Thesis Title: "Design of Broadcasting Single Frequency Network (SFN) for effective frequency management in Rwanda, Improvement of Coverage Probability"

Submitted by

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Master of Science in ICT (Option: Operational Communication)

June 2017

Research and Postgraduate Studies (RPGS) Unit

Thesis Title: "Design of Broadcasting Single Frequency Network (SFN) for effective frequency management in Rwanda, Improvement of Coverage Probability"

By

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A dissertation submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE IN ICT (Option: Operational Communications)

In the College of Science and Technology

Supervisor: Dr. Said RUTABAYIRU

June 2017

DECLARATION

I, Eurald GAKWANDI declare that this Dissertation contains my own work and is the result of my own research and investigations; it has never been presented in other University or Higher Learning institutions, all texts and results which have been obtained from other sources/workers are fully referenced.

I understand that cheating and plagiarism constitute a breach of University regulations and will be dealt with accordingly;

Student Name and Number

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Signed………………….

Date……………………..

Certificate

This is to certify that the project work entitled "Design of Broadcasting Single Frequency Network (SFN) for effective frequency management in Rwanda, Improvement of Coverage Probability" is a record of original work done by ***Eurald GAKWANDI*** *with Reg no:* ***217302270*** *in partial fulfilment of the requirements for the award of Master of Science in Information and Communication Technology of College of Science and Technology, University of Rwanda during the academic year 2016-2017*

Dr. Said RUTABAYIRU	**Mr. Dominique HALERIMANA**
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Supervisor	**Head Department of Information Technology**

AKNOWLDGEMENT

I am most grateful to my Supervisor, Dr. Said RUTABAYIRU who supervised this work and offered all the necessary guidance. He assisted a lot to make this work a success, without him, this work would not have been possible.

My special thanks go to the lecturers of Master of Science in Operational Communications at College of Science and Technology (CST) for their effort in teaching different courses and our classmates who helped in one way or another during the assignments.

My sincere thanks further go to my wife Mrs Kayiranga Annet Comfort for her spiritually and courage support during the two years course.

Finally, my gratitude thanks go to Rwanda Utilities Regulatory Authority, my employer who financed me for taking the course and gave regular authorization of attending classes.

ABSTRACT

The increased demand for mobile broadband services has led the increasingly demand of more frequency spectrum in mobile services. The frequency band 470-862 MHz initially assigned to terrestrial television broadcasting has been identified suitable for mobile services. The trend is that broadband services will acquire more frequencies from television broadcasting and already the band 694-862MHz making a total of 168MHz bandwidth have been assigned to mobile broadband services. Therefore, regulators of telecommunication services are looking alternative way for effective utilization of the available frequency band 470-694MHz [9].

In this thesis we will focus on re-planning the available television frequencies and enhance the coverage probability of OFDM based SFNs network. The simultaneous transmissions of same frequencies in SFN create severe inter-symbol interference at the receiver and this thesis has addressed such type of interference by choosing the appropriate guard band interval. An analysis on the receiver performance has been performed resulting into obtaining the minimum transmitter required of 7 for achieving maximum diversity gain in the random model.

Further, we prove that for a site that initially had 4 or 5 broadcasting frequencies, it is possible to use 9 frequencies in single frequency networks and in order to obtain 100% of television signals coverage in the territory of Rwanda, three more sites Mushubati, Bumbogo and Rucamatako have been added in the terrestrial television coverage analysis.

Lastly, the proposed SFN frequencies plan shall help the regulator of telecommunication services to effectively assign the frequencies to the number of signal distributors and more TV stations shall come into the market hence increasing job creation.

Key Words

Single frequency networks, multiple frequency networks, Signal distributors, content providers, terrestrial digital video broadcasting, analog broadcasting, head-end, and international telecommunication union

List of Symbols and Acronyms

ATU	Africa Telecommunication Union
ATSC	Advanced Television Systems Committee
CNR	Carrier to Noise Ratio
COFDM	Coded orthogonal frequency division multiple
DAB	Digital Audio Broadcasting
DC	Direct Current
DVB-T	Digital Video Broadcasting – Terrestrial
DVB-T2	Digital Video Broadcasting – 2nd Generation Terrestrial
DTTB	Digital Terrestrial Television Broadcasting
DTT	Digital Terrestrial Television
EBU	European Broadcasting Union
EACO	East African Communication Organization
FM	Frequency Modulation
GDP	Growth Domestic Product
GPS	Global Positioning System
UTC	Universal Time Coordinated
VPN	Virtual Private Network
RBA	Rwanda Broadcasting Agency
RF	Radio Frequency
Rs	Symbol rate
RURA	Rwanda Utilities Regulatory Authority
SFN	Single Frequency network
SIR	Signal
TOD	Time of Days
TV	Television

1PPS	One Pulse per Second
TS	Time Synchronization
SI	Service Information
SIP	Second Frame Initialization packet
OFDM	Orthogonal Frequency Division Multiplexing
PTN	Packet Transmission Network
PCR	Program Clock Reference
MPEG	Moving Picture Expert Group
MIP	Megframe
MFN	Multiple Frequency Network
MHz	Megahertz
WRC	World Radio Communication Conference
3G	Third Generations
4G	Fourth Generations
Δf	Spacing of Sub-carriers

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CHAPTER1: INTRODUCTION

1.1 Introduction

The World Radio Communication Conferences 2012 and 2015 (WRC-12 & WRC-15) allocated a portion of frequency spectrum initially allocated to Broadcasting Service to Mobile Service. The frequency band 694MHz- 862 MHz assigned to IMT services with bandwidth 168MHz have left Rwanda with fewer frequencies in television broadcasting than originally assigned. The original assignment before WRC-12 was from channel 21 to channel 69 and now it is from channel 21 to channel 48.

This has brought a lot of limitations in the DVB-T frequencies planning and the MFN currently adopted of assigning television frequencies is seen inefficient in DVB-T frequencies assignment. MFN is the type of frequencies assignments where neighboring sites have different frequencies assignments. A Signal distributor is assigned different frequencies at each neighboring sites and this requires many frequencies to signal distributors than would be the case for SFN [2]. Due to the fewer DVB-T frequencies available [25], the regulator has opted to license only two signal distributors for laying the network and content providers aggregates the contents that are sent to signal distributors for transmission in the network. The multiple frequency network frequencies assignments have not solved the scarcity of frequencies available and hence Rwanda and different countries are considered the possibility of adopting SFN model to address the issues of spectrum scarcity in TV Broadcasting.

The introduction of single frequency networks in broadcasting services is seen as another effective method for proper management of scarce frequencies in broadcasting, efficient utilization of radio spectrum and allowing more number of radio and TV programs in the network than MFN does.

Single Frequency Network (SFN) synchronizes all transmitters in the same network so that they radiate identical signals using the same frequency channel. Signals transmitted in a SFN network are synchronous in time, use the same frequency and have identical multiplex contents [26].

1.2 Motivation

In Rwanda, terrestrial broadcasting in FM and TV services have been experiencing scarcity of frequency spectrum compared to the demand of frequencies by potential applicants interested in operating in the broadcasting industry. This has resulted into few assignments of frequencies to applicants while a big number of application seeking for frequencies are pending due to unavailability of spectrum.

With the studies, the design and implementation of SFN network study for Rwanda, the issue of broadcasting frequency scarcity shall be solved and potential operators shall invest in digital broadcasting business, hence many jobs and increased revenue for operators, government and the industry in general will be generated.

1.3 Research Background

Rwanda is facing the issues of scarcity in digital terrestrial broadcasting frequencies and no implementation of SFN network due to the fact that the planning of SFN frequencies is very difficult.

Therefore, the studies shall be based in the scarcity of terrestrial digital broadcasting frequencies and designing a network that shall resolve scarcity of frequencies in broadcasting.

1.4 Problem statement

With high demand of broadband applications and high demand of frequencies in broadband applications. WRC-12 and WRC-15 conferences resolutions decided to allocate the band 694-862MHz to broadband applications and this caused the reduction of digital terrestrial broadcasting spectrum allocated to Broadcasting Services. Further the use of multiple frequency network (MFN) has shown loop in the management of few broadcasting frequencies, therefore, there is a need to have appropriate network which can be installed for effective management of DVB-T frequencies.

The introduction of single frequency network (SFN) [11] has been seen as the solution to be adopted by Rwanda in the effective management of digital terrestrial video broadcasting (DVB-T).

This shall allow the increase of more radio frequencies to the signal distributors and hence increase the number of content providers in the market. The availability of more frequencies and increase of TV channels shall enhance revenues to the government and creates more jobs to the citizen.

1.5 Objectives of the work

The objective of this thesis is to design SFN network and re-planning Rwanda television broadcasting frequencies by enhancing the coverage probability with the aim of solving the existing frequency scarcity in terrestrial broadcasting services.

1.6 Specific Objectives

The objectives of the thesis shall involve;

- ❖ Plan for Rwanda terrestrial broadcasting frequencies in SFN mode.
- ❖ Design an SFN network and investigate the modules needed to make MFN transmitter work in SFN mode.
- ❖ Improve the coverage properties and estimate coverage probability which provides the maximum diversity gain in the network reliability.
- ❖ Coverage simulation of the SFN network on the map.

1.7 Scope and limitation of the work

The work aims at designing Rwanda terrestrial television frequencies into SFN network and the field visit of 14 broadcasting sites shall be conducted for understanding the real situation for the existing MFN. The SFN frequency planning [3] and SFN network design shall solve the frequency scarcity in broadcasting and enhance terrestrial broadcasting coverage.

This work was conducted within 24 weeks in Rwanda. However, some data were obtained within the country and outside the country from the different players in the broadcasting industry, other research studies in broadcasting as well as in ITU database and other ITU resources.

The limitation of the project is administrative procedure for frequency coordination with neighboring administrations to ensure appropriate and non-harmful and interference free environment.

1.8 Justification of the study

The introduction of SFN network has shown that if frequencies are not well planned, there is high self-interference [6] and external interference [11] due to many signals from different transmitter's arriving at the receiver in out of guard band duration. Further, the implementations of MFN in Rwanda have shown gaps in the effective management of digital broadcasting frequencies where it has shown that there are content providers licensed by RURA and spent more than one year without operation.

This study comes timely as it shall help regulator for effective assignment of digital television frequencies and signal distributors for having enough frequencies for the plan of their networks and further, strengthen the increase of TV content providers in the market.

1.9 Organization of the work

This work is organized according to the following chapters:

Chapter1 This chapter is composed of introduction of the work, motivation why the study is being conducted, research background, project statement, objectives of the study, specific objectives, scope and limitation of the study and justification of the study.

Chapter 2 is the literature review and highlights what other researchers have done on the implementation of SFN network.

Chapter 3 discusses system model and research methodology where methods and techniques used in this work are described. Sources and data collected are indicated and analyzed.

Chapter 4 describes the numerical analysis of the thesis and shows the results of the study.

Chapter 5 is the analysis of broadcasting SFN network design and implementation in Rwanda. The chapter shows different parameters considered in order to arrive to the SFN plan with good coverage and simulation of the map was also done.

Chapter 6 describes the challenges in the implementation of the broadcasting SFN networks. The requirements from each stakeholder are explained in more details.

Chapter 7 will finally highlight the conclusion and recommendations of the study

CHAPTER2. LITERATURE REVIEW

2.1 Introduction

The International Telecommunications Union (ITU) in their sessions of 2001 and 2002 decided to start the digital terrestrial broadcasting planning for the areas covering Region 1 including African countries, European countries and other countries signed the regional broadcasting agreement of 1989 in Geneva. The planning of terrestrial digital broadcasting was established after ITU agreed on migration from analogue to digital video broadcasting. In July 2006 the processes for planning of terrestrial digital broadcasting were completed. (RURA, 2008).

The analogue television frequencies included 170-230MHz and 470-862MHz. After the digital terrestrial broadcasting frequencies plan, the part of analogue broadcasting television frequencies 170-230MHz were assigned to audio digital broadcasting (DAB).

In WRC-12 conference [26] the band 790-862MHz allocated to digital broadcasting were assigned to IMT services leading to more reduction of frequencies for digital terrestrial broadcasting.

In WRC-15 Conference [2], another band 694-790 MHz originally assigned to digital broadcasting was taken by international mobile telecommunication (IMT) services. This caused more reduction in the digital terrestrial frequencies from 470-694MHz and a total of 168MHz frequency bandwidth originally assigned to digital television broadcasting has been assigned to international mobile telecommunication services.

The introduction of analogue to digital migration and assigning digital terrestrial broadcasting frequencies to IMT services have left a total frequency bandwidth 228 MHz taken from terrestrial broadcasting.

The reallocation of frequency spectrum initially assigned to broadcasting service to mobile services had a huge impact mainly to African countries as more developed and western countries use cable televisions and satellite televisions. African countries have been struggling in the meetings of WRCs to maintain a big portion of terrestrial broadcasting frequencies than other continents because serving the citizens with cable TV in Africa is not possible due to infrastructures issues and the cost of satellite services in Africa is very high, therefore terrestrial broadcasting is the easiest method for reaching TV viewers in Africa.

Single frequency network (SFN) [11] have been thought as another alternative method for effective spectrum management of existing digital broadcasting frequencies replacing the old method of multiple frequency network (MFN). With SFN more than one site can use same frequency to broadcast the same contents.

The thesis aims to re-plan Rwanda digital television frequencies into SFN network for obtaining more frequencies for assignment for each site. This shall bridge the gap that has been existing for the digital terrestrial broadcasting for more than 3 years.

2.2 Digital Terrestrial Broadcasting

Digital broadcasting technology is the broadcasting technology that employs digital data instead of analogue waveforms, to transmit audio or video via radio frequency or television channels.

Digital broadcasting can use different means or medium for transmission of broadcasts to the viewers. These include cable, satellite, terrestrial and internet protocol. Therefore, the technologies are referred to as Cable TV, Satellite TV, digital terrestrial TV (DTT) and IPTV depending on the means employed for transmission of TV programs.

Digital broadcasting provides three (3) basic models which are; free to air, pay TV or subscriber service and a hybrid model. All of them are able to coexist on the same network as standalone as well as working with mobile network operators to provide return path. (RURA, 2008)

The free to air TV programs are the programs that everybody with TV receiver have right to receive without paying any money or subscribing to any broadcasting operator. A pay TV or subscriber program is a program that can only be received after paying some amount of money or subscribing to the operator

2.3 Advantages of Digital Broadcasting

The operation of the digital decoder in digital terrestrial broadcasting (DTT) is guided by the data which is incorporated in the transmitted data stream. It uses service information (SI) in decoders in order to tune to and decode information being conveyed within the signal. In order to differentiate one service from another, there are identifiers in decoders that are used. These characteristics give digital broadcasting more advantages over the analogue broadcasting.

Digital terrestrial television (DTT) with the use of COFDM modulation makes the signal highly immune to multipath reflections. This means that DTT can operate where an analogue signal would not tolerate interference due to multipath reflections reaching receiver at different times

Digital broadcasting transmits many audio, audiovisual signals in one frequency channel that in analogue would require separate frequency channels thus making digital broadcasting more frequency efficient. It has also low cost transmission, constructive additional of received signals at the receiver and has diversity in content and information offered through digital broadcasting.

Digital Broadcasting allows for more content providers to enter into the market since there is more slots available for carrying contents in one frequency channel for DVB-T high standard definition, one frequency channel transmits twenty TV programs. Therefore, with introduction of digital television, there are increased demands for new services that were not available before.

With wide range of choices, desire to have experience at home similar to that in the theatre for convenience and the need for interactivity and internet, the consumer demand is expected to increase with the digital broadcasting.

The increased revenue associated with new features and controls plus interactivity derived from the next generation home digital entertainment systems attracts the interest of new content providers on the market.

2.4 Digital Broadcasting Value Chain

The broadcasting value chain involves the whole process from capturing contents, creating content in studio and transmission to the end receiver. Normally the digital broadcasting value chain involves a number of activities that are owned by different players. The figure below shows the key activities that are involved in the whole value chain.

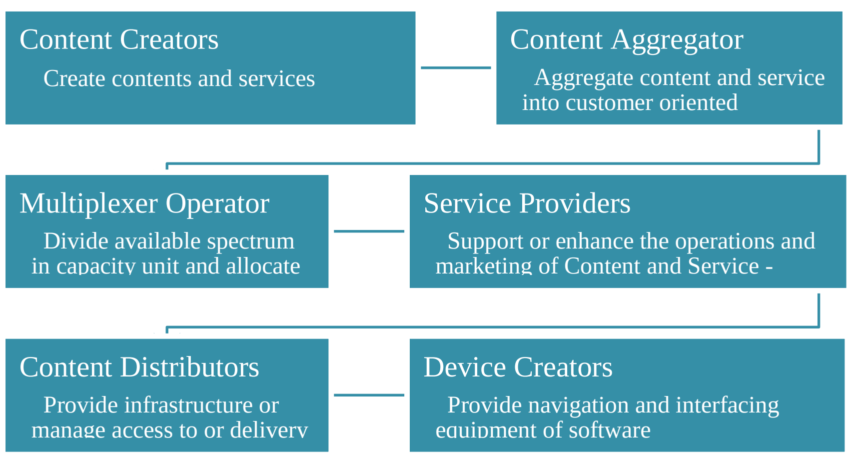


Figure 1: Main Activities involved in the Digital Broadcasting Value Chain

2.4.1 FUNCTIONS OF EACH PLAYER IN THE DIGITAL BROADCASTING

In digital broadcasting, the content creator is responsible for creation of digital content in form of animations, images, graphics, audio and video. This stage involves many activities which are capturing of audio, audio visual, audio/video editing and composing.

Content aggregator is responsible for packaging the content, manages it and works as the advertising agency. He or she packages the content into bouquets that are suitable for customers.

The multiplex operator divides spectrum into capacity units and allocates to it services and/or packages. The service provider in the value chain enhances the operations. Advertises the content and manages the relationship with the consumers.

The content distributor is charged with infrastructure construction. He or she manages the accessibility and delivery of the content to the consumer.

The device creator is responsible for the provision of navigation and interfacing equipment of software. This can be the manufacture of the equipment or the programmer of the software.

However, it is not a mandatory that all the above activities should be owned by different players, but some activities can be combined to two, three or four players depending on the market availability and size of the country.

In Rwanda, the digital broadcasting value chain is divided into two key players, content service provider and signal distributor. The content service provider is responsible for content creation while signal distributor is responsible for content aggregation and transmission.

Most countries like South Africa, United Kingdom, Hong Kong and Australia have adopted three players in the delivery process of digital broadcasting services. These are Content Service Provider, Multiplex operator and Network Service Provider. In this case, the activities are distributed among the three players.

Content Service Provider: This player would be referred to as the broadcaster in the analogue environment. In digital environment, this player is charged with content offering in the broadcasting process and determines whether the content should be audio, video or data.

Multiplex operator: This is the player which deals with compiling, operating and marketing for the content to be broadcasted and decide on the conditional access (CA) and subscriber management system (SMS) to use.

Network service provider: This player is responsible for operating the networks and transmitters or infrastructure.

2.4.2 UPGRADING OF DVB-T TO DBB-T2

DVB-T is the digital terrestrial television standard developed in 1995 and has been adopted by more than half of all countries in the world. It is the first standard developed for transmission of digital television contents through terrestrial. This technology allows maximum eight TV contents for transmission in one frequency. Since its publication, research in transmission technology has increased, capacity demand has increased and releasing more frequencies for other services like IMT has also increased. In 2008, DVB project developed DVB-T2 standard to replace the existing DVB-T standard with the aim of catering new demands in terrestrial broadcasting. It is clear that now more than 20 TV channels are carried by DVB-T2 and hence capacity increase is provided by DVB-T2 in comparison to DVB-T. Further, DVB-T2 shows more efficiency in SFN performance and allows increase of symbol period.

2.5 Single Frequency Network (SFN)

Single Frequency Network (SFN) [1] is a broadcast network where several transmitters simultaneously send the same signal over the same frequency channel. Signals transmitted in an SFN are synchronous in time (with a precisely controlled delay); nominally coherent in frequency (within a few Hz) and have identical multiplex content.

In a single- frequency network (SFN) all transmitters operate at exactly the same frequency. Hence SFN network requires much less spectrum, less power consumption and allows more TV programs in comparison to traditional multiple frequency network (MFN). SFN network also increases the coverage area and decrease the outage probability in comparison with MFN since the total received signals increase in the middle between transmitters.

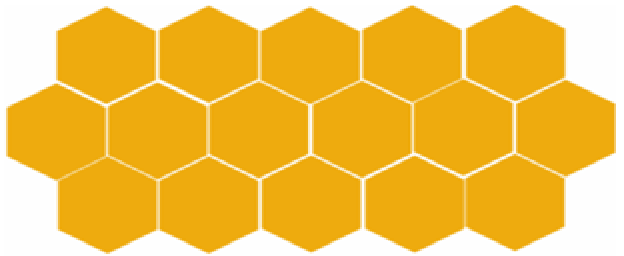


Figure 2: SFN Network

Figure 3: MFN Network

2.6 SFN Principles

In Single Frequency Network, all transmitters are synchronously modulated with the same signal and radiate same frequency. Due to the multipath capabilities of the multi-carrier transmission system (COFDM) signal from several transmitters arriving at the receiving antenna are contributing constructively to the total wanted signal.

However, in SFN planning the limiting effects is called self-interference of the network. In case the signal from far distant transmitters are delayed more than allowed by the guard interval the signals behave as noise interfering signals rather than constructive signals.

There are two main methods of creating single frequency network. The first method is using one channel booster; one channel booster receives from the main transmitter and retransmits the signal in the same frequency. This method has no error correction; this means any error received at the reception is retransmitted with Echo produced by booster. Further, there is limit in placement of the booster; the booster should be located in the line of sight with the original transmitter.

The second method is distributed transmission where the signal reaches all transmitters via microwave links. Through the use of GPS or VPN, a reference clock at each transmitter is synchronized so each transmitter can emit signals containing the same contents and the symbol data. To get each transmitter synchronized in both time and frequency domains some extra data is added into the serial data streams which are a time reference signal provided by SFN adapter. At each transmitter the OFDM modulator uses this time stamp to calculate the local delay signals which allows transmitters synchronized to transmit signals on the same time though transmitters are located at different locations.

2.7 Orthogonal Frequency Division Multiplex (OFDM)

An OFDM signal consists of a number of closely spaced modulated carriers. When modulation of any form of signal (voice or data) is applied to a carrier, then sidebands spread out either side. It is necessary for a receiver to be able to receive the whole signal to be able to successfully demodulate the data. As a result, when signals are transmitted close to one another they must be spaced so that the receiver can separate them using a filter and there must be a guard band between them. This is not the case with OFDM. Although the sidebands from each carrier overlap, they can still be received without the inter-interference between carriers that might be expected due to orthogonality to each another during transmission. This is achieved by having the carrier spacing equal to the reciprocal of the symbol period.

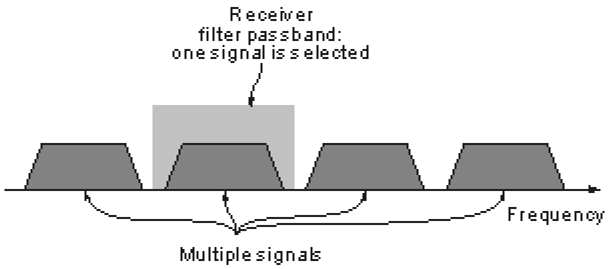


Figure 4: OFDM Signal

For observing how OFDM works, it is necessary to look at the receiver. This acts as a bank of demodulators, translating each carrier down to DC. The resulting signal is integrated over the symbol period to regenerate the data from that carrier. The same demodulator also demodulates the other carriers. As the carrier spacing equal to the reciprocal of the symbol period means that they will have a whole number of cycles in the symbol period and their contribution will sum to zero meaning no interference contribution.

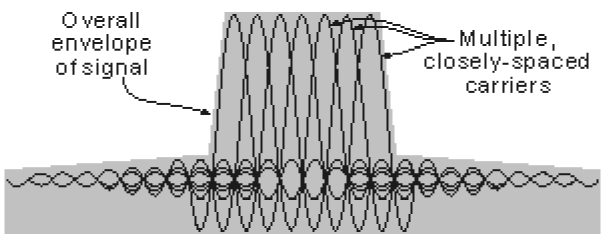


Figure 5: OFDM Spectrum

One requirement of the OFDM transmitting and receiving systems is that they must be linear. Any non-linearity will cause interference between the carriers as a result of inter-modulation distortion. This will introduce unwanted signals that would cause interference and impair the orthogonality of the transmission.

In terms of the equipment to be used the high peak to average ratio of multi-carrier systems such as OFDM requires the RF final amplifier on the output of the transmitter to be able to handle the peaks whilst the average power is much lower and this leads to inefficiency. In some systems the peaks are limited. Although this introduces distortion that results in a higher level of data errors, the system can rely on the error correction to remove them.

2.8 Transmission of Data on OFDM

The data to be transmitted on an OFDM signal is spread across the carriers of the signal, each carrier taking part of the payload. This reduces the data rate taken by each carrier. The lower data rate has the advantage that interference from reflections is much less critical. This is achieved by adding a guard band time or guard interval into the system. This ensures that the data is only sampled when the signal is stable and no new delayed signals arrive that would alter the timing and phase of the signal.

2.9 DVB-T Transmitter

The block diagram of DVB-T transmitter and receiver is shown below showing different modules making the system;

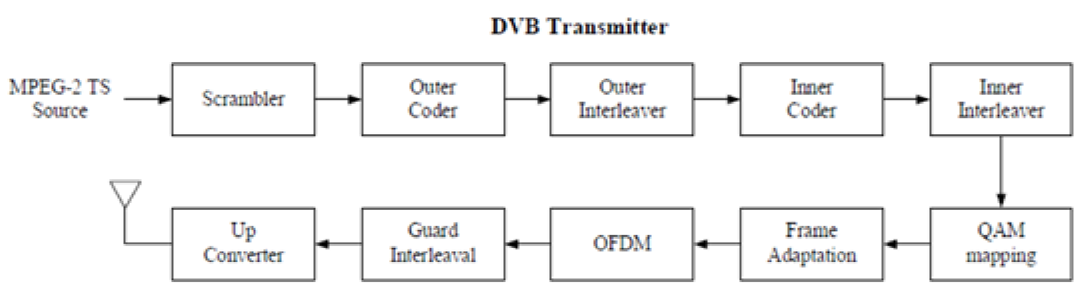


Figure 6: Shows DVB-T Transmitter Parts

The core of the OFDM transmitter is the modulator which modulates the input data stream into frame by frame. Data is divided into frames based on variable which refers to the number of symbols per frame per carrier. It is not obvious that the number of transmitting data is a multiple of the number of carriers. The modulator converts the input data stream from serial to parallel and pads a number of zeros to the end of the data stream in order for a data stream to fit into a 2-D matrix dimension. For example, if a frame of data of 10,000 symbols are transmitted by 350 carriers with a capacity of 30 symbols/carrier. The modulator pads 500 zeros at the end to form a matrix of 30 by 350.

2.10 Signal Communication Channel

Another factor to be considered in SFN network design is the communication channel. The communication channel is the radio link between transmitter and receiver. The signals transmitted through communication channel face different obstacles and it is expressed by propagation models. Propagation models are used to calculate signal level at the receiver taking into consideration the propagation losses suffered by the signal due to different propagation mechanisms such as reflection, refraction and scattering.

In SFN network design, a terrestrial propagation model which considers path loss component, a slow varying long-term (shadowing) and a fast (short-term) varying component [11] is considered. The path loss component is modelled as a deterministic function describing the distance dependent losses while long-term and short-term varying components depend on the receiver location.

Radio signals are not subjected to distance propagation losses, but also to path loss affected by the topography of Rwanda terrain. The shadow fading is caused by large obstacles in the terrain between transmitter and receiver examples include Mountains, high buildings and toll trees. Moreover, reflections of various types of scatters, both movable and stationary cause a multipath propagation environment at the receiver. The received radio signals thus consist of a sum of many signals from reflected signals and many signals from different transmitters which is called short term fading and long-term fading [11].

Short term fading is generated by scattering in the vicinity of receivers. The multipath fading is often modelled as a wide sense stationary uncorrelated scattering channel [12]. The channel for transmitter I is modelled as M-tap delay line, where each channel tap represents reflection of the transmitted signal in the vicinity of the receiver. The impulse response of the channel is given by

$$h(t) = \sum_{\boldsymbol{c=1}}^{\boldsymbol{M}} \quad hi(c)\partial(t - \tau i(c)) \qquad (2.1)$$

Where $\tau i9(c)$ is the delay of tap i(c). The delays are assumed to be independent random variables uniformly distributed between $[\tau i,\ \tau i + To]$, where τi is a constant defined as the propagation delay between receiver and transmitter. To is the mean delay spread channel [13]. The envelope of channel tap i(c) is assumed to be Rayleigh distributed, where h_i (c) has the following probability density function;

$$Pr\ (hi(c) = a)\ = a\frac{a}{\sigma m2}e - a2/2\sigma m2 \tag{2.2}$$

Where $\sigma m2$ is the function of the expected local receiver power Pr and further, we assume that the expected receive power from each tap is constant.

2.11 OFDM DVB-T2 Receiver

When the signal is received by OFDM receiver, a trunk of received signal in a selective length is processed in the frame detector in order to determine the start of the signal frame. The received signal is sampled to a shorter discrete signal with a sampling rate defined by the system. A moving sum is taken over this sampled signal. The index of the minimum of the sampled signal is the approximate start of the frame guard while one symbol period from this index is the approximate location for the start of the useful signal frame.

After the signal is detected, it is sent to periodic guard time removal for removing the synchronization signal (guard time) inserted during transmission and finally sent to OFDM demodulator for demodulating the signal and capture the useful information for analysis or viewed by the end receiver.

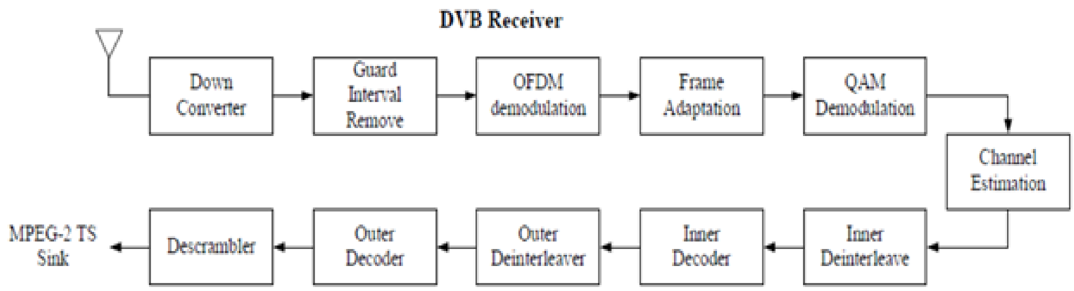


Figure 7: Shows DVB-T2 Receiver Modules

2.11 MFN deployment and operational in Rwanda

The digital terrestrial television broadcasting using multiple frequency networks in Rwanda have been in use since 2014 and RURA through broadcasting policy has licensed two signal distributors namely Star Africa Media Ltd and Rwanda Broadcasting Agency (RBA). These signal distributors are responsible for management of broadcasting networks while content provisions are responsibilities of TV channels.

Star Africa media Ltd has deployed its network in 6 sites and each site host three DVB-T2 transmitters, three frequencies are needed per site. Due a large number of TV channels to be carried and scarcity of TV frequencies, star Africa media has opted to over compress their hosting TV channels to 30 or more. This has led to low signal quality of TV channels carried in star Africa network.

RBA has deployed its network in 14 sites and each site host one DVB-T transmitter. The DVB-T transmitter owned by RBA carries 8 channels and these channels are carried in all 14 sites. The TV channels carried are very few and there is a need for upgrade to DVB-T2 where more TV channels can be carried in one transmitter.

Below is the current assignment;

Nr.	Site	Channels	RBA	Star Africa Media Ltd
1	GIHUNDWE	25 26 30 41	26	25 4121
2	KINANIRA	21 24 35 47	24	
3	HUYE	21 38 40 48	40	21 31 38
4	JARI	28 43 47	28	29 47 22 23
5	BYUMBA	25 33 36 44	25 33	
6	RUBONA	22 25 27 28	22	25 27 41 50
7	KARISIMBI	24 45	62	
8	KARONGI	31 34 36 37	34 36	
9	NYARUPFUBIRE	31 34 37 41	34 41	3136 37
10	RUSHAKI	39 48 42	39 48	
11	REBERO	22 23 26 27 29	22 26	
12	GITWE	21 30 36	30	
13	NYABITIMBO	40 43 21 46	4	
14	MUGOGO	32 46	60	32 46 41

Table 1: Showing the current MFN assignment in Rwanda

2.12 Comparison of MFN and SFN broadcasting networks

Multiple frequency networks are the network where each broadcasting transmitter is assigned its own frequency channel separate from another transmitter in the vicinity of coverage area while single frequency network is the network where same frequency is assigned to different transmitters in a given service area.

For network deployment and Rwanda case of television frequencies scarcity, we have to compare the two networks and come up with the good network than the other;

	SFN	**MFN**
Advantages	➢ Excellent spectral efficiency, low spectrum is used and hence other frequencies can be used for other services or can be used to expand broadcasting services. ➢ Network Gain, for constructive SFN signals contribute towards higher received signal by combining two or more signals to the end receiver to form one signal. ➢ Good power efficiency, SFN uses lower energy power	➢ Network splitting is easy, different multiplexes are installed at different sites and no interference to the end TV receivers. ➢ MFN can re-use the existing infrastructure of analogue TV and antennas that existed before the analogue switch-off. ➢ No need for synchronization of all transmitters in frequency and time domain.

	during transmission. This is due to the fact that the constructive combination of two signals at the receiver leads lower power consumption ➢ Provides good indoor reception	
Disadvantages	➢ Network splitting for local contents are very difficult and hence not suitable for broadcasting which is not countrywide. ➢ The network requires excellent synchronization in frequency and time domain otherwise internal interference shall occur. ➢ New aerials like antennas have to be changed at the end user's side	➢ Not good for DVB-H networks where mobile handsets like phones are used. ➢ Not good for spectrum efficiency, more frequencies are needed for each transmitter is a service area ➢ Lower power efficiency ➢ Cannot assure indoor reception

Table 2: Comparison of SFN and MFN operation

2.13 Other Researches done in the field of Broadcasting Single Frequency Networks

In May 1999, Gilles BUREL and Pierre MAGNEZ [27], proved that OFDM transmission in SFN has drawbacks in the long packets and proposed array processing, source separation, signals synchronizations and summation. However, this proposal also has drawbacks of needing multisensor array but on the other hand the requirements on the precision of electronics devices such as local oscillators are very low.

A research by Sanja Maksimoviċ, Danijela Ŝikanja and Željen Trpovisk [28], showed that optimizing the spectrum usage and bandwidth is made possible with SFN topology, all the transmitters will radiate synchronously, based on information provided by the SFN adapter. Two kinds of synchronization were found in use, 1pps+10MHz and 1MHz frequency references. The more accurate these references are, the more precise Radio Frequency (RF) coverage is. The research noted that an inaccuracy of frequency synchronization (10MHz) will result in a very bad RF coverage (strong Inter-carriers interferences). The research further highlighted that defining the boundaries of an SFN network is not easy at all as it depends on the number of elements. A simulation software is required and huge amount of data is required for insertion into the software. These include, coordinates of transmitters in the SFN network, transmitters power, antenna radiation patterns, antenna heights, signal propagation model and antenna gains. The research done showed DVB-T2 improves by 30% of capacity than DVB-T usage.

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter is meant to show methods used in the “design of broadcasting single frequency work (SFN) for an efficient and effective management television broadcasting frequencies while improving the coverage probability”. The Chapter shows system model and steps taken to reach a maximum coverage probability of television signals in Rwanda and further research process conducted from the beginning of the thesis up to the conclusion. In this thesis, the main question is what is going to be the service area of the designed network and the population covered. The answer to this question is the calculation and improvement of coverage probability.

3.2 System Model

The system model comprises three transmission components, transmission, channel propagation and reception. The main objective of the thesis is to improve the coverage probability of broadcasting services by effective planning of the SFN deployment in Rwanda. 16 television broadcasting transmitters located in different areas of Rwanda are considered with the random location of receivers in the service area and out-side the service area. The transmitters are put into three zones for analysis simplification.

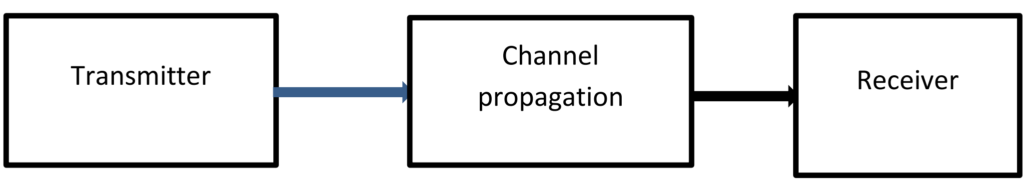


Figure 8: The System Model of DVB-T Signal Transmission

Since the coverage probability is calculated at the receiver’s side, below is the random statistics showing the areas covered by SFN and areas not covered by the existing MFN transmitters. The numbers of receivers are chosen randomly.

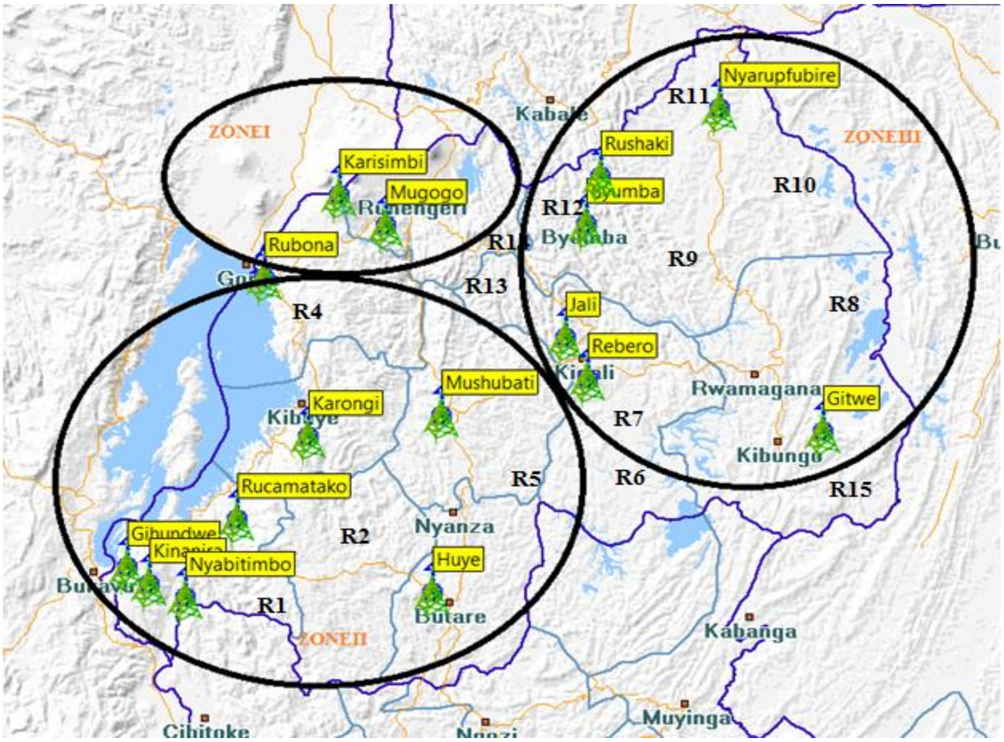


Figure9: Rwanda MFN Broadcasting and Distribution of receivers

3.3 Coverage probability

Coverage probability is defined as the ratio of the number of covered receivers (all receivers receiving signal field strength greater than noise level) to the total number of receivers in the network, where coverage of a transmitter refers to the geographical region inside which the receiver is able to communicate.

Coverage probability(Ø)=N-Cov_rw/N_rw (3.1)

Where N_Cov_rw is the total number of receivers in the signal coverage area.

N_rw is the total number of receivers in the network.

Taking an example of Fig9, the number of receivers in the current Rwanda MFN DVB-T signals is 10 while the total number of receivers in the network is 15. Therefore, the coverage probability is given by=10/15*100=0.666*100=66.6%.

Therefore, the thesis is going to study the SFN plan so that the coverage probability becomes 100% or 99%.

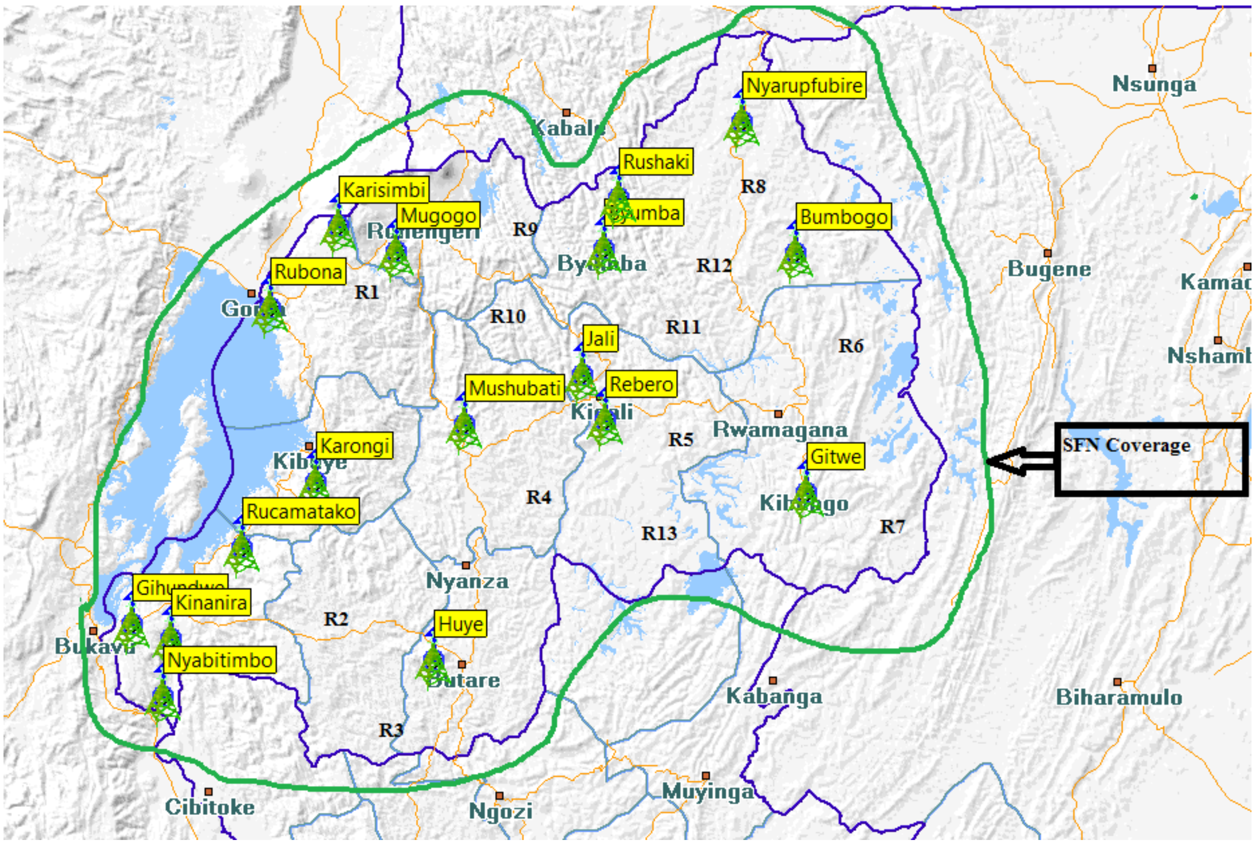


Figure 10: Rwanda proposed SFN Plan and receivers distributions

Taking an example of figure10 for SFN proposed frequencies planning of Rwanda, the total number of receivers in the network are 12 and the receiver in the coverage service area is 12.

Therefore, the Coverage probability is given by the formula (Ø)=N-Cov_rw/N_rw

Given that N-Cov_rw/=12 and N_rw=12 then,

Coverage probability (Ø)=12/12*100=100%

Therefore, from Figure10, the coverage probability of Rwanda territory when 17 transmitters are used is equal to 100%.

3.4 Simulation Model

The simulation model is used to calculate the coverage probability and for this case the static model is used. Static model is the model in which the receivers are static and don't move from one place to another.

3.4.1. Static model

In this model three zones each is considered independently;

Symbol	Parameter	Value
N_tx	Number of transmitters	ZoneI:3, ZoneII: 8 & ZoneIII: 6
N-rx	Total number of receivers in the network	ZoneI:8, ZoneII:5 & ZoneIII: 15
N-Cov	Number of receivers in the service area	ZoneI:8, ZoneII:5 & ZoneIII:15

Table 3: Parameters of SFN network with three local area networks

From the above parameters it is seen that for three zones, coverage probability is equal to 8/8*100%=100%, 5/5*100%=100 and 15/15*100=100%.

3.5 Research Process

To design an SFN network suitable for solving scarcity of terrestrial television of broadcasting frequencies in Rwanda, a flow chart below is used to reach a tangible result;

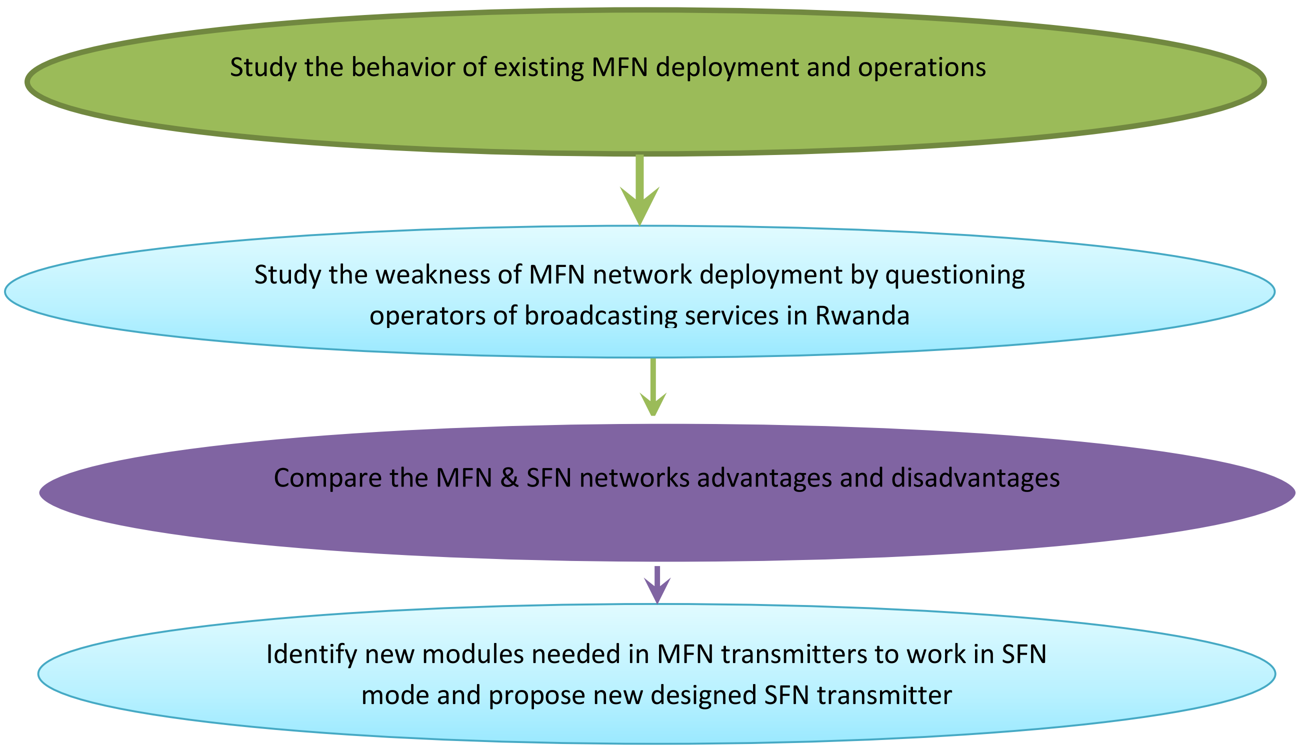


Figure 11: Diagram Showing the Research Process

During this research a purposive technique of sampling to collect data from the components of the sample and this made researcher capable of acquiring enough information during the research study.

Purposive sampling is defined as a method of sampling or type of sampling in which the researcher uses his/her judgment and or knowledge on which respondents are appropriate to suit the purpose of the study and the objectives of the study and then choose only those suitable for the research purpose.

For this study, the sample size is comprised of the technical staff from signal distributors, content providers, regulator side and manufacturers of equipment including staff from Harris Company and Rohde and Schwarz Company.

3.5.1 METHODS USED FOR DATA COLLECTION

For the purpose of achieving the objectives of this research, the following methods were used to collect data from the interested groups including primary data, secondary data and interviews.

3.5.2 PRIMARY DATA

Primary data is first-hand information that is collected through investigation or interview. First-hand information collected through investigation and interviews of people was used in this research; the group of people that were interviewed includes engineers from Rwanda Broadcasting Agency (RBA), engineers from Startimes media Ltd, Engineers from RURA and technical officers from Content providers like TV one, Flash TV, Big television network and Ishema TV.

3.5.3 SECONDARY DATA

This is data obtained through leading and not in direct contact; it includes consulting books, articles and similar projects that were done by others and the use of internet. During this research different books, research on internet and email exchange with manufacturers of DVB-T SFN equipment were used.

3.5.4 DATA COLLECTION INSTRUMENTS

Qualitative research method of data collection was employed. Qualitative research method is the type of research method that does not involve numbers or numerical value. It often involves words or languages, but sometime involves use of pictures, photographs and observations.

3.5.5 INTERVIEW

This method of data collection requires that a researcher goes direct to the field and face respondents live depending on the objectives of the study and ask questions to a selected group of people.

In this research, we interviewed engineers from Rwanda Broadcasting Agency (RBA), engineers from Startimes media Ltd, Engineers from RURA and technical officers from Content providers like TV one, Flash TV, Big television network and Ishema TV. The information obtained was useful for the design of SFN network because the scarcity of TV frequencies emerged to be the main issue for the development of digital terrestrial television industry.

3.5.6 FIELD SURVEY

Field survey is whereby the researcher is obliged to go to the field in person to witness the reality on the ground. In this case, the researcher does not have to ask questions. The advantage of this is that, the researcher is able to obtain the true current situation or information, analyze it and gives his or her personal observation.

Fourteen broadcasting sites were surveyed to access the current frequency assignment, types of DVB-T transmitters on the sites, technical specifications of the transmitters and taking geographical coordinates including longitudes/latitudes and heights above sea level.

3.6 DATA ANALYSIS

Analysis of data is the process of inspecting, cleaning, transforming, and modelling data with the aim of highlighting useful and meaningful information, suggesting conclusions and supporting decision making.

3.6.1 INFORMATION OBTAINED FROM INTERVIEWERS

In this Research, I have approached RURA staff in charge of frequency licensing, staffs of signal distributors and content providers by using interviews data collection method.

From the interviews, the following are noted;

- ➢ Regulator faces challenges of having few television broadcasting frequencies for assignment. New requests for television broadcasting in MFN networks are responded negatively, therefore there exists limitations in network expansion to the signal distributors.

- ➢ Star Africa Media as signal distributor faces the challenges of expanding their network and accommodate more content providers. This leads to over compression of TV contents at the multiplexer to allow at least more TV channels, however this leads to low TV signal quality and further new TV channels have no space for accommodation at Star network.

- ➢ Rwanda broadcasting agency (RBA) as a signal distributor has limited number of TV channels to host. Only eight (08) TV channels are hosted and there is a need to upgrade their network to DVB-T2 networks and further install more than one transmitter. This shall be facilitated by the introduction of SFN network instead of MFN which has limited number of frequencies.

- ➢ Existing content providers like Isango TV, Flash TV, Contact TV, Royal TV, Clouds TV, TV10 and TV1 are facing with challenges of high cost for being hosted to signal distributor's networks. The hosting price per year of one TV is 40 million Rwandan Francs. Comparing the income of TV channel and running cost, the running cost overweigh the income cost and therefore two TV channels have decided to vacate the business of TV broadcasting.

➢ New comers in the business of TV broadcasting like Big television network (BTN) and Victory TV have failed to secure space for being hosted. This is due to lack of space for accommodation caused by few frequencies in MFN network. Provided that these TV channels have set up studios having modern equipment, rent houses for a long period, hired staffs and secured authorization from RURA, they are encountering a lot of loss in their business which is not yet to start due to limitation of frequencies in MFN broadcasting networks.

In conclusion SFN network is required to solve weaknesses found in MFN broadcasting currently in use.

CHAPTER 4. NUMERICAL RESULTS

4.1 Introduction

To estimate the coverage probability of a local area SFN, Monte-Carlo simulation has been used and static model is considered. For this coverage probability studies ZoneIII having seven transmitters is also considered (Gitwe, Rebero, Jali, Byumba, Rushaki, Nyarupfubire and Bumbogo). Let also consider fixed SINR of 10dB while number of transmitters increases and valuable SINR from 0 to 10dB with the number of transmitters fixed to 3. The number of active carriers (k=13,633), Symbol rate (Ts=1792μs), transmitter power of 1Kw and guard interval time (Tg=448μs) is also taken into consideration.

4.2 Static Model

As described earlier, static model is the simulation method where receivers are positioned in one area and do not move. Figure12 illustrates the coverage probability of MFN vs SFN networks with the increase of the number of transmitters.

4.2.1 Coverage probability for MFN and SFN with the increase number of transmitters

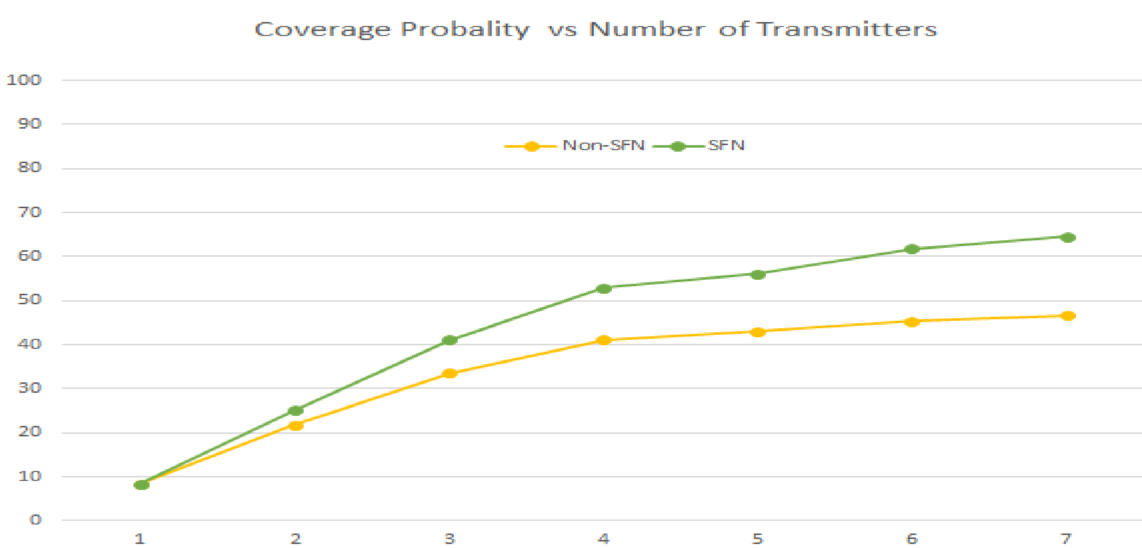


Figure 12: Shows the coverage probability of MFN Vs SFN with the increase of the number of

transmitters

From the above figure12, it is observed that the coverage probability of difference between MFN and SFN increases with the number of transmitters, which means that when increasing the number of transmitters in the network, greater coverage is achieved in SFN network compared to MFN network. A network with one transmitter in the local area network does not provide any diversity gain. By inserting more transmitters in the local service area, decreases the outage due to diversity gains and hence increasing the coverage probability. Therefore, SFN network needs more transmitters to increase the number of diversity gain.

4.2.1 Coverage probability for MFN and SFN with the varying values of SINR from 0 to 10dB.

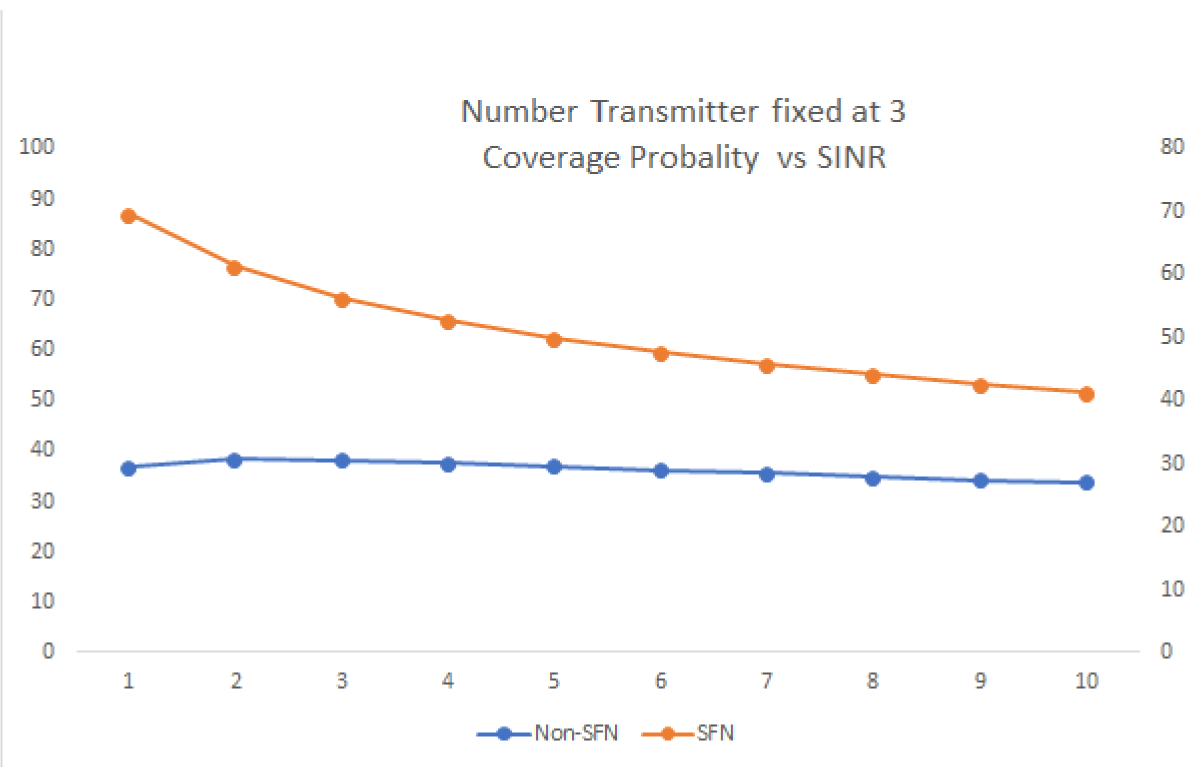


Figure 13: MFN Vs SFN coverage probability with varying SINR

From the above figure13, it is observed that the coverage probability of MFN and SFN decreases with the varying SINR values. However, the greater coverage is achieved in SFN network compared to MFN network.

Apparently the number of transmitters in the local area network is crucial; the results show that with the increase in the number of transmitters also the coverage probabilities increase and the results show that at least 7 transmitters is the good planning of SFN network. The varying SINR also shows decrease of coverage probability and it is recommended to use a fixed SINR in the planning.

5.3 Summary

Based on the numerical results obtained, the thesis proposes the following for better designing SFN network in Rwanda;

- Use many transmitters as necessary, for the case of Rwanda 7 transmitters is preferred for local area network.
- Use high antenna elevation to cover a large area with the same transmitter power.
- Higher frequencies band are to prefer, provided that the Doppler spread is neglected.

CHAPTER 5: ANALYSIS OF BROADCASTING SFN NETWORK DESIGN AND IMPLEMENTATION IN RWANDA

5.1 Introduction

Terrestrial digital video broadcasting using multiple frequency networks was established in 2009 by Startimes Media and later in 2014 Rwanda Broadcasting Agency switched from analogue TV to digital TV. It was a follow of ITU recommendation that all member states of ITU should migrate from analogue to digital broadcasting by the end of July 2015. Further, due to increasing demands of more frequencies in broadband services, WRC-12 and 15 allocated the frequency band 694-862MHz to broadband services while initially it was allocated to television broadcasting. Since 2015 signal distributors have started suffering from the scarcity of digital television frequencies assignment.

In the SFN design, the thesis considers the outputs of chapter 3 on “system model” especially in coverage probability and chapter 4 on “numerical results,” where a local area network of 7 transmitters are preferred. Other considerations include calculations of the minimum distance required between two consecutive carriers from the same transmitter. This would allow to understand the time spend without any formation of the next carrier.

5.2 Determination of SFN Area

5.2.1 Considerations for SFN planning in Rwanda

Rwanda has 21 sites identified for digital terrestrial broadcasting services, however, 14 sites have necessary infrastructure such as road access and electricity, and these sites are currently being used as main terrestrial broadcasting sites in Rwanda. Five (07) remaining sites with no appropriate infrastructure have not been exploited and three of the sites have been included in the proposed new SFN network.

The design of the SFN plan is based on the mentioned parameters in the introductory part and the following parameters are considered: sites coordinates, distance separation between broadcasting sites, heights of antenna above ground, allowed antenna polarizations, antenna gains and transmitters power.

Further considering that, the number of orthogonal sub-carrier waves in DVB-T2 standard is 2048 (for 2k mode), 4096 (for 4k mode), 8192 (for 8k mode), 16384 (for 16k mode) and 32768 (for 32k mode) [15]. In the actual transmission of information data, not all the sub-carriers are used. Part of sub-carrier is used as pilot signals where these sub carriers carry information about the parameters of the modulation used. Therefore, in 2k mode, the number of active sub-carriers being n= 1705, in 4k mode, the number of subcarriers being n= 3,409, in 8k mode, n= 6817 as active sub-carriers, in 16k mode, the active sub-carriers n=13,633 and in 32k mode, the active sub-carriers n=27,275.

FFT Mode	Sub–carriers	Active sub–carriers (n)
32K	32768	27,275
16K	16384	13,633
8K	8192	6817
4K	4096	3,409,
2K	2048	1705

Table 4: Summarizes the sub-carriers and active sub-carriers of DVB-T 8MHz

The spacing of sub-carriers frequencies Δf must conform to the bandwidth (BW) of the assigned frequency channel (for video broadcasting 8, 7, 6 MHz) and represents, in fact, the symbol rate Rs of OFDM modulation.

For 8 MHz bandwidth channels, used in Rwanda (the exact bandwidth value is 7.61 MHz) and the spacing of sub-carrier frequencies Δf, which also represents the symbol rate Rs, can be written as;

$\Delta f = Rs = BW / n$;

For 32k FFT mode, Rs=7.61*1000KHz/27,265=0.279KHz, 16k FFT mode, Rs=7.61*1000KHz/13633=0.558KHz, 8k FFT mode, Rs=7.61*1000KHz/6817=1.116KHz, 4K FFT mode, Rs=7.61*1000KHz/3409=2.232KHz, 2k FFT mode, Rs=7.61*1000KHz/1705=4.463KHz

The corresponding time extended symbol Ts is then given by the formula Ts = 1/(Rs);

For different FFT modes the symbol rate Ts for 32k is 1/0.279KHz=3.584ms, 16k =1/0.558KHz=1.792ms, 8k=1/1.116KHz=0.896ms, 4K=1/2.232KHz=0.448ms and 2k =1/4.463KHz=0.224ms

The time extended symbol Ts is then further extended by the so-called guard interval TG, which is often defined as a part (kT) of symbol time, i.e. kT = TG/Ts = 1/4, 1/8, 1/16, 1/32.

During the guard interval TG, no useful information is transmitted. It is only used to eliminate reception of delayed signals and thus influences the possible choice of transmitter distances in the single frequency network.

- The length of guard interval is calculated from the formula TG=kT*Ts, where kT is the guard interval fraction and Ts symbol time when sub-carrier is produced. Below is the table summarizing guard interval in all FFT modes;

		Guard Interval Fraction						
FFT	Ts(us)	1/128	1/32	1/16	19/256	1/8	19/128	1/4
32k	3584	28.0 µs	112.0 µs	224 µs	266 µs	448 µs	532 µs	N/A
16k	1792	14.0 µs	56.0 us	112 µs	133 µs	224 µs	266µs	448 µs
8k	896	7.0 µs	28.0 µs	56.0 µs	66.5 us	112.0 µs	133.0 µs	224 µs
4k	448	NA	14 µs	28 µs	NA	56 µs	NA	112 µs
2k	224	NA	7 µs	14 µs	NA	28 µs	NA	56 µs

Table 5: Summarizes the length of guard interval in different FFT modes

The distance the carrier can travel without the formation of another carrier in the digital television transmitters is calculated by the formula= (speed of light) [m/s] x (Guard interval time) [s]. This distance is the minimum distance required to avoid undue interference to all receivers in the same SFN zone and from the distance calculations, code rate and bit rate it is possible to plan SFN network that can suit Rwanda effective television frequency management.

Below is the limit in distances according to the chosen FFT Mode and guard interval fraction.

Maximum distances between Transmitters in Km for Single Frequency Networks							
	Guard Interval Fraction						
FFT	1/128	1/32	1/16	19/256	1/8	19/128	1/4
32k	8.4 km	33.6 km	67.2 km	79.8 km	134.4 km	159.5 km	N/A
16k	4.2 km	16.8 km	33.6 km	39.9 km	67.2 km	79.8 km	134.4 km
8k	2.1 km	8.4 km	16.8 km	19.9 km	33.6 km	39.9 km	67.2 km
4k	NA	4.2Km	8.4Km	NA	16.8Km	NA	33.6Km
2k	NA	2.1Km	4.2km	NA	8.4Km	NA	16.8Km

Table 6: Shows the distances one carrier travel before the second carrier is produced in one Transmitter

Further, in the design of DVB-T2 SFN network. The consideration of data rate versus guard interval is taken into consideration. The reason is that guard interval reduces the amount of time available for data transmission; its setting has an effect on the DVB-T2 bit rate requirements. Lengthening the guard interval than the required decreases the bit rate.

Table below indicates the net bit rate in Mbits/s for various modulations, combinations of guard interval settings and error protection code rates. The frequency bandwidth planned is 8MHz.

Modulation	Code rate	Guard interval			
		1/4	1/8	1/16	1/32
QPSK	½	4.98	5.53	5.85	6.03
	2/3	6.64	7.37	7.81	8.04
	¾	7.46	8.29	8.78	9.05
	5/6	8.29	9.22	9.76	10.05
	7/8	8.71	9.68	10.25	10.56
16-QAM	½	9.95	11.06	11.71	12.06
	2/3	13.27	14.75	15.61	16.09
	¾	14.93	16.59	17.56	18.10
	5/6	16.59	18.43	19.52	20.11
	7/8	17.42	19.35	20.49	21.11
64 QAM	½	14.93	16.59	17.56	18.10
	2/3	19.91	22.12	23.42	24.13

	¾	22.39	24.88	26.35	27.14
	5/6	24.88	27.65	29.35	30.16
	7/8	26.13	29.03	30.74	31.67

Table 7: Shows the Capacity Through put generated by combination of code rate, guard interval and modulation type

With the consideration of distance separations between transmitters, considerations of internal interference, best error correction method, data capacity and minimizing the external interference especially cross-border interferences. The plan has managed to obtain three local area SFNs zones and each site has 9 channels for assignment. Originally 2 to 5 channels were available for each site and now each site has 9 channels. The increase in frequencies assignment is more than 40% improvement.

No	SFN AREA	ZONED SITES	Separation distance(Km)	Technical specifications	Channels
1	ZONEI	Rubona, Mugogo and Karisimbi	**36.93**	19/256 (GIF) Mode: 16k K=13,633 Ts=1792μs Guard interval(G)=133μs, Code rate: 2/3	22,24,27,28,29,32,33,39 & 45

2	ZONEI I	Karongi, Huye, Mushubati, Nyabitimbo, Gihundwe, Kinanira & Rucamatako	**98.29**	1/4 (GIF) Mode: 16k K=13,633 Ts=1792 µs G=448µs Code rate: 2/3	21,26,30,38,40,42,43,47 & 48
3	ZONEI II	Gitwe, Rebero, Jali, Byumba, Rushaki. Bumbogo & Nyarupfubire	100.2	1/4 (GIF) Mode: 16k K=13,633 Ts=1792 µs G=448µs Code rate: 2/3	23,25,31,34,36,37,41,44 & 46

Table 8: Zoning of appropriate sites for SFN after analysis of the best coverage probability

Three zones are represented on the map as shown below;

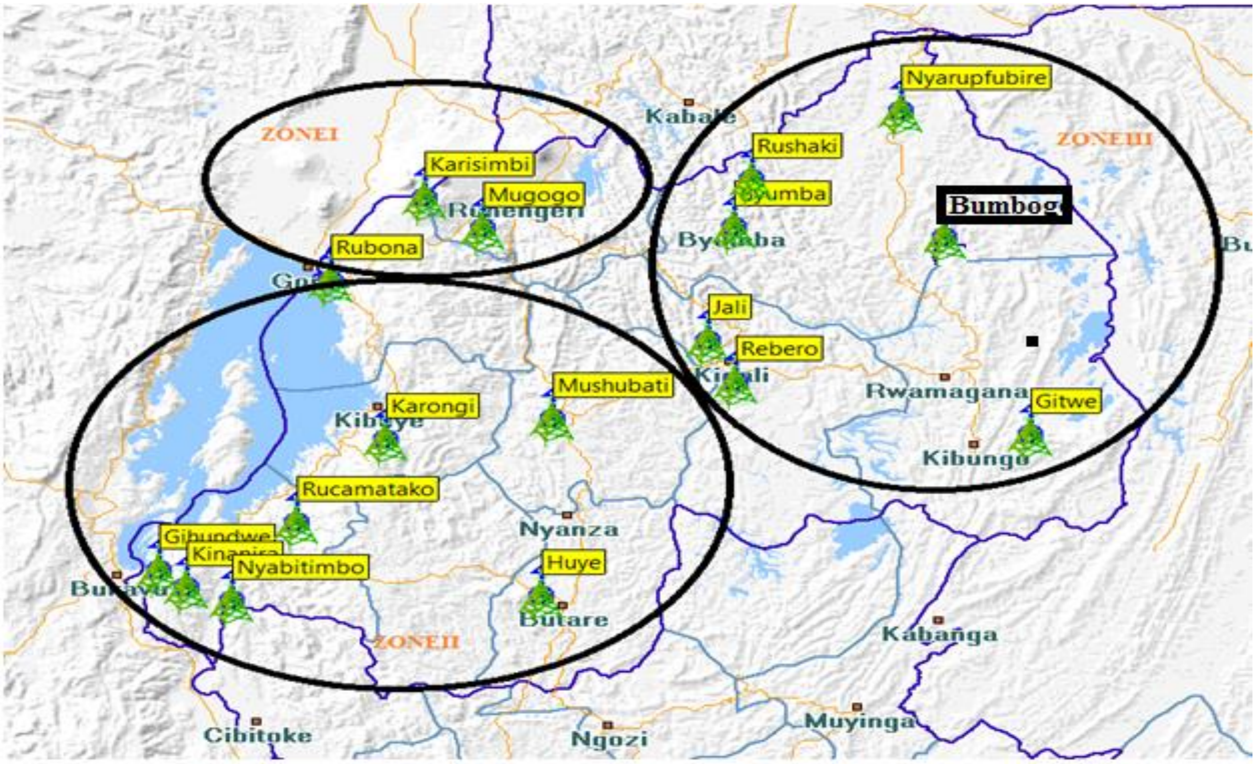


Figure 14: Map showing the broadcasting sites zoned together for the purpose of SFN network

5.2.2 SFN COVERAGE SIMULATION USING ICS TELECOM SOFTWARE

After planning the SFN local area networks, the design should also simulate the real coverage on the terrain for verifying the reality of planning and for this purpose ICT telecom software is used for coverage simulation.

ICS telecom software is simulation software that incorporates all ITU requirements for network planning and operation.

By using this software each zone is simulated independently and finally the three zones are combined to make sure that interference is eliminated for our network.

Parameters for ZoneI of Rubona, Mugogo and Karisimbi

(Transmitter power=1000W, Frequency=490MHz, antenna gain=10dBi, Coverage threshold=35dBuv/m, Antenna Height=70m, bandwidth=8MHz, propagation model=ITU-R 525, Diffraction geometry=Deygout 94 method, Subpath attenuations=standard, height of receiver antenna=1.5m, Guard band interval=133µs, mode=16k FFT, Ts=1792µs)

Parameters for Zone II of Gihundwe, Kinanira, Nyabitimbo, Rucamatako, Karongi, Huye and Mushubati

(Transmitter power=1000W, Frequency=474MHz, antenna gain=10dBi, Coverage threshold=35dBuv/m, Antenna Height=60m, bandwidth=8MHz, propagation model=ITU-R 525, Diffraction geometry=Deygout 94 method, Subpath attenuations=standard, height of receiver antenna=1.5m, Guard band interval=448µs, mode=16k FFT, Ts=1792µs)

Parameters for ZoneIII of Gitwe, Rebero, Jali, Byumba, Rushaki, Bumbogo and Nyarupfubire

(Transmitter power=1000W, Frequency=490MHz, antenna gain=10dBi, Coverage threshold=35dBuv/m, Antenna Height=60m, bandwidth=8MHz, propagation model=ITU-R 525, Diffraction geometry=Deygout 94 method, Subpath attenuations=standard, height of receiver antenna=1.5m, Guard band interval=448µs, mode=16k FFT, Ts=1792µs).

Below is the simulation of coverage when all zones are combined.

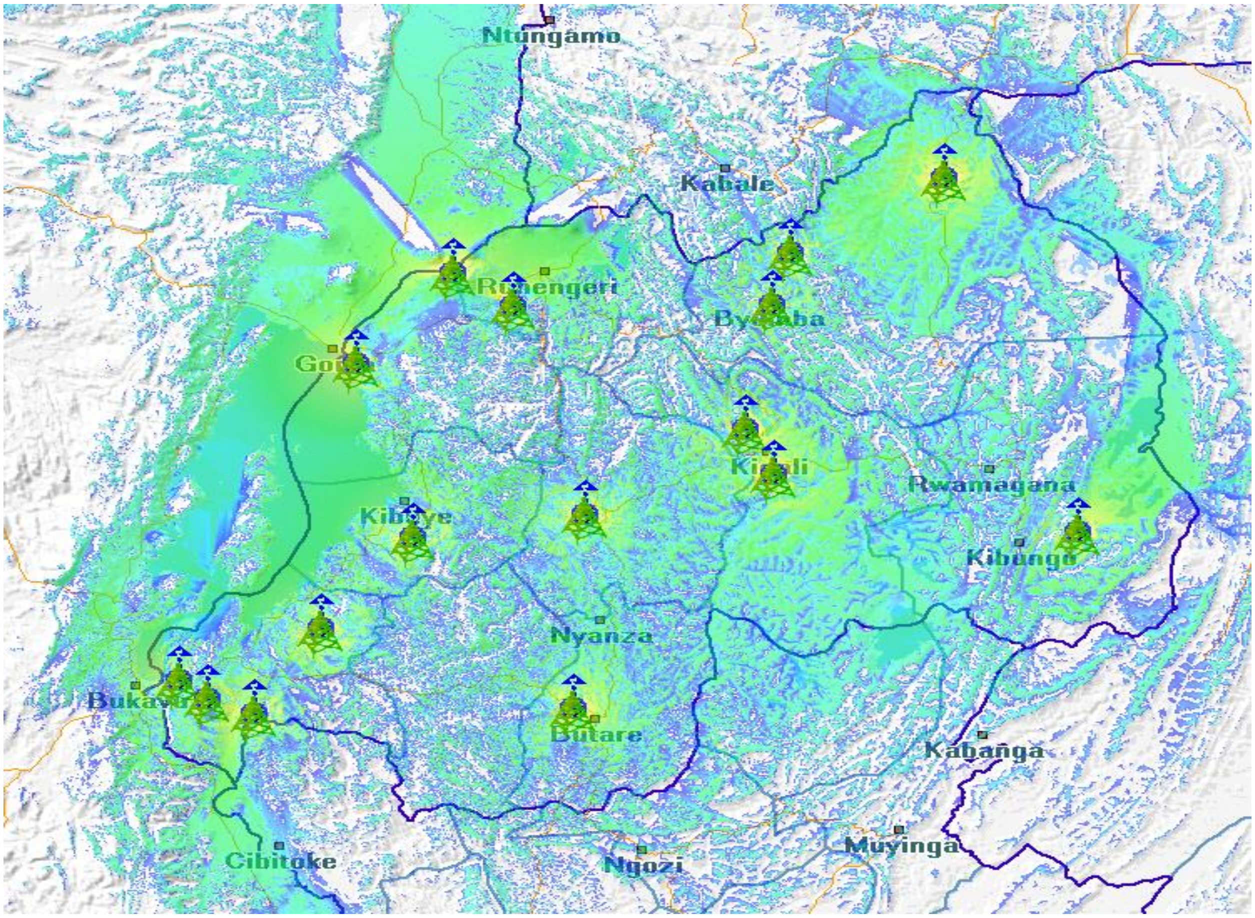


Figure 13: Shows the coverage of all three SFN Zones covering the whole of Rwanda territory

Chapter 6: Challenges in the Implementation of SFN network

6.1 Introduction

Considering that Rwanda has already implemented MFN terrestrial digital video broadcasting multiple frequency network (MFN DVB-T), the change from MFN to SFN networks shall have challenges either positive or negative. These changes shall affect signal distributors for upgrading their network to SFN and Regulators for putting new regulations and getting low frequency regulatory fees.

With the implementation of single frequency networks, all transmitters in the same zoned area shall transmit over the same frequency, thus enabling spectrum and bandwidth optimization.

The challenge shall include modifying the existing MFN transmitters into SFN transmitters, therefore additional of SFN adapters and PTN devices are required hence increasing the capital expenditure of setting up digital video broadcasting in Rwanda.

6.2 Frequencies Coordination with neighboring countries

At the level of international telecommunication union (ITU), the African countries completed the coordination of terrestrial digital video broadcasting frequencies in 2015. The frequencies assigned to Rwanda in the ITU database belong to Rwanda and these frequencies are used in accordance with technical specifications found at ITU database, however in the implementation of SFN the change of frequencies location shall be done and this might affect neighboring countries. In the design of SFN network, the frequencies found in one region were put into a zone for avoiding cross-border interference.

Though, the cross-border interference has been minimized, before putting SFN transmitters into air. The frequencies coordination with DRC, Burundi, Uganda and Tanzania is necessary for avoiding any cross-border interference and allowing Rwanda to ask ITU for saving the new changes at the ITU database (Master International Frequency Register (MIFR)).

The challenges involved is that, Rwanda may ask frequencies coordination for the already proposed SFN plan. Some frequencies may be rejected showing areas these frequencies might affect in their respective countries. If a large number of proposed frequencies for SFN are rejected, then SFN implementation shall get challenges of net being practical.

6.2 Upgrade of MFN transmitters into SFN transmitters

In the existing MFN transmitters owned by RBA and Startimes media Ltd, additional of two modules are necessary. The modules to be added include SFN adapters and PTN devices. These modules shall increase the cost of transmitters and sometimes might be found non-compatible with the existing transmitters.

Therefore, more expertise from Harris and Rohde & Schwarz companies supplied the equipment to Rwanda is needed. This shall involve the additional cost for the upgrade and feasibility studies on the compatibility of existing transmitters and additional modules.

6.4 Establishing new Regulations for SFN broadcasting

Rwanda utilities regulatory authority (RURA) has established law on broadcasting services. The law caters for MFN network in Rwanda, how the network is implemented and radio communication fees. The challenge here is to implement SFN network without regulation, therefore RURA after identification of the importance of SFN frequencies planning shall revise the existing law of broadcasting services by including articles dealing with introduction of SFN broadcasting services.

CHAPTER 7 CONCLUSION

7.1 Conclusion

The thesis has been designing broadcasting SFN network in Rwanda by enhancing coverage probability. The study has shown that, it is possible to plan local SFN network with three zones, the first zone has 3 transmitting sites while two remaining zones each has 7 transmitters. It has also shown that local SFN network with 7 transmitters has high diversity gain of 11.8dB in random model and is preferred for assignment in Rwanda.

The study has shown that with the implementation of SFN network, for the sites initially had 4 or 5 frequencies for assignment. The new plan shows that at each site, 9 frequencies are available for assignment and this is an increment of between 44 to 55% of the availability of frequencies for assignment. However, the change of network planning shall incur some costs to the signal distributors, this is the cost for buying SFN adapters and hiring company to install them in the head-end for allowing the synchronization of transmitter.

The clients DVB-T2 receivers shall also be changed for having equipment able to synchronize signals coming from different transmitters and have maximum diversity gain.

The thesis has proven important for Rwanda DVB-T frequencies re-planning in SFN mode. The new frequencies plan shall solve the scarcity in frequencies assignment and therefore more companies shall invest in broadcasting sector.

7.2 Recommendation

With the importance of DVB-T frequencies increase in SFN network, the study has shown that the advantages of having SFN network planning outweigh the disadvantages and each stakeholder in the market shall play part for the successful implementation of SFN networks.

Signal distributors shall change their networks by inserting SFN adapters at the head-end. The SFN adapters shall help for synchronizing all transmitters in the same zoned area so that signals are emitted at the same time.

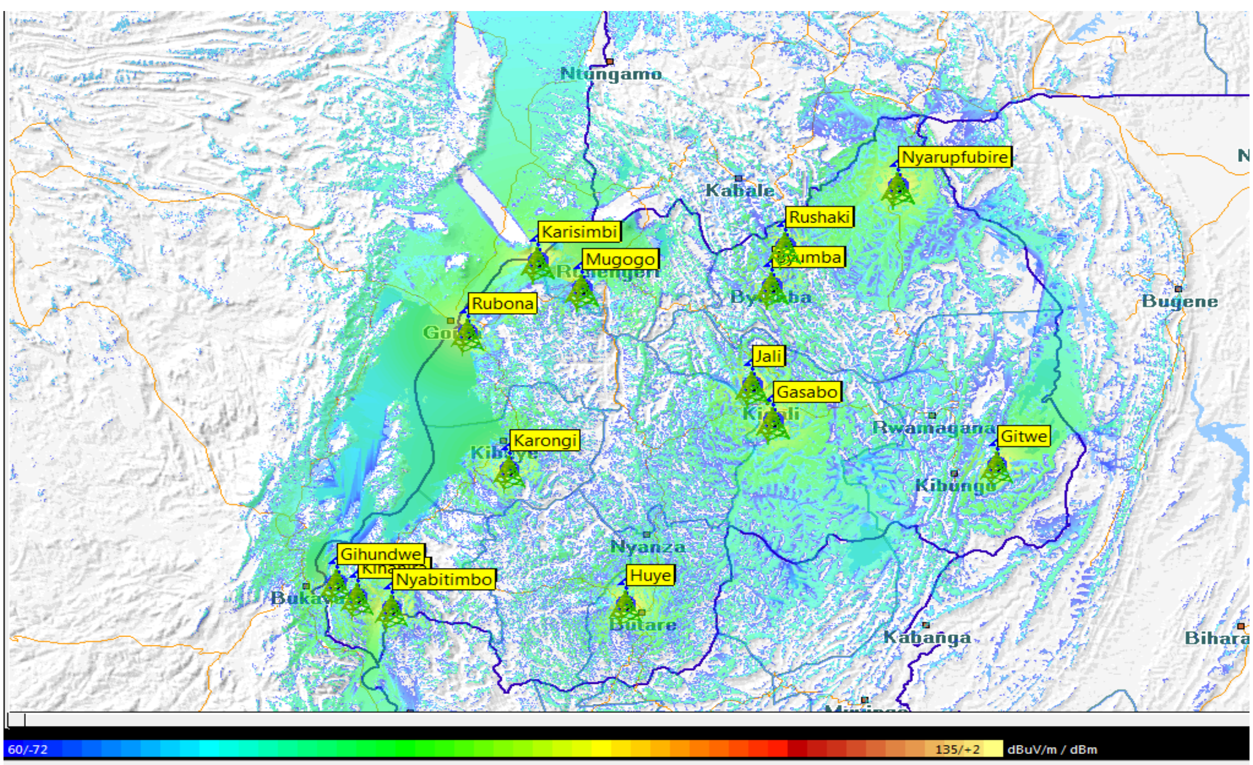
Signal distributors are also advised to hire competent company for the revision of their networks and install SFN adapters. This company shall make sure that the systems of clients are working properly and make some changes whenever required.

The regulator is advised to adopt the proposed frequency plan of SFN networks and make it as regulation for terrestrial television broadcasting frequencies in Rwanda. This shall allow regulator to have enough frequencies for assignment unlike in the past where at some broadcasting sites, there has been limited assignment due to fewer frequencies and the demand is high.

The regulator is also advised to subsidize for SFN receivers at the end customers. This is caused by the fact that the changes of DVB-T networks planning are proposed by regulator and not viewers of TV contents., therefore the regulator is the one to benefit by having more frequencies for assignment and since it is the benefit of regulator to have enough frequencies for assignment, the regulator shall subsidize the importation of new set tox boxes capable of capturing signals in SFN mode.

ANNEXES:

Annex A: MFN network Simulation in Rwanda



Annex B: Table showing Values used to obtain Figure12 (SINR 10dB).

Number of transmitters	MFN network(Non-SFN)	SFN network
1	8.351485714	8.324628571
2	21.71417143	24.988
3	33.56748571	41.08325714
4	41.10657143	52.9076
5	42.904	56.11382857
6	45.26971429	61.726
7	46.54542857	64.56074286

Annex C: Table showing Values used to obtain Figure13 (with varying SINR from 0 to 10dB).

SINR	MFN network(Non-SFN)	SFN network
1	36.63657143	69.3764
2	38.21274286	61.10417143
3	38.0216	56.03794286
4	37.51371429	52.442
5	36.81034286	49.66234286
6	36.0828	47.39382857
7	35.41325714	45.43388571
8	34.69377143	43.88582857
9	34.10885714	42.37337143
10	33.59822857	41.10188571

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