Design and Simulation of a Single Feed Dual-Band Symmetrical/Asymmetrical U-slot Patch Antenna

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Abstract –**This paper presents the design of dual band U-slot patch antenna with a single feed. The antenna is also used for circular polarization application with a single resonant frequency. The effects of different substrate thickness will be studied. It is found that the axial ratio bandwidth could be enhanced considerably when a thicker substrate is used and when the unequal arms of the U-slot is used; a parametric study has been carried out to investigate the effects caused by equal arm lengths of U-slot with symmetrical structure and by unequal arm lengths of U-slot with asymmetrical structure.**

Keywords – **dual-band, U-slot patch antenna**

I. INTRODUCTION

In the past two and a half decades, many techniques have been developed to broaden the impedance bandwidth of probe feed microstrip patch antennas. In particular, the U-slot patch [1] enables a single patch single layer microstrip antenna to attain over 30% impedance bandwidth. The U-slot introduces a capacitance which compensates for the inductance of the feeding probe. The use of thick and low permittivity substrates is the main reason for achieving wide impedance bandwidth. Although many papers have been devoted to the U-slot patch in the last decade [1-9], the studies were concerned with linear polarization. There has been no systematic study of the application of these techniques to single feed circularly polarized (CP) patch antennas. The objective of this paper is to present such a study for the case of a single feed notch corner patch antenna on two U-slot patch antenna structure.

Circular polarization is one of the common polarization schemes used incurrent wireless communication systems, for example: radar and satellite systems, since it can provide better mobility and weather penetration than linear polarization. The circularly polarized antenna could have many different types and structures where the basic operation principle is to radiate two orthogonal field components with equal amplitude but in phase quadrature. The axial ratio bandwidth of a rectangular microstrip patch antenna could be increased, by decreasing the Q of the antenna or by using thicker substrate. Finite ground plane structure has been considered in this simulation. Simulation results are obtained by commercial software, Zeland IE3D version 11.5.

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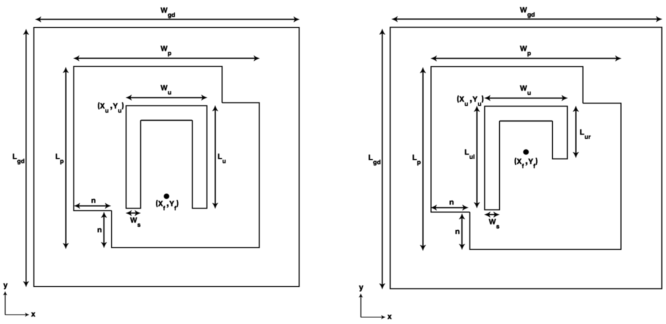


(a) U-slot (symmetrical) (b) U-slot (asymmetrical)

Figure 1. Geometry of a single probe-fed notched microstrip antenna

II. ANTENNA GEOMETRY

The geometry of the conventional probe fed notched corner microstrip antenna with U-slot (Symmetrical) is shown in Figure 1(a). A pair of opposite corner of a square patch is notched is excite two orthogonal modes. The square shaped structure of the patch limits the freedom in tuning the impedance matching of this antenna. The input impedance could be tuned by changing the position of the feeding probe (f), while the AR bandwidth could be tuned by changing the length of the notched corner (n). The geometry of the conventional probe fed notched corner microstrip antenna with U-slot (Asymmetrical) is shown in Figure 1 (b). One of the arms of U-slot was shorten to achieve the desired circular polarization. By adjusting the length of an arm of U-slot (either L_{ul} or L_{ur}) to the optimum position in *y*-direction, good circularly polarized radiation can be achieved in Fig 1 (b), the left arm of U-slot (L_{ul}) is larger than the right arm of U-slot $L_{ur.}$ i.e ($L_{ul} > L_{ur}$), the antenna is left hand circularly polarized. Right hand circularly polarization can be obtained if (L_{ul}) is shorter than (L_{ur}). The entire antennas presented in this paper have patch dimensions of 30mm (*W*) X 30mm (*L*). Air substrate (ε_r = 1) and infinitely large ground plane are used in the simulation while for the fabricated antenna prototypes, foam ($\varepsilon_r \approx 1$) is used, and the dimensions of the ground plane are 100mm X 100mm. For different substrate thickness (H), the position of the probe (*f*) and the corner notch length (n) are tuned to obtain wide *AR* bandwidth, while maintaining the impedance matching bandwidth to overlap with the *AR* bandwidth.

The dimensions and the the position of the U-slot are tuned to broaden the impedance matching bandwidth of the antenna in thick substrate case. The dimensions of the antennas are tabulated in Table 1.

TABLE 1
DIMENSION OF A SINGLE FED NOTCHED CORNER MICROSTRIP ANTENNA (UNIT: mm)

Case	Substrate Thickness (*H*)	Configuration	n	(x_f,y_f)	(x_u,y_u)
1	6mm	U-slot (symmetrical), probe	4	(15,12)	(9,22)
2	7mm	U-slot (symmetrical), probe	5	(15,14)	(9,22)
3	8mm	U-slot (symmetrical), probe	6	(15,13)	(9,22)
4	6mm	U-slot (asymmetrical, probe	4	(15,12)	(9,22)
5	7mm	U-slot (asymmetrical, probe	5	(14,12)	(9,22)

W_S	W_U	L_U	L_{UL}	L_{UR}
2	14	16	-	-
2	14	16	-	-
2	14	16	-	-
2	14	-	16	10
2	14	-	16	10

It can be seen from Table 1 that the corner notch length (n) is required to be increased with increase the substrate thickness (*h*).

III. RESULTS AND DISCUSSIONS

The performance of the antennas is tabulated in Table 2. Simulation results are obtained by commercial software, Zeland IE3D version 11.5.

In cases 1 to 3 [Figures 2-4], a symmetrical structure of the U-slot is used to broaden the impedance matching bandwidth and to tune the impedance matching frequency band to overlap the AR frequency band. Moreover, in cases 1 to 3 , the RL bandwidth could be tuned to overlap the *AR* bandwidth and there is dual frequency band occurred. The CP is generated by a pair of opposite notched corners of a square patch with symmetrical structure of the U-slot and the dual band frequency occurred.

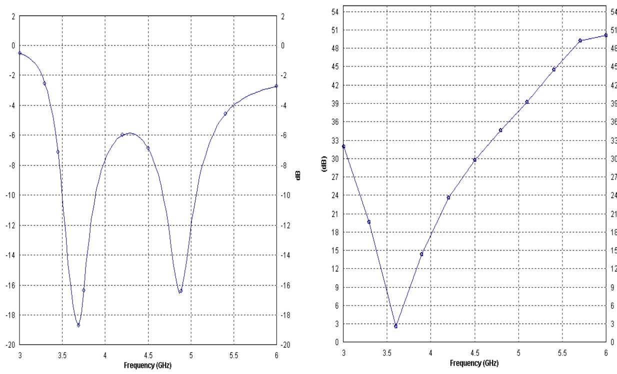
In [4], it was demonstrated that *RL* bandwidth is in the range 20-30% when the substrate thickness of a rectangular U-slot microstrip antenna is about 0.08 λ_o. Since rectangular patch , instead of square patch is used in [4], it is predicated that the U-slot may function better on rectangular patch than square patch.

In [13], a single feed “asymmetric U-slot” microstrip antenna is presented. CP is generated by the unequal arms of the U-slot and no dual band frequency occurred but in our design the dual band frequency is occurred

In case of 4 and 5 (see Figures 5, 6), an asymmetrical structure of the U-slot to improve impedance matching bandwidth and axial-ratio bandwidth. Moreover, in case 5, the *AR* bandwidth enhanced to (4.15%) and there is dual frequency band occurred. The CP is generated by the unequal arms of the U-slot (Asymmetrical structure of the U-slot) and the dual band frequency occurred. The RL and AR of case 4 are shown in Figure 5. Also, the RL and AR of case 5 are shown in Figure 6 .

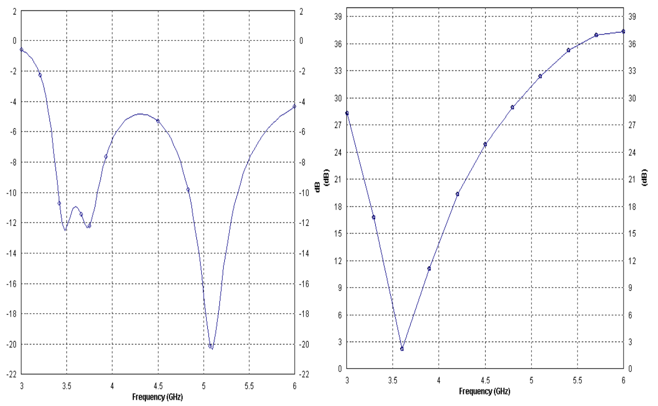
TABLE 2
PERFORMANCE OF A SINGLE PROBE-FED NOTCHED CORNER MICROSTRIP ANTENNA

Case	Substrate Thickness (*H*)	Configuration	Simulation (GHz) (RLBW)	Simulation (GHz) (ARBW)
1	6mm	U-slot (symmetrical), probe	3.504-3.882, f_0=3.69 (10.24%) 4.68-5.052, f0=3.86 (9.64%)	3.594-3.606,f0=3.6 (0.33%)
2	7mm	U-slot (symmetrical), probe	3.408-3.834 f_0=3.48 (12.24%) 4.836-5.37 f_0=5.1 (10.47%)	3.624-3.588 F_0=3.6 (1%)
3	8mm	U-slot (symmetrical), probe	3.744-3.942 f_0=3.84 (5.156%) 4.674-4.998 f_0=4.84 (6.69)	3.594-3.618 F_0=3.6 (0.66%)
4	6mm	U-slot (asymmetr.), probe	6.444-3.666 f_0=3.54 (6.27%) 5.274-5.532 f_0=5.4 (4.77%)	3.876-3.93 F0=3.9 (1.38%)
5	7mm	U-slot (asymmetr.), probe	3.372-3.534 f_0=3.45 (4.69%) 5.22-5.394 f_0=5.31 (3.27%)	3.834-3.996 f_0=3.9 (4.15%)



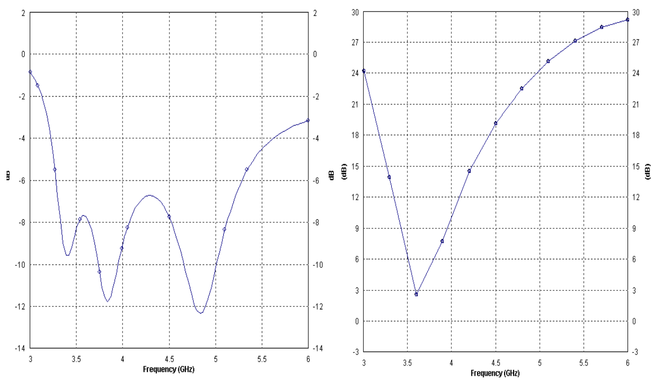
Return loss against frequency Axial ratio against frequency

Figure 2. Return loss and Axial ratio for case 1



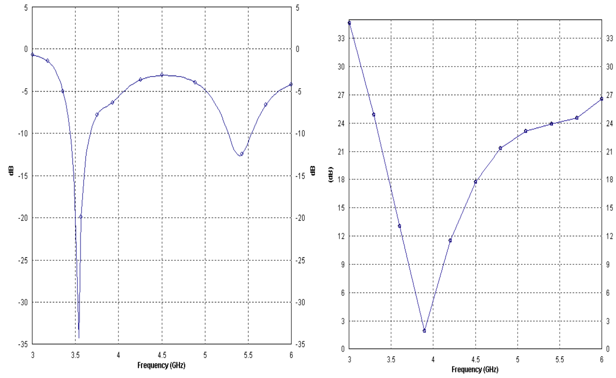
Return loss against frequency Axial ratio against frequency

Figure 3. Return loss and Axial ratio for case 2



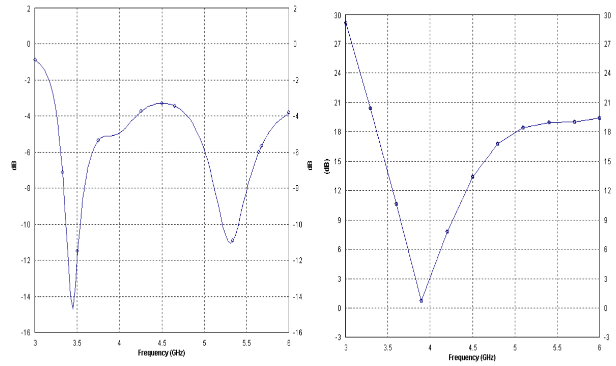
Axial ratio against frequency Axial ratio against frequency

Figure 4. Return loss and Axial ratio for case 3



Axial ratio against frequency Axial ratio against frequency

Figure 5. Return loss and Axial ratio for case 4



Axial ratio against frequency Axial ratio against frequency

Figure 6. Return loss and Axial ratio for case 5

IV. CONCLUSION

This paper presents study and simulation of a compact U-slot patch antenna (symmetrical and asymmetrical) which gives dual band operation. Also, circularly polarized of this antenna have been obtained. The U-slot can not only be used for increasing the impedance bandwidth, but also used for obtaining circular polarized operation. The symmetrical structure of the U-slot provides two different current paths for two orthogonal modes for circular polarization. The simulated impedance bandwidth ($|S11| <-10$dB) and the 3dB axial ratio bandwidth of the antenna are about (10.39%, 2.67%) and 1.83% respectively, which indicated in case 2. Asymmetrical structure of the U-slot provides also two orthogonal modes which causes the circular polarization. The simulated impedance bandwidth of this antenna are about (3.27%, 4.69%) and 4.41% respectively which indicated in case 5. Thus, using asymmetrical structure of the U-slot improved impedance bandwidth and axial ratio bandwidth of antenna are obtained.

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