An Active Downlink Photonic Antenna

N.F Nanyan, R. Ngah, T. Prakoso, Y. Rahayu, and T.A Rahman

***Abstract*— This paper presents an active photonic antenna concept whereby an interface circuit is introduced in order to integrate the antenna with the photodiode. The operating frequencies ranges are 1.8 to 3.5 GHz which support the GSM 1800, WLAN and WiMAX applications. The simulated and measured results of interface circuit and antenna are presented. Thus, the photonic antenna is developed by integrating photodiode, interface circuit, RF amplifier and printed antenna and fabricated on FR4 board. The experiment was setup and spectrums at desired frequencies were measured. Measurement results show that an active downlink photonic antenna (ADPha) is successfully developed.**

***Index Terms*— downlink, photodetector, photonic antenna, and wideband antenna.**

I. Introduction

Statement from Wireless World Research Forum (WWRF); which has motivated our efforts to provide better mobile communications for people; *7 trillion wireless devices serving 7 billion people in 2017* [1]. This essentially means that the entire world population will be served by wirelessly communicating devices. Therefore, future wireless devices will have strict performance requirements such as wide bandwidth, high efficiency, high speed, and dramatic reduction in size and weight. The state-of-the-art optical wireless solutions are incredibly outperform the existing RF wireless rivals in terms of large information bandwidth, low transmitted power, high speed data transmission, highly secure data transmission, reduced size and weight of the optical components [2]. Accordingly, extensive researching and developing efforts are currently conducting worldwide to fully take advantage of optical fibers in wireless transmission

industry.

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Remarkably, the so-called Radio-over-Fiber (RoF) technology is a fusion of both the fiber network, in which optical wave is used as a carrier, and the wireless system in which the radio wave is the major communication media [3]. RoF technology employs the optical fiber as a link to distribute the RF-signals from a central base station (CBS) to several radio access points (RAPs) and vice versa. The RAP acts as a remote antenna that receives and transmits signals to mobile users. Whereas CBS collects signals from many RAPs for processing and distributes signals to all the RAPs. The RAP consists of optical receiver (downlink), optical modulator (uplink), amplifier, and an antenna. The RAP performs optoelectronic conversion, amplification function, and wireless distribution.

Notably, this photonic antenna is an enhanced version of conventional antenna design so that it can be compatible with the radio-over-fiber technology. Photonic antenna can be defined as an antenna that is radically developed to be integrated into optoelectronics. This integration allows performance augmentation, such as: duplexing, filtering, beamforming, impedance matching, and also rugged as well as lightweight system design [4]. However, this photonic antenna has low gain which is not suitable for high performance, point-to-point and long distance wireless links. Nevertheless, this antenna has the potential to distribute WiFi signals throughout building, hotels, campuses, and airports [5]-[7] of proven distinctive performance.

The purpose of this project is to design and develop an active downlink photonic antenna (ADPhA) with wideband operating frequency; namely, 1.8 GHz to 3.5GHz. The proposed ADPhA utilizes 1550nm optoelectronic and a single mode optical fiber. In this project, the InGaAs PIN photodiode from TrueLight™; TMC-2C33-002 is used. Among the many interesting features that led to the use of this photo diode are high responsitivity of 1550nm, low inter-modulation distortion and package with cap lens [8]. Moreover, the microstrip antenna is designed with omnidirectional antenna of 3dBi directivity, which has many advantages for covering wide serving areas and also to be applied within buildings as well as picocell areas.

II. Design and Fabrication

A. Interface Circuit

In order to integrate the antenna with the photodiode (PD), the interface circuit was designed by using Advanced Design System (ADS) software. The interface circuit is designed by combining the transmission line and reversely biasing the

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photodiode. The main aim of this circuit is to ensure that the circuit would function well at the desired frequency range; i.e., 1.8 GHz to 3.5 GHz. The diagram of the interface circuit is shown in Figure 1 with a size of around 30 mm x 34 mm. The circuit was etched on a microstrip board (FR4 ε_r= 4.7 and 1.6 mm thickness). The typical bias tee consists of inductor and capacitor. The function of the bias tee is to allow a DC bias voltage and a RF test signal to be applied to the port of a transistor during measurement [9]. The inductor, RF choke in Figure 1, will prevent the RF signal from entering the DC part, whereas the capacitor will prevent the DC signal from coming into the RF part. A 1.8 µH inductor and a 2.4 nF capacitor are chosen.

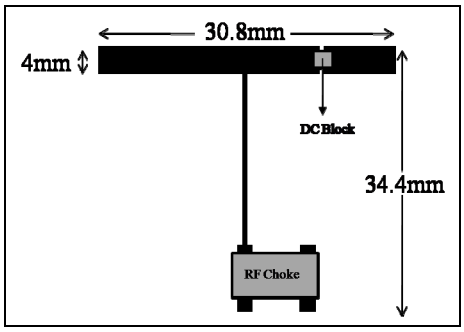
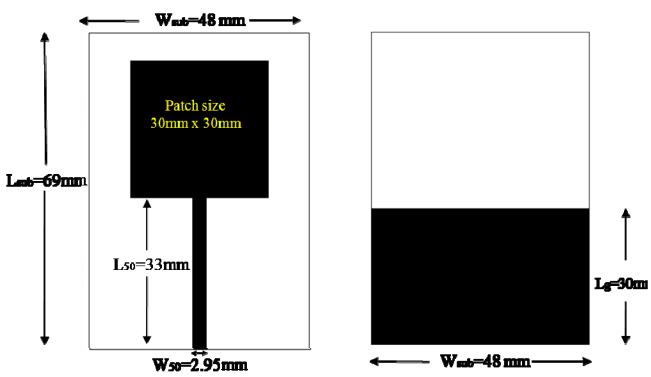


Figure 1The schematic diagram of interface circuit

B. Antenna Design

The antenna is designed and simulated using CST Microwave Studio software. The geometry and fabrication of the proposed microstrip antenna are shown in Figure 2 and Figure 3, respectively. The antenna consists of square patch with dimensional length, *L* and width *W* of 30 mm. The antenna is printed on the FR4 substrate (L_{sub} x W_{sub}) with the height (*h*) of 1.6 mm and relative permittivity (ε_r) of 4.7. The half-ground plane has a dimension of (W_{sub} x L_g) is used so that wideband characteristic is achieved.



(a) (b)

Figure 2 The geometry of the propose microstrip antenna: (a) top and (b) bottom view

(a) (b)

Figure 3 The fabricated antenna: (a) top and (b) bottom view

III. Results and Discussion

A. Interface Circuit Characteristic

Figure 4 presents the simulated and measured return loss S_{11} of the interface circuit. Obviously, good return loss is achieved at the desired frequencies in the range of 1.74 GHz to 3.9 GHz, which is lower than -10 dB and represents 90% of the transmitted signal.

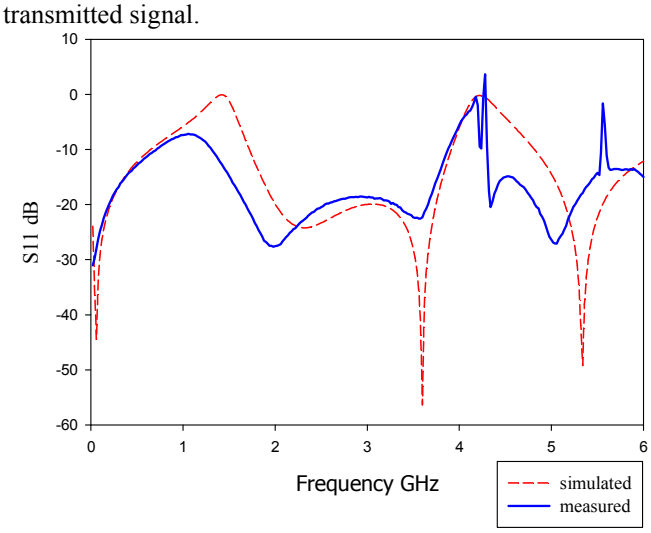


Figure 4 Simulated and measured for the S_{11} of the interface circuit

B. Antenna Characteristics

The return loss of fabricated antenna is measured using Rohde & Schwarz™ network analyzer. The simulated and measured return loss, S_{11} are compared as shown in Figure 5. The antenna covers 1.83 GHz bandwidth which is from 1.75 GHz to 3.58 GHz. Figure 6 shows simulated antenna radiation pattern. Clearly, the antenna radiation pattern is omnidirectional.

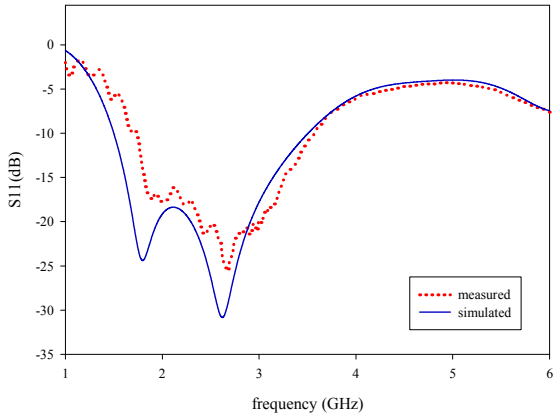
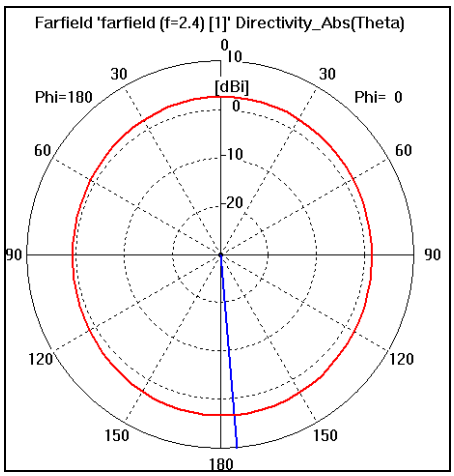
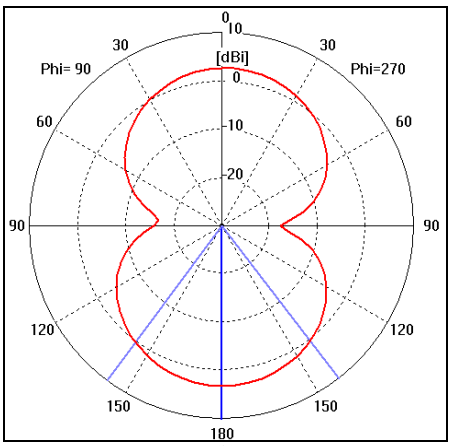


Figure 5 Simulated and measured S_{11} for the antenna



(a)



(b)

Figure 6 Simulated radiation pattern of antenna: (a) horizontal plane (b) vertical plane

IV. Photonic Antennas Fabrication and Performance Measurement

The photonic antenna 1 consists of two parts; an interface circuit together with a photodiode at the input, and a microstrip antenna. These two parts are connected using SubMiniature type A (SMA) connector. The fabricated photonic antenna 1 is shown in Figure 7. Next, the RF amplifier is added between the interface circuit and the antenna as depicted in Figure 8. In Figure 9, the interface circuit, RF amplifier, and the antenna are integrated together onto the same FR4 board in order to eliminate the connector loss. The experimental setup is shown in Figure 10. The PSI 1601 from PHOTONIC Systems™ Inc is utilized as optical transmitter. The PSI 1601 is an amplifierless link offering bandwidth in excess of 12 GHz and wide spur-free dynamic range (SFDR).

The link gain S_{21} of the photonic antennas is measured using network analyzer and shown in Figure 10. The main point to draw from the graph is that the intergrated photonic antenna gives better link gain compared to the photonic antenna 1 and photonic antenna 2 due to the elimination of the SMA connector loss.

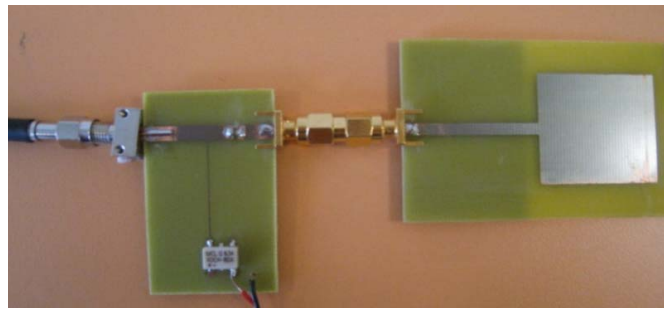


Figure 7 Fabricated photonic antenna 1(without amplifier)

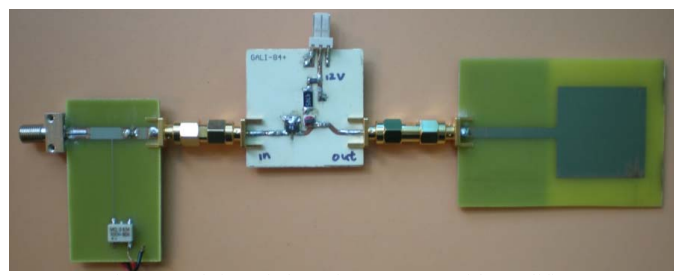


Figure 8 Fabricated photonic antenna 2 (with amplifier)

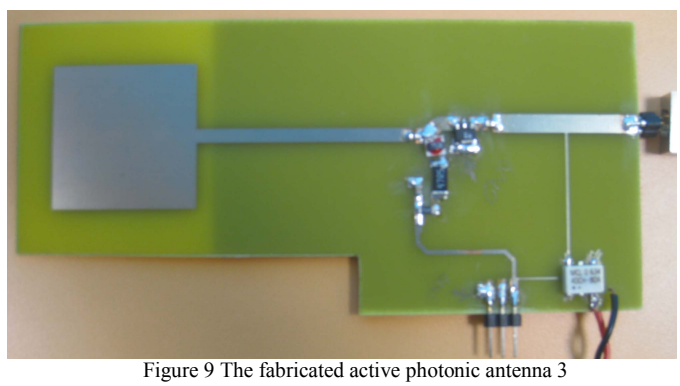


Figure 9 The fabricated active photonic antenna 3

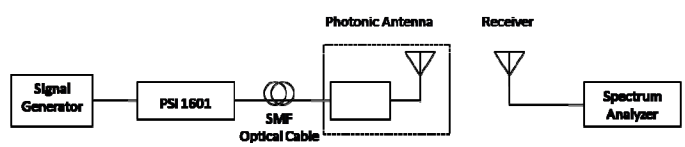


Figure 10 The experimental setup for measuring signal transmitted from the photonic antennas

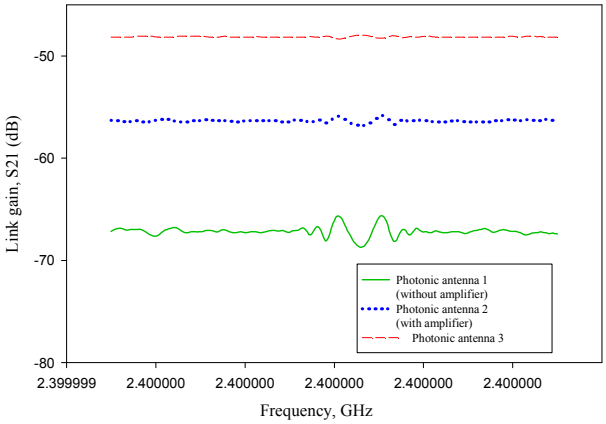


Figure 11 Link gain, S_{21} of photonic antennas

The spectrum of the received signal is measured at various frequencies; i.e., 2.4 GHz, 2.3 GHz and 2.5 GHz and considered suitable to the WLAN, and WiMAX applications. The spectra obtained at frequencies 1.8 GHz, 2.3 GHz and 2.4 GHz are in Figure 12, Figure 13 and Figure 14, respectively. The peak values of the spectra for 1.8 GHz, 2.3 GHz and 2.4 GHz are -55 dB, -43 dB, and -39 dB, respectively. It follows that the measured variations of the peak values are largely dependent on the reflected energy from a transmitted signal-return loss S_{11} of the antenna. By comparing the measured return loss results in Figure 5, clearly, there is a positive relationship among them. Referring to Figure 5, the return loss decreases as frequency approaches the value of 2.4 GHz. Interestingly, this trend causes an increase in spectrum peak values as frequency approaches 2.4 GHz. This relationship is makes it obvious that the lower return loss gives better performance.

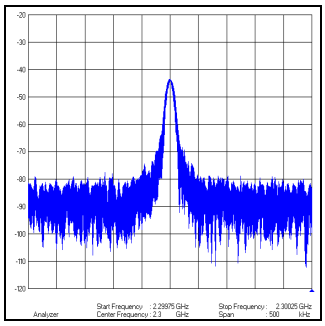


Figure 12 Measured spectrum at 2.3 GHz input signal

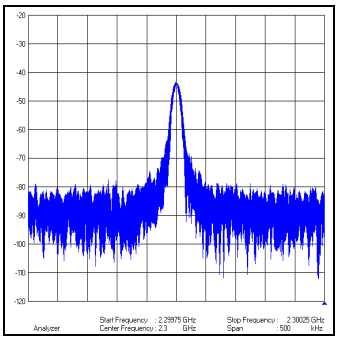


Figure 13 Measured spectrum at 2.4 GHz input signal

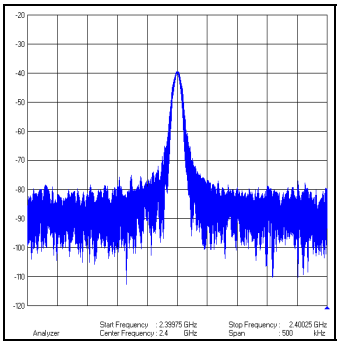


Figure 14 Measured spectrum at 2.5 GHz input signal

V. CONCLUSION

In this paper an active downlink photonic antenna has been implemented by means of integrating a photodiode, an interface circuit amplifier, and a microstrip antenna. The experiment is setup and the received spectrum are measured at the desired frequencies. These results indicate that an active downlink photonic antenna is successfully designed and fabricated. The designed photonic antenna can be used for many practical applications such as GSM 1800, WLAN and WiMAX.

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