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A Review on Radio over Fiber communication System

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ABSTRACT

Radio-over-fiber (RoF) is the technique by which light signal is modulated by a radio signal. This modulated signal is transmitted over an optical link to extend the wireless access. RoF system has been planned for the advanced performance of radio system having higher bandwidth for mobile communications. These systems have numerous advantages including lower attenuation compared to the coaxial cable. RoF systems have higher bandwidth and immunity to the RF interference. In this review paper we have presented an overview of existing research in RoF technology and its various applications. We have also presented the working principle and advantages of MZM Modulator which is a most preferred modulator for optimum performance of RoF systems.

Keywords: Radio over Fiber (RoF), Radio Frequency (RF), Control Station (CS), Base Station (BS), Central Office (CO), Mach-Zehnder Modulator (MZM).

INTRODUCTION

Optical Fiber communication has grown exponentially in the present modern era and has enabled telecommunications link to be made over greater distance and with lower levels of losses in transmission medium. Fiber optical communications are enabled to accommodate much higher data rates [1]. These systems are increasing in complexity on an almost daily basis. For achieving the consumer needs and reliabilities, optical fiber communication is the fastest and secure telecommunication technology. It is reliable in handling and transmitting data through hundreds of kilometers with low bit error rate. The Wavelength Division Multiplexing (WDM) technique is the most preferred way to increase the information transmission capacities of a fiber system. The plan and analysis of optical communication systems are normally include nonlinear devices and non Gaussian noise sources and these are highly complex and time-intensive. These tasks can now only be performed efficiently and effectively with the help of advanced new software tools. The Mach-Zehnder Modulator is a versatile external modulator which makes it attractive for radio-on-fiber systems. Optical communications systems are widely employed for application ranging from major telecommunications backbone infrastructure to Ethernet systems, broadband distribution and general data networking [2].

Principle of ray propagation:
The light ray enters the fiber core from a medium and strikes the core-cladding interface at such an angle that it is totally internally reflected, and is passing through the axis of guide after each reflection. As shown in figure 1. A typical fiber consists of core and cladding having different refractive indices that is n1 and n2 [3].

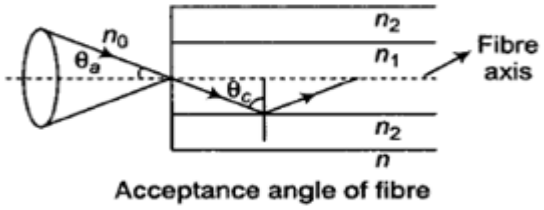

Figure 1: Light Ray Propagation

General overview of optical fiber communication system:

Fiber optics is a medium used for carrying information from one point to another in the form of light. An optical fiber cable that carries the light and a receiver that accepts the light signal and converts it back into an electrical signal Fiber optics is not electrical in nature [2]. A basic fiber communication optic system consists of a transmitting device that converts an electrical signal into a light signal. A fiber optic system is very simple as the system shown in Figure 2.

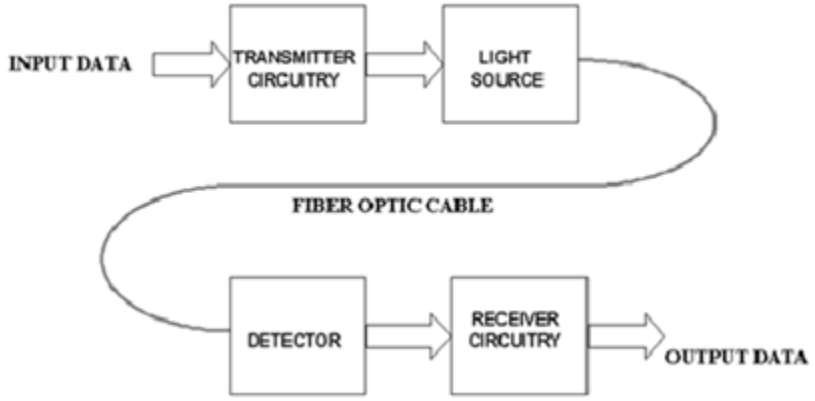

Figure 2: Overview of Optical Fibre Communication

It can be built economically using a LED, plastic fiber, a silicon photo detector, and with some simple electronic circuitry. The various components that make up a fiber optic communication system are shown in Figure 2. It includes Transmitter circuitry, light source, fiber optics cable, detector and receiver circuitry [3].

Radio-over-Fiber (RoF)

Radio over Fiber is basically an analog optical link which transmits modulated RF signals. Radio-over-fiber technology uses the optical fiber links to distribute RF signals from a central location to the remote antenna units (RAUS). It transmits RF signal downlink and uplink. It transmits RF signal to central station (CS) from base station (BS) and vice versa**.** The demand for network bandwidth is large due to the growth in traffic such as video on demand, internet usages, and voice over IP, steaming video and voice. This can be provided by RoF system because of its advantages as, large bandwidth, immunity to radio frequency interference, reduced power consumption, multi-operator and multi-service operation, dynamic resource allocation etc. Hence, it is more preferably compared to RF signal processing. The main requirements of RoF link architecture are duplex operation (downlink-uplink), reasonable length and high performance optical components [4].

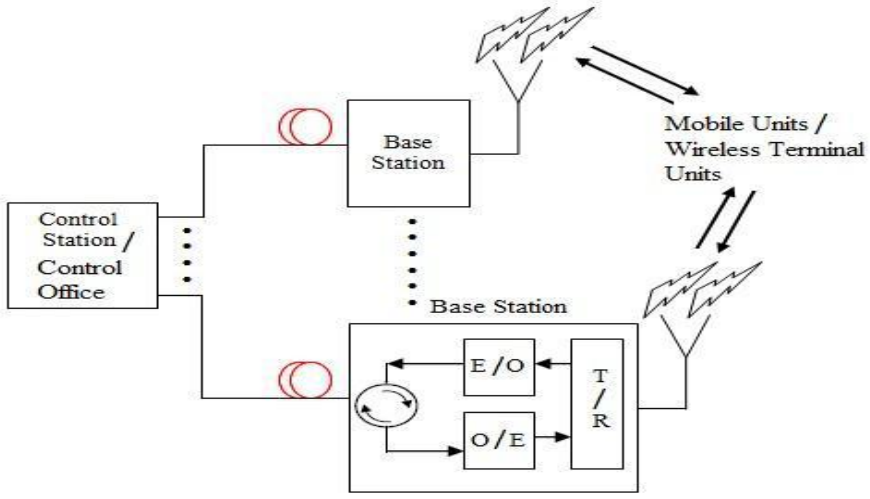

Figure 3: General RoF System

As shown in figure 3, Control Station is used for the generation of signal. In this, RF signal is transmitted with the help of optical fiber link. At Control office modulation and signal processing is used in order to build the baseband signal. There is negligible Attenuation loss in this transmitted signal then, this transmitted signal is detected at the BS. At the Base Station Unit (BSU) the operations of both the electrical to optical (E/O) and optical to electrical (O/E) conversion take place.

The signal transmission between Wireless Terminal Unit (WTU), BSU and user take place with the help of antenna which is placed at the base station unit. Communication between BSU and CS takes place with the help of optical signal. Therefore cost of transmission equipments such as antenna, amplifiers are getting reduced. Hence, RoF system looks a more efficient system than the conventional wireless networks [3] [7].

Mach-Zehnder Modulator (MZM)

In optical transmission systems, communications traffic is conveyed by optical carriers. The intensity of carriers is modulated by the communications traffic. The optical carriers can be Amplitude Modulated (AM) or Phase Modulated. Modulation technique is the most significant processes in RoF system where the RF electrical signal is applied to modulate the optical carrier. RoF modulation methods can be categorized into two main groups that are either integrated with Mach-Zehnder interferometers or Electro Absorption Modulator (EAM).

There are two types of modulation:

1. Direct Modulation
2. External Modulation

Direct Modulation technique which is also known as intensity modulation (IM) directly modulates the amplitude of the laser beam according to input RF Signal. In External modulation method, devices such as MZM can be used to modulate the phase of the optical carrier. External modulation is preferred due to the fact that direct modulation is ideal for inexpensive transmitters, but it causes an undesirable wavelength chirp, which causes excessive chromatic dispersion at high speeds.

For higher frequency range which is used in worldwide interoperability for microwave access (WiMAX) and MMW. Intensity-modulation (IM) is preferred mainly due to the simplicity and is based on a photo detector. For example a photodiode is operates as a simple amplitude threshold detector. Therefore, external modulation is needed for higher speeds or when the light cannot be directly modulated [6]. A Mach-Zehnder Modulator is used for controlling the amplitude of an optical wave. The input waveguide is split into two waveguide interferometer. A phase is induced for the wave passing through arms, if voltage is applied across one of the arms

When two arms are recombined, the phase difference between two waves is converted to an amplitude modulation. Mach-Zehnder modulator (MZM) is the most preferred modulator generally termed as an electrical to optical (EO converter). Recent researches in the field of MZM reveal that, MZM can be used more than just an EO converter like to achieve linearization or for the compensation of dispersion introduced in the signal while travelling through an optical path. Specially designed MZM can resolve both the issues simultaneously [4] [10].

Working Principle of MZM

The Lithium Niobate (LiNbO3) Mach- Zehnder Modulator is the most popular modulator in optical communication systems. Mach-Zehnder modulator can be categorized as single drive Mach- Zehnder Modulator and dual-drive Mach-Zehnder Modulator. The optical wave enters from the input side and then splits equally into its two arms. The structure of the dual-drive MZM has two arms and electrodes. Mach- Zehnder modulator is used to control the amplitude of an optical wave. Input waveguide splits into two waveguide interferometer arms and bias is applied to these arms, A phase shift is induced in the wave passing through the arm, due to the applied voltage. The optical signal travelling through both arms of the interferometer are recombined at the output of MZM and the phase difference between the two waves is converted to an amplitude modulated signal.

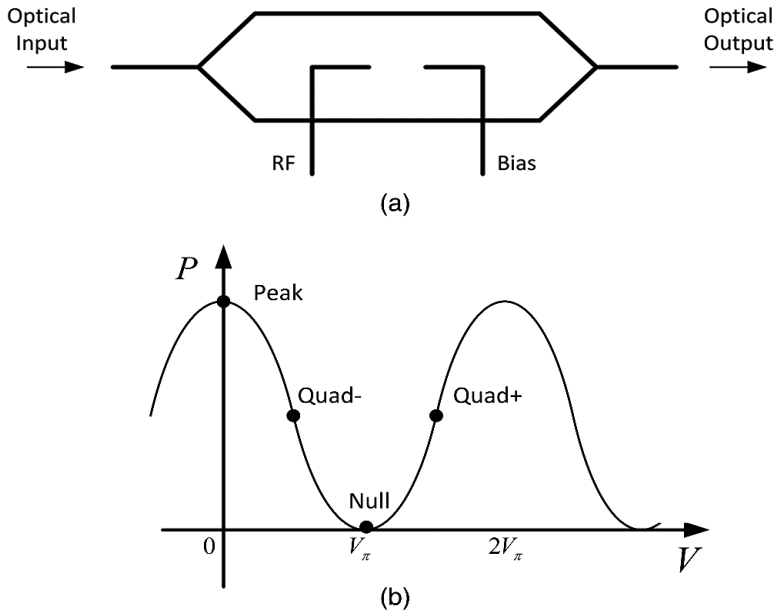

Figure 4: Layout of Mach Zehnder modulator

The RF signals are applied to the two arms of the interferometer with different phase shifts. Both arms are biased with different DC voltages. By changing the applied voltage on the electrode, the optical phase in each arm can be controlled [1][10].

Advantages of MZM- Flexibility in fringe location can be provided by the Mach-Zehnder Modulator, but it is not possible with other interferometers. In Mach-Zehnder interferometers rectangular arrangement is commonly used.

LITERATURE SURVEY

Kamaljit Singh Bhatia et.al [1] In this paper, we studied to overcome the dispersion losses and degradation of signal due to power fading which a signal experiences while travelling through an optical fiber, various optical devices, Mach Zehnder modulator is introduced in the Radio over Fiber system. The projected RoF system was analyzed for switching bias voltage and extinction ratio of Lithium Niobate (LiNbO3) Mach-Zehnder modulator (MZM) and from all the observations and findings it can be concluded that for the proposed system the appropriate switching bias voltage is 4V and the extinction ratio is 30 dB so as to achieve the optimum results that is maximum Q –Factor with minimum BER. The performance of RoF system depends upon various parameters of Mach-Zehnder modulator (MZM) like RF bias, bias voltage, extinction ratio and insertion loss. In this paper the behavior of Lithium Niobate (LiNbO3) MZM is studied on various bias and extinction ratio ranges and a particular bias and extinction ratio is fixed at which the proposed ROF system gives the optimum results.

Wei, Hanyi Zhang et.al [2]. In **t**his paper the authors have proposed a method to establish a millimeter-wave photonic up-converter, a frequency doubled OEO, or a low-interference dual-direction RoF links. There may be more potential applications using such kind of manipulation. Carrier phase and amplitude modulation is an important signal processing technique in microwave photonics. The authors also planned a series of work by realizing such modulation with a single drive dual-parallel Mach-Zehnder modulator (DPMZM).

Pradeep R et.al [3] In **t**his paper, the characteristics of Mach Zehnder Modulator is studied and different modulation schemes are analyzed. Improper biasing creates harmonic distortion and the modulated signal cannot be recovered. But other modulation formats like AM and suppressed carrier showing satisfactory performance over a distance up to 10KM without using amplifiers. The experimental analysis verified the transfer characteristics of MZM.

Jincys Johny et.al [4] In this paper the authors have theoretically investigated the transmission performance of the optical millimeter (mm)-wave generated by a structure of optical modulation dedicated to Radio-over-Fiber (RoF) system**.** A radio over fiber system was planned and simulated using the Optisystem software. Its various parameters (such as Q factor, BER, Eye height, etc) were compared for different categories of coding (such as NRZ and RZ coding). NRZ may suffer from

more nonlinearity due to higher peak power, whereas RZ may suffer from more dispersion which is due to shorter pulse width. Study shows that in general we can operate better by using RZ modulation in high power regime than NRZ coding.

Kamal Ghoumid et.al [5] The structure 16-QAM modulator based of the DD-MZMs for photonic generation of millimeter-wave for the RoF system is proposed and demonstrated. High bit rate signals can be generated by this structure because modulation rate R and the number of MZIs N can be increased simultaneously. Clear eye opening was achieved at R = 20 Gbaud. The system has many advantages, such as stability, simplicity, interference immunity and is a competitive low cost system which does not need the use of other special optical devices [5].

M. Zhu et.al [6] This paper introduces two radio-over-fiber (RoF) architectures for the future broadband optical-wireless access network- all-band RoF and band-mapped 60-GHz RoF that can be integrated in ultra-dense wavelength division multiplexing passive optical network (UDWDM-PON). Legacy wireless services and multi gigabit millimeter-wave (mm-wave) applications are integrated and delivered simultaneously under one shared infrastructure. With centralized system control and signal processing, the proposed systems provide cost-effective and protocol-transparent solutions for the next-generation multi-service bundle in heterogeneous networks (HetNets). By mapping various wireless signals into 60-GHz sub-bands, the novel architecture achieves higher spectral efficiency and lower power consumption.

Balinder Singh et.al [7] In this review paper, main advantages are described along with applications of RoF system. The main advantages of RoF system are as large bandwidth, low attenuation loss, easy installation & maintenance, immunity to RF interface, dynamic resource allocation & operation flexibility and low power consumption. The applications of RoF system (such as in Video Distribution systems, Satellite Control, Cellular networks, vehicle communication, Wireless LANs and Mobile Broadband Services etc) are discussed. Thus optical fiber has vast bandwidth and less attenuation losses which make it more useful than coaxial cables and conventional wireless transmission. Research is still going on to minimize its limitations.

A. Bahrami et.al [8] This paper investigate the bit error rate (BER) performance of a radio over fiber (RoF) system. The RF signal is modulated using the Mach Zehnder modulator (MZM). In this BPSK and QPSK modulation schemes are used in order to calculate the performance of RoF system in terms of the BER and it compared to the RF wireless communication systems. Hence, RoF communication systems are better option compared to RF wireless communication systems.

Bhumika A et.al [9] In this paper, design and simulate DWDM system for 320 Gbps data rate at 70km of fiber length. In this system for 32-channel amplification was analyzed with 34±4db gain flatness from 1527 nm to 1552 nm bandwidth. By Simulation, the output power of 21.255dBm for a fiber length of 5m and 250mw pump power were obtain. This magnification procedure is providing better performance of optical link. Optimum results of gain, output power, BER and Q-factor are obtained proper choosing of input power, pump power, EDF length and concentration of erbium ions.

Himani Sharma et.al [10] In this paper, basic focus is on learning the basics of an OFDM system and have carry out various methods to reduce the PAPR in the system so that this system can be used more efficiently. The distortion falls in two band i.e both in-band and out of band. Filtering cannot be implementing to reduce the in-band distortion. To solve this problem, a repeated filtering and clipping operation can be taken.. Single carrier waves are being switched by multicarrier for improved transmission. Multicarrier system like CDMA and OFDM are currently being commonly implemented. In the OFDM system, orthogonally placed subcarriers are being used to carry the information from the transmitter side to the receiver side. There are many problems in OFDM systems, the problem of ISI and noise can be removed using guard band , But the large Peak to average power ratio of these signal have some undesired effect on the system.

Sai Naing Min Htet [11] This paper presents the generation of optical carrier suppressed signal for RoF system. Signal modulation and optical carrier suppression are made by using a Dual-Drive Mach-Zehnder modulator (DD-MZM). In this paper, the carrier suppression and performances of RoF system are investigated by simulation. The various values of optical carrier suppression ratio can be obtained by adjusting the extinction ratio of the DD-MZM. The performances of RoF system and optical carrier suppression was investigated with the simulation. The performance of RoF system and the optical carrier suppression using DD-MZM was theoretically studied.

Ajay Kumar et.al [12] In this paper we investigated the effect of nonlinear distortion on RoF link. We analyzed the parameter which has importance role to mitigate the effect of NLD on RoF link .The amplitude of the output signal is reduced by ~ 97 % due the NLD effect & output power can be increase ~76% by increasing the laser power. The future work for this research is to develop the pre-distorter to reduce the effect of this nonlinearity for radio over fiber applications at higher frequencies.

ADVANTAGES OF ROF SYSTEM

There are many advantages of RoF system. Some of those are given as below**:**

1 Large Bandwidth: The optical fiber has unlimited band-width. The increase in information being transmitted over the optical fiber is ensured due to the high frequency carrier. Most of the optical systems which are run at the bit rate 10 Gbps. We observe that there is big room for improving the system bandwidth. There are two main technologies to increase the system bandwidth:

(a) Wavelength Division Multiplexing (WDM) (b) Optical Time Division Multiplexing (OTDM)

2 Low Attenuation Loss: In RoF system optical fiber is used between the CO and BS which has several advantages over free space and copper cable transmission media. The optical fibers available in the market have very low attenuation, thus they can be used to serve the purpose of reducing the losses between CO and CS which are separated far apart.

3 Easy installation and Maintenance- In RoF systems remote antenna units are made simpler. The most RoF techniques eliminate the need for a LO and related equipment at the RAU. In these cases a photo detector, an RF amplifier, and an antenna make up the RAU. Modulation and switching equipment is kept in the headed and it is shared by several RAUs. This system leads to smaller and lighter RAUs, effectively reducing system installation and maintenance costs. This arrangement makes the installation and maintenance cost to be reduced at an appreciable level.

4 Immunity to RF interference- Protection to Electromagnetic Interference is a very important property of optical Fiber communications. It provides security and privacy for microwave transmission. This is because of the signals are transmitted in the form of light through the Fiber [9]. Since the RF signal is transmitted over the optical fiber, there is not any chance for electromagnetic interference. The quality and integrity of the information are preserved in optical communication.

5 Dynamic Resource Allocation & Operational flexibility- It allows to allocating the capacity because of it uses new modulation equipments and the switching at the CS. It is possible to allocate more capacity to a certain areas in peak time while reducing the capacity allocation in off- peak. The allocation of channels to different users can be made dynamically to ensure efficient resource management as it would be a wastage of resources to allocate the capacity to unpopulated area.

6 Low Power Consumption- Complex equipments are kept at the CS, to reduce the power consumption. For this purpose the BS which are not active at certain point of time can be switched to passive mode. It may be a possibility of nonlinear effects as well as dispersion in optical fiber. We can minimize these types challenges present in RoF system by developing some modulation techniques as a proposed solution. Research is also going on to the different kind of modulation techniques which are capable, to minimize the nonlinear effect and dispersion. RoF is a consistent system for users which provides communication with negligible degradation of wireless range [7].

APPLICATIONS OF ROF SYSTEM

As there is good quality of signal provided by RoF system, it has many applications; some of those are discussed below.

1. Video Distribution Systems (VDSs)- The large bandwidth provided by the RoF system is a key factor to VDs. The Common-Antenna Television (CATV) network that has used in electrical communication technique is a good example of it. The replacement of low bandwidth coaxial cables by the optical fiber provides better quality of service in terms of number of users. For example the coaxial cable bandwidth cannot exceed 1GHz but this value can exceed in case of optical fiber easily.

2. Satellite Control A remote antenna located at satellite earth station can be controlled via optical fiber. In order to service many remote satellite earth stations the CO/CS can be centralized at a specific location. The choice of deploying the optical fiber between the CO/CS and the satellite earth station is the best choice since the satellite earth stations require high bandwidth in order to manage the efficient working of the satellites. This is a cost-effective method.

3 Cellular Networks- Cellular networks have become more attractive nowadays and all mobile network service providers are deploying their resources to cope with the increase in capacity needs. For capacity, we automatically understand that the

RoF system is the best option since the optical fiber relayed between CO/CS and BS has a large capacity. Therefore with increase in capacity, more services can be provided in the broadband network.

4. Vehicle Communication- The RoF system can be use to control the traffic of vehicle by deploying several BSs along the roads. These BSs communicate with the vehicles moving in the road through the microwave signal while the BSs are connected to the CO/CS. High frequency signal is a necessity for the tracking of fast moving vehicles. Thus the RoF system is well suited for this purpose.

5. Mobile Broadband Services- It requires large bandwidth for fast growing of the mobile broadband services. For example, the 4G services which use the bit rate in several MBs. Thus, the RoF system is the best choice to deal with the need of large bandwidth to support more users. The RoF will help to provide good quality signal as the losses, reflections and other impairments are minimized [7].

SUMMARY

An optical fiber has very less attenuation and large bandwidth which makes it better useful than coaxial and other cables. These systems have several advantages including lower attenuation compared to the coaxial cable, higher bandwidth, immunity to the RF interference, and durability. In this review paper we have presented an overview of existing research in RoF technology and its various applications. Further in future we will carry out performance analysis of RoF based communication and all the results will be simulated in OPTISYSTEM simulator.

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