Performance Comparison Of Rf Level Multiplexing And Optical Level Multiplexing In Radio Over Fiber Systems With Direct Optical Modulation Techniques

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Abstract

Communication in the world is developing very rapidly, not only limited to voice but data communication. Many techniques have been used to support multimedia services. Radio over Fiber is expected to support communication for long distances. Therefore, a Comparison of Performance Analysis was carried out using optisystem. Radio over Fiber is simulated by radio frequency signals of 10 GHz and 15 GHz. Radio over Fiber technology for long-distance communication is very vulnerable to high BER and attenuation values, so it requires a mature system design and adequate equipment specifications.

Keywords: Fibers, RoF, OptiSystem

1. Introduction

The need for wireless communication services continues to increase from year to year. This increase was caused by two things, namely the increasing number of subscribers and the increasing demand for bandwidth from subscribers. The increase in customer bandwidth requirements is caused by the presence of smartphones and tablets that enable multimedia services. Macro cells owned by telecommunications operators currently have relatively long wireless channels, so they cannot support very high bit rates. The longer the distance between the wireless transmitter and receiver, the bit rate that can be supported by the channel will decrease (Zheng, 2008). One way that can be used to shorten the wireless channel is to increase the number of radio access points (Fuada, 2017).

Radio access points are usually connected using point-to-point microwave channels. If there are too many radio access points, connecting radio access points using microwave channels becomes ineffective. Radio over Fiber (RoF) technology can be used as a substitute for point-to-point microwave channels (Kong et al., 2020).

RoF is a technique by which radio frequency (RF) signals are transmitted over optical fiber to provide wireless communication services. The RoF system is realized by modulating the optical signal with the RF signal from the wireless network. A simple RoF system architecture is shown in Figure 1 (Kong et al., 2020), where the RF signal from the central office (CO) first propagates through the fiber optic radio access point (RAP) and then reaches the user via the wireless channel.

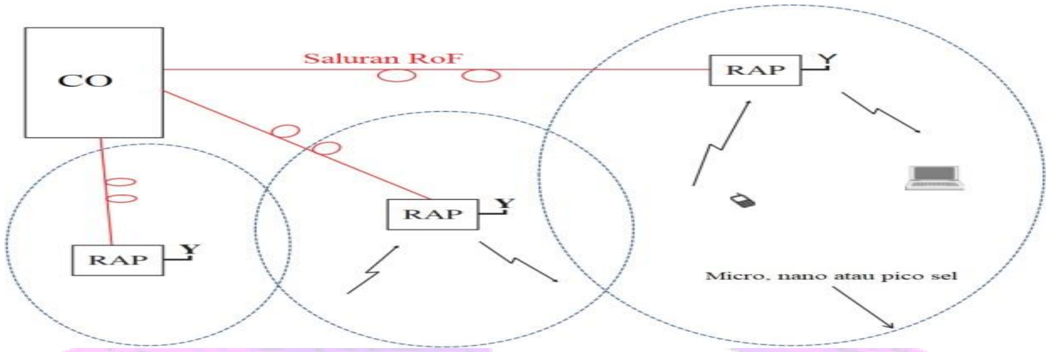

Figure 1. Simple RoF system architecture

Modulation is the process of laying an information signal with a lower frequency to a carrier signal with a higher frequency (Khairunisa et al., 2017). Demodulation is a technique of converting a digital signal into an analog signal (Halomoan et al., 2018). An optical modulator is a component that is used to convert the information signal into a carrier signal in the form of a light beam so that it can be transmitted to the destination. In general, there are two types of optical modulators, namely internal modulators (direct modulators) and external modulators (indirect modulators) (Alwie et al., 2020). The IM-DD system is the most widely used system for fiber optic lines because it is very simple and easy to implement.

The internal modulator modulates the light within the light source device. The working principle of the internal modulator is that light is emitted from a semiconductor laser source only when the signal-sending sign represents the value “1”. Indirectly it can be ensured that light will not be emitted when the value obtained is "0" (Aini et al., 2021).

In external modulation, the voltage from the modulating signal is used to control the parameters of the laser output light by adding an external modulator device (Khair et al., 2016).

The following are several types of multiplex on RoF systems including:

1. Frequency-Division Multiplexing (FDM)

Frequency Division Multiplexing is an analog technique in which the available bandwidth of a single transmission medium is divided into multiple channels. The main goal of FDM is to divide the available bandwidth into different frequency channels and allocate them to different devices. FDM is primarily used in radio broadcasting and TV networks. The advantages of the FDM technique are: FDM is used for analog signals, the FDM process is very simple and easy to modulate, most signals can be sent via FDM simultaneously, and FDM does not require synchronization between sender and receiver. The weakness of the FDM technique is that the FDM technique is only used when low-speed channels are needed, requires a lot of modulators, and requires high bandwidth channels (Zhang et al., 2019).

2. Wavelength Division Multiplexing (WDM)

Wavelength Division Multiplexing (WDM) is almost the same as FDM, the difference is that the optical signal is transmitted over a fiber optic cable. WDM is used in fiber optics to increase the capacity of a single fiber. This technique is used to take advantage of the high data rate capabilities of fiber optic cables. WDM is an analog multiplexing technique. Optical signals from different sources are combined to form a wider optical band with the help of a multiplexer. At the receiving end, the demultiplexer separates the signals to send them to their respective destinations (Feng et al., 2020). Multiplexing and Demultiplexing can be achieved using a prism. The prism can perform the role of a multiplexer by combining various optical signals to form a composite signal, and the composite signal is transmitted through the fiber optic cable. The prism also performs the inverse operation, i.e., signal demultiplexing. So in this study, we compared the performance of RoF systems using RF-level multiplexing with those using optical-level multiplexing. The optical modulation technique used is direct modulation (Lim, D. S., Morse, E. A., Mitchell, R. K., & Seawright, K. K. Ins 34(3), 2010).

2. Method

a. Two Types Of Multiplex In ROF Systems

Multiplexing is a technique of combining several information signals to be sent simultaneously on one transmission channel. The device that performs multiplexing is called a multiplexer or also known as a transceiver/mux. At the receiving end, the combined signals are again separated according to their respective destinations, this process is called Demultiplexing. The receiver or device that performs Demultiplexing is called a Demultiplexer or also known as a Demux.

In RoF systems, multiplexing can be done at the RF level or the optical level.

1. Multiplexing at RF Level

A. multiplexing system by dividing the bandwidth or carrier frequency range into several sub-carrier frequencies. Each frequency is modulated with a different frequency of the modulating signal (information signal). Each modulated sub-carrier frequency is added together to form multiple signals. The advantage of this system is that it can transmit multiple audio signals using only one carrier signal frequency. While the disadvantage of this system is that it requires a wide bandwidth and the information frequency range is limited by the presence of LPF at the input of the system.

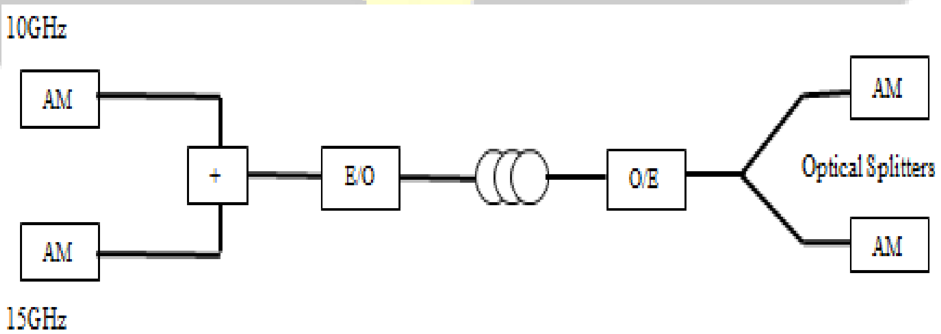

Figure 2. RF Multiplexing

B. Multiplexing at the Optical Level

A transmission technique that utilizes light of different wavelengths as information channels, so that after multiplexing, all of these wavelengths can be transmitted through an optical fiber. DWDM technology is a technology that utilizes the SDH (Synchronous Digital Hierarchy) system by multiplexing existing signal sources.

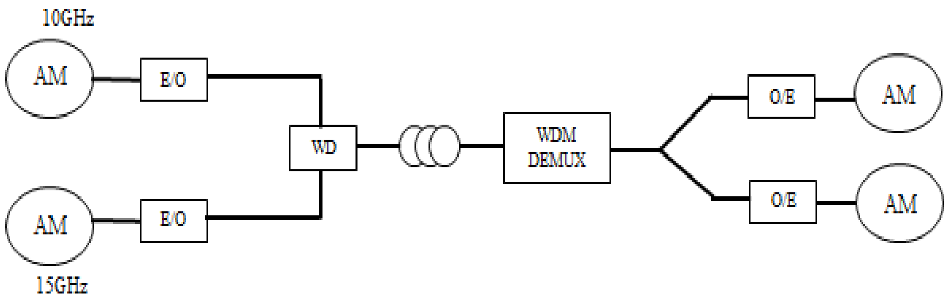

Figure 3. Optical Level Multiplexing

2. Simulation
   A comparison of performance in this study was carried out by simulation using the OptiSystem software. The components used in the simulation consist of optical sources, modulators, and transmission media in the form of optical fiber. The modulator used is the Direct Laser Measured Modulator. The simulations are carried out with different specifications, the first is the RF Multiplexing circuit and the second is the Optical Multiplexing circuit. The simulation results will come out in the form of the BER and Q Factor. Analysis of the results of the simulations carried out is then adjusted to the parameters that have been determined, including the maximum value of BER 10-9, and minimum Q-Factor 6 dB.

The simulation circuit is assembled using several components, RF Multiplexing is formed from the components of a Pseudo-Random Bit Sequence Generator, Pulse Generator, Electrical AM, 2x1 Combiner, Direct Modulator, Optical Fiber, 1x2 Power Splitter, Photodetector, and 3R Regenerator. In Optical Multiplexing, the components used are the same as in RF Multiplexing with the addition of several other components such as WDM Mux and WDM Demux.

Table 1: Parameters Of Rf Multiplexing Circuit Components

Component	Parameter
AM frequency	10GHz & 15GHz
Directly Frequency	193.1 THz
Power	10dBm
Fiber Length	1-10 kilometers
Cutoff Frequency	1.5GHz

Table 2: Components Of Multiplexing Optical Components Parameters

Component	Parameter
AM frequency	10GHz & 15GHz
Directly 1 frequency	193.1 THz
Directly 2 frequency	193.3 THz
power	10dBm
Fiber Length	1-10 kilometers
Cutoff Frequency	1.5GHz

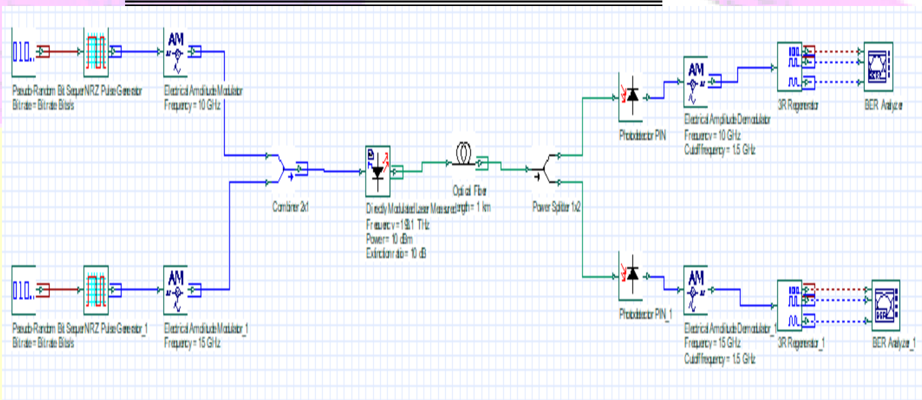

Figure 4. RF Multiplexing Modeling

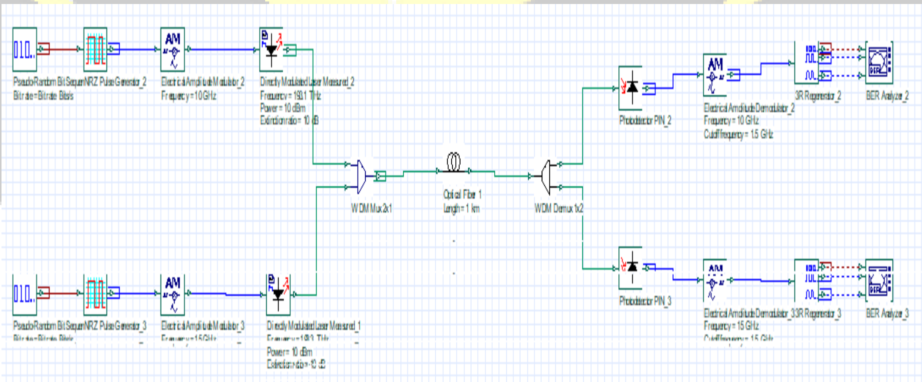

Figure 5. Multiplexing Optical Modeling

3. Result and Discussion

The analysis obtained from the RF Multiplexing series can be seen in Table 1, it is proven that the farther the fiber optic cable is, the lower the performance value. On the Q Factor, the best value is 18.5849 at a distance of 1 km where the minimum value of the Q

Factor is 6 dB. At BER, the best value is when the optical fiber is given a distance of 1 km which is equal to 2.12594e-077 where the maximum value of BER is 10-9 or 1e-09.

Table 3: Q-Factor And Ber Values For Rf Multiplexing

Distance (km)	BER	Q Factor
1	2.12594e-077	18.5849
2	7.21896e-079	18,765
3	1.28854e-077	18.6107
4	6.71959e-068	17.3708
5	9.06395e-052	15,092
6	8.99316e-052	15.0931
7	9.80084e-050	14.7804
8	2.93356e-047	14.3913
9	1.22929e-042	13.6355
10	2.88347e-037	12.7017

Based on the best results from the RF Multiplexing circuit, the following is a BER image with a value of 2.12594e-077 with a Q Factor of 18.5849.

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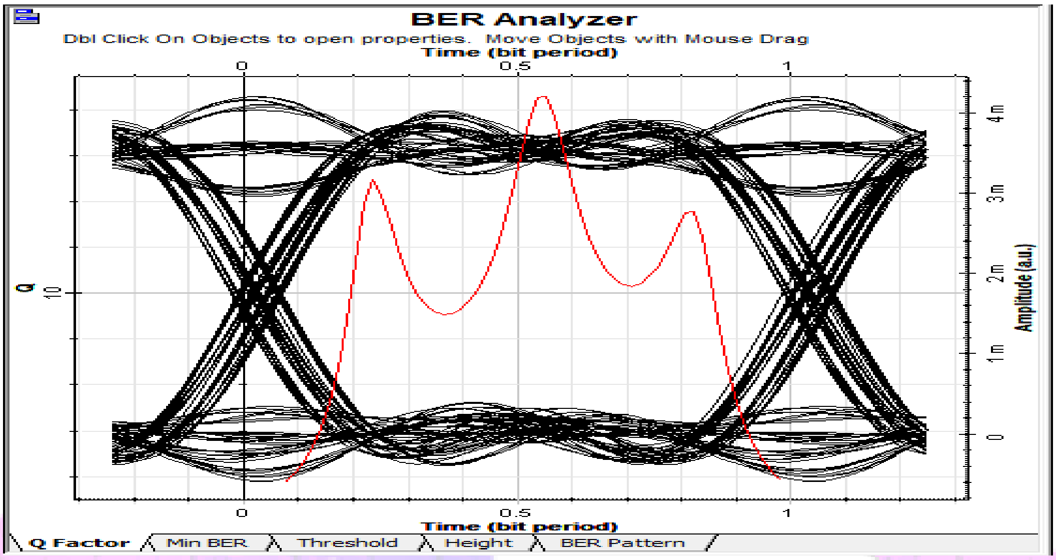

Figure 6. BER results for RF Multiplexing

The results of the RF Multipexing circuit are compared with the results of the Optical Multiplexing circuit. The analysis obtained from the Optical Multiplexing circuit can be seen in Table 2. On the Q Factor, the best value is 76.7349 at a distance of 1 km. In this Optical Multiplexing circuit, the BER value in all-optical fiber distance ranges has the same value, namely 0.

Table 4: Q-Factor And Ber Calculation Results For Optical Multiplexing

Distance (km)	BER	Q Factor
1	0	76.7349
2	0	75.0062
3	0	71.5146
4	0	66.0693
5	0	61.3875
6	0	56.1431
7	0	51.4836
8	0	47.2154
9	0	43.4505
10	0	40.6853

Based on the best results from the RF Multiplexing circuit, the following is a BER image with a value of 0 with a Q Factor of 76.7349.

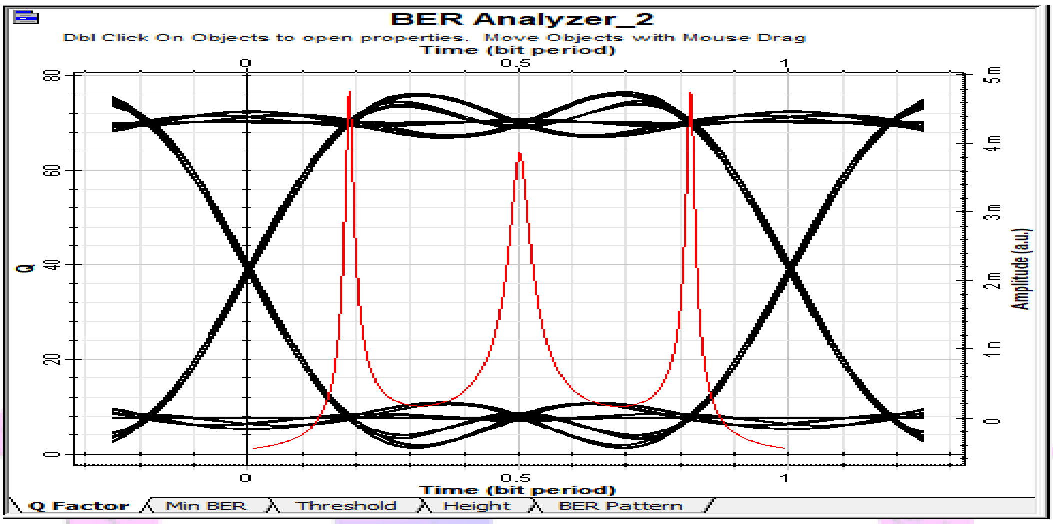

Figure 7. BER results for Multiplexed Optics

4. Conclusion

The conclusion of this study are as follows:

1. The performance of Optical Fiber in both circuits that meet eligibility is at a distance of 1 kilometer. BER value on RF Multiplexing 2.12594e-077 and Q-Factor 18.5849. In Optical Multiplexing, the BER value is 0, and the Q-Factor value is 76.7349.
2. The best performance between RF Multiplexing and Optical Multiplexing is the Optical Multiplexing circuit with a BER value of 0 and Q-Factor 76.7349.

5. References

Aini, N., Sudiarta, P. K., & Putra Sastra, N. (2021). Pengembangan Modul Praktikum Untuk Modulator Optik Internal Dan Eksternal. *Jurnal SPEKTRUM*, *8*(1), 129. https://doi.org/10.24843/spektrum.2021.v08.i01.p15

Alwie, rahayu deny danar dan alvi furwanti, Prasetio, A. B., Andespa, R., Lhokseumawe, P. N., & Pengantar, K. (2020). Tugas Akhir Tugas Akhir. *Jurnal Ekonomi Volume 18, Nomor 1 Maret201*, *2*(1), 41–49.

Feng, C., Ying, Z., Zhao, Z., Gu, J., Pan, D. Z., & Chen, R. T. (2020). Wavelength-division-multiplexing (WDM)-based integrated electronic-photonic switching network (EPSN) for high-speed data processing and transportation High-speed optical switching network. *Nanophotonics*, *9*(15), 4579–4588. https://doi.org/10.1515/nanoph-2020-0356

Fuada, S. (2017). Kajian Aspek Security pada Jaringan Informasi dan Komunikasi Berbasis Visible Light Communication. *Jurnal Infotel*, *9*(1), 108. https://doi.org/10.20895/infotel.v9i1.163

Halomoan, A., Rohmah, Y. S., & Aulia, S. (2018). *Perancangan Simulator Modulasi Dan Demodulasi Am Pada Kanal Awgn Dan Rayleigh Simulator Design of Modulation and Demodulation Am on Awgn and Rayleigh Channel*. *Vol.4*(2), 2–7.

Khair, F., Fakhriy Hario, P., Wayan Mustika, I., & Setiyanto, B. (2016). Performance analysis of digital modulation for coherent detection of OFDM scheme on radio over fiber system. *International Journal of Electrical and Computer Engineering*, *6*(3), 1086–1095. https://doi.org/10.11591/ijece.v6i3.9656

Khairunisa, K., Hapsari, D. W., & Aminah, W. (2017). Kualitas Audit, Corporate Social Responsibility, dan Ukuran Perusahaan Terhadap Tax Avoidance. *Jurnal Riset Akuntansi & Komputerisasi Akuntansi (JRAK)*, *9*(1), 39–46.

Kong, Y., Cao, Y., Wang, L., Wang, G., Feng, X., & Guan, B. O. (2020). Microwave photonic frequency conversion based on a wavelength swept laser. *Applied Sciences (Switzerland)*, *10*(11). https://doi.org/10.3390/app10113813

Lim, D. S., Morse, E. A., Mitchell, R. K., & Seawright, K. K. Ins 34(3), 491-516. https://doi.org/10.1111%2Fj.1540-6520.2010.00384.x. (2010). No 主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析Title. *Titutional Environment and Entrepreneurial Cognitions: A Comparative Business Systems Perspective. Entrepreneurship Theory and Practice.*, *564*, 1–73.

Zhang, Y. X., Fu, S. Y., Chen, Y. S., Ding, Z. W., Shan, Y. Y., Wang, F., Chen, M. M., Zhang, X. P., & Meng, Z. (2019). A visibility enhanced broadband phase-sensitive OTDR based on the UWFBG array and frequency-division-multiplexing. *Optical Fiber Technology*, *53*, 2023. https://doi.org/10.1016/j.yofte.2019.101995

Zheng, R. (2008). Asymptotic bounds of information dissemination in power-constrained wireless networks. *IEEE Transactions on Wireless Communications*, *7*(1), 251–259. https://doi.org/10.1109/TWC.2008.060474