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Design and Modeling of S Band Circular Patch and Ka Band Horn Antenna, Integration with Future Multifunctional Radio over Fiber Network

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Abstract

Radio over Fiber is an integration of microwave and optical fiber technologies having numerous benefits. RoF technology can give a scope of advantages including the capacity for backing multiple radio services and standards. In coming future, there is need of integrated wireless service with high speed satellite broadband and multifunctional indoor/outdoor antennas. Radio over fiber is one of the most favorite candidates to meet all these requirements of future multifunctional integrated wireless communication. Due to planer profile, small size and low cost patch antennas are most favorite to use for multi-frequency applications. In this paper, we present system level design for future multifunctional radio over fiber network. Under FTTH (Fiber To The Home) technology, it will be possible to use multi-frequency applications on single fiber medium. Firstly, we designed S band circular patch antenna (2.5 GHz) and Ka band (29 GHz) horn antenna. Circular patch antenna performance is estimated with different substrate height. After getting S parameters and far-field results, we did modeling of Radio over Fiber system over (10 Km) with same parameters from antenna results.

Keywords

Radio over Fiber, S-Band, Ka-Band, March Zehnder Modulator, CW Laser

1. Introduction

Future high speed wireless communication is based on millimeter waves but High Air link loss reduces the communication distance in millimeter wave systems. Radio over fiber is one good technology to extend the coverage in which Rf signal transmitted through optical fiber. Radio over Fiber is just sending the radio signals over optical fiber. Easy maintenance, low power units, simple remote antennas, low attenuation loss, large bandwidth and reduced power consumption are few benefits of RoF link. RoF is an auspicious solution to accomplish the increasing demand of wireless and user bandwidth. In RoF system, the only task of Base station is to convert optical signal into Radio signal. In recent advancement laser, photodiode and circulator are replaced with a single electronic device called electro absorption modulator [1]-[7]. EAM acts as photodiode for downlink and modulator for uplink. No light source is needed at RAU which makes it much simpler and cheaper. In 2012, A. Kumar & N. Agarwal worked on RoF integration microwave and optical communication was accessible to broadband wireless communications [6]. Three methods are implemented into RoF and compared with Attenuation: Scattering, BER and CNR. Satellite communication, mobile radio communication, broadband and wireless LAN are few more applications of RoF [3] [5] [6]. Radio-over-fiber (RoF) is an attractive technology for multi broadband services [8]-[16].

Due to light weight, low cost and small size, micro strip antennas are getting popular for future high speed communication. Most commonly used patch antennas are circular and rectangular shaped antennas. In triangular shape antenna, bandwidth is the biggest problem in many applications. Because of this factor, circular patch antennas are widely used in numerous wireless communications [17] [18]. Micro strip antennas are always preferred for integrated wireless applications due to its broad bandwidth for maximum performance [19].

In this paper, we first designed S band (2.5 GHz) circular patch antenna and Ka band (29 GHz) horn antenna. Antennas were designed and simulated in CST 2017 and after performance analysis, S parameters were imported in Optic System 14 via MATLAB file. Both (2.5 and 29 GHz) antennas S parameters were simulated in multi frequency RoF network for indoor communication. **Figure 1** shows a typical RoF network for indoor communication.

2. Antenna Design

Future RoF needs multi-functional and multi-frequency antennas, because indoor wireless applications work on different frequencies. To do RoF system demonstration we designed two different frequencies antenna and use parameters for RoF system simulation.

2.1. S band Circular Patch Antenna (2.5 GHz)

Circular patch antennas are attention seekers in both single elements [20]-[25] and in arrays [26] and [27]. Cavity Model [21] [24] [25] can be used for conveniently analysis of circular patch antenna. Circular patch antenna occupies less space as compared to rectangular patch antenna. We deigned 2.5 GHz circular patch antenna and get S parameters. Design Parameters of antenna is shown in **Figure 2**. Due to low cost and small size such antenna can be used for multi-

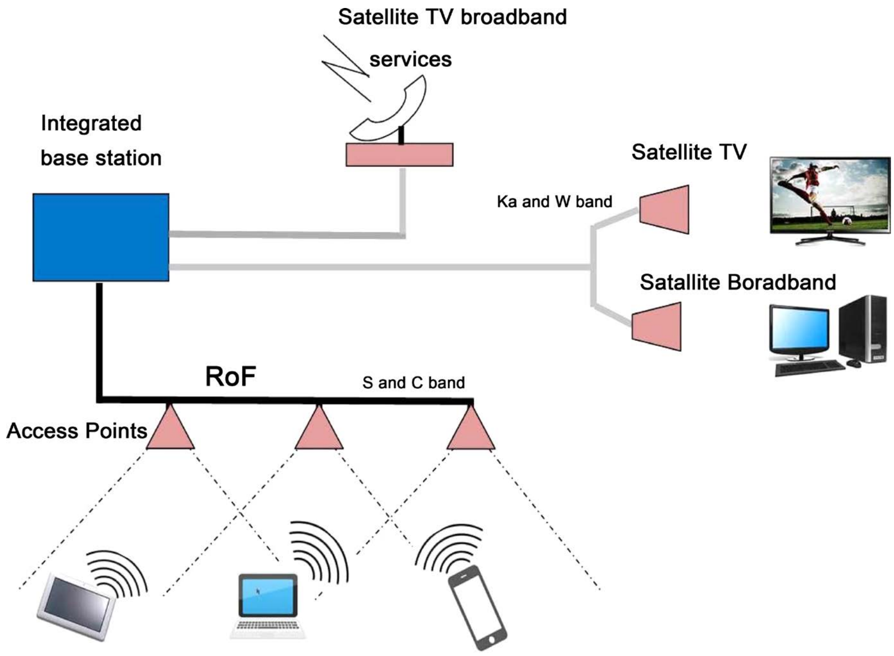


Figure 1. Radio over Fiber Integrated Wireless System design.

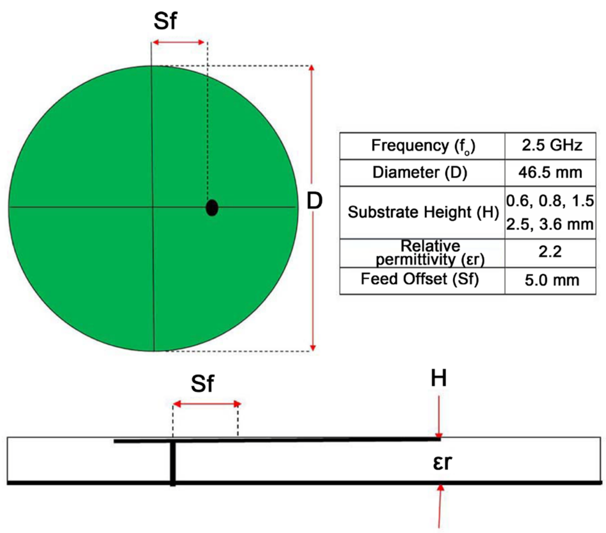


Figure 2. 2.5 GHz Circular patch antenna design parameters.

functional application in future radio over fiber activities. Radius of patch is found by Equation (1) [28] [29].

$$r_{eff} = r\sqrt{1 + \frac{2h}{\pi r \varepsilon_r}\left[\ln\frac{\pi r}{2h}\right] + 1.7726} \tag{1}$$

where r = physical radius of circular patch

h= height or thickness of the substrate

ε_r = Dielectric Constant.

2.2. Ka Band Horn Antenna 29 GHz

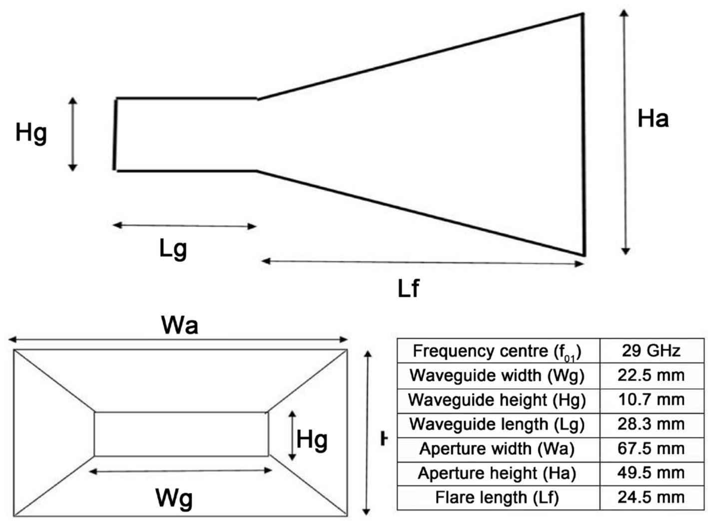
First horn antenna was constructed by Indian radio researchers in 1897. In 1962 they become widely used for microwave and satellite antennas. Horn antenna has very little loss so directivity is roughly equals to its gain. Due to absent of resonant elements horn can operate over wide bandwidth. Low SWR, wide band width and simple architecture are advantages of horn antennas. We designed waveguide-fed pyramidal horn antenna for Ka band (29 GHz). This can be used for satellite and broadband application in Radio over fiber network. Parameters of antenna are shown in Figure 3.

3. Antenna Results

S parameters show input and output relationship. S11 shows total reflected power from antenna also called reflection coefficient. Figure 4 shows S parameters for circular patch antenna with different substrate height while Figure 5 shows S parameters of Ka band Horn antenna.

3.1. VSWR (Voltage Standing Wave Ratio)

VSWR (Voltage standing wave ratio) also related to S parameters, smaller the



Frequency centre (f_{01})	29 GHz
Waveguide width (Wg)	22.5 mm
Waveguide height (Hg)	10.7 mm
Waveguide length (Lg)	28.3 mm
Aperture width (Wa)	67.5 mm
Aperture height (Ha)	49.5 mm
Flare length (Lf)	24.5 mm

Figure 3. 29 GHz Horn Antenna design parameters.

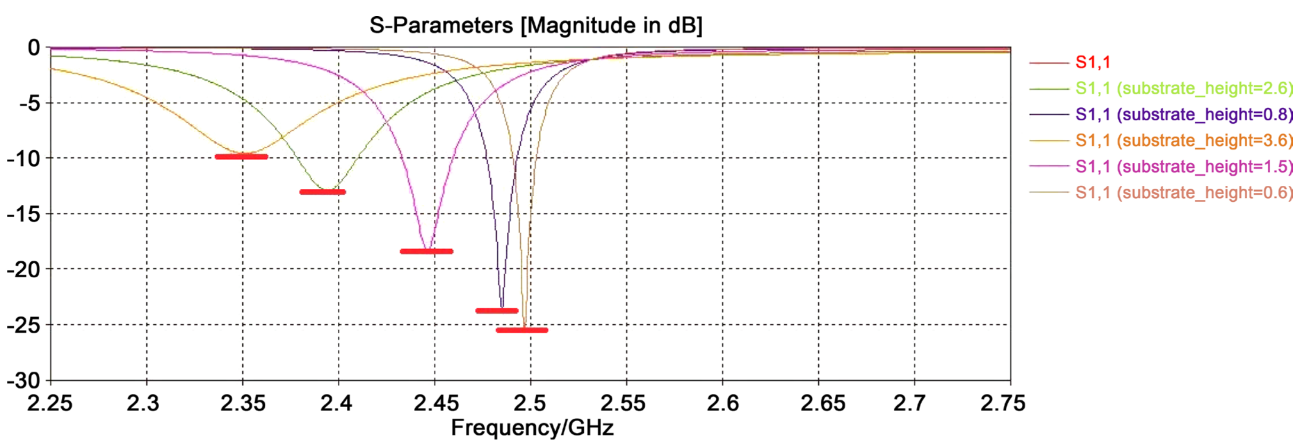


Figure 4. S parameters for circular patch with different substrate height.

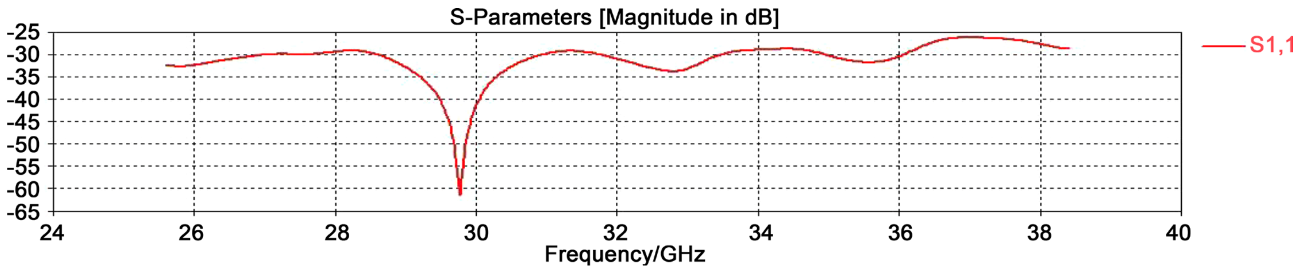


Figure 5. S parameters for Ka band Horn antenna.

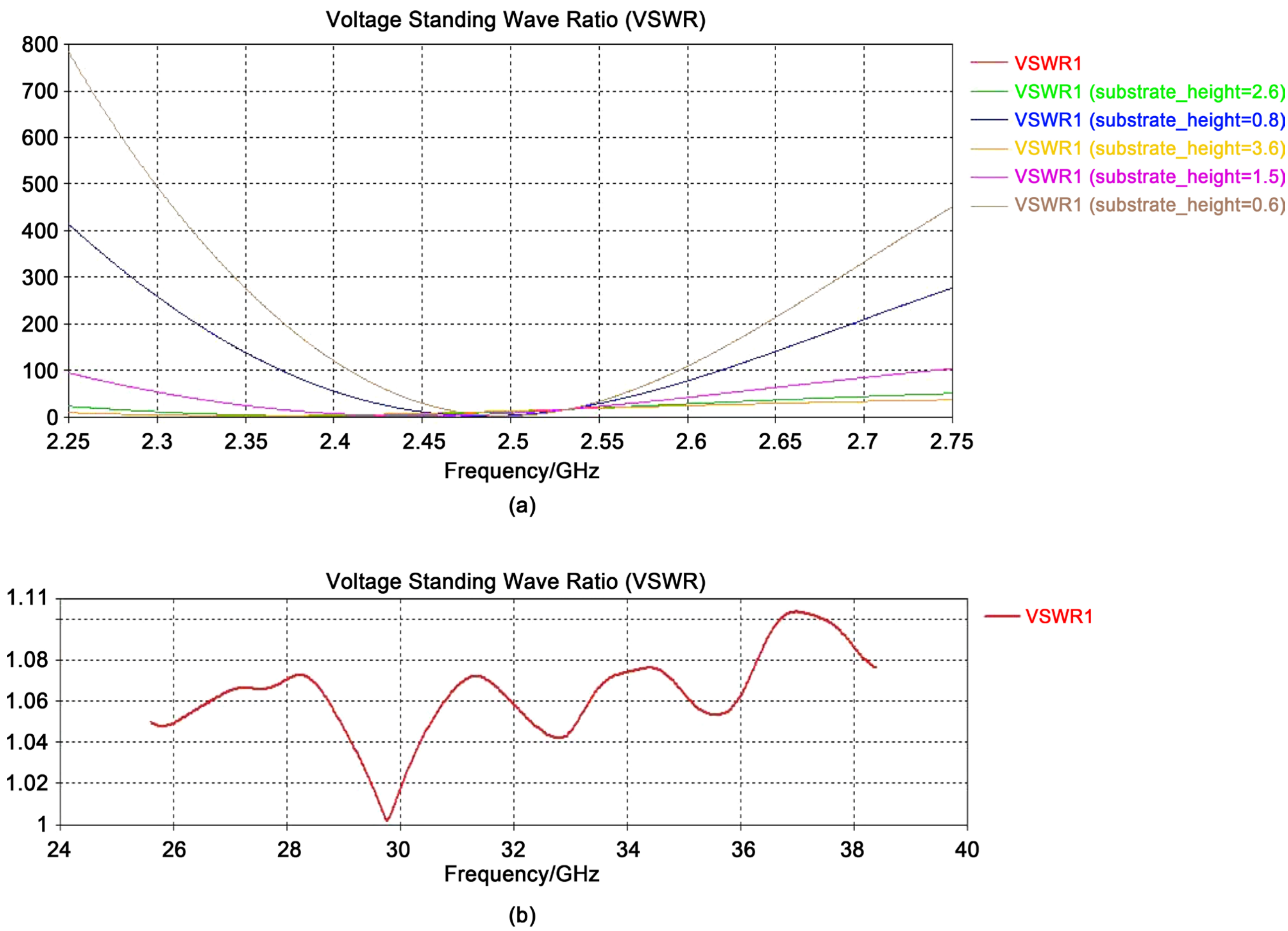


Figure 6. (a) VSWR for 2.5 GHz circular patch antenna with different substrate height. (b) VSWR for 2.9 GHz horn antenna.

VSWR more power will be delivered to antenna. It's necessary to calculate reflection coefficient Equation (2). If reflection coefficient is given by Γ then VSWR can be calculated by Equation (3). **Figure 6** shows VSWR for both horn and patch antennas.

$$\Gamma = \frac{V_{rev}}{V_{fwd}} \tag{2}$$

where Γ = Complex Number (magnitude & phase shift of reflection)

$$VSWR = \frac{|V_{\max}|}{|V_{\min}|} = \frac{1+|\Gamma|}{1-|\Gamma|} \tag{3}$$

3.2. Radiation Pattern

In Reference [30], Radiation Pattern is defined as "A mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates. In most cases, the radiation pattern is determined in the far-field region and is represented as a function of the directional coordinates." Antenna transmitted and receiving power can be seen by radiation pattern. Figure 7 shows radiation pattern for 29 GHz Horn antenna. Figure 8 and Figure 9 shows 2.5 GHz circular patch antenna radiation pattern. There is quite difference with different substrate height.

4. Radio over Fiber Design

Figure 10 shows system diagram of experiment. On transmitter side we used S parameters of 2.5 GHz antenna and also 29 GHz RF signal, both signals are received successful on receiver through 10 Km optical link.

On transmitter side two different frequencies Rf signals are input and on receiver side successful received. Figure 11 shows RoF system diagram designed in Opti System 14. In transmission side two Rf signal generator are used instead of antenna module. In first generator the s parameters were used from 2.5 GHz antenna and 29 GHz antenna s parameters were used in second Rf signal generator. Dual Drive March Zehnder Modulator is used with CW laser and both Rf signals were transmitted through single optical fiber of 10 Km length. Figure 11 shows Eye diagram of both signals successfully received.

5. Conclusion and Future Work

We designed 2.5 GHz circular patch and 29 GHz horn antenna for RoF wireless applications. Both antennas show good results. S band circular patch antenna performance is compared in Table 1 [31] [32]. Secondly S parameters and Ka band RF signal were used in RoF system design and on receiver side, received different frequencies signal with eye Diagram shown in Figure 12. In future multi-

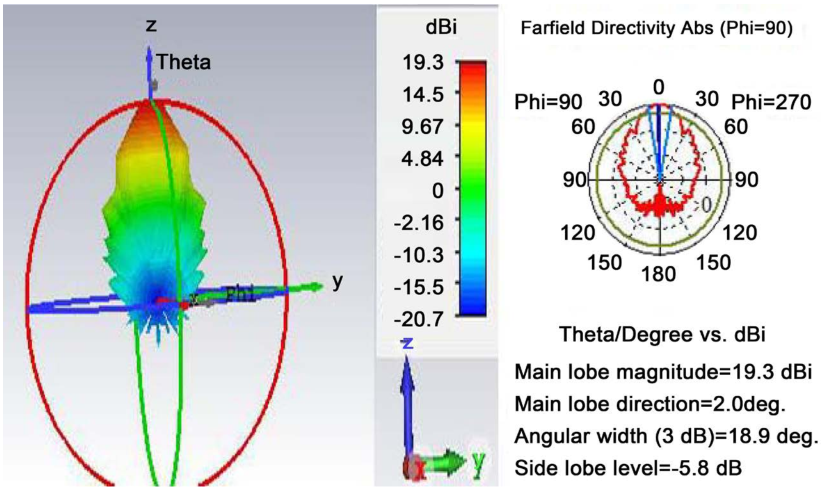


Figure 7. Far Field Directivity for 29 GHz horn antenna.

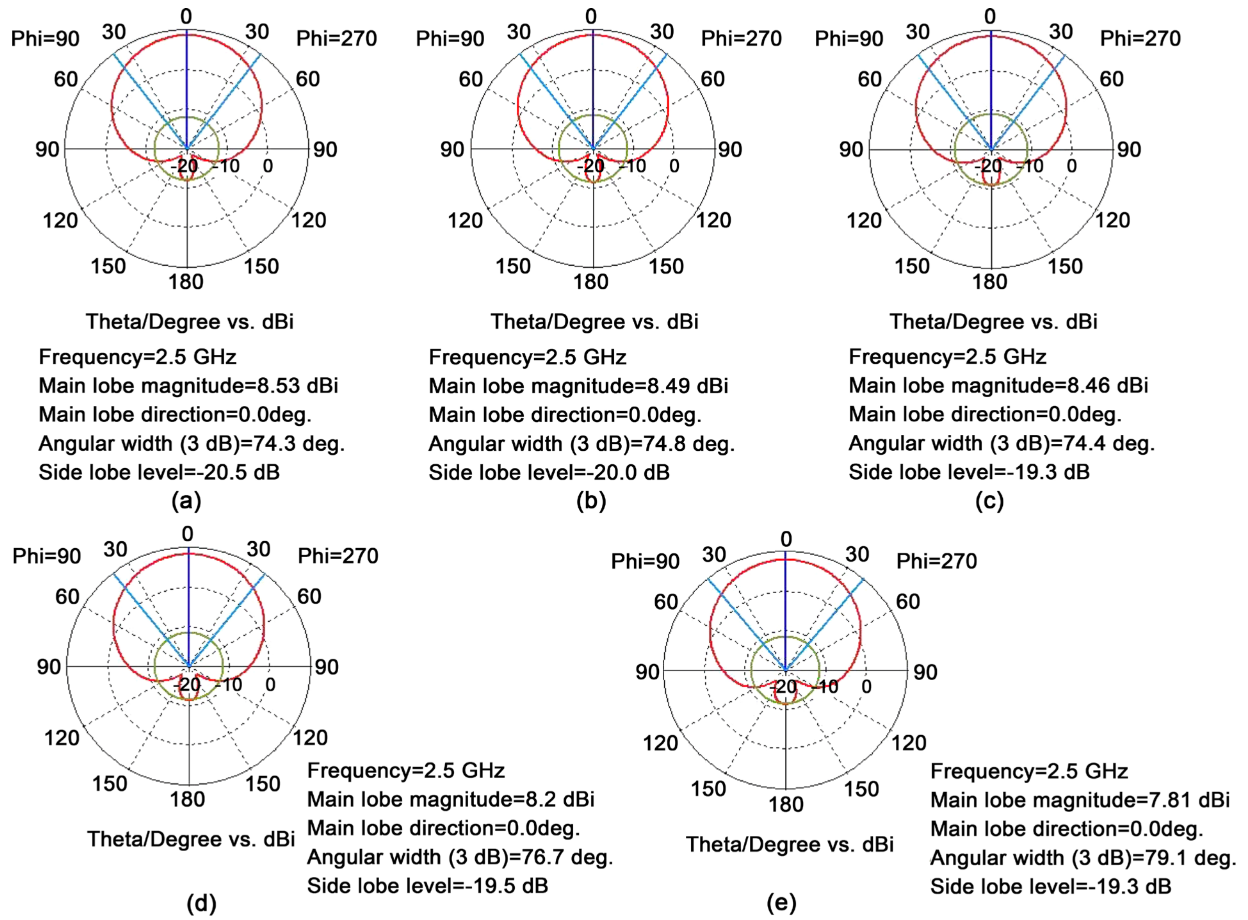


Figure 8. Far field for 2.5 GHz antenna with different substrate height. (a) 0.8mm (b) 0.6 mm (c) 1.5 mm (d) 2.6 mm (e) 3.6 mm.

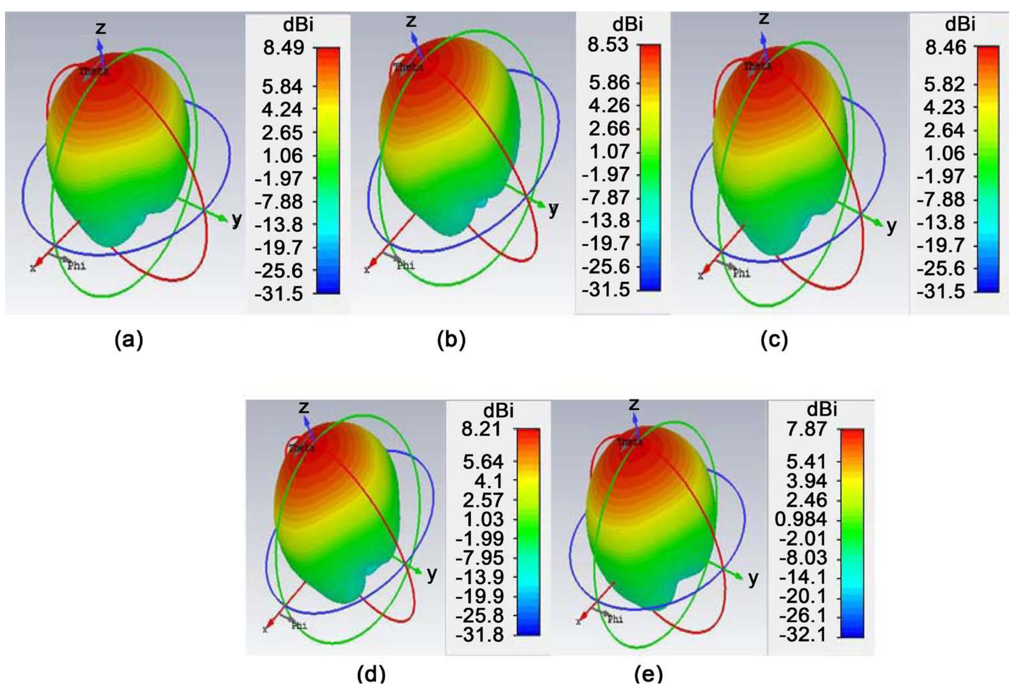


Figure 9. Radiation Pattern for 2.5 GHz antenna with different substrate height (a) 0.6 mm (b) 0.8 mm (c) 1.5 mm (d) 2.6 mm (e) 3.6 mm.

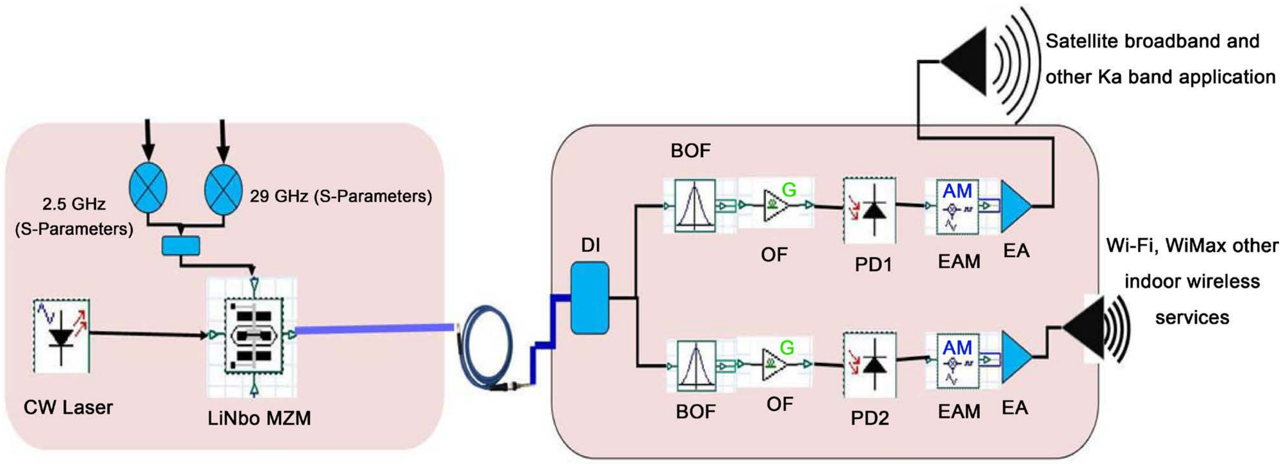


Figure 10. Experiment Radio over Fiber system over view. DI = Delay Interferometer, BOF = Bessel Optical Filter, OA = Optical Amplifier, PD = Photodiode, EAD = Electrical Amplitude Demodulator, EAD = Electrical Amplitude Demodulator.

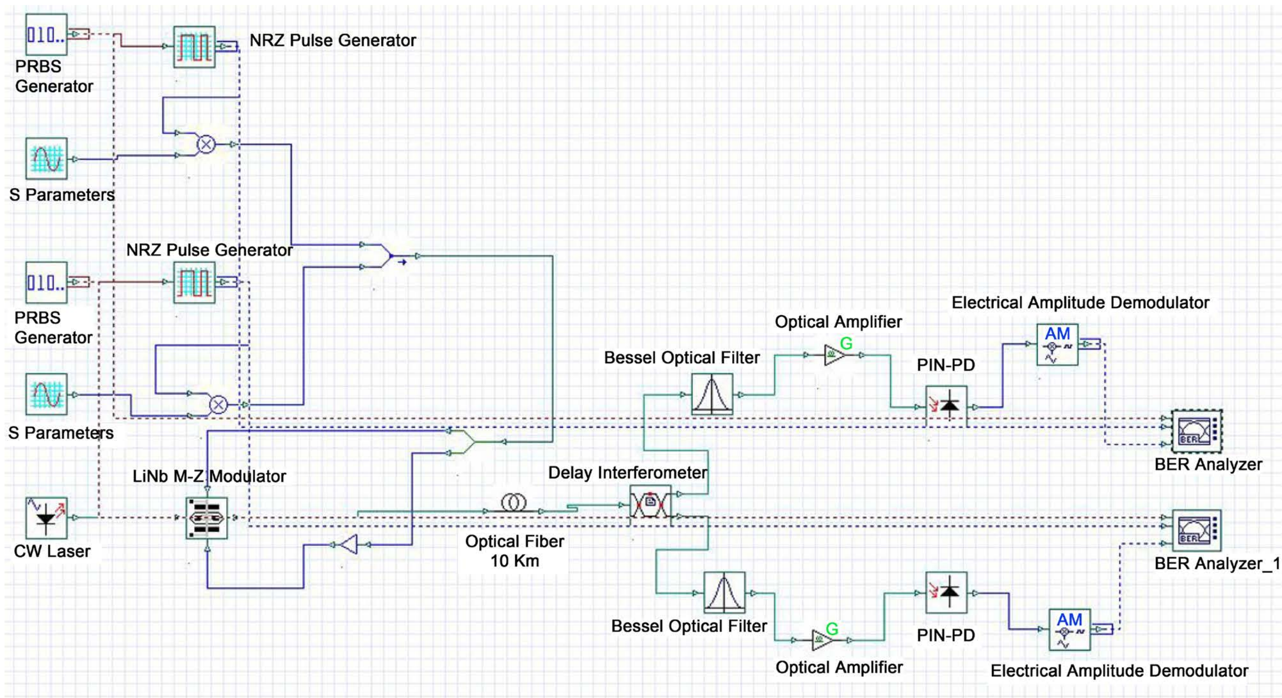


Figure 11. Multi-Frequency Radio over Fiber System.

Table 1. Far-Field Comparison.

No.	Frequency (Fo)	Far-Field (dBi)
[31]	2.5 GHz	8.1
[32]	2.5 GHz	4.53
Presented	2.5 GHz	8.53

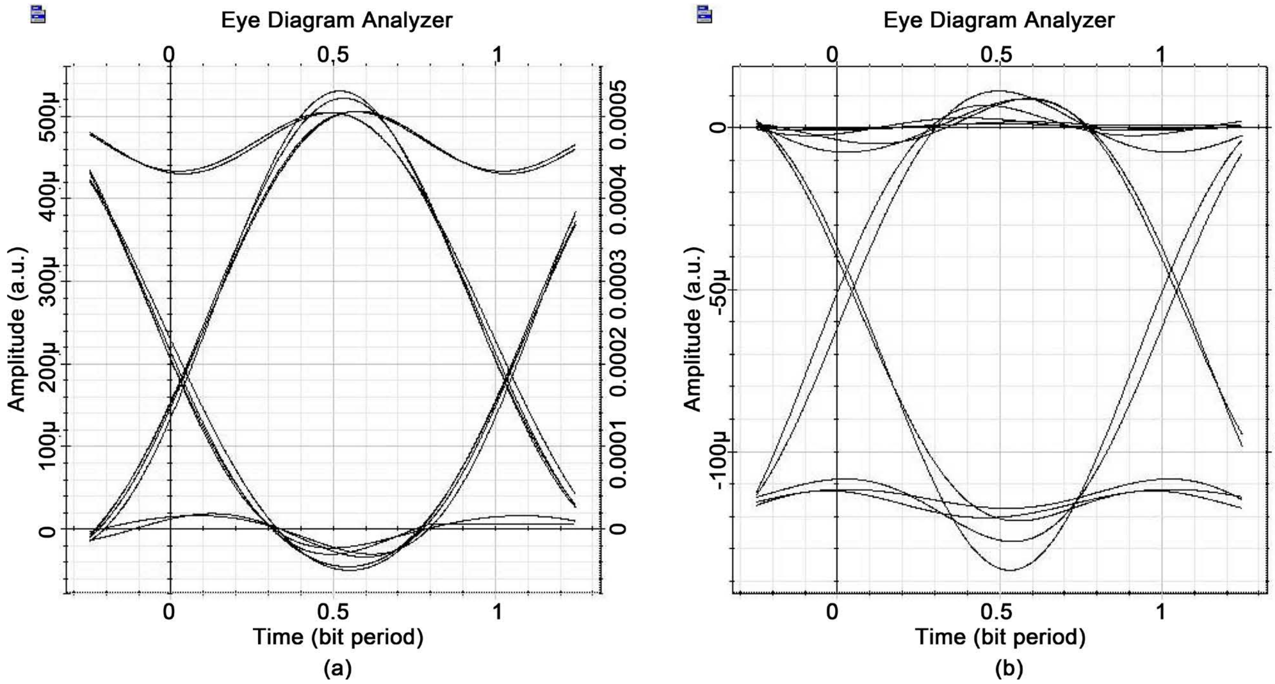


Figure 12. Eye diagram for 2.5GHz and 29 GHz received signal.

band antennas will be designed and parameters will be using in RoF system. As RoF is integrated with multi frequencies applications, So on system level it's important to consider emission wavelength of laser, length of fiber and transmitted frequencies for better signal integrity. RoF is easy to expand and flexible. RoF will be core technology for future indoor and outdoor wireless applications.

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