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A Circularly Polarized Small-Size Microstrip Antenna using a Cross Slot with Enhanced Bandwidth & Gain

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Abstract*: In the recent years the development in communication systems requires the development of low cost, minimum weight, low profile antennas that are capable of maintaining high performance over a wide spectrum of frequencies. This technological trend has focused much effort on the design of a Microstrip patch antenna. 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 measured results verify the circular polarization, and the antenna radius was reduced by about 22% 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 investigated [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. The single-fed type has the advantage of not requiring an external polarizer such as a 90^0hybrid 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.

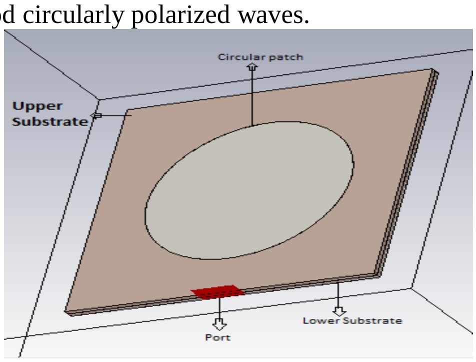


Fig.1.Structure Without Slot

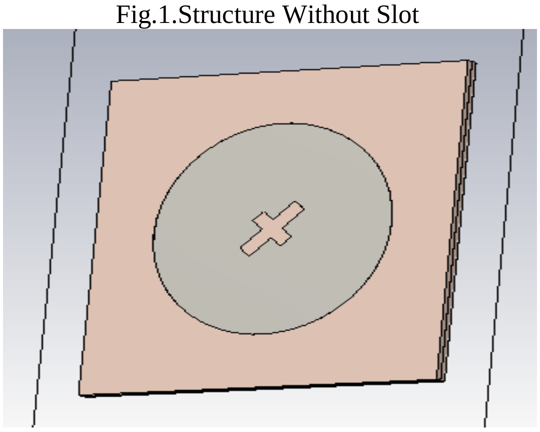


Fig.2Structure With Slot

II. Proposed Configuration

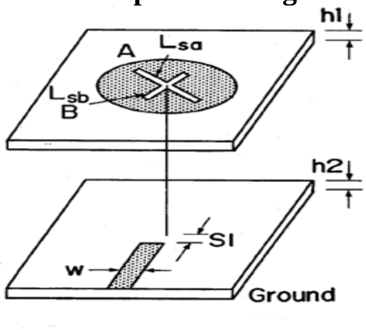


Fig. 3 Configuration of the Proposed Patch Antenna

Another suitable feed method is anelectromagneticallycoupled method which is also known as the proximity-coupled method. This type of antenna has several advantages overa directly fed patch antenna. By using a proximity-coupledmethod, an optimal feed point of amicrostrip antenna has beenproposed for linear polarization [4]. Moreover, a circularly polarized rectangularmicrostrip 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 a patch antenna with a 90^0 hybrid [6].Therefore, it is difficult to arrange an antenna element at about half wavelength in the case of the above-patch antenna. The purpose of this paper is to propose a small-size circular patch antenna using across slot with unequal slot lengths. The proposed antenna can achieve circular polarization without the need for a 90^0hybrid coupler. The measuredresultsare presented to demonstrate the usefulness of the proposed antennaconfiguration. Good impedance and axial ratio characteristics are realized.

III. Antenna Configuration

The proposed antenna configuration is shown in Fig. 1. Thecircular patch with a cross slot and the microstrip line are formed by the substrates with a dielectric constant **Ɛr**and thickness hl 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**. SIis the distance between the end of the microstrip line and the center of the patch antenna.

IV. Experimental Results

The resonant frequency of the linearly polarized circular patch with a slot can be controlled by changing the slot 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 are madeof **FR-4 Epoxy** substrate with ***Ɛr*= 4.3** and the thickness ***h 1*= *h2* = 1.6 mm**.

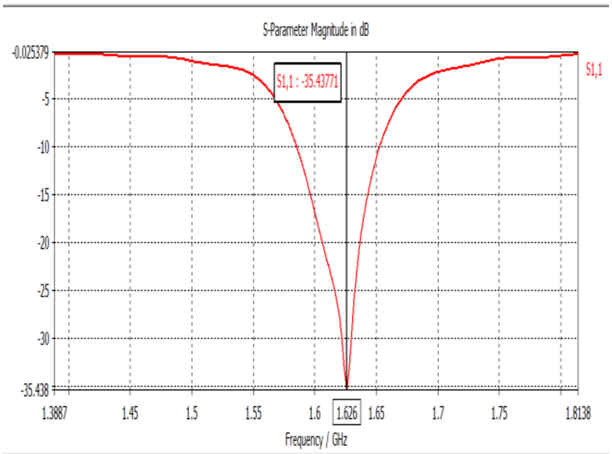


Fig.4 s-parameter

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 **1.646 GHz**. The patch antenna was designed by using the simple cavity method[8] Fig. 2 shows the measured impedance and return loss for the Lsa= 20.0 mm, Lsb= 12.0 mm, and SI = **45.0** mm. Reference plane is the edge of the circular patch. Good impedance matching was obtained. The **bandwidth** VSWR less than 2 was**4.08%.** The resonant frequency of the circular patch antenna without a cross slot was 1.626 GHz. Therefore, the antenna radius can be reduced by about 2% using the crossslot configuration compared with that of the circular patchwithout a slot.Fig.6 shows the measured axial ratios as a parameter of the slot length Lsb. **A** 0.98-dB boresight axial ratio was obtained at 1.626 GHz when Lsa= 20.0 mm and Lsb= 12.0 mm.Fig.5 shows the measured gain was 7.4dBi at the boresight.To verify the possibility of achieving a reduction of the antenna size by using this proposed method, an antenna with Lsa= 50.0 mm and Lsb= 36 mm, nearly equal to the diameter of the circular patch antenna, was tested. Fig.3 shows the radiation pattem in the 1.071 GHz. An axial ratio of about 3.0 dB was obtained in the &45^{0} range. Thus,the radius of the circular patch with a cross slot was reduced by about 22% compared with the radius of a circular patch without a cross slot. The gian was about 7.5 dB,which is greater than that the theoretical value of a probe-fed patch antenna without a cross slot.

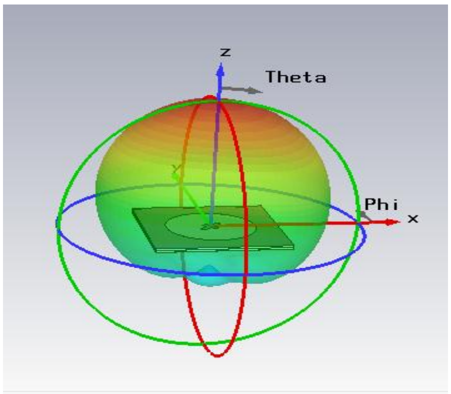


Fig.5Radiation Pattern

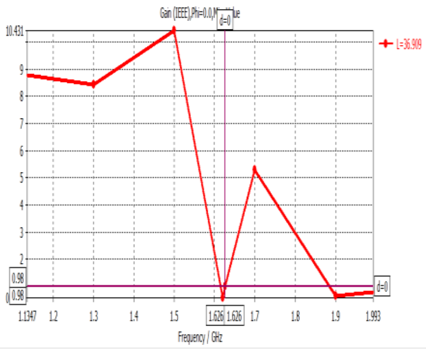


Fig.6Axail Ratio

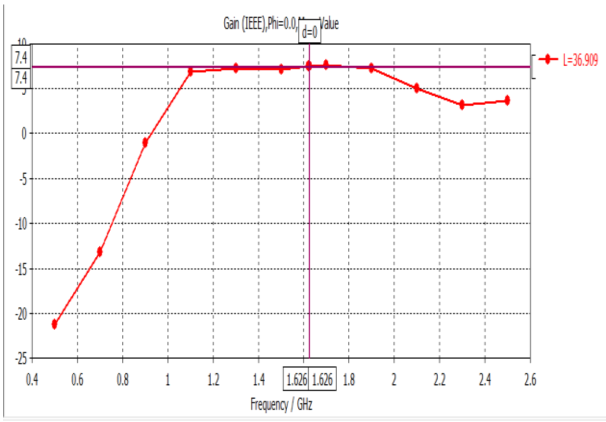


Fig.7Gain

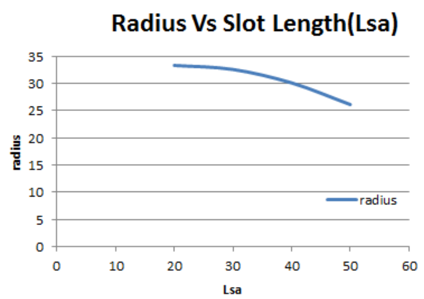
V. Table

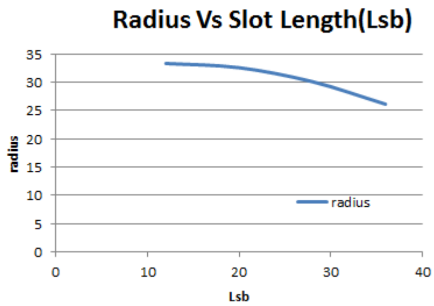
COMPARISION TABLE OF VARIOUS SIMULATEDPARAMETERS.

Lsa(mm)	20	30	40	50
Lsb(mm)	12	20	28	36
f(GHz)	1.626	1.626	1.626	1.626
r(mm)	33.31	32.56	30.09	26.11
S11(dB)	-35.43	-28.8	-35	-30
Gain(dB)	7.6	7.3	7.39	7.5
AR(dB)	0.98	2.36	2.78	0.98
fa(GHz)	1.626	1.54	1.432	1.071
%BW	4.40	3.51	3.98	4.08

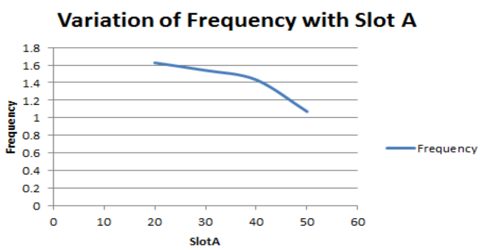
Where,
Lsa is length of slot A
Lsb is length of slot B
f is resonance frequency
r is radius of circular patch
S11 is return loss
AR is axial ratio
fa is frequency after varying the slot length.

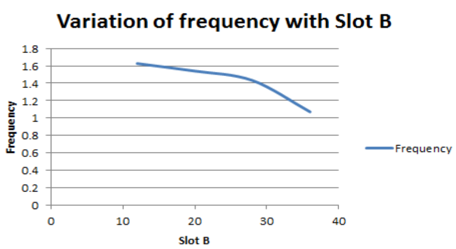
REDUCTION OF PATCH RADIUS WITH INCREASE INSLOT LENGTH





REDUCTION OF RESONANCE FREQUENCY WITH INCREASE IN SLOT LENGTH





s-parameter magnitude in dB

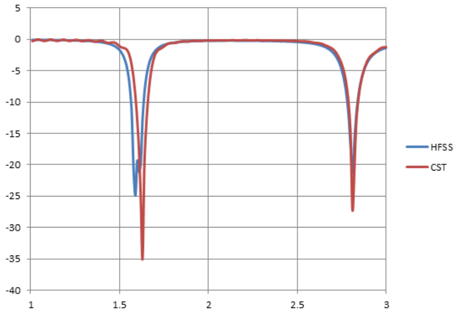


Fig.8

Fig.8 shows the simulated CST and simulated HFSS matching frequency band of the proposed antenna for dB reflection coefficient from 1.56 GHz to 1.63 GHz with a bandwidth of **4.61%** in simulation HFSS and the frequency band of 1.46 GHz to 1.52 GHz with a bandwidth of **4.08 %** in simulation CST respectively. We can observe the good agreement between the HFSS and CST simulated radiation patterns.

VI. Conclusion

This paper describes the results of measurements of a new single-fed circularly poalrizedmicrostrip 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 22% by of using slot lengths which are nearly equal to the diameter ofthe 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 microwavedevices.

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