission of analogue and digital TV while waiting for the total switch-off. The NTA-Star TV Network, with the working name “Startimes” which is a joint venture between the Nigerian Television Authority (NTA) and Beijing Star group, is the first digitalization pilot project in Nigeria. It is a key partnership between the biggest Television Network in Africa (NTA), and China's most powerful radio TV endeavor [3].

Long Term Evolution (LTE) is the 4th generation mobile communication Network standard for wireless broadband communication for mobile devices and data terminals, it increases the capacity and speed using a different radio interface together with core network improvements [4]. The Third Generation Partnership Project (3GPP), the organization of mobile device manufacturers, infrastructure developers and mobile network operators responsible for the GSM and UMTS specification, redesigned both the Radio Access Network (RAN) and the core network. The redesigned result is commonly referred to as Long Term Evolution or LTE for short and has been included in 3GPP Release 8 [5]. The main advantage of LTE is to provide a high data rate, low latency and packet optimized radio access technology supporting flexible bandwidth deployments. SMILE 4G LTE Communication Network, Port Harcourt Nigeria was adopted as the LTE Network for this research work.

The receiver of a digital Terrestrial TV system always receives the desired signal as well as undesired Signals such as noise, or undesired signals of other radio systems. Based on the spectrum situation, various coexistence scenarios exist, where the signal of one system may act as an unwanted (interfering) signal to the respective other systems. Depending on the severity of the interference, this may cause degradation of the received signal quality, e.g., frozen images in case of digital TV reception or complete failure to receive the wanted signal. A situation where the long-term evolution

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transmitter signal act as an interferer on the DTTV Receiver which is the scope of the research is shown in figure 1. Like all mobile radio technologies, LTE transmits in both the downlink (DL) and the Uplink (UL) directions, while DTTV broadcasting uses only the downlink (DL) direction. Interference in digital terrestrial television network is one of the major and most common issues that affect the performance and quality of service of a DTTV network system, and its management is one of the research interests of this paper. The independent and equitable analysis of the interference is essential as any system cannot start to operate in the newly formed frequency band without evaluation of possible harmful influence to the existing systems [6].

Interference management can be described as a technique or process employed for the control and mitigation of interference. It can be further described as a scheme for interference cancellation, avoidance, or reduction in a system. Several mitigation techniques are available to address interference issues in the broadcast industry. Based on recent contributions in both academia and industry, the various interference mitigation techniques may be categorized into the family of active and passive approaches [8].

Mitigation techniques are required either to further reduce the risk of interference or to solve the possible interference cases which would occur despite the application of the general measures in terms of out-of-band emission limitations. Guard bands and Protection distances is an interference avoidance method (Active Approach). A guard band is an allocation of spectrum used to separate adjacent transmit and receive bands within a given service or to separate bands of different services for the purpose of protecting operations within the separated bands from interference while protection distance is minimum separation distance between the DTTV and LTE systems.

The study area of the research work is Port Harcourt – the capital of Rivers State. It lies along the Bonny River and is located in the Niger Delta area with coordinate 4°49'27" N 7°21'1"E and a land mass of about 360 km2 and 9 km2 of water [9]. The goal of this paper is to present the Interference Management for the coexistence of DTTV and LTE Systems within the proposed digital dividend band in Nigeria. The result of this study will find usefulness in the academics, the broadcast, and telecommunication industries as there is no known detailed research work on the proposed coexistences of DTTV and LTE in Nigeria.

II. RELATED RESEARCH WORK

In a research paper [10], engaged in a research work on the coexistence of Digital Terrestrial Television and next-generation cellular networks in the 700 MHz band. The authors analyzed the coexistence problem in the 700 MHz bands and evaluated the interference of LTE signals to DTT services. The coexistence of DTT and LTE in the 700 MHz band was analyzed for fixed outdoor and portable indoor DTT reception.

In another paper [11], carried out the Analysis of the interference from the LTE system in the ISDB-TB Digital TV system at 700 MHz. The author presented the results of field measurements and computer simulation of the interference from LTE in the ISDB-TB Digital TV systems in the 700 MHz band. The scenarios from a field measurement campaign were created in SEAMCAT simulations, achieving similar results. The SEAMCAT tool was considered suitable to assess the coexistence of LTE and Digital TV systems in more complex scenarios with multiple interfering transmitters and victim receivers. A research work [12] investigated measured interference of LTE Uplink Signals on DVB-T Channels. The obtained results highlighted the TV receiver features, as well as the presence or absence of a masthead amplifier in the receiving chain, may heavily affect the DVB-T signal QoS received by the user. Several simulation scenarios were analyzed and result in terms of Protection ratio and protection distance was also carried out.

In another related paper [13], investigated LTE transmissions from base stations, i.e., the downlink to DTTV receiver and discovered that the impact from base stations on the DTT roof-top reception is significant and measures are needed to mitigate the risk of interference when implementing a mobile network in an area covered by an adjacent broadcasting channel. A related work [14] looked at interference issues and their causes in Heterogeneous cellular Networks (HetNets) and how they have been combated using different management techniques. The study however did not consider Digital Terrestrial Television Networks. In another related paper [15], presented Inter-cell interference management for cellular systems, the author looked at Inter-cell interference coordination (ICIC) based on coordinated beamforming. Digital Terrestrial Television Network was also not considered by the author. Frequency coordination techniques are available to address interference issues in the broadcast industry. Frequency coordination is an effective method in which a guard space is used to separate systems sharing the same spectrum or occupying an adjacent spectrum. Coordination is usually thought of as a formal process by which a frequency and a coverage area are assigned to an applicant. In cellular systems, a frequency reuse pattern is basically an informal approach to coordinating frequencies and controlling interference.

Based on recent contributions in both academia and industry, the various interference mitigation techniques may be categorized into the family of active and passive approaches [7]. Interference cancellation and suppression are referred to as the Passive Approach while interference avoidance and the usage of Smart antennas are regarded as Active Approach. From the reviewed works, there has been no known comprehensive research work carried out on the interference management between DTTV and LTE systems using the minimum protection distance and the guard band (Interference avoidance method) between LTE base station and Digital Terrestrial Television Receiver operated on.
III. INTERFERENCE ASSESSMENT

There are two fundamental approaches for the interference assessment of the coexistence of DTDTV and LTE systems: The Minimum Coupling Loss method and the SEAMCAT analysis method.

A. Minimum Coupling Loss (MCL) Approach

The Minimum Coupling Loss (MCL) approach uses deterministic calculations to analyze the maximum level of interference from interfering transmitter into victim receiver. The MCL method is useful for the initial assessment of compatibility. The required Path loss, L(required path loss), between the interfering transmitter (I) and the victim receiver (Vv) to ensure that there is no harmful interference is obtained from [6].

\[
L(\text{required path loss}) = P_{\text{BSTX}} + G_{\text{DTRX}} - P_{\text{IDTTRX}} \tag{1}
\]

where \( P_{\text{BSTX}} \) is the Power of the interfering LTE base station and \( G_{\text{DTRX}} \) is the victim Digital Terrestrial Television (DTTV) system antenna gain. The interference level at the Digital Terrestrial Television (DTTV) fixed outdoor reception receiver, \( P_{\text{DTT Rx}} \), is obtained from [6].

\[
P_{\text{IDTTRX}} = P_{\text{NDTTRX}} + I/N \tag{2}
\]

where \( P_{\text{NDTTRX}} \) is the noise power at the DTT receiver and I/N is the interference to noise ratio.

\[
P_{\text{n}} = NF + 10 \cdot \log _{10}(K \cdot T_0 \cdot B) \tag{3}
\]

where \( P_{\text{n}} \) is the receiver noise input power (dBW), \( NF \) is the receiver noise figure (dB), \( k \) is the Boltzmann’s constant \((k = 1.38 \times 10^{-23} \text{ J/K})\), \( T_0 \) is the absolute temperature \((T_0 = 290 \text{ K})\), \( B \) is the receiver noise bandwidth \((7.6 \times 10^6 \text{ Hz for 8 MHz DVB-T channel, and } 7.77 \times 10^6 \text{ Hz for 8 MHz DVB-T2 channel})\).

The result of a MCL calculation is an isolation figure which can subsequently be converted into a physical separation, choosing an appropriate path loss model [16].

The isolation is then converted into a separation distance using the Free-space attenuation, L (loss), between isotropic antennas by formula

\[
L(\text{loss}) = 32.4 + 20 \log_{10}(f) + 20 \log_{10}(d), \tag{4}
\]

where \( f \) – frequency (MHz); \( d \) – distance (km).

The required protection distance, \( d_{\text{req, DTV-T BS}} \), is between LTE base station and the DTDTV Receiver is [16].

B. Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT)

SEAMCAT (Spectrum Engineering Advanced Monte Carlo Analysis Tool) is a statistical simulation model that uses a method of analysis called Monte Carlo to estimate the potential interference between different radio communication systems such as broadcasting, point to point, point to multipoint, radar, Mobile networks, aeronautical and satellites as shown in Fig. 2.

SEAMCAT is a radio spectrum system-oriented software tool that allows you to build your own libraries (such as antennas, spectrum masks, propagation models, radio systems) or use those provided by other users to ease the effort to build complete scenarios for investigation. SEAMCAT is distributed with a predefined set of libraries so that you do not need to reinvent the wheel every time you have studies to perform.

SEAMCAT models one single victim link receiver (VLR) connected to a victim link transmitter (VLT) operating amongst a population of one or more interfering link transmitters (ILT) which are linked to an interfering link receiver (ILR). These interferers may belong to the same system as the victim, a different system, or a mixture of both.

In the Monte Carlo (MC) simulation used for this study, a series of trials were repeated using a set of varied, user-defined parameters in order to calculate a protection criterion, such as the carrier-to-interfering (CI) or the interfering-to-noise (I/N) ratio, for each trial. After a sufficient number of trials (i.e., 10,000 snapshots), the probability of interference \( P_{\text{int}} \) can be calculated as follows:

\[
P_{\text{int}} = 1 - P_{\text{non-int}}', \tag{6}
\]

where \( P_{\text{non-int}} \) is the probability of non-interference of the victim receiver when \( \text{(DE/IE)} > \text{C/I} \). Here, DE is the desired signal power and IE is the interference power.

The interference signal IE is composed of two sources, unwanted emission \( (I_{\text{E, unwanted}}) \) and receiver imperfection \( (I_{\text{E, blocking}}) \):

\[
I_{\text{E}} = I_{\text{E, unwanted}} + I_{\text{E, blocking}} \tag{7}
\]

The probability of interference is been calculated by two different calculation modes namely compatibility and translation according to SEAMCAT software (ECC Report 252). For this research, the calculation model used is the compatibility mode that provides a single-figure estimate as the probability of interference in a given interference scenario, the interference criterion used is the Carrier-to-Interference ratio (C/I) and the interference signal type considered for the calculation is the unwanted signal type.
The protection ratio (PR) is the minimum power margin between the desired and interfered signals and can be calculated using the equation [18].

\[
PR = \frac{|C/I| \text{ wanted}}{|C/I| \text{ interfered}} \quad (8)
\]

If the resulting C/I is below the protection criteria (19dB), the probability of interference as calculated by SEAMCAT (Interference Calculation Engine Control) is equal to one (1) i.e there’s the possibility of interference occurrence and if the resulting C/I is above the protection criteria (19dB), the probability of interference as calculated by SEAMCAT (Interference Calculation Engine Control) is equal to zero (0) i.e., there’s no possibility of interference occurrence or minimal rate of interference occurrence [17].

IV. MATERIALS AND METHOD

A test-bed approach method was adopted for this research. In this context, the test-bed, also known as the test environment is within the 6km radius of Star time Transmitter in Port Harcourt, Nigeria. The Star Time transmitting Station located inside the Premises of National Television Authority (NTA) at Mgbuoba, Port Harcourt on latitude 4°51’48.43”N and longitude 6°57’42.66”E which is on an elevation of 16m above the sea level with a transmitter height of 100m is the Victim Link Transmitter (VLT). Using the Google Earth map software, twelve concentric circles of radius of 0.5 km spacing were drawn with star times transmitter located within NTA premise in Port Harcourt taken as the center of the circles. A line of distance 6.0km due West (W), North-West (NW), North (N), North-East (NE), East (E), South East (SE), South (S), South West (SW) and West (W) of star time transmitter was created using the same Google Earth software. The point of intercept between the created lines and concentric circles gave the ninety six (96) measuring points. The Smile 4G LTE (eNB) Cell Sites in Port Harcourt, which is the interfering link transmitter (ILT) were also indicated on the same Port Harcourt Google earth Map indicating the physical distance between DTTV signal receiver and Smile 4G LTE.

![Fig. 3. A prototype coexistence location between DTTV receivers and LTE eNBs in Port Harcourt.](Image)

DVB-T2 Analysis meter with the cable system connected to a directional receiving antenna used for the measurement of the received signals strength as shown in figure 4 is the Victim Link Receiver (VLR).

**Fig. 4. DS2400T DVB-T2 Analysis meter is the Victim Link Receiver (VLR).**

A. Star Time (DTTV) Transmitter and Smile 4G LTE System Parameters

The values in Table I show the Victim Link Transmitter (VLT) properties which are the star time transmitter (DTTV) parameter used for this study while Table II presents the Interfering Link Transmitter (ILT) properties which is also Smile 4G LTE parameters used for this investigation.

**TABLE I: DTTV TRANSMITTER (VLT) PARAMETERS AND SPECIFICATIONS**

| S/No | Properties             | Value  |
|------|-----------------------|--------|
| 1    | Transmitter antenna height (m) | 116.0  |
| 2    | Thermal noise (dBm)   | -121.00|
| 3    | Noise figure (dB)     | 6.0    |
| 4    | Noise floor (dBm)     | -99.1  |
| 5    | Sensitivity (dBm)     | 80.7   |
| 6    | Antenna height (m)    | 10     |
| 7    | Antenna Pattern       | ITU-R BT.419: DVB-T2 |
| 8    | Antenna peak gain     | 6.0    |
| 9    | Frequency (MHz)       | Channel 17 = 490.0 |
| 10   | Transmitter Power (dBm)| 64.01  |
| 11   | Bandwidth (KHz)       | 200.0  |

**TABLE II: SMILE 4G LTE TRANSMITTER (ILT) PARAMETERS AND SPECIFICATIONS**

| S/No | Properties             | Value         |
|------|-----------------------|---------------|
| 1    | Power (dBm)           | 33.0          |
| 2    | Antenna height (m)    | 30.0          |
| 3    | Antenna Pattern       | LTE 800 MHz   |
| 4    | Antenna peak gain     | 15.0          |
| 5    | Frequency (MHz)       | 800.0         |
| 6    | Propagation model     | Extended Hata |
| 7    | Channel Bandwidth (MHz)| 10           |

B. Coexistence Simulation of Star time TV Signal and Smile 4G LTE Cell Site

The coexistence Simulation of DTTV and LTE Systems was carried out using Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT) Software with the System parameters and specifications of Star Time transmitting Station in Port Harcourt (Table I) and Smile LTE 4G Communication LTD Base Station (eNBs) Networks also in port Harcourt (Table II) adopted as the simulated Victim Link Transmitter (VLT) and Interfering Link Transmitter (ILT) respectively.

Table III presents the distances between Star time TV Receiver (VLR) and Smile 4G LTE Transmitter (ILT) as
demonstrated in Fig. 3 and it was also adopted for the coexistence simulation study. The simulated result of the probability of interference when VLR 0117 coexist with ILT 01 and simulated with Channel 17 (490 MHz) operating frequency is shown in Fig. 4 while table IV presents the probability of interference as calculated by SEAMCAT resulting C/I is above the protection criteria (19dB) operating frequency is shown in Fig. 5. 

The result of probability of interference when VLR 0117 coexist with ILT 01 and simulated with Channel 17 (490 MHz) operating frequency is shown in Fig. 5.

### TABLE III: DISTANCES BETWEEN STAR TIME TV RECEIVER (VLR) AND SMILE 4G LTE TRANSMITTER (ILT) ADOPTED FOR THE COEXISTENCE SIMULATION STUDY

| S/No | DTTV Receiver Location Tag on the Test-bed | DTV Receiver (VLR) Simulation Tag | LTE Location Tag on the Test-bed | LTE (ILT) Simulation Tag | Distance between DTTV Receiver (VLR) and LTE (ILT) measured in (Km) |
|------|------------------------------------------|----------------------------------|----------------------------------|-------------------------|--------------------------------------------------|
| 1    | SE 8                                     | VLR 0117                         | VLR 0151                         | eNB 19                  | ILT 01                                           |
| 2    | SE10                                     | VLR 0217                         | VLR 0251                         | eNB19                   | ILT 02                                           |
| 3    | NW12                                     | VLR 0317                         | VLR 0351                         | eNB 24                  | ILT 03                                           |
| 4    | NW12                                     | VLR 0417                         | VLR 0451                         | eNB 48                  | ILT 04                                           |
| 5    | NE10                                     | VLR 0517                         | VLR 0551                         | eNB 41                  | ILT 05                                           |
| 6    | E6                                       | VLR 0617                         | VLR 0651                         | eNB 41                  | ILT 06                                           |
| 7    | E11                                      | VLR 0717                         | VLR 0751                         | eNB 58                  | ILT 07                                           |
| 8    | SW8                                      | VLR 0817                         | VLR 0851                         | eNB 49                  | ILT 08                                           |
| 9    | SE6                                      | VLR 0917                         | VLR 0951                         | eNB 13                  | ILT 09                                           |
| 10   | NE11                                     | VLR 1017                         | VLR 1051                         | eNB 42                  | ILT 10                                           |

![Image](image.png)

Fig. 5. Probability of interference when VLR 0117 coexist with ILT 01.

### TABLE IV: PROBABILITY OF INTERFERENCE FOR DTTV RECEIVER (VLR) AND LTE CELL SITE (ILT)

| S/No | Channel 17 (490MHz) | Channel 51 (693MHz) | Distance between DTTV Receiver (VLR) and LTE (ILT) measured in (Km) | Probability of Interference |
|------|---------------------|---------------------|---------------------------------------------------------------------|----------------------------|
| 1    | VLR 0117            | VLR 0151            | 0.5                                                                 | 0.783                      |
| 2    | VLR 0217            | VLR 0251            | 1.0                                                                 | 0.575                      |
| 3    | VLR 0317            | VLR 0351            | 1.5                                                                 | 0.429                      |
| 4    | VLR 0417            | VLR 0451            | 2.0                                                                 | 0.338                      |
| 5    | VLR 0517            | VLR 0551            | 2.5                                                                 | 0.257                      |
| 6    | VLR 0617            | VLR 0651            | 3.0                                                                 | 0.210                      |
| 7    | VLR 0717            | VLR 0751            | 3.5                                                                 | 0.170                      |
| 8    | VLR 0817            | VLR 0851            | 4.0                                                                 | 0.139                      |
| 9    | VLR 0917            | VLR 0951            | 4.5                                                                 | 0.119                      |
| 10   | VLR 1017            | VLR 1051            | 5.0                                                                 | 0.095                      |

C. Compatibility Analysis of the Coexistence of DTTV Receiver and LTE Base Station

Compatibility mode provides a single figure estimate of the probability of interference in a given interference scenario. From equation (7), the interference signal $I_E$ is composed of two sources, the unwanted emission ($I_{\text{E_{unwanted}}}$) and the receiver imperfection ($I_{\text{E_{blocking}}}$):

$$I_E = I_{\text{E_{unwanted}}} + I_{\text{E_{blocking}}}$$

If the resulting C/I is below the protection criteria (19dB), the probability of interference as calculated by SEAMCAT (Interference Calculation Engine Control) is equal to one ($1$) i.e., there’s the possibility of interference occurrence and if the resulting C/I is above the protection criteria (19 dB), the probability of interference as calculated by SEAMCAT (Interference Calculation Engine Control) is equal to zero ($0$) i.e., there’s no possibility of interference occurrence or minimal rate of interference occurrence (ECC Report 252).

The compatibility Analysis carried out during the simulation of the coexistence of DTTV receiver and LTE Base stations is presented in Table V.

D. Protection Distances between DTTV Receivers and LTE Base Stations

The DTTV transmission-based DVB-T2 standard for SFN loss is analyzed by using the UHF propagation free space loss formula which given as [19].

$$L_{SFN}[dB] = 20\log_{10}f + 20\log_{10}d + 32.4$$

where $d$ is the distance between the transmitter (Tx) and the receiver (Rx) and is expressed in km. $f$ is the frequency of operation which is expressed in MHz. and $L_{SFN}[dB]$ is the Path loss between the DTTV transmitter and the Receiver measured in decibel (dB).
TABLE V: Compatibility Analysis Table for the Coexistence of DTTV Receiver and LTE Base Station

| S/N | Victim wanted Signal (dRSS) measured dBm | Interfering Signal (dRSS) measured dBm | Distances between DTTV Receiver and LTE cell site measured in (Km) | C/I=μRSS – μRSS Protection Criteria measured in dBm |
|-----|-------------------------------------|-------------------------------------|-------------------------------------------------|-------------------------------------|
|     | Channel 17                           | Channel 51                           | Channel 17                                      | Channel 51                           |
| 1   | -87.30                               | -94.06                              | -146.051                                       | -132.10                              |
| 2   | -71.47                               | -92.25                              | -148.40                                        | -169.87                              |
| 3   | -83.74                               | -63.95                              | -172                                            | -175.84                              |
| 4   | -62.54                               | -94.40                              | -142.07                                        | -167.16                              |
| 5   | -65.55                               | -78.20                              | -167.69                                        | -146.37                              |
| 6   | -74.71                               | -62.32                              | -92.45                                         | -163.71                              |
| 7   | -69.87                               | -87.76                              | -169.32                                        | -167.56                              |
| 8   | -92.58                               | -42.64                              | -188.24                                        | -151.90                              |
| 9   | -80.62                               | -61.12                              | -176.76                                        | 157.56                               |
| 10  | -91.52                               | -89.79                              | 189.52                                         | 185.74                               |

TABLE VI: Protection Distances Between Star Time TV Receiver (VLR) and Smile 4G LTE Transmitter (ILT)

| S/No | DTTV Receiver Location Tag on the Test-bed | Protection distance between DTTV Receiver and LTE (Km) | LTE Receiver Location Tag on the Test-bed | Distance between DTTV Transmitter (VLT) and Receiver (VLR) measured in (Km) | Path loss between DTTV Tx and Rx (dB) | Distance between DTTV Receiver (VLT) and LTE (ILT) measured in (Km) |
|------|------------------------------------------|-------------------------------------------------|------------------------------------------|--------------------------------------------------------------------------------|-------------------------------------|---------------------------------------------------------------------|
|      | Channel 17 (490MHz)                      | Channel 51 (693MHz)                             | Channel 17 (490MHz)                      | Channel 51 (693MHz)                                                                | Channel 17 (490MHz)                      | Channel 51 (693MHz)                                                                |
| 1    | SE 8                                     | 0.31                                            | 0.44                                     | eNB 19                                                                          | 0.5                                  | 80.35                                                                             |
| 2    | SE10                                     | 0.62                                            | 0.87                                     | eNB19                                                                         | 1.0                                  | 86.24                                                                             |
| 3    | NW12                                     | 0.92                                            | 1.30                                     | eNB 24                                                                         | 1.5                                  | 89.74                                                                             |
| 4    | NW12                                     | 1.23                                            | 1.74                                     | eNB 48                                                                         | 2.0                                  | 92.24                                                                             |
| 5    | NE10                                     | 1.53                                            | 2.17                                     | eNB 41                                                                         | 2.5                                  | 94.17                                                                             |
| 6    | E6                                       | 1.84                                            | 2.60                                     | eNB 41                                                                         | 3.0                                  | 95.75                                                                             |
| 7    | E11                                      | 2.14                                            | 3.03                                     | eNB 48                                                                         | 3.5                                  | 97.09                                                                             |
| 8    | SW8                                      | 2.45                                            | 3.47                                     | eNB 49                                                                         | 4.0                                  | 99.25                                                                             |
| 9    | SE6                                      | 2.76                                            | 3.90                                     | eNB 13                                                                         | 4.5                                  | 100.18                                                                            |
| 10   | NE11                                     | 3.06                                            | 4.33                                     | eNB 42                                                                         | 5.0                                  | 104.02                                                                            |

The required protection distance, \(d_{\text{sep,DVB-T-BS}}\), between the LTE base station and the DTTV receiver is [16].

\[
d_{\text{sep,DVB-T-BS}} = 10^{\frac{L(\text{loss}) - 32.4 + 20 \log_{10}(f)}{20}} \quad (11)
\]

where \(f\) is the frequency of operation of the LTE base station and \(L\) is the path loss between DTTV Transmitter and Receiver measured in dB.

E. Guard Band Estimation for LTE

Guard bands are an interference avoidance method. A guard band is an allocation of spectrum used to separate adjacent transmit and receive bands within a given service or to separate bands of different services for the purpose of protecting operations within the separated bands from interference. The guard band in LTE is defined to be 10% of available bandwidth. It is only 1.4 MHz bandwidth that does not correspond to 10%. It is equal to 22.85% as shown in Table VII [20].

\[
\text{OB} = \text{CB} - \text{GB} \quad (12)
\]

where \(\text{OB}\) is Max. Occupied Bandwidth, \(\text{CB}\) is the Channel Bandwidth and \(\text{GB}\) is the Guard band.

TABLE VII: Channel Bandwidth, Occupied Bandwidth and Guard Band for LTE [20]

| S/No. | Channel Bandwidth (MHz) | Number of Resource Block (RB) in Frequency Domain | Maximum Bandwidth (MHz) | Guard band on Each Side (KHz) |
|-------|------------------------|--------------------------------------------------|-------------------------|-------------------------------|
| 1     | 1.4                    | 6.0                                              | 1.08                    | 160                           |
| 2     | 3.0                    | 15.0                                             | 2.70                    | 150                           |
| 3     | 3.5                    | 25.0                                             | 4.50                    | 250                           |
| 4     | 10.0                   | 50.0                                             | 9.00                    | 500                           |
| 5     | 15.0                   | 75.0                                             | 13.50                   | 750                           |
| 6     | 20.0                   | 100.0                                            | 18.00                   | 1000                          |
V. RESULTS AND DISCUSSION

The key performance indicator used for the DTTV signal analysis is Modulation Error Rate (MER), Path loss, and the Received Signal Power. The MER, Path loss, and the Received Signal Power for channel 17 and channel 51 of Star time television Signal are analyzed as the signal travels due West (W), North-West (NW), North (N), North-East (NE), East (E), South East (SE), South (S), South West (SW) and West (W) of star time transmitter.

A. Modulation Error Rate (MER) Analysis

The higher the value of MER measured, the better the signal performance since low MER is not desirable in signal evaluation. The MER has a direct relationship with the Received signal power. That is, as the signal power increases, the MER increases and if the MER drops, it will also affect the signal strength. The MER Analysis of channel 17 in the regions considered is shown in Fig. 7 while Fig. 8 shows the MER analysis of channel 51 in all the regions considered.

B. Compatibility Analysis of DTTV and LTE Systems

The results of the compatibility study of the DTTV and LTE systems show that they can both coexist in the proposed digital dividend band in Nigeria. The Comparative Analysis of Compatibility of DTTV Channel 17 and channel 51 with LTE system is shown in Fig. 8.

The Compatibility analysis result shows that the resulting C/I is above the protection criteria (19 dB), that is there’s minimal rate of interference. Since compatibility mode provides a single figure estimate of the probability of interference in a given interference scenario. It can be observed from Fig. 8 that the two channel considered are compatible with the LTE system as there is no significant interference issue.

C. Probability of Interference between DTTV and LTE.

It was observed from the simulation result that the probability of interference is a function of the separation distance between Smile 4G LTE base stations (ILT) and Star time Television Receivers (VLR). Fig. 10 depicts a plot that compares the probability of interference of channel 17 and channel 51 when it is plotted against the distance between DTTV receiver and LTE Transmitter.

The result obtained from the MER analysis shows that Channel 17 has better MER compared to Channel 51 as the signal travels outwards from the transmitter. It was also observed from the analysis that one may have a good MER, even in the presence of degraded BER. This is particularly true when intermittent interference is occurring, the MER may be fine, while the BER is not.
interference results is due to the closeness of channel 51 to the proposed LTE frequency spectrum in the proposed digital dividend band.

D. Protection Distances between DTTV Receivers and LTE Base Stations

The required protection distance between the LTE base station and the DTTV receiver was calculated using equation (11) and Fig. 11 presents the comparative analysis of the protection distances between the DTTV Receivers and the LTE base stations.

Fig. 11 was able to establish that when the DTTV receiver is 0.5 km away from the transmitter, the minimum allowable protection distance for channel 17 and channel 51 are 0.31 km and 0.44 km, respectively at a separation distance of 0.5 between the DTTV receiver and the LTE base station. It was also observed that the Protection distance is a function of the separation distance between DTTV receivers and the LTE base stations. From the study, DTTV Channel 51 requires a higher protection distance relative to channel 17 and as the separation distance reduces so also is the protection distance, hence for effective interference mitigation, the DTTV transmitter should be collocated with the LTE base station.

VI. CONCLUSION

Conclusively, the result obtained from the DTTV MER analysis shows that Channel 17 has better MER compared to Channel 51 as the signal travels outwards from the transmitter. The results of the compatibility study of the DTTV and LTE systems show that they can both coexist in the proposed digital dividend band in Nigerian. It was observed from the simulation result that the probability of interference is a function of the separation distance between Smile 4G LTE base stations (ILT) and Star time Television Receivers (VLR) and DTTV channel 51 suffer more interference when compared with DTTV channel 17 for the same separation distance. The study was able to establish that when the DTTV receiver is 0.5 km away from the transmitter, the minimum allowable protection distance for channel 17 and channel 51 are 0.31 km and 0.44 km, respectively at a separation distance of 0.5 between the DTTV receiver and the LTE base station.

VII. RECOMMENDATION

The following interference management techniques are hereby recommended for use when DTTV and LTE systems coexist in the proposed digital dividend band.

✓ To co-site LTE base stations and DTTV transmitters, so as to keep the difference between the wanted and interfering signal constant everywhere.

✓ To reduce the power of the LTE base station; this will decrease the interfering signals received in the vicinity of the DTTV receiver.

✓ Increasing the power of the DTTV transmitters, to overcome the interference.

✓ Installing rejection filters in the DTTV receivers, to attenuate the interfering base station signal levels.

✓ Since the uplink traffic is less than the downlink traffic in developing countries, the conventional LTE duplex arrangement is the preferred approach for this study.

Further studies can be carried out on the LTE reception in Nigeria when DTTV act as an interferer in they both coexist in the proposed digital dividend band.

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