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Bidirectional Antenna for 2.4-ghz WLAN Application Inside Train

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Abstract: In this paper, a bidirectional antenna is presented for a WLAN application inside monorail train. The Yagi Uda antenna has directional characteristic that is suitable for the long path service area. The design concept of the proposed antenna has two directional antennas combined pointed in opposite direction which only involves the driven element and directors. The Yagi Uda design of bidirectional antenna operates in the frequency band of 2.4 GHz. The antenna is proposed with a thickness of 1.6mm and relative permittivity of 4.3 on FR4 substratum. Resonant frequency is set at 2.42 GHz with a bandwidth of 390 MHz from simulation work. The proposed antenna also met the estimated antenna bandwidth at a range of 2.23 GHz-2.63 GHz, and the bidirectional pattern. Both simulated and measured result are well matched.

Keywords: bidirectional antenna; wireless local area network (WLAN); Yagi Uda design

1. Introduction

Radiation pattern with sector beam radiates most of the energy to a particular direction. This pattern is widely used in wireless communication. The radiation pattern for Wi-Fi coverage in train coach need the bidirectional in broadside directions. The smart device in hand connect wirelessly to the Internet using Wi-Fi requires a hotspot. Therefore, the connectivity in the railway can be seen as a tool to attract passenger and increase consumer satisfaction. For Wi-Fi inside train carriage, installation of multiple hotspot along the train provide complete coverage to the passenger. Wireless coverage inside the carriages is provided by antenna per access point. The type of antenna to use is an important factor to consider the cover-age using radiation pattern. Thus, the design of antenna should have the compact size, radiation pattern with characteristic of particular direction and high efficiency for selected frequency. Therefore, the antenna with the directional radiation pattern is suitable for the long path service area.

Designs of directional antenna were developed for Wi-Fi application in [1], [2], and [3]. The proposed antenna is suitable for application in a WLAN access point which requires a directional antenna. It is a good choice to target with good directional characteristic of Yagi Uda antenna. The proposed structure in design only involves the driven element and directors. The size will be smaller than the combination of two single Yagi Uda antenna.

An omnidirectional antenna is required to cover the circular area for a base station. However, bidirectional antennas, such as the railway, are favored for long path service area. Basically, it is possible to achieve the bidirectional antennas by integrating two directional antennas, such as the Yagi antenna pointing in opposite direction. Yagi Uda antenna employs the reflector and director to enhance the directivity. Generally, the length of reflector should longer

than driven element dipole. This is because the long reflector retards and reflects back the power radiated from powered element. The director should be shorter than driven element to drag forward the energy.

Microstrip patch antenna are used in various application areas with-in communication system. Microstrip antenna have high performance where low profile, simple construction and cost effectiveness [4]. Microstrip antenna are also called radiating patch antenna. This printed antenna consists of a metallic sheet on the dielectric substratum. The ground plane is positioned on the substratum rear side. The dimension of the patch will determine the frequency operation and performance of the antenna [5]. Printed antenna are inexpensive to fabricate using modern printed circuit technology. The radiating patch can be square, circular, elliptical, rectangular, etc [6]. Substrates can be varieties of dielectric material with the dielectric constant in the epsilon range between 2.2 and 12.

The most commonly used directional radiator worldwide is the Yagi Uda antenna. A Yagi Uda antenna is categorised into three element types. The elements are driven element, directors and reflectors [7]. The driven element is radiating the power from a feeder. Basically, this active element is a half or slightly less than wave dipole. The Yagi antenna has one reflector behind the driven main element. The reflector is about 5% greater than the driven element. This causes the good reflection and increase gain in the forward direction. The directors are made to be 5% smaller than driven element. The directors are put before the guided item in order to achieve better benefit and directness [8]. Each director will increase the gain as number of directors increases.

The radiation pattern for Wi-Fi coverage in train coach need the bidirectional in broadside directions. Therefore, the directional radiation pattern is suitable for the long path service area. Designs of directional antenna were developed for Wi-Fi application in [1-3]. The printed linear array antenna consisting of three half-wave folded dipole elements is provided in [1], with the first two elements operating in the 5 GHz band and the third one operating in the 2,4 GHz band for WLAN operation. The array antenna produces vertical polarization of the spatial radiation patterns for frequencies around the 2.4 and 5 GHz WLAN bands. The proposed antenna is suited for application in a WLAN access point demanding a directional antenna.

Besides WLAN applications a compact planar directive antenna is presented in [2]. The planar directive antenna is Yagi-Uda which has a compact size and is designed to work at a frequency band of 5 GHz. The antenna comprises of a a ground plane with an integrated balun feeding, a parasitic strip and two printed dipoles. The larger dipole and the smaller dipole, serve respectively as a driver and reflector. In the proposed structure the parasitic strip is acting as a director. A compact dual-polarized stacked bidirectional antenna has been presented in [3] for 2.4 GHz WLAN applications. The antenna consists of an orthogonal coupling feed driver and stacked director array. The antenna proposed is made up of two parts, the coupling feed driver and the stacked operator array. The array of stacked directors is composed of four-square directors in each direction of radiation. The peak gain values for each port at 2,45 GHz along one path of radiation is 9,65 dBi and 9,30 dBi, with highly symmetrical bidirectional beam pattern.

In this paper, the bidirectional antenna with Yagi Uda design operating in the 2.4 GHz frequency band was used. The antenna was constructed on FR4 substrate of thickness 1.6 mm and relative permittivity with 4.3. The resonant frequency from simulation work is 2.42 GHz with bandwidth of 390 MHz. The measured bandwidth of the antenna at range of 2.23 GHz - 2.63 GHz and the bidirectional pattern has also been attained by the proposed antenna. Both simulated and measured result are well matched.

2. Antenna Configuration

Simulation Technology software (CST) is used for antenna design. CST Studio Suite is an electromagnetic simulation software. The parameters of the antenna patch can be adjusted to achieve the desired 2.4 GHz band for WLAN application. This need the simulation with help of CST Studio Suite. CST software simulate using time domain solver. The simulation result of CST software clearly shows the parameters of designed antenna such as radiation pattern, gain in dB and efficiency.

The antenna proposed comprises of a microstrip fed monopole which covering the 2.4 GHz WLAN band. The bidirectional monopoly antenna installed on 1.6mm thick FR4 substratum and relative permittivity of 4.3. In other side, the ground plane is printed in backside of the substrate.

The design consists of a driven element, directors element and ground planes acting as a reflector. The power given to the driver dipole element will not radiate and return to the ground plane itself if the ground plane is not utilized. In addition, the ground planes also act as impedance matching element. The bandwidth is mainly con-trolled by the ground dimensions and the length L1 of the driven element. The parameters of the ground plane are adjusted so as to obtain the second resonance closed to first resonance. The ground plane dimensions affect the resonant frequency and the operating bandwidth.

All parameters of the proposed antenna were optimized with the help of CST Studio Suite. The driven dipole is mounted on the substrate and a connector with a characteristic impedance of 50 Ohm is used to excite the driven antenna dipole. Besides that, the distance L4 and W3 are important parameters in determining the sensitivity of impedance bandwidth matching. The dark areas represent the structure on the top metal layer based on the description in Figure 1, while the slightly gray areas represent the structure of the bottom layer substrate. For dielectric materials, the length of the driver de-pends on the resonant frequency and can simulated experimentally using CST software. The width of the driven element on top layer will affects the impedance slope. The width also can be calculated using software. Copper printed thickness which is 0.035 mm. The proposed antenna dimensions are listed in Table 1.

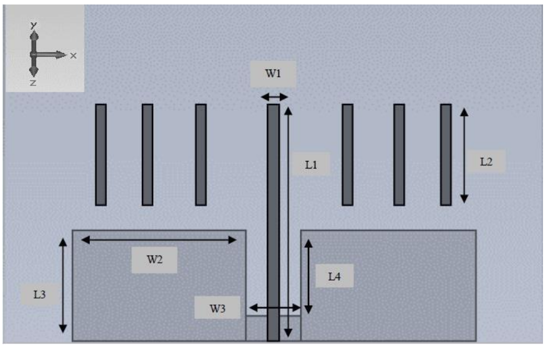

Fig. 1 - Geometry of the proposed antenna (substrate was set transparent)

Table 1 - Dimensions of the proposed antenna

Structure	Symbol	Value (mm)	Structure	Symbol	Value (mm)
Top layer metal	L1	70.00	Bottom layer metal	L3	33.00
	L2	30.00		L4	25.50
	W1	3.08		W2	52.00
				W3	16.00

Once the simulation results have been collected, the proposed antenna is produced using wet etching technique. The FR4 board is used as substrate with thickness of 1.6mm. The copper used with thickness of 0.035 mm. First, the process begins by attach the photo-resist layer to the substrate board. The attachment of photoresist layer is laminated using laminator machine. Then, the second process is a patterned mask placed on the board to block light. With this, the unprinted regions of the material will be exposed to light. Next, the third stage is the microstrip board exposed to the UV light. The photoresist layer is a light sensitive chemical substance and will become polymerized after exposed to the UV. The non-polymerized photo-resist layer region is then washed over the photoresist.

The microstrip board is then going to the process of chemical etching. This process selectively removes the unprotected parts from the substrate. The baths of temperature regulated etching chemicals can create an antenna with the desired shape by using etching machine. After the etching process, the SMA connector is needed to be soldered into the antenna. The fabrication process is significant factor to ensure that an accurate measurement results can be obtained. Next, the measurement of result will be made. Figure 2 shows the front view of the fabricated antenna, while Figure 3 shows the back view of the fabricated antenna.

Fig. 2 - Front view of the fabricated antenna

Fig. 3 - Back view of the fabricated antenna

3. Results and Discussions

In CST software the antenna proposed was simulated. Simulated parameters will be visualized below. The return loss plot showing the 2.24 GHz spectrum frequency band-2.63 GHz. This bandwidth is below -10 dB and was found to be 2.42 GHz in resonant frequency. The return loss value is as shown in Figure 4, at -30.5 dB.

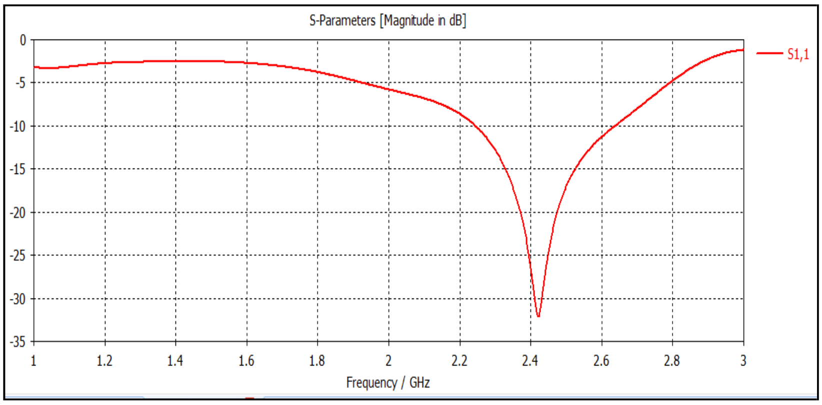

Fig. 4 - Simulated S-parameters (dB) of antenna

The polar plot of the proposed antenna was shown in the Figure 5. The directivity measures the power density of the antenna radiates in the direction of its strongest emission. The value of directivity of the proposed antenna is around 5.9 dBi at the desired operating frequency. The bidirectional radiation pattern in 3D are shown in figure 6.

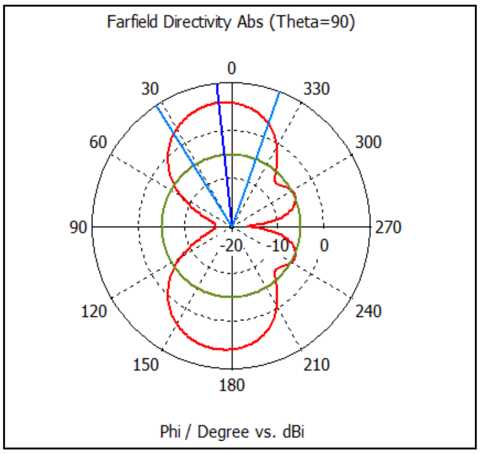

Fig. 5 - Radiation pattern in polar

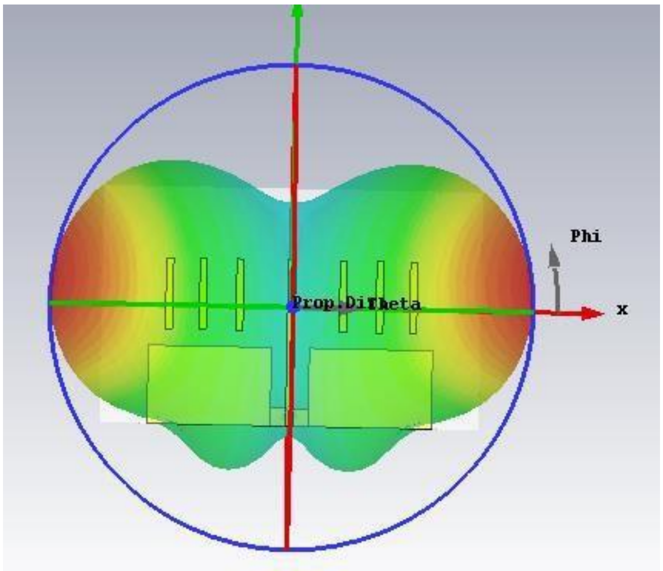

Fig. 6 - Radiation pattern in 3D

A train coach model is designed and the proposed antenna is set to install at the roof top of train coach. The bidirectional radiation pat-tern is following the direction of the directors. The simulated radiation pattern in the train coach is shown in the Figure 7.

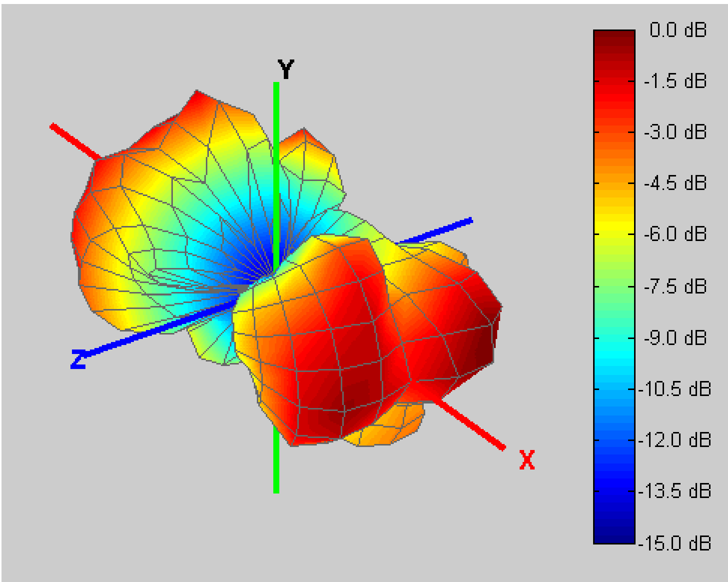

Fig. 7 - Simulated radiation pattern in the train coach model

This section presents the experimental results for the proposed antenna. The results of simulated and measured S parameters are given in Figure 8. The measured return loss plot showing the frequency band at range of 2.23 GHz - 2.63 GHz. This resonant frequency is found to be 2.5 GHz. The return loss value is at -35.5 dB. The simulated and measured S11 parameters result agree well.

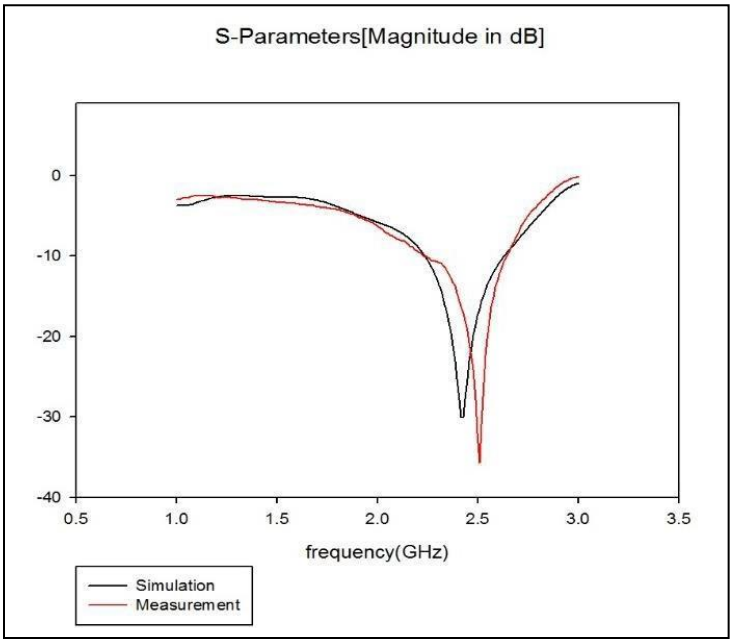

Fig. 8 - Simulated radiation pattern in the train coach model

4. Conclusions

In this study, the paper mainly focusses on antenna with bidirectional radiation pattern to provide WLAN coverage. The antenna proposed was based on the Yagi Uda design which is combining two directional antennas pointed in opposite direction and only involves the driven element and directors. The design of antenna will influence the broadside main beams propagate towards the desired direction. The frequency operation of this antenna is about 2.4 GHz for Wi-Fi application. The simulated frequency band is adjusted to the range of 2.24 GHz - 2.63 GHz and resonant frequency is found to be 2.42 GHz which relevant for Wi-Fi application. The result for measured bandwidth of the antenna is at range of 2.23 GHz - 2.63 GHz with resonant frequency of 2.5 GHz. The proposed antenna is measured to have the bidirectional radiation pattern. This is well match with the simulated result. Based on the simulated radiation pattern in the train coach, the signal from antenna propagates along x-axis to provide the coverage along the train coach. Hence, the proposed antenna is suitable for Wi-Fi application and should be installed at the roof top of train coach follow the direction of the directors.

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