An efficient 110 x 8 GHz WDM RoF System design for 5G & advance wireless networks

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An efficient 110 x 8 GHz WDM RoF System design for 5G & advance wireless networks

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Abstract

High speed networks over long distance with superior transmission efficiency is the need & demand of current and next generation networks. For which, millimetre wave (mm-wave) based many Radio over Fiber (RoF) networks are proposed earlier with several modulation and multiplexing techniques. This paper presents an efficient RoF network comprising of cascaded combination of an Mach Zehnder Modulator (MZM) & a Li-Nb MZM in transmitter alongwith Optical Phase Conjugator (OPC) in the link to improve the extensive bandwidth quality transmission over longer distances. The proposed model reports successful transmission of 8 channel WDM signal with RF signal of 110 GHz over a range of 100 km at 12 Gbps data rate. The model provides an average Bit Error Rate (BER) of 10^{-58} and an average Q-factor of 15.64 when channel spacing is kept at 0.5 nm.

Keywords: Bit Error Rate, Li-Nb MZM, Optical Phase Conjugator, millimetre wave, Radio over Fiber, Multiplexing

1 Introduction

Rapidly increasing subscribers for wireless communication with high speed transmission rates requires transition from lower frequency band to higher frequency band like mm-wave [1]. High frequency range is of utmost importance due to its large bandwidth and high transmission rate over a wireless channel to fulfill the increasing demand per user [2]. But it experiences attenuation due to its small wavelength characteristics, thus forcing frequency reuse for long transmission and security is also a sign of concern [3].

With ideal characteristics required for communication, optical fiber possess numerous information carrying capacity with low cost and attenuation [4]. Adapting optical fiber interconnections along with radio systems provides an optimal solution to meet the demand of subscribers for voice, data, multimedia etc. at a reasonable cost with flexibility and easy access [5]. High transmission rates with several available coding formats like Return to Zero (RZ) code, and Non Return to Zero (NRZ) code over an optical fiber provides ultra long haul communication over traditional optical communication [6]. RoF network system is amongst the most prominent solution for wireless

and next generation networks as studied from the previous decade with lots of upcoming possibilities in the network characteristics [7].

Next generation networks based on 5G and further communication standards, all make use of RoF network system due to its mobility and access properties [8]. RoF comprises of Base Station(s) (BS) [9], Central Station(s) (CS) and optical fiber. CS comprises of transmitters, receivers, modulators and other optical devices, CS is responsible for the downlink and uplink transmission of Radio Frequency (RF) signals to the BS via optical fibers and antenna which transmits them to the end users (receiver) [10–12]. The transmission is made via RF signal or intermediate frequency signals. Applications using RoF network system is widely use carrier signals of GHz frequency with various modulation schemes [8]. Thus, high frequency next generation wireless network offers several advantages which are summarized as follow:

1. Large bandwidth and high frequency of mm-wave and radio wave provides large data transmission capacity ranging from Gbps to Tbps [13].
2. Limited number of devices required with mobility and flexible properties of RoF networks requires less cost which helps in scaling of network with ease and maintenance can be done easily.
3. Since the wave beam at high frequency possess low wavelengths i.e. beam is highly directional providing a good BER. Although it may suffer from some interference as the system is not always ideal, still it is relatively stable and secure for transmission [14].

1.1 Brief Literature Review

Wavelength Division Multiplexing (WDM) helps the link achieve high transmission capacity with high data rate with relatively low cost and flexibility to scale the network [12]. Using WDM, the system can also be made bidirectional for transmission between transmitter and receiver over a single optical fiber.

The phased array fed reflector antenna can be used for wireless communication as it permits high antenna gains with focused radiation characteristics and multiplexing gain by multiple beam generation [15].

The carrier suppressed RZ signal is less sensitive to the effects of nonlinear fiber and provides better strength against transmission interference. The RZ system reduced scatter tolerance and spectral efficiency of RZ based WDM systems. The NRZ system has improved dispersion tolerance but has the effect of interference between signal pulses, therefore, the NRZ fluctuations format is not suitable for high data rate and large transmission distance [16].

Two configurations were modified to produce mm-waves with dual LiNb-MZM in [17]. Initial configuration is a relatively inexpensive method, which uses WDM demultiplexer and optical splitter to produce two unmodified optical signals and a modified optical signal. Each unmodified optical signal and modified signal will create optical single sideband modulation and thus benefit simultaneously Q-band (45 GHz) and V-band (60 GHz) mm-wave receivers. The second configuration can receive maximum data rate, where few visual tools are redesigned to produce only 60 GHz mm waves with a signal of 40 Gb/s 4-Quadrature Amplitude Modulation Orthogonal Frequency Division Multiplexing (4-QAM OFDM).

Using WDM techniques, an advanced transport system that carries 16 or more waves per fiber have been developed in [18]. The NRZ system is used in [5] to encrypt 10 Gbps - 60 GHz data and the WDM system to transmit four channels over a 60 km fiber optical connector.

During long distance transmission, the light signal fades and in order to boost up the signal strength, an optical amplifier is deployed. The erbium doped fiber amplifier enables a wide range of link distances without turning on the power supply and facilitates WDM transmission due to its wide bandwidth, optimum BER and crosstalk avoidance features [19, 20].

Utilizing the integration of the sub-channels provided by the Optical Frequency Comb (OFC) demonstrates improved performance and energy efficiency in optical fiber-based light systems [20]. OFC reduces the need for security bands between smaller stations and thus enables improved visual efficiency compared to the use of free-flowing laser [20]. The OFC when used with the demultiplexer provides filtering, enlargement and conversion of combed tones, all in one device with multiplexing [25].

Table 1: Brief overview of current literature (adopted & modified from [21])

	Veselka et.al. (1998) [18]	Beas et.al. (2013) [3]	Zacharias et.al. (2017) [22]	Tao et.al. (2017) [17]	Mukherjee (2017) [23]	Sharma et.al. (2017) [5]	Kanno et.al. (2018) [24]	Konstantinou et.al. (2020) [15]	Deepak Jain et.al. (2021) [21]	Proposed Work
Carrier Fre- quency (GHz)	50	45 & 60	60	0.9 – 1.8	60	60	92 – 100	28	100	110
Data Rate (Gbps)	2.8	2.5 & 7.5	25	2.5–9	10	10	10 & 20	4.8	10	12
Optical Band	C	Q & V Band	C	C	C	C	C	C	C	C
BER	10^{-5}	10^{-9} & 10^{-8}	10^{-8}	10^{-11}	10^{-6}	-	10^{-9}	10^{-9}	10^{-9}	10^{-14}
Distance (Km)	25	50	25	60	60	60	30	60	70	100

OFDM can be labeled as a multicarrier modulation that data information is managed by various low-level carriers. OFDM's two main advantages can be realized, namely its durability in channel dispersion and its simplicity of channel and phase alignment in a flexible environment [12]. A 25 Gb/s 60 GHz OFDM RoF system based on mm-wave generation using Fabry-Perot Laser Diode (FPLD) as described and modeled in [22] shows the impact of signal interference is very low. Good performance in terms of BER is obtained for downlink 4-QAM OFDM. 25 Gb/s OFDM RoF signal can reach BER at 10^{-8} .

Spectral spacing of data channels causes an increase in Inter Channel Interference (ICI), thus requiring effective compensation strategies to recover data. Cascaded conjugate wave generations and phase, amplitude, & delay adjustments can be used to reduce ICI [26].

Active antenna systems, central baseband unit structures, cloud radio access networks etc. have the potential to make a significant contribution to the development of integrated visual and wireless networks. The main challenge is the very large bit rates per cell site to be supported. The analog visual distribution networks may provide an alternative to common digital fiber optic links between

remote radio head and baseband units in the next generation of integrated networks [27].

Further, summary of related literature is documented in table 1.

2 System Design

The designed simulative model for WDM-RoF network mainly consists of a laser source which emits light with wavelength of 1550 nm as shown in figure 1. This optical signal is modulated by RF signal (100-120 GHz) and a pair of MZM modulators. The modulated optical signal is further transmitted through a pair of optical fibers over the range of 30-120 km. An OPC is utilized to separate the pair of optical fiber. Finally the optical signal is detected by deploying an Avalanche Photo Diode (APD). Several measurement components like BER meter, Q meter, electrical scope, OSNR meter etc are utilized at the receiver end. In order to minimize the dispersion and retain the signal quality over long distance with high frequency, OPC is introduced in the link. OPC, also known as wavefront retraction, is a technique that involves the construction of an optical beam with a different wavefront of it, or phase, that is reversed

Fig. 1: Block diagram of proposed RoF network

Fig. 2: Simulative schematic model of proposed single channel WDM-RoF network

Fig. 3: Transmitter

in relation to the reference beam. When the optical field is represented as a product of amplitude and a complex exponential phase,

$$E_{in}(t) = A(t)e^{j\phi(t)} \quad (1)$$

then the process of rewinding a phase sign is equivalent to making a complex conjugate of the

original field, the identification that results in the name phase conjugation.

$$E_{out}(t) = \eta A(t)e^{-j\phi(t)}e^{j\phi_{shift}} \quad (2)$$

where η is device efficiency and ϕ_{shift} as extra constant phase shift.

Fig. 4: Receiver

When OPC is combined with the reversal of the transmission direction, it allows compensation for the distortion of the optical beam, which

develops as a result of the distribution through distorted media.

Figure 2 shows proposed simulation model of single channel WDM-RoF network with OPC. Figure 5 shows the proposed 8 channel WDM-RoF model with transmitter and receivers as block and their internal implementation is represented in fig. 3 and fig. 4 respectively.

Table 2 gives the list of major parameters and their values used for simulation which is carried out in optisystem 17.0 version.

Table 2: Simulation Parameters

Parameter	Value
Length of fiber	30–120 Km
Carrier frequency	105–120 GHz
Data rate	10–14 Gbps
Reference wavelength	1550 nm
Dispersion	16.75 ps/nm/km
Dispersion slope	0.075 ps/nm ² /km

3 Results and Discussions

3.1 Performance against Transmission Distance

The modulated 110 GHz NRZ carrier signal is multiplexed over a 8 x 1 multiplexer over a fiber with dispersion of 16.75 nm/ps. In order to analyze how far the signal can travel, the transmission channel distance is varied from 30 to 120 km for all the 8 channels with a wavelength over 1550 nm to 1553.5 nm separated by 0.5 nm.

Table 3, 4, 5 & 6 represent measured BER, Q-factor, OSNR & optical gain respectively when carrier frequency is kept at 110 GHz with input data rate of 12 Gbps. Figure 6a, 6b, 6c & 6d shows the plot for variation of logarithmic BER, Q-factor, OSNR & optical gain respectively against varying transmission distance for all the 8 channels.

From table 3 and figure 6a, it can be seen that the designed link provides quality transmission since BER obtained is well above than 10^{-10} over transmission range of 30 to 100 km for all the 8 channels. At 110 & 120 km, channels from

Fig. 5: Simulative schematic model of proposed 8 channel WDM-RoF network

Table 3: Obtained BER values for 8 Channel WDM-RoF system against transmission distance

Distance	Wavelength (nm)							
	1550	1550.5	1551	1551.5	1552	1552.5	1553	1553.5
30 Km	8.00e-96	2.06e-92	2.36e-97	5.38e-96	2.18e-94	5.18e-90	1.55e-87	1.69e-79
40 Km	9.46e-98	5.78e-95	1.85e-87	7.16e-91	3.67e-87	1.57e-87	6.07e-83	4.37e-69
50 Km	1.27e-93	4.36e-105	1.47e-86	4.15e-90	3.89e-92	1.18e-84	8.03e-80	6.28e-67
60 Km	1.69e-91	6.62e-95	1.29e-94	2.16e-84	2.59e-86	4.99e-84	3.09e-79	8.54e-51
70 Km	2.35e-88	8.41e-86	3.81e-86	1.44e-89	3.99e-79	9.55e-84	3.66e-68	1.46e-44
80 Km	1.87e-82	2.39e-86	3.02e-89	2.06e-82	1.23e-81	1.37e-73	1.18e-58	7.32e-32
90 Km	1.43e-79	8.41e-82	1.04e-78	5.86e-78	5.26e-75	3.39e-64	4.67e-45	3.85e-22
100 Km	2.82e-79	2.34e-74	3.45e-74	2.35e-76	2.01e-65	1.47e-51	1.61e-34	7.03e-14
110 Km	8.38e-62	1.61e-70	2.30e-67	4.23e-66	1.03e-58	3.43e-46	1.88e-22	3.38e-09
120 Km	9.30e-49	1.56e-60	2.19e-62	3.80e-52	7.09e-46	5.41e-31	8.05e-15	1.14e-05

Table 4: Obtained Q-factor values for 8 channel WDM-RoF system against transmission distance

Distance	Wavelength (nm)							
	1550	1550.5	1551	1551.5	1552	1552.5	1553	1553.5
30 Km	20.71	20.33	20.88	20.73	20.55	20.06	19.77	18.82
40 Km	20.93	20.61	19.76	20.16	19.73	19.77	19.23	17.50
50 Km	20.47	21.72	19.66	20.07	20.30	19.43	18.86	17.22
60 Km	20.23	20.61	20.58	19.40	19.63	19.36	18.79	14.91
70 Km	19.87	19.57	19.61	20.01	18.77	19.33	17.38	13.93
80 Km	19.17	19.63	19.97	19.17	19.08	18.08	16.08	11.66
90 Km	18.83	19.1	18.72	18.63	18.26	16.85	14.01	9.58
100 Km	18.79	18.18	18.16	18.43	17.01	15.03	12.17	7.36
110 Km	16.52	17.69	17.27	17.11	16.08	14.19	9.65	5.77
120 Km	14.60	16.34	16.60	15.12	14.14	11.49	7.65	4.21

Table 5: Obtained OSNR values for 8 channel WDM-RoF system against transmission distance

Distance	Wavelength (nm)							
	1550	1550.5	1551	1551.5	1552	1552.5	1553	1553.5
30 Km	76.28	73.93	77.34	76.40	75.29	72.28	70.57	65.02
40 Km	77.61	75.69	70.52	72.87	70.31	70.56	67.40	57.84
50 Km	74.77	82.67	69.89	72.34	73.74	68.58	65.25	56.36
60 Km	73.30	75.65	75.45	68.40	69.72	68.15	64.84	45.23
70 Km	71.13	69.37	69.61	71.97	64.77	67.96	57.21	40.93
80 Km	67.06	69.75	71.75	67.04	66.51	60.95	50.65	32.17
90 Km	65.08	66.61	64.48	63.96	61.93	54.47	41.27	25.47
100 Km	64.87	61.48	61.36	62.86	55.32	45.76	34.01	19.77
110 Km	52.82	58.83	56.66	55.79	50.69	42.06	25.68	16.54
120 Km	43.83	51.95	53.22	46.16	41.84	31.57	20.42	14.11

1550 nm to 1553 nm perform well but channel 8 (1553.5 nm) show degraded performance. The same trend of performance for all the channels is observed while analyzing the obtained Q-factor

and OSNR as presented in table 4, 5 and figure 6b, 6c respectively.

Table 6: Obtained Optical Gain values for 8 channel WDM-RoF system against transmission distance

Distance	Wavelength (nm)							
	1550	1550.5	1551	1551.5	1552	1552.5	1553	1553.5
30 Km	25.27	26.15	26.58	26.82	26.95	28.58	21.56	26.41
40 Km	23.25	24.15	24.57	24.83	24.96	26.46	20.46	24.41
50 Km	21.27	22.15	22.58	22.82	22.96	24.59	18.45	22.41
60 Km	19.27	20.15	20.58	20.82	20.96	22.56	16.62	20.41
70 Km	17.27	18.15	18.58	18.82	18.96	20.55	14.31	18.41
80 Km	15.28	16.15	16.58	16.82	16.96	18.57	12.56	16.42
90 Km	13.25	14.15	14.58	14.82	14.95	16.47	10.40	14.41
100 Km	11.26	12.17	12.57	12.82	12.96	14.49	8.70	12.40
110 Km	9.26	10.16	10.58	10.81	10.95	12.59	6.22	10.40
120 Km	7.31	8.16	8.57	8.83	8.95	10.59	4.58	8.40

(a) $\log_{10}$ BER vs transmission distance

(b) Q-factor vs transmission distance

(c) OSNR vs transmission distance

(d) Gain vs transmission distance

Fig. 6: Performance of 8 channel WDM-RoF system against transmission distance

3.2 Performance against Bit Rate

To ascertain the system performance against data rate, the input bit rate has been varied from 10

Table 7: Obtained BER values for 8 channel WDM-RoF system against bit rate

Bit Rate	Wavelength (nm)							
	1550	1550.5	1551	1551.5	1552	1552.5	1553	1553.5
10 Gbps	1.81e-84	2.60e-86	4.06e-78	1.11e-76	2.55e-83	7.45e-79	1.33e-57	1.06e-30
11 Gbps	5.78e-38	2.33e-43	6.90e-36	3.24e-37	1.21e-33	9.90e-33	7.63e-28	2.96e-20
12 Gbps	6.14e-26	1.62e-24	1.04e-24	9.85e-25	7.96e-25	3.50e-23	3.40e-21	6.72e-16
13 Gbps	9.11e-15	1.45e-14	1.64e-14	8.04e-14	8.48e-15	1.93e-14	4.84e-13	1.69e-11
14 Gbps	3.36e-10	7.30e-11	1.26e-10	4.40e-10	8.41e-10	4.65e-10	1.43e-09	6.49e-09

Table 8: Obtained Q-factor values for 8 channel WDM-RoF system against bit rate

Bit Rate	Wavelength (nm)							
	1550	1550.5	1551	1551.5	1552	1552.5	1553	1553.5
10 Gbps	19.41	19.63	18.65	18.47	19.28	18.74	15.93	11.43
11 Gbps	12.79	13.72	12.41	12.66	12.00	11.82	10.83	9.11
12 Gbps	10.43	10.11	10.16	10.16	10.18	9.81	9.33	7.95
13 Gbps	7.61	7.55	7.54	7.33	7.62	7.52	7.08	6.58
14 Gbps	6.12	6.36	6.27	6.08	5.97	6.06	5.88	5.63

Table 9: Obtained OSNR values for 8 channel WDM-RoF system against bit rate

Bit Rate	Wavelength (nm)							
	1550	1550.5	1551	1551.5	1552	1552.5	1553	1553.5
10 Gbps	65.13	66.40	60.75	59.76	64.34	61.26	46.60	28.05
11 Gbps	33.06	36.78	31.63	32.54	30.08	29.45	26.08	20.85
12 Gbps	24.77	23.79	23.92	23.94	24.00	22.87	21.50	17.84
13 Gbps	17.06	16.92	16.89	16.41	17.08	16.84	15.87	14.81
14 Gbps	13.91	14.37	14.21	13.83	13.64	13.82	13.48	13.03

to 14 Gbps with a carrier frequency of 110 GHz and over the distance of 100 km for all the 8 channels with a wavelength over 1550 nm to 1553.5 nm separated by 0.5 nm.

Table 7, 8 & 9 shows the BER, Q-factor & OSNR perceived respectively at the receiver end with respect to bit rate. Figure 7a, 7b & 7c shows the plot for variation of logarithmic BER, Q-factor & OSNR respectively against varying bit rate for all the 8 channels.

From table 7 and figure 7a, it can be seen that the designed link provides quality transmission since BER obtained is well above than 10^{-10} over varying bit rate of 10 Gbps to 13 Gbps for all the 8 channels. At 14 Gbps, channels from 1550 nm to 1552.5 nm perform well but channels 7 & 8 (1553 nm, 1553.5 nm) show relatively poor output which is also evident in table 8, 9 and figure 7b & 7c for Q-factor and OSNR respectively.

3.3 Performance against Carrier Frequency

The carrier frequency is varied over a range of 105 GHz to 120 GHz at transmission distance of 100 km and bit rate of 12 Gbps for all 8 channels with a wavelength over 1550 nm to 1553.5 nm separated by 0.5 nm.

Table 10, 11 & 12 shows the BER, Q-factor and OSNR perceived respectively at the receiver end with respect to carrier frequency. Figure 8a, 8b & 8c shows the plot for variation of logarithmic BER, Q-factor & OSNR respectively against varying carrier frequency for all the 8 channels.

From table 10 and figure 8a, it can be seen that the designed link provides quality transmission as BER obtained is well above than 10^{-10} over a carrier frequency of 105 GHz to 115 GHz for all the 8 channels. At 120 GHz, all the channels yielded poor results. The same behaviour of performance

(a) $\log_{10}$ BER vs bit rate

(b) Q-factor vs bit rate

(c) OSNR vs bit rate

Fig. 7: Performance of 8 channel WDM-RoF system against bit rate**Table 10:** Obtained BER values for 8 channel WDM-RoF system against carrier frequency

Carrier Frequency	Wavelength (nm)							
	1550	1550.5	1551	1551.5	1552	1552.5	1553	1553.5
105 GHz	6.97e-94	2.31e-92	7.89e-89	1.94e-94	1.49e-88	5.48e-81	1.42e-56	1.60e-32
110 GHz	7.13e-87	3.04e-93	7.50e-80	8.08e-85	8.06e-81	1.44e-72	3.59e-52	4.92e-31
115 GHz	1.29e-24	7.77e-30	9.70e-18	3.36e-18	3.82e-18	4.05e-15	2.89e-15	8.68e-13
120 GHz	6.22e-06	1.72e-06	9.71e-05	2.15e-04	2.13e-4	6.89e-4	2.07e-4	4.07e-4

Table 11: Obtained Q-factor values for 8 channel WDM-RoF system against carrier frequency

Carrier Frequency	Wavelength (nm)							
	1550	1550.5	1551	1551.5	1552	1552.5	1553	1553.5
105 GHz	20.50	20.33	19.92	20.56	19.90	19.00	15.78	11.79
110 GHz	19.70	20.43	18.86	19.45	18.98	17.95	15.12	11.50
115 GHz	10.13	11.24	8.44	8.56	8.55	7.71	7.75	6.99
120 GHz	4.28	4.55	3.64	3.43	3.44	3.12	3.43	3.24

Table 12: Obtained OSNR values for 8 channel WDM-RoF system against carrier frequency

Carrier Frequency	Wavelength (nm)							
	1550	1550.5	1551	1551.5	1552	1552.5	1553	1553.5
105 GHz	71.63	70.58	68.14	72.01	67.95	62.73	45.90	29.31
110 GHz	66.79	71.18	61.95	65.37	62.62	56.92	42.86	28.28
115 GHz	23.85	27.45	19.11	19.43	19.39	17.31	17.41	15.70
120 GHz	10.97	11.35	10.15	9.91	9.91	9.56	9.92	9.72

(a) $\log_{10}$ BER vs carrier frequency

(b) Q-factor vs carrier frequency

(c) OSNR vs carrier frequency

Fig. 8: Performance of 8 channel WDM-RoF system against carrier frequency

is observed while analyzing the obtained Q-factor and OSNR as presented in table 11, 12 and figure 8b, 8c respectively.

Figure 9a shows the eye diagrams of WDM-RoF network for each channel at 12 Gbps data rate, 110 GHz carrier frequency for a transmitting distance of 100 km.

It is observed from the results that as higher wavelengths are being launched for transmission,

the system performance starts degrading especially for channel 7 & 8 (1553 nm & 1553.5 nm). Such relatively substandard response of higher wavelengths in WDM system is mainly because of the fiber non linearities including Kerr non linearities & stimulated Raman Scattering induced crosstalk [11, 28]. The multiple wavelengths start interacting with each other when input optical power is kept substantially high to ensure longer

Fig. 9: Eye diagram of WDM-RoF network for different channels at 100 km transmission distance, 110 GHz carrier frequency & 12 Gbps data rate

Table 13: BER comparison of proposed WDM-RoF network against existing contribution

Channels	Reported by Deepak Jain et.al. [21]			Proposed 8 channel WDM-RoF at 12 Gbps & 110 GHz				
Distance	30 Km	50 Km	70 Km	30 Km	50 Km	70 Km	90 Km	110 Km
Channel 1	5.50e-043	1.87e-019	3.15e-009	8.00e-96	1.27e-93	2.35e-88	1.43e-79	8.38e-62
Channel 2	7.49e-041	1.68e-017	1.48e-008	2.06e-92	4.36e-105	8.41e-86	8.41e-82	1.61e-70
Channel 3	1.41e-042	5.22e-021	2.42e-010	2.36e-97	1.47e-86	3.81e-86	1.04e-78	2.30e-67
Channel 4	1.10e-047	1.48e-020	2.15e-009	5.38e-96	4.15e-90	1.44e-89	5.86e-78	4.23e-66
Channel 5	-	-	-	2.18e-94	3.89e-92	3.99e-79	5.26e-75	1.03e-58
Channel 6	-	-	-	5.18e-90	1.18e-84	9.55e-84	3.39e-64	3.43e-46
Channel 7	-	-	-	1.55e-87	8.03e-80	3.66e-68	4.67e-45	1.88e-22
Channel 8	-	-	-	1.69e-79	6.28e-67	1.46e-44	3.85e-22	3.38e-09

Table 14: OSNR comparison of proposed WDM-RoF network against existing contribution

Channels	Reported by Deepak Jain et.al. [21]			Proposed 8 channel WDM-RoF at 12 Gbps & 110 GHz				
Distance	30 Km	50 Km	70 Km	30 Km	50 Km	70 Km	90 Km	110 Km
Channel 1	65.32	61.39	57.43	76.28	74.77	71.13	65.08	52.82
Channel 2	64.35	60.41	56.38	73.93	82.67	69.37	66.61	58.83
Channel 3	60.34	56.34	52.35	77.34	69.89	69.61	64.48	56.66
Channel 4	55.37	51.41	47.52	76.40	72.34	71.97	63.96	55.79
Channel 5	-	-	-	75.29	73.74	64.77	61.93	50.69
Channel 6	-	-	-	72.28	68.58	67.96	54.47	42.06
Channel 7	-	-	-	70.57	65.25	57.21	41.27	25.68
Channel 8	-	-	-	65.02	56.36	40.93	25.47	16.54

transmission range. This interaction of wavelengths leads to impairment in signal transmission. Moreover, as the transmission wavelengths away from reference wavelength of 1550 nm are utilized, these offer more attenuation and losses compared to lower range of frequencies. Hence, higher range of channels provides degraded output performance.

Table 13 gives a comparison of BER obtained by the author in [21] and BER obtained from our proposed model. Similarly, 14 gives a comparison of OSNR obtained by the author in [21] and OSNR obtained from our proposed model. It can be seen that proposed network improved signal transmission over larger distances with higher data rate.

4 Conclusion

An advanced WDM-RoF network is designed and investigated for high frequency & larger transmission oriented next generation wireless networks.

The BER reported for 8 channels at 100 km transmission distance, 110 GHz carrier frequency with a bit rate of 12 Gbps is 2.82e-79, 2.34e-74, 3.45e-74, 2.35e-76, 2.01e-65, 1.47e-51, 1.61e-34, 7.03e-14 respectively. Q-factor obtained for the 8 channels is 18.79, 18.18, 18.16, 18.43, 17.01, 15.03, 12.17, 7.36 respectively. OSNR measured for all channels is 64.87, 61.48, 61.36, 62.86, 55.32, 45.76, 34.01, 19.77 respectively.

The obtained results present significant improvement in the WDM-RoF networks compared to existing RoF network designs. A detailed comparison of reported improvement is presented in table 13 and 14. This improved behaviour is due to the use of cascaded combination of MZM modulators and OPC which collectively mitigate the network limitations effectively and efficiently. Further, it is also revealed that a couple of higher wavelength channels [channel 7 (1553 nm); channel 8 (1553.5 nm)] yield relatively deteriorated output compared to lower wavelength channels.

The performance of the designed network may be improved further by optimizing system parameters and managing the channel spacing so that higher wavelengths also offer output at par with the lower wavelength channels. Finally, it is concluded that proposed WDM-RoF network outperforms existing network designs to cater the next generation wireless subscriber's need.

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