Multi-segment Printed Monopole Antenna for Multi- band Wireless Communication

Sumana Kumari[1] and Nisha Gupta[2]

Abstract- **A novel planar monopole antenna capable of multi-band operation is proposed. The proposed antenna has eight segment planar rectangular radiation patches placed on a baseline segment, fed by a CPW-feed. The proposed structures cover the useful bands such as IEEE 802.11 a, b, etc. Details of the proposed design along with the simulation and experimental results obtained are presented and discussed.**

Keywords – **Co-planar waveguide feed, Multi-band Wireless, Scan angle, Reconfigurable antenna, Reflection Coefficient.**

I. INTRODUCTION

There is an ever growing demand of reducing antenna area due to the space constraint on the PCB while maintaining or increasing bandwidth. High-performance miniaturized front-end printed circuit board antennas are essential in portable wireless devices for the development of wireless local and personal area networks. In addition, in view of the limited power availability on such devices, the antennas must be highly efficient in order to achieve power saving. Because of their simple structure, broad bandwidth, omni directional radiation properties, and easy fabrication, an effective antenna for this purpose is a quarter-wave monopole collapsing on the PCB [1-8].

This paper presents several multi-band, compact, lightweight and low-cost planar monopole antennas suitable for applications in the wireless local area network (WLAN) and mobile communications. Since the antenna is printed on a substrate, it can be easily integrated with the associated microstrip circuits lying on the same plane of the substrate. The antenna has been designed by using IE3D, a full wave MoM simulator [9] from Zeland, USA. The reflection coefficient shows two to four operating frequency bands. The reflection coefficient spectra and radiation patterns are suggestive of reconfigurability in frequency as well as in radiation pattern.

The antenna has been designed with a view to provide flexibility and introduce reconfigurability to the several monopole structures studied and developed in the past, such that the shape of the radiating element could be reconfigured to achieve a particular structure as per requirement or application. The eight segments chosen have a wide flexibility in terms of both symmetrical and asymmetrical structures as it includes all the alphabetical and numeric characters and is easy to reconfigure. Further, the structure dimensions were so chosen such that the frequency response meets the WLAN bands.

II. ANTENNA DESIGN

These antennas are multi-arm antenna fed by a co-planar waveguide (CPW) line which is cross-shaped. Both, lines as well as the ground plane are etched on a low-cost FR4/Epoxy substrate. The radiating element is basically composed of eight segments placed on a baseline radiating element of dimensions 3mm by 13.64mm. The four segments (B, C, E and F) out of the set of eight, have a dimension of 3mm by 8mm, two segments (A and D) are of 3mm by 5.64mm while the other two segments (G and H) have a dimension of 2.32mm by 3mm. A vertical spacing of d=1.24mm is maintained away from the ground plane.

The cross-shaped CPW feed line, designed with fixed signal strip thickness of 3.64mm and two horizontal short strips each with dimension of 10mm by 5mm are placed at a distance of 7.63mm away from the feeding point, is used for exciting the radiating elements and a gap distance of 0.35mm between the feedline and coplanar ground plane is maintained. The two finite ground planes are of width 18.95mm and length 18.42mm and are situated symmetrically on each side of the CPW feeding line. Eleven short connecting metallic strips of dimension 1mm by 1mm, (as shown in Figure 1) are placed between two adjacent radiating segments. With all the strips connected the radiating element represents a digital figure of eight, Figure1.

Thus the several variations of the radiating element, that is, from digit zero through digit nine, are achieved by disconnecting the required strips. On replacing these connecting strips by PIN diodes or RF MEMS the topology of the single antenna structure can be changed by simply switching the required MEMS/diodes. On changing the topology, the resonant frequencies and the direction of maximum gain in the radiation patterns change, thus providing reconfigurable multi-band operations.

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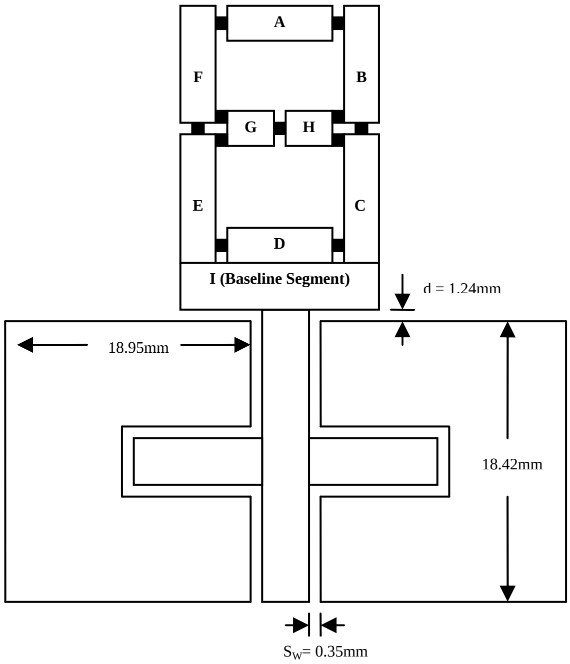

Figure1: Schematic Representation of the Proposed Structure

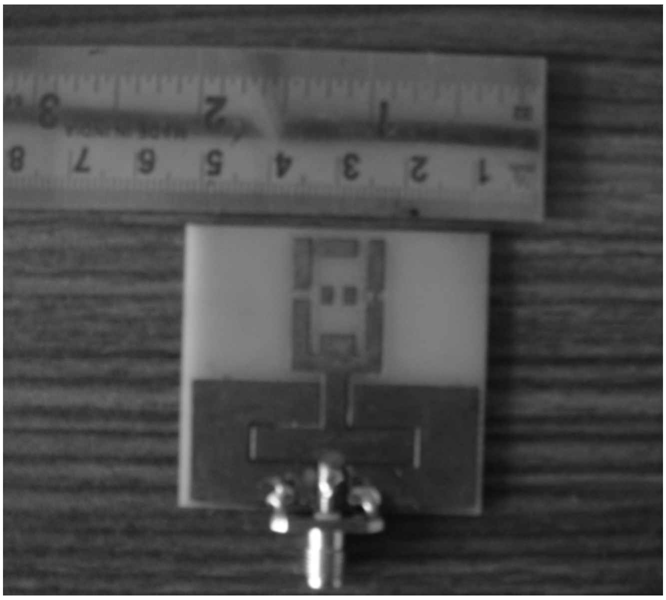

Figure 2: Photograph of the prototype developed for Structure 1.

III. Results and Discussions

The antenna performance was investigated by simulation via a commercially available full wave simulator IE3D [9] by Zeland, USA, based on Method of Moments. To start with the simulations, the first structure under consideration is the figure of digit eight, as it consists of all the segments, A through F interconnected by the short metallic strips and fed by the cross-shaped CPW feedline. Gradually, one or more segments are disconnected from the main structure by eliminating the respective strips and each of the figures, 0 through 9 are simulated. The prototype developed with the structure 1 is shown in Figure 2.

The figures 3-5 show the reflection coefficient characteristics of the structures under consideration. It is seen that the resonant frequencies vary from 2.06GHz to 7.51GHz with the cross-shaped feed. Hence, the desired frequency can be selected by eliminating required the metallic strips to give the corresponding radiating structure. Table I shows the resonant frequencies, reflection coefficients and VSWR bandwidth for each structure. Figure 6 shows the simulated and measured reflection coefficient spectra for the structure 1. The simulated resonant frequencies for the structure 1 are 2.36GHz, 3.57GHz, 5.33GHz and 7.45GHz while the measured response shows the resonant frequencies at 2.63GHz, 3.81GHz, 5.63GHz and 7.18GHz respectively. The error can be expressed as 11.4%, 4.5%, 5.6% and 3.6% respectively.

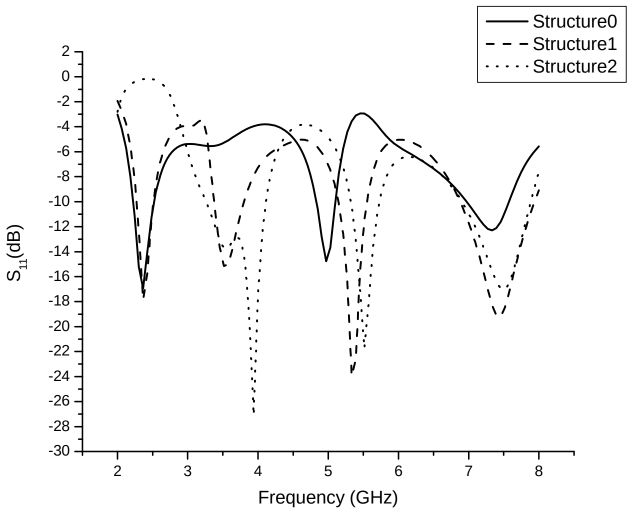

Fig. 3: Reflection coefficients of the structures 0, 1 and 2.

The maximum gain exists at different angle for each structure, except a few repetitions, as depicted by the E-plane radiation patterns and summarized in Table II. The azimuth radiation pattern exhibits omni directional properties for all the structures. The simulated and measured E-plane and H-plane radiation patterns for the structure 1 are exhibited in Figures 7-14.

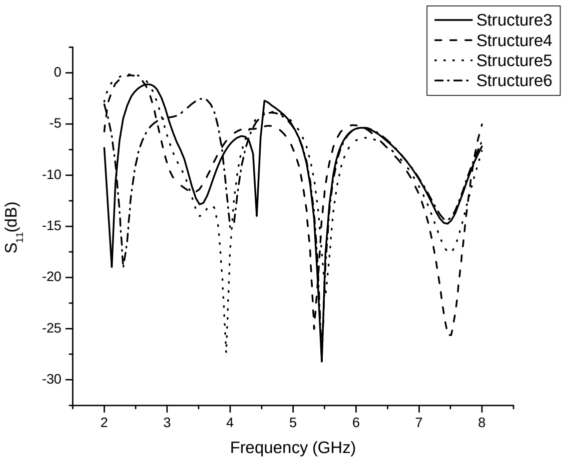

Fig. 4: Reflection coefficients of the structures 3, 4, 5 and 6.

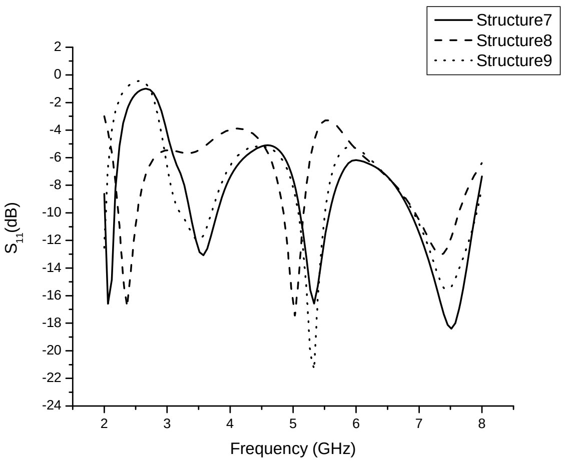

Fig. 5: Reflection Coefficients of structures 7, 8 and 9.

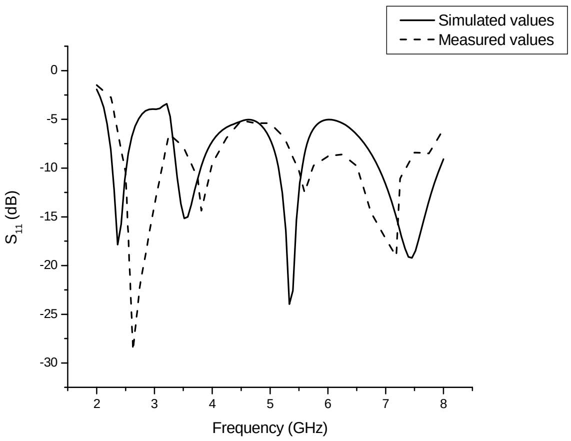

Fig. 6: Reflection Coefficient of the structure 1; simulated and measured values.

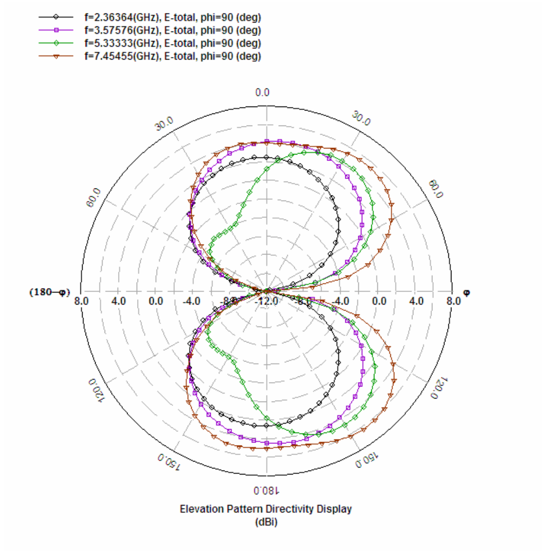

Fig. 7: E-plane Radiation Pattern for structure 1

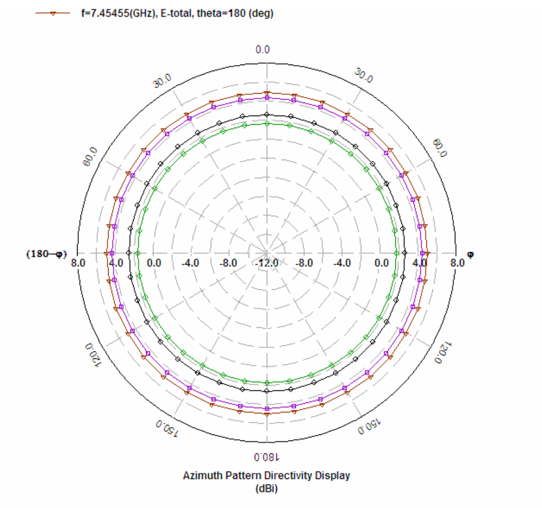

Fig. 8: H-plane Radiation Pattern for the structure 1

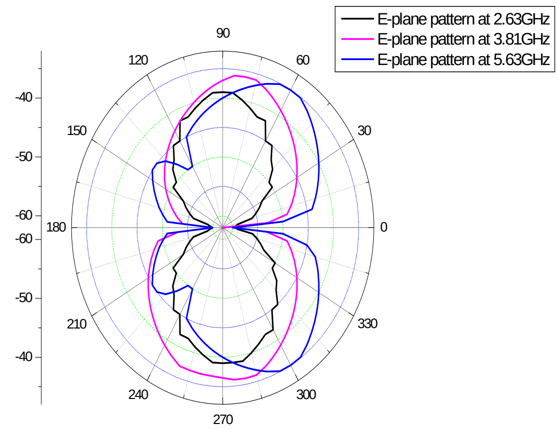

Fig 9: Measured E-plane radiation pattern for the structure 1 with cross-shaped CPW feed at 2.63GHz, 3.81GHz and 5.63GHz.

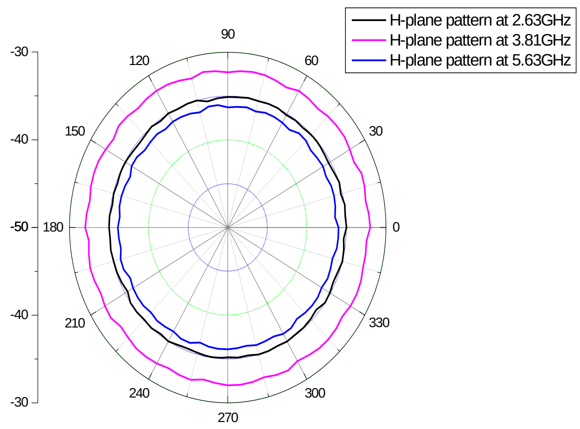

Fig 10: Measured H-plane radiation pattern for the structure 1 with cross-shaped CPW feed at 2.63GHz, 3.81GHz and

IV. Conclusion

A novel low-profile CPW-fed planar monopole antenna suitable for multi-band operation has been proposed. A prototype of the proposed antenna has been successfully implemented. As suggested by the radiation pattern for each set of structures, the antenna exhibits scan angle reconfigurability. PIN diodes or RF MEMS can be attached in place of the inter-segment metallic connection as the inter-segment distance is 1mm by 1mm, which is suitable for placing RF MEMS [10-11]. Then, the frequency or pattern reconfigurability can be achieved by simply switching the required set of switches to form the desired structure.

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Table I: The Antenna Characteristics

Structure	Resonant frequency (GHz)	S_{11} (dB)	VSWR Bandwidth (GHz)
0	2.36 4.96 7.33	-17.8 -16.6 -12.2	0.34 0.37 0.72
1	2.36 3.57 5.33 7.45	-17.6 -15.2 -23.8 -19.2	0.25 0.46 0.43 1.14
2	3.93 5.51 7.51	-27.0 -21.4 -17.1	0.9 0.44 1.07
3	2.12 3.52 4.42 5.46 7.45	-18.9 -12.8 -13.6 -27.3 -14.8	0.17 0.45 0.06 0.43 0.94
4	3.45 5.39 7.45	-11.7 -24.5 -25.6	0.68 0.44 1.04
5	3.93 5.51 7.51	-27.3 -21.5 -17.6	0.89 0.46 1.08
6	2.32 4.06 5.45 7.45	-18.8 -15.0 -27.0 -15.2	0.29 0.27 0.44 0.83
7	2.12 3.57 5.33 7.51	-16.5 -13.0 -16.5 -20.7	0.16 0.48 0.52 1.1
8	2.36 5.03 7.33	-16.7 -17.5 -13.01	0.34 0.36 0.80
9	3.51 5.32 7.45	-12.0 -21.3 -15.6	0.59 0.46 1.08

TABLE II: MAXIMUM GAIN FOR EACH OF THE STRUCTURES

Structure	**Resonant Frequency (GHz)**	**Angle Theta (Degrees)**	**Directive Gain (dBi)**	**Structure**	**Resonant Frequency (GHz)**	**Angle Theta (Degrees)**	**Directive Gain (dBi)**
0	2.36	0/180	2.58/3.2	5	3.93	25/155	3.78/4.02
	4.96	35/145	5.87/6.32		5.51	20/160	3/3.53
	7.33	-5/185	5.73/6.23		7.51	40/140	5.3/6.07
1	2.36	0/180	2.5/3.2	6	2.3	-5/18.5	2.49/2.58
	3.57	10/170	4.49/5.1		4.06	25/155	3.56/3.81
	5.33	30/150	4.6/4.8		5.45	25/155	3.52/3.97
	7.45	45/135	5.8/6		7.45	45/135	4.4/5.08
2	3.93	25/155	3.75/4	7	2.12	0/180	2.35/2.43
	5.51	20/160	3.12/3.6		3.57	0/180	3.58/3.81
	7.51	40/140	5.3/6.1		5.33	30/150	4/4.47
3	2.12	0/180	2.4/2.4		7.51	40/140	4.92/5.65
	3.52	0/180	3.61/3.85	8	2.36	-5/185	2.6/2.67
	4.42	30/150	5.6/5.88		5.03	35/145	5.81/6.16
	5.46	25/155	3.85/4.31		7.33	-5/185	5.82/6.09
	7.45	40/140	5.34/6.06	9	3.5	0/180	3.75/3.95
4	3.45	0/180	3.66/3.8		5.32	30/150	4.78/5.19
	5.39	30/150	4.42/4.82		7.45	-5/185	6.01/6.51
	7.45	45/135	5.71/6.34				