An Analysis of Modified Scarecrow Antenna with Boat Shaped Ground

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Abstract *– In this article, an analysis of modified version of the Scarecrow antenna with boat shaped ground for wideband application is presented. The proposed monopole configuration consists of composite shaped radiating element and truncated ground plane which is modelled on FR-4 substrate ($\tan(\delta)=0.02, \varepsilon_r=4.3$)The overlapping and tuning of resonating modes is achieved by augmenting composite slot on top edge of the boat shaped ground plane. The electromagnetic energy is delivered to radiating patch through the feed line which is connected with SMA connector. The proposed antenna has exhibited the fractional bandwidth of 128.76 % from 1.3 GHz to 6 GHz for $|S_{11}|<-10$ dBwith resonating frequencies 1.53, 2.45, 3.47, 4.85 and 5.54 GHz. To predict electromagnetic behavior of the antenna, structural parametric analysis is also carried out with the help of CST Microwave Studio.*

***Keywords**: Impedance Bandwidth, Hybrid slot, Resonating modes*

I. Introduction

Printed monopole antennas have received valuable attention in wireless technology because of their attractive characteristics like wide impedance bandwidth and far-field pattern. Apart from these features, monopole antennas also exhibit characteristic like easy integration with microwave circuitry, small volume and cheap fabrication cost [1-2]. Fractional bandwidth of the planar antenna depends on tuning and overlapping of the resonating modes which is achieved by proper selection of geometry of the slot, radiating patch and feed structure [3]. In printed antennas, slot introduces the slow wave effect that alters the phase velocity ($v_p=1/\sqrt{LC}$) of the resonating modes (TM_{10}, TM_{01},$T_{12}$and TM_{20}) by changing the value of inductance (L) and capacitance (C) [4-6]. In addition, bandwidth of printed monopole antennas can be altered by reshaping of feed structure which is responsible for tuning of resonating modes [7-10]. Apart from above mention techniques, shape of radiating structure changes the fractional bandwidth of the monopole antennas because it changes the mutual coupling with ground plane. Some reported shapes are theta shaped, cross shaped, ring shaped and hybrid shaped [11-14]. Truncation of ground plane introduces the capacitive effect and generates new edges for fringing [15]. Such truncation improves the impedance matching throughout the frequency band. By adding the shorting stub [16] and flaring the arm of the ground plane [17],

the bandwidth of the monopole antenna can be also enhanced. In this communication, we present modified Scarecrow antenna [18] with boat shaped ground plane for wideband application. The radiating patch of Scarecrow antenna has been modified by adding small elliptical shape element while ground plane is amended by adding four triangular slots and elliptical slot. For bandwidth improvement, a hybrid elliptical slot (combination of two elliptical slots) is loaded on top edge of the boat shaped ground plane. This structure covers the bandwidth of 128.76% from 1.3 GHz to 6 GHz for $|S_{11}|<-10$ dB.

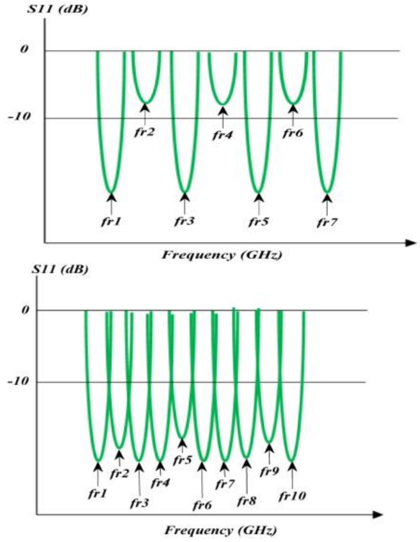

Fig. 1 Schematic of overlapping of modes a) Before tuning, b) After tuning of modes.

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II. Antenna Configuration

The physical geometry along with parameters of the proposed modified Scarecrow shaped antenna is shown in figure 2. The optimized dimensions are listed in table 1. The proposed antenna is fabricated on FR4-epoxy substrate ($\tan(\delta)=0.02, \varepsilon_r=4.3$ and h=1.6 mm) which is placed on Z=0 plane. The overall volume of antenna is $85\times70\times1.6$ mm^3. A hybrid radiating patch (Combination of two elliptical elements) and feed line have been printed on top of the dielectric layer. For bandwidth improvement, two elliptical shaped slots have etched on partial ground plane. These slots introduce capacitive effect and control the impedance bandwidth of the antenna. Further, four triangular shaped slots are truncated on the corners of the partial ground plane for impedance matching. These triangular slots improve the VSWR characteristics in frequency band 1 to 6 GHz. The radiating structure is excited by optimized feed line which is connected with inner conductor of sub-miniature version A (SMA) connector. In numerical analysis, the radius of inner and outer conductor is taken 0.7 mm and 0.02 mm respectively. In simulation, we have taken 0.035 mm thin conducting layer and the structure is excited by wave guide port.

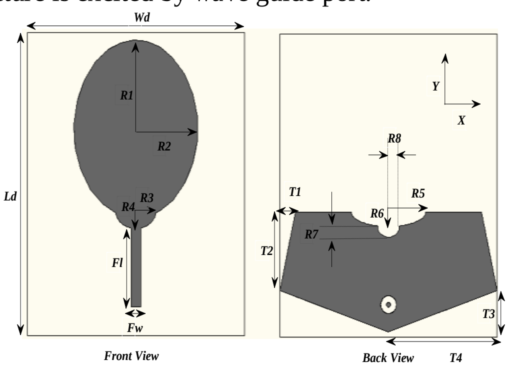

Fig. 2. Geometry of modified Scarecrow antenna (a) Front view, (b) Back view.

Table 1. Structural parameters and dimensions of modified Scarecrow antenna.

Parameter	Dimension (mm)	Parameter	Dimension (mm)
F_l	23	R_5	12
F_w	3	R_6	4
R_1	25	R_7	3
R_2	20	R_8	3.5
R_3	6.5	T_1	5
R_4	5	T_2	22
L_d	85	T_3	13
W_d	70	T_4	35

III. Development of the Modified Scarecrow Antenna

The Evolution of modified Scarecrow shaped antenna and compared frequency response characteristic are displayed in figure 3 and 4 respectively. Antenna 1 consists of hybrid radiating patch, feed line and partial ground plane. After numerical analysis, this structure shows poor impedance bandwidth in entire spectrum (1 to 6 GHz) due to less mutual coupling between patch and ground plane or due to dominating inductive nature of the antenna. Slots play prominent role in printed antenna. They introduce capacitive effect and modify the value of inductance and capacitance of the antenna. For proper impedance matching, an elliptical shaped slot has incorporated in antenna 2 which nullify the inductive nature of the antenna. Antenna 2 exhibits dual band response (1.3 to 3.65 GHz and 4.54 to 6 GHz for $S_{11}<-10$ dB). Bandwidth of the antenna depends on the proper tuning and overlapping of the resonating modes. Slots also introduce slow wave effect and alter the phase velocity of the resonating modes. In antenna 3, a small elliptical slot is truncated on the circumference of the previous elliptical slot that suppresses the notched frequency band from 3.65 to 4.54 GHz. This antenna covers the frequency range from 1.3 GHz to 6 GHz for $S_{11}<-10$ dB. Further, four triangular shaped slots are etched at the corners of the partial ground plane of the antenna 4. These triangular slots lower the value of VSWR. Antenna 4 (proposed) exhibits five resonating frequencies (1.53, 2.45, 3.47, 4.85 and 5.54 GHz) and covers the frequency range from 1.3 GHz to 6 GHz for $S_{11}<-10$ dB with the fractional bandwidth of 128.76 %.

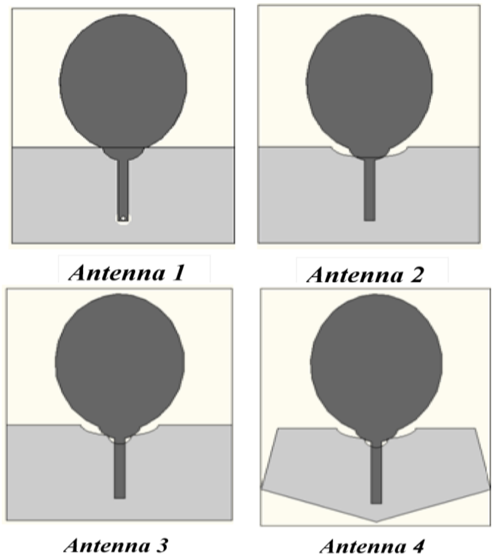

Fig. 3. Schematic of development of modified Scarecrow antenna.

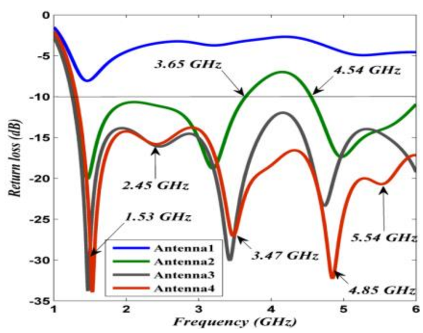

Fig. 4. Compared frequency response characteristics of antenna 1, 2, 3 and 4.

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IV. Results and Discussion

IV.1 S_11 characteristic

The S_11 characteristic of proposed antenna has been simulated through CST Microwave Studio in frequency range from 1 GHz to 6 GHz. Figure 5 represents the simulated S_11 characteristics. The proposed antenna has exhibited the fractional bandwidth of 128.76 % from 1.3 GHz to 6 GHz for |S_11 |<-10 dBwith resonating frequencies 1.53, 2.45, 3.47, 4.85 and 5.54 GHz. Fringing fields are responsible for radiation from the patch antenna. Because of fringing fields electrical dimension of the printed antenna is increased. Lower edge frequency of the proposed antenna is estimated by following equations [19].

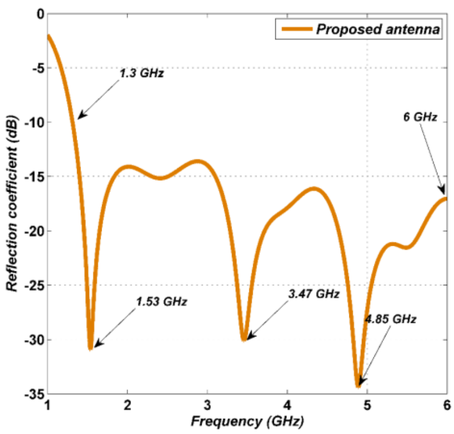

Fig. 5. Frequency response characteristics of proposed antenna.

$$f_l = \frac{72}{(L + r + p)k}\ GHz \quad (1)$$

$$L = 2 * R_1 + R_4 \quad (2)$$

$$r = \pi(2 * R_1 + R_4) * (R_2)/(2 * (2 * R_1 + R_4)) \quad (3)$$

Where L is total length of the monopole and the calculated value of it is 53 mm. r is radius of cylindrical monopole which is equal to 5 mm. P is the feed gap which is equal to zero for proposed structure and k=1.15, which is constant. The calculated value of Lower edge frequency is 1.079 GHz. An error of 17 % has been estimated by equation 4 between calculated (1.079 GHz) and simulated (1.2 GHz) lower edge frequency.

$$E\ (\%) = \frac{f_{l\ simulated} - f_{l\ calculated}}{f_{l\ simulated}} * 100 \quad (4)$$

IV.2 Input Impedance

Figure 6 illustrates the variation of input impedance (Z_in) of the modified Scarecrow antenna that varies with respect to frequency. Simulated real part of the input impedance (Z_in (Real)) is oscillating around 50Ω while Imaginary part of the input impedance (Z_in (imaginary)) (Measured and simulated) fluctuates around 0Ω.

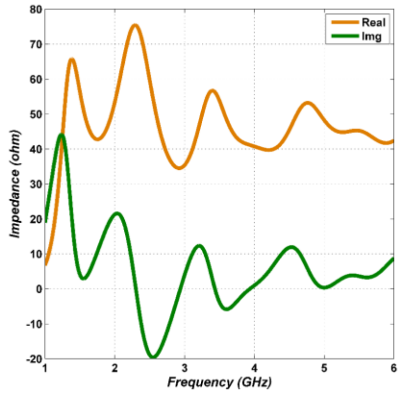

Fig. 6. Impedance characteristics of proposed antenna.

IV.3 Radiation Pattern

The far field pattern of modified Scarecrow antenna is displayed in figure 7. At resonating frequencies 1.53, 3.47 and 4.85 GHz, the radiation patterns have been simulated in y-z plane and x-z plane. Omni-directional pattern has been measured at frequencies 1.53 GHz in y-z plane. Due to presence of higher order modes radiation pattern is altered. At frequency 3.47 and 4.85 GHz, omni-directionality has been vanished which confirms that the existence of higher order modes.

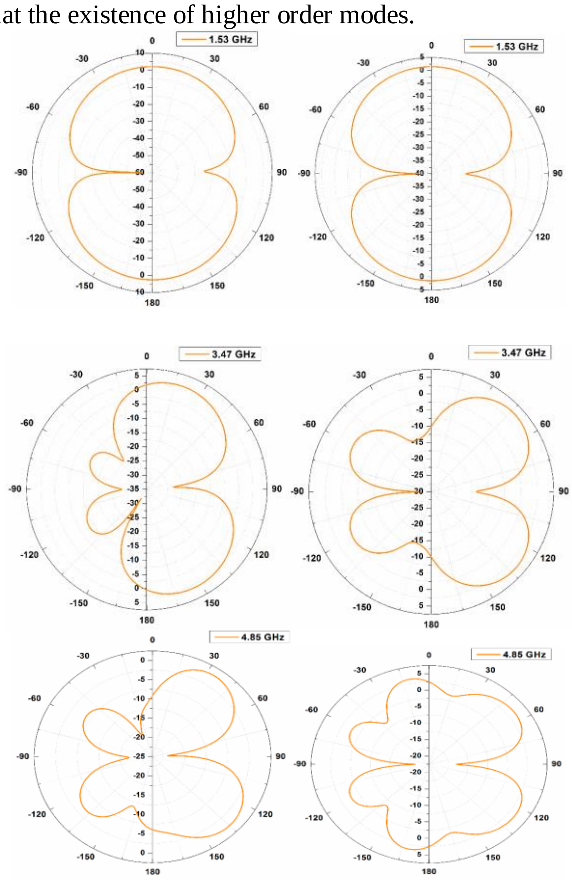

Fig.7. E plane (left) and H plane pattern at frequencies 1.53 GHz, 3.47 GHz and 4.85 GHz.

V. Conclusion

A modified version of Scarecrow antenna with boat shaped ground has been studied. It has been investigated that wide band property of the antenna depends on geometry of hybrid slot which is truncated at top edge of the ground plane. This topology offers the fractional bandwidth of 128.76 % from 1.3 GHz to 6 GHz for |S_11 |<-10 dB with resonating frequencies 1.53, 2.45, 3.47, 4.85 and 5.54 GHz. The far field pattern has been studied in X-Z and Y-Z plane. The distorted radiation patterns are found at frequency 3.47 and 4.85 GHz due to existence of higher order modes.

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