A Circularly Polarized Small-Size Microstrip Antenna with a Cross Slot

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***Abstract*— A new, circularly polarized small-size microstrip antenna using a proximity coupled feed method is proposed. A simple configuration based on a cross slot with unequal slot lengths on a circular patch is adopted to realize a small-size element antenna. The proposed antenna has no 90° hybrid coupler for circular polarization. The measured results verify the circular polarization, and the antenna radius was reduced by about 36% by using the slot lengths which are nearly equal to the diameter of the circular patch antenna. Good impedance and axial ratio characteristics have been obtained.**

I. Introduction

A circularly polarized antenna with a low profile, small size, and light weight is required in mobile satellite communications. Many types of microstrip antennas have been proposed and ivnestigated [1].

Circularly polarized microstrip antennas are classified as single-fed type or dual-fed type, depending on the number of feed points necessary to generate the circularly polarized waves. Th single-fed type has the advantage of not requiring an external polarizer such as a 90° hybrid coupler. The relationship between the optimum probe location and the frequency of the obtained circularly polarized wave has been clarified, and good experimental results have been reported [2]. Recently, aperture-coupled feed methods have been attracting much attention because their geometries are suitable for monolithic integration with microwave or milliwave devices. The feed position for a circularly polarized operation and the input impedance of several microstrip antennas fed by the slot-coupled method have been investigated [3]. However, with this type of microstrip antenna it is difficult to excite good circularly polarized waves.

Another suitable feed method is an electromagnetically coupled method which is also known as the proximity-coupled method. This type of antenna has several advantages over a directly fed patch antenna. By using a proximity-coupled method, an optimal feed point of a microstrip antenna has been proposed for linear polarization [4]. Moreover, a circularly polarized rectangular microstrip antenna, fed by proximity coupled method using an offset microstrip line, was proposed by the author [5].

On the other hand, the element of a phased-array antenna must be arranged at almost about half wavelength to obtain wide-angle beam scanning. The resonant frequency of a single-fed circularly polarized microstrip antenna with a thin diagonal center slot on the patch radiator was almost the same as that of a patch antenna with a 90° hybrid [6]. Therefore, it is difficult to arrange an antenna element at about half wavelength in the case of the above-patch antenna.

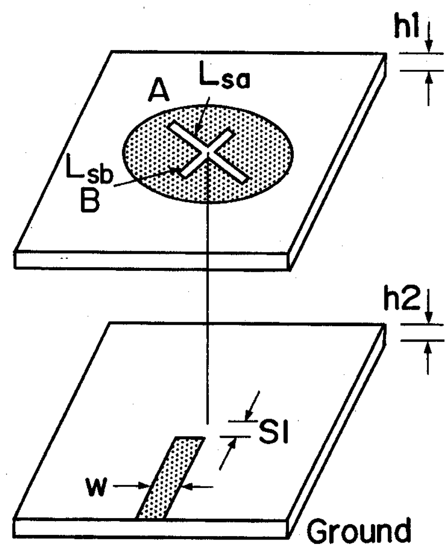

Fig. 1. Configuration of the proposed patch antenna.

The purpose of this paper is to propose a small-size circular patch antenna using a cross slot with unequal slot lengths. The proposed antenna can achieve circular poarization without the need for a 90° hybrid coupler. The measured results are presented to demonstrate the usefulness of the proposed antenna configuration. Good impedance and axial ratio characteristics are realized.

II. Antenna Configuration

The proposed antenna configuration is shown in Fig. 1. The circular patch with a cross slot and the microstrip line are formed by the substrates with a dielectric constant ϵr and thickness $h1$ and $h2$, respectively. The radius of the circular patch is r. Slot A with length Lsa and slot B with length Lsb, cross orthogonally at the center of each slot, which is the center of the circular patch. The characteristic impedance of the microstrip line is 50 Ω. Sl is the distance between the end of the microstrip line and the center of the patch antenna.

III. Experimental Results

The resonant frequency of the linearly polarized circular patch with a slot can be controlled by changing the slot

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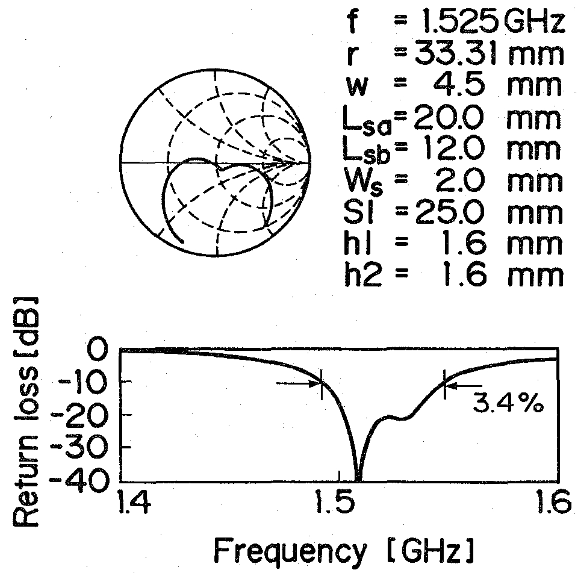

Fig. 2. Measured input impedance and return loss.

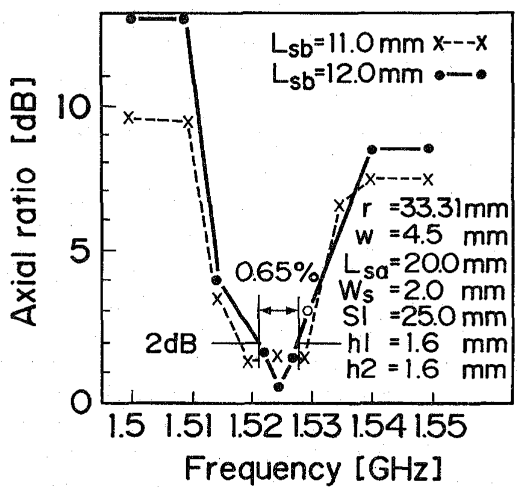

Fig. 3. Measured axial ratio as a parameter of the slot length Lsb.

length [7]. The resonant frequency decreases monotonically with increasing slot length. Therefore, resonant frequencies of orthogonal modes, as a result of the perturbation caused by a cross slot, as shown in Fig. 1, will decrease with increasing slot lengths Lsa and Lsb. Thus, the resonant frequency of the proposed patch antenna can be reduced. Consequently, the proposed antenna can be made small size and compact compared with a linearly polarized patch antenna with a single slot.

The proposed antenna was designed and tested to verify circularly polarizing operation. The experimental models were made of copper-clad substrate with $\epsilon r = 2.6$ and the thickness $hl = h2 = 1.6$ mm. The width of the microstrip line W was 4.5 mm. The radius of the circular patch without a cross slot was $r = 33.31$ mm, and the resonant frequency was 1.55 GHz. The patch antenna was designed by using the simple cavity method [8].

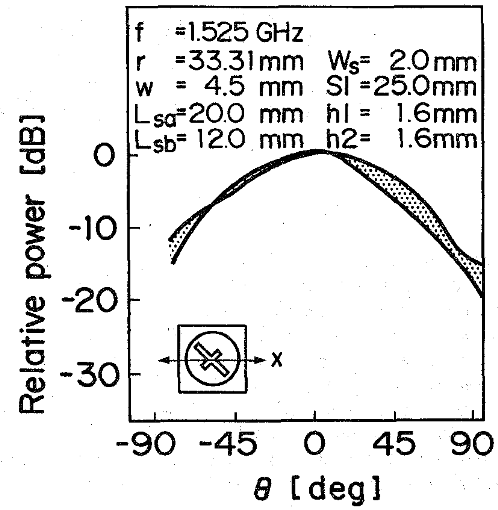

Fig. 4. Measured radiation pattern ($x - z$ plane, $f = 1.525$ GHz).

Fig. 2 shows the measured impedance and return loss for the $Lsa = 20.0$ mm, $Lsb = 12.0$ mm, and $Sl = 25.0$ mm. Reference plane is the edge of the circular patch. Good impedance matching was obtained. The bandwidth VSWR less than 2 was 3.4%. The resonant frequency of the circular patch antenna without a cross slot was 1.55 GHz. Therefore, the antenna radius can be reduced by about 2% using the cross-slot configuration compared with that of the circular patch without a slot.

Fig. 3 shows the measured axial ratios as a parameter of the slot length Lsb. A 0.5-dB boresight axial ratio was obtained at 1.525 GHz when $Lsa = 20.0$ mm and $Lsb = 12.0$ mm. The 2-dB bandwidth of axial ratio was 0.65%. This bandwidth was almost the same as that of the conventional patch antenna. The measured gain was 6.0 dBi at the boresight.

Fig. 4 shows the radiation pattern in the $x-z$ plane at 1.525 GHz. An axial ratio of about 3.0 dB was obtained in the $\pm 60°$ range.

To verify the possibility of achieving a reduction of the antenna size by using this proposed method, an antenna with $Lsa = 61.0$ mm and $Lsb = 60.5$ mm, nearly equal to the diameter of the circular patch antenna, was tested. Fig. 5 shows the radiation pattern in the $x - z$ plane at 0.98 GHz. A 0.5-dB boresight axial ratio was obtained at 0.98 GHz. An axial ratio of about 3.0 dB was obtained in the $\pm 45°$ range. Thus, the radius of the circular patch with a cross slot was reduced by about 36% compared with the radius of a circular patch without a cross slot. The gian was about 7.5 dB lower than that the theretical value of a probe-fed patch antenna without a cross slot.

IV. Conclusion

This paper describes the results of measurements of a new single-fed circularly poalrized microstrip antenna. A small-size element antenna for circular polarization was realized by using a circular patch antenna with a cross slot having different arm lengths. The antenna radius was reduced by about 36% by

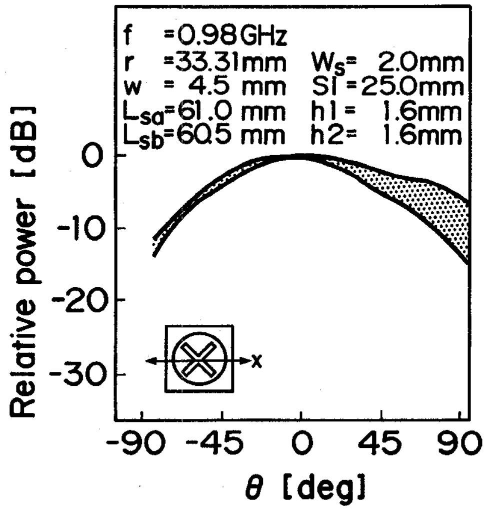

Fig. 5. Measured radiation pattern ($x - z$ plane, $f = 0.98$ GHz).

using slot lengths which are nearly equal to the diameter of the circular patch antenna.

The proposed antenna is suitable for application in the field of mobile satellite communications as a phased-array antenna using a multilayered feed network integrated with microwave devices.

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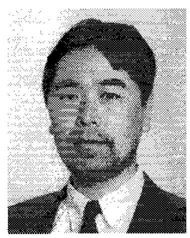

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