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Optimization for Next Generation Wireless System Using Radio Over Fiber in Terms of Topology

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Abstract

This dynamic execution of Radio over Fiber (RoF) joins utilizing minimal effort optoelectronic parts are evaluated for dispersed receiving wire applications in cutting edge remote frameworks. Vital configuration issues are examined and an illustrated the outline is exhibited for a remote framework requiring the transmission of four radio channels for every connection course. Each of these channels has 100 MHz transmission capacity, balance many-sided quality of 256-QAM and 2048 OFDM subcarriers. The Radio Access Network (RAN) is using for all types of mobile system, each of this RAN have a different topology such as star, circle, tree, etc. On the other hand, to creating and using a new RAN is better to use mesh topology which is suitable for the new system. In the same way, in the field of using new RAN, topology can be apply as a mesh, which includes RoF. It also call as next generation mobile system for the new system, instead of using microwave it can use fiber optic that is why microwave are ignored. This type of use is more useful in terms of quality and system optimization for 4G and similar systems.

Keywords: Next generation, New Radio Access Network (RAN), Radio over Fiber (RoF), Mesh topology, Dispersion of fiber optic.

Yeni Nesil Kablosuz Sistemlerin Fiber Üzerinde RF Kullanılarak Topoloji Açısından Optimizasyonu

Özet

Bu çalışmada, minimum maliyete sahip optoelektronik elemanlar kullanılarak oluşturulan fiber üzerinden radyo (RoF) dalgalarının dinamik iletiminde uzak sistemlerdeki zayıflama dağıtık kablolu alıcı uygulamaları için değerlendirildi. Önemli gruplama sorunları incelendi ve bir örnek ile açıklandı. Sonuçlar, her bir bağlantı yolu için dört radyo kanallı iletime gereksinim duyan uzak sistemle sunuldu. Bu kanalların her biri, 100 Mhz iletim kapasitesine, 256-QAM çok yönlü kalite dengeleyicisine ve 2048-OFDM ara taşıyıcılarına sahiptir. Radyo Erişim Ağı (RAN) mobil sistemlerin tüm türleri için kullanılıyorken, bu RAN sistemlerinin her biri ise farklı bir topolojiye sahiptir: yıldız, halka, ağaç, vb. Diğer yandan, yeni bir RAN tasarlamak ve kullanmak için örgü ağ topolojisinin kullanımı, yeni sistemler için daha uygundur. Benzer şekilde, yeni RAN kullanımında, örgü ağ topoloji RoF yapısına dahil olabilmesi nedeniyle daha uygulanabilirdir. Bu yeni sistemler için, mikro dalga kullanımı yerine mikrodalganın göz ardı edilerek doğrudan fiber optik hattın kullanımı yeni nesil mobil sistem olarak da adlandırılır. Bu tarz kullanım, 4G ve benzer sistemler için kalite ve sistem optimizasyonu açısından daha kullanışlıdır.

Anahtar Kelimeler: Yeni nesil, Yeni Radyo Erişim Ağı (RAN), Radyo Üzerinden Fiber (RoF), Örgü ağ topolojisi, Fiber optik dağılım.

1. Introduction

Change in the nature of the service, new frequency bands and non-backwards compatible transmission technology is generally called the next generation. New generations have risen again in every 10 years from 1981, analog 1^{st} G to analog 2^{nd} G network, then the 3^{th} G multimedia support followed the two previous generations. And finally, the 4^{th} G comes, in last years a great growth in the industry of wireless, both subscribers, and mobile technology. A dramatic change from fixed to mobile cellular telephony. Together, the vendors and mobile network operators have important role of effective networks with the equally effective anning coming into focus. The 5th G is multi Technology Core as given in Table 1. The assemblage of new technologies such as Nano-technology, Cognitive Radio, Cloud Compute, and based on all IP Platform form a core [1]. Table 1 is the mobile generation evolution from 1G to 5G.

Table 1. Evolution of mobile radio standards [1]

N.G	1G	2G	3G	4G	5G
Year	1970	1980	1990	2000	2012
Standards	AMPS, NMT, HICAP	GSM, I-DEN, D-AMPS	CDMA 2000, WCDMA	Signal Standard LTE, Advance	Single Unified Standard
Data Bandwidth	1.9 Kbps	14.4 Kbps	2 Mbps	200 Mbps	1 Gbps & Higher
Core Network	PSTN	PSTN	Packet Network	INTERNET	INTERNET
Multiplex	FDMA	CDMA, TDMA	CDMA	OFDMA	CDMA, BDMA
Service	Analog Voice	Digital Voice	Higher capacity, Broadband Data	Broadband Data With High Speed	Dynamic Information Access

RoF systems use optical fiber, which has minimum lack and wide band width transmission area that allow the spreading of broadband data or high frequency signals into many Base Station (BS) is easy. [2]

The benefits of Radio over Fiber technology makes it an important for the future of wireless communication and makes the companies race to know that technology and implement it to obtain a system that more efficient and has better performance. The technology of Fiber optic gives technical works advantage over commercial.

2. Materials and Method

2.1. Radio over fiber

RoF indicates to a technology that using light to tone radio signal and transfer it over an optical fiber connected to divide radio signals of a centric place to remote stations as shown in Figure 1. The radio signals frequencies are divided into RoF systems cover a great range (often in the GHz region), which rely on the kind of the apps. The electrical signal may be baseband the current modulated RF signal, design. This development leads to optimization related services and Network Pl modulated IF (Intermediate Frequency), or data to be distributed. RoF conveyance systems are divided into 2 general categories (RF Fiber; IF-over-Fiber) rely on the range of frequency of the radio signal to be transmitted In RF-over-Fiber design, a data (usually more than 10 GHz) is imposed on a light signal wave prior to transported over the optical link. In IF-over-Fiber architecture, an IF radio signal together with less frequency (Less than 10 GHz) is utilized for tone light before being transported over the optical link [4].

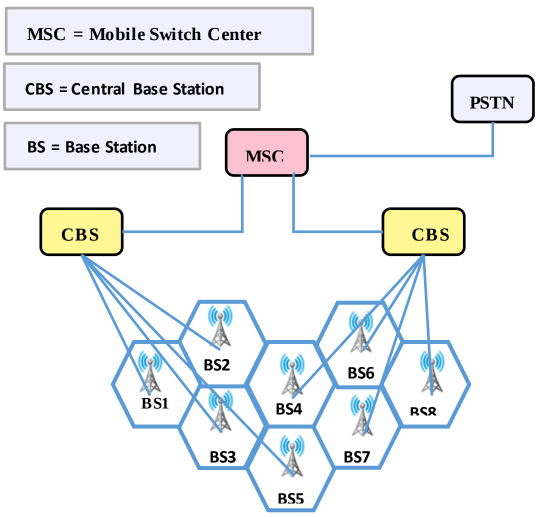

Figure 1. Remote network antenna for micro-cell for RoF system

RoF, is composed of a CS (Control Station) with BS joined by an optical fiber network or link as shown in Figure 2.

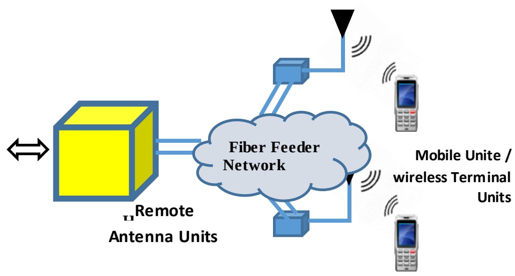

Figure 2. The radio over fiber system concept

The transmitting of peak frequency signals is more affronts due to the requirement of peak frequency part and bigger bandwidth link. This refers to larger frequency signals are more sensitive to the transmission, transmitter and receiver link signal failure [5].

Transmitting of the constant frequency of RF signal, it is not important. For example, an LO signal, if present, may be utilized to down-convert the uplink holder to an IF in the RAU (Radio Access Unit). Performing it would permit the use of low-frequency components for the up-link way in the RAU – directing to a system for reducing cost. By putting a different LO in the RAU, it can transmit from the head end to the RAU by the RoF system. As it available at the RAU, the LO can be used to tone down conversion of the uplink signals [6].

RoF technology advantages are compares with electronic signal distribution are mentioned as follow;

- Low Attenuation Loss
- Large Bandwidth
- Radio Frequency Interference Immunity
- Reduced Power Consumption

2.2. Cell planning

Therefore, RAN in the mobile system Next generation contains a group of BTS (Base Transceiver Station) that all of them are designed next together. Each BTS contains cell that called six dimensions or squib. Also, each cell contains three Antennas. When we want to send the frequency for all of the BTS we have to make them as a group because it is easier to send the frequency for each group. So, BTS groups are arranging like (3,7,9,12,…) and they called cluster size. However, it has a special rule to make them. Cluster size rule is (i, j) to finding (N) it can be use this rule (N= i2 + ij + j2). For distance of the (i, j) rule and it can be use $D = \sqrt{3N}$, in the picture below will illustrate how we classify BTS over the groups as shown in Figure 3 [7].

Where is i= blue line, j= black line, D= red line, i= vertical, j= horizontal, D= distance between two cell.

Table 2 is the cluster size calculation for the cell planning procedure.

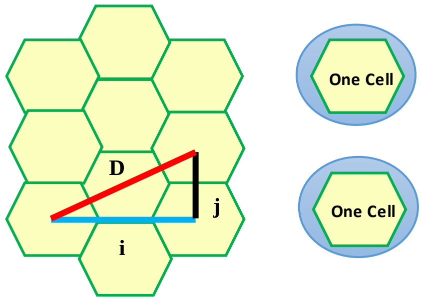

Figure 3. Cell planning in cluster size

Table 2. Cell planning in cluster size [7]

i	j	N = i² + ij + j²	$D = \sqrt{3\,N}$	Radius Cells
0	0	0	$D = \sqrt{3*0}$	0
0	1	1	$D = \sqrt{3*1}$	1.73 ≅ 2
1	0	1	$D = \sqrt{3*1}$	1.73 ≅ 2
1	1	3	$D = \sqrt{3*3}$	3
0	2	4	$D = \sqrt{3*4}$	3.46
2	0	4	$D = \sqrt{3*4}$	3.46
1	2	7	$D = \sqrt{3*7}$	4.58
2	1	7	$D = \sqrt{3*7}$	4.58
2	2	12	$D = \sqrt{3*12}$	6
0	3	9	$D = \sqrt{3*9}$	5.19
3	0	9	$D = \sqrt{3*9}$	5.19
3	1	13	$D = \sqrt{3*13}$	6.24
1	3	13	$D = \sqrt{3*13}$	6.24
3	2	19	$D = \sqrt{3*19}$	7.54
2	3	19	$D = \sqrt{3*19}$	7.54
3	3	27	$D = \sqrt{3*27}$	9

2.3. Problem of statement

To reduce and increase all of the problems that mentioned above and to solve the disconnection between BTS and BSC (Base Station Central), it is better to use fiber optic instead of using microwave, because by using fiber optic in the case of calling those problems are an increase.

Same challenge between two Base Stations (BSs) or between BSs and BSC as shown in Figure 4.

a. In old RAN Communication was done Directly between Two BTS by Microwave Link as shown in figure (a).

b. The problems that rise between two BTS during sending a signal to occur because of Mountain and Hills as shown in figure (b).

c. Or because of Rain, Snow, Storm, and Airplane in Airport as shown in figure (c).

d. The aim from this topic is design a new RAN to solving this problem by removing of Microwave Link between two BTS in place of it, using Fiber optic between all BTS then a group of BTS connected to one BSC then Connected to Core Network after connected to the Internet as shown in figure (d).

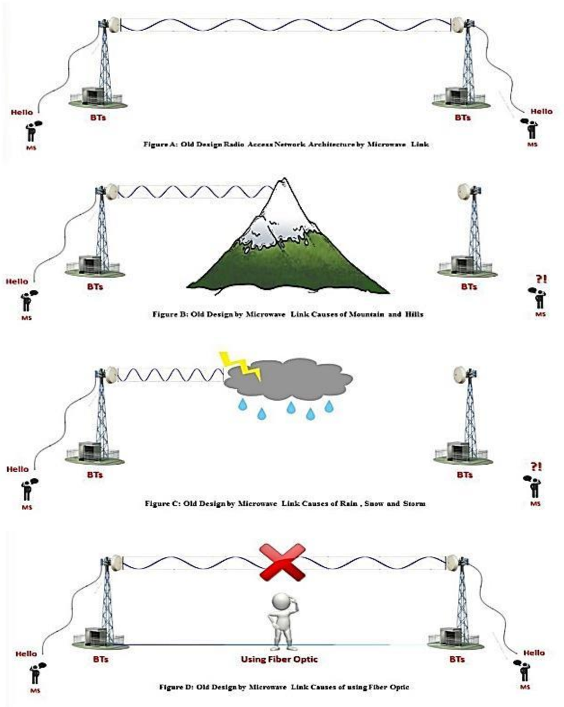

Figure 4 (a,b,c,d). Same challenge between two base stations

2.4. Method

2.4.1. Design and optimization for new RAN by matlab environment

Dispersion is divided into two main parts (Intermodal and Intermodal dispersion) and (Intermodal). Also (Intermodal) is divided into two parts: Step and Graded Index; all of the parts will make the Total Dispersion (σ_T) [8].

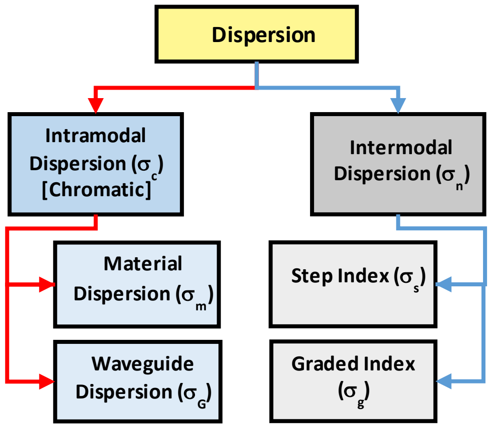

Figure 5. Design and optimization for the challenges of optical fiber

First dispersion, material dispersion (σ_m) in intramodal dispersion (σ_c), also (σ_m) = (σ_c) because waveguide dispersion (σ_G) near of zero therefor (σ_m) = (σ_c) [8].

First dispersion, material dispersion (σ_m) in intramodal dispersion (σ_c), also (σ_m) = (σ_c) because waveguide dispersion (σ_G) near of zero therefor (σ_m) = (σ_c) [8].

$$\sigma_m = \frac{\sigma_\lambda L}{c} \left| \lambda \frac{d^2 n_1}{d\lambda^2} \right| \qquad (1)$$

Where σ_m= material dispersion, σ_λ = constant, c = 2.998x10^8 constant, L = length of the fiber optic, n_1=constant, λ= wavelength of the light.

Second dispersion, step index (σ_s) in intermodal dispersion (σ_n), has been explained dispersion by Δ or NA. [9]

$$\sigma_s = \frac{L n_1 \Delta}{2\sqrt{3}c} = \frac{L(NA)^2}{4\sqrt{3 n_1 c}} \qquad (2)$$

Where σ_s = step index, L = length of the fiber optic, n_1 = constant, Δ= relative refractive index difference, relative with (NA) Numerical Aperture n_1 and n_2, c = constant.

Total dispersion (σ_T) is the result of intermodal and intramodal; dispersion, by finding the total dispersion we can calculate the data bit rate by dividing total dispersion by (0.2). [10]

$$\sigma_T = \sqrt{\sigma_c^2 + \sigma_n^2} \qquad (3)$$

Where σ_T = Total dispersion, σ_c = intramodal dispersion, σ_n = intermodal dispersion.

The Total Dispersion (σ_T) has been measured, because of the find out Data rate by this equation as follow:

$$BT_{Max} = maximum\ bit\ rate = \frac{0.2}{\sigma_t} \qquad (4)$$

2.4.2. Designing topology with optisystem software

Furthermore, in terms of creating new design for next generation mobile system that topology is a mesh, after we create Matlab code by using optimization, then using the process of Optisystem for creating new design in the shape of software, then we use (1 km) or (2 km) fiber optic cable for this system, so some information are collecting before using the system. As shown in Figure 6 [11].

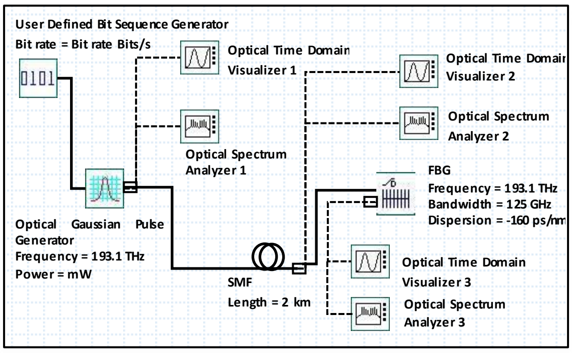

Figure 6. Compensation of dispersion ideal dispersion compensation

2.4.3.Hardware implementation using optical components

The simulation of the proposed design with optisystem software, which is a new RAN design for the system, it is topology well be in a mesh topology, for next generation mobile system of 4^{th} generation or above. The aim from this topic is to design a new RAN to solving this problem by removing of microwave link between two BTS in place of it, using fiber optic between all BTS. After, the practically work included a few instrument connected in sequence as (RF Generator, Attenuator, RoF Transmitter, Fiber Optic Cable, RoF Receiver, Spectrum Analyzer, Optical Spectrum Analyzer), presented in Figure 7.

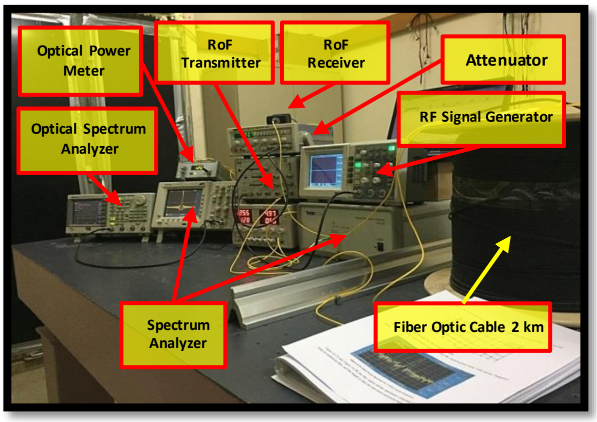

Figure 7. Spectrum analyzer and optical spectrum analyzer

The mentioned instruments practically have been connected to gain the results which came to those achieved by optisystem simulation, shown in Figure 8.

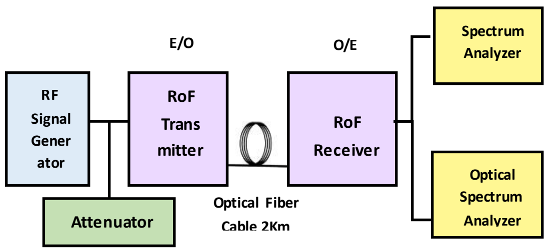

Figure 8. Connected between all parts

First, RF signal Generator has been used as a laser source, then connecting to attenuator part, that used the increasing and decreasing of power during reading the results. After the connection to RoF transmitter part, which is composed of (E/O and light source), and 2 km fiber optic cable has been connected, after that the RoF receiver connected as comprised in (O/E and detector), finally connected to the both parts of spectrum analyzer and optical spectrum analyzer.

3. Result and Discussion

The proposed RAN architecture employs grouping the overall coverage base stations into a number equal to the cluster size. For example, for cluster size N = 3, there will be three groups, and seven groups when N = 7, etc. The contribution of this work is that the 4G mobile system will have central base stations (CBSs) for each group connected to these central base stations, unlike the GSM system which has many base transceivers (BTS). In the GSM system, each group of these BTSs is connected to a base switching control (BSC), and these BSCs are connected to the Mobile Switching Center (MSC), with all of these connections between BTSs, BSCs, and the MSC made via a microwave link.

In this work, each group of base stations will be connected directly to CBSs through the use of the RoF technique, using a fiber optic channel instead of a microwave link. Figure 9 shows the connection of one group of base stations to their central base station (the black nodes represent base stations and the red lines are fiber optic links using RoF technique). A practical view for the proposed RAN is shown in Figure 10.

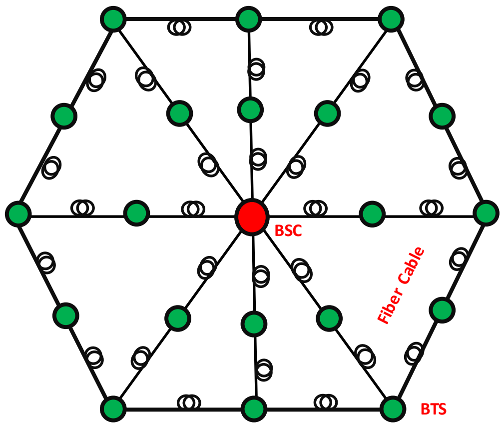

Figure 9. Proposed base station mesh topology to each group

The length of the fiber optic cable between two adjacent base stations BS must be greater than twice the reuse distance D of each base station for cluster size N, therefore, the length of the fiber for different cluster sizes can be obtained as given in Table 3.

For the proposed RAN, for each group of base stations and additional central base station, the first tier base station number = 6, second tier = 12, third tier = 18, i.e. 6 base stations will be added for each subsequent tier. Now the total number of base stations needed for a certain coverage area and cluster size can be obtained, after calculation for each group as shown in Table 4.

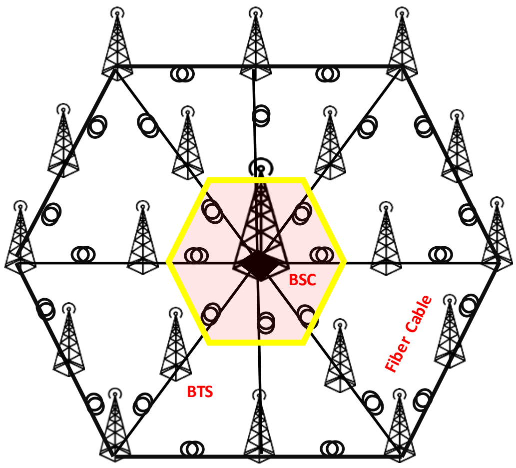

Figure 10. Proposed practical view mesh topology to each group

Table 3. The fiber length radius cells and cluster size calculation

Cluster Size (N)	L (Fiber Length, km)
0	$0 \Rightarrow R$
1	$1.73 \cong 2 \Rightarrow R$
3	$3 \Rightarrow R$
4	$3.46 \Rightarrow R$
7	$4.58 \Rightarrow R$
9	$5.19 \Rightarrow R$
12	$6 \Rightarrow R$
13	$6.24 \Rightarrow R$
19	$7.54 \Rightarrow R$
27	$9 \Rightarrow R$

Table 4. Fiber length (radius cells) and (N) cluster size calculation

No. of (N)	No. of Tiers	BSs	Radius Cells	Coverage Area
0	1	0	0	$(2.6 \times R^2) \times 1$
1	7	127	2	$(2.6 \times R^2) \times 127$
3	7	381	3	$(2.6 \times R^2) \times 381$
4	7	508	3.46	$(2.6 \times R^2) \times 508$
7	7	889	4.58	$(2.6 \times R^2) \times 889$
9	7	1143	5.19	$(2.6 \times R^2) \times 1143$
12	7	1524	6	$(2.6 \times R^2) \times 1524$
13	7	1651	6.24	$(2.6 \times R^2) \times 1651$
19	7	2413	7.54	$(2.6 \times R^2) \times 2413$
27	7	3429	9	$(2.6 \times R^2) \times 3429$

If, Cluster Size N = 7 seven groups, BTS radius cell = 4.58 km, the number of Base Transmission Station BTS = 889 and the commonly coverage area = 48,484.85 km^2.

3.1. Proposed design and optimization results using matlab environment

Figure 11 shows the relation between data rate and the fiber length using multimode graded index fiber optics with different relative refractive index differences (Delta). It is shown that fiber length is about 2 km. Thus, relative refractive index difference must be less than 0.04 for a higher data rate.

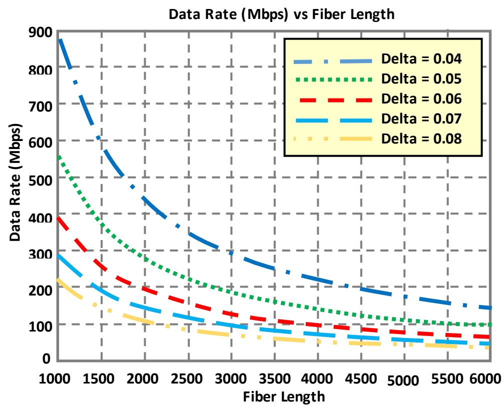

Figure 11. Experimental setup components and connection

Figure 12 shows the relationship between fiber length and data rate with different Numerical Apertures (NA), using multimode step index fiber optics, it is found that for higher data rate and fiber length about 2 km, the numerical aperture must be less than 0.028.

Figure 13 shows the relationship between data rate and relative refractive index difference delta for different cluster sizes (N) using multimode step index fiber optics. It is shown that without clustering (N=1), the data rate is higher, but this causes higher CCI (Co-Channel Interference) and ACI (Adjacent Channel Interference), and hence SIR (Signal-to-Interference Ratio) will be decreased. Therefore, N=3 and N=7 clustering would be more optimal.

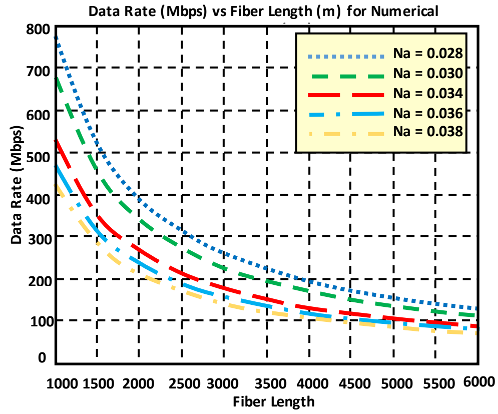

Figure 12. Data rate versus fiber length for step index fiber

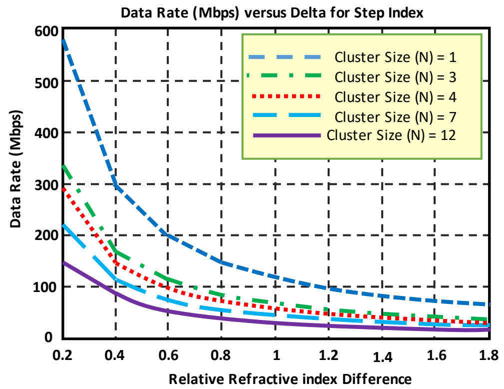

Figure 13. Data rate versus relative refractive index difference for step index

3.2. Proposed design results in design using optisystem software

The optimization to obtain best values of dispersion and then data rate, using OptiSystem software the RAN design using RoF done, the designed system whereas Figure 14 is the transmitted pulse, Figure 15 is the received pulse at the end of the fiber, Figure 16 is the output pulse after minimization of the pulse broadening and dispersion using Fiber Bragg Grating (FBG) technique for dispersion minimization.

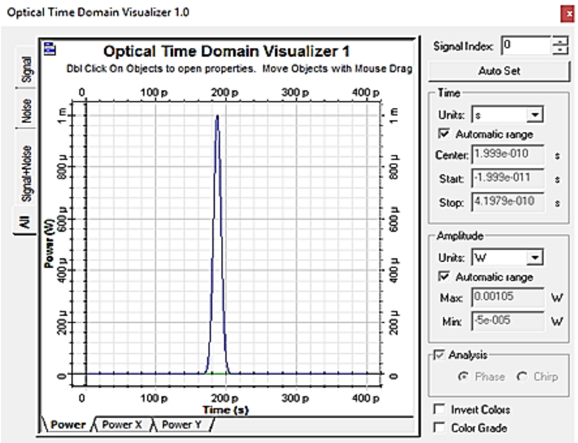

Figure 14. The transmitted pulse launched top the fiber optic

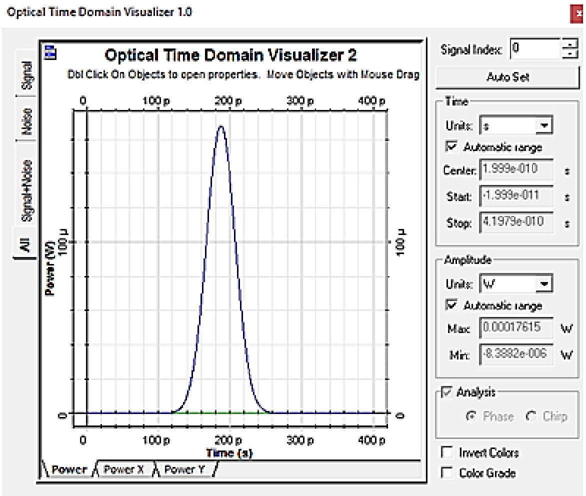

Figure 15. The output pulse from the fiber optic

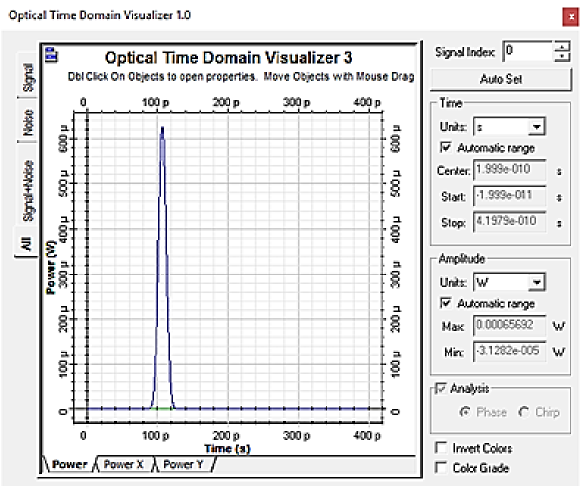

Figure 16. The output pulse from FBG

3.3. Proposed design results for the practical parts

Figure 17 is the input power spectrum from the experimental setup with carrier frequency 2GHz.

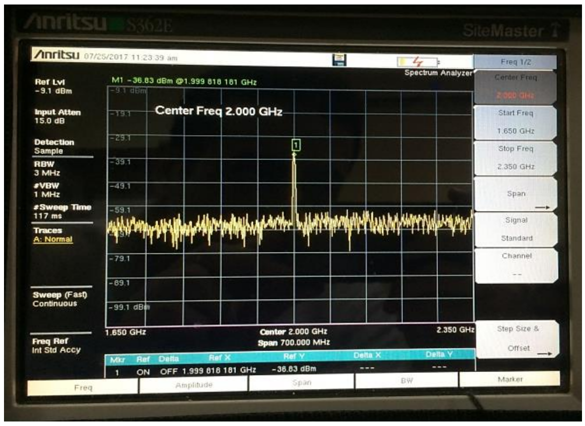

Figure 17. Input power spectrum for 2 GHz carrier frequency

Figure 18 and Figure 19 are the output power spectrums obtained in the experimental setup for multimode fiber, and the length is 2 km for sine wave and pulse inputs respectively. It is shown that the output power for sin wave input has greater (which is about -48dB) than that when the input is a pulse (which is about-75 dB) because of the optical fiber will affect more when the input is a pulse which is by the effect of dispersion.

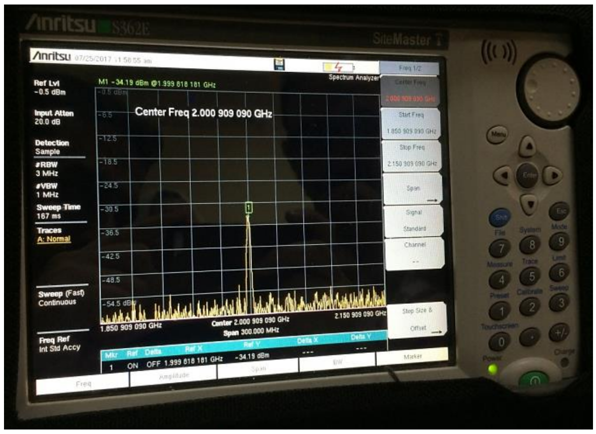

Figure 18. Output power spectrum for 2 GHz carrier frequency with sine wave input

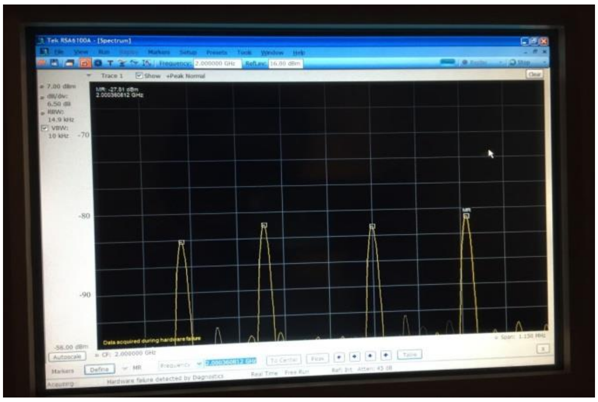

Figure 19. Output power spectrum for 2 GHz carrier frequency with sine wave input

4. Conclusions

A new RoF topology is proposed for the 4G mobile system. The topology involved grouping the coverage into N groups. Each group has many base stations connected to a central base station; thus, there are N central base stations connected to the core network through access gateways, and finally, to the Internet. The use of fiber optic channels allows for high data rate and improved signal quality. Moreover, no interference and free space losses were observed. The maintenance of the proposed topology would be easier, and the overall network would be more reliable. Thus, despite its high installation cost, the proposed RoF topology should provide low running costs.

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