CHAPTER ONE

INTRODUCTION

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1.1 Preface

Broadband is an opposite of baseband. Baseband transmission is the transmission of a single signal over a transmission medium. Broadband is the transmission of more than one signal over a transmission medium.

Wireless Communication is becoming an integral part of today's society. Wireless communications is one of the most active areas of technology development of this time. This development is being driven primarily by the transformation of what has been largely a medium for supporting voice telephony into a medium for supporting other services, such as the transmission of video, images, text, and data [1].

The predicted growth in mobile phone traffic and move towards enhanced mobility will lead to a need for wireless infrastructure that provides increased bandwidth per user. Future wireless networks will require an optical network to provide antenna base station with sufficient bandwidth to provide individual users with more bandwidth. The requirement for high data needs to use system that provides higher carrier frequency to increase the capacity of the feeder network [2].

RoF systems utilize optical fiber as low-loss and wide-bandwidth transmission medium, which makes distribution of broad-band data and/or high frequency signals into many base stations easy [3].

Radio-over-fiber (RoF) techniques are attractive for realizing high performance integrated networks. The growth of mobile and wireless communications fuels increasing demand for multimedia services with a guaranteed quality of service. This requires realization of broadband distribution and access networks. Within this framework, (RoF) schemes can be applied for realizing seamless wireless networks since they allow for the easy distribution of microwaves and millimeter waves over long distances along optical fibers. Some of the applications of (RoF) technology include cellular networks, satellite communications, multipoint video distribution services (MVDS), mobile broadband system (MBS), wireless LANs over optical networks [4].

The benefit s of Radio over Fiber technology makes it an important for the future of wireless communication and makes the companies race to know that technology and implement it to obtain system that more efficient and has better performance. Fiber optic technology offers technical performance benefits over traditional coaxial feeds plus almost unlimited bandwidth and distance, RF over Fiber systems are the obvious choice for existing and next generation electronic signals platforms. High dynamic range, low noise and good communications security covering low frequency to extremely high frequency RF spectrum is the point of RF over Fiber links. Fiber optic systems can transport RF signals over kilometers with minimal loss and can be engineered for unity gain RF links. Low Noise Amplifiers can be implemented to raise the RF signal above the laser noise and post RF amplifiers can be used to overcome any optical link loss and to add signal gain at the far end receive site[5].

1.2 Problem Statement

Present communication systems are primarily designed for one specific application, such as voice on mobile telephone or high data in wireless LANS.The requirement for high data rates will push carrier frequencies into mm-waves (60GHz); because of that for a wireless networks to go broadband, the capacity of the feeder network must also be increased so the current wired LANs will not be adequate in addition to some limitation such as loss in transmission, numbers of repeaters, costs of system installation and maintenance, need to more secure system and delay that result from switching operation …

1.3 Objectives

In this research the team going to design and simulate RoF to improve wireless broadband system by solve some problems related to performance of wireless system and make it flexible to future requirements by integrate the advantages of RoF technology with wireless system.

This research aims to discuss the concepts of radio over fiber technology and techniques for transporting radio signals over optical fiber including its multiplexing and modulation techniques and discover its importance in wireless communication systems and understand the causes of why the future wireless networks will require optical networks and study and simulate 802.11a WLAN with ROF system and evaluate the performance of this system.

1.4 Research Methodology

The teamwork will present the overview of RoF technology, and then discusses the concept of Radio over fiber (RoF) technology and its techniques, after that they will give a brief overview of multiplexing and modulation techniques that related to RoF system and how to configure the (RoF) transmitter and receiver according to specific parameters.

In this research the team research focus on the feasibility of using RoF technology in broadband wireless communication systems through modeling, simulations, and experiments, the behavior and performance of a radio-over-fiber and discuss some applications based on RoF technology ,and then modeling and simulation of the downlink system with RoF using suitable parameters for laser diode, fiber and photodiode and perform a simulation works by using a OPTIWAVE software packages to observe and compare the performance of the wireless broadband system with and without RoF technology and finally the conclusion of the results and recommendation for future works will be presented.

1.5 Research outlines

Chapter 1: Introduction about RoF. In this chapter also present generally about the project including the objectives, problem statement and the outline regarding of this research.

Chapter 2: The discussion of the concepts of radio over fiber technology and its techniques for transporting radio signals over optical fiber including its multiplexing and modulation techniques.

Chapter 3: Give a brief overview about Wireless LAN and Quadrature Amplitude Modulation QAM as modulation technique.

Chapter 4: The simulation using OPTIWAVE software package, the physical model, mathematical model, the program steps and output were discussed.

Chapter 5: Conclusion and summarizes the work done in this research and recommendations for the future work.

CHAPTER TWO

RADIO OVER FIBER CONCEPTS

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2.1 Radio Wave

Radio waves propagate (travel) much like surface water waves. They travel near the Earth's surface and also radiate skyward at various angles to the Earth's surface. As the radio waves travel, their energy spreads over an ever-increasing surface area. A typical radio wave has two components, a crest (top portion) and a trough (bottom portion). These components travel outward from the transmitter, one after the other, at a consistent velocity (speed). The distance between successive wave crests is called a wavelength [6].

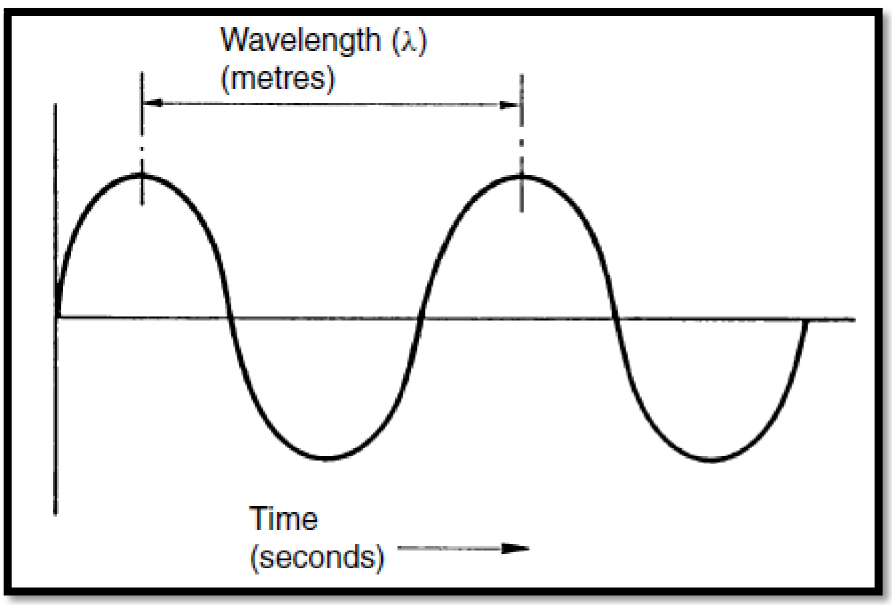


Figure 2.1: Frequency and wavelength

The electromagnetic wave spectrum is shown in Figure 2-2 the part
Usable for radio communication ranges from below 10 kHz to over
100 GHz [6].

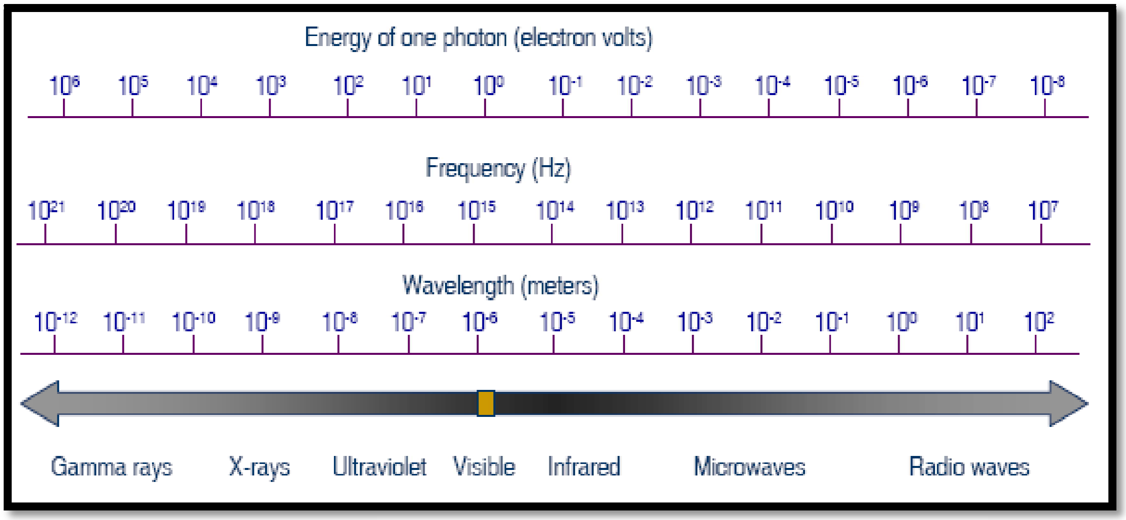


Figure 2-2: The radio frequency spectrum

The radio spectrum is divided into bands and the designation of the bands,.Waves of different frequencies behave differently and this, along with the amount of spectrum available in terms of radio communication channels in each band, governs their use [7].

Table 2-1: Ranges of radio waves

Frequency Range	Symbols	Symbols
3-30 KHz	VLF	Very Low Frequency
30-300 KHz	LF	Low Frequency
300-3000 KHz	MF	Medium Frequency
3-30MHz	HF	High Frequency
30-300 MHz	VHF	Very High Frequency
300-3000 MHz	UHF	Ultra High Frequency
3-30GHz	SHF	Super High Frequency
30-300 GHz	EHF	Extremely High Frequency

2.2 Optical Communication

A communication system transmits information from one place to another, whether separated by a few kilometers or by transoceanic distances. Information is often carried by an electromagnetic carrier wave whose frequency can vary from a few megahertz to several hundred terahertzes. Optical communication systems use high carrier frequencies (100 THz) in the visible or near-infrared region of the electromagnetic spectrum. They are sometimes called light wave systems to distinguish them from microwave systems, whose carrier frequency is typically smaller by five orders of magnitude (1 GHz). Fiber-optic communication systems are light wave systems that employ optical fibers for information transmission [8].

2.2.1 Fiber optic communication

The motivation for developing optical fiber communication systems started with the invention of the laser in the early 1960s. The operational characteristics of this device encouraged researchers to examine the optical spectrum as an extension of the radio and microwave spectrum to provide transmission links with extremely high capacities. As the research progressed, it became clear that many complex problems stood in the way of achieving such a super broadband communication system.[9]

2.2.2 Advantages of Optical fiber

Fiber optic systems have many attractive features that are superior to electrical systems. These include improved system performance, greatly increased bandwidth and capacity, immunity to electrical noise, Immune to noise (electromagnetic interference and radio-frequency interference, lower signal attenuation (loss), lower bit error rates, No crosstalk, signal security, and improved safety and electrical isolation.

Other advantages include reduced size and weight, environmental protection and signal economy.

2.2.3 Total Internal Reflection

Total internal reflection is an optical phenomenon that occurs when a ray of light strikes a medium boundary at an angle larger than a particular critical angle with respect to the normal to the surface. If the refractive index is lower on the other side of the boundary, no light can pass through and all of the light is reflected. The critical angle is the angle of incidence above which the total internal reflection occurs.

When light crosses a boundary between materials with different refractive indices, the light beam will be partially refracted at the boundary surface. However, if the angle of incidence is greater (i.e. the ray is closer to being parallel to the boundary) than the critical angle – the angle of incidence at which light is refracted such that it travels along the boundary – then the light will stop crossing the boundary altogether and it is totally reflected back internally. This can only occur where light travels from a medium with a higher to a lower refractive index. For example, it will occur when passing from glass to air, but not when passing from air to glass [10].

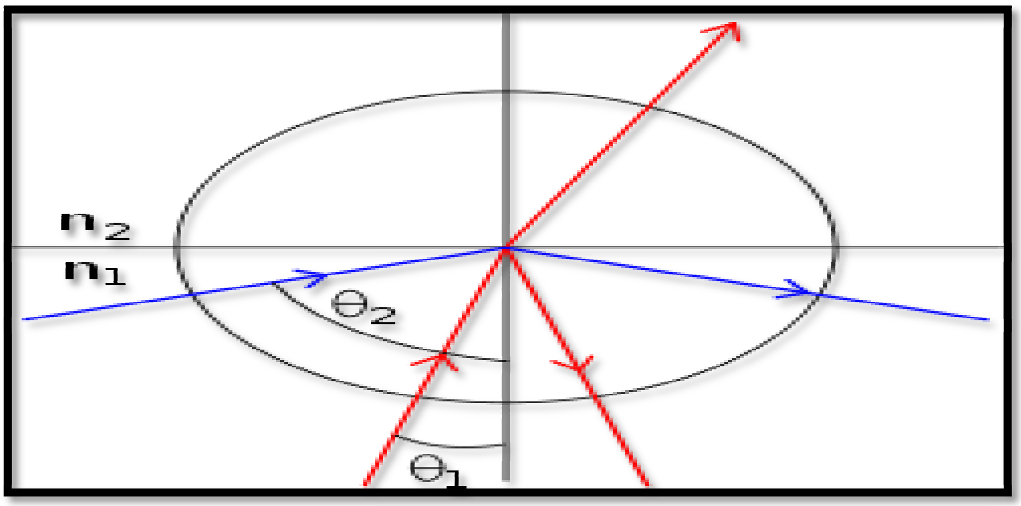


Figure 2-3: Total internal reflections(n1>n2)

The larger the angle to the normal, the smaller is the fraction of light transmitted, until the angle when total internal reflection occurs.

The critical angle is the angle of incidence above which total internal reflection occurs. The angle of incidence is measured with respect to the normal at the refractive boundary. The critical angle θ_c is given by:

$$\theta_c = \arcsin(n_2 / n_1) \qquad (2\text{-}1)$$

Where n_2 is the refractive index of the less optically dense medium, and n_1 is the refractive index of the more optically dense medium. If the fraction: (n_2/ n_1) is greater than 1, then arcsine is not defined--meaning that total internal reflection does not occur even at very shallow or grazing incident angles, So the critical angle is only defined when (n_2/ n_1) is less than 1[10].

2.2.4 Types of Fibers

According to the number of modes of propagation in optical fiber there are two kinds of modes.

2.2.4.1 Single-mode fiber

Fiber with a core diameter less than about ten times the wavelength of the propagating light cannot be modeled using geometric optics. Instead, it must be analyzed as an electromagnetic structure, by solution of Maxwell's equations as reduced to the electromagnetic wave equation. The electromagnetic analysis may also be required to understand behaviors such as speckle that occur when coherent light propagates in multi-mode fiber. As an optical waveguide, the fiber supports one or more confined transverse modes by which light can propagate along the fiber. Fiber supporting only one mode is called single-mode or mono-mode fiber. The behavior of larger-core multi-mode fiber can also be modeled using the wave equation, which shows that such fiber supports more than one mode of propagation (hence the name).

The results of such modeling of multi-mode fiber approximately agree with the predictions of geometric optics, if the fiber core is large enough to support more than a few modes.

The waveguide analysis shows that the light energy in the fiber is not completely confined in the core. Instead, especially in single-mode fibers, a significant fraction of the energy in the bound mode travels in the cladding as an evanescent wave.

The mode structure depends on the wavelength of the light used, so that this fiber actually supports a small number of additional modes at visible wavelengths. Multi-mode fiber, by comparison, is manufactured with core diameters as small as 50 micrometers and as large as hundreds of micrometer.[10]

2.2.4.2 Multi-mode fiber

Fiber with large core diameter (greater than 10 micrometers) may be analyzed by geometrical optics. Such fiber is called multi-mode fiber, from the electromagnetic analysis (see below). In a step-index multi-mode fiber, rays of light are guided along the fiber core by total internal reflection. Rays that meet the core-cladding boundary at a high angle (measured relative to a line normal to the boundary), greater than the critical angle for this boundary, are completely reflected. The critical angle (minimum angle for total internal reflection) is determined by the difference in index of refraction between the core and cladding materials. Rays that meet the boundary at a low angle are refracted from the core into the cladding, and do not convey light and hence information along the fiber. The critical angle determines the acceptance angle of the fiber, often reported as a numerical aperture. A high numerical aperture allows light to propagate down the fiber in rays both close to the axis and at various angles, allowing efficient coupling of light into the fiber. However, this high numerical aperture increases the amount of dispersion as rays at different angles have different path lengths and therefore take different times to traverse the fiber.

In graded-index fiber, the index of refraction in the core decreases continuously between the axis and the cladding. This causes light rays to bend smoothly as they approach the cladding, rather than reflecting abruptly from the core-cladding boundary. The resulting curved paths reduce multi-path dispersion because high angle rays pass more through the lower-index periphery of the core, rather than the high-index center. The index profile is chosen to minimize the difference in axial propagation speeds of the various rays in the fiber. This ideal index profile is very close to a parabolic relationship between the index and the distance from the axis[10].

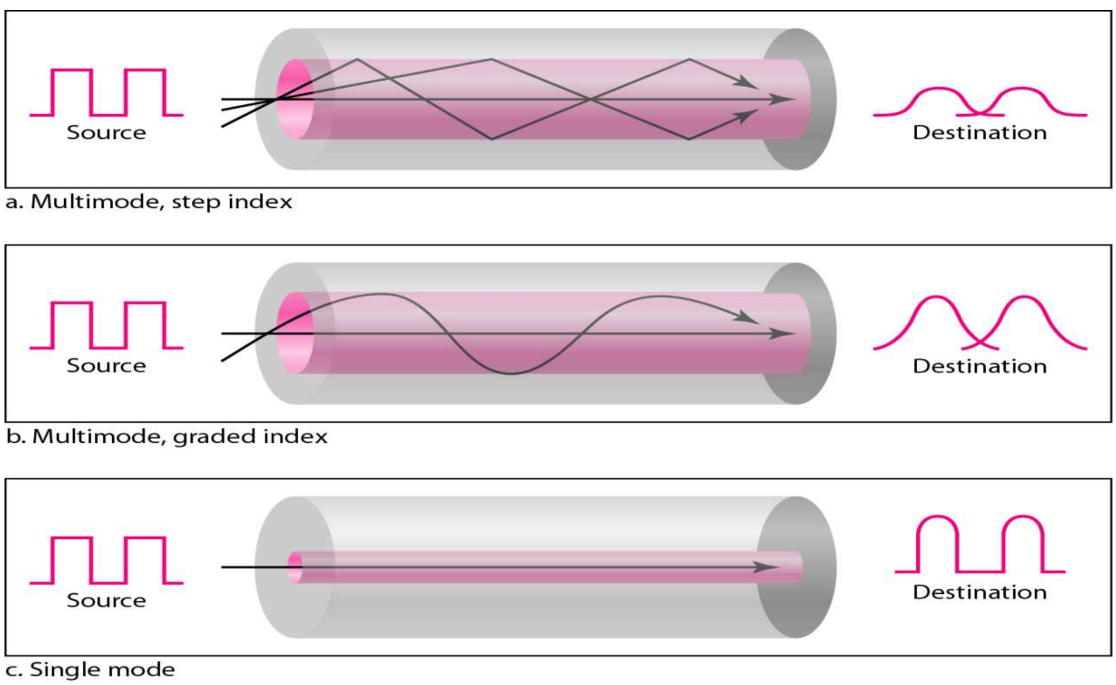


Figure 2-4: Optical Fiber types

2.3 Radio over Fiber (RoF) concept

RoF based on (Radio over Fiber) that refers to a technology that use light to modulate electrical signal (radio signal) and transmit it over optical fiber link to distribute radio signals from central location to remote stations.

The frequencies of the radio signals distributed by RoF systems span a wide range (Usually in the GHz region) and depend on the nature of the applications.

The electrical signal may be baseband data, modulated IF, or the actual modulated RF signal to be distributed. RoF transmission systems are usually classified into two main categories (RF-over Fiber; IF-over-Fiber) depending on the frequency range of the radio signal to be transported.

In RF-over-Fiber architecture, a data-carrying RF (Radio Frequency) signal with a high frequency (usually greater than 10 GHz) is imposed on a light wave signal before being transported over the optical link.

In IF-over-Fiber architecture, an IF (Intermediate Frequency) radio signal with a lower frequency (less than 10 GHz) is used for modulating light before being transported over the optical link[11].

2.3.1 RoF system

A RoF system consists of a Central Site (CS) and a Remote Site (RS) connected by an optical fiber link or network as shown in figure below.

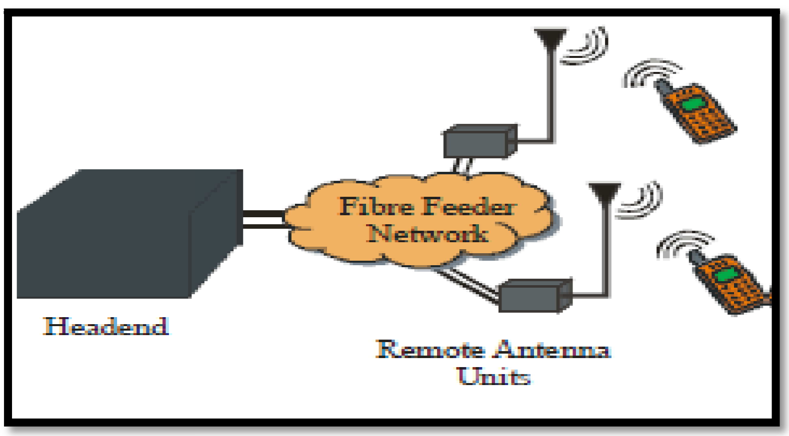


Figure 2-5: The Radio over Fiber System Concept

The transportation of high-frequency signals is more challenging because it requires high frequency components, and large link bandwidth. This means that high-frequency signals are more susceptible to transmitter, receiver, and transmission link signal impairments [1].

The transmission of the RF signal at its frequency, it is not always necessary to do that. For instance, a Local Oscillator (LO) signal, if available, may be used to down-convert the uplink carrier to an IF in the RAU. Doing so would allow for the use of low-frequency components for the up-link path in the RAU – leading to system cost savings. Instead of placing a separate LO in the RAU, it may be transported from the headend to the RAU by the RoF system. Once available at the RAU, the LO may then be used to achieve down-conversion of the uplink signals [12].

The main advantage of RoF systems is the ability to concentrate most of the radio signal processing functions such as frequency up-conversion, carrier modulation, and multiplexing, are performed at the BS or the Radio Access Point (RAP), and immediately fed into the antenna. RoF makes it possible to centralize the RF signal processing functions in one shared location (headend)[1].

A simple RAP means small and light enclosures (easier and more flexible installation) and low cost (in terms of equipment cost and maintenance costs). Centralization results in equipment sharing, dynamic source allocation and more effective management. All of this adds up to an access technology that makes life easier and cheaper for operators. Reduction in base station or remote antenna unit complexity is an attractive outcome of using radio-over-fiber links. Reducing the remote base station complexity is attractive because equipment, construction, and maintenance costs may be reduced [13].

The optical links in RoF are analog in nature, in that they reproduce the carrier waveform. The radio carrier can be modulated with a digital modulation scheme such as GMSK (in GSM) or QPSK (in UMTS)[13].

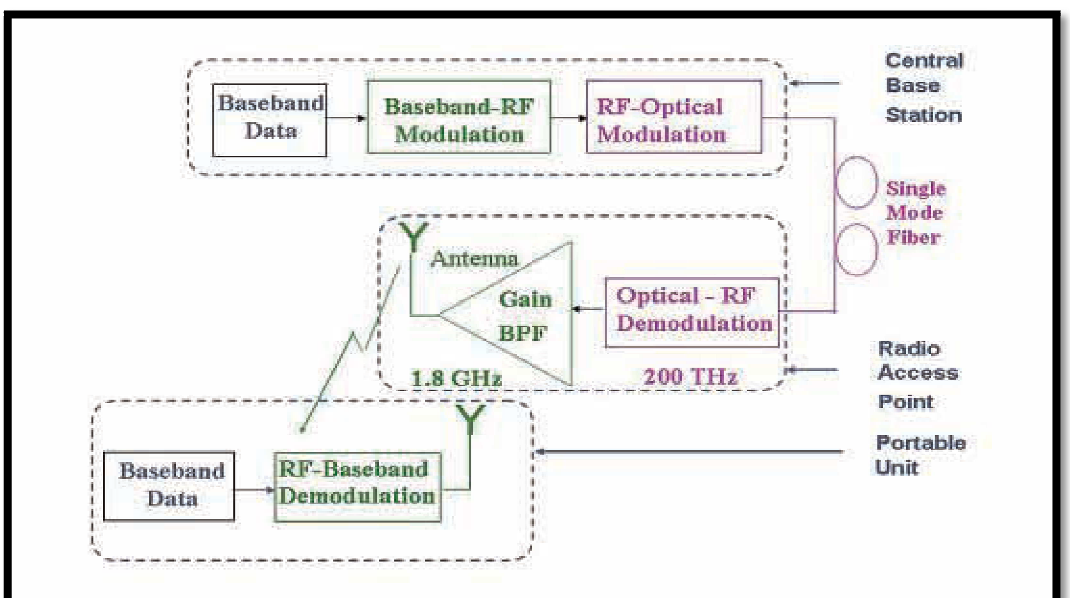


Figure 2-6: Two types of modulation involved with the radio-over fiber

2.3.2 Benefits of RoF Technology

Some of the advantages and benefits of the RoF technology compared with electronic signal distribution are given below.

2.3.2.1 Low Attenuation Loss

Electrical distribution of high-frequency microwave signals either in free space or through transmission lines is problematic and costly. In free space, losses due to absorption and reflection increase with frequency. In transmission lines, impedance rises with frequency as well, leading to very high losses. Therefore, distributing high frequency radio signals electrically over long distances requires expensive regenerating equipment. As for mm-waves, their distribution via the use of transmission lines is not feasible even for short distances. The alternative solution to this problem is to distribute baseband signals or signals at low intermediate frequencies (IF) from the switching centre (headend) to the BS. The baseband or IF signals are up-converted to the required microwave or mm-wave frequency at each base station, amplified and then radiated.

This system configuration is the same as the one used in the distribution of narrowband mobile communication systems shown in Figure (2.4). Since, high performance LOs would be required for up-conversion at each base station, this arrangement leads to complex base stations with tight performance requirements. However, since optical fiber offers very low loss, RoF technology can be used to achieve both low-loss distribution of mm-waves, and simplification of RAUs at the same time [1] .

Commercially available standard Single Mode Fibers (SMFs) made from glass (silica) have attenuation losses below 0.2dB/km and 0.5 dB/km in the 1550 nm and the 1300 nm windows, respectively. Polymer Optical Fibers (POFs), a more recent kind of optical fiber exhibits higher attenuation ranging from 10 – 40 dB/km in the 500 – 1300 nm regions. These losses are much lower than those encountered in; say coaxial cable, whose losses are higher by three orders of magnitude at higher frequencies. For instance, the attenuation of a ½ inch coaxial cable (RG-214) is >500 dB/km for frequencies above 5 GHz. Therefore, by transmitting microwaves in the optical form, transmission distances are increased several folds and the required transmission powers reduced greatly [1].

2.3.2.2 Large Bandwidth

Optical fibers offer enormous bandwidth. There are three main transmission windows, which offer low attenuation, namely the 850 nm, 1310 nm, and 1550 nm wavelengths. For a single

SMF optical fiber, the combined bandwidth of the three windows is in the excess of 50 THz. However, today's state-of-the-art commercial systems utilize only a fraction of this capacity (1.6 THz). But developments to exploit more optical capacity per single fiber are still continuing [1].

2.3.2.3 Immunity to Radio Frequency Interference

Immunity to Electromagnetic Interference (EMI) is a very attractive property of optical fiber communications, especially for microwave transmission. This is so because signals are transmitted in the form of light through the fiber. Because of this immunity, fiber cables are preferred even for short connections at mm-waves.

Related to EMI immunity is the immunity to eavesdropping, which is an important characteristic of optical fiber communications, as it provides privacy and security [12].

2.3.2.4 Easy Installation and Maintenance

In RoF systems, complex and expensive equipment is kept at the headend, thereby making the RAUs simpler. For instance, most RoF techniques eliminate the need for a LO and related equipment at the RAU. In such cases a photodetector, an RF amplifier, and an antenna make up the RAU. Modulation and switching equipment is kept in the headend and is shared by several RAUs. This arrangement leads to smaller and lighter RAUs, effectively reducing system installation and maintenance costs. Easy installation and low maintenance costs of RAUs are very important requirements for mm-wave systems, because of the large numbers of the required RAUs. In applications where RAUs are not easily accessible, the reduction in maintenance requirements leads to major operational cost savings. Smaller RAUs also lead to reduced environmental impact [12].

2.3.2.5 Reduced Power Consumption

Reduced power consumption is a consequence of having simple RAUs with reduced equipment. Most of the complex equipment is kept at the centralized headend. In some applications, the RAUs are operated in passive mode.

For instance, some 5 GHz Fiber-Radio systems employing pico-cells can have the RAUs operate in passive mode. Reduced power consumption at the RAU is significant considering that RAUs are sometimes placed in remote locations not fed by the power grid [12].

2.3.2.6 Multi-Operator and Multi-Service Operation

RoF offers system operational flexibility. Depending on the microwave generation technique, the RoF distribution system can be made signal-format transparent. For instance the Intensity Modulation and Direct Detection (IM-DD) technique can be made to operate as a linear system and therefore as a transparent system. This can be achieved by using low dispersion fiber (SMF) in combination with pre-modulated RF subcarriers (SCM). In that case, the same RoF network can be used to distribute multi-operator and multi-service traffic, resulting in huge economic savings [12].

2.3.2.7 Dynamic Resource Allocation

Since the switching, modulation, and other RF functions are performed at a centralized headend, it is possible to allocate capacity dynamically. For instance in a RoF distribution system for GSM traffic, more capacity can be allocated to an area (e.g. shopping mall) during peak times and then re-allocated to other areas when off-peak (e.g. to populated residential areas in the evenings). This can be achieved by allocating optical wavelengths through Wavelength Division Multiplexing (WDM) as need arise. Allocating capacity dynamically as need for it arises obviates the requirement for allocating permanent capacity, which would be a waste of resources in cases where traffic loads vary frequently and by large margins. Furthermore, having the centralized headend facilitates the consolidation of other signal processing functions such as mobility functions, and macro diversity transmission [12].

2.3.3 Millimeter waves

Extremely high frequency is the highest radio frequency band. EHF runs the range of frequencies from 30 to 300 gigahertz, above which electromagnetic radiation is considered to be low (or far) infrared light, also referred to as terahertz radiation. This band has a wavelength of ten to one millimeter, giving it the name millimeter band or millimetre wave, sometimes abbreviated MMW or mmW[14].

Millimeter waves offer several benefits. However, mm-waves cannot be distributed electrically due to high RF propagation losses. In addition, generating mm-wave frequencies using electrical devices is challenging. The most promising solution to the problem is to use optical means. Low attenuation loss and large bandwidth make the distribution of mm-waves cost effective. Furthermore, some optical based techniques have the ability to generate unlimited frequencies [13].

2.3.3.1 Advantages of mm-waves

They provide high bandwidth due to the high frequency carriers. Secondly, due to high RF propagation losses in free space, the propagation distances of mm-waves are severely limited. This allows for well-defined small radio sizes (microcells and picocells), where considerable frequency re-use becomes possible so that services can be delivered simultaneously to a larger number of subscribers [13].

2.3.3.2 Disadvantages of mm-waves

Negative side of mm-waves is the need for numerous BSs, which is a consequence of high RF propagation losses. Unless the BSs are simple enough, installing and maintaining the mm-wave system can be economically prohibitive owing to the numerous required BSs [13].

2.3.4 Applications of RoF

Some of the applications of RoF technology include satellite communications, mobile radio communications, broadband access radio, Multipoint Video Distribution Services (MVDS), Mobile Broadband System (MBS), vehicle communications and control, and wireless LANs over optical networks [12].

2.3.4.1 Cellular Networks

The field of mobile networks is an important application area of RoF technology. The ever-rising number of mobile subscribers coupled with the increasing demand for broadband services have kept sustained pressure on mobile networks to offer increased capacity. Therefore, mobile traffic (GSM or UMTS) can be relayed cost effectively between the SCs and the BSs by exploiting the benefits of SMF technology. Other RoF functionalities such as dynamic capacity allocation offer significant operational benefits to cellular networks [13].

2.3.4.2 Satellite Communications

Satellite communications was one of the first practical uses of RoF technology. One of the applications involves the remoting of antennas to suitable locations at satellite earth stations. In this case, small optical fiber links of less than 1km and operating at frequencies between 1 GHz and 15 GHz are used. By so doing, high frequency equipment can be centralized [13].

The second application involves the remoting of earth stations themselves. With the use of RoF technology the antennae need not be within the control area (e.g. Switching Centre). They can be sited many kilometers away for the purpose of, for instance improved satellite visibility or reduction in interference from other terrestrial systems. Switching equipment may also be appropriately sited, for say environmental or accessibility reasons or reasons relating to the cost of premises, without requiring being in the vicinity of the earth station antennas [13].

2.3.4.3 Video Distribution Systems

One of the major promising application areas of RoF systems is video distribution. A case in point is the Multipoint Video Distribution Services (MVDS). MVDS is a cellular terrestrial transmission system for video (TV) broadcast. It was originally meant to be a transmit-only service but recently, a small return channel has been incorporated in order to make the service interactive. MVDS can be used to serve areas the size of a small town [13].

Allocated frequencies for this service are in the 40 GHz band. At these frequencies, the maximum cell size is about 5 km. To extend coverage, relay stations are required. In MVDS a transmitter serves the coverage area, which is located either on a mast or a tall building. The rooftop equipment can be simplified by employing RoF techniques. For instance, instead of using Gunn oscillators with their own antennas and heat pipes for frequency stabilization, an optical fiber link may be used to feed either a traveling wave tube or a solid state amplifier at the transmit frequency. This greatly reduces the weight and wind loading of the transmitter. In addition, a single optical fiber could feed the transmitter unit from a distance of several hundred meters [13].

2.3.4.4 Mobile Broadband Services

The Mobile Broadband System or Service (MBS) concept is intended to extend the services available in fixed Broadband Integrated Services Digital Network (B-ISDN) to mobile users of all kinds. Future services that might evolve on the B-ISDN networks must also be supported on the MBS system. Since very high bit rates of about 155 Mbps per user must be supported, carrier frequencies are pushed into mm-waves. Therefore, frequency bands in the 60 GHz band have been allocated. The 62-63 GHz band is allocated for the downlink while 65-66 GHz is allocated for the uplink transmission [13].

The size of cells is in diameters of hundreds of meters (microcells). Therefore, a high density of radio cells is required in order to achieve the desired coverage. The microcells could be connected to the fixed B-ISDN networks by optical fiber links. If RoF technology is used to generate the mm-waves, the base stations would be made simpler and therefore of low cost, thereby making full scale deployment of MBS networks economically feasible [13].

2.3.4.5 WLANs

As portable devices and computers become more and more powerful as well as widespread, the demand for mobile broadband access to LANs will also be on the increase. This will lead once again, to higher carrier frequencies in the bid to meet the demand for capacity. For instance current wireless LANs operate at the 2.4 GHz ISM bands and offer the maximum capacity of 11 Mbps per carrier (IEEE 802.11b). Next generation broadband wireless LANs are primed to offer up to 54 Mbps per carrier, and will require higher carrier frequencies in the 5 GHz band (IEEE 802.11a)[13].

Higher carrier frequencies in turn lead to microcells and picocells, and all the difficulties associated with coverage discussed above arise. A cost effective way around this problem is to deploy RoF technology. A wireless LAN at 60 GHz has been released by first transmitting from the BS, a stable oscillator frequency at an IF together with the data over the fiber.

The oscillator frequency is used to up-converts the data to mm-waves at the transponders (Remote Stations). This greatly simplifies the remote transponders and also leads to efficient base station design [13].

2.3.4.6 Vehicle Communication and Control

This is another potential application area of RoF technology. Frequencies between 63-64 GHz and 76-77 GHz have already been allocated for this service within Europe. The objective is to provide continuous mobile communication coverage on major roads for the purpose of Intelligent Transport Systems (ITS) such as Road-to- Vehicle Communication (RVC) and Inter-Vehicle Communication (IVC). ITS systems aim to provide traffic information, improve transportation efficiency, reduce burden on drivers, and contribute to the improvement of the environment. In order to achieve the required (extended) coverage of the road network, numerous base stations are required [13].

These can be made simple and of low cost by feeding them through RoF systems, thereby making the complete system cost effective and manageable [13].

2.4 Optical Distributing and Generating

Several techniques for distributing and generating microwave signals via optical fiber exist. The techniques may be classified into two main categories namely Intensity– Direct Detection (IM-DD) and Remote Heterodyne Detection (RHD) techniques. The electrical signal at the headend of the optical link may be one of three kinds namely, baseband, modulated IF, or the modulated RF signal itself. Whatever the case, the aim is to produce appropriate RF signals at the remote station, which meet the specifications of the wireless application. This means that apart from signal purity (frequency), robustness against noise, and power issues, the generated RF signals must also contain data in appropriate modulation format. If only baseband data is available at the headend, the RoF system must also perform the modulation function in addition to modulation transporting and frequency up-conversion of the data. Therefore, a RoF system may have to perform radio-system functions as well, apart from signal transportation [1].

Apart from functionality, there are other factors such as performance, complexity and power issues to consider when selecting a suitable RoF system to employ. Overall, the RoF system must be cost-effective for the application concerned. This chapter presents the various RoF techniques available. However, whenever the intention is to use these and other terms to describe the frequency level, this is stated explicitly [1].

2.4.1 Direct Intensity Modulation

The simplest method for optically distributing RF signals is simply to directly modulate the intensity of the light source with the RF signal itself and then to use direct detection at the photodetector to recover the RF signal. This method falls under the IM-DD technique [12].

There are two ways of modulating the light source. The laser diode can itself be modulated directly by using the appropriate RF signal to drive the laser bias current. The second option is to operate the laser in continuous wave (CW) mode and then use an external modulator such as the Mach-Zehnder Modulator (MZM), to modulate the intensity of the light. The two options are shown in Figure 2.6. In both cases, the modulating signal is the actual RF signal to be distributed. The RF signal must be appropriately pre-modulated with data [1].

After transmission through the fiber and direct detection on a PIN photodiode the photocurrent will be a replica of the modulating RF signal applied either directly to the laser or to the external modulator at the transmitter [1].

The photocurrent undergoes trans-impedance amplification to yield a voltage that is in turn used to excite the antenna. If the RF signal used to modulate the transmitter is itself modulated with data, then the generated RF signal will be carrying the same data.

The modulation format of the data is preserved. Since the RF signal itself must be present at the headend, this technique can be used for distribution purposes only as it provides no other radio-system functions [1].

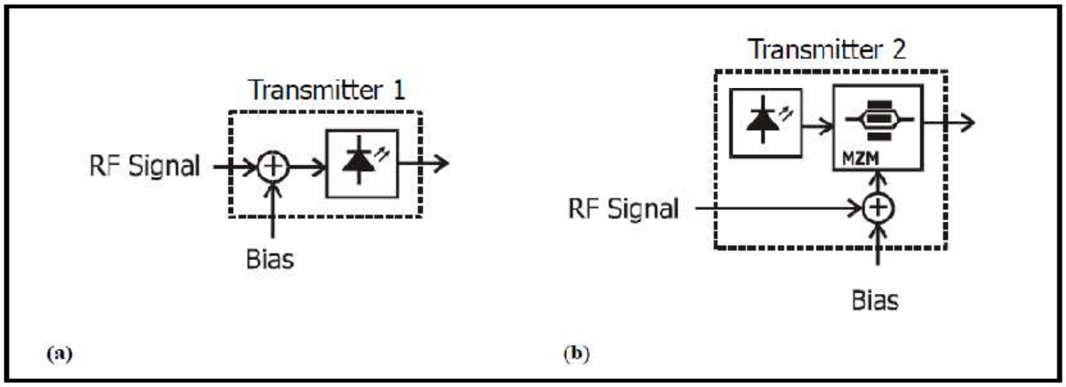


Figure 2.7: Generating RF Signals by Direct Intensity Modulation (a) of the Laser, (b) using an external modulator

2.4.1.1 Advantages

The advantage of this method is that it is simple. Secondly, if low dispersion fiber is used together with a (linearized) external modulator, the system becomes linear. Consequently, the optical link acts only as an amplifier or attenuator and is therefore transparent to the modulation format of the RF signal. That is to say that both Amplitude Modulation (AM) based schemes and constant envelop based modulation schemes such as Phase Modulation (PM / QPSK) can be used. Such a system needs little or no upgrade whenever changes in the modulation format of the RF signal occur. Sub-Carrier Multiplexing (SCM) can also be used on such a system. Furthermore, unlike direct laser bias modulation, external modulators such as the Mach Zehnder Modulator (MZM) can be modulated with mm-wave signals approaching 100 GHz, though this comes with a huge cost regarding power requirements [12].

2.4.1.2 Disadvantages

The disadvantage of this method depends on the fact that only low RF frequency signals can be generated (distributed). This is so because to generate higher frequency signals such as mm-waves, the modulating signal must also be at the same high frequency. For direct laser modulation, this is not possible due to lack of bandwidth, and laser non-linearity, which leads to inter-modulation product terms that cause distortions. On the other hand, external modulators such as the MZM can support high frequency RF signals. However, they require high drive voltages, which in turn lead to very costly drive amplifiers [12].

A further disadvantage has to do with the fact that analogue applications are more sensitive to system non-linearities. As a result, linearity requirements of system components are more stringent in IMDD based RoF systems. For instance, drive amplifiers must compensate for inherent static and dynamic non-linearity of the external modulators used, especially when high frequencies are involved. This leads to more complex systems [12].

2.4.2 The Optical Heterodyning

Most RoF techniques rely on the principle of coherent mixing in the photodiode. These techniques are generally referred to as Remote Heterodyning Detection (RHD) techniques [1].

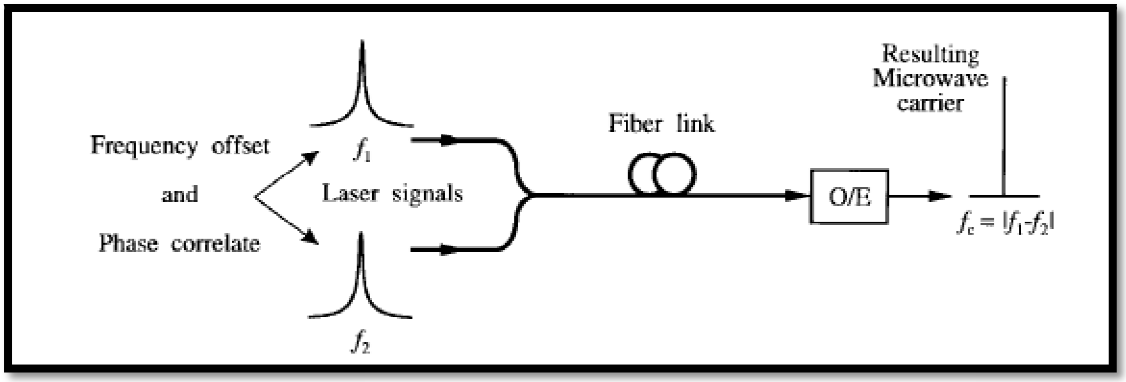


Figure2.8: Remote Heterodyning Detection (RHD) techniques.

While performing O/E conversion, the photodiode also acts as a mixer thereby making it a key component in RHD based RoF systems. However, this does not necessarily make it the most complex or expensive component in the entire system. Since most methods utilize coherent mixing, the principle is discussed first [1].

Two optical fields of angular frequencies Ω1 and Ω2 can be represented as:

$E1=E01\cos(\Omega 1t)$

$E2=E02\cos(\Omega 2t)$ (2-2)

If both fields impinge on a PIN photodetector, the resulting photocurrent on the surface will be proportional to the square of the sum of the optical fields. That is the normalized photocurrent will be:

$I_{PIN} = (E1+ E2)^2$ (2-3)

$I_{PIN} = E01\ E02\cos[(\Omega 1 - \Omega 2)\ t] + E01\ E02\cos[(\Omega 1 + \Omega 2)\ t]$ (2-4)

If we consider optical power signals instead of optical fields, then the generated photocurrent is given by equation. (2-5)[12].

$I_{PIN}(t) = 2R\ \overline{\qquad\qquad}\ .\cos[\{w_1(t)-w_2(t)\}t + \phi_1(t) - \phi_2(t)]$ (2-5)

2.4.2.1 Advantages of Optical Heterodyning

Using optical heterodyning, very high frequencies can be generated, limited only by the photodetector bandwidth. Furthermore, heterodyning yields high-detected power (higher link gain) and higher carrier-to-noise ratio (CNR). This is so because all the optical powers of the two optical fields contribute to the power of the generated microwave signal [1].

Remote heterodyning has an inherent advantage concerning chromatic dispersion. If only one of the two optical carriers is modulated with data, system sensitivity to chromatic dispersion can be reduced greatly. This is not possible in direct intensity modulation based methods, where the two optical sidebands end up both being modulated with data [1].

Reducing chromatic dispersion effects is very important in phase noise sensitive applications such as Orthogonal Frequency Division Multiplexing (OFDM) and systems carrying phase modulated data such as QPSK [1].

An important attribute of RHD is that it permits low frequency data modulation at the switching centre since the high frequency microwave is not generated there but at the remote station. Therefore, in contrast to IMDD, the RHD modulator at the switching centre may be driven either with baseband data or by a low frequency RF signal. Low frequency modulators generally have low π V and therefore require lower drive levels. Consequently, low frequency modulators are easier to linearize. Furthermore, linear drive amplifiers are more readily available and less costly for baseband or low frequency modulation applications. At the remote side, the need for mm-wave frequency filters is eliminated when baseband data is used [1].

A further advantage of optical heterodyning is that it is capable of producing signals with 100% intensity modulation depth. Other benefits of RHD include photonic signal processing and radio system function capabilities such as phase control, filtering, frequency conversion, to name but a few [1].

2.4.2.2 Disadvantages of Optical Heterodyning

The major drawback of this method is the requirement for the two optical carriers to be phase correlated. In other words, the phase noise in the laser sources directly translates into phase noise of the generated RF signal as shown in equation (2-4). Therefore, the generated RF signal is very sensitive to phase noise occurring in the optical link. Since semiconductor lasers are prone to phase noise, extra measures to minimize the noise have to be taken. These measures often lead to more complex systems [12].

2.4.3 Optical Frequency Multiplying

A third method deploys the generation of many harmonics by the so-called Optical Frequency Multiplying (OFM) technique.

The optical frequency of a wavelength-tunable laser diode in the headend station is periodically swept over an optical frequency range $\beta\omega$ with a harmonic sweep signal having frequency ω. After passing the fixed MZI, by FM-to-IM conversion many harmonics of the sweep frequency are generated. The strengths of the harmonics can be set by adjusting the frequency modulation index β. At the antenna site, when neglecting the fiber's attenuation and dispersion, the output current signal $I_{out}(t)$ of the photodiode contains all these harmonics n. ω with n^{th} order Bessel function, according to

$$I_{out}(t) = I_0 .\{1+ \cos[2\beta.\sin(\frac{1}{2}\omega_{rw}\tau).\cos(\omega_{rw}(t-\frac{1}{2}\tau)) + \omega_0\tau + \varphi\tau \qquad (2\text{-}6)$$

In which I0 is the DC current proportional to the received optical power, τ is the delay difference in the MZI arms, ω is the central frequency of the laser diode, and $\theta= d(t) /dt$ is its phase noise[15].

The data signal is present on all the harmonics. After photo detection, a band pass filter extracts the desired harmonic (or several harmonics), which is amplified and emitted as a microwave carrier bearing the data signal. The laser phase noise has negligible impact if $\Phi\tau/ 2\pi$, i.e. when the laser line width is much smaller than a quarter of the Free Spectral Range $\Delta\omega FSR = 2\pi/ \tau$ of the MZI. This condition is easily met, as the MZI's FSR is typically around 10 GHz, and thus the OFM process effectively suppress the laser phase noise. Hence very pure microwave signals can be generated. Linewidths below the measurement resolution (< 100 Hz) have been obtained when generating a 38.4 GHz carrier as the 6th harmonic of a 6.4 GHz sweep signal, whereas the line width of the laser diode was more than 1 MHz OFM permits to use only a relatively low frequency sweep generator in the headend, which can be of high quality while still at low cost [15].

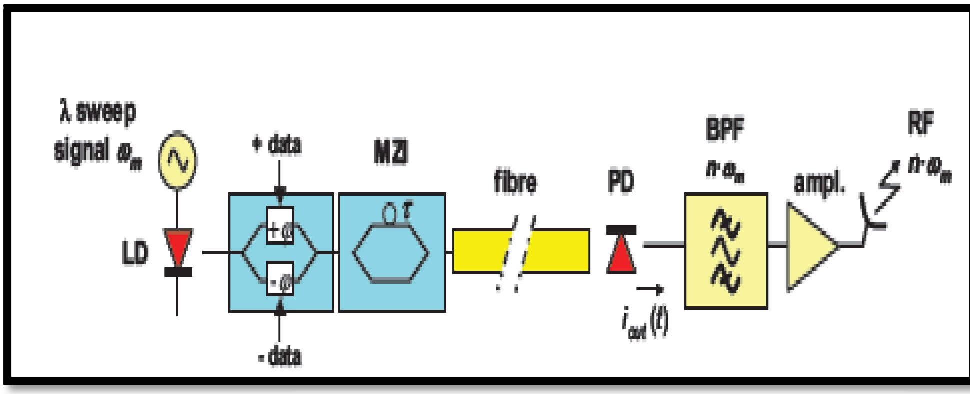


Figure 2.9: Optical frequency multiply

2.5 Wavelength-Division Multiplexing

Wavelength-division multiplexing (WDM) is a method of combining multiple signals on laser beams at various infrared (IR) wavelengths for transmission along fiber optic media. Each laser is modulated by an independent set of signals. Wavelength-sensitive filters, the IR analog of visible-light color filters, are used at the receiving end.

In fiber-optic communications, wavelength-division multiplexing (WDM) is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using different wavelengths (colors) of laser light to carry different signals. This allows for a multiplication in capacity, in addition to enabling bidirectional communications over one strand of fiber. This is a form of frequency division multiplexing (FDM) but is commonly called wavelength division multiplexing.

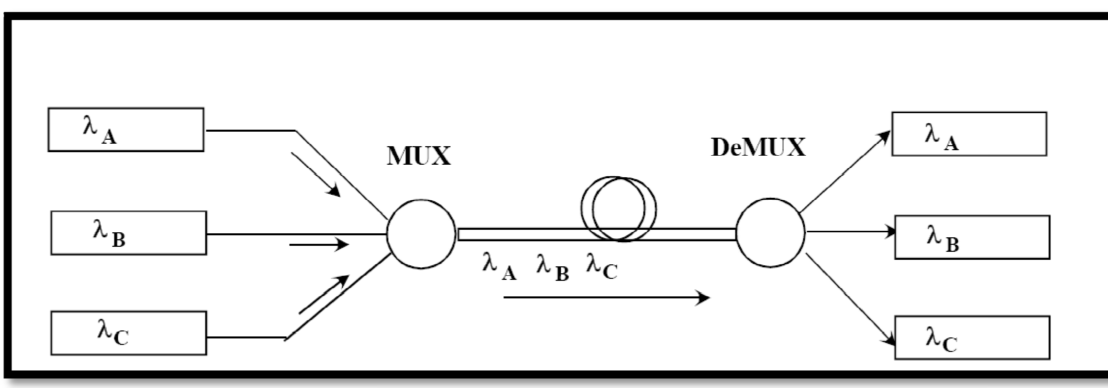


Figure2-10: WDM concept

The use of Wavelength Division Multiplexing (WDM) for the distribution of RoF signals has gained importance recently. WDM enables the efficient exploitation of the fiber network's bandwidth. However, the transmission of RFoF signals is seen as inefficient in terms of spectrum utilization, since the modulation bandwidth is always a small fraction of the carrier signal frequency. Therefore, methods to improve the spectrum efficiency have been proposed [1].

CHAPTER THREE

WIRELESS LOCAL AREA NETWORK

CHAPTER THREE
WIRELESS LOCAL AREA NETWORK

3.1 Introduction

A wireless system for Local Area Network (LAN) is an important landmark in the history of the internet and electronics applications. It make possible for the systems, databases and intranet to connect to the mobile equipment such as hand phone through a graphical customer interface. WLAN is independent over different mobile technologies that are used in different parts in the world. This is the most important advantage of WLAN. WLAN is the networking technology that allows the connection of computers without any wires or cables. The radio waves and infrared frequency technology is being used in WLAN as the transmission medium. The term LAN is applies because the range is within an office, a building, a small campus or just a house.[16]

A wireless Local Area Network (WLAN) is a flexible data communications system implemented as either an extension to, or as an alternative to the conventional wired LAN. The bulk of wireless LAN systems use Radio Frequency (RF) transmission technology. However, the Infrared (IR) spectrum is also used by some systems, mainly noncommercial systems. The focus of this project is on RF wireless LANs. Wireless LANs are typically fed through the wired LAN as shown in the figure below radio Access Point (AP) consists of a bridge and a base station, and acts as the interface between the wired LAN and the wireless LAN. [1]

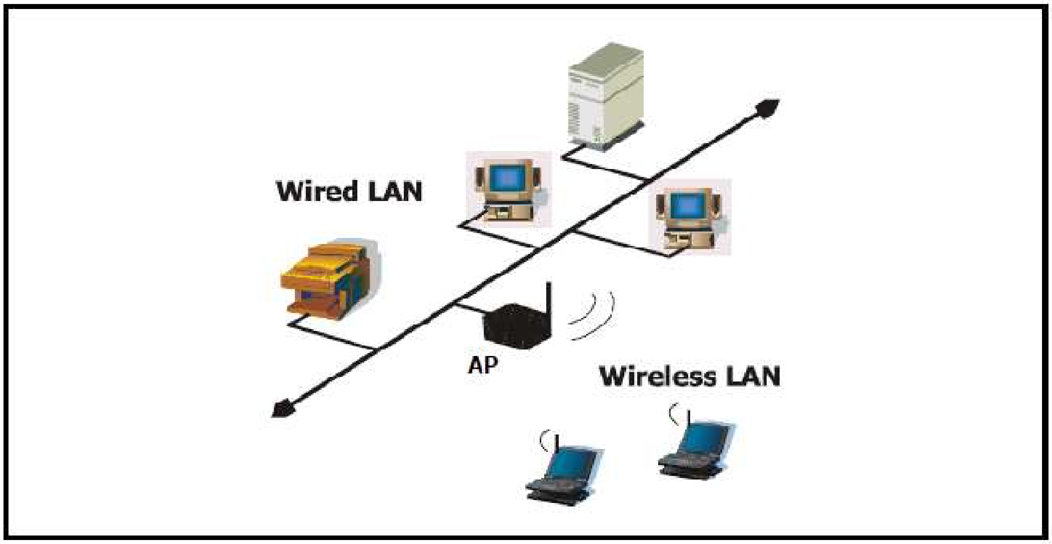


Figure 3-1: feeder network for wireless LAN

The architecture of WLAN is consisting of station, basic service set, extended service set and distribution system. Station is all components that can connect into a wireless medium in a network. All these stations are equipped with wireless network interface cards (WNICs). There are two categories of wireless station. First is the access point which is the base stations for the wireless network. They transmit and receive radio frequencies for wireless enabled devices to communicate with. The second one is clients such as laptops, personal digital assistants, IP phones, or fixed devices such as desktops and workstations that are equipped with a wireless network interface. The basic service set (BSS) is a set of all stations that can communicate with each other and consist of Independent BSS (also referred to as IBSS), and infrastructure BSS. An independent BSS (IBSS) is an ad-hoc network that contains no access points, which means they cannot connect to any other basic service set while an infrastructure BSS can communicate with other stations not in the same basic service set by communicating through access points. An extended service set (ESS) is a set of connected BSSes. Access points in an ESS are connected by a distribution system. A distribution system (DS) connects access points in an extended service set. The DS concept can be used to increase network coverage through roaming between cells.[16]

The WLAN has been specified by the IEEE 802.11group. The original version of the standard IEEE 802.11, released in 1997 and clarified in 1999, specified two raw net bit rates of 1 or 2 megabits per second (Mbit/s), plus forward error correction code, to be transmitted in industrial scientific medical (ISM) frequency band at 2.4 GHz. Legacy 802.11 was rapidly supplemented and popularized by 802.11b. The 802.11 family includes over the air modulation techniques that use the same basic protocol. The most popular are those defined by the 802.11b and 802.11g protocols which both use the 2.4 GHz ISM band. Because of this choice of frequency band, 802.11b and g equipment may occasionally suffer interference from microwave ovens and cordless telephones. Meanwhile, the Bluetooth devices that operating in the same band, in theory do not interfere with 802.11b/g because they use a frequency hopping spread spectrum signaling method (FHSS) and 802.11b/g uses a direct sequence spread spectrum signaling method (DSSS). 802.11a uses the 5 GHz U-NII band, which offers 8 non-overlapping channels rather than the 3 offered in the 2.4GHz ISM frequency band [16]. Wireless LANs using the RF spectrum employ either narrowband or wideband radio technology. For narrowband wireless LANs the end user must obtain an FCC license. However, wideband wireless LANs normally uses the Instrumentation (or Industrial),Scientific, and Medical (ISM) frequency bands of 915 MHz, 2.4 GHz, and 5 GHz, which do not require licensing. The ISM spectra are used not only by wireless LANs but other electronic devices as well, such as microwave ovens, and portable mobile devices (Bluetooth). Therefore, wireless LAN technologies utilizing the ISM bands must be equipped to deal with interferences of all kinds in these spectra. Commercially available wireless LAN technologies employ spread-spectrum technology to provide reliable and secure transmission in the ISM bands. Spread spectrum technologies trade-off bandwidth efficiency for reliability and security [1].

3.2 Wireless LAN Standards

The pioneer wireless LAN standard IEEE 802.11 allows for speeds of up to 2 Mbps and uses FHSS and DSSS at 2.4 GHz. It also supports operation at infrared frequencies. This standard was modified to IEEE 802.11b offering data rates up to 11 Mbps and operating in the 2.4 GHz band as well. This standard uses a modified DSSS technique. In the quest for high-speed data rates, two new standards IEEE 802.11a and the European Telecommunications Standards Institute (ETSI)'s High Performance Local Area Network type 2, (HIPERLAN/2) are in place. The standards use OFDM and provide for up to 54 Mbps data rates. The operating frequencies have consequently been raised to the 5 GHz ISM and the Unlicensed National Information Infrastructure (UNII) bands [1].

Table 3-1: wireless LAN standards

IEEE Standard	Speed (max)	Frequency	Transmission Method
802.11legacy	2 Mbps	2.4 GHz	DSSS, FHSS
802.11a	54 Mbps	5.0 GHz	OFDM
802.11b (Wi-Fi)	11 Mbps	2.4 GHz	DSSS
802.11g	54 Mbps	2.4 GHz	DSSS, OFDM
802.11n	200+ Mbps	2.4/5 GHz	MIMO

Bluetooth	2 Mbps	2.45 GHz	FHSS
HomeRF	10 Mbps	2.4 GHz	FHSS
HiperLAN/1	20 Mbps	5 GHz	CSMA/CA
HiperLAN/2	54 Mbps	5 GHz	OFDM

Wireless coverage of the end-user domain, be it outdoors or indoors (in-building), is poised to become an essential part of broadband communication networks. In order to offer integrated broadband services (combining voice, data, video, multimedia services, and new value added services), these systems will need to offer higher data transmission capacities well beyond the present-day standards of wireless systems Wireless LAN (IEEE802.11a/b/g) offering up-to 54 Mbps and operating at 2.4 GHz and 5 GHz[12].

3.3 IEEE 802.11a

The Institute of Electrical and Electronics Engineers [IEEE] has developed 802.11a, a new specification that represents the next generation of enterprise-class wireless LANs. Among the advantages it has over current technologies are greater scalability, better interference immunity, and significantly higher speed, up to 54 Mbps and beyond, which simultaneously allows for higher bandwidth applications and more users [17].

Devices utilizing 802.11a are required to support speeds of 6, 12, and 24 Mbps. Optional speeds go up to 54 Mbps, but will also typically include 48, 36, 18, and 9 Mbps. These differences are the result of implementing different modulation techniques and FEC levels. To achieve 54 Mbps, a mechanism called 64-level quadrature amplitude modulation (64QAM) is used to pack the maximum amount of information possible (allowable by the standard) on each subcarrier. Just as with 802.11b, as an 802.11a client device travels farther from its Access Point, the connection will remain intact but speed decreases (falls back). As the following picture illustrates, 802.11a can have a significantly higher signaling rate than 802.11b at most ranges [17].

3.4 RoF System Requirements

The ever increasing demand for high data rate transmission combined with the desire to connect end devices wirelessly led to intense research activities on new network architectures and technologies for in-building, small cell communication networks. The goal is to connect up to hundreds of remote antenna units, which are simple in design, with a centralized head-end unit via fiber-optic transport systems, resulting in a flexible yet simple overall network design and therefore low-cost implementation. Radio-over-Fiber (RoF) is an attractive technology for these networks as it allows for centralization of signal processing and network management as well as radio signal generation. The radio signal then just needs to be transported to the remote antennas and radiated. Due to the high frequencies, optical fiber is widely considered as a transport medium due to its very low loss over long distances and over wide frequency ranges. Further, optical fiber is very light, flexible, bendable, and allows for consideration of wavelength-division multiplex (WDM) techniques [1].

In general, the RoF system to be designed must be able to distribute the wireless LAN signals efficiently and in conformity with all aspects of the appropriate standard, such as signal purity and power levels. The system must also be easy to upgrade for operation with future systems.[1]

The main issues and parameters that are likely to influence the design of such a system are discussed below.

3.4.1 System Cost

The fact that future wireless LANs will consist of a high density of small radio cells makes the issue of system cost a major one. It is imperative to have simple and easy to maintain base stations (i.e. APs). The complexity of the APs is related to the RoF techniques employed. Therefore, the choice of the microwave generation method is important. The kind of feeder network infrastructure is another crucial one. While standard single mode fiber offers the most bandwidth, it has high installation and maintenance costs associated with it [1].

3.4.2 Bandwidth Requirements and Link Lengths

The required RoF system must not only meet the present demand for capacity, but it must also be suited to meet anticipated future bandwidth demands. The requirement for broadband wireless services translates into the requirement for increased capacity in the distribution and feeder networks Future high bandwidth systems will occupy more bandwidth and operate at mm-wave carriers (60 GHz).As stated above, optical fiber is the best candidate for this for example SMF offers enormous bandwidth [1].

3.4.3 Data Modulation Formats

The RoF system to be designed must be capable of generating microwave signals with appropriate data modulation. The RoF system is capable of distributing Phase Shift Keying (PSK) or Quadrature Amplitude Modulation (QAM).

3.4.4 Choice of Microwave Generation Technique

There are several optical techniques for generating and transporting microwave signals over fiber. By considering the frequency of the RF signal fed into the RoF link at the headend in comparison with the signal generated at the RAU the RoF techniques may be classified into three categories – namely RF-over-fiber (RFoF), IF over Fibre (IFoF), or baseband-over-Fiber (BBoF) . RFoF involves the transmission of the actual RF signal over the fiber. However, in IFoF and BBoF the desired microwave signal is generated at the RAU through up-conversion with a LO, which is either provided separately at the RAU, or is transported remotely to the RAU. Therefore, depending on the transmission method used, the RAU may be more complex or simpler [1][3].

3.5 Quadrature Amplitude Modulation (QAM)

Quadrature Amplitude Modulation or QAM is a form of modulation which is widely used for modulating data signals onto a carrier. It is widely used because it offers advantages over other forms of data modulation such as PSK, although many forms of data modulation operate alongside each other [18].

Quadrature amplitude modulation (QAM) takes advantages of Phase Shift Modulation (PSK) and Amplitude Shift Modulation (ASK) and provides high performance and more flexibility and robustness. Quadrature amplitude modulation (QAM) is a modulation scheme in which two sinusoidal carriers, one exactly 90 degrees out of phase with respect to the other, are used to transmit data over a given physical channel. One signal is called I signal, and the other is called Q signal.

Because the orthogonal carriers occupy the same frequency band and differ by a 90 degree phase shift, each can be modulated independently, transmitted over the same frequency band, and separated by demodulation at the receiver. For a given available bandwidth, QAM enables data transmission at twice the rate of standard pulse amplitude modulation (PAM) without any degradation in the bit error ratio (BER) .

The QAM modulator is of the type shown in Figure (3-2) below. The two paths to the adder are typically referred to as the 'I' (in-phase), and 'Q' (quadrature), arms.

Mathematically two independent signals XI (t) and XQ (t), each band limited by are transmitted.

One signal is modulated by a cosine the other signal by a sinus carrier. Thus the signal:

$$x_I(t).\cos(\omega_0 t) - x_Q(t)\sin(\omega_0 t) \tag{3-1}$$

The in-phase signal $X_1(t)$:

$$[x_I(t).\cos(\omega_0 t) - x_Q(t)\sin(\omega_0 t)]\cos(\omega_0 t)$$

$$= x_I(t).\cos^2(\omega_0 t) - x_Q(t).\sin(\omega_0 t).\cos(\omega_0 t)$$

$$= \frac{Xi(t)}{2}[1+\cos(2\omega_0 t)] - \frac{XQ(t)}{2}.\sin(2\omega_0 t) \tag{3-2}$$

After low pass filtering:

$$[\frac{Xi(t)}{2}[1+\cos(2\omega_0 t)] - \frac{XQ(t)}{2}.\sin(2\omega_0 t)]* r_{\omega g}(t)$$

$$= \frac{Xi(t)}{2} \tag{3-3}$$

The Q-phase signal X_Q (t):

$$-[x_I(t).\cos(\omega_0 t) - x_Q(t)\sin(\omega_0 t)]\sin(\omega_0 t)$$

$$= -x_I(t).\sin(\omega_0 t).\cos(\omega_0 t) + x_Q(t).\sin^2(\omega_0 t)$$

$$= -\frac{\quad}{\quad}.\sin(\omega_0 t) + \frac{\quad}{\quad}[1-\cos(\omega_0 t)] \qquad (3\text{-}4)$$

After low pass filtering:

$$= -\frac{\quad}{\quad}.\sin(\omega_0 t) + \frac{\quad}{\quad}[1-\cos(\omega_0 t)] * r_{\omega g}(t)$$

$$= \frac{\quad}{\quad} \qquad (3\text{-}5)$$

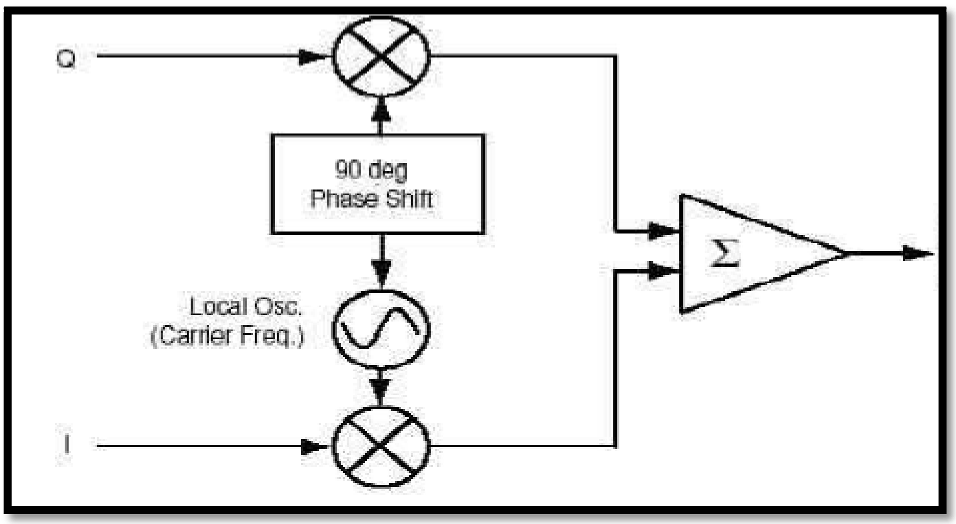


Figure (3-2): QAM Modulator

The motivation for QAM comes from the fact that a DSBSC signal occupies twice the bandwidth of the message from which it is derived. This is considered wasteful of resources. QAM restores the balance by placing two independent DSBSC, derived from message #1 and message #2, in the same spectrum space as one DSBSC. The bandwidth imbalance is removed [18].

The QAM receiver follows the similar principles to those at the transmitter, and is illustrated in idealized from in the block diagram of Figure below.

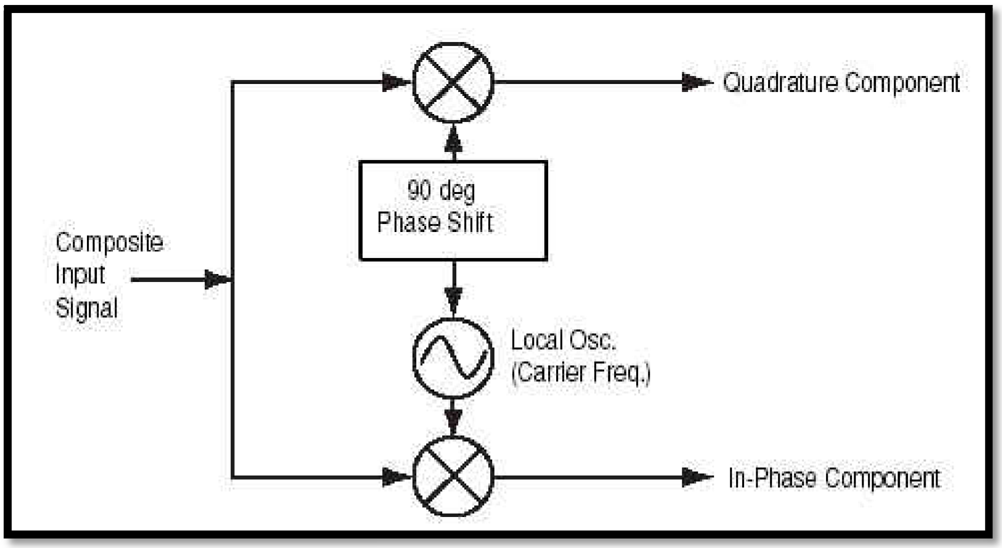


Figure (3-3): QAM demodulator

3.6 Bit Error Rate

One of the changes that modern digital communications systems have brought to radio engineering is the need for end-to-end performance measurements. The measure of that performance is usually bit-error rate (BER), which quantifies the reliability of the entire radio system from “bits in” to “bits out,” including the electronics, antennas and signal path in between. On the surface, BER is a simple concept its definition is simply:

BER = Errors/Total Number of Bits (3-6)

With a strong signal and an unperturbed signal path, this number as small as to be insignificant. It becomes significant when we wish to maintain a sufficient signal-to-noise ratio in the presence of imperfect transmission through electronic circuitry (amplifiers, filters, mixers, and digital/analog converters) and the propagation medium (e.g. the radio path or optical fiber).

Any in-depth analyses of the processes that affect BER require significant mathematical analysis. Noise is the main enemy of BER performance. Noise is a random process, defined in terms of statistics [21].

When BER threatens the usefulness of a system, there are many courses of action. First, the troubleshooting process must identify the cause of the errors. Is it circuit related or path related? What is the cost of the remedy? Should we improve the hardware, pursue changes to the transmission environment, or choose a different modulation format?

CHAPTER FOUR
SIMULATION

CHAPTER FOUR
SIMULATION

4.1 Introduction

This chapter presents the simulation of the overall WLAN system using OptiSystem Software version 7. Optiwave Systems Inc, the leading provider of optical component and system design tools, today announced the immediate availability of OptiSystem 7.0 - the latest version of its optical communication system design suite. This major release delivers a number of exciting new features, which facilitate the simulation and design of emerging optical network technologies.

In addition to new functionality, OptiSystem is now available in a newly designed 64-bit edition, addressing complex computing simulations requiring a significant amount of memory. The optimized code structure results in improved computing performance and efficient memory utilization. Users are now capable of running large scale 'real world' simulations, without the memory restrictions limited to 32-bit operating systems. This simulation consists of three parts Headend (HE), fiber link and Remote Antenna Unit (RAU).

At the headend (HE), the generation and modulation of electrical signal was occurring and after that it modulated with optical signal and passed through the optical link.

The Remote Antenna Unit (RAU) detects the electrical signal and sends this simulation consists of four parts Headend (HE), fiber link and Remote Antenna Unit (RAU) and end user.

At the downlink the Headend (HE) generates and modulates electrical signal and after that it modulated with optical signal and passed through the optical link.

The Remote Antenna Unit (RAU) detects the electrical signal and sends it to the end user. At the uplink the whole operations are done but in reverse order from the end user to the headend.

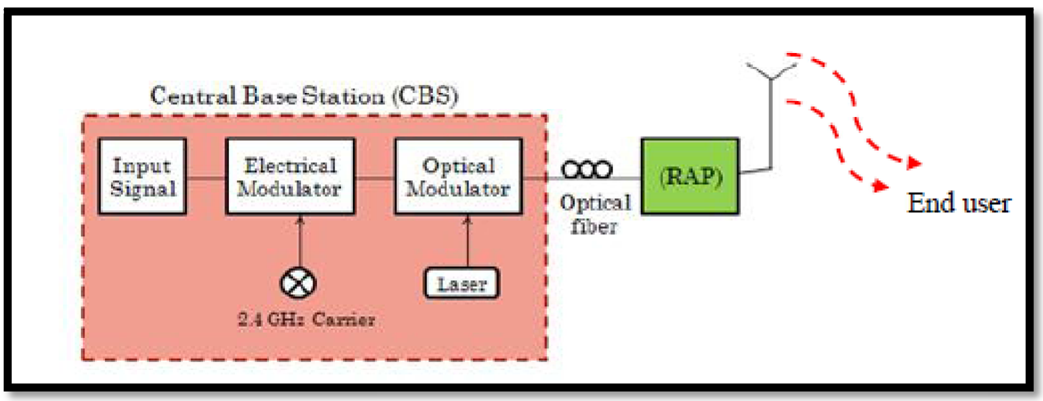


Figure 4-1: Central Base Station or headend

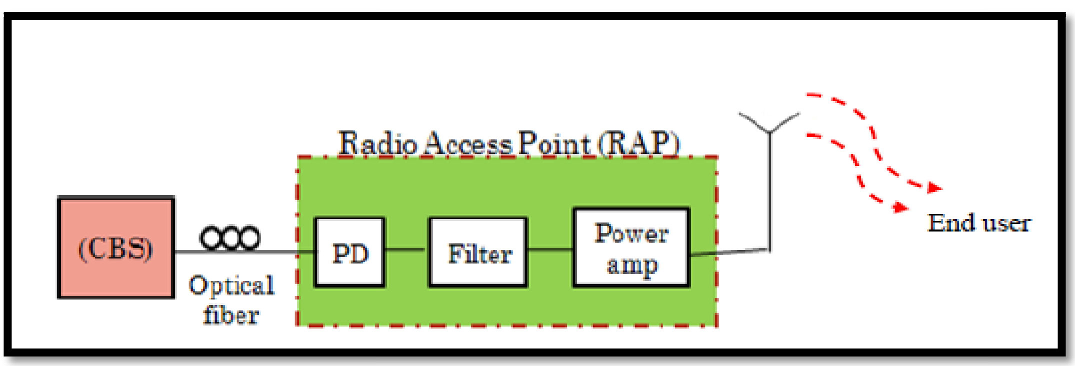


Figure4-2: Radio Access Point

4.2 Headend

The headend includes the operations that generating electrical and optical signals as follow:

4.2.1 Electrical signal

At the downlink, the source signal is generated by using Pseudo-random bit sequence generator. It is a binary signal that has characteristics of IEEE 802.11a standard. The generated signal is mapped to QAM sequence generator which generates two parallel M-ary symbols sequences from binary signals using quadrature amplitude modulation (QAM).The QAM modulator conveys two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme.

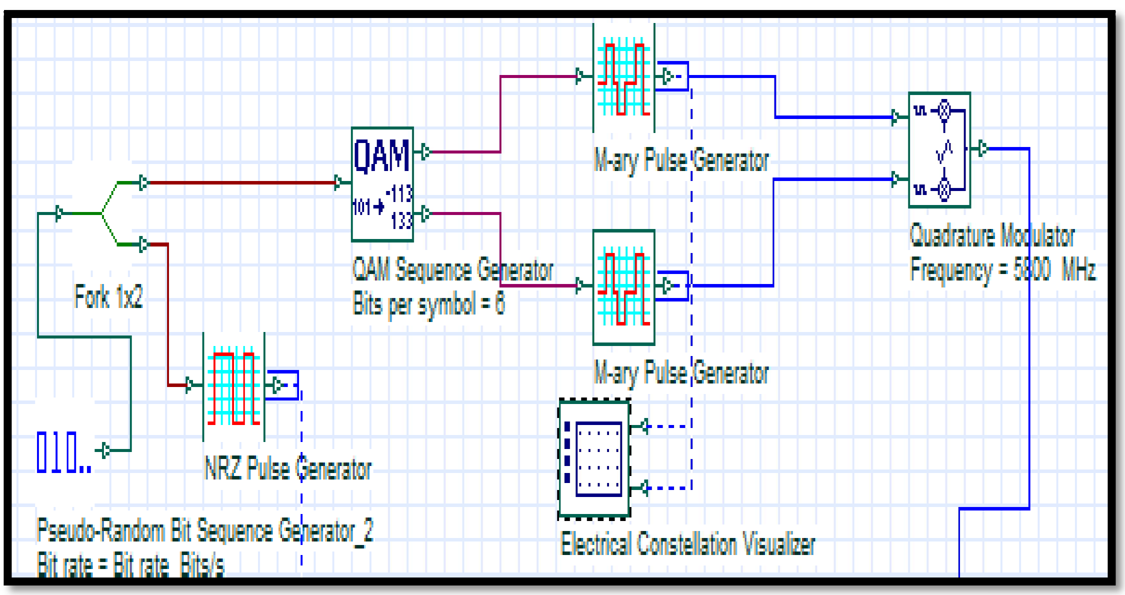


Figure 4-3: Generating electrical signal in downlink

At the uplink the detection of modulated electrical signal from optical signal and then demodulation is followed.

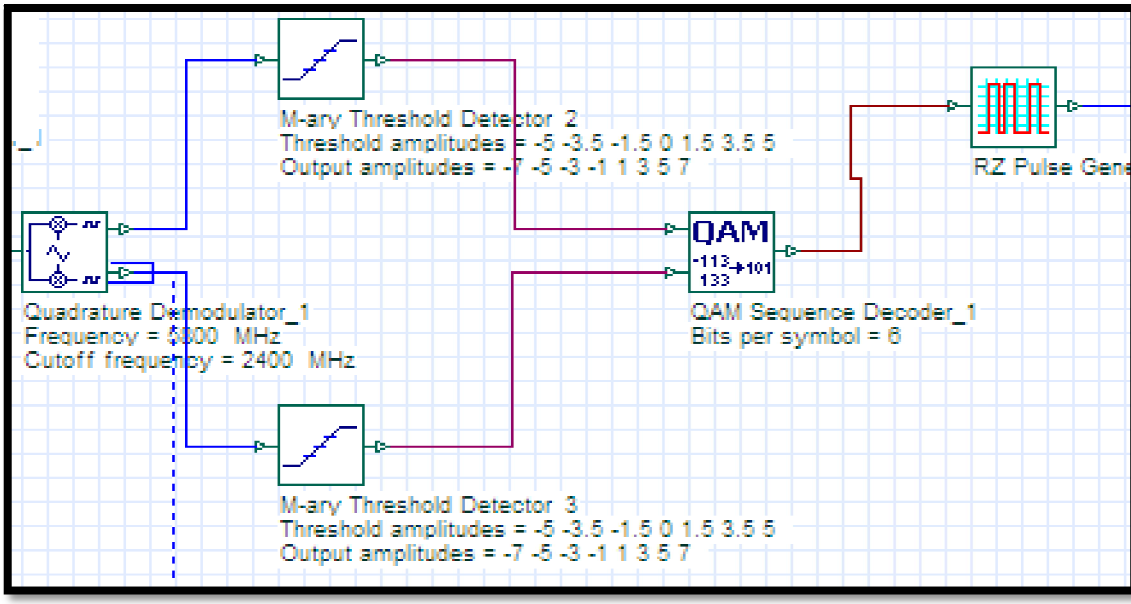


Figure 4-4: Demodulation of electrical signal in uplink

4.2.2 Optical signal

The optical modulation scheme using in this simulation is consist of a CW laser and the Mach Zehnder optical Modulator (MZM). The CW laser is radiating in the range of 1550nm with power of 10dBm. 1550nm is chosen because it gives zero dispersion and the only dominant scattering occurs at this wavelength is Rayleigh scattering. Thus, the loss is minimized in the range of 1550nm. This modulation scheme would convert electrical signal to optical signal to enable the transmission via the optical fiber. This simulation uses single mode optical fiber with length of 50km because it is a good estimation of macro cell radius.

The Mach-Zehnder modulator is an intensity modulator based on an interferometric principle. It consists of two 3 dB couplers which are connected by two waveguides of equal length. By means of an electro-optic effect, an externally applied voltage can be used to vary the refractive indices in the waveguide branches.

The different paths can lead to constructive and destructive interference at the output, depending on the applied voltage. Then the output intensity can be modulated according to the voltage.

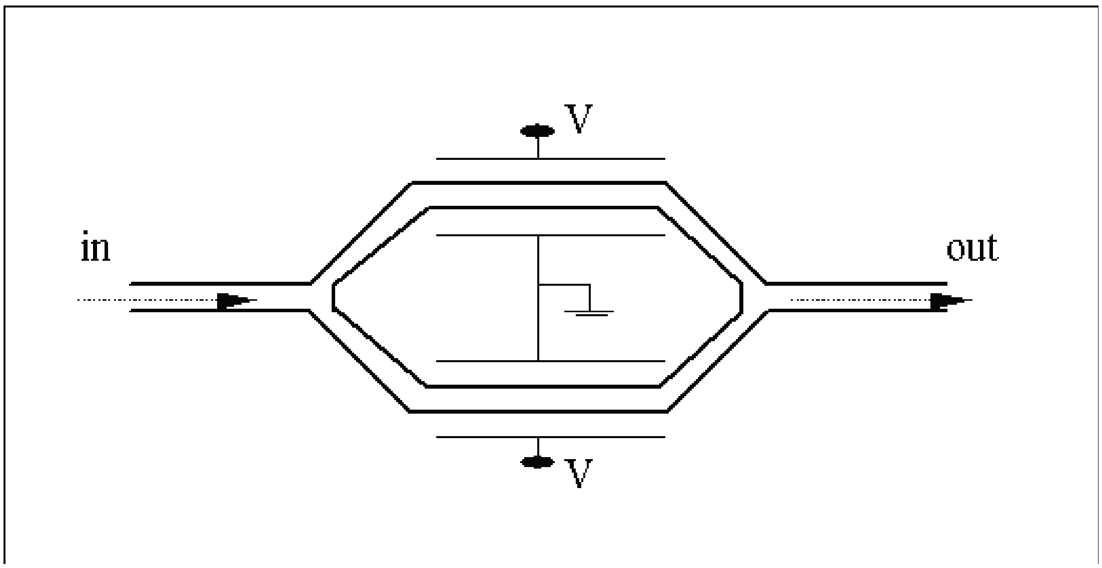


Figure 4-5: Mach-Zehnder modulator

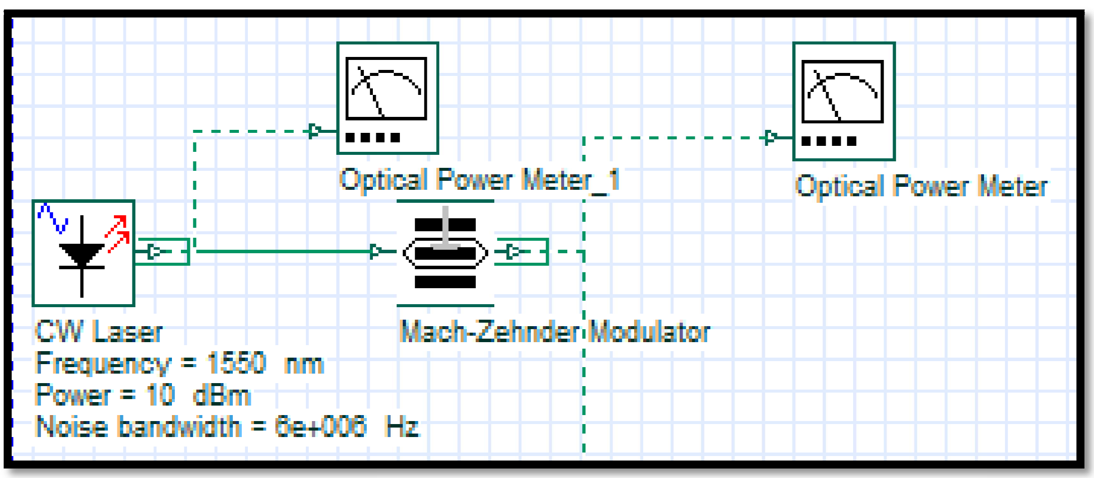


Figure 4-6: Generating optical signal

The detection of electrical signal is implemented in the uplink as shown in figure below:

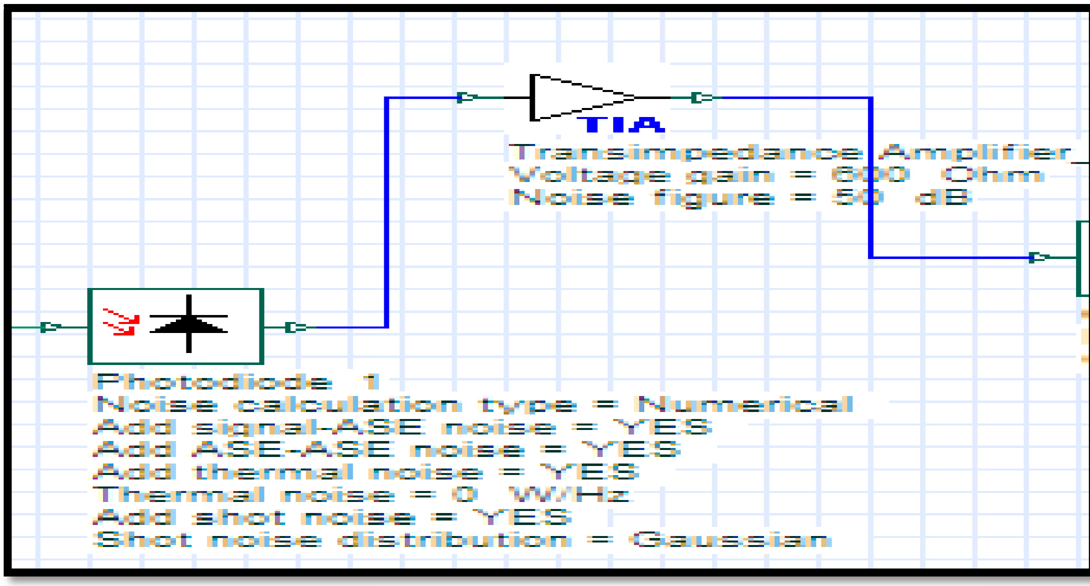


Figure 4-7: The Detection of the electrical signal

4.3 Fiber link

This simulation uses bidirectional single mode optical fiber with length of 50km because it is a good estimation of macro cell radius. Single mode fiber doesn't have modal dispersion, modal noise, and other effects that come with multimode transmission; single mode fiber can carry signals at much higher speeds than multimode fibers. They are standard choice for high data rates or long distance span (longer than a couple of kilometers) telecommunications which use laser diode based fiber optic transmission equipment [8].

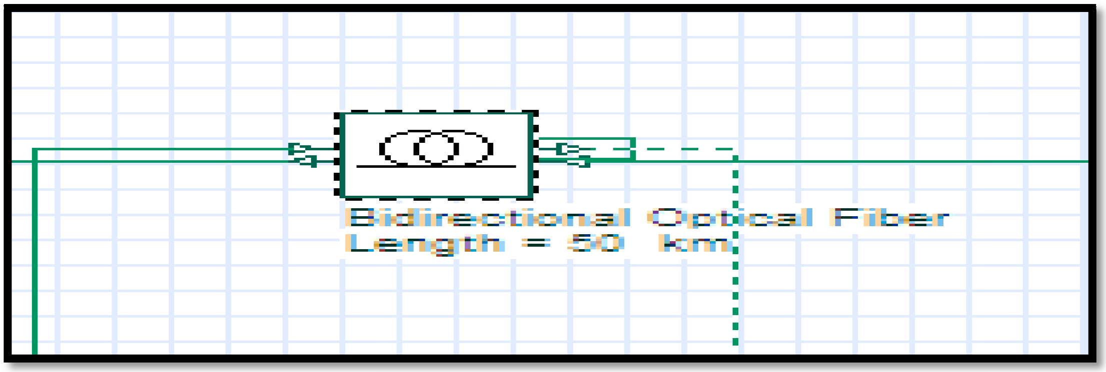


Figure 4-8: SMF 50Km fiber

4.4 Remote Antenna Unit (RAU)

The photodetector senses the light signal falling on it and converts the variation of the optical power to a correspondingly varying electric current. Since the optical signal generally is weakened and distorted when it emerges from the end of the fiber, the photo detector must meet strict performance requirements.

Among the most important of these are high sensitivity to the emission wavelength range of the received light signal, minimum addition of noise to the signal and fast response speed to handle the desired data rate

The data is converted back into electrical form by the PIN photodetector. The generated electrical signal must meet the specifications required by the wireless LAN 802.11a.the photocurrent obtained from photodiode is replica of the modulating signal applied at the headend. This current undergoes transimpedance amplification by using TIA to yield a voltage that is in turn used to excite the RF antenna.

The FR antenna has gain; this antenna is used both in transmitting mode during downlink and receiving mode at the remote station. Free space is used as to link the antenna and the remote station with the distance of 10km and frequency of 5.8GHz. Propagation loss can be calculated using free space loss (FSL) equation below that resulting loss of 127.7dB.

$$FSL=32.44+20\log f\,(MHz)+20\log d\,(km) \quad (4\text{-}1)$$

In this simulation the attenuator is used to simulate the antenna function with its FSL.

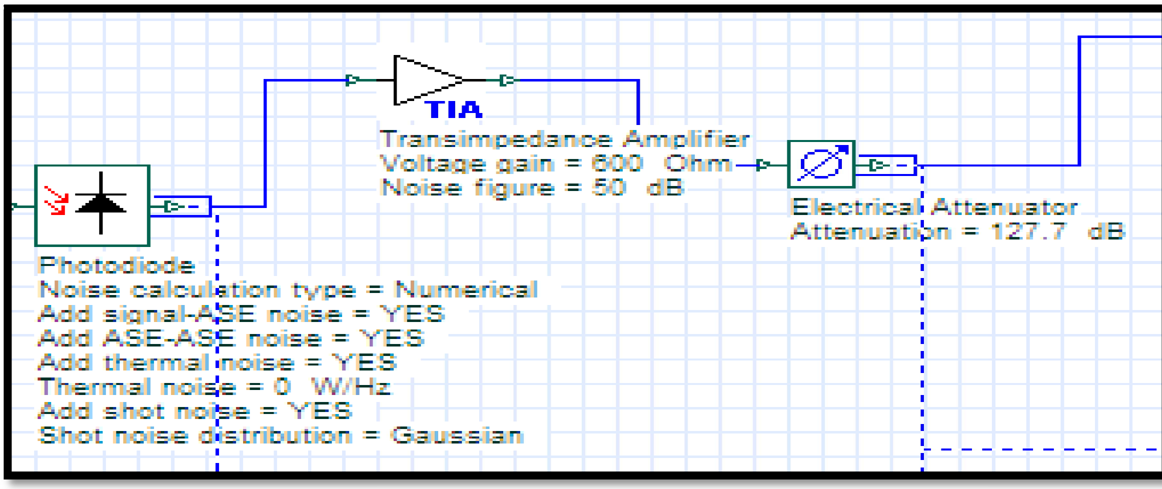


Figure 4-9: RAU in down link

At the uplink, modulated optical signal must be obtained from the radiated RF signal by using CW laser to generate the optical carrier and MZM for modulation.

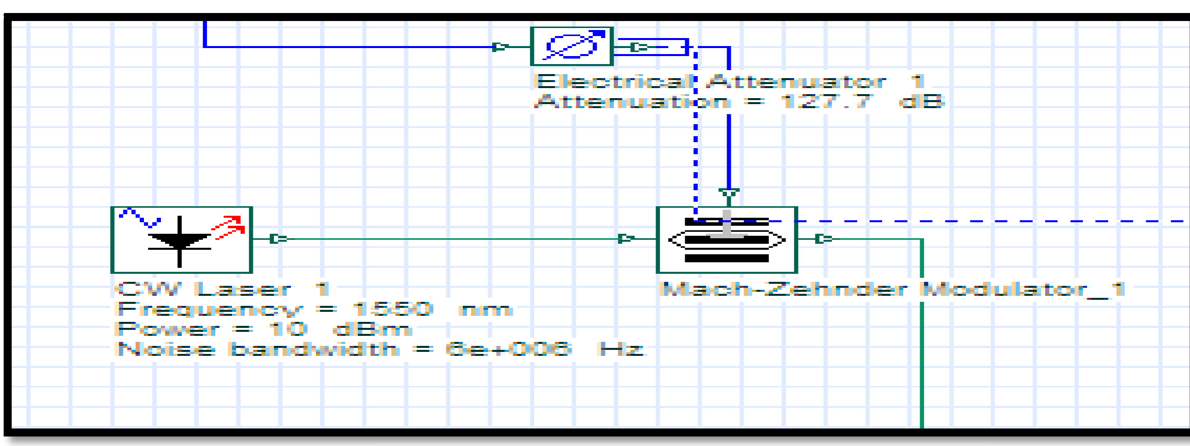


Figure 4-10: RAU in uplink

4.5 The End User

At the downlink, the end user device recovers the radiated RF signal and then down converts it to 2.4GHz .this signal demodulated by using QAM demodulator to obtain desired information.

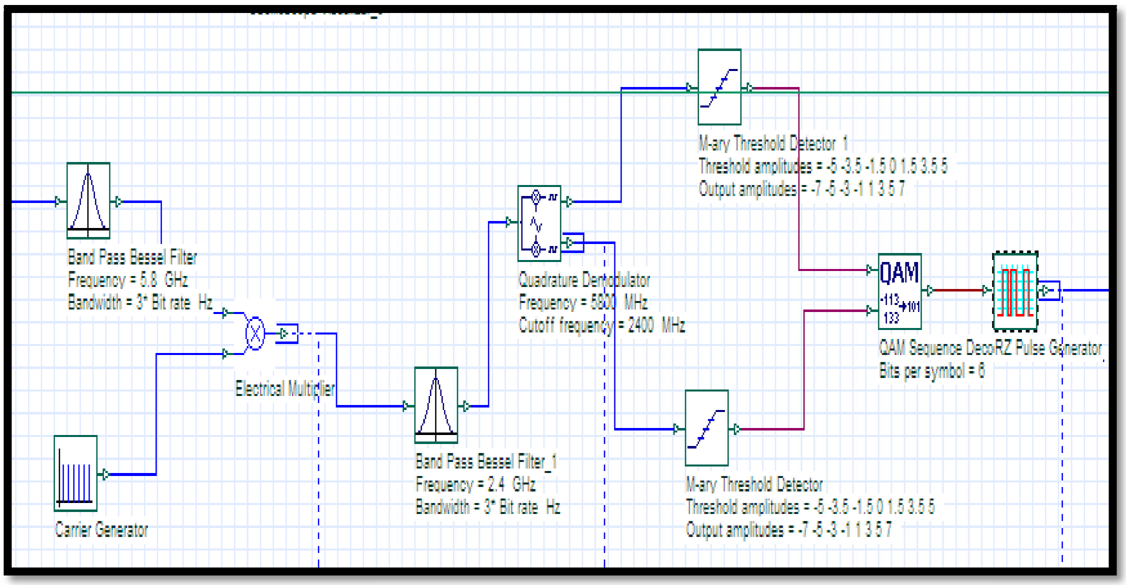


Figure 4-11: The end user in downlink

At the uplink the information signal is modulated by QAM modulator and up converted to 5.8 GHz and radiated by RF antenna.

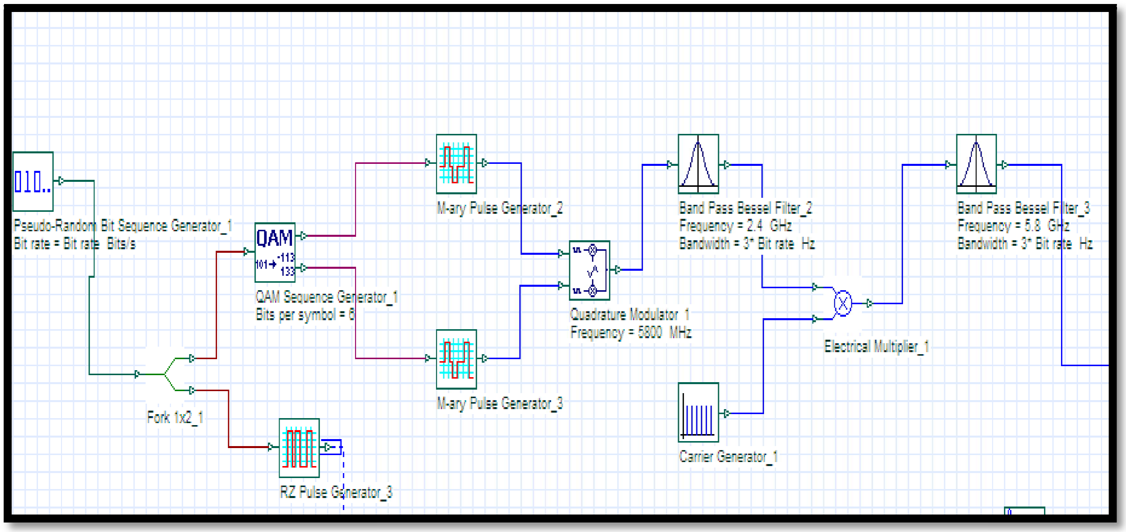


Figure 4-12: The end user in uplink

The whole parameters of the designed simulation are summarized at the table shown below:

Table 4-1: The parameters of the simulation design

Parameters	Values
Baseband modulation	64QAM
Data rate	54Mbps
Bit per symbol	6
RF carrier frequency	5.8GHz
Optical fiber type	Single mode fiber (SMF)
Optical fiber length	50km
Optical source	Continuous wave (CW) laser
Optical detector	PIN photodiode
Antenna type	RF antenna
Filter type	Bessel BPF
Amplifier type	Transimpedance amplifier

4.6 Results

The input signal produced is about 54Mbps is presented by pseudo random bit sequence (PRBS) with 2048 bits sequence length, 64 samples per bit which gives total samples of 131072 samples. The signal is shown in Figure 4-13 that taken from the oscilloscope visualizer locates after the output from PRBS. The signal is decode using NRZ format which convert the signal into bit stream.

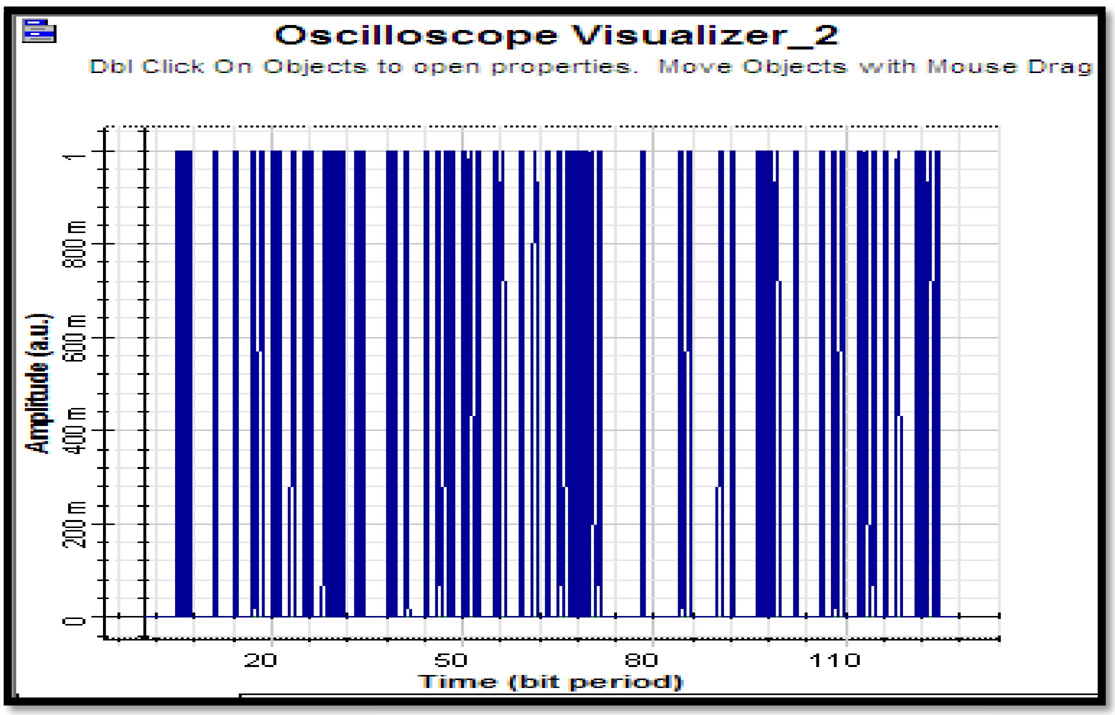


Figure 4-13: The input data in the form of binary signal

After that, the binary bits were maps into 64-QAM using QAM sequence generator with bits per symbol equal to 6, then QAM sequence generator Generates two parallel M-ary symbol sequences from binary signals using (QAM).

A constellation diagram is a representation of a signal modulated by a digital modulation scheme such as quadrature amplitude modulation or phase-shift keying. It displays the signal as a two-dimensional scatter diagram in the complex plane at symbol sampling instants. In other words, it represents the possible symbols that may be selected by a given modulation scheme as points in the complex plane. In this simulation, the constellation visualizer is locates at the output of I and Q signal of M-ary pulse generator. Figure 4-14 shows the constellation diagram for 64-QAM signal used in the simulation.. The constellation signal is taken from the output of I and Q signal of M-ary pulse generator.

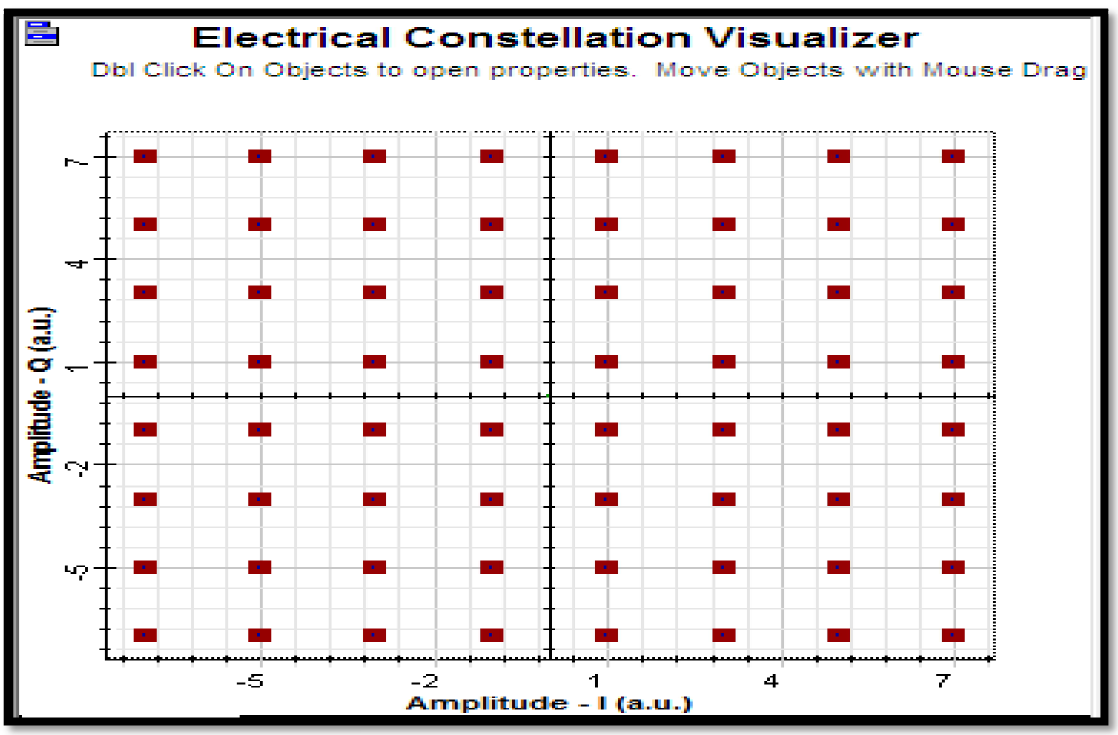


Figure 4.14: QAM constellation diagram

The optical modulation process is done by the Mach Zehnder modulator as the external modulator with the optical source of continuous wave (CW) laser with power of 10dBm. This laser is used to convert the electrical signal into light spectrum of 1550nm to be transmitted via optical fiber. The modulated optical signal was taken from the output of Mach Zehnder modulator by optical spectrum visualizer. The result is shown in which presents the modulated signal at radio frequency of 5.8GHz with power of 14dBm.

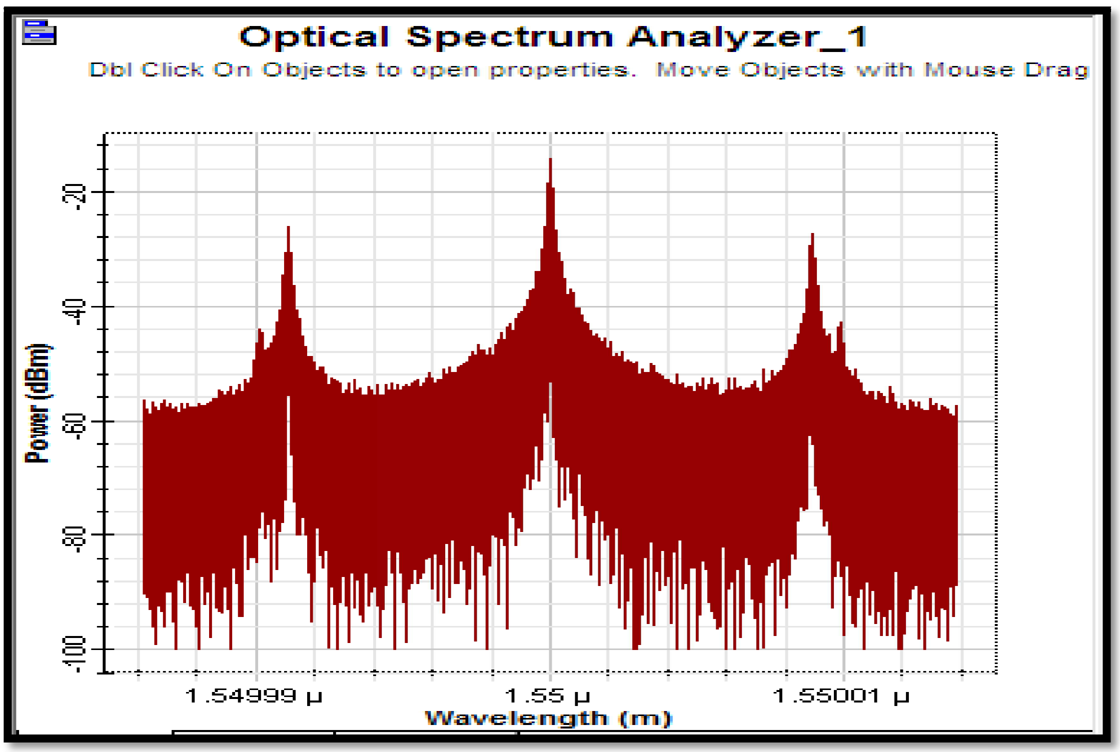


Figure 4-15: Modulated optical signal

In the RAU side, the distributed signal by single mode fiber is amplified by TIA and then radiated via RF antenna as shown in figure.

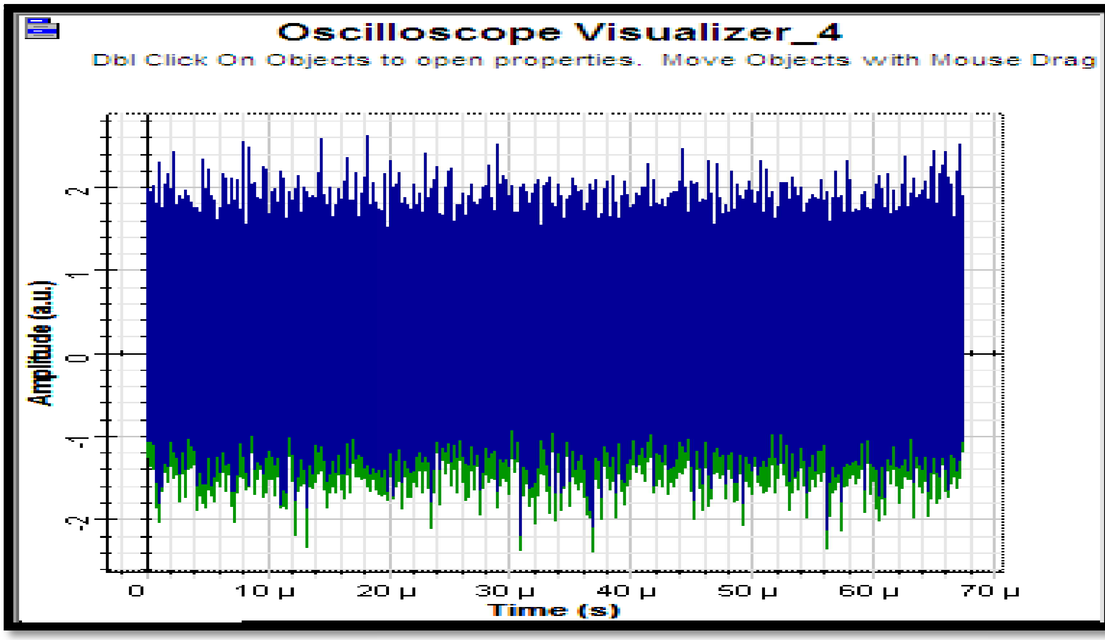


Figure4-16: The electrical signal after TIA

At the receiver side, after RF signal received from RF antenna is down converted from 5.8GHz to 2.4GHz then it is demodulated by QAM demodulator to obtain the desired information as shown in figure 4-17.

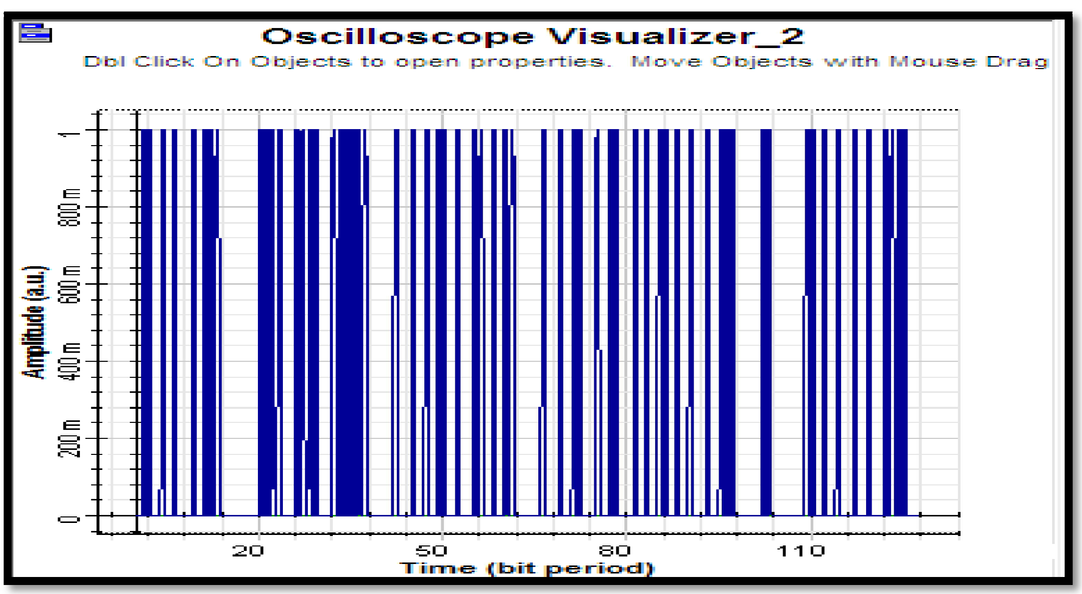


Figure 4-17: The received signal

After that to calculate the bit error rate, BER analyzer is required
And the result is shown in figure.

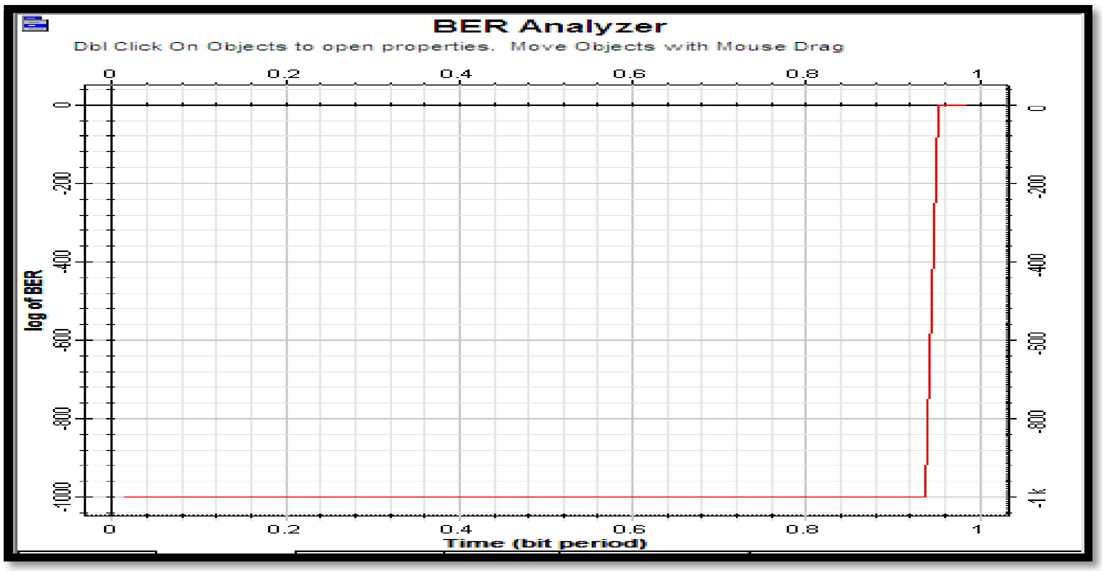
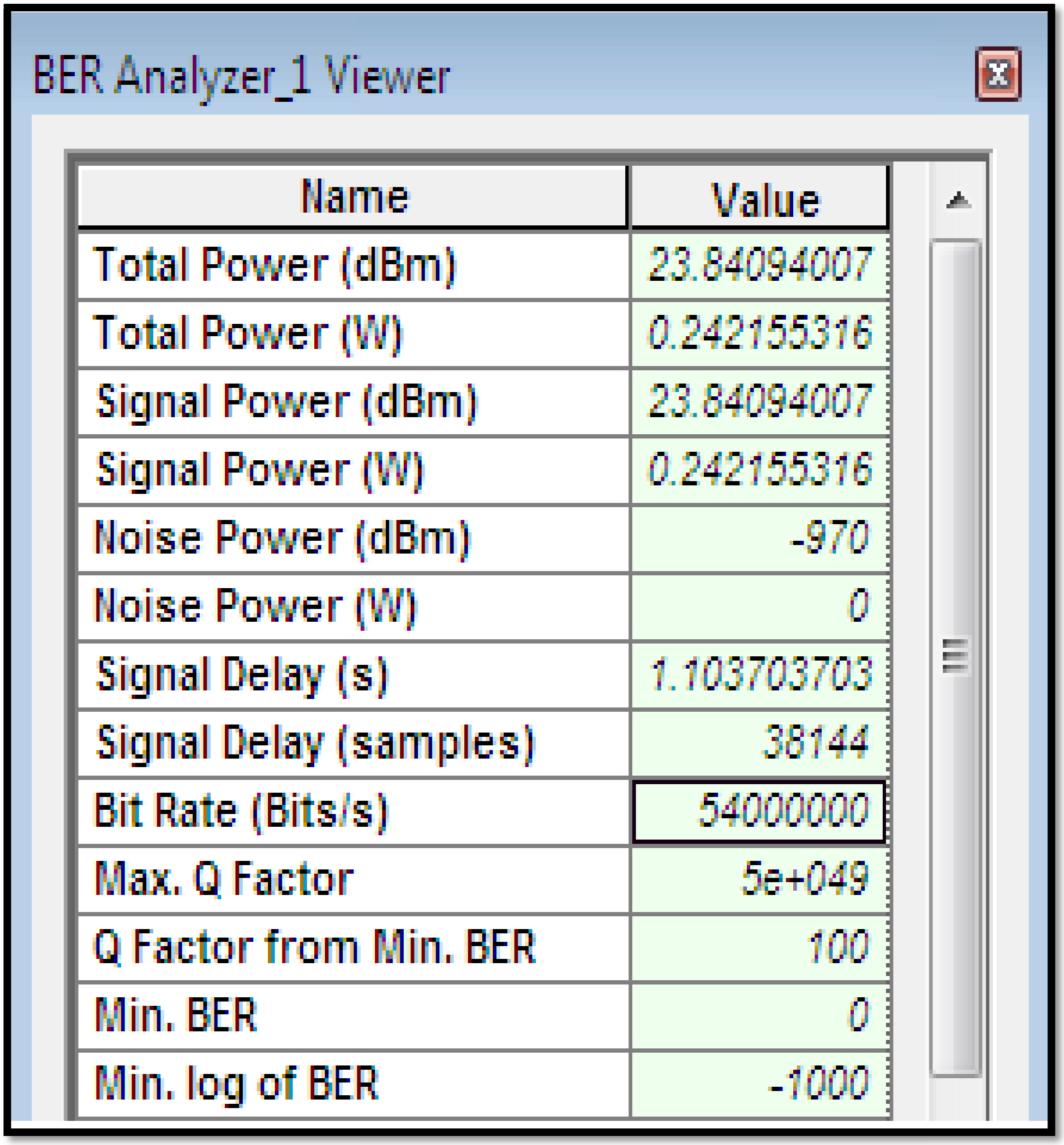


Figure 4-18 BER Analyzer

We notice that the min BER in dB equal to -1000dBm and it is very low as compared with (-20dBm to-70dBm) this decrease of BER is result by using SMF and QAM modulation.

The table below shows the output values for the downlink at the receiver terminal.

Table 4-2: the output readings(downlink)



BER Analyzer_1 Viewer

Name	Value
Total Power (dBm)	23.84094007
Total Power (W)	0.242155316
Signal Power (dBm)	23.84094007
Signal Power (W)	0.242155316
Noise Power (dBm)	-970
Noise Power (W)	0
Signal Delay (s)	1.103703703
Signal Delay (samples)	38144
Bit Rate (Bits/s)	54000000
Max. Q Factor	5e+049
Q Factor from Min. BER	100
Min. BER	0
Min. log of BER	-1000

At the uplink, the whole operation is done but in reverse order. The RF signal is generated by the end user device and transported to RAU which convert it to optical signal and send it through SMF to head end.

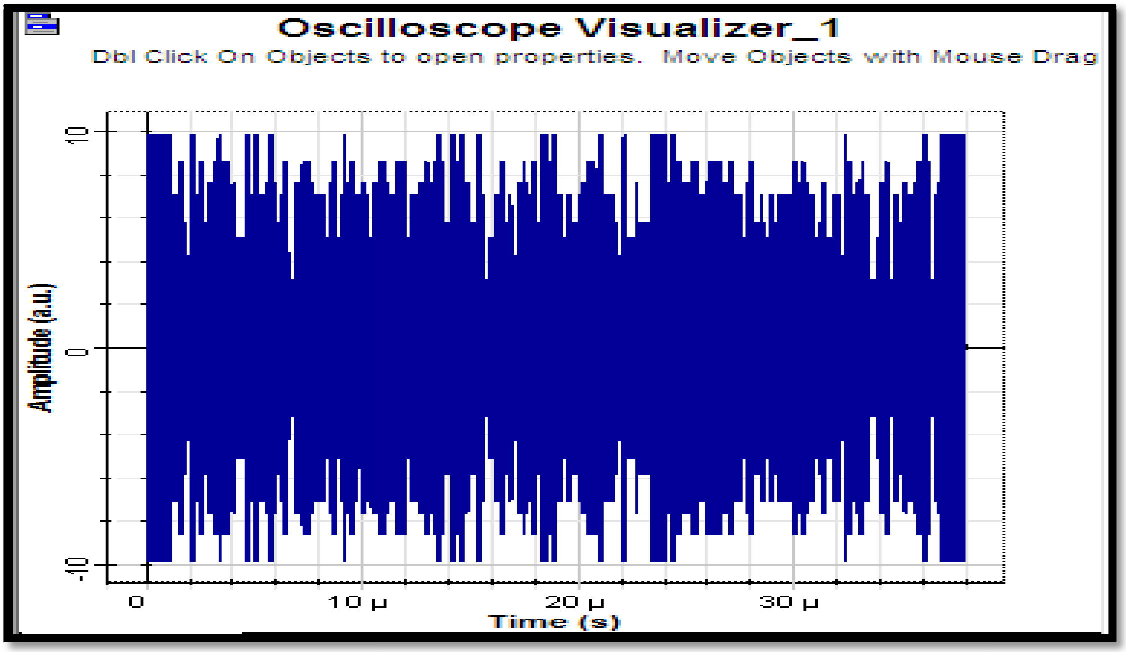


Figure 4-19: RF signal generated by end user device

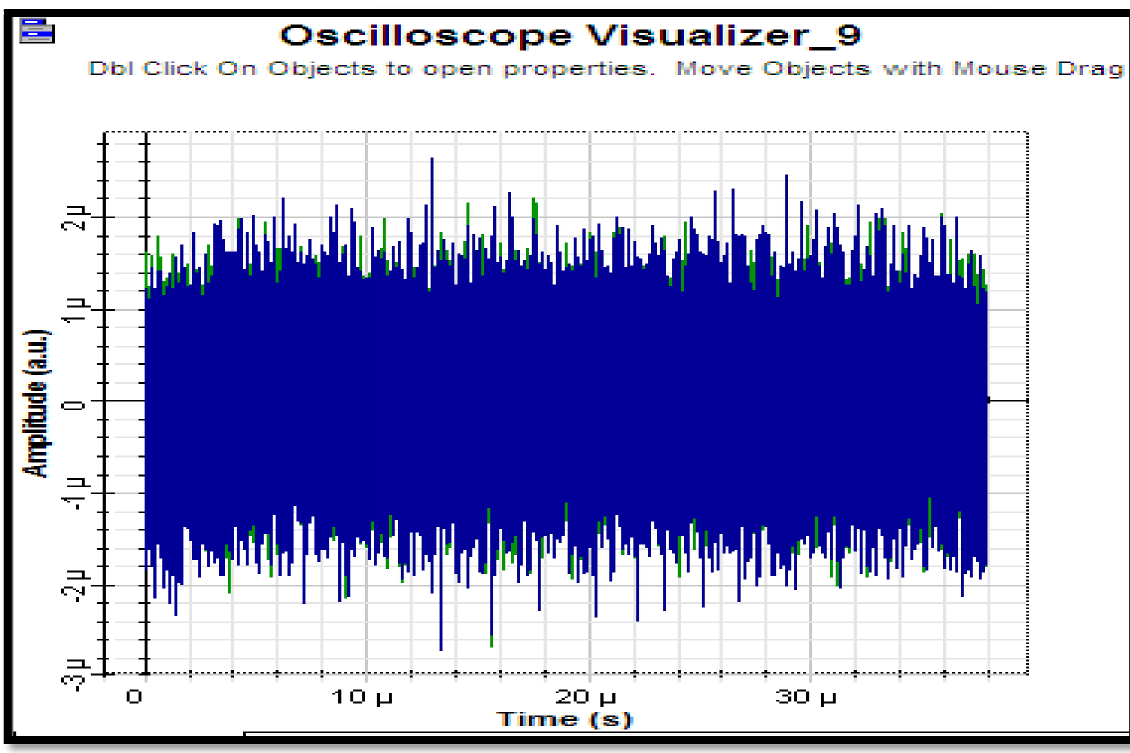


Figure4-20: Detected electrical signal at the headend

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER FIVE
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The design of simulation had combined the two important aspects that are the implementation of RoF technology and the WLAN of IEEE 802.11a standard in uplink and down link that using RF modulated signal with frequency 5.8GHz. The simulation that is done has shown that the 54Mbps, 64 QAM with 5.8GHz can be supported by the system that use 50km of optical fiber and wireless distance of 10km using RF modulated signal at 5.8GHz. The antenna with high gain is helping in term to make the system suitable for longer distance point to point applications. Frequency down conversion at the receiver has been implemented to ensure the end user can connect to the WLAN at the down link.

The implementation of RoF technology and the WLAN of IEEE 802.11a standard and using QAM modulation provide more reliability by reducing BER as compared with IEEE 802.11a with wireless feeder network.

As shown in design simulation the RAU consists of photodiode, amplifier and FR antenna which make RAU simpler and cheaper than other fully wireless network and provide more flexibility in the case future requirements such as other extension the system to obtain more capacity and larger area coverage.

Single subcarrier multiplexed ROF link can provide high capacity and it is possible to carry different kinds of signals such as WLAN, cellular system and CATV simultaneously ;because of that RoF system is an integration technique can provide broadband wireless communication system include transmission of various kind of multimedia information . Even though the cost to laying the optical fiber under the ground is high, it provides long term benefit in communication because it supports high-speed multimedia. When compared to copper cable, the use of this technology also provides a cost-effective benefit.

5.2 Recommendations

The current trends suggest that communication networks will converge into what are referred to as next generation Wireless Broadband Multimedia Communications Systems (WBMCS).

Wireless Broadband Multimedia Communication Systems (WBMCSs) or WMCS, provide data rates higher than 2 Mb/s and up to 155 Mb/s. The aim of the Wireless Broadband Multimedia Communication Systems (WBMCS) is to provide its users a means of radio access to broadband multimedia supported on customer premises networks or offered directly by public fixed networks. WBMCS will provide a mobile (or at least movable) non-wired extension to wired networks for information rates exceeding 2 Mbps with applications foreseen in wireless Local Area Network (LAN) or mobile broadband systems. Thus, WBMCS will be a wireless extension to the B-ISDN (Broadband Integrated Services Digital Networks). It will be achieved with the transparent transmission of ATM (Asynchronous Transmission Mode) cells.

Research and development of WBMCS is in progress in North America, Europe and Japan in the microwave and millimeter wave bands in order to accommodate the necessary bandwidth. The research in the field of WBMCS has drawn a lot of attention because of the increasing role of multimedia and computer applications in communications.

There is a major thrust on three research areas, namely, microwave and millimeter wave bands for fixed access in outdoor, public commercial networks; evolution of wireless LANs for in-building systems; and use of LAN technology outdoors rather than indoors.

Orthogonal Frequency Division Multiplexing (OFDM) technique distributes the data over a large number of carriers that are spaced apart at precise frequencies with overlapping bands.

By Appling RoF technology with OFDM as modulation and multiplexing technique can satisfy the requirements of WBMCS.

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Sudan University of Science and Technology
College of Engineering
Electronics Engineering Department

Radio-over-Fiber Technology for Broadband Wireless Communication Systems

A Research Submitted in Partial fulfillment for the Requirements of the Degree of B.Sc. (Honors) in Electronic Engineering

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Aug, 2010

سورة النمل

الاهـــــــــــــداء

بدانا بأكثر من يد وقاسينا أكثر من هم وعانينا الكثير من الصعوبات وهانحن اليوم والحمد لله نطوي سهر الليالي وتعب الإيام وخلاصة مشوارنا بين دفتي هذا العمل المتواضع.

- إلى منارة العلم والامام المصطفي إلى سيد الخلق إلى رسولنا الكريم سيدنا محمد صلى الله عليه وسلم.
- إلى الينبوع الذي لا يمل العطاء إلى من حاكت سعادتي بخيوط منسوجة من قلبها إلى والدتي العزيزة.
- إلى من سعى وشقى لأنعم بالراحة والهناء الذي لم يبخل بشئ من أجل دفعي في طريق النجاح الذي علمني أن أرتقي سلم الحياة بحكمة وصبر إلى والدي العزيز.
- إلى من حبهم يجري في عروقي ويلهج بذكراهم فؤادي إلى أخواتي وأخواني.
- الى روح صديقنا وزميلنا هاشم احمد الفاضل نسأل الله ان يسكنه فسيح الجنان
- إلى من سرنا سوياً ونحن نشق الطريق معاَ نحو النجاح والإبداع إلى من تكاتفنا يداً بيد ونحن نقطف زهور المعرفة إلى رفقاء الدرب الأصدقاء والزملاء.
- إلى من علمونا حروفا من ذهب وكلمات من درر وعبارات من أسمى وأجلى عبارات في العلم إلى من صاغوالنا علمهم حروفا ومن فكرهم منارة تتير لنا سيرة العلم والنجاح إلى أساتذتنا الكرام.

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First of all we would like to thank Allah for giving us the strength, good health, idea and talent to complete this research project.

A special acknowledgment must be given to our mothers for thier Motivation help and support. We indebted to them and words will never express the gratitude I owe to them.

We would like to gratefully acknowledge our fathers for all the help and support; they also encourage us for perfect work.

I would like to thank Dr.Salah El-faky El rofai for supervising and guiding us even with his busy schedule.

We sincerely thank my lecturers and all my friends for their support and helping directly or indirectly.

Abstract

The rapid growth of wireless communications is mainly attributed to their ease of Installation in comparison to fixed networks. In contrast, WLANs originally designed to provide fixed data network Extension, support Mbps data transmission rates. The WLAN standard – IEEE 802.11, also known as *Wi-Fi*, it is offered 2 Mbps. Since then, the standard has evolved several times responding to the sustained user demand for higher bit-rates .Currently, WLANs are capable of offering up-to 54 Mbps for the IEEE 802.11a/g, and HiperLAN2 standards operating in the 2.4 GHz and 5 GHz. However, WLANs do not offer the kind of mobility.

For broadband wireless communication systems to offer the needed high capacity must be increase the carrier frequencies. Higher carrier frequencies offer greater modulation bandwidth, but may lead to increased costs of radio front-ends in the RAUs and the MUs/WTUs.

In this project, The system is consists of head end with the electrical and optical modulator followed by single mode fiber(SMF) to carry the modulated RF signal between the radio antenna unit(RAU) and head end station. RAUs are simplified significantly, as they only need to perform optoelectronic conversion and amplification functions. The simulation of the RoF system is carried out using

OptiSystem software and the results are analyzed and determine bit error rate (BER).

المستخلص

النمو السريع فى الاتصالات اللاسلكية يرجع الى سهولة تركيبها مقارنة بالشبكات الثابتة . صممت الشبكات اللاسلكية اصلا لتزويد امتداد للشبكات الثابتة وذلك بدعم سرعة نقل البيانات لتصل الى عدة ميغابت فى الثانيه. المعيار IEEE802.11a من معايير الشبكات الثابته معروف باسم " Wi-Fi " وهو يقدم سرعة نقل بيانات تصل الى 2 ميغابت فى الثانية.

بعد ذلك تطورت المعايير عدة مرات استجابة الى حوجة المستخدم لسرعة نقل بيانات عالية وحاليا" الشبكات اللاسلكيه تقدم سرعة نقل بيانات تصل الى 54 ميغابت فى الثانية للمعايير" IEEE802.11a/g و HiperLAN2 "والتى تعمل بترددات 2.4 و5 قيقاهيرتز .

فى هذا المشروع النظام يحتوى على"Head end" الذي يتضمن مضمن للاشارة الكهربية ومضمن للاشارة الضوئية يليه ناقل من الالياف الضوئية لنقل الإشارة الراديوية المضمنة بالحامل الضوئي .هذا الناقل يربط ال"Head end" مع ال"RAU".

ال"RAU" تتبسط بكفاءة بحيث ينحصر عملها فقط على عملية التحويل من اشارة ضوئيه الى اشارة كهربية وعمليات التكبير وبث الإشارة.

نظام المحاكاة لنظام ال"RoF" يتم باستخدام برنامج " Optisystem" بعد ذلك تحلل النتائج وتحدد ال" BER".

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List of symbols

Symbol	Description
θ_c	The critical angle
n	The refractive index
Ω	Angular frequencies
I_{PIN}	The photocurrent
t	The time
p	Optical power
R	Resistor
I_{out}	The output current signal
β	Frequency modulation index
ω	Frequency
τ	The delay difference
π	Pi

List of Abbreviations

AM	Amplitude Modulation.
AS	Antenna Site.
AP	Access Point.
ASK	Amplitude Shift Modulation.
BBoF	Baseband-over-Fibre.
BER	Bit-Error-Rate.
B-ISDN	Broadband Integrated Services Digital Network
BPSK	Binary Phase Shift Keying.
BS	Base Station
BSS	Base Station Subsystem
CFECSMA/CA	Carrier Sense Multiple Access With Collision Avoidance
CNR	Carrier-to-Noise Ratio.
CS	Central Site / Station.
CW	Continuous Wave.
DS	Distribution System.
DSSS	Direct-sequence spread spectrum
DSBSC	Double-sideband suppressed-carrier transmission.
EMI	Electromagnetic Interference
ESS	Extended Service Set.
ETSI	European Telecommunications Standards Institute .

EVM	Error Vector Magnitude
FCC	Federal Communication Commission
FDM	Frequency Division Multiplexing
FHSS	Frequency-Hopping Spread Spectrum
FSR	Free Spectral Range.
Gbps	Gigabit per second
GHz	Giga-Hertz
GMSK:	Gaussian Minimum Shift keying.
GSM	Global System for Mobile communications.
IBSS	Independent Basic Service Set.
IM-DD	Intensity Modulation with Direct Detection.
IEEE	Institute of Electrical and Electronics Engineers.
IF	Intermediate Frequency
IFoF	Intermediate Frequency-over-Fibre
IP	Internet Protocol
IR	InfraRed
ISM	Industrial, Scientific, and Medical
ITS	Intelligent Transport Systems
IVC	Inter-Vehicle Communication
LAN	Local Area Network
LO	Local Oscillator
Mbps	Megabit per second
MBS	Mobile Broadband System
MHZ	Mega-Hertz
MIMO	Multiple-Input and Multiple-Output
MMF	Multimode Fibre
MVDS	Multipoint Video Distribution Services

MZI	Mach-Zehnder Interferometer
MZM	Mach-Zehnder Modulator
O/E	Opto-Electrical
OFDM	Orthogonal Frequency Division Multiplexing
OFM	Optical Frequency Multiplication
PAM	Pulse Amplitude Modulation
PD	Photodetector
PM	Phase Modulation
POF	Polymer Optical Fibre
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RAP	Radio Access Point
RAU	Radio Access Unit / Remote Antenna Unit
RF	Radio Frequency
RFI	Radio Frequency Interference
RFoF	Radio Frequency-over-Fibre
RHD	Remote Heterodyning
RoF	Radio-over-Fibre
RS	Remote Site / Station
RVC	Road-to- Vehicle Communication
SC	Switching Centre
SCM	Sub-Carrier Multiplexing
SMF	Single Mode Fibre
THz	Tera-hertz
UMTS	Universal Mobile Telecommunication System
U-NII	Unlicensed National Information Infrastructure

WBMCS	Wireless Broadband Multimedia Communication System
WDM	Wavelength Division Multiplexing
WLAN	Wireless Local Area Networks
WNICs	Wireless Network Interface Cards