Ultra Wideband Square Planar Monopole Antenna with V-Shaped Coupling Elements

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***Abstract*—Planar monopole antennas have many advantages. They are compact, low-profile and low-cost. There are several techniques to increase their bandwidth easily. In this paper, a novel technique to increase the bandwidth of a square planar monopole antenna with V-shaped coupling elements is presented. It is shown that V-shaped coupling elements improve the bandwidth without changing the radiation pattern of the antenna.**

Keywords-antenna; planar monopole antenna; square monopole antenna; wideband antenna; coupling antenna

I. INTRODUCTION

Wireless communication systems operate in a few frequency bands. For example, cellular phone systems operate in 900 MHz, 1800/1900 MHz, as well as 3G (2.1-2.6 GHz) and Wi-Fi (2.4 and 5.2 GHz) frequency bands. In many conventional systems, the above mentioned frequency bands are covered by means of separate narrow-band antennas which may create undesirable situations such as usage of extra space, high cost and unnecessary usage of matching elements. These problems however, are omitted by employing a single wideband Planar Monopole Antenna (PMA) with proper matching units.

Bandwidth of PMAs can be increased by means of many elaborate techniques [1-7] such as beveling [2], shorting the planar element [3], combination of both [4]-[5] and usage of increased number of feed points [6]. On the other hand, adding coupling elements in near-field region of the antenna is a reliable method to increase the bandwidth [7].

Therefore, in this paper, we investigated the effect of V-shaped coupling elements on the bandwidth of a square planar monopole antenna (SPMA). It is shown that usage of V-shaped couplers significantly improves the bandwidth without perturbing the radiation pattern of the antenna.

II. ANTENNA DESIGN

A. Calculation of the Lower Edge Frequency

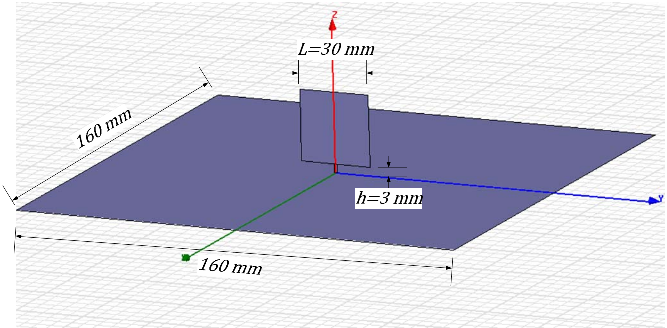
For an SPMA, the lower edge frequency of the bandwidth is given by [8],

$$f_L\,(GHz) = \frac{61.9}{L} \tag{1}$$

where L is the edge length of the square element in mm.

In the first experiment, let us investigate the insertion loss variation of an SPMA over 1-6 GHz. For this purpose, we select the feed gap as $h = 3\ mm$ and the lower edge frequency as $2.0\ GHz$, which yields an L of approximately $30\ mm$. Furthermore, let us use a $160x160\ mm^2$ square ground plane as depicted in Fig.1.

The return loss of the above SPMA is simulated using High Frequency Structure Simulator (HFSS) [9] and the results are shown in Fig. 2.



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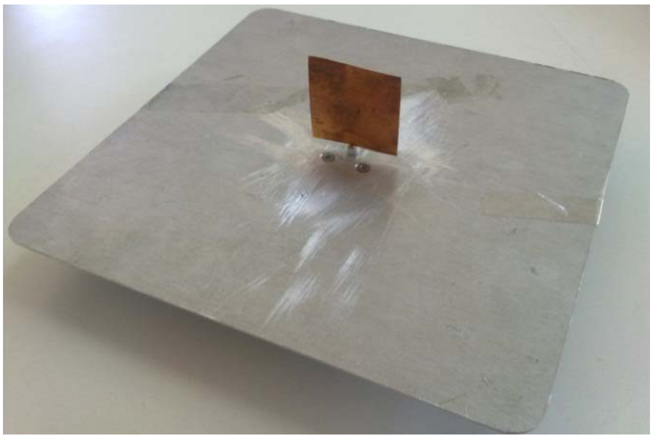

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Figure 1. SPMA: (a) HFSS Layout, (b) Constructed prototype.

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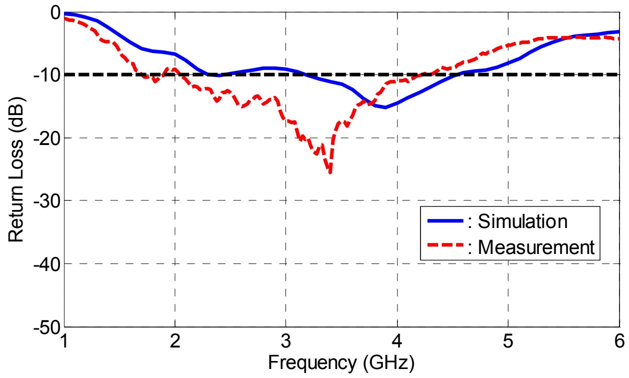
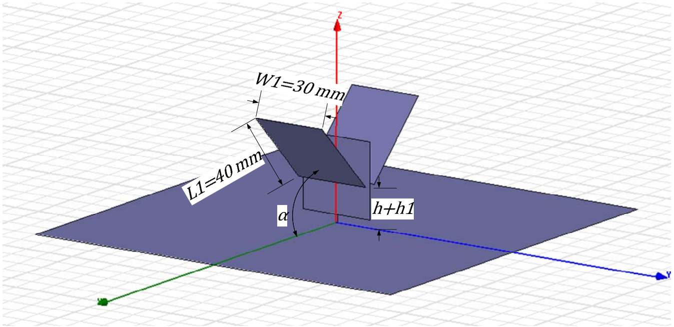


Figure 2. Return loss (in dB) of SPMA.

Measured results indicate that, this SPMA without coupling elements provides less than -10 dB insertion loss over 2-4 GHz which may be accepted as the bandwidth of the plain antenna. Let us now fine tune the bandwidth of the antenna by employing two coupling elements in the near field region to expand the lower edge of the frequency band down to 1.4 GHz as shown in Fig. 3. Stands for coupling elements were made of white foam with relative permittivity of $\varepsilon_r = 1$. Thus, these stands will act as air without perturbing the electromagnetic field pattern of the antenna. Therefore, simulation results are compatible with measurements.



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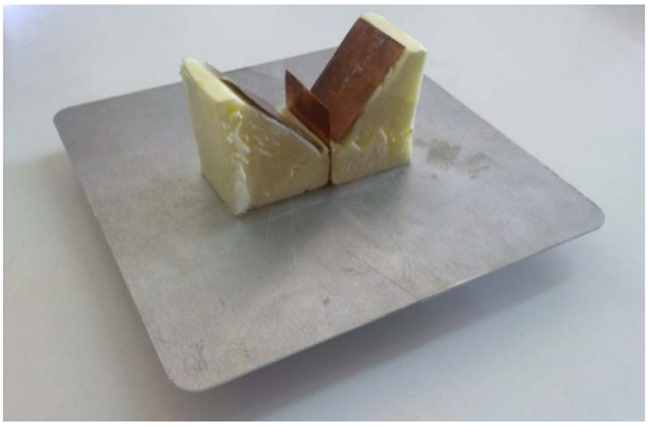


(b)

Figure 3. The SPMA with two coupling elements:
(a) HFSS Layout, (b) Constructed prototype.

B. Effect of Coupling Elements

Copper conductive surfaces of coupling elements are $L1$ *by* $W1$ rectangular plates pasted on white foams.

Referring to Fig. 3, coupling elements are described in terms of 6 parameters. These are given as following:

$L1 = 40\ mm.$
$W1 = 30mm.$
α: The angle measured between coupling element and the ground plane as shown in Fig. 3.
h: The height of the feed-gap.
$h1$: The height of the coupling elements to the feed point.
D: The distance between the bottom edge of the coupling element to the SPMA.

By fixing the rectangular sizes of the coupling elements, the effect of $h1, \alpha,\ h$ and D on the antenna bandwidth is investigated in the following sections.

1) Effect of angle α on the bandwdith

In this section, by fixing $W1 = 30\ mm$,$L1 = 40\ mm$, $h = 3\ mm$, $h1 = 13\ mm$ and the gap distance $D = 3\ mm$, the return loss variation with respect to angle α is investigated over 1-6 GHz; HFSS simulation results are presented in Fig. 4.

As shown in Fig. 4, the best bandwidth is achieved at $\alpha = 45^o$. Hence, we fix α at 45^o and investigate the effect of the remaining parameters on the bandwidth.

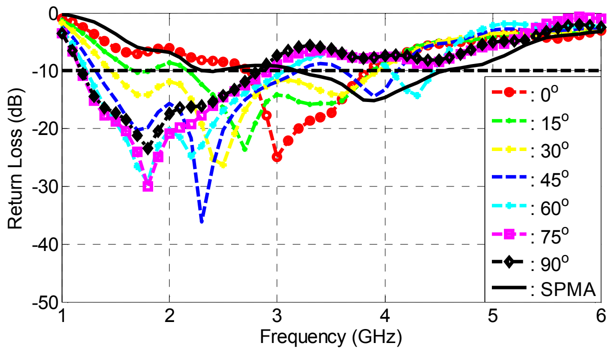


Figure 4. Effect of changing angle α of coupling elements.

2) Effect of feed gap distance h on the bandwidth

In this section, we fix $W1 = 30\ mm$, $L1 = 40\ mm$, $\alpha = 45^o$, $h1 = 13\ mm$ and $D = 3\ mm$ then, investigate the effect of gap distance h on the bandwidth .

As mentioned in [7], the feed gap distance affects the bandwidth of the antenna. Simulation results are given in Fig. 5. The best bandwidth is obtained at $h = 2\ mm$ but we are forced to make it $3\ mm$ due to the physical limitations in practical implementation.

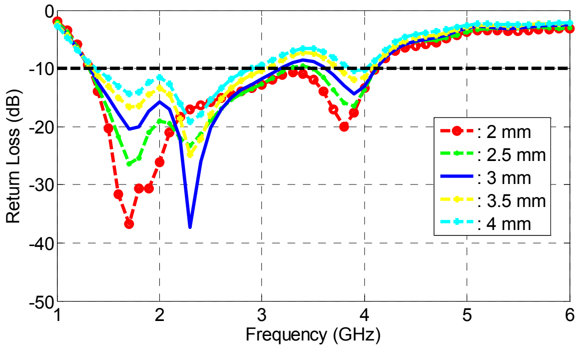


Figure 5. Effect of changing feed gap distance h of square antenna element.

3) *Effect of gap distance D on the bandwidth*

In this section, $W1 = 30\,mm$, $L1 = 40\,mm$, $\alpha = 45^o$, $h = 3\,mm$ and $h1 = 13\,mm$ are fixed then, the effect of D on the bandwidth is investigated. Simulation results are given in Fig. 6. It is interesting to observe that D does not have significant effect on the badwidth. Nevertheless, we fixed it at $D = 3mm$.

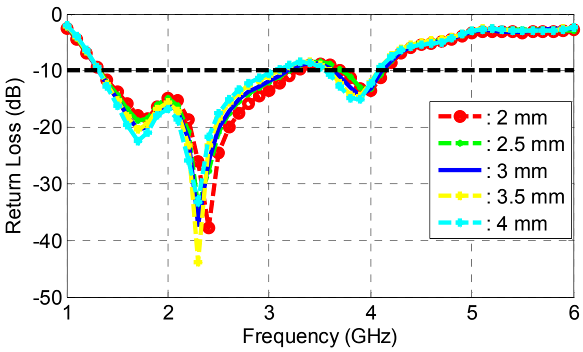


Figure 6. Effect of changing D.

4) *Effect of height $h1$ on the bandwidth*

$h1$ is the height of the coupling elements to the feed gap distance h. Hence, the total height of the coupling elements measured from the ground plane is $h + h1$. In this section we fix $W1 = 30\,mm$, $L1 = 40\,mm$, $\alpha = 45^o$, $h = 3\,mm$ and $D = 3\,mm$ then vary $h1$. Simulation results are given in Fig.7. As we see from Fig. 7, $h1$ does not affect the bandwidth much. For easy practical implementation, we have chosen it as $h1 = 13\,mm$.

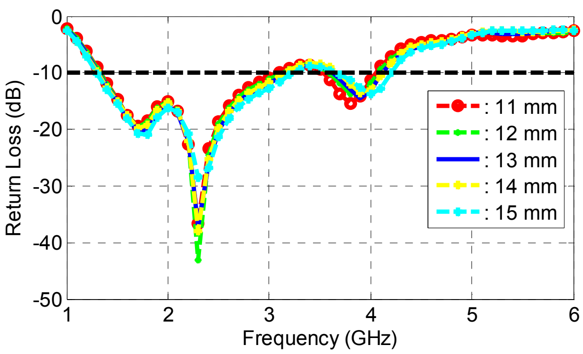


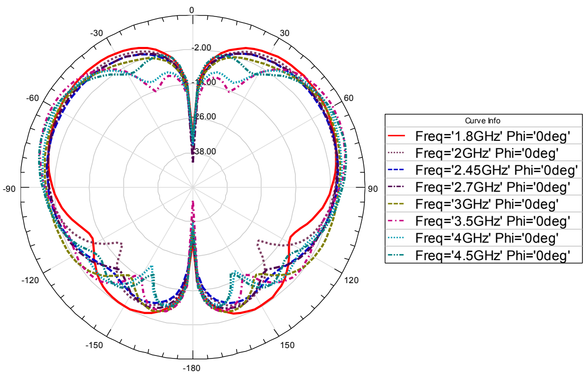
Figure 7. Effect of changing $h1$.

Thus, we end up with the optimum dimensions of $\{W1 = 30\,mm$, $L1 = 40\,mm$, $\alpha = 45^o$, $h = 3\,mm$ and $D = 3\,mm$ and $h1 = 13mm\}$ for the antenna under consideration which yields the best bandwidth of 1.4 to 4 GHz.

C. *Computation of Radiation Pattern*

In this section, the radiation patterns of the antennas are obtained by HFSS with and without V-shaped coupling elements.

For $W1 = 30\,mm$, $L1 = 40\,mm$, $\alpha = 45^o$, $h = 3\,mm$, $h1 = 13\,mm$ and $D = 3\,mm$, radiation patterns of the SPMA are given in Fig. 8 and the radiation patterns of SPMA with V-shaped coupling elements are given in Fig. 9 These patterns are generated on the selected frequencies of $1.8\,GHz$, $2\,GHz$, $2.45\,GHz$, $2.7\,GHz$, $3\,GHz$, $3.5\,GHz$, $4\,GHz$ and $4.5\,GHz$. Close examination of these figures reveals that the V-shaped coupling elements do not have significant effect on the radiation patterns.



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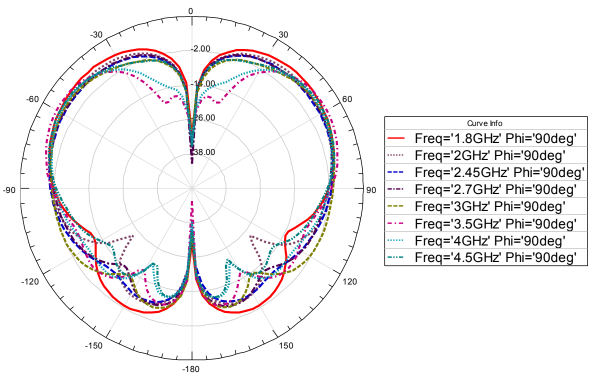
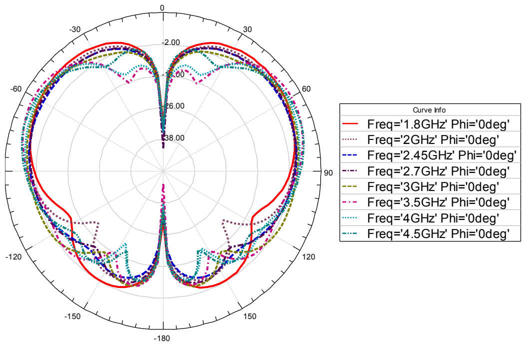


(b)

Figure 8. Radiation pattern of SPMA:
(a) E-Plane (b) H-Plane



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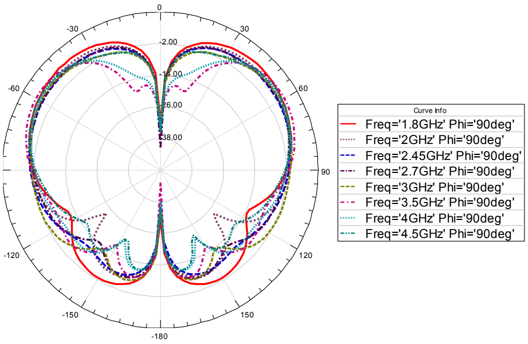

(b)

Figure 9. Radiation pattern of SPMA with V-shaped coupling elements: (a) E-Plane (b) H-Plane

D. *Measurement Results*

The return loss and the gain of the SPMA with V-shaped coupling elements are measured by HP 8510 Network Analyzer. Corresponding measurement and simulation results are compared in Fig. 10 and 11 respectively.

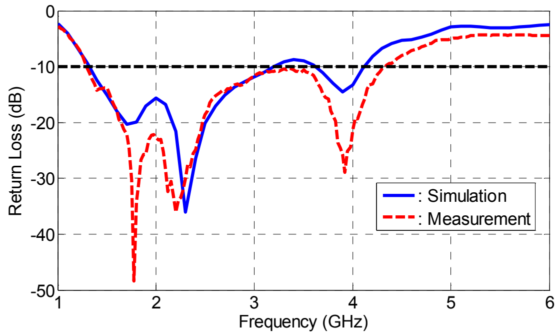

Figure 10. Measured and simulated return loss results.

For the gain measurements, we used 1 kHz bandwidth span with 1 kHz resolution and the video bandwidth is set to 10 kHz. In Fig. 11, the radiation field of the SPMA with V-shaped coupling element at 2.5 GHz is shown. As shown in this figure, antenna is simulated on the $xy\,plane$ (green axis $x-axis$ and blue axis $y-axis$). The simulated and measured gain of the SPMA with V-shaped coupling elements are summarized in Table 1.

TABLE 1. GAIN OF THE SPMA WITH V-SHAPED COUPLING ELEMENTS

Frequency (GHz)		1.5	1.7	2	2.5	2.7	3
Max. Gain (dB)	***Simulation***	3.7	5.1	4	5.1	5.1	4.7
	Measurement	4.6	4.2	5.5	5.2	4.2	5.2

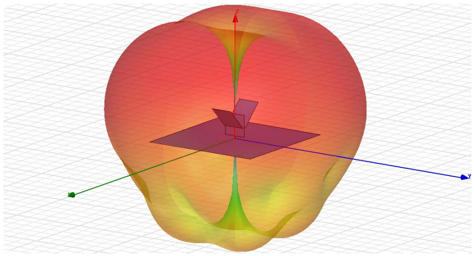

Figure 11. Radiation field of the antenna at *2.5 GHz*.

III. CONCLUSION

In this paper, design of a wideband Square Planar Monopole Antenna with V-shaped coupling elements is presented. Parameters of the coupling elements are optimized over 1.4-4.1 GHz. Bandwidth, gain and the radiation patterns of the antennas are investigated in detail with respect to varying geometric dimensions. It is found that V-shaped coupling elements considerably expand the bandwidth by about 50% at the lower edge of the frequency band. On the other hand, coupling elements do not have significant effect on the antenna gain and the radiation pattern. Furthermore, it has been experienced that the tolerance on the geometric dimensions is pretty robust. Based on our production experience, we expect that manufacturing errors in the dimensions up to 15% will not affect the electrical performance of the antenna.

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