A Vertically Circular Patch Antenna with Cross Strip above Vertically Rectangular Reflector

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Abstract

In this paper, a vertically circular patch antenna excited by probe with cross strip above vertically rectangular reflector is proposed. The proposed antenna is used for Base station of WLAN system. The antenna is analyzed by CST (Microwave studio) program. A prototype antenna operating at 2.45 GHz. with an impedance bandwidth (2:1 VSWR) of 37.62 % from measured result (about 2.105-3.000 GHz). The proposed antenna is unidirectional radiation pattern with front-to-back ratio (F/B) of greater than 20 dB in H-plane and E-plane radiation patterns. Maximum gain is about 9 dBi from measured result. The half-power beamwidth (3dB) is about 58.8 degree in E-plane and 65.0 degree in H-plane. The cross polarization greater than 20 dB has been obtained.

1. INTRODUCTION

Recently, wireless communication system is very important especially, the wireless local area networks (WLAN) are growing very fast. The IEEE 802.11 group has been responsible for setting the standards of WLAN [1-2] at operating frequency of 2.4 GHz. The microstrip antennas are popular in WLAN system due to their advantages such as low profile, easy fabrication and good radiation characteristics [3-5]. However, general patch antennas have narrow bandwidth and low gain. The resonant length is approximately half-wavelength which are the disadvantages. Recently, a circular vertical patch antenna (VPA) [6-7] was proposed for reducing the area of patch antenna. The VPA has simple configuration with an area smaller than the annular-ring patch and enhance bandwidth of over 10%. Also, it has higher gain in broadside direction. However, the front-to-back ratio (F/B) is lower than 15 dB and cross-polarization is rather strong.

This paper proposes to develop the unidirectional antenna for base station of WLAN systems. The antenna is analyzed by using CST program. The proposed antenna is designed to cover bandwidth of 2.420-2.484 GHz. The principle of the proposed antenna is based on a vertically circular patch antenna and probe-fed circular ring antenna with a cross-strip [8].

2. THE PROPOSED ANTENNA DESCRIPTION

A. Vertically circular patch with flat rectangular reflector

The configuration of the proposed antenna is shown in Fig.1 where the vertically circular patch has the dimension of the diameter *D*, and height *t*. The height of two sides of the vertically circular patch can be adjusted for the improvement of beamwidth in both planes, the matched input impedance and makes it lower from the upper edge by parameter *l*.

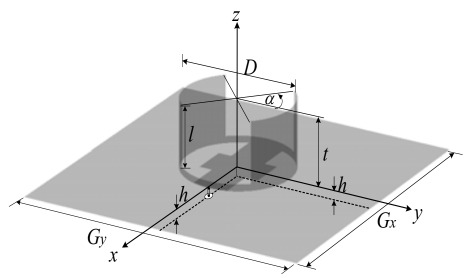

Fig. 1: The configuration of vertically patch antenna excited by probe with cross strip above flat rectangular reflector

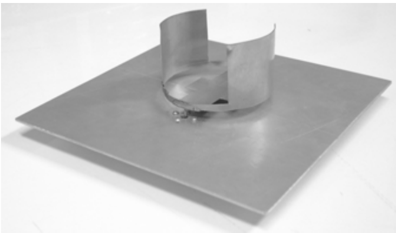

Fig. 2: The prototype of vertically patch antenna excited by probe with cross strip above flat rectangular reflector.

The prototype of the vertically patch antenna excited by probe with cross strip above flat rectangular reflector are shown in Fig.2. The prototype antenna was fabricated from brass plate of thickness 0.4 mm. The flat rectangular reflector was made of the aluminum of thickness 1 mm. Fig.3 shows the configuration of the cross strip. The cross strip placed at the centre of the circular ring with the width *w* that is shorted with the ring at the bottom edge (closed to the reflector) between the opposite side. The other arms of the cross strip are free with length *s* from the shorted arms as depicted in Fig. 1. The antenna is positioned on a horizontal rectangular reflector and separated by a thickness *h* of the air-layer substrate with dielectric constant close to unity. The vertically rectangular reflector is paralleled to the vertically circular patch radiator.

TABLE 1: PARAMETERS OF VERTICALLY CIRCULAR PATCH WITH FLAT RECTANGULAR REFLECTOR

Parameters	Dimension(mm)
D	*61.00*
t	*31.00*
l	*28.00*
s	*3.69*
w	*16.62*
h	*3.00*
Gx	*186.00*
Gy	*186.00*

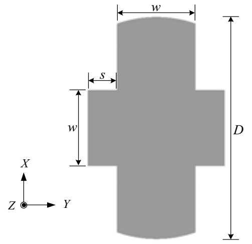

Fig. 3 Configuration of cross strip

The single probe feeder is placed at the centre of the long cross strip in the place of lower edge of the vertically circular patch radiator. The method of feeding design has been described in [11]. As shown in Fig. 1, the dimensions of an antenna were analysed using CST program. Consequently, the length of diameter and height of the vertically circular patch are chosen under the assumption that the geometrically configuration is a cross section part of a cylindrical waveguide about half wavelength and quarter wavelength. In addition, the diameter of the vertically circular patch is used to determine the impedance matching and radiation pattern that was used in the study. A cross strip width was chosen to be the same as that of the 50 Ohm microstrip line. It is corresponding to air substrate layer. Therefore, the antenna resonant frequency covers at 2.4 GHz. For the dimension of the flat rectangular reflector, it has relatively smaller effect. The other parameters are d = 61 mm t = 31 mm l = 28 mm h = 3.0 mm w = 16.62 mm, s = 3.69 mm. All parameters are used for the mid resonant frequency to cover at 2.4 GHz. For the dimension of the flat reflector, it has relatively smaller effect on the antenna resonant frequency but mainly on the gain and half power beamwidth of the antenna radiation patterns. The flat rectangular reflector has *Gx* and *Gy* equal to 186 mm. The antenna is simply constructed. It made of brass plate. Fig. 4 shows simulated and measured return loss of vertically circular patch antenna above flat rectangular reflector. The theoretical and experimental results of return loss agree very well as presented in Fig. 4. The return loss of the fabricated antenna is measured using HP8520C network analyzer. The level of return loss from simulation at 2.4 GHz is about-40 dB and -37 dB at 2.45 GHz from measured result. The measured return loss has a bandwidth (VSWR < 2) of 25.39% that cover the frequency range of 2.20-2.84 GHz. It is similar to the simulation result. The level of return loss is controlled by the dimension of *t* and *s*. The vertical thickness *h* is used for tuning the impedance matching. The operating frequency is relatively sensitive to the length *d*. The parameter *w* is calculated by approximate equation of microstrip line 50 Ohm.

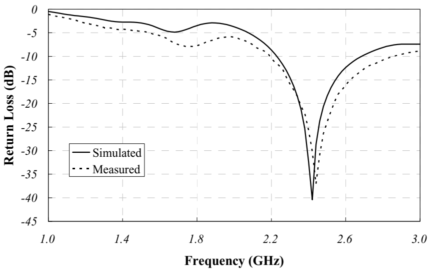

Fig. 4: The simulated result and measured result of return loss

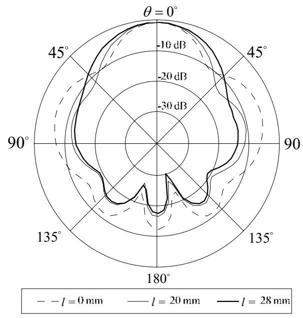

Fig. 5: The radiation pattern in E-plane with adjusted parameter *l* (simulated)

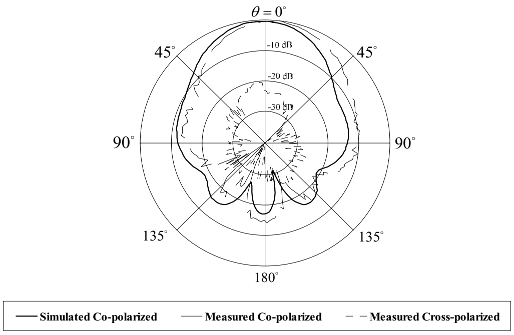

Fig. 6: Simulated and measured radiation pattern in E-plane. (antenna parameters in table 1).

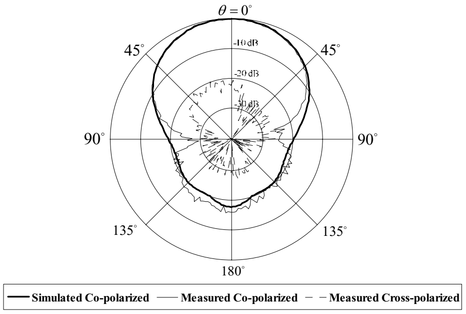

Fig. 7: Simulated and measured radiation pattern in H-plane. (antenna parameters in table 1).

Fig. 5 shows the radiation pattern in E-plane. The proposed antenna is unidirectional radiation pattern. It is seen that asymmetry radiation pattern when compared with H-plane. It can be improved the radiation pattern by adjusting the parameters *l*. The parameter *l* is suitable at *l* = 28 mm for symmetry in both planes. The measured and simulated results of radiation patterns in E-plane and H-plane at the frequency of 2.4 GHz are shown in Fig. 6 and Fig.7. The pattern has front-to-back ratio (F/B) of greater than 15 dB in E-plane and H-plane. The maximum gain is about 10 dBi from simulated result and about 8 dBi for measured result. The front-to-back ratio in both planes is greater than 15 dB. The cross polarization greater than 20 dB has been obtained for simulated and measured results. The parameter *l* can be adjusted for symmetrical pattern of H-plane and E-plane.

B. Vertically circular patch with vertically rectangular reflector

Based on the characteristic of vertically circular patch antenna described in the previous section, it is found that some characteristics can be improved. In the previous section, the front-to-back ratio of the antenna is strong (about 15 dB) and the large size of reflector is used that are the disadvantages to be improved. The vertically rectangular reflector is used to reduce the size of the flat rectangular reflector (36% reduction) while maintaining the radiation characteristics same as the previous antenna. Moreover, the bandwidth is increased and the front-to-back ratio is better than the flat rectangular reflector. Fig. 8 shows configuration of the vertically circular patch antenna excited by probe with cross strip above vertically rectangular reflector. The dimension of the new proposed antenna is shown in table 2. The size of the radiator is the same as in table 1 except for the dimension of the horizontal reflector. The dimension of the horizontal reflector *Gx* and *Gy* is about 100 mm and the additional vertically reflector *Gz* is equal to 43 mm. The theoretical and experimental results of return loss agree very well as presented in Fig. 10. The return loss of the fabricated antenna is measured using network analyzer. The measured return loss has a bandwidth (VSWR < 2) of 37.62 % centre at 2.5 GHz in the frequency range of 2.105-3.000 GHz. It is almost the same as the simulation result. The wideband of return loss is controlled by the dimension of *t* and *Gz*. The operating frequency is relatively sensitive to the length *d* and the width *t*. The parameter *w* is calculated by the approximate equation of microstrip line with 50 Ohm. Moreover, the bandwidth can be enhanced at the higher operation frequencies. The wider bandwidth will be obtained by varying parameter *Gz*. The return loss level is shown in Fig. 11. The parameter *Gz* is for vertical reflector. The measured and simulated results of radiation patterns in H-plane at the frequency of 2.4 GHz are shown in Fig. 12. The half power beamwidth from the simulation is about 65.0 degree and the measurement is about 67.0 degree in H-plane.

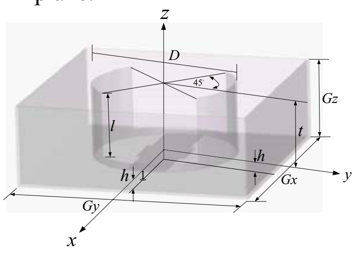

Fig. 8: The configuration of vertically patch antenna excited by probe with cross strip above vertically rectangular reflector

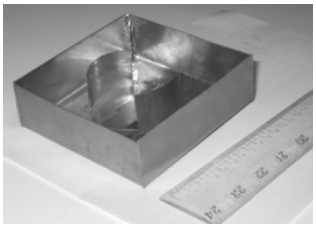

Fig. 9: The prototype of vertically patch antenna excited by probe with cross strip above vertically rectangular reflector. (antenna parameters in table 2).

TABLE 2: PARAMETERS OF VERTICALLY CIRCULAR PATCH WITH VERTICALLY RECTANGULAR REFLECTOR

Parameters	Dimension(mm)
D	*61.00*
t	*31.00*
l	*28.00*
s	*3.69*
w	*16.62*
h	*3.00*
Gx	*100.00*
Gy	*100.00*
Gz	*34.00*

The measured and simulated results of radiation patterns in E-plane at the frequency of 2.4 GHz are shown in Fig. 13. The half power beamwidth from the simulation is about 58.8 degree and the measurement is about 55 degree in E-plane. The maximum gain is about 10.7 dBi from the simulation and 9 dBi from the measurement. The front-to-back ratio in both planes is greater than 20 dB for the simulated and measured results. The parameter *l* can be adjusted for symmetrical pattern in H-plane and E-plane.

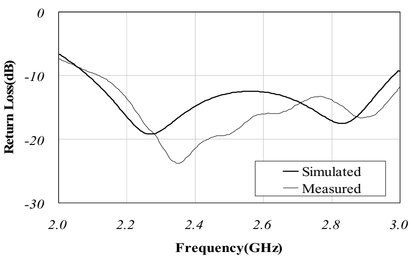

Fig. 10: Simulated and measured return loss of vertically circular patch with vertically rectangular reflector

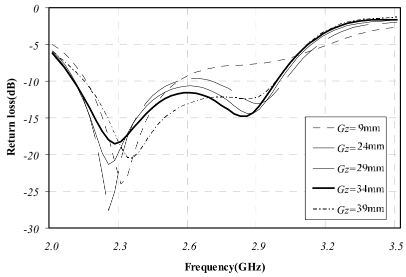

Fig. 11: Simulated return loss of vertically circular patch antenna with varied parameter *Gz* (other parameters are defined in the table.1)

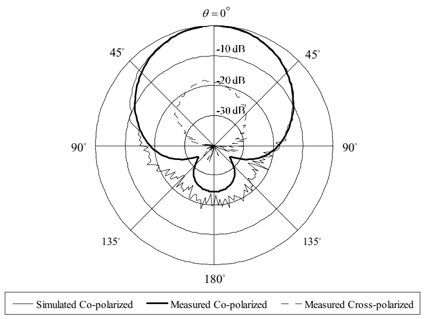

Fig. 12: Simulated and measured results in H-plane of co and cross-polarized radiation patterns

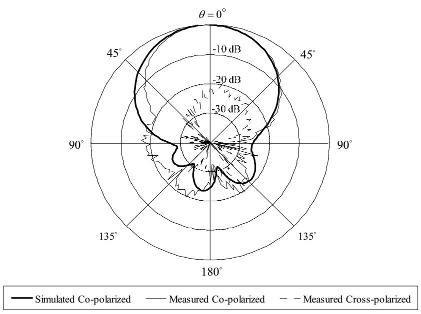

Fig. 13: Simulated and measured results in E-plane of co- and cross-polarized radiation patterns

3. CONCLUSION

A vertically circular patch antenna with a cross strip above vertically rectangular reflector is proposed. From the analysis, it was found that the dimension of diameter *D*, and height *t*, affects the operating frequency. Parameter *l* control beamwidth in E-plane and enhance impedance bandwidth by adjusting parameter *Gz*. It can be adjusted the parameter *s* instead of parameter *t* for matching impedance. The impedance bandwidth from measurement (2:1 VSWR) is 37.62 % (about 2.105-3.000 GHz). The proposed antenna has unidirectional radiation pattern with front-to-back ratio (F/B) of greater than 20 dB in H-plane and E-plane. The maximum gain is about 9 dBi from measurement. The dimension of horizontal reflector is about 100 mm (36% reduction) less than horizontal dimension of a vertically circular patch antenna with flat rectangular reflector. The vertically reflector has size about 34 mm. We can choose parameter *Gz* equal to the total height of the vertically circular patch antenna. The cross-polarization is less than -20 dB in both planes. Good agreement between theory and experiment confirm the usefulness of the proposed antenna. The proposed antenna has simple structure and can be easily constructed with a very low cost. In addition, good antenna gain and boresight radiation patterns have also been obtained. The proposed antenna is suitable for application in modern wireless communication.

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