UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

AN ASSESSMENT OF PROPAGATION MODELS FOR DIGITAL TELEVISION BROADCAST NETWORK IN THE ASHANTI REGION OF GHANA

PATRICIA AMPOFOWAA BOSO

NOVEMBER, 2017

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A Thesis in the Department of ELECTRICAL AND AUTOMOTIVE TECHNOLOGY EDUCATION, Faculty of TECHNICAL EDUCATION, submitted to School of Graduate Studies, University of Education, Winneba, in partial fulfilment of the requirement for the award of Master of Technology in (Electrical/Electronics Technology Education) degree.

NOVEMBER, 2017

DECLARATION

STUDENT'S DECLARATION

I, **Patricia Ampofowaa Boso**, declare that this Thesis, with the exception of quotations and references contained in the Published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE:……………………………….

DATE:………………………………………..

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of Dissertation as laid down by the University of Education, Winneba.

SUPERVISOR"S NAME: **PROF. W. K. OFOSU**

SIGNATURE:………………………………..

DATE:…………………………………………..

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DEDICATION

This Thesis is dedicated to Rev. Joseph Appiah Kubi for his support and encouragement.

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LIST OF ABBREVIATIONS AND ACRONYMS

APC	Association for Progressive Communications
ATSC	Advanced Telecom Systems Committee
ATSC-M/H	Advanced Television Systems Committee – Mobile/Handheld
ATV	Advanced Television
BTS	Broadcast Transport Stream
DTMB	Digital Terrestrial Multimedia Broadcasting
DTT	Digital Terrestrial Television
DTTV	Digital Terrestrial Television
DVB	Digital Video Broadcasting
DVB-T	Digital Video Broadcasting Terrestrial
DVB-T2	Digital Video Broadcasting-Terrestrial (Second Generation)
FEF	Future Extension Frames
GI	Guard Internal
HD	High Definition
HDTV	High Definition Television
ISDB	Integrated Services Digital Broadcasting
ISDB-T	Integrated Services Digital Broadcasting for Terrestrial
ITU	International Telecommunication Union
MCM	Multi-Carrier Modulation
MER	Modulation Error Ration
MSF	Modulation Signalling Frequency
MUSE	Multiple Sub-Nyquist Sampling Code
NDBMTC	National Digital Broadcasting Migration Technical Committee
NTSC	National Television Systems Committee

OFDM	Orthogonal Frequency Division Multiplex
RRC-06	Regional Radio Communications Conference
SCM	Single-Carrier Modulation
SD	Standard Description
SDTV	Standard Definition Television
STB	Set-Top-Box
SUI	Stanford University Interim
T-R	Transmitter-Receiver

ABSTRACT

In radio communication, signal losses are major factor in transmission. To this end, various propagation models have been used in the field of transmission engineering to minimised transmission losses. With the introduction of Digital Terrestrial Transmission (DTT) and the subsequent migration from analogue to digital transmission, it is worthwhile to define which propagation model would best fit this digital migration in any area. Using Ashanti Region of Ghana as a case study, this project examined the behaviour of digital transmission by analysing three signal propagation models – Free Space, the ITU_R P.370 propagation prediction and the Extended COST 231 HATA models. Plots of graphs showed that the ITU-R P370 prediction propagation model predicted relatively poor signal strength as compared to the ideal Free Space path loss propagation model. The study also observed that there was a large disparity between the deviations of the ITU-R P370 model and Free Space path loss model. Results obtained from the investigations, indicated that the Extended COST 231 Hata model delivers a more consistent received power and loss prediction as compared to REC ITU-R P.370. The REC ITU-R P.370 propagation prediction model had limitation since it was developed for limited kinds of land. The study therefore concluded that the Extended COST 231 HATA model performed better than the REC ITU-R P.370 model. The study recommended that for a good reception of the digital terrestrial transmission in Ashanti region, there is the need for gap-filler. This can be achieved by siting repeaters and boosters at convenient locations to maintain or improve the transmitting power. It further recommended the use of a geographical information system to store geographical locations points for every 10 m^2 and their corresponding categories.

CHAPTER ONE

INTRODUCTION

Innovations in global broadcasting has occasioned a shift from analogue to digital broadcasting (Brahima, 2012). At a Regional Radio Communications Conference (RRC-06) held in Geneva in 2006, an agreement was signed by member states of a move from analogue to digital transmission. Subsequently, the International Telecommunication Union (ITU) declared that analogue signals will no longer be protected after 2015 (ITU, 2012). Therefore, nations around the round including Ghana are changing from analogue transmission to digital. The discourse of this chapter is focused on background of the digital revolution globally and Ghana in particular, it discusses statement of problem, significance of study and objectives of this project. It further talks about the research questions, limitation and delimitation of study and concludes with organization of project.

1.1 Background of the Study

"Digital television is now an integral part of the information superhighway that is being built to deliver large amounts of information at very low cost compared to analogue technology" (Armoogum' Mohamudally & Fogarty, 2010. p.1). Following the ITU digital switchover announcement in 2006 (DigiTAG, 2013), there has been significant developments globally to switch to digital broadcast. Subsequently, many countries have already switched over or had set up timelines for the changeover (See Appendix A). The European Union also recommended that all member states cease all analogue television by January, 2012 (European Commission, 2003). In 1999, the Federal Communications Commission (FCC) of the United States set 31st December 2006 as a target date to totally terminate analogue broadcasting (Federal

Communications Commission, 1997). These global changeover from analogue to digital could be attributed to benefits of digital transmission. Digital television can deliver more programmes than traditional analogue television over one transmission channel (Plum, 2014). Digital broadcasting can totally be incorporated into digital transmission networks. Undeniably, pictures in digital transmission can be modified, compressed, stored and transmitted (Armoogum et. al, 2010).

One advantage of the digital format is that, it can be combined with telephone exchanges as well as computer data and then transmitted from one network to other broadcast networks (Ocholi, 2009: Armoogum et. al, 2010; Ihechu & Uche, 2012). Additionally, digital broadcasting greatly lowers the power consumption of transmitters and enhances high picture and sound quality. It also makes it possible to access mobile TV services (Balaraba, 2013). As an advantage, introduction of digital transmission in the TV broadcasting will allow consumers the option of continuously receiving open TV through the current way using analogue TV, acquire a set top box which allows receiving of digital signal and converting it into a video and audio standard available in the user's TV and also acquire a new TV which already has a set top box (Plum, 2014).

To this end, it is imperative for Ghana to join the rest of the world for the migration. Subsequently, Ghana has begun to digitise its television broadcasting industry. Owing to the advantages in digital TV transmission and reception, the country cannot afford to miss the opportunity to draw experience from other countries that have passed the test in digitising their TV broadcasting sector.

1.2 Statement of Problem

The implementation of the digital transmission has taken considerable time to be fully realised in Ghana. The digital TV signal, unlike the analogue signal, provides better video quality due to the elimination of interference. Even though various propagation models have been employed to reduce losses associated with digital transmission, it is still very difficult to determine whether a signal, after going through separate processes and transmission paths, will reach the consumer in a correct audio and picture format.

1.3 Significance of Study

The need to assess and validate REC. ITU-R P.370 transmission model for digital television broadcasting in the Ashanti Region cannot be over-emphasised for the following reasons:

- To look at the variation and disparities of the received field strength and the path loss for selected parts of the Ashanti Region with respect to the ITU-R P370 model.
- To determine for the Ashanti ideal model for the region with the ITU-R transmission model with minimal losses in its implementation in the region.
- Transmission engineers and technicians would be exposed to the propagation model which would best fit the migration into the digital world.

1.4 Objectives

The broad objective of this study is to assess and validate REC. ITU-R P.370 transmission model for digital television broadcasting in the Ashanti Region of Ghana. To operationalise this aim, the study has the specific objectives to:

i. Estimate the path loss signal using the Free Space Model to determine the signal strength at various locations.
ii. Compare other propagation model results with Rec. ITU-R P.370 Propagation Prediction Method.
iii. Validate results with ITU recommendations.

1.5 Research Questions

In order to achieve the above-stated purpose of study, the conceptual framework was guided by the following questions:

1. What are some of the approaches to propagation models?
2. What are some of the parameters to be considered in propagation prediction models?
3. How does the Rec ITU-R P.370 propagation prediction method compare with free space propagation?

1.6 Limitation and Delimitation of Study

Due to the failure of the pilot project in the Ashanti Region, getting information on the progress of the switch over process was not available. During my visit to the Ashanti Regional office of the Ghana Broadcasting Corporation, most of my questions on DTT were not answered to my satisfaction because personnel were not well briefed on the project.

1.7 Organization of Project

This Project report is organised into five (5) chapters as follows: Chapter One introduced the research by spelling out the background, the research problem as well as the justifications for embarking on the inquiry. The chapter also includes objectives as well as the limitations and delimits of the research. Chapter Two reviews relevant literature, Chapter Three talks about project methodology. Chapter Four focuses on data analysis, results and discussion and finally in Chapter Five a conclusion is drawn based on results and findings and the necessary recommendations and conclusions made.

CHAPTER TWO

REVIEW OF THE LITERATURE

This chapter reviews the literature on previous empirical research work done on the propagation predication method for digital television broadcast. It also considers some technical issues in radio propagations. The discussion of the intellectual discourse is grouped under the following headings: Digital Terrestrial Television (DTT) In the World, DTT Pilot Programme in Ghana, Propagation method and losses, Principle of operation of DVB-T2 System, Principle of Operation of the DVB-T2 System, Fast Fading (Multiple Propagation) and Propagation Models.

2.1 Digital Terrestrial Television (DTT) in the Global Broadcasting

Digital Terrestrial Television (DTT or DTTV) is the technological evolution of broadcast television and an advancement of analogue television. It is an implementation of digital technology to provide a greater number of channels and better quality picture and sound through a conventional antenna instead of satellite dish or cable. The purpose of digital terrestrial television is to reduce the use of spectrum, provide a higher channel capacity than analogue and to lower operational cost for broadcast and transmission (ITU, 2012).

There are competing variants of digital broadcast television systems/standards and these include Digital Video Broadcasting (DVB), Advanced Television Standards Committee (ATSC), Integrated Services Digital Broadcasting (ISDB), and Digital Terrestrial Multimedia Broadcasting (DTMB). DTT is transmitted on radio frequencies i.e. UHF, VHF and SHF, through terrestrial space with the primary implementation of multiplex transmitters to allow reception of multiple channels on a single frequency range. DTTV is received either via an integrated tuner included with television sets or a digital set-top-box (STB). (Digital TV facts, 2007).

The Advanced Telecom Systems Committee (ATSC) developed a set of standards for digital television transmission. In 2009, ATSC replaced the National Television Systems Committee (NTSC) in the United States (Stoller, 2009). Canada fully made a changeover to ATSC in 2011 (Pham, 2012), whilst South Korea switched over in 2012. Similarly, Mexico will replace the analogue transmission by 2015 (Pham & Ashishn, 2012). El Salvador hopes to make the change over by January 2019 (Pham Hai. 2012). The Integrated Services Digital Broadcasting (ISDB-T) is a Japanese standard (Pham & Ashishn 2012). Its derivative, ISDB-T International (ISDB-Tb), was developed by the Brazilian government and is being widely adopted in South America. The Digital Terrestrial Multimedia Broadcast is the standard used in the People"s Republic of China, Hong Kong and Macau. It is applicable for both mobile and fixed reception digital terrestrial television (Pham & Ashishn, 2012).

Admittedly, the move to digital broadcasting is capital intensive however, the ITU is facilitating the switch over to digital broadcasting because it is easier to obtain the optimum digital picture than it is in the case of the optimum analogue picture. Moreover, digital broadcasting also provides other fascinating interactive services. The ITU explains that the analogue to digital migration will make viewing more convenient than ever before. The transition to digital broadcasting will offer more channels, which has the potential of increasing the revenue generation streams of operators (National Digital Broadcasting Migration Technical Committee, 2012). Subsequently, Ghana cannot afford to miss out on these global broadcasting trajectories. Indeed, Ghana switching over to digital transmission will completely enhance the TV experience of Ghanaians (Boah-Mensah, 2010). Ghana signed the Geneva 2006 (GE06) Agreement to switch off analogue television transmissions by June 2015 (APC, 2011; National

Digital Broadcasting Migration Technical Committee, 2010) and has since begun the digitalising process. Failing to switch over to digital broadcasting by June 2015, would mean that Ghana will no longer be protected by the international telecommunication governing body if other countries interfere in its broadcasting territory.

A pilot project was begun by the three major Television broadcasting stations in the country, namely, Ghana Television, Metro TV and TV Africa and it has so far yielded mixed results in the two regions being considered (NCA, 2015). In 1997, a private broadcasting station such as TV3 went commercial on the terrestrial digital television technology in Accra, Takoradi, Koforidua and Kumasi.

2.2 DTT Pilot Programme in Ghana

The migration from analogue to digital transmission has seen significant strides in the country and the world as a whole. In a workshop organized in Bangkok, Thailand in 2012, a report compiled by Pham (2012) gave a thorough study of the general status of the digital transition in world. In particular, Ghana was shown to complete its switch over by 2014 and send in an appraisal report of the whole switch over process. "Ghana's migration from analogue to digital TV broadcasting is to going be the largest initiative to impact the Ghana TV broadcasting since the conversion from black and white to colour TV in the 1980‟s" (Association for Progressive Communications (APC) and Balancing Act, 2011. p. 3). In June 2010, a National Digital Broadcasting Migration Technical Committee (NDBMTC) was set up by the government to start a pilot programme (Digital migration report, 2010). The committee projected December 2014 as the completion of the switch over. The digital pilot project is a co-operation between GBC, NGB and Ghana‟s four major channels -Ghana Television, TV3, TV Africa and Net 2 Television.

A pilot project started in Ashanti region on 30th April 2010. Ashanti region has three main transmitting sites: Obuasi, Gyamase and Kumasi. Only one transmitter was brought in Ashanti region and it was located at Kumasi. It started transmitting using Vodafone‟s fibre optic cables. Fibre optic cable was preferred because it had minimal loses and was reliable. Fibre optic cable was used to receive digital signals from GBC – Accra before the received signals were broadcast to viewers across the region. GBC started with smart TV, with some free to air channels such as GTV Sports plus and some paid channels such as „hi Nolly‟, in the Ashanti region but the transmission was cancelled due to poor infrastructural setup. Among the DTT transmission systems available, the National Communication Authority- Ghana has adopted DVB -T2 as the transmission standard for digital video broadcasting in Ghana (National Digital Broadcasting Migration Technical Committee Report, 2010). The first version of DVB -T2 was published in 1995 (DigiTAG, 2009). DVB-T2 is the world‟s most advanced digital terrestrial television system. It offers more robustness, flexibility and 50% more efficiency than any other DTT system. It supports Standard Description (SD), High Definition (HD), mobile TV and any combination thereof. DVB-T2 also provides the ability to reuse existing reception antennas. (DVB-T2 Fact Sheet, 2012).

2.3 Principle of Operation of the DVB-T2 System

The Terrestrial broadcasting (DVB-T) uses Orthogonal Frequency Division Multiplex (OFDM) modulation. This modulation delivers a robust signal and has the ability to deal with very severe channel conditions. OFDM is a broadband multicarrier method that offers superior performance and benefits over older, more traditional single carrier modulation methods because it is a better fit with today‟s high-speed data requirements and operation in the UHF and microwave spectrum. It mitigates the severe problem of multipath propagation. OFDM is based on the concept of Frequency Division Duplex, the method of transmitting multiple data streams over a common broadband medium. In this work, the medium is the radio spectrum. Each data stream is modulated onto multiple adjacent carriers within the bandwidth of the medium and are all transmitted simultaneously (parallel channel transmission). The use of OFDM with appropriate guard interval is a valuable tool for single frequency network. The guard band prevents the parallel modulated carriers from interfering with one another (Dusan Matiae, 1998).

Orthogonal Frequency Division Multiplex is similar to the DVB-T. It allows for hierarchical modulation. Hierarchical modulation is where two complete separate data streams are modulated onto a single DVB-T2 signal with a high priority stream embedded within a low priority stream. This type of modulation offers a range of different modes, namely QPSK, 16QAM, 64QAM and 256QAM. It applies low density parity check combined with Base-Chaudhuri –Hocquengham coding for error correction coding (Xiaoying, & Slump, 2013).

Additional new technologies used in DVB-T2 are Multiple Physical Layer, Alamouti coding and Future Extension Frames (FEF). The Multiple Physical Layer Pipes allow separate adjustment of the robustness of each delivered service within a channel to meet the required reception conditions (for example in-door or roof-top antenna). It also allows receivers to save power by decoding only a single service rather than the whole multiplex of services. The Alamouti coding is a transmitter diversity method that improves coverage in small-scale single-frequency networks. Constellation Rotation provides additional robustness or low order constellations, extended interleaving including bit, cell, time and frequency interleaving. Future Extension Frames (FEF) allows the standard to be compatibly enhanced in the future.

As a result, DVB-T2 can offer a much higher data rate than DVB-T or a much more robust signal.

For comparison, the two bottom rows in Table 2.1 show the maximum data rate of a fixed Channel to Noise ratio and the required Channel to Noise ratio at a fixed (useful) data rate.

Table 2.1: Differences between DVB-T and DVB-T2 Standards

Characteristics	**DVB-T**	**DVB-T2(new/improved options in bold)**
FEC	Convolutional coding+reed Solomon 1/2, 2/3 ,3/4, 5/6, 7/8	LDPC+BCH 1/2, 3/5 ,2/3, 3/4, 4/5, 5/6
Modes	QPSK, 16 QAM, 64 QAM	QPSK, 16 QAM, 64 QAM, 256QAM
Guard Interval	1/4 , 1/8, 1/16, 1/32	1/4, 19/128, 1/8, 19/256, 1/16, 1/32, 1/128
FFT Size	2K, 8K	1K, 2K, 4K, 8K, 16K, 32K
Scattered Pilots	8% of total	1%, 2%, 4%, 8% of total
Continual Pilots	2.0% of total	0.4%-2.4% (0.4%-8% in 8K-32K)
Bandwidth	6, 7, 8 MHz	1, 7, 5, 6, 7, 8, 10 MHz
Typical data rate (UK)	24 Mbit/s	40 Mbit/s
Max. data rate (@20 dB C/N)	31.7 Mbit/s	45.5 Mbit/s
Required C/N ratio (@24 dB C/N)	16.7 Db	10.8 dB

Source: Generation Terrestrial, DVB-T2 Fact Sheet (2012)

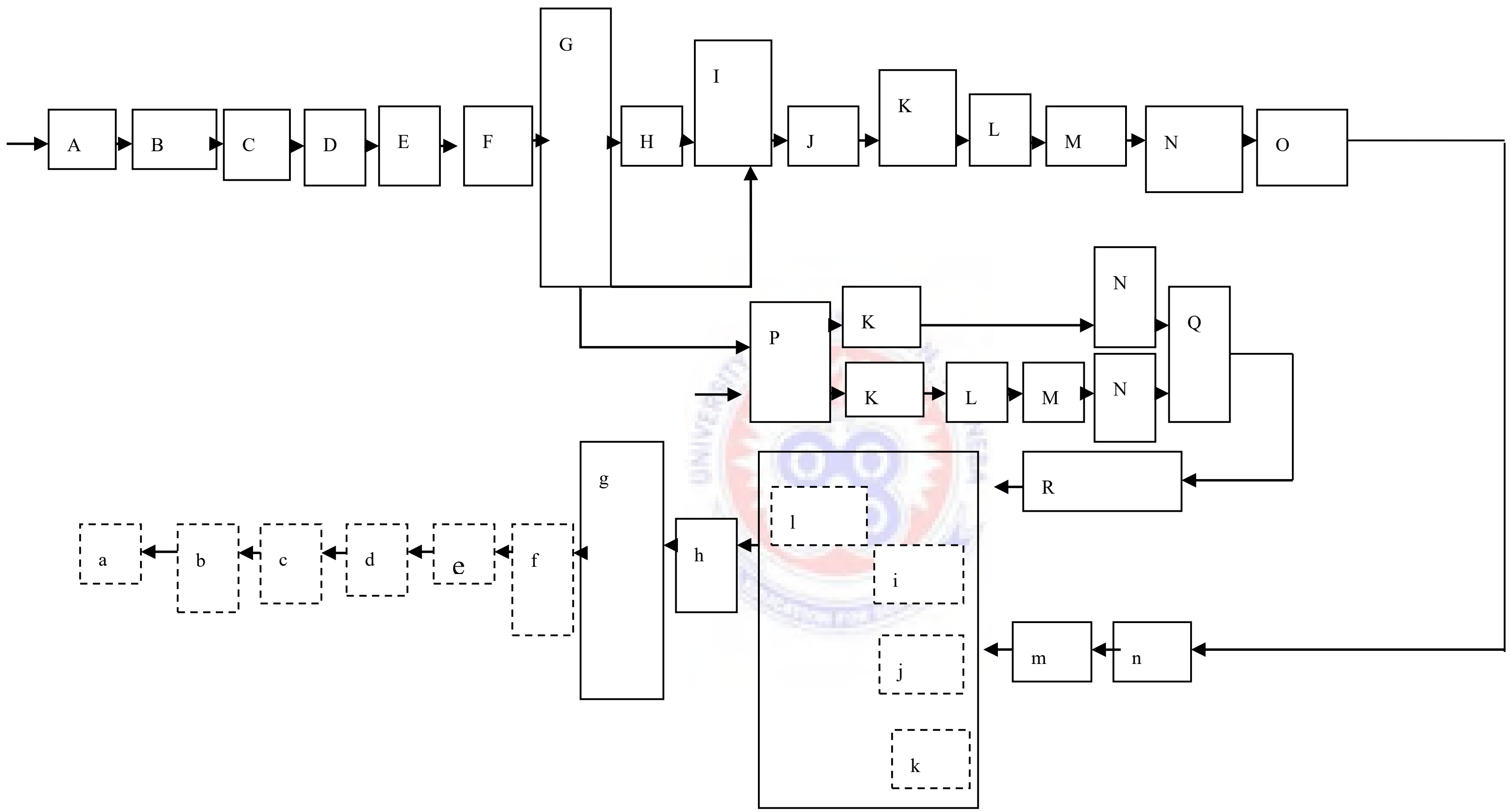

Figure 2.1: Architecture of a DVB-T2 system. (Source: www.low-powerwireless.com)

Legend

A – Input Interface	a - DAC
B – Input Stream Synchronise	b - P1 symbol insertion
C – Compensating Delay	c - Guard Interval Insertion
D – Null Packet Deletion	d - PARP reduction
E – CRC encoder	e - IFFT
F- BB Header Insertion	f - pilot insertion and dummy
G – Scheduler	g – MISQ processing
H- Frame Delay	h – frequency Interleaver
I- Padding Insertion	i - Assembly of data plp cells
J- BB Scrambler	j - Sub-slice pFEC
K- FEC encoding	k – Assembly of common PLP cells
L- Bit Interleaver	l - Assembly of cells
M- Demux bits to cells	m – Time Interleaver
N- Gray Mapping	n – Cell Interleaver
O-Constellation rotation	Q- MUX
P- L1 signalling generation	R- Compensating Delay

2.4 Technological Issues

Radio waves travel from the transmitter to the receiver by means of space waves, ground waves and ground reflected waves or by sky waves (RHODES, 2003, pp. 2-3). There are factors that impede the accuracy of transmission models. These factors are reflection and diffraction (Chandler, 1994).

Reflection is the result of digital TV signal hitting on obstructions with properties (thickness, length) much larger than the wavelength of the radio wave (e.g. smooth surface of walls and hills/mountains). Diffraction occurs when radio waves strikes the edges or corners of obstacles. These act as secondary sources re-radiating into the shadow region. It is due to the diffraction effect that radio frequency energy travels in dense urban environments where there is no clear Line-of-Sight between two antennas (e.g. from edges such as building rooftops and mountaintops). The directional characteristics of both the transmitter and the receiver antennas (Saunders 2005). All these factors are called multiplicative noise. It is more conventional to subdivide these factors as path loss, shadowing or slow fading and fast fading or multipath fading.

2.5 Fast Fading (Multipath Propagation)

As radio waves are reflected or diffracted or scattered by trees, hills and mountains, buildings and other obstacles, they establish various transmission paths from the transmitter to the receiver antennas. Many reflections are produced in an urban environment and few reflections in rural areas. The multipath creates the most difficult problem in the digital broadcast environment (Walfisch & Bertoni, 1988). Looking at the topography or the demographic characteristics of Ashanti Region as indicated above it is important for transmission engineers to transmit signals using a transmission module with high efficiency to avoid fading.

2.6 Propagation Loss Prediction Models

The common approaches to propagation modelling include Empirical and Physical models (Ayyappan & Dananjayan, 2008). Whilst the Empirical model predict mean path loss as a function of various parameters, the physical model of path loss uses principles of radio waves such as free space transmission, diffraction or reflection (Abhayawardhana, Wassell, Crosby, Sellars & Brown, 2005).

Empirical models can be split into two sub categories namely; time dispersive and non-time dispersive (Anderson, 2005). Time dispersive models are designed to provide information relating to the multipath delay spread. Non-time dispersive empirical models use measurement data to model a path loss equation. Examples of such empirical propagation models include the ITU-R and the Hata models (1980). These models to conceive these models, a correlation was found between the received signal strength and other parameters such as antenna heights and terrain profiles, through the use of extensive measurement and statistical analysis. The accuracy of a particular model in a given environment depends on the fit between the parameters required by the model and those available for the area concerned. Examples of these models are Ikegami, Ibrahim and Parsons (Tapan et al. 2003), Free-Space (Friis 1946 cited in Saunders 2005 & Tapan et al. 2003), Extended COST-231 (COST 231 Final Report 1999 cited in Tapan et al. 2003), Perez-Vega and Zamanillo‟s model (Perez-Vega & Zamanillo, 2002), Plane Earth Loss, Hata model (Hata, 1980), Lee model (Lee, 1985), COST 231 Walfisch–Ikegami model (Ikegami et al. 1984), Walfisch–Bertoni model (Walfisch & Bertoni, 1988), and ITU-R P.370 (ITU Report 1997).

2.7 Free Space Propagation Model

The free space propagation model is used to predict received signal strength when the transmitter and receiver have a clear, unobstructed line-of-sight path between them. As with most large-scale radio wave propagation models, the free space model predicts that received power decays as a function of the Transmitter-Receiver separation distance raised to some power. The free space power received by a receiver antenna which is separated from a radiating Transmitter antenna by a distance d is given by the Friis free space equation:

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\ \ )^2 d^2} \qquad (1.1)$$

Where:

P_t is the transmitted power.

G_t is the transmitter gain.

G_r is the receiver gain.

λ is the wave length.

d is the distance from transmitter to receiver.

P_t is the transmitted power,

$P_r(d)$ is the received power,

Gt is the transmitter antenna gain,

G_r is the receiver antenna gain.

d is the Transmitter Receiver separation distance in meters and

λ is the Wavelength in meters.

The Friis free space equation shows that the received power falls off as the square of the Transmitter-Receiver (T-R) separation distance. This implies that the received power decays at a rate of 20 dB/decade with distance (Vinaye, Ramraj & Sheeba, 2010).

2.8 REC ITU-R P.370 Propagation Prediction Method

Prediction of the coverage provided by a given transmitting station is normally done on the basis of the field strength for the wanted signal predicted. Rec ITU-R P.370 is a commonly agreed field strength method for broadcasting services. The propagation curves given in this recommendation represent field strength values in the VHF and UHF bands as a function of various parameters (Anderson, 2003).

The power received at a distance d, Pr is given by:

$$P_r = \frac{|E|^2}{120} A_e \tag{1.2}$$

$$P_r(\mathrm{dB}) = 20\log_{10}E - 10\log_{10}(120\ ) + 10\log_{10}A_e \tag{1.3}$$

$$P_r(\mathrm{dB}) = 2E_{\min} - 10\log_{10}(120\ )/\Omega\ \mathrm{A}\ _e(\mathrm{dBm}^2) \tag{1.4}$$

Where:

$E_{\min}$ is the equivalent minimum field strength at receiving place.

$A_e$is the effective antenna aperture (dBm^2).

120 is the value of intrinsic impedance of free space (in ohms) (Armoogum, Soyjaudah, Mohamudally & Fogarty, 2007).

In the design of any transmission system, certain factors are of relevance to the design process. Losses in particular, factor in as an important consideration in the design of most communication systems. In a paper by Armoogum et al (2007), analysis were made with field strength, carrier-to-noise ratio and bit-error rate as measurement parameters to determine the minimum path loss with respect to the Free space, Lee, Hata and Extended COST-23 propagation models. Based on different terrain topologies, research showed that the effects of the slow fading effect (shadow) and fast fading effect were more pronounced in the southern part of Mauritius than the northern part due to the dense forests, sugar cane plains, mountain ranges and gorges, and thus causing a higher probability of signal errors. Furthermore, they realized that Lee and Free Space models are not in agreement with the values obtained for both regions; observations however, showed that Hata and Extended COST-231 models gave better agreement and hence could be used to model areas in Mauritius.

There are various propagation models that are also implemented to minimize losses as well. A study by Pullen (1999) found out that the prediction model ITU-R P. 370, used a set of curves which defined field strength versus distance from the transmitter. The model was however found out to lack information on the terrain. In a further research by Armoogum et el, propagation models were put into focus; the Free Space model and ITU-R P. 370 prediction propagation model were used in comparison to determine which one would suit the general area of Mauritius in terms of minimum losses and efficient transmission (Fogarty, Soyjaudah, Armoogum, & Mohamudally, 2006). Their analysis however brought to light the fact that the empirical models lacked accuracy to be able to measure the small mountain ranges of Mauritius used as a case study. It was found out that the existing models also had limitations primarily because it had limited categories for land (open area, sub-urban, urban areas).

Ostlin, Suzuki and Zepernick (2008) compared and analysed a newer model proposed by ITU. The validation of the ITU-R P.1546 was analysed using three versions (P.1546, P.1546-1, and P.1546-2) and these were measured against simple models. The study revealed that P. 1546-0 and P. 1546-1 provided better overall prediction of path loss compared to traditional models, such as the Okumura-Hata model. The comparison also indicated that measurement results of P. 1546-2 averagely underestimated the field strength by more than 10 dB for typical Australian rural areas. It was however found that P. 1546-2 improved the standard deviation of the prediction error compared to previous versions of the recommendations.

Similarly, a study undertaken by Abhayawardhana et al (2008) considered a set of propagation measurements taken at 3.5 GHz in Cambridge, UK to validate the applicability of some selected empirical models and how they perform in rural, urban and suburban environments. Abhayawardhana et al (2008), found out that the Stanford University Interim (SUI) model and Extended COST-231 Hata model mostly over-predicted the path loss in all the environments. However, the ECC-33 model showed the best results especially in the urban area. Test measurements taken at Cambridge University were compared to the predictions of the three empirical models. Based on the results gathered, the researchers concluded that the ECC-33 model showed the closest agreement with measured results and recommended it for the urban environment.

Although transmission models are taken into consideration, the digital television standards are also of importance. Li Zong and Bourbakis (2001) have provided an in-depth analysis on the major digital television standards which are Japan‟s MUSE (Multiple Sub-nyquist Sampling Code), Europe‟s DVB (Digital Video Broadcasting), and US‟ DTV (Digital Television), exploring their various advantages and disadvantages. The paper also analysed the consumer acceptance and market potential of all digital High Definition Television, and predicted the future merge of broadcast video and computers. Notwithstanding, other countries have also developed their own standards.

Another study by Liang, et.al (2007), discussed a new digital television standard developed by China. The standard was found out to be in developmental phases since 1994. The new standard, issued by the Chinese digital industry was the merged standard “Frame Structure, Channel Coding, and Modulation for a Digital Television Terrestrial Broadcasting System”. The standard was said to contain single and multicarrier options and offers support for various multi-program standard and high definition (SDTV/HDTV) broadcasting services.

A paper by Chung-Yen, vJian Song, Changyong Pan and Yangang Li (2006) also discussed the new Digital Terrestrial Television Broadcasting (DTTB) standard that China had developed to suit its own demands. The work of Chung-Yen et al‟s (2006) standard, Digital Television Terrestrial Multimedia Broadcasting (DTMB), was ratified and made the mandatory standard in all of China (Digital Terrestrial Television Broadcasting in China, 2007). The innovation of their standard was that it supported both fixed and mobile terminals and was estimated to serve nearly two thirds of the television viewers nationwide. This new standard adopted time-domain synchronous (TDS)-OFDM technology using a pseudo random sequence as the header of the signal frame to serve as both the guard internal (GI) of the OFDM block and the training symbol.

Linglong, Zhaochen and Zhixing (2012) discussed the European DVB-T2 (Digital Video Broadcasting-Terrestrial Second Generation), the American ATSC-M/H (Advanced Television Systems Committee-Mobile/Handheld), and Japanese Integrated Services Digital Broadcasting for Terrestrial multimedia broadcasting (ISDB-Tmm). According to Linglong et al. (2012), the demand for more powerful DTTB systems with higher data rate and more reliable performance became evident and as such around 2000, research work for the next-generation DTTB standards started worldwide. Their article addressed these key technologies and research trends relating the next-generation DTTB systems. The first category of performance-oriented technologies is OFDM-based transmission, modulation and channel coding, and MIMO, whiles the second category of applications-oriented technologies are return channel for interactive services, wireless localization, and multi-services supporting. They concluded that even though great achievements have been gained, some challenging problems remain to be solved, and further improvements, especially in the aspect of the application-oriented technologies, are highly expected.

Tero, Miika, and Jarkko (2010) evaluated the robustness of the physical layer signalling in the DVB-T2 system. The system was studied and compared to corresponding robustness of data path with help of computer simulations. The robustness is studied in both mobile and static broadcasts. It is observed that the transmission of the most important system parameters as well as detection of the presence of the DVB-T2 signal from the P1 symbol was very robust. P1 symbols consisted of a 1K OFDM symbol which is DBPSK modulated in frequency direction by pseudo random binary modulation signalling frequency (MSF) S1 and S2. It also included two frequency shifted cyclic extension C and B. Rodriguez et.al (2009) also undertook a comparison of various urban radio wave propagation models with measurements. A measurement campaign was performed at 1.8 GHz in an urban environment in Cartagena, Spain. The measurement procedure and data results were properly described and the experimental results were compared with various urban propagation models in order to study their validity in predicting radio signal losses. The analysis carried out showed that some considerations that implicitly lie within the models such as the assumption of the type of wave incidence over the series of buildings can be highly significant in the obtaining of more precise and realistic signal loss predictions.

The Re-Multiplexing of ISDB-T Broadcast Transport Stream (BTS) into DVB TS for single frequency network was reviewed in a paper presented by Cristiano Akamine, et al. (2009) and some other researchers. A new remultipex method to transmit and receive a BTS over DVB networks was presented. As the signal from

ISDB-T BTS is not an efficient method to transmit, the TS/BTS adapter algorithm was proposed to operate with DVB equipment in a more skilled and flexible way.

Digital Video Broadcasting Terrestrial (DVB-T) systems affected by in-channel interference were dealt with in a research paper by Angrisani, Farias, Fortin, and Sona (2007). Attention was paid to the effects the interference produces especially in terms of the video quality perceived by the end user. A number of experiments were therefore conducted through a proper test bed which enlists a high-performance measurement apparatus, a flexible DVB-T transmission platform, a typical receiver stage and a calibrated interference source. The ultimate goal of the research was to provide helpful information and hints for designers and broadcasters; to be applied whenever optimizing the performance of a DVB-T system affected by a detrimental interference is of primary concern. The experiment analysis highlighted significant relationships between Video Quality Measurement and Modulation Error Ration (MER). It also showed that two DVB-T signals characterized by the same MER value may lead to completely different video quality indices. The analysis also showed that AWGN and burst-like modulated interference provide same efforts in terms of VQM degradation.

In discussing changes that will arise as a result of digital transmission, Wu and Caron (1994) argued that the approach to allocation of television channels will change, hence, compel broadcasters to master a new set of parameters for optimizing service coverage. Wu and Caron (1994) also analysed modulation and channel coding issues related to digital television terrestrial broadcasting, such as data throughput, spectrum efficiency, single- and multi-carrier modulations, and interferences under simulating conditions, multilayer services and DTTB coverage. They concluded in their work that existing advanced television (ATV) for terrestrial propagation in the

Very High Frequency /Ultra High Frequency bands are congregating toward a complete digital application.

2.9 Conclusion

Conclusive research and analysis showed that single-carrier and multi-carrier modulation were two promising modulation techniques offering comparable performance on a Gaussian noise channel. Single-Carrier Modulation (SCM) was seen to be robust to frequency domain impulse or tone interference, while sensitive to time domain impulse interference. Multi-Carrier Modulation (MCM) on the other hand, was robust to the time domain impulses, but vulnerable to tone interference. As such they suggested that the possibility of implementing a layered service in a 6 MHz bandwidth needed more investigation. Taking all these reviews into consideration and observing that the migration from analogue to digital transmission is imminent now more than ever, this study seeks to validate the ITU propagation prediction model P.370. (ITU, 1997). In doing so, it brings Ghana into the fray as far as digital transmission is concerned.

CHAPTER THREE

RESEARCH METHODOLOGY

This chapter discussed on how the research was carried out. It detailed out the research design, procedure for gathering data, propagation models, simulations and comparisons.

3.1 Research Design

A research design is the blueprint for conducting a study. Yin (2009) submits that a research design is the logical arrangement that connects the empirical data to the initial research questions and finally conclusions drawn. The main design of this project is a case study research. A case study is an empirical investigation into an existing phenomenon within its real-life context (Yin, 2003). The use of case study approach to examine phenomena as they happened in their natural contexts is suitable for this study mainly because it allows for a wide range of data sources and types to be employed in parallel or in sequence (Creswell, 2007; Miles & Huberman, 1994; Pettigrew, 1992, 1997; Yin, 2009). Further, this design is appropriate for this study because it allows for testing whether scientific models and principles essentially work in real world

3.2 Procedure

Data collected was acquired and compiled due to measurements taken from the field with the aid of a signal strength meter. Data for this study was gathered from 10th July 2013 – 30th September, 2014 with each day having its set of values. The measurements were conducted within the range of about 1 – 20 kilometres from the Ghana Broadcasting Cooperation (GBC) station in Kumasi. The measurements were also done for receiving antenna heights of 1.5 m and 10 m. Once the received signal had been captured, the signal strength, the Bit Error Rate (BER), and the Signal-to-Noise ratio (SNR) were recorded for the digital TV signal.

Figure 3.1: Photo Shot of the Signal Strength Meter Screen

Table 3.1: Sample data of measured values

Date	Signal Strength	BER	Signal to noise Ratio
10th July 2014	-61.4dBm	1.6E-07	20.9dB
	-62.7dBm	7.1E-07	20.3dB
31st July 2014	-61.3dBm	2.3E-07	21.3dB
	-61.4dBm	2.2E-07	21.4dB
1st August 2014	-61.6dBm	5.9E-07	21.4dB
	-60.8dBm	2.2E-07	21.4dB
	-61.0dBm	2.2E-06	21.4dB
4th August, 2014	-61.3dBm	8.2E-08	21.0dB
	-61.0dBm	2.1E-07	21.3dB
	-61.5dBm	1.1E-07	21.3dB
28th August, 2014	-63.1dBm	2.3E-07	19.9dB
	-62.8dBm	4.1E-06	20.8dB
	-64.8dBm	4.9E-05	19.8dB
1st September, 2014	-64.6dBm	2.2E-05	19.6dB
	-63.9dBm	8.7E-06	19.8dB
	-63.9dBm	5.1E-06	19.5dB
30th September, 2013	-63.8dBm	1.1E-05	20.1dB
	-64.1dBm	1.4E-05	19.1dB

3.3 Propagation Models

The various measurement computations by the two models (i.e. the Free Space path loss model and the ITU-R P370 prediction propagation model) were carried out using general formulae and propagation curves. The aforementioned propagation models can be grouped into two types of propagation models: physical propagation model and empirical propagation model respectively. These are collectively referred to as Large-scale propagation models because they characterize signal strength over large Transmitter-Receiver separation distances (several hundreds or thousands of meters).

3.3.1 Free Space Propagation Model

This model is used to predict received signal strength when the transmitter and receiver have a clear, unobstructed line-of-sight path between them. As with most large-scale radio wave propagation models, the free space model predicts that received power decays as a function of the T-R separation distance raised to some power. The free space power received by the receiver antenna which is separated from a radiating transmitter antenna by a distance d, is given by the Friis free space equation,

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\ )^2 d^2 L} \qquad (3.1)$$

Where P_t is the transmitted power, P_r (d) is the received power, $G_t$is the transmitter antenna Gain, G_r is the receiver antenna gain, anddis the Transmitter Receiver separation distance in meters, L is the systems loss factor not related to propagation and λ is the Wavelength in meters.

The gain of an antenna is related to its effective aperture,A_e by

$$G \quad \frac{4\ A_e}{\lambda^2} \qquad (3.2)$$

3.3.2 ITU-REC P370 Propagation Prediction Model

The ITU model being an empirical approach means it is based on its own set of fitting curves or analytical expressions that recreate a set of measured data. This further aids in interpolation and extrapolation of data. This model is a commonly agreed field strength method for broadcasting services. The propagation curves given in this recommendation represent field strength values in the VHF and UHF bands as a function of various parameters (Anderson, 2003).

The power received at a distance d, $P_r$is given by:

$$P_r = \frac{|E|^2}{120} A_e$$

$$P_r(dB) = 20\log_{10}E - 10\log_{10}(120\ \ ) + 10\log_{10}A_e$$

$$P_r(dB) = 2E_{min} - 10\log_{10}\,(120\ \ )/\Omega\ A\ _e\left(dBm^2\right) \qquad (3.3)$$

Where:

E_{min} = minimum field strength at receiving place

A_e = effective antenna aperture $\left(dBm^2\right)120$ intrinsic impedance of free space (in ohms) (Armoogum et al., 2010).

However, the above equation relates electric field (with units of V/m) to received power (with units of watts). Often, this equation is used to relate the received power level to a receiver input voltage, as well as to an induced electric field at the receiver antenna. In situations where practical values of field strengths are available in $dB\ \ V/m$ from measurements, the corresponding path loss in dB can be calculated as follows if the values for transmitted power and effective receiver antenna aperture are known:

$$PL(dB)\ P\ _t(dB) - P_r(dB)$$

$$PL(dB)\ P\ _t(dB) - E_{min} - A_e(dB) + 10\log_{10}(120\ \ )$$

$$PL(dB)\ P\ _t(dB) - 2E_{min}(dB\ \ V/m) + 240 - A_e(dB) + 10\log_{10}(120\ \ ) \qquad (3.4)$$

Where $E_{min}\ \ E_{min}(dB\ \ V/m) - 120$

3.3.3 An Excerpt of the ITU REC P.370 Model Field Strength Graph

The measurements concerning the ITU-R P370 propagation model were taken from fitting curves that had field intensity in $(dB\ \ V/m)$ plotted against distance numbering from 10 km – 1 000 km. Therefore, based on the various parameters established, interpolation was conducted and the relating field strengths were obtained. These field intensities were in turn converted from [$^{dB\mu V}/_{m}$ to (dBm)]to ensure uniformity in the various simulations and computations.

3.4 Simulations and Comparisons

Simulations were done with the aid of the MATLAB programming software. Having acquired the needed field intensities, simulations were made with MATLAB and graphs of the field intensity were plotted against the distances for both propagation models. After doing this, deviations of the ITU-R P370 model with respect to the Free Space path loss model were conducted. Per meter deviations and the total deviations were of particular concern here. The Mean Squared Error of the model was obtained using the equation,

$$E \quad \sqrt{\frac{\Sigma(\text{Measuredvalues} - \text{Simulatedvalues})^2}{N}} \qquad (3.5)$$

Where N Number of samples taken

These results were also modelled with the MATLAB software as well. Further simulations were made and correction factors were later included in the ITU-R P370 propagation prediction model to observe the possible changes that these factors would have on the propagation prediction model.

CHAPTER FOUR

ANALYSIS OF RESULTS AND DISCUSSION

This chapter presents a report of the results of the analysis of the two models. The graphs presented below all have received power (dBm) plotted against distance (meters). These graphs were all done with the help of the MATLAB programming software (See Appendices A, B, C, D, E, F, G and H).

4.1 Analysis of Signals against Distance using Smart TV Channels 21 and 22 and Skyy TV

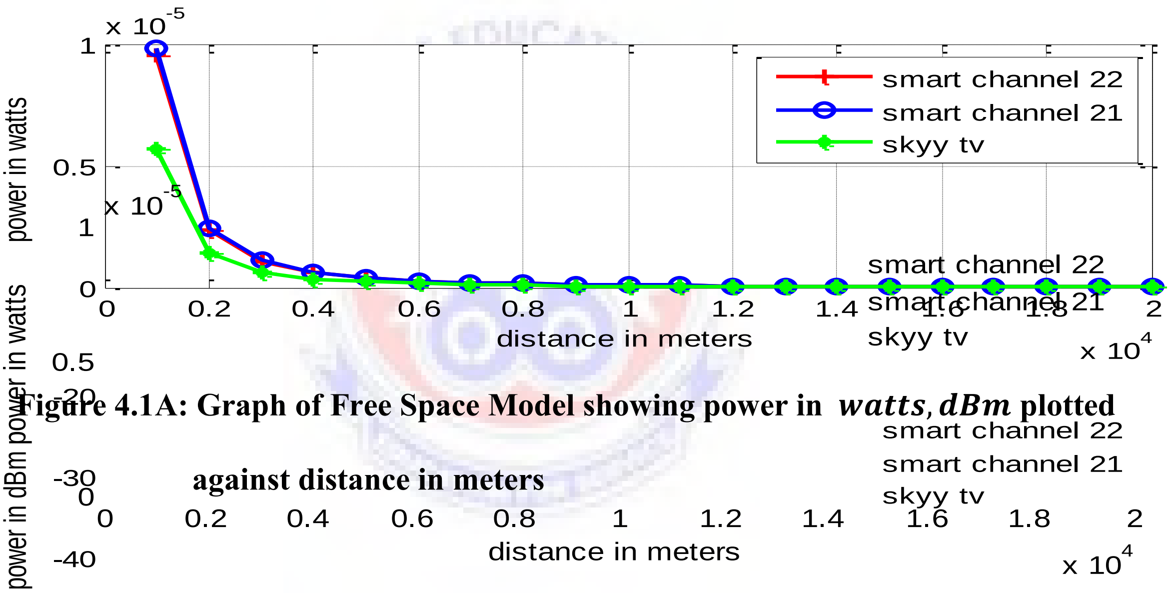

Figure 4.1A: Graph of Free Space Model showing power in *watts*, *dBm* plotted against distance in meters

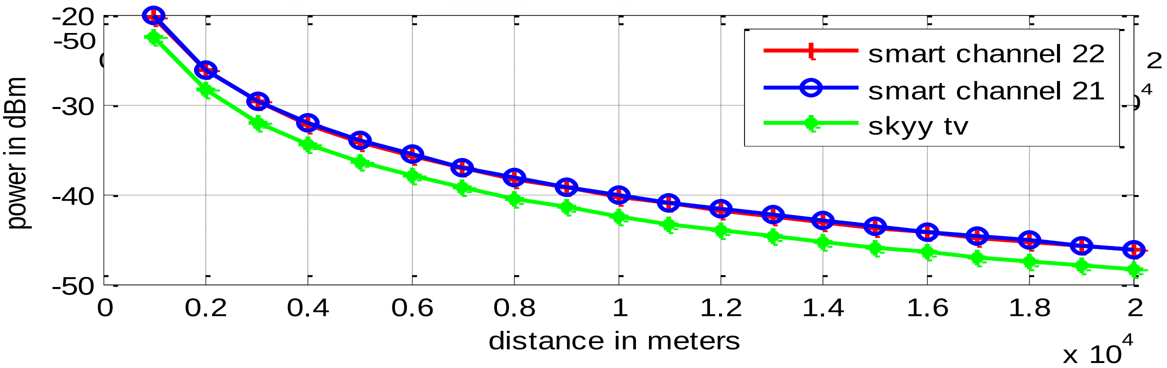

Figure 4.1B: Graph of Free Space Model showing power in *watts*, *dBm* plotted against distance in meters

In Figure 4.1, it is observed that the received power reduces as the distance from the transmitter increases. Frequencies for Smart TV channels 21 and 22 as well as that of SKYY TV were used to plot the graphs. This is the expected behaviour similar to most propagation models since the Free Space model assumes that there is no obstacle to impede transmission.

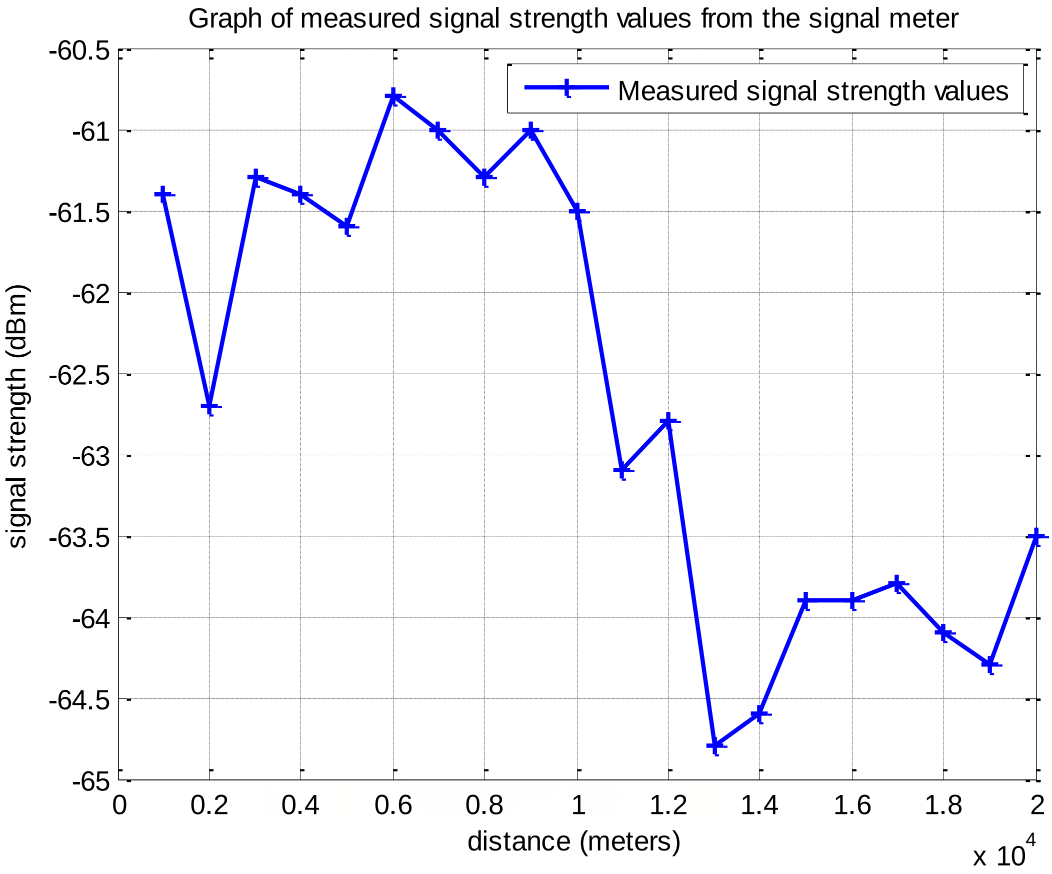

Figure 4.2: Graph of measured signal strength dBm plotted against distance in metres

In Figure 4.2, the graphs shows field measured signal strength which was measured using the signal strength meter. Theoretically it was expected that the signal strength decreases with increasing distance. It is worth noting that as the distance increases from the transmitting antenna the signal rises and falls but decreases more rapidly after 12000 m this is due to the topology of the land since it is a non-uniform surface causing the signal strength to rise and fall.

4.2 Analysis of Received Power against Distance

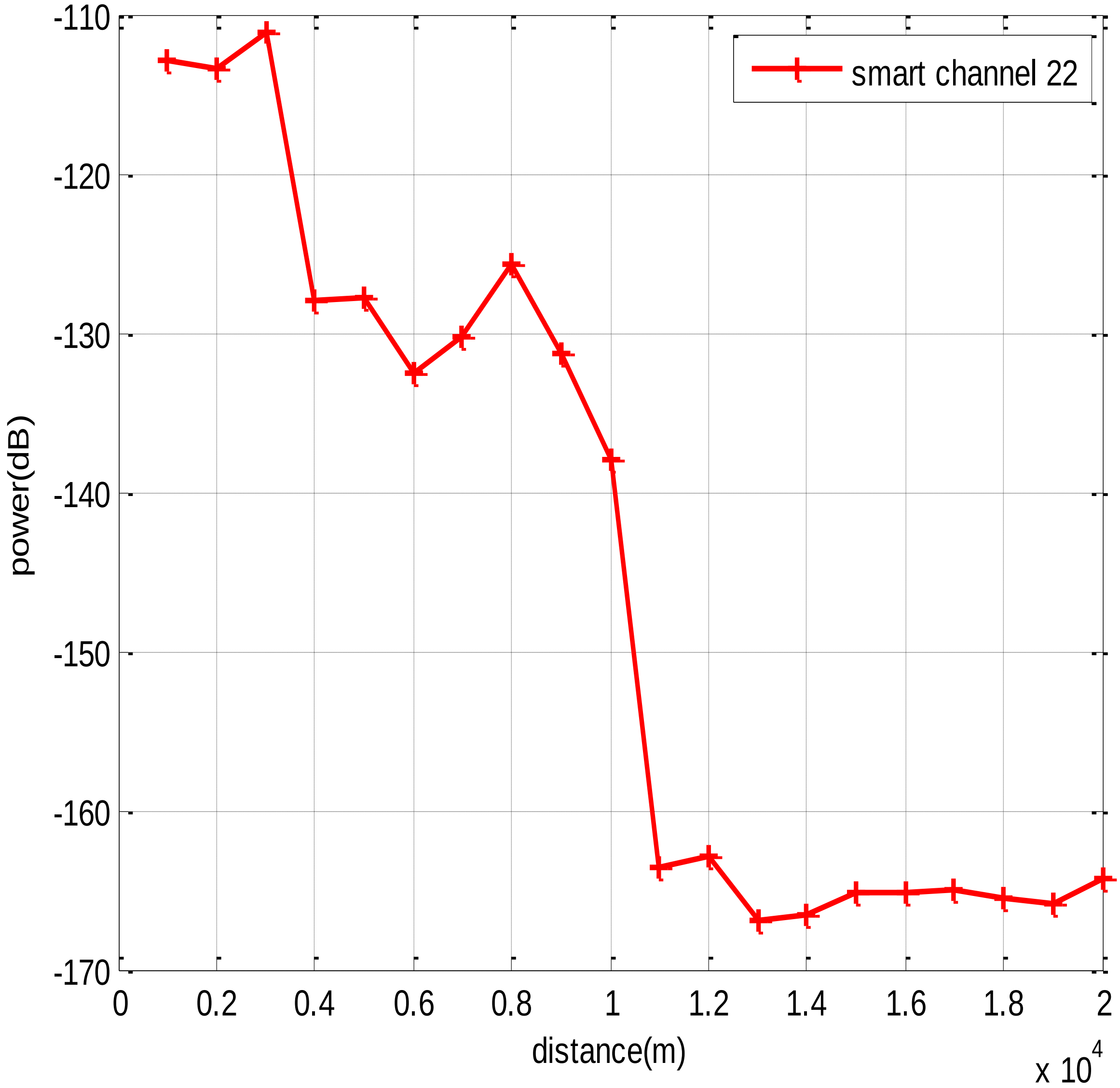

Figure 4.3: Graph of ITU REC P.370 Model with received power in dBm plotted against distance in $meters$ with respect to Smart TV channel 22

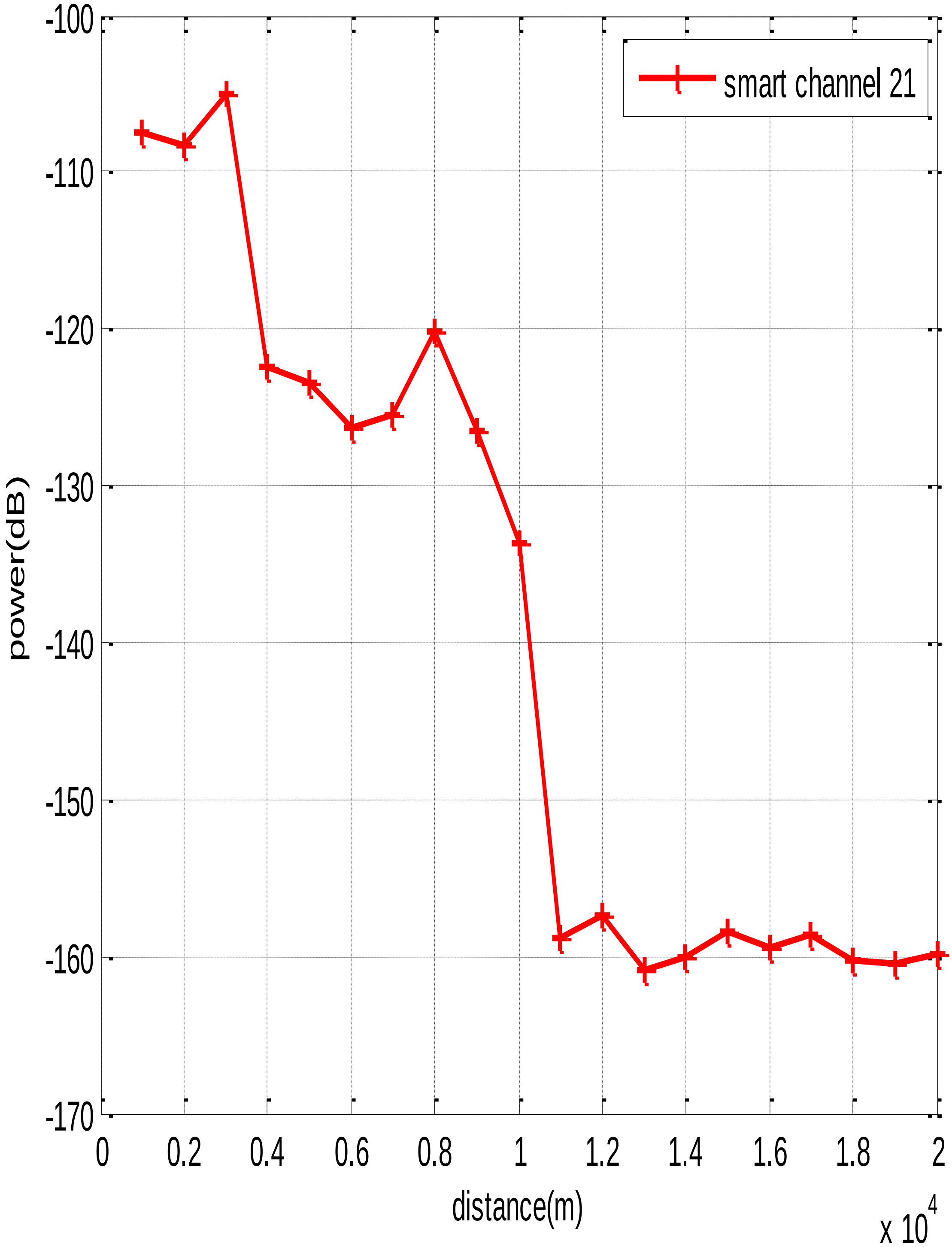

Figure 4.4: Graph of ITU REC P.370 Model with received power in dBm plotted against distance in meters for Smart TV channels 21

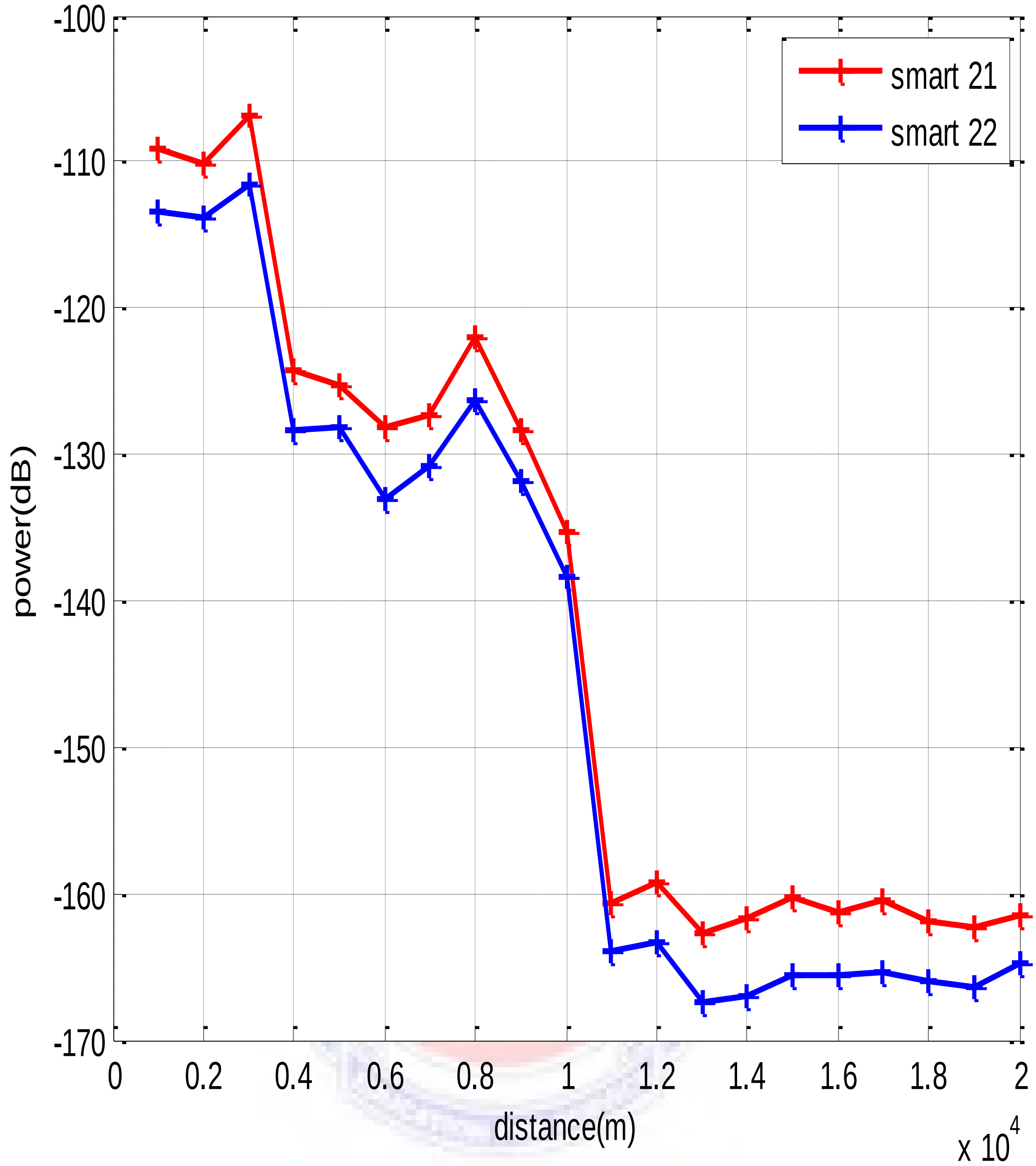

Figure 4.5: Graph of ITU REC P.370 Model with received power in dBm plotted against distance in meters using smart TV channels 21 & 22

The graphs (Figure 4.3, 4.4, 4.5) illustrate predicted received power against distance using ITU REC P.370 Model. Like the Free Space model, the predicted ITU REC P.370 received power also decreased with increasing distance but was spiky and erratic mainly due to the topology of the land.

Table 4.1: Received Power and their corresponding Path Loss for ITU REC P.370 Propagation prediction model

Distance	Received Power (dbm)	Path Loss (dbm)
1 m	-65.2280	128.2380
2 m	-84.6280	147.6380
3 m	-87.4280	150.4380
4 m	-103.6280	166.6380
5 m	-111.0280	174.0380
6 m	-116.4280	179.4380
7 m	-120.2280	183.2380
8 m	-124.6280	187.6380
9 m	-129.6280	192.6380
10 m	-133.8280	196.8380
11 m	-136.1280	199.1380
12 m	-138.4280	201.4380
13 m	-139.4280	202.4380
14 m	-140.8280	203.8380
15 m	-142.2280	205.2380
16 m	-144.8280	207.8380
17 m	-148.8280	211.8380
18 m	-152.2280	215.2380
19m	-154.4280	217.4380
20m	-156.0280	219.0380

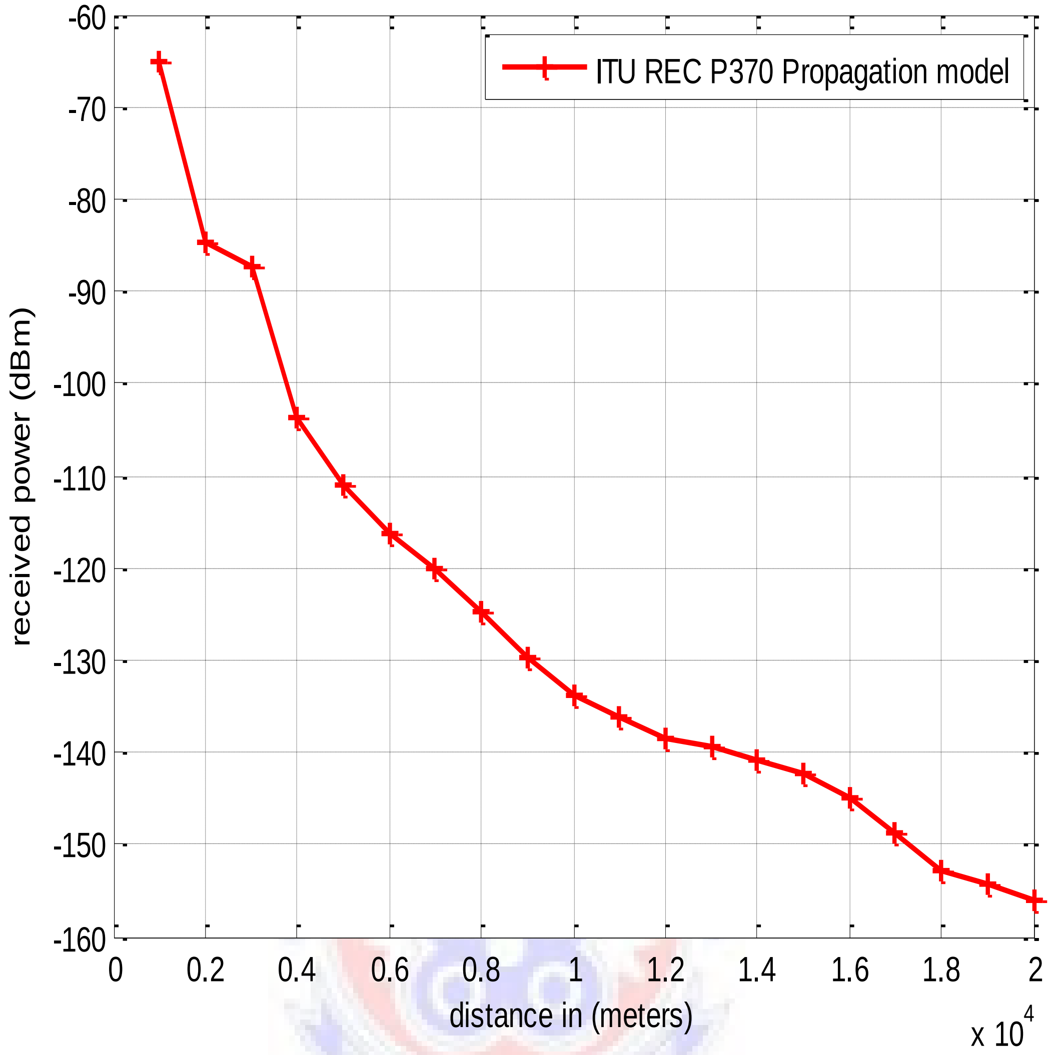

Figure 4.6: Graph of received power in dBm against distance in $meters$ for ITU REC P.370 propagation prediction model

In the Figure 4.6 graph, it is observed that the received power reduces as the distance away from the transmitter increases. This is the expected behaviour as akin to most propagation models.

Table 4.2: Per Meter Deviation of the ITU REC P.370 Propagation Prediction Model

Distance (Meters)	Error (dBm)
1	3.8560
2	21.9560
3	35.1560
4	42.2560
5	49.4560
6	55.6560
7	59.2560
8	63.3560
9	68.6560
10	72.3560
11	73.0560
12	75.6560
13	74.6560
14	76.2560
15	78.3560
16	80.9560
17	85.0560
18	88.1560
19	90.3560
20	94.1560

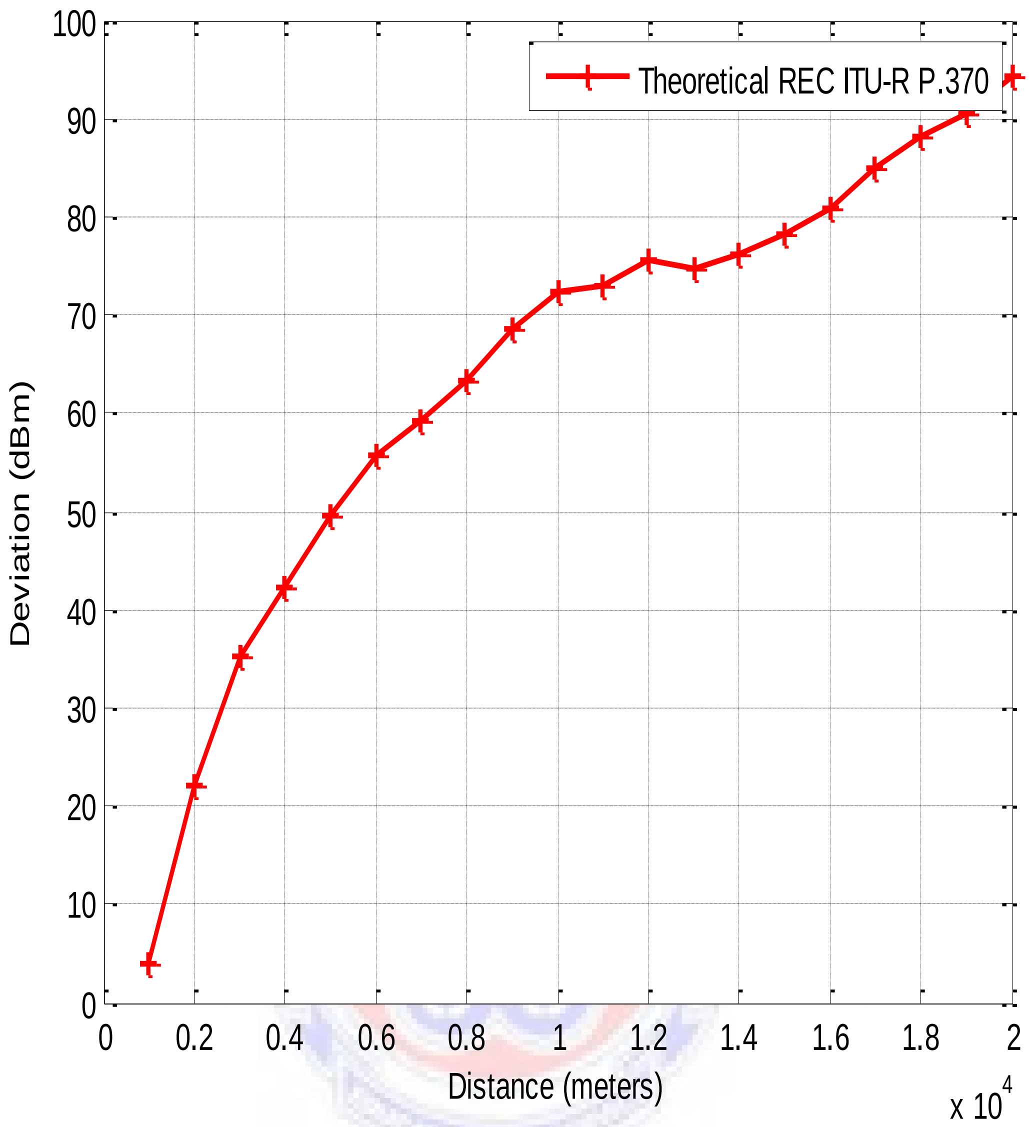

Figure 4.7: Graph showing Mean Squared Error (MSE) against distance in meters

Mean Squared Error (Deviation) of the model

$$E = \sqrt{\frac{\Sigma(Measured\ values - Simulated\ values)^2}{N}}$$

$$N = Number\ of\ samples\ taken$$

Total Deviation of the Model = 260.24 dBm

Table 4.3: Per Meter Values of the correction factor

Distance	Correction Factor (C.F)
1	1.02
2	1.12
3	1.2096
4	1.263
5	1.32
6	1.3769
7	1.4119
8	1.4565
9	1.5067
10	1.5432
11	1.7733
12	1.5862
13	1.5753
14	1.6244
15	1.6431
16	1.6798
17	1.7293
18	1.7648
19	1.6853

To find the path loss for the ITU REC P.370 model, the field intensity, E, is read from a field intensity graph and inserted in the formula below;

$$PL(dB) = \ Pt(dB) - (2E) + 240 - Ae(dB) + 10log(120\pi)$$

$$E = Field\ Intensity\ (dB\mu V/m)$$

A correction Factor, CF, was introduced into the equation to enhance the prediction on our terrain. Therefore the new equation will be;

$$PL(dB) = \ Pt(dB) - (2E * CF) + 240 - Ae(dB) + 10log(120\pi)$$

Table 4.4: Received powers and their corresponding Path Loss (Cost 231)

Distance	Received Power (dBm)	Path Loss (dBm)
1 m	-26.6420	92.6620
2 m	-36.5202	102.5402
3 m	-42.2985	108.3185
4 m	-46.3984	112.4184
5 m	-49.5784	115.5984
6 m	-53.1767	118.1967
7 m	-54.3736	120.3936
8 m	-56.2765	122.2965
9 m	-57.9551	123.9751
10 m	-59.4566	125.4766
11 m	-60.8149	126.8349
12 m	-62.0549	128.0749
13 m	-63.1956	129.2156
14 m	-64.2517	130.2717
15 m	-65.2350	131.2550
16 m	-66.1547	132.1747
17 m	-67.0187	133.0387
18 m	-67.8333	133.8533
19	-68.4581	134.4781
20	-69.3094	135.3294

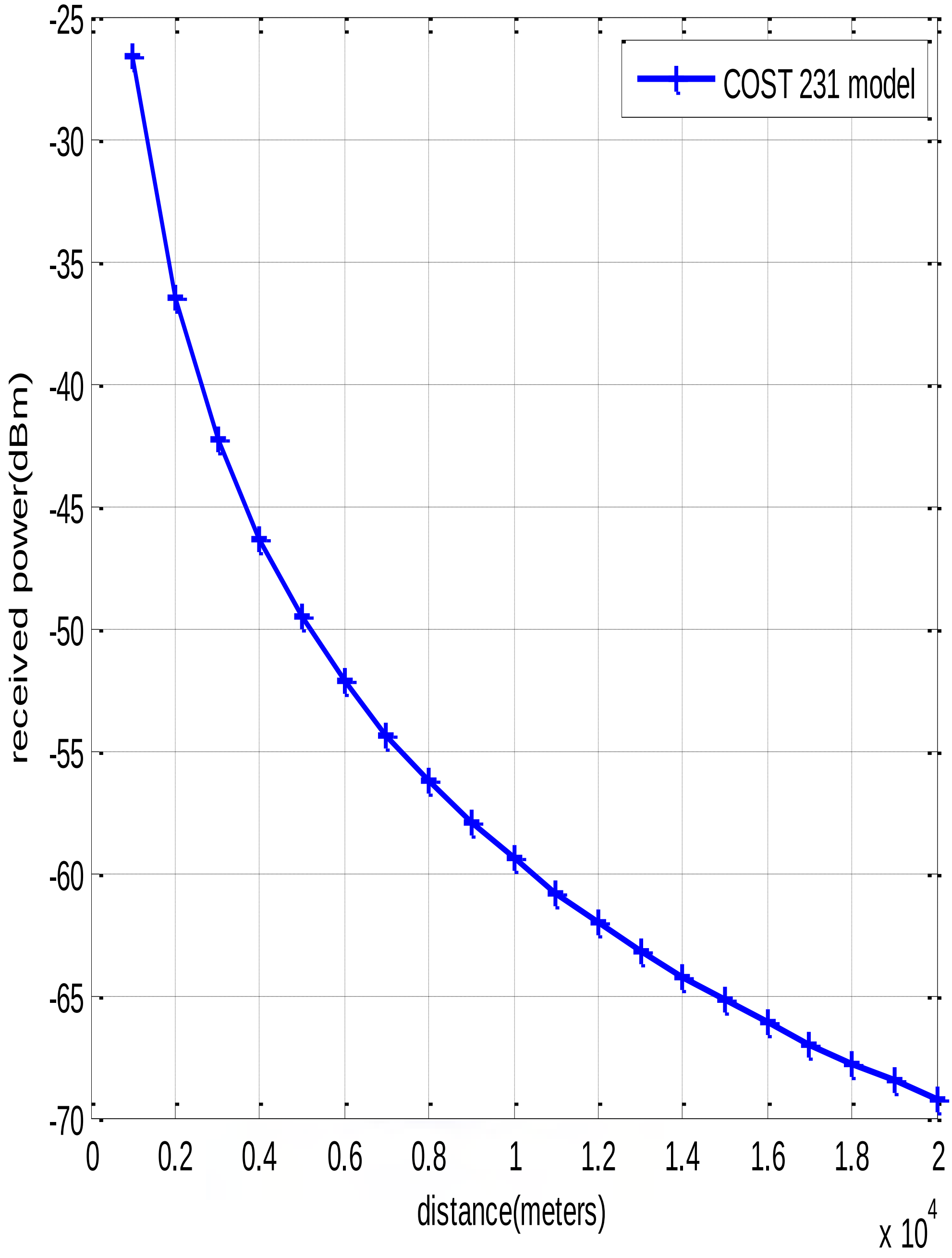

Figure 4.8: Graph of received power in dBm against distance in meters for Cost 231

The graph in Figure 4.8 illustrates predicted received power against distance using Cost 231 Model. Like the Free Space model, the predicted received power also decreased with increasing distance and the decrease this time round is smoother compared to the ITU REC P.370 model.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents a summary of key findings of the study and further proposes recommendations for future studies.

5.1 Summary of Findings

Plots of graphs showed that the ITU-R P370 prediction propagation model predicted relatively poor signal strength as compared to the ideal Free Space path loss propagation model. The study also observed that there was a large disparity between the deviations of the ITU-R P370 model and Free Space path loss model.

5.2 Conclusions

Modelling and coverage predictions are essential for efficient utilisation of the limited frequency spectrum and performance assessment of existing systems. A reliable model of predicting path loss helps in reducing load in base stations and in designing digital broadcasting networks including TV services. Considering Ashanti region as a case study, this study assessed propagation models for digital transmission. The study observed that existing models such as REC ITU-R P.370 propagation prediction model had limitation since it was developed for limited kinds of land. In analysing results of received power for REC ITU-R P.370 propagation prediction model and Extended COST 231 Hata, it concludes that the Extended COST 231 Hata model delivers a more consistent received power and loss prediction as compared to REC ITU-R P.370 propagation prediction but not so much that its improvement was appreciable. The study noted that for a good reception of the digital terrestrial transmission Ashanti region, there is the need for gap-filler. This can be achieved by siting repeaters and boosters at convenient locations to maintain or improve the transmitting power.

5.3 Recommendations

This study recommends extensive research be made on the geographic and the topology profile of Ashanti region and other sites of digital terrestrial television deployment in the country. This will potentially assist in getting exact correction factors to integrate in propagation models of interest. The field tests to be undertaken should also be diverse in that different land setting. These tests should consider areas like urban, suburban and open rural thereby promoting the use of appropriate factors where necessary. Additionally, various field tests should be undertaken with different transmitting and receiving antenna heights so that a general modification can be to done to the propagation prediction models. Site locations should also be studied to know areas where transmission would suffer minimum noise and interference and subsequently plan for the coverage probability in wherever wanted service area. Finally, this project recommends the use of a geographical information system to store geographical locations points for every 10 m^2 and their corresponding categories.

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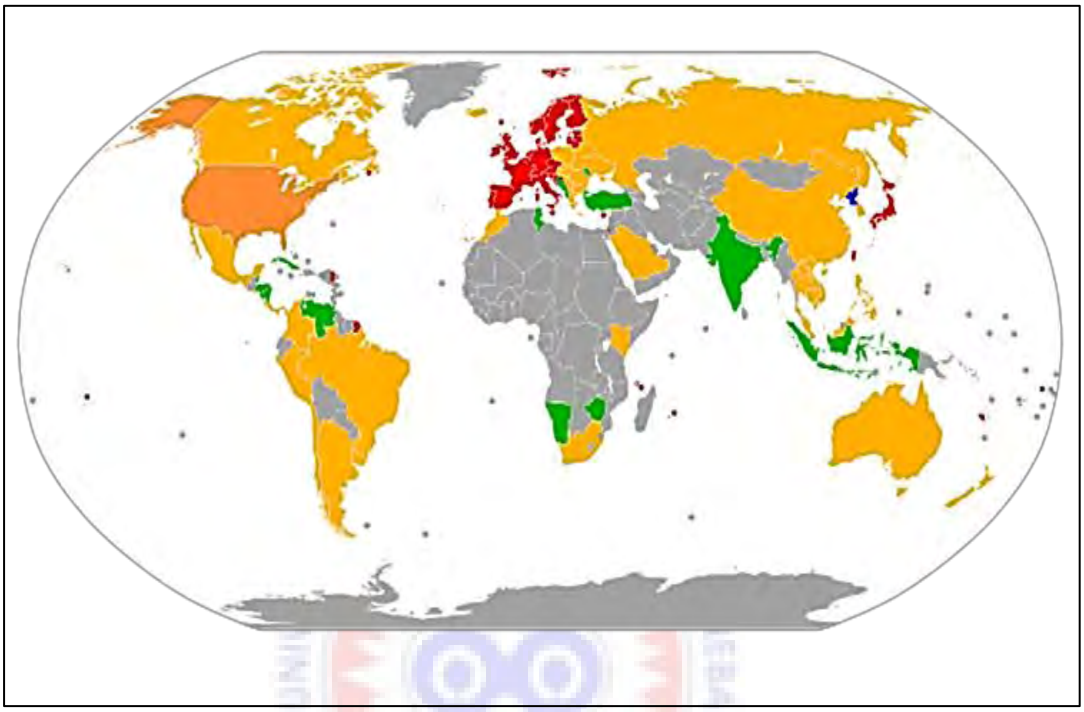
APPENDICES

Appendix A: World Map of Digital Television Transition in Progress.



Legend:

- Transition completed, all analog signals terminated
- Transition completed for full-power signals only; LPTV stations still be
- Transition in progress, broadcasting both analog and digital signals
- Transition not yet started, broadcasting analog signals only
- Does not intend to transition, broadcasting analog signals only
- No information available

Appendix B: Programme Code for Propagation Model, Cost 231.m

```
E2=[-26.6420,-36.5202,-42.2985,-46.3984,-49.5784,-52.1767,-54.3736,-56.2765,-
57.9551,-59.4566,-60.8149,-62.0549,-63.1956,-64.2517,-65.2350,-66.1547,-67.0187,-
67.8333,-68.4581,-69.3094];

d=1000:1000:20000;

p=plot(d,E2,'+');

set(p,'lineStyle','-','Color','blue','LineWidth',2)

xlabel('distance(meters)');

ylabel('received power(dBm)')

grid

legend('COST 231 model');
```

Appendix C: Programme Code for Propagation Model, Devcost.m

```
E1=[3.8560,21.9560,35.1560,42.2560,49.4560,55.6560,59.2560,63.3560,68.6560,72.3560,73.0560,75.6560,74.6560,76.2560,78.3560,80.9560,85.0560,88.1560,90.3560,94.1560];

d=1000:1000:20000;

q=plot(d,E1,'+');

set(q,'lineStyle','-','Color','red','LineWidth',2)

xlabel('Distance (meters)');

ylabel('Deviation (dBm)')

grid

legend('Theoretical REC ITU-R P.370');
```

Appendix D: Programme Code for Propagation Model, Fsmart2122.m

```
function [ Pr1dB,G,Ae1,E1,E2] = fsmart2122( ~ )

d=1000:1000:20000;

fsmart21=482*10^6;

fsmart22=490*10^6;

G1=13;

G2=15

Pt=10*log10(1000);

E1=[-35.7,-36.2,-34.5,-43.2,-43.7,-45.2,-44.8,-42.1,-45.3,-48.8,-61.4,-60.7,-62.5,-
62.0,-61.2,-61.7,-61.3,-62.1,-62.3,-61.9];  %% true values measured on the field

E2=[-37.8,-38.0,-36.9,-45.3,-45.2,-47.6,-46.5,-44.2,-47.0,-50.3,-63.1,-62.8,-64.8,-
64.6,-63.9,-63.9,-63.8,-64.1,-64.3,-63.5];  %% true values measured on the field

E3=E1+107+5;

E4=E2+107+5;

c2=(3*10^8)^2;

y1=c2/fsmart21^2;

y2=c2/fsmart22^2;

Ae1=(G1*y1)/4*pi;

Ae2=(G2*y2)/4*pi;

disp(Ae1)

disp(Ae2)

PL1=Pt-2*E3+240-Ae1+10*log10(120*pi);

PL2=Pt-2*E4+240-Ae1+10*log10(120*pi);

Pr1dB=Pt-PL1;

Pr2dB=Pt-PL2;
```

```
p=plot(d,Pr1dB,'+');
set(p,'lineStyle','-','Color','red','LineWidth',2)
hold on
p1=plot(d,Pr2dB,'+');
set(p1,'lineStyle','-','Color','blue','LineWidth',2)
xlabel('distance(m)');
ylabel('power(dB)')
grid
legend('smart 21','smart 22');
end
```

Appendix E: Programme Code for Propagation Model, Iturealremix.m

```
function [ Pr1dB,G,Ae1,E1,E2] = iturealremix( ~ )
d=1000:1000:20000;
fsmart22=490*10^6;
G=15;
Pt=10*log10(1000);
E1=[-37.8,-38.0,-36.9,-45.3,-45.2,-47.6,-46.5,-44.2,-47.0,-50.3,-63.1,-62.8,-64.8,-
64.6,-63.9,-63.9,-63.8,-64.1,-64.3,-63.5];  %% true values measured on the field
E2=E1+107+5;
c2=(3*10^8)^2;
y1=c2/fsmart22^2;
Ae1=(G*y1)/4*pi;
disp(Ae1)
PL1=Pt-2*E2+240-Ae1+10*log10(120*pi);
Pr1dB=Pt-PL1;
p=plot(d,Pr1dB,'+');
set(p,'lineStyle','-','Color','red','LineWidth',2)
xlabel('distance(m)');
ylabel('power(dB)')
grid
legend('smart channel 22');
end
```

Appendix F: Programme Code for Propagation Model, new measured.m

```
E2=[-65.2280,-84.6280,-87.4280,-103.6280,-111.0280,-116.4280,-120.2280,-
124.6280,-129.6280,-133.8280,-136.1280,-138.4280,-139.4280,-140.8280,-
142.2280,-144.8280,-148.8280,-152.8280,-154.4280,-156.0280];
d=1000:1000:20000;
p=plot(d,E2,'+');
set(p,'lineStyle','-','Color','red','LineWidth',2)
xlabel('distance in (meters)');
ylabel('received power (dBm)')
grid
legend('ITU REC P370 Propagation model');
```

Appendix G: Programme Code for Propagation Model, Project.m

```
function [ PrdBsmart22,PrdBsmart21,PrdBskyy,a,b1,b2,b3 ] = project(j)
fsmart22=490*10^6;
fsmart21=482*10^6;
fskyy=632*10^6;
c2=(3*10^8)^2;
Pt=4*10^3;
a=Pt*c2;
d=1000:1000:20000;
b1=(4*pi*d*fsmart22).^2;
b2=(4*pi*d*fsmart21).^2;
b3=(4*pi*d*fskyy).^2;
Prsmart22=a./b1;          %./ is used to divide a scaler by a matrix
Prsmart21=a./b2;
Prskyy=a./b3;
PrdBsmart22=10*log10(Prsmart22*10^3);
PrdBsmart21=10*log10(Prsmart21*10^3);        %changing from watts to dbm
PrdBskyy=10*log10(Prskyy*10^3);
%%graphics
subplot(2,1,1)
p=plot(d,Prsmart22,'+');
set(p,'lineStyle','-','Color','red','LineWidth',2)       %used to set the color of the line
hold on
p1=plot(d,Prsmart21,'o');
```

```
set(p1,'lineStyle','-','Color','blue','LineWidth',2)          %% 490mhz ,    482mhz smart
tv channel 22,21 % skyy  632mhz
hold on
p2=plot(d,Prskyy,'*');
set(p2,'lineStyle','-','Color','green','LineWidth',2)
xlabel('distance in meters');
ylabel('power in watts')
grid
legend('smart channel 22','smart channel 21','skyy tv');
subplot(2,1,2)
q=plot(d,PrdBsmart22,'+');
set(q,'lineStyle','-','Color','red','LineWidth',2)
hold on
w=plot(d,PrdBsmart21,'o');
set(w,'lineStyle','-','Color','blue','LineWidth',2)
hold on
g=plot(d,PrdBskyy,'*');
set(g,'lineStyle','-','Color','green','LineWidth',2)
xlabel('distance in meters');
ylabel('power in dBm')
grid
legend('smart channel 22','smart channel 21','skyy tv');
end
```

Appendix H: Programme Code for Propagation Model, signalmeter.m

```
E2 = [-61.4,-62.7,-61.3,-61.4,-61.6,-60.8,-61.0,-61.3,-61.0,-61.5,-63.1,-62.8,-64.8,-64.6,-63.9,-63.9,-63.8,-64.1,-64.3,-63.5];

d = 1000:1000:20000;

f = plot(d,E2,'+');

set(f,'lineStyle','-','Color','blue','LineWidth',2)

xlabel('distance (meters)')

ylabel('signal strength (dBm)')

title('Graph of measured signal strength values from the signal meter')

grid

legend('Measured signal strength values')
```

Appendix I: Programme Code for Propagation Model, smart21.m

```
function [ Pr1dB,G,Ae1,E1,E2] = smart21( ~ )

d=1000:1000:20000;

fsmart21=482*10^6;

G=19;

Pt=10*log10(1000);

E1=[-35.7,-36.2,-34.5,-43.2,-43.7,-45.2,-44.8,-42.1,-45.3,-48.8,-61.4,-60.7,-62.5,-
62.0,-61.2,-61.7,-61.3,-62.1,-62.3,-61.9];  %% true values measured on the field

E2=E1+107+5;

c2=(3*10^8)^2;

y1=c2/fsmart21^2;

Ae1=(G*y1)/4*pi;

disp(Ae1)

PL1=Pt-2*E2+240-Ae1+10*log10(120*pi);

Pr1dB=Pt-PL1;

p=plot(d,Pr1dB,'+');

set(p,'lineStyle','-','Color','red','LineWidth',2)

xlabel('distance(m)');

ylabel('power(dB)')

grid

legend('smart channel 21');

end
```