Design of a Novel Broadband Monopole Antenna for UWB Application

S.M. Mazinani, H. R. Hassani

Electrical & Electronic Eng. Dept., Shahed University,
Persian Gulf highway, Tehran, Iran
m_mazinani83@yahoo.com, hassani@shahed.ac.ir

***Abstract*—The Planar Monopole (PM) antenna is shown to provide extremely wideband impedance characteristics. Recently, many techniques to tailor and optimize the impedance bandwidth of these antennas have been investigated. These reported PM antennas have large dimension and their azimuth radiation pattern does not remain omni-directional with changes in frequency. A novel technique to achieve a low profile and broadband omni-directional Planar Monopole antenna is introduced here. This is obtained by loading the simple rectangular planar monopole antenna with a pair of parallel small thin plates placed on the two radiating edges of the PM antenna. The addition of the plates increases the upper edge frequency significantly resulting in a bandwidth of 2.9-16.7GHz. With change in frequency, the antenna produces a good omni-directional pattern with almost stable beam peak position in the E-plane. The local null in the E-plane at θ = 0º, can be cancelled by using a curved ground plane instead of the usual flat ground plane. To improve the impedance matching performance, two pairs of parallel plates can be employed. Details of the experimental and simulation results for the proposed PM antenna are presented.**

I. INTRODUCTION

UWB systems have attracted much attention in recent years, due to their various applications [1]. Many systems operating in UWB require an antenna with good impedance matching, stable and omnidirectional radiation pattern. Among the many candidates reported for UWB [2], Planar Metal-Plate Monopole Antennas have the attractive feature of very wide impedance bandwidth due to their low profiles and easy fabrications. Low profile antennas are particularly interesting for mobile or indoor and public-safety applications.

Recently, many techniques to tailor and optimize the impedance bandwidth of the planar monopole antennas have been investigated. The techniques that have been reported to increase the impedance bandwidth from an experimental point of view can be divided in two groups:

- Changing the geometry of the radiating element: Beveling [3], Shorting Strip [4], employing both of them [5] and the folded structure [6].
- Changing the position of the feed: Offset Feed [7] and Multi Feed [8].

For all the above PM antennas, the size of the antennas is large and the azimuth radiation pattern does not remain omni-directional over all the frequencies.

In this paper, a novel technique to achieve a low profile and broadband omni-directional planar monopole (PM) antenna is introduced. This is obtained by loading the rectangular planar monopole (RPM) antenna with a pair of parallel small thin plates placed on the two radiating sides of the PM antenna. The addition of the plates increases the upper edge frequency significantly resulting in a bandwidth of 2.9-16.7 GHz. The antenna produces a good omni-directional pattern and the local null in the E-plane at θ = 0º which is common to all PM antennas, can be cancelled by using a curved ground plane instead of the usual flat ground. By using double pairs o loading plates the impedance matching of the antenna can be improved. Simulation via software package CST and experimental results on impedance bandwidth and radiation pattern are discussed.

II. ANTENNA DESIGN

Through the study of the current flow on a rectangular planar monopole antenna the antenna can be modelled as a transmission line loaded with the radiation resistance of the antenna [6], as shown in Fig. 1(a). To increase the impedance bandwidth of the transmission line model (TLM), one can add a shunt stub transmission line to the model [9] as shown in Fig. 1(b).

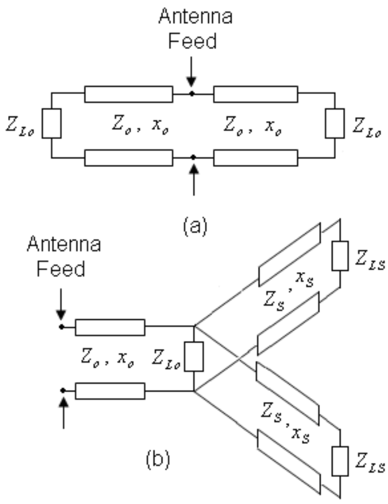

Fig. 1 (a) The transmission line modelling of the simple RPM antenna (b) The TLM of the antenna with shunt stub transmission line

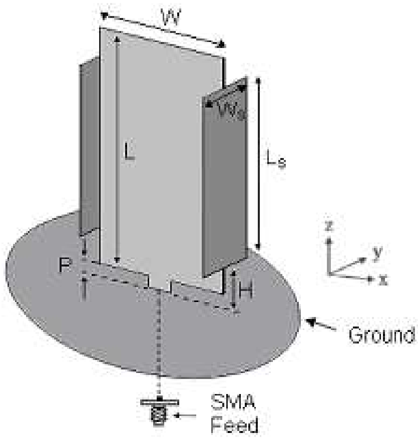

Fig. 2 PM antenna loaded with a pair of rectangular plate

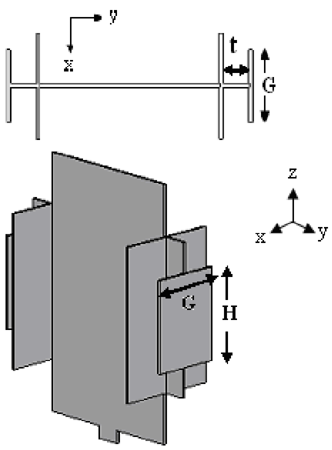

Fig. 3 PM antenna loaded with two pairs of rectangular plates

The TLM shown in Fig. 1(b) can be represented by a rectangular planar monopole antenna loaded with a pair of parallel plates, placed on the two radiating edges of the antenna. The proposed antenna structure and its parameters are shown in Fig. 2. The parallel plates placed on the two sides of the radiating element are determined by two parameters L_S and W_S. Fig. 3 shows the same antenna structure but loaded with two parallel rectangular plates on each side. The dimension of the second loading plate is *H* and *G*. The space between the two loading plates is *t*.

In this paper, the PM antenna is constructed using copper sheet of thickness 0.2 mm, and dimension L = 20 mm and W = 12 mm, placed on a small circular ground plane of radius 50 mm. The feed gap parameter, g, is set at 1mm. A 50 Ω coaxial probe feeds the bottom of the antenna through the ground plane via a 1.2 mm connector.

III. Simulation and Experimental Results

Initially, the simulation results of a simple RPM antenna with dimensions L and W, as stated earlier, is considered. The antenna shows a bandwidth of 2.9 to 5.3 GHz.

TABLE I

Parameters and Bandwidth of the Proposed Antenna

Size of W_S (mm)	Size of L_S (mm)	Bandwidth (GHz)
Without plates	Without plates	2.9 – 5.3
4	12	2.9 – 6.2 , 8.9 – 13.5 , 14.7 – 17.5
6	12	2.9 – 16.7
8	12	2.9 – 15.6
6	10	2.9 – 12.5
6	14	2.9 – 6.7 , 9.2 – 18.5

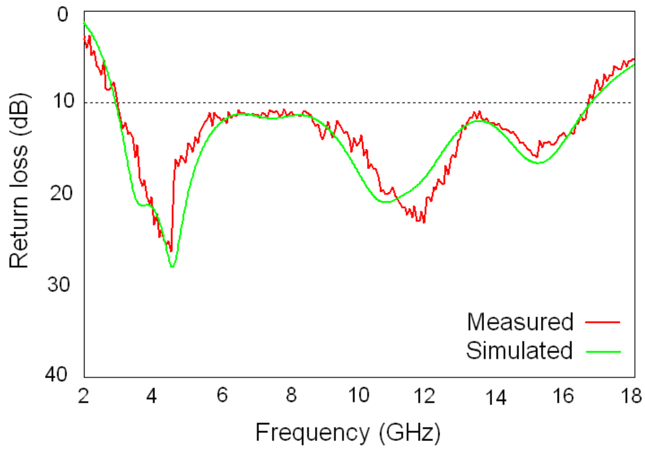

Fig. 4 Simulated and measured return loss of the proposed antenna with W_S = 6 mm and L_S = 12 mm

Then, the effect of the size of a pair of rectangular loading plate L_S and W_S on the frequency of operation and bandwidth are checked and results based on a return loss of 10dB, are listed in Table I. From this table, it is obvious that the size of the loading plate has a pronounced effect on the upper resonant frequency and thus on the impedance bandwidth of the monopole antenna. For various dimensions of the loading plate, L_S and W_S, multiband or wideband behaviour can be obtained. Simulation results show that with a loading plate dimensions of W_S = 6 mm and L_S = 12 mm the upper frequency limit would be 16.7 GHz. A prototype of the proposed antenna with L = 20 mm, W = 12 mm, P = 1 mm, W_S = 6 mm, and L_S = 12 mm have been fabricated and tasted. The simulated and the measured return loss results are shown in Fig. 4 which shows a good agreement between the two.

In Fig. 5, the measured normalized E and H-plane radiation patterns of the proposed antenna at 4, 10 and 16 GHz are shown respectively. In the H-plane, the antenna shows good acceptable omni-directional behaviour at all frequencies. At higher frequencies, in the simple RPM antenna, due to the asymmetry in the configuration of the antenna in the two orthogonal planes omnidirectional pattern is not achievable [10]. Whereas, by adding the loading plates to the RPM antenna much improved omnidirectional radiation

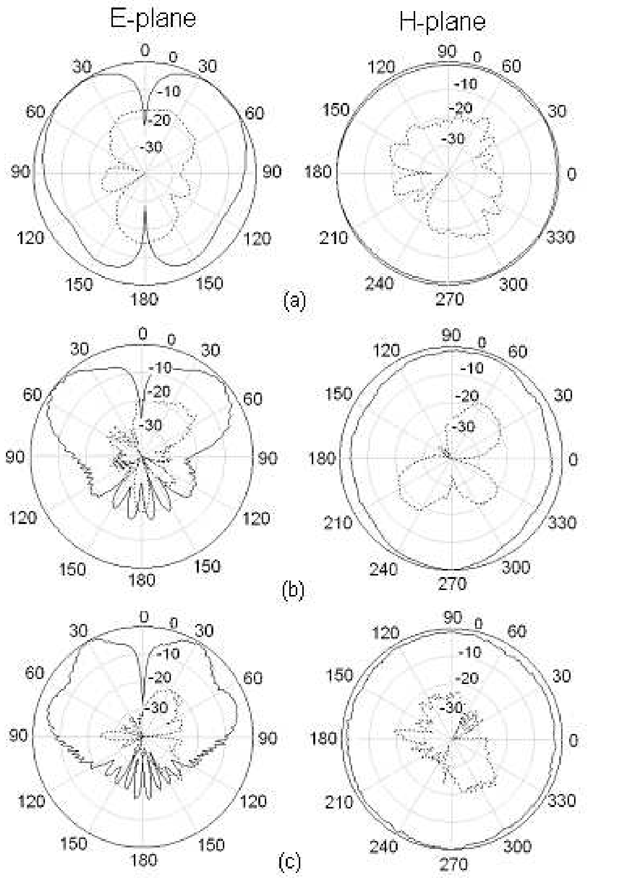

Fig. 5 Measured co-polar (solid) and cross-polar (dash) pattern of the proposed antenna at (a) 4 GHz (b) 10 GHz and (c) 16 GHz

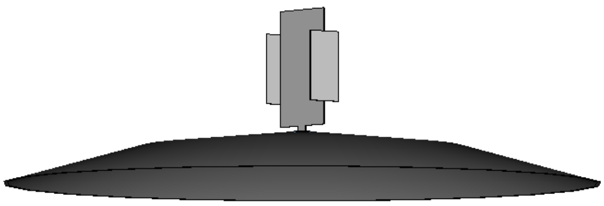

Fig. 6 The proposed antenna on the curved ground plane instead of the flat ground plane

characteristics in the azimuthal plane is obtained. The E-plane radiation patterns are similar to those of the RPM antenna. With increase in the frequency of operation, a dip in the main beam in the E-plane pattern is in evidence. This is due to the large electrical size of the antenna.

The local null in the E-plane at θ = 0º, can be cancelled by using a curved ground plane instead of the flat ground, as shown in Fig. 6. The curved ground is 9 mm in height taken from a sphere of 150 mm radius. The simulated radiation pattern of this antenna is shown in Fig. 7. Return loss of the proposed antenna on curved ground plane is shown in Fig. 8 and compared with the results of flat ground plane. From this result it is seen that the impedance bandwidth of the curved ground plane is slightly higher than that of the flat ground.

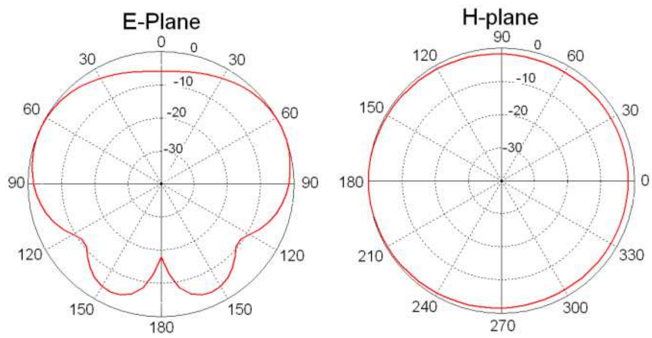

Fig. 7 The simulated radiation pattern of the proposed antenna on curved ground plane with W_S = 6 mm and L_S = 12 mm

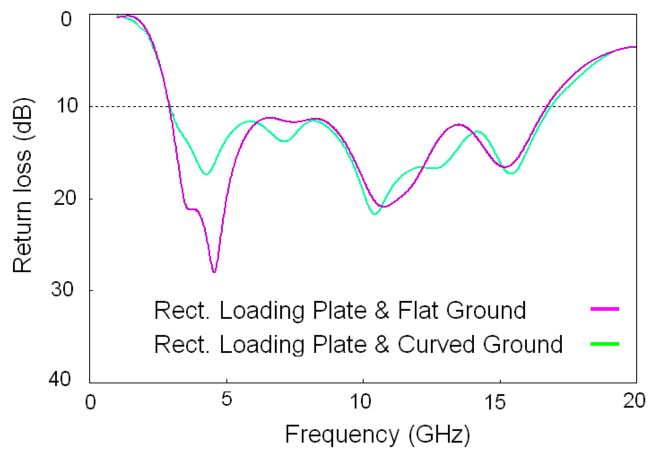

Fig. 8 Comparison of the simulated return loss of the proposed antenna on flat and on curved ground plane

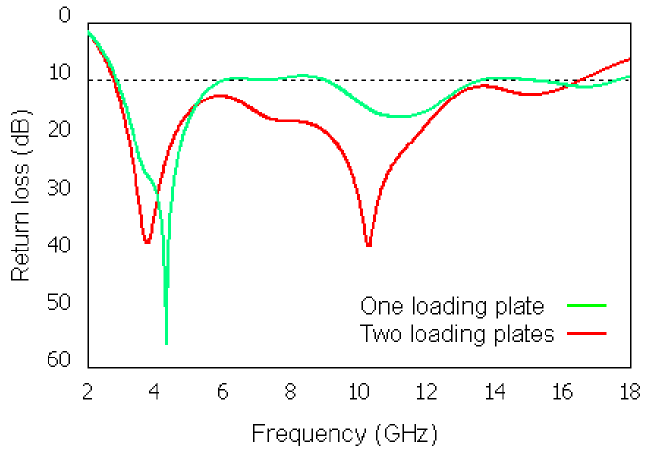

Fig. 9 Simulated return loss of the RPM antenna loaded with one and two pairs plates. W_S = 4 mm and L_S = 12 mm, G = 2 mm, H = 7.2 mm and t = 2 mm

The process of loading the monopole antenna with plates can be repeated to obtain the structure of Fig. 3. The dimension of the initial loading plates are kept as before at W_S = 4 mm and L_S = 12 mm. Through simulation, the dimensions of the second set of loading plates to produce a better impedance matching are found to be G = 2 mm, H = 7.2 mm and t = 2 mm. Fig. 9 shows the simulated return loss for the RPM antenna loaded with one and two pairs of loading plates. Comparing the results it can be seen that the return loss is improved at the expense of lower bandwidth.

IV. CONCLUSIONS

A low profile planar plate monopole antenna loaded with plates at its radiating edges has been proposed. The presence of the loading plates increases the upper resonance frequency and with proper choice of the loading plate dimensions either multi band or very broadband behaviour is achievable. It has been shown that for the rectangular loading plate a bandwidth of 2.9-16.7 GHz is achievable. The null in the E-plane pattern common to PM antennas can be removed through the use of a curved ground plane and the impedance matching of the antenna can be improved through the use of two parallel set of loading plates.

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