Offset fed slot antenna for broadband operation

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Abstract. In this paper, a microstrip fed rectangular slot antenna with wideband characteristics is proposed. Both the impedance and radiation characteristics of the proposed antenna are presented. It is shown that a properly offset feed can give a dual resonance nature, which can be optimized to enable wideband behavior. From HFSS simulation, an impedance bandwidth (-10 dB) of 49.92 % (2.51 GHz to 4.18 GHz) about the center frequency of the band is obtained. Prototype measurement demonstrates a bandwidth of 45.30 % (2.51 GHz to 3.98 GHz). Simulated radiation patterns show bidirectional behavior, which is stable in the band with a peak gain of 5.7 dBi and a gain variation of 2 dBi.

1. Introduction
In the past several years, multiband and wideband wireless technologies received considerable attention. Hence the development of antennas with multiple / wide bandwidth, small size, ease of fabrication and low cost are required. One of the good candidates bearing wideband properties is the slot antenna and the characteristics of microstrip fed slot antennas have been extensively studied [1][2][3]. Slot antennas dominate patch antennas in several aspects such as (i) larger bandwidth (ii) bidirectional radiation pattern (iii) low cross-polarization and (iii) less sensitive to manufacturing tolerances etc [3]. Also various investigations on enhancing the bandwidth of wide slot antenna are reported [4][5][6][7]. The bandwidth enhancement is based on the principle of merging of dual resonances produced by the offset fed rectangular slot antenna.

In the present paper, a compact wideband slot antenna, excited by a simple microstrip transmission line is proposed. The wideband performance is achieved by generating dual-resonances of a slot antenna, offset-fed with a microstrip line. ANSYS HFSS has been used for modeling the antenna and optimizing the design. A prototype is fabricated and the bandwidth characteristics are measured and compared with the simulation result.

2. Antenna Configuration
The geometry of the proposed antenna is shown in Figure 1. As shown in the figure, the antenna has overall size L = W = 100 mm. and the rectangular slot has size Ls= 34 mm., Ws= 17 mm. The antenna is printed on FR4 microwave substrate of thickness 1.6 mm, relative permittivity of 4.4 and loss tangent of 0.002. This slot is excited by a 50 Ω microstrip line with a simple tuning stub having a length G = 13.5 mm and offset parameter d =12.58 mm. The microstrip is printed on the back side of the substrate. A conventional center-fed (i.e. d =0) printed slot antenna with a simple tuning stub has
been taken for comparison. All the design parameters of center-fed antenna are the same as those of the offset-fed antenna except the length of stub (G) that need to be varied for impedance matching.

![Figure 1. Geometry of microstrip line fed printed rectangular slot antenna with offset parameter of 'd' (Image)](image)

### 3. Results and discussion

#### 3.1. Impedance Characteristics:

By optimizing the off-centered parameter 'd' in Figure 1, the measured reflection coefficient of proposed offset-fed antenna and center-fed antenna are shown in Figure 2. A comparison study of the design parameters and corresponding simulated data are listed in Table 1. From the obtained results, it is seen that the proposed antenna which is fed by (d = 0.37Ls mm) off-centered microstrip feed has an impedance bandwidth as large as 1.67 GHz or 49.92% about the center frequency of the band. This is nearly about seven times that (230 MHz) that of the center-fed antenna. This bandwidth is increased because a second resonant mode in addition to the fundamental mode can be excited by the off-centered microstrip line fed rectangular slot antenna. It has been found that dual-resonant characteristics are enhanced as the microstrip line is moved off center i.e. towards the edge of the slot. And these dual resonances can be merged below -10 dB reflection coefficient together to give wide bandwidth behavior by properly optimizing the off-centered microstrip line feed location.

![Figure 2. Reflection coefficient versus frequency, for the designs shown in Table 1. (Image)](image)
Table 1. Comparison between the center-fed and the offset-fed proposed antennas with parameters.

| Antenna       | d (mm.) | G(mm.) | $f_L$(GHz) | $f_H$(GHz) | Impedance B.W.(GHz) | Percentage B.W. (%) |
|---------------|---------|--------|------------|------------|---------------------|--------------------|
| (a) Centre-fed| 0       | 10.5   | 2.46       | 2.69       | 0.23                | 8.93               |
| (b) Offset-fed | 12.58   | 13.5   | 2.51       | 4.18       | 1.67                | 49.92              |

Once optimized the geometry of the slot antenna, a prototype has been fabricated and measured. Figure 3 shows the top and bottom views for the fabricated prototype of the offset-fed slot antenna with SMA connector. The Keysight N-9928A Vector Network Analyzer is used for measurement of impedance characteristics. Figure 4 shows the measured and simulated reflection coefficient against frequency for the proposed antenna. Measured bandwidth is 1.47 GHz or 45.30 % about the center frequency. The difference is attributed to the fabrication tolerances.

Figure 3. Photograph of the antenna prototype for $\varepsilon_r = 4.4$, $h = 1.6$ mm, $L=W=100$ mm, $L_s =37$ mm, $W_s = 17$ mm, $G=13.5$ mm, and $d=12.58$ mm.

Figure 4. Measured and simulated reflection coefficients against frequency, for the design shown in Figure 3.
3.2. Radiation characteristics:
Figure 5 shows the radiation patterns of this antenna in the two principal planes (XZ and YZ) at three different frequencies in the band 2.68 GHz, 3.12 GHz and 3.74 GHz. The patterns are broadsided, having very little variation with frequency indicating the usefulness of the design. Also note that the slot antenna being open on both sides radiates bi-directionally. Figure 6 represents the antenna gain within the operating bandwidth of this antenna. The gain varies from 3.9 dBi to 5.7 dBi in the impedance band showing a variation less than 2 dB.

![Image](image-url)
Figure 5. Simulated (i) XZ-plane and (ii) YZ-plane radiation patterns of proposed slot antenna (a) $f = 2.68$ GHz (b) $f = 3.12$ GHz and (c) $f = 3.74$ GHz, for the design shown in Figure 3.

Figure 6. Simulated antenna gain against frequency for proposed slot antenna design shown in Figure 3.

4. Conclusion
A printed rectangular slot antenna fed by a 50 $\Omega$ offset microstrip line for bandwidth enhancement was investigated. Results show that the -10 dB impedance bandwidth can be significantly improved by selecting suitable offset location of the microstrip feed. For the optimized offset parameter $(d/L_s = 0.37, \ d=12.58 \ mm)$, simulated bandwidth becomes nearly 1.67 GHz or 49.92% while the measured bandwidth is 1.47 GHz or 45.30%. This is about seven times that of a centre-fed slot antenna. Within this wide impedance band, the peak antenna gain is 5.7 dBi with a gain variation of less than 2 dB.

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