# Performance Comparison of Analog and Digital Radio Over Fiber Link

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*Abstract*— **In order to meet the ever increasing demand for larger transmission bandwidth, Wireless network based on radio-over-fiber technologies is a very beneficial solution. Various disadvantages of Analog Radio over Fiber link such as non-linearity, chromatic Dispersion can be mitigated by use of Digital Radio over Fiber link. A digitized RF-over-Fiber transmission scheme based on Bandpass Sampling theory is being introduced, Which provides mobility as well as large bandwidth. Comparison of Analog and digital Radio over Fiber is presented.**
**Bit Error Rate and Signal to Noise Ratio for various input schemes such as BPSK,QPSK and 16 QAM are analyzed for Analog and Digital link and comparison is presented. Digital Radio Over Fiber link shows improved performance in terms of Bit Error Rate. Presence and absence of Optical Fiber Link is also analyzed and discussed.**
**Keywords- Bandpass Sampling, Chromatic Dispersion,Fiber wireless, Central Office, Optical fiber , Dynamic Range**

## I. INTRODUCTION

Radio Over Fiber (ROF) system is a hybrid architecture of optical fiber and wireless systems. The key requirements of future generation broadband access like large operating bandwidth, Mobility and high flexibility can be well met by integration of Fiber and wireless networks[1]. The most widely used technology behind Fi-Wi is the radio-over-fiber (RoF) technology. Various advantages of ROF are:-

- Simple configuration
- It is independent of modulation format and protocol.
- It is useful for future flexible and high capacity access networks
- High bandwidth and Low Attenuation
- It is immune to Electromagnetic Interference (EMI)[2].

The paper is organized as follows: Section II gives an overview of Fiber wireless network ,Section III discusses the Analog radio over Fiber Link. Section IV describes Digital Radio over fiber link.Section V and VI describes OFDM and Chromatic Dispersion respectively.Section VII focusses on Proposed system of DROF. Section VIII displays the results and discussion of all the results is presented in Section IX. Paper concludes with section X.

## II. ARCHITECTURE OF FIBER WIRELESS NETWORK

Fiber Wireless network refers to the integration of optical fiber and wireless broadband infrastructures.ROF refers to the transmission of radio frequency signal from the central office(CO) to the base station (BS) over optical fiber and using wireless communication for the transmission between the base station and the custom user as shown in Figure 1.

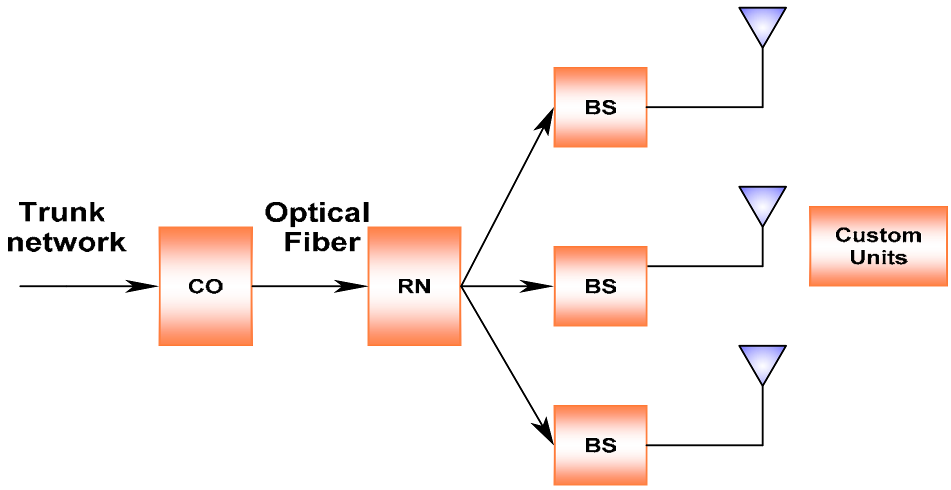


Figure 1. Architecture of Fiber wireless network [3]

Central Office(CO) is connected to the various Bs's via Route nodes(RN's) connection between CO and BS is through the optical fiber. Advantage of this system is that it combines the capacity of optical networks with the flexibility and mobility of wireless networks to provide broadband multimedia access[3]

## III.DIGITIZED RADIO OVER FIBER LINK

### *A. Digital Radio Over Fiber Link (DROF)*

Disadvantages of Analog Optical links are:-

• It inherently suffer 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[5]

Advantages of Digital optical links are [6]

• 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.

### *B. Orthogonal Frequency Division Multiplexing (OFDM)*

Orthogonal Frequency Division Multiplexing(OFDM) is based on the principle of transmitting simultaneously many narrow-band orthogonal frequencies, called OFDM subcarriers or subcarriers. Different digital modulation schemes are used for frequency channel [7]. The attraction of OFDM is mainly due to how the system handles the multipath interference at the receiver. Multipath generates two effects: frequency selective fading and intersymbol interference (ISI).The "flatness" perceived by a narrow-band channel overcomes the former, and modulating at a very low symbol rate, which makes the symbols much longer than the channel impulse response, diminishes the latter. Using powerful error correcting codes together with time and frequency interleaving yields even more robustness against frequency selective fading, and the insertion of an extra guard interval between consecutive OFDM symbols can reduce the effects of ISI even more. Thus, an equalizer in the receiver is not necessary. Each frequency channel is modulated with a different digital modulation The frequency bandwidth associated with each of these channels is then much smaller than if the total bandwidth was occupied by a single modulation.

Advantages of OFDM are [7]

- OFDM is spectrally efficient
- Subcarriers are orthogonal to each other as a result
- Intercarrier interference is avoided. Frequency of each subcarrier is small and time period is small and as a result OFDM is immune to multipath interference

## III. PROPOSED DIGITIZED RADIO OVER FIBER LINK

### A. *Block Diagram*

Figure 2 and Figure 3 illustrates Digital Radio over Fiber link. A digitized RF-over-fiber (DRoF)is being proposed which uses technique based on Bandpass Sampling. Inorder to avoid Aliasing effect and to assure exact reconstruction of the signal, sampling rate for Bandpass Sampling should strictly follow the rules given in [8].

### B *Uplink Transmission*

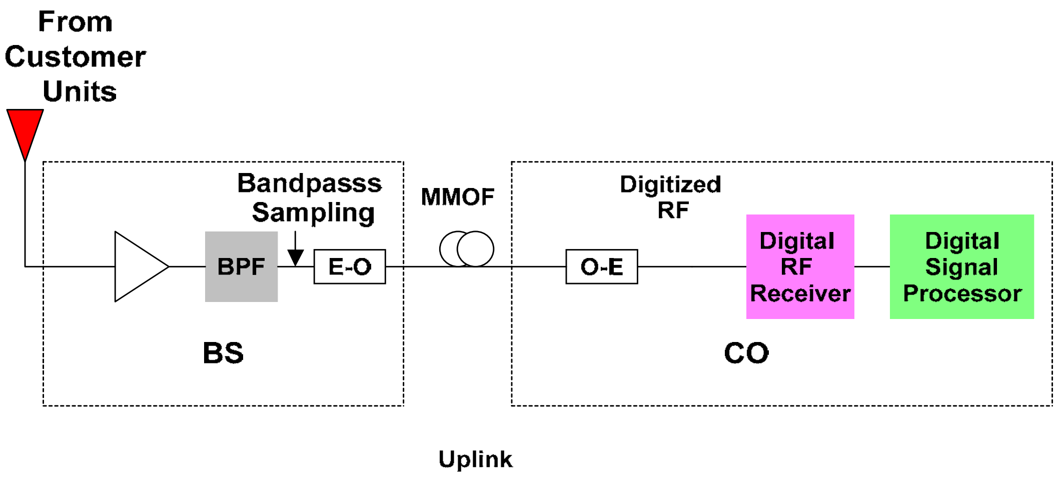


Figure 2. Proposed Digitized Radio over Fiber (DROF) Uplink[3,6]

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 Bandpass 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 bandpass filter (BPF).

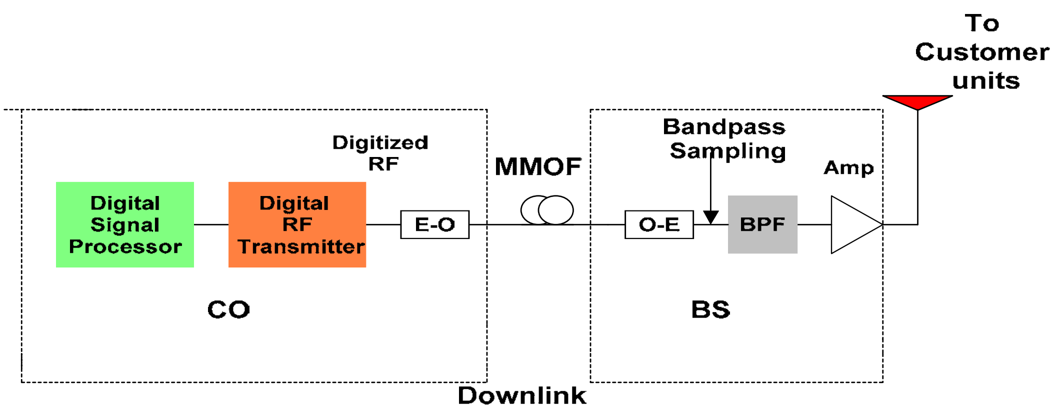


Figure.3.Proposed Digitized Radio over Fiber (DROF) Downlink[3,6]

Figure 3 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 bandpass sample microwave signals from wireless system such as WiMAX 802.16a. The modulation format specified in WiMAX 802.16a is 16 QAM with a symbol rate of 125 Msymbols/s [4].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.Mutimode optical fiber is used. Maximum and Minimum frequency of 2.5 GHz and 2.45 GHz respectively is used. Proposed system is implemented in MATLAB

### *C. Uplink Transmission*

Bandpass Sampling is used to digitize the passband microwave signals,. The choice of sampling frequency is dependent on the maximum and minimum frequencies of the bandpass microwave signal, which are defined as fmax and ,fmin respectively. To ensure the exact reconstruction of the bandpass signal and prevent spectral aliasing upon sampling, must satisfy the following relationships [8]

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

$$1 \leq n_z \leq I_g\left[\frac{f_{max}}{f_{max} - f_{min}}\right] \qquad (3)$$

Where $n_z$ is an integer, fmax-fmin is the signal bandwidth of the passband 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 Bandpass Sampling is that it must be able to effectively operate on the highest frequency component of the passband modulated signal while performing the sampling function at a sampling rate greater or 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 Equations (2) and (3)

## IV.RESULTS

### *A. Analog and Digital links Results*

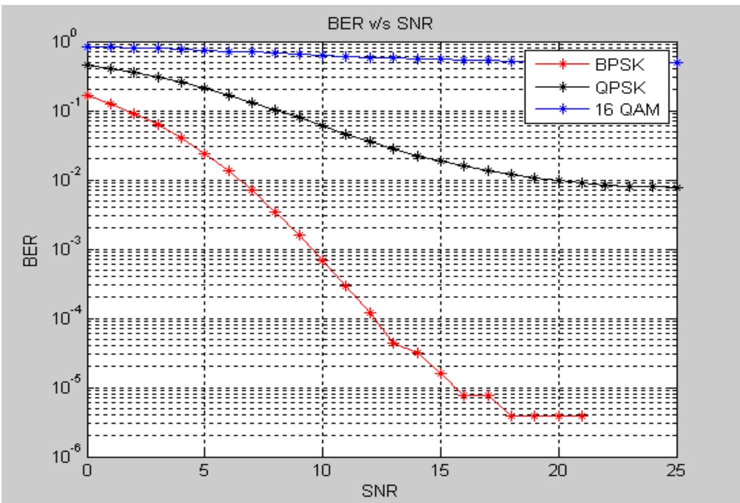


Figure 4. Graph of BER v/s SNR for Analog Link

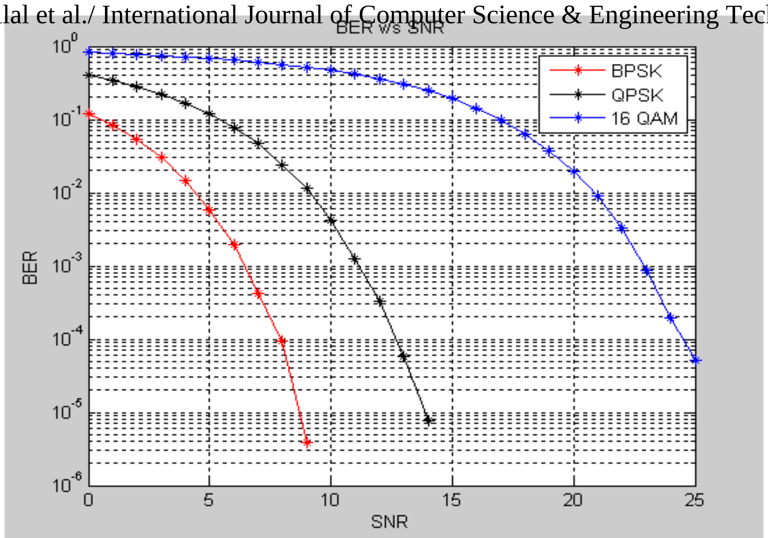


Figure.5. Graph of BER v/s SNR for Digital Link

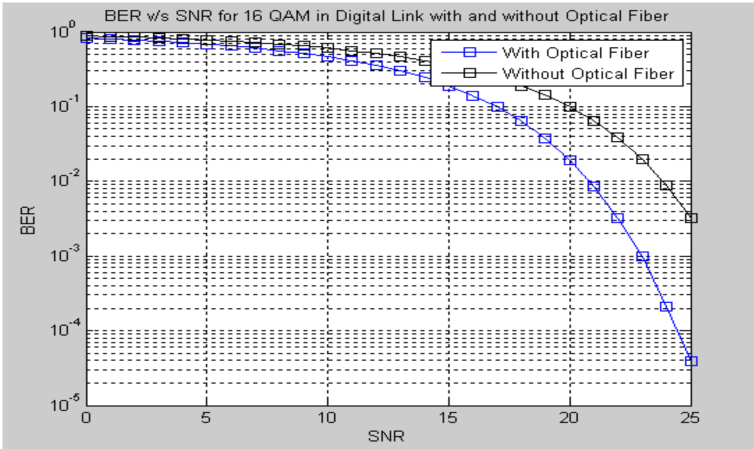


Figure 6.Graph showing variation of BER v/s SNR for Digital link with and without Optical Fiber

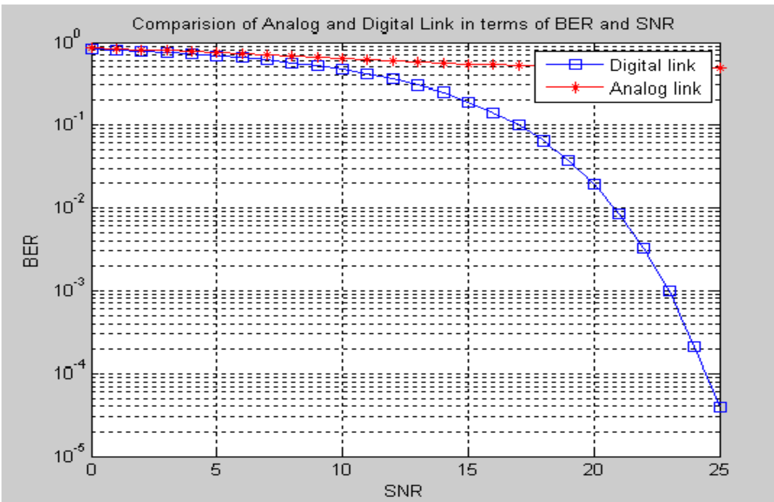


Figure 7.Graph showing Comparison of Digital Link and Analog Link in terms of BER v/s SNR

## V. DISCUSSION OF RESULTS

Figure 4 shows BER v/s SNR Plot for Analog Radio Over Fiber link. Modulation schemes like BPSK, QPSK and 16 QAM are used. It is found that BER for 16 QAM is more as compared to BPSK and QPSK which agrees with the literature. For BPSK when SNR=15, BER=0.000176, For QPSK, BER=0.035914,For 16 QAM BER is high and has a value of 0.5907.BER of 16 QAM is more as compared to BPSK and QPSK in Analog link

Figure 5 shows BER v/s SNR for Digital Link. Various modulation schemes such as BPSK, QPSK and 16 QAJM are discussed with regards to their performance that is BER v/s SNR. In Digital link 16 QAM shows improved performance as compared to Analog link. For SNR=25, BER $3.91 \times 10^{-5}$ bps as compared to

0.49743 in Analog Link

Figure 6 shows variation of BER v/s SNR for 16 QAM for Digital link with and without Optical Fiber. It discusses the effect on BER in the absence and presence of Optical Fiber Link. The modulation scheme discussed is 16 QAM. It is clear that System shows improved performance when there is presence of Optical Fiber which is seen by decrease in BER. When Optical fiber is included in the Digital link the BER is decreased drastically which is an indication of improved performance. For SNR=25dB, BER = $3.91 \times 10^{-5}$ with optical fiber. When there is absence of optical Fiber the BER increases to 0.003434 showing degraded performance. Figure 7 shows Comparison of Digital Link and Analog Link in terms of BER v/s SNR The graph is shown for 16 QAM case. It is seen that when Analog Radio over Fiber link is used for SNR=25 dB, BER has very high value of 0.48982.For Digital link the performance is greatly improved which is seen by low value of BER. For SNR=25dB the BER is $3.91 \times 10^{-5}$.For all the values of SNR the Analog Link shows degraded performance as compared to Digital Link.BER of Analog Link does not show drastic decrease as the SNR of the link is increased from 0 to 25.In contrast Digital Link shows improved performance where BER decreases from a value of 0.82588 for SNR=0 to a value of $3.91 \times 10^{-5}$ for SNR=25.

## VI. CONCLUSION

The digitized RF-over-fiber (DROF) link based on the bandpass sampling is a high performance digital optical links. This link not only combines the features of Large Bandwidth, Flexibility and Mobility but also simplifies the architecture of the base stations.In this work, a system modeling of a complete optical link with different digital modulation front ends are investigated. The study brings out the BER possible in all the three cases of modulation (BPSK,QPSK and 16-QAM) for a multimode fiber.Optical Fiber is optimized for less chromatic Dispersion so that pulse spreading is kept minimum and then used in the proposed system.

AROF and DROF links are compared and it can be concluded that Bit Error Rate (BER) of Digital link is less as compared to Analog link and hence has superior performance. BER of BPSK is seen to be less than QPSK and 16 QAM in Analog as well as Digital Link. Performance of BPSK is improved as regards to BER even though it is spectrally less efficient.

It is also seen that presence of optical Fiber in the Digital link shows a improved performance in terms of BER. Digital Link with Optical Fiber shows improved performance where BER is low as compared to the absence of Optical link. When the optical link is absent Digital link shows degraded performance with regards to BER.

Though Noise resilience of BPSK is slightly higher than that of 16 QAM, because of its spectral efficiency 16 QAM is better choice for Digital Link.

Digital Radio over Fiber shows improved performance over Analog link. Greater the data symbol modulation the more is the spectrum efficiency but less is the system robustness. The high dynamic range of the digitized RF transport offers a distinct advantage over analog RoF links

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