PERFORMANCE ANALYSIS OF DIGITAL RADIO OVER FIBER (ROF) LINK IN 40 & 60 GHz.

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DECLARATION

We hereby declare that, this Thesis **"Performance analysis of Digital Radio over Fiber Link in 40 & 60 GHz"**has been done by us under the supervision of **Md. Zahirul Isalam, Lecturer, Department of ETE,** and Daffodil International University. We also declare that neither this project nor any part of this project has been submitted elsewhere for award of B.Sc. in Electronics & Telecommunication Engineering degree.

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ABSTRACT

Radio over fiber (RoF) technology is the technology since it provides functionally simple BSs that are interconnected to a central control station (CS) via an optical fiber In order to reduce the system cost. Extensive research efforts have been devoted to the development of physical layer such as simple BS development and radio signal transport techniques over fiber, but few have been reported about upper layer and resource management issues for ROF networks. In this thesis performance analysis of analog and digital radio over Fiber Link in 40 & 60 GHz has been done based on Bit Error Rate (BER) and Spectrum analysis has been done. Optiwave Systems simulation software is used for the simulation and performance analysis.

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Chapter 1

Introduction

1.1 Introduction

Radio over Fiber (ROF) refers to a technology whereby light is modulated by a radio signal and transmitted over an optical fiber link to facilitate wireless access, such as 3G and Wi-Fi simultaneous from the same antenna.[1] In other words, radio signals are carried over fiber optic cable. Thus, a single antenna can receive any and all radio signals (3G, Wi-Fi, cell, etc..) carried over a single fiber cable to a central location where equipment then converts the signals; this is opposed to the traditional way where each protocol type (3G, Wi-Fi, cell) requires separate equipment at the location of the antenna.

Although radio transmission over fiber is used for multiple purposes, such as in cable television (CATV) networks and in satellite base stations, the term RoF is usually applied when this is done for wireless access.

In RoF systems, wireless signals are transported in optical form between a central station and a set of base stations before being radiated through the air. Each base station is adapted to communicate over a radio link with at least one user's mobile station [3] located within the radio range of said base station. The advantage is that the equipment for Wi-Fi, 3G and other protocols can be centralized in one place, with remote antennas attached via fiber optic serving all protocols. It greatly reduces the equipment and maintenance cost of the network.

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.

a) In **RF-over-Fiber** architecture, a data-carrying RF (Radio Frequency) signal with a high frequency is imposed on a light wave signal before being transported over the optical link. Therefore, wireless signals are optically distributed[2] to base stations directly at high frequencies and converted from the optical to electrical domain at the base stations before being amplified and radiated by an antenna. As a result, no frequency up/down conversion is required at the various base stations, thereby resulting in simple and rather cost-effective implementation is enabled at the base stations.

b) In **IF-over-Fiber** architecture, an IF (Intermediate Frequency) radio signal with a lower frequency is used for modulating light before being transported over the optical link. Therefore, before radiation through the air, the signal must be up-converted to RF at the base station.

1.2 Goal of the research work

In this thesis analysis has been done between Analog & digital radio over fiber link in 40 & 60 GHz. In This thesis there are several simulation tools that can be used to design RoF systems. Popular commercial tools have been developed by Opitwave Systems Inc. We Find several eye diagram and spectrum Analysis in upstream and downstream 40 & 60 GHz. we also Calculate Bit Error Rate (BER) in 40 & 60 GHz Analog and Digital radio over fiber.

1.3 Organization of the thesis

The first chapter of this thesis gives a brief introduction of Radio over fiber

The second chapter presents details of the system architecture of ROF, optical transmission link, real life of ROF work, advantages & and application of ROF. Optical transmission fiber, no. of channel, current technologies and basic idea of optisystem software

The third chapter presents ROF link configuration, system configuration, optical heterodyning, up & down stream conversion, optical transceiver, external modulation and ROF wavelength division multiplexing (WDM).

Chapter four introduction of digital radio over fiber (DROF) , advantage & disadvantages of DROF, uplink & downlink transmission.

The chapter five are presents working principle of Analog & Digital ROF , simulation and result for 40 & 60 GHz analog and digital ROF.

The last chapter presents the conclusions from the work performed and also gives insight into the future work.

Chapter 2

Radio over Fiber

2.1 Radio over Fiber

Radio over Fiber technology (RoF), which can integrate both advantages of fiber optic networks and wireless has been studied intensively, due to numerous applications in broadband wireless communications (e.g. WLAN, GSM, UMTS). In contrast to other transmission media, optical fiber has superior properties, such as light weight, low attenuation loss, small size, and especially the large bandwidth and insensitivity to electromagnetic radiation[1]. These advantages make it the optimal solution for efficiently transporting radio signals in wireless network.

2.1.1 Radio over Fiber System architecture

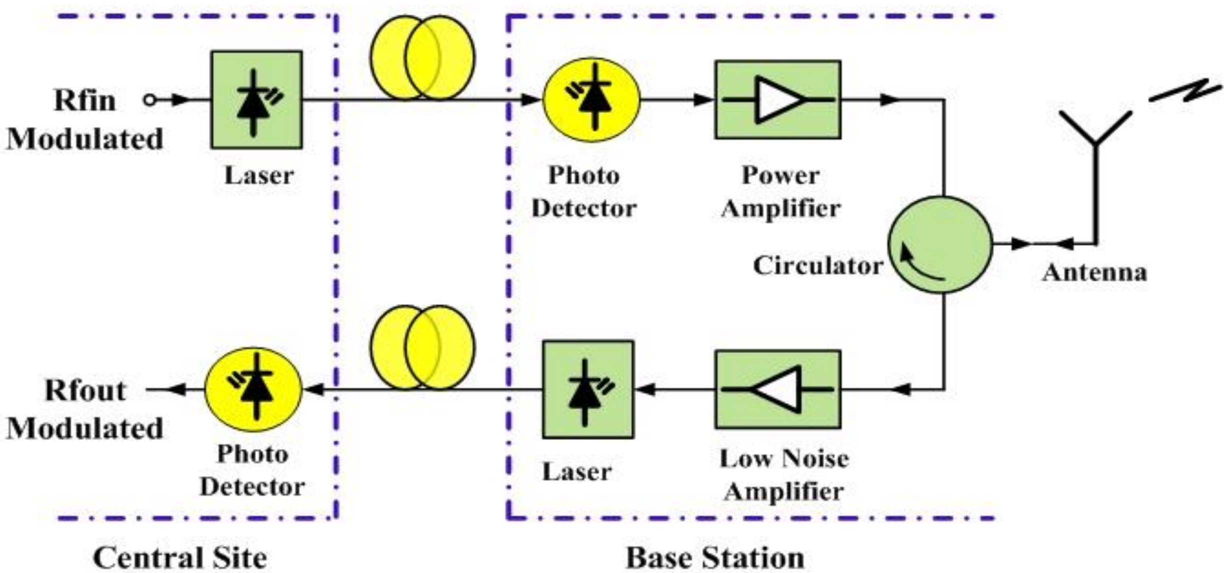


Figure 1: Radio over Fiber System

A typical RoF system is shown in Figure 1. Generally, direct modulation of semiconductor laser, e.g. distributed-feedback laser diode (DFB LD) is used to achieve the most cost effective solution in comparison to others, such as Electro-absorption Modulator (EAM), Mach-Zehnder modulator (MZM). In anRoF system, both modulation and photo detection devices can contribute to the link distortion, which degrades the linearity of optical links [2]. Therefore, it is essential to suppress nonlinear distortion to improve the performance of the system.

When two frequencies are presented simultaneously to a DFB LD, harmonic distortion and intermodulation are generated. Although both harmonic and intermodulation distortions arise from the same underlying mechanism, second-order intermodulation and third-order intermodulation are normally larger than second and third harmonics, respectively. Fourth order and higher orders terms typically are considered as negligible because of low power levels, or they fall well outside the operational bands. Here, we target third intermodulation compensation due to its strong influence on the system.

2.1.2 Optical Transmission Link

In the first part of this section, a general optical transmission link , shown figure is briefly described for which we assume that a digital pulse signal is transmitted over optical fiber unless otherwise specified. The optical link consists of an optical fiber, transmitter, receiver and ampler, each of which is dealt with in the subsequent subsections.

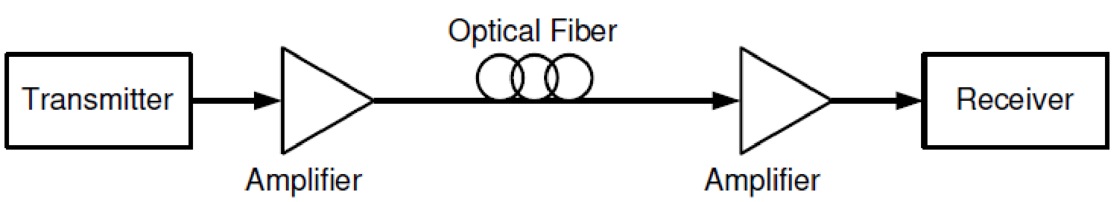


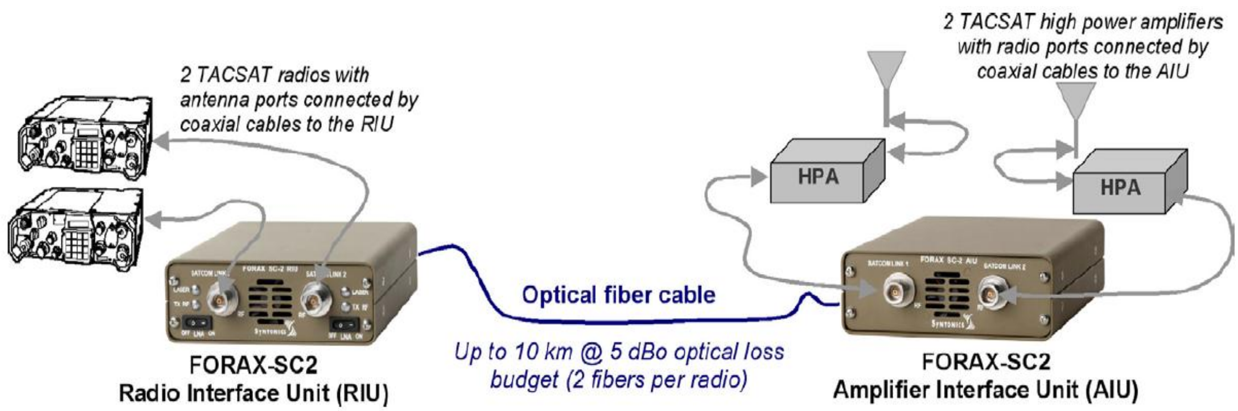
Figure.2: Optical transmission link.

Among various linearization techniques, two general methods: feed forward compensation and predistortionare adopted to suppress the nonlinear distortion generated by lasers to meet such stringent requirements for linearity. The feed forward technique usually requires a greater number of components such as additional laser diodes, photodiodes, and optical couplers, resulting in higher costs and complexity of the system. Comparing with feed forward techniques, predistortion is superior since it is cost-saving and easy to implement. The predistortion approach inserts an inverse transfer function nonlinear component in front of the nonlinear laser, as illustrated in Figure 2. The cascaded stage realizes improved linearity performance than the laser itself.

A typical analog laser predistorter was introduced in [6]. In this work, the RF signal is separated into two paths: one linear path consists of a time delay line and the other nonlinear path for quadratic-law and cubic-law generation. The magnitude and phase of the distortion generation path can be adjusted through phase shifters and Variable Gain Amplifier (VGA). Finally the linear path and the correction signal are recombined and fed to the laser. In this predistorter prototype, linearity is achieved at the expense of increasing cost and system complexity since phase shifters, VGA, and extra power splitters are used. Predistortion circuit also can be designed using standard CMOS technology. Multiple tank cells and tunable gain cells involved in this predistorter design lead to additional power dissipation, and its operation bandwidth is only300MHz.

In this work, we are developing a low-cost, high efficiency, broadband analog CMOS predistortion circuit to reduce third-order intermodulation of a DFB laser, which can be widely used in multiservice RoF industrial systems. Such a design can be easily integrated with other components. Power dissipation, noise, and bandwidth are optimized in this design. In the future, this design approach can extended to suppress higher order distortions in universal strategy of compensation. A prototype design in 90 nm CMOS is planned.

2.1.3 Real life Radio over Fiber Work Diagram



An RF signal can be transmitted, up to many GHz depending on the laser and its modulation scheme. The RF Out must be amplified to provide a useable signal.

2.1.2Advantages

2.1.2.1 Low attenuation

It is a well-known fact that signals transmitted on optical fiber attenuate much less than through other media, especially when compared to wireless medium. By using optical fiber, the signal will travel further, reducing the need of repeaters.

2.1.2.2 Low complexity

RoF makes use of the concept of a remote station (RS). This station only consists of an optical-to-electrical (O/E) (and an optional frequency up or down converter), amplifiers, and the antenna. This means that the resource management and signal generation circuitry of the base station can be moved to a centralized location and shared between several remote stations, thus simplifying the architecture.

2.1.2.3 Lower cost

Simpler structure of remote base station means lower cost of infrastructure, lower power consumption by devices and simpler maintenance all contributed to lowering the overall installation and maintenance cost. Further reduction can also be made by use of low-cost Graded Index Polymer Optical Fiber (GIPOF)

2.1.2.4 Future-proof

Fiber optics are designed to handle gigabits/second speeds which means they will be able to handle speeds offered by future generations of networks for years to come. RoF technology is also protocol and bit-rate transparent, hence, can be employed to use any current and future technologies.

The most popular use for RF over fiber is for cable TV systems. It is impossible to run RF signals over copper cable to more than few hundred feet. Theyare transporting their entire CATV channel lineup over a single fiber optic cable, because this way they can transport the signal for hundreds of km. It works like this: An electrical RF signal usually in the range of 54 – 870 MHz is converted to modulated light using RF 1310 nm or 1550 nm laser optics. The light travels over single-mode fiber to the fiber optic RF receiver where is converted back to electrical RF. Electrical RF is directly connected to a TV or set-top box. 1550 nm is more popular because it has less loss in the fiber and by using fiber optic amplifier known as EDFA it is possible to extend the transport distance. 1310 nm is losing about 0.35 db/KM of optical signal, 1550 nm is losing only 0.25 db/km. Optical budget between transmitter and receiver varies, depending on the transmitter power and receiver sensitivity.

2.1.3 Applications

2.1.3.1 Access to dead zones

An important application of RoF is its use to provide wireless coverage in the area where wireless backhaul link is not possible. These zones can be areas inside a structure such as a tunnel, areas behind buildings, Mountainous places or secluded areas such as jungles.

2.1.3.2 FTTA (Fiber to the Antenna)

By using an optical connection directly to the antenna, the equipment vendor can gain several advantages like low line losses, immunity to lightning strikes/electric discharges and reduced complexity of base station by attaching lightweight Optical-to-Electrical (O/E) converter directly to antenna.

2.1.4 Deployment

As of April 2012, AT&T had 3000 systems deployed in the USA in places like stadiums, shopping malls and inside buildings. "We continue to go very, very aggressively on distributing the antenna system solutions", said CEO Randall Stephenson in 2012.

In China, systems are being widely deployed in industrial zones, harbors, hospitals and supermarkets. Plans are in place to expand into rural zones along rail lines, and in new residential and commercial construction spaces. It is believed China will be the leading user of the technology and this will bring down the cost of equipment.

2.1.5 Optical Transmission in Fiber

Light can travel through any transparent material, but the speed of light will be slower in the material than in a vacuum. The ratio of the speed of light in a vacuum to that in a material is known as the material's refractive index (n) and is given by n = c=v, where c is the speed in a vacuum and v is the speed in the material. When light travels from one material of a given refractive index to another material of a different refractive index (i.e., when refraction occurs), the angle at which the light is transmitted in the second material depends on the refractive indices of the two materials as well as the angle at which light strikes the interface between the two materials. According to Snell's law, we have na sin _a = nb sin _b, where na and nb are the refractive indices of the first substance and the second substance, respectively; and _a and _b are the angles from the normal of the incident and refracted lights, respectively. We see that the fiber consists of a core completely surrounded by a cladding (both of which consist of glass of different refractive indices). Let us first consider a step-index fiber, in which the change of refractive index at the core-cladding boundary is a step function. If the refractive index of the cladding is less than that of the core, then the total internal reflection can occur in the core and light can propagate through the fiber as shown in Fig. . The angle above which total internal reflection will take place is known as the critical angle and is given by

$$\sin \theta_c = \frac{n_{clad}}{n_{core}}$$

Where Nclad and Ncore are the refractive indices of cladding and core, respectively

The maximum value of _air can be derived from,

Then, We can rewrite it as:

$$n_{air} \sin \theta_{air} = n_{core} \sin(90^\circ - \theta_c)$$

$$n_{air} \sin \theta_{air} = \sqrt{n_{core}^2 - n_{clad}^2}$$

The quantity Nair sin θair is referred to as the numerical aperture (NA) of the θber and _air is the maximum angle with respect to the normal at the air-core boundary, so that the incident light that enters the core will experience total internal reflection inside the θber.

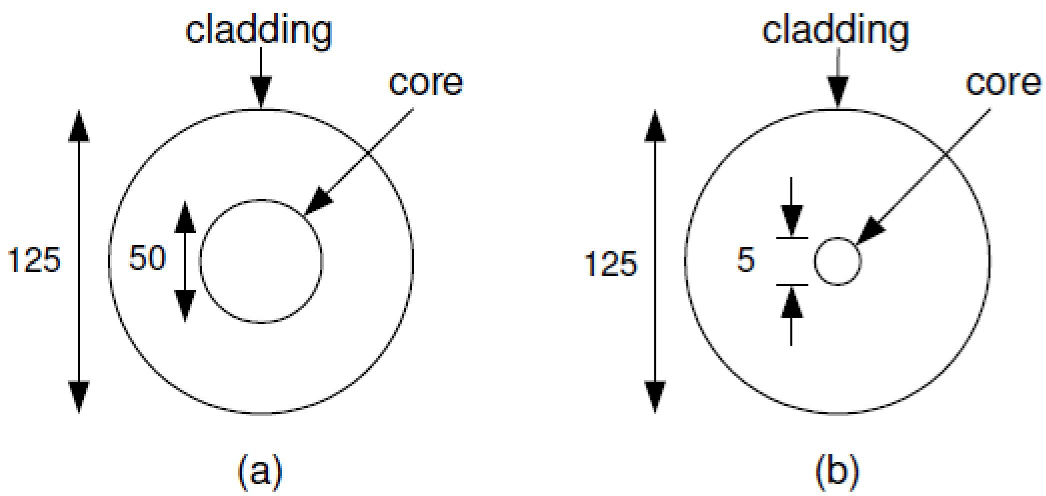


Figure 3: multi-mode (a) and single-mode (b) optical fibers

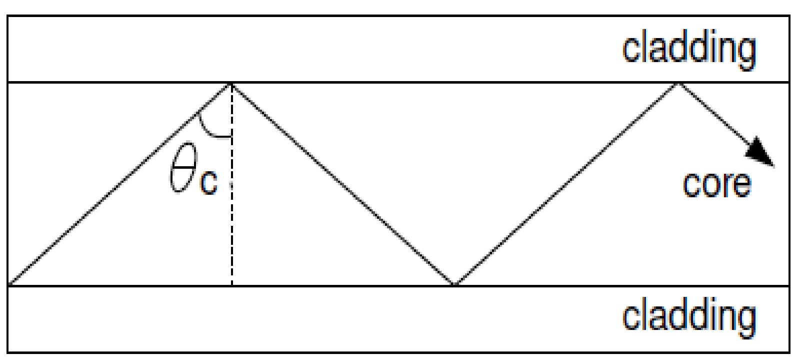


Figure 4: Light traveling via total internal reflection within an optical fiber.

2.1.6 The Number of Channels

If we assume that the total system bandwidth (BWtotal) is _xed, guard bandwidth (BWg) is zero, and downlink and uplink channel bandwidths are of the same size (BWdown = BWup ,BWch), the sum of all channel bandwidth (2C BWch) must be less than or equal to BWtotal. This is

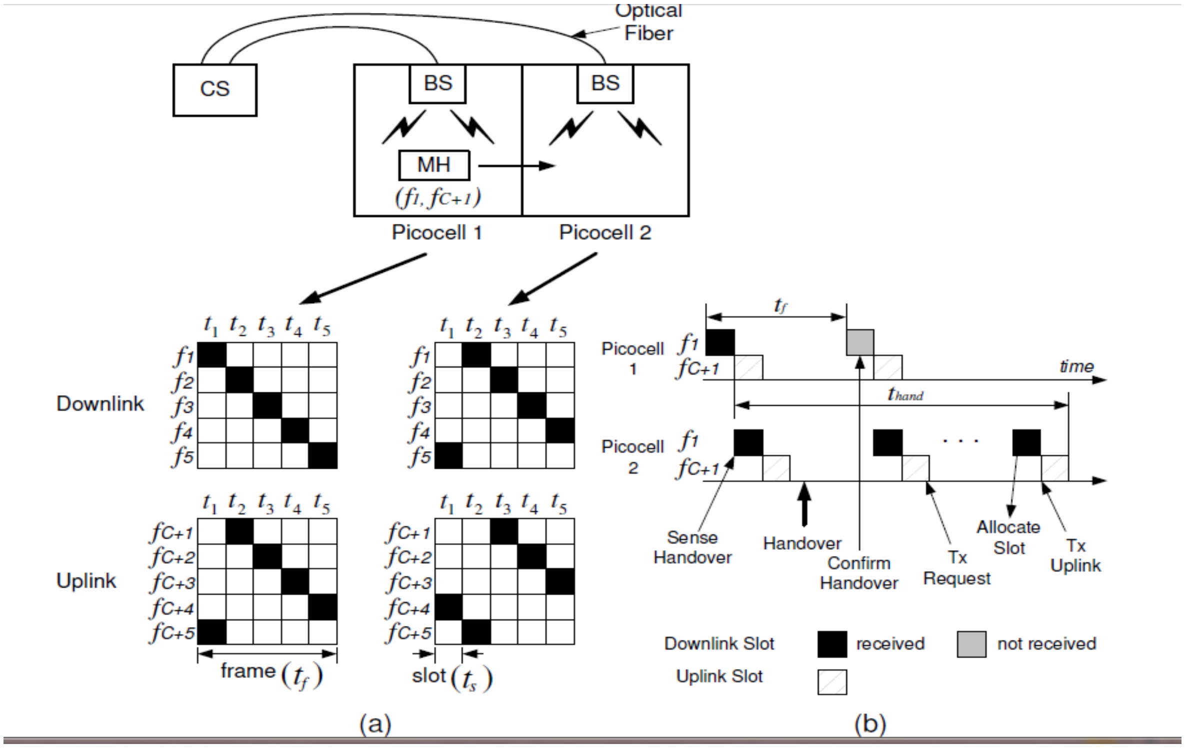


Figure 5: Handover example. MH using (f1; fC+1) moves from Pico cell 1 to Pico cell 2. (a) FS pattern used in each cell and(b) handover latency.

2.1.7 Other Examples

One of the pioneer RoF system implementations is depicted in the following figure. Such a system may be used to distribute GSM signals, for example.

The RF signal is used to directly modulate the laser diode in the central site (headend). The resulting intensity modulated optical signal is then transported over the length of the fiber to the BS (RAU).

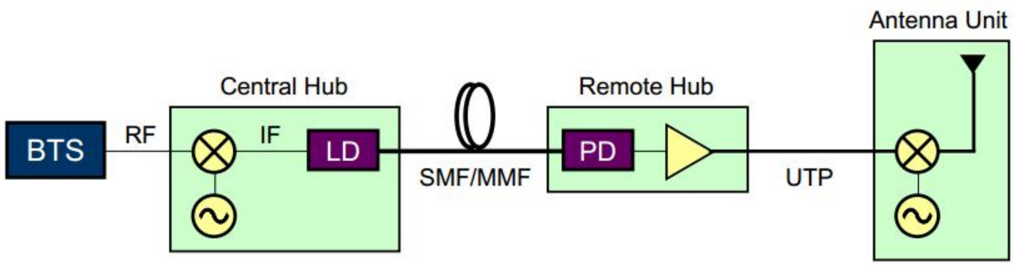
At the RAU, the transmitted RF signal is recovered by direct detection in the PIN photo detector. The signal is then amplified and radiated by the antenna. The uplink signal from the MU is transported from the RAU to the headend in the same way.

This method of transporting RF signals over the fiber is called Intensity Modulation with Direct Detection (IM-DD), and is the simplest form of the RoF link.

2.1.8 Current Technologies

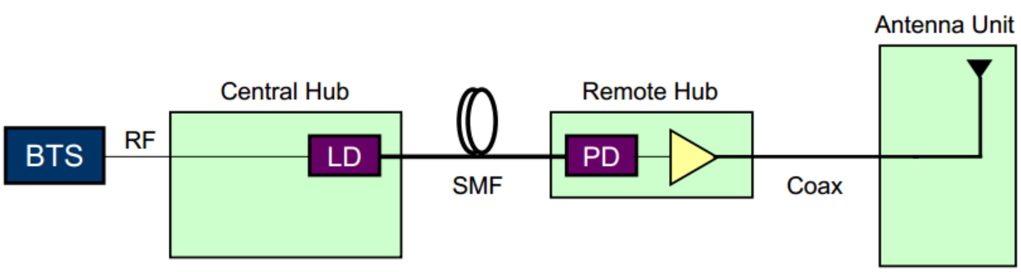
2.1.8.1 IF over Single Mode Fiber (SMF) and Multimode Fiber (MMF)

Type	Example	Company	Comments
IF over SMF/MMF	LGCell 	LGC Wireless	Added complexity (cost) at remote unit. Can use pre-installed fiber



2.1.8.2 RF over Single Mode Fiber (SMF)

Type	Example	Company	Comments
RF over SMF	BriteCell FiberDAS 	Andrew Remec	Simple remote unit but relatively expensive optics. Uses specially installed fiber.



2.1.9 OptiSystem

In an industry where cost effectiveness and productivity are imperative for success, the award winning OptiSystem can minimize time requirements and decrease cost related to the design of optical systems, links, and components. OptiSystem is an innovative, rapidly evolving, and powerful software design tool that enables users to plan, test, and simulate almost every type of optical link in the transmission layer of a broad spectrum of optical networks from LAN, SAN, and MAN to ultra-long-haul. It offers transmission layer optical communication system design and planningFrom component to system level and visually presents analysis and scenarios. Its integration with other Optiwave products and design tools of industry leading electronic design automation software all contribute to OptiSystem speeding your product to market andreducing the payback period.

2.1.9.1 OptiSystem enables users to plan, test, and simulate:

• WDM/TDM or CATV network design

• SONET/SDH ring design

• Transmitter, channel, amplifier, and receiver design

• Dispersion map design

• Estimation of BER and system penalties with different
Receiver models

• Amplified System BER and link budget calculations

2.1.9.2 SPECIFIC BENEFITS

• Provides global insight into system performance

• Assesses parameter sensitivities aiding design
Tolerance specifications

• Visually presents design options and scenarios to
Prospective customers

• Delivers straightforward access to extensive sets of
system characterization data

• Provides automatic parameter sweep and optimization

• Integrates with the family of Optiwave products

Chapter 3

ROF Link Configurations

3.1 ROF Link Configurations

In this section we discuss a typical RoF link configuration, which is classified based on the kinds of frequency bands (baseband (BB), IF, RF bands) transmitted over an optical fiber link. Representative RoF link configurations are schematically shown in Fig. Here, we assume that a BS has its own light source for explanation purpose; however, as will be seen in section BS can be configured without light source for uplink transmission. In each configuration of the figure, BSs do not have any equipment for modulation and demodulation, only the CS has such equipment. In the downlink from the CS to the BSs, the information signal from a public switched telephone network (PSTN), the Internet, or other CS is fed into the modem in the CS. The signal that is either RF, IF or BB bands modulates optical signal from LD. As described earlier, if the RF band is low, we can modulate the LD signal by the signal of the RF band directly. If the RF band is high, such as the mm-wave band, we sometimes need to use external optical modulators (EOMs), like electro absorption ones. The modulated optical signal is transmitted to the BSs via optical fiber. At the BSs, the RF/IF/BB band signal is recovered to detect the modulated optical signal by using a PD. The recovered signal, which needs to be up converted to RF band if IF or BB signal is transmitted, is transmitted to the MHs via the antennas of the BSs. In the configuration shown in Fig. 3.8 (a), the modulated signal is generated at the CS in an RF band and directly transmitted to the BSs by an EOM, which is called .RF-over-Fiber.. At each BS, the modulated signal is recovered by detecting the modulated optical signal with a PD and directly transmitted to the MHs. Signal distribution as RF-over-Fiber has the advantage of a simplified BS design but is susceptible to fiber chromatic dispersion that severely limits the transmission distance .In the configuration shown in Fig. 3.8 (b), the modulated signal is generated at the CS in an IF band and transmitted to the BSs by an EOM, which is called .IF-over-Fiber.. At each BS, the modulated signal is recovered by detecting the modulated optical signal with a PD, up converted to an RF band, and Transmitted to the MHs. In this scheme, the effect of fiber chromatic dispersion on the distribution of IF signals is much reduced, although antenna BSs implemented for RoF system incorporating IF-over- Fiber transport require additional electronic hardware such as a mm-wave frequency LO for frequency up- and down conversion. In the configuration (c) of the figure, the modulated signal is generated at the CS in baseband and transmitted to the BSs by an EOM, which is referred to as. `BB-over-Fiber.At eachBS, the modulated signal is recovered by detecting the modulated optical signal with a PD, up converted to an RF band through an IF band or directly, and transmitted to the MHs. In the baseband Transmission, influence of the fiber dispersion effect is negligible, but the BS configuration is the most

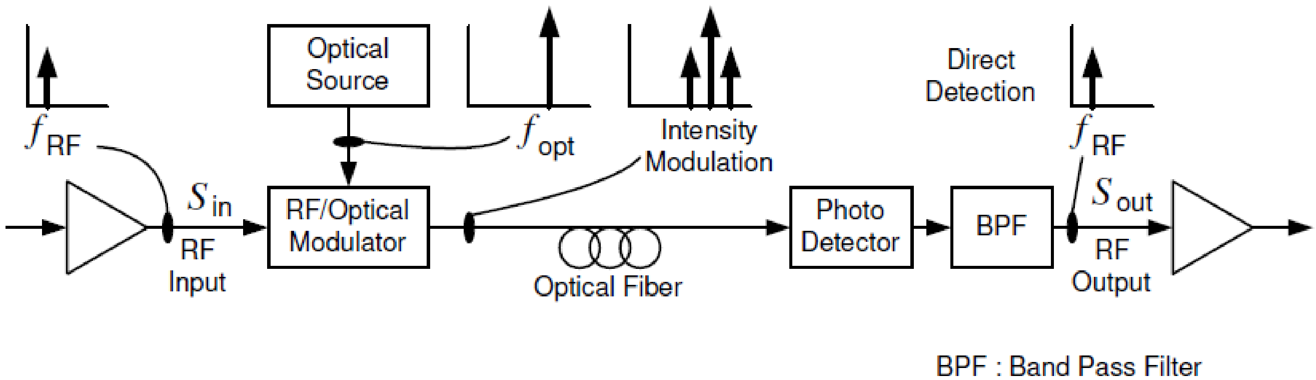
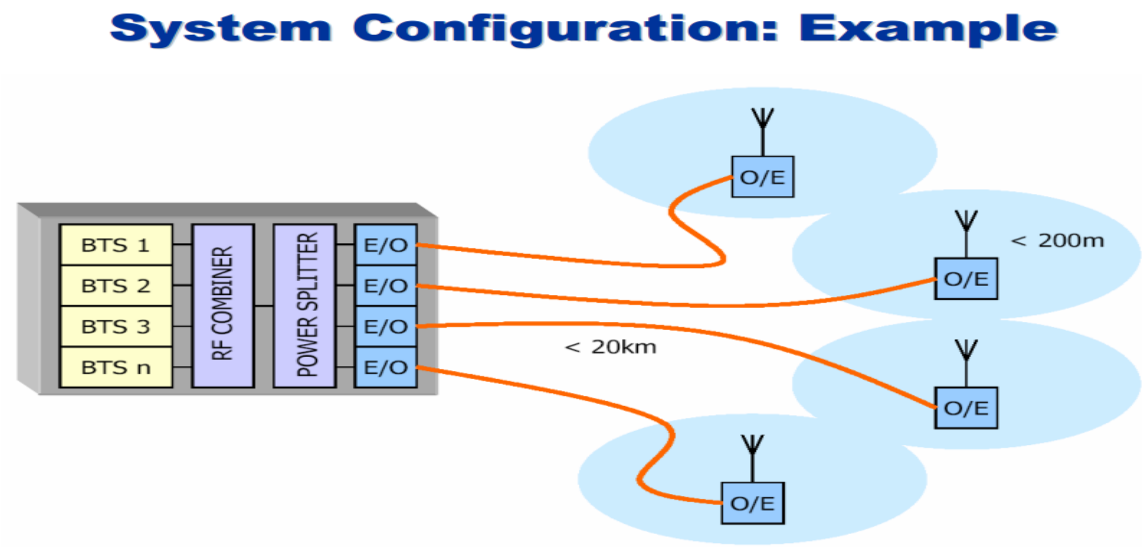


Figure 6: Intensity-modulation direct-detection (IMDD) analog optical link

Without light source for uplink transmission. In each configuration of the figure, BSs do not have any equipment for modulation and demodulation, only the CS has such equipment.

3.1.1 System configuration



Radio-over-Fiber (RoF) technology entails the use of optical fiber links to distribute RF signals from a central location (headed) to Remote Antenna Units (RAUs).

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 (head end), 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.

By so doing, 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.

3.1.2 Optical Heterodyning

In optical heterodyning technique, two or more optical signals are simultaneously transmitted and are heterodyned in the receiver. One or more of the heterodyning products is the required RF signal.

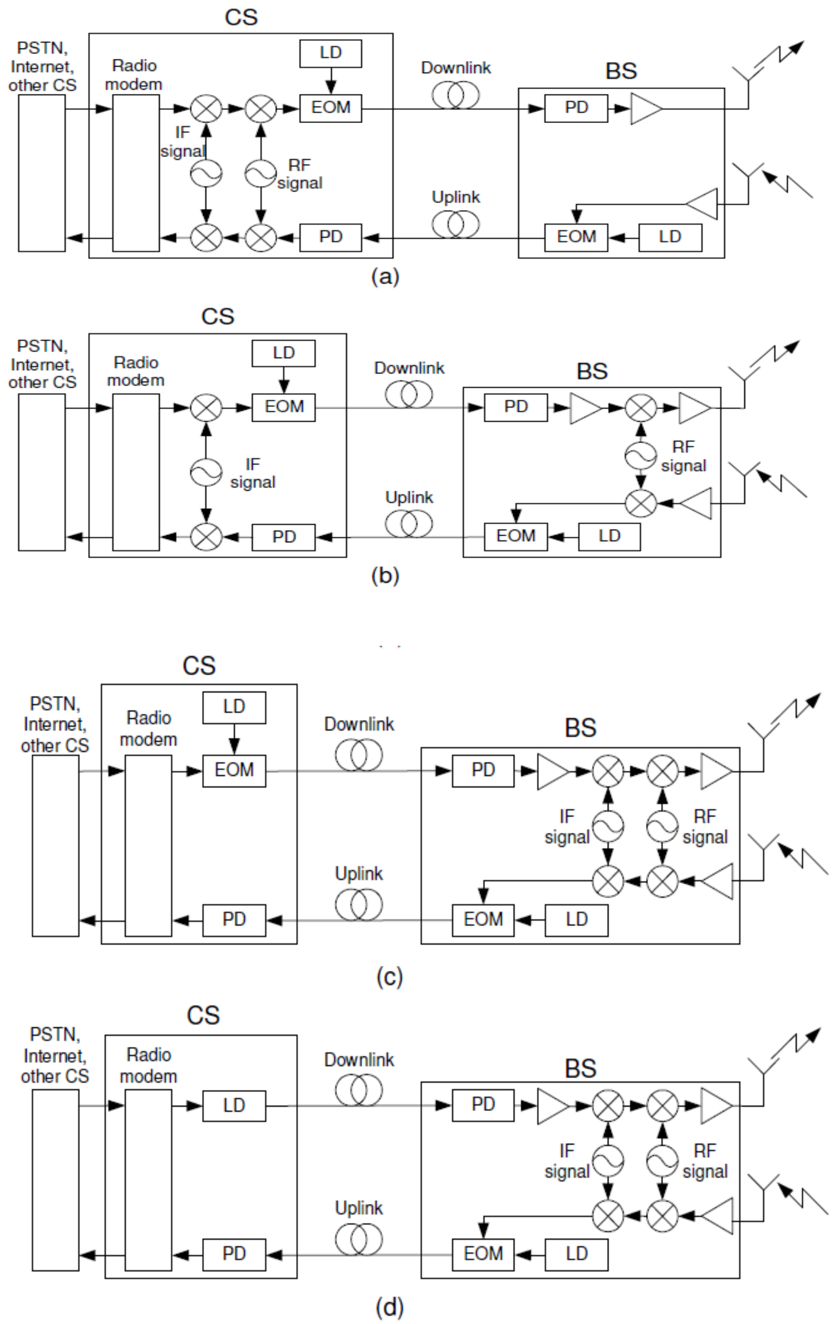


Figure 7: Representative RoF link configurations. (a) EOM, RF modulated signal. (b) EOM, IF modulated signal, (c) EOM, baseband modulated signal. (d) Direct modulation

3.1.3 Up- and Down-conversion

In this technique IF band signal is transported over optical fiber instead of RF band signal. The transport of the IF-band optical signal is almost free from the fiber dispersion effect, however, the electrical frequency conversion between the IF-band and mm-wave requires frequency mixers and a mm-wave LO, resulting in the additional cost to the BS[10]. Another advantage of this technique is the fact that it occupies small amount of bandwidth, which is especially beneficial.

3.1.4 Optical Transceiver

The simplest BS structure can be implemented with an optical transceiver such as electro-absorption transceiver (EAT). It serves both as an O/E converter for the downlink and an E/O converter for the uplink at the same time. Two wavelengths are transmitted over an optical fiber from the CS to BS. One of them for downlink transmission is modulated by user data while the other for uplink transmission is undulated. The undulated wavelength is modulated by uplink data at the BS and returns to the CS. That is, an EAT is used as the photodiode for the data path and also as a modulator to provide a return path for the data, thereby removing the need for a laser at the remote site. This device has been shown to be capable of full duplex operation in several experiments at mm-wave bands. A drawback is that it suffers from chromatic dispersion problem. RoF system based on EATS developed in. Note that two wavelengths are always needed for up- and downlink communication, and full-duplex operation is possible.

3.1.5 External Modulation

Although direct intensity modulation is by far the simplest, due to the limited modulation bandwidth of the laser this is not suitable for mm-wave bands [11]. This is the reason why at higher frequencies, say, above 10 GHz, external modulation rather than direct modulation is applied. External modulation done by a high speed external modulator such as electro-absorption modulator (EAM).It configuration is simple but it has some disadvantages such as fiber dispersion effect and high insertion loss. Representative configurations are shown in Fig. where intensity modulation is employed. In conventional intensity modulation, the optical carrier is modulated to generate an optical field with the carrier and double sidebands (DSB). When the signal is sent over fiber, chromatic dispersion causes each spectral component to experience different phase shifts depending on the fiber link distance, modulation frequency, and the fiber dispersion parameter. If the relative phase between these two components is 180fs, the components destructively interfere and the mm-wave electrical signal disappears.To reduce such dispersion effects, optical single-sideband (SSB) is widely used . Specially designed EAM was developed and experimented at 60 GHz band RoF system in , while a Mach- Zehnder modulator (MZM) and a fiber Bragg grating filter were used in and , respectively, to Produce single-sideband optical modulation.

3.1.6 Up- and Down-conversion

In this technique IF band signal is transported over optical fiber instead of RF band signal. The transport of the IF-band optical signal is almost free from the fiber dispersion effect, however, the electrical frequency conversion between the IF-band and mm-wave requires frequency mixers and a mm-wave LO, resulting in the additional cost to the BS. Another advantage of this technique is the fact that it occupies small amount of bandwidth.

3.1.7 ROF and Wavelength Division Multiplexing (WDM)

The application of WDM 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. Thus, WDM in combination with optical mm wave transport has been widely studied. A schematic arrangement is illustrated in Fig. where for simplicity, only downlink transmission is depicted. Optical mm-wave signals from multiple sources are multiplexed and the composite signal is optically amplified, transported over a single fiber, and DE multiplexed to address each BS. Furthermore, there have been several reports on dense WDM (DWDM) applied to RoF networks. Though a large number of wavelengths is available in the modern DWDM technologies, since mm-wave bands RoF networks may require even more BSs wavelength resources should be efficiently utilized. A challenging issue is that the optical spectral width of a single optical mm-wave source may approach or exceed WDM channel spacing. Shows an optical spectrum of DWDM. mm-wave RoF signals with optical DSB modulation (a) and SSB modulation (b), where we assume that the carrier frequency of the mm-wave signal is 60 GHz. Fig. (a) indicates that to transmit single data channel at 60 GHz band, more than 120 GHz bandwidth is necessary for DSB modulation. In addition, from a viewpoint of cost reduction, it is preferable to use the channel allocation in accordance with ITU grid because of the availability of optical components. Then, the minimum channel spacing in this case is 200 GHz . In case of SSB modulation, this is 100 GHz as shown in .To increase the spectral efficiency of the system, the concept of optical frequency interleaving has been proposed another issue is related to the number of wavelengths required per BS. It is desirable to use one wavelength to support full-duplex operation. In , a wavelength reuse technique has been proposed, which is based on recovering the optical carrier used in downstream signal transmission and reusing the same wavelength for upstream signal transmission.

Chapter 4

Digital Radio over Fiber (DROF)

4.1 Digital Radio over fiber (DORF) : The transmission of analog signals requires high-quality performance on the linearity and dynamic range of the optical link. There are a number of distortions arising from the non-linear characteristics and frequency response limitations associated with the laser or the external modulator as well as the effect of fiber dispersion.

4.1.1 Disadvantages of Analog Optical links

• It inherently suffers from intermodulation distortions arising from the nonlinearity of both microwave and Optical components that make up the optical link.

• The dynamic range of an analog optical link decreases linearly with the increasing length of the optical fiber Link due to the attenuation in the optical fiber.

4.1.2 Advantages of Digital optical links

• Architecture of BS is highly Simplified BSs and cost effectiveness of RF network is achieved

• It can maintain its dynamic range independent of the fiber distance

• Digitized RF-over-fiber can be based on low-cost digital transmitters and receivers

• It has high dynamic range which can be sustained over a long distances in comparison to that of analog optical links.

4.1.3 Block Diagram

A digitized RF-over-fiber (DROF) is being proposed which uses technique based on Band pass Sampling. In order to avoid Aliasing effect and to assure exact reconstruction of the signal, sampling rate for Band pass Sampling should strictly follow the rules given in figure:

4.1.4 Uplink Transmission

Band pass Sampling is used to digitize the pass band microwave signals,. The choice of sampling frequency is dependent on the maximum and minimum frequencies of the band pass microwave signal, which are defined as fmax and, fmin respectively. To ensure the exact reconstruction of the band pass signal and prevent spectral aliasing upon sampling, must satisfy the following relationships.

$$\frac{f_{max}}{n_z} \leq f_s \leq \frac{2f_{min}}{n_z - 1}$$

$$1 \leq n_z \leq I_g\left[\frac{f_{max}}{f_{max} - f_{min}}\right]$$

Where Nzis an integer, fmax-fmin is the signal bandwidth of the pass band signal, and Ig[X] is the floor function that returns the largest integer within the inverse of the fractional bandwidth. An important consideration for an ADC designed for Band pass Sampling is that it must be able to effectively operate on the highest frequency component of the pass band modulated signal while performing the sampling function at a sampling rate greateror equal to twice the message bandwidth. Therefore, it is assumed that the analog bandwidth and sampling rate of the ADC used in the analysis satisfy both criteria mentioned in two Equations.

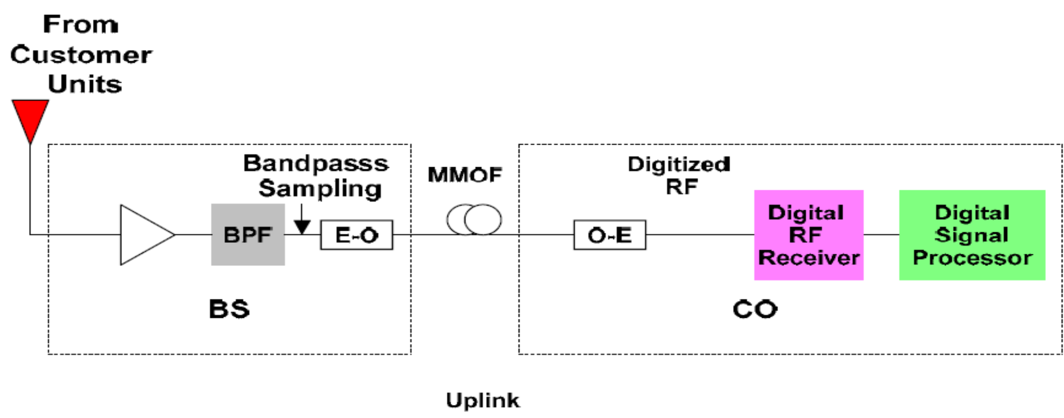


Figure 8: Proposed Digitized Radio over Fiber (DROF) Uplink

The uplink transmission is from BS to CO In this path, the RF wireless WIMAX signal received at the base station is sampled and quantized by an ADC with a sampling rate chosen based on Band Band pass sampling theory. After an IMDD optical link, the digital data is detected in the central office and the uplink wireless signal is reconstructed and recovered using a DAC, in conjunction with a band pass filter (BPF).

4.1.5 Downlink Transmission

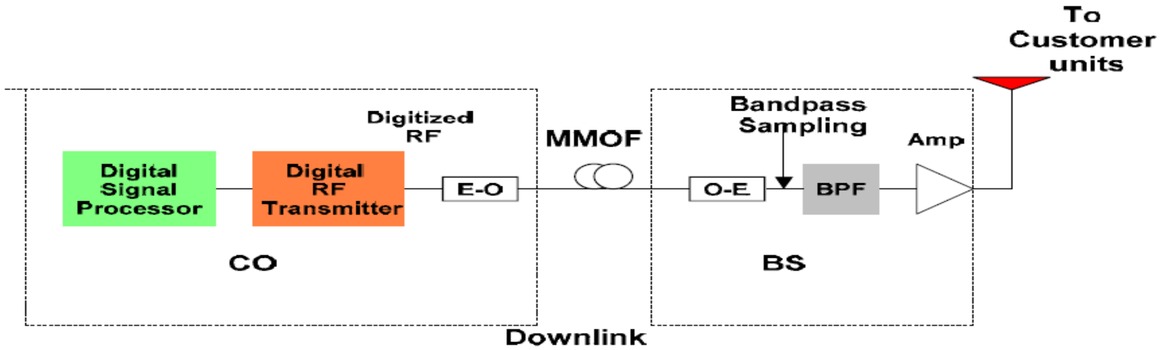


Figure: 9 Digitized Radio over Fiber (DROF) Downlink

Figure 7 shows the downlink transmission link of DROF. The downlink transmission is a link is from CO to BS. Here the Digitized RF is sent over the Optical fiber link after converting it from electrical to optical form. It is received at the BS where signal is converted from optical to electrical form. Signal is filtered and amplified .the final signal is then transmitted to its intended custom user. In the proposed system, the sampling frequency was chosen so that it could band pass sample microwave signals from wireless system such as Wi-MAX 802.16a. The modulation format specified in Wi-MAX 802.16a is 16 QAM with a symbol rate of 125 Symbols/s . In the proposed system the various types of inputs such as BPSK, QPSK and 16QAM are compared with regards to parameters like BER v/s SNR. Multimode optical fiber is used. Maximum and Minimum frequency of 2.5 GHz and 2.45 GHz respectively is used. Proposed system is implemented in **OptiSystem**.

Chapter 5

Simulation

& Result

5.1.1 Working Principle of Analog &Digital Optical Radio over fiber

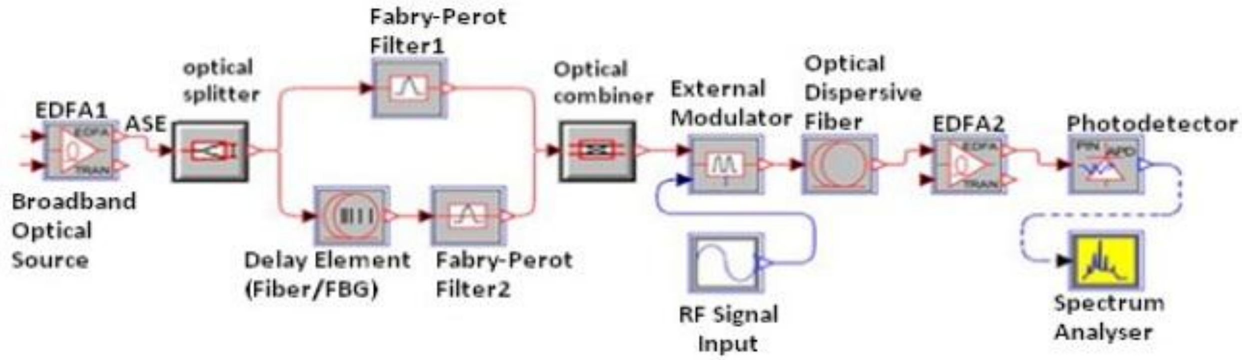


Figure 10: Radio over fiber Simulation Topology

In this figure a signal of Erbium doped fiber amplifier can be passed broadband optical source to optical splitter by ASE. Optical splitter is used for distributing signal to more than one optical receiver can degrade the overall RF performance of the analog fiber optical link. Then the signal reached to fabryperot filter 1. A signal passed to the fabryperot 2 & delay element. Then the signal goes to optical combiner. An optical combiner module with two input ports has been developed which is aimed at applications in Raman amplifiers, high-power optical amplifiers for DWDM (dense-wavelength-division multiplexing) systems, and ADM Then the signal goes to external modulator of RF input signal. External modulators allow the amount of light passed to vary from some maximum amount to some minimum amount. Then the signal can be sent to the optical dispersive fiber. Now the signal can be reached to Erbium doper fiber amplifier 2. Then the signal can be sent to the photo detector. Photo detector converts light signal to electrical signal. Then the signal can be reached to the spectrum analyzer measure the magnitude of an input signal versus frequency within the full frequency range of the instrument.

5.1.2 Output Result for 40 & 60 GHz Upstream

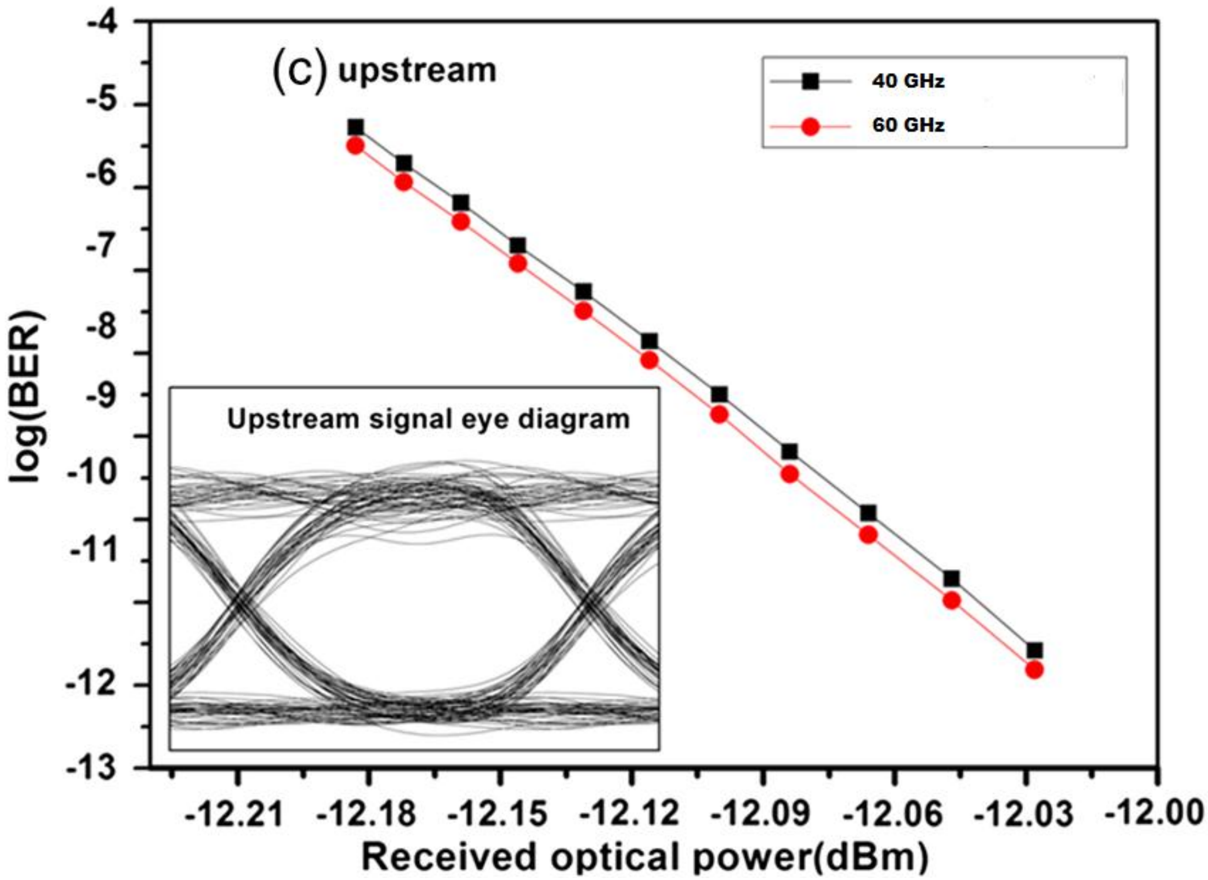


Figure 11: ROF Upstream signal Eye Diagram of 40 & 60 GHz

In this figure, shown in upstream signal eye diagram of bit error rate versus Received optical power for 40 & 60 GHz in Radio over Fiber (RoF) signal. In this figure 40 GHz symbol is black point & 60 GHz symbol is red point. The eye diagram analyzer block of the optisystem software displays multiple traces of a modulated signal to produce an eye diagram. In telecommunication, an eye pattern, also known as an eye diagram is an oscilloscope display in which a digital data signal from a receiver is respectively sampled and applied to the vertical input. While the data rate is used to trigger the horizontal sweep. It is so called because, for several types of coding the pattern looks like a series of eyes between a pair of rails. An open eye pattern corresponds to a minimal signal distortion of the signal waveform due to inter symbol interference (ISI) and noise appears as an eye diagram. When bit error rate -5.5 dB than received optical power is -12.05 dBm.

5.1.3 Output Result for 40 & 60 GHz Downstream

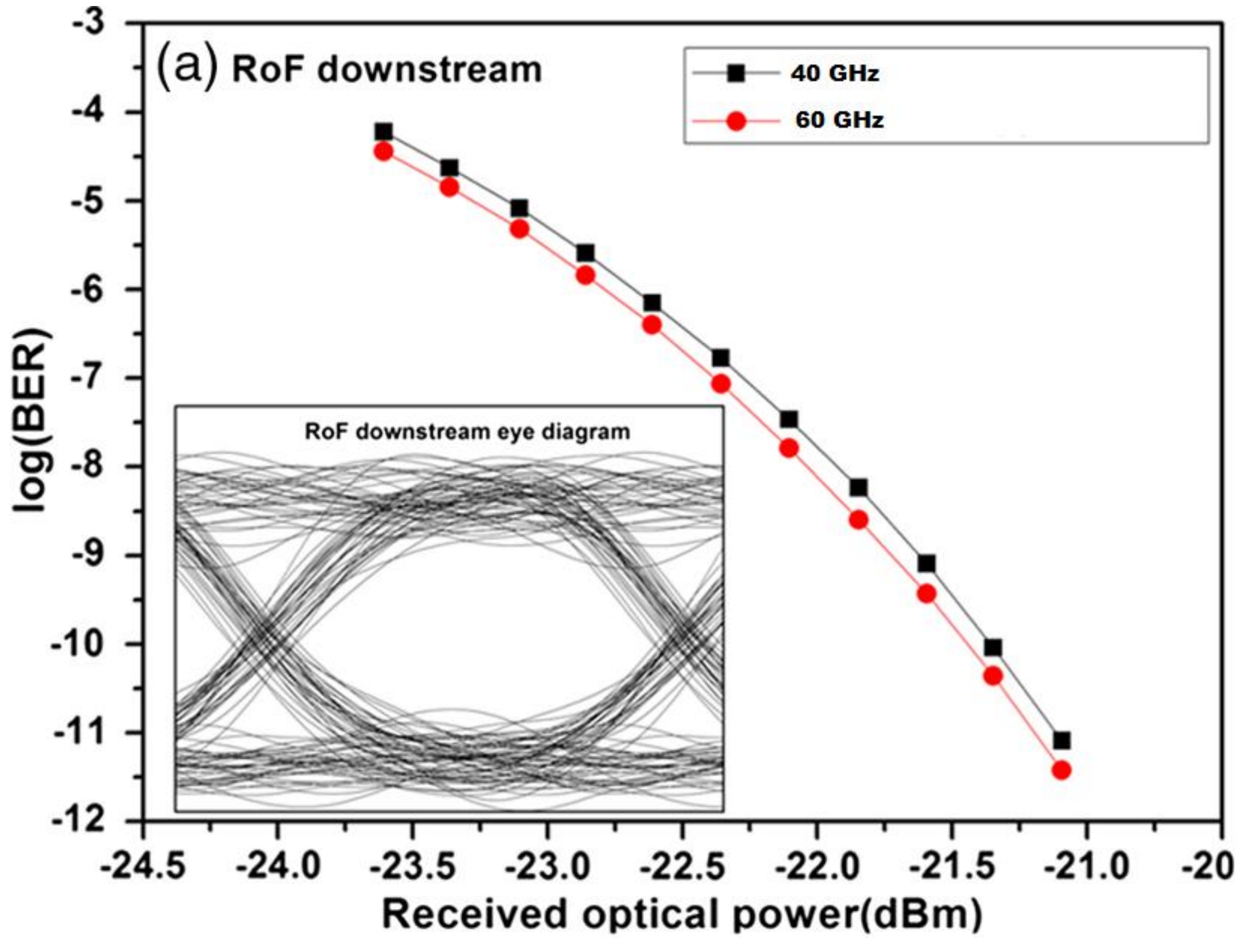


Figure 12: ROF Downstream signal Eye Diagram of 40 & 60 GHz.

In this figure, shown in downstream signal eye diagram of bit error rate versus Received optical power for 40 & 60 GHz in Radio Over fiber (RoF) signal. In this figure 40 GHz symbol is black point & 60 GHz symbol is red point. The eye diagram analyzer block of the optisystem software displays multiple traces of a modulated signal to produce an eye diagram. In downstream eye diagram we have calculate Bit error rate (BER) & Received optical power (dBm). In telecommunication, an eye pattern, also known as an eye diagram is an oscilloscope display in which a digital data signal from a receiver is respectively sampled and applied to the vertical input. While the data rate is used to trigger the horizontal sweep It is so called because, for several types of coding the pattern looks like a series of eyes between a pair of rails. In downstream when bit error rate -4 dB than received optical power is -21 dBm.

5.1.4 Simulation Result for 60GHz

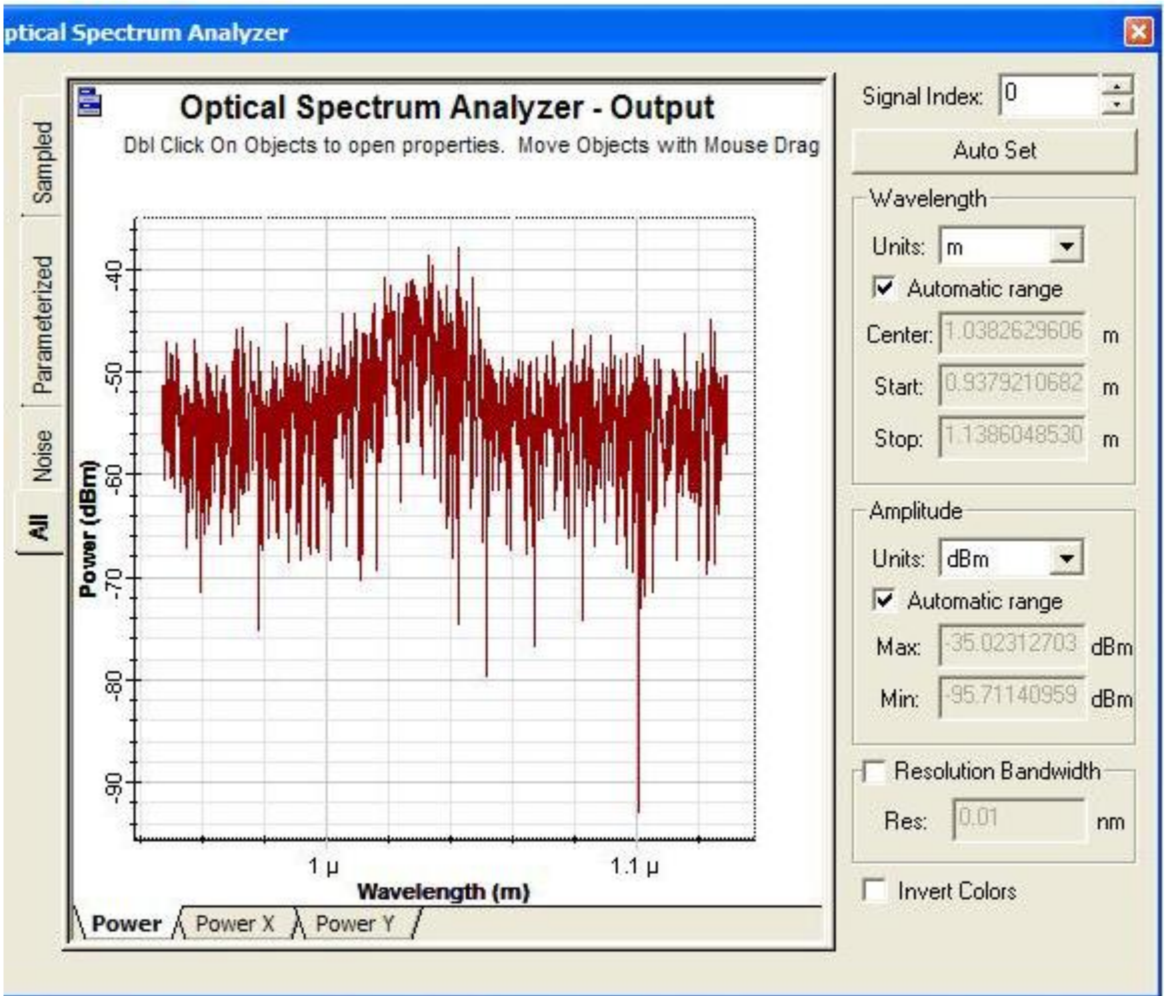


Figure 13: Optical Spectrum Analyzer Output for 60 GHz

In this figure shows that power (dBm) versus wavelength (m). In figure we calculate optical spectrum analyzer output for 60 GHz Radio over fiber signal. The wavelength center point is 1.0382629606 m and the starting point 0.9379210682 m, stop point 1.1386040959 m which all points are automatically range. The amplitude of the maximum point is -35.02312703 dBm and the minimum point is -95.71140959 dBm which point range is automatically. The resolution bandwidths have 0.01 nm in this figure. In this figure also shows that power have -40 dBm and wavelength does not exit to 1.1 micrometer.

5.1.5 Simulation Result for 40GHz

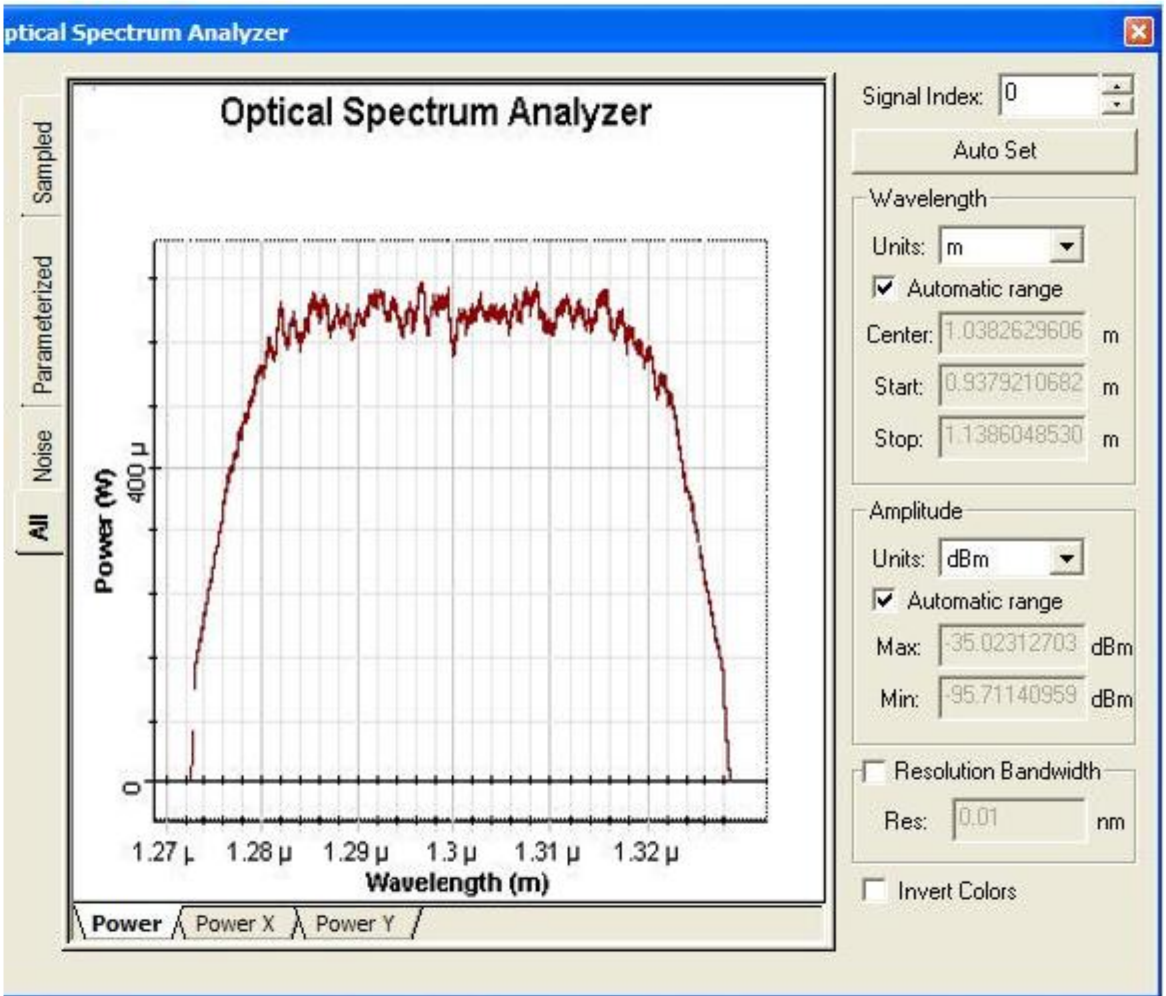


Figure 14: Optical Spectrum Analyzer Output for 40 GHz

In this figure shows that power (dBm) versus wavelength (m). In figure we calculate optical spectrum analyzer output for 40 GHz Radio over fiber signal. The wavelength center point is 1.0382629606 m and the starting point 0.9379210682 m, stop point 1.1386040959 m which all points are automatically range. The amplitude of the maximum point is -35.02312703 dBm and the minimum point is -95.71140959 dBm which point range is automatically. In this figure power 400 micrometer up and the wavelength does not exit to 1.32 micrometer.

Chapter 6

Conclusion

6.1. Conclusion

In conclusion a radio over optical fiber (ROF) has works in light signal can be modulated by radio signal than it can be transmitted fiber optics cable. In thesis we analysis analog & Digital radio over fiber performance in 40 & 60 GHz, we have proposed a simple ,cost effective ,and scalable rof architecture and experimentally demonstrated simultaneous generation and transmission of the upstream and downstream in base band of 40 and 60 GHz signal using optical Spectral analyzer. The generated RoF signal can also be demodulated by anoptical coherent receiver designed for optical baseband transmission, thus making the generatedsignal suitable for the dual purposes of optical

Appendix

Appendix A

Acronyms

AP	**Access** Point
BER	**Bit** Error Rate
BLER	Block Error Rate
BS	Base Station
CBR	Content Bit Rate
CDMA	Code Division Multiple Access
CIR	Carrier-to-Interference Ratio
CS	Control Station
CSMA	Carrier Sense Multiple Access
DFB	Decision Feedback
DSB	Double Side Band
DWDM	Dense Wave Division Multiplexing
EDFA	Erbium. Doped Fiber Ampler
EOM	External Optical Modulator
EAT	Electro absorption Transceiver
EMI	Electromagnetic Interference
FCC	Federal Communications Commission
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
GSM	Global System for Mobile Communications
IAPP	Inter-access-point Protocol
IF	Intermediate Frequency
IP	Internet Protocol
ITS	Intelligent Transportation System
ITU	International Telecommunication Union The former CCITT.
LED	Light Emitting Diode
LD	Laser Diode
LO	Local Oscillator
LOS	Line of Sight

MAC	Medium Access Control
MAHO	Mobile-Assisted Handover
MCHO	Mobile-Controlled Handover
MH	Mobile Host
NA	Numerical Aperture
NCHO	Network-Controlled Handover
NLOS	Non-Line of Sight
OADM	Optical Add/Drop Multiplexer
PD	Photo detector
PSC	Passive Star Coupler
QoS	**Quality** of Service
RF	Radio Frequency
ROF	Radio over Fiber
RSS	Received Signal Strength
RVC	Road Vehicle Communication
SDH	Synchronous Digital Hierachy
SER	Symbol Error Rate
SIR	Signal-to-Interference Ratio
SONET	Synchronous Optical Network
SRP	Spatial Reuse Protocol
SSB	Single Side Band
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TIM	Traffic Indication Map
UMTS	Universal Mobile Telecommunications System
WDM	Wave Division Multiplexing
WLAN	Wireless Local Area Network
A/D	Analogue-to-Digital
ACP	Adjacent Channel Power
ACP	Adjacent Channel Power
ADC	Analogue-to-Digital Converter

ADS	Agilent Distortion Suite
AM	Amplitude Modulation
AT	Alcatel Thales
ATT	Attenuator
AWG	Arrayed-Waveguide Grating
AWGN	Additive White Gaussian Noise
BB	Baseband
BER	Bit-Error-Rate
BPF	Band Pass Filter
BS	Base Station
BW	Bandwidth
CAPEX	Capital Expenditures
CCDF	Power Complementary Cumulative Distribution Function
CDMA	Code Division Multiple Access
CMS	Control And Management System
CMS	Control / Monitoring / Synchronization
CNR	Carrier-to-Noise Ratio
COTS	Commercial off the shelf
CPRI	Common Public Radio Interface
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CSR	Carrier-Suppression Ratio
CU	Central Unit
CW	Continuous Wave
CWDM	Coarse Wavelength Division Multiplexing
D/A	Digital-to-Analogue
DAC	Digital-to-Analogue Converter
DBWS	Distributed Broadband Wireless System
DC	Direct Current
DFB	Distributed Feedback
DL	Downlink
DML	Directly Modulated Laser

DR	Dynamic Range
DSP	Digital Signal Processing
DWDM	Dense Wavelength Division Multiplexing
E/O	Electrical-to-Optical
EDGE	Enhanced Data rates for GSM Evolution
EIRP	Effective Isotropic Radiated Power
EPON	Ethernet Passive Optical Network
ETSI	European Telecommunication and Standardization Institute
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
EVM	Error Vector Magnitude
FC/APC	Fixed Connection/Angled Physical Contact
FDD	Frequency Division Duplex
FDM	Frequency Division Multiplexing
FFT	Fast Fourier Transform
FPGA	Field-Programmable Gate Array
FUTON	Fibre Optic Networks for Distributed and Extendible Heterogeneous Radio Architectures and Service Provisioning
GPON	Gigabit-capable Passive Optical Network
GS	Giga Samples
GSM	Global System for Mobile Communications
GUI	Graphical User Interface
HSDPA	High-Speed Downlink Packet Access
IBI	Inter-Bin Interference
IEEE	Institute of Electrical and Electronics Engineers
IF	Intermediate Frequency
IFFT	Inverse Fast Fourier Transform
IIP3	3rd order Input Intercept Point
IM-DD	Intensity Modulation with Direct Detection
IP	Intercept Point
IQ	In-phase and quadrature
JPU	Joint Processing Unit

JPUe JPU	electrical part
LAN	Local Area Network
LMS	Least Mean Squares
LNA	Low Noise Amplifier
LO	Local Oscillator
LOS	Line-of-Sight
LTE	Long-Term Evolution
MAC	Medium Access Control
MCS	Modulation Coding Scheme
MDF	Medium Dispersion Fibre
MIMO	Multiple-Input Multiple-Output
MS	Mobile Station
MT	Mobile Terminal
MZM	Mach-Zehnder Modulator
NA	Network Analyser
NF	Noise Figure
NMSE	Normalized Mean Square Error
O/E	Optical-to-Electrical
OADM	Optical Add-Drop Multiplexer
OBSAI	Open Base Station Architecture Initiative
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency-Division Multiple Access
OPEX	Operational Expenditure
PA	Power Amplifier
PAPR	Peak-to-Average Power Ratio
PCB	Printed Circuit Board
PD	Photodiode
PHY	Physical
PI	Power Current
W-CDMA	Wideband Code Division Multiple Access
WDM	Wavelength Division Multiplexing

Wi-MAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WP	Work package

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