Co-existence Study between Analog TV (PAL-I) and LTE in Digital Dividend Band: South African Case Study

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***Abstract*— Due to spectrum demand for mobile communication services, many studies has considered the impact of coexistence of two services in the same band. This paper presents a coexistence study between analog television (ATV) frequency using PAL-I systems and Long Term Evolution (LTE) in the digital dividend frequency band using South Africa as a case study. Four different scenarios between ATV and LTE are presented and simulated in SEAMCAT. The ATV as the primary user of the band while DTV is a secondary user. The results obtained from the simulation shows that the ATV and LTE can coexist.**

Keywords*— *Long Term Evolution (LTE), Analog Television (ATV), Coexistence, SEAMCAT, Guard Band Introduction (*Heading 1*)

I. Introduction

Over the last decade there has been an emerging increase of users and services in the mobile communications. Thus, the spectrum used by these mobile services in particular for fourth generation (4G)/ Long Term Evolution (LTE) is not enough to cope with the increasing demand[1]. This has caused significant modifications in terms of the technology, usage demands and the market structure, consequently leading to the need of more radio frequency (RF) spectrum to accommodate these changes. With the growing demand of RF spectrum for telecommunication services, the spectrum has become scarce and expensive. Another challenge in telecommunication is that the licensed frequency bands are underutilized most of the time which leads to spectrum being underutilised.

There are existing studies conducted by the national regulatory like Independent Communications Authority of South Africa (ICASA), the Federal Communications Commission (FCC) of United states of America (USA), and the Office of communications (Ofcom) of United Kingdom (UK) clearly stipulated and confirmed this RF spectrum underutilization [2]–[4]. Figure 1 below shows channel 21, 22 not being used while channel 23 is used by South African broadcasting corporation one (SABC1). The whole ATV band is allocated for TV broadcasting but it is not fully utilised.

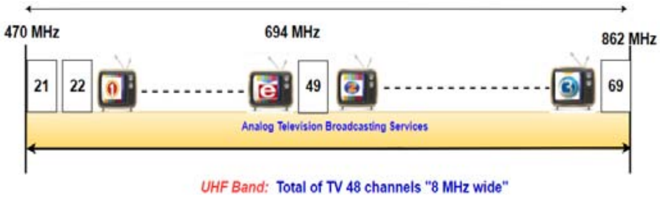

Figure 1: UHF band spectrum allocation

Other channels such as channel 48, channel 50 and channel 68 are used by SABC 2, SABC 3 and the fifth terrestrial television channel (e-tv) respectively. The allocation of spectrum is also static.

To address the aforementioned spectrum dilemma; (i.e. spectrum scarcity and inefficient use of the spectrum) the International Telecommunication Union (ITU) radio regulations has released 700 MHz and 800 MHz band for LTE services [10] through digital migration. The released 700 MHz and 800 MHz spectrum for LTE services is only available after digital television (DTV) migration. The advantages of the released LTE is, once it is deployed in 700 MHz it could provide data rates of up to 100 Mbps in the downlink and 50 Mbps in the uplink [5]. Furthermore, LTE could produce a larger area of coverage.

Figure 2 below shows the allocation of spectrum after digital migration in South Africa. Most countries have migrated to digital broadcasting in 2015 but South Africa has not migrated yet, they are still using ATV. There is digital signal though is not currently utilized.

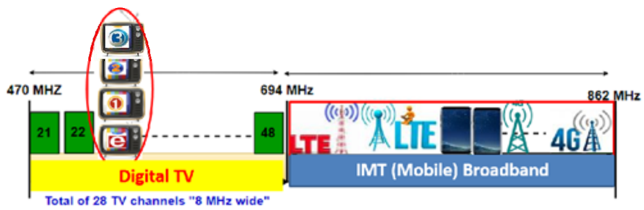

Figure 2: UHF band spectrum allocation after digital migration

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This implies that there are frequency spaces that can be used by LTE services within the 700 MHz and 800 MHz band while waiting for DTV migration. The ATV services can share the band with LTE services as secondary users of the band. The level of coexistence between ATV and LTE needs to be investigated so that these services can be protected from interference. There is therefore a need to carry out a compatibility study between ATV and LTE services. There are many compatibility studies that have been done on DTV and LTE [6]–[11], while only two papers on ATV and LTE compatibility studies in 700 MHz band were found [12], [13]. One paper studied the interference analysis on coexistence between ATV and LTE to define the minimum requirement of protection distance and guard band has to be taken into account [12]. And the other paper [13] presents the field evaluation of the coexistence between LTE system at the APT 700 MHz band in Peru and the ATV (ATV/NTSC-M) and Digital Terrestrial Television (DTT/ISB-T). In their evaluation, they found that the major interference take place from the LTE user equipment over digital and analog TV.

In this paper an interference analysis is carried out for ATV and LTE in 700 MHz and 800 MHz using SEAMCAT (Spectrum Engineering Advanced Monte Carlo Analysis tool) software tool to determine the level of coexistence between the services [14]. This can be a breakthrough for South Africa and to other African countries that have not digitized TV broadcasting to utilize the 700/800 MHz band while attending to the pertaining issues regarding digital migration.

II. SYSTEM DESCRIPTION

Due to the delay in South Africa to migrate to digital; ATV and LTE services are infuse in one band. ATV as a primary user of the band.

A. Analog Television (ATV)

ATV broadcasting uses PAL-I (Phase Alternating Line) system with 8 MHz channel bandwidth and also a simplex system. A simplex system is when one signal is transmitted and it goes same direction, downlink. This link is a relation between TV broadcasting transmitter towards TV receiver.
Table 1 displays the specification of ATV service for TV transmitters in South Africa.

TABLE 1: ANALOG TV SPECIFICATION

Parameters	Specification
Bandwidth	8 MHz
Power	92.23 dBm
Transmit Gain	15.9 dBi
Receiver Gain	10 dBi
Transmitter Height	328 m
Receiver Height	10 m (outdoor antenna)
Service Radius	45 km
Propagation Model	ITU-R 1546, Rural/Urban, Broadcasting Analog

B. Long Term Evolution (LTE)

LTE use duplex system, it has downlink and uplink [15]. E-UTRA (Evolved UMTS Terrestrial Radio Access) is the air interface of 3GPP's LTE; it system consists of two devices, namely the base station (BS) and User Equipment (UE). Both the devices have functions as a receiver and a transmitter. The parameters and specification of LTE are shown in Table 2 that have been used in this simulation modelling using the standardized SEAMCAT specification.

TABLE 2: LTE TV SPECIFICATION

Parameters	Specification
Bandwidth	5 MHz
Base Station Transmit Power	Min. = 43 dBm. Max. = 61 dBm
Base Station Height	30 m
Base Station Gain	15 dBi
User Equipment Height	1.5 m
User Equipment Gain	10 m (outdoor antenna)
Service Radius	45 km
Propagation Model	ITU-R 1546, Rural/Urban, Broadcasting Analog

C. INTERFERENCE SCENARIO SYSTEM DESCRIPTION

In order to study ATV and LTE coexistence in UHF band, four scenarios were formulated in order to determine the Protection ratio (PR) in the 700 MHz range. Scenarios 1 and 2 consists of ATV as the victim link and LTE downlink or uplink respectively as the interferer. Scenarios 3 and 4 has LTE downlink or uplink respectively as the victim link and ATV as the interferer. These scenarios can be seen graphically in Figure 3 to Figure 6 [12].

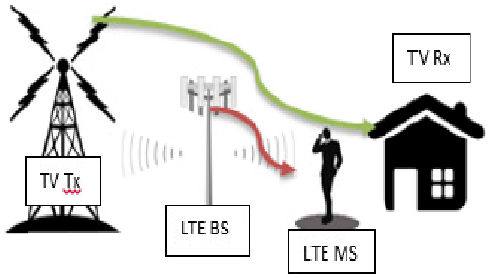

Figure 3: Scenario 1; LTE downlink interfere with ATV [12]

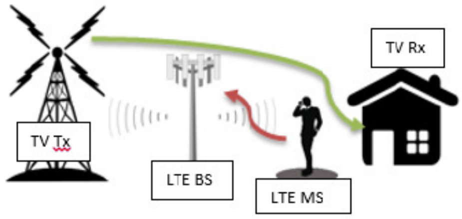

Figure 4: Scenario 2; LTE uplink interfere with ATV [12]

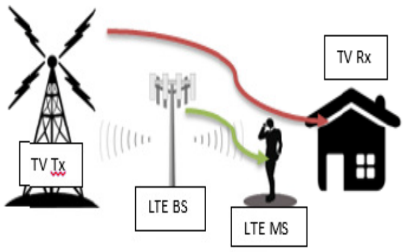

Figure 5: Scenario 3; ATV interfere with LTE downlink [12]

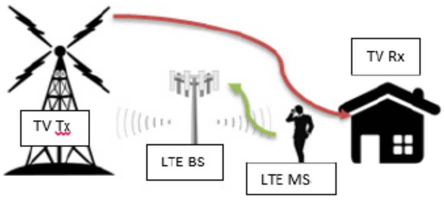

Figure 6: Scenario 4: ATV interfere with LTE uplink

From the figures above in section C; there are two types of connection. Figure 3 and Figure 4 shows that the LTE is the interferer to the ATV signal. Figure 5 and Figure 6 illustrate that ATV transmitter is interfering with LTE signal (uplink and downlink). All four scenarios were simulated in SEAMCAT.

III. INTERFERENCE ANALYSIS METHOD

A. SIMULATION TOOL

SEAMCAT is a software simulation tool using the Monte-Carlo calculation method. It uses statistical analysis to perform compatibility studies for radio communication is the same or adjacent frequency bands[14].

The parameters discussed in Table 1 and Table 2 are used in the simulation for each of the four scenarios mentioned in section C. SEAMCAT uses two components: a victim link and an interference link as shown in Figure 7.

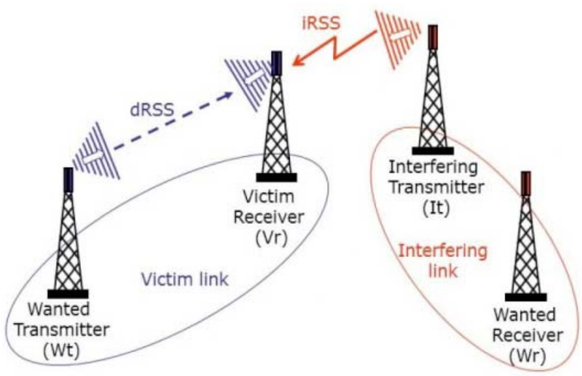

Figure 7: SEAMCAT general scenario

B. INTERFERENCE ASSESSMEN METHOD

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 (1).

$$\frac{C}{I} = dRSS\ [dBm] - iRSS\ [dBm] \qquad (1)$$

The protection ratio (PR) is the minimum power margin between the desired and interfered signals and can be calculated using equation (2)

$$PR = [C/I]_{wanted} - [C/I]_{interfered} \qquad (2)$$

An absence of information regarding the protection ratio required for LTE interference with ATV or in reverse is encountered. It is assumed that ATV and LTE has similar interference characteristics and furthermore, the calculations can be conducted accordingly. The results obtained in equation (2) are shown in Table III.

TABLE 3: PROTECTION RATIO FOR DIFFERENT SCENARIOS

Interferer	Victim	Protection Ratio [dBm]
LTE Downlink	ATV	-4
LTE Uplink	ATV	17
ATV	LTE Downlink	-17
ATV	LTE Uplink	-17

The two interfering systems can be separated with a guard band (GB) as shown Figure 8.

$$F_{centre} = 760.5 - 2.5 - GB - 4 = 754 - GB\ [MHz] \qquad (3)$$

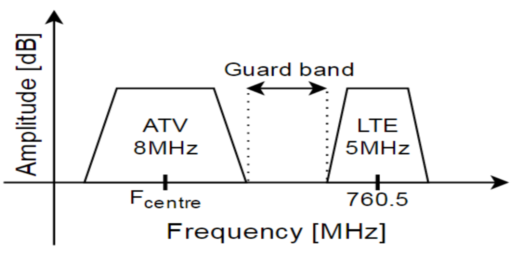

Figure 8: Guard band implementation

Equation (3) is used to determine the ATV channel center frequency according to different guard bands.

TABLE 4: ATV CENTRE FREQUENCY FOR DIFFERENT GUARD BANDS

Guard band [MHz]		Analog TV Centre frequency [MHz]
Same channel		760.5
0		754
5		749
10		744
15		739
20		734

IV. RESULTS AND ANALYSIS

Following the methods described in the previous sections and ATV and LTE specification as input to SEAMCAT.

A. LTE interfering with ATV

The ATV transmitter power was simulated at 1 MW, 100 kW and 100 W with a constant gain of 15 dB at a height of 300m as seen in scenario 1. Scenario 1 was simulated for a protection distance of 0 km to 5 km. This range can be increased if necessary.

Figure 9: Scenario 1; C/I vs. Protection distance for different guard bands

The possible interfering cases were indicated in scenario 1 with a thick line. The required transmitter power, height, guard band and protection ratio to avoid interference are summarized in Table 5. For example, interference will be improbable for a transmitter power of 90 dB.

TABLE 5: PROTECTION RATIO FOR DIFFERENT SCENARIOS

Tx power [dB]	Tx height [m]	Guard band [MHz]	Protection distance [km]
90	300	20, 0, or same channel	0
70	300	20, 0, or same channel	0
50	300	20	5
50	300	0	5
50	300	Same channel	>5

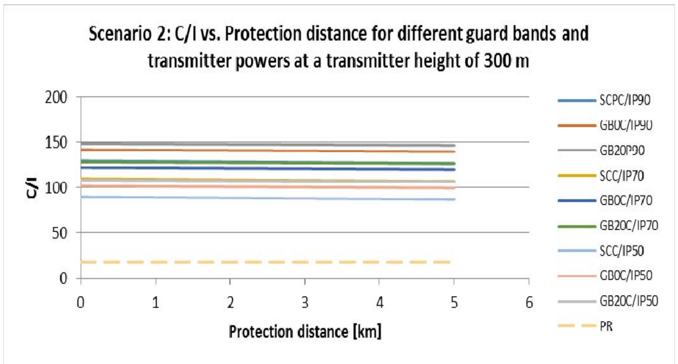

Figure 10: Scenario 2; C/I vs. Protection distance for different guard bands

Interference was improbable for scenario 2 since the C/I was above the protection ratio for each parameter combination.

The required parameters to avoid interference are shown in Table 6.

TABLE 6: PROTECTION RATIO FOR DIFFERENT SCENARIOS

Tx power [dB]	Tx height [m]	Guard band [MHz]	Protection distance [km]
90	**300**	**20, 0**	**0**
90	**300**	**Same channel**	**40**
70	**300**	**20, 0**	**0**
70	**300**	**Same channel**	**10**
50	**300**	**20, 0, same channel**	**0**

B. ATV interfering with LTE

The possible interfering for scenario 3 can be observed with thick lines. The required parameters to avoid interference are shown in Table 7.

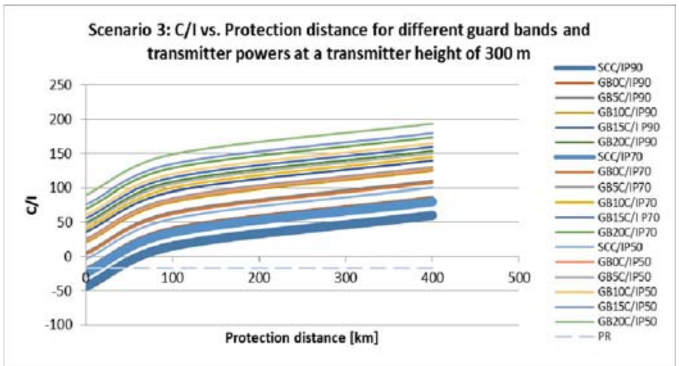

Figure 11: Scenario 3: C/I vs. Protection distance for different guard bands

The possible interfering scenarios for scenario 4 can be observed with thick lines. The required parameters to avoid interference are shown in Table 7.

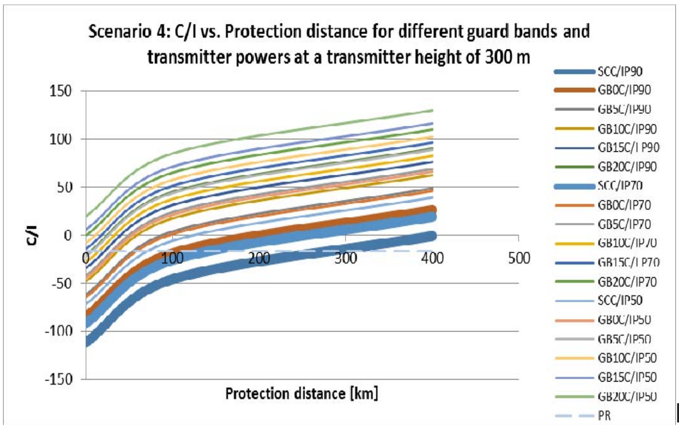

Figure 12: Scenario 4: C/I vs. Protection distance for different guard bands

TABLE 7: THE REQUIRED PARAMETERS FOR SCENARIO 4 TO AVOID INTERFERENCE

Tx power [dB]	Tx height [m]	Guard band [MHz]	Protection distance [km]
90	300	20	5
90	300	15	20
90	300	10	40
90	300	5	60
90	300	0	110
90	300	Same channel	275
70	300	20, 15	0
70	300	10	15
70	300	5	30
70	300	0	60
70	300	Same channel	140
50	300	20, 15, 10	0
50	300	5	5
50	300	0	35
50	300	Same channel	70

The C/I for scenarios 1 and 2 are safely above the protection ratio; refer to Table 5 and Table 6. The interference of LTE on ATV is very low and wouldn't affect current ATV communication. Possible interference may occur for ATV transmission power below 50 dB as seen in Table 6 where LTE downlink interfere with ATV. The C/I for scenarios 3 and 4 are not above the required protection ratio.

V. CONCLUSION

The design parameters were simulated in SEAMCAT to determine the C/I between ATV and LTE in the 700 MHz band. The simulation results were compared and verified according to the results found in [12]. The parameters were altered to meet South African standards after the verification phase. It was shown that it is possible for LTE and ATV to coexist in the same frequency band for a specified protection distance and guard band. The measured simulated graph has a much higher incline than the theoretical graphs.

Methods were proposed to reduce the interference of ATV on LTE are to increase the protection distance between ATV transmitters and LTE receivers and to increase the guard band used during transmission. It was shown that it theoretically possible for LTE and ATV to coexist in the same frequency band for a specified protection distance and guard band. The measured simulated graph has a much higher incline than the theoretical graphs and should be investigated.

REFERENCES

[1] W. H. Chin, Z. Fan, and R. Haines, "Emerging technologies and research challenges for 5G wireless networks," *IEEE Wirel. Commun.*, vol. 21, no. 2, pp. 106–112, 2014.

[2] TATT (Telecommunications Authority of Trinidad and Tobago), "Spectrum Plan for the Accommodation of Public Mobile Telecommunications Services," no. July, 2013.

[3] ICASA, "Final (Draft) IMT Roadmap 2014," vol. 31, no. 38213, 2014.

[4] H. L. O, Holland, O. Sastry, N Ping S Knopp, R. Kaltenberger, F. Nussbaum, D Hallio, J. Jakobsson, M. Auranen, J. Ekman, R. Paavola, J. Kivinen, A. Tran, H. Ishizu, K. Harada, H. Chawdhry, P. Chareau, J. Bishop, J. Bavaro, M. Anguili, E. Gao, Y. Dionisio, R. Ma, "A series of trials in the UK as part of the Ofcom TV white spaces pilot," *2014 1st Int. Work. Cogn. Cell. Syst. CCS 2014*, 2014.

[5] S. Hartley and J. Grivolas, "LTE: The Future of Mobile Broadband Technology," *Forbes Cust.*, 2013.

[6] A. De Vita, D. Milanesio, B. Sacco, and A. Scotti, "Assessment of interference to the DTT service generated by LTE signals on existing head amplifiers of collective distribution systems: A real case study," *IEEE Trans. Broadcast.*, vol. 60, no. 2, pp. 420–429, 2014.

[7] M. Fuentes, C. Garcia-Pardo, E Garro, D. Gomez-Barquero, "Coexistence of digital terrestrial television and next generation cellular networks in the 700 MHz band," vol. 21, no. September, pp. 63–69, 2015.

[8] P. Grant and N. Kirkman, "Report for GSMA on the Coexistence of ISDB-T and LTE," vol. 44, no. 0, 2014.

[9] G. Martinez-Pinzon, N. Cardona, C. Garcia-Pardo, A. Fornes-Leal, and J. A. Ribadeneira-Ramirez, "Spectrum Sharing for LTE-A and DTT: Field Trials of an Indoor LTE-A Femtocell in DVB-T2 Service Area," *IEEE Trans. Broadcast.*, vol. 62, no. 3, pp. 552–561, 2016.

[10] D. Okamoto, S. Mello, M. Almeida, and C. Rodriguez, "Performance evaluation of digital TV and LTE systems operating in the 700 MHz band under the effect of mutual interference," vol. 15, no. 4, pp. 441–456, 2016.

[11] L. Polak, L. Klozar, O. Kaller, J. Sebesta, M. Slanina, and T. Kratochvil, "Study of coexistence between indoor LTE femtocell and outdoor-to-indoor DVB-T2-Lite reception in a shared frequency band," *Eurasip J. Wirel. Commun. Netw.*, vol. 2015, no. 1, 2015.

[12] S. C. Varinia and Iskandar, "Interference analysis between Analog TV (PAL-G) and LTE (E-UTRA) in UHF band," *Proceeding 2015 9th Int. Conf. Telecommun. Syst. Serv. Appl. TSSA 2015*, no. 10, pp. 0–4, 2016.

[13] M. Odiaga, H. Joussef, Y. Medina, and M. Augusto, "Interference between UHF analog/digital television and LTE APT 700 MHz band: A field evaluation," *2016 8th IEEE Latin-American Conf. Commun. LATINCOM 2016*, 2016.

[14] D. Więcek and D. Wypiór, "New SEAMCAT Propagation Models : Irregular Terrain Model," *J. Telecommun. Inf. Technol.*, pp. 131–140, 2011.

[15] Z. Shen, A. Khoryaev, E. Eriksson, and X. Pan, "Dynamic uplink-downlink configuration and interference management in TD-LTE," *IEEE Commun. Mag.*, vol. 50, no. 11, pp. 51–59, 2012.