LTE and Future DTV Compatibility Study in the UHF band in Nigeria.

O.I. Sanusi, A.O. Gbenga-Ilori

Abstract - This paper presents a compatibility study between future digital television (DTV) and Long Term Evolution (LTE) in the UHF band using Nigeria as a case study. This is done by carrying out an adjacent interference analysis to evaluate the impact of LTE base station on DVB-T2 reception using SEAMCAT software. Results obtained from simulations suggest that deploying LTE in an adjacent band would result in interference. Introducing a 1MHz guard band reduced the interference by 64.76% when a single interferer is deployed and an average of 20.91% with multiple interferers at 5km separation distance between the DVB-T2 transmitter and receiver. Further increase in the frequency separation did not show any substantial reduction in interference probability. This implies that DVB-T2 may coexist with LTE in the case of a single base station when the receiver is not more than 5 km away from the transmitter but may not when a high density of LTE base stations are deployed in the coverage area of DVB-T2. Finally, recommendations were made and further studies were suggested regarding coexistence issues between LTE and DTV.

Index Term- *DTV (Digital Television), DVB-T2 (Digital Video Broadcasting-Terrestrial Second generation), LTE (Long Term Evolution), Coexistence, Interference, Spectrum.*

1. INTRODUCTION

The explosion in the demand by wireless broadband communication for frequency space has called for more efficient management of the radio spectrum resources. This is because spectrum is scarce and sharing has become necessary as more radio communication services are emerging and are competing for allocation of space in the UHF band. This implies that the subject of interference has to be highly considered since spectrum sharing among users increases the possibility of one user interfering with the other.

The broadcast spectrum released by the transition from analogue to digital transmission will be made available for new range of services in which wireless broadband is a major competitor. Among the wireless broadband services, LTE has been adopted by the telecommunication regulatory body in Nigeria, NCC, as the mobile technology to occupy the digital dividend in Nigeria while the Nigeria Broadcasting Corporation (NBC) has opted for DVB-T2 as the system variant to be implemented for digital terrestrial broadcasting [1], [2].

For sharing to be possible between two wireless communication services, the level of coexistence needs to be investigated so that these services can be protected from interference. There is therefore the need to carry out compatibility studies between the DTV and LTE services. In this paper, an adjacent interference analysis is carried out for DVB-T2 and LTE using the SEAMCAT software tool to determine the level of coexistence between the services.

- *Olufunmilayo Sanusi is a Graduate Assistant at the Computer and Electrical Engineering Department, Olabisi Onabanjo University, Ogun State, Nigeria, PH-+234-7037964056. E-mail: funmi_sanusi@yahoo.co.uk*
- *Abiodun Gbenga-Ilori is a Senior Lecturer at the department of Electrical and Electronics Engineering, University of Lagos, Nigeria. PH-+234-8034731440. E-mail: gbengailori@unilag.edu.ng*

2. Compatibility Studies

This section gives an overview of some of the research works that have been carried out in the area of compatibility between digital terrestrial television and LTE.

In a research work [3], an uplink co-channel interference analysis was carried out in the 800 MHz channel for different scenarios. Several Monte-Carlo simulations were performed to evaluate the impact of co-channel interference due to LTE mobile station on DVB-T2 receivers for different configurations of DVB-T transmitter height and ERP. It was shown that there was performance degradation in DVB-T broadcasting services since the required minimum SNR for the receiver is 21dB, the degradation of SNR due to the neighboring LTE interfering system resulted in reduction of the service area coverage.

In another work [4], scenarios between DVB-T and LTE in 700MHz were performed to determine the potential interference from LTE user equipment (UE) to the rooftop DVB-T reception. The simulation was carried out using Monte-Carlo simulation, with LTE 10 MHz carrier placed at the center frequency of 708 MHz. The nearest DVB-T is the channel 48 at the center frequency of 690 MHz. The second DVB-T channel below 694 MHz is from 678-686 MHz with a center frequency of 682 MHz. Results show that urban areas with medium power DVB-T coverage range of 12.6 Km, the interference probability is 0.02%.

In another paper [5], interference analysis was performed using SEAMCAT software to carry out a study of coexistence between LTE and DTV. The interference effect of LTE on DTV was considered by analysing the protection distance from the reference LTE base station and mobile station to DTV receiver. It was shown in the result that the case where 8 MHz guard band is required and the assumed emission mask of LTE base station is used, the required protection distance between the LTE base station

and DTV receiver is about 2 km. In the case of interference between LTE mobile station and DTV receiver considering the assumed emission mask of LTE mobile station, the protection distance is negligible above 8 MHz of guard band.

The first work [3] focused on uplink, co-channel mutual interference between DVB-T and LTE and obtained results for various Effective Radiated Power (ERP) and antenna heights. The second paper [4] also considered an uplink analysis between DVB-T and LTE. The relationship between protection distance and guard band for protecting DTV from LTE was considered in the last paper [5]. However, this paper analyzes the impact of downlink, adjacent channel interference of LTE on DVB-T2 receiver and obtained the probability of interference by placing the DVB-T2 receiver at several fixed distances from the DVB-T2 transmitter where a single LTE base station (BS) is placed within the coverage area of the DVB-T2 transmitter. In the case of multiple interfering signals, the LTE base stations were randomly deployed within the coverage area of DVB-T2 transmitter.

3. SEAMCAT TOOL

SEAMCAT (Spectrum Engineering Advanced Monte Carlo Analysis Tool) is a statistical simulation model developed by European Radio-communication Office (ERO). It uses a method of analysis called Monte-Carlo to assess the potential interference between different radio-communication systems. The software is used to implement generic co-existence studies for radio systems operating in same or adjacent band. SEAMCAT is used to assess potential interference using the probability density function for system and propagation parameters (such as antenna heights, power and pattern, operating frequencies, relative position of the transmitter and receiver) are used to generate random samples based on the Monte Carlo method called snapshots of the subject parameter. In each snapshot, SEAMCAT calculates the interfering and desired signal strength at the victim receiver in each snapshot against an interference criterion, for example C/I, I/N, C/(N+I), [6]. Figure 1 illustrates the major components of SEAMCAT interference scenarios.

The condition for interference to occur is for victim receiver, V_r, to have a carrier-to-interference ratio (C/I) less than the minimum allowable value. To calculate the victim's C/I, the victim's wanted signal/desired Received Signal Strength (dRSS) which corresponds to 'C', as well as the interfering signal (iRSS) which corresponds to 'I' needs to established. For each random event where dRSS is greater than sensitivity of the victim receiver, then if

$$C/I_{trial^i} > C/I_{target} : \text{we have good event (Ngood)} \quad (1)$$

$$C/I_{trial^i} < C/I_{target} : \text{we have "interfered" (Nint)} \quad (2)$$

After a cycle of N_{all} events, probability of interference is therefore given as:

$$P_{interference} = 1 - (N_{good} / N_{all}) \quad (3)$$

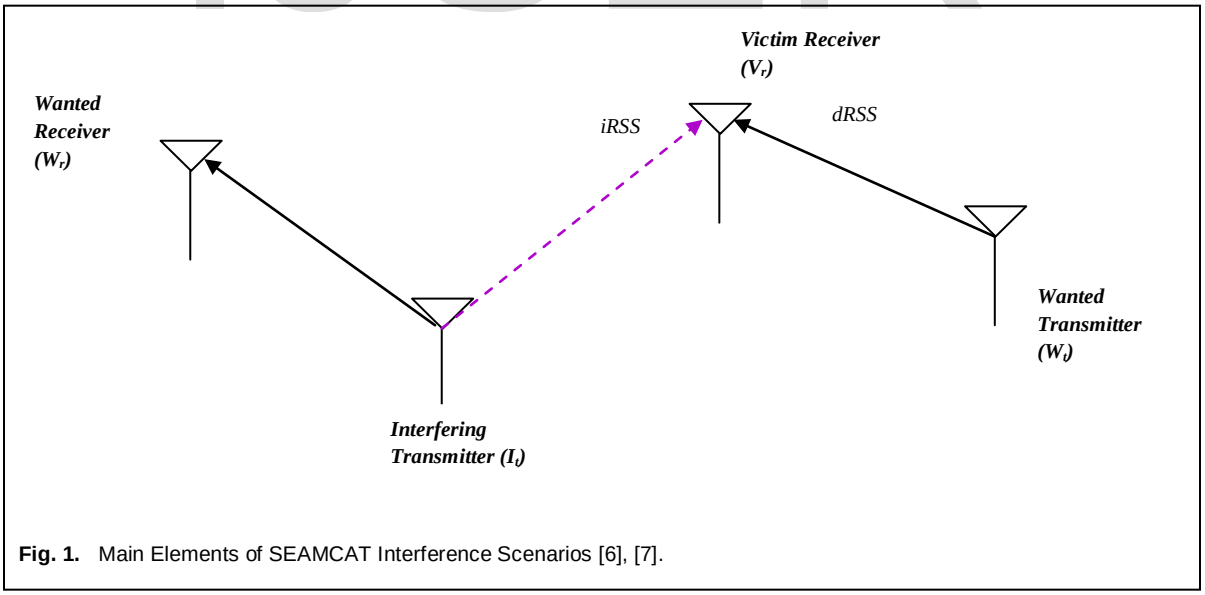

Fig. 1. Main Elements of SEAMCAT Interference Scenarios [6], [7].

3.1. System Parameters

Tables 1 and 2 give the technical parameters and specifications of DVB-T2 and LTE to be modeled in the simulation.

TABLE 1

IMPORTANT DVB-T2 PARAMETERS REQUIRED FOR COEXISTENCE ANALYSIS [8], [9].

Parameter	Factor Used
Centre Frequency	627.25 MHz

Receiver Antenna Height	10 m
Transmitter Antenna Height	100 m
Receiver Antenna Peak Gain (G_{rp})	13.00 dB
Receiver Antenna Pattern	ITU-R BT 419-3
Transmitter Antenna Peak Gain	0 dB
Transmitter EIRP	72.15 dB
Receiver Noise Figure F	6 dB
Minimum Required C/N	18.4dB
Bandwidth B	7.77MHz
Receiver Noise Floor (N_f)	-99.1 dB
Receiver Sensitivity	80.7 dB
Coverage Radius	28.715 Km
Propagation Model	ITU-R P1546-1
Minimum Protection Requirement	95% of locations protected from LTE interference 53.99 dBμV/m

The equations used to derived some of the parameters are given below:

The receiver antenna peak gain, G_{rp} is derived from (4).

$$G_{rp} = 11dB_d + 10\log\left(\frac{f_1}{f}\right) + 2.15dB \quad (4)$$

The receiver Noise floor (N_f) is given in (5) as:

$$N_f = -174 + 10\log B + f \quad (5)$$

Receiver Sensitivity (R_s) is given in (6) as:

$$R_s = N_f + C/N \quad (6)$$

The field strength at other frequencies asides the reference frequency can be calculated by interpolation as shown in (7).

$$E_{S1} = E_S + 20\log_{10}(f_1/f) \quad (7)$$

where,

f_1 is the frequency of the victim receiver in MHz,

f is the reference frequency of 650 MHz,

E_s is the minimum median equivalent field strength at the receiving location using 650 MHz frequency, and

E_{s1} is the minimum median equivalent field strength at the receiving location using f_1 MHz

TABLE 2
LTE BASE STATION PARAMETERS [10].

Parameter	Factor Used
Base Station Antenna Height	30m
Base Station Receiver Antenna Gain	15dbi
ERP (Effective Radiated Power)	43dBm
Simulation Radius	2km
Bandwidth	5MHz
Propagation Model	Extended Hata

4. SIMULATION AND RESULTS

The UHF band in Nigeria occupies 471.25MHz – 855.25MHz band (Channel 21 to 69), [11]. In accordance with the Bamako 2012 ATU Frequency coordination meeting, UHF channels 21 to 48, that is 28 channels, will be used to provide frequency band allocated for nationwide coverage [12]. In this work we assume the digital television services will occupy the lower band (471.25 MHz – 631.25 MHz, that is, Channel 21 to 40) of the frequency allocation after the analogue-to-digital television transition while the savings (Channel 41 to 48) will be available for mobile services.

Scenario 1: Simulations were performed to evaluate the effect of adjacent channel interference of LTE base station to DVB-T2 receiver. DVB-T2 receiver is placed at several fixed distances from the DVB-T2 transmitter. One LTE-BS is randomly placed within the coverage area of the DVB-T2 transmitter. DVB-T2 is deployed in channel 40 while LTE is deployed in channel 41. Results were obtained for no frequency separation and inserting guard band ranging from 1MHz up to 5MHz at an interval of 1MHz between DVB-T2 and LTE. Interference probability is obtained using unwanted signal type. Figure 2 shows the channel arrangement for different frequency separation, where f_c is the center frequency.

Table 3 shows the interference probability at various fixed distance for different frequency separation. As seen from the table, the interference probability increases as the distance between DVB-T2 transmitter and receiver increases but shows no significant change as the frequency

separation increased beyond 1MHz. Figure 3 shows the graph of the interference probabilities recorded in Table 3.

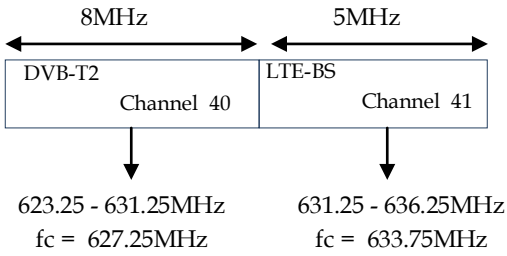

Fig. 2a: Channel Arrangement with no guard band

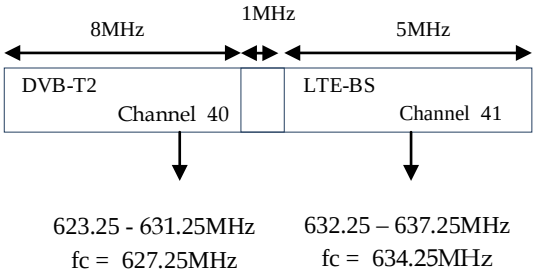

Fig. 2b. Channel Arrangement with 1MHz guard band

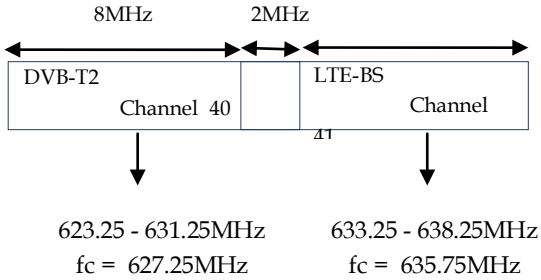

Fig. 2c. Channel Arrangement with 2MHz guard band

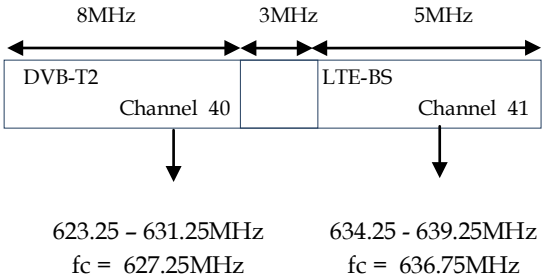

Fig. 2d. Channel Arrangement with 3MHz guard band

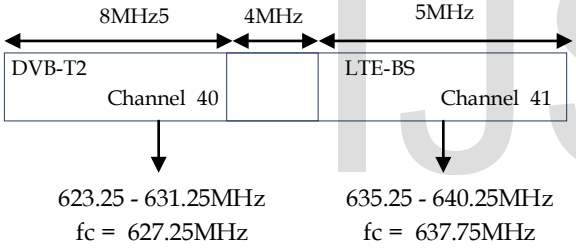

Fig. 2e. Channel Arrangement with 4MHz guard band

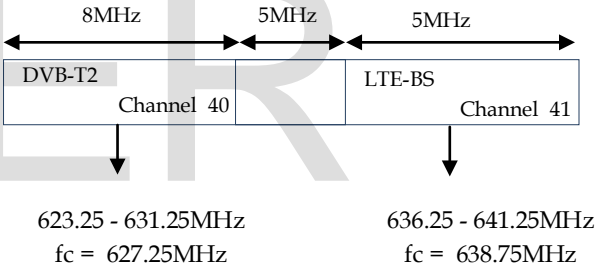

Fig. 2f. Channel Arrangement with 5MHz guard band

Fig. 2. Channel Arrangements for different frequency separation.

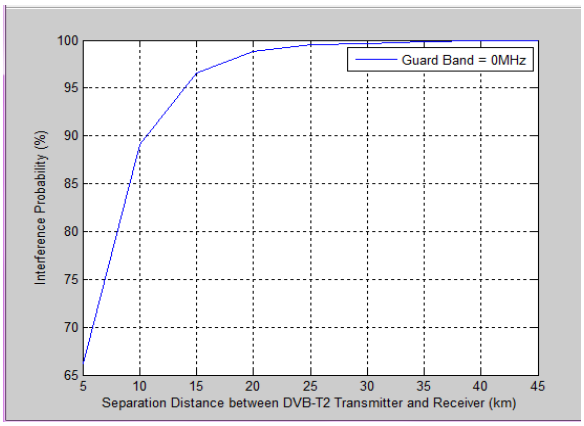

Fig. 3a. Interference Probability at 0MHz Guard band

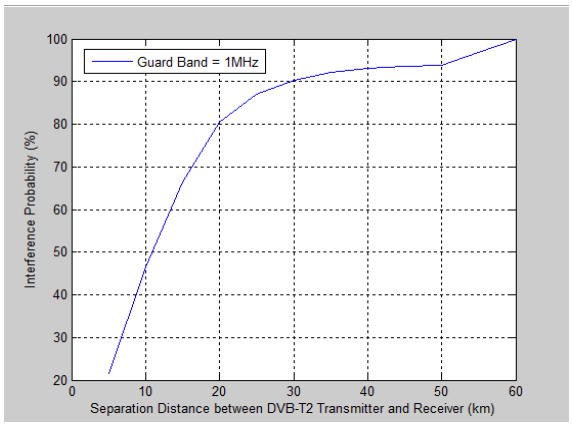

Fig. 3b. Interference Probability at 1MHz Guard band

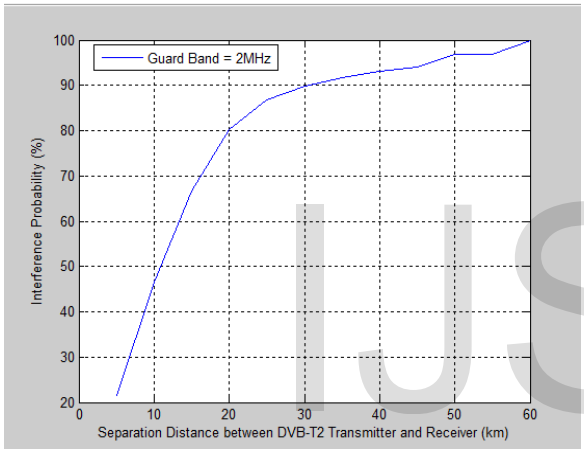

Fig. 3c. Interference Probability at 2MHz Guard band

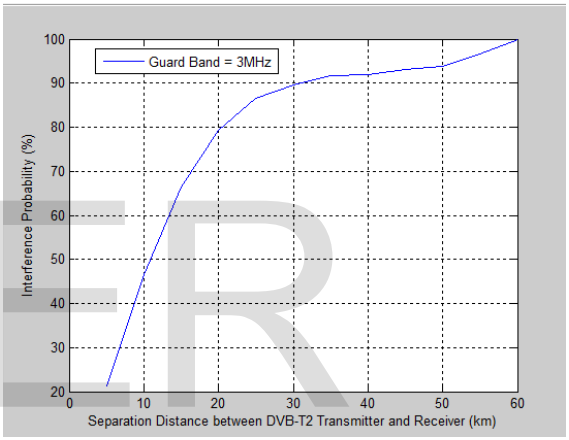

Fig. 3d. Interference Probability at 3MHz Guard band

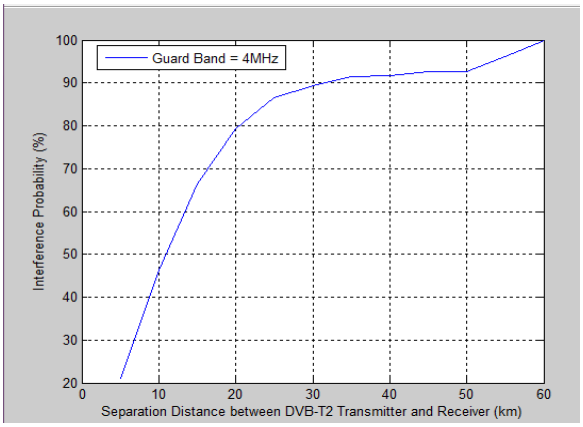

Fig. 3e. Interference Probability at 1MHz Guard band

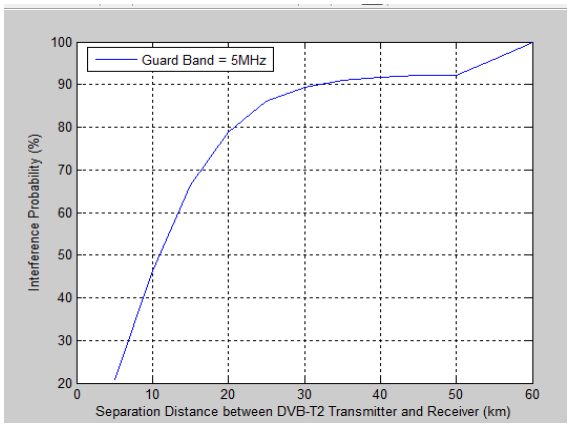

Fig. 3f. Interference Probability at 1MHz Guard band

Fig. 3. Interference Probability for Different Guard Bands at Various Fixed Distances between the Victim Transmitter and Receiver.

TABLE 3

INTERFERENCE PROBABILITY FOR DIFFERENT FREQUENCY SEPARATION AND VARYING SEPARATION DISTANCE

Separation Distance (Km)	Frequency Separation (MHz)					
	0	1	2	3	4	5
5	66.18	21.53	21.50	21.25	21.08	20.93
10	89.13	46.66	46.58	46.49	46.28	46.21
15	96.56	66.53	66.67	66.46	66.44	66.43
20	98.79	80.38	80.14	79.27	79.26	78.93
25	99.51	87.08	86.69	86.52	86.49	86.01
30	99.64	90.26	89.85	89.62	89.45	89.45
35	99.82	92.08	91.74	91.60	91.42	91.06
40	99.94	93.16	93.93	91.92	91.69	91.63
45	100	93.55	93.04	92.99	92.52	92.23
50	100	93.77	96.77	93.82	92.57	92.26
55	100	96.88	96.88	96.55	96.12	96.00
60	100	100	100	100	100	100

Scenario 2: Multiple LTE base stations with same technical parameters are randomly deployed within the coverage area of the DVB-T2. Results are obtained for using 3, 7, 19, 21, and 57 LTE base stations in the system with different frequency separation between 1 and 5MHz. Table 4 shows the probability of interference for multiple deployment of LTE base station and Figure 4 shows the chart for the interference probabilities in Table 4.

TABLE 4

INTERFERENCE PROBABILITY FOR MULTIPLE LTE-BS

Frequency Separation (MHz)	Number of LTE-BS in DTV Coverage Area				
	3	7	19	21	57
0	95.43	95.46	95.47	95.57	95.75
1	75.41	75.48	75.50	75.52	75.88
2	75.33	75.37	75.41	75.56	75.72
3	74.77	74.72	74.80	74.85	74.89
4	74.41	74.53	74.57	74.61	74.63
5	74.14	74.21	74.36	74.40	74.42

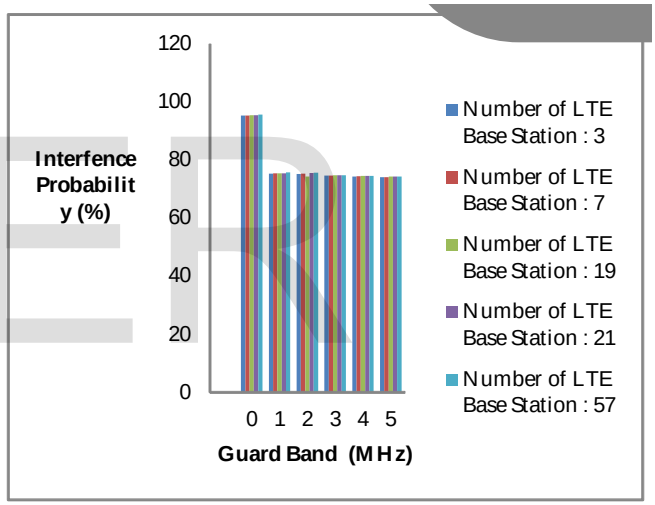

Fig. 4. Interference Probability for Multiple LTE Base Stations.

5. RESULTS AND DISCUSSION

For scenario 1, different interference probabilities were obtained for frequency separation ranging from 0 to 5 MHz between the DVB-T2 and LTE. With the DVB-T2 receiver sited 5km from the transmitter, the interference probability was reduced from 67.18% to 21.53% when 1MHz guard band was assumed. Further increase in frequency separation from 2 to 5 MHz did not reflect any significant change in interference probability. As seen from Table 2, when the relative distance between the receiver and transmitter increased, the probability of interference increased but showed no substantial difference as the guard band is increased from 2 to 5 MHz. This suggests that using frequency separation beyond 1 MHz does not help prevent interference and will result in a waste of bandwidth.

For scenario 2, the interfering signal strength for multiple LTE-BS is the sum of the signal strength of active transmitters. As the number of base stations increase from 3 to 57, there was no apparent change in the interference probability but a reduction was recorded when a 1 MHz guard band was introduced. From the Table 3, it can be seen that further increase in frequency separation between 2 and 5MHz did not significantly affect the interference probability. Introducing a 1MHz guard band reduced the interference by 64.76% when a single interferer is deployed and an average of 20.91% with multiple interferers. Further increase in the frequency separation did not show any substantial reduction in interference probability.
Expectedly, the probability of interference is much greater when there are multiple interferers active within the coverage area of the DVB-T2.

DVB-T2 may coexist with a single LTE base station when the receiver is not more than 5 Km away from the transmitter when a guard band of 1MHz is used. The interference level of multiple LTE base stations in the DVB-T2 is pronounced even with guard bands and therefore not compatible with DVB-T2.

6. CONCLUSION AND RECOMMENDATION

The coexistence of LTE and DVB-T2 in the UHF television band has been presented in this paper. Results from simulations predicted that deploying LTE in an adjacent band would result in interference. Introducing a 1MHz guard band reduced the interference by 64.76% when a single interferer is deployed and by an average of 20.91% with multiple interferers at 5km separation distance between DTV transmitter and receiver. Further increase in the frequency separation did not show any substantial reduction in interference probability.

We therefore recommend that DVB-T2 may be deployed in adjacent bands with LTE when the separation distance between DTV transmitter and receiver is not more than 5km but may not when there is a density of LTE base stations in the coverage area of DVB-T2. Further studies may consider varying the relative position of the LTE base stations with respect to the DVB-T2 receiver since increasing the size of the guard band did not make any considerable difference in the interference probability beyond 1MHz. Also, interference from DVB-T2 transmitter and receiver into LTE receiver should also be considered.

References

[1]. Slow race to digital broadcasting, http://www.nationalmirroronline.net/news/slow-race-to-dgital-Broadcasting, [Accessed 19/12/2013].

[2]. Digital Transition does need the Changeover, http://www.thenationonlineng.net/new/entertainment/digital-transition-does-need-the-changeover, [Accessed 19/12/2013].

[3]. Guidotti A. et al., "*Analysis of Coexistence and Mutual Interference between Mobile and Digital Television Systems*", Vehicular Technology Conference (VTC Spring) Proceedings, IEEE 73rd conference, Japan, pp 1 - 22, 2012.

[4]. Electronic Communication Committee (ECC), "*Simulation of potential interference from LTE UL to DVB-T and determination of UE-OOBE level*", CPG-13 PTD, pp 1-17, 2012.

[5]. In-Kyoung et al, "*Study on Coexistence between Long Term Evolution and Digital Broadcasting Services*", International Journal of Advanced Science and Technology, Vol.38, pp 1-18, 2012. *www.sersc.org/journals/IJAST/vol38/7.pdf*

[6]. European Communication Office (ECO), "*SEAMCAT Handbook 2010*", pp 7-29, 2010. http://www.cept.org/eco/eco-tools-and-services/seamcat-spectrum-engineering-advanced-monte-carlo-analysis-tool.

[7]. Aegis Spectrum Engineering, "*Digital Dividend (Interference Analysis of Mobile Wimax, DTT and DVB-H System*", Final Report for Ofcom, pp 7, 2007.

[8]. European Broadcasting Union, "*Frequency and Network Planning Aspects of DVB-T2*", TECH 3348, pp 16-96, 2012. https://tech.ebu.ch/docs/tech/tech3348.pdf.

[9]. Seybold J.S., "*Introduction to RF Propagation*", John Wiley and Sons Inc., Hoboken, New Jersy, pp 66-161, 2005.

[10]. Z.H., Talukder et al, "*Cell Coverage Evaluation for LTE and WiMAX in Wireless Communication System*" World Applied Sciences Journal, Vol. 22 (10), pp 3-6, 2013. *www.idosi.org/wasj/wasj22(10)13/15.pdf*

[11]. A.O. Gbenga-Ilori and T.S. Ibiyemi, "*Directing the Digital Dividend towards Bridging the Digital Divide in Nigeria*", European Journal of Scientific Research, Vol. 45 No. 1, July 2010, pp. 79-88, 2009.

[12]. African Telecommunication Union (ATU), "*Recommendations from the 2nd Digital Migration and Spectrum Policy Summit for Africa*", Final Report of the Workshop and Frequency Coordination meeting on the Transition to Digital Terrestrial Television and Digital Dividend, pp 2-5, Ghana, 2012.