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Digital Radio Over Fiber Link to Overcome Impairments in Fiber Wireless Networks

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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. This architecture provides flexibility,mobility and high Bandwidth. A digitized RF-over-Fiber transmission scheme based on Bandpass Sampling theory is being introduced. Various Impairments of Analog Radio over Fiber link such as nonlinearity , Intermodulation distortion,chromatic Dispersion can be mitigated by use of Digital radio over fiber link. Comparison of Analog and digital radio over fiber is presented. BER and SNR for various input schemes such as BPSK,QPSK and 16 QAM are analyzed for Analog and Digital link and comparison is presented. Impairments of Fiber wireless networks such as nonlinearity is being overcomed by using Digital Radio over Fiber link.

***Keywords*: Bandpass Sampling, Chromatic Dispersion, Fiber wireless, Central Office, 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]. Transmission of analog signals on this system requires high-quality performance on the linearity and dynamic range of the optical link. There are also 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. 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 describes Digital Radio over fiber link. Section IV describes Chromatic Dispersion. Section V focuses on Proposed system of DROF. Section VI displays the results and discussion of all the results is presented in Section VII. Paper concludes with section VIII.

II.ARCHITECTURE OF FIBER WIRELESS NETWORK

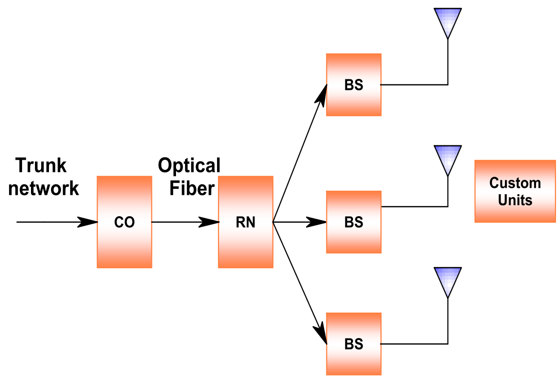

Figure 1. Architecture of Fiber wireless network [3]

Fiber Wireless network leads 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 Fig 1. 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.DIGITAL RADIO OVER FIBER LINK (DROF)

The transmission of analog signals requires high-quality performance on the linearity and dynamic range of the opticallink.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]

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

- Large BW optical link is achieved

- Dynamic range is 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

IV CHROMATIC DISPERSION

Chromatic dispersion refers to the wavelength-dependent pulse spreading that occurs as the optical signal propagates along the fibre. The two contributing factors to chromatic dispersion are material Dispersion and Waveguide Dispersion. The dependence of the fibre material's refractive index on the wavelength is referred to as material dispersion. The waveguide dispersion occurs due to dependency of the propagation constant on the wavelength. The effect of this dispersion is that different spectral components arrive at slightly different times, leading to wavelength-dependent pulse spreading, or dispersion.The pulse spreading due to chromatic dispersion is then given by

$$\Delta T = D(\lambda).\Delta\lambda.L \qquad (1)$$

where $D(\lambda)$ is the dispersion parameter (in ps/nm· km). This parameter tells us how many picoseconds the pulse broadens per kilometer of fiber per nanometer of pulse spectral, $\Delta\lambda$ is the spectral width of the light source, and L is the length of the fibre. Thus, the broader the spectral width, the greater is the dispersion.

V.PROPOSED DIGITIZED RF OVER FIBER LINK

Fig 2 and Fig 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 [7,8]

A.Block Diagram of Uplink Transmission

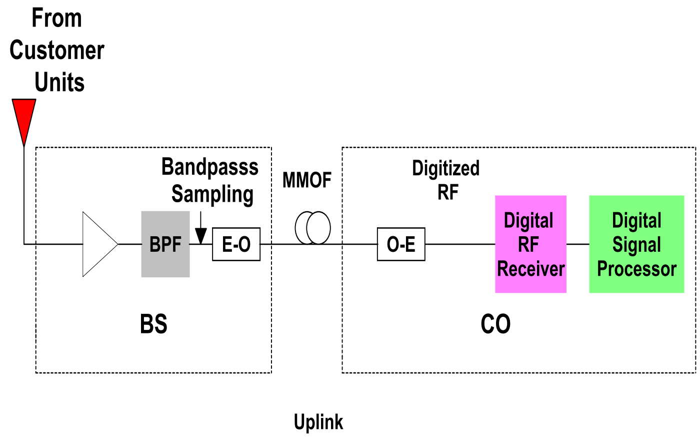

Figure. 2.Proposed Digitized Radio over Fiber (DROF) Uplink[3]

The uplink transmission is from BS to CO as shown in Fig 2. 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)

B.Block Diagramof Downlink Transmission

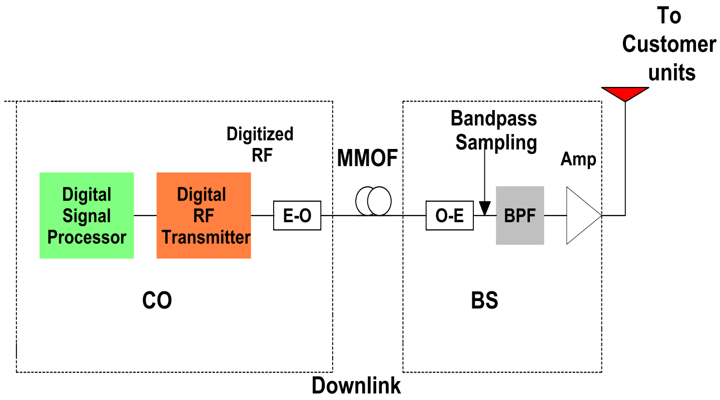

Figure.3.Proposed Digitized Radio over Fiber (DROF) Downlink[3]

Fig 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 inWiMAX 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. Bandpass Sampling

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 [7,8]

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

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

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 $f_{max}/f_{max} - f_{min}$.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) For the modeling of a-profile multimode fiber channel results described in [9],[10] are being used.In this analysis, class of a-profile multimode optical fibers with negligible mode mixing is used. The propagation of cladding modes is assumed negligible and fiber is assumed to be relatively lossless. For MMOF channel, the output intensity spectrum $I_0(f)$of the channel in terms of the input intensity spectrum $I_i(f)$ is

$$I_0(f) = [H(\Omega)]^2 I_i(f) \qquad (4)$$

Here $[H(\Omega)]$ is field intensity transfer function. The $[H(\Omega)]^2$magnitude squared of field intensity transfer function is required in order to relate the input field intensity spectrum to the output field intensity spectrum.

VI. RESULTS

A. Chromatic Dispersion Results

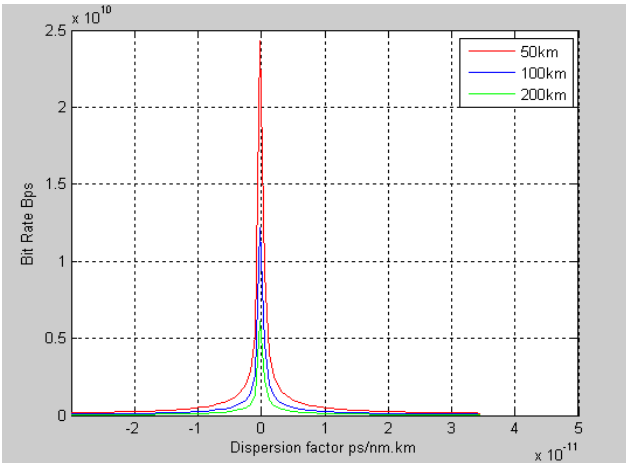

Figure. 4. Bit Rate v/s Dispersion factor, D ps/nm,km

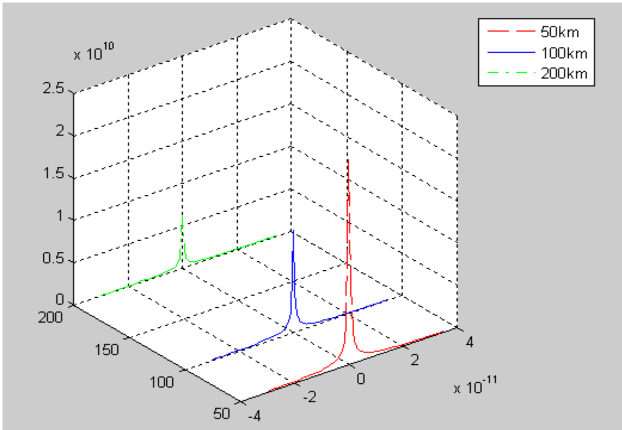

Figure 5.Variation of Bit Rate v/s D and Fiber Distance

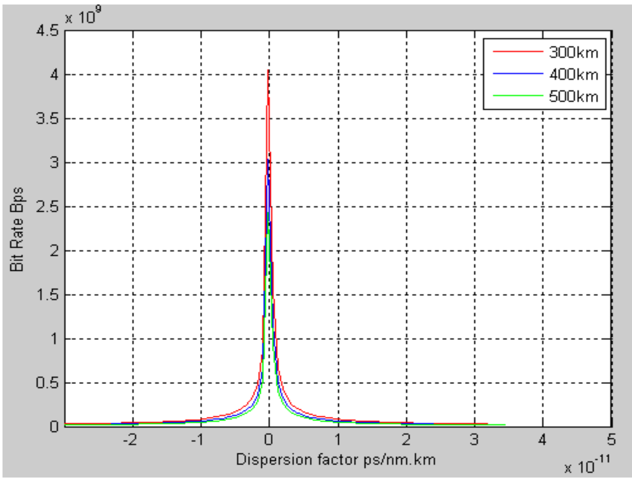

Figure 6.Bit Rate v/s Dispersion factor, D ps/nm,km

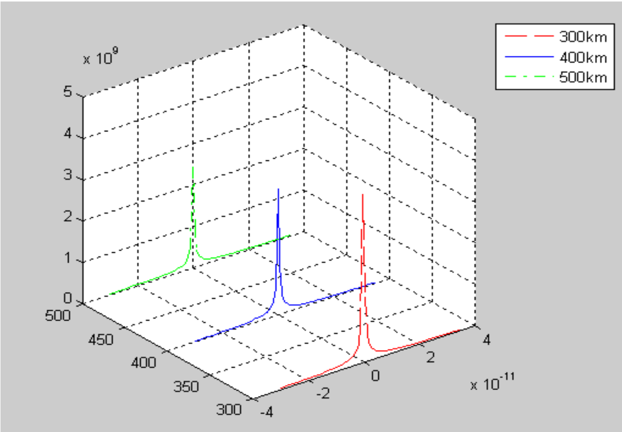

Figure 7.Variation of Bit Rate v/s D and Fiber Distance

B. Analog and Digital link results

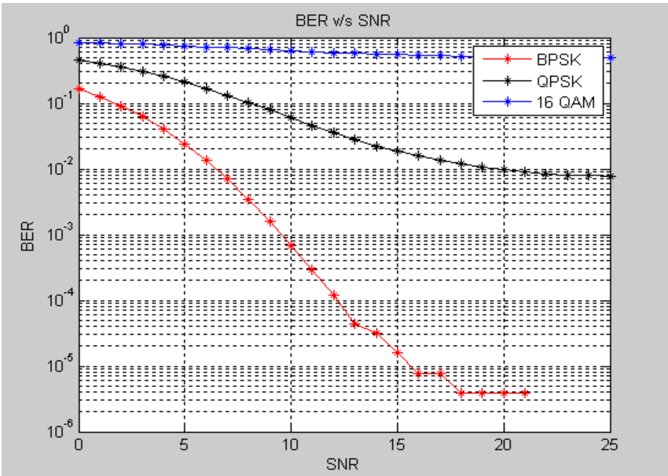

Figure 8. Graph of BER v/s SNR for Analog Link

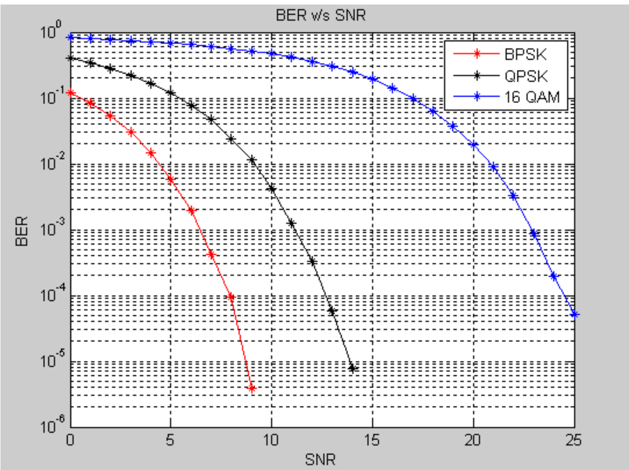

Figure 9. Graph of BER v/s SNR for Digital Link

VII. DISCUSSION OF RESULTS

Fig 4 shows variation of Bit rate v/s Dispersion factor (D) for Fiber lengths (L) of 50,100,200 kms .As D increases for a particular length, bit rate goes on decreasing. Bit rate is maximum when D is Zero.It is seen that Bit Rate is maximum for 50 kms (24Gbps) and Minimum for 200 Kms (7Gbps).For L= 100 Kms Bit rate= 12 Gbps.
Fig 5 shows variation of Bit rate v/s D and fiber lengths of 50,100,200 kms.As L increases , ΔT increases according to the Eq (1) and more and more pulse Spreading takes place .Increased pulse spreading is an indication of increase in D.As pulse spreading increases,Bit Rate goes on decreasing
Fig 6 shows variation of Bit rate v/s Dispersion factor (D) for Fiber lengths (L) of 300,400,500 kms.As D increases for a particular length, bit rate goes on decreasing.It is seen that Bit Rate is maximum for 300 kms (4Gbps) and Minimum for 500 Kms (2.3 Gbps).For L= 400 Kms ,Bit rate= 3Gbps. It is clear from the results that system shows degraded performance in terms of Bit Rate as length increases.

B. BER v/s SNR for Analog and Digital Link

Fig 8 shows BER v/s SNR Plot for Analog 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=$10^{-4.8}$,For QPSK,BER=$10^{-1.8}$,For 16 QAM BER is high.BER of 16 QAM is more as compared to BPSK and QPSK in Analog link
Fig 9 shows BER v/s SNR for Digital Link.In Digital link 16 QAM shows improved performance as compared to Analog link.For SNR=25,BER is $10^{-4.4}$ bps

VIII. CONCLUSION

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.The value of Dispersion factor is less when the fiber length is less and hence the Bit rate is more. As the length of the fiber increases the pulse broadening increases and hence decreases the Bit rateAROF and DROF links are compared and it can be concluded that 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.BPSK stands out for its BER even though it is spectrally less efficient. 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

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