CIRCULARLY POLARIZED TUNABLE MICROSTRIP PATCH ANTENNA USING AN ADJUSTABLE AIR GAP

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1. Introduction

Microstrip antennas [1] have many advantages such as low profile, light weight and easy integrability into arrays. They have been found applications in various areas such as mobile communications and satellite communications. A service of radio communication systems becomes increasingly prominent in a microwave and millimeter wave band region. In addition, sophisticated antennas operating at different frequencies and polarization with peculiar radiation patterns are required. Recently, antennas using a MEMS (Microelectromechanical-Systems) technology have been studied intensively, for they are excellent in loss, cost and power consumption compared with those made of semiconductor [2],[3],[4].

In order to improve the frequency agility and bandwidth of the microstrip patch antennas techniques using an impedance matching network and parasitic elements have been proposed. We have reported so far the method using an adjustable air gap, which was considered to be difficult for the coaxial probe feed. We utilized a mechatoronics technology to solve the difficulty in the connection of the feed. A conducting patch on a substrate separated by an air gap can be moved while keeping in touch with the coaxial line feed. Thus the resonant frequency of the microstrip patch antenna with a linear polarization could be changed continuously by adjusting the air gap [5].

In this report we propose a circularly polarized tunable microstrip patch antenna using the same technique as the previous one [5]. We have demonstrated its fundamental operation at the X band. The adjustable operating frequency obtained was 18.6% when using an alumina substrate with thickness 0.6mm.

2. Operation and structure of an antenna

Figure 1 shows a structure of the proposed antenna. The square patch antenna with a side length *a* was printed on a substrate of thickness *t* and relative permittivity ε_{r1}. The opposite two corners of the patch were partially cut. The area of the truncated corners was $\Delta s/2$. The feed point was placed at the point F in Fig. 1 and the distance between the feed point and the center of the patch was *x*. The antenna height was *h*. The antenna was designed using the equivalent circuit of the microstrip patch antenna [6]. The antenna's operating frequency f_0 was given by the following equation,

$$f_0 = f_r(1 + \Delta s / S), \tag{1}$$

where f_r is the antenna's resonant frequency of the square patch antenna and *S* is the area of the square patch. As the air gap width increases, the resonant frequency increases, but the dependence of the frequency on the width is not a linear one. We drilled a hole (0.3mm in diameter) in the center conductor of a coaxial connecter (0.6mm in diameter) and attached it to the ground plane. The copper wire fixed to the feeding point of the rectangle patch antenna, the diameter of which was slightly smaller (0.25mm in diameter) than that of the hole in the center conductor, was inserted into the hole. Although the air gap existed between the copper wire and the central conductor hole, it was connected through a capacitor in a high frequency region. We used the two kinds of dielectric substrates. One was the teflon substrate including a glass with ε_{r1}=2.2. The other was an alumina substrate with ε_{r1}=9.7. The design parameters are presented in Table 1. The size of the ground plane was 200 by 200mm and the aluminum thickness was 2mm. Although a continuous variation was desirable, we varied the

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antenna height using different thick dielectric spacers to confirm its basic operation. The insertion of the dielectric spacer was carried out manually.

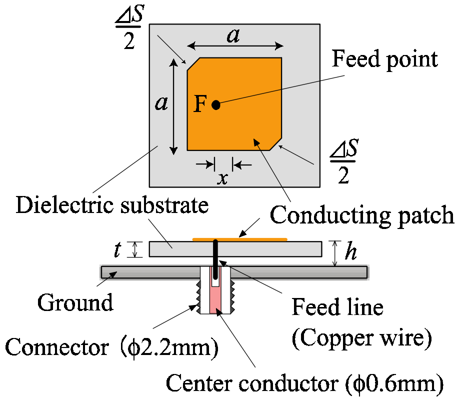


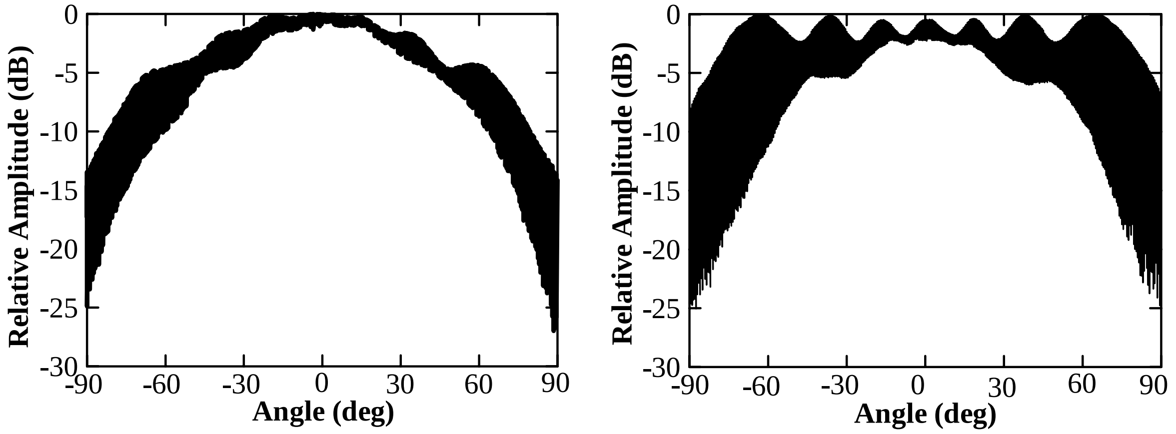
Fig.1. Structure of the proposed antenna.

Table 1. The parameters of the antennas.

ε_{r1}	a (mm)	t (mm)	$\varDelta s$ (mm^2)	x (mm)
2.2	10	0.4	1.21	2.2
		0.6	1.82	2.3
		0.8	2.25	2.4
9.7	4.5	0.6	0.13	0.5

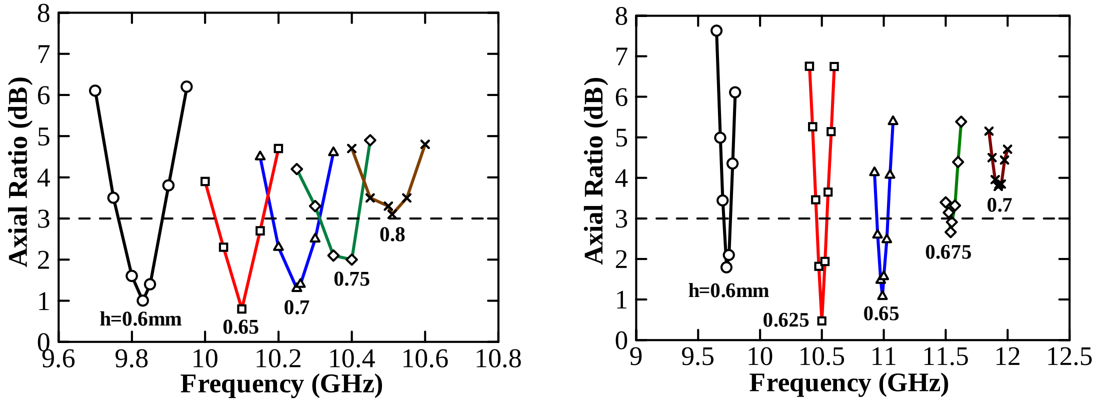
3. Experiment results

Figure 2 shows the radiation pattern of the two kinds of the antennas for the teflon substrate (ε_{r1}= 2.2, t=0.6mm) and the alumina substrate (ε_{r1}=9.7, t=0.6mm). The axial ratios at the boresight for Fig.2 (a) and (b) were 0.8dB and 1.8dB, respectively, and we confirmed that the tested antennas operated as the circularly polarized antenna. The measured frequency characteristics of the axial ratios for the tested antennas are shown in Fig. 3. The operating frequency increased as increasing the antenna height. However, the axial ratios exceeded 3dB in any frequency for the large antenna height.



(a) ε_{r1}=2.2, t=0.6mm, h=0.65mm, at 10.1GHz (b) ε_{r1}=9.7, t=0.6mm, h=0.6mm, at 9.73GHz

Fig. 2 Measured radiation pattern.



(a) ε_{r1}=2.2, t=0.6mm (b) ε_{r1}=9.7, t=0.6mm

Fig. 3 Measured frequency characteristics of the axial ratios.

Figure 4 shows the absolute gain of the antennas as a function of the normalized height h/λ. The maximum and minimum gains were 8.0dBi and 5.3dBi when the teflon substrate was used, and they were 4.7dBi and 3.2dBi when the alumina substrate was used. Because the permittivity of the alumina substrate was high and the area of the patch was small, the gain became small. Furthermore, the gain increases as an increase in h/λ.

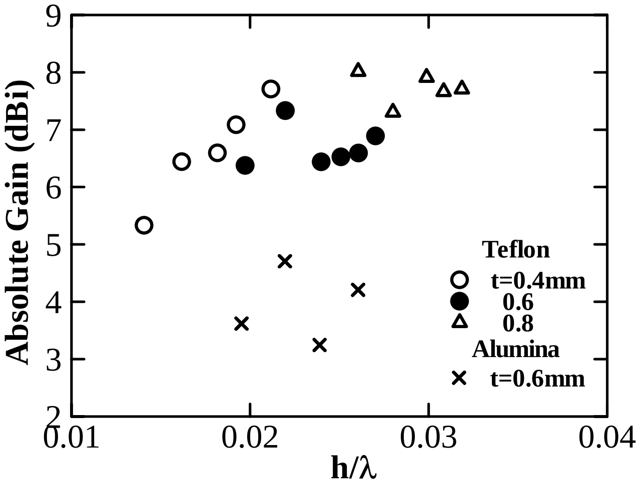
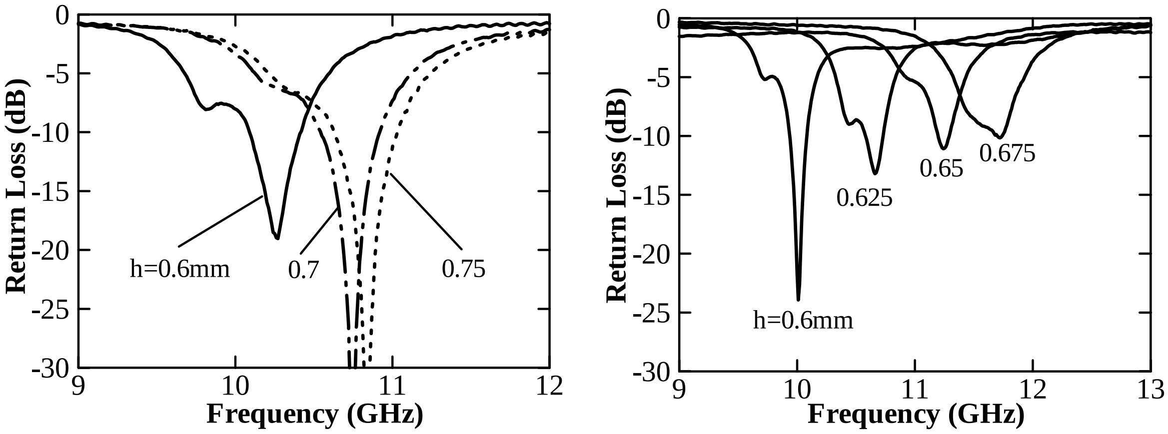


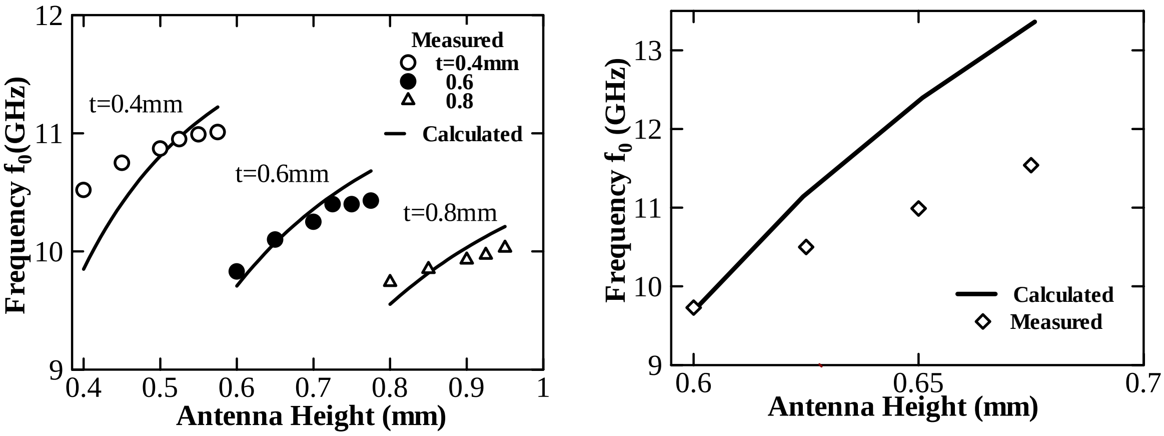
Fig. 4 Measured absolute gain.

Figure 5 shows the measured frequency characteristics of the return losses as a parameter of the antenna height. The values of the return losses were larger than -10dB in some frequency range corresponding to the matching between the antenna and the feed. Figure 6 shows the relation between the antenna height and the operating frequency for the teflon and the alumina substrates. The plotted points are the measured results and the solid lines are the results calculated using eq.(1). Table 2 summarizes the measured results of the attainable operating frequencies. The operating frequency was changed from 9.83GHz to 10.43 GHz (6.1%) when the teflon substrate with the thickness of 0.6mm was used. When the alumina substrate of high permittivity was used, the large frequency agility was obtained. The measured results were much smaller than the calculated results in a high frequency region. The frequency agility increases as the thickness of the substrate decreases. However, the frequency agility for *t*=0.4mm was smaller than *t*=0.6mm. An excessive air layer appeared due to the distortion of the substrate may be attributed to this decline.



(a) ε_{r1}=2.2, *t*=0.6mm (b) ε_{r1}=9.7, *t*=0.6mm

Fig. 5 Measured frequency characteristics of the return loss for the tested antenna.



(a) ε_{r1}=2.2, *t*=0.6mm (b) ε_{r1}=9.7, *t*=0.6mm

Fig. 6 Operating frequency vs. antenna height.

Table 2.
Measured results operating frequency range.

	t=0.4mm	*t*=0.6mm	*t*=0.8mm
teflon substrate ε_{r1}=2.2	10.52～11.01GHz 4.7%	9.83～10.43GHz 6.1%	9.74～10.03GHz 3.0%
alumina substrate ε_{r1}=9.7		9.73～11.54GHz 18.6%	

4. Conclusion

This paper presents the circularly polarized microstrip patch antenna with the structure of variable antenna height resulting in an adjustable air gap. We have demonstrated the operation of the proposed antenna. The operating frequency agility was achieved by the amount of 6.1% when the teflon substrate was used and 18.6% when the alumina substrate was used. In the future, we are planning to control an antenna height by using a mechatronics technology such as an actuator.

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