RESONANCE BEHAVIOR OF SINGLE U–SLOT AND DUAL U–SLOT ANTENNA

R. Bhalla* and L. Shafai
Department of Electrical and Computer Engineering
University of Manitoba, Winnipeg, Manitoba, Canada, R3T 5V6
Emails: umbhalla@ee.umanitoba.ca and shafai@ee.umanitoba.ca

1. Introduction

The broadband characteristic of a microstrip patch antenna with a U–shaped slot has been confirmed by many published results [1–2], in which two different but close resonant frequencies in a single patch are combined to give a wideband operation. On the other hand, if the excited resonant frequencies are far apart, a dual–frequency operation can be achieved with the U slot antenna [3].

In the present work, the resonance behavior of a single U slot microstrip patch antenna as shown in Figure 1 is studied. Two approximate equations for the operating frequencies of a single U slot microstrip patch antenna are derived by analyzing the surface current distribution on the microstrip patch. The two proposed equations for the operating frequencies of a single U slot antenna are accurate within about 5%. In this paper, the design simulation results of a microstrip patch antenna with two asymmetric U–shaped slots for dual–frequency operation are also presented. The two operating frequencies of the proposed antenna shown in Figure 5 are found to have the same polarization and similar broadside radiation characteristics. The frequency ratio of the two operating frequencies is found to be $f_2 / f_1 = 1.57$. The details of the antenna design and simulation results are presented and discussed.

2. Resonance behavior of a single U slot microstrip antenna

The geometry of the rectangular microstrip patch antenna with a single U–shaped slot used to analyze the resonance behavior is shown in Figure 1. The rectangular patch with dimensions L = 37.5 mm and W = 26 mm is separated from the ground plane with a foam substrate of height h = 5.5 mm. The U slot with dimensions W_s = 12 mm and L_s = 19.5 mm is located in the middle of the patch such that a = 3.7 mm, b = 2.8 mm and t = 2.1 mm. The microstrip patch is fed using a 50Ω coaxial probe with the inner diameter of 1.27 mm. The coaxial probe is located slightly below the center of the patch with F = 15 mm. Figure 2 shows the simulation results of the return loss of the antenna using the software Ansoft Ensemble. The computed −10 dB bandwidth of the antenna is 32.7%. By observing the return loss of the single U slot microstrip antenna in Figure 2, it can be seen that there are two resonances occurring near f_1 = 4.12 GHz and f_2 = 5.08 GHz. Figure 3 and 4 show the surface current distribution on the microstrip patch at f_1 = 4.12 GHz and f_2 = 5.08 GHz. For the case of f_1, the surface current distribution of the TM_{01} mode is strongly affected due to the arms of the U slot. An approximate equation for f_1 is derived by analyzing the current distribution and written as

$$f_1 = \frac{c}{(2(\frac{W_s}{4} + \frac{L}{4} + W - \frac{b}{2})\sqrt{\epsilon_e})} \tag{1}$$

For the case of f_2 = 5.08 GHz, the surface currents originate at the probe location and circulate around the arms of the U slot as shown in Figure 4. An approximate equation for the case of f_2 is written as

$$f_2 = \frac{c}{(2(L_s - W + \frac{W_s}{4} + 2F + b + \frac{t}{2})\sqrt{\epsilon_e})} \tag{2}$$

The obtained values of f_1 and f_2 using the equations (1) and (2) are f_1 = 4.06 GHz and f_2 = 4.94 GHz. The error between the formulated values and simulated values of f_1 and f_2 is 1.46% and 2.76%, respectively.

3. Antenna design and simulation results of the Dual U slot antenna

Figure 5 shows the geometry of the rectangular microstrip patch antenna with two asymmetric U−shaped slots for dual−frequency operation. Two asymmetric U−shaped slots are cut on a rectangular microstrip patch of dimensions $L \times W$ = 38.5 mm × 28 mm, which is separated from the ground plane with a foam substrate of height h = 5 mm. The dimensions of the inner U slot are W_{s1} = 12 mm and L_{s1} = 19.5 mm. The inner U slot is located in the middle of the patch such that a_1 = 1.5 mm, b_1 = 7 mm and t_1 = 2.1 mm. Similarly, the dimensions of the outer U slot are W_{s2} = 24 mm and L_{s2} = 24 mm with a_2 = 1 mm, b_2 = 3 mm and t_2 = 2.1 mm. The antenna is fed using a single 50Ω coaxial probe feed with the inner diameter of 1.27 mm. The probe feed is located just below the center of the microstrip patch with F = 16 mm.

Simulated results of the antenna by Ansoft Ensemble for return loss are shown in Figure 6. Figure 6 shows that the two resonant frequencies occur near f_1 = 3.88 GHz and f_2 = 6.08 GHz with the frequency ratio f_2 / f_1 = 1.57. The computed −10 dB bandwidth of the antenna for frequencies f_1 = 3.88 GHz and f_2 = 6.08GHz is 6.19% and 9.49%, respectively. The computed gain patterns at f_1 = 3.88 GHz in Phi = 0 plane and Phi = 90 plane are shown in Figure 7. Figure 8 shows the computed gain patterns in Phi = 0 plane and Phi = 90 plane at f_2 = 6.08 GHz. It can be seen that both operating frequencies have similar gain patterns and the same polarization. The crosspolarisation level in ϕ = 0 plane for f_1 = 3.88 GHz is below −13 dB. However, the crosspolarisation level in ϕ = 0 plane for f_2 = 6.08 GHz is slightly higher. In ϕ = 90 plane, the crosspolarisation level for both f_1 and f_2 is below −35 dB, which is very low.

4. References

[1]T. Huynh and K.F. Lee, "Single–layer single–patch wideband microstrip antenna", *Electronics Letters*, Vol. 31, No. 16, August 1995, pp. 1310–1312.

[2]K.F. Lee, K.M. Luk, K.F. Tong, S.M. Shum, T. Huynh and R.Q. Lee, "Experimental and simulation studies of the coaxially fed U–slot rectangular patch antenna, *IEE Proc.–Microw. Antennas Propagat.*, Vol. 144, No. 5, 1997, pp. 354–358.

[3]Y.X. Guo, K.F. Lee and K.M. Luk, "A dual–band patch antenna with two U–shaped slots", *Microwave and Optical Technology Letters*, Vol. 26, No. 2, July 2000, pp. 73–75.

[4]H.M. Chen and Y.F. Lin, "Dual–Frequency operation of a single–feed rectangular microstrip antenna with a π–shaped slot", *International Symposium on Antennas and Propagation – ISAP2000*, Fukuoka, Japan, August 22 – 25, 2000, pp. 1107–1110.

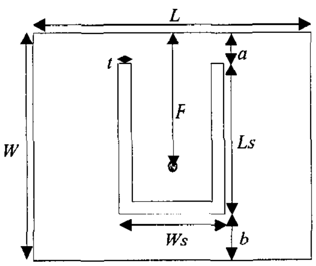

Figure 1: Geometry of the microstrip antenna with a single U–shaped slot.

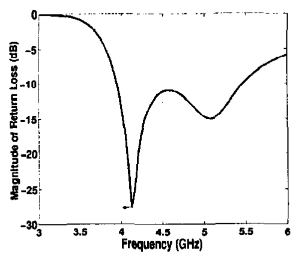

Figure 2: Return Loss of the microstrip antenna with a single U–shaped slot.

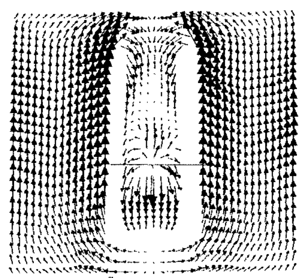

Figure 3: Surface current distribution on the microstrip patch at f_1 = 4.12 GHz.

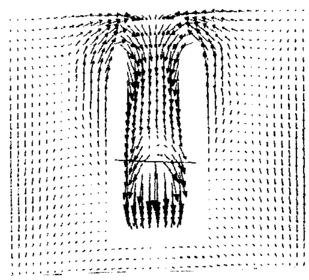

Figure 4: Surface current distribution on the microstrip patch at f_2 = 5.08 GHz.

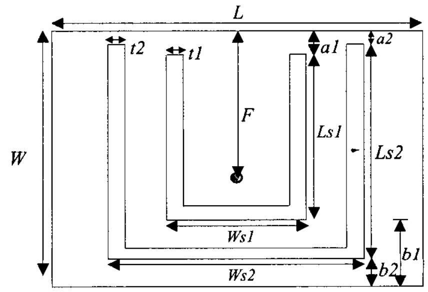

Figure 5: Geometry of the microstrip antenna with two asymmetric U−shaped slots.

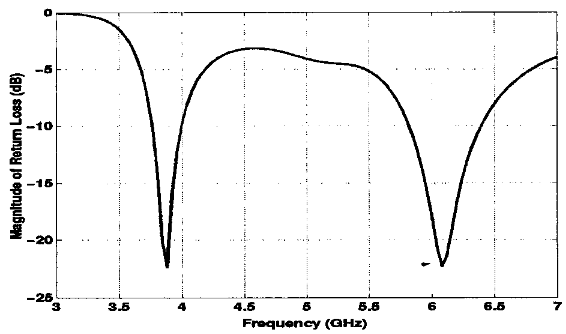

Figure 6: Return Loss of the microstrip antenna with two asymmetric U−shaped slots.

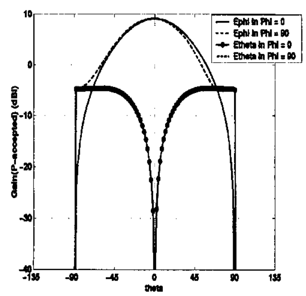

Figure 7: Gain patterns in $\phi = 0$ and $\phi = 90$ plane at $f_1 = 3.88$ GHz.

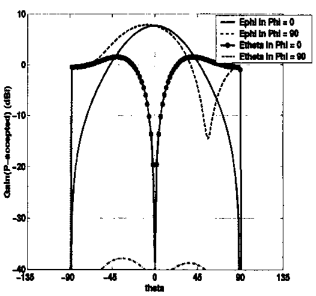

Figure 8: Gain patterns in $\phi = 0$ and $\phi = 90$ plane at $f_2 = 6.08$ GHz.