Full Duplex Transmission in RoF System using WDM and OADM Technology

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***Abstract t*— Radio over Fiber (RoF) is a technology where light is modulated with radio frequency signals and transmitted over the optical fiber to facilitate wireless access and transmission. The convergence of wired and wireless networks is a promising solution for the increasing demand of transmission capacity and flexibility, as well as offering economic advantages due to its broad bandwidth and low attenuation characteristics. The full duplex transmission of RoF is accomplished by means of Wavelength Division Multiplexing (WDM) and Optical Add Drop Multiplexer (OADM), where WDM enables transmission of different signals through a single mode fiber over large distance and OADM permits transmission of both down-link and uplink data via the same single-mode fiber. In addition, the performance analysis of RoF system employing various line coding techniques has also been done. The simulation is done using a commercial optical system simulator named OptiSystem 12.0 by Optiwave.**

***Keywords: Radio over Fiber; Wavelength Division Multiplexing; Optical Add Drop Multiplexer; NRZ; RZ*.**

I. INTRODUCTION

To meet the explosive demands of high capacity and broadband wireless access, modern cell-based wireless networks have trends, i.e., continuous increase in the number of cells and utilization of higher frequency bands. It leads to a large amount of Base Stations (BSs) to be deployed; therefore, cost-effective BS development is a key to success in the market. This requirement has led to the development of system architecture where functions such as signal routing/processing, handover and frequency allocation are carried out at a Central Station (CS), rather than at the BS. Furthermore, such a centralized configuration allows sensitive equipment to be located in safer environment and enables the cost of expensive components to be shared among several BSs.

An attractive alternative for linking a CS with BSs in such a radio network is via an optical fiber network, since fiber has low loss, immunity to EMI and broad bandwidth. The transmission of radio signals over fiber, with simple optical-to electrical conversion, followed by radiation at remote antennas, which are connected to a CS, has been proposed as a method of minimizing costs. The reduction in cost can be brought about in two ways. Firstly, the remote antenna BS or radio distribution point needs to perform only simple functions and it is small in size and low in cost. Secondly, the resources provided by the CS can be shared among many BSs. This technique of modulating the Radio Frequency (RF) subcarrier onto an optical carrier for distribution over a fiber network is known as "Radio over Fiber" (RoF) technology. RoF makes it possible to centralize the RF signal processing functions in one shared location (headend), and then to use optical fiber, which offers low signal loss (0.3 dB/km for 1550 nm, and 0.5 dB/km for 1310 nm wavelengths) to distribute the RF signals to the RAUs as shown in Figure 1. In addition to the advantage of potential low cost, RoF technology has the further a benefit of transferring the RF signal to and from a CS that can allow flexible network resource management and rapid response to variations in traffic demand due to its centralized network architecture.

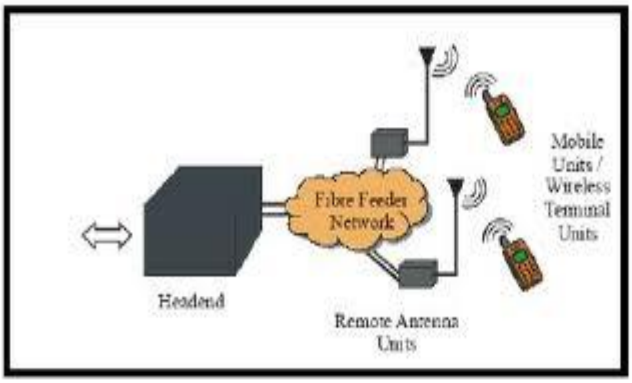


Fig.1 Radio over Fiber System Concept

II. WDM AND OADM

A. *WDM*

Wavelength-division multiplexing (WDM) is a technology which multiplexes multiple optical carrier signals on a single optical fiber by using different wavelengths of laser light to carry different signals. This allows for multiplication in capacity of an optical fiber by adding new channels, each channel on a new wavelength of light, 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. The term wavelength-division multiplexing is commonly applied to an optical carrier (which is typically described by its wavelength), whereas frequency-division multiplexing typically applies to a radio carrier (which is more often described by frequency). The use of WDM for the distribution of RoF signals has gained importance. WDM enables the efficient exploitation of the fiber network's bandwidth. Its application in RoF networks has many advantages including simplification of the network topology by allocating different wavelengths to individual BSs, enabling easier network and service upgrades and providing simpler network management.

B. OADM

An optical add-drop multiplexer (OADM) is a device used in wavelength-division multiplexing systems for multiplexing and routing different channels of light into or out of a single mode fiber (SMF) as shown in Figure 2. This is a type of optical node, which is generally used for the construction of optical telecommunications networks. "Add" and "drop" here refer to the capability of the device to add one or more new wavelength channels to an existing multi-wavelength WDM signal, and/or to drop (remove) one or more channels, passing those signals to another network path. An OADM may be considered to be a specific type of optical cross-connect.

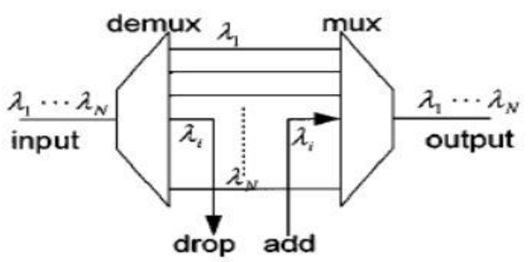


Fig. 2 Internal Structure of an OADM

A traditional OADM consists of three stages: an optical demultiplexer, an optical multiplexer, and between them a method of reconfiguring the paths between the optical demultiplexer, the optical multiplexer and a set of ports for adding and dropping signals. The reconfiguration can be achieved by a fiber patch panel or by optical switches which direct the wavelengths to the optical multiplexer or to drop ports. The optical demultiplexer separates wavelengths in an input fiber onto ports. The optical multiplexer multiplexes the wavelength channels that are to continue on from demultiplexer ports with those from the add ports, onto a single output fiber.

III. SYSTEM DESIGN

In transmitter side, two Continuous Wave (CW) lasers at 0.1 dBm power emit light at frequencies 193.1 THz and 193.2 THz. A MZM modulates optical carrier from CW laser by an electrical signal of data rate 5 Gbps coming from NRZ pulse generator. The modulated signals from both channels are multiplexed using a WDM multiplexer and then the multiplexed signal is fed to a single mode fiber.

After transmitting the multiplexed signal up to BS, appropriate frequency (193.1 THz) is dropped by the OADM. This downlink data signal is passed through a PIN detector of responsivity 1 A/W and a Bessel low pass filter. The resulting electrical signal is then given to a BER tester for analyzing the downlink signal. At the same time, another optical carrier of same frequency 193.1 THz modulated by baseband signal of data rate 5 Gbps is added from BS to fiber backbone, as uplink data, by OADM. Now the multiplexed signal which contains carrier frequency (193.2 THz) other than that dropped at the BS along with the uplink data of frequency 193.1 THz added from base station is transmitted towards CS.

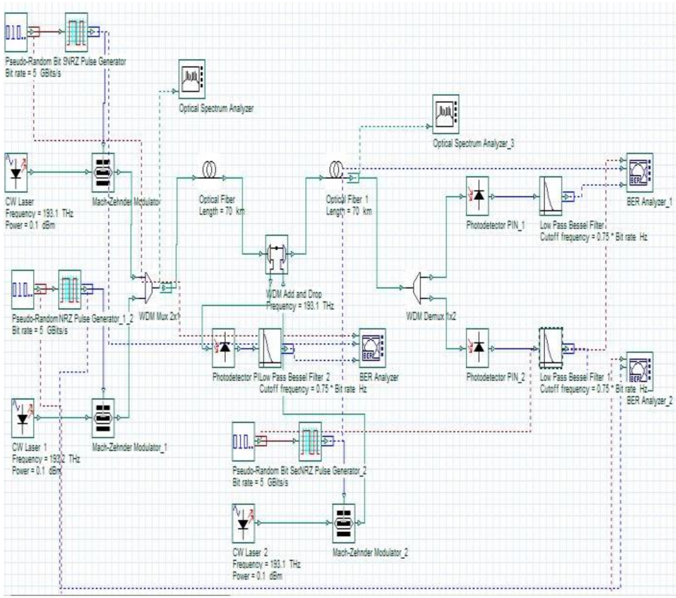


Fig. 3 Simulation layout of full duplex RoF system

At the central station, a WDM demultiplexer separates the signal and fed to corresponding detectors. The resulting electrical signals are then passed through low pass filters and given to BER analyzer through which the Q factor and BER of the signal is analyzed. The entire simulation is shown in Fig. 3.

In intensity-modulated direct-detection (IM/DD) systems, there are two possible modulation formats, Non Return-to-Zero (NRZ), in which a constant power is transmitted during the entire bit period, and Return-to-Zero (RZ), in which power is transmitted only for a fraction of the bit period.

Fig.4. shows simulation of RoF system employing RZ modulation. The optical carriers of frequencies 193.1 THz and 193.2 THz are emitted by two CW lasers. These carriers are modulated by electrical signal of data rate 2.5 Gbps generated by PRBS and RZ encoder. The modulated optical carriers from two channels are multiplexed by WDM multiplexer and given to SMF through which it reaches the BS, addressed to a frequency of 193.1 THz. At the BS, signal with frequency 193.1 THz is simultaneously added and dropped as uplink and downlink data respectively.

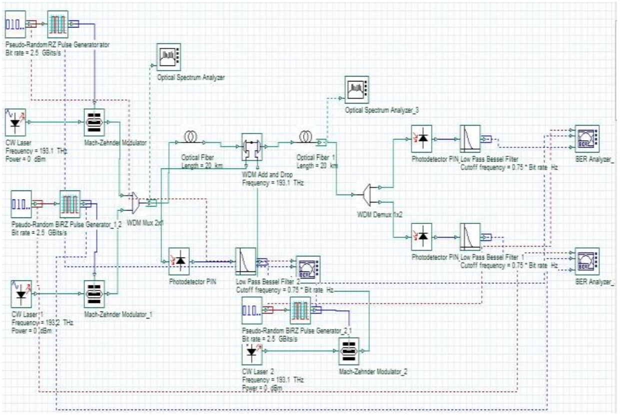


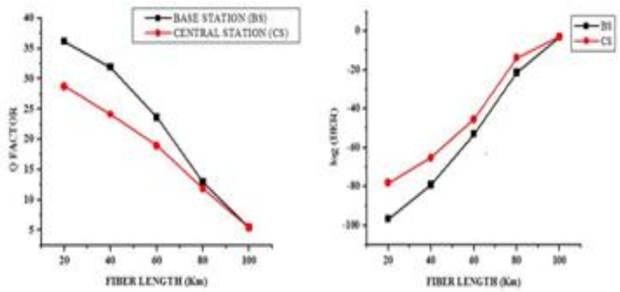
Fig. 4 Full duplex RoF system with RZ modulation

The Q factor and BER of downlink data is analyzed at BS using BER analyzer. The multiplexed signal with frequency 193.2 THz along with uplink data of frequency 193.1 THz, added from BS, is transmitted to CS via SMF of attenuation 0.2 dB/Km. The signal is demultiplexed and detected using a PIN detector of responsivity 1 A/W. The recovered electrical signal is filtered using a low pass Bessel filter and given to a BER analyzer for the analysis of uplink data. The RZ encoder is replaced by an NRZ encoder and performed the same operation. The two modulation formats are compared on the basis of Q factor and BER.

IV. RESULTS AND DISCUSSION

A. Relationship of Q factor and BER with fiber length.

The Q factor and BER observed by varying the fiber length is plotted in Fig. 5. The fiber length was varied from 10 km to 100 km at a transmitter power of 0.1 dBm and input bit rate of 5 Gbps. From the graph, it is observed that with increase in fiber length, Q factor decreases and BER increases.

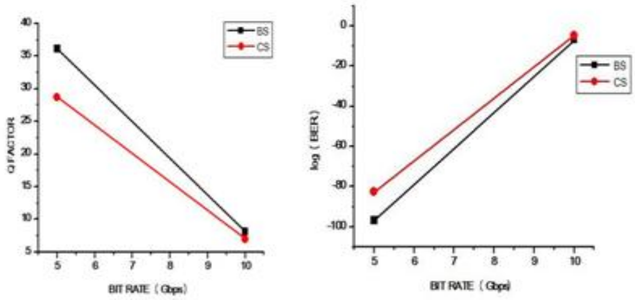


(a) (b)

Fig. 5Variation of (a) Q factor Vs fiber length (b) log(BER) Vs fiber length

B. Relationship of Q factor and BER with bit rate.

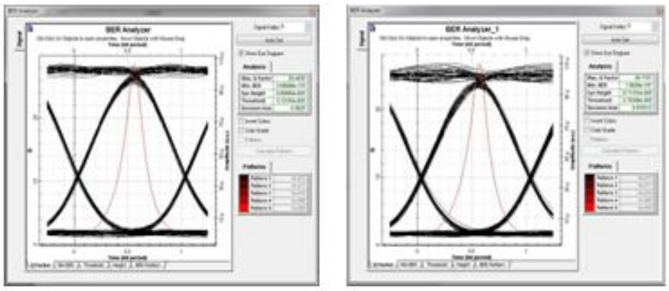
The variation of Q factor and BER with bit rate is shown in Fig. 6. Both Q factor and BER are analyzed for bit rates 5 Gbps and 10 Gbps. Here input power and fiber length are kept constant at 0.1 dBm and 20 Km respectively. From the analysis, it is clear that as bit rate increases, Q factor decreases and BER increases.



(a) (b)

Fig. 6 Variation of (a) Q factor Vs bit rate (b) log(BER) Vs bit rate

Fig.7. shows eye diagrams of downlink and uplink data obtained from BS and CS respectively



(a) (b)

Fig. 7 Eye diagrams showing (a) downlink data at BS (b) uplink data at CS

C. Comparison of RZ and NRZ modulation

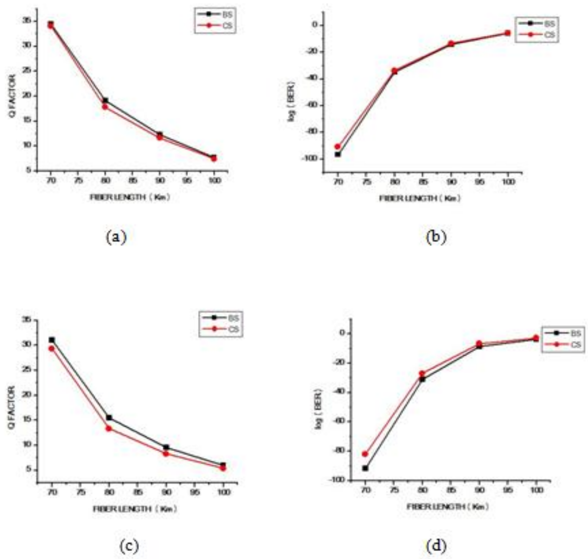


Fig. 8 Variation of Q factor Vs fiber length for (a) RZ modulation (b) NRZ modulation and log(BER) Vs fiber length for (c) RZ modulation (d) NRZ modulation

The variation of Q factor and BER with fiber length for RoF system employing RZ and NRZ modulation is plotted in Fig. 8. The fiber length was varied from 70 km to 100 km at a transmitter power of 0.1 dBm and input bit rate 2.5 Gbps. NRZ modulation is normally affected by non linearities and RZ by dispersion. By analyzing the graphs of RoF with RZ and NRZ modulation, it is clear that RZ modulation provides better performance for high bit rate and long distance application. The eye diagrams of downlink and uplink data for RZ and NRZ modulation are shown in Figure 8.

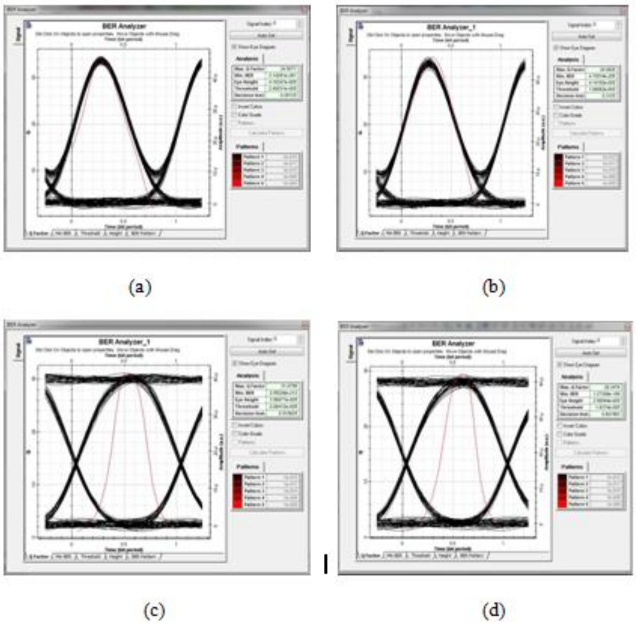


Fig 9. Eye diagrams showing (a) downlink data (b) uplink data for RZ modulation and (c) downlink data (d)uplink data for NRZ modulation

V. CONCLUSION

A full duplex radio over fiber system employing WDM and OADM techniques is simulated using optisystem 12.0. WDM enables transmission of multiple signals through a single fiber over large distance whereas OADM permits simultaneous transmission of downlink and uplink data via same single mode fiber. The performance of RoF system with different number of users and base stations, RZ and NRZ modulation and various digital modulation formats is analyzed. Better Q factor and low BER is achieved for all the simulations, which implies better performance of the system. The NRZ pulses have a narrow optical spectrum. The reduced spectrum width improves the dispersion tolerance but it has the effect of inter symbol interference. The RZ pulse occupies just a part of the bit slot, so it has a duty cycle smaller than 1 and a broad spectrum. The RZ pulse shape enables an increased robustness to fiber non-linearities and Polarization Mode Dispersion (PMD) effects. From the analysis, it is concluded that RZ modulation yields better performance for high bit rate and long distance applications.

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