A Compact Slotted Bowtie Patch Antenna

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1. Introduction

Communication systems are growing up to achieve smaller sizes with better performances. Compact circuits have improved by advances in microelectronics, but providing integrated and compact antenna is one of the most important fields of antenna study. In new antenna design, smaller antenna with wider bandwidth is the objective to achieve.

Microstrip antennas have good characteristics to compact an antenna. They are lightweight, small volume and low profile. They can be made integrated with MICs with low cost and also they allow for dual- or triple frequency operations. Beside these advantages they also have some drawbacks; they have narrow bandwidth and lower gain [2-3].

Antenna size depends on the desired resonance frequency [1]. In all Microstrip antenna designs, there is a compromising challenge between the size of the antenna and its bandwidth; therefore, antenna researchers have attempt to present small area microstrip antenna with larger bandwidth [4-6]. Different techniques have been used to reduce the size of the microstrip antenna, such as using substrate with larger permittivity [2, 6], imposing a shorting plate or a shorting pin [7] and embedding proper slots in the patch [8-9].

With a size reduction at a fixed operating frequency, the bandwidth of a microstrip antenna is decreased. There are some techniques to improve the bandwidth of the microstrip antenna, for instance, using different resonator [10], impedance matching [11] and applying slots to the geometry [6]. Slots based on their location and geometry have different effects on the antenna bandwidth.

This work presents a probe-feed compact slotted bowtie patch antenna operating at the resonance frequency of 2.1GHz. It has significant reduction in size and achieved to larger bandwidth, in comparison to a rectangular patch presented in [3] and a bowtie patch proposed in [1]. Simulation results prove the design.

2. Theory and Design

The designed and analyzed geometry in this paper is shown in fig. 1. This shape without slots as a conventional structure of a bowtie patch have been proposed in [1], so slots added to achieve larger bandwidth with smaller radiating patch area. The geometry based on rectangular patch presented in [3] with two steps modification; first, remove two triangles and catch bowtie and second, add slots to the shape.

The patch dimensions are based on simplified formulations described for rectangular patch in [1]. It is assumed that the dielectric constant of the substrate (ε_r), the resonant frequency (f_r), and the height of the substrate (h) are specified and then width (W) and length (L) of the patch can be determined by means of equations (1) and (2) respectively.

$$W = \frac{C}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

$$L = \frac{C}{2f_r\sqrt{\varepsilon_{eff}}} - 2\Delta L \tag{2}$$

Where C is light speed in free space and

$$\varepsilon_{eff} = \left(\frac{\varepsilon_r + 1}{2}\right) + \left(\frac{\varepsilon_r - 1}{2}\right)\left(1 + 12\frac{h}{W}\right)^{-1/2} \quad (3)$$

$$\Delta L = 0.412 \frac{\left(\varepsilon_{eff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{eff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \quad (4)$$

By using mentioned equations, a good starting point to catch the required design could be achieved. The general performance of the bowtie antenna is very similar to that of rectangular antenna [4]. By indentation in the middle of length, the bowtie geometry will be performed. The width in the middle is equal to W_c and in the equations given above W_i will be used instead of W.

$$W_i = \frac{W + W_c}{2} \quad (5)$$

3. Results

Based on the mentioned equations, different sets of dimensions result desired resonance frequency. The coaxial probe has been chosen as feeding method because of its simplicity and also it can feed the antenna at any point of the structure. The coordinates of the feed point for best impedance matching found through simulations at X=8mm and Y=5.5mm. The antenna is simulated using a 3D electromagnetic simulator.

Different bowtie antennas with different values of W, L, and W_c were designed on a substrate with ε_r=4.4 and thickness h=1.6mm. The specified resonance frequency was 2.1GHz. Resonance frequency, bandwidth and area for different sets of bowtie patch are compared in table 1. It has been shown when W increases with the constant L the resonance frequency are reduced and for larger area, larger bandwidth has been obtained therefore a trade-off between size and bandwidth is required. The best bandwidth achieved by W=43.5mm, W_c=19mm and L=23mm around 70MHz for reflection coefficient (S_{11}) less than -10dB. Fig. 2 shows the S_{11} and it confirms the narrow band characteristics of the bowtie presented in [1]. These chosen dimensions result good area in comparison with [1], it is about 21% smaller. Although this design achieved same bandwidth with significant smaller area but still the bandwidth is narrow.

Due to enlarge the bandwidth, slots as shown in fig. 1 are added to the geometry. The optimum results were achieved by SW=34.5mm, SW2=13.4mm, SL=2.4mm and SL2=1mm. It can be observed from fig. 2 that this design caught 150MHz bandwidth at resonance frequency of 2.14GHz (7%) for S_{11} less than -10dB while the antenna proposed in [1] had 105MHz bandwidth at resonance frequency of 2.43GHz (4%). It means 75% improvement in bandwidth.

It is shown in fig. 3A and 3B, radiation patterns of the simple bowtie and slotted bowtie antennas are very similar to each other. Total gain for φ=0deg and φ=90deg at the resonance frequency of 2.1 GHz are presented in fig. 3, part A and part B respectively.

4. Conclusion

It is confirmed that, a single element bowtie patch antenna is very narrow band, especially when the size of the antenna is reduced. It has been shown how W and L influence on resonance frequency and bandwidth of the antenna. It is possible to choose the best values for dimensions of the geometry and then keep the patch area small and do an attempt to enlarge bandwidth.

By 3D simulations, it has been watched that adding slots to the shape of the antenna, can make the bandwidth of a bowtie patch wider without any serious changes in the radiation pattern of the antenna. The shape of the patch is main parameter and determines the antenna bandwidth. Thus, by embedding appropriate slots in the radiating patch, compact geometry of microstrip antenna at the same frequency can be obtained.

For lower frequency the larger area is needed but in this design the area is reduced. For more bandwidth also the larger area is demanded while this design has achieved more bandwidth with smaller area. Therefore in comparison with the antenna presented in [1], the area is 21% reduced and the bandwidth is 75% enlarged at resonance frequency of 2.1GHz. Thus by adding slots and changes in geometry more bandwidth in smaller area is achieved.

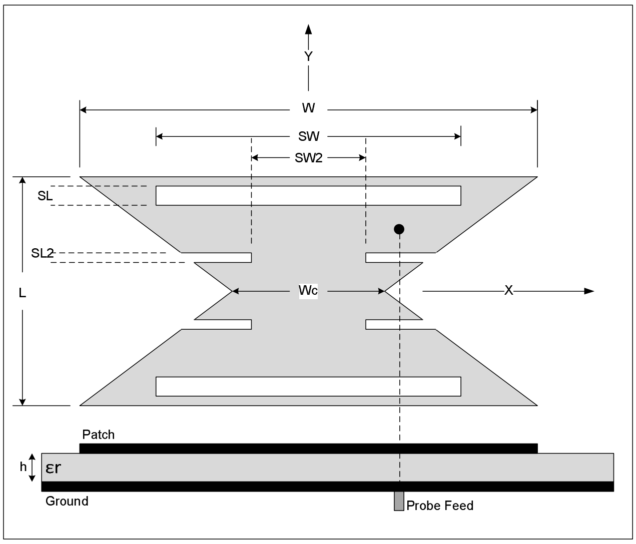

Figure 1: Geometry of the antenna

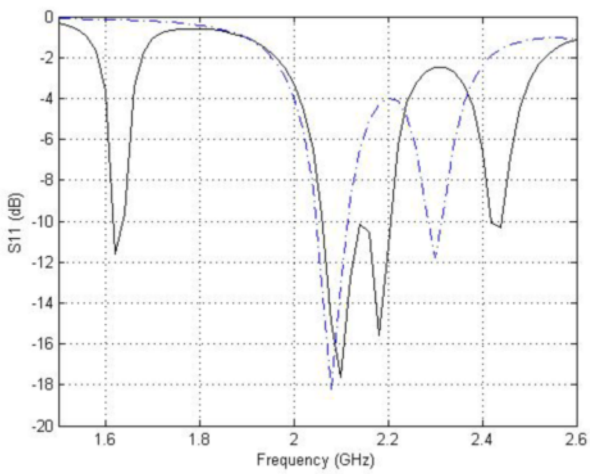

Figure 2: Reflection coefficient; (-): Slotted bowtie, (-.-): Simple bowtie

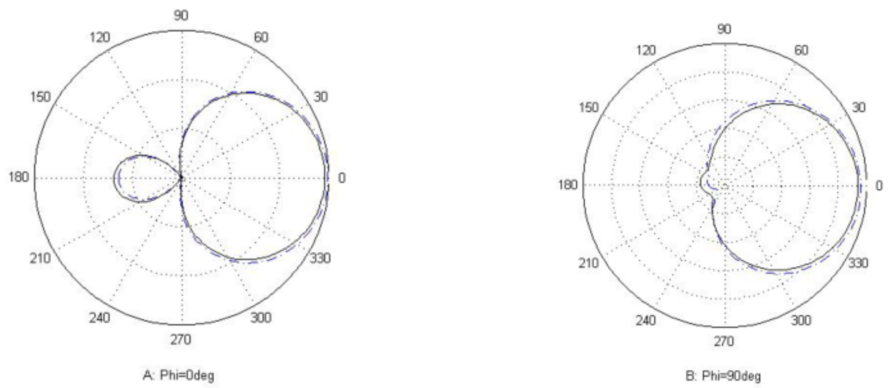

Figure 3: Radiation Pattern; (-): slotted bowtie, (-.-): Simple bowtie (–) a: φ=0deg, b: φ=90deg

Table 1: Resonance frequency and bandwidth for different sets of bowtie patch

ε_r=4.4 h=1.6mm W_c=19mm		Antenna Characteristics		
		f_r (GHz)	BW (MHz)	Area (mm^2)
Bowtie patch				
L=18mm	W=37	2.34	35	504
	W=43.5	2.08	30	563
	W=50	1.64	40	621
L=23mm	W=37	2.31	60	644
	W=43.5	2.08	70	719
	W=50	1.87	60	794
L=28mm	W=37	2.24	70	784
	W=43.5	2.03	110	875
	W=50	1.80	30	966
Bowtie patch with slots				
L=23mm	W=43.5	2.14	150	719 (531 if minus slots from area)

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