COMPARATIVE ANALYSIS ON RECEPTION OF DIGITAL VIDEO BROADCAST-TERRESTRIAL: A CASE STUDY OF ARUSHA CITY

By

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CERTIFICATION

The undersigned certify that they have read and hereby recommend for acceptance by the University of Dodoma the dissertation entitled; **" Comparative Analysis on Reception of Digital Video Broadcast-Terrestrial: A Case Study of Arusha City "** in partial fulfillment of the requirements for the degree of Master of Science in Telecommunications Engineering at the University of Dodoma.

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DECLARATION

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I, Ibrahim Iddi declare that this dissertation is my own original work and that it has not been presented and will not be presented to any other university for a similar or any other degree award.

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DEDICATION

To my lovely parents, Alhaji Iddi Abdallah Juma and Amina Suleiman Mussi, you must have had hard time keeping this naught boy within the line. Thanks for making me to be who I am today

ABSTRACT

Tanzania has been among the earliest countries in Africa to employ Digital Video Broadcast-Terrestrial (DVB-T) System. The deadline for Analogue Switch Off (ASO) was set to be in 2015, but Tanzania decided to have phased switch off since 2010. DVB-T is a new system in Tanzania and hence the extent of quality of the signal needs to be established.

This research compares the reception of DVB-T second generation spatial signal strength as offered by Star Media Limited, Agape Associates Limited and Basic Transmission Limited multiplexing companies in five locations of the Arusha City. The research involved two phases, first was field measurement of DVB-T signals using four different antennas and a spectrum analyzer, and secondly, customers perception on quality of the signal they receive was established using a guided interview. Measurements have shown that overall DVB-T signal strength was quiet strong in Arusha city centre, which allows spectrum analyzer to have a set point of -10 dBm. In other areas, overall DVB-T signal strength was weak which forced to have the spectrum analyzer set point lowered to -30 dBm. The research also found all of the Digitek and Agape decoder customers were satisfied with the quality of DVB-T signal they were receiving. 9 out of 10 customers of Continental decoders and 4 out of 5 Tanzania Broadcast Corporation (TBC) decoders were also satisfied with quality of signal as offered by their MUXs. Research results recommend to Multiplexers to either increase power of their existing towers in allowable ranges or to increase number of towers to strengthen signal reception in remote areas and areas in low altitude. Gap filler can be employed in town to those areas obstructed by high rise structures.

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LIST OF ABBREVIATIONS AND ACRONYMS

AAL	Agape Associates Limited
APL	Average Penetration Loss
ASO	Analogue Switch Off
ATSC	Advanced Television System Committee
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BST	Band Segmented Transmission
BTL	Basic Transmission Limited
COFDM	Coded Orthogonal Frequency Division Multiplexing
CSP	Content Service Providers
DAC	Digital to Analogue Converter
DTMB	Digital Terrestrial Multimedia Broadcast
DTT	Digital Terrestrial Television
DTTB	Digital Terrestrial Television Broadcasting
DTV	Digital Television
DVB-C	Digital Video Broadcast-Cable
DVB-H	Digital Video Broadcast-Handheld
DVB-S	Digital Video Broadcast-Satellite
DVB-T	Digital Video Broadcast-Terrestrial
EBU	European Broadcasting Union
EU	European Union
FEC	Forward Error Correction
FFT	Fast Fourier Transform
FTA	Free to Air

GF	Gap Filler
GPS	Global Positioning System
HD	High Definition
HDTV	High Definition Television
IF	Intermediate Frequency
IPTV	Internet Protocol Television
ISDB-C	Integrated Services Digital Broadcasting-Cable
ISDB-S	Integrated Services Digital Broadcasting-Satellite
ISDB-T	Integrated Services Digital Broadcasting-Terrestrial
ISI	Inter Symbol Interference
ITU	International Telecommunication Union
ITV	Independent Television
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MAC	Multiplexed Analogue Component
MFN	Multi Frequency Network
MPEG	Moving Picture Expert Group
MUX	Multiplexer
NSP	Network Service Providers
OFDM	Orthogonal Frequency Division Multiplexing
PAL	Phase by Line
PAPR	Peak to Average Power Ratio
QAM	Quadrature Amplitude Modulation
QEF	Quasi Error Free
QPSK	Quadrature Phase Shift Keying

RF	Radio Frequency
RS	Reed Solomon
RURA	Rwanda Utilities Regulatory Agency
SFN	Single Frequency Network
SMS	Subscriber Management System
STB	Set Top Box
TCRA	Tanzania Communications Regulatory Authority
TS	Transport Stream
TV	Television
UHF	Ultra High Frequency
UK	United Kingdom
US	United States
VHF	Very High Frequency
VSB	Vestigial Side Band

CHAPTER ONE

INTRODUCTION

1.0 General Introduction

The analogue system of broadcasting television has been in place for over 60 years. During this period, viewers saw the transition from black and white to color Television (TV) technology. This migration required viewers to purchase new TV sets and TV stations had to be equipped with new broadcasting equipment. Today the industry is again going through a profound transition as it migrates from conventional TV to digital technology. TV operators are upgrading their existing networks and deploying advanced digital platforms.

While the old analogue-based system has served the global community for quiet sometime, it has reached its limits. Analogue system is characterized with low standard picture quality, its system cannot accommodate new data services, bandwidth utilization is so inefficient and also the signal is subject to degradation and interference from objects such as low-flying airplanes and household electrical appliances.

Those shortcoming forced scientists and engineers to look on ways to improve quality of picture signals. In the eighties, a number of attempts was taken to improve picture quality to no avail, such as an attempt to depart from traditional analogue TV by way of Multiplexed Analogue Component system (MAC). For various reasons, this did not succeed and MAC vanished from view (Walter, 2010).

In Europe, the Phase by Line (PAL) system was given a slight boost with the introduction of PALplus and Extended PAL but these too, did not achieve much success in the TV set market, either. At the same time, various approaches were tried, mainly in Japan and in the United States (US) to achieve success with the transmission of High Definition Television (HDTV), but it also failed to gain the universal popular appeal hoped for due to the bandwidth size it required. Hence, as a result digital television transmission was imminent, though it as well, was earlier characterized with huge bandwidth requirements.

Tanzania has recently joined in the process of shifting from the analogue television transmission to meet 2015 International Telecommunication Union (ITU) world deadline for Analogue Switch Off (ASO). DVB-T has been tasked to replace analogue transmission. Introduction of DVB-T has resulted in saving sizeable portion of bandwidth, which may be used for other functions.

Earlier, DVB in Tanzania was mainly practiced through its other two versions, Digital Video Broadcast via Cable and Satellite i.e. DVB-C and DVB-S respectively. Main challenge facing these two systems on being used as a substitute to analogue transmission to cover large number of customers that are phased out, is their high operating cost of service which hinders growth of customer base. Their connection cost and monthly payment seem to be higher than what many customers could afford. Hence DVB-T remains as the only reliable and affordable option to handle these customers.

There are three registered DVB-T Multiplexing companies (MUXs) in Tanzania, namely Star Media (T) Limited, Agape Associates Limited (AAL) and Basic Transmission Limited (BTL) (Mvungi *et al*, 2013). These multiplexing companies have a duly duty of aggregating and transmitting information received from Content Service Providers (CSP) and selling Set Top Boxes (STBs) to final customers.

DVB-T transmits signals in a digital form. Upon reception, the digital signal is converted to analogue signal that can be processed to give out audio signal and picture signal to be displayed on television screens. Some of the television sets incorporate a decoder within its system, but for old model television systems, decoders have to be outside the television set and only digital to analogue converted signal is passed to the television set. The quality of received signal among other factors highly depends on signal strength at the place where the receiver is located. Huge distances from receiver, signal blockage by tall structures and presence of interfering signal may all hinder the reception of digital video signals.

Transmission and reception of digital television has several characteristics which are different to transmission and reception of analogue television signals, hence comprehensive assessment of transmitting parameters is therefore a key measure to understand performance and coverage of DVB-T.

1.1 Statement of the Problem

The number of DVB-T customers has increased since its introduction in Tanzania. Digital reception is of required standard as long as the signal of minimum threshold level is achieved. As per Tanzania specification, shown on appendix B and C respectively, minimum threshold corresponds to input signal level of -33 dBm to -81 dBm for first generation DVB-T and -35 dBm to -85 dBm for second generation DVB-T (TCRA, 2013). The expectation after ASO was for digital television transmission to be capable of providing good quality of picture signal to all customers who were served by analogue television transmission.

Unfortunately, a comprehensive assessment on digital signal coverage by each of the MUXs has not been carried out in Arusha region. The TCRA digital migration assessment report of 2013 briefly shows that more than 20 testing points in Arusha were measured and they provided good results on digital television signal coverage and reception. It further states that most of selected tested points provided good signal reception for both indoor and outdoor receptions. That report lacked information on coverage provided by specific MUXs and actually, the reference of comparison was done only with respect to analogue television reception.

As shown in the Table 1, on the same research by TCRA, overall customers' satisfaction on DVB-T was assessed, the audio and visual quality were given a rank of satisfied. As with the case on reception part, this comparison was between audio and visual quality as perceived by customer in DVB-T against the former analogue transmission. Hence the comparison of audio and visual quality as offered by different MUXs was not carried out.

This research therefore, on one hand, intends to perform a comparative analysis by measuring quality of DVB-T signal received in different areas of Arusha city as provided by different MUXs. On the other hand, it works out to establish consumers' perception on quality of signal received.

Table 1: Overall Satisfaction Rating (Scale: 1 = Very Satisfied …… 5= Not Satisfied at all)

	Dar es salaam	Tanga	Arusha	Dodoma	Mbeya	Moshi	Mwanza	Total
Decoder Price	4	4	4	4	4	4	4	4
Decoder usage Bills	4	4	4	4	4	4	4	4
Bill payments System	3	1	2	3	2	2	3	2
Availability of Channels	3	3	3	3	3	3	3	3
Audio and Visual Quality	3	2	2	2	2	2	2	2
Customer Services	3	2	3	2	2	3	3	3
Number of Channels	3	3	3	3	3	3	3	3
Quality of Programmes	2	2	2	2	2	2	2	2
Average	3	3	3	3	3	3	3	3

Source: (TCRA, 2013)

1.2 Objective

1.2.1 General Objective

The main objective of this research is to conduct comparative analysis on quality of the received digital video broadcast-terrestrial offered by different MUXs in Arusha city.

1.2.2 Specific objectives

In order to achieve the general objective of the research, the following specific objectives have to be accomplished:

1. To measure indoor and outdoor field strength of the received DVB-T signal by the antenna, as offered by different MUXs in different locations of Arusha city.

2. To assess customers' perception on quality of digital signal received as offered by different MUXs.
3. To investigate best practice of signal reception on different locations of Arusha city.

1.3 Research Questions

1. What is the measured signal strength received by antenna on each of the identified locations and as per each MUX?
2. What are the customer perceptions on received digital signal as offered by different multiplexing companies?
3. What are the best practices on DVB-T signal reception as per specific location of Arusha City?

1.4 Significance of study

The research will help MUXs to improve coverage of their signals in areas where measured performance is not appreciable at the time of measurement, through either adoption of repeaters (more transmitting towers) to strengthen signal quality or giving advice to customers on specific type of antenna relevant to their areas. The MUXs will also have a reviewed customer perception of their service and hence be capable of exploring on areas on which they could make some improvements. The research will also be helpful to customers on selection of MUXs based on quality of measured signal strength depending of their location.

1.5 Conclusion

This chapter has provided introductory evolution on television transmission from analogue to the digital system. Problems associated with analogue transmission and the reasons to engage into digital transmission were brief reviewed. The chapter further shows the steps Tanzania passed to adopt DVB-T, statement of problem, general objective, specific objectives, research questions and significance of study were also presented.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

Number of factors may account to different field strength received. These includes a model of DVB-T transmission adopted by a Multiplexer (whether it is a DVB-T1 or DVB-T2), network arrangement (such as transmitter power and positioning, use of Single Frequency Network and Multi Frequency Network), earth terrain, types of STBs employed, types of receiving antenna used, location of the antenna (indoor or outdoor), time of the day and etc.

Several studies that analyze the strength of received digital signals for outdoor and indoor reception have been performed. In both cases the reception is influenced by multipath effect and is especially critical for indoor environments where obstacles such as walls or windows increase the signal variability. This situation deserves a more exhaustive study (Martínez *et al,* 2012).

The literature review will be structured into discussing DVB-T transmission/reception platform, which includes key players, basic transmission/reception media, evolution of digital terrestrial transmission and different systems adopted in different parts of the world, DVB-T system overview and overview of European and Tanzania digital market.

Era of DVB-T has changed almost the whole platform of television transmission/reception practice. In analogue systems, CSP were capable of directly transmitting Free to Air channels (FTAs) to consumers. In DVB-T, transmission and signal distribution responsibilities have been given to MUXs while Content Service Providers (CSPs) provide content in line with the converged licensing framework adopted in 2005 (TCRA, 2012).

In DVB-T there are mainly three main players in broadcasting value chain to viewer, as identified by the report of Rwanda Utilities Regulatory Agency (RURA) of 2008. These players are MUXs, CSPs and Network Service Providers (NSPs). The report has further shown that in a number of countries which adopted DVB-T, the role of NSPs has been merged in MUXs functions.

Currently, DVB-T can be received in two ways, either with the digital TV (DTV) or STB . As (Satitsamitpong *et al*, 2013) defined, a DTV is a television set which contains all the components necessary to receive and display digital transmissions. DTV can generally be distinguished by wide screens, high level audio capability and high resolution displays. In addition DTVs can receive all the enhanced services that DVB-T can offer. Therefore, the prices of DTVs are much higher than those of STBs.

2.1 Multiplexing Companies

In the same report by RURA of 2008, it has defined a Multiplex Operator to be an entity that compiles, operates and markets a content offering on a digital multiplex and that decides on the Condition Access and Subscriber Management System (SMS) to be used.

As per Electronic and Postal Communication Act (CAP.306) of 2011, a multiplex operator in Tanzania has to comply with the number of network configuration requirements, such as the use of Single Frequency Network (SFN) configuration for national coverage and Multiple Frequency Network (MFN) configuration for gap-fillers for deployment of digital terrestrial signal transmission, based on the national frequency spectrum plan.

2.2 Content Service Providers

The RURA report of 2008 has also defined Content Service Provider (CSP) as a term that shall be used to imply broadcasters and others involved in providing content only, hence not involved in its distribution or transmission. This term is used to avoid confusion with the current understanding of the term broadcaster.

2.3 Digital Terrestrial Set Top Boxes

STBs are devices used to interface a TV display which has no built in Digital to Analogue Converter (DAC) with the received digital signal. As (Mvungi, 2011) explained, the concept of STB did not start with the introduction of the digital television, as it dates back to the 1960s when the STB known as Ultra High Frequency (UHF) converter was used to shift down a portion of the UHF-TV spectrum onto low-Very High Frequency (VHF) channels for viewing. He further explained that the current STB serves as an interface to convert transmitted digital video signals transmitted through satellite, cable, terrestrial or networks (IPTV) to the form that can be displayed on the standard Liquid Crystal Display (LCD), Light Emitting Diode (LED), Plasma and Analogue TVs.

The quality of signal displayed on screen is highly dependent of the type of STB used. In TCRA report of 2012, Tanzanian government has set a minimum standard for STBs to be imported and used in the country. The report addresses basic required functions to meet minimum demand for digital signal reception, other functions have been left for MUXs to decide.

The digital terrestrial STB main parts are the RF tuner of VHF/UHF range and Coded Orthogonal Frequency Division Multiplexing (COFDM) chip with Forward Error Correction (FEC) decoder. The tuner amplifies the received RF signal, performs channel selection, and converts the selected signal down to Intermediate Frequency (IF) of 36 MHz. The COFDM demodulation is performed by applying a 2k or 8k Fast Fourier Transform (FFT) to the IF output. In case some carriers are damaged during the propagation, the lost bits can be restored by FEC (Jain *et al*, 2010).

The simplest receiver is the FTA STB. It can only be used to receive unencrypted signals. In recent years, pay TV has become more popular and people are quite interested in more specialized channels. Pay TV is based on encrypting the channels and the viewer will need a receiver capable of decrypting the signals. In addition, most encryption systems require a smart card with keys and subscription information. (Lundström, 2006).

2.4 VHF/UHF Propagation

At broadcast frequencies in the VHF and UHF bands, propagation is usually by ground waves which consist of direct wave, ground reflected and surface wave. Therefore, in these frequency bands, the electrical parameters of the ground, curvature of the earth surface, height of the antenna and weather conditions influence wave propagation. The degree to which these factors affect propagation depends primarily on the frequency of the wave and the polarization. The electric field strength at a given distance from the transmitter is attenuated by these parameters, with the result that radio services in the VHF and UHF bands are limited to distances close to the transmitter (Ajewole *et al*, 2013).

2.5 Transmitter Service Area and Coverage

All electromagnetic waves obey the inverse-square law in free space. The inverse-square law states that the power density of an electromagnetic wave is proportional to the inverse of the square of the distance from the source. That is, if the distance from a transmitter is doubled, the power density of the radiated wave at the new location is reduced to one-quarter of its previous value. Also, the electromagnetic waves coming from a transmitter may experience three other phenomena: reflection, diffraction, and scattering. All of these factors affect the transmitted signal as it is carried through the air medium to the distant receiving antenna (Ajewole *et al*, 2013).

When planning a transmitter network great care is taken on selecting sites to meet objectives such as the maximization of population coverage, the minimization of Co-Channel Interference, and other issues such as environmental impact, ease of access, and cost. By locating a transmitter main-station close to centers of population and by using aerial beam tilt on the transmit antenna system to direct the main lobe of radiated power below the horizon, it can be arranged that little radiation is transmitted beyond the service area. (O'leary, 2010)

The antenna gain will tend to concentrate the transmitter radiation into a beam, which will ensure that adequate field strength is achieved for reception of services within the service area of that transmitter. The gain process is similar to that of placing a magnifying glass into strong sunlight, the radiation from the antenna is concentrated into a beam, which can be directed toward the ground within the service area (O'leary, 2010).

The service area of a transmitter is limited by among other things, the earth's curvature, so that for a transmitter broadcasting from an aerial at a height h (meters) above sea level, the edge of the service area will be located at a radial distance d (km) away, where d = $\sqrt{17h}$ [km] (O'leary, 2010).

2.6 Transmission medium

Digital terrestrial television services are provided via the VHF/UHF bands. In contrast with satellite and cable systems, the terrestrial transmission of signals often suffers from multipath interference. A broadcast signal can be reflected, for example, by high buildings or mountains. The reflections are added to the main signal at the receiving end. Because the reflections travel via a different route, these signals are delayed and therefore are called echoes. Additionally, depending on the power used, co-channel interference may be caused when a different station transmits its programs on the same frequency.

In cities with high buildings and in mountain areas, echoes are likely to appear. When terrestrial signals are received by a fixed antenna, the antenna can be aimed at the strongest signal. Hence, the influence of echo signals will be minimized. This channel can be seen as a Rice channel, which is described by the main signal and the sum of all echo signals together. However, in the case of portable reception, the power of the main signal drops more or less to the same power level as that of the echo signals. The channel can now be considered a Rayleigh channel, which is described by the sum of all signals received.

2.7 Digital Television Standards

It is desirable that the consumer should be able to receive digital television signals with the same receive antenna installation as was used to receive analogue television signals. Suitable channels must be picked from the same channel group as the existing analogue services for any particular main-station site. This means that the broadcaster or network provider must use some of the channels that were not available for analogue television usage. Mvungi *et al, 2013* explained, nowadays there are four main Digital Terrestrial television Broadcasting (DTTB) standards around the world:

i. Japanese Integrated Services Digital Broadcasting-Terrestrial standard (ISDB-T),
ii. U.S. Advanced Television System Committee standard (ATSC),
iii. Chinese standard (DTMB) and
iv. European standard Digital Video Broadcasting-Terrestrial (DVB-T).

The U.S. standard was the first to be announced, and was applied mainly in North America, while the European standard that followed has prevailed among European countries. The Japanese standard was the third to be developed and standardized followed by the Chinese standard.

2.8 Digital Terrestrial Television Broadcasting (DTTB) Generations

Television broadcasting systems are divided in first and second generation systems as shown in Table 2. The first generation systems are described in recommendation ITU-R BT.1306. These systems can be divided in single carrier and multicarrier systems. All systems can be used in 6, 7 and 8 MHz channel arrangements. (ITU report, 2013)

The main distinctive features of DTTB are:

i. Single carrier standards provide a higher bit rate at given C/N in a Gaussian channel.
ii. Multi-carrier standards provide maximum ruggedness against multipath interference. This is important in case of reception with simple antennas; a means of reception commonly used in many countries. Furthermore multi-carrier standards allow the use of single frequency networks.

Recommendation ITU-R BT.1877 describes second generation television broadcasting systems. These systems offers higher data rate capacity per Hertz and better power efficiency in comparison to first generation systems. Currently, one second generation system is recommended, DVB-T2. Other second generation systems are being developed, for instance ATSC 2.0, which was expected to be completed by the end of 2012 (ITU report, 2013).

Among these standards, DVB-T plays the most important role. Since first approved in 1997, DVB-T has become the dominant terrestrial broadcasting standard in Europe and is also popular in other continents (Ming *et al*, 2013). That's because of the technology characteristics and the benefits of economy of scale. As the public demand for high-definition TV rises, the cost to adopt DVB-T falls and DVB-T offers more effective operation experience (Huang *et al*, 2012).

Table 3 shows first generation digital terrestrial television standards with their respective bandwidth requirements, modulation systems, interleaving methods, multiplexing ways, video and audio compression techniques, bitrates, whether its adopt SFN or MFN, possibility of mobile reception and the first countries to adopt that standard.

Table 2: First and Second Generation DTTB Systems

Standard	ITU recommendation	Technology	Payload in an 8MHz Channel
ATSC	Rec. BT.1306-6 System A	Single carrier	6.0-27.5 Mbit/s
DVB-T	Rec. BT.1306-6 System B	Multi-carrier (OFDM)	5.0-31.7 Mbit/s
ISDB-T	Rec. BT.1306-6 System	C Multi-carrier (segmented OFDM)	4.9-31.0 Mbit/s
DTMB	Rec. BT.1306-6 System D	Single carrier or multi-carrier (OFDM)	4.8-32.5 Mbit/s
DVB-T2	* Rec. BT.1877	Multi-carrier (OFDM	5.4-50.4 Mbit/s

* *Second generation standard.*

Source: (ITU report, 2013)

2.8.1 Digital Terrestrial Multimedia Broadcast (DTMB)

After 12 years of developing, the Chinese (DTMB) standard was finally ratified in August 2006, and began to be a mandatory national standard in August 2007. DTMB consists of single carrier modulation (C = 1) and multicarrier modulation (C = 3780) which are originated from two former proposals: the single-carrier Advanced Digital Television Broadcasting-Terrestrial (ADBT-T) and the multi-carrier DMB-T (Digital Multimedia/TV Broadcasting-Terrestrial) respectively, providing flexible combinations of working modes for different application scenarios. Because of the enormous TV market in China and the novel signal processing techniques integrated in it, the Chinese DTMB draws great interests from both industries and researchers (Ming *et al*, 2010).

It uses the Orthogonal Frequency Division Multiplexing (OFDM) transmission modulation scheme, 8 MHz analogue bandwidth and has novel signal processing techniques integrated in it (Mvungi *et al,* 2013).

2.8.2 Advanced Television Systems Committee (ATSC)

Established in 1982, the Advanced Television Systems Committee is the group that developed the ATSC digital television standard for the United States, also adopted by Canada, Mexico, and South Korea (Michael, 2008).

In the terrestrial digital television (DTV) standard of the ATSC, 8-vestigial side band (8-VSB) modulation was adopted as a modulation standard in the United States in December 1996 (Yong *et al,* 2004).

The system can deliver about 19 Mb/s in a 6-MHz terrestrial broadcasting channel and about 38 Mb/s in a 6-MHz cable television channel. This means that encoding HD video essence at 1.106 Gb/s (highest rate progressive input) or 1.244 Gb/s (highest rate interlaced picture input) requires a bit-rate reduction by about a factor of 60.3. To achieve this bit-rate reduction, the system uses complex video and audio compression technologies. These compression schemes optimize the scarce resource of the transmission channel by representing the video, audio, and data sources with as few bits as possible while preserving the level of quality required for the given application (Richer *et al,* 2006).

ATSC is for fixed transmission/reception mode. It is argued to perform better in rural areas with low population densities requiring large transmitters and resulting in large fringe areas (Mvungi *et al,* 2013).

The ATSC system is more robust in an additive white Gaussian noise (AWGN) channel, has higher spectrum efficiency, a lower peak-to-average power ratio, and is more robust against impulse noise. It also has a good performance comparable with DVB-T and ISDB-T systems on low-level ghost ensembles and is more robust against analogue TV interference (Yong *et al*, 2004).

Therefore, the ATSC system might be more advantageous for multi-frequency network (MFN) implementation as well as for providing high-definition television (HDTV) service within 6 MHz channels on fixed receivers *(*Yong *et al*, 2004).

2.8.3 Integrated Services Digital Broadcasting-Terrestrial (ISDB-T)

ISDB is the set of Japanese standards that covers terrestrial (ISDB-T), satellite (ISDB-S) and cable (ISDB-C) communication. Multiple transport streams are re-multiplexed into a single transport stream. A key feature of ISDB is hierarchical transmission. The Transport Stream (TS) packets are divided into sets of packets according to program information, into a maximum of three parallel processing sections, known as hierarchical separation. Each section performs energy dispersal, byte interleaving and convolution encoding (Michael, 2008).

ISDB-T uses H.262/Moving Picture Expert Group-2. The standard has a variant that use H.264/MPEG-4 compression standard which is known as ISTD-T International used in Latin America. It uses Band Segmented Transmission (BST) OFDM modulation scheme and frequency, time, bit and byte interleaving (Mvungi *et al* 2013).

Table 3: Four Major Digital Terrestrial Television Standards

	DVB-T	ATSC	ISDB-T	DMB-T/H
Bandwidth	6,7,8Mhz	6Mhz	6Mhz	
modulation	COFDM	8VSB	BST-OFDM	TSD-OFDM
	DQPSK/QPSK/16QAM/64QAM/MR-16QAM/MR-64QAM	8VSB	DQPSK/QPSK/16QAM/64QAM	QPSK/16QAM/64QAM
Interleaving	Frequency	Time	Frequency/Time	Frequency/time
Multiplexing	MPEG-2	MPEG-2	MPEG-2	
Video	MPEG-2	MPEG-2	MPEG-2	MPEG-2 Part2, H.264
Audio	MPEG-2	DolbyAC-3	MPEG-2	MPEG-2, DolbyAC-3
Bitrate (Mbps)	4.35~31.67	19.39	5.6Mhz:3.68~21.46 432Khz:283~1.65K	
Single Frequency Network	YES	YES	YES	single frequency network/ multi-frequency network
Mobile Reception	YES	NO	YES	YES
Adoption	countries within Europe, New Zealand, Australia, Taiwan	the U.S., Canada, Argentina, Singapore	Japan, Brazil	China, Macau, Hong Kong

Source: Huang *et al* (2012)

Since the ISDB-T system uses the same modulation and channel coding schemes as the DVB-T system, it has similar performance advantages. It is also designed to operate under large-scale SFNs and, particularly, in a mobile reception environment (Yong *et al*, 2004).

2.9 Digital Video Broadcast

The DVB-S system for digital satellite broadcasting was developed in 1993. It is a relatively straightforward system using Quadrature Phase Shift Keying (QPSK). The specification described different tools for channel coding and error protection which were later used for other delivery media systems.

The DVB-C system for digital cable networks was developed in 1994. It is centered on the use of 64 QAM, and for the European satellite and cable environment can, if needed, convey a complete satellite channel multiplex on a cable channel. The DVB-CS specification described a version which can be used for satellite master antenna television installations.

The digital terrestrial television system DVB-T was more complex because it was intended to cope with different noise and bandwidth environment and multi-path. The system has several dimensions of receiver 'agility', where the receiver is required to adapt its decoding according to signaling. (www. dvb.org/about/history)

The key element for DVB-T is the use of OFDM. OFDM is a multicarrier transmission technique with equally spaced subcarriers and overlapping spectra, which divide a data stream into several parallel bit streams. Each of the sub-channels has a much lower bit rate and is modulated onto a different carrier (Arya *et al*, 2012).

The OFDM modulation has many advantages: it is more bandwidth efficient, overcomes the effect of Inter Symbol Interference (ISI), and combats the effect of frequency selective fading and burst errors. It also has some disadvantages: it is more sensitive to carrier frequency offset, suffers in presence of phase noise, has high Peak to Average Power Ratio (PAPR) (Shankar *et al*, 2013).

The DVB-T system is currently operating within the existing 470-870 MHz Frequency Band. There are two modes of operations namely 2k mode and 8k mode. The 2k mode has been defined for DVB-T transmission and the 8k mode has been defined for Digital Video Broadcasting-Terrestrial (DVB-H) transmission. For limited distance digital video broadcasting the 2k mode is considered suitable. On the other hand, for long distance digital video broadcasting the 8K mode is preferable (Arifuzzaman *et al,* 2013).

2.10 Digital Video Broadcasting-Terrestrial Reception Measurement

Characterization of the signal quality is an aspect in which digital systems differ most from their analogue counterparts. With analogue TV signals, engineers can readily measure the transmitted or received power at the peak of the sync pulse. The average power varies depending on picture content. Methods are available for separately measuring aural and chroma carrier power levels. Nonlinear distortions are characterized by differential gain and phase, luminance nonlinearity. Linear distortions are evaluated in terms of swept response and group delay.

Knowledge on signal reception is of high importance as it enables RF designers to determine the required field strength for a reliable coverage in a specific area. There are several factors which may account to weak signal reception, such as Average Penetration Loss (APL) as a result of material used for windows, doors and other signal entrance point (Caluyo *et al*, 2011).

The landscape shape or improperly planned signal coverage can cause gaps in the signal coverage, and, therefore, some areas may be uncovered by the signal from the primary network. To improve coverage of this type of areas, the broadcasting device called a Gap Filler (GF) is used (Dvorsky *et al,* 2013).

Application of different filters on reception of digital broadcast caused by channel impairments may also be the reason to variation of quality of signal received, as research by (Arifuzzaman *et al,* 2013) shows that an elliptic filter is a good candidate for DVB signal reception under AWGN channel. The Chebyshev filter performs poor in this type of channel. The research further states that Butterworth filter shows a fair performance. The results for Rayleigh fading channel shows that the Chebyshev filter is good candidate for Rayleigh fading channel. Although an elliptic filter is the best candidate for AWGN channel condition, it performs poor under Rayleigh fading channel condition. The other observation shows that the Butterworth filter is the best candidate for Ricean channel condition and the performances of the elliptic and Chebyshev filters are almost similar.

Further, the reception of DVB-T can be assessed by either using spatial variation of signal strength or time variation of signal strength or both *(*Angueira *et al* 2013). Measurements can also be categorized as static or mobile depending on way they have been taken. In most of the digital television broadcast, coverage assessment follows to counter check the predictions models.

Recognition of measuring parameters to enhance coverage of digital television broadcast is the most important issue on evaluation of whether the predictions models developed through the use of software actually meets required on field parameters.

As indicated, transmission channels are, unfortunately, not error-free, but rather error-prone due to a lot of disturbances which can combine with the useful signal (noise, interference, echoes). However, a digital TV signal, especially when almost all its redundancy has been removed, requires a very low BER for good performance (BER of the order of 10^{-10} to10^{-12}, corresponding to 0.1–10 erroneous bits in 1 hour for a bit-rate of 30 Mb/s). A channel with such a low BER is called quasi-error-free (QEF) (Benoit, 2006).

It is therefore necessary to take preventive measures before modulation in order to allow detection and, as far as possible, correction in the receiver of most errors introduced by the physical transmission channel (Benoit, 2006).

Before the base band signal can be transmitted, it has to undergo channel coding and modulation. FEC is required which enables the receiver to correct errors that have occurred as a result of noise and other disturbances in the transmission path (Ladebusch et *al* 2006).

One way of applying preventive measure is through source and channel coding, the inner coding associated with DVB-T signal is a convolution coding and the outer coding is a Reed–Solomon code RS (204, 188, T = 8) which is a shortened version of the code RS (255, 239, T = 8) (Benoit, 2006).

Additional RF parameters have been defined and can be tracked. They include several values giving the user-added clues as to the reception capabilities of a digital television signal. As an example, a received signal can be quite strong but have one or more large notches in its spectrum. This could make decoding impossible. Therefore, in addition to measuring and recording RF field intensity levels, it is useful to track and record notches in the received spectrum, tilt across the channel and peak power within the band-pass. All these parameters are useful in characterizing DVB-T transmitted signals and in gaining confidence while delivering acceptable and receivable signals (Angueira *et al* 2013).

A number of countries have developed networks based on an SFN configuration, whereby transmitters are placed far apart. In such networks, the use of the maximum permissible guard interval together with high code rate (i.e. 3/4 or 5/6) results in a very complex impulse response with a lot of reflected rays, both natural and artificial falling on the shoulder, or outside, the guard interval (ITU report, 2012).

The situation is further complicated, due to field-strength variations at the receiving point originated by the farthest transmitters. Such variations impact on the positioning of the window in the receiver, depending on the strategy implemented by manufacturers, and sometimes one or more rays of sufficient energy fall outside the guard interval (ITU report, 2012).

A single location can be deemed to be covered if the required signal-to-noise ratio is achieved for 99 % of the time. The coverage criterion for a sub-area is also influenced by the extent to which the signal-to-noise ratio varies as a function of the location. A high probability of interference-free reception within a particular subarea results in high costs for the network operator. In an initial approach by the European Broadcasting Union (EBU), the coverage was described as good if at least 95 % of the sub-area is served for 99 % of the time and as acceptable if at least 70 % of the sub-area is served for 99 % of the time (Weck, 1996).

(Weck, 1996) further stated that signals from different transmitters in a single frequency network may arrive at the receiving location with different delays, to form a sum signal which is a function of the individual path delay differences. The signal components which are within the guard interval make a constructive contribution to the signal-to-noise ratio (C/N) or signal to- interference ratio (C/I) which can be determined in the case of COFDM simply by adding the powers of the signal components. All signal components received outside the guard interval disturb the usable signal, an effect known as the inherent interference of a single-frequency network.

The ITU has sighted type of measurements that can be carried in DVB-T and it has also recommended how those measurements should be carried on Recommendation ITU-R SM. 1682-1 of September 2011. On the Recommendation, the following parameters have been proposed as measurable: frequency and bandwidth, power and field strength, extraction of transmitter identification and determination of type of service, sound and picture quality, quality of transmitted signal, coverage, RF channel characteristics and other technical parameters.

For the sake of this research, frequency and bandwidth, power and field strength and coverage parameters will be taken into consideration as they all contribute to quality of the received DVB-T signal.

2.10.1 Power and Field Strength

As specified by ITU, power and field strength measurements are important in cases of interference. Shown in Table 4 is the recommendation ITU-R SM. 1682-1 which specifies the parameter to be measured, reasons for the measurement, measuring equipment and method.

Table 4: ITU Power and Field Strength Measurement Recommendation

Parameter	Measurement method	Reason	Rec.	Equipment
Field strength	With antennas at different heights	Determination of signal strength in "real life" situations	ITU-R SM.378 Handbook on Spectrum Monitoring (edition 2011), Chapter 4.4	Spectrum analyzer, receiver or field strength meter and a calibrated antenna

Source: Recommendation ITU-R SM.1682-1

2.10.2 Frequency and Bandwidth

The main purpose of bandwidth measurement is the verification of the bandwidth and interference in adjacent channels as shown in the Table 5.

Table 5: ITU Frequency/Bandwidth Measurement Recommendation

Parameter	Measurement method	Reason	Rec.	Equipment
Maximum spectrum	Maskmethod	Quick determination of compliance with rules and/or licence conditions	ITU-R SM.328, ITU-R SM.329, ITU-R SM.443; Handbook on Spectrum Monitoring (edition 2011), Chapter 4.12	Spectrum analyzer or receiver

Source: Recommendation ITU-R SM.1682-1

2.10.3 Coverage

Table 6 represents coverage measurement recommendation as suggested by the ITU in order to check that coverage area comply with the theoretical coverage.

Table 6: ITU Coverage Measurement Recommendation

Parameter	Measurement method	Reason	Rec.	Equipment
Field strength	With antennas on different heights, both stationary or along a route	Determination of physical signal quality in “real life” situations	ITU-R SM.1447 ITU-R SM.1875 Handbook on Spectrum Monitoring (edition 2011), Chapter 4.11	Spectrum analyzer or receiver and a calibrated antenna. Positioning devices like (D)GPS or GLONASS receiver
Field strength	With fixed antenna	Determination of signal strength fluctuations	Handbook on Spectrum Monitoring (edition 2011), Chapter 5.2	Spectrum analyzer or receiver and a calibrated antenna. Positioning devices like (D)GPS or GLONASS receiver

Source: Recommendation ITU-R SM.1682-1

2.11 Overview of the European Digital Television Market

The European Union (EU) DTV market has experienced substantially greater growth than that in the United States (US). European digital satellite television was first introduced in March 1996 in France; cable services followed shortly and DTTV was introduced in the United Kingdom (UK) in late 1998. (Christopher Marsden *et al*, 2011).

Currently DTV services, whether pay-TV or FTA, are available in all EU countries. Four DTV markets have been developed in different ways depending on migration paths from analogue television. Consequently, important divergences between EU markets can be observed. DTV take-up proved to be more successful in those countries where the majority of consumers previously only accessed analogue FTA (mainly France, UK, Italy and Spain), as compared to Germany, Austria and the Benelux, where multi-channel existed in analogue either by basic cable or by satellite. (Christopher Marsden *et al,* 2011).

Consumers' primary motive appears to be access to premium content on pay-TV whether analogue or digital, so analogue pay-TV subscribers are predictive of DTV subscribers. Even where cable or satellite is used for reception by the main television set in the house, secondary and portable sets still depend on FTA terrestrial reception. (Christopher Marsden *et al,* 2011).

EU DTV penetration at the end of 2002 was:

• Satellite 21.5 million (13.9 percent of all television households);

• Cable 8.1 million (5.2 percent); and

• DTTV 2.6 million (1.7 percent) (CEC, 2002a). (Christopher Marsden *et al* 2011)

2.12 Television adoption in Tanzania

Tanzania mainland engaged in terrestrial television transmission since 1994, when license to transmit was offered to four television stations (ITV, CTN, DTV and Abood) using analogue terrestrial broadcasting networks. As shown in Table 7, number of television stations increased to 28 in 2012, on which 23 were FTA and 5 Pay Television stations. DVB-C transmission was provided through 8 cable service providers by 2012 (TCRA, 2013).

Table 7: Number of TV Stations in Tanzania

	2005	2006	2007	2008	2009	2010	2011	2012
FTA	11	21	21	21	22	23	23	23
Pay TV	0	1	3	4	5	5	5	5
Total	11	22	24	25	27	28	28	28
Terrestrial	11	21	21	21	22	23	23	23
Cable	1	1	2	2	3	6	7	8

Source: (TCRA, 2013)

Digital broadcasting was introduced in 2010. The introduction of digital terrestrial TV broadcasting follows ITU agreement to do away with analogue TV broadcasting transmitters worldwide by 17th June 2015. However, East African countries agreed to switch off earlier on the 31st December, 2012 to minimize dual illumination costs and to develop enough experience to manage its challenges before the worldwide switch-off deadline (TCRA, 2013).

Although some of East African countries had further decided to postpone the switch off date, Tanzania continues with a phase switch off of analogue transmission and shifting to digital transmission. Government through the Ministry of Communication Science and Technology endorsed and announced the phased plan of switching off the analogue TV Transmitters in phases in September 2012. The service areas involved were Dar Es Salaam, Tanga, Mwanza, Dodoma, Mbeya, Arusha and Moshi. The phases were as follows: Phase IA 31st December 2012 ASO was done in Dar es Salaam, phase IB 31st January 2013 was done in Dodoma and Tanga, phase IC 28th February 2013 was done in Mwanza, phase ID 31st March 2013 was done in Arusha and Moshi and finally phase IE 30th April 2013 was done in Mbeya (TCRA, 2013).

The Analogue switch off has been characterized with licensing Multiplexing companies to bridge between content service providers (television stations) with the end users (viewers). Star Media (T) Limited, Agape Associates Limited (AAL) and Basic Transmissions Limited (BTL) were the first three Multiplexing companies to be offered license to provide Digital terrestrial television (DTT) multiplexing, signal distribution and transmission services (TCRA, 2012). Azam Television and Sahara Media are the latest multiplexers to be licensed by the TCRA.

Currently, some of the multiplexers in certain Tanzania's regions have switched from DVB-T1 to Digital Video Broadcasting Terrestrial second generation (DVB-T2) in 2013. Data provided by TCRA, shows Arusha is one of those regions (Kibona L *et al*, 2014).

2.13 Conclusion

Chapter two has reviewed the literature on different digital television standards, DTTB generations, the key holders of DVB-T system, general VHF/UHF transmission theory, transmitter service area and coverage, transmission medium and DVB-T reception measurements. It has also provided overview of the European digital television market as well as television adoption in Tanzania

CHAPTER THREE

METHODOLOGY

3.0 Research Design

The research design adopted is the experimental-case study**.** The proposed study work was mainly focused on finding out the indoor and outdoor received field strength of the DVB-T as provided by three MUXs, Basic Transmission Limited, Startimes and Agape. Measurements were done in selected five different areas of Arusha through the use of Instek spectrum analyzer, Global Positioning System (GPS) receiver, indoor omni-directional, folded dipole and open dipole antenna provided when buying STB or DTV, Yagi antenna was used to asses outdoor signal strength. The other part of the research includes observation of customer's perception on quality of the DVB-T signal. This was captured through the use of guided interview.

3.1 Research Method

For the sake of this report on which practically measured data and data obtained through the use of guided interview in a questionnaire are sought, a mixture of quantitative and qualitative approaches was used.

3.2 Data Collection and Instruments

The research was conducted to cover two scenarios, first static spatial variation of the field strength of each MUXs was measured through the use of spectrum analyzer and antennas. Yagi antenna was used for outdoor measurement whereas omnidirectional antenna, folded dipole and open dipole antenna were used to measure indoor signal strength. The spectrum analyzer was set to receive signal in a range of 470 MHz-780 MHz which falls within all Multiplexers operating frequencies in Arusha given by TCRA as shown in the appendix A. Due to variation of DVB-T signal strength, a reference of -10 dBm was used at places where signal is strong and it was lowered to -30 dBm on weak receiving areas. Secondly, customers perception on quality of signal received was measured through the use of guided interview.

3.2.1 Yagi Antenna

Five directors and one reflector were coupled with an open dipole to form seven element Yagi antenna represented in figure 1. In all measurements to be shown later, Yagi antenna was rotated horizontally in 8 positions at the displacement of 45° relative increment, starting with 0°/360° which is being referred to North, 45° North-East, 90° East, 135° South-East, 180° South, 225° South-West, 270° West and 315° North West. Elevation of 5 meters for outdoor measurements was fixed. On each of the measurement the received power were taken under reference of -10 dBm in areas where received signals were strong enough to be displayed on spectrum analyzer screen, reference point was lowered to -30 dBm in places with weaker received signals.

3.2.2 Folded Dipole Antenna

Shown on figure 2 is a folded dipole antenna, the antenna was rotated in four directions as it has capacity of receiving signal equally from any of two directions it points at a time. 0°/180° North/South direction, 90°/270° East/West direction, 45°/225° North-East/South-West direction and 135°/315° North-West/South-East direction were the sides on which Television signal strength was measured from, the received signal strength was then read through the Spectrum analyzer and captured on a laptop which was linked with the analyzer.

Figure 1: Yagi Antenna

Figure 2: Folded Dipole Antenna

3.2.3 Open dipole

As with the folded dipole, open dipole antenna was rotated in four directions horizontally. In each direction the measurement were captured through spectrum analyzer and recorded in a laptop.

Figure 3: Open Dipole Antenna

3.2.4 Omnidirectional Antenna

This antenna had one vertical measured position, as it is assumed to receive signal strength generated from all direction equally.

3.4.5 Spectrum analyzer

A GSP 830 Instek Spectrum analyzer shown in figure 4, has up to 3GHz frequency range, and as low as -172 dBm/Hertz noise floor was used to read the strength of the DVB-T signal received.

Figure 4: Instek GSP 830 Spectrum Analyzer

3.3 Study Area

Arusha city was selected to be an area of interest to this research due to number of factors. First, Arusha is the working place of the researcher and he has an unlimited access to measuring equipment from his office. Secondly, referring to research conducted by TCRA (2013) as shown in Table 8 , based on number of set boxes bought, Arusha is the second region to have many customers subscribed to digital video broadcasting terrestrial and hence makes it a right place to conduct research.

Table 8: Number of Set Top Boxes Sold

S/No	Service Area	Number of Set Top Box Sold as per ASO date		
		Star Media	Agape Associates Ltd	Basic Transmission LTD
1	Dar es salaam	300,000	10,000	None
2	Dodoma Town	20,000	100	None
3	Tanga City	12,000	70	None
4	Mwanza City	35,000	150	None
5	Moshi Town	14391	40	None
6	Arusha City	45,000	100	None
7	Mbeya City	14,000	40	None
8	Total	440,391	10,500	Non

Source: TCRA, 2013

3.4 Study Population and Sample

The study population included all people who were receiving Digital Video Broadcast via terrestrial method. The study sample was created by dividing Arusha city in five major groups depending of the location. In each location, a systematic sampling method was used to get at most 12 people who will then be interviewed. Whenever possible, among those 12 people to be interviewed, a proportionate inclusive sample based on different multiplexer was considered. Hence at the end of the research, expectation was to interview at least 60 people.

Most important aspect of inclusion in systematic sampling as was done on this research, was to have a diversity of MUXs users.

3.5 Conclusion

Chapter three introduces the way on which the research was conducted. Type of research design, research method, data collection and instruments were all specified and discussed. Further, the study area together with study population and sample were brief reviewed.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.0 Introduction

In this chapter, the questionnaire empirical data and field measured data will be analyzed, starting with data obtained from actual measurements in five areas of Arusha town. Measurements presented and discussed here have been taken in Arusha City centre, Moshono, Ngaramtoni, Kisongo and Usa River.

Data provided by TCRA shows channel 22 in UHF band IV, channels 45 and 55 in UHF band V were used to transmit signal by Basic Transmission Limited which hosts Digitek and Continental decoders. Channel 28 and 34 in UHF band IV and channel 42 in UHF band V were used by Agape Associates Limited which host TING decoder, whereas channel 38, 40, 44, 46 and 50 in UHF band V were used to transmit Star Media Limited (startimes decoders) DVB-T signal. Each of the channels had a bandwidth of 8 MHz. Henceforth in this analysis the channels will be mostly referred by their channels numbers.

Data provided by TCRA as the research measurement was already taken, has also shown that currently, all the MUXs have been asked to transmit signal using the DVB-T second generation system in Arusha, as it is much more robust and power effective as compared to DVB-T first generation. Therefore as discussion will be carried the signal strength minimum threshold of -85 dBm will be referred as the cut-off point for proper reception of the DVB-T signal.

Data were collected in each of the researched area by the use of four antennas and spectrum analyzer. For analysis on this research, maximum signal strength received by the antenna and direction of reception of that signal with respect to each antenna has been presented on Tables. Furthermore, the mean value of signal strength for each television station in a specific area was established by averaging the maximum received signal strength of all antennas with respect to that channel on that area.

4.1 Arusha City Centre Data

Power measurement exercise for Arusha city centre was taken at Arusha Technical College, indoor and outdoor measurements were taken as shown on the appendix E and represented on tables . As compared to other measurements locations, it was seen signal received in city centre were much stronger and hence a reference of -10 dBm set on spectrum analyzer was enough to allow DVB-T2 signal reception.

4.1.1 Folded Dipole Antenna

The observation of the measured data through the use of folded dipole revealed unavailability of channel numbers 28, 42 and 55. Other channels and their maximum signal strength received and direction of that reception are as shown in the Table 9.

Channel 38 had the strongest signal of all channels and it can be argued that best practice would have been to position the antenna on North-West/South-East direction for reception of most of the DVB-T second generation channels using folded dipole antenna at city centre.

The signals at city centre as shown on the table would have been excellent received using a folded dipole antenna, as signal strength for all channels is above -85 dBm, which is minimum threshold for DVB-T second generation as set by TCRA.

Table 9: Maximum Signal Strength Received at Arusha Town Using Folded Dipole Antenna

NO	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-62.1	North-East/South-West
2	34	-64.2	East-West
3	38	-55	North-South
4	40	-57.7	North-West/South-East
5	44	-60	North-West/South-East
6	45	-59	North-West/South-East
7	46	-57.4	North-South
8	50	-59.1	North-West/South-East

4.1.2 Open Dipole Antenna

Channel 28, 42 and 55 were again not available when using an open dipole antenna. Table 10 shows maximum signal strength received for each of the available channel and its respective antenna direction. The same as was with the folded dipole antenna, all channels here can correctly be received using an indoor open dipole antenna.

Channel 38 was also the strongest signal receiving channel in an open dipole setting in North-South direction. North-West/South-East dominates again as the direction on which reception of most of the maximum signal strength was found. Overall best practice would have been to direct antenna on North-West/ South- East direction.

Table 10: Maximum Signal Strength Received at Arusha Town Using Open Dipole Antenna

NO	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-62.2	North-East/South-West
2	34	-64.7	North-East/South-West
3	38	-54.1	North-South
4	40	-59.2	North-South
5	44	-57.9	North-West/South-East
6	45	-56.7	North-West/South-East
7	46	-60	North-South
8	50	-60.8	North-West/South-East

4.1.3 Omnidirectional Antenna

Unavailability of channels 28, 42 and 55 were also observed when using an omnidirectional antenna. Shown in Table 11 are the maximum DVB-T second generation signal strength received using an omnidirectional antenna.

Table 11: Maximum Signal Strength Received at Arusha Town Using Omnidirectional Antenna

NO	Channel	Maximum Power Received (dBm)
1	22	-66.3
2	34	-63.4
3	38	-59.9
4	40	-61.6
5	44	-60.5
6	45	-54.7
7	46	-60.9
8	50	-59.9

As shown in Table 11, channel 45 had the best performance in terms of strength of the received DVB-T signal. Here as well, an omnidirection antenna could have been used to receive DVB-T signals of all channels without any problem.

4.1.4 Yagi Antenna

Yagi was the only antenna used for outdoor measurement, as with other antennas, channel 28, 42 and 55 were also unavailable. Though not uniformly, the use of Yagi antenna has improved reception of some channels.

Table 12:Maximum Signal Strength Received at Arusha Town Using Yagi Antenna

Number	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-64.3	East
2	34	-64.2	North-West
3	38	-53.1	North
4	40	-55	South-East
5	44	-59.3	South-East
6	45	-53.4	South-East
7	46	-58.2	North
8	50	-61.8	West

Channel 38 in North side setting performed better with the Yagi antenna as compared to other channels. Best practice is to direct the antenna on South-East direction for reception of most channels.

Shown in figure 5, overall performance in Arusha city center when maximum received signals were considered shows that Starmedia had the best coverage through channels 38 which had the mean of -55.525 dBm, channel 40 with mean value of -58.375 dBm, channel 44 with mean of -59.425 dBm, channel 46 with mean of -59.125 dBm, channel 50 with -60.4 dBm. Digitek has the second best performance with its channel 45 having the mean of -59.125 dBm received signal strength. Continental mean signal strength was -63.725 dBm and Agape had the weakest signal with the mean strength of -64.125 dBm.

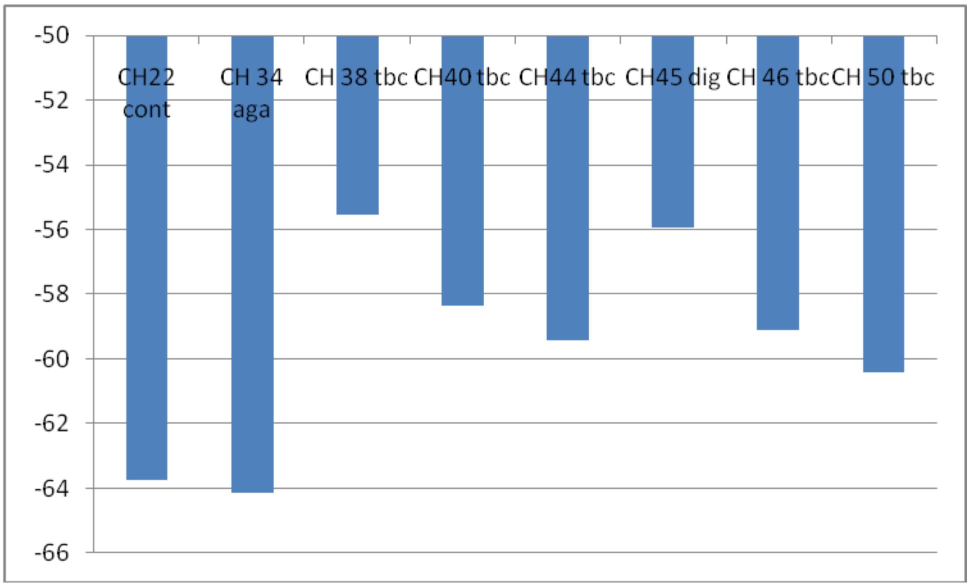

Figure 5: Mean Signal Strength Per All Antennas at Arusha City Centre

4.2 NGARAMTONI

Ngaramtoni was one of the places where signal reception was not good generally. The spectrum analyzer was unable to distinguish between noises and DVB-T signal at -10 dBm and hence reference was set at -30 dBm. Even though the spectrum analyzer was at least capable to capture DVB-T signal at -30 dBm, still that power was so low as it was highly affected with noises as shown on the tables. A number of signals with peak amplitude in DVB-T ranges were detected and read on spectrum analyzer over that area, but the researcher had to stick to the frequency ranges of channels as allocated to MUXs by the TCRA and ignore other signals. Channel 55 was seen to have strong signal here and hence it was included on the analysis, though other channels such as channel 28 were seen to have high amplitude closer to them, but not within the ranges and hence they were considered not to be available.

4.2.1 Folded Dipole Antenna

General reception of DVB-T signal was not good, power levels as weak as-88 dBm were received. Channels 28 and 42 were not available. As shown in Table 13, channel 22 had the strongest signal of all in North-West/South-East direction.

As per operational standards of TCRA DVB-T, channels Continental channel 22, Agape channel 34, TBC channels 38, 40 and 46, together with Continental channel 45 have strong signals to be seen on this area using an indoor folded dipole antenna.

The North-West/South-East direction had more reception of DVB-T channels than the other sides and hence, best practice would have been to rotate antenna towards that direction.

Table 13: Maximum Signal Strength Received at Ngaramtoni Using Folded Dipole Antenna

NO	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-67.6	East/West
2	34	-78.9	North-East/South-West
3	38	-84.6	East/West
4	40	-84.6	North-West/South-East
5	44	-88	North-West/South-East
6	45	-83.6	North-West/South-East
7	46	-83.7	North-West/South-East
8	50	-88	North
9	55	-85.4	North-East/South-West

4.2.2 Open Dipole Antenna

Table 14 shows that the North-West/South-East direction had the best overall performance as the side to direct the antenna, with the channel 22 being the strongest signal received channel**.** Continental channel 22, Agape 34, TBC 38, 40 and 46, Digitek 45 and 55 were all above minimum signal strength threshold and hence they were within the watchable range at Ngaramtoni if an indoor open dipole antenna is used.

Table 14: Maximum Signal Strength Received at Ngaramtoni Using Open Dipole Antenna

NO	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-67.5	North-East/South-West
2	34	-79.4	North-West/South-East
3	38	-83.2	North/South
4	40	-84.2	North-West/South-East
5	44	-85.1	East/West
6	45	-83.3	North/South
7	46	-84.3	North-West/South-East
8	50	-88	North
9	55	-84.7	North-West/South-East

4.2.3 Omnidirectional Antenna

Shown in Table 15, strength of channel 22 was a bit lowered when using an omnidirectional antenna, though it stays strong as compared to others. Using an omnidirectional antenna at Ngaramtoni would have given customers possibility of watching only Continental channel 22, Agape channels 34 and BTL channel 55 which were within the required rang as specified by TCRA.

Table 15: Maximum Signal Strength Received at Ngaramtoni Using Omnidirectional Antenna

Number	Channel	Maximum Power Received (dBm)
1	22	-73.4
2	34	-74.4
3	38	-86
4	40	-87
5	44	-86
6	45	-86
7	46	-86
8	50	-86
9	55	-82.8

4.2.4 Yagi Antenna

As an outdoor antenna, Yagi had some improvements in the strength of the received signal, though it was not a considerable improvement. Shown in the Table 16, channel 22 had maximum of signal strength received as compared to all other channels and better than in any other antenna. Continental channel 22, TBC channels 38, 40, 44 were all above the minimum threshold when Yagi antenna was used.

Table 16: Maximum Signal Strength Received at Ngaramtoni Using Yagi Antenna

Number	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-61.7	North-West
2	34	-88	North-West
3	38	-84.3	South-East
4	40	-85.1	North/South
5	44	-83.5	North/South
6	45	-84.7	North-West
7	46	-87.6	North
8	50	-87.9	West
9	55	-88	North

General observation by taking the mean value of the maximum signal strength received in Ngaramtoni as shown in Figure 6, shows that Continental channel 22, was consistently performing above the TCRA given levels with mean value of -67.55 dBm. Agape channel 34 had the second overall performance with the mean power received level of -80.175 dBm Digitek channel 45 had the mean power of -84.4 dBm while TBC channel 38 mean signal strength was -84.525 dBm which is within the accepted level in a DVB-T second generation technology used. Other channels were below the required levels as set by TCRA and hence watching them was difficult on that area.

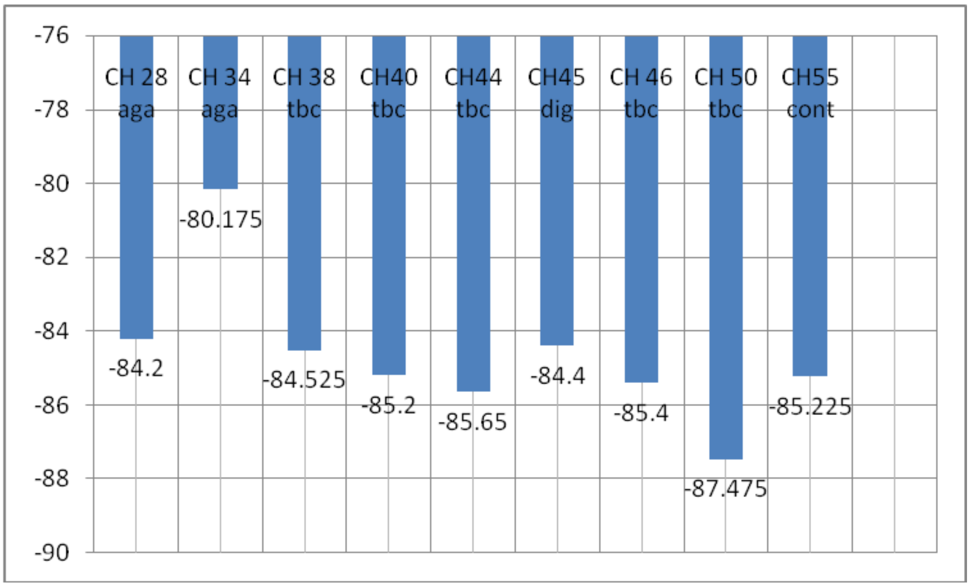

Figure 6: Mean Signal Strength Per All Antennas at Ngaramtoni

4.3 MOSHONO

Moshono was one of the places with weak received DVB-T signal, the spectrum analyzer was pushed to set a reference of -30 dBm for the DVB-T signal to be displayed on the screen.

4.3.1 Folded Dipole Antenna

The performance of folded dipole is as shown in Table 17. Best performance was found to be on channel 22. Continental channel 22, Agape channel 34, TBC channels 38, 40, 44 and Digitek channel 45 were all within the required standard of DVB-T second generation signal reception and hence they were receivable using indoor folded dipole antenna at Moshono Area.

Table 17: Maximum Signal Strength Received at Moshono Using Folded Dipole Antenna

NO	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-79	North-West/South-East
2	34	-82.9	North/South
3	38	-83.3	North-West/South-East
4	40	-83.8	North-East/South-West
5	44	-82.6	North/South
6	45	-82.9	North-East/South-West
7	46	-85.1	North-East/South-West
8	50	-85.1	East/West
9	55	-88	North/South

4.3.2 Open Dipole Antenna

Table 18 shows DVB-T signal strength received, North-West/South-East direction received most of good strength signals and channel 22 continues to have the strongest signal. Continental channel 22, Agape channel 34, TBC channels 38, 40, 44, 46 and digitek channel 45 were all above the DVB-T second generation minimum receivable threshold and hence they were receivable using an open dipole antenna at Moshono area.

Table 18: Maximum Signal Strength Received at Moshono Using Open Dipole Antenna

NO	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-79.8	North-West/South-East
2	34	-81	North-West/South-East
3	38	-82.3	East-West
4	40	-81.8	East-West
5	44	-82	North/South
6	45	-80	North-West/South-East
7	46	-83	North/South
8	50	-85.4	East/West
9	55	-86.4	North/South

4.3.3 Omnidirectional Antenna

The performance of omnidirectional antenna at Moshono was unique, as all channels were within the receivable range of DVB-T2 signal of -35 dBm to -85 dBm. This means all channels can be received using an indoor omnidirectional antenna .

Table 19: Maximum Signal Strength Received at Moshono Using Omnidirectional Antenna

Number	Channel	Maximum Power Received (dBm)
1	22	-82.5
2	34	-81.9
3	38	-84
4	40	-84.5
5	44	-84
6	45	-84.1
7	46	-84.5
8	50	-84
9	55	-82.8

4.3.4 Yagi Antenna

DVB-T signal strength received was considerably increased when Yagi antenna was used, channel 45 being the strongest followed with channels 22 and 38. The North-East direction being the good side for antenna positioning. As shown in Table 20, by some factor, Agape channel 22, TBC channels 38, 40, 44, 46 and 50 were all having their best performance in Yagi as compared to other antennas, the same to Digitek channel 45.

Table 20: Maximum Signal Strength Received at Moshono Using Yagi Antenna

Number	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-75.6	North
2	34	-87.5	North
3	38	-75.6	North-East
4	40	-80	North-East
5	44	-79.3	North-East
6	45	-75.3	North-East
7	46	-79.9	North-East
8	50	-77.3	West
9	55	-88	North

Referring to Figure 7, Continental channel 22 had the best mean maximum signal level of -79.225 dBm at Moshono, Digitek channel 45 had the second best mean value of -80.575 dBm which allows reception of both signal. Further, as it can be observed in Figure 7, also all other channels had their mean maximum DVB-T second generation signal strength within the allowed range as given by TCRA with exception of Digitek channel 55.

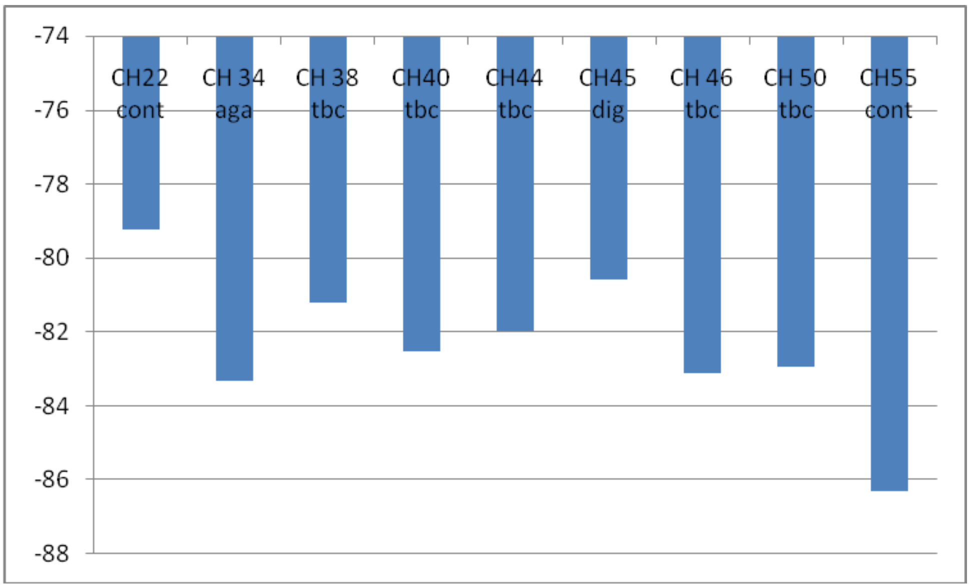

Figure 7: Mean Signal Strength Per All Antennas at Moshono

4.4 KISONGO

DVB-T signal reception in Kisongo was not as good as in Arusha town, but it had good reception compared to other measured areas. At -10 dBm on Spectrum analyzer, the signals were hardly received and hence the reference point was also set at -30 dBm.

4.4.1 Folded Dipole Antenna

North-East/South-West direction received most of the strongest signal using folded dipole antenna at Kisongo. Channel 22 was received with the strongest signal of all other channels.

Table 21 shows that Continental channel 22, Agape channel 34, TBC channels 40, 44, 46 and 50 as well Digitek channel 55 were all having DVB-T2 signal within the required range.

Table 21: Maximum Signal Strength Received at Kisongo Using Folded Dipole Antenna

NO	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-69.7	North-East/South-West
2	34	-75.5	North-East/South-West
3	38	-87	North-East/South-West
4	40	-84	North-East/South-West
5	44	-84.2	North-West/South-East
6	45	-83.4	North-West/South-East
7	46	-80.7	East/West
8	50	-81.2	North-West/South-East
9	55	-81.4	East/West

4.4.2 Open Dipole Antenna

Table 22 shows little variations on reception of DVB-T signals from what was observed on folded dipole. In this type of antenna all Television stations were within the acceptable range of operation as far as DVB-T second generation signal reception is considered.

Table 22: Maximum Signal Strength Received at Kisongo Using Open Dipole Antenna

NO	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-69.9	North/South
2	34	-73.6	North-East/South-West
3	38	-84.2	North/South
4	40	-85.1	North-East/South-West
5	44	-86	North/South
6	45	-82.7	North/South
7	46	-83.9	North-West/South-East
8	50	-83.6	North-East/South-West
9	55	-82.2	North-East/South-West

4.4.3 Omnidirection Antenna

Table 23 shows channels 34 and 55 performed well on received signal strength, channel 22 signal strength has gone down as compared to other antenna systems. The general reception shows all channels with exception of TBC channel 38, were having signals much stronger than the minimum threshold set by TCRA and hence they could have been received using an omnidirectional antenna.

Table 23: Maximum Signal Strength Received at Kisongo Using Omnidirectional Antenna

Number	Channel	Maximum Power Received (dBm)
1	22	-78.8
2	34	-72.5
3	38	-86.6
4	40	-79
5	44	-84.7
6	45	-80
7	46	-84.5
8	50	-84.1
9	55	-72.9

4.4.4 Yagi Antenna

Overall strength of the received signal almost to all channels was increased with the use of Yagi antenna as shown in Table 24. North-West side received most of the strong DVB-T channels. The use of an outdoor Yagi antenna has made all television stations to have their signals above the minimum threshold of -85dBm used for reception of DVB-T second generation signals.

Table 24: Maximum Signal Strength Received at Kisongo Using Yagi Antenna

NO	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-67.1	North-West
2	34	-80.5	North
3	38	-83.4	North-West
4	40	-80.9	North-West
5	44	-81.7	North-West
6	45	-71.8	North-West
7	46	-70.9	North-West
8	50	-82.8	North-West
9	55	-71.4	North-West

In Kisongo area, Continental channel 22 performs best with mean maximum DVB-T signal strength of -71.375 dBm followed with Agape channel 34 which had a mean value of -75.525 dBm. Continental channel 55 came third with mean value of -76.975 dBm followed by Digitek channel 45 and TBC channel 46 which were all in operable range of DVB-T second generation signal. As shown in the Figure 8, with exception of TBC channel 38 which is slight out of the allowed range, all channels were receivable.

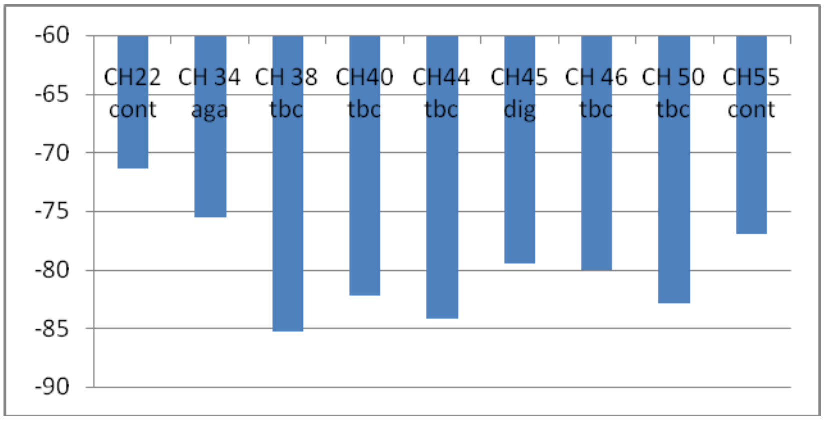

Figure 8: Mean Signal Strength Per All Antennas at Kisongo

4.5 USA RIVER

In general signal reception was weak at Usa River with -10 dBm reference point on spectrum analyzer and hence, as with Moshono, Ngaramtoni and Kisongo, the spectrum analyzer amplitude reference point was set at -30 dBm.

4.5.1 Folded Dipole Antenna

Table 25 shows that all channels with exception of BTL channel 55 and TBC channel 44 were within the operable DVB-T second generation range as set by TCRA, and hence an indoor folded dipole could have been used to receive those channels without any problem. North-West side of Usa River being the strongest receiver of the DVB-T signal.

Table 25: Maximum Signal Strength Received at Usa River Using Folded Dipole Antenna

NO	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-77.3	North-West/South-East
2	28	-80.1	North-East/South-West
3	34	-80.1	North-West/South-East
4	38	-84.1	North-West/South-East
5	40	-84.1	North-West/South-East
6	44	-85.9	North-West/South-East
7	45	-84.5	North/South
8	46	-83.6	North-West/South-East
9	50	-86	North-West/South-East
10	55	-84.1	North/ South

4.5.2 Open Dipole Antenna

Table 26 shows that channel 34 had the strongest signal in North- West /South- East. Continental channel 22, Agape Channels 28 and 34 and TBC channel 46 were the only channels having DVB-T2 signal above minimum, and hence it was difficult to receive other channels at Usa River which had signal strength below minimum threshold using an open dipole antenna.

Table 26: Maximum Signal Strength Received at Usa River Using Open Dipole Antenna

NO	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-80.1	North/South
2	28	-78.8	East/West
3	34	-75	North- West /South- East
4	38	-87.2	North/South
5	40	-85.1	North-East/South-West
6	44	-86	North/South
7	45	-85.9	North/South
8	46	-83.9	North-West/South-East
9	50	-86.9	North-East/South-West
10	55	-86.1	North-East/South-West

4.5.3 Omnidirectional Antenna

Table 27 shows signal received using an omnidirection antenna, the overall strength of the signal was quite weak as Agape channel 34, which is considered to have high power received here, has had only -83.5 dBm. Other channels which could have been received using omnidirectional antenna are TBC channels 46 and 50. Other channels had their signal strength below the minimum threshold set.

4.5.4 Yagi Antenna

Table 28 shows a slight improvement on overall signal strength received to almost all channels. North-West dominates as the side of that strong signal reception.

Except for TBC channel 50 and Digitek channel 55, all channels had their signal above the TCRA threshold of -85 dBm and hence they were receivable using an outdoor Yagi antenna.

Table 27: Maximum Signal Strength Received at Usa River Using Omnidirection Antenna

Number	Channel	Maximum Power Received (dBm)
1	22	-86.8
2	28	-86.9
3	34	-83.5
4	38	-87.1
5	40	-86.9
6	44	-87.2
7	45	-87.6
8	46	-85
9	50	-84.1
10	55	-86.1

Table 28: Maximum Signal Strength Received at Usa River Using Yagi Antenna

NO	Channel	Maximum Power Received (dBm)	Antenna Direction
1	22	-79.5	North-West
2	28	-80.6	North-West
3	34	-82.3	North-West
4	38	-83.8	North-West
5	40	-82.3	West
6	44	-83.3	North-West
7	45	-80.2	North-West
8	46	-80.4	North-West
9	50	-86.8	West
10	55	-88	North-West

The mean values of DVB-T second generation signal strength at Usa River shown in Figure 9 reveals that, Continental channel 22 had the mean value of -80.925 dBm, Agape channel 34 had mean of -80.225 dBm, Agape channel 28 with the mean of -81.6 dBm, TBC channels 40 and 46 with mean values of -84.6 dBm and -83.225 dBm respectively and Digitek channel 45 with the mean of -84.55 dBm. Other television stations were below the required threshold.

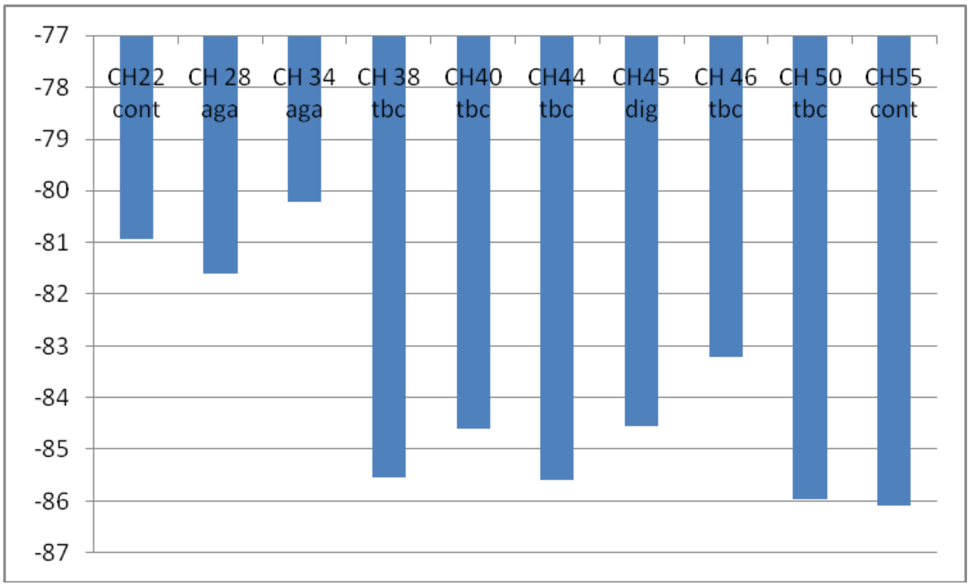

Figure 9: Mean Signal Strength Per All Antennas at Usa River

4.6 Customers Perception On Quality of Received DVB-T Signal Strength

Through the use of guided interview shown on appendix D, a total of 59 customers were interviewed. Among them 32 were using Starmedia decoders, 9 were using Basic Transmission Limited/Continental decoders, 12 were using Basic Transmission Limited/Digitek decoders and 6 were using Agape Associates decoders (TING).

Figure 10 shows over 44 percent of the interviewed Continental's decoder customers had perception that signal reception was excellent, whereas other 22 percent viewed the reception as very good, the same percentage to those who said it was good reception.

11 percent said the reception was satisfactory referring to number of times when the station was not available, with none viewed it as not good.

The same figure has shown that almost 44% of the TBC customers viewed the reception as excellent, 12% viewed it as very good, 22% had a view that it was good, 15% viewed it as satisfactory and the other 9% said it was not good reception.

Figure 10 further shows that 67% of Digitek customers had an excellent signal reception perception, 16% said it was very good and good reception per each group respectively and neither saying it was the satisfactory nor not good reception.

16% of Agape viewers said the quality of received signal strength was excellent, 67% viewed it as very good and 16% said it was good. None viewed it as either satisfactory or not good reception.

An indoor to outdoor antenna setting was also used as a means to establish quality of the received signal. A channel which had many customers with indoor antenna setting was considered to have strong signal strength received on that area. The results are shown on pie chat Figure 11.

On which it shows that 53% of TBC customers were using indoor antenna setting and the other 46% using outdoor antenna setting, 33% of agape viewers were using indoor antenna and 66% using outdoor antenna configuration. It also shows that 66% of continental viewers were using indoor antennas with 33% others using outdoor antennas, whereas 75% of Digitek customers were having an indoor antenna setting and only 25% of them were using outdoor antennas.

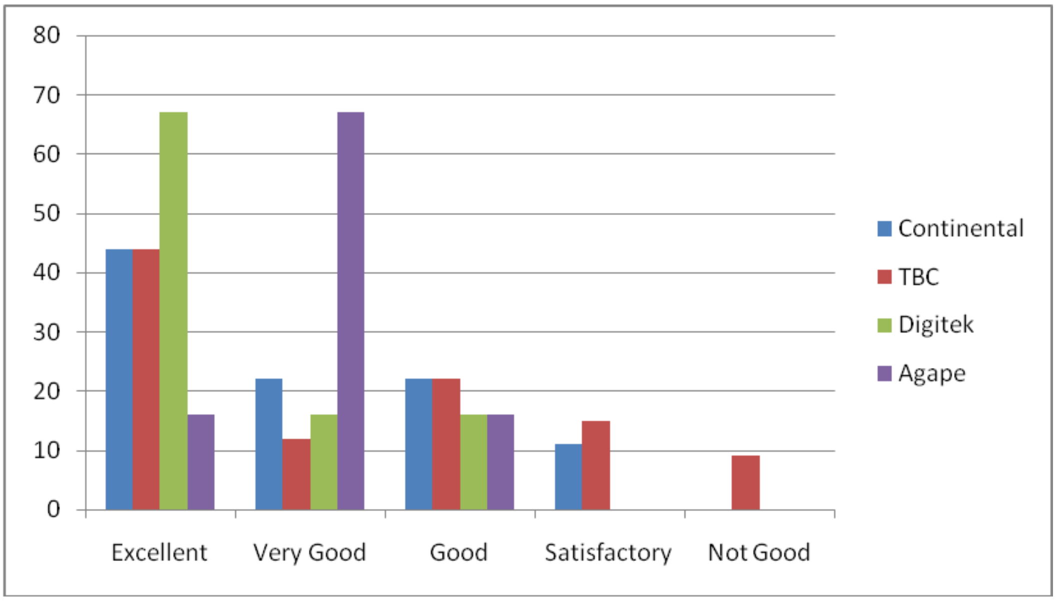

Figure 10: Percentage of Customers Perception on Quality of Received DVB-T Signal Strength

Data shown on Figure 11 reveals that, when antenna configuration is used to compare quality of received DVB-T signal strength, then Digitek came first with other BTL ally continental being second followed by Starmedia and Agape associates

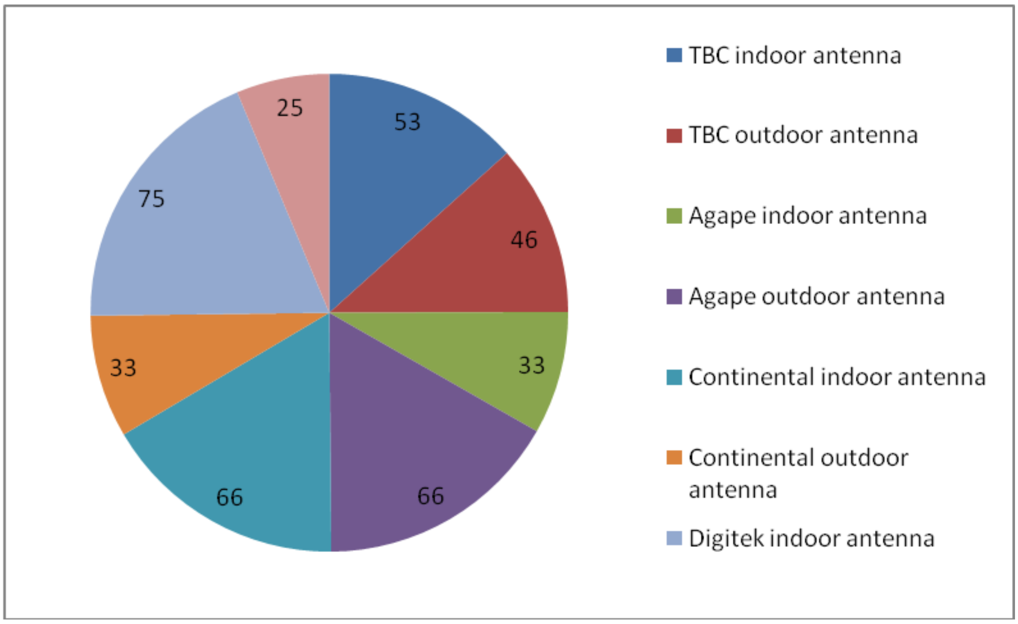

Figure 11: Percentage Indoor To Outdoor Antenna Setting

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

It has been shown in the research that, the coverage of DVB-T is still not uniform in the whole Arusha town. Multiplexers have concentrated the directivity of their transmitting antennas toward city centers where reception in terms of signal strength is good and leaving peripheral areas scrambling for the signal.

The study has shown the overall signal reception in Arusha city centre ranges between -53.1 dBm and -66 dBm, which is within the range provided by TCRA of -35 dBm to -85 dBm suitable for reception of DVB-T signal. The operating range of 53.1 dBm and -66 dBm shows there were no problem on receiving Continental channel 22, Agape channel 34, StarMedia channels 38, 40, 44, 46 50 and Digitek channel 45, and at the city centre, the other three channels were not found on that range. Strong signal received did not necessitate the use of an outdoor antenna, as even with the mostly used antenna, an indoor omnidirectional antenna, the received signal falls on the range between -54.9 dBm and -67.2 dBm.

The study also shows signal reception in Ngaramtoni was not acceptable as only Continental channel 22, Agape channel 34, Digitek channel 45 and TBC channel 38 had DVB-T signal levels satisfying the standards given by TCRA. Other channels were all out of range as they were below -85 dBm. Channel 55 was showing to have strong signals in Ngaramtoni than in Arusha city centre, but for most of the time they were still unable to match the required TCRA levels.

Research shows using indoors folded antenna dipole at Moshono would allow reception of all channels with exception of channel 56, 50 and 55 which were outside the accepted TCRA signal ranges. An omnidirectional antenna would receive all signals correctly. An outdoor Yagi antenna at height of 5 meters made channel continental 22, Starmedia channels 38, 44, 46 and 50 to be within the allowed reception range, channel 34 and 55 had weak signal reception. The North- East direction is the proper direction for Yagi antenna reception of DVB-T signals.

The study shows that in Kisongo, channels 22 and 34 were having a consistent good signal reception as referred to TCRA levels. Using an omnidirectional antenna, Continental channel 22, Agape channel 34, Starmedia channels 40, Digitek channel 45 and 55 were within the required levels, Yagi antenna improves omnidirectional antenna performance by including channel Starmedia channel 46 to be within the range.

Further, the study reveals that in Usa river channels Continental channel 22, Agape channels 28 and 34 were within required operating range when the signals are received by either an open or folded dipole. None of the channel was within the operating range when omnidirection antenna was used. There was slight improvement with the use of Yagi antenna.

Overall, it was seen DVB-T signal strength were very strong at the city centre. Almost all antennas were performing above the required standards. Performance of antenna in other areas varied from point to point with exception of Yagi antenna which had good overall performance in almost all areas.

Most of the DVB-T users were located in city centre, Starmedia were having a majority of them. Assessment on customers on their views as quality of DVB-T signal is concerned, shows that 88% of Continental customers, almost all of the Digitek and Agape customers and 78% of TBC customers were satisfied with the signal reception as offered by their Multiplexer.

When the quality of DVB-T signal reception is assessed through location of an antenna, whether it's indoor or outdoor, then Digitek holds the lead with 75% of its customers using indoors antenna, 66% of Continental users, 53% of TBC customers and 33% of the Agape customers.

5.2 Recommendations

The study has shown that the general reception of DVB-T signal in areas out of Arusha city centre is not good. Hence it first recommends to DVB-T users, to use outdoor Yagi antennas to those areas on which the reception is below the required standards of -33 dBm to 81 dBm for DVB-T1 and -35 dBm to -85 dBm for DVB-T2 standards. The direction on which those antennas have to be directed has been shown on this report with reference to a specific residential area.

Second, to Multiplexers, the study recommends establishment of new towers to cover peripheral areas such as Ngaramtoni, Usa river and Kisongo which have systematical below standard level reception and some of the city centre areas which requires towers to be used as filler gaps to serve low altitude areas.

5.3 Suggestion for Further Studies

Even though the quality of DVB-T signal is always dependent on signal strength at the receiver, but there are other factors which are also of high importance when the broad analysis is needed.

The studies on the received Bit Error rate (BER), Carrier to Noise and Signal to Noise ratio is among the areas on which further studies on quality of DVB-T signal can be taken in Tanzania.

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APPENDICES

APPENDIX A: UHF BANDS ALLOCATION FOR MUX IN ARUSHA

BAND		CHANNEL	CHANNEL SPACING	VISION CARRIER	SOUND CARRIER
IV		21	470-478	471.25	477.25
	BTL	22	478-486	479.25	485.25
		23	486-494	487.25	493.25
		24	494-502	495.25	501.25
		25	502-510	503.25	509.25
		26	510-518	511.25	517.25
		27	518-526	519.25	525.25
	AGAPE	28	526-534	527.25	533.25
		29	534-542	535.25	541.25
		30	542-550	543.25	549.25
		31	550-558	551.25	557.25
		32	558-566	559.25	562.25
		33	566-574	567.25	573.25
	AGAPE	34	574-582	575.25	581.25
V		35	582-590	583.25	589.25
		36	590-598	591.25	597.25
		37	598-606	599.25	605.25
	STARMEDIA	38	606-614	607.25	613.25
		39	614-622	615.25	621.25
	STARMEDIA	40	622-630	623.25	629.25
		41	630-638	631.25	637.25
	AGAPE	42	638-646	639.25	645.25
		43	646-654	647.25	653.25
	STARMEDIA	44	654-662	655.25	661.25
	BTL	45	662-670	663.25	669.25
	STARMEDIA	46	670-678	671.25	677.25
		47	678-686	679.25	685.25
		48	686-694	687.25	693.25
		49	694-702	695.25	701.25
	STARMEDIA	50	702-710	703.25	709.25
		51	710-718	711.25	717.25
		52	718-726	719.25	725.25
		53	726-734	727.25	733.25
		54	734-742	735.25	741.25
	BTL	55	742-750	743.25	749.25
		56	750-758	751.25	757.25
		57	758-766	759.25	765.25
		58	766-774	767.25	773.25

		59	774-782	775.25	781.25
		30	782-790	783.25	789.25
		61	790-798	791.25	797.25
		62	798-806	799.25	805.25
		63	806-814	807.25	813.25
		64	814-822	815.25	821.25
		65	822-830	823.25	829.25
		66	830-838	831.25	837.25
		67	838-846	839.25	845.25
		68	846-854	847.25	853.25
		69	854-862	855.25	861.25

APPENDIX B: DVB-T MINIMUM TECHNICAL SPECIFICATIONS BY TCRA

1.0	**RF tuner & DVB-T Channel**	Input impedance	75Ω
		Modulation	COFDM: QPSK, 16QAM, 64QAM
		Frequency	VHF (174-230MHz) - optional, UHF (470–
		Input signal level	-33dBm to -81dBm
		FEC coding	Convolutional Coding + Reed Solomon 1/2, 2/3, 3/4, 5/6, 7/8
		FTT Size	2k, 8k
		C/N range	3dB (QPSK) to 7dB (64QAM)
		Guard intervals	1/4, 1/8, 1/16, 1/32
		Channel raster (width)	7MHz (VHF), 8MHz (UHF)
		Signal Bandwidth	7.61 MHz in the 8 MHz channel; 6.66 MHz in the 7 MHz channel
		Interleaving	Bit+ Frequency
		Max Bit Rates (8MHz)	32 Mbit/s
		Used Bit Rates (8MHz)	5 to 32 Mbit/s
2.0	**MPEG Transport stream video and Audio Decoding**	Transport stream	MPEG-2 ISO/IEC13818
		Video decoding	MPEG-2/MPEG4AVC
		Aspect Ratio (image rate)	4:3,16:9
		Frame frequency	25Hz (PAL)
		Video Resolution	720X576 (PAL) - standard definition, 1920X1080 (High definition)
		Audio decoding	MPEG-2 MUSICAM Layer I&II/HEAAC
		Audio mode	Single track/dual track/stereo
		Audio sampling rate	32KHz, 44.1KHz, 48KHz., 96KHz (optional)
3.0	**Scanning function**	The STB should include a frequency scanning function to detect the availability of DVB-T signals	
		It should also automatically list the content of the terrestrial	
		Be capable of programme memory in case of cut off	
		It should be able to display the number of channel currently	
		It should be able to display number of services located	

		Where the multiplex is seized, the decoder shall display details of its name, network ID, signal strength and

APPENDIX C: DVB-T2 MINIMUM TECHNICAL SPECIFICATION BY TCRA

1.0	**RF tuner & DVB-T2 Channel**	Input impedance	75Ω
		Modulation	COFDM:QPSK, 16QAM, 64QAM, 256QAM
		Frequency	VHF(174-230MHz)-optional, UHF(470–700MHz)
		Input signal level	-35dBm to -85dBm
		FEC coding	LDPC Code+ BCH Code, Code rates :1/2, 3/5, 2/3, 3/4, 4/5, 5/6
		FTT Size	1K, 2K, 4K, 8K, 16K, 32K
		C/N range (Rice channel)	3dB (QPSK1/2) to 24dB (256QAM5/6)
		Pilot Pattern	PP1 to PP8
		Guard intervals	1/4, 1/8, 1/16, 1/32, 1/128, 19/128, 19/256
		Channel raster	7MHz (VHF),8MHz(UHF), 1.7MHz (VHF)-optional
		Signal Bandwidth	8MHz corresponds to 7.61 MHz in the normal carrier mode, 7.71 MHz for 8k, while 7.777 MHz for 16k and 32k
		Service specific robustness	Physical Layer Pipes (PLP)
		Interleaving	Bit+ Cell + Time + Frequency
		Diversity	SISI, MISO, (SIMO, MIMI if diversity receiver)
		Rotated constellations	Significant robustness gain in channels with severe degradations (multipath, SFN
		Mode of Extensions	Future Extension Frame(FEF)
		Max Bit Rates (8MHz)	50.3Mbit/s,(32Ke,256QAM,CR=5/6,GI=1/28,PP7)
		Used Bit Rates (8MHz)	Portable SFN:25.0Mbit/s, Fixed SFN:37.0Mbit/s, Fixed MFN:40.2Mbit/s
		GE06	Signal is under the mask of DVB-T2

APPENDIX D: GUIDED INTERVIEW TEMPLATE

USER GENERAL INFORMATION

1. Gender of the respondent (Please tick)

(i) Male [ ] (ii) Female [ ]

2. Age of the respondents (Please tick)

(i) Between 16-25 [ ] (ii) between 26-35 [ ] (iii) between 36-45 [ ]

a. (iii) Above 45[ ]

3. Relationship of the respondent with the head of household(Please tick)

(i) Head of household [ ] (ii) Father [ ] (iii) Mother [ ] (iv) Wife [ ]

b. (v) Husband [ ] (vi) Son [ ] (vii) Daughter [ ] (viii) House-girl [ ]

c. (viii) House-boy [ ] (ix) Next of kin [ ]

d. (x) Others, please name ....

4. Respondent area of residence

(i) District...

(ii) Ward...

USER TECHNICAL DATA

5. Did you use any other decoder before this one? If Yes proceed with question 2.2 otherwise jump to question 2.9

(i) Yes [ ] (ii) No [ ]

6. What type of a terrestrial decoder were you using?

(i) Startimes [ ] (ii) Digitek [ ] (iii) Continental [ ] (iv) Ting [ ]

7. Give reasons which made you to leave that MUXs if choice (ii) proceed to question 2.4, otherwise jump to question 2.9

(i) Monthly payment was too high [ ] (ii) Signal reception was not good [](iii)not interested with the type of channels it had [ ] (iv) Low number of channels

b. (v) Others, please explain.........................

8. Were you using indoor or outdoor antenna? if indoor proceed with question 2.5, otherwise jump to question 2.7?)

a. (i) Indoor [ ] (ii) Outdoor [ ]

9. Did you changed your antenna from indoor to outdoor? if yes proceed with question 2.6, otherwise jump to question 2.7

(i) Yes [ ] (ii) No [ ]

10. Was there any improvements on quality of signal received?

(i) Very much [ ] (ii) Somehow[ ] (iii) Same[ ] (iv) worse[ ] (v) much worse[]

11. Did you tried to rotate the outdoor antenna?

a. (i) Yes [ ] (ii) No [ ]

12. If Yes, was there any improvement on reception?

(i) Very important[ ] (ii) Important [ ] (iii) Somehow [ ] (iv) Same [ ]

b. (v) worse [ ]

13. What type of a terrestrial decoder are you current using?

a. (i)Startimes [ ] (ii) Digitek [ ] (iii) Continental [ ] (iv) Ting [ ]

14. Why did you decide to use this decoder?

(i) Monthly price is cheap [] (ii) It has good quality signal reception in our area [ ]

(ii) It was the first on market[ ] (iv) Interested with the channels it contains

15. (v) No other option (vi) Others, please explain.................................

16. Where do you position your antenna for reception of DVB-T with the current decoder?

(i) Indoor antenna[ ] (ii) Outdoor antenna[ ]

17. What type of antenna is currently used for DVB-T reception at your home?

(i) Yagi-Uda [ ] (ii) Open Dipole [ ] (iii) Folded dipole[ ] (iv) Helical [ ]

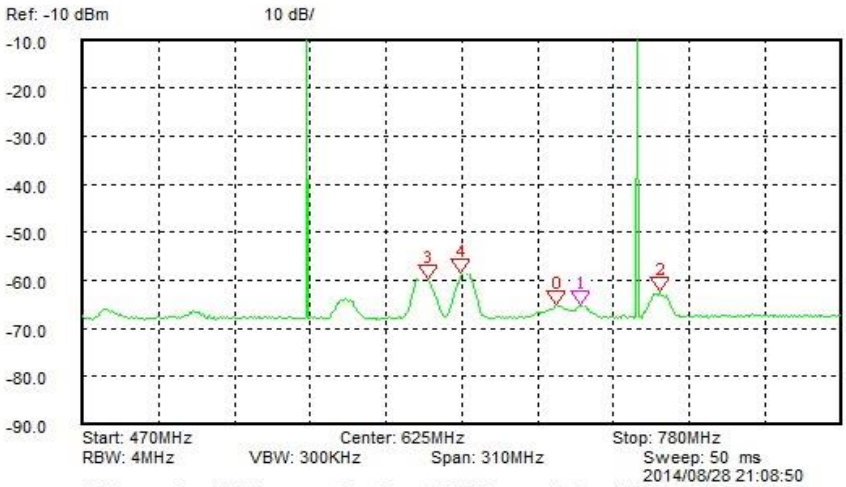
b. (v) Omnidirectional antenna[ ] (vi) Don't know [ ]

18. How do you rank the reception of DVB-T signal through the use of current decoder?

(i) Excellent [ ] (ii) Very Good [ ] (iii) Good [ ] (iv) satisfactory[ ] (v) Not good [ ]

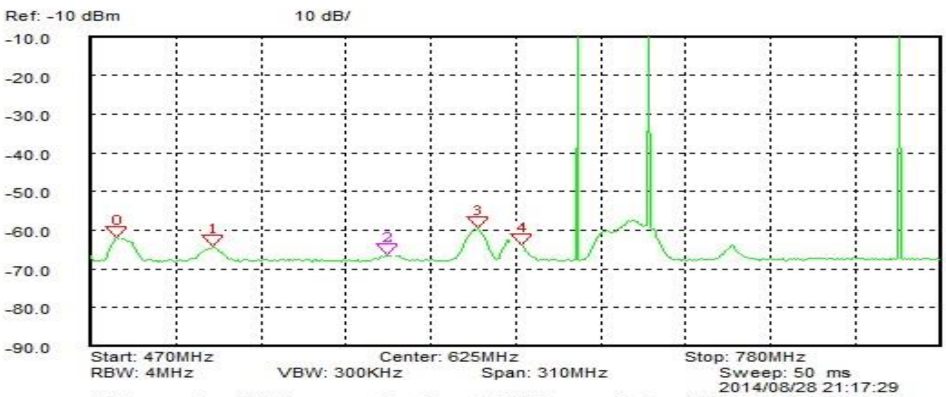
APPENDIX E: FOLDED DIPOLE ANTENNA-ARUSHA CITY CENTRE

NORTH



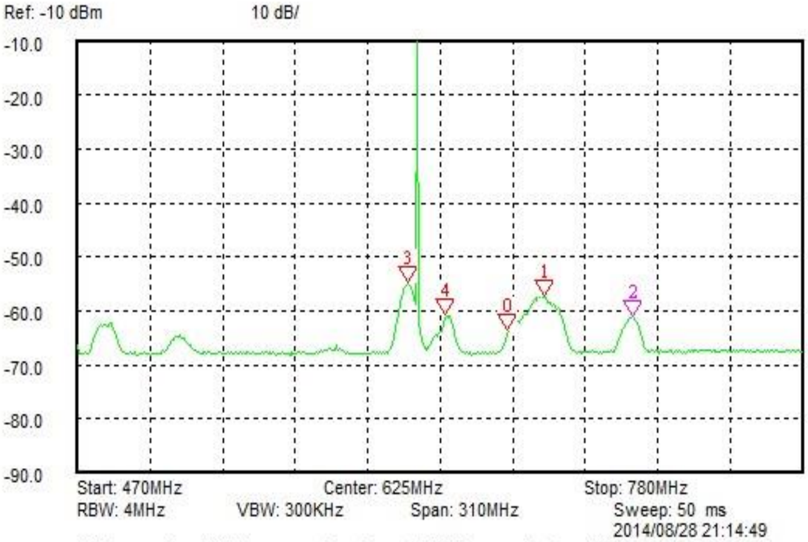
MKR	Freq.(MHz)	Level	D_MKR	D_Freq.(MHz)	D_Level
0	664.06	-65.4			
1	673.98	-65.2			
2	706.22	-62.6			
3	611.36	-60.1			
4	625	-58.7			

NORTH EAST/SOUTH-WEST



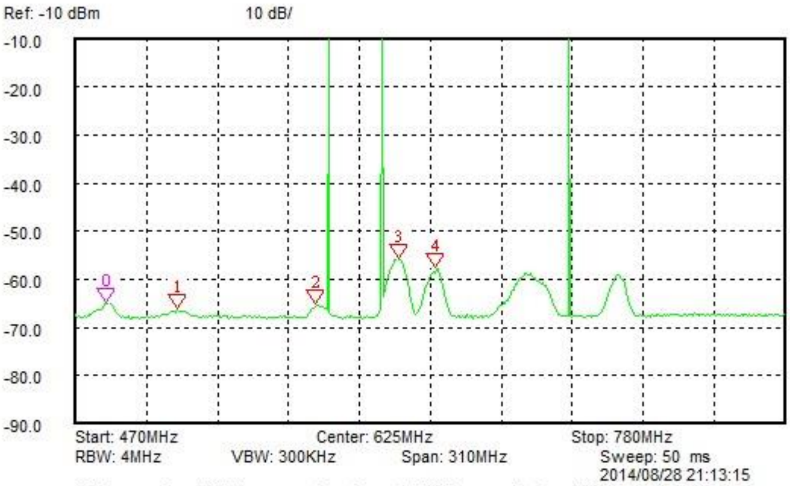
MKR	Freq.(MHz)	Level	D_MKR	D_Freq.(MHz)	D_Level
0	479.92	-62.1			
1	514.64	-64.3			
2	578.5	-66.8			
3	611.36	-59.8			
4	627.48	-64.1			

WEST-EAST



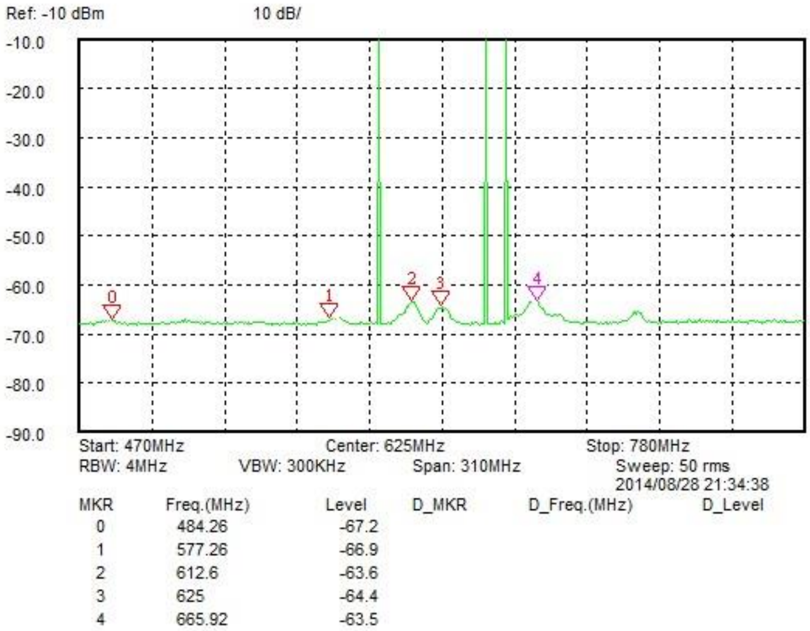
MKR	Freq.(MHz)	Level	D_MKR	D_Freq.(MHz)	D_Level
0	654.14	-63.9			
1	670.26	-57.4			
2	708.08	-61.4			
3	611.36	-55.0			
4	627.48	-61.1			

NORTH-WEST/SOUTH-EAST



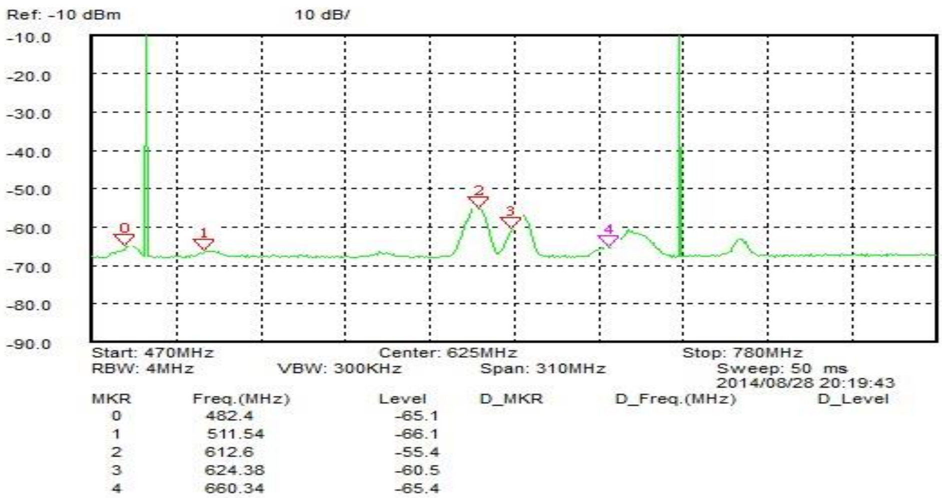
MKR	Freq.(MHz)	Level	D_MKR	D_Freq.(MHz)	D_Level
0	483.64	-65.1			
1	514.64	-66.3			
2	575.4	-65.2			
3	611.36	-55.7			
4	627.48	-57.7			

OMNIDIRECTIONAL ANTENNA-ARUSHA CITY CENTRE

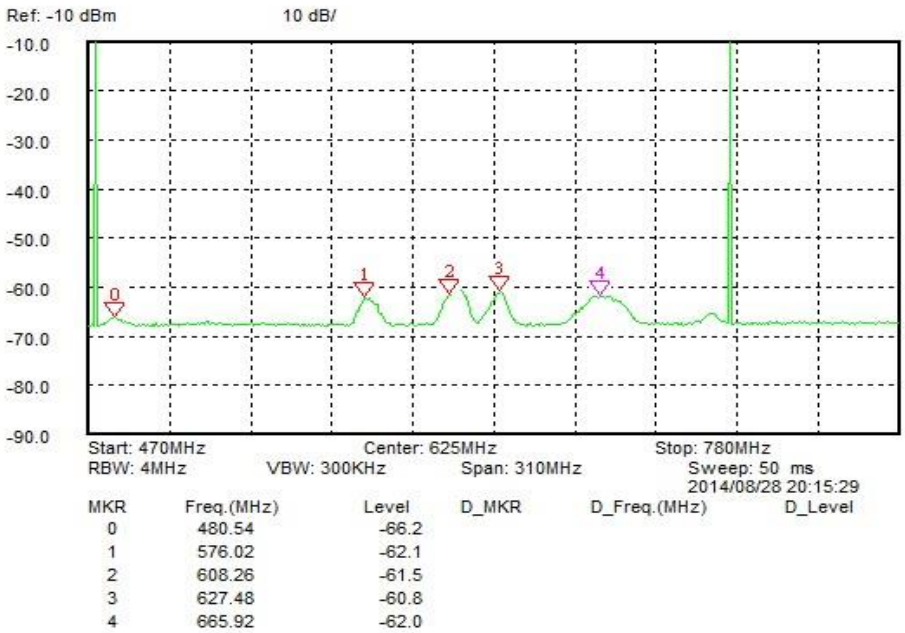


OPEN DIPOLE-ARUSHA CITY CENTRE

NORTH-WEST/SOUTH-EAST

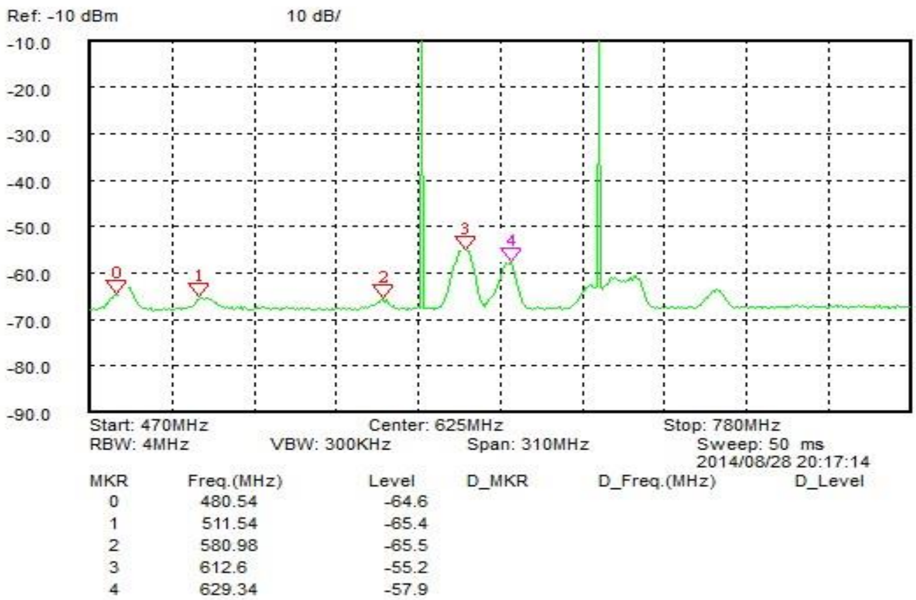


EAST-



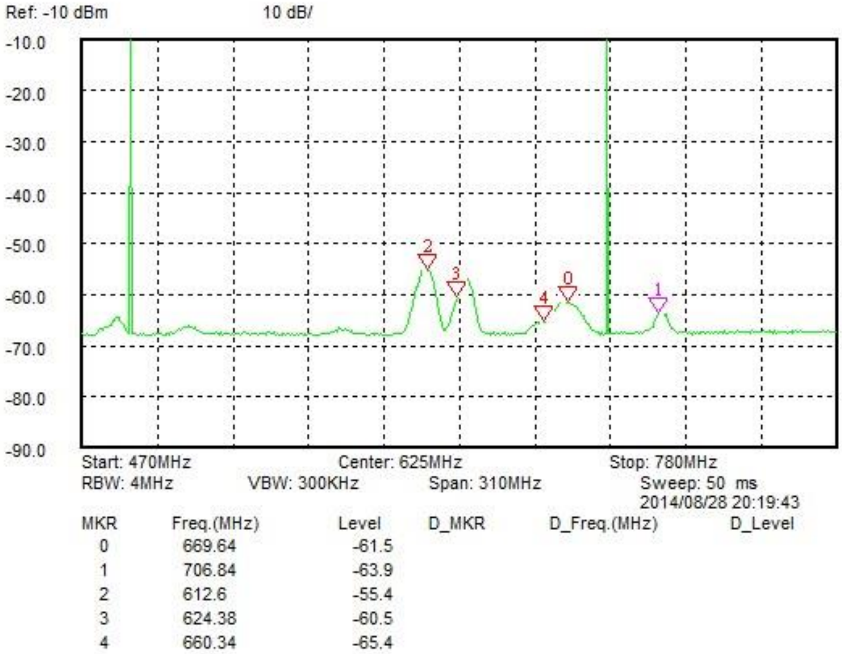
WEST

NORTH-EAST/SOUTH-



WEST

NORTH-


Ref: -10 dBm
10 dB/
-10.0
-20.0
-30.0
-40.0
-50.0
-60.0
-70.0
-80.0
-90.0
2
3
4
0
1
Start: 470MHz
Center: 625MHz
Stop: 780MHz
RBW: 4MHz
VBW: 300KHz
Span: 310MHz
Sweep: 50 ms
2014/08/28 20:19:43
MKR Freq.(MHz) Level D_MKR D_Freq.(MHz) D_Level
0 669.64 -61.5
1 706.84 -63.9
2 612.6 -55.4
3 624.38 -60.5
4 660.34 -65.4

SOUTH