Comparative Study, Design and Performance Analysis of Wide Slot Antenna with Patch-Feed for Bandwidth Enhancement

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Abstract: *This paper presents a design of triangular wide slot antenna with same shaped patch which is fed by CPW. Patch is working as a radiating element and wide slot working as a ground. Detail simulation is conducted to understand its behaviour and optimize for broad band operation. The results are analysed and discussed in terms of return loss, VSWR, Gain, current distribution etc. The result shows that the Impedance bandwidth is greatly enhanced 116 %(2.1 Ghz-7.9 Ghz). This large operating bandwidth is optained by choosing suitable combination of Feed- Slot shapes, Feed gap width and Waveguide width. To understand the effects of various dimentional parameters numerical sensitivity analysis is also done*
Keywords: *Band width, Co planar waveguide, Patch-feed, Feed-gap, wide slot antennas.*

I. Introduction

In recent years, there have been a growing research activities on CPW feed wide slot antennas [1]-[5], because of there favourable impedance characteristics. These antennas have several appealing advantages over common patch antennas like wide band width, good impedance matching and bidirectional as well as unidirectional radiation patterns. The CPW feeding line also has advantages over microstrip feed lines such as low dispersion, low radiation leakage, their easy integration with active devices or MMICs and ability to control their characteristics impedance.

Although many CPW feed wide slot antennas are proposed for wide band applications but studies on the effect of the interaction between feed and slot on impedance bandwidth are rare. In this paper attention is paid on the effects on the interaction between slot and small patch, feed gap width (h) and waveguide width (g). It was found that properly choosing suitable combination of the antennas (slot as well as feed) and by tuning their dimensions significant enhanced bandwidth can be obtained.

II. Antenna Design

“Fig 1” shows the geometry of proposed antenna fabricated on the FR4 substrate with thickness of 0.8 mm and dielectric constant 4.4. Antenna has a triangular-shape slot and an equilateral triangular-patch feed with an edge length of 15 mm. Patch is working as a radiating element fed by CPW and wide slot working as a ground. By study of various papers [1]-[10] three design rules are followed:

A. Feed and slot shape should be similar
B. The widths and lengths for both feeds are about one third of the slot size
C. Lengths are close to but less than the quarter wavelength measured at the lower frequency edge. The lengths are shorter than a printed monopole at the same frequency, because the slot edge acts as a capacitive load to the monopole.

Theoretical formulas

The resonance frequency corresponding to the various modes can be given by

$$f_r = \frac{ck_{mn}}{2\Pi\sqrt{\varepsilon_r}} = \frac{2c\sqrt{m^2+mn+n^2}}{3a\sqrt{\varepsilon_r}}$$

$$k_{mn} = \frac{4\Pi\sqrt{m^2+mn+n^2}}{3a}$$

Where, c = free velocity of light and **…..** is the wave number For lowest order the resonance frequency is given by

$$f_r = \frac{2c}{3a\sqrt{\varepsilon_r}} \quad \text{--------} \quad (1)$$

In these formulas the effects of fringing fields are not considered. The resonant frequency can be determined more accurately, if dielectric constant and length of the patch **a** is replaced by effective dielectric constant “ε_{reff}” and effective length “a_{eff}”, Effective Dielectric constant of substrate determined by “Resonant line method” is given by**:**

$$\varepsilon_{reff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-\frac{1}{2}}$$

And $a_{eff} = a + \frac{h}{\sqrt{\varepsilon_r}}$.

Hence, the resonant frequency is

$$f_r = \frac{2c}{3a_{eff}\sqrt{\varepsilon_{eff}}} \quad \text{--------} \quad (2)$$

As we know that the wide slot antennas should have very low aspact ratio (close to 1), so the length of the patch is calculated from equation (2) is further modified and taking round figure. Length and width of the patch is 15mm and Length and width of the slot is 52.7mm.

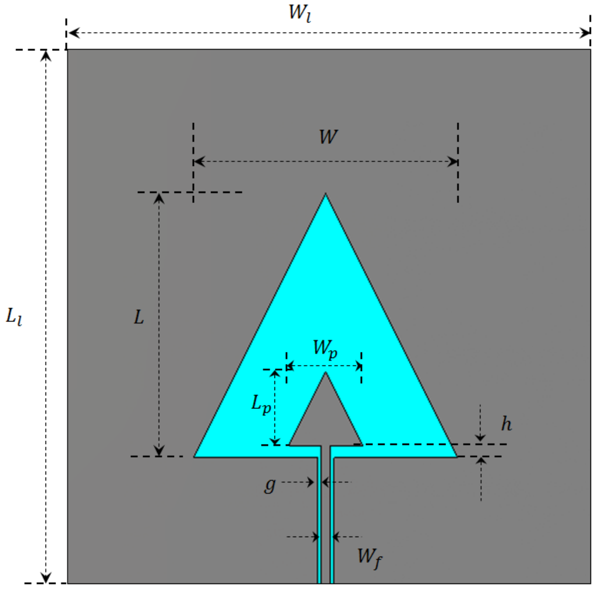


Figure 1: Geometry of proposed antenna

All dimensions in **mm**

L_l	W_l	L_p	W_p	L	W	W_f	h	g
110	110	15	15	52.7	52.7	2	2.5	0.7

III. Smulated Results and Discussion

A. Return loss and antenna bandwidth

The center frequency is selected as the one at which the return loss is minimum. The bandwidth of the antenna is said to be those range of frequencies over which the return loss is greater than 7.3 dB, Thus we measure required band at return loss -10dB. From return loss plot given in “fig 2” it is found that impedance band width is 116% and center frequency is 5 GHzs

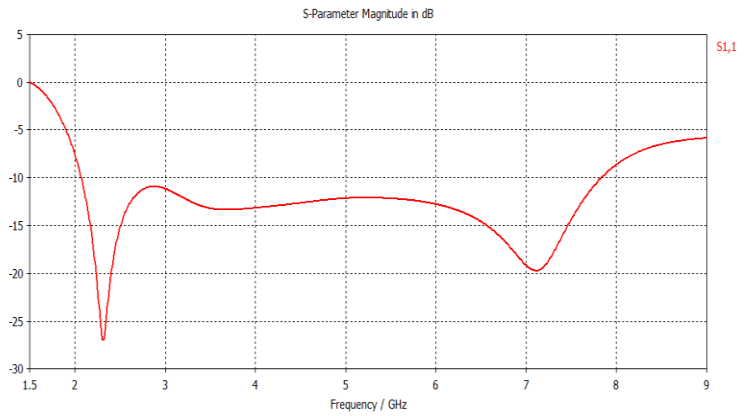


Figure 2: Return Loss Characteristics (S_{11} < -10 dB)

B. VSWR Plot

Voltage standing wave ratio (VSWR) of wide slot antenna shown in “fig 3” shows most of the frequency band VSWR lies between 1.5 – 2 which is excellent. At f = 5 GHz the value of VSWR is 1.6

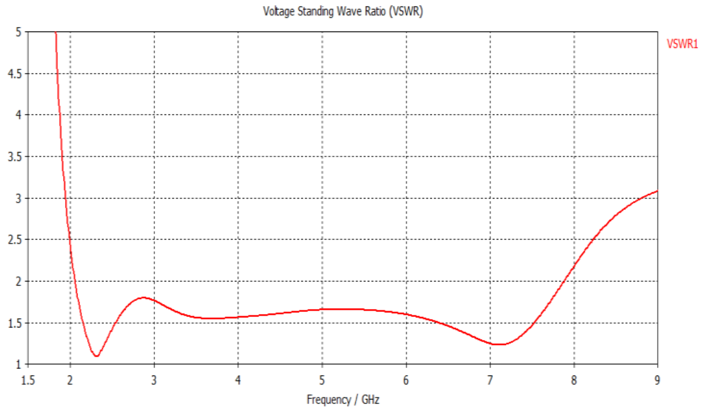


Figure 3: VSWR Characteristics (VSWR < 2)

C. Gain Vs Frequency Plot

"Fig 4" shows that simulated results at the desired frequency band. At frequency 6 GHz the gain is maximum 7.6 dbi.

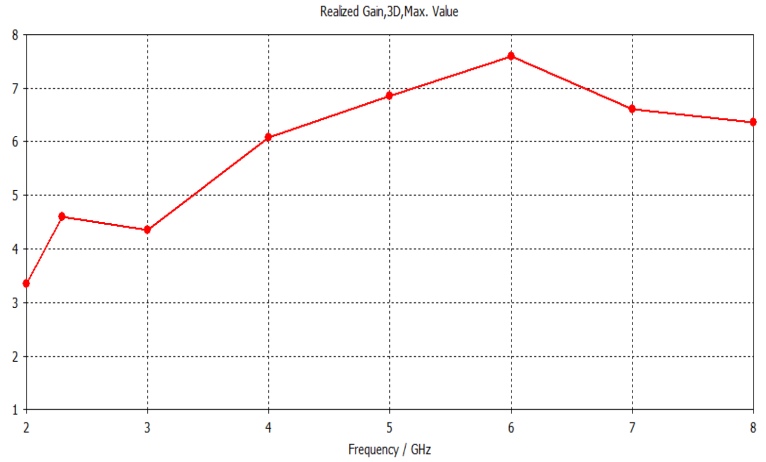
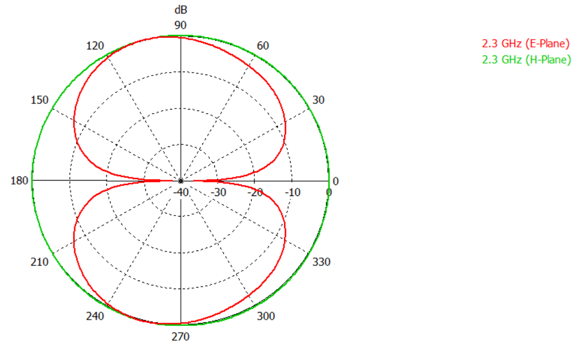
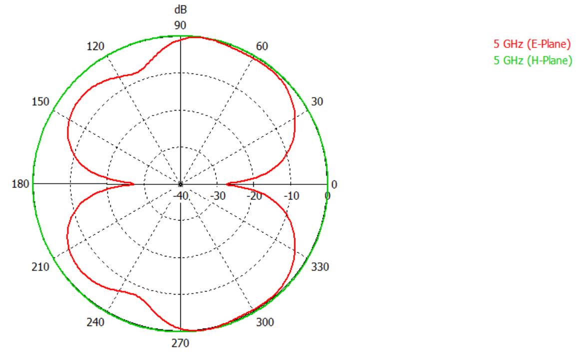


Figure 4: Gain Characteristics

D. Radiation pattern

E-field and H-field plots are given in "fig 5" at frequencies 2.3 GHz, 5 GHZ and 7 GHz. Antenna radiates in nearly omni direction to its surface





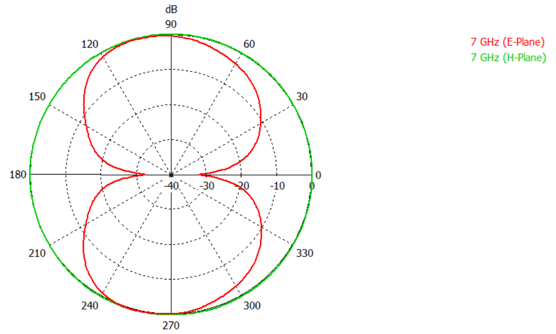


Figure 5: Radiation Pattern Characteristics for 2.3GHz, 5GHz and 7 GHz(E and H plane)

E. Current Distribution

Through the study on different slot shapes, it is found that currents flowing on the edge of the slot will increase the cross-polarization component in the H-plane and cause the main beam to tilt away from the broadside direction in the E-plane. From the simulation, "fig 6" shows the surface current distribution for resonant frequencies 2.3 GHz and 7 GHz and at center frequency 5 GHz. The patterns of the antenna generated by triangular slots, among the different slot shapes, are the most stable across the operating band and the antenna is linearly polarized.

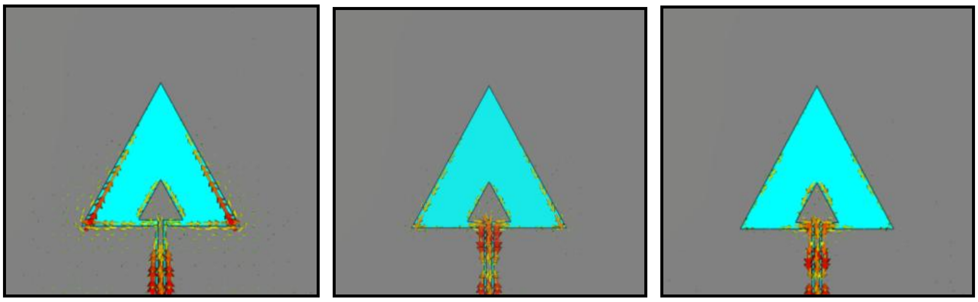


Figure 6: Surface Current Distribution for 2.3GHz, 5 GHz and 7 GHz

IV. Numerical Sensitivity Analysis

A. Patch length Lp and Wp

As the patch length increased upto 17 mm, the resonating frequency decreases and as the length decreases to 13 mm the band width reduces. "Fig 7" shows the graph for Length and Width. At Lp = Wp= 15 mm, there is an optimized performance.

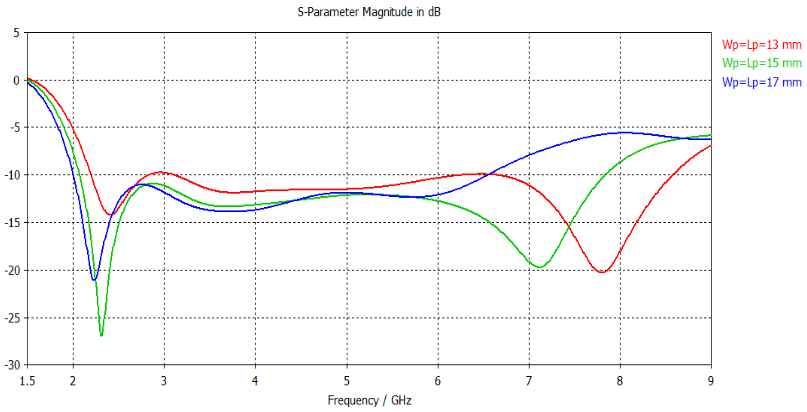


Figure 7: Return loss characteristics for different Wp and Lp of antenna

B. Feed Graph 'h' (coupling between feed and slot)

The feed gap effect on the impedance matching is investigated in [1] and it is found that good impedance matching can be obtained by enhancing the coupling between the feed and slot. When the coupling is increased to a certain value, an optimum impedance bandwidth can be obtained. However, if the coupling is further increased beyond this value, the impedance matching will deteriorate; showing that over coupling can also degrade the impedance matching as under coupling. "Fig. 8" shows the simulated return losses of Antenna with feed gaps of 1.5, 2 and 2.5 mm. It can be observed that the frequency corresponding to the lower edge of the bandwidth is fairly independent of the feed gap 'h', but the frequency corresponding to the upper edge is heavily dependent on it. Moreover, tapering the feed gap will further increase the impedance bandwidth.

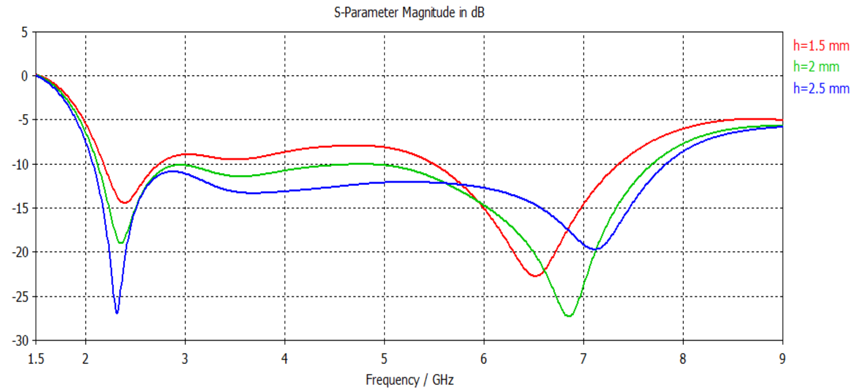


Figure 8: Return loss characteristics for different h of antenna

C. Width of the waveguide ‘g’

Width of waveguide ‘g’ also has major influence to the Return loss characteristics. “Fig 9” shows that g = 0.7 mm gives constant pattern and wide frequency range. For g = 0.5 mm pattern crosses the -10 dbi reference line.

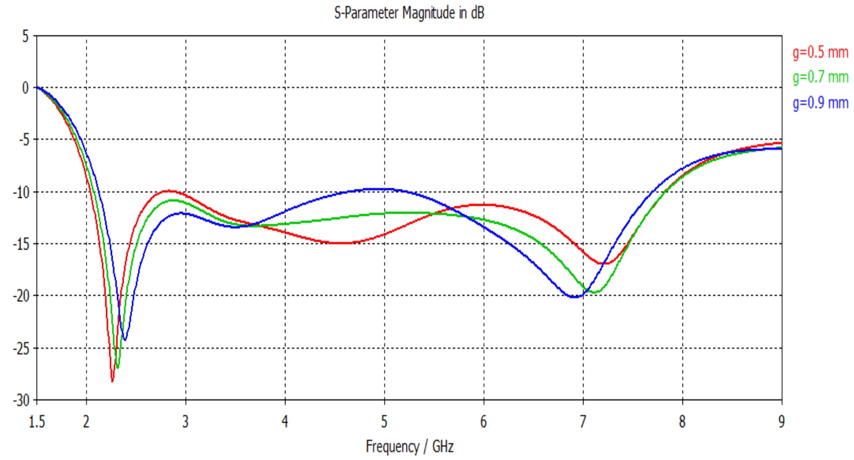


Figure 9: Return loss characteristics for different g of antenna

V. Conclusion

A CPW feed wide slot antenna has been developed and 116% bandwidth is achieved with stable radiation patterns across the whole band. It is found that the antenna feed and slot shapes should be similar for optimum impedance matching, but for better radiation patterns, a triangular shape slot should be used. In addition, the proposed antenna has small size, exhibit stable and almost omni directional radiation patterns in entire operating frequency band, relatively high gain and low cross polarization. Based on these findings the proposed antenna can be further improved for commercial purpose like WLAN, Wi-Fi, Wi- MAX, WTM.

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