Design and Analysis of a Multiresonant Slotted Microstrip Antenna with Modified Ground Plane.

Mahendra kumar Soni, Pratibha Devi Umesh

Abstract— **In this paper, a multi slotted microstrip antenna with modified slots and ground plane for multiresonant and wideband operation is designed and proposed. The designed antenna dimension is only about 48 (0.64λ) x 60(0.8λ) mm and where, λ is the wavelength of the resonant frequency of the conventional antenna (i.e., 4.2 GHz). The measured result shows four distinct resonant frequencies at 2.4, 2.8, 4.2 and 6.5 GHz. A 10-dB wide-impedance bandwidth of 200 and 150 for 4.2 and 6.5 GHz is also obtained for the proposed antenna design. The simulated results shows that the size of the proposed antenna has achieved two extra bands in comparison to the conventional rectangular microstrip antenna with same size, and the operating bandwidth is also enhanced up to 45%, while maintaining a small overall size of 48x 60x 1.6 mm . The return-loss impedance bandwidth values are increased significantly for four or more resonant frequencies. The proposed antenna is characterize relatively stable gain around 1–4 dBi over the resonant bands.**

Index Terms—**modified ground plane, multiresonant, impedance bandwidth, slotted antenna etc.**

I. Introduction

The Microstrip antenna has drawn maximum attention nowadays in the antenna community for wireless communication applications. Apart from its various attractive features, the microstrip antenna suffers from an natural limitation of narrow impedance bandwidth typically of about 2%–5%. Thus, along with other researches, bandwidth improvement of microstrip antenna has become a major branch of work in the field of printed microstrip antennas [1]–[7]. Researchers have offered many methods like Defect ground structure, aperture coupling[1], stacked patch[2], modifications in the feed[3], and introduction of slots on the radiating patch [5]–[7] to enhance the bandwidth of microstrip antenna. Maximum bandwidth of 16% has been achieved ranging from 2.2 to 2.8 but it is not suitable for 2.4 GHz WLAN/WiMAX and 6.5 GHz HYPERLAN systems. The simulated microstrip antenna proposed in [2] gives bandwidth of 47%, but it is using thick substrate, which increases the length of the antenna. The use of L-probe feed microstrip patch antenna proposed in [3] has obtained bandwidth of 11% only, which is not enough to cover the bandwidth usage of the modern wireless communication systems. Mandal *et al.* [4] have obtained the increase in the bandwidth of a microstrip antenna up to 26%, but the large size of the antenna is a main problem. The designed frequency reconfigurable U-slotted antenna proposed in [5] has achieved bandwidth of 750 MHz ranging from 2.6 to 3.35 GHz, but it does not support the bandwidth requirement of high-speed 4.5-GHz WLAN. The small patch antenna proposed in [6] which achieved a size reduction of 49% and bandwidth of 52%. The microstrip fed microstrip antenna proposed in [7] has enhanced the bandwidth up to 25%, but the large size problem of the antenna is still. In this paper, a single-layer coaxially probe fed slotted microstrip patch antenna with modified ground plane has been designed and presented. The proposed antenna covers most important design aspects of microstrip patch antennas, such as, multi frequency operation, and bandwidth enhancement. The innovation of our work is multiresonant frequency characteristics and good operating impedance bandwidth in small size without using thick foam substrate, or shorting pin, or stacked patch, or any other modifications in the feed. The proposed antenna is designed with inexpensive, low-dielectric-constant FR4 thin substrate. The structure of the proposed antenna is plain and easy to fabricate. The proposed antenna provides much better multiband and operating bandwidth with simple and new design geometry in comparison to the previously antennas [1]–[7].

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II. Antenna Design

The proposed antenna is designed by four slits on the top of the patch with different and same dimensions than other as shown in Fig. 1. Due to cutting of these slits in antenna increases the current path results in increased current density due to which efficiency is also enhance. In this research first a rectangular micro-strip patch antenna is designed based on standard design procedure is to calculate the length (L) and width (W) for resonance frequency. The resonance frequency and the size of the radiation patch can be found out by using these following formulas.

$$f = \frac{C}{2L\sqrt{\varepsilon}} \quad (1)$$

$$W = \frac{C}{2f}\sqrt{\frac{2}{\varepsilon+1}} \quad (2)$$

$$L = \frac{C}{2f\sqrt{\varepsilon}} - 2\Delta L \quad (3)$$

where *f* is the resonant frequency of the antenna, *c* is the free space speed of the EM waves equal to speed of light, L is the actual length of the current element, ε_r is the effective dielectric constant of the substrate material and ΔL is the length of equivalent radiation parameter.

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The proposed Multiband slotted patch antenna is patterned on 48x60x1.6 mm^3, FR4_epoxy with relative permittivity (ε_r=4.4) and loss tangent of 0.02 as shown in Fig. 1. A conventional rectangular patch antenna is chosen with dimensions 28x40 mm. two Notches of T-shaped slits are introduced on one side and modified slot on other edge of the patch for multifrequency operation as shown in Fig. 2.

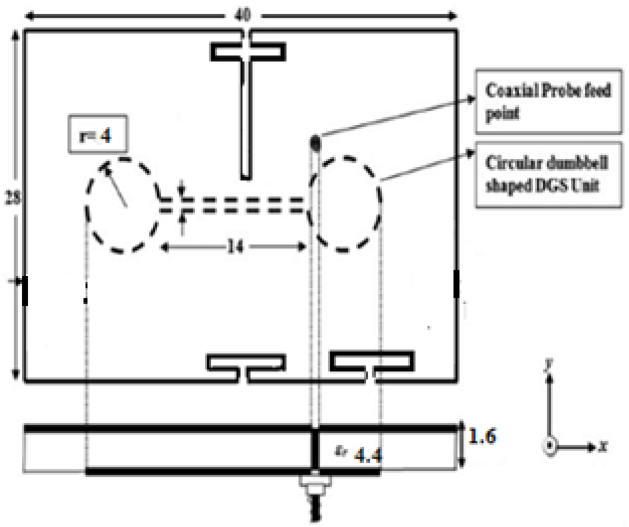

Fig. 1. Geometry of the proposed antenna.

A circular- shaped dumbbell DGS of 14x 1 mm and circles of radius is chosen as the defect element on the ground plane forming dumbelled shaped in ground plane as illustrated in Fig 3. By controlling the dimensions of T-shaped rectangular slots placed on the two edges of the radiating patch along with DGS, the antenna work at multibands. The antenna consists of two similar T-shaped slits with length 7 mm and width 1 mm at a spacing of 0.5 mm from the side. The optimized slot with one more rectangular slot of 10.5 x0.5 mm of and are placed at the center of broad dimension of the patch. The dumbbell DGS with radius 4 mm is carved on the middle of the ground plane.

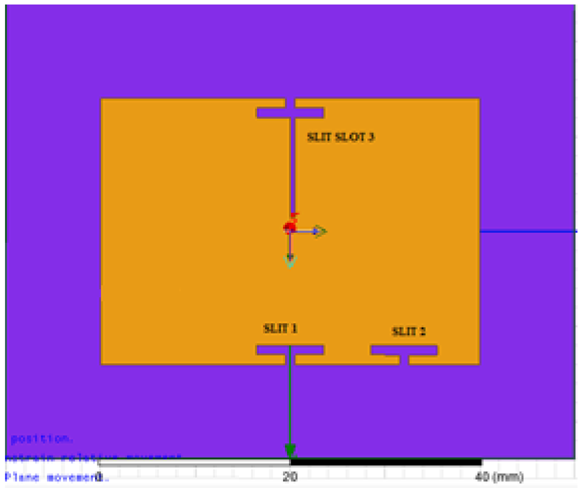

Fig. 2 Proposed and simulated design.

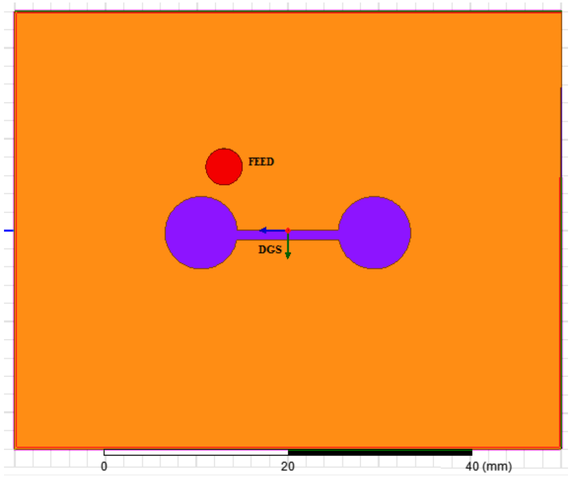

Fig 3 Ground dumbbell shaped structure.

III. SIMULATION AND RESULTS

The simulation of micro-strip patch antenna is done by using HFSS simulation software. The variations of return loss with frequency of rectangular patch antenna with a single slot shaped, with second slots, with third and proposed final with all four slots. The return loss is stated as the ratio of the Fourier transform of the incident power and the reflected power. It is an important parameter to decide the usage of antenna in wireless application.

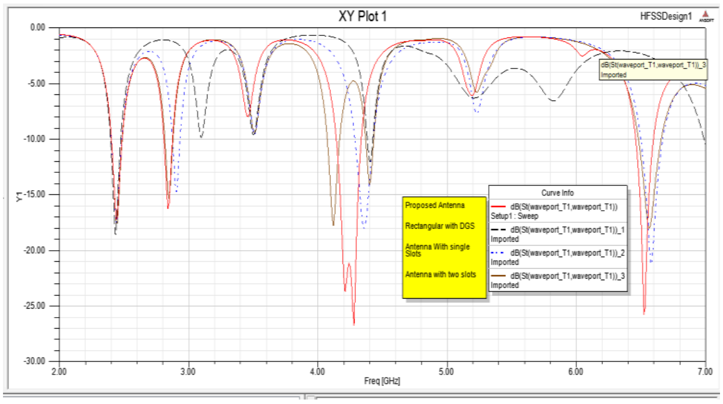

Figure 4: Return loss Vs Frequency curve for designs

The simulated results are shown in Table I for all three designs.

Table I Simulated Results for two slot antenna.

Results	F 1 2.2GHz	F2 2.8 GHz	F3 4.28 GHz	F4 6.5 GHz
S_{11}	-17.4 dB	-16.64dB	-26.2 dB	-25.2dB
VSWR	1.27	1.11	1.67	1.11
Directivit y	2.25 dBi	1.5 dBi	2 dBi	2.5 dBi
B/W	80 MHz	70 MHz	200 MHz	150 MHz

The simulated reflection coefficient of the proposed antenna is shown in Fig. 4. The measured 3-dB beamwidth of radiation patterns for the proposed antenna varies in between 70 –200. The radiation patterns of the proposed antenna are almost bidirectional.The proposed antenna may be used in bidirectional radar. The simulated directivity of the proposed antenna are shown in Table I. The measured peak gain of the antenna is about 2.5 dBi. The gain of the antenna is measured using standard- gain antenna procedure. The standard-gain

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horn antenna is used as a reference antenna for measurement. The probe feed technique is chosen due to its direct contact mechanism with the antenna, and mainly of the feed is isolated from the patch, which minimize unauthentic radiation. The probe point is selected on the diagonal of the radiating patch to match four bands constantly. Through simulations, the position and dimensions of the slots are optimized for multiband operation.

By varying the dimensions of the dumbbell-shaped, the resonant frequencies may be shifted by changing the length and width of the patch. With addition of DGS, the current distribution gets disturbed and influences the impedance and current flow of the antenna. It can also be control electromagnetic waves which is propagating through the substrate layer. Dumbbell-shaped corners on the DGS introduce excitation of multi-resonant modes accompany with good impedance over the operating bands. Though, the gain of the antenna is reduced for the antenna structure when DGS is apply to a conventional patch antenna. It is significance mentioning that the geometry of the ground plane also affect the characteristics of the antenna.

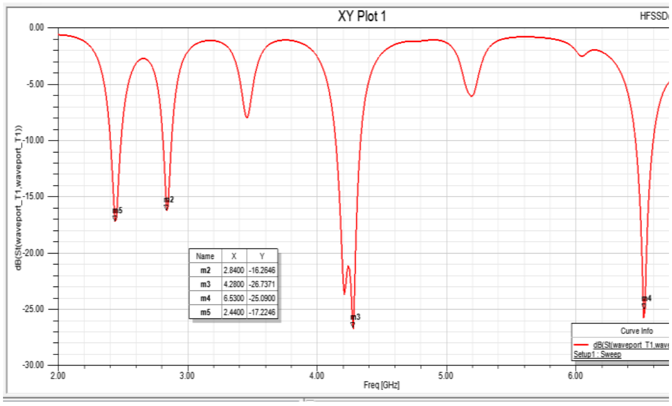

Fig.5 Return loss Vs frequency

Table I provides the results of proposed antenna to the existing probe-feed multiband planar antennas in the available literature. The presented antenna gives with a slight decay in the measured gain. The variation in the length of the DGS slot would seriously affect the impedance matching, whereas less change is seen for the first and second operation bands. DGS show a vital role in shifting the frequencies and improving bandwidth for the working bands. Miniaturization of the antenna is obtained by introducing DGS and with a change in the resonant frequencies.

The antenna radiates robustly for four resonant modes in the broadside direction. Moreover, the antenna has separate broadside radiation patterns at all the four bands.

IV. CONCLUSION

Slotted microstrip patch antenna with optimized ground plane is presented in this paper. Multiresonant wideband operation is achieved by changing the ground plane of the proposed antenna. Furthermore, good radiation pattern characteristics with almost stable gain and acceptable amount of 3-dB beamwidths are also obtained for the proposed antenna. The antenna could be promising for a number of modern wireless communication systems such as INSAT (4.5–4.8 GHz), WLAN/WiMAX (2.25–2.85 GHz), HiperLAN (6.47–6.725 GHz), wireless application bands due to its low cost, light weight, compact size, and wide operating bandwidth.

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