

# Simulation of full duplex data transmission in ROF system using Optisystem

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## Abstract

Wireless coverage of the end-user domain; be it outdoors or indoors, 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), systems will need to offer higher data transmission capacities. The need for increased capacity per unit area leads to higher operating frequencies, smaller radio cells and large number of base stations (BSs), therefore cost-effective BS development is a key success to the market. For this radio over fiber (RoF) technology has been proposed since it provides functionally simple BSs that are connected to a central station (CS) via an optical fiber. A full-duplex data and video signal transmission over single-mode fiber (SMF) based on wavelength-division-multiplexing (WDM) and an optical add-drop multiplexing (OADM) technique is proposed and simulated. Four data signals of 1.25 Gb/s /9.1-9.4GHz are transmitted over long-haul single-mode fiber for downlink transmission. For uplink transmission, four data signals, each from a BS, of 1.25 Gb/s/9.6-9.9GHz is used. Good bit error rate (BER) performances were achieved for both down-link and up-link transmissions in our full-duplex RoF transport system.

**Keywords:** Radio-over-fiber, Wavelength-division-multiplexing, Optical add-drop multiplexing, Erbium-doped fiber amplifier.

## I. INTRODUCTION

Radio over fiber (RoF) is an analog optical link transmitting modulated RF signals. It serves to transmit the RF signal downlink and uplink, to and from central station (CS) to base station (BS) also called as radio ports. The main requirements of radio over fiber link architecture are duplex operation (i.e., downlink-uplink), reasonable length (a few tens of kilometers), need a few millimeter-wave components only in the base stations and also need of only few high-performance optical components.

RoF systems are now being used extensively for enhanced cellular coverage inside buildings such as offices, shopping malls and airport terminals. It has emerged as a cost effective approach for reducing radio system costs because it simplifies the remote antenna sites and enhances the sharing of expensive radio equipment located at appropriately sited switching centers or central 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.

## Simulation of full duplex data transmission in ROF system using Optisystem

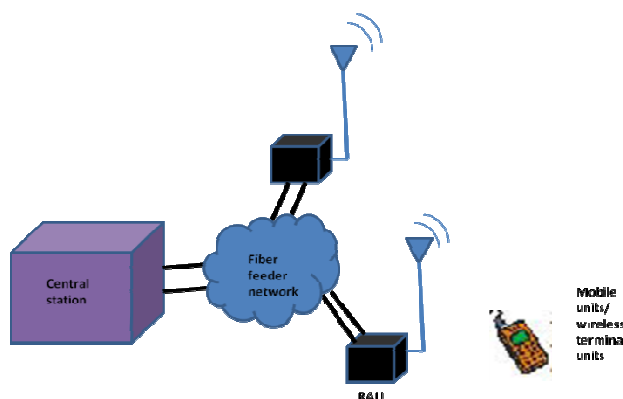


Figure 1 Radio over Fiber System Concept

RoF technology entails the use of optical fiber links to distribute RF signals from a central location to remote antenna units (RAU). In narrowband communication systems and WLANs, RF signal processing functions such as frequency up-conversion, carrier modulation, and multiplexing are performed at the BS or the RAP, and immediately fed into the antenna. RoF makes it possible to centralize the RF signal processing functions in one shared location and then to use optical fiber, which offers low signal loss (0.3 dB/km for 1550nm and 0.5 dB/km for 1310 nm wavelengths) to distribute the RF signals to the RAUs as shown in Figure 1. By doing so, RAUs are simplified significantly, as they only need to perform optoelectronic conversion and amplification functions. The centralization of RF signal processing functions enables equipment sharing, dynamic allocation of resources and simplified system operation and maintenance. These benefits can translate into major system installation and operational savings, especially in wide-coverage broadband wireless communication systems, where a high density of BS/RAPs is necessary.

For a multifunctional RoF system, the required electrical signal at the input of the RoF system depends on the RoF technology and the functionality desired. The electrical signal may be baseband data, modulated IF, or the actual modulated RF signal to be distributed. The electrical signal is used to modulate the optical source. The resulting optical signal is then carried over the optical fiber link to the remote station. Here, the data is converted back into electrical form by the photodetector. The generated electrical signal must meet the specifications required by the wireless application. By delivering the radio signals directly, the optical fiber link avoids the necessity to generate high frequency radio carriers at the antenna site.

## 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 a 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). Most WDM systems operate on single mode fiber optical cables, which have a core diameter of 9  $\mu\text{m}$ . Certain forms of WDM can also be used in multi-mode fiber cables which have core diameters of 50 or 62.5  $\mu\text{m}$ .

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

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 construction of optical network as shown in Figure 2. Add and drop here refer to the capability of the device to add one or more new wavelength channels to an existing multiwavelength WDM signal, and to drop one or more channels, passing those signals to another network path. An OADM may be considered to be specific type of optical cross-connect.

A traditional OADM consists of an optical demultiplexer, an optical multiplexer and between them a method of reconfiguring the paths between demultiplexer, multiplexer and a set of ports for adding and dropping signals. Physically, there are several ways to realize an OADM. There are a variety of demultiplexer and multiplexer technologies including thin film filter, fiber Bragg gratings and optical circulators.

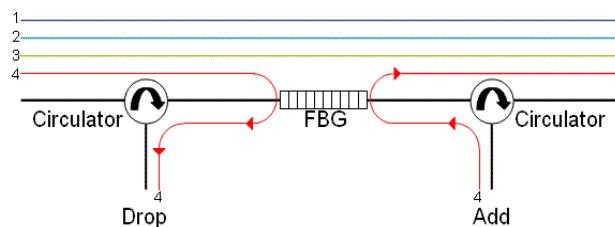


Figure 2. OADM using a fiber Bragg grating and two circulators

## III. APPROACH AND METHOD

In this work, we proposed and simulated full duplex data signal over single mode fiber in ROF transport system based on wavelength division multiplexing (WDM) and optical add drop multiplexing (OADM). Figure 3 shows the block diagram for our proposed system. For downlink transmission, the central station is composed of four microwave signal generators, four continuous wave (CW) lasers, four electroabsorption modulators (EAM), erbium-doped fiber amplifiers (EDFA) and wavelength division multiplexer. The central wavelengths of the four laser diodes are 1550nm, 1551nm, 1552nm and 1553nm respectively.

The full-duplex transmission over fiber exploit the bandwidth of 1530-1560nm to address multiple BSs. In our proposed system we have used wavelengths which fall under C-Band, which is also known as "conventional" or "erbium window". The window which is around 1500 nm is most widely used, as this region has the lowest attenuation losses and hence it achieves the longest range. As many base stations are deployed, all down-link wavelengths are employed within the wavelength range of 1530-1560nm.

These four laser diodes provide four optical carriers to the EAMs. The 1.25 Gb/s data stream are mixed with 9.1 GHz and 9.4 GHz microwave carriers to generate the binary phase-shift keying data signals. The resulting microwave data signals are then supplied to the EAMs along with the optical carrier from the laser diodes. The bandwidth of the EAM possesses a 3-dB frequency of 12 GHz; it means that 9.1 and 9.4 GHz microwave signals can be transmitted through the optical links. All these four signals are amplified using erbium-doped fiber amplifier and multiplexed using wavelength division multiplexer. Finally, the multiplexed signal is fed into the fiber transmission link i.e., single-mode fiber of length 50 km.

## Simulation of full duplex data transmission in ROF system using Optisystem

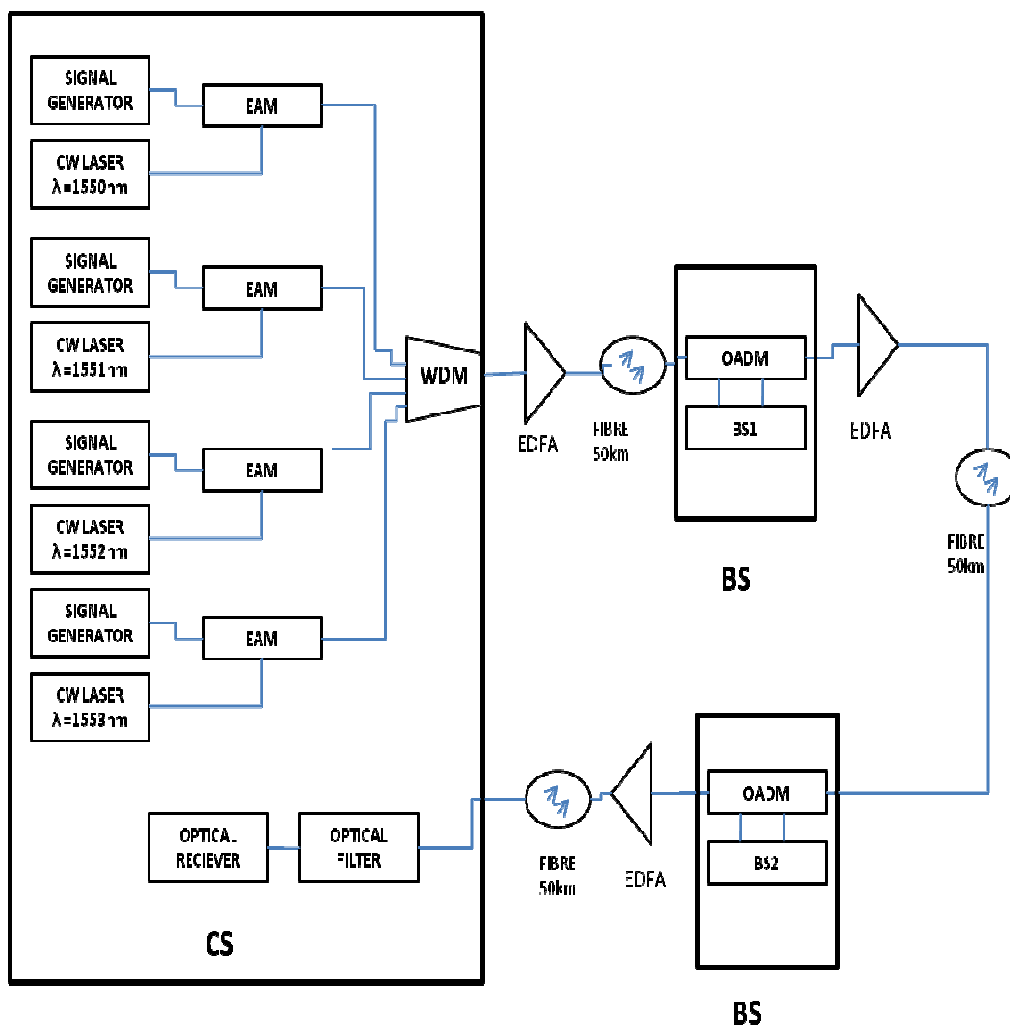


Figure 3 Simulation model of our proposed full duplex system

After transmitting the multiplexed signal up to the first base station, the appropriate wavelengths are dropped by the optical add-drop multiplexer (OADM). The OADM, with 40 dB add-drop channel isolation, consists of one fiber Bragg grating (FBG) located between two optical circulators. The OADM is used to drop the down-link optical carriers to the dedicated BS, and add the uplink optical carrier to the fiber transmission network. The downlink data signal is passed through an optical tunable band pass filter (TBPF) and then to an optical receiver. Thus the electrical signal received is demodulated and then passed to the multiplot and BER tester for analysing the received signal. The multiplexed signals having different carrier frequency other than that dropped at the first BS is transmitted towards the second base station. This signal also contains the uplink data that is added in the first base station. After transmitting the multiplexed data through single-mode fiber of 40km up to the second base station, again same procedure is followed as that in the first base station. One set of signals is dropped in this base station and other data signal is added using OADM. Finally, the multiplexed data is transmitted through further length of single-mode fiber.

Finally, when the multiplexed uplink data is transported upto the central station via single-mode fiber, it is

splitting using optical splitter and passed through optical tunable band pass filter to separate two different signals from two base stations, which are modulated using different optical carrier frequency. After separating the two signals, they are passed through optical receiver and electrical demodulator for getting back the electrical signal. This signal is passed through the multiplot and BER for signal analysis.

#### A. Simulation Schematic

Simulation is done using simulation software Optisystem 9.0. Figure 4 shows the simulation schematic drawn in optisystem 9.0 window using various in-built blocks provided by the software. Optisystem 9.0 is an advanced optical communication system simulation package designed for professional engineering. It can be used to design optical communication systems and simulate them to determine their performance given various component parameters. Optisystem 9.0 is designed to combine the greatest accuracy and modelling power with ease of use on both window and UNIX platforms. It includes the most advanced component models and simulation algorithms, validated and used for research documented in numerous peer-reviewed professional publications, to guarantee the highest possible accuracy and real world result. Simulation results that are produced by optisystem 9.0 include signal waveform plots and eye diagrams at any point within the system, and bit error rate (BER) plots. Other simulation results are also available including signal spectra, frequency chirp, power, dispersion map and more.

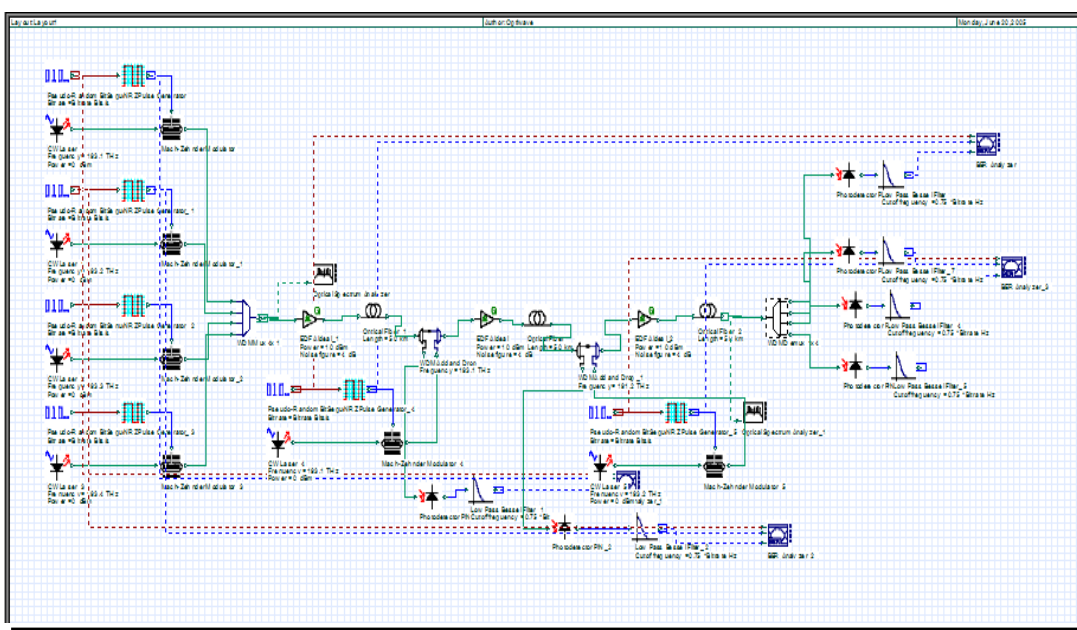


Figure 4 Simulation schematic of our proposed system

### IV. RESULTS AND DISCUSSION

The proposed full duplex data in ROF transport system was successfully simulated using optisystem 9.0. For downlink we are generating four data signals which are optically modulated using optical carriers of different wavelengths. For uplink we have generated two data signals, each at a base station and optically modulated using different wavelengths. The spectrum of the multiplexed signal for these four signals for downlink is shown in Figure 5. Figure 6 shows the eye diagram of data1 received at BS1 and figure 7 shows the eye diagram of data2 received at BS2. The spectrum of the multiplexed signal for these four signals received at the CS is shown in Figure 8. Figure 9 and figure 10 shows the eye diagrams of the data signal received at the CS.

Simulation of full duplex data transmission in ROF system using Optisystem

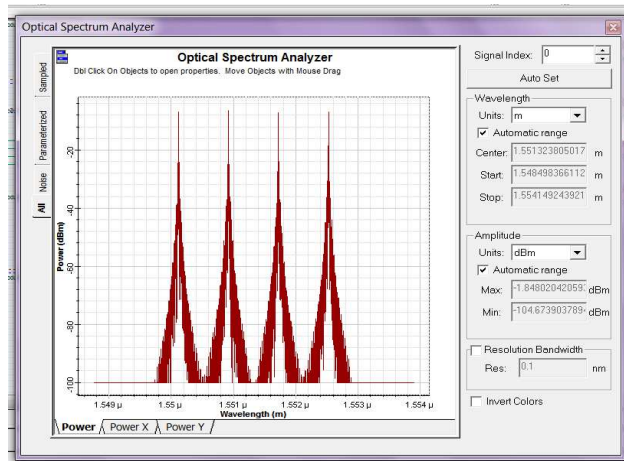


Figure 5 Wavelength spectrum of multiplexed signal

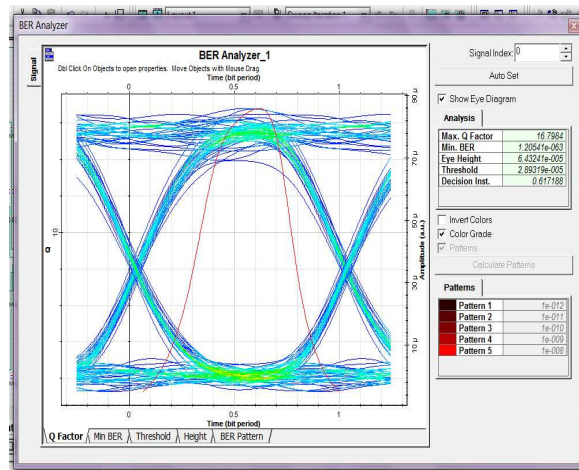


Figure 6 eye diagram of data1 at BS1

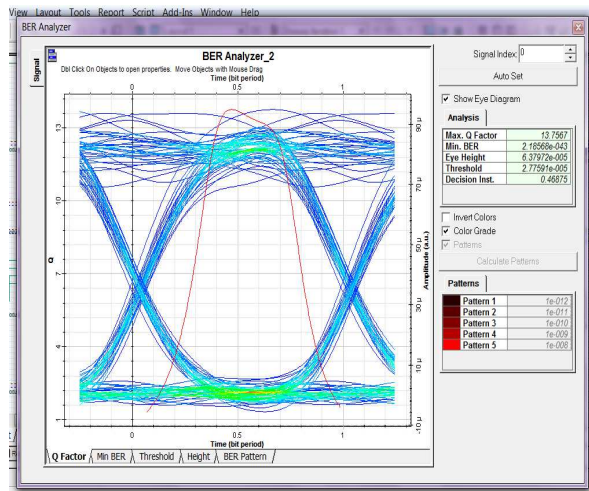


Figure 7 eye diagram of data2 at BS2

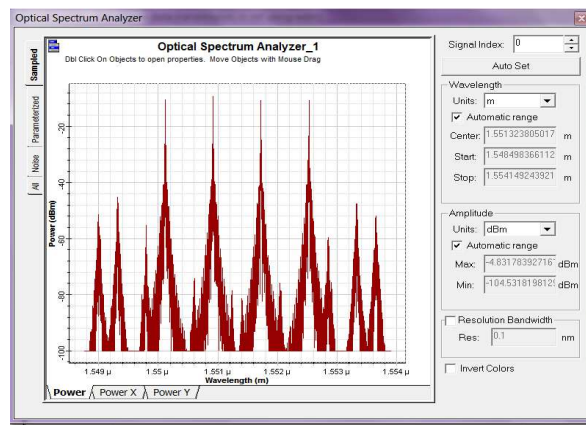
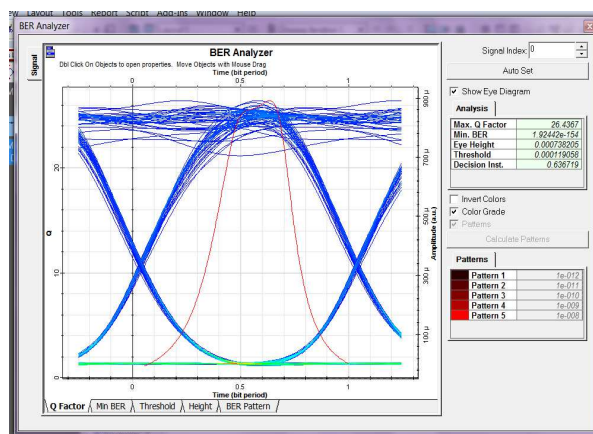


Figure 8 Wavelength spectrum of multiplexed signal received at CS



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Figure 9 Eye diagrams of the data1 received at the CS.

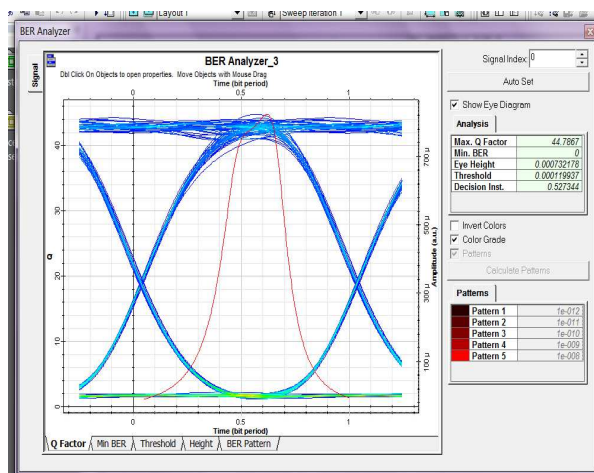


Figure 10 Eye diagrams of the data2 received at the CS.

We achieved a good BER of  $10^{-25}$  for BS1 and  $10^{-14}$  for BS2. The difference in bit error rate at two base stations is because the signal is travelling a longer distance along the fiber for BS2 than BS1 and also we are using optical carrier of different wavelength for modulating two signals. As the distance increases dispersion increases for all wavelengths. Since we have used wavelengths within a small range of 1550nm to 1553nm the dispersion values for all these wavelengths are almost same for different distances except some negligible difference for large distance.

## V. CONCLUSION

A full duplex data signal over single mode fiber in ROF transport system employing wavelength division multiplexing and optical add-drop multiplexing techniques was proposed and demonstrated using Optisystem 9.0. By using WDM, we are able to transmit four different signals through a single fiber over a large transmission distance and by using OADM, we are able to transmit both down-link and uplink data via the same single-mode fiber. Erbium doped fiber amplifiers are used to amplify the signals at different points of the transmission link. Good eye diagram and low BER was achieved, which implies the better performance of the system. Our proposed system is suitable for high bit rate and long-haul microwave optical links. We can improve the efficiency of the RoF transport system by using dispersion compensation techniques, like using dispersion compensated fibers (DCF), advanced fibers like photonic crystal fibers (PCF), polymer fibers. The technique that we have proposed here can be extended by using multimedia signals for transmission over fiber which includes data, video as well as voice signals.

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