International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 10 | Oct - 2021 ISSN: 2582-3930

INVESTIGATING O-OFDM SIGNAL BY VARYING CYCLIC PREFIX AND RAMAN AMPLIFIER GAIN

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ABSTRACT: To achieve the objective of investigating the O-OFDM system performance, a single channel system is utilized at 10-Gbps data rate by varying the cyclic prefix values. Also the effect of Raman Amplifier is established for the proposed system set-up. Raman amplifier's pump power is varied and different results are investigated by varying fiber length using simulation tool. Gain variation of Raman amplifier is observed by increasing the pump power values and it is observed that system performance is enhanced with incrementing the pump power values. Also it is revealed that transmission distance is increased by applying a Raman amplifier. Further the effect of cyclic prefix variation is observed on received power (electrical).

Key Words: Optical Orthogonal Frequency Division Multiplexing (O-OFDM), Cyclic Prefix (CP), Raman Amplification, Received Optical Power, Fiber Length.

1. INTRODUCTION:

OFDM is a leading technique in the optical fiber communication domain for solving the problems related to higher data rates. Numerous signal conditioning constraints are utilized for fault detection in the optical systems [1]. Recently, Optical-OFDM transmission has seen a dramatic increase in interest. It has great potential for improving the transmission of next generation networks. Meanwhile, research in field of optical OFDM presents many opportunities as well as challenges in areas like DSP algorithms, rapid photonic and electronic ICs etc. OFDM is used to transmit a high-speed serial data by separating this data into parallel form and then Fourier transform is used for encoding this data on individual sub carriers [2]. Above 10 Tb/s transmissions rate is achievable in single channel optical systems. Authors reported 10.8 Tb/s of transmission rate utilizing single channel optical transmitter as well as all optical DFT receivers [3]. To overcome the various losses of the long distance transmissions, fiber amplifiers are utilized. First use of Raman Optical Amplifier (ROA) is reported [4]. Phase modulation can be utilized to implement OFDM systems. System distortion is normally increased when distance is increased but implication of Raman amplifier can greatly reduce this distortion. Thus Raman amplifier can increase transmission distance without any decline in power also system noise is greatly reduced [5]. Different optical OFDM forms are observed that are suitable in designing optical camera communication (OCC) networks. A comparison of BER versus SNR is established for the proposed OCC system with diverse clipping factors such as 0.7, 1.4, and 2.6. This research focuses on designing the OCC systems that introduces the clipping noise and SNR gain by choosing an optimal clipping factor [6]. For high speed transmission of data, RoF system can be used with OFDM modulation for long haul as well as short distance networks. Research work examines the feasibility of OFDM over RoF modulation system. Among various modulation techniques, a fair level of distinction is achieved by OFDM [7]. Optical-OFDM is very promising technique for future generation high speed data transmission networks. OFDM is a unique technique of FDM that is multi-carrier-modulation (MCM). OOFDM system is examined using several cyclic prefix lengths for eliminating the

ISI and ICI effects. Whereas, different effective area values of optical fiber are utilized for observing the bit error rate (BER) of proposed system [8]. In another research, a coherent optical OFDM system is investigated with different cyclic prefix lengths and different effective areas for achieving high bit rates and long haul transmission for a single mode fiber. System performance is deliberated in terms of BER, OSNR, and SNR. The optimal BER value is achieved as $75*10^{-6}$ and cyclic prefix is obtained as 1/16 (6.25%) along with effective area of 150 μm^2 [9]. Optical phase conjugation (OPC) is a technique that is applied for boosting the system performance of long-haul communication by eliminating the fiber nonlinearity impairments. Nonlinear distortion is mitigated in OPC by the introduction of backward Raman amplifier to the conjugator. The performance of Raman-enhanced OPC is investigated in back-to-back (BTB) transmission system with 3 × 25 Gbaud O-OFDM signals. Raman amplification is boosting the system nonlinearity tolerance to achieve 3-dB output power improvement, 2.4-dB Q factor improvement in the, and 6-dB input dynamic range improvement [10]. Fiber optical parametric amplifiers (FOPAs) due to their superior gain bandwidth product, high gains, and comparatively low value of noise figure are particularly useful as future optical amplifiers. Recently, FOPAs, working on the basis of Four-Wave Mixing phenomenon occurring in the optical fiber, is getting a great attention because these are providing broadband amplification and easily replacing the erbium-doped based fiber amplifiers [11].

In this paper, **Section 1** describes the comprehensive literature review of various papers published by different authors on optical-OFDM. The simulative model is presented in **Section 2**. Various results and their discussions are described in **Section 3**. Finally, **Section 4** provides a conclusion of the proposed research work

2. SIMULATION MODEL FOR OPTICAL-OFDM SYSTEM

To achieve this objective of the proposed research work, Optical-OFDM system is simulated by using the Raman amplifier. Different Raman amplifier parameters are utilized for evaluating the system design in terms of transmission distance and received optical power. **Fig. 1** provides five main blocks utilized for designing an optical-OFDM system.

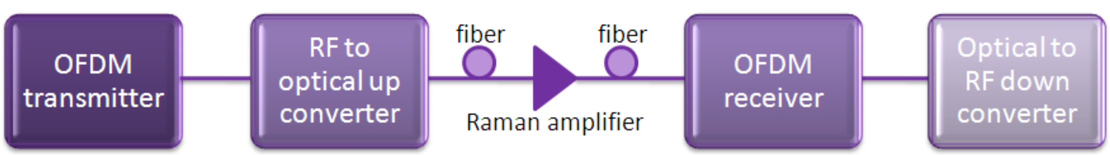

Figure 1: Optical-OFDM system schematic

Optical-OFDM simulation model is depicted by **Fig. 2.** Phase modulator is acting as an exterior modulator for up-converting the radio frequency signal into the optical domain. CWL (Continuous wave laser) usually operate at 193.4 THz frequency with 0 dBm optical power and line width of 10 MHz full width at half maximum. A 3dB constant loss is introduced by the phase modulator. The amplification of optical signal is obtained by utilizing a Raman amplifier. For obtaining the Raman amplification, a co-propagating pump is utilized in which uses single pumping.

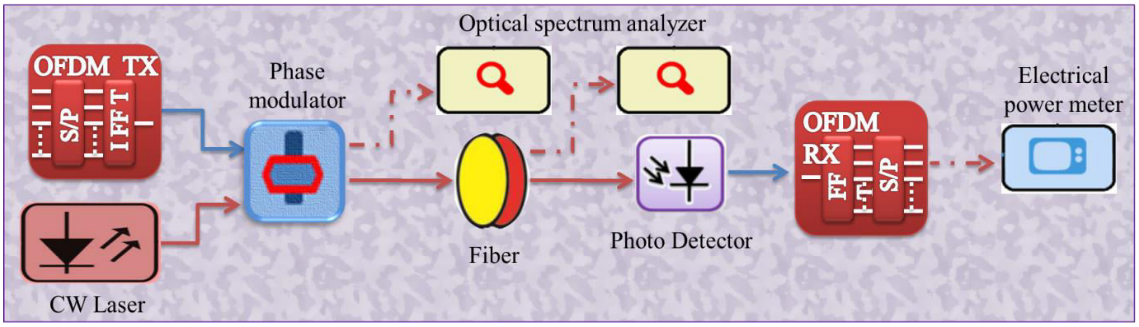

Figure 2: Optical-OFDM simulation model

Table 1 specifies the different fiber parameters which includes dispersion, nonlinearity, loss etc.

Table 1: Fiber parameters

Parameter	Value
Loss	0.02 dB/km
Dispersion at the reference frequency	-20.40717ps^2/km
Dispersion derivative at reference frequency	0.14746 ps^3/km
Zero dispersion frequency	215.44014 THz
Fiber non-linearity coefficient	1.26677 /W/km

A PIN photodiode is operating at 193.4 THz frequency. Its quantum efficiency is 0.7 and responsivity is 0.8751A/W. PIN photodiode is also introducing the dark current as well as quantum noise.

3. RESULTS AND DISCUSSIONS

Simulation of an optical-OFDM system is performed over a wide transmission distance range as well as Raman amplifier's pump power and system performance is assessed accordingly. Also the cyclic prefix (CP) of an optical-OFDM signal is varied between 0.1 and 0.9. Whereas, the injected fiber pump power is varied between the range of 0 dBm and 24 dBm. Also the transmission distance is varied between 0 km and 210 km. Also, the CW Raman amplifier's pump frequency is set at 206.4 THz which is approximately 13 THz greater than original signal frequency. Various simulating results are reported in this section for different Raman amplifier parameters utilized for O-OFDM system by varying the cyclic prefix with received optical power.

Variation in cyclic prefix corresponding to the received optical power is reported in **Fig. 3**. For different values of cyclic prefix, the received optical power is evaluated. The maximum value of received optical power is obtained at cyclic prefix of 0.7.

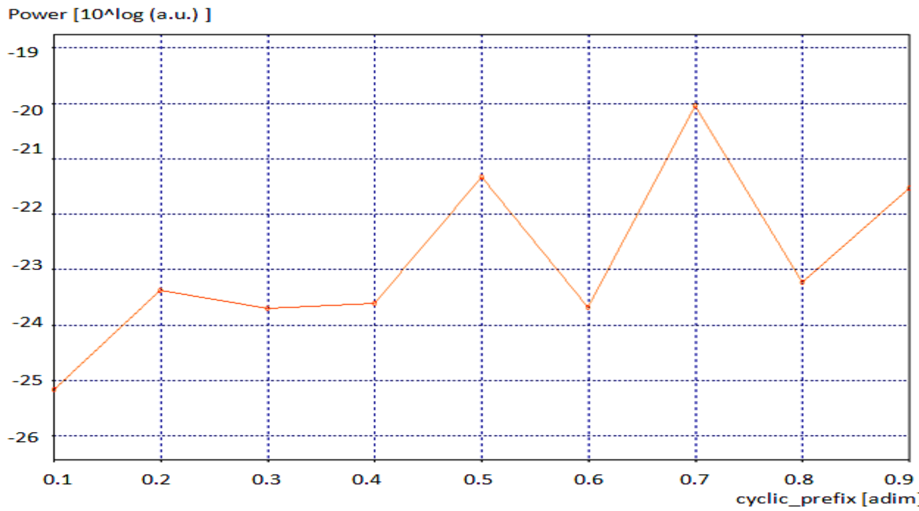

Figure 3: Cyclic prefix variation with respect to received power

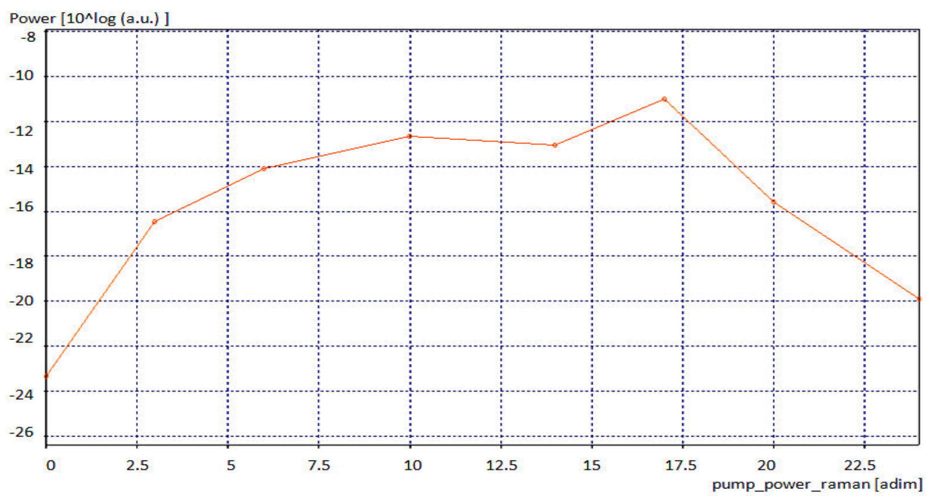

Figure 4: Variation of pump power with respect to received power

The effect of variation of pump power of a Raman amplifier is achieved by evaluating the received optical power with different parametric runs. A correlation graph showing the received optical power corresponding to pump power of Raman amplifier is reported by **Fig. 4**. It is depicted that the received optical power is increased when pump power is increased up to an optimum pump power value of 17 dB and afterwards it starts reducing.

Fig. 5 depicts the variation of received optical power by varying the transmission length up to 210 km by utilizing or not utilizing the Raman amplifier. The results indicated that up to a transmission length of 60 km, there is no need of an optical amplifier but after this distance optical amplifier is necessary. Also maximum received power is obtained at the transmission length between 50 and 150 km without using an optical amplifier.

Fig. 6 depicts the variation of pump power with fiber length at 206.4 THz frequency. The fiber length is increased from 0 km to upto 210 km and variation in pump power is detected accordingly. As depicted from this plot that initially up to 70 km fiber length, the pump power decreases slowly but after 70 km length, pump power is decreased rapidly and minimum pump power value of approximately -5 dB is reported at 210 km fiber length. Parameters like pump attenuation as well as noise figure of Raman amplifier lead to this rapid reduction in pump power.

Figure 5: Received power variation with transmission length

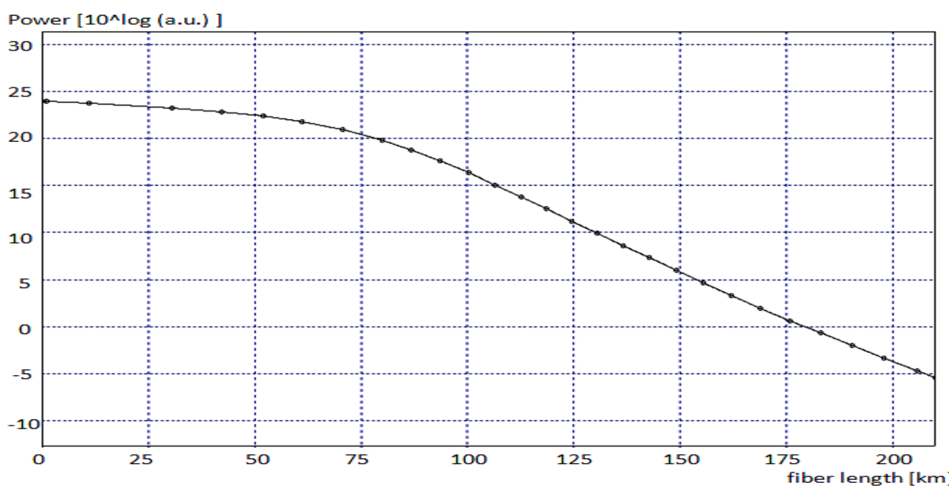

Figure 6: Variation of pump power with fiber length

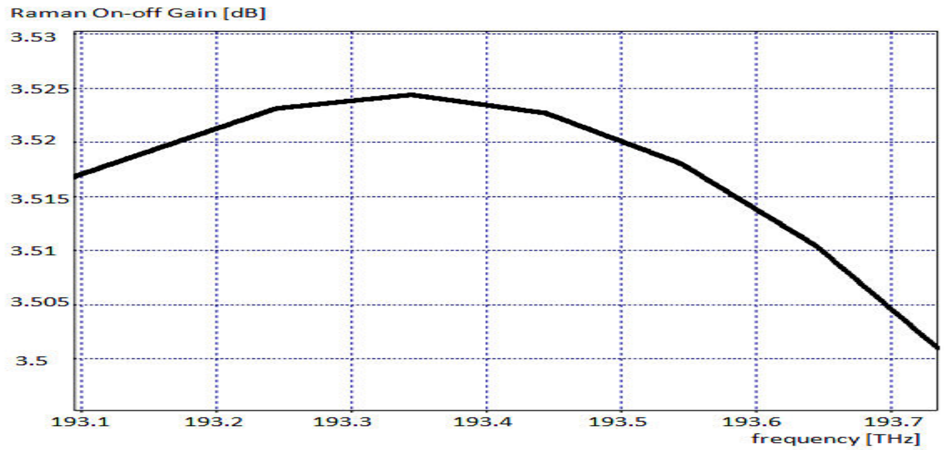

Figure 7: Raman on-off gain versus operating frequency

Variation in Raman on-off gain is examined with increasing the operating frequency at a fixed transmission length of 120 km and constant pump power of 14dB as shown in **Fig. 7.** At 193.4 THz frequency, the on-off gain of Raman amplifier is obtained as 3.523 dB.

The analysis of the optical signal is observed by obtaining the optical spectrum before the transmission (red graph) as well as after the transmission (green graph) at various fiber lengths and pump power values. **Fig. 8** provides the optical spectrum at 0 km fiber length and 0 pump power value. **Fig. 9** depicts the optical spectrum at 120 km fiber length and 14 dB pump power value. Whereas, **Fig. 10** depicts the optical spectrum at 210 km fiber length and 2 dB pump power value.

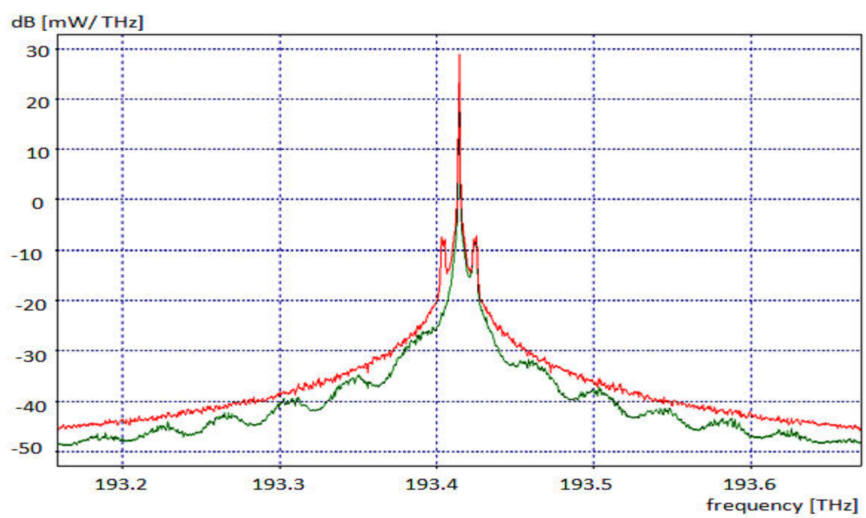

Figure 8: Optical spectrum at 0 km fiber length and 0 dB pump power

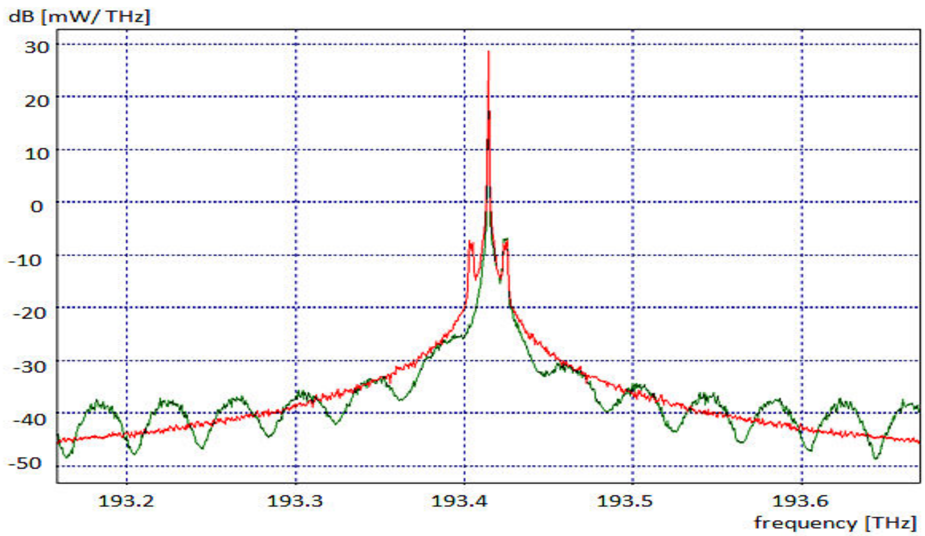

Figure 9: Optical spectrum at 120 km fiber length and 14 dB pump power

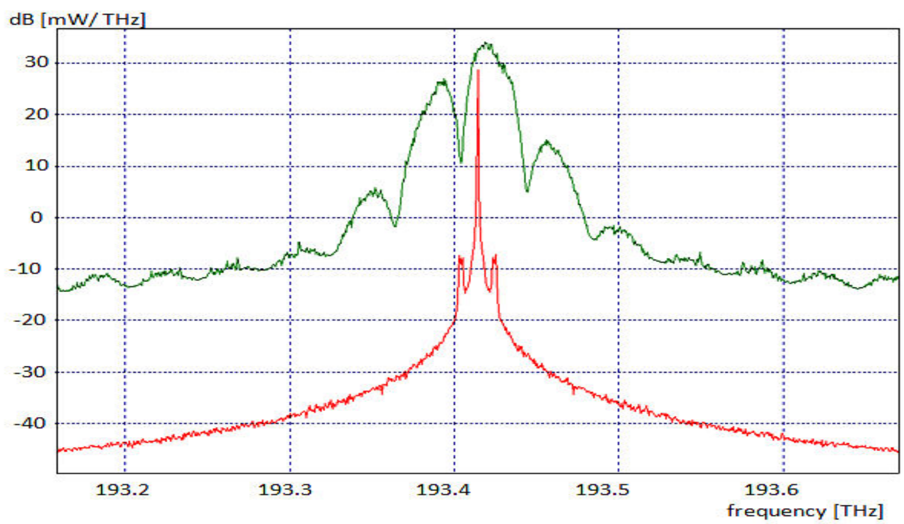

Figure 10: Optical spectrum at 210 km fiber length and 2 dB pump power

Fig. 11 depicts the variation in received peak power of the optical spectrum at a reference frequency value with and without employing an optical amplifier. Without utilizing an optical amplifier, the maximum value of optical power (26.75 dB) is obtained at a reference frequency for back to back propagation. But as the distance is increased, the value is decreased. But, by utilizing an optical amplifier, the maximum value of optical power (38.782 dB) is obtained at a fiber length of 180 km and pump power of 20 dB.

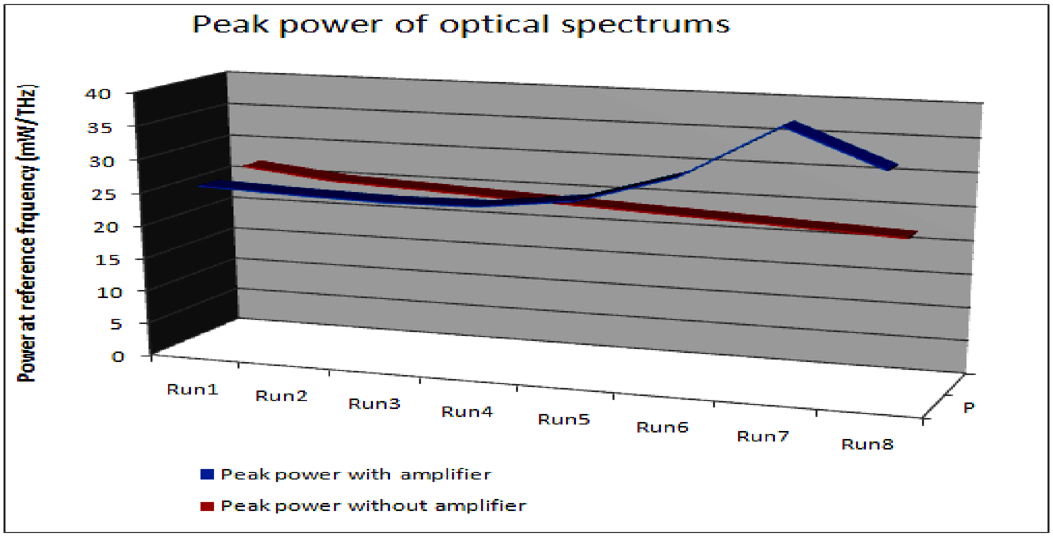

Figure 11: Peak powers of optical spectrum at the reference frequency

4 CONCLUSIONS

The effect of the Raman amplifier is analyzed with an increase in its fiber length as well as pump power. Simulative result depicted that a power of -11.1 dB is obtained by system at a pump power of 17 dB for signal transmission at 150 km distance. Distance of transmission is increased using a Raman amplifier by choosing appropriate parameter values. Further, the system is analyzed with the variation in the cyclic prefix of OFDM signal. Maximum power value is acquired at cyclic prefix of 0.7. Without using an amplifier, the optical power is decreased with an increase in distance and peak value obtained is 26.751 dB. When an optical amplifier is used, then 38.782 dB peak power values are obtained with pump power of 20 dB at transmission distance of 180 km.

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