The Simulation of Indoor Service Range Prediction of Wireless Radio Access Point for Radio over Fiber System

Z. Kornain, M. A. Abu, and M. Y. Yacob

Abstract—**Wireless Radio Access Point (RAP) For Radio Over Fiber (ROF) System is becoming an increasingly important technology for the indoor wireless market. The dynamic range requirements and optimum choice of laser are identified for this application. A novel architecture based on the radio over fiber application is proposed for indoor application, which gives important benefits in terms of design, installation and operation of the systems used. To meet increasing of user bandwidth and wireless demands, the Wireless design based on ROF technology has been proposed as a promising cost effective solution. In this network, a central station (CS) is connected to numerous RAP using an optical fiber to indoor connection. The aim of this project is to predict the service range for RAP for downlink transmission. The indoor RF front end consists of a photodiode, bandpass filter (BPF), power amplifier (PA) and an antenna which operating at 2.4GHz band. BPF is needed to remove out the frequency from nonlinear effect of fiber and pass through the signal at the operating frequency. The RF front end components are modelled using S-Parameter measured data from factory. Indoor picocells are used power lower than 1 Watt (30 dBm) and service range of more than 100 meters.**

Index Terms—**Radio over fiber, radio access point, optisystem.**

I. Introduction

A key enabler for supporting very high data rates in advanced networks is the reduction in cell size, which serves two main purposes which are maintained the high SNR at the receiver while limiting the transmit power to moderate levels and limiting the number of users per cell [1][2]. Unlike wired networks with dedicated connections to the user, a wireless network consists of a shared bandwidth and cells with multiple users. One solution to increasing the data rate is through the use of a larger bandwidth and developing special diversity antenna systems in a multiple-input–multiple-output (MIMO) configuration [3]. However, the most effective way to improve the throughput per user is to reduce the number of users per cell by designing networks with a very small cell size. For indoor applications with very high user density, a cell may only have a radius of a few meters. Such systems are typically called picocellular networks. By reducing the cell size, the number of radio interfaces in the deployment area can be very high. In some deployment scenarios, hundreds of antennas need to be supported. This results in significant challenges for the wired infrastructure that is required to connect the numerous antennas to a central control station.

The most effective and efficient way of providing this coverage with good service quality is to place one or more base stations at a central location inside the building and use a distributed antenna system (DAS) transmission infrastructure to distribute the wireless signals from the base stations to the various antenna locations around the building [4]. Although DASs can be constructed using coaxial cable, the preferred option for larger installations is optical fiber cable. This is due to the very high attenuation of coaxial cable, which makes longer transmission spans impractical.

II. Related Work

There are several projects that focusing on indoor radio transmission performance. However, the objective and method used is a little bit different. The first paper is a prediction of propagation characteristics in indoor radio communication environments by N. Yarkoni and N. Blaunstein, 2006 [5]. This paper presented a semi empirical and analytical model approach to predict the total path loss in various indoor communication channel links by taking the effects of fading floors and corridors respectively by estimated the slow and fast fading caused by multipath and diffraction phenomena. This paper proposed an unified approach of comparison with the analytical Bertoni's model which are common method that used to calculated the link budget in indoor environment. The result also comparable with the measurement carried for different propagation method along corridor and between floors that occurs in the indoor environments for communication channels. The second paper is ITU field strength prediction methods for terrestrial point to area services by Rainer Grosskopf, 2007 [6] develops propagation prediction and recommendations providing information methods for various communication services on the wotk carried out in International Telecommunication Union (ITU) radiowave propagation study group for terrestrial point to area services such as land mobile services and terrestrial broadcasting services. This paper cover propagation in the Very high Frequency (VHF) and Ultra High Frequency (UHF) range, short range indoor and outdoor services for frequency range from 1 to 100 GHz and from point to multipoint services the the frequency range from 3 to 60 GHz. The third paper is a coverage prediction and optimization algorithms for indoor environments by David Plets *et al*, 2012 [7] developed about a heuristic algorithm for prediction of indoor wireless WiFi 802.11b/g coverage. The measurements on a single floor of an office building are performed to investigate the propagation characteristics. The prediction method that used based on the free space loss model for each environment to reduce the

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dependency of the test model based on the case with many other models. The result of the algorithm to a wireless network is discussed based on the site experiment. This method proposed a physically accurate prediction of the path loss model for different building types.

III. Proposed Technique

The objective of this project is to design and simulate the radio access point (RAP) for radio over fiber system (ROF) and to predict the range of RAP for indoor application using Optisystem software. This project mainly focused on the design ROF using OptiSystem. Fig. 1 shows the flow chart of this project process, which involve literature review study, software study, and design study.

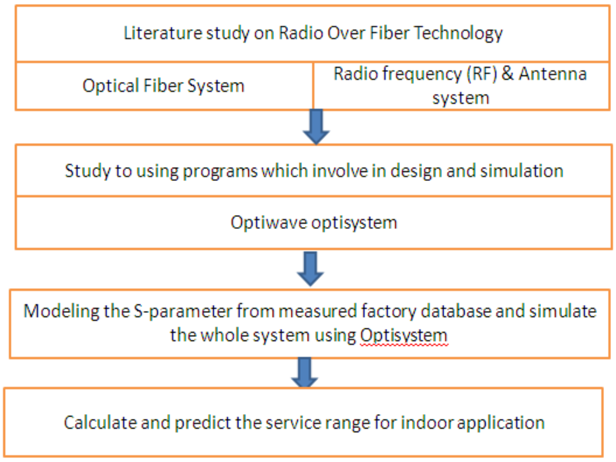

Fig. 1. Flow chart of the project process.

By starting of this project, the study the fiber optic system needed to make more understanding on the optical system. With more knowledge on this technologies can help in using the program of OptiSystem to make suitable design for generating optical microwave frequency and using components. Besides that, the literature study on radio frequency (RF) component also important to apply the knowledge on designing suitable component. The final part is to combine the two designs to make the combination of optical signal to propagate by antenna designed. Thus the simulation on the performance and usability need to be considered.

In order to predict the service range, the Keenan-Motley indoor channel equation has been used [8].

$$L = S + 10n.\log(d) \qquad (1.0)$$

L: total propagation loss (*dB*), *S*: path loss at 1m from transmitter (*dB*), *n*: power law index, *d*: distance between transmitter and receiver (*m*)

where $n=3$; $S = 21 + 20\log(f/1.7)$ *dB*; *f* in GHz

IV. Software Developement

In this paper, the design required to be simulated by using OptiSystem software. Fig. 2 shows the overall architecture of downlink radio over fiber design by using optisystem.

In this optical fiber design, the optical transmitter and optical receiver design need to be consider in order to achieve a good an optical system performance.

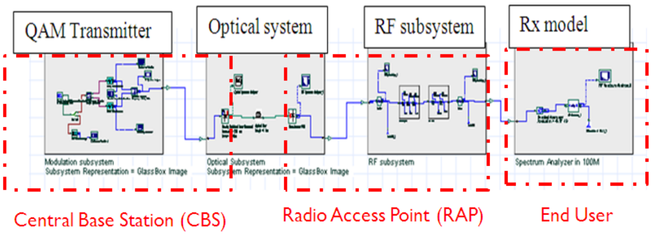

Fig. 2. Overall design for radio over fiber system

A. Optical Transmitter Design

The optical transmitter design is design by using OptiSystem to supply the radio carrier frequency at 2.4 GHz and modulated with 64QAM. The design is shown in Fig. 3 below. The 64QAM modulation is a QAM modulation, using 6 bits per symbol and a delay of one bit in the quadrature signal. This QAM modulation technique is use to cater the data rate up to 54 Mbps.

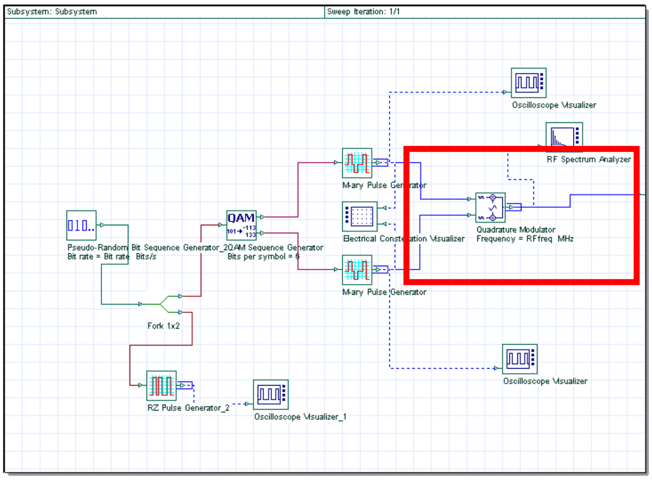

Fig. 3. QAM Optical transmitter design

In order to modulate the radio frequency in the optical format, the directly modulated measured laser modulator is used to modulate the signal in the optical form. The laser with 1550nm wavelength is use to modulate the signal from QAM modulator. Fig. 4 below shows the design of optical modulator design by using directly modulated laser.

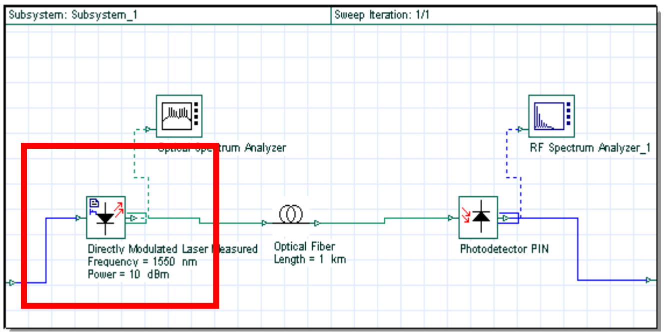

Fig. 4. Optical Modulator design

B. Optical Receiver Design

To receive the optical signal those transmit by laser, the optical receiver design needs to perform for this project. Table I shows the design goal for optical receiver design.

TABLE I: OPTICAL RECEIVER SPECIFICATIONS

Optical Link	
Length (KM)	0-150 KM
Fiber Loss	0.2 dB/KM
Fiber Dispersion Constant	16.75 ps/nm/km
Optical Receiver	
Responsivity	1 A/W
Dark Current	10 nA

The design parameter is fetch from the literature review that has been studied from the previous part. Fig. 5 below show the connection between optical transmitter (laser) and the photo detector that use to convert the optical signal into the RF signal that will be used by the RF component.

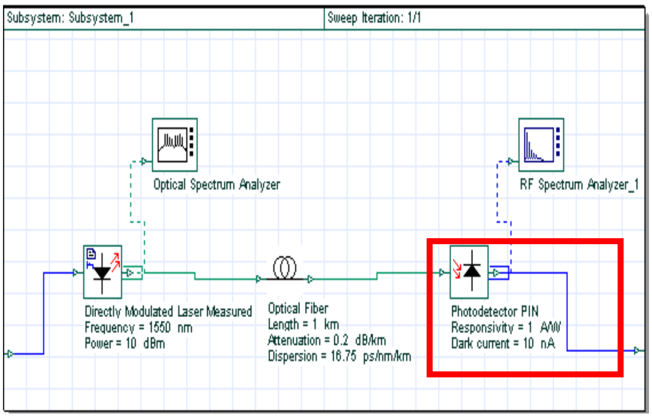

Fig. 5. Photo detector optical receiver design

C. BPF in Optisystem.

The s-2 parameters that obtain from the microwave office will be used in this optisystem software. The signal from photodiode RF form will be filtered by Pre-BPF and signal from power amplifier will be filtered by post BPF. Fig. 6 below show the design of BPF in optisystem software.

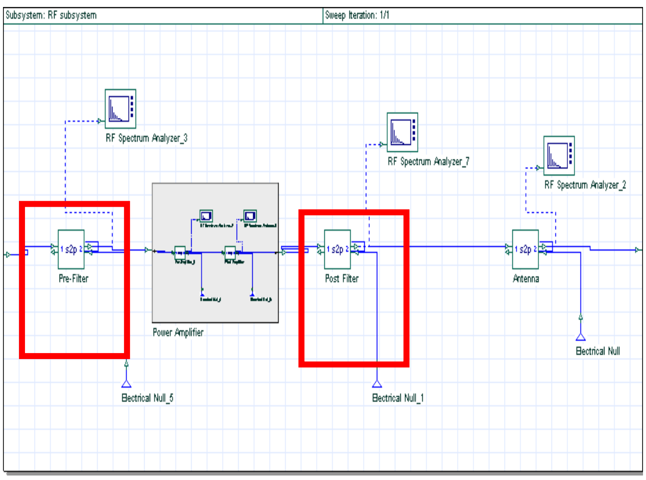

Fig. 6. BPF design in optisystem.

D. Optisystem Power Amplifier

In optisystem software, the s2p block diagram of electrical amplifier was used to model the power amplifier. This design needs two power amplifiers because it's hard to find one power amplifier that can have a gain more than 60dB. Fig. 7 shows the design of power amplifier in optisystem software.

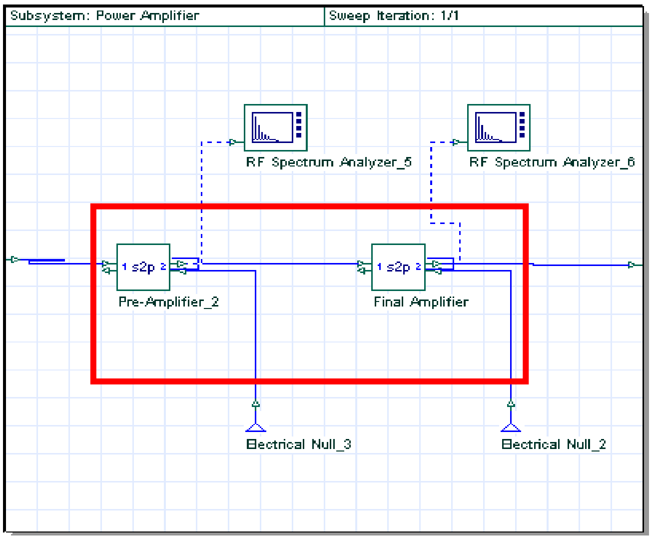

Fig. 7. Power amplifier block in optisystem

E. Antenna Block in Optisystem

Since in the optisystem software doesn't have antenna block representations, the 2 port s-parameter block will be used to model the antenna in 2 port s-parameter [8]. Fig. 8 below shows the 2-port parameter antenna model.

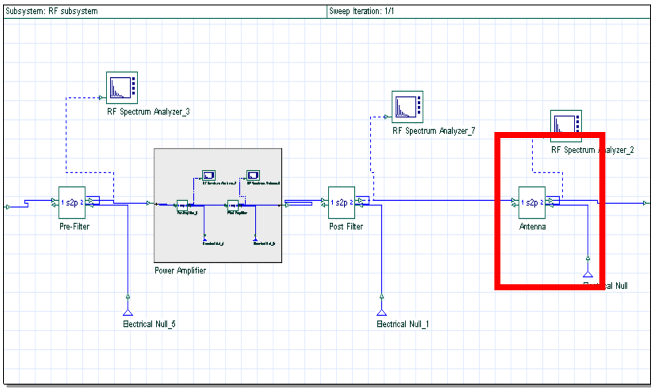

Fig. 8. 2-port S2-parameter antenna model

V. APPLYING PROPOSED TECHNIQUE

This section will provide a write-up on how the simulation is carried up including all assumptions used and how important parameters are chosen. These sections also discuss the simulations which are relevant to show the effectiveness or superiority of the proposed technique.

From the Keenan-Motley indoor channel equation in the section before, the attenuation at 100 meter is 84.14dB. Fig. 9 below shows the modelling of service range prediction. Antenna is used in received mode.

VI. Result and Discussion

Since the objective of this project is to develop and simulate the downlink radio access point (RAP) for radio over fiber system (RoF) and to analyze the performance of the RAP for downlink transmission using Optisystem software, this section will show the result of simulation and the output result from actual measured test board .Fig. 10 below shows the output after receive antenna. The spectrum power after receive antenna for simulation part is -58.7 dBm.

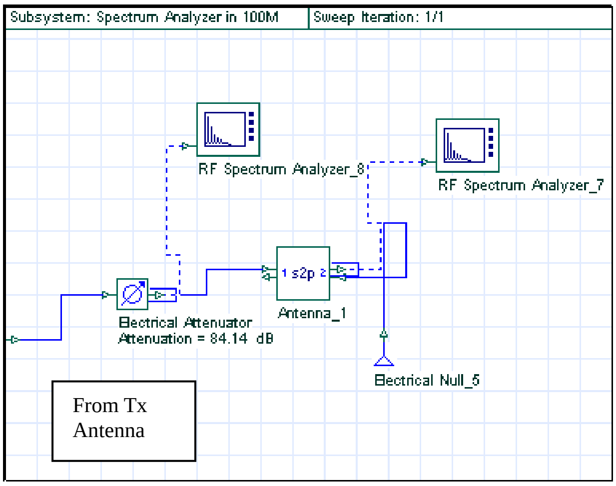

Fig. 9. Indoor Path loss model in optisystem

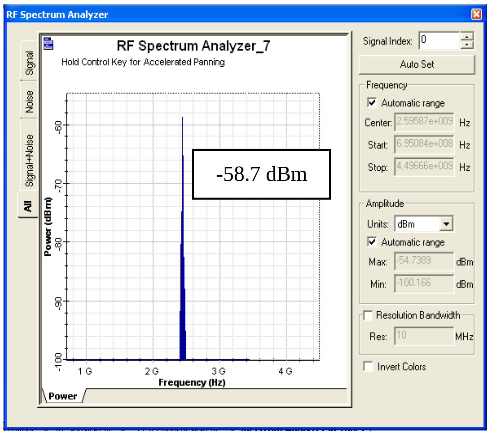

Fig. 10. Simulation result of service range after 100m

Fig. 11 below shows the output after receive antenna. The spectrum power after receive antenna for measured part is -60.8 dBm.

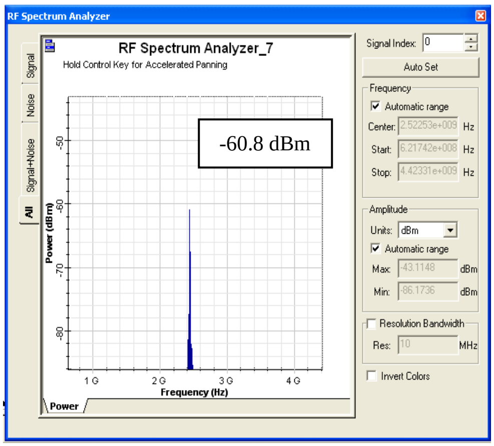

Fig. 11. Spectrum result with measured component after 100m

Result for attenuation at minimum sensitivity which is -65 dBm is 90.44 dB. The maximum service range for simulation part is 162.2 meter using Keenan Motley model.

Table II below shows the link budget of simulation result based on output result for every part such as RF modulator, laser, photodiode, filter, amplifier, transmit antenna and received antenna.

TABLE II: The Link Budget of Simulation Result

Component	Stages	ouput power (dBm)	
		Simulation	Spec (dBm)
RF Modulator		0	<= 0
Laser		10	<= 10
Photodiode		-18.2	>= -20
Pre Filter	Pre-Filter 1	-26.3	>= -32
Power Amplifier	Pre- Amplifier 1	0.6	<= 30
	Final Amplifier	27.5	
Post Filter	Post Filter 1	19.3	<= 30
TX Antenna		22.4	<= 30
Propagation Loss (100m)		-61.8	>-62
RX Antenna		-58.7	>-65
Maximum Range		162.2 m	> 100 m

VII. Conclusions

Radio over fiber (RoF) is the device that proposes to replace the conventional Radio Frequency (RF) electronic equipments. The conventional devices need a lot of electronic circuit to function as switch and hub, for multiple access application. However the proposed RoF with only simple components integrated will able to function as well as the processing of switch and hub did by center server. In this project, the target point is to replace the conventional radio access point using currently. From the design which presented at the design chapter, the RoF is shown by OptiSystem software which integrated with the required components, and tested under current radio access point system. The design of RAP was successfully simulated using Optisystem software. The front end consists of BPF, PA and Antenna which used for the RoF technology. Those of components are placed after the photodiode in the RAP. The BPF is used for remove out the band interference of operating frequency at WLAN 2.4 GHz band. While PA can be used for increases the power level of the signal which satisfied for the picocell application and the antenna is used to radiate the signal. For the maximum service range, the simulation result gives the maximum range of 162.2 meters. However, it's hard to find the measured component that has a good S-parameter result because if the manufacturing design constrains.

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