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Interference Analysis for the Co-existence of DTTV and LTE Systems in the Digital Dividend (700MHz) band in Nigeria

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Abstract
This paper seeks to present the coexistence simulation of Digital Terrestrial Television (DTTV) and Long Term Evolution (LTE) Systems in Nigeria using Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT) software. This research work investigated the interference Probability of Channel 17 (490MHz) and Channel 51 (693MHz) when DTTV and LTE systems coexist within the proposed Digital Dividend (700MHz) band. The study focused on cellular system 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 simulation data used were obtained from Star Time transmitting Station in Port Harcourt and Smile LTE 4G Communication LTD Base Station (eNBs) Network also in Port Harcourt. The Star time transmitting station was adopted as the Victim Link Transmitter (VLT) while the Smile LTE 4G Communication was taken as the Interfering Link Transmitter (ILT) respectively. From the Monte-Carlo simulation result, the probability of interference for channels 17 and Channel 51 are 0.783 and 0.84 when the DTTV receiver (VLR) and LTE Base station (ILT) are separated by a distance of 0.5Km while their probability of interference are 0.095 and 0.138 when VLR and ILT are separated by a distance of 5Km respectively. 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). It was observed from the analysis that as the separation distance between DTTV and LTE systems decreases, the interference probability of the two systems will increase and the value will tend to infinity. It was established that DTTV channel 51 suffer more interference when compared with DTTV channel 17 for the same separation distance. The difference in the probability of interference results is due to the closeness of channel 51 to the proposed LTE frequency spectrum in the proposed digital dividend band. The results of the study show that when LTE and Digital terrestrial television services operate in the Digital Dividend bands, LTE transmitters can cause harmful Interference to the television reception.

Keywords: Broadcasting, Coexistence, Digital Dividend, Interfering Link Transmitter, Victim Link Transmitter.

1. Introduction

The 2012 World Radio communication Conference allocated the 694 MHz-790 MHz (700 MHz) band to the International Telecommunication Union Region 1, which includes Africa and also Europe, for the mobile service on a co-primary basis with other services to which this band is allocated on a primary basis. However, countries of Region 1 will also be able to continue the use of these frequencies for their digital terrestrial television services, if necessary (Ancans*et al*., 2015). Most spectrum regulators worldwide have already auctioned and awarded the Digital Dividend (DD) band to fourth generation (4G) Long Term Evolution (LTE) mobile services. Japan, United States and some European countries have already allocated a portion of their DD for mobile communication services (Wang *et al*, 2010), but many countries including Nigeria are still in the process of regulating the use of their DD.

The migration from Analogue Television (ATV) to Digital Terrestrial Television (DTTV) released a wide range of frequency band (689MHZ-802MHZ) called Digital Dividend (Mathe*et al*., 2014). The Digital Divided (DD) is made up of Channel 52(689MHz) to Channel 69(802MHz) 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). The allocation of Long Term Evolution (LTE) in the Digital Dividend (DD) band is going to be a major concern for Digital Terrestrial Television (DTTV) service providers as radio waves do not respect boundaries, which suggests that the coexistence of DTTV and LTE is capable of causing interference between the two systems. It is important that the interference expectations be established and the impact investigated before the released spectrum (DD) is allocated for use in Nigeria.

The broadcast spectrum released by the transition from analogue to digital transmission will be made available for a new range of services in which wireless broadband is a major competitor. Among the wireless broadband services, LTE has been adopted by Nigeria Communication Commission (NCC), as the Mobile technology to occupy the proposed digital dividend band in Nigeria, while the National Broadcasting Commission (NBC) has opted for DVB-T2 as the system variant to be implemented for digital terrestrial television broadcasting (Sanusi&Gbenga-Ilori, 2014). As the government is working on policy and logistics to achieve full Digital Switch Over (DSO), so also Communication engineers are engaged in various engineering studies that will ensure Quality of Service (QoS) for DTTV Signals and Coexistence of DTTV and LTE systems in the proposed Digital Dividend band in Nigeria.(Akinbolati *et al*., 2017).

Spectrum flexibility is one of the key features of LTE. In addition to the flexibility in transmission bandwidth, LTE also supports operation in both paired and unpaired spectrum by supporting both Frequency Division Duplex (FDD) and Time Division Duplex (TDD) operation. Long Term Evolution Time Division Duplex (LTE TDD) is the version of LTE that uses the TDD modulation scheme in unpaired spectrum, whereby the same frequency channel is used for both downlink and uplink communication and signals are timed to enable smooth delivery of data. In contrast, Long Term Evolution Frequency Division Duplex (FDD) is a paired spectrum, with a separate channel for uplinks and downloads. LTE-TDD and LTE-FDD also operate on different frequency bands with LTE-TDD working better at higher frequencies, and LTE-FDD working better at lower frequencies. Frequencies used for LTE-TDD range from 1900 MHz to 2400 MHz, with band 33 to band 40 being used while the frequencies used for LTE-FDD range from 698 MHz to 2690MHz, with band 1 to band 21. Band 15 and Band 16 are the reserved band of LTE-FDD. Most LTE- capable devices also support other radio technologies such as GSM and UMTS. As a consequence, a typical high- end LTE device today not only supports more than 20 LTE frequency bands between 700 and 2600 MHz but also supports those for the other radio technologies (Elnashar *et al*., 2014).

Fundamentally, the word interference is seen as an unwanted signal that modifies and disrupt the desire signal travelling from the source to the sink. Digital terrestrial television reception generally gives a good quality picture until the interference is so large that it can no longer be eliminated by the error checking systems in the receiver, at this point the video display becomes pixelated, distorted, or goes blank. In the case of digital TV reception, harmful interference means an interruption in the reception of programs, frozen images or a black screen. Interference can simply be defined in wireless communication as an unwanted signal that corrupt the desired signal, thereby reducing the quality of the desired signal. They operate in the same frequency band and share similar structure and characteristics, hence always difficult to terminate. In contrast, interference can be distinguished from thermal noise in its physical statistical features, because thermal Noise is normally distributed, whereas interference has the same structure as the desired signal. It is good to note that interference is desired signals in other systems and for other users (Oguejiofor *et al*., 2018).

Reviewing the coexistence analysis of DTTV and LTE systems, Sakic and Grgic (2010) investigated the influence of the LTE System on DVB-T Reception. The authors described the interference caused by the LTE system to the DVB-T system and the required interference Protection from the LTE system was also highlighted. They simulated the interference scenarios caused by the LTE Base Stations both for fixed and portable DVB-T reception operating on adjacent channels using SEAMCAT Software. Further studies was recommended in order to determine and evaluate the best possible mitigation techniques which could minimize the influence of LTE-Base Stations on DVB-T reception and the influence of LTE User equipment on DVB-T reception. In a related development, Kassaw*et al.*, (2017) presented the Digital Dividend and its Opportunities for Long Term Evolution Mobile Network: the Case of Ethiopia. The authors investigated interference mitigation techniques for a possible coexistence of the LTE and television broadcast services Deployed in the city of Addis Ababa, Ethiopia. Monte Carlo based interference analysis method and cognitive radio-based Interference signal detection technique are used for the analysis. Existing parameters of the digital television and LTE are used for the analysis. The simulation results verified the feasibility of the coexistence of the two systems.

Chaves and Ruismaki (2014) considered LTE 700 MHz: Evaluation of the Probability of Interference to Digital TV. This work provided studies on the coexistence requirements for the LTE deployment in the 700 MHz band and the DTT Service in adjacent frequency bands. The studies were based on Monte Carlo simulations to assess the potential of interference from LTE UL operating in the lower 700 MHz frequencies into DTT frequencies below 694 MHz Statistical elements of real-life behaviour of mobile terminals and interference were modelled, enabling a realistic estimate of the potential Interference. It was concluded that a reasonably high DTT ACS is sufficient to avoid harmful interference to DTT receivers. Basnet (2014) looked at Interference Analysis in Digital TV Reception with LTE Systems in Adjacent Bands in Australian Context. The author studied the compatibility of operating LTE services in the digital Dividend spectrum identified in Australia based on the recently allocated band plan in Australia. He used the interference analysis method to calculate the minimum separation distance between LTE and DVB-T1 system and Monte Carlo Simulation for outage probability. The results of the study show that when LTE and Digital television services operate in adjacent UHF bands, LTE transmitters can cause harmful Interference to the television reception.

This study was inspired by the limitation of the compatibility study carried out by Sansi and Gbenga-Ilori (2014) on LTE and Future DTTV in the UHF band in Nigeria. The authors presented a compatibility study between future digital television (DTTV) and Long Term Evolution (LTE) in the UHF band using SEAMCAT software. However, the results obtained from the simulations did not consider the interference probabilities of the lower and upper DTTV spectrum (channel 17 and channel 51) band respectively. From the reviewed literatures, it is possible to have a coexistence scenarios where LTE systems will have influence on Digital Terrestrial Television (DTTV) systems. In this coexistence scenario, the LTE signals have impact on the Digital Terrestrial Television (DTTV) receiver. Generally, LTE system generates either an LTE terminal User Equipment (UE) uplink (UL) signal, or an LTE base station (eNBs) Downlink (DL) signal. This research work is restricted to the downlink (DL) signals of the LTE Base station existing within the coverage area of the DTTV transmitter using Digital Terrestrial Television (DTTV) fixed outdoor receiver. This study will demonstrate the feasibility of deploying DTTV and LTE systems with in the proposed Digital Dividend (700MHz) band and the goal of this paper is to quantify the interference probabilities when DTTV and LTE systems coexist in the proposed digital dividend band in Nigeria. The result of this study will find usefulness in the regulatory authorities, the academics, the broadcasting industries and the telecommunication industries as there is no known detailed research work on the proposed coexistences of DTTV and LTE in Nigeria.

2.0 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. SEAMCAT is a radio spectrum system oriented software tool which 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. The locations of the interferers are distributed around the victim, either completely randomly or with some relation to the location of victim in a manner that can be specified by the user. In the Monte Carlo (MC) simulation used for this study, a series of trials was repeated using a set of varied, user-defined parameters in order to calculate a protection criterion, such as the carrier-to-interfering (C/I) 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_{int} can be calculated as follows:

$$P_{int} = 1 - P_{non-int} \quad (1)$$

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

In each trial (or snapshot), the victim receiver obtains a desired DE (dBm) and an interference IE (dBm) signal. The desired signal, DE, is given by

$$D_E = P_{Wt} + G_{Wt} + G_{vr} - L_p \qquad (2)$$

Where Pwt is the transmitting power of the desired transmitter (dBm), Gwt is the antenna gain of the desired transmitter (dBi), G_{vr} is the gain of the victim receiver (dBi), L_p is path loss (dBm) based on an extended Hata model, P_{it} is the power of interference (dBm), and G_{it} is the gain of the interfering antenna (dBm).

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

$$I_{\text{E}} = I_{\text{E}_{unwanted}} + I_{\text{E}_{blocking}} \qquad (3)$$

The dRSS (desired received signal strength) and iRSS (interference received signal strength) are calculated by SEAMCAT. The C/I can be calculated in dBm using the following equation (Dludla*et al.*,2018):

$$\frac{C}{I} = dRSS(dBm) - iRSS(dBm) \qquad (4)$$

3.0 Coexistence of Digital Television (DTTV) and Long Term Evolution (LTE)

In a bid to achieve the research objective, a test-bed approach method was adopted for this research. In a service oriented system setting up the test-bed, a skeletal framework that mimic the service to be provided to the user, is a very important step that can generate the required research data to be used for further evaluation and investigation. 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 0.5km spacing were drawn with star times transmitter located within NTA premise in Port Harcourt taken as the centre 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.

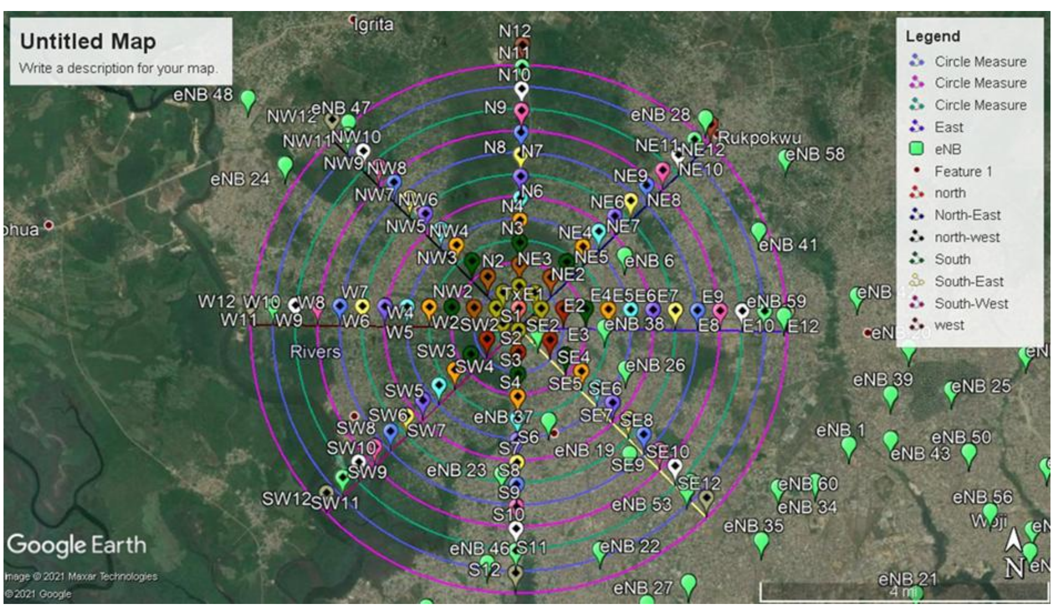

Figure 1: A prototype coexistence locations between DTTV receivers and LTE (eNBs) Cell Sites in Port Harcourt

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. The DTTV measurement points and the LTE cell site were marked and noted (landmark, description, elevation, longitude and latitude) as shown in figure 1. The DS2400T 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 2 is adopted as the Victim Link Receiver (VLR**).**

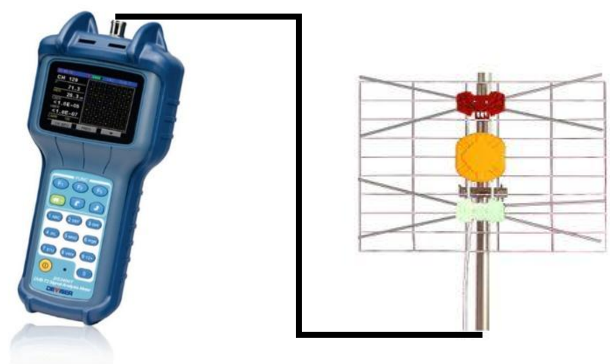

Figure 2: DS2400T DVB-T2 Analysis meter is the Victim Link Receiver (VLR)

4.0 System Parameters

The values in Table 1 shows the Victim Link Transmitter (VLT) properties which is the star time transmitter (DTTV) parameter used for the simulation and evaluation while Table 2 present the Interfering Link Transmitter (ILT) properties which is also the LTE parameters used for the simulation and performance evaluation. Table 3 presents the distance between DTTV Receiver (VLR) and LTE Transmitter (ILT) extracted from the Prototype Coexistence location between DTTV receivers and LTE (eNBs) Cell Sites in Port Harcourt as shown in figure 1 and used for the coexistence simulation study.

Table 1: 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 Channel 51 = 693..0
10	Transmitter Power (dBm)	64.01
11	Bandwidth (KHz)	200.0

Table 2: 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

Table 3: 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	DTTV 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)
		Channel 17 (490MHz)	Channel 51 (693MHz)			
1	SE 8	VLR 0117	VLR 0151	eNB 19	ILT 01	0.5
2	SE10	VLR 0217	VLR 0251	eNB19	ILT 02	1.0
3	NW12	VLR 0317	VLR 0351	eNB 24	ILT 03	1.5
4	NW12	VLR 0417	VLR 0451	eNB 48	ILT 04	2.0
5	NE10	VLR 0517	VLR 0551	eNB 41	ILT 05	2.5
6	E6	VLR 0617	VLR 0651	eNB41	ILT 06	3.0
7	E11	VLR 0717	VLR 0751	eNB58	ILT 07	3.5
8	SW8	VLR 0817	VLR 0851	eNB49	ILT 08	4.0
9	SE6	VLR 0917	VLR 0951	eNB13	ILT 09	4.5
10	NE11	VLR 1017	VLR 1051	eNB42	ILT 10	5.0

5.0 Simulation and Results

The coexistence Simulation of DTTV and LTE Systems was carried out using Spectrum Engineering Advanced Monte Carlo Analysis Tool (SEAMCAT) Software. The System parameters and specifications of Star Time transmitting Station in Port Harcourt shown in table 1 and Smile LTE 4G Communication LTD Base Station (eNBs) Networks also in Port Harcourt shown in Table 2 were adopted as the Victim Link Transmitter (VLT) and Interfering Link Transmitter (ILT) respectively.

5.1 coexistence simulation when the VLR is operated at channel 17 (490 MHz) and spaced 0.5km apart

Figure 3 and Figure 4 present the coverage areas of the Victim Link Transmitter (VLT) and the Interfering Link Transmitter (ILT) when the Victim Link Receiver (VLR) is 0.5 km away from the LTE base Station (ILT) while figure 5 is the interference Probability result after simulation.

(i)Victim Link Transmitter (VLT) Coverage for VLR 0117 operated at 490MHz

The coverage area diagram for the Victim Link Transmitter (VLT) when Star time Signal Receiver (VLR0117) and Smile 4G LTE cell site (ILT 01) are spaced 0.5km apart and Simulated using VLT Channel 17 (490 MHz) is shown in figure 3

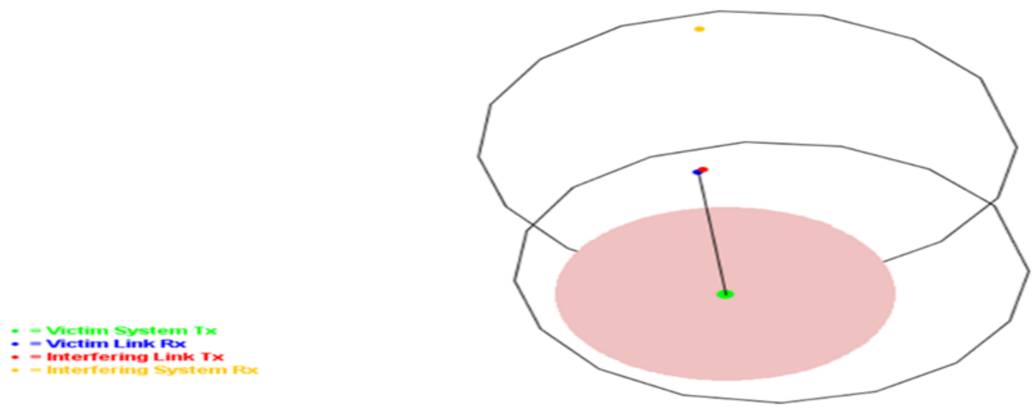

Figure 3: Victim Link Transmitter (VLT) coverage area diagram for VLR 0117

When the Victim Link Receiver (VLR 0117) represented with a blue dot in figure 3 is operated at channel 17(490MHZ) and placed 0.5Km away from the Victim Link Transmitter (VLT), the coverage area of the VLT will overlap the Interfering Link Transmitter (ILT 01) coverage area as shown in figure 3. The blue and the red dot in figure 3 and figure 4 represent the Victim Link Receiver (DTTV Receiver System) and the Interfering Link Transmitter (LTE Base Station System) while the green and yellow dot represents the Victim Link Transmitter (DTTV Transmitting System) and Interfering Link Receiver (LTE User Equipment) respectively.

(ii)Interfering Link Transmitter Coverage (ILT 01)

The coverage area diagram for the Interfering Link Transmitter (ILT) when Star time Signal Receiver (VLR0117) and Smile 4G LTE cell site (ILT 01) are spaced 0.5km apart and simulated using VLT channel 17 (490 MHz) is shown in figure 4

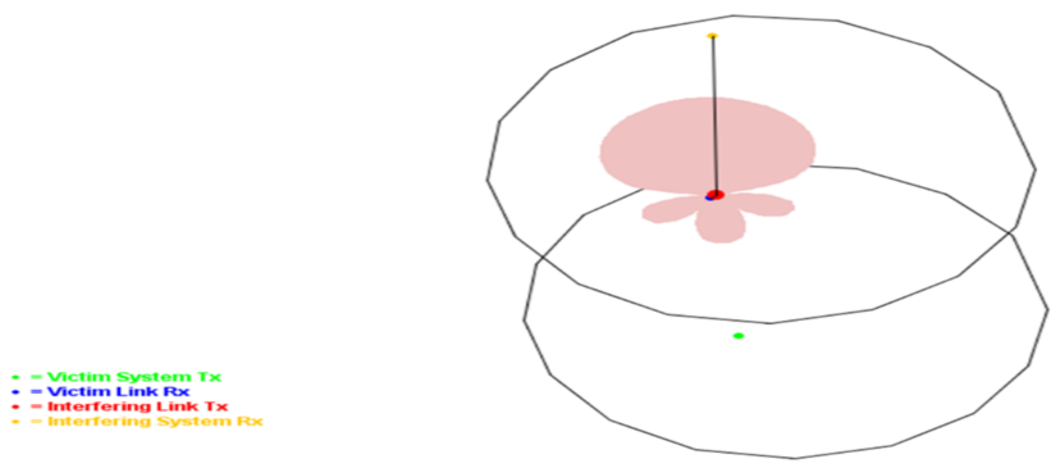

Figure 4: Interfering Link Transmitter (ILT 01) Coverage area diagram for VLR 0117

When the DTTV receiver represented with a blue dot and the LTE (eNBs) Cell Sites represented with a red dot are placed 0.5Km away from each other as shown in figure 4, the probability of interference of the two systems when unwanted emission and the receiver imperfection is considered will give a value of 0.783 as demonstrated in the simulation result shown in figure 5.

(iii)Probability of interference when VLR 0117 coexist with ILT 01

The probability of interference result when VLR 0117 coexist with ILT 01 and simulated with Channel 17 (490MHZ) is shown in Figure 5

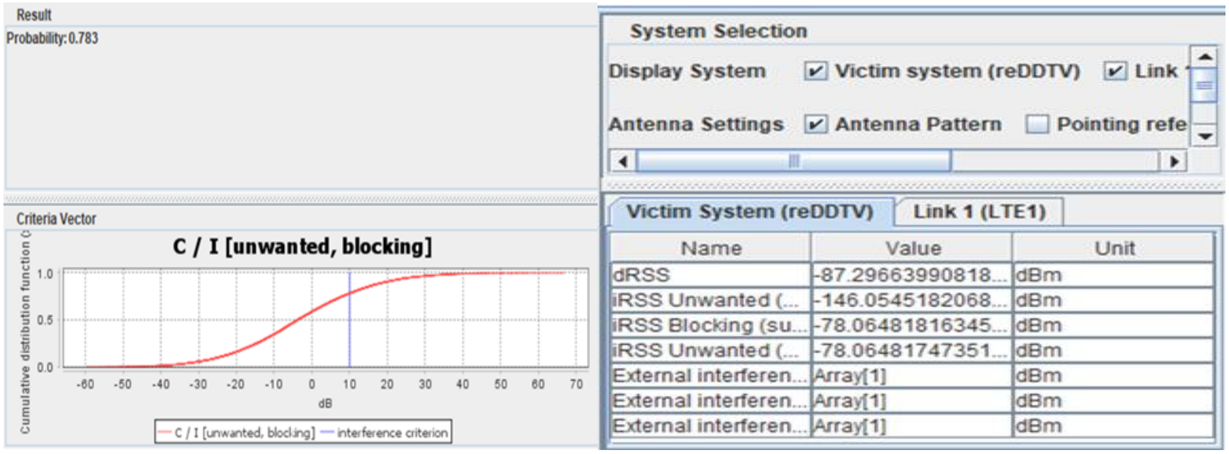

Figure 5: Probability of interference when VLR 0117 coexist with ILT 01

5.2 coexistence simulation when the VLR is operated at channel 51 (693 MHz) and spaced 0.5km apart

Figure 6 and Figure 7 presents the coverage areas of the Victim Link Transmitter (VLT) and the Interfering Link Transmitter (ILT) when the Victim Link Receiver (VLR) is 0.5 km away from the LTE base Station (ILT) while figure 8 is the interference Probability result after simulation.

(i)Victim Link Transmitter (VLT) Coverage for VLR 0151 Operated at 693MHz

The coverage area diagram for the Victim Link Transmitter (VLT) when Star time Signal Receiver (VLR0151) and Smile 4G LTE cell site (ILT 01) are spaced 0.5km apart and Simulated using VLT Channel 51 (693 MHz) is shown in figure 6

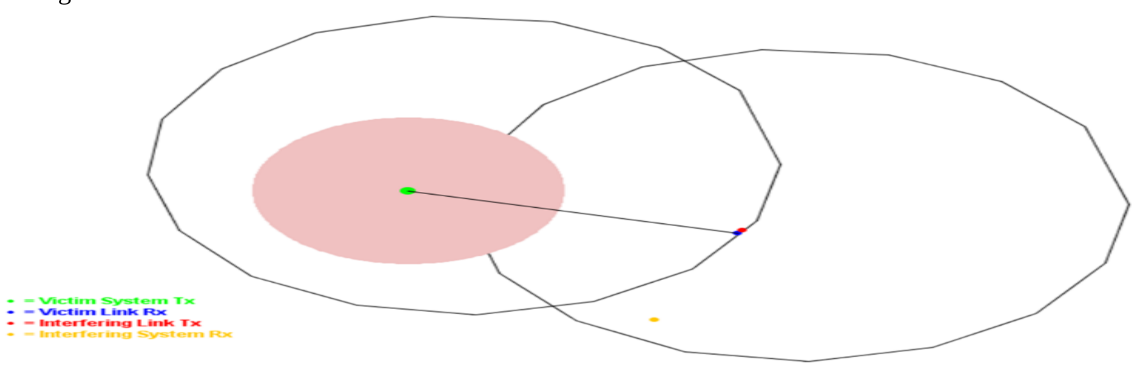

Figure 6: Victim Link Transmitter (VLT) coverage area diagram for VLR 0151

When the Victim Link Receiver (VLR 0151) represented with a blue dot in figure 6 is operated at channel 51(693MHZ) and placed 0.5Km away from the Victim Link Transmitter (VLT), the coverage area of the VLT will overlap the Interfering Link Transmitter (ILT 01) coverage area as shown in figure 6. The blue and the red dot in figure 6 and figure 7 represent the Victim Link Receiver (DTTV Receiver System) and the Interfering Link Transmitter (LTE Base Station System) while the green and yellow dot represents the Victim Link Transmitter (DTTV Transmitting System) and Interfering Link Receiver (LTE User Equipment) respectively.

(ii)Interfering Link Transmitter (ILT) Coverage

The coverage area diagram for the Interfering Link Transmitter (ILT) when Star time Signal Receiver (VLR0151) and Smile 4G LTE cell site (ILT 01) are spaced 0.5km apart and simulated using VLT channel 51 (693 MHz) is shown in figure 7

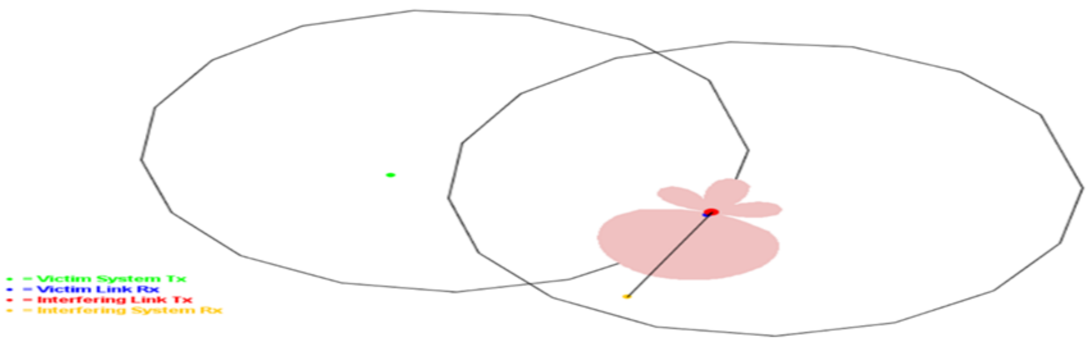

Figure 7: Interfering Link Transmitter (ILT 01) Coverage area diagram for VLR 0151

When the DTTV receiver represented with a blue dot and the LTE (eNBs) Cell Sites represented with a red dot are placed 0.5Km away from each other as shown in figure 7, the probability of interference of the two systems when unwanted emission and the receiver imperfection is considered will give a value of 0.84 as demonstrated in the simulation result shown in figure 8.

(iii)Probability of interference when VLR 0151 coexist with ILT 01

The probability of interference result when VLR 0151 coexist with ILT 01 and simulated with Channel 51 (693MHz) is shown in Figure 8

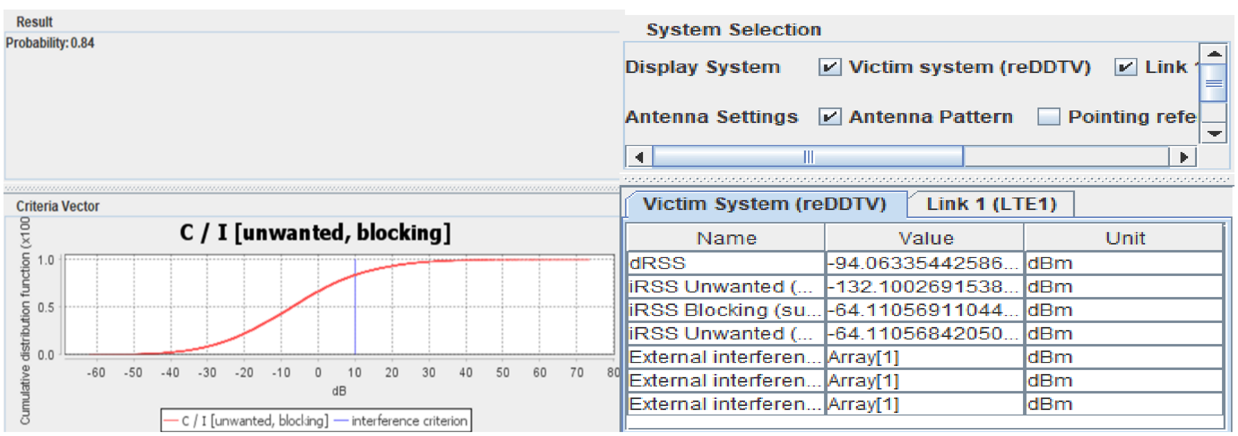

Figure 8: Probability of interference when VLR 0151 coexist with ILT 01

6.0 Results and Discussion

Table 4 presents the interference probability result when DTTV Receiver (VLR) and LTE Cell site (ILT) coexist at various distances and different frequencies of operation (Channel 17 and Channel 51).

Figure 9 presents the graph of the coexistence analysis of DTTV receiver (VLR) and LTE base station (ILT) when the DTTV receiver operate at channel 17 (490MHz). The graph is a plot of the probability of interference against the separation distance between the DTTV receiver and LTE base station. It can be observed from figure 9 that as the separation distance between DTTV and LTE systems increases,the interference probability of the two systems will reduce and tend to 0. Hence, **i**t was established from the simulation result that the probability of interferenceis a function of the separation distance between Smile 4G LTE base stations (ILT) and Star time Television Receivers (VLR). It was also established that the frequency of operation of the DTTV Receiver affects the interference probability result.

Table 4: Probability of Interference when DTTV Receiver (VLR) and LTE cell site (ILT) coexist.

S/No	DTTV Receiver (VLR) Location Tag		LTE (ILT) Locations tag	Distance between DTTV Receiver (VLR) and LTE (ILT) measured in (Km)	Probability of Interference	
	Channel 17	Channel 51			Channel 17	Channel 51
1	VLR 0117	VLR 0151	ILT 01	0.5	0.783	0.840
2	VLR 0217	VLR 0251	ILT 02	1.0	0.575	0.656
3	VLR 0317	VLR 0351	ILT 03	1.5	0.429	0.519
4	VLR 0417	VLR 0451	ILT 04	2.0	0.338	0.411
5	VLR 0517	VLR 0551	ILT 05	2.5	0.257	0.332
6	VLR 0617	VLR 0651	ILT 06	3.0	0.210	0.271
7	VLR 0717	VLR 0751	ILT 07	3.5	0.170	0.229
8	VLR 0817	VLR 0851	ILT 08	4.0	0.139	0.195
9	VLR 0917	VLR 0951	ILT 09	4.5	0.119	0.167
10	VLR 1017	VLR 1051	ILT 10	5.0	0.095	0.138

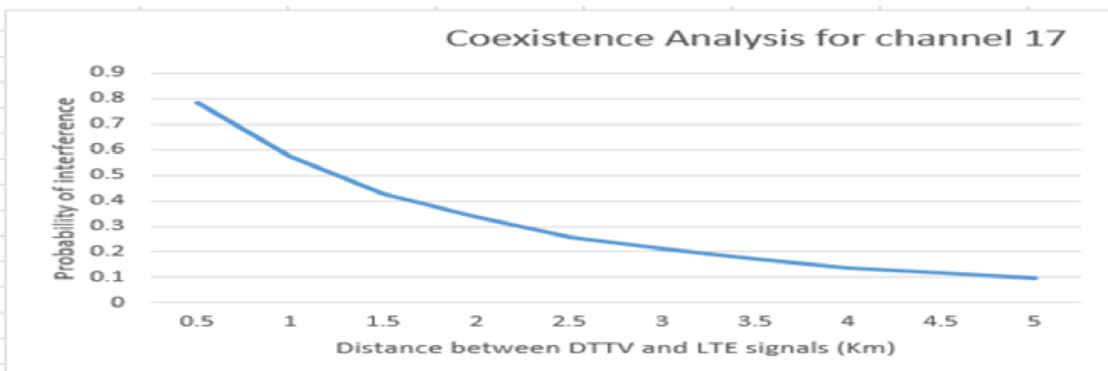

Figure 9: Probability of interference when VLR 0151 coexist with ILT 01

Figure 10 presents the graph of the coexistence Analysis of DTTV receiver (VLR) and LTE base station (ILT) when the DTTV receiver operate at channel 51 (693MHz). The graph is a plot of the probability of interference against the separation distance between the DTTV receiver and LTE base station.

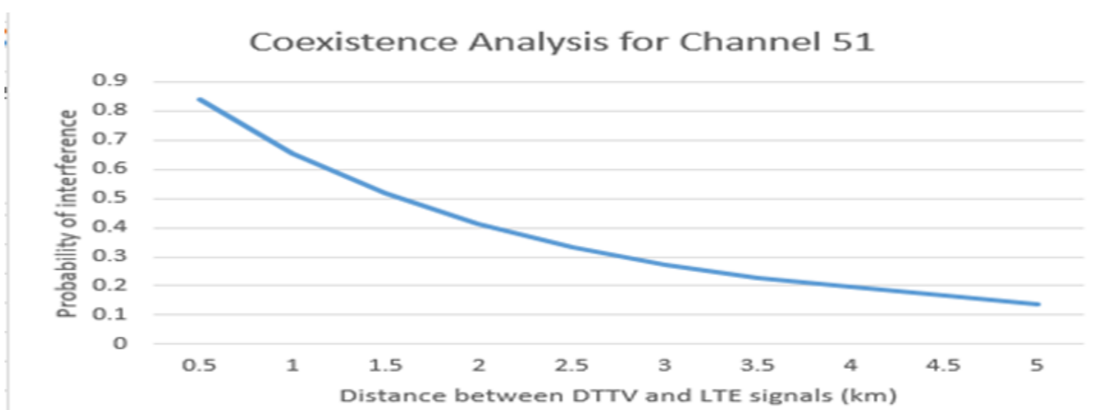

Figure 10: Probability of interference when VLR 0151 coexist with ILT 01

It can be observed from figure 10 that as the separation distance between DTTV and LTE systems decreases, the interference probability of the two systems will increase and tend to infinity. Hence, **i**t was established 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).
Figure 11 presents the comparative Analysis of DTTV receiver (VLR) and LTE base station (ILT) when the DTTV receiver operates at both channel 17 and Channel 51 respectively.

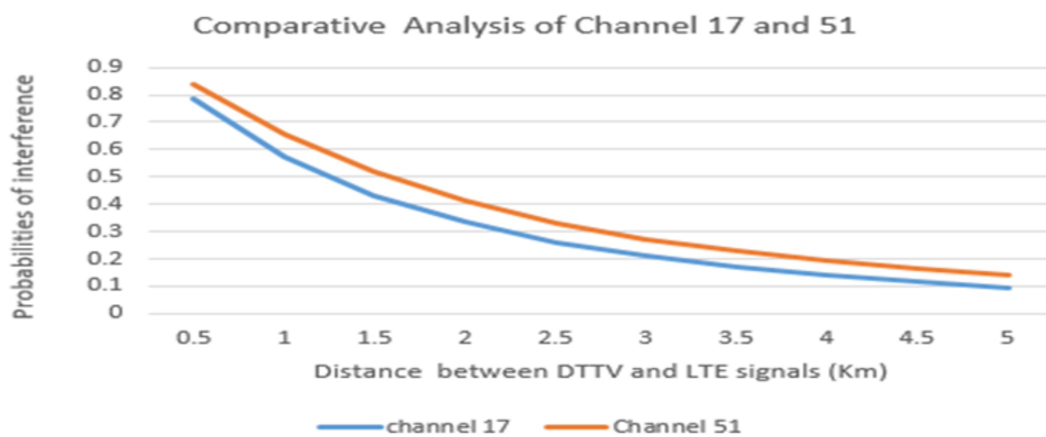

Figure 11: Probability of interference when VLR 0151 coexist with ILT 01

Figure 11depicts a plot that compares the probability of interference of channel 17 and channel 51 when it was plotted against the separation distance between DTTV receiver and LTE Transmitter. It was observed from the figure that DTTV channel 51 suffer more interference when compared with DTTV channel 17 for the same separation distance. The difference is due to the closeness of channel 51 to the proposed LTE frequency spectrum in the digital dividend band

8.0 Conclusion
Conclusively, this paper has been able to quantify the interference probability when DTTV and LTE systems coexist in the proposed digital dividend (700MHz) band at different separation distance in Port Harcourt, Nigeria. From the simulation result, the probability of interference for channels 17 and Channel 51 are 0.783 and 0.84 when the DTTV receiver (VLR) and LTE Base station (ILT) are separated by a distance of 0.5Km while their probability of interference are 0.095 and 0.138 when VLR and ILT are separated by a distance of 5Km respectively. 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). It was observed from the analysis that as the separation distance between DTTV and LTE systems decreases,the interference probability of the two systems will increase and the value will tend to infinity. It wasestablished that DTTV channel 51 suffer more interference when compared with DTTV channel 17 for the same separation distance. The difference in the probability of interference results is due to the closeness of channel 51 to the proposed LTE frequency spectrum in the proposed digital dividend band.

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