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Analysis and Design of Multiband Antenna Using Modified Geometry

Laxmi Prasad Mishra, Mihir Narayan Mohanty*
Department of Electronics and Communication Engineering
ITER, Siksha 'O' Anusandhan University (Deemed to be University)
Bhubaneswar

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Abstract
As the digital age grows, the communication techniques increase day by day. The backbone of communication is antenna, for which this area of research is still in demand. In this paper, authors try to design an antenna that can be used with multiple bands. By etching the corners of the rectangular patch, an U-slot is inserted to enhance this gain and two stable bands have been generated. To prove it the transmission line model is developed and analysed. As a result the bands are generated and used for 2.9 GHz and 9.8 GHz respectively. From the result it can be observed that the bandwidth and gain of the proposed antenna is increased.

Keywords: *Microstrip Antenna, Multiband Antenna, Slot, Gain, Bandwidth, Radiation Pattern.*

I. Introduction

The major limitation of patch antenna is its narrow bandwidth. Hence, many researchers have developed different methods for improvement of microstrip antenna impedance bandwidth.

The impedance bandwidth and patch antenna size are generally complementary to each other. So, the characteristics development of one results in deterioration of the other. Under these conditions the research workers developed many different methods to enhance such limitations, basically improving the impedance bandwidth, and proposed different antenna design [1-4].

The integration of all the important characteristics like high gain, wide bandwidth, better efficiency and good radiation into a single radiator design is very complicated task. Some limitations are overcome by this innovative work presented in this paper which is based on ultra wideband U-slot insertion and incorporation of two identical corner truncation in a metallic patch. The antenna characteristics are analysed on the basis of corresponding circuit approximation using cavity model analysis and circuit theory concept. [5-8].

II. Proposed Antenna Geometry and Model Analysis:

Figure 1 depicts the geometrical configuration and fabricated photograph of the intended radiator with optimized dimensions. The intended radiator consists of a pair of corner truncated rectangular microstrip patch with an inserted U-slot. The dimension of the rectangular patch is

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$L \times W = 34.6 \times 25\ mm^2$with centre frequency at 7.2 GHz. The truncation length is δl= 8.5 mm. The rectangular patch is designed on Rogers R04350 (tm) dielectric substrate (size: $70 \times 50\ mm^2$) with dielectric constant (ε_r)3.6 of height (h) 6 mm, loss tangent (tan δ)0.003 and having full ground plane. The U- slot having dimensions$(l_{vs} \times w_{hs} \times t = 16.9 \times 12 \times 2\ mm^3)$is inserted in the centre of the patch. The three arms of the U- slot are symmetrically placed w.r.t the feed point$y_f = 1.5$ mm.

Based on transmission line model, the equivalent circuit of the radiating element is:

$$R_{patch} \| L_{patch} \| C_{patch}$$

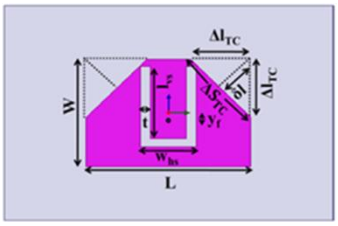

Figure 1

Figure 1 proposed antenna configuration for UWB application

$$R_{patch} = \frac{Q_{patch}}{\omega_{patch}\ C_{patch}} \quad (1)$$

$$L_{patch} = \frac{1}{\omega_{patch}^2\ C_{patch}} \quad (2)$$

$$C_{patch} = \left[\frac{\varepsilon_0 \varepsilon_{eff}\ LW}{2h}\right] \cos^{-2}\left(\frac{\pi y_f}{L}\right) \quad (3)$$

Where, ω_{patch} = angular frequency

$$Q_{patch} = \frac{c\sqrt{\varepsilon_{eff}}}{4fh} \quad (4)$$

f = design frequency

The impedance of the truncated rectangular microstripradiator is:

$$Z_{patch} = R_{patch} + jX_{patch} \quad (5)$$

$$= \frac{1}{\left[\frac{1}{R_{patch}} + \frac{1}{j\omega L_{patch}} + j\omega C_T\right]}$$

Where, $C_T = C_{patch} + C_{TC}$

The three slots coupled together form U-slot depicted in Figure 1. The corresponding equivalent circuit of the inserted U-slot depicted in Figure 3 is based on duality relationship of slot and dipole. From this U-slot, the two vertical slots (L_{vs}) are in vertical direction and base slot (W_{hs}) is in horizontal direction. The resonant frequency of the basic patch antenna is changed due to the insertion of U-slot in the radiating element and which in turn changes the radiator electrical dimension. The path length increases due to the current flow throughout the inserted slot and on the boundaries. This consequence can be modelled by considering a series connection of reactive component (X) and radiation resistance (R) of the two perpendiculars and one parallel arm of the insertedU_{slot}. Then the individual series combination will be connected in parallel to realize the effective reactive components and radiation resistance$(R_{vs}, X_{vs}$ and R_{hs} , $X_{hs})$ of the U- slot.[2,9-11].

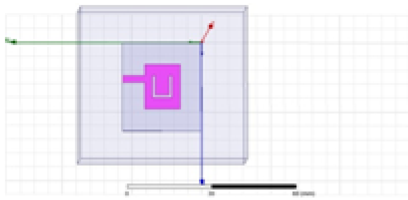

Fig.2 (<u>Single U-Slot Patch</u>)

So, the corresponding equivalent circuit of the inserted U- slot can be developed which is presented in Figure 3.

Since the impedance consists of both real and imaginary parts, where the real part is equivalent to the radiation resistance of dipole (i.e. slot) and the imaginary part is reactance of the slot which is given by.

$$X_{slot} = 30\{2S_i(KL) + \cos KL\ [2S_i(KL) - Si2KL - \sin KL\ 2CiKL - Ci2KL - Ci2Kt2L(6)$$

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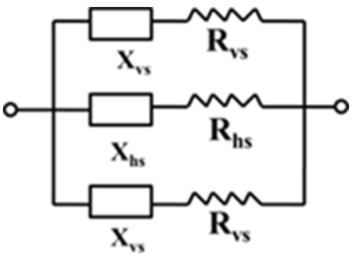

Figure 3Equivalent circuit of inserted U-slot

Where, K = phase constant $=\frac{2\pi}{\lambda}$

$S_i(X)$ = Sine integral $=\int_0^x \frac{\sin X}{X}\,dx$

$C_i(X)$ = Cosine integral $= \int_0^X - \frac{\cos X}{X}\,dX$

andt = Slot width

By putting all the parameters values in equation 6, the value of X_{slot} will appear as negative. So, the slot reactance on the patch is capacitive.

In this technique, the capacitive reactance is in parallel with the reactance of the radiating element for inserted U- slot rectangular microstrip radiator analysis.

So, the input impedance of the intended radiator is given as:

$$Z_{input} = Z_{patch} \| Z_{Uslot} = \frac{Z_{patch}\ Z_{Uslot}}{Z_{patch} + Z_{Uslot}} \qquad (7)$$

The gain of the intended radiator can be determined.

$$G = \eta \cdot D$$

Where,η=efficiency of antenna=$\frac{\text{Radiated power } (P_r)}{\text{Input power } (P_t)}$

$$P_r = \frac{1}{2\omega_{patch}\ C_{patch}}$$

C_{patch} is defined in equation (1,2,3)

$$P_t = \frac{1}{\omega_{patch}\ C_{patch}}$$

D= Directivity of the proposed antenna

$$= \frac{4W^2\Pi^2}{I_1\lambda_0^2}$$

$$I_1 = \int_0^\pi \sin^2\left(\frac{k_0 W \cos\theta}{2}\right)\tan^2\theta \sin\theta\, d\theta \qquad (8)$$

III. Simulation and Experimental Results:

The proposed antenna is simulated by HFSS simulator, and found the results in terms of the return loss (S_{11}),gain and bandwidth. Without U- slot varies from 2.5 GHz to 2.73 GHz (simulated B.W. % = 8%) and with centre frequencies at 2.6 GHz and 2.71 GHz. Due to corner etching length (δl), thickness (h) of substrate, width of horizontal slot (W_{hs}) and width of vertical slot (L_{vs}) the return loss characteristics at different values are presented in Figure 6. The larger impedance bandwidth is due to the insertion of U- slot in the radiating element. As, δl increases, the upper resonant frequency shifts toward the lower side. Also the bandwidth decreases from 105.5 % to 102.15%. Figure 6(b) depicts variation of substrate thickness (h) from 6 mm to 3 mm, when length of vertical slot(L_{vs}), width of horizontal slot (W_{hs})and truncation corner (δl) are kept constant. This plot shows thatdecrease in substrate thickness (h), increases capacitance and decreases inductance. Therefore, the upper resonant frequency shifts slightly towards lower side. Similarly, as W_{hs} decreases from 11.8 mm to 8.8 mm, the lower resonant frequency shifts towards the lower side. Figure 6(d) presents the parametric study of different values of (L_{vs}) for the proposed antenna. The variation of vertical slot length (L_{vs}) is from 19.3 mm to 16.3 mm in 1 mm difference with reference to centre of the radiating element.

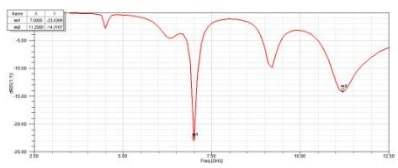

Fig:4

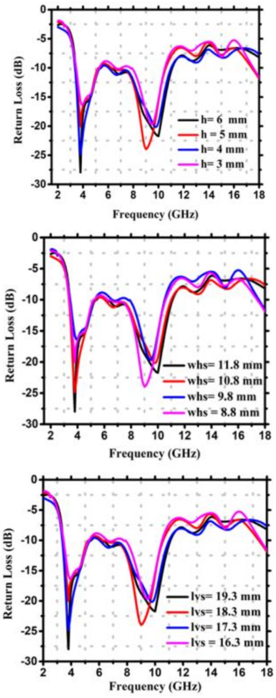

Fig:5

Figure 5Variation of return loss graph for the intended radiator variation of substrate thickness (h), variation of horizontal slot width(W_{hs}), variation of vertical slot width (L_{vs})

<u>Single U-Slot Patch</u>

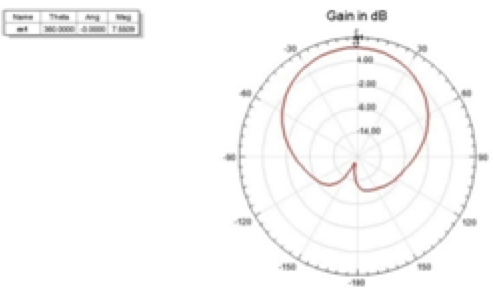

Fig.6

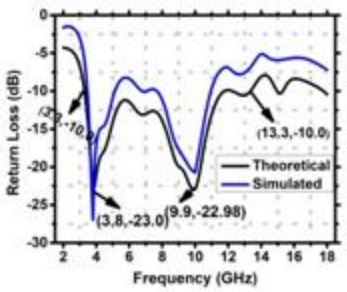

Fig.7, Simulated and theoretical return loss plot against frequency intended antenna

Conclusion:

In this work the effect of etching and slot have been well analysed .For further improvement the slot orientation may be varied and observed. The proposed antenna is found to be useful for two bands for the use of communication.

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