TECHNICAL CHALLENGES OF THE TRANSITION FROM ANALOG TO DIGITAL TELEVISION TRANSMISSION IN GHANA (2015):

CASE STUDY: Digital and Terrestrial Analogue Television Transmission in Accra and Tema Environs

BY

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A Project

Submitted in the Requirements for the Masters of Science Degree in Telecommunication Engineering

DECLARATION

I hereby declare that this submission is my own work towards the MSc and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

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Head of Dept. Name **Signature** **Date**

ABSTRACT

Countries across the world are moving their analogue television broadcasting system to digital platform. Ghana has set 2015 as the deadline for it analogue television shutdown in agreement with the Geneva 2006 agreement.

The project reviews the analogue and digital transmission in Ghana which is currently carried out in this period of dual illumination, "time period whereby analogue and digital transmission will be carried out simultaneously", outlining the technical, infrastructural and regulatory challenges during the period, using the current analogue and digital transmission in Accra and Tema as a case study.

Technically, it has been established that, poor sitting of existing DVB-T transmitting stations has affected quality reception of the DTT transmissions at certain locations in Accra and Tema, especially areas between the two transmitters.

Evaluation of STBs distributed by present service operators (SOs) was carried out, it has been established that DVB-T STBs currently available do meet the specifications for the variant of DTT network (DVB-T2) recommended in the Bidding document for DTT network in Ghana, one of the STB do not indicate signal levels beyond 45dBμV/m and also does not output converted DTT signals in its RF-Out.

Possible regulatory issues concerning band usage, channel assignments, service licensing was also reviewed and the findings published in the main body of the thesis.

Based on the findings, it is recommended that DTT transmitters should be co-sited, and aside the main transmitters used by each multiplex operator, gap-fillers would be needed to ensure total coverage of transmitted signals in the Accra-Tema environs. All imported receivers should have a common conditional access system to ensure reception of encrypted services from the various multiplex. One of the minimum requirements of the STBs should be it ability to output converted DTT signals to its RF-Out, so more than one analogue TV set would use a single STB to minimize the cost of the transition to the public.

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GLOSSARY

ASI: Asynchronous Serial Interface, 270Mbps line rate (consistent with SDI clock), 27 Mbps data rate (consistent with PCR clock standard).   .

Auxiliary streams: sequence of cells carrying data of as yet undefined modulation and coding, which may be used for future extensions or as required by broadcasters or network operators.

Basic T2-Gateway: device taking one input stream per data PLP and producing at its output a T2-MI stream.   .

Code Rate (CR): Code Rate (or information rate) of a forward error correction code is the proportion of the data-stream that is useful (non-redundant). That is, if the code rate is k/n, for every k bits of useful information, the coder generates totally n bits of data, of which n-k are redundant.

C/N: Carrier-to-Noise ratio is the ratio of carrier signal to the noise generated in the signal.

DS3: A Digital Signal 3 (DS3) is a digital signal level 3 T-carrier with a signal rate of 44.736.

DVB-T2: DVB-T2 is the Second Generation of Terrestrial Digital Video Broadcasting.

ETS 302 755: DVB specifications subsequently standardized in one of the European statutory standardization bodies, usually the European Telecommunication Standards Institute (ETSI), for Frame structure, channel coding and modulation for a second generation DVB-T.   .

FFT: A **fast Fourier transform** (**FFT**) is an efficient algorithm to compute the discrete Fourier transform (DFT) and it's inverse. An FFT computes the DFT and produces exactly the same result as evaluating the DFT definition directly; the only difference is that an FFT is much faster.

FEC: forward error correction (FEC) (also called channel coding) is a system of error control for data transmission, whereby the sender adds systematically generated redundant data to its messages.

Guard Interval: Guard interval are used to ensure that distinct transmissions do not interfere with one another. These transmissions may belong to different users (as in TDMA) or to the same user (as in OFDM). The purpose of the guard interval is to introduce immunity to propagation delays, echoes and reflections, to which digital data is normally very sensitive.

GPS: General Position System is a navigational system involving satellites and computers that can determine the latitude and longitude of a receiver on Earth by computing the time difference for signals from different satellites to reach the receiver.

idTV: is a television which has an inbuilt digital demodulator (digital tuner) to received digital television.

IDU: Indoor Unit is the unit of transmission equipment usually placed in the shelter with other transmitting equipment. .

ITU-R Region- International Telecommunication Union-Radio Regulation divides the world into three ITU regions for the purposes of managing the global radio spectrum. Each region has its own set of frequency allocations, the main reason for defining the regions.

- Region1 comprises Europe, Africa, the Middle East west of the Persian Gulf including Iraq, the former Soviet Union and Mongolia
- Region 2 covers the Americas, Greenland and some of the eastern Pacific Islands
- Region 3 contains most of non-former-Soviet-Union Asia, east of and including Iran and most of Oceania.

MCR: Master Control Room is the room usually in broadcasting studio premises where equipments at the head-end of broadcasting are situated. Transmitted signals are also monitored here.

MIMO: In radio, multiple-input and multiple-output, or MIMO, is the use of multiple antennas at both the transmitter and receiver to improve communication performance. It is one of several forms of smart antenna technology. The terms input and output refer to the radio channel carrying the transmitted signal. .

ODU: Out Door Unit is the unit of transmission equipment usually placed closer to the transmitting antenna on the tower, outside of the shelter where other transmitting equipments are located.

PAPR: Peak-to-Average Ratio is the peak divided by the Root mean square (RMS) of the waveform.

PLP (Physical layer pipe): A PLP is a logical channel that may carry one or multiple services. Each PLP can have a different bit rate and error protection parameters. For example, it's possible to split SD and HD services to different PLPs. Another example is the New Generation Handheld (**DVB-NGH**) standard that will be based on multiple PLP feature to enable broadcast mobile TV over DVB-T2. .

PRBS: Pseudorandom Binary Sequence**,** a binary sequence (BS) is a sequence of N bits, a_j for j =

$0,1,\ldots,N-1$, i.e. m ones and N-m zeros. A BS is pseudo-random (PRBS) if its autocorrelation function, is random in a sense that the value of an a_j element is independent of the values of any of the other elements, similar to real random sequences. .

SIMO: Single-Input and Single-Output, or SIMO, is the use of a single antenna at the transmit end and multiple antennas at the received end to improve communication performance.

SNMP: Simple Network Management Protocol is an "Internet-standard protocol for managing devices on IP networks. Devices that typically support SNMP include routers, switches, servers, workstations, printers, modem racks, and more. It is used mostly in network management systems to monitor network-attached devices for conditions that warrant administrative attention. SNMP is a component of the Internet Protocol Suite as defined by the Internet Engineering Task Force (IETF). It consists of a set of standards for network management, including an application layer protocol, a database schema, and a set of data objects. .

STB: Set-To-Box, a device used to decode digital transmission to an analogue format so that analogue devices (analogue TV sets, TV combos, analogue PC card etc) can view digital transmission.

Web GUI: Web GUI is a web application framework and web content management system that puts the publishing power in the hands of the people who create the content, rather than the IT staff.

CHAPTER ONE: INTRODUCTION

1.1 Background

Aside DStv whose transmission in Ghana was on a digital platform before May 2008, all the other television broadcasting services enjoyed in Ghana has always been distributed in an analogue format [1]. Analogue broadcasting format requires more bandwidth per TV program and the reception quality for both the sound and image degrades with distance [2].

The quest by countries around the world to save the limited bandwidth that support television services and also to improve the quality of both the sound and image of television broadcasting has led to the introduction of digital television services which uses more efficient compression algorithm to preserve the limited bandwidth used for radio communication whilst keeping the quality of the image and sound of TV programs at excellent condition [3].

At the Regional Radio-Communication Conference held in Geneva 2006 (RRC-06), Europe, Africa, Middle East and the Islamic Republic of Iran agreed (GE06) to complete switchover from analogue to digital television broadcasting by June 2015 [4]. Ghana is a signatory of this agreement. As part of these measures the National Communications Authority (NCA) which is the frequency regulatory body in Ghana undertook re-planning of frequencies in the bands 174-230MHz and 470-862 MHz from 2004 to 2006 which was finalized at the ITU's Regional Radio communication Conference (RRC-06) [4].

1.2 Motivation

Stakeholders in public and private broadcasting industries in Ghana are in the initial stages of transition to the digital world in television broadcasting. The Ghana Broadcasting Corporation (GBC), the state broadcaster has deployed pilot DVB-T transmission (DVB-T, MPEG-4/AVC/H.264) in Accra and Kumasi SKYY Digital and Cable Gold privately own television stations, have also launched DVB-T transmissions in some cities in Ghana (MPEG 2 and MPEG 4 platforms respectively) and the other private stations soon to follow suit [5] . Delivery through satellite is underway and is carried out by DStv and Multi TV and Cable Gold is delivering a digital television through cable. When fully implemented quality services in terms of image and sound would be improved for television viewers across Ghana and the nation will save a lot of bandwidth which can be used for other radio communication service or improve the existing ones.

1.3 Objectives

The objectives of the project are to identify:

- The Technical Challenges
- The Infrastructural Challenges
- The Regulatory Challenges
- Findings and Recommendations

1.4 Outline of How Project Was Executed

Chapter One outlines the background and objectives of the Study. Chapter Two deals with the theoretical part of the Study. Chapter Three focuses on the Project Implementation in Ghana. Based on the findings, comments and recommendation is then drawn.

CHAPTER TWO

2.1 TECHNICAL CONSIDERATIONS

The technical considerations taken into account in digital television broadcasting in this Study include:

- Technological Issues: Standards to be adopted, format of content etc
- Bands for DTT transmission
- Network Planning
- Transmitter Sitting
- Receiver Requirements

2.1.1 Technological Issues

2.1.1.1 Standards Adopted for Digital Television Broadcasting Around the World

The main standards adopted for digital television broadcasting around the various ITU-R Regions of the world are Digital Video Broadcasting (DVB), used in Europe, the Advanced Television System Committee (ATSC), in American, the Integrated Services Digital Broadcasting (ISDB), the standard used in Japan, and the Digital Multimedia Broadcasting (DMB), the standard in Korean [6]. Technical details of the above mentioned standards for digital television broadcasting are presented in Table 2.1 [6-12].

Table 2.1: Comparison of Parameters of different DVB Platforms [6 - 12].

Standard	**System Type**	**Video Coding**	**Audio Coding**	**Modulation Scheme/s**	**Channel Bandwidth (MHz)**	**Bit rate (Mbps)**
DVB	DVB-S	MPEG-2 MPEG-4	MPEG-2/1 Digital sound	QPSK [8]	26 – 54	16.300 – 47.200
	DVB-S 2			QPSK, 8PSK, 16/62APSK		Up to 58.8
	DVB-T			QPSK/QAM/ OFDM	6,7,8	6.032 - 31.668
	DVB-T2			QPSK/16 – 256 QAM / OFDM	1,2,4,8,16,32	7.444 – 50.324
	DVB-C			16 – 4096 QAM	2,4,8,10	6.410 – 64.110
	DVB-C2					
	DVB-H	MPEG-4	MPEG-4 Digital sound	QPSK,16QAM 64-QAM	5,6,7,8	15.0
ATSC	ATSC-T	MPEG-2 MPEG-4	AC-3	8-VSB	6	19.28
	ATSC-C					38.57
ISDB	ISDB-S	MPEG-2 MPEG-4	MPEG-2 AAC	TC8PSK/QPSK /BPSK	34.5	52
	ISDB-T			DQPSK/QAM	5.6	21.47 4.06 (Mobile)
	ISDB-C			64QAM	6	31.644
DMB	S-DMB	MPEG-4	MPEG-4 Digital sound	QPSK	1.536	0.8 ~ 1.7
	T-DMB			Differential QPSK	1.5	1.5

2.1.2 Bands for DTT Transmission in ITU-R Region One and the Radio Wave

2.1.2.1 Propagation Characteristics in These Bands

The broadcasting areas across the world are divided into three regions for frequency allocation. For instance, Region One consists of the European Broadcasting Area, Africa Broadcasting Area, Russia, the Middle East, and parts of Asia as shown in Figure 2.1.

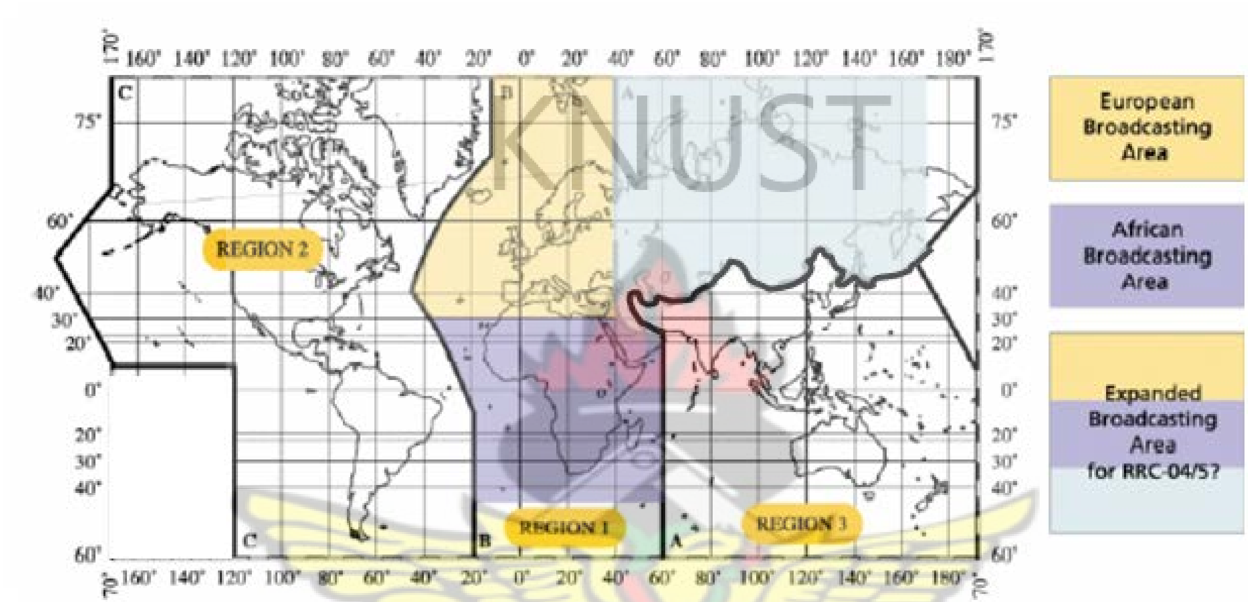


Figure 2.1: Map of Broadcasting Areas around the World [13].

At the Regional Radio-communications Conference (RRC-06) held in 2006 at Geneva, an Agreement (GE06) was established to plan digital terrestrial broadcasting in Bands III, IV and V which are within the VHF and UHF Bands of the electromagnetic spectrum [6].

2.1.2.2 Radio Wave Propagation

Radio waves travels from the transmitter to the receiver by means of space waves, ground waves, ground reflected waves or by sky waves [14]. This illustrated in figure 2.2.

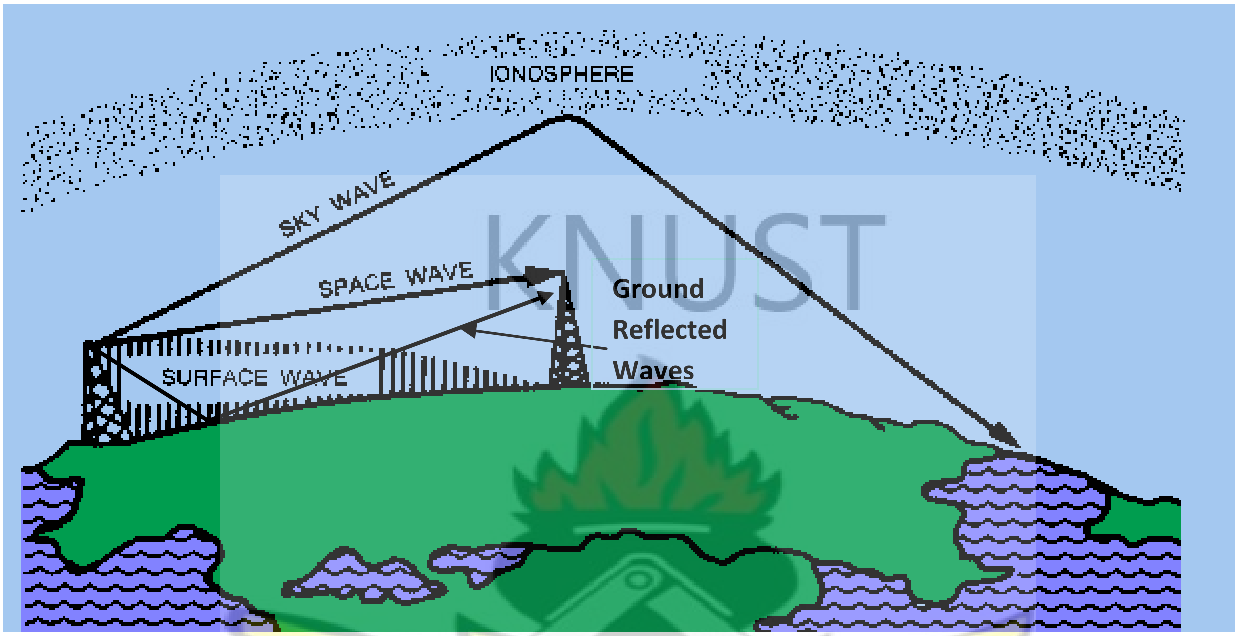


Figure 2.2: Propagation Path of Radio Waves for Terrestrial Transmission [15].

2.1.2.3 Characteristics of the various Waves Propagation

2.1.2.3.1 Space Wave Characteristics

The direct wave travels directly from the transmitting antenna to the receiving antenna. It is limited to the line-of-site (LOS) distance between the transmitting antenna and the receiving antenna plus the short distance added by atmospheric refraction and diffraction of the wave around the Earth's curvature. This distance can be extended by increasing the transmitting or the receiving antenna height, or both [14].

2.1.2.3.2 Surface Wave Characteristics

The surface wave follows the Earth's curvature. It is affected by the Earth's conductivity and dielectric constant [14].

2.1.2.3.3 Ground Reflected Wave Characteristics

The ground reflected wave reaches the receiving antenna after being reflected from the Earth's surface. Cancellation of the radio signal can occur when the ground reflected component arrive at the receiving antenna at the same time and are 180^0 out of phase with each other [14].

Beyond the horizon the direct and reflected waces are blocked by the curvature of the Earth, and the signal is purely made up from the diffracted surface wave [14].

2.1.2.4 Propagation of Radio Waves in VHF and UHF Bands

Propagation in the VHF and UHF is mainly by space waves since surface wave is rapidly attenuated at VHF and UHF [16]. In the VHF band, diffraction allows short-range reception into build-up areas, however, in the UHF band, signals tend to diffract only slightly around hills and mountains compared to VHF band, thus, diffraction loss around hills is less in VHF Band than UHF Band [32]. Therefore, it is very easy to predict the transmitter service area at UHF, once the terrain data is available together with the transmitter location, ERP, and aerial height [16].

At frequencies above the 500 MHz, tropospheric scatter provides a limited degree of reception at ranges up to about 300-600 km [16]. Wider bandwidth per channels per waveband is attractive for television, as well as higher gain antennas [16].

Table 2.2 shows the influences that the atmosphere and terrain have on radio-wave propagation in these spectrums and also highlight the system considerations and typical services offered in these spectrums.

Table 2.2: Characteristics of the VHF and UHF Wavebands [16].

VHF	UHF
Atmospheric Influence	
Refraction and reflection by refractive-index irregularities producing transhorizon paths; some sporadic E and ionospheric-scatter transhorizon effects, and Faraday rotation and ionospheric scintillation on Earth-space path	Reflection effects; reflection from layers at lower frequencies; ducting possible at higher frequencies; refractive-index fluctuations-forward scatter beyond horizon above 500 MHz
Terrain Influence	
Screening by major hills, but some diffraction into valleys; surface reflections off large areas (sea, lakes, flat ground) causing multipath effects on line-of-sight paths	Screening by hills and collections of buildings
System Consideration	
Multi-element dipole (Yagi-Uda) antennas, or slots, helixes etc; several MHz per radio channel where required	Multi-element dipole (Yagi-Uda) antennas; wide bandwidths available; parabolic dishes for higher frequencies
Typical VHF Services	
Sound and television broadcasting (to about 100km); land, aeronautical and marine mobile; portable and cordless telephone; aeronautical radionavigation becons	Television broadcasting; some aircraft navigation, landing etc; most surveillance and secondary radars; fixed (terrestrial point-to-point); mobile manpacks and vehicles; satellite mobile; satellite tracking, telemetry and command network; cellular radio; cordless telephones
Comments	
line-of-sight terrestrial transmission and somewhat beyond	Line-of-sight and very slightly beyond; also tropospheric scatter transhorizon for higher frequencies

2.1.3 Planning the Network of Terrestrial Digital Television Broadcasting

DVB-T/T2 network can be planned as Single Frequency Network (SFN), Multi Frequency Network (MFN) or a Mixed of the two.

2.1.3.1 Single Frequency Network (SFN)

Principle of SFN

In a SFN, all transmitters are synchronously modulated with the same signal and radiate on the same frequency [17]. This can be planned as a large area SFN or small area SFN.

The limiting effect of the SFN technique is the self-interference of the network. If signals from far distant transmitters are delayed more than allowed by the guard interval, they behave as noise-like interfering signals rather than as wanted signals. The strength of such signals depends on the propagation conditions, which will vary with time. The self-interference of an SFN for a given transmitter spacing is reduced by selecting a large guard interval [17]. Fig. 2.3 below illustrates a single frequency network.

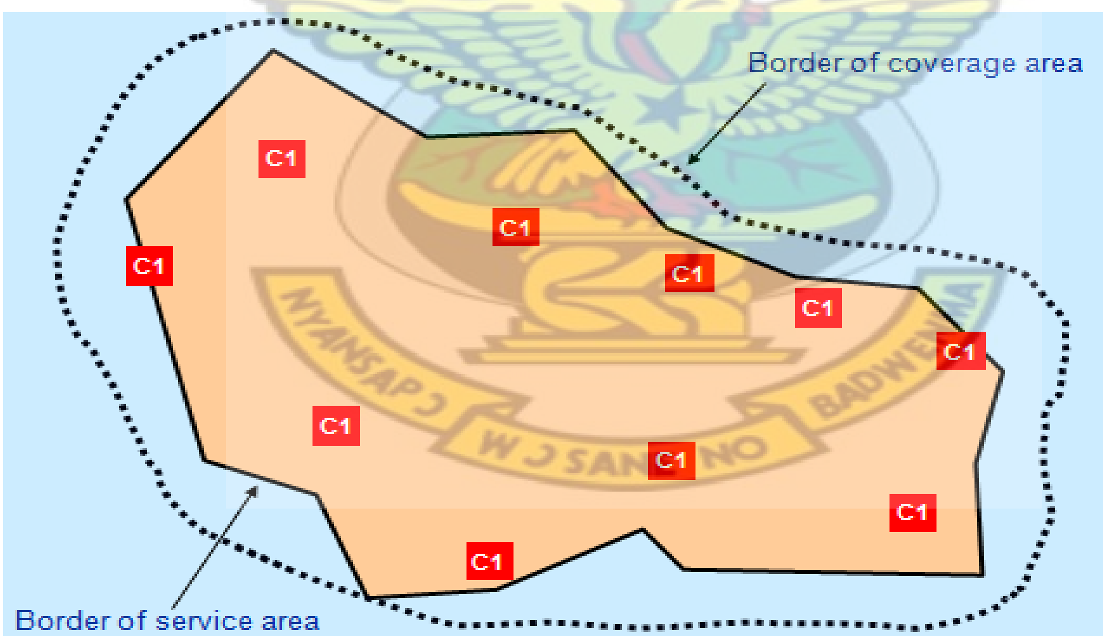


Figure 2.3: Single Frequency Network [18].

Advantages of the SFN [18]

- Frequency Efficiency

  The SFN is with the factor of 3 better than the MFN's

- Power Efficiency

  Lower transmitter power is required in SFN because:

  (i) Addition of all signals components from different transmitters and reflection at the receiving antenna with lower transmitter output power and also if gaps exist in the coverage (deep valley, tunnels, etc) these gaps can be filled

Disadvantages of the SFN Network [15-16]

- The transmitters provides a common coverage area and can't be operated independently- they must carry identical multiplex content
- Interference potential to neighbouring countries could be much higher
- Reduced bitrate due to large guard interval
- More complicated frequency planning

2.1.3.1.1 Single Frequency Network (SFN) in DVB-T/T2

DVB-T made it possible to build SFN networks but with a longest guard interval (GI) of only 224µs and that limited the size of the SFN network in DVB-T. In DVB-T2 16 and 32K modes it is possible to have a much longer GI's as shown in Table 2.3 (differences between DVB-T and DVB-T2) which makes it possible to build very large SFN networks.

Table 2.3: Differences between DVB-T and DVB-T2 [19].

	DVB-T	DVB-T2
Modulation (Max)	QPSK, 16QAM, 64 QAM	QPSK, 16QAM, 64QAM, 256-QAM
FTT Size (Max)	8k	32k
Guard Interval	1/4, 1/8, 1/16, 1/32	1/4, **19/256**, 1/8, **19/128**, 1/16,1/32, **1/128**
FTT Size	2k, 8k	**1k**, 2k, **4k**, 8k, **16k**, **32k**
FEC	2/3CC +RS	3/5LDPC +BCH
Scattered Pilot	8.3%	4.2 %
Continual Pilot	2.0%	0.38 %
Carrier Mode	Standard	Extended
Capacity	32.21 Mbps	50.32 Mbps

2.1.3.2 Multi Frequency Network (MFN)

Principle of MFN

MFN planned DVB-T networks consist of transmitters with independent programme signals and with individual radio frequencies [17].

For MFN configuration, in order to cover large areas with one DVB-T signal a certain number of radio-frequency channels are needed to be assigned to each transmitter. The number of channels depends on the robustness of the transmission, i.e. the type of modulation associated with the applied channel code rate and on the objective of planning, (full area coverage or coverage of densely populated areas only). Reuse of channel is possible in MFN given a sufficient geographical separation of transmitters. The distance at which a given frequency can be used again in the MFN set-up is called the re-use distance. Figure 2.4 is a diagrammatic illustration of an MFN setup [17].

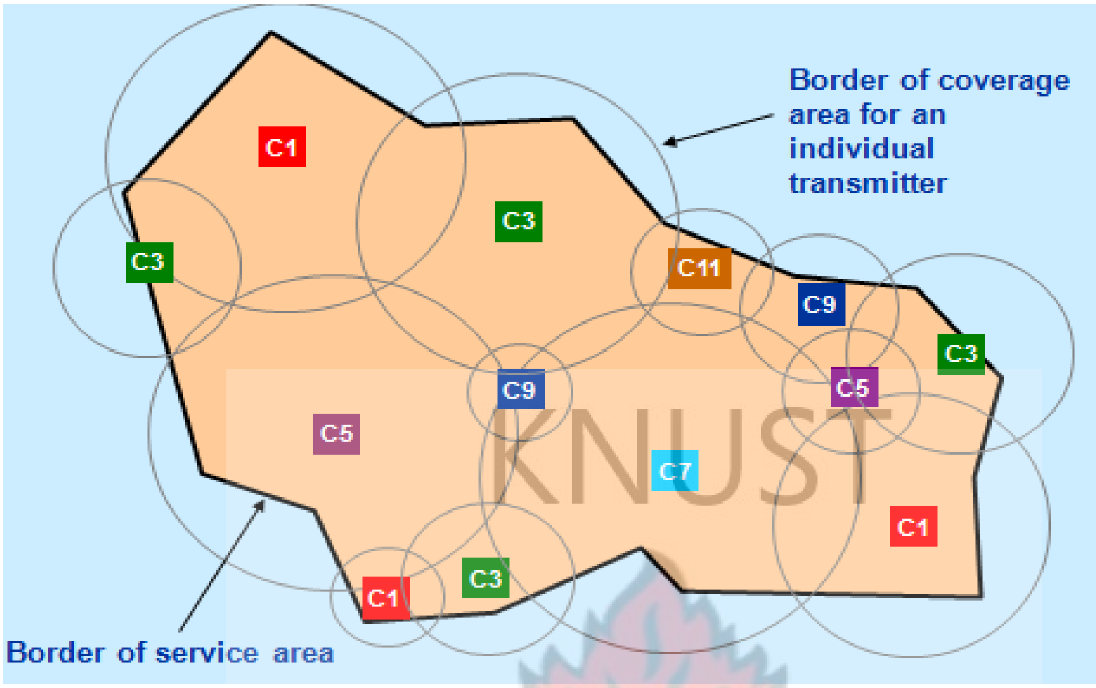


Figure 2.4 MFN Network [17].

Advantages of MFN

- In MFN configuration, it is possible to broadcast local programmes per site and with higher bit rate because a long guard interval is not needed [17].
- Ideal for conversion of existing analogue services:

If transmitter is a conversion of an existing analogue it is already compatible existing services

Disadvantages of MFN

- Inefficient utilization of the frequency spectrum

Example of countries around the world using Multi Frequency Networks (MFNs) includes the UK [20].

2.1.3.3 Mixed MFN and SFN

- Within an MFN of main stations, lower power stations may complete the coverage using the same frequency as the associated main station [17].
- An MFN structure for transmitting a national multiplex and an SFN structure for transmitting a regional multiplex [17].

2.1.3.4 Coverage Area Planning

In planning for the coverage area for both SFNs and MFNs, two parameters are taken into consideration to ensure effective transmission [16]:

(i) Protection Ratio

- Co-channel
- Adjacent Channel

(ii) Minimum Protected Field Strength

2.1.3.4.1 Protection Ratio

The protection ratio is defined as the minimum ratio of the power of the wanted signal to the power of the unwanted signal measured at a receiver [21]. Thus it specifies the extent to which unwanted field strength must be less than wanted field strength.

Protection ratios are required for compatibility considerations with regard to other radio systems. These cover intra-protections ratios (DVB-T1/T2 vs. DVB-T1/T2) and inter-protection ratios (DVB-T1/T2 vs. other non-T1/T2 radio systems, broadcasting as well as non-broadcasting), co-channel as well as adjacent channel protection ratios [22].

Protection Ratio is expressed as [22]:

Protection Ratio (dB) = Wanted Signal Level (dBm) – Unwanted Signal Level (dBm)

Co-channel protection ratios for digital television are very dependent on the system employed to modulate both the wanted and interfering signals, and also the relative power levels between them [23].

Adjacent channel protection ratios are dependent on the level of filtering employed in the transmission system to limit out of band emissions, and also on the selectivity of the tuner front end in the receiver. A high selectivity channel filter will reduce the adjacent channel levels reaching the demodulator, and therefore reduce the level of interference [23].

In planning the frequency for DTT coexistence with analogue television, the main factors that determine the feasibility of DTT on a channel are [23]:

- Interference incoming from the existing analogue television services – a key issue for determining the suitability of potential channels.
- DTT not causing interference to the existing analogue services and
- DTT not causing interference to other DTT services within the same or adjacent coverage

In Appendix A is shown the needed protection ratio (Co-channel and Adjacent Channels: Upper Adjacent and Lower Adjacent) for:

- DVB-T interfered with by DVB-T
- DVB-T interfered with by analogue television and
- Analogue TV interfered with by DVB-T

2.1.3.4.2 Minimum Field Strength (Signal Level)

Minimum field strength is the lowest value of wanted field strength for which protection can be claimed [18]. In other words, at all locations where the wanted service achieves the protected field strength or more, all unwanted field strength must be less than the wanted field strength minus the protection ratio [24].

2.1.3.4.2.1 Minimum receiver signal input levels

The minimum signal levels to overcome noise are given as the minimum receiver input power and the corresponding minimum equivalent receiver input voltage [20]. No account is taken of any propagation effect. However, it is necessary to consider these effects when considering reception in a practical environment [22].

To calculate the minimum median power flux density or equivalent field strength needed to ensure that the minimum values of signal level can be achieved at the required percentage of locations, the following formulas are used for reception under fixed, portable and mobile conditions [22]:

$P_n = F + 10 \log (k T_0 B)$

$P_{s\,min} = C/N + P_n$

$A_a = G + 10 \log (1.64\lambda^2/4\pi)$

$\phi_{min} = P_{s\,min} - A_a + L_f$

$E_{min} = \phi_{min} + 120 + 10 \log_{10}(120\pi) = \phi_{min} + 145.8$

$E_{med} = \phi_{med} + 120 + 10 \log_{10}(120\pi) = \phi_{med} + 145.8$

For fixed Reception: $\phi_{med} = \phi_{min} + P_{mmn} + C_l$

Thus: $E_{med} = \phi_{min} + P_{mmn} + C_l + 145.8$

For portable outdoor reception, Class A, mobile reception and, handheld portable outdoor reception, Class H-A, and handheld mobile vehicular reception, Class H-C:

$\phi_{med} = \phi_{min} + P_{mmn} + C_l + L_h$

Thus: $E_{med} = \phi_{min} + P_{mmn} + C_l + L_h + 145.8$

For portable indoor reception, Class B, and handheld portable indoor reception, Class H-B

$\phi_{med} = \phi_{min} + P_{mmn} + C_l + L_h + L_b$

Thus: $E_{med} = \phi_{min} + P_{mmn} + C_l + L_h + L_b + 145.8$

For handheld mobile reception, Class H-D

$\phi_{med} = \phi_{min} + P_{mmn} + C_l + L_h + L_v$

Thus: $E_{med} = \phi_{min} + P_{mmn} + C_l + L_h + L_v + 145.8$

Where:

P_n : receiver noise input power (dBW)

F : receiver noise figure (dB)

k : Boltzmann's constant ($k = 1.38 \times 10^{-23}$ (J/K))

T_0 : absolute temperature (T0 = 290 (K))

B : receiver noise bandwidth (B = 7.61 × 106 (Hz))

$P_{s\ min}$: minimum receiver input power (dBW)

C/N : RF signal to noise ratio required by the system [dB]

ϕ_{min} : Minimum power flux density at receiving place [dBW/m^2]

E_{min} : Equivalent minimum field strength at receiving place [dBμV/m]

L_f : Feeder loss [dB]

L_h : Height loss (10 m a.g.l. to 1.5 m a.g.l.) [dB]

L_b : Building penetration loss [dB]

L_v : Vehicle entry loss [dB]

P_{mmn} : Allowance for man-made noise [dB]

C_l : Location correction factor [dB]

ϕ_{med} : Minimum median power flux density, planning value [dBW/m^2]

E_{med} : Minimum median equivalent field strength, planning value [dBμV/m]

A_a : Effective antenna aperture [dBm2] [$A_a = G_{iso} + 10\log_{10}(\lambda^2/4\pi)$].
G_{iso} is the antenna gain relative to an isotropic antenna.

$P_{s\ min}$: Minimum receiver input power [dBW]

In defining coverage it is indicated that due to the very rapid transition from near perfect to no reception at all, it is necessary that the minimum required signal level is achieved at a high percentage of locations. These percentages have been set at 95% for "good" and 70% for "acceptable" reception [25].

For calculating the location correction factor C_l a log-normal distribution of the received signal is assumed [25].

$C_l = \mu * \sigma$

Where:

μ : distribution factor, being 0.52 for 70%, 1.28 for 90%, 1.64 for 95% and 2.33 for 99%;

σ : standard deviation taken as 5.5 dB for outdoor reception.

2.1.3.5 Parameters Used in DVB-T/T2 Minimum Field Strength Planning Configuration

The minimum field Strength for the reception of DVB-T/T2 at a given location depends on the following parameters [25]: location coverage probability, guard interval/data rate, Fast Fourier Transform (FFT) size and band/channel of operation.

2.1.3.5.1 Location coverage probability

Because of the abrupt degradation of digital television signals when passing from receiving conditions with perfect audio and picture quality to conditions with no reception at all [26], for satisfactory coverage, it is therefore necessary to guarantee good reception conditions with a high probability. The natural statistical variation of field strengths with location is described by the quantity location coverage probability which is a measure for the coverage quality. Normally, to achieve a satisfactory coverage, a location coverage probability of 95% is required for fixed and portable reception and 99% for mobile reception. Sometimes the value of 70% is requested for a lower coverage quality target [26].

2.1.3.5.2 Guard interval and Data capacity

Large service area SFNs need a large guard interval of 1/4 of the useful symbol time, T_u, in order to cope with the large delay times in a large scale SFN. Small service area SFNs and dense SFNs can be operated with 1/8 T_u – in advantageous cases even 1/16 T_u may be possible. A single transmitter may be operated with a guard interval of 1/16 or 1/32 T_u. Since in the DVB-T system self-interference immunity is paid for by data capacity, single transmitter or small SFN implementations with smaller guard intervals have a higher data capacity for the same DVB-T planning configuration than large area SFNs have [26].

2.1.3.5.3 FFT Size

Compatibility aspects are not affected by the choice of a 2k or 8k FFT. However, the 2k FFT is not able to cope with SFN signal configurations with large time delays unless a dense network approach is chosen. The reason is that the guard interval length of a 2k FFT amounts to only 1/4 of that of an 8k FFT [26].

Table 2.5 shows the minimum field strength set by the ITU-R for the reception of DVB-T under the various reception modes for 64QAM modulation and 2/3 code rate:

Table 2.5: Minimum Field Strength for DVB-T Reception for Fixed, Indoor and Mobile Reception [25].

BAND	**III**	**IV**	**V**
Fixed Reception – 64 QAM, 2/3 Rice Channel			
	Signal Strength / dBµV/m		
70% Locations	39	44	48
95 % Locations	45	50	54
Portable Outside Reception – 64 QAM, 2/3 Rayleigh Channel			
70% Locations	59	65	69
95 % Locations	64	71	75
Portable Indoor Reception – 64 QAM, 2/3 Rayleigh Channel			
70% Locations	66	73	77
95 % Locations	73	83	87
Portable Indoor Reception – 16 QAM, 1/2 Rayleigh Channel			
70% Locations	59	66	70
95 % Locations	68	76	80
Mobile Reception – Typical Urban: Typical Urban antenna diversity			
Maximum Speed (km/hr)	254	102	64
70% Locations	58	65	69
95 % Locations	64	71	77
99 % Locations	68	75	79

For fixed DTT reception (Rice Channel), Tables 2.6 and 2.7 further outlines the minimum field strength under the various modulation schemes for a code rate of 2/3 (most widely used code rate) and guard interval of 1/4 for DVB-T and DVB-T2 respectively.

The minimum field strengths are calculated for [24]:

a) Three frequencies representing, Band III, Band IV and Band V [24]:

- 200 MHz;
- 550 MHz;
- 700 MHz.

b) Three representative C/N ratios in the range 8 dB to 20 dB in steps of 6 dB.

Representative C/N values are used for these examples. Results for any chosen system variant may be obtained by interpolation between relevant representative values.

Table 2.6: Minimum field strength DVB-T 8 MHz system (Rice Channel) [22].

Frequency (MHz)	200			550			700		
System variant guard interval 1/ 4	QPSK 2/3	16-QAM 2/3	64-QAM 2/3	QPSK 2/3	16-QAM 2/3	64-QAM 2/3	QPSK 2/3	16-QAM 2/3	64-QAM 2/3
Receiver noise figure, F (dB)	5	5	5	7	7	7	7	7	7
Receiver carrier/noise ratio (C/N) (dB)	8	14	20	8	14	20	8	14	20
Feeder loss A_f (dB)	3	3	3	3	3	3	5	5	5
Antenna gain, G (dB)	5	5	5	10	10	10	12	12	12
Minimum field strength for fixed reception, E_{min} (dBμV/m)	27	33	39	33	39	45	35	41	47

Table 2.7: Minimum field strength DVB-T2 8 MHz system (Rice Channel) [22].

Freq(MHz)	**Band III**				**Bands IV/V**			
System Variant GI 1/4	QPSK	16 QAM	64 QAM	256 QAM	QPSK	16 QAM	64 QAM	64 QAM
Receiver Noise Figure	5	5	5	6	7	7	7	6
Receiver C/N (dB)	8	14	20	18.9	8	14	20	
Feeder Loss A_f (dB)	3	3	3	2	3	3	3	4
Antenna Gain (dB)	5	5	5	7	10	10	10	11
Minimum field strength for fixed reception, E_{min} (dBμV/m)	27	33	39	46.3	33	39	45	47.1

2.2 NETWORK INFRASTRUCTURE FOR DTT TRANSMISSION

Generally, digital television transmitter networks consist of the following parts [27]:

- **The Head End**: made up of Central multiplex centre and Central monitoring and operations centre
- **The Transmission Link:** (Multiplex-to-Transmitter Link: radio relay, fiber optic or satellite) and
- **Distribution links**: (radio relay [Main and Fill-In Transmitters], satellite or cable);

2.2.1 Architecture of DVB-T/T2 Network

Figures 2.5 and 2.6 shows the architectural illustration of how DVB-T and T2 network is implemented [28]. The difference in the two networks is addition of new network nodes (T2 Gateway), a change in the modulator/transmitter to T2 modulator and implementation of the transmission link in T2 (T2-MI (Modulator interface)) can be both in ASI or IP whilst that in T1 is strictly ASI [28].

The specifications of the additional nodes (T2 gateway and T2 modulator) for Ghana are as listed in Appendix E.

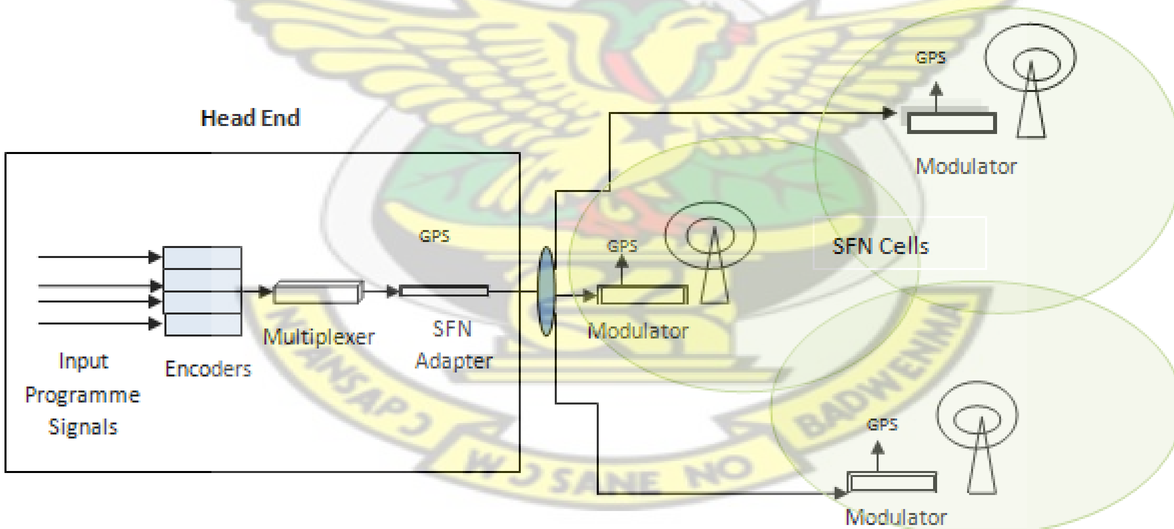


Figure 2.5: T1 DVB-T Typical Architecture [28].

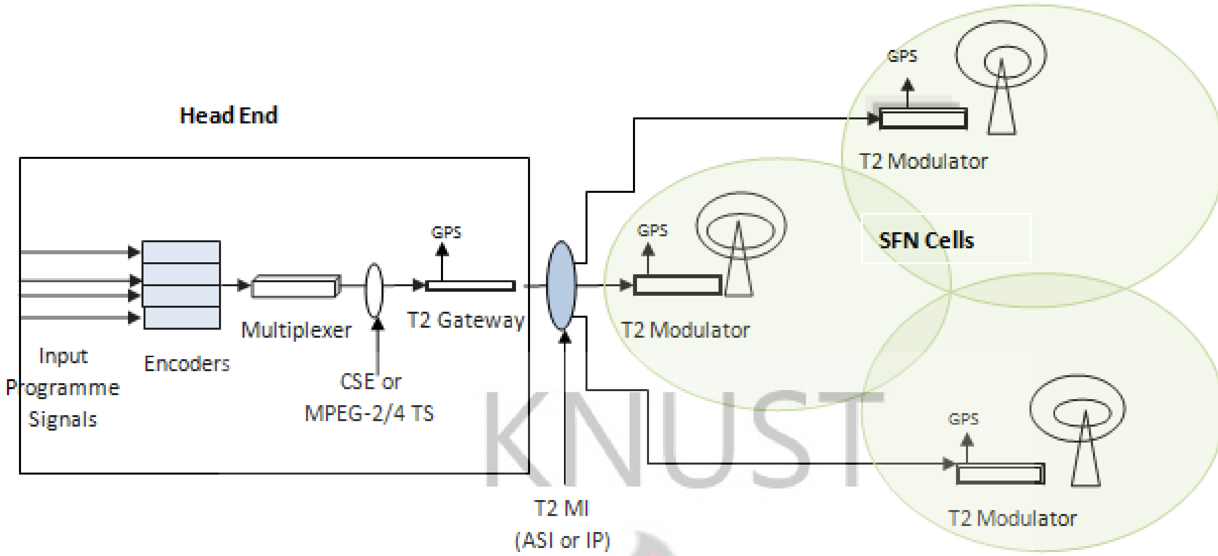


Figure 2.6: T2 DVB-T Typical Architecture **[28].**

Below are the key features needed for DVB-T2 implementation [28]:

- T2-MI
- SFN MISO, with seamless switch
- Multi-PLP support
- TFS (optional)

2.2.2 Distribution Link for DVB-T/T2 (Transmitting Site)

A block diagram of a transmitting site for a typical DTT transmission servicing programs from more than one multiplex where a single transmitting antenna is used is as shown in Figure 2.7 below. In such setups, a reserve transmitter configuration, (n+1), which can be used in case of maintenance or transmitter breakdown is incorporated. The reserve transmitter should then be adjusted to the frequency and the power of the transmitter it replaces. Better still a more robust transmitter configuration of (1+1) can be implemented as shown in Fig. 2.8:

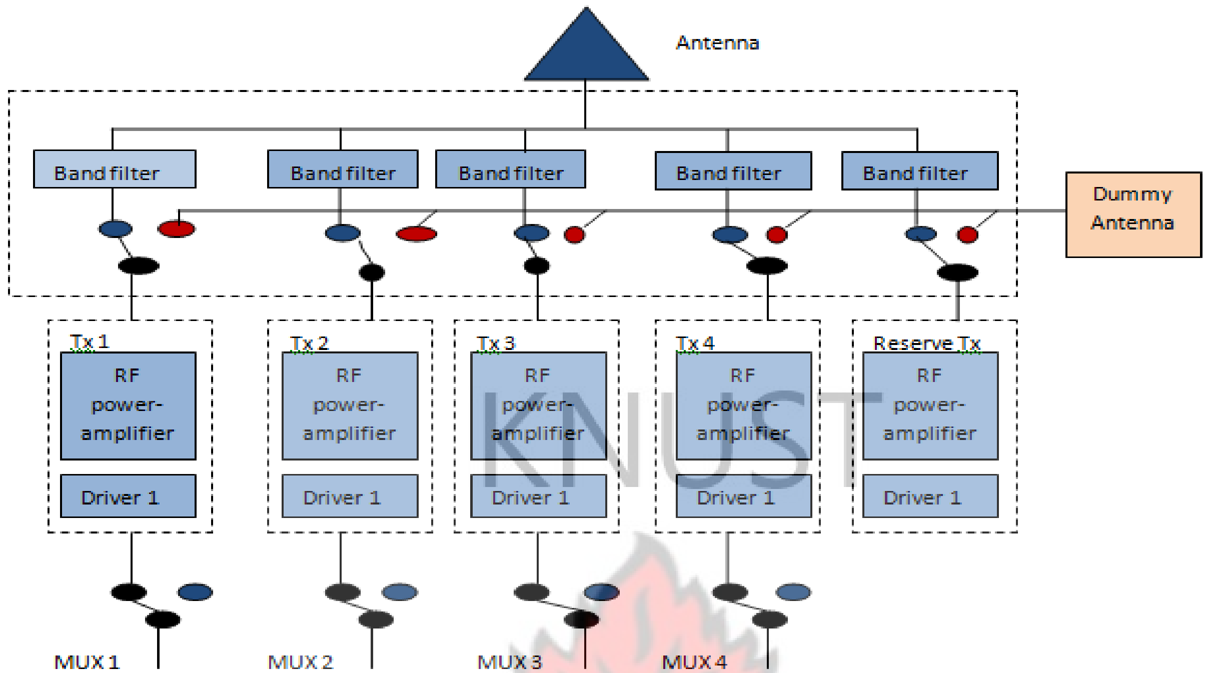


Figure 2.7: Typical Transmitting Site for Multiple Multiplexes using a single feeder cable and Antenna (n+1) [27].

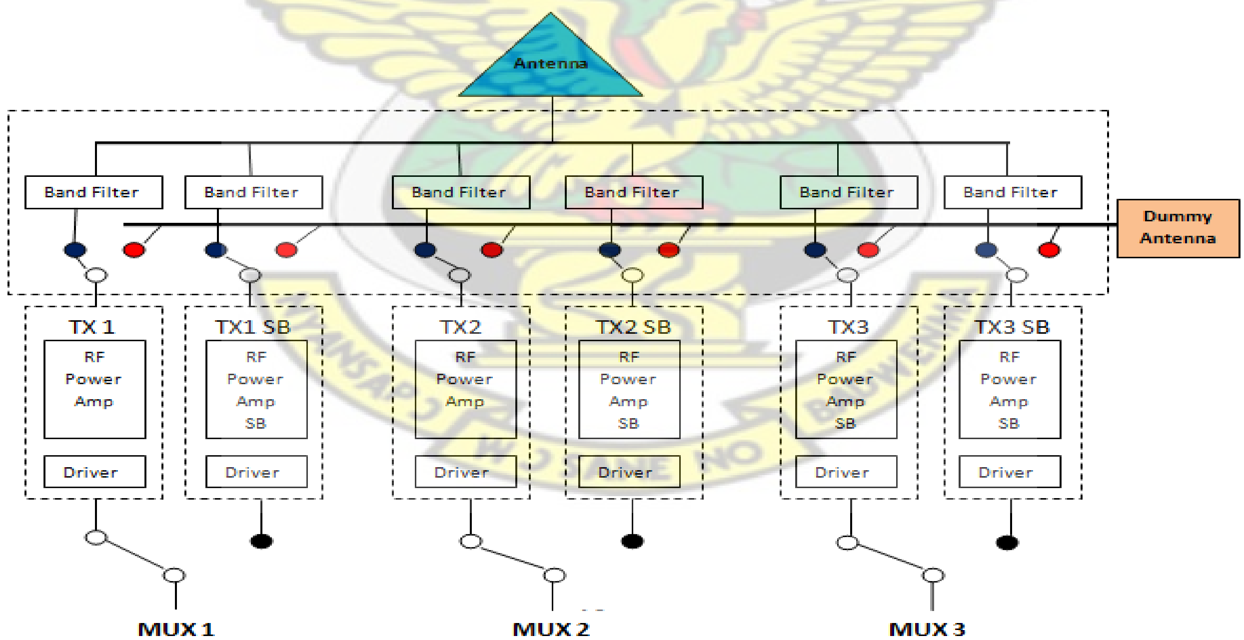


Figure 2.8: Typical Transmitting Site for Multiple Multiplexes using a single feeder cable and Antenna (1+1).

2.2.3 Sitting of Digital Transmitters

To ensure minimal technical and economic constraints in digital terrestrial television (DTT) implementation, DTT transmitters generally re-use the same sites as existing analogue TV transmitters [13]. However, other factors can drive the use of different sites by network operators.

2.2.3.1 Use of common sites

The use of common transmission site may be implemented when [17]:

- Different operators make uses of different frequencies within the same coverage
- The operators make use of similar network structure.

Advantages of the Usage of a Common Site

Use of common sites for transmission of existing and new multiplexes has the following advantage [27]:

- Existing facilities, like distribution link, transmitter building, mast, antenna and reserve transmitter, can be shared.
- Receiving systems of the transmitted signals will face little challenges with antenna orientation since both analogue and digital transmitters are co-sited.

Disadvantage of the Usage of a Common Site

The following disadvantages are identified when engineering and installing a common broadcasting site [27]:

- Initial setup must extensively take into account future extensions that may be needed, since it is often far more expensive to modify links, buildings, masts and antennas at a later date.
- Priority rules have to be made for use of limited space in buildings and masts. Common use of antenna combiners and antennas also requires clear agreements on responsibilities, costs and maintenance.
- When additional multiplexes are intended for a different kind of network, common use of sites is only partially possible.

Practices Used Around the World for DTT Transmitter Sitting

1. ***DTT Transmitter Sitting in UK** [29-30]**:***

- A total of 81 sites were planned for the transmission of UK's Digital Terrestrial Television Transmission to cover major conurbation and maximize population coverage. 51 were main stations and the remaining 30 relay stations (fillers)

- Each Transmitting Site (both main and fillers), accommodate the transmitters of all the six multiplexes (Collocation) planned for UK's DTT transmission (Use of Common Site)

- Existing UHF analogue transmitting sites were selected for DTT transmission (to maximize infrastructure costs and to ease reception by existing receiving antennas)

- The ERP needed by each transmitting site for the best coverage of transmitted signals (both mains and fillers) during and after the transition were outlined.

2. **DTT Transmitter Sitting in Hong Kong [21]**

- The main transmitters of all the multiplexes (A-E: 5 Multiplexes) are sited at 7 stations (Temple Hill, Castle Peak, Kowloon Peak, Golden Hill, Cloudy Hill, Lamma Island), thus a common site is used by the multiplex operators
- Standards for the ERPs used by each multiplex at each site well defined

2.2.3.2 Use of different sites

Different network sites may be necessary if [28]:

- Several operators make use of the same frequency band;
- Some multiplexes make use of dense networks.

Disadvantages of the use of different transmitting sites

The problem with the use of different sites for DTT broadcasting (non co-sited stations) includes [28]:

- Adjacent channel interference when the use of the first, second, or third adjacent channel on both sides of the wanted channel or the image channel.

2.3 RECEIVER REQUIREMENTS

2.3.1 Receiver (STB or Integrated Digital TV) Requirements for Reception of DTT Signals

STBs and Integrated Digital TVs used for the reception of DTT/DTH meets some Hardware and Functional Requirements set by the country or region they operate in. These requirements touches on issues pertaining to the Radio Frequency (RF), Demodulator, Demultiplexer, Decoding, Interfaces, Conditional Access (CA), Middleware and other general requirements such as power rating, frequencies and the likes. In Tables 2.8A, 2.8B and 2.9 are outlined the Hardware and Software Requirements for STBs for a given country [31-32]:

Table 2.8A: Hardware Specification for DTT STB [31-32].

Hardware Requirements		
R.F Input	Input Connector	IEC 169-2, Female
	Loop-through	IEC 169-2, Male
	Input signal level	To be determined by country
	Frequency range V.H.F	174 – 230 MHz
	Bandwidth in VHF	6MHz or 7 MHz (dependent on country VHF raster)
	Frequency range UHF	Normally 470-862 MHz
	Bandwidth in UHF	7 or 8 MHz (dependent on country UHF raster)
Demodulator	Demodulation	according to EN 300 744 v1.6.1
	Carrier Mode	Should support both DVB-T and DVB-T2
	FEC Rate	Should be able to support the minimum and maximum that are used for DTT broadcast
	Guard Interval	Should be able to support the minimum and maximum that are used for DTT broadcast
	SFN Operation	According to TS 101 191 V1.4.1
Demultiplexer	compliance	ISO/IEC 13818-1, ETSI TS 101 154 v1.8.1
	Data Rate	Up to a maximum rate, 32 Mbit/s for DVB-T and 51 Mbps for DVB-T2
Video Decoder (MPEG-4 or MPEG-2)	Transport stream	ISO/IEC 13818-1, ETSI TS 101 154 v1.8.1
	Video profile and level	ISO IEC 14496-10 for MPEG-4 and ISO/IEC 13818-2 Main Profile@Main level, ETSI TS 101 154 v1.8.1for MPEG-2
	Video Resolution	
	Audio Decoding	ISO/IEC 13818-3 (Mpeg1 layer 2) , ETSI TS 101 154 v1.8.1
	Audio Mode	

Table 2.8B: Hardware Specification for DTT STB [31 - 32].

Hardware Requirements		
Interfaces	Output format	Format of TV transmission adopted in the country (PAL variant, SECAM variant, or NTSC variant)
	R.F connectors	IEC 169-2, Female and IEC 169-2 Male
	Video Connectors	SCART (EN 50049-1 and EN 50157-2-1)
	Audio Connectors	
	Conditional Access	EN50221
General	Input Voltage	Voltage used by the country + 10%
	Input frequency	Frequency used by the country
	A.C Plug	Should be compliant with a set standard
	E.M.C (Radiated RF)	Should be compliant with a set standard
	E.M.C (RF Immunity)	Should be compliant with a set standard

Table 2.9: Summary of Functional Requirements of a DVB STB [31-32]

Aspect Ratio	
WSS Compliance	ETSI EN 300 294 V1.4.1
EPG	
Compliance	ETSI EN 300 468 v1.9.1
Character Set	ISO/IEC 8859-7
Tele Text	
Teletext transport	ETSI EN 300 472 V1.3.1
Teletext transcoding	ETS 300 706 level 1.5, to ITU-R BT.653-3
Character Set	ISO/IEC 8859-7
Subtitles	
Subtitles Compliance	ETSI EN 300 743 v1.3.1
Character Set	ISO/IEC 8859-7
Software Upgrade	
Compliance	ETSI TS 102 006 v1.3.2, simple profile
Language Support	
The Receiver must support language in accordance of the user preference. The languages must be supported in all menus in the Receiver software.	

2.4 REGULATORY CONSIDERATION

Regulatory decisions regarding the use of the frequency spectrum are taken by national regulatory bodies, on the basis of international treaties and recommendations. For this purpose, national administrations work together in international forums such as the International Telecommunication Union (ITU) and others if any (for example countries in Europe will, aside the ITU, also involve the European Conference of Postal and Telecommunications (CEPT) in their regulatory consideration) [27].

Digital terrestrial television transmissions make use of the frequency bands III (173-230 MHz) and IV/V (470-862 MHz). In addition mobile television can also make use of part of the L-band (1452-1479.5 MHz). This Section of the project deals with the main regulatory provisions for use of these bands, such as [27]:

- Service allocation in the Radio Regulations;
- Frequency Plans;
- Digital switch-over Policies

2.4.1 Service Allocation in the Radio Regulations

2.4.1.1 *General*

Radio Regulations prescribe the use of frequency bands and give procedures for managing the use of these bands.

A recent tendency, particularly in the European Union (EU), has been to regulate spectrum on a service and technology neutral basis. This approach may lead to the use of the same frequency band by services with very different technical characteristics, hence avoiding interference needs careful considerations [27].

2.4.1.2 *Band Allocations*

In Europe, the Middle East and Africa, band III (174-230 MHz) is allocated to broadcasting services and, in some countries, to mobile services whilst Band IV/V (470-862 MHz) is allocated to broadcasting services and, as a result of decisions made at WRC-07, for mobile services in the frequency range 790-862 MHz (TV channels 61 to 69) from 17 June 2015.

WRC-07 agreed that broadcasting services in GE06 should be protected from mobile services and that countries planning to implement mobile services in the frequencies between 790-862 MHz must coordinate with neighbouring countries prior to implementation. Furthermore, WRC-07 calls on the ITU to study compatibility between mobile and broadcasting services in the frequency range 790-862 MHz [27].

In addition Band IV/V is allocated to the following other services:

- Radio astronomy (channel 36), in some countries;
- Radio navigations services (645-862 MHz), in some eastern European countries;
- Fixed communication services in 790-862 MHz;
- Services ancillary to broadcasting (such as radio microphones) provided that broadcasting and mobile services are protected, in some countries.

2.4.2 Frequency Planning

2.4.2.1 *General*

For most broadcasting bands international a-priori frequency plans have been established, such as the GE-06 Agreement. The main conditions for a successful frequency plan are:

- Equitable access to the frequency band for all countries concerned [27];
- Avoidance of unacceptable interference;
- Flexibility for future developments.

Frequency plans provide [27]:

- The rights of the participating countries for use of transmissions of which the technical characteristics are described in detail;
- Procedures for the execution of the agreement;
- Procedures for modifications of the frequency plan;
- Procedures for notification of operational transmissions.

2.4.2.2 *Band III, and IV/ V*

The use of Band III and IV/ V for broadcasting and non-broadcasting services is regulated by the GE06 Agreement. Band III has been planned for digital radio (T-DAB) and digital television (DVB-T). Results of GE06 are often expressed in the number of "layers". "Layers" are not defined in GE06, but are in general understood as the number of channels that can be received in an area. Most countries achieved three T-DAB and one DVB-T "layer" in Band III. Almost all European countries have adapted a 7 MHz channel raster in Band III. Band IV/V has been planned for DVB-T in an 8 MHz channel. Most countries achieved seven or eight DVB-T "layers" in Band IV/V [33].

The procedures of the GE06 Agreement make a flexible implementation of the Plan possible. The main provisions in this respect are [33]:

- Plan entries can be used for broadcasting transmissions with different characteristics than specified in the Plan entry, provided that the interfering field strength of the Plan entry, calculated at a great number of points, is not exceeded; the so-called conformity check ;
- Plan entries can be used for different applications of broadcasting or mobile services provided that the band is allocated to the relevant service in the Radio Regulations and that the power density limit of the Plan entry is not exceeded;
- Plan entries can be modified after agreement of countries that are potentially affected by the change. It should be noted that the modification procedure can take a considerable time before all agreements have been reached. If after about 2 ¼ years the necessary agreements have not been reached, the proposed modification will lapse.

The GE06 Agreements contains two frequency plans, an analogue TV plan and a digital broadcasting plan. These two plans are not mutually compatible. After a transition period, the analogue TV plan will cease to exist and analogue television transmissions are no longer protected. The transition period ends on 17 June 2015. However in a number of African countries, including northern Africa, analogue television in Band III needs to be protected until 17 June 2020 [33].

2.4.3 Digital Switch-Over

National governments need to adopt a clear strategy for the transition from analogue to digital television that is supported by all organizations concerned. A number of elements that should be included in the strategy are [27]:

- Date for analogue switch-off.
- Coordination of frequencies with neighbouring countries for digital television during the transition period.
- Licensing process for digital terrestrial television;
- Agreements regarding termination of analogue television licenses;
- Provisions for simulcasting.
- Agreements with consumer equipment manufactures to ensure that a sufficient number of adequate digital receiving equipment is available in time.
- Provisions to enable low income households to buy digital receiving equipment.
- Communication campaigns to inform the public.

The manner in which digital television is introduced and the time period necessary to complete the process depends on the market and differs very much from country to country. The simulcast period, when broadcast services are transmitted in both digital and analogue formats in a given area, depends very much on the market and the switch-over strategies adopted. In practice, simulcast periods ranging from zero to fourteen years can be observed [16].

2.4.3.1 *Analogue switch-off*

Analogue television will no longer be protected after 17 June 2015 (and an additional five years for Band III in a number of African countries). However, the European Commission proposes that member-states complete digital switch-over by 2012 [33].

2.4.3.2 *Licensing*

National administrations prepare legislation taking into account ITU, CEPT agreements and, among EU member-states, EC policies and directives. On the basis of national legislation licenses for digital television are granted. Throughout Europe, the licensing processes for digital terrestrial television vary considerably. In some countries, network operators are granted licenses, in others, multiplex operators or content providers. Selection of applicants is sometimes done on the basis of auctions, in other cases by means of comparative tests ("beauty contests"). In most cases, public broadcasting transmissions are licensed by priority. License costs differ considerably, in some cases a fee is required that covers the costs of the licensing process by the regulator, in other cases "administrative pricing" of spectrum is used where the fee is related to the market value of the part of spectrum concerned [33].

2.4.3.3 Switch-Off Methods

The switch of analogue services could employ any of the following methods:

- Phase switch-off of analogue services.
- Nationwide switch-off of analogue services or
- Partial switch-off of analogue services.

The Switch-Off methods could be in phase, nationwide or partial:

2.4.3.3.1 *Phased switch-off of analogue services*

In a phased approach, analogue switch-off takes place by region. A digital broadcasting timetable is prepared detailing when analogue transmitters will be shut off in the regions. This approach has several benefits. Firstly, the lessons learnt in one region can be applied to improve the process. Secondly, the released frequencies can be re-used in a neighbouring region in order to increase its digital coverage and expand the digital service offering. Finally, this approach allows the cost and effort of migration over time [33].

Examples of Countries Using Phased shut-off of analogue services

Approach used in Germany, Brazil, Sweden, Switzerland, Czech Republic, Austria, Spain and the United Kingdom [33].

2.4.3.3.2 *Nation-wide switch-off of analogue services*

In a national approach, analogue terrestrial television services are shut off at the same time in the country. This approach allows all viewers to simultaneously benefit from the advantages of digital switchover, ensuring that all viewers are treated equally and given the same access to all services [27].

Examples of Countries Using National shut-off of analogue services

Approach used in the United States, Netherlands, Finland, Andorra, Luxembourg, etc [27].

2.4.3.3.3 ***Partial switch-off of analogue services***

In a partial approach, some analogue terrestrial television services are shut off in order to make frequencies available for a subsequent digital broadcasting launch.

This eliminates the need for prolonged simulcasting period. However, because the digital launch is preceded by analogue switch-off, viewers will temporarily lose access to some services until they are restored on the digital platform [27].

CHAPTER THREE

3.1 TECHNICAL CONSIDERATION

3.1.1 Digital Television Broadcasting in Ghana

3.1.1.1 Technology Issue

3.1.1.1.1 *Standard Adopted for Digital Television Broadcasting in Ghana*

The regulatory authority in Ghana, NCA, upon considering international agreements/treaties has opted for the DVB standards (DVB-T/T2, DVB-S and DVB-C) for its Digital Television Broadcasting to fixed services according to the decisions taken at RRC-06 [5].
However, a technology neutral approach has been proposed to be adopted for mobile TV broadcasting in Ghana. Presently, Terrestrial Digital Multimedia Broadcasting (T-DMB) and Digital Video Broadcasting for Handheld (DVB-H) are the two standards used by the two operators on the market (Black Star TV and Multi-Choice Ghana Limited in collaboration with MTN and Nokia) [5].

3.1.1.1.2 General Technical Requirements for Digital Television in Ghana

The transmission standard shall be DVB-T2 (EN 302 755) in a presentation standard of standard definition television (SDTV) until analogue switch off (ASO) and High definition television (HDTV) to be considered after ASO. H.264/AVC/MPEG-4 (part-10) and Advanced Audio Coding (AAC) shall be the compression technology to be adopted and MHEG-5 application programming interface (API) would be adopted for additional and interactive services [5].

3.2 Network Planning for the DTT Service in Accra

Ghana's DTT service is to operate in the frequency bands IV/V. As seen in Table 3.1A and B, some of the channels in these bands are currently used in the broadcasting of some existing terrestrial analogue television transmission in the Accra-Tema environs. For an interference free reception of both analogue and digital television broadcasting services in these bands, proper protection ratio and required minimum signal level of transmitted signals need to be established.

Table 3.1A: Current Occupancy for UHF Bands IV/V in the Greater Accra Region [35]

Band of TV Transmission	TV Stations	Channel Assigned in Accra and Tema Environs	Frequency/ MHz	Channel Status
Band IV		21	470 – 478	Not Used
	GTV Digital TV	22	478 – 486	Used
	GTV Digital TV	23	486 – 494	Used
		24	494 – 502	Not Used
		25	502 – 510	Not Used
	Metro Sports	26	510 – 518	Used
		27	518 – 526	Not Used
		28	526 – 534	Not Used
		29	534 – 542	Not Used
	Viasat 1	30	542 – 550	Used
		31	550 – 558	Not Used
		32	558 – 566	Not Used
		33	566 – 574	Not Used
		34	574 – 582	Not Used

Table 3.1B: Current Occupancy for UHF Bands IV/V in the Greater Accra Region [35].

Band V		35	582 – 590	Not Used
		36	590 – 598	Not Used
	Cable Gold	37	598 – 606	Used
	Cable Gold	38	606 – 614	Used
	Crystal X'tra	39	614 – 622	Used
	SKYY Digital	40	622 – 630	Used
		41	630 – 638	Not Used
	Crystal Plus	42	638 – 646	Used
		43	646 – 654	Not Used
	NET 2	44	654 – 662	Used
		45	662 – 670	Not Used
		46	670 – 678	Not Used
		47	678 – 686	Not Used
	eG (eTV)	48	686 – 694	Used
		49	694 – 702	Not Used
		50	702 – 710	Not Used
		51	710 – 718	Not Used
	Crystal Prime	52	718 – 726	Used
		53	726 – 734	Not Used
		54	734 – 742	Not Used
		55	742 – 730	Not Used
		56	730 – 738	Not Used
		57	738 – 746	Not Used
		58	746 – 754	Not Used
		59	754 – 762	Not Used
		60	762 – 780	Not Used

(red) →	DVB-T Channels	(blue) →	Analogue TV	(blank) →	Unassigned Channels

3.2.1 Protection Ratio Required for DTT and Analogue TV Transition in Accra and Tema Environs

Because digital television broadcasting can be operate at immediate adjacent channels of existing analogue channels and other DTT channels [21], a careful planning for protection ratio (for both co-channel and adjacent channels) need to be done to ensure interference-free transmission to other DTT services and also to existing analogue television services. As discussed at Chapter 2 of the project, protection ratio depends on three parameters: modulation scheme, guard interval and code rate.

The modulation parameters used by current DTT broadcasters serving Accra-Tema environs are as listed in Table 3.2.

Table 3.2: Modulation Parameters Used by Existing DTT Operators Serving Accra-Tema.

Multiplex		Skyy Digital	GTV		Cable Gold	
			MUX 1	MUX 2	MUX 1	MUX 2
Modulation Parameters	**Modulation Scheme**	64 QAM	64 QAM	64 QAM	64 QAM	64 QAM
	Guard Interval	1/8	1/8	1/8	1/8	-
	Code Rate	5/6	2/3	2/3	-	-

With a modulation scheme of 64 QAM and a code rate of 5/6 for SKYY Digital and 64 QAM and code rate 2/3 for the two multiplexes of GTV DTT transmission and also considering the present channel occupancy of terrestrial analogue television transmissions in the UHF Bands IV and V, the planning parameters that need to be considered for the Protection Ratio and Minimum Field Strength to ensure an effective running of the two systems (double illumination) are discussed for the three conditions below:

(i) DVB-T interfering with DVB-T
(ii) DVB-T interfering with PAL B/G
(iii) PAL B/G interfering with DVB-T

Considering the current occupancy of the UHF Bands IV/V indicated in Table 3.1, planning of DTT channels for the present UHF Band IV/V will take the form in Figures 3.1 and 3.2 below.

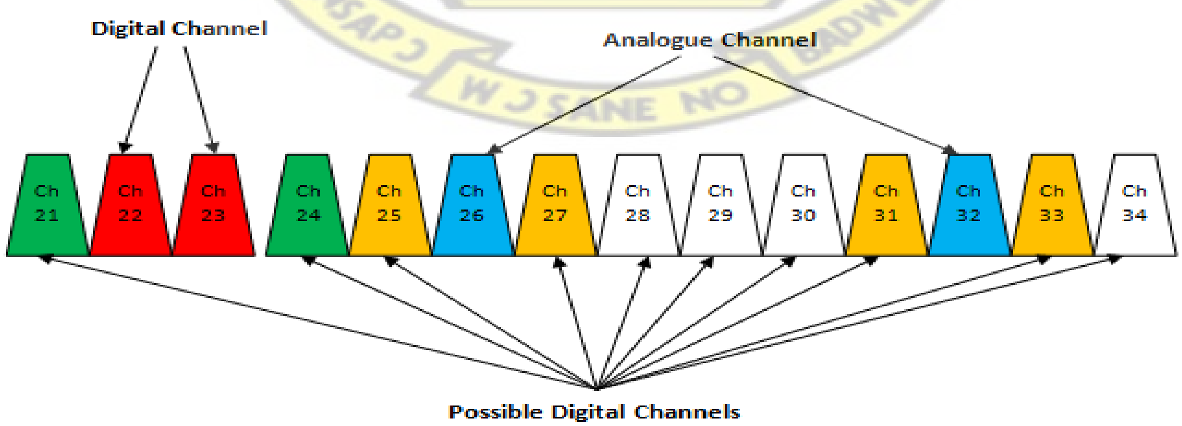


Figure 3.1: Possible Channel Planning in UHF Band IV for Accra in the Transition Period [35].

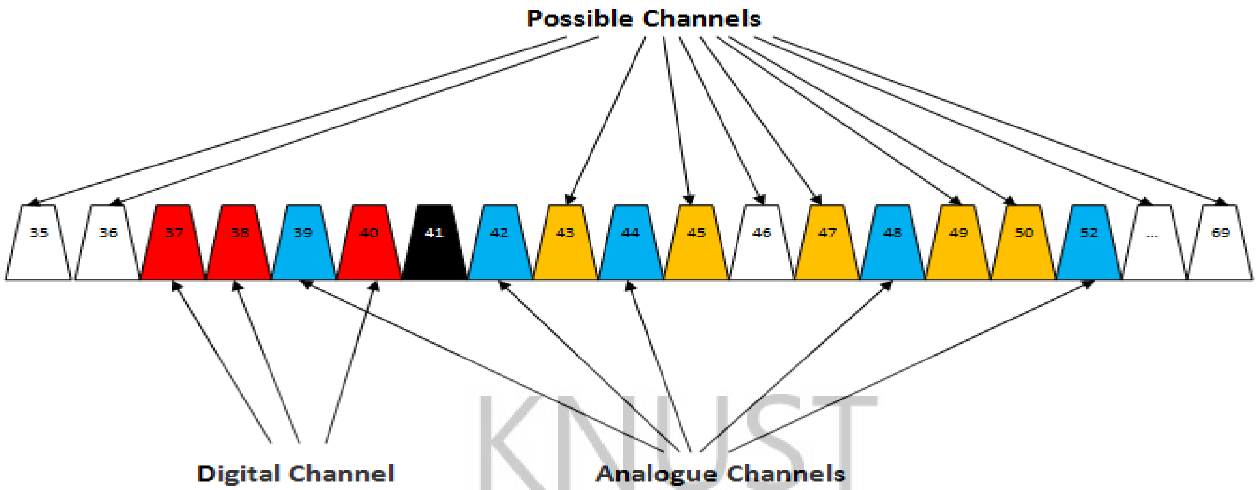


Figure 3.2: Possible Channel Planning in UHF Band V for Accra in the Transition Period [35].

In the Figures, the *Blue Coloured* channels are operational analogue television channels, the *Red Coloured* channels are operational DTT channels, those in *Yellow*, *White* and *Black* are unassigned channels, hence they constitute the potential channels that can be assigned for DTT services in Accra.

The unassigned channels at Ch 21 and 24 for Band IV are the immediate adjacent channels (n-1 and n+1) to the channels used by GTV for their pilot DTT transmission, as such, protection ratios considerations needed for DVB-T transmission on these two channels that will ensure interference-free operation will be -30 dB as indicated in Table 3.14, which represent protection ratio for DVB-T interfering with another DVB-T transmission in the lower (n-1) and upper (n+1) adjacent channels respectively.

On the other hands, the *Yellow Coloured* channels (Ch 25, 27, 31 and 33 for Band IV), are channels adjacent to existing analogue television channels (Ch 26 and Ch 32) operating in Accra. Thus, the protection ratio needed for the occupancy of these channels for DVB-T transmission that will ensure an interference free transmission to the existing analogue channels will be 34 dB for tropospheric interference and 40 dB for continuous interference.

The Protection Ratios for the channels in Green (which are the n+2, n+3, n-2, n-3 channels) has not yet been indicated by the ITU-R. However, protection to and from these channels, if indicated will be minimal compared to those at the n+1 and n-1 channels.

Taking Ghana’s terrestrial analogue and digital television standards adopted (PAL B/G and DVB-T), protection ratios needed to considered for co-channel and adjacent channels (n+1 and n-1) for the Accra and Tema environs will be as shown in Table 3.3.

Table 3.3: Protection Ratio for DVB-T and Analogue TV Transmission in Ghana.

<table>
<tr><td colspan="6">DVB-T INTERFERING DVB-T</td></tr>
<tr><td colspan="6">Co-channel protection ratios (dB) for DVB-T interfered with by DVB-T/ dB</td></tr>
<tr><td rowspan="2">ITU-Mode</td><td rowspan="2">Modulation</td><td rowspan="2">Code rate</td><td colspan="3">Protection Ratio</td></tr>
<tr><td>Gaussian</td><td>Rice</td><td>Rayleigh</td></tr>
<tr><td>M3</td><td>64-QAM</td><td>2/ 3</td><td>19</td><td>20</td><td>22</td></tr>
<tr><td colspan="6">Adjacent Channel Protection Ratio for DVB-T interfered with by another DVB-T/ dB</td></tr>
<tr><td rowspan="2">Wanted System</td><td rowspan="2">Interfering System</td><td colspan="4">`Protection Ratio</td></tr>
<tr><td colspan="2">Lower Adjacent (n-1)</td><td colspan="2">Upper Adjacent (n+1)</td></tr>
<tr><td>DVB-T</td><td>DVB-T</td><td colspan="2">-30</td><td colspan="2">-30</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">DVB-T INTERFERED WITH BY ANALOGUE TELEVISION / dB</td></tr>
<tr><td colspan="6">Co-channel protection ratios for DVB-T interfered with by Analogue TV (code rate=2/3 and Modulation = 64 QAM)</td></tr>
<tr><td>Wanted System</td><td colspan="2">Interfering System</td><td colspan="3">Protection Ratio/dB</td></tr>
<tr><td>DVB-T</td><td colspan="2">PAL</td><td colspan="3">4</td></tr>
<tr><td colspan="6">Adjacent Channel Protection Ratio for DVB-T interfered with by Analogue PAL / dB</td></tr>
<tr><td>Wanted System</td><td colspan="2">Interfering System</td><td>Upper Adjacent</td><td colspan="2">Lower Adjacent</td></tr>
<tr><td>DVB-T</td><td colspan="2">PAL B</td><td>-43</td><td colspan="2">-</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="6">ANALOGUE TV (PAL) INTERFERED WITH BY DVB-T/ dB</td></tr>
<tr><td colspan="6">Co-channel protection ratio for analogue TV signals interfered with by DVB-T Signals</td></tr>
<tr><td rowspan="2">Wanted System</td><td rowspan="2">Interfering System</td><td colspan="4">Co-channel Protection Ratio</td></tr>
<tr><td colspan="2">Tropospheric interference</td><td colspan="2">Continuous interference</td></tr>
<tr><td>PAL B,G</td><td>DVB-T</td><td colspan="2">34</td><td colspan="2">40</td></tr>
<tr><td colspan="6">Adjacent channel protection ratio for analogue TV signals interfered with by DVB-T Signals</td></tr>
<tr><td>Wanted System</td><td>Interfering System</td><td colspan="2">Tropospheric interference</td><td colspan="2">Continuous interference</td></tr>
<tr><td>PAL B,G</td><td>DVB-T</td><td colspan="2">-7</td><td colspan="2">-4</td></tr>
</table>

3.2.2 Proposed Site for DVB-T Transmission in Greater Accra Region

In the Greater Accra Region, bidders for DTT transmission are required to select from the list of sites in Table 3.4. Bidders may propose new sites for areas where no existing broadcasting site is suitable for their proposed DTT solution being mindful of the Guidelines for the Deployment of Communications Infrastructure, 2010 [5].

Table 3.4: Proposed Site for DVB-T Transmission for Greater Accra Region.

Name/Location of Site	Coordinates		Site Altitude	Height of Tower
	Latitude	Longitude		
Adjangote	05°43’27,12”N	000°14’05,28”W	286	130
University of Ghana, Legon	05° 38’ 56.2”N	000° 11’ 52.2”W	121	90
Kokomlemle	05^{0} 34’ 42.7"N	000^{o} 11’ 00.5"W	69	61
MacCarthy Hill	05^{o} 36’ 49.8”N	000^{o} 18’ 00.1" W	130	60
Maamobi	05^{o} 35' 55.4"N	000^{O} 11' 19.0"W	53	-
Tetsonya	05^{o} 49' 54.2"N	000^{O} 36' 33.8"E	2	45
Ashongman	05^{o} 50' 0"N	000^{O} 11' 0.5"W	158	30
Tema New Town	05^{o} 39' 28.4"N	000^{O} 01' 35.3"E	26	50
Asylum Down	05^{O} 34' 06.2"N	000O 12' 13.0"W	22	60

3.2.2.1 Sites Presently Used by DTT Transmitters Servicing Accra and Tema Environs

Four sites are currently used by existing DVB-T broadcasters serving Accra and Tema environs. The two DVB-T transmitters used by GBC are at Adjangote with SKYY Plus transmitter at McCarty Hill and the other two transmitters used by Cable Gold DVB-T transmission located at Sakumono and GIMPA legon campus. Figure 3.3 is the map of Accra indicating the present sites of the four DTT transmitters servicing Accra and Tema environs and the geographical coordinates of these sites are further given in Table 3.5:

Table 3.5: Location of DTT Transmitters Servicing Accra and Tema Environs.

	GTV DVB-T Transmitter	**SKYY Digital DVB-T Transmitter**	**Cable Gold Transmitter**
Transmitter Location	Adjangote 05^0 43' 23.72" N 00^0 13' 00.6" W	McCarthy Hill N 05^0 33' 48.0" W 0^0 17' 59.0"	Sakumono and GIMPA, Legon 05° 38' 56.2"N 000° 11' 52.2"W
Altitude of Transmitter Sites / m	286 m	113m	112m
Height of Transmitting Antenna /m	55 m	40 m	35 m

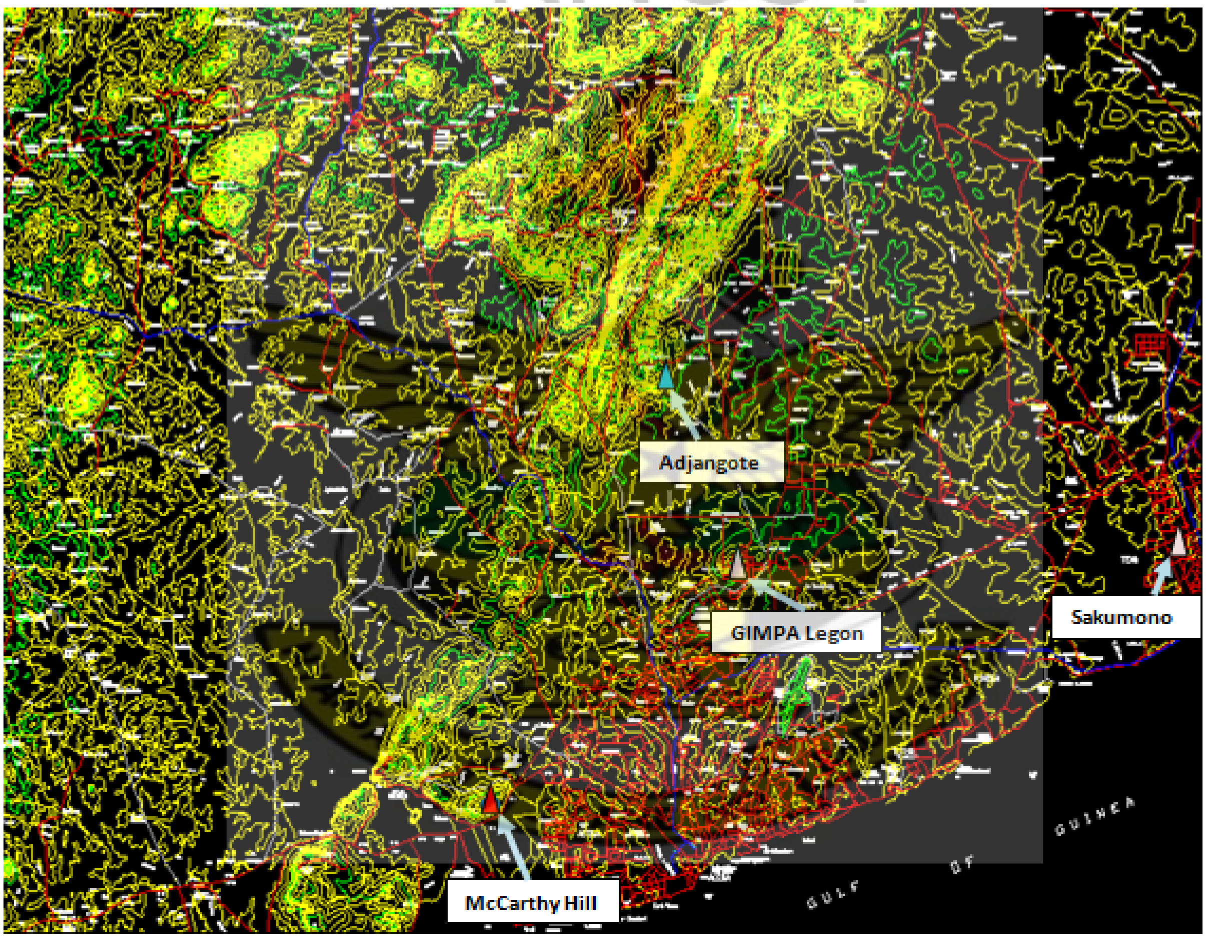
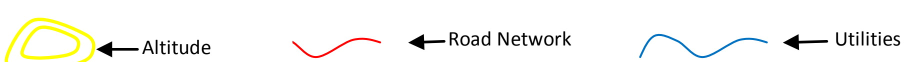


Figure 3.3: The Map of Accra and Tema Environs.



3.2.2.1.1 Issues Raised with the Sitting of Transmitter Servicing Accra and Tema Environs

- The Existing DTT Transmitters are not co-located.
- The Transmitters are also not collocated with existing analogue UHF transmitters.

3.2.2.1.2 Implications of Current Transmitter Sitting to Transition

- Because the existing DTT transmitters are not co-located, the use of a single antenna for the reception of signals from them is difficult at some locations in Accra.
- Because the two transmitters are also not collocated with the sites used by existing terrestrial analogue transmitters, it makes it difficult to use a single antenna for the reception of both the analogue and digital television transmission, thus, raise the cost for reception since viewers who want to enjoy both the analogue and digital services at this present time of double illumination will have to acquire more than a single receiving antenna.

3.2.2.2 Comparison of Current DVB-T Transmitter Sitting with Practices around the World

Table 3.6 compares current sitting of DVB-T transmitters servicing Accra and Tema with available practices in transmitter sitting in countries considered in Chapter Two of this Study:

Table 3.6: Comparison of DVB-T Transmitter Sitting in Accra to Practice across the World.

Practice Across the World	Current Practice in Ghana	Comments/Remark
Transmitters (main and fillers) used for DTT transmission are collocated with each other (Example : UK, Hong Kong)	Current DTT Transmitters (main and fillers) used in DTT transmission in Accra are not collocated.	The current DTT transmitters sitting in Accra (not collocated), makes reception of the two DTT multiplex difficult (and not possible) at certain locations in Accra
Transmitters for DTT transmission are located in the same sites as UHF analogue Transmitters	Current DTT transmitters are not located at sites for DTT Transmitters	Present DTT Transmitter Set-up makes reception of both UHF terrestrial Analogue TV and DTT difficult and sometimes more expensive, since the direction of existing UHF antennas will have to be changed from their existing positions to make reception of both terrestrial analogue and digital television possible
Standards are set for the Transmitter ERP to be used at the various transmission sites that service intended coverage areas to check interference with other DTT and analogue TV services	Standard for Transmitter ERP to be used at the transmitter sites not yet set	Because the ERP for the various sites in Accra (and around the country) has not been defined, operators of DTT transmitters may not transmit at the required power for DTT reception for the whole of Accra and Tema environs.

3.2.3 Assessment of the Minimum Field Strength for DTT Transmission in Accra

Using the formulae in Appendix A and noise bandwidths provided in Table 3.6, the expected minimum field strength that should be recorded at the receiver end for various modulation schemes and code rate is as shown Table 3.6.

Table 3.6: Minimum Field strength for fixed reception for various modulation parameters.

Frequency (MHz)	200			550			700		
System variant guard interval ¼	QPSK 2/3	16-QAM 2/3	64-QAM 2/3	QPSK 2/3	16-QAM 2/3	64-QAM 2/3	QPSK 2/3	16-QAM 2/3	64-QAM 2/3
Noise bandwidth, *B* (MHz)	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6
Receiver noise figure, *F* (dB)	5	5	5	7	7	7	7	7	7
Receiver noise input voltage, U_N (1) (dB(μV))	8.4	8.4	8.4	10.4	10.4	10.4	10.4	10.4	10.4
Receiver carrier/noise ratio (*C*/*N*) (dB)	6.9	13.1	18.7	6.9	13.1	18.7	6.9	13.1	18.7
Urban noise (dB)	1	1	1	0	0	0	0	0	0
Minimum receiver input voltage, U_{min} (dB(μV))	16.3	22.5	28.1	17.3	23.5	29.1	17.3	23.5	29.1
Conversion factor *K* (dB)	12.4	12.4	12.4	20.5	20.5	20.5	24.5	24.5	24.5
Feeder loss A_f (dB)	3	3	3	3	3	3	5	5	5
Antenna gain, *G* (dB)	5	5	5	10	10	10	12	12	12
minimum field strength for fixed reception, E_{min} (dB(μV/m))	26.7	32.9	38.5	31.8	37.6	42.6	35.8	41.6	46.6

From Table 3.6, fixed reception in Band V, the minimum signal level for DVB-T using 64 QAM and a code rate of 2/3 (parameters used by SKYY Digital) is 46.6 dBμV/m for 70% location probability (acceptable reception) and 75 dBμV/m for 95% location probability (good reception).

GTV's pilot DVB-T also uses the same parameters for the modulation and code rate but is assigned to operate in Band IV. Hence a minimum signal level of 42.4 dBμV/m is required for 70% coverage and 50 dBμV/m for 95% coverage.

Section 3.2.1.3 gives field strength measurements taken at selected sites in Accra and Tema environs to assess the quality of signal received for the two DTT transmissions.

3.2.3.1 Measured Field Strength for DTT Reception in Accra and Tema Environs

Two Set-Ups, outlined in Appendix B, were used in assessing the reception quality of the DTT transmissions in Accra and Tema environs. The assessments of qualities of the received DTT signals were based on three parameters: Signal Level (**SL**), Modulation Error Rate (**MER**) and Bit Error Rate (**BER**).

3.2.3.1.1 Selected Sites for DTT Reception Analysis

Twenty selected sites were considered. These sites were selected based on their varying topological makeup. Tables 3.15 A and B gives the geographical coordinates and altitudes of the selected sites as well as the distances of the sites from the two existing DVB-T transmitters servicing Accra and Tema environs. Figures C1, C2 and C3 in Appendix C are the maps indicating the distances from the selected sites to the location of the two DTT transmitters (Broadcasting House (BH) and McCarthy Hills).

Based on the digital map digital map of Accra, the path profile of the selected sites to the two DTT transmitter locations is outline in Figures C3 to C38 in Appendix C.

Table 3.7 A: Geographical Coordinates of the Locations where Measurements were Taken.

Location	Geographical Coordinate	Distance from GTV transmitter/km	Distance from SKYY Digital Transmitter/km	Altitude of location/m
BH 2	**Latitude** 6^{o} 22'12.4366" N **Longitude** 1^{o} 14' 38.0555" W	0.816	12.976	80.40
Osu	**Latitude** 6^{0} 22' 48.6669" N **Longitude** 1^{0} 13' 48.8661" W	3.53	12.56	81.88
GAEC	**Latitude** 6^{0} 23' 44.5814" N **Longitude** 1^{0} 15' 23.1799" W	10.41	14.98	93.13
Kokomlemle	**Latitude** 6^{0} 22' 45.5436" N **Longitude** 1^{0} 15' 06.8807" W	2.918	10.54	49.8
Gbatsona	**Latitude** 6^{0} 22' 47.0852" N **Longitude** 1^{0} 13' 56.9012" W	9.89	22.04	98.31
Osu (House)	**Latitude** 6^{0} 22' 47.6704" N **Longitude** 1^{0} 13' 57.7943" W	3.21	12.34	49.29
Ablenkpe (Skyy House)	**Latitude** 6^{0} 22' 47.0963" N **Longitude** 1^{0} 13' 31.8813" W	3.81	7.95	49.38
Air Port Residential Area	**Latitude** 6^{0} 23' 57.6518" N **Longitude** 1^{0} 14' 02.6872" W	2.45	13.45	87.68
Tema (Comm. 3 Qt)	**Latitude** 6^{0} 22' 50.8050" N **Longitude** 1^{0} 11' 38.3505" W	18.88	32.56	43.61
Spintex	**Latitude** 6^{0} 23' 01.9961" N **Longitude** 1^{0} 13' 50.0725" W	7.71	19.88	61.82

Table 3.7B: Geographical Coordinates of the Locations where Measurements were Taken.

Location	Geographical Coordinate	Distance from GTV transmitter/km	Distance from SKYY Digital Transmitter/km	Altitude of location/m
Dansoman (Yellow Kiosk)	**Latitude** 6^0 21' 53.1190" N **Longitude** 1^0 15' 44.7608" W	6.562	3.53	43.76
New Bortianor	**Latitude** 6^0 21' 30. 9360" N **Longitude** 1^0 17' 35.3500" W	17.89	5.98	102.81
Gbawe	**Latitude** 6^0 22' 02.6821 N **Longitude** 1^0 16' 50.6767 W	13.08	2.41	115.06
Kokrobite	**Latitude** 6^0 20' 38.9962 N **Longitude** 1^0 17' 53.9403 W	21.3	9.37	107.83
Weija	**Latitude** 6^0 22' 04.0540 N **Longitude** 1^0 17' 22.7104 W	16.3	3.96	123.12
Accra New Town	**Latitude** 6^0 21' 21.5937" N **Longitude** 1^0 14' 49.3405" W	2.78	11.01	41.07
Kaneshie	**Latitude** 6^0 21' 35.1464" N **Longitude** 1^0 16' 18.9864" W	5.78	6.31	40.98
Korle-Bu	**Latitude** 6^0 24' 28.0479" N **Longitude** 1^0 13' 52.2937" W	6.8	8.01	49.09
Ashonman Estate	**Latitude** 6^0 23' 53.2431" N **Longitude** 1^0 15' 29.3947" W	13.45	18.58	96.25
Ashaley-Botwe	**Latitude** 6^0 24' 00.0779" N **Longitude** 1^0 13' 30.7822" W	12.89	22.76	92.31
Ablekuman	**Latitude** 6^0 23' 02.7284 N **Longitude** 1^0 16' 54.1221 W	14.66	7.95	100.71

3.2.3.2 Signal Quality (SL, BER and MER) Measured at Selected Sites Compared to the Minimum Signal Level Set by ITU-R for DVB-T Reception (Using Set-Up A)

Table 3.8 gives records of the measured signal level (SL), Bit Error Rate (BER) and the Modulation Error Rate (MER) at selected sites, for SKYY Digital Transmission in Accra and Tema environs, using Set-Up A when receiving antenna was directed towards McCarthy Hill (Site for SKYY Digital DTT Transmitter) and Broadcasting House 3, BH 3, (Site for GTV's DTT Transmitter) respectively.

On the other hands, Table 3.9 provides the recorded values for the received SL, BER and MER at the selected sites, for GTV's DVB-T transmission in Accra and Tema environs using Set-Up A, when the receiving antennas were directed towards McCarthy Hills and BH 3 respectively.

The comparison of the received signal strength (SL) is in relation to that set by the ITU-R for 70% location probability (acceptable reception as in Table 3.6) whilst that of the modulation error rate is base on the minimum indicated at Appendix E.

Table 3.8: Measured Signal Level (SL) of SKYY Digital Transmissions at Selected Sites When Antennas were Directed towards McCarthy Hill and BH 1's Direction **(Set-Up A).**

	Antenna in McCarthy Hill's Direction					Antenna in BH 1's Direction				
Location	**Measured SL at Selected Sites / dBμV**	**Deviation from Min. SL by ITU-R / dBμV**	**Bit Error Rate (BER)**	**MER / dB**	**Dev. Of MER from Min. / dB**	**Measured SL at Selected Sites / dBμV**	**Deviation from Min. SL by ITU-R / dBμV**	**Bit Error Rate (BER)**	**MER / dB**	**Dev. Of MER from Min. / dB**
BH 2	45	4	3	24	4	0	49	0	0	20
Osu (Oxford Street)	40	9	4	24	4	23	25	2	15	5
GAEC	45	4	2	25	5	33	13	6	21	1
Kokomlemle	44	5	2	24	4	23	25	4	16	4
Gbatsona	35	14	3	24	4	0	49	0	0	20
Osu (Near State House)	39	10	4	21	1	23	25	213	16	4
Ablenkpe	45	4	0	25	5					
Airport Rs. Ar.	45	4	0	25	5	23	25	213	10	14
Tema (Com. 3)	43	6	0	24	4					
Spintex	41	8	2	24	4	36	13	5	15	5
Dansoman, Yellow Kiosk	45	4	2	23	3	29	20	6	16	4
New Bortianor	45	4	3	20	0	20	29	7	15	5
Gbawe	42	7	3	23	3	28	21	4	19	1
Kokrobete	0	49	0	0	20	0	49	0	0	20
Weija	45	4	0	25	5	45	4	3	25	5
Accra New Town	44	5	3	25	5	23	25	7	14	6
Kaneshie	45	4	0	25	5	45	4	2	25	5
Korle-Bu	45	4	0	25	5	29	20	3	18	2
Ashonman Estate	45	4	0	24	4	0	49	0	0	20
Ashaley-Botwe	33	16	6	19	1	0	49	0	0	20
Ablekuman	29	20	8	18	2	0	49	0	0	20

Table 3.9: Measured Signal Level (SL) of GTV's Digital Transmissions at Selected Sites When Antennas were Directed towards McCarthy Hill and BH 1's Directions Respectively (**Set-Up A**).

	Antenna in McCarthy Hill's Direction					**Antenna in BH 1's Direction**				
Location	**Measured SL at Selected Sites / dBµV**	**Deviation from Min. SL by ITU-R / dBµV**	**Bit Error Rate (BER)**	**MER / dB**	**Dev. Of MER from Min. / dB**	**Measured SL at Selected Sites / dBµV**	**Deviation from Min. SL by ITU-R / dBµV**	**Bit Error Rate (BER)**	**MER / dB**	**Dev. Of MER from Min. / dB**
BH 2	45	1	1	25	5	45	1	0	25	5
Osu	45	1	2	25	5	45	1	0	25	5
GAEC	38	6	213	13	7	40	4	4	21	1
Kokomlemle	45	1	2	24	4	45	1	0	25	5
Gbatsona	24	20	213	11	9	13	31	213	16	4
Osu (Near State House)	45	1	0	25	5	45	5	0	25	5
Ablenkpe	45	1	0	24	4	43	1	3	24	4
Airport Rs. Ar.	45	4	1	24	4	45	1	0	25	5
Tema (Comm. 3)	35	10	4	24	4	37	7	4	24	4
Spintex	29	15	3	20	0	34	10	2	24	4
Dansoman, Yellow Kiosk	39	5	5	24	4	44	0	3	24	4
New Bortianor	31	13	4	20	0	39	5	3	23	3
Gbawe	25	19	8	18	2	34	10	4	21	1
Kokrobete	0	44	0	0	20	23	21	0	0	20
Weija	36	8	1	24	4	39	5	0	25	5
Accra New Town	45	1	0	25	5	45	1	0	25	5
Kaneshie	43	1	1	24	4	45	1	0	24	4
Korle-Bu	38	6	3	24	4	39	6	2	24	4
Ashonman Estate	28	16	7	19	1	35	9	5	21	1
Ashaley-Botwe	27	17	8	19	1	31	13	5	21	1
Ablekuman	0	44	0	0	20	0	44	0	0	20

3.2.3.2.1 Analysis of the Received Signals for SKYY Digital and GTV's DVB-T Transmission at the Selected Sites When Set-Up A Was Used

3.2.3.2.2 Reception for SKYY Digital and GTV's DVB-T Transmission at Selected Sites

Figures 3.4 and 3.5 compares the received signal levels recorded for SKYY Digital and GTV's DVB-T transmission at the selected sites when;

- The receiving antenna was directed towards McCarthy Hill and
- The receiving antenna was directed towards BH 3

The signal levels recorded were compared to the set minimum (for signal level) by the ITU-R for 70% location probability (acceptable reception).

In the figures, the bars in blue represent measured signal levels recorded at the selected sites, when antenna is directed towards McCarthy Hill's (where SKYY Digital's DVB-T transmitter is located) directions whilst those in red indicate measured signal level at the sites when the antenna is directed towards BH 3 (BH 3 at Kanda: where GTV's DVB-T transmitter is located). The green bar represent the minimum signal level set by the ITU-R for the reception of DVB-T to fixed reception in band V using 64 QAM and code rate of 2/3.

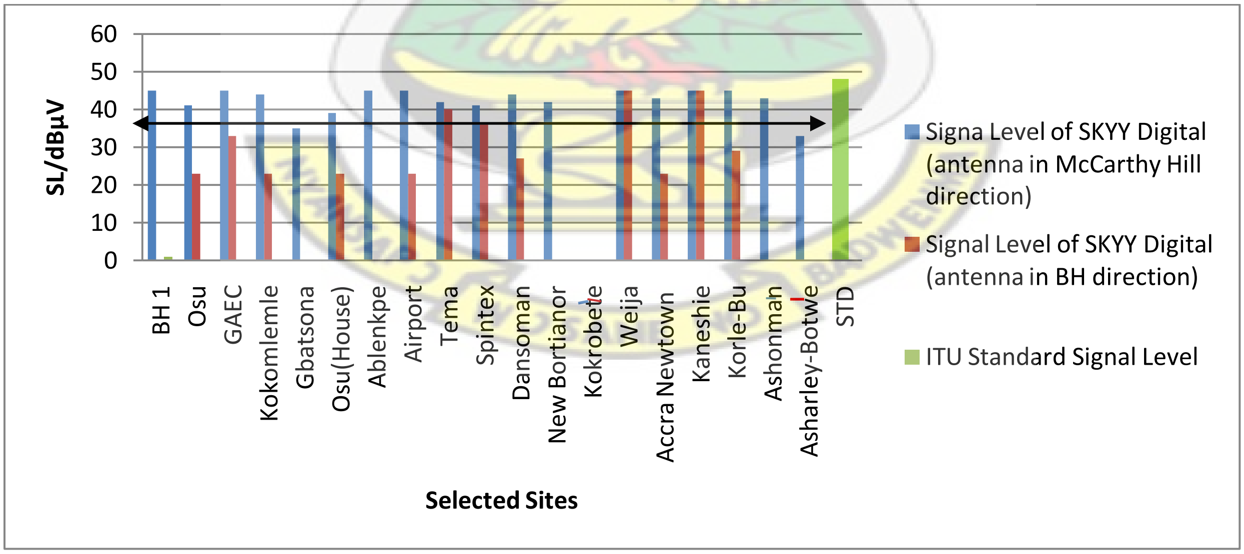


Figure 3.4: Comparison of Signal Level Received for SKYY Digital DVB-T Transmission at Selected Sites to that set as minimum by ITU-R.

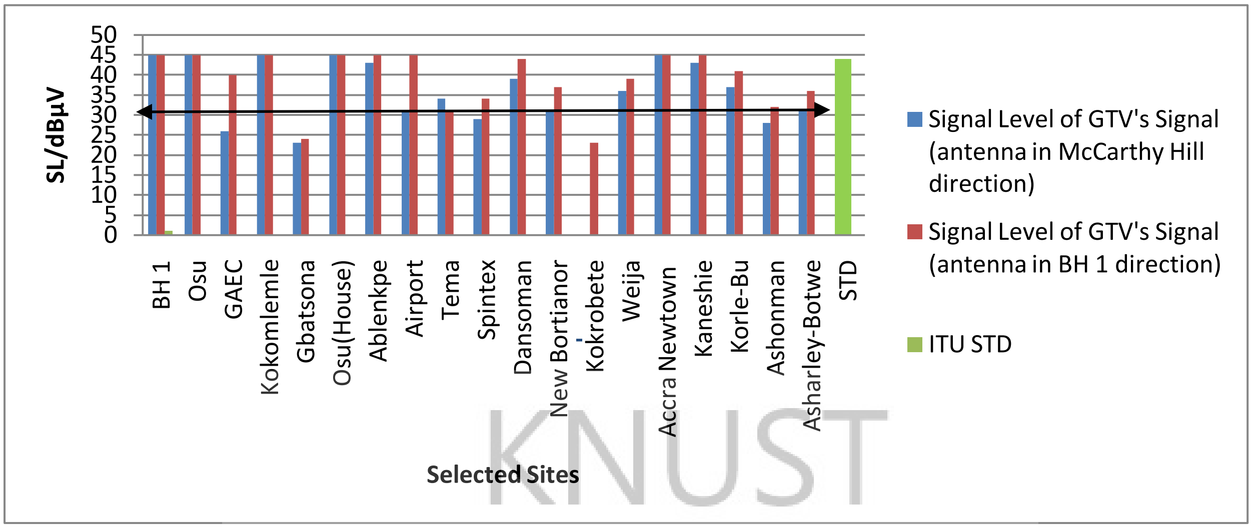


Figure 3.5: Comparison of Signal Level Received for GTV's DVB-T Transmission at Selected Sites to that set as minimum by ITU-R.

3.2.3.2.3 Findings for the Values Recorded for SKYY Digitals Reception at the Selected Sites (for Set-Up A)

- The direction of the receiving antenna had a great influence on the reception quality of both multiplex at a time.

  When antenna direction was towards one of the DTT transmitters, reception quality of signals from the other transmitter is poor. The level of digital signal degradation of the affected multiplex at some sites (Example Atomic Energy Commission and Ashaley-Botwe) were so bad it renders the reception of the affected multiplex unable to be interpreted by the STB (no reception). Figures 3.6 and 3.7 illustrate reception when antenna was directed toward one of the DTT transmitters.
- For sites closer to one of the DTT transmitters (Example Kanda, Osu, kokomlemle for GTV's DTT Transmitter and Weija, Gbawe for SKYY Digital's DTT Transmitter), antenna direction directed to the distance transmitter makes reception of both multiplex possible. However the antenna used in the reception for this exercise was Yagi-Uda antenna, which back lobs help in the reception of the less distance transmitter and so may not be same for some other antenna types.

- Presently, reception of both multiplex at Areas like Kokrobete, Labor and some part of Kasua is non existence. Despite SKYY Digital's antenna closer to these sites.

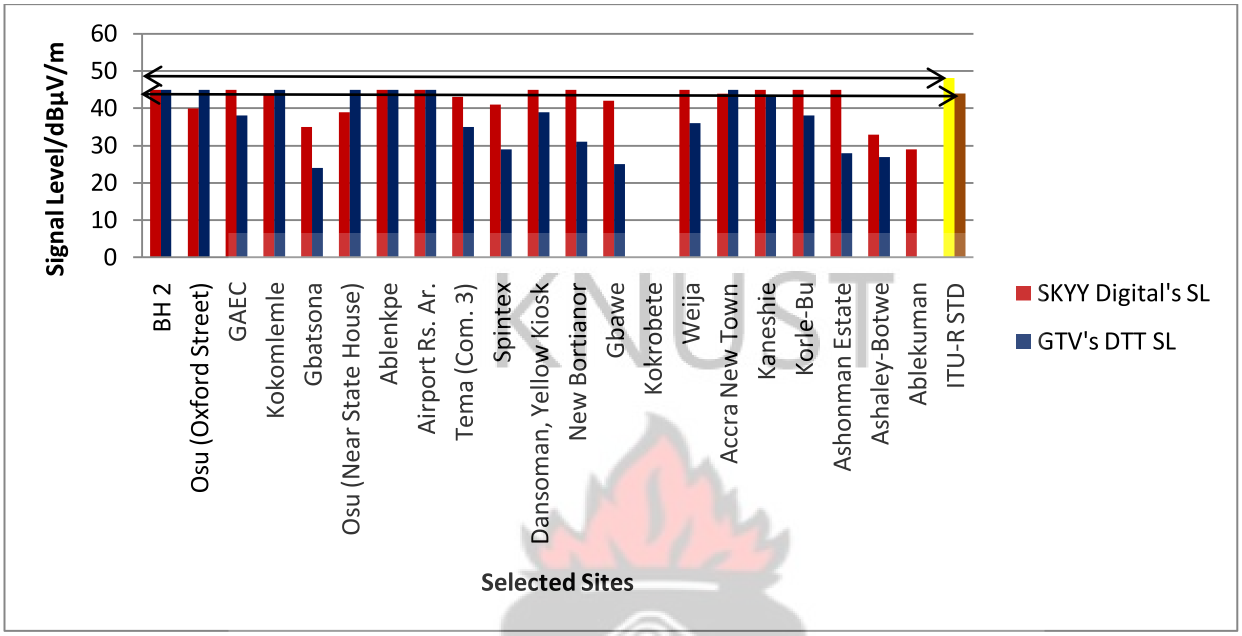


Figure 3.6: Received Signal Level for SKYY Digital and GTV's DTT Transmission at Selected Sites when Antenna was Panned toward McCarthy Hill's Direction.

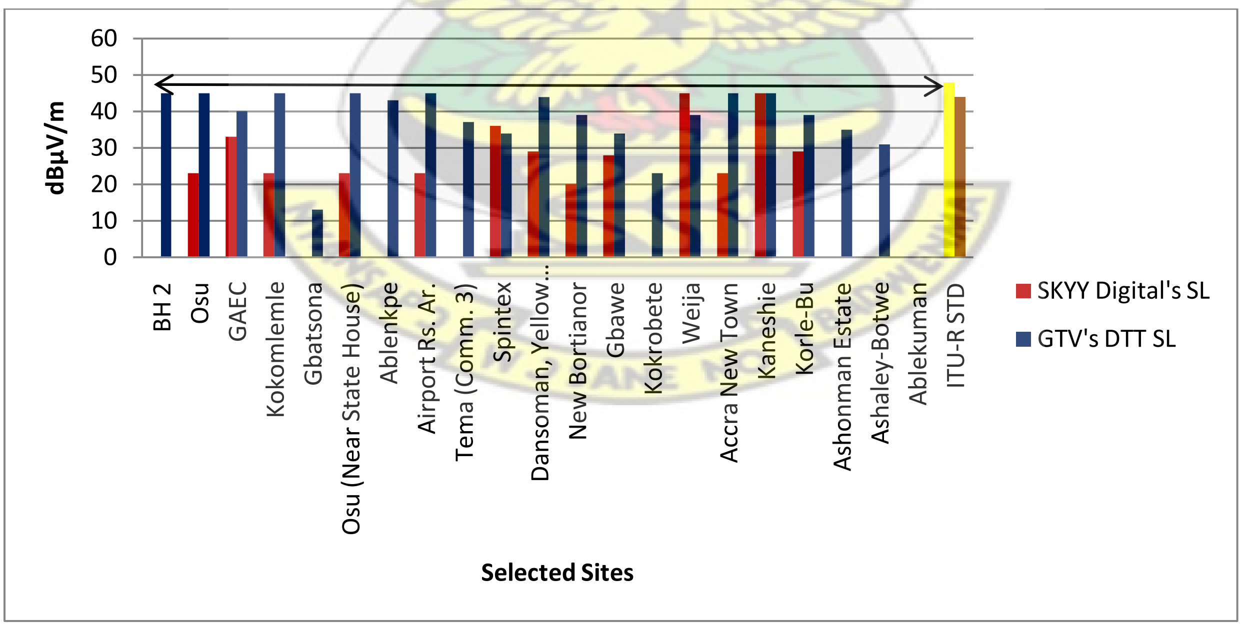


Figure 3.7: Received Signal Level for SKYY Digital and GTV's DTT Transmission at Selected Sites when Antenna was Panned toward BH 3's Direction.

3.2.3.2.3 Comparison of the Signal Quality (SL, BER and MER) Measured at Selected Sites (Using Set-Up B) to the Minimum Level Set by ITU-R for DVB-T Reception

Using Set-Up B, the quality of DVB-T reception at the selected sites for the two operating DVB-T multiplex are as in Table 3.10. The Table also indicates the deviation of the measured signal level from the ITU-R set minimum for DVB-T reception (for 70% coverage).

Table 3.10: Reception of DVB-T at Selected Sites Using Set-Up B.

Location	SKYY Multiplex					GTV's Multiplex				
	SL/ dBµV	Dev. From Min. SL/ dBµV	BER	MER/ dB	Dev. From Min. MER/ dB	SL/ dBµV	Dev. From Min. SL/ dBµV	BER	MER/ dB	Dev. From Min. MER/ dB
BH 2	36	13	4	21	1	39	5	3	24	4
Osu (Oxford Street)	28	21	213	25	5	45		0	25	5
Kokomlemle	40	9	4	21	1	43	1	1-4	24	4
Gbatsona	29	20	3	14	6	23	21	214	24	4
Osu (Near State House)	37	12	3	19	1	45		1	24	4
Air Port	45	4	3	24	4	37	7	0 - 5	19 -24	3
Tema (Comm. 3 Qt)	43	6	0	24	4	34	10	0 - 4	24	4
	41	7	0	24	4	37	7	0	24	4
Spintex (Setmat Ar.)	35	14	2	24	4	29	15	1-3	20	0
`Dansoman (Yellow Kiosk)	40	9	5	21 - 25	3	38	6	1-6	24	4
Accra New Town	40	9	5	21	1	45		0 - 3	25	5
Kaneshie	44	5	0	25	5	44	0	0 - 1	24	4
Korle-Bu	29	20	0	25	5	37	7	0-4	21	1
Ashonman Estate	38	11	1	24	4	23	21	214	19	1

3.2.3.2.3 Analysis of the Received Signals for SKYY Digital and GTV's DVB-T Transmission at the Selected Sites When Set-Up B Was Used

Figures 3.8 and 3.9 compares the ITU-R minimum level for the reception of DVB-T to that received at the selected sites for SKYY Digital and GTV's DVB-T transmissions respectively when Set-Up B was used. The bars in blue represent the measured signal at the selected sites whilst those in red represent the minimum set by the ITU-R to be the medium level for accepted signal reception.

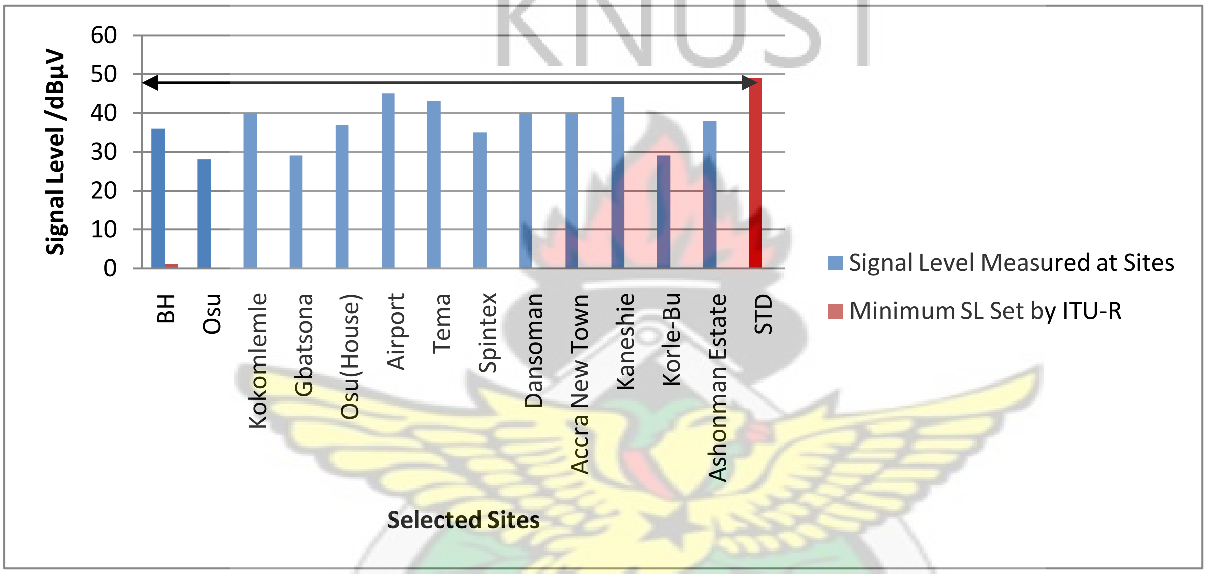


Figure 3.8: Signal Level Measured at Various Sites for SKYY Digital DVB-T Transmission Compared to ITU-R Set Minimum for 70% Coverage Using Set-Up B.

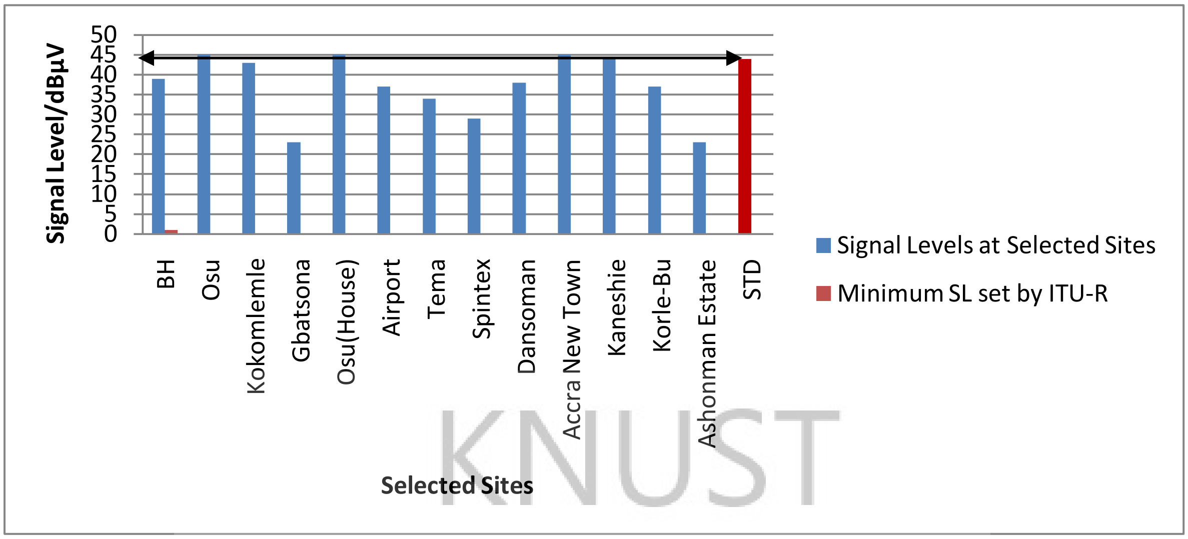


Figure 3.9: Signal Level Measured at Various Sites for GTV's DVB-T Transmission Compared to the Minimum Set by the ITU-R for 70% Coverage Using Set-Up B.

Findings from Set-Up B

- Reception of both GTV and SKYY Digital Transmission using Set-Up B is poorer than in Set-Up A at all selected sites.

Recommendations

- For efficient reception of both digital and analogue terrestrial television, Set-Up A will be recommended
- In situations where one is constrained to use Set-Up B, a professional VHF/UHF combiners and splitters must be engaged to make sure the only feed from the UHF antenna get to the STB.

3.2.3.2.4 Other Observations Made for Reception Quality of Terrestrial Digital and Analogue TV

- Using SKYY Digital STB, it was observed that Quality of Reception of DVB-T is good for signal levels above 30 dBμV for a low BER (which ranges from 0-5) and a high and stable MER (which ranges from 19 – 25 dB).

- At locations further away (about 10 km) from the DVB-T transmitters, when the antenna is mounted on an unstable pole, received signal has images which freeze.

3.3 RECEIVER EVALUATION FOR DVB-T/2 RECEPTION

The digital migration report for Ghana recommends an MPEG-4 receiver capable of receiving DVB-T/T2 signals. Such a receiver must have specifications as listed in Appendix D.

3.3.1 Current DVB-T Receiver in Ghana

Two DVB-T Receivers are currently available on the Ghanaian market. These STBs are distributed by SKYY digital in conjunction with Smart TV and Cable Gold TV. Both are only DVB-T compliant and their physical features are provided in Appendix E.

The following can be deduced from the evaluation made in Appendix E:

- Both STBs are only DVB-T compliant and hence would not be capable to receive DVB-T2 transmission recommended for Ghana in the Bidding document [5].
- Both STB uses smart card for their conditional access system, hence would ensure the usage of conditional access system for the operators that would be involved in the business
- Both STBs lack functionalities for return-channel interactive services and also recording of live programs
- The earlier STB distributed by Skyy Plus cannot take signal levels beyond 45dBμV/m, this do not give true reflection of the signal levels of DTT received at areas with a reception.

3.4 REGULATORY ISSUES FOR DVB-T TRANSMISSION IN GHANA

3.4.1 Present Service Allocation in the Radio Regulation in Bands III, IV and V

Services that has been adopted for VHF Band III and UHF Bands IV and V are as in Table 3.12

Table 3.12: Present Services in Bands III, IV and V in Ghana

Band	Services Allocated	Comment
III	Analogue Television Broadcasting, DVB-H, T-DMB, other future services will include T-DAB	Services here are presently technology neutral. Hence need more planning skill to avoid interference
IV	Analogue Television Broadcasting and DVB-T	Services are strictly broadcasting services
V	Analogue Television Broadcasting and DVB-T	Services are strictly broadcasting services

Service Allocation in the Radio Regulation across the World

A recent tendency, particularly in the EU, has been to regulate spectrum on a service and technology neutral basis. This approach may lead to the use of the same frequency band by services with very different technical characteristics.

3.4.2 Digital Switch-Over Policies in Ghana

Presently, the National Digital Broadcasting Migration Technical Committee has been tasked to set a clear strategy for the transition from analogue to digital. Among the elements that have already been considered for the switch-over are [6]:

- Date for analogue switch-off (2015, as agreed in the GE-06 agreement);
- Coordination of frequencies with neighbouring countries for digital television during the transition period;
- Agreements regarding termination of analogue television licenses;
- Provisions for simulcasting;

The other factors considered in a typical switch-over that has not yet been made include the following;

- Licensing process for digital terrestrial television;
- Agreements with consumer equipment manufactures to ensure that a sufficient number of adequate digital receiving equipment is available in time;
- Provisions to enable low income households to buy digital receiving equipment;
- Communication campaigns to inform the public.

3.4.3 Analogue Switch-Off Methods Recommended for Ghana

The National Communications Authority envisages two (2) paths for the migration from analogue to digital broadcasting:

- Market driven technological transition which involves the progressive replacement of analogue technology with digital technology by broadcasters; and
- Policy driven transition primarily focused on free-to-air terrestrial broadcasting services that indicates a target date for analogue switch-off.

FINDINGS AND RECOMMENDATIONS

The following are the findings obtained from the study:

1. Signals received from the two DVB-T transmissions broadcast by the two operators during the period of study for most part of Accra and Tema environs where just above the minimum required level with some below the minimum received level set by ITU for DVB-T reception.
2. Concurrent receptions of the two DVB-T multiplexes available during the period of study were challenging using a single receiving antenna since the transmitters of the operating multiplexes were not co-sited.
3. Receivers currently distributed and also those available during the time of the study specifications do not meet DVB-T2 receptions requirements as recommended in the bidding document for DTT networks in Ghana.
4. One of the STBs distributed by one of the DTT operators cannot give received signal levels beyond 45dBµV/m
5. One of the STBs provided by one of the operators (SKYY Digital) does not use smart card for their conditional access system but rather uses an inbuilt conditional access system, this will impair the usage of common conditional access by all DTT operators which would force consumers to acquire more than one box if they want to enjoy encrypted services from other operators.
6. One of the STBs provided by one of the operators (SKYY Plus) does not output it received DTT signals to an RF format.

Based on the findings made the following are recommended:

1. Co-sitting of existing DTT transmitters to ensure effective reception of signals from the various multiplex.
2. More than one transmitter would be needed for each multiplex for a total coverage of Accra-Tema environs (One main transmitter and a gap-filler)
3. Receivers should have a common conditional access system, so that encrypted services provided by the various multiplexes would be received by one STB of the consumer choice provided he has made payments for programs from multiple multiplex.

4. STB should be able to output it signal in RF form so that analogue devices (some TV combos and TV cards) which do not have video/audio jack would be able to received converted digital signals through their RF-In ports.
5. To make good use of the available bandwidth, license should be given based on capability to fill a multiplex, so that same programs are not repeated in the various multiplex.

CONCLUSION

Based on the measured results obtained for received signal level for DTT transmission in the Accra-Tema environs, it can be concluded that co-sitting of the main DVB-T/T2 transmitters and a number of fill-in transmitters (gap-fillers) need to be enforced to minimize reception cost for consumers so as to enhance a smooth transmission.

For a good reception of DVB-T/T2 transmission in the Accra-Tema coverage areas, there would be the need for gap-fillers if the current transmitters transmitting power is to be maintained. The current DTT receivers specifications do not meet the requirements for DVB-T2 reception, thus a clear policy must be put in place for replacement when T2 transmission takeoff.

DVB-T2 STB that would be recommended should have access to a system of conditional access that would enable subscribers to access encrypted services from the various multiplexes available in the air. Also minimum requirement for STB should include RF-Output parts so that existing analogue systems with only RF-In can also be served.

APPENDIXES

APPENDIX A

A.1 Protection Ratio and Minimum Field Strength Calculation for DVB-T Transmission

A.1.1 Protection Ratio and Field Strength Concept Explained

The concept of protection ratio and field strength is illustrated in Figure A1, which shows two transmitters separated by 100 km. The field strength of the transmitters, plotted in solid curves, fall with distance from the transmitter. The broken lines represent the maximum interference field strength which each service can tolerate, the vertical distance between the full and broken lines being everywhere equal to the protection ratio in dB. The separation of the two transmitters is such that, at the point where each wanted signal has fallen to the minimum protected field strength, the unwanted signal has just become lower by the required protection ratio. It is clear that for positive protection ratio a gap must exist between adjacent service areas [16].

In the set-up illustrated in Figure A.1, if both transmitters increase power by the same amount, neither would gain a larger service area. The curves would simply move upward on the dB scale but not change relative to each other. Thus, for the most effective and economical use of available frequencies, neighbouring services should be interference limited, but the field strength at the edge of a service area only just above the minimum reference field strength. This means that no more transmitter power than necessary is used to achieve the service areas [16].

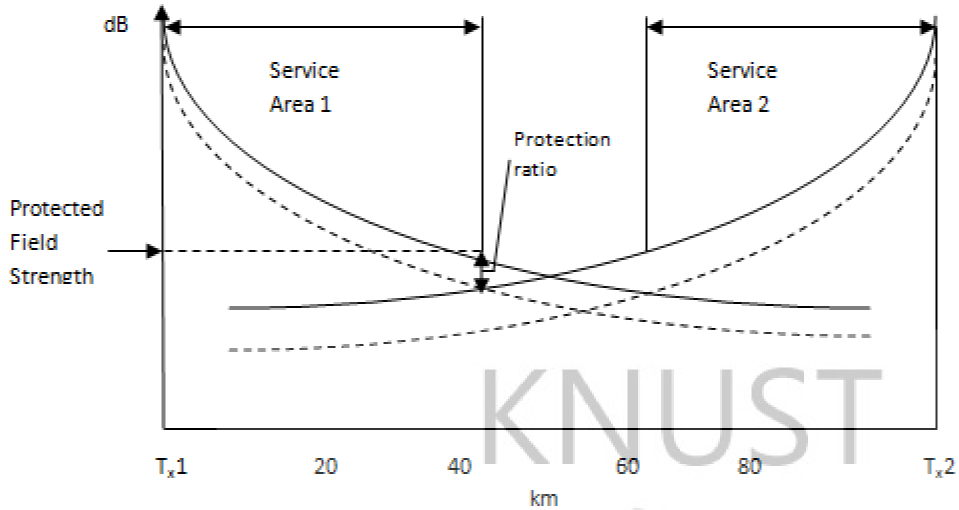


Figure A.1: Interference-limited service area [16].

A.1.1.1 Protection Ratio for Digital and Analogue Television Transmission

Protection ratio for the digital and analogue television transmission set by the ITU-R are as outlined in the sections below;

A.1.1.1.1 Protection Ratio for DVB-T interfered with by DVB-T

Table A1 gives co-channel Protection Ratios (rounded to the nearest integer), obtained by measurements or by the extrapolation method for DVB-T signals interfered with by another DVB-T signal for the various modulation schemes and propagation channel.

Table A1: Co-channel protection ratios (dB) for DVB-T interfered with by DVB-T [36].

ITU-Mode	**Modulation**	**Code rate**	**Protection Ratio**		
			Gaussian	Rice	Rayleigh
	QPSK	1/ 2	5	7	8
M1	16-QAM	1/ 2		13	14
	16-QAM	3/ 4	14	16	20
M2	64-QAM	1/ 2		18	19
M3	64-QAM	2/ 3	19	20	22

Protection ratios for the various modes and for the various channel types (i.e. Gaussian, Ricean, or Raleigh) can be derived by the required C/N, increased by a system implementation loss Δ_1 of 3 dB. For fixed and portable reception, the figures relevant to the Ricean and Rayleigh channels respectively should be adopted [36].

For **adjacent and image channel interference** a protection ratio of -40 dB is assumed to be an appropriate value due to lack of data.

For **overlapping channels**, in the absence of measurement information, the protection ratio is extrapolated from the co-channel ratio figure as follows:

$PR = PR(CCI) + 10 \log_{10} (BO / BW)$;

Where;

- PR(CCI) is the co-channel ratio;
- BO is the bandwidth (in MHz) in which the two DVB-T signals are overlapping;
- BW is the bandwidth (in MHz) of the wanted signal;
- PR = -40 dB should be used when the above formula gives PR < -40 dB.

A.1.1.1.1.1 *Co-channel Protection Ratio for DVB-T interfered with by DVB-T*

Table A.2 outlines the co-channel protection ratio for a DVB-T signal interfered with by another DVB-T signal under various modulation schemes and channels:

Table A.2: Co-channel protection ratios (dB) for a DVB-T signal interfered with by another DVB-T signal [21].

Modulation	Code Rate	Gaussian Channel	Rice Channel	Rayleigh Channel
QPSK	1/ 2	5	6	8
QPSK	2/ 3	7	8	11
16-QAM	1/ 2	10	11	13
16-QAM	2/ 3	13	14	16
16-QAM	3/ 4	14	15	18
64-QAM	1/ 2	16	17	19
64-QAM	2/ 3	19	20	23
64-QAM	3/ 4	20	21	25

A.1.1.1.1.2 *Adjacent Channel Protection Ratio for DVB-T interfered with by another DVB-T*

Protection Ratio given in ITU-R Rec BT.1368-2 for some typical values for 64 QAM rate 2/3 Ricean Channel are as listed in Table A.3 [17]:

Table A.3: Protection Ratio of wanted DTT (DVB-T 8MHz, 64 QAM, 2/3 code rate) [17].

Wanted System	**Interfering System**	**Protection Ratio (dB)**		
		Co-channel (n)	Adjacent Channel	
			Lower Adjacent (n-1)	Upper Adjacent (n+1)
DVB-T	DVB-T	20	-30	-30

A.1.1.1.2 Protection Ratio of DVB-T interfered with by analogue television

A.1.1.1.2.1 *Co-channel protection ratios for DVB-T interfered with by Analogue TV*

Table A.4 gives the various protection ratios for DVB-T signals interfered with by terrestrial analogue TV transmission. According to the available measurements the same protection ratio values are applicable for 2k and 8k modes.

Table A.4: Co-channel protection ratios (dB) for 7 and 8 MHz interfered with by analogue TV and CW (non-controlled frequency condition) [17].

	Protection Ratio														
Constellation	**QPSK**					**16-QAM**					**64-QAM**				
Code Rate	1/ 2	2/3	3/ 4	5/6	7/8	1/ 2	2/3	3/ 4	5/6	7/8	1/ 2	2/3	3/ 4	5/6	7/8
ITU-Mode															
CW and PAL/SECAM with teletext and sound carriers	-12	-8	-5	2	6	-8	-4	0	9	16	-3	4	10	17	24

Table A.5: Protection Ratios (dB) for DVB-T interfered with by analogue TV in the upper adjacent channel (n + 1).

Wanted Signals			**Interfering Signal**					
System	BW/ MHz	Mode	PALB	PAL B1, G	PAL I	PAL D/K	SECAM L	SECAM D/K
		M1			-46			
DVB-T	8	M2			-40			
		M3			-38			
		M1	-43					
DVB-T	7	M2	-38					
		M3	-36					

A.1.1.1.2.2 ***Adjacent channel protection ratio for analogue TV signals interfered with by DVB-T Signals***

The adjacent channel protection ratio needed for analogue TV signals interfered with by DVB-T signals for 8 and 7 MHz channel bandwidths are as shown in Table A.6.

Table A.6: Adjacent Channel Protection Ratio for Analogue TV interfered with by DVB-T [17].

Lower adjacent channel (n - 1)		
Protection ratio (dB) for an analogue vision signal interfered with by lower adjacent channel DVB-T 8 MHz		
Wanted analogue system	Tropospheric interference	Continuous interference
PAL B, B1, G, D, K	-7	-4
PAL I	-8	-4
SECAM L	-9	-7
SECAM D,K	-5	-1
Protection ratios (dB) for an analogue vision signal interfered with by lower adjacent channel DVB-T 7 MHz		
PAL B	-11	-4
Upper adjacent channel (n - 1)		
Protection ratio (dB) for an analogue vision signal interfered with by lower adjacent channel DVB-T 8 MHz		
Wanted analogue system	Tropospheric interference	Continuous interference
PAL B, B1, G	-9	-7
PAL I	-10	-6
SECAM L	-1	-1
SECAM D,K	-8	-5
Protection ratios (dB) for an analogue vision signal interfered with by lower adjacent channel DVB-T 7 MHz		
PAL B	-5	-3

A.1.1.1.3 Protection Ratio for Analogue TV interfered with by DVB-T

The values of protection ratio quoted apply to interference produced by a single source. In this the protection ratios for a wanted analogue signal interfered with by an unwanted digital signal apply only to the interference to the vision and colour signals, i.e. excluding sound signals.

The tropospheric interference corresponds to impairment grade 3, that is, acceptable for a small percentage of the time, between 1% and 10%. The continuous interference corresponds to an impairment grade 4, that is, acceptable for 50% of time.

A.1.1.1.3.1 *Co-channel protection ratio for analogue TV signals interfered with by DVB-T Signals*

For analogue and DVB-T channels operating in the same channels, the protection ratio needed for the analogue TV signal for non-interference of the two transmitting signals is shown in Table A.7.

Table A.7: Protection ratio (dB) for an analogue vision signal interfered with by DVB-T 8 MHz.

Wanted analogue system	Tropospheric interference	Continuous interference
PAL B, B1, G, D, K	34	40
PAL I	37	41
SECAM L	37	42
SECAM D,K	35	41
Protection ratio (dB) for an analogue vision signal interfered with by DVB-T 7 MHz		
PAL B	35	41

APPENDIX B

B.1 Reception of Terrestrial Analogue and Digital Television in Accra and Tema Environs

In Assessing the Quality of Service (QoS) of the two operating DVB-T and also terrestrial analogue television transmission in Accra and Tema environs, field strength readings were taken for twenty selected locations across Accra and Tema.

B.2 Process Involved in Taking Readings at the Sites

- With the aid of a Silva Handheld GPS, the geographical Location of the place of installation is taken. The distance from the location of installation to the locations where the two DVB-T transmitters are sited is also noted with the same device.
- The land profile is then drawn for the distance between the location of the transmitter and the selected sites where measurements are taken using the soft copy of the geographical map of Accra provided by the Geological Service Department in Accra. Appendix A shows the land profile drawn for the selected sites to the DVB-T transmitter locations in Accra.
- With the use of two antennas (one UHF Yagi-Uda antenna and a VHF/UHF dipole antenna) assessment is made on the reception quality of the two existing DVB-T transmissions in Accra and also existing terrestrial analogue television at the selected sites when:
  1. A separate antenna connections is made to the RF-In of the STB and another to the RF-In of the analogue television set.
  2. The two antennas (one facing the direction of where digital transmitters are located and the other towards where the analogue television transmitters are located) are combined and their resultant RF signal is fed to the RF-In of the STB and the RF-Out of the STB connected to the RF-In of the analogue television set to make viewing of terrestrial analogue television possible.
- The Quality of both digital and analogue reception is then recorded for this kind of set-up (Typical values recorded for assessment of digital transmission is Signal Level (**SL**), Bit Error Rate (**BER**), and the Modulation Error Rate (**MER**)).
- When necessary, the height of the receiving antenna is increased to 10m and above

B.3 Set-Ups Used for Taking the Signal Quality Measurements

Two separate setups were used in taking the measurements of both analogue and digital terrestrial reception at the selected sites. The details of these setups are outlined in sections B.3.1 and B.3.2 of this Appendix which are labeled SETUP A and SETUP B respectively.

B.3 Devices Used for the assessment of the Quality of Service:

(1) DRT-1000 DVB-T Set-Top-Box (STB) (SKYY Digital STB)
(2) A UHF Yagi-Uda Antenna
(3) A VHF/UHF antenna
(4) HU2200 Hybrid TV USB 2.0 Stick DVB-T/Analog/H.264 MPEG4
(5) Analogue TV Sets
(6) Laptop with Total Media Monitor (a software that aids the DVB-T/Analogue USB Stick to view the reception quality of digital and analogue signals pick on a laptop) installation.
(7) Silva Handheld GPS

B.3.1 **SETUP A**

Aim:

Assessment of the reception quality of Analogue and Digital Television Transmission when a Separate antenna connection is made to the RF-In of the STB and another antenna connection is made to the RF-In of an analogue television set. Figure B.1 gives description of the connection.

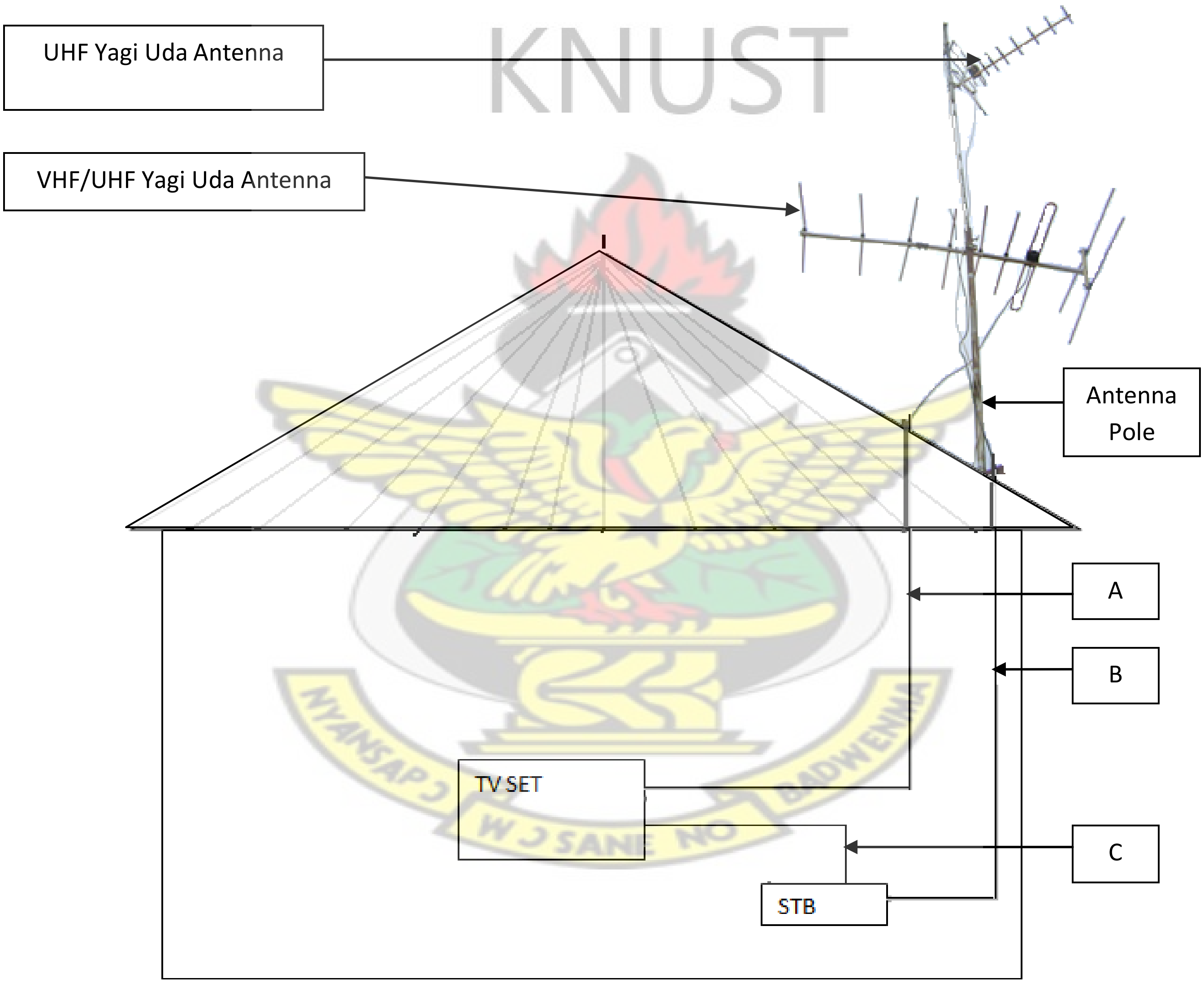


Figure B.1: Diagrammatic Outline for Set-Up A

A : Coaxial Cable from VHF/UHF antenna going to the RF-In of the Analogue TV set

B : Coaxial Cable from UHF Yagi Uda antenna going to the RF-In of the STB

C : Video/Audio cable (Phono cable) from Video/Audio Output of STB to Video/Audio Input of Analogue TV Set

B.3.1.1 Set-Up A Description

B.3.1.2 Set-Up for the Reception of Digital Television Services

- A UHF Yagi Uda antenna directed to the position where the DTTB transmitters are located is connected by means of a coaxial cable to the RF-In of the STB
- The STB converts the digital signal received by antenna to an analogue signal
- The Video/Audio Output of the STB is fed to the Video/Audio Input of the analogue TV set.
- The Output from STB can then be viewed on the analogue TV set.
- The signal Level (SL), bit error rate (BER) and the modulation error rate (MER) of the received signals from GTV and SKYY Digital DTT multiplex are then taken with the aid of STB and the TV set. Figure B.2 below is an example of a display indicating the SL, BER and MER of one of the sites

Figure B.2: Example of Figure Indicating the Quality of DVB-T Reception at a given Site

B.3.1.3 Outline for the Reception of Analogue Television Services Using Set-Up A

- A VHF/UHF antenna directed towards the position where the Terrestrial Analogue TV transmitters are located is connected by means of a coaxial cable to the RF-In of a field strength meter.
- The field strength meter is tune to receive the various analogue television channels broadcast to Accra and Tema and the signal levels at the sites are recorded.

B.3.2 SET-UP B

Aim:

Combining two antennas (a UHF and a VHF) whose directions are towards digital transmitters and analogue transmitters respectively, so that a single cable connection from the antenna will run to the STB, so that analogue reception will be taking from the STB's RF loop-through.

B.3.2.1 Set-Up B Description:

- The UHF Yagi-Uda antenna directed toward the location of digital television transmitters is combined with a VHF/UHF antenna directed toward the location of analogue television transmitters by means of a coaxial cable
- The RF received from the combined antennas is then fed to the RF-In of the STB
- The RF-Out of the STB is fed to the RF-In of the analogue TV Set
- The video/audio out-put of the STB is connected to the video/audio input of the analogue television set and the received signal quality (SL, BER and MER) is then recorded. Recorded values for the selected sites using Set-Up B is as shown in Table 3.6
- Reception qualities of the terrestrial analogue television using Set-Up B at the selected sites were viewed by tuning the field strength meter to the various channels occupied by the analogue television stations. Table 3.7 shows the recorded values for the signal level for the terrestrial analogue television recorded at the selected site using Set-Up B.

Figure B3 gives the description of the connection.

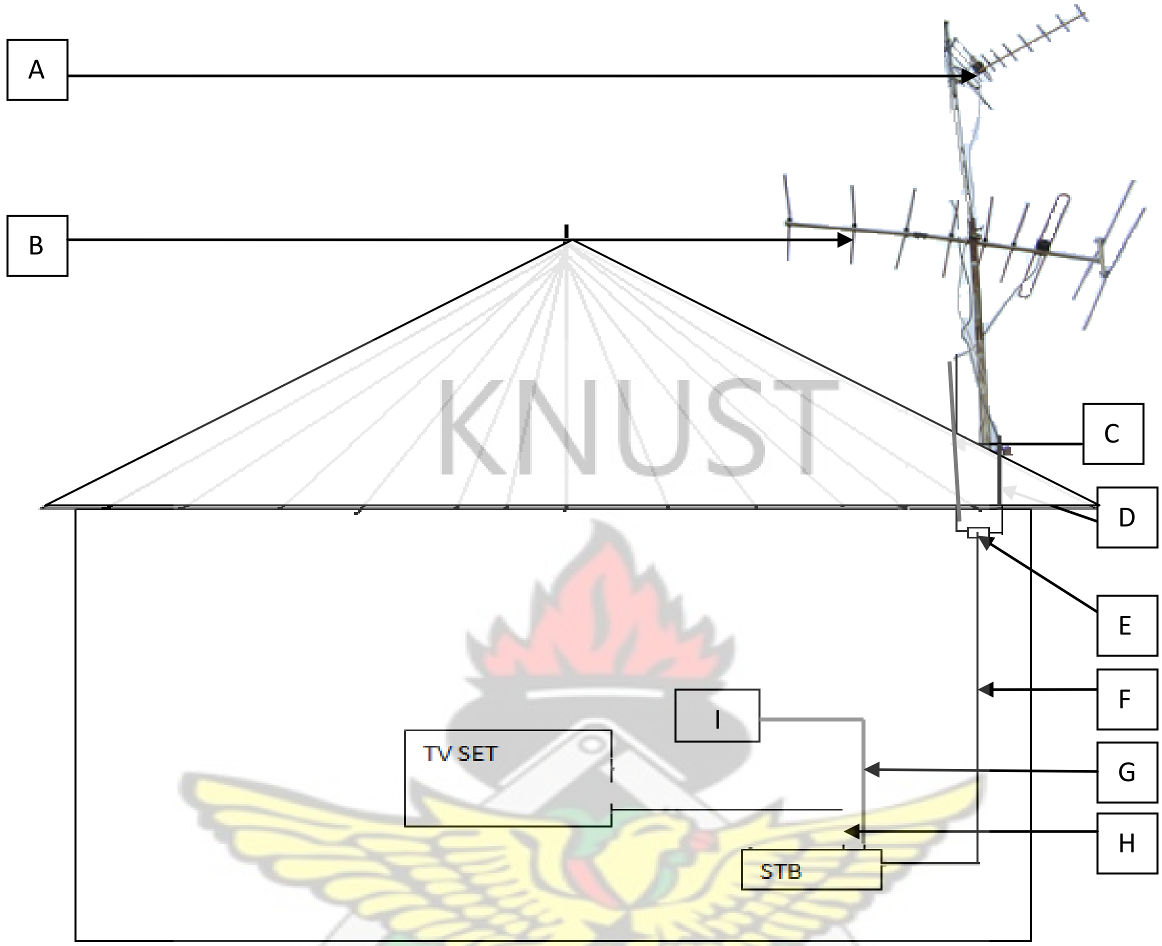


Figure B.3: Set-Up Describing Set-Up B when an analogue TV Set is used to display signals received

A : UHF Yagi-Uda Antenna

B : VHF Yagi-Uda Antenna

C : Coaxial Cable Connecting VHF Yagi-Uda Antenna to T-Connector

D : Coaxial Cable Connecting UHF Corner Reflector Antenna to T-Connector

E : T-Connector

F : Coaxial Cable taking Combined RF feed from Combined Antenna to the STB

G : 0.8 m Coaxial Cable taking RF-Out from STB to Field Strength Meter

H : Phono Cable Taking Video and Audio Output from STB to the Video/Audio Input of TV Set

I : Field Strength Meter

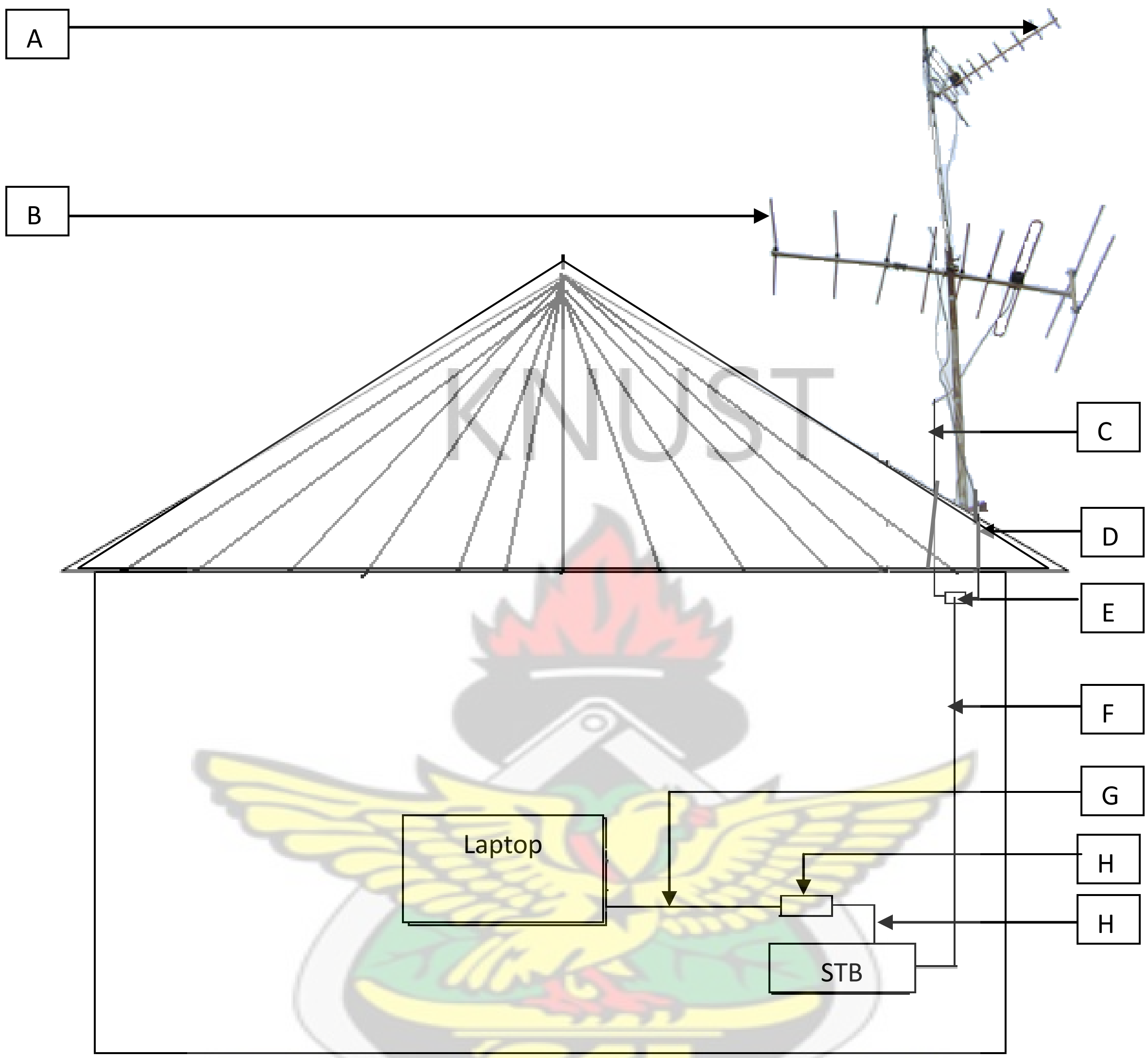


Figure B.4: Set-Up Describing Scenario B when a laptop is used to display the signals received

A : UHF Yagi-Uda Antenna

B : VHF Yagi-Uda Antenna

C : Coaxial Cable Connecting VHF Yagi-Uda Antenna to T-Connector

D : Coaxial Cable Connecting UHF Yagi-Uda Antenna to T-Connector

E : T-Connector

F : Coaxial Cable taking Combined RF feed from Combined Antenna to the STB

G : USB Cable Connecting HU2200 Hybrid TV USB 2.0 Stick DVB-T/Analog/H.264 MPEG to . . Laptop

H : HU2200 Hybrid TV USB 2.0 Stick DVB-T/Analog/H.264 MPEG

APPENDIX C

C.1 Selected Sites where Measurements were taken and the respective Land Profile from the Sites to the two DTT Transmitters Servicing Accra

Map of Selected Sites Where Readings Were Taken

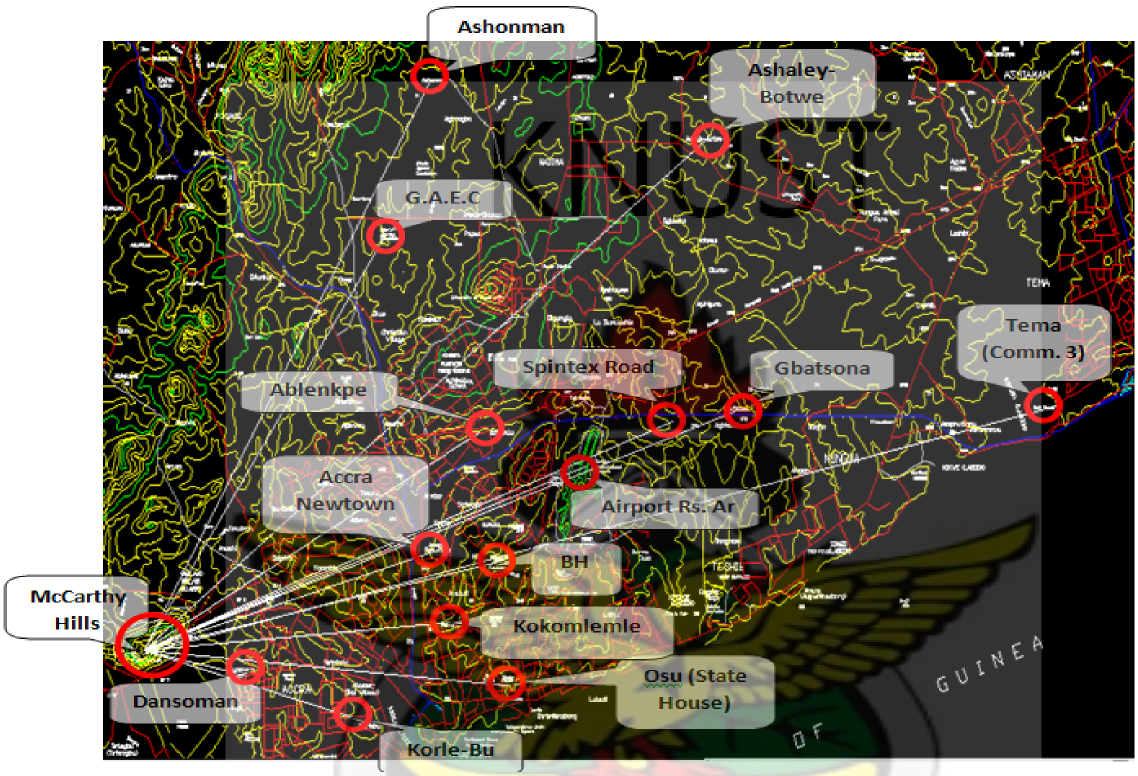
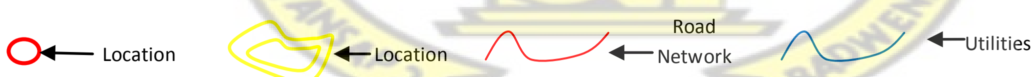


Figure C.1: Map of Accra Showing Distances from one Side of McCarthy Hill to Selected Sites where Measurements were Taken.



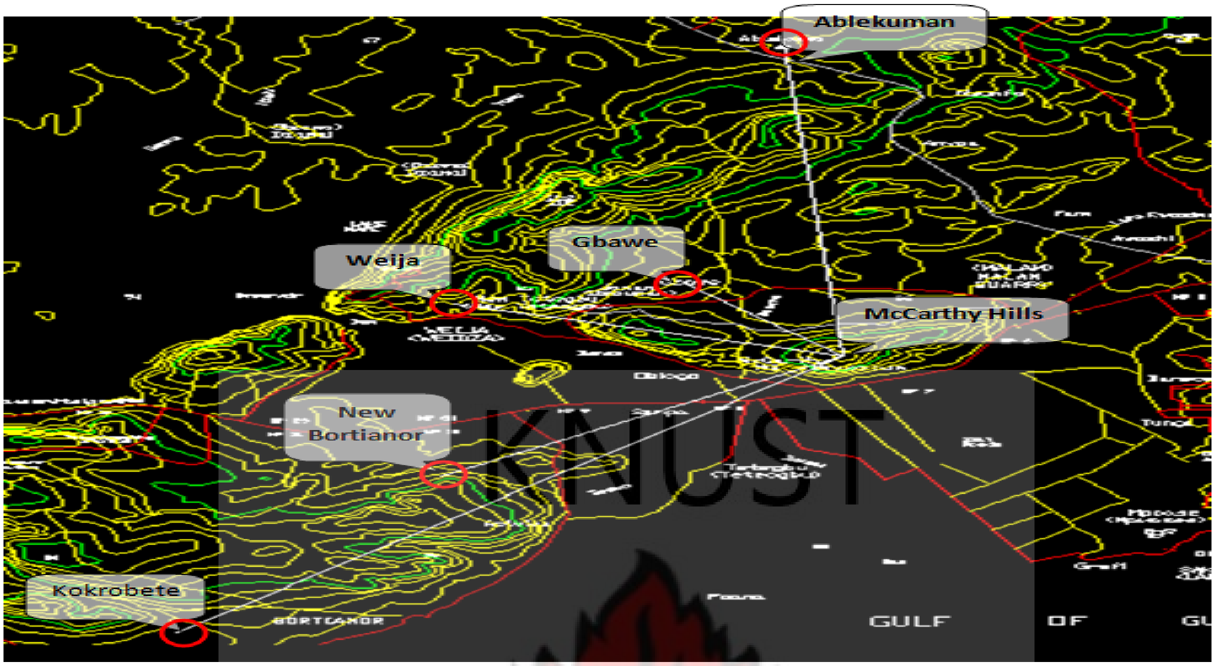


Figure C.2: Distances from one Side of McCarthy Hill to Selected Sites where Measurements were taken.

Location Altitude Road Network Utility

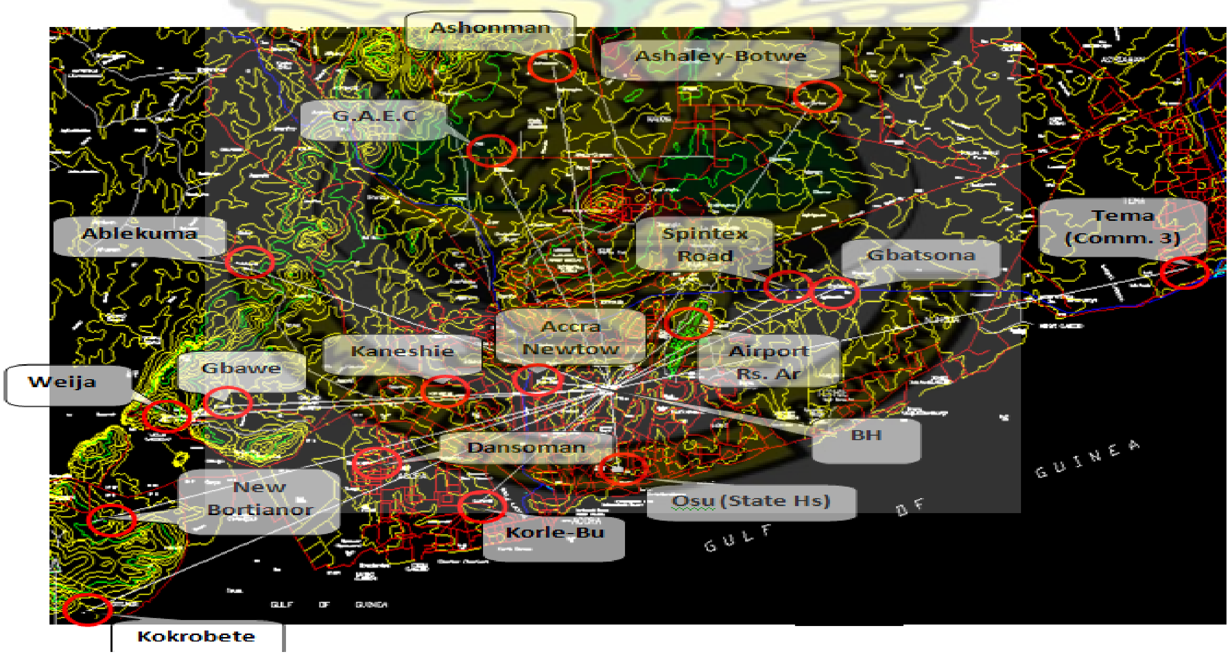


Figure C.3: Map of Accra Showing the various locations from BH where measurements were taken.

Location Altitude Road Network Utility

APPENDIX D

OPERATIONAL DIGITAL TELEVISION TRANSMISSION IN ACCRA AND TEMA ENVIRONS

D.1 Details of Operational DTT in ACCRA

Currently, there are four operational DTT transmissions in Accra. Two are broadcast to mobile/handheld devices using T-DMB and DVB-H standards, whilst the other two are broadcast to fixed/portable reception using the DVB-T standard [5].

D.2 Operational DTT to Fixed/Portable Devices

The two operating DTT multiplex to fixed/portable devices (TV sets etc) available in the Accra and Tema environs are broadcast by:

(i) SKYY Digital TV

(ii) GTV

Table D.2A: Details of the two Operating DTT Multiplexes in Accra (GTV and SKYY Digital) [37], [38].

Transmitting Antenna and its Description		
Type	Quad Dipole Panel	Panel
Polarization	Horizontal	Horizontal
Panel/Bay	3	8
Face Plane	120, 240, 360	300, 360
Gain	7.80 dB	10 dB
Height	81.25 m above the ground	40.0 m above the ground
HASL	173m + 81.25m	400m + 40m
Cable Type		
Cable Type	Hitachi HF-77D	
Cable Length	110 m	60 m
Splitter End Connector	3 1/8 EIAD	1 5/8

D.2.1 SKYY Plus DVB-T Project Profile:

The profile outline of SKYY Digital DVB-T project implemented in Ghana consists of [39]:

- DVB-T service in 3 main cities: Accra, Kumasi and Takoradi. Figure D1 below shows this setup
- 3 high power transmitters of 1000W, 2 medium power transmitters of 200W
- 450km microwave PDH contribution link with 12 hops as shown Figure C2
- Omni-directional and directional panel antenna designed for subscriber coverage
- Central digital TV headend including MPEG2 encoders, remux, scramblers, satellite IRD. This is as shown in Figure D.3
- Regional headend with central headend channels and local channel insertion

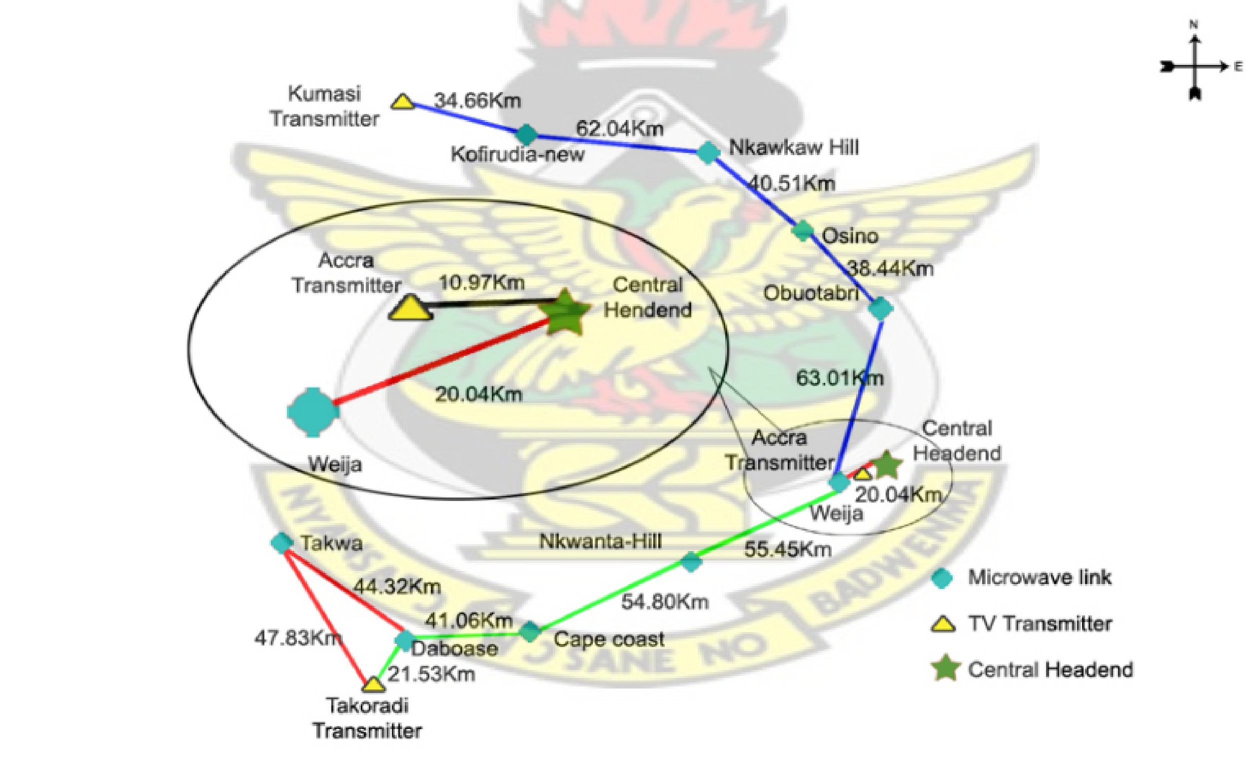


Figure D.2: PDH Microwave Link for SKYY Digital DVB-T Transmission Nationwide [39].

D.2.1.1 Set-Up of How Signals is Routed from Studio to Transmitter Site of SKYY Plus Multiplex

The programs from the studios which are in ASI format are encoded, multiplexed, scrambled and then converted to DS3 format at the studio side, it is then link to the transmitter site by a microwave link for the necessary modulation and then broadcast to the public.

At the transmitter site, the signals in DS3 format are converted back to ASI which is then fed to a 1 kW transmitter which modulated the signals using the parameters below [38];

Modulation	–	64 QAM
Transmission Mode	–	8k
Guard Interval	-	1/32
Code Rate HP	-	2/3

The modulated signals are then sent to the transmitting antenna to be broadcast to the end users. Figure D.5 gives the diagrammatic processes that signals undergoes at the studio site whilst Figure D.6 give the diagrammatic processes the signals undergoes at the transmitter site before final delivery to the end users.

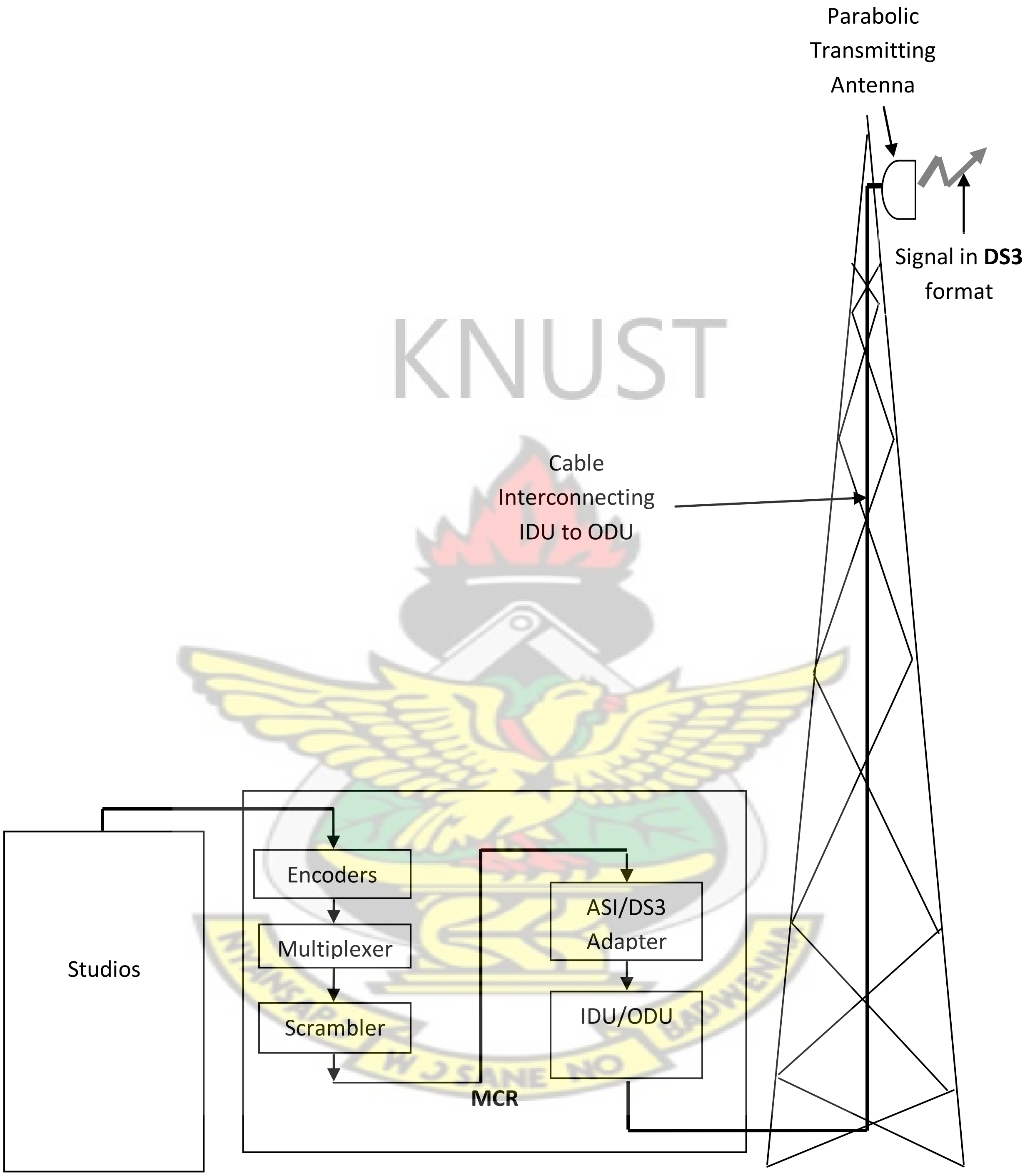


Figure D.5: How Signals are routed in SKYY Digital Multiplex before Transmitted from Studio to the Transmitter Site (Studio Site).

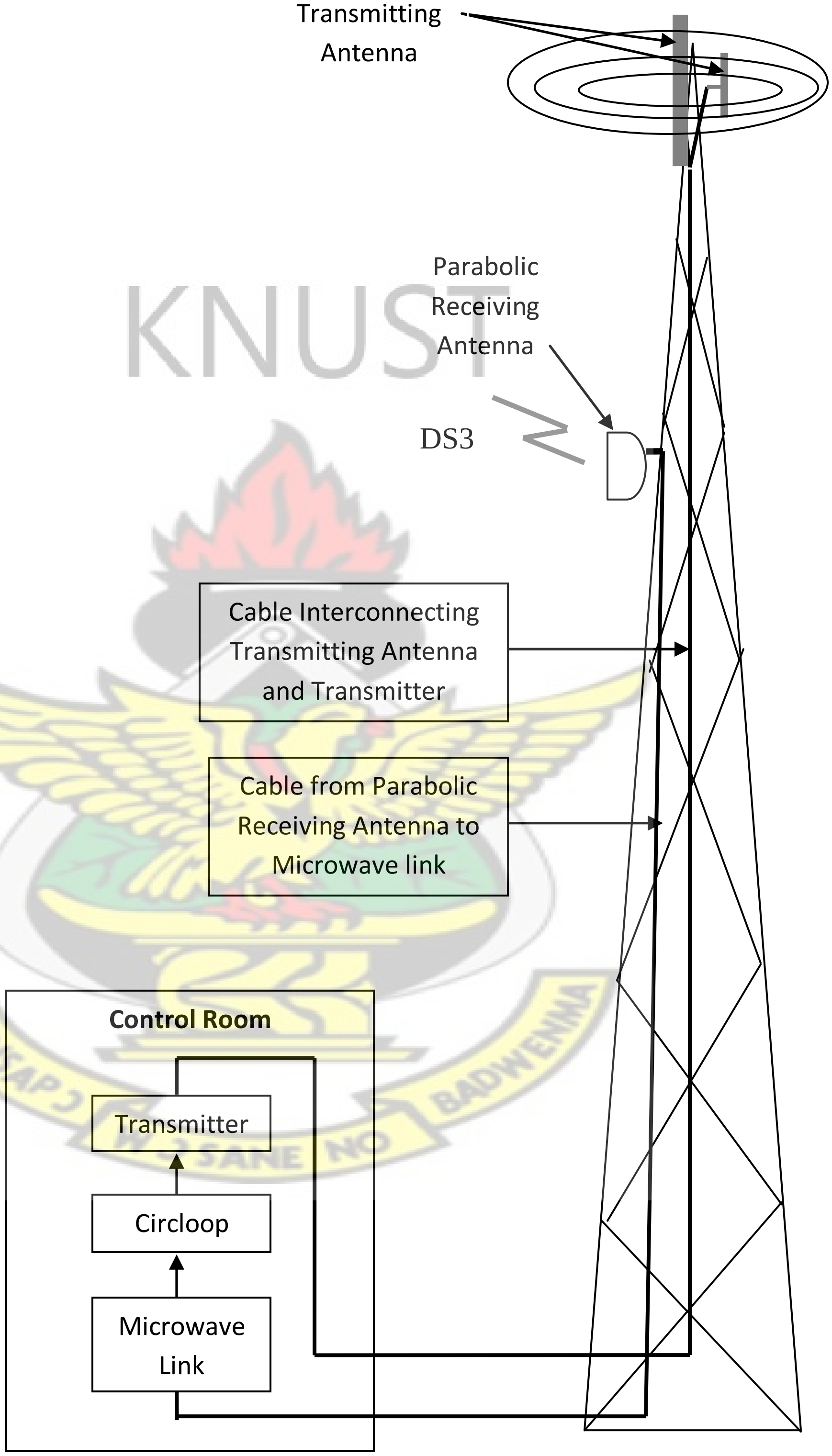


Figure C.6: How Signals from the Studio is received and Broadcast at the Transmitter Site of SKYY Plus DVB-T Transmission (Transmitter Site).

APPENDIX E

STBS FOR DIGITAL TELEVISION TRANSMISSION

E.1 STB Variants

As indicated in Chapter Three, three main variants of STBs available on world market include the basic zappers, interactive box and personal video recorder.

E.1.1 *Basic Zappers*

This type of STBs has the basic functions needed for the reception of digital signals. They lack the capability to perform additional services (interactive and recording).

E.1.2 *Interactive Box*

This variant of STB has some advance features that makes it perform interactive services. The interactive services that can be performed by these STBs could be either with return channel or without a return channel. Table E.1 below shows the distinction between return channel and non return channel interactive STBs.

Table E.1: Distinction between Interactive STBs with Return Channel and those without Return Channel.

Service	Interactive Box with return channel	Interactive Box without return channel
Electronic Program guide	✓	✓
t-commerce	✓	
Email	✓	
Web access	✓	
Multi-user gaming	✓	
SMS Messaging	✓	
Downloading simple games	✓	

E.1.3 *Personal Video Recorders (PVR)*

This variant of STB has hard disk recorder, the main features of PVR STBs include;

- Time-shifted viewing
- Pause and rewind live TV
- Usually twin receiver and decoder that makes it possible to watch one digital channel and record another

E.2 Digital TV Measurements on STB

Among the measurements that a basic STB can take, as indicated in Chapter Two are the BER, MER and Signal Level etc. Below are the descriptions of these measurements;

E.2.1 ***Bit Error Rate (BER):*** In digital transmission, the **bit error rate** or **bit error ratio** (BER) is the number of received binary bits that have been altered due to noise and interference, divided by the total number of transferred bits during a studied time interval [13].

BER is a unitless performance measure, often expressed as a percentage number [13]. The lower the BER the better the quality of received signal.

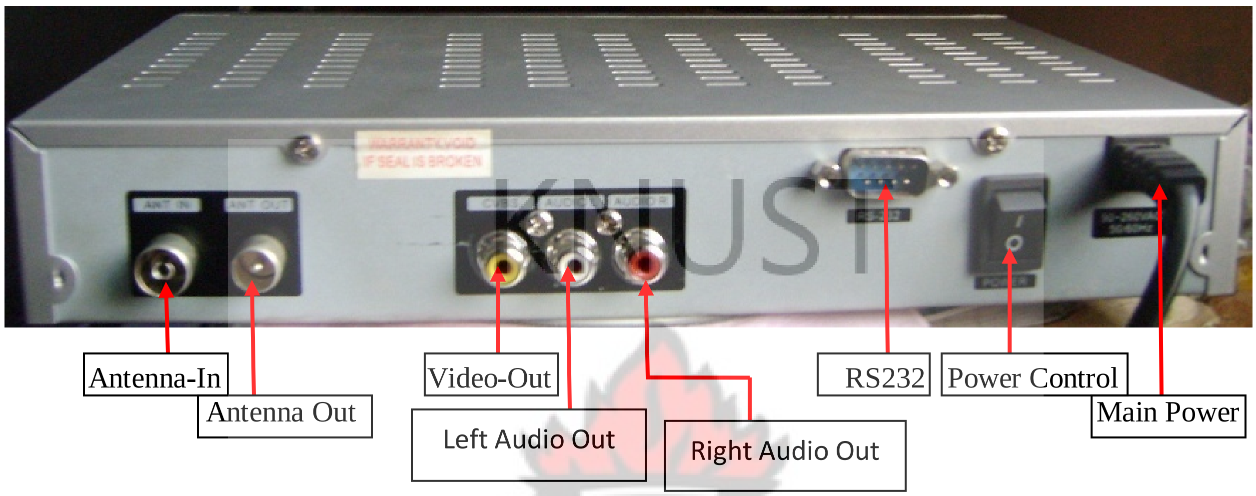
For a given STB measurement, a recorded BER of zero indicate no bit received is by the STB in error.

E.2.2 *Modulation Error Ratio (MER)*

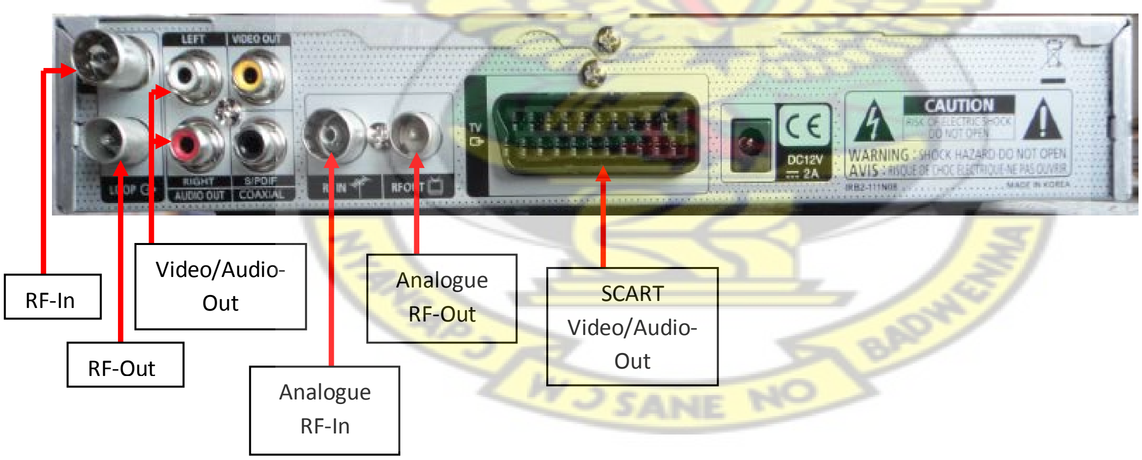
It is a measure of the sum of all interference that affects a digital TV signal [14]. Thus, MER indicate the figure of merit for a vector-modulated signal (such as a COFDM signal). It is expressed in dB and allows a receiver to give a figure of merit for the COFDM carrier ensemble [15]. A high MER value indicates good signal quality. In practice, the MER lies in the range of 0 dB to 40 dB [40]. When receiving DVB-T/H signals over a roof antenna with gain, a MER of 20 dB to 30 dB would be measurable at the antenna box. Values between 13 dB and 20 dB are expended for portable receivers with a room antenna [**15**].

E.3 DTT Receivers Used in Ghana

There are presently two kinds of STBs for DVB-T reception in the Greater Accra region. These are those provided by GTV for their pilot project and those by SKYY Digital TV.



Picture E.1: Back Panel of Receiver Distributed by SKYY Plus



Picture E.2: Back Panel of Receiver Distributed by SKYY Plus in conjunction with Smart TV

TableE.1: Differences Between First STB Distributed and Current STB

Service	First STB	Second STB
SCART Output	No	Yes
RF-Out for converted Digital Signal	No	Yes
Other RF Input for Analogue Signals	Use the same RF-In for both analogue and digital systems	Yes
Means to upgrade STB software	Yes	No

E.3 TYPICAL SPECIFICATIONS FOR DVB-T2 RECEIVER

E.3.1 TUNER AND DEMODULATOR

The STB/IDTV-T2 should include at least one tuner/demodulator for reception of signals from terrestrial transmitters in accordance with DVB Blue Book (DVB-T2). The STB/IDTV should be able to receive channels in the VHF band III and UHF bands IV, V.

The front-end shall for the supported frequency ranges be capable of tuning to the centre frequency f_c of the incoming DVB-T2 RF signal [40].

E.3.1.1 Signal bandwidths [40]

For a DVB-T signal, an 8 MHz DVB-T signal corresponds to a signal bandwidth of 7.61 MHz and a 7 MHz DVB-T signal corresponds to a signal bandwidth of 6.66 MHz

The STB/idTV-T2 should support both the normal and extended carrier modes, for 8 MHz DVB-T2 signal, a normal carrier mode corresponds to a signal bandwidth of 7.61 MHz and an extended carrier mode corresponds to a signal bandwidth of 7.71 MHz for FFT size of 8K and 7.77 MHz for FFT size of 16K and 32K.

For 7MHz DVB-T2 signal, a normal carrier mode corresponds to a signal bandwidth of 6.66 MHz and an extended carrier mode corresponds to a signal bandwidth of 6.80 MHz.

For 1.7 MHz DVB-T2 signal, a normal carrier mode corresponds to a signal bandwidth 1.54 MHz and an extended carrier mode corresponds to a signal bandwidth of 1.57 MHz.

VHF Bands.

E.3.2 MODES [40]

The STB/idTV-T2 terrestrial front-end shall be capable of correctly demodulating all allowed configurations DVB-T2 modes (non-hierarchical and hierarchical modes specified in DVB Blue Book (DVB-T2).

STB/idTV-T2s should support Time-Frequency Slicing (TFS) for 8MHz DVB-T2 signals with modulation parameters {32K, 256-QAM, CR=3/5, GI=1/16} on all data PLPs. The STB/idTV-T2 should support reception of variable-bit rate PLPs in TFS.

• Constellation (QPSK, 16-QAM, 64-QAM, **256-QAM**), both rotated and non-rotated
• Code rate (1/2, **3/5**, 2/3, 3/4, **4/5**, 5/6)
• Guard interval (1/4, **19/256**, 1/8, **19/128**, 1/16, 1/32, **1/128**)
• Transmission mode (1K, 2K, 4K, 8K normal and extended, **16K** normal and extended, 32K normal and extended)
• SISO/MISO
• FEC Frame length (64800, 16200)
• Input Mode A (single PLP) or Input Mode B (Multiple PLPs – Common PLP, Type 1 and 2 up to the maximum allowed)
• Single RF frequency or Time Frequency Slicing (TFS)
• Normal Mode or High Efficiency Mode
• FEF parts
• Auxiliary streams

The STB/idTV for DVB-T2 is not required to support the following features:
• Transmission modes 16K and 32K for 1.7 MHz RF bandwidth
The STB/idTV should automatically detect which mode is being used

E.3.3 RECEPTION QUALITY/TUNING/SCANNING PROCEDURES

E.3.3.1 General [40]

The STB/idTV should provide a scanning procedure over the whole (supported) frequency range (For example in Ghana, 470-860 MHz).

The STB/idTV-T2 should be able to provide reception quality information for a selected received frequency according to the specifications below:

- Channel id
- Centre frequency
- Signal strength (dBm or dBμV/m)
- Signal strength indicator, SSI (%)
- Signal quality indicator, SQI (%)
- C/N (dB)
- BER before Reed Solomon decoding (DVB-T) or BCH decoding (DVB-T2)
- Uncorrected packets

The formulas to calculate the signal strength indicator (SSI) value in [%] are defined below.

SSI = 0 if $P_{rel} < -15dB$

SSI = (2/3) * (P_{rel} + 15) if $-15 \text{ dB} \leq P_{rel} < 0dB$

SSI = 4 * P_{rel} + 10 if $0 \text{ dB} \leq P_{rel} < 20 \text{ dB}$

SSI = (2/3) * (P_{rel} - 20) + 90 if $20 \text{ dB} \leq P_{rel} < 35 \text{ dB}$

SSI = 100 if $P_{rel} \geq 35 \text{ dB}$

Where:

$P_{rel} = P_{rec} - P_{ref}$

P_{rec} is referred to signal level expressed in [dBm] at receiver RF signal input.

P_{ref} is reference signal level value expressed in [dBm] specified in Table E.2 for DVB-T2.

Table E.2: Specified P_{ref} values expressed in dBm for a PLP, all signal bandwidths, guard intervals and 32k FFT for DVB-T2 signals [40].

Modulation	**Code Rate**	**Reference signal level [dBm]**
QPSK	½	To Be Provided
QPSK	2/3	To Be Provided
QPSK	¾	To Be Provided
QPSK	5/6	To Be Provided
QPSK	7/8	To Be Provided
16-QAM	½	To Be Provided
16-QAM	2/3	To Be Provided
16-QAM	¾	To Be Provided
16-QAM	5/6	To Be Provided
16-QAM	7/8	To Be Provided
64-QAM	½	To Be Provided
64-QAM	2/3	To Be Provided
64-QAM	¾	To Be Provided
64-QAM	5/6	To Be Provided
64-QAM	7/8	To Be Provided
256-QAM	½	To Be Provided
256-QAM	2/3	To Be Provided
256-QAM	¾	To Be Provided
256-QAM	5/6	To Be Provided
256-QAM	7/8	To Be Provided

The signal quality indicator (SQI) in [%] shall be calculated according to the following formulas.

SQI = 0 if $C/N_{rel} < -7$ dB

SQI = $(((C/N_{rel} - 3)/10) + 1)$ * BER_SQI if $-7 \text{ dB} \leq C/N_{rel} < +3$ dB

SQI = BER_SQI if $C/N_{rel} \geq +3$ dB

Where: C/N_{rel} is DVB-T mode depended of the relative C/N of the received signal value in [dB] and $C/N_{rel} = C/N_{rec} - C/N_{NordigP1}$

Where: C/N NordigP1 is the required C/N value in [dB] for the non-hierarchical DVB-T.

C/N_{rec} is the C/N value in [dB] of the received signal

E.3.3.2 Status check: Basic

The STB should provide at least a basic status check function (accessible through the Navigator) that presents reception quality information for a selected frequency (currently viewed by the user). The basic status check shall include:

- Channel id
- Centre frequency
- Signal Strength Indicator, SSI (%)
- Signal Quality Indicator, SQI (%)

E.3.3.3 Status check: Advanced

The STB/idTV should provide an advanced status check function (accessible through the Navigator) that presents the following information [43]:

- Channel id
- Centre frequency
- Signal strength (dBm or dBμV)
- Signal strength indicator, SSI (%)
- Signal quality indicator, SQI (%)
- C/N (dB)
- BER before Reed Solomon decoding (DVB-T) or BCH decoding (DVB-T2)
- Uncorrected packets

It is recommended to make the end-user antenna installation easier by providing an overall view of reception quality (Status check: Basic) for all installed multiplexes (frequencies) or enable the end-user to change the installed multiplexes (frequencies) easily. Reception quality information should be updated cyclically until this mode is exited.

In addition, it is recommended that the following information can be presented for the received frequency, transport stream and service:

- DVB-T2 mode
- transport stream id
- Network id
- Service id
- T2 system id
- PLP id

E.3.3.4 Installation mode: Automatic Search, best service

The STB/idTV should provide an automatic search that finds all of the multiplexes and services in the whole (supported) frequency range, before the automatic search is started, all service lists shall be deleted (if present).

The STB/idTV shall only display a service once in the service list (i.e. avoiding duplicate of the same services), even if the same service (same triplet original_network_id, transport_stream_id and service_id) is received from multiple transmitters. If the same service can be received from several transmitters, the one with best reception quality should be selected. The criteria for selection of the best received service (i.e. best reception quality) should be based on the combination of the signal strength and signal quality.

E.3.3.5 RF Input Connector

The STB/idTV should have one input tuner connector, type: IEC female in accordance with IEC 60169-2, part 2. The input impedance shall be 75 ohm.

If the RF input supports DC power to an external antenna with amplifier, it should not degrade to the performance of the RF input characteristics. The DC power supply should be protected against short circuit. Furthermore, there should be an alternative in the menu system to turn the DC power supply source on/off. In the first time initialization and resetting to factory default settings, the DC power supply shall be switched off.

E.3.3.6 RF Output Connector (option) [40]

For a STB/idTV equipped with a RF bypass (RF in - RF out), the connector should be of type: IEC male in accordance with IEC 60169, part 2. The frequency range for the RF bypass should be from 47MHz to 862 MHz and the RF bypass gain should be from –1 dB to +3 dB.

The RF signals should be bypassed from RF_{in} to RF_{out} independently from the status of the STB/IDTV (operational or stand by), so that connected equipment (e.g. TV set) can operate even if the STB/idTV is in standby.

E.3.3.1.7 Time Interleaving [40]

The STB/idTV-T2 shall at least include time interleaving capability corresponding to the maximum time interleaving according to DVB Blue book, i.e. 219+215 OFDM cells for a data PLP and its common PLP together [43].

E.3.3.8 Input/Output Data Formats

The STB/IDTV-T2 shall be able to support TS bit rates ≤ 72 Mbit/s.

NOTE: The maximum total input bitrate to the DVB-T2 system (considering the sum of all input streams) is therefore 72Mbit/s * 255. The maximum input bit rate in terms of payload, taken over all input streams is limited by the T2 transmission capacity [40].

D.3.4 PERFORMANCE

D.3.4.1 General

A wide set of performance requirements are defined for a limited set of DVB-T2 modes, see Table E.3 for an example for a more limited set of performance requirements are defined for a wider set of DVB-T2 modes.

Table E.3: A limited set of DVB-T2 modes for performance requirements [40].

	VHF III 7MHz SFN			**VHF III 7MHz MFN**			**UHF 8MHz SFN**				**UHF 8MHz MFN**	
Constellation	256-QAM rotated			256-QAM rotated			256-QAM rotated				256-QAM rotated	
Code Rate	3/5	2/3	3/4	3/5	2/3	3/4	3/5	2/3	3/5	3/5	2/3	¾
Guard Interval	1/8			1/128			1/16		1/32		1/128	
Transmission Mode	32K Normal			32K Normal			32K Extended				32K Extended	
PAPR	TR-PAPR			TR-PAPR			TR-PAPR				TR-PAPR	
SIMO/MIMO	SIMO			SIMO			SIMO				SIMO	
FEC Frame Length	64800			64800			64800				64800	
Input Mode	Mode A			Mode A			Mode A				Mode A	
TFS	No			No			No				No	
Normal mode (NM)/high efficiency mode (HEM)	HEM			HEM			HEM				HEM	
FEF	Not Used			Not Used			Not Used				Not Used	
Auxiliary streams	Not Used			Not Used			Not Used				Not Used	

APPENDIX F

Based on the architecture of DVB-T2 transmissions, three additional nodes need to be added to that of the T1 network: T2 gateway, T2 modulator (transmitter) and a new interface for transmission. The specifications for the additional network elements outlined in the Bidding document for DTT networks in Ghana are as below [5]:

F.1 DVB-T2 Transmitters

A DVB-T2 transmitter comprises all functions of a chain starting with the input of a MPEG-2 Transport Stream with a bit rate as specified in ETS 302 755 (for DVB-T2 standard), and ending with the power output of the DVB-T2 signal after the output filter. All transmitters shall be capable to operate in a Single Frequency Network and/or Multiple Frequency Network as appropriate depending on the Network design.

F.1.1 *General Requirements for DVB-T2 Transmitter*

The general requirements for DVB-T2 transmitter should take into account: the noise requirements, connector types, local interface, remote interface, Web GUI, SNMP interface and the event log. Details of these specifications for Ghana are outlined the Bidding document for DTT network of Ghana.

F.1.2 *Technology used DVB-T2 Transmitter*

The technologies employed by the various working parts of the DVB-T2 transmitters need to be studied to ensure it comply with the standards Ghana intends adopting. These include the following parts:

- Modulator (Input Signal and Test Signal/PRBS)
- Working frequency (Frequency Range, IF, External Reference)
- Synchronization (Frequency and time reference, Stability, Internal Reference, Behavior In case of GPS Failure, SFN Propagation Delay Compensation, Dynamic Delay Compensation, Static Delay Compensation),
- Transmitter power (Output power, Nominal Power, Power consumption, Stability, Return loss, Efficiency),
- Outage stage, measurement/test point(transport stream, RF test point and isolation point),

References

[1] Digital Television Transmission in Ghana, http://www.myskyyonline.com/SKYY_NEWS/Entries/2008/6/1_Entry_1.html,[Accessed 16/02/10].

[2] Digital Television Transmission http://en.wikipedia.org/wiki/Digital_tv [Accessed 16/02/10].

[3] http://www.wikipedia.org/wiki/digital_tv [Accessed 24/06/09].

[4] National Communication Authority, "NCA Advisory on Migration from Analogue to Digital Broadcasting".

[5] Bidding Document (Single -Stage) for Digital Terrestrial Television Network Solution for the Republic of Ghana, Issued on 20th June 2011, pp. 156 – 157.

[6] NCA, "NCA Advisory on Migration from Analogue to Digital Broadcasting", p. 5.

[7] DVB-S, http://www.complextoreal.com/tdvbs.htm [Accessed 13/12/2009].

[8] DVB-T, http://en.wikipedia.org/wiki/DVB-T [Accessed 13/12/2009].

[9] DVB-C, http://en.wikipedia.org/wiki/DVB-C [Accessed 13/12/2009].

[10] DVB-H, www.wikipedia.org/wiki/DVB-H [Accessed 13/12/2009].

[11] S-DMB, http://www.itu.int/ITU-D/tech/digital-broadcasting / MiscMeetings/ ITU_ AIBD_ Pakistan_Nov07_ITUPresentation.pdf . [Accessed 19/12/2009].

[12] Remi Cazenave and Benjamin Rivier, "T-DMB for TV on Mobiles", p. 11.

[13] Stanko Perpar, RTV Slovenija, and OE Oddajniki, "Frequency Planning and Opportunities for new service in DVB-T/H", p. 13.

[14] Antenna handbook, Department of the Navy Headquarters United State Marine Corps Washington D.C, 2003, pp. 2-3.

[15] http://www.fas.org/man/dod-101/navy/docs/es310/propagat/Propagat.htm, [Accessed 16/02/2010].

[16] M.P.M Hall, L.W Barclay and M.T Hewitt, "Propagation of Radiowaves, published by Institution of Electrical Engineers", 1996, pp. 14-15, pp. 374-376.

[17] EBU Technical Report on Digital Video Broadcasting: "Implementation guideline for DVB-T Services: Transmission Aspect", 1997, pp. 28-31.

[18] Nigel Laflin, Approaches to Frequency Planning for RRC-04/05, September 2003, Slide 23.

[19] DigiTAG Report, 'Understanding DVB-T2, Key Technical, Regulatory and Business Implecations', p. 6.

[20] David White," Overview Study into the Experiences and Practices of DTT in the UK", September 2007.

[21] Seamus O'Leary, "Understanding Digital Terrestrial Television", ARTECH HOUSE, INC, 2000, pp. 133-177.

[22] EBU Tech 3348, Frequency and Network Planning Aspects of DVB-T2, pp. 25-29, p. 66.

[23] Executive Summary of the Second DTT Frequency Planning Study, "DTT frequency plan for Hong Kong based on the findings and recommendations of PA", pp. 5-6.

[24] DVB; "Implementation Guideline for DVB-T Service; Transmission Aspects", 1997, pp. 38-46.

[25]Stanko Perpar, ITU-R T/G 6/8, "Technical Characteristics of Digital Systems", Slides 22-24.

[26] ECC REPORT 49, "Technical Criteria of Digital Video Broadcasting Terrestrial (DVB-T) and TerrestriaL – Digital Audio Broadcasting (T-DAB) Allotment Planning, Copenhagen, April 2004", p. 16.

[27] DigiTAG Report, "Network in Evolution, Making Changes to the digital terrestrial television platform", May 2008, pp. 13-28.

[28] Emmanuel Jacques, "DVB-T2: The New Story", Bangkok, 2010, p 9-11.

[29] Nigel Laflin, "Practical experience gained during the introduction of Digital Terrestrial Television broadcasting in the UK", 18 - 19 September 2003, slide 2.

[30] Ofcom office of communication, "Digital Switchover Transmitter Details (Existing 81 sites)", October 2007, pp. 2-5.

[31] Specifications for Free-To-Air DTT Receiver in Greece as per DIGEA Broadcasting Standards, Minimum Requirements, June 2009, pp. 7-11.

[32] Requirement Specifications for DVB-T Receivers Used in Republic of Slovenia, Version 1.0, 2008, p. 13.

[33] Ministry of Information and Communication Republic of Kenya, Report of Taskforce for the Migration from Analogue to Digital Broadcasting in Kenya, September 2007, p. 21.

[34] NCA, "Advisory on Migration from Analogue to Digital Broadcasting", 2009, p. 5.

[35] Questionnaire Prepared to the National Communication Authority, NCA, 2009.

[36] Olov Carlsson, "Frequency and Network Planning for Terrestrial Digital Sound and Television Broadcasting", slide 7.

[37] Questionnaire for GTV.

[38] Questionnaire for SKYY Digital.

[39] SKYY Digital DVB-T Project Outline, http://www.dh-tv.com/Product/Ghana.htm [Online] [Accessed 15/07/2011].

[40] Requirements to NorDig-T2 compliant IRDs Addendum to the Nordig Unified Requirements (ver 2.1) for Integrated Receiver Decoders for use in cable, satellite, terrestrial and IP-based networks, 2010.