

# RADIO OVER FIBER FOR WIRELESS COMMUNICATION

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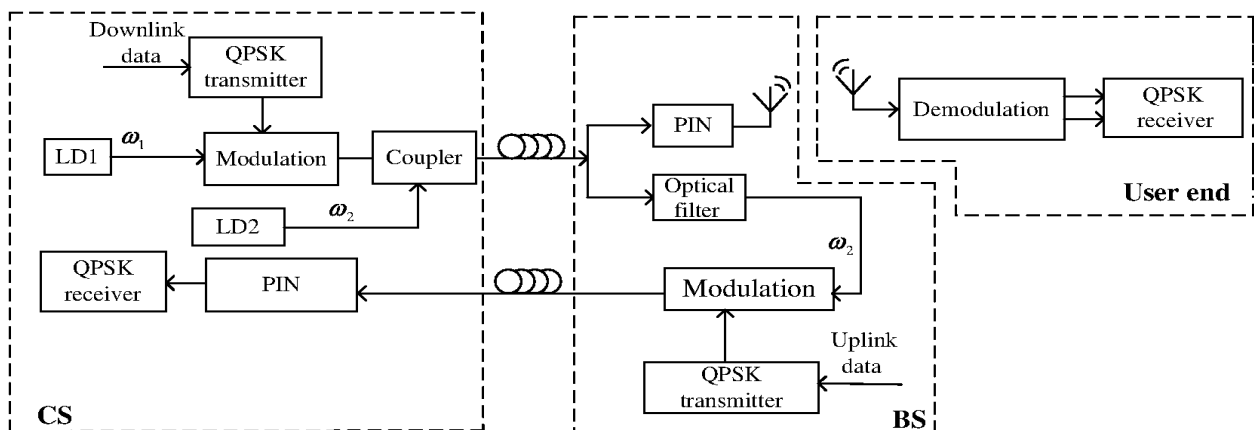
**ABSTRACT**

The demand for broadband services has driven research on millimeter-wave frequency band communications for wireless access network due its spectrum availability, and compact size of radio frequency devices. The millimeter-wave signals are affected by losses along the transmission as well as atmospheric attenuation. One of the solution to overcome these problems is by using low-attenuation, electromagnetic interference-free optical fiber. Radio-over-Fiber (ROF) is considered to be cost-effective, practical and relatively flexible system configuration for long-haul transport of mill metric frequency band wireless signals using multicarrier modulation OFDM.

**Keywords:** *Fast Fourier Transform, GSM, Orthogonal frequency division multiplexing, Radio over fibre, UMTS.*

**I. INTRODUCTION**

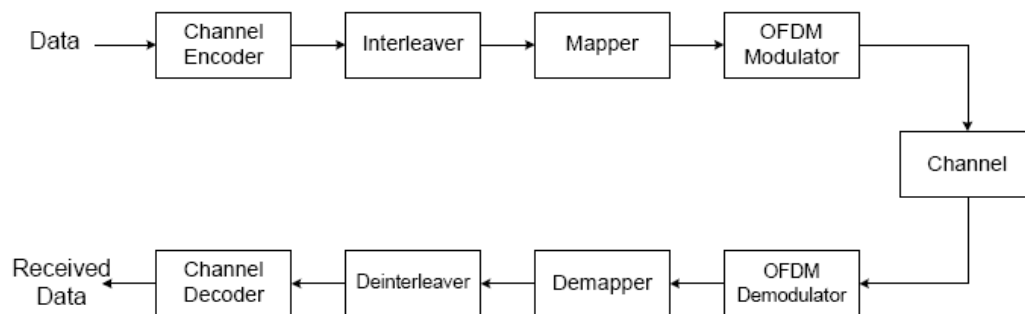
ROF is very attractive technique for wireless access network infrastructure, because transmission of microwaves and millimeter-waves through optical fibers for a long distance is very much simpler than the other existing techniques. ROF is a technic by which high frequency signals are transmitted by means of optical components. A ROF system consists of a Central Site (CS) and a Remote Site (RS)/user end connected by an optical fiber link or network. One of the major advantages of system requirements for ROF technology is the use simple and cost effective circuit [2].



**Fig.1.1 Block Diagram Of Radio Over Fibre**

The electrical signal distributed may be baseband data, modulated IF, or the actual modulated RF signal. The resulting optical signal is then carried over the optical fiber link to the destination station. Here, the data is converted back into electrical form by the photo detector. The block diagram of ROF is shown in figure 1.1. ROF link using a direct modulation scheme has been developed to support some important future wireless systems such as wireless local area networks (WLAN), intelligent transport systems (ITS), and the 4th generation cellular systems. The generated electrical signal must meet the specifications required by the wireless application be it GSM, UMTS, wireless LAN or other [3].

Orthogonal Frequency Division Multiplexing (OFDM) is best modulation technique for future broadband wireless communications because it provides increased robustness against frequency selective fading and narrowband interference, and is efficient in dealing with multi-path delay spread [9]. In this paper QPSK-OFDM is used as a modulation technique to transmit baseband signal over single mode optical fiber link. Laser diode and photodiode have been used optical modulator and optical demodulator respectively. The paper model has simulated using MATLAB software. The block diagram of OFDM is shown in Figure 1.2



**Fig. 1.2 Block diagram of OFDM Trans-receiver**

## II. BENEFITS OF RADIO-OVER-FIBRE SYSTEMS

ROF technology has several benefits such as reduced power consumption, large bandwidth that enables multiplexing of several radio channels, ability to use existing dark/dim fibers to transmit the radio signal (dim fiber can be used with WDM techniques), inherent immunity to electromagnetic interference and allowing for transparent operation because the RF to optical modulation is typically independent of the baseband to RF modulation.

### 2.1 Higher Immunity

Electrical distribution of high frequency microwave signals either in free space or through transmission lines is problematic and costly. An alternative solution is to use optical fibres, which offer much lower losses. Commercially available standard Single Mode Fibres (SMFs) made from glass (silica) have attenuation losses below 0.2 dB/km and 0.5 dB/km in the 1.5  $\mu\text{m}$  and the 1.3  $\mu\text{m}$  windows, respectively. Polymer Optical Fibres (POFs), a more recent kind of optical fibers exhibit higher attenuation ranging from 10 – 40 dB/km in the 500 - 1300 nm regions. These losses are much lower than those encountered in free space propagation and copper wire transmission of high frequency microwaves [4]. Therefore, by transmitting microwaves in the optical form, transmission distances are increased several folds and the required transmission powers reduced greatly.

**2.2 Large Bandwidth**

The enormous bandwidth offered by optical fibres has other benefits apart from the high capacity for transmitting microwave signals. Processing in the optical domain makes it possible to use cheaper low bandwidth optical components such as Laser Diodes and modulators, and still be able to handle high bandwidth signals [5,6].

**2.3 Immunity to Radio Frequency Interference**

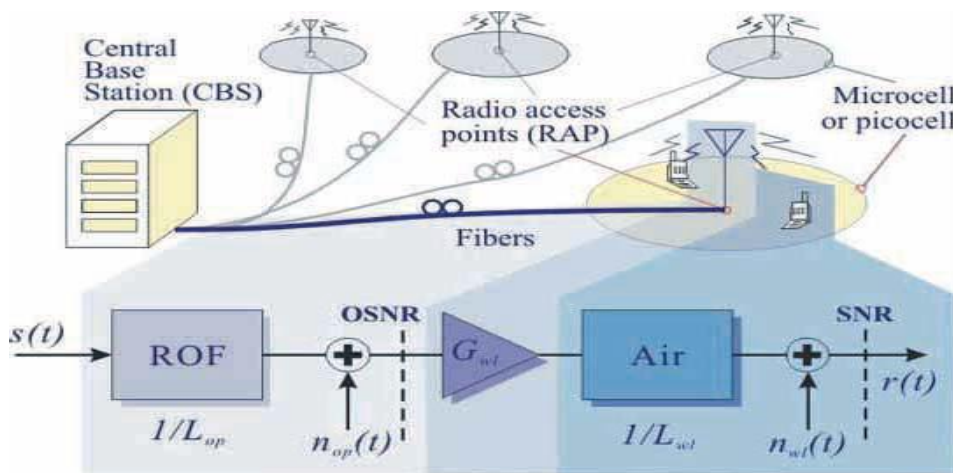
Immunity to electromagnetic interference is a very attractive property of optical fibre communications, especially for microwave transmission. This is so because signals are transmitted in the form of light through the fibre. Because of this immunity, fibre cables are preferred even for short connections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

**2.4 Easy Installation and Maintenance**

In ROF systems, complex and expensive equipment is kept at the Switching Centre (SCs), thereby making remote base stations simpler. For instance, most ROF techniques eliminate the need for a local oscillator and related equipment at the Remote Station (RS). This reduces the installation and maintenance cost. Easy installation and low maintenance costs of RS are very important requirements for mm-wave systems, because of the large numbers of the required antenna sites.

**2.5 Radio-Over-Fiber for Fi-Wi Systems**

The fiber-wireless solution for cellular networks is shown in Figure 2.1 (the fiber-wireless downlink). This solution increases the frequency reuse and enables broadband access by providing a micro/pico cell scenario for cellular radio networks.



**Fig.2.1 Fiber-wireless solution for cellular radio networks**

**III. SUPPORTING MULTIPLE WIRELESS STANDARDS**

Studying the effects of transmitting multiple wireless standards over a single ROF link can be very beneficial. Today, 4G wireless technologies have a bit rate up to 20 Mbps and wireless local area network (WLAN) technologies can provide a bit rate as high as 54 Mbps with IEEE 802.11. The integration of these two technologies can increase the bit rate available for applications, while maintaining reasonable mobility for end users.



## IV. ISSUES WITH THE FI-WI SYSTEM

Several observations can be made from Figure 2.1. First, signal processing should not be done at the Radio access point (RAP) for cost considerations. Therefore, compensation should be done at the portable unit or at the central base station. By performing most of the signal processing at the central base station, i.e. by asymmetric distribution of the complexity, the cost can be shared by many users and therefore helps reduce overall system cost.

Second, the compensation of the concatenated fiber-wireless channel should be handled jointly. This is a challenging task because of the time varying multipath wireless channel in series with the nonlinear optical channel. Furthermore, the uplink and downlink require different solutions.

The third issue with ROF is the nonlinear distortion of the optical link. This is due mainly to the laser diode used in a multiuser environment. Several approaches have been proposed to characterize and solve the problem of nonlinear distortion

## IV. SOLUTIONS FOR THE ISSUES

### 4.1 Nonlinearity Compensation

An adaptive baseband model for the ROF link was developed and two different pre-distortion schemes for the nonlinearity were proposed; one is currently being implemented in an FPGA platform. With the first scheme, the pre-distortion is done using a look-up table. In the second scheme, higher order adaptive filters are trained to inverse model the ROF link. With both of these approaches, simulation results show good performance improvement, but sometimes requiring a power back off. Asymmetric compensation is a scheme that allows for most of the signal processing to be done at the central base station. This is achieved by doing pre-distortion for the downlink and post compensation for the uplink.

### 4.2 Estimation and Equalization

Even though ROF provides an excellent broadband link allowing for the communication of several channels, the wireless channel introduces inter symbol interference (ISI) at high bit rates. Along with the nonlinearity, available linear dynamic range becomes a major concern, especially in the uplink [1]. A large linear dynamic range is required in the uplink, where the received signal first travels through the wireless channel (resulting in path losses, fading and shadowing) before entering the optical fiber. Several researchers address the issue where rapidly fading dispersive linear channels are estimated and equalized. However, in the Fi-Wi system, the ISI is coupled with the nonlinear distortion of the optical link, thereby demanding nonlinear channel estimation and equalization techniques [7].

#### 4.2.1 Estimation

In order to limit the effect of nonlinear and ISI distortions, estimation, and subsequently equalization, of the concatenated fiber-wireless system should be done. Estimation of the concatenated fiber-wireless channel is an important step towards equalization of the linear channel and linearization of the nonlinear channel. In our estimation algorithms we always consider both wireless channel noise and optical channel noise (quantum, thermal and relative intensity) which are shown in Figure 2.1 as  $n_{wL}(t)$  and  $n_{op}(t)$  respectively. It should be noted



that our identification was performed using multiple maximal-length pseudonoise (PN) sequences. This is a major advantage because multiple PN sequences are already widely used in spread spectrum communications.

#### 4.2.2 Equalization

Once the channel is estimated, an appropriate equalizer must be devised for the compensation of the linear and nonlinear parts. The fiber-wireless uplink is a Wiener system and therefore a Hammerstein type decision feedback equalizer (DFE) was developed to compensate for it. This equalizer compensates for the linear and nonlinear distortions separately. This modular architecture is attractive for commercial implementation [8]. The receiver consists of a polynomial filter, which inverse models the optical link, and a linear DFE arrangement that compensates for the wireless channel dispersion.

### V. APPLICATIONS OF RADIO-OVER-FIBER TECHNOLOGY

There are many applications of ROF technology. As portable devices and computers become more and more powerful as well as widespread, the demand for mobile broadband access to LANs will also be on the increase. This will lead once again, to higher carrier frequencies in the bid to meet the demand for capacity. For instance current wireless LANs operate at the 2.4 GHz ISM bands and offer the maximum capacity of 11 Mbps per carrier (IEEE 802.11b). Next generation broadband wireless LANs are primed to offer up to 54 Mbps per carrier, and will require higher carrier frequencies in the 5 GHz band. Higher carrier frequencies in turn lead to micro- and pico-cells [3].

The field of mobile networks is an important application area of ROF technology. The ever-rising number of mobile subscribers coupled with the increasing demand for broadband services have kept sustained pressure on mobile networks to offer increased capacity. Therefore, mobile traffic (GSM or UMTS) can be relayed cost effectively between the SCs and the BSs.

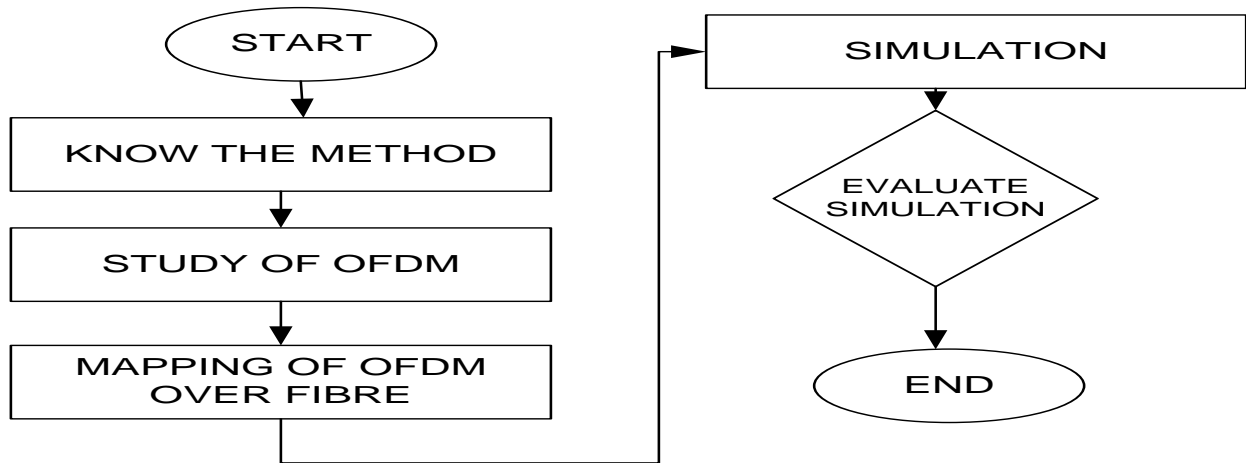
Satellite communications was one of the first practical uses of ROF technology. One of the applications involves the remoting of antennas to suitable locations at satellite earth stations. In this case, small optical fibre links of less than 1 km and operating at frequencies between 1 GHz and 15 GHz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

One of the major promising application areas of ROF systems is video distribution. A case in point is the Multipoint Video Distribution Services (MVDS). MVDS is a cellular terrestrial transmission system for video (TV) broadcast. It was originally meant to be a transmit-only service but recently, a small return channel has been incorporated in order to make the service interactive. MVDS can be used to serve areas the size of a small town. Allocated frequencies for this service are in the 40 GHz band. At these frequencies, the maximum cell size is about 5km. To extend coverage, relay stations are required [4].

The Mobile Broadband System or Service (MBS) concept is intended to extend the services available in fixed Broadband Integrated Services Digital Network (B-ISDN) to mobile users of all kinds. Future services that might evolve on the B-ISDN networks must also be supported on the MBS system. Since very high bit rates of about 155 Mbps per user must be supported, carrier frequencies are pushed into mm-waves. If ROF technology is used to generate the mm-waves, the base stations would be made simpler and therefore of low cost, thereby making full scale deployment of MBS networks economically feasible [7].

**VI. SIMULATION OF ROF TECHNOLOGY**

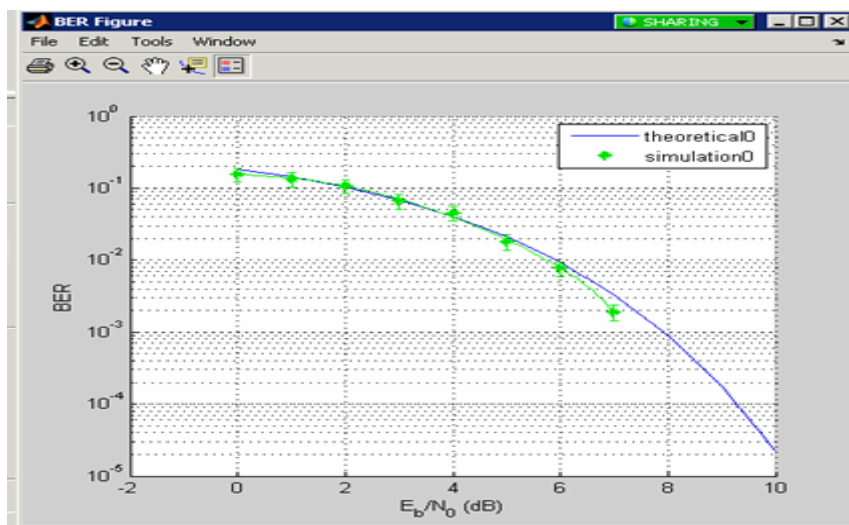
This paper shows the MATLAB simulation of ROF system. The first step to carry out this paper is the understanding Radio Over Fiber Technology and the second is Study an OFDM modulation technique. The next step is mapping the simulation model of OFDM over Fiber for wireless systems. Simulate and evaluate QPSK-OFDM transmitted and received signal, power spectrum and BER. The software used for the simulation is MATLAB. The methodology of this paper is presented in the following flowchart.



**Fig. 7.1 Flow Chart Of Proposed Algorithm**

**VI. RESULTS AND DISCUSSION**

In this paper result of the simulation model is shown by using MATLAB software, version 7. Figure shows Comparison between Theoretical and Simulation BER. Both of Theoretical and Simulation BER are close to each other. At the receiver the signal is filtered by the FFT stage, thus making the receiver noise free within the signal bandwidth. Increasing the cyclic prefix duration improves the BER performance for the OFDM system. The BER performance is in all cases improved by increasing the OFDM symbol length.



**Figure 8.1: Comparison between Theoretical and Simulation BER**



## VII. CONCLUSION

In today's modern world, the interconnection and interfacing of differing technologies are becoming commonplace. Therefore, gaining an understanding of how these interconnects and interfaces interact is critical to successful system design. . In order to meet this demand, a fiber based wireless access scheme using radio-over-fiber (ROF) technology is used and is discussed in this paper.

The system identification technique has been devised for a concatenated fiber-wireless channel, and has proposed various compensation schemes to equalize the time varying linear wireless plus static nonlinear optical channel. Also, it has been focused on supporting both cellular OFDM and IEEE 802.11 signals over the fiber-wireless channel. As well as performed various experimental studies on the ROF approach and have been working with optical and electrical signal processing for performance improvement. The deployment of optical fiber technology in wireless networks provides grate results obtained from the first part OFDM over AWGN channel which were close for expected results. The results of transmit QPSK-OFDM signal over fiber were good specially in the transmitter part but it still need to improve and as a result, the photodiode can used as optical demodulator with laser diode as optical modulator. The studying of OFDM modulation and radio over fiber technology became very important because both of them have been developed to support some important future wireless systems. Finally this paper was transmitting of QPSK-OFDM baseband signal over fiber and it is able to improve to transmit radio signal over fiber.

## VIII. FUTURE OF WORK AND RECOMMENDATIONS

The future work is to complement and extend the results further, it is recommended to add IQ modulator to the system, which will convert from baseband to RF signal then carried over optical fiber link. It is also recommended to enhance the BER for the signal transmitted over fiber by using Mach-Zehnder as optical modulator and photodiode as optical demodulator or modify the photodiode design to works well with laser diode. Most highly recommendation is to develop OFDM modulation and radio over fiber technology to support the 4th generation cellular systems. Finally, Based on the results and calculations which made in this paper, it should be in the interest to design an effective compensation technique so that a good quality and availability of the service is provided.

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