Low-Profile Aperture-Coupled Circular Dielectric Resonator Antenna for Application in WLAN

Yih-Chien Chen#, Kai-Hao Chen

Department of Electrical Engineering Lunghwa University of Science and Technology, Gueishan Shiang,Taoyuan Country, Taiwan

ycchenncku@yahoo.com.tw

***Abstract*— In this paper, the measurement results of the dielectric resonator antenna with high permittivity have been presented. With this technique, a 5.4% bandwidth (return loss < -10 dB) of center frequency at about 5.2 GHz for application in WLAN has successfully been achieved. The co-polarization radiation is strongest at $\theta \cong 0^{O}$ from the broadside in the E-plane. The cross-polarized patterns are about 10 dB less than the co-polarized patters in the broadside direction. The antenna has a 3 dB beam angle of about 105^{O}. Peak antenna gain is about 6.29 dBi, with gain variations less than 2.0 dBi for frequencies within in the -10 dB S_{11} bandwidth.**

***Keywords*— dielectric resonator antenna, WLAN, return loss, bandwidth.**

1. INTRODUCTION

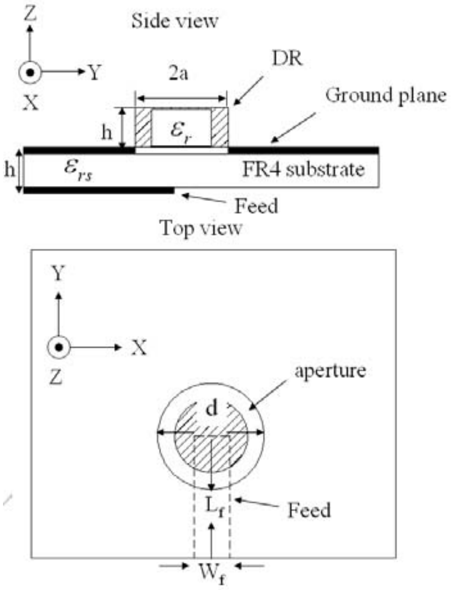
There are many commercial applications, such as mobile radio and wireless communications that use microstrip antennas. Microstrip antennas however have limitations in size, bandwidth, and efficiency. On the other hand, the dielectric resonator (DR) antenna is attractive due to its small-size, high radiation efficient, and ease of excitation.[1-3] Two dielectric properties of materials must be considered for DR antenna used: a high dielectric constant and a high quality factor. The size of the DR antenna decreases with increasing the permittivity of the dielectric resonator. The quality factor is representative of the antenna losses. Typically there are radiation, conduction, dielectric, and surface wave losses. Therefore the total quality factor is influenced by these losses. The DR antenna offers very high radiation efficiency due to its low dielectric loss and it has no metallic loss.

In traditionally, the DR with relatively small permittivity around 10 is chosen for DR antenna to enhance the radiation capability. [4-9] However, low profile DR antenna with relatively low resonant frequency can be achieved by using high permittivity. In our study, aperture-coupled circular DR antenna composed of DR with high permittivity of 57 was designed and built. The resonant frequency of the DR antenna is around 5.2 GHz. The DR antenna can be application in the IEEE 802.11a 5.2 GHz licensed band of WLAN (Wireless LAN). The characteristics of aperture-coupled circular DR antenna, such as return loss, input impedance, radiation pattern, and gain, have been measured and discussed.

2. SIMULATION and MEASUREMENT

One advantage of the DR is ease of excitation. Among the various excitation methods for the DR antenna, the aperture coupling has been widely used as it allows the DR antenna to be integrated with the MMICs.[9-10] The configuration of DR antenna composed of high permittivity DR is as shown in Fig. 1. The rectangular RF4 substrate has dimensions of 50.0 $\times$ 50.0 mm^2 and thickness of 1.6 mm. The DR antenna is fed with microstrip line. Impedance matching could be realized by adjusting the length of the microstrip feed line to DR antenna. Therefore, the bandwidth could be adjusted by modifying the length of the microstrip feed line. Dimensions of the microstrip feed line on FR4 substrate were calculated by close-form formulas given in [11], assuming infinite ground plane and finite dielectric thickness. The microstrip feed line dimensions were confirmed by AWR Microwave Office. The microstrip feed line dimensions were compatible with a subminiature version A (SMA) connector. The diameter of dielectric core of conventional SMA connector was about 4.5 mm. The microstrip feed line has length L_f of 13 mm and width of W_f of 4 mm are stretched in a circle aperture with diameter d of 10.4 mm. The DR is $Ca_{0.97}Zn_{0.03}La_4Ti_5O_{17}$ (CZLT) with 0.5 wt.% CuO additives and sintered at 1450 ^{O}C for 4h. Following is a list of the microwave parameters of the CZLT.

Permittivity, ε_r =57
Loss tangent, tan δ = 0.0004
Diameter of the dielectric resonator =8.8 mm
Thickness of the dielectric resonator =4.2 mm



DR			Feed	
h	a	ε_r	L_f	W_f
4.2	4.4	57	13	4

FR4 50*50mm²		Aperture
h	ε_{rs}	d
1.6	4.4	10.4

Fig. 1 Configuration of DR antenna composed of high permittivity DR

Simulation has been carried out by using a commercial electromagnetic simulator. In simulation, the conducting grounds and the substrates were assumed to be finite in transverse plane. The microstrip feed line was fabricated by using wet etching process. A coaxial connector was soldered to the microstrip feed line to output signal from the DR antenna to the port 1 of network analyzer. Reflection coefficient was measured on a PNA-L network analyzer (N5230A). Radiation pattern measurement was measured in a chamber. A standard double ridged horn antenna was used as a transmitting antenna. The DR antenna fed with microstrip line is mounted on a position which is controlled by a computer.

3. RESULTS

The measurement and simulation return loss of the DR antenna fed with microstrip line is as shown in Figure 2. The measurement and simulation frequency range is from 5.0 GHz to 5.7 GHz. The measurement return loss of the DR antenna is -30 dB at 5.36 GHz. The measurement resonant frequency is very close to the simulation resonant frequency of 5.28 GHz as shown in Fig. 2. As seen from the measurement results, the DR antenna has a -10 dB S_{11} bandwidth of 5.4 %. Caused of DR antenna composed of high permittivity DR was used in our study, the bandwidth is smaller than the typical value of 6 ~ 12% using conventional DR antennas with permittivity around 10.[3-8] However, the achieved bandwidth is enough for many practical applications.

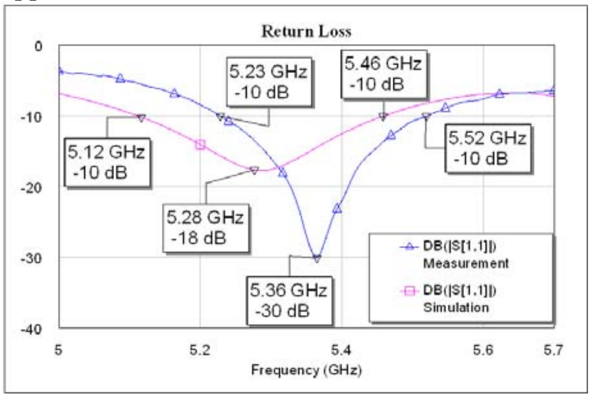


Fig. 2 The measurement and simulation return loss of the DR antenna fed with microstrip line

The corresponding Smith Chart representation of the S_{11} from 5.23 GHz to 5.52 GHz is shown in Fig. 3. To match an antenna, the impedance locus should be shifted as near as possible to the center of the Smith Chart to obtain a low return loss at resonant frequency. As seen from the measurement results, the input impedance values of the DR antenna is 49 – j3.37 ohm at the resonant frequency of 5.36 GHz. A matching point is near the point of 5.2 GHz and the matching point is very close to the center of the Smith Chart.

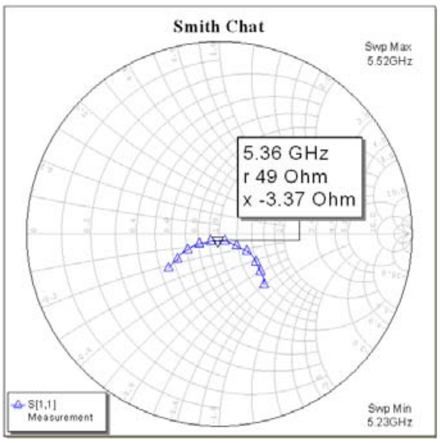


Fig. 3 Input impedance of the DR antenna fed with microstrip line

The measured radiation pattern of the DR antenna in the E-plane at resonant frequency of 5.36 GHz is shown in Fig. 4. The patterns are observed to be stable across the return loss $\leq$ -10 dB bands. As seen from Fig. 4, the co-polarization radiation is strongest at $\theta \cong 0^O$ from the broadside in the E-plane. The DR antenna has a 3 dB beam angle of about 105^O. The cross-polarized patterns are also shown in the same figure for comparison. It is seen from the figure, the cross-polarized patterns are about 10 dB less than the co-polarized patters in the broadside direction.

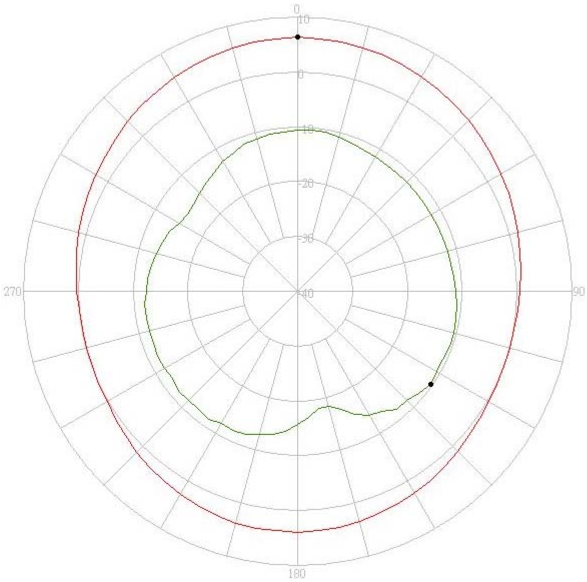


Fig. 4 Radiation pattern of the DR antenna fed with microstrip line in the E-plane at resonant frequency

The measured DR antenna gain in the broadside direction is shown in Fig. 5. As observed from Fig. 5, the peak is 5.36 GHz, close to the resonant frequency as expected. Peak DR antenna gain is about 6.29 dBi at 5.36 GHz. The gain variations are less than 2.0 dBi for frequencies within the -10 dB S_{11} bandwidth.

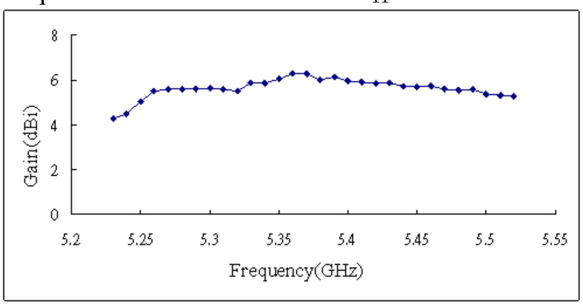


Fig. 5 Measured antenna gain of the DR antenna fed with microstrip line

4. CONCLUSION

Successful design of aperture-coupled circular DR antenna composed with high permittivity for application in WLAN has been presented. Characteristics of the DR antenna have been investigated in this paper. The return loss is -30 dB at 5.36 GHz, which corresponds to a -10 dB S_{11} bandwidth of 5.4 %. The co-polarization radiation is strongest at $\theta \cong 0^O$ from the broadside and a 3 dB beam angle of about 105^O of the DR antenna in the E-plane. Peak DR antenna gain is about 6.29 dBi in the E-plane. The gain variations are less than 2.0 dBi for frequencies within the -10 dB S_{11} bandwidth. The diameter and thickness of the presented DR antenna with high permittivity are 8.8 and 4.2 mm, respectively. A compact size of DR antenna with high permittivity as compared to a conventional DR antenna has been successfully achieved.

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