DESIGN OF A FIBER OVER RADIO FREQUENCY COMMUNICATION SYSTEM

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***Abstract*— This research focus on the conceptual development, design and analysis of the fiber over radio frequency communication system is presented. This communication system is inspired from the fiber-wireless technology which is a combination of optical-fiber-based network and wireless network to enhance the current technology in order to reach extra miles away. This technology has been a current interest among the researchers. The designed system utilized a transceiver to convert the signals. The conversion from raw signal of optical to rf and vice versa is perform by receiver and transmitter. This work concluded that the higher the frequency, the higher the power needed to transmit signals and as the power increases, the wavelength also increases.**

***Keywords*—Fiber over radio frequency, transceiver, transimpedance amplifier, optical rf links.**

I. Introduction

Expecting that optical fiber paves all the way to and penetrates into the home of residential and business customers in the near to midterm, we elaborate on the final frontier of optical networks, namely, the convergence with their wireless counterparts.

Due to the difficulty and prohibitive costs of supplying optical fiber to all end-user premises as well as the spectrum limitations of wireless access networks, hybrid fiber and radio access networks seem to be more attractive than relying on either standalone access solution. This networks are realized by integrating wireless access technologies, e.g., cellular, WiMAX, and WiFi, with installed optical fiber infrastructure that has been pushed ever closer toward end Fiber-RF is the combined use of "*optical*" (optical fiber) and "*wireless*" (radio frequency) communication to provide telecommunication services to the clusters of end points which are geographically distant. It is the combination of passive optical networks (PONs) and wireless mesh networks (WMNs). Optical networks are designed to provide long-distance, high-bandwidth communications with the help of wireless networks to provide ubiquitous, flexible communications in community areas. The high- capacity optical fiber is used to span the longest distances, and a lower cost wireless link carries the signal for the last mile to nearby users. This network can support various types of communications such as upstream, downstream,and peer- to-peer (P2P) communication[2].

The traditional link between the radio base station (RBS) and the antenna has previously been a copper coaxial cable. To use an optical fiber cable instead, makes both design of new sites, as well as the physical deployment of the hardware, much easier. In Fiber over RF systems, wireless signals are transported in optical form between a central station and a set of base stations before being radiated through the air. A head-end office generates the UWB signals, which are distributed over low-loss and low-cost optical fibers to a number of subscribers (different apartments or different rooms inside an apartment). At the subscriber ends, the received optical UWB signals are radiated via an optical pulse triggered photonic transmitter (PT) to broadcast the UWB signals to the UWB-ready televisions or computers. It will be especially important for rural areas and other dead spots where broadband wireless isn't available. The advantage is that the equipment for WiFi, 3G and other protocols can be centralized in one place, with remote antennas attached via fiber optic serving all protocols. It greatly reduces the equipment and maintenance cost of the network.

The fiber signal is used to modulate the RF source in transmitter. The resulting RF signal is launched to the air. At the other end, an antenna will received thus require an RF receiver that converts the RF to optical signal. The outline of this letter is as follows. In Section II, the fiber over radio frequency system design is presented. In Section III, transimpedance amplifier and analogue modulation used in optical-rf links to convert optical signal to radio frequency or vice versa by using Current to Voltage converter or Analogue Modulation and optimum result can be achieved. In Section IV, the analysis of the system. Fiber Over Radio Frequency System Design

II. Design of Fiber over RF Communication System

A. *System Concept*

Fiber over Radio Frequency Communication System concept is integrating wireless and optical access. It combines the two media; fiber optics and radio, and is a way to easily distribute radio frequency as a broadband or baseband signal over fiber. It utilizes analog fiber optic links to transmit and distribute radio signals[4]. It is expected to work in the following manner refer to fig. 1, and fig. 2. The early analysis is by transmiting raw signal which is the light source transmit to the converter. The receiver will convert the optical signal from the light source into radio frequency signal and then received by the antenna. The antenna will transmit and receive at the other end and then analysed using spectrum analyzer in the first stage. While in the second stage is the continuous at the other end of the antenna, where there is a transmitter that convert radio frequency signal back to optical signal and the result is then analysed using optical analyzer.

The receiver which convert optical to radio frequency has a bandwidth of 45MHz until 1000MHz and has wavelength of 1100nm to 1600 nm. The input optical power is from -8dB to 2dBm. While the transmitter which convert radio frequency to optical signal has a bandwidth of 45MHz to 1000MHz and wavelength of 1310nm. The optical ouput power is 4.1 dBm and RF input power is from -29dBm to 35dBm.

The objective of this project is to do direct modulation in TV frequency of 400 to 1000 MHZ using UWB antenna is almost achieve as the antenna used does not achieve the targeted bandwidth which is from 0MHz to 1000MHz but instead achieve a 800MHz to 1.5GHz. But the result was convincing that the system can still apply to higher bandwidth eventhough it exceed 1000MHz but this will require a much higher power for the signal to be transmitted in this range. The use of TV antenna give good result at very high and sharp peak which indicate the availability of the strong signal coming from the system.

The second objective is to analyze the relation of optical wavelength and radio frequency is achieved where there are actually no direct relation of between the two. If input of 1310nm is given, it does not give specific frequency as the radio frequency has its own wavelength in radio while the optical wavelength is merely about the window at where signal has the best transmission.

Third objective is to analyze the relation of power level with radio frequency and optical wavelength. This has also achieve as the hypothesis can be that the higher the frequency, the higher power is needed to transmit the signal and as the power input increase, the wavelength increase.

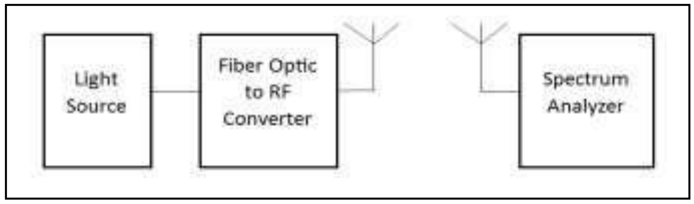

Figure 1. System Design Flowchart with Spectrum Analyzer

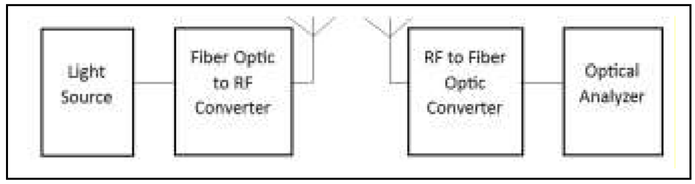

Figure 2. System Design Flowchart with Optical Analyzer

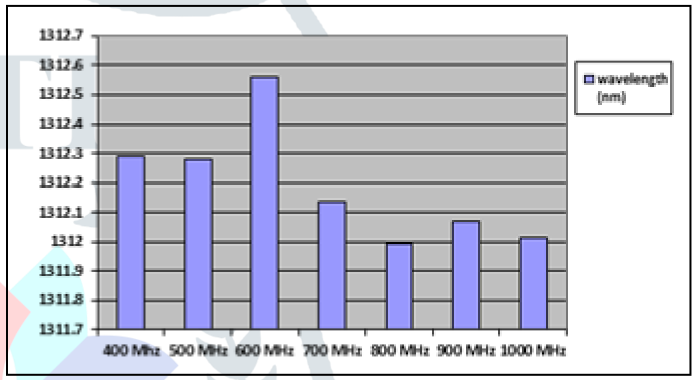

Figure 3. Wavelength Parameter Chart

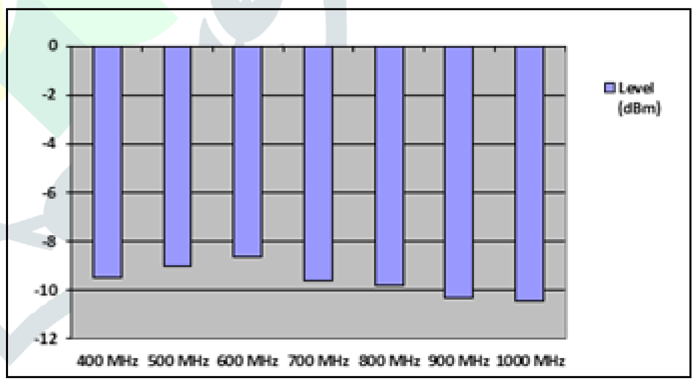

Figure 4. Level Parameter Chart

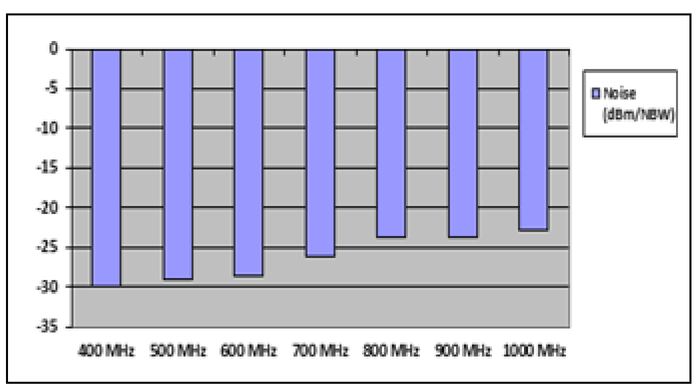

Figure 5. Noise Parameter Chart

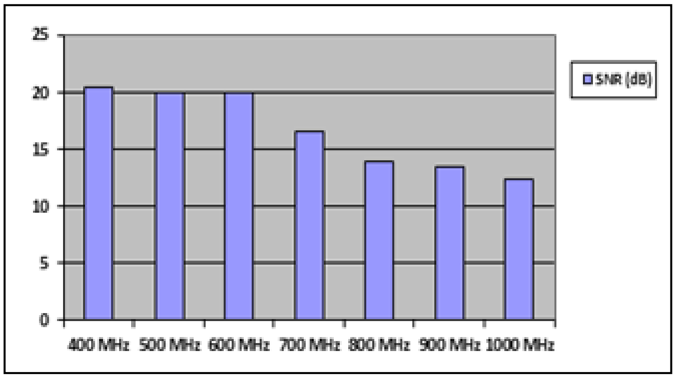

Figure 6. SNR Parameter Chart

B. *Overview of Signal Parameters*

The parameters is based on the analysis of the optical signal results data which is taken from 400 MHz until 1000 MHz. This is to fulfill the objective of the fiber over radio frequency communication system which is to focus on TV frequency or in other words, the UHF frequency. Further analysis is represented in chart for detail discussion on each parameters of the optical signal analyzer.

The transmitter used in this project is at 1310nm wavelength. Based on fig.3, there is an almost constant wavelength at 400MHz and 500MHz but as the radio frequency increase, at 600MHz, there is sudden increase reaching to 1312.5592nm. This means that at this frequency, the wavelength start to move out of range from the optic ideal transmission second window which is 1310nm. Therefore signal start to degrade at 600MHz. To obtain a good transmission with low losses, the wavelength must stay in the second window range. If the wavelength start to increase and move out of the range there will be high losses. At the frequency 700MHz, the wavelength start to decrease until at 800MHz, we obtain the lowest point of wavelength which is 1311.9951nm. This means that the best signal obtain is at 800MHz because it is transmitted at much lower loss with wavelength nearer to 1310nm compared to other frequency and at 1000MHz the wavelength decrease reaching the ideal transmission window.

Based on fig. 4, level is the power of the laser source to transmit the optic signal. Shown on this chart, the power starts to increase from 400MHz to 600MHz which is from - 9.474dBm to -8.603dBm. This shows that at 600MHz, more power is needed to transmit the optical signal. While it start to decrease from 700MHz to 1000MHz which is from - 9.564dBm to -10.442dBm, this means that at 1000MHz, requires the lowest consumption of laser source power to transmit the signal.

From fig. 5, the lower the noise the better is the signal therefore from this chart, 400MHz has the lowest noise which is -29.938dBm/NBW. While at 1000MHz has the highest noise which is -22.848dBm/NBW. This means that at lower frequency, the result of the signal is better compared to at the higher frequency where the result of the signal has more interruptions. There are almost a constant level of noise between 800MHz and 900MHz which is -23.784dBm/NBW and -23.719dBm/NBW, at this frequency the signal results are only a slight difference but the noise is still higher compared to 600MHz and 700MHz.

TABLE I. RADIO TO OPTIC RESULTS DATA

RF requency (MHz)	velength (nm)	Level (dBm)	Noise (dBm/NBW)	SNR (dB)
400	1312.2920	-9.474	-29.938	20.464
500	1312.2808	-9.030	-29.028	19.998
600	1312.5592	-8.603	-28.620	20.016
700	1312.1367	-9.564	-26.159	16.596
800	1311.9951	-9.809	-23.784	13.975
900	1312.0689	-10.28	-23.719	13.439
1000	1312.0162	-10.44	-22.848	12.406

TABLE II. FREQUENCY AND POWER RELATIVITY RESULTS DATA

Frequency (MHz)	Wavelength @-29 dBm	Wavelength @ 0dBm	Wavelength @ 20dBm
400	1311.5578	1311.5729	1311.8937
500	1311.5748	1311.5924	1311.9141
600	1311.5857	1311.5979	1312.0690
700	1311.6051	1311.6118	1311.9464
800	1311.6000	1311.6074	1311.8148
900	1311.5899	1311.6114	1311.9577
1000	1311.6154	1311.6228	1312.0138

SNR is the ratio of signal power and noise. Hence, the higher the ratio, the better the signal. Based on fig. 6, 400MHz has the highest SNR which is 20.464dB and the second highest is at 600MHz which is 20.016dB. While the lowest SNR is at 1000MHz which is 12.406dB. Signal starts to degrade as the radio frequency start to increase but there are slight irregularities between 400MHz to 600 MHz since at 500MHz the SNR drop to 19.998dB. Overall, the signal is better at lower frequency with high SNR.

III. Analysis and Discussions

A. *RF to Optics Analysis*

Based on table I, at 400MHz, with 1312.2920nm wavelength, -9.474dBm power, -29.938dBm/NBW, and 20.464dB SNR. With average point of wavelength and power, lowest noise and has the highest SNR. Shows that, the signal has the best signal quality out of the other frequency even though the wavelength and power is just at average. At 500MHz, with 1312.2808nm wavelength, -9.030dBm power, -29.028dBm/NBW noise, and 19.998dB SNR. Shows that, it transmits average signal quality with wavelength and power at average value. Analysis at 800MHz, with 1311.9951nm wavelength, -9.809dBm power, -23.784dBm/NBW noise, and 13.975dB SNR. With smallest wavelength, low power, high noise, low SNR. Shows that, even at the wavelength nearest to 1310nm, and low power usage, the signal quality is of average. Analysis at 1000MHz, with 1312.0162nm wavelength, -10.442dBm power, -22.848dBm/NBW noise, and 12.406dB SNR. With smaller wavelength, lowest power, highest noise and lowest SNR. Shows that, even though the signal is transmitted at lowest power level and wavelength close to the ideal transmission, it does not give the best signal result.

Therefore, the conversion on radio frequency to fiber does not have linearity. The values of the wavelength, the power level, noise and signal to noise ratio varies with frequency. An average level of wavelength and power could give the best signal with lowest noise and highest signal to noise ratio, while the smallest level of wavelength nearest to 1310nm at which fiber operates best and also the lowest power usage could give the lowest signal quality with highest noise and lowest signal to noise ratio. Hence, there might be other factors that causes the non-linearity of the values. It could also due to the transmitter where it can operate best depends Malaysia TV frequency allocations. Overall, the difference of the data is very small from one another therefore, the signal quality would not be much different as it still can be transmitted.

B. *Frequency and Power Relativity Analysis*

The result is taken from the system using optical analyzer. The range taken from 400 MHz until 1000 MHz with each of this frequency has power level ranging from -29dBm , 0dBm, and +20dBm. This is to see the relativity of a radio frequency with power level given by the radio source.

Table II, shows that the data remain in the same wavelength which is at 1311 nm even there is slight difference and there is an increase to 1312 at 20dBm od 1000MHz. Hence, the relation between power level and frequency does not really affected but there is an increase of value when the power is increased. The graph for wavelength of each of the frequency also become wider as the power level increase shows that the wavelength spread and is being transmitted. The higher the power, the wider SNR. With average wavelength and power consumption, lower noise and high SNR. Shows that, 500MHz give out an optical signal with average transmission quality. Analysis at 600MHz, with 1312.5592nm wavelength, -8.603dBm power, -28.620dBm/NBW noise, and 20.016dB SNR. With highest wavelength and highest laser power, lower noise and higher SNR. The signal transmitted is of better signal even though it reach the highest wavelength in the second window range and highest power usage.

At 700MHz, with 1312.1367nm wavelength, -9.564dBm power, -26.159dBm/NBW noise, and 16.596dB SNR. With small wavelength and low power, average noise and average and longer the optical signal is transmitted.

C. *Conclusion*

The development of the system carry the concept to benefit everyone. If the used of correct equipment, the design of this system has achieved where the fiber over radio frequency system convert the optical signal into radio signal and transmit to the air, while at the other end the radio signal is convert back to optical signal and reach the consumer. This system potentially has more than a few advantages over the conventional optical communication system: (i) Low Attenuation Loss, (ii) Large Bandwidth, (iii) Immunity to Radio Frequency Interference, (iv) Easy Installation and Maintenance[5]. Besides that, its has advantages of low line losses, immunity to lightning strikes/electric discharges and permits transmission over longer distances and at higher bandwidths (data rates) than other forms of communication.

The receiver had perform well in converting the optical signal to radio signal in UHF frequency and also the transmitter has perform well in converting radio signal into optical signal. The frequency of 400MHz to 1000MHz has been shown to achieve result. Testing also has shown some limitations where the laser source could only transmit raw signal and the receiver can only receiver already modulated signal. This restricted the further analyzation of the system.

The testing of Fiber over Radio Frequency Communication System also will need further improvement due to the external problems of the equipment such as the laser source and the receiver. Therefore the conventional has been used to test the entire system. Another way that can help with the system is if there is another transmitter that can be put at the other of the antenna. In this way, the integrated of fiber over rf and rf over fiber can produce a system that transmit the signal through the air with condition to have a transmitter at another end. Suggestion for future works on to further improve the system is the design of a quality antenna to focus on just UHF frequency and by investigating the white space usage that can help everyone to have free wifi in the future and by that, this system can be implemented for a wider and broader connections everywhere.

Hence, in order for this system to achieve favorable result, suitable equipment must be made available for further testing and analysis. This system is seen to benefit the future as there will be less deployable of fiber underground and the use of radio frequency can reach miles away especially for the rural area to enjoy the benefit of today's technology. All in all, this system will require more research and development method.

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