Digital Radio over Fiber System with OFDM & O-ACI Reduction and Its Performance Evaluation

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***Abstract*— Radio over Fiber (RoF) system uses re-modulation technique to reduce the hardware requirement at every Base Station. This paper reports a study of Radio over Fiber system using remodulation along with Digital Modulation scheme of OFDM, in which the same optical carriers are used for both downlink and uplink connection. The main drawback of remodulation ROF system is Optically Generated Adjacent Channel Interference (O-ACI), which is likely to reduce Q-Factor. To overcome this issue, a Single Drive Mach Zehnder Modulator (SD-MZM) is used to tune up the phase and amplitude of carrier signal which can reduce the interference, thereby improving the efficiency level of the system. Instead of a simple Mach Zehnder Modulator used for the conversion of RF signal to Optical signal, a Single Drive Dual Parallel Mach Zehnder Modulator (SD-MZM) at the control station and an MZM modulator at the base station are used. Using a multiuser RoF model, observations are made at various power levels, in terms of Q factor, Eye Height and etc. A Data Envelopment Analysis (DEA) technique is applied to identify the optimum transmission power to achieve high Q factor, eye height and a threshold value of 0.5.**

***Index Terms*— Data Envelopment Analysis; OFDM; Optically Generated Adjacent Channel Interference; Radio Over Fiber.**

I. INTRODUCTION

Mobile phones have become an integral part of our lives and the number of mobile users in world is increasing day by day. To match with this, there is a great need to improve the data rate, security, bandwidth and capacity of the existing network. One way to meet this need is to increase the number of antennas. However, the increase in the number of antennas may increase the Specific Absorption Rate (SAR), which has to be kept within 1.6 W/Kg, due to health related issues. In India, more than 8000 antennas are developer every year to meet the technological advancements for which hardware and skilled labourers are required in abundance. Even though we cannot compromise on the number of antennas; we can reduce the hardware requirement by using a Radio over Fiber system (RoF) as the data transmission medium. This can effectively reduce the complexity and overall cost of the system. Radio over Fiber system also provides enhanced speed, bandwidth and resistance to a number of disturbances like noise, interference etc. Hence, RoF system is considered as one of the best solutions for many of the current technological issues on mobile communication.

Radio Over Fiber system also has the advantage of both the wired as well as the wireless medium as shown in Figure 1. The control base stations are connected to routing nodes as well as radio access points with the help of fiber optical cables, thus forming a wired network, while the mobile stations have a wireless connection to radio access points for enabling portability feature.

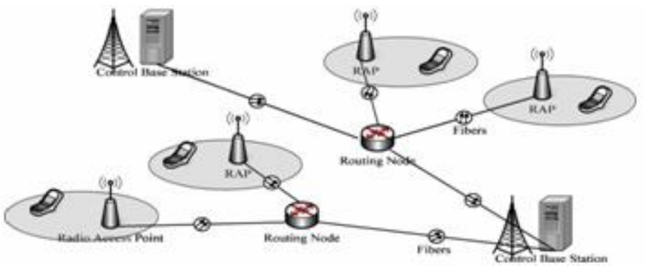

Figure 1: Radio over Fiber architecture

Using re-modulation technique, which is an improved form of RoF system, the complexity of the system can be reduced significantly. In this model the optical carrier starting from the control station will reach to the base station as a part of the down link connection and the same optical carrier is fed back to the control station as a part of the uplink connection. The problem due to re-modulation that optically generates adjacent channel interference can be reduced by using dedicated SD-MZM (Single Drive Dual Parallel Mach Zehnder Modulator) instead of MZM alone. OFDM scheme is also introduced in association with this RoF model to make the system digital RoF. OFDM also offers advantages such as resilience to fading effects, interference, noise, efficient spectrum utilization etc. Upon reducing the power of light source, interference level will be reduced.

Various stages in the implementation of RoF scheme is described here. In [1], a RoF scheme with re-modulation is executed. O-ACI reduction is also performed, but it lacks an efficient digital modulation scheme like OFDM that can come across a number of disturbances existing in the channel. [2] focuses on the problem of O-ACI by filtering techniques, but this approach in turn requires accurate and precise design of filters. Further, it adds to the cost and hardware complexity of the model. [3] emphasises controlling the phase of optical carrier alone and not the amplitude. [4] improves the system performance by reducing the effect of dispersion using amplifiers; but amplifiers will make the system bulky and expensive.

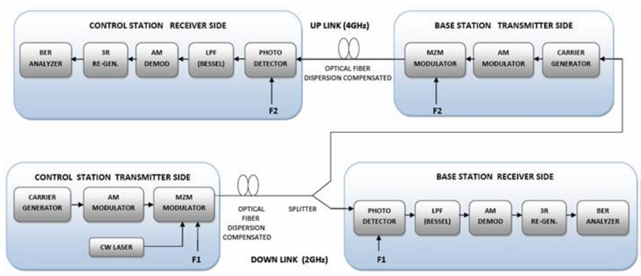

Figure 2: RoF AM modulation & re-modulation

In the proposed model, we use dispersion compensation fibers analogous to DCF-38 as per industrial standards. Using this type of fiber will reduce the effect of dispersion. It also further reduces the number of amplifiers required for the system.

OFDM modulator is developed with 516 subcarriers and QAM modulation is preferred. OFDM modulator is developed in MATLAB for a flexible design of OFDM modulation, while the rest is carried out with the help of Optisystem 7.0, dedicated software for optical communication works.

Paper [5] and [6] describe the implementation of Middle ware for communication. Fuzzy control based mobility framework for evaluating mobility models in MANET of smart devices is given in paper [7]. Paper [8] and [9] discuss about the design and implementation of Ad Hoc Networks of Android Devices. Paper [10] proposes an algorithm for accessing traffic database using wireless technologies.

OFDM modulation scheme is one of the most successful modulation schemes employed nowadays due to its unique qualities, such as optimized spectrum utilization and maximum number of users. Remodulation scheme is employed here for Radio over Fiber Technique to ensure reduced hardware. When remodulation scheme is used, there can be a problem of optically generated adjacent channel interference (O-ACI). In order to reduce this, a single Drive Dual Parallel Zehnder Modulator (SD –DPMZM) is used. A specially designed dedicated dispersion compensation fiber is used to reduce the attenuation throughout the network. Thus, the proposed model is an efficient and completely optimized communication scheme that ensures high data rate, optimized user allocation, large bandwidth, reduced hardware, reduced noises and improved signal strength.

The rest of the paper is organized as follows. Section II gives a description of remodulation and O-ACI reduction. Proposed model with necessary details is presented in Section III. Section IV provides basic idea of the mathematical technique Data Envelopment Analysis (DEA) used for analyzing the experimental results obtained through the proposed model. Experimental results and its analysis using DEA are discussed in Section V. Finally, concluding remarks are presented in Section VI.

II. REMODULATION & O-ACI REDUCTION

In wireless communication models, we use different channels with equal frequency space. Adjacent channel interference is a common problem encountered with spectral broadening because of the non linearity in electrical devices. RoF system with re-modulation has advantages as well as disadvantages. It can reduce hardware requirement at the base stations. However, one has to deal with the optically generated adjacent channel interference (O-ACI). Here, we use the same optical carrier used at downlink as well as in uplink, so that the use of a laser diode or light source can be avoided. Important operations such as switching, medium access control (MAC), frequency management functions are carried out by control station (CS), thereby reducing the functions to be performed at the base station.

In order to deal with the issue of O-ACI in remodulation technique, as shown Figure 2 at the downlink, modulation signal and carrier frequency f_1 are modulated with optical signal and transmitted to the base station. A splitter is used to split the optical carrier into two parts, in which one part is fed to the receiver side of the base station and the other half is re-modulated with carrier frequency f_2 and sent back to the control station. Figure 3 shows the optical spectrum of the model after the downlink modulation.

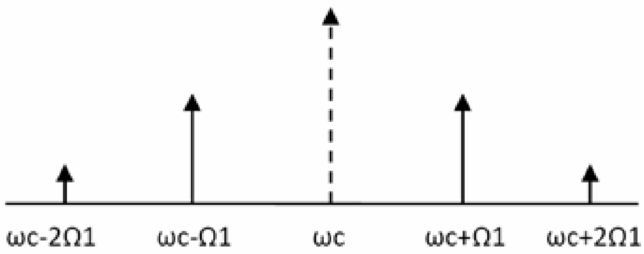

Figure 3: Optical spectrum after the downlink modulation

Signals received at the control station will now have 4 microwave components f_1, f_2, $2f_1$-f_2, $2f_2$-f_1. The newly generated microwave components named $2f_1$-f_2 & $2f_2$-f_1 will generate O-ACI or adjacent channel interference.

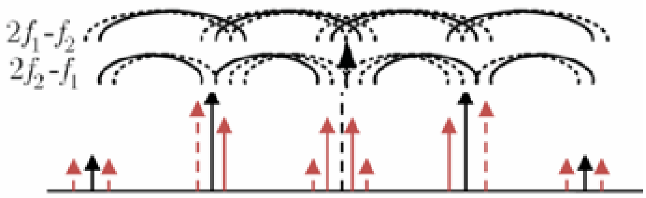

Figure 4: Optical spectrum after the uplink modulation

Mach Zehnder Modulators, which are basically used as electrical to optical conversion is employed. By using a Single Drive dual parallel Mach Zehnder Modulator, we can reduce the effect of optically generated adjacent channel interference.

III. PROPOSED MODEL

The reduction of optically generated adjacent channel interference is implemented using a technique called carrier amplitude phase control double sideband (CAPC-DSB) modulation. It is performed in downlink. Both the phases as well as the amplitude have to be controlled in order to

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achieve a better performance level and a lesser O-ACI. This is done by tuning up modulation voltage to control both phase as well as amplitude. In Figure 4, the red dashed lines represent the phase and amplitude that are to be controlled and it is done by varying modulation voltage. A single drive dual parallel mach zehnder modulator (SD-DPMZM) which in fact has 3 Mach Zehnder Modulators is used. OFDM modulation scheme is also included as a part of the project as it has a number of advantages, such as better spectrum utilization and resilience from different types of fading, noise and interference. The main change from the previous model (Figure 6) is the use of SD-DPMZM instead of a normal MZM intended for electrical to optical conversion and OFDM modulation instead of normal AM modulation, as can be seen in Figure 5.

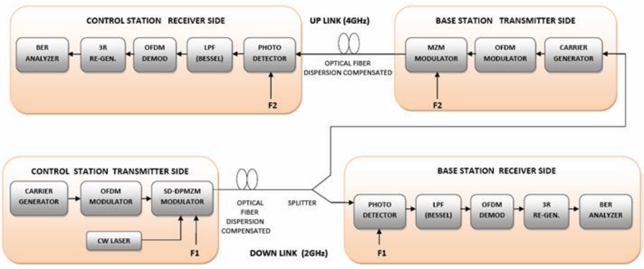

Figure 5: Proposed model of RoF with OFDM & O-ACI reduction

A. Model of SD-DPMZM

SD-DPMZM has 3 MZM modulators connected in a fashion as shown in Figure 6. MZM-1 & MZM-2 are sub-modulators. MZM-1 modulator is driven by DC-bias voltage V1 and the Radio Frequency (RF) signal. MZM-2 is driven by DC-bias voltage V2 only.

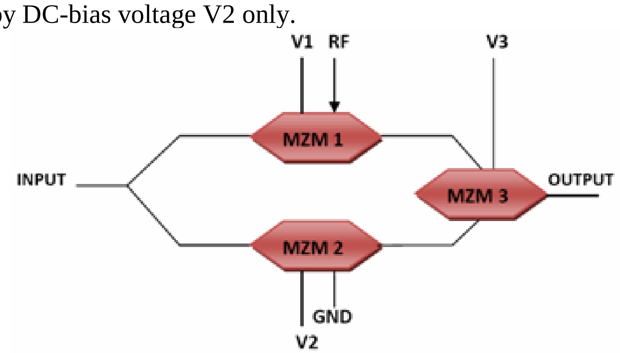

Figure 6: Model of SD-DPMZM

As seen from Figure 6, two sub-modulators serve as the arms of parent modulator MZM-3. DC bias voltage V3 of parent modulator can be varied to reduce the effect of O-ACI. V3 controls the phase relation of the 2 sub MZM modulators. MZM-1 is biased in such a way that it nulls optical carrier to produce modulated side bands as output. The main advantage of this scheme is that we can control the phase of modulated side bands by just changing the bias voltage V1. The phase of the first arm, which is ϕ1 will be changed upon varying the voltage. By properly adjusting the phase dispersion, compensation feature can be introduced into the model. The second arm which is driven by DC-bias voltage V2 works differently as it is biased in such a way that it nulls side bands and allows optical carrier to pass through. This feature is mainly included for the sake of controlling the two arms separately. Varying V2 will make changes in the amplitude of optical carrier. The change in DC bias voltage will cause a change in the phase of the second arm ϕ2. In order to avoid the difference between the first and the second arm, DC-bias voltage V3 will be turned up and phase of the third arm ϕ3 will be brought to zero. This action will cancel the differences between the first and second arm, thereby producing a complete spectrum as the final output with reduced O-ACI.

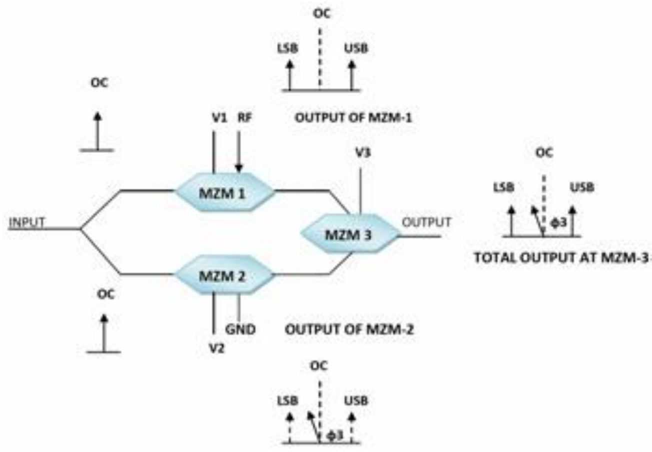

Figure 7: Working of SD-DPMZM

In fact modulation voltage is the most important parameter to be controlled because controlling the V3 of parent MZM-3 can bring up improved performance and will reduce O-ACI to a great extent.

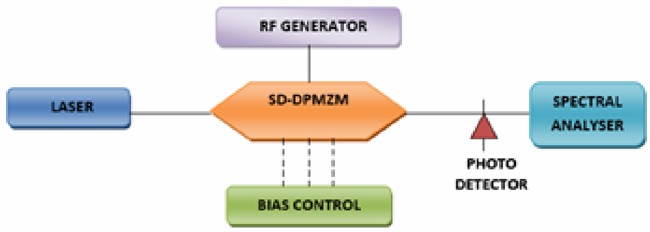

Figure 8: Connection scheme of SD-DPMZM

When evaluating the Q-factor and bit error rate for different power levels, the modulation voltage to be set can be decided as the voltage modulation corresponding to the maximum Q-factor. This can be implemented with the help of software at CS so that flexibility can be achieved. For a range of possible values, a high Q factor at downlink will not necessarily produce high Q-factor at uplink and high Q-factor at the downlink is more important.

B. OFDM Modulator & Demodulator

Orthogonal Frequency Division Multiplexing (OFDM) is a method in which data in digital form is carried across multiple carrier frequencies. OFDM focuses mainly on the slowly modulated narrow band signals than rapidly modulated wide band signal. OFDM is popularly used in wideband digital communications, such as digital television, wireless networks & 4G mobile communications. OFDM is preferred as it is more efficient, resilient to different forms of noise, inter symbol interference and different kinds of fading effect. FFT, which can be implemented faster than other methods is used. Here a small amount of data is only carried by orthogonally spaced subcarriers to avoid the cross talks and inter carrier guard bands that lead to effective spectral utilization.

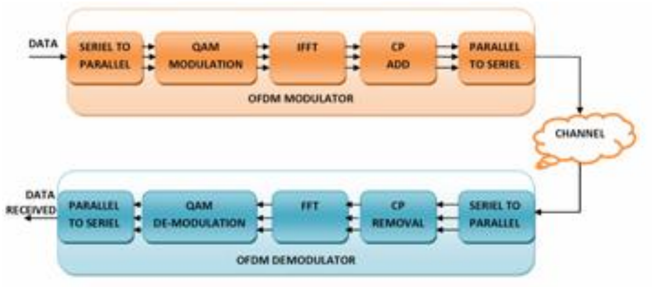

Figure 9: OFDM modulator & demodulator

Figure 9 shows the block diagram of OFDM modulation and demodulation used in our proposed model. 512 subcarriers were used to meet the important requirements, such as high data rate, high band width and etc.

IV. MATHEMATICAL MODELING

Data Envelopment Analysis is a method used to assess the relative efficiency of homogeneous group of decision making units (DMUs). Efficiency is measured based on the idea of Farrell, which is concerned with non-parametric frontier analysis. An “efficient frontier” or a sort of “envelope” formed by a set of DMUs that exhibits the best practices first established in this approach and later the assignment of the efficiency level to other non-frontier units according to their distances to the efficient frontier [11]. A wide range of variations in measuring efficiency has been generated by the basic idea.

DEA has a wide variety of applications in finance, health, education, manufacturing, transportation etc. DEA identifies a “frontier” used to evaluate observations, which represent the performances of all the entities to be evaluated, namely the different Decision Making Units. The parameters used to measure performance in this study are Q-factor, eye height and threshold. Each of the different models capable of supporting 30 simultaneous users are developed and the “degree of efficiency” obtained ranges between zero and unity. The DMUs located on the efficiency frontier are considered to be efficient. The efficiency score of a unit, measured on a bounded ratio scale is the ratio of a weighted sum of its outputs to a weighted sum of its inputs. In order to maximize its relative efficiency, the weights for inputs and outputs are estimated to the best advantage for each unit. The underlying mathematical model is linear programming which is given in either the multiplier form(Primal) or in the envelopment form (Dual) form. The former makes explicit use of the efficiency ratio, the latter gives an explicit representation of the envelope formed by the efficient frontier as well as the orientation with which the assessments are made (i.e. input or output oriented model). An output multiplied by the corresponding weight is called virtual output in the multiplier form. The total virtual output is the sum of the virtual outputs over all the output factors that form the numerator of the efficiency ratio.

Let there be m inputs $x_{ij}, i = 1,2, \dots, m$ and s outputs $y_{rj}, r = 1,2, \dots, s$. Let n be the number of decision making units (DMUs) under the consideration of producing m inputs and s outputs. Then, the efficiency score of a DMU that is DMUo is obtained by the LP model [12, 13].

$$Max \sum_{r=1}^{s} u_r y_{rj_0}$$

Subject to constraints

$$\sum_{i=1}^{m} v_i x_{ij_0} = 1 \qquad (1)$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \; j = 1,2,\dots n$$

$$u_r, v_i \geq 0, \text{ for all r and i.}$$

where j is the DMU index, j=1,2,….,n, r is the output index ,r=1,2,…,s, i is the input index, i=1,2,….,m, , , u_r the weight of the r[th] output , v_i the weight of the i[th] input. From the optimal weights of u_r and v_i, the efficiency scores of DMUo can be determined.

In this method, it requires to solve n LP problems to determine the efficiency of n DMUs. Another disadvantage is that each DMU assigns weights to inputs\outputs to achieve efficiency and these weights can be different. Hence, a comparison of the performance of DMUs based on such efficiency scores is not logical. This can be overcomed by introducing common set of weights for DMUs [14-15]. By the common weight approach only one hyper plane is generated for efficiency evaluation. Common weights that are derived by multi-objective linear programming (MOLP) [16-17] for a DEA are supported by the concept of Pareto efficiency. Both DEA and MOLP are searched for the set of non-inferior solutions. Hence, characterizing the DEA model by multi-objective programming is both reasonable and appropriate.

A. *Common Weight Model in DEA*

The virtual positive ideal DMU is a DMU with minimum inputs of all of DMUs as its input and maximum outputs of all of DMUs as its output [18-19]. An ideal level is one straight line that passes through the origin and positive ideal DMU with slope 1.0. ie, for any DMU$_j$, Δ_j^I and Δ_j^O are the horizontal and vertical virtual gaps respectively.

If we let $\Delta_j^I + \Delta_j^O$ be Δ_j and M be the maximum value of Δ_j, then using the minimum weights obtained for efficient DMUs, a new model is given by[20-21]:

Minimize

$$\sum_{j=1}^{n} \Delta_j + M$$

Subject to the constraints

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} + \Delta_j = 0 \qquad (2)$$

$$\Delta_j \geq 0$$

$$M - \Delta_j \geq 0, \; j=1,2,\dots n$$

$$u_r \geq \varepsilon > 0, r = 1,2,\dots s$$

$$v_i \geq \varepsilon > 0, i = 1,2,...m$$

where ε is the minimum weight restriction obtained by solving the following model, which uses normalized values for inputs and outputs. The normalization can be performed by using the following equations:

$$\hat{x}_{ij} = x_{ij} \Big/ \sum_{k=1}^{n} x_{ik} \quad , i = 1,2,...m; \ j = i,2,....n \tag{3}$$

$$\hat{y}_{rj} = y_{rj} \Big/ \sum_{k=1}^{n} y_{rk} \quad , r = 1,2,...s; \ j = 1,2,....n \tag{4}$$

DEA efficient units will not be affected by this normalization process because CCR efficiency has a good property of unit-invariance and is independent of the scale transformations of inputs and outputs. The transformed inputs meet the conditions of $\sum_{j=1}^{n} \hat{x}_{ij} = 1$ for i=1, 2, …m, as shown below[22]:

Maximize ε

Subject to $\sum_{i=1}^{m} v_i = 1$

$$\sum_{r=1}^{s} u_r \hat{y}_{rj0} - \sum_{i=1}^{m} v_i \hat{x}_{ij0} = 0 \tag{5}$$

$$\sum_{r=1}^{s} u_r \hat{y}_{rj} - \sum_{i=1}^{m} v_i \hat{x}_{ij} \leq 0, j = 1,2,...,n$$

$$u_r \geq \varepsilon, r = 1,2,...,s$$

$$v_i \geq \varepsilon, i = 1,2,...,m$$

where $\hat{x}_{ij}$ (i=1,2,…,m and j=1,2,…,n) and $\hat{y}_{rj}$ (r=1,2,…,s and j=1,2,…,n) are normalized input and output data. For convenience, we refer to the above LP model (III) as max min weight model for DEA efficient units.

In the traditional DEA, ε is a given very small constant which is usually referred to as a non-Archimedean infinitesimal. However, ε in the above LP model (III) is a decision variable rather than a constant and is not necessarily very small. By solving LP model (III) for each of the DEA efficient unit, respectively, we can obtain a set of maximin weights, $\varepsilon_{i_1}^*, \varepsilon_{i_2}^*, ..., \varepsilon_{i_k}^*$ for all DEA efficient units, where $i_1, i_2, ..., i_k$ are the labels of k DEA efficient units. In this paper, the efficiency of proposed model is evaluated by taking the power as the input and Q-factor, eye height & threshold as the outputs.

V. Results And Discussions

OFDM modulation scheme is used in the proposed model. Power spectral density of the OFDM signals shows that signal strength is confined within frequency range of -500Mhz to 500Mhz ; -1000Mhz to -500Mhz. 500Mhz to 1000Mhz is the side lobes of the transmit spectrum.

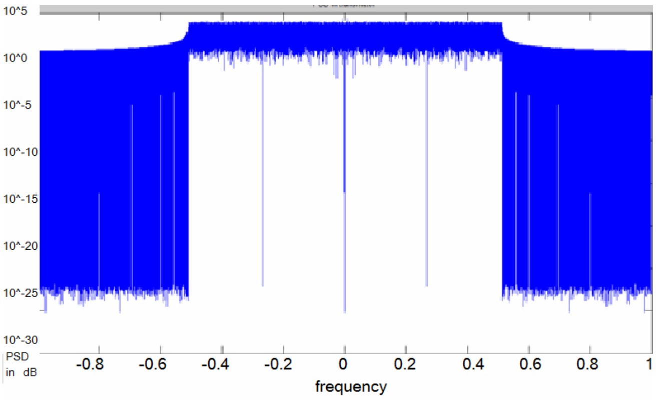

Figure 10: Power spectral density of OFDM signal

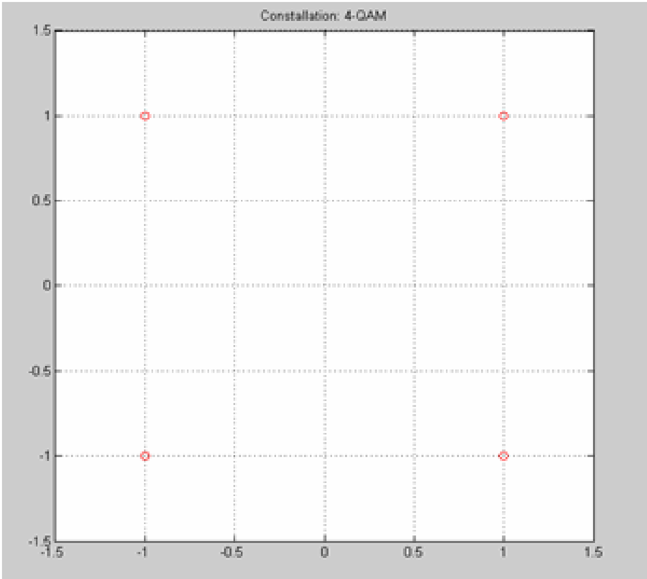

Figure 11: 4-QAM constellation diagram transmitted

QAM modulation is preferred in OFDM modulation than the QPSK and BPSK as QAM modulation schemes have better power spectral density. 4-QAM is used and upon increasing the modulation levels, we can improve the power spectral density; thereby, improving the efficiency level of OFDM scheme implemented. Constellation diagram of the proposed model for QAM schemes prove that data transmission is successful. Figure 11 and Figure 12 show the constellation diagram of transmitted and received signals respectively.

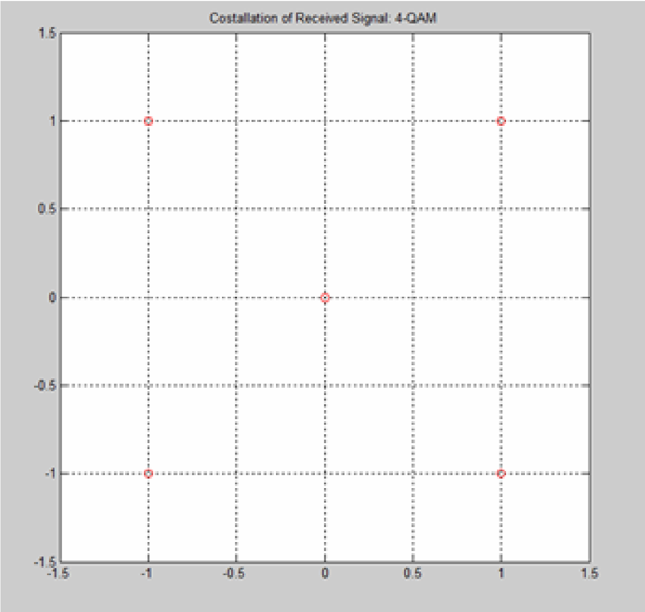

Figure 12: 4-QAM constellation diagram received

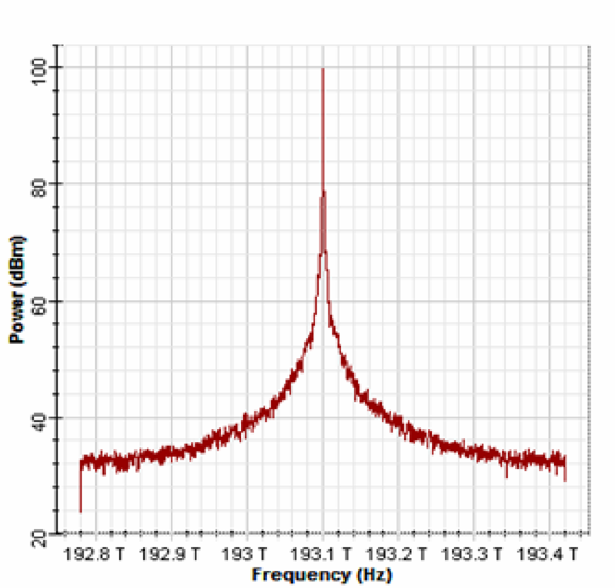

Figure 13: Optical spectrum before optical modulation

Figure 13 and 14 show the optical spectrum of before and after optical modulation. It can be seen that power level is improved.

Experimental results are mainly evaluated using Eye patterns and aspects like Q-factor, eye height, minimum BER, decision instant, delay etc.

Using the proposed model we get the values for different modulation voltage. When the modulation voltage is set at downlink, it cannot be shifted or changed for uplink to keep a single SD-DPMZM and reduce the hardware at the base station.

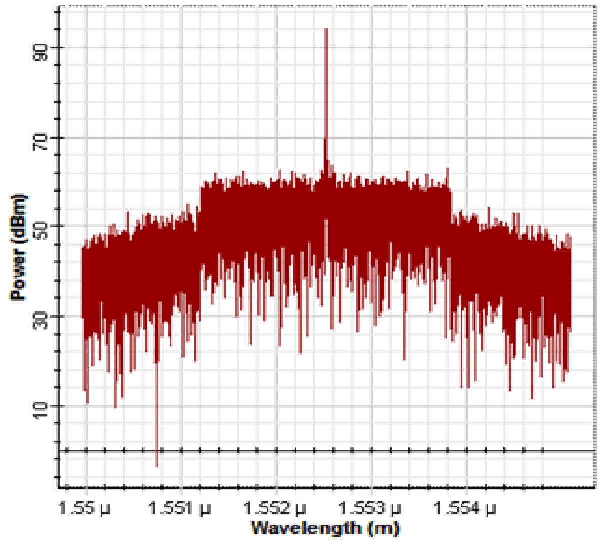

Figure 14: Optical spectrum after optical modulation

Eye pattern is closely spaced as we are using OFDM scheme that employs a multiple subcarrier data transmission. The red line depicts the Q-factor. Values highlighted in Table 1 and 2 show the values for which the peak efficiency level is achieved.

Table 1
Downlink performance at 100 dbm

Modu. Vol.(v)	Q-factor	Min-BER	Eye height	Decs. inst.
1	9.879	2.54e-023	0.701	0.593
1.444	9.561	5.35e-022	0.692	0.421
1.888	9.092	4.29e-020	0.660	0.578
2.333	10.584	1.74e-026	0.730	0.640
2.777	9.417	2.32e-021	0.680	0.484
3.222	9.366	3.76e-021	0.672	0.531
3.666	10.674	6.70e-027	0.723	0.453
4.111	10.515	3.65e-026	0.718	0.546
4.555	9.594	4.20e-022	0.683	0.453
5	9.225	1.40e-020	0.667	0.359

Table 2
Uplink performance at 100dbm

Modu. Vol. (v)	Q-factor	Min-BER	Eye height	Decs. Inst.
1	31.084	1.93e-212	0.902	0.593
1.444	30.056	8.23e-199	0.902	0.421
1.888	29.028	1.26e-185	0.892	0.578
2.333	33.046	8.84e-240	0.914	0.640
2.777	29.809	1.48e-195	0.898	0.484
3.222	29.841	5.64e-196	0.896	0.531
3.666	33.608	6.21e-248	0.912	0.431
4.111	33.125	6.42e-241	0.911	0.546
4.555	30.442	7.41e-204	0.900	0.453
5	29.417	1.64e-190	0.894	0.359

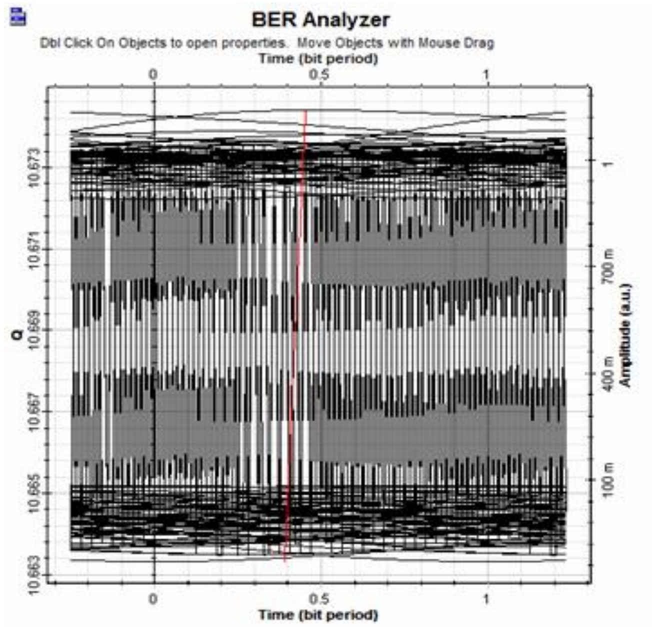

Figure 15: Eye diagram of downlink peak performance at 100dbm.

Figure 16 shows eye pattern of the model with the chosen modulation voltage of 3.666 from 10 different modulation voltages ranging from 1V to 5V as it produces high Q-factor. Table 2 shows the performance of uplink at 100 dbm.

As power of the transmitter and interference of the system are directly proportional with the reduced power, interference is also reduced; hence, Q-factor is improved.

Table 3 shows that the performance is improved as the transmission power is increased. The eye pattern is also improved when the transmission power is reduced from 100 dbm to 90 dbm.

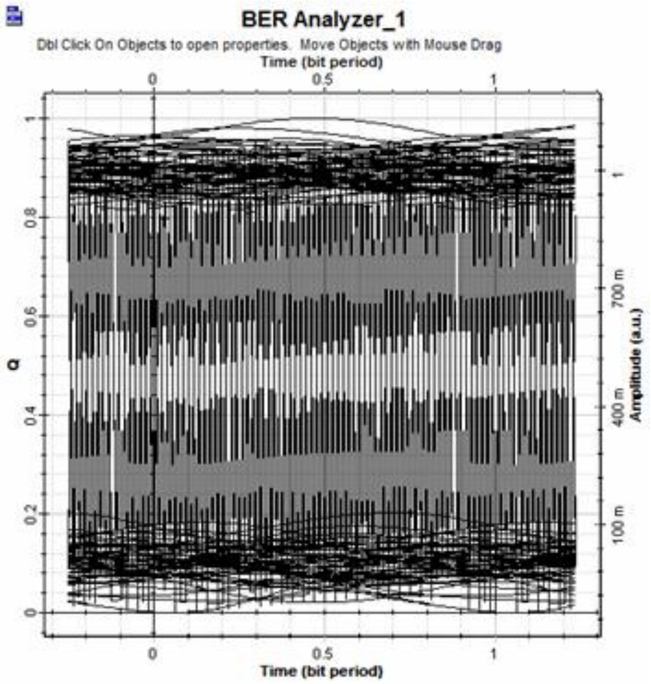

Figure 16: Eye diagram of uplink performance at 100 dbm

Table 3
Downlink performance at 90 dbm

Modu. Vol.(v)	Q-factor	Min-BER	Eye height	Decs. inst.
1	9.762	8.14e-023	0.694	0.796
1.444	11.971	2.49e-033	0.749	0.484
1.888	9.956	1.17e-023	0.694	0.812
2.333	11.105	5.90e-029	0.726	0.296
2.777	9.059	6.51e-020	0.670	0.578
3.222	8.973	1.42e-019	0.672	0.406
3.666	11.264	9.86e-030	0.729	0.296
4.111	10.344	2.21e-025	0.702	0.640
4.555	10.357	1.93e-025	0.710	0.531
5	10.342	2.25e-025	0.718	0.453

The range of Q-factor values is improved from 9-11 to 29-35. Q-factor of 35.765 is achieved at the modulation voltage of 3.666 in the uplink and 33.608 at the downlink for the same modulation voltage.

From this analysis, it is evident that 3.666 is the modulation voltage to be set at SD-DPMZM to achieve good efficiency. Better performance is only expected when the modulation voltage is 3.666V, because the Q-factor is also the highest for 3.666V in all cases.

Table 4
Uplink performance at 90 dbm

Modu. Vol. (v)	Q-factor	Min-BER	Eye height	Decs. Inst.
1	26.981	1.22e-160	0.889	0.490
1.444	31.951	2.59e-224	0.904	0.443
1.888	26.790	2.07e-158	0.887	0.482
2.333	31.265	6.96e-215	0.904	0.480
2.777	31.182	9.07e-214	0.903	0.503
3.222	25.895	3.77e-148	0.883	0.474
3.666	28.896	6.58e-184	0.896	0.519
4.111	28.077	9.30e-174	0.893	0.589
4.555	32.262	1.16e-228	0.905	0.533
5	24.821	3.23e-149	0.843	0.432

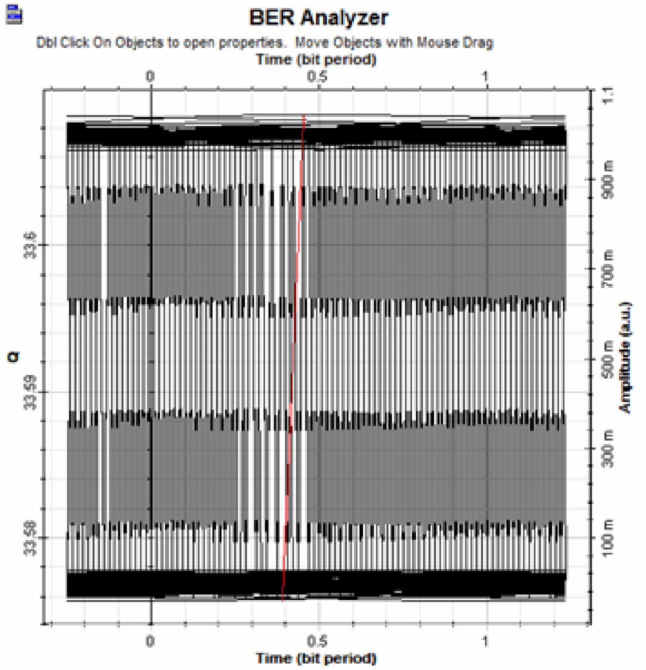

Figure 17: Eye diagram of downlink performance at 90 dbm

Here, instead of a continuous wave laser, a multi user wavelength division multiplexing Transmitter (WDM transmitter) is used. Models capable of supporting 30 simultaneous users are now developed, which is then multiplexed for transmitting data through a single optical fiber at the downlink.

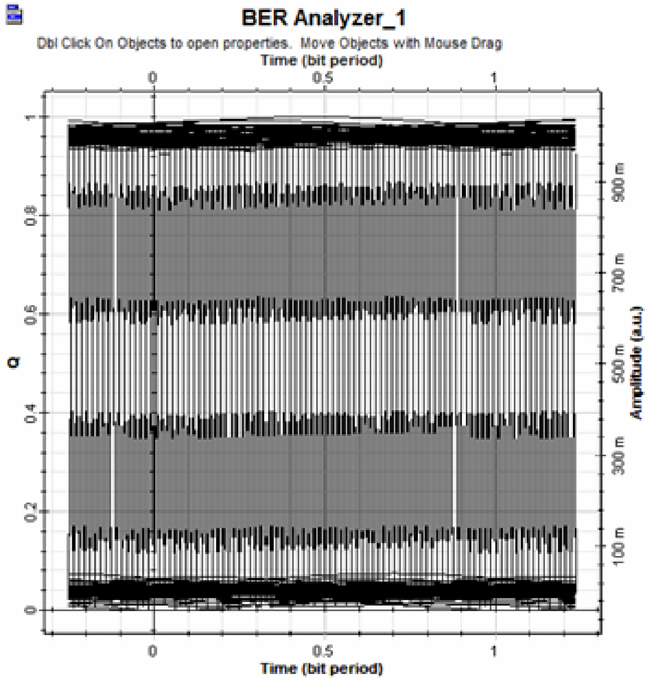

Figure 18: Eye diagram of uplink performance at 90 dbm.

Table 5 shows that there is a reduced in the multiuser scheme and the transmission power of 80dbm can only produce a Q-factor value ranging between 26 to 32.

Table 5
Downlink performance for multiuser at 80 dbm

Modu. Vol.(v)	Q-factor	Min-BER	Eye height	Decs. inst.
1	30.806	1.05e-208	0.903	0.796
1.444	37.838	1.32e-313	0.920	0.484
1.888	31.623	8.82e-220	0.903	0.812
2.333	35.245	2.00e-272	0.913	0.296
2.777	28.610	2.44e-180	0.895	0.578
3.222	28.177	5.51e-175	0.896	0.406
3.666	35.765	1.92e-280	0.914	0.296
4.111	32.958	1.58e-238	0.905	0.640
4.555	32.754	1.30e-235	0.908	0.531
5	32.442	3.40e-231	0.910	0.453

Table 6
Uplink performance for multiuser at 80 db

Modu. Vol. (v)	Q-factor	Min-BER	Eye height	Decs. Inst.
1	30.642	6.73e-200	0.904	0.451
1.444	36.718	1.84e-295	0.914	0.539
1.888	28.540	1.86e-179	0.891	0.449
2.333	29.725	1.79e-194	0.901	0.583
2.777	28.251	6.71e-176	0.893	0.515
3.222	27.078	8.76e-162	0.884	0.492
3.666	3.933	4.53e-224	0.908	0.466
4.111	32.996	4.63e-239	0.911	0.421
4.555	33.263	6.41e-243	0.913	0.466
5	26.068	7.16e-142	0.881	0.431

Table 7
Performance evaluation using Data Envelopment Analysis

DMUs	INPUT power	OUTPUTS Q factor (Down Link)	Eye height (Down Link)	Threshold (Down Link)	Q factor (Up Link)	Eye height (Up Link)	Threshold (Up Link)	Efficiency Level
1	100	10.674	0.7235	0.4995	11.264	0.7393	0.4933	0.8523
2	95	18.929	0.844	0.5015	20.082	0.8477	0.4933	0.9235
3	90	33.608	0.912	0.5029	35.765	0.9145	0.493	1.0000
4	85	59.713	0.95	0.3238	63.6525	0.9518	0.298	0.7711
5	80	106.134	0.972	0.1821	113.244	0.9729	0.1677	0.6084
6	75	188.682	0.984	0.1024	201.433	0.9831	0.0976	0.5815
7	70	335.473	0.991	0.0575	358.261	0.9914	0.053	0.6918
8	65	596.503	0.995	0.0323	637.15	0.9952	0.0298	1.0000

Based on the analysis of Table 5 and 6, it can be seen that the peak efficiency of the modulation voltage is achieved at 4.555. We will not consider multiuser scheme in this modeling as our research is confined to finding the best possible and efficient transmission power; setting constant modulation voltage of 3.666 V. Therefore, we consider the transmission powers from 65dbm to 100dbm (8 different values) and their associated properties, such as the Q-factor, threshold and eye height. The power levels are considered as the decision making units or DMUs. Each DMU will produce efficiency values: a value between zero and one. Table 7 shows the efficiency values of the DMUs, in which the high values yield the best transmission power condition that can have efficient data transmission and error free data delivery. We require high Q-factor values and eye heights, but the value closed to 0.5 as the threshold value. Among those DMUs that satisfy the above criteria, the one with the highest efficiency and a threshold value close to 0.5 will be selected as the best.

VI. Conclusion

In this study, a multi user RoF model with OFDM and O-ACI reduction is developed. In order to reduce optically generated adjacent channel interference due to re-modulation scheme implemented in RoF as a part of reducing hardware, we used SD-DPMZM for different modulation voltage from 1V to 5V(10 different values). The performance evaluation is done using Data Envelopment Analysis. It is found that for the modulation voltage at 3.666, efficiency is at its maximum even with changes in the transmission power values. Therefore, in order to find out the optimum transmission power on behalf of other important properties, such as the Q-factor, eye height and threshold, DEA is used. DEA computes the efficiency at different power levels and identifies 90dbm as the optimum power transmission power. It is to be mentioned that 65dbm power level also gives the same efficiency, but the threshold value for this is 0.0325, which is not desirable.

Thus, it can be concluded that the proposed model is working under the modulation voltage of 3.666V for SD-DPMZM with a transmission power of 90dbm and 4-QAM modulation for OFDM. In this case, the proposed model can result in an efficient communication scheme capable of meeting the future requirements. On the other hand, based on the evaluation of the mutli-user scheme, we will get 4.555 V as the optimum modulation voltage. The proposed model is assessed to be efficient in terms of reducing error, noise, interference and fading effects with improved data rate, bandwidth and security.

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