Horse-Shoe ShapedStacked Micro-strip Patch Antenna for WLAN, WiMAX and IMT Applications

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ABSTRACT—

Orthogonal method has been used to synthesis of linear array antenna with Aperture Coupled Microstrip Antenna (ACMA) elements to obtain a shaped beam radiation pattern. The ACMA has been used as the array element because of its wide bandwidth return loss. Also, to achieve the correct excitation for the array elements, mutual coupling between them has been considered in the synthesis procedure. The mutual coupling effect has been shown by comparing the simulation results with and without of this effect in the orthogonal synthesis procedure. Finally, based on the optimum results of the orthogonal synthesis method a suitable feeding network has been designed for the array.

KEYWORDS: orthogonal method; mutual coupling; aperture coupled microstrip antenna; array antenna

I. INTRODUCTION

Because of the advantages of array antennas these configurations are used for beam forming problems in communication systems [1]. Different methods have been used for synthesis and optimization of the array antennas. Many parameters should be considered in the synthesis of the array antennas. One of the most important of these parameters is mutual coupling between thearray elements [2]. Different methods have been applied to compensate the mutual coupling by calculating the coupling coefficients such as Fourier decomposition and so on. In the synthesis of the array antennas the processing time and accurate results are so important. The orthogonal method that is extended and generalized for the synthesis of the array antennas can be used to obtain the excitation of the array elements with considering the mutual coupling to achieve the desired radiation pattern [3]. In the present work, to consider the mutual coupling the E Field radiation pattern of each element in the presence of the other elements (Active P has been obtained from HFSS the active radiation patterns are used to synthesis the array by the orthogonal method to obtain the desired radiation pattern.

II. ORTHOGONAL

Orthogonal method is the technique that use the orthogonally between functions and obtain the excitation of array elements. If the mutual coupling between the elements will not be considered, derivation of the excitation is a simple procedure [3]. To this end, the array factor has the following form: Design of Shaped Beam Linear Aarray of Aperture Coupled Microstrip Antenna by Orthogonal Method , and M. Saberi 2 , Tehran, Iran. Young Researchers and Elite club, Central Tehran Branch, Islamic Azad University, array elements [2]. Different methods have been applied to compensate the mutual coupling by calculating the coupling urier decomposition and so on. In the synthesis of the array antennas the processing time and accurate results are so important. The orthogonal method that is extended and generalized for the synthesis of the array antennas can be used to obtain the tion of the array elements with considering the mutual coupling to achieve the desired radiation pattern [3]. In the present work, to consider the mutual coupling the EField radiation pattern of each element in the presence of the other elements (Active Pattern) has been obtained from HFSS Ansoft. Then the active radiation patterns are used to synthesis the array by the orthogonal method to obtain the desired radiation pattern.

Orthogonal method is the technique that use the orthogonally between functions and obtain the excitation of array elements. If the mutual coupling between the elements will not be considered, derivation of the excitation is a simple procedure [3]. To this end, the array factor has the following form:

$$AF\,(\theta,\varphi) = \sum_{n=1}^{N} I_n e^{j\beta(x_n \sin\theta\cos\varphi + y_n \sin\theta\sin\varphi + z_n\cos\theta)}$$

$$= \sum_{n=1}^{N} I_n \varphi_n\,(\theta,\varphi) \qquad (1)$$

where, (x, y, z) is the position of each element. ϕθ, ϕare the non-orthogonal independent functions. Based on the gramSchmidt theorem [4], ϕθ, ϕ can be used to construct the orthonormalized basis functions Ψθ, ϕas:

$$\Psi_n(\theta,\varphi) = \sum_{i=1}^{N} C_i^{(n)}\, \varphi_i(\theta,\varphi) \qquad (2)$$

$$AF(\theta,\varphi) = \sum_{i=1}^{n} B_i\, \Psi_i(\theta,\varphi) \qquad (3)$$

where

$$B_i = \langle AF(\theta,\varphi), \Psi_i(\theta,\varphi) \rangle \qquad (4)$$

From (4), (3) and (1), the excitation coefficients of the array are determined as [3]:

$$I_i = \sum_{j=i}^{N} B_j\, C_i^j \qquad (5)$$

(A) Orthogonal synthesis Method and Mutual coupling Compensation

For the isolated array elements, the array factor is defined as (6). In which I is the excitation coefficient of nth element when mutual coupling is not taken to account and f θ, ϕis the isolated radiation pattern of the elements. The excitation coefficients will be determined based on the orthogonal method procedure in the previous section, to shape the AF in a desired form.

$$AF(\theta,\varphi) = f^{i}(\theta,\varphi).\sum_{n=1}^{N} I_n^d e^{j\beta(x_n \sin\theta\cos\varphi + y_n \sin\theta\sin\varphi + z_n\cos\theta)} \qquad (6)$$

In the real array antenna the mutual coupling between the array elements affects the radiation patterns of elements and therefore, the radiation pattern of the array. In this case the array factor is defined as:

In which, I is the excitation of each element with mutual coupling consideration and fθ, ϕ is the radiation pattern of each element in presence of the other elements. To use the orthogonally to synthesis the array, the fθ, ϕ is expressed as a sum of independent functions ϕ

(θ, ϕ).

and f θ, ϕ is isolated radiation pattern of the elements and Knm is coupling coefficient. In this case to compensate the mutual coupling effect and to correct the excitation of the elements, it is necessary to calculate the coupling coefficients matrix K. The orthogonal method is used to derive the coupling coefficient between the elements. To calculate this coupling coefficient it is necessary to measure or calculate the radiation pattern of each element fθ, ϕ. In this work, this function is derived by HFSS simulator. By determining the coupling coefficients, compensated excitation coefficients to create the desired radiation pattern can be derived as [5]:

II. ARRAY CONFIGURATION

(A) Array Element

Because of the advantages of microstrip antenna such as light weight, low cost and easy fabrication this antenna have been used widely in communication systems. In this paper the aperture coupled technique is used to excite the array elements [6]. Also to increase the return loss bandwidth, the H shape coupling aperture is used to illustrates the design and performance analysis of proposed stacked horse-shoe shaped micro strip patch antenna. In the proposed stacked antenna design, a rigid substrate having thickness 1.57mm and flexible substrate having thickness 0.2mm has been stacked. In the proposed antenna design, there are total two layers of substrates, where the flexible substrate has been placed on the upper surface of rigid substrate. The rigid and flexible substrates employed in the proposed antenna design are of duroid material having dielectric constant of 2.2. In the proposed antenna design, the rigid substrate has ahorse-shoe shaped patch on the upper surface and a ground on the bottom surface. The performance of the proposed antenna design has been analysed in terms of resonant frequency, impedance bandwidth, VSWR, impedance, return loss, gain and directivity. The proposed antenna design has resonant frequencies at 2.18 GHz and 5.2 GHz having return loss of -22.496dBand - 55.012dB, respectively. The proposed design has two operating bands having operating frequency range of 2.02GHz-2.43GHz and 3.22GHz-6.13GHz. The proposed antenna has been designed and simulated using CST microwave studio 2014. The proposed antenna design can be used for WLAN, WiMAX and IMT applications

Antenna Geometry The proposed stacked horse-shoe shaped micro strip patch antenna has been designed using CST microwave studio 2014. In the proposed antenna design, a 0.2mm thick flexible substrate has been stacked with the 1.57mm thick rigid substrate as shown in Fig. 1. The employed substrates are of duroid material having dielectric constant of 2.2. The top and bottom view of the bottom rigid substrate is shown in Fig. 2and Fig 3, respectively.A horse-shoe shaped patch has been placed on the upper surface of the rigid substrate and a ground has been placed on the bottom substrate of the rigid substrate as shown in Fig. 1.The flexible substrate has been placed on the upper surface of rigid substrate a shown in Fig. 1. The upper and lower surface of stacked flexible substrate has no copper on the upper and lower surface. The top view of the proposed antenna is shown in Fig. 4. The parameters of proposed antennas design are given in Table 1

Fig. 1 Side view of the proposed horse shaped stacked MPA

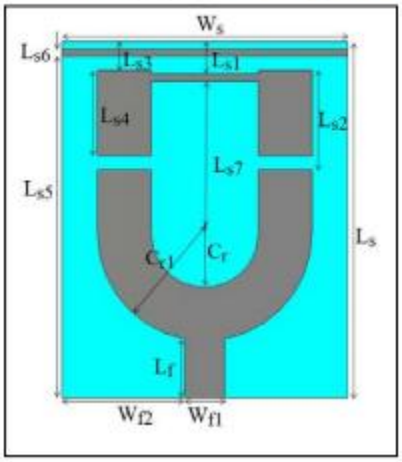


Fig. 2 Top view of rigid substrate

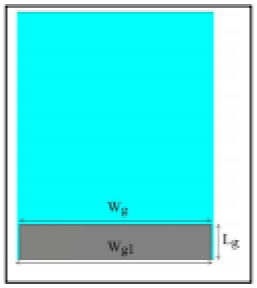


Fig. 3 Bottom view of rigid substrate

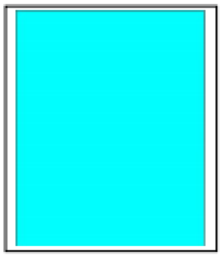
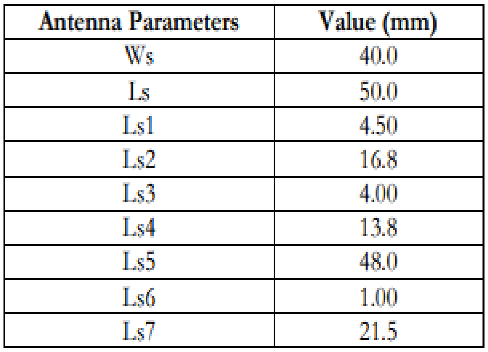


Fig. 4 Top view of the proposed horse-shoe shaped MPA antenna

Table 1. Antenna Parameters



Antenna Parameters	Value (mm)
Ws	40.0
Ls	50.0
Ls1	4.50
Ls2	16.8
Ls3	4.00
Ls4	13.8
Ls5	48.0
Ls6	1.00
Ls7	21.5

Results The performance of proposed stacked horse-shoe shaped micro strip patch antenna has been observed in terms of resonant frequency, VSWR, return loss, directivity, gain, impedance bandwidth and impedance. The proposed antenna design has been designed and simulated using CST microwave studio 2014. The proposed antenna design has two operating bands having frequency range of 2.02GHz-2.43GHz and 3.22GHz- 6.13GHz. It has been observed that 2.02GHz-2.43GHz and 3.22GHz-6.13GHz band has impedance bandwidth of 0.41GHz and 2.91GHz, respectively.

The Fig. 5 illustrates the return loss plot (S11) of the proposed antenna design. It has been observed that the proposed antenna design has resonant frequencies at 2.18GHz and5.2 GHz with return loss of -22.49dB and -55.01dB respectively. It has been observed that the proposed antenna design has gain of 2.75dB and 5.83dB at resonant frequencies2.18GHz and 5.2GHz, respectively. The Fig. 6(a) and Fig. 6(b) demonstrates the 3D plot of gain at 2.18GHz and 5.2GHz, respectively. It has been observed that the proposed antenna design has directivity of 2.42dBi and 5.68dBi at resonant frequencies 2.18GHz and 5.2GHZ, respectively. The Fig. 7(a) and Fig. 7(b) depicts the directivity plot of the proposed antenna design at 2.18GHz and 5.2GHz resonant frequencies, respectively. It has been observed that the stacked horse-shoe shaped micro strip patch antenna has impedance of 49.26 Ω. The Fig.8 demonstrates the smith chart plot of the proposed antenna. It has been also observed that the VSWR value of the proposed antenna design is less than the maximum acceptable value i.e. 2. The Fig. 9 illustrates that the VSWR value of the proposed antenna design lies below 2 within the operating impedance bandwidth.

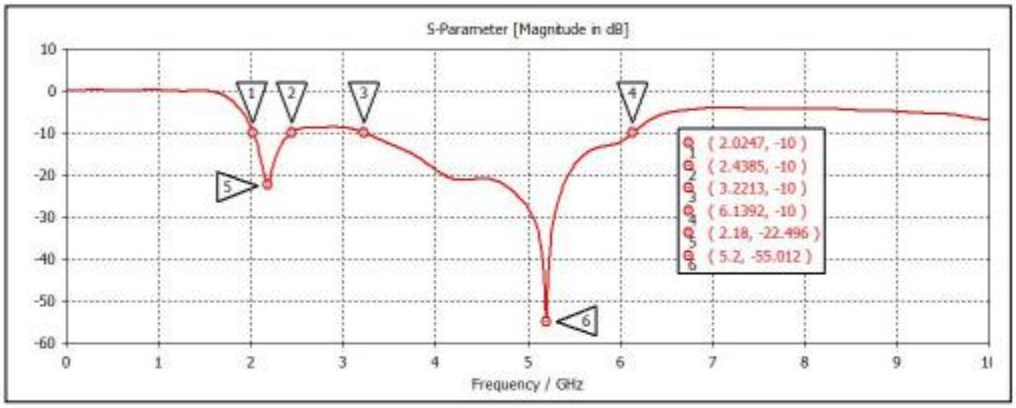


Fig. 5 Return loss plot of the proposed stacked antenna design

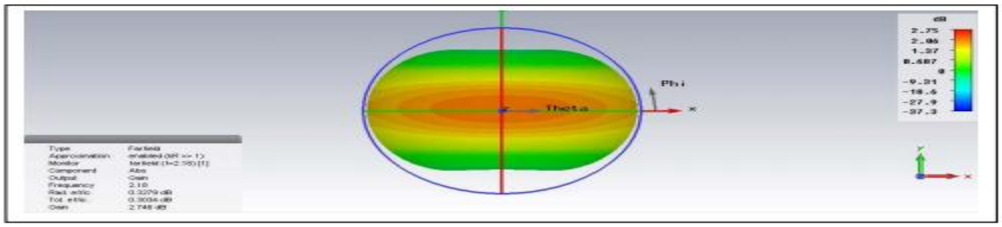


Fig. 6(a) 3D plot of gain of proposed stacked antenna design at 2.18GHz

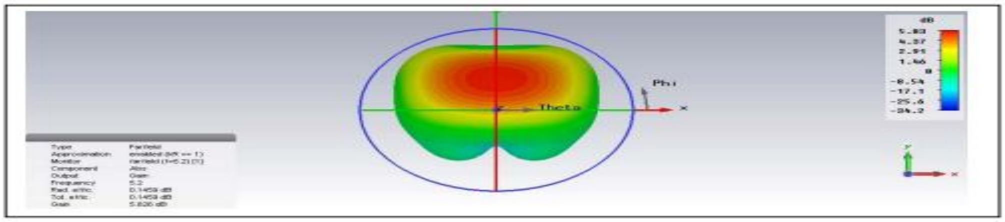


Fig. 6(b) 3D plot of gain of proposed stacked antenna design at 5.2GHz

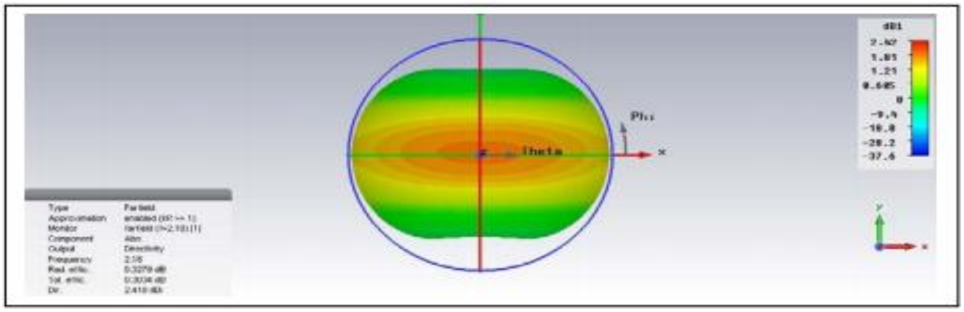


Fig. 7(a) 3D plot of directivity of proposed stacked antenna design at 2.18GHz

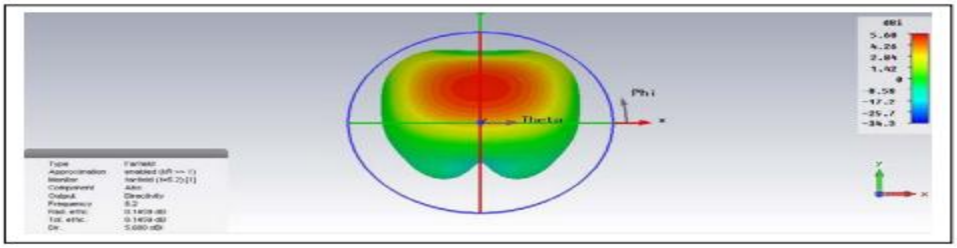


Fig. 7(b) 3D plot of directivity of proposed stacked antenna design at 5.2GHz

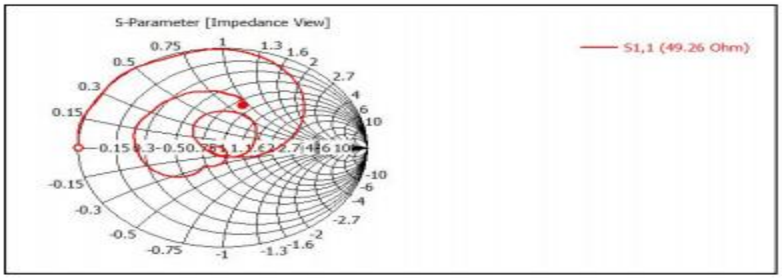


Fig. 8 Smith chart plot of the proposed stacked antenna design

Conclusion

The proposed horse-shoe shaped micro strip patch antenna has designed using CST microwave studio 2014. In the proposed antenna design, the rigid and flexible substrate of duroid material having dielectric constant of 2.2 has been stacked. The rigid substrate has thickness of 1.57mm whereas the flexible substrate has thickness of 0.2mm. The proposed antenna design has two operating bands having operating frequency ranges of 1.94GHz-2.17GHz and 3.91GHz-6.63GHzwithcorresponding impedance bandwidth of 0.41GHz and2.91GHz, respectively. It has been observed that the proposed antenna design has resonant frequencies at 2.18GHz, and 5.18GHz with return loss of -22.49dB and -55.01dB, respectively. The proposed antenna has gain of 2.75dB and 5.83dB at 2.18GHz and 5.18 GHz resonant frequencies, respectively. It has been observed that the proposed design has directivity of 2.42dBi and 5.68dBi at resonant frequency 2.18GHz and5.18GHz, respectively. The proposed design has impedance of 49.26 Ω

Applications

The proposed horse-shoe shaped micro strip patch antenna has operating frequency range of 2.02GHz-2.43GHz and 3.22GHz-6.13GHz resonant at 2.18GHz and 5.2GHz resonant frequencies, respectively. It has been concluded that the proposed antenna can be used for WLAN (5.15GHz-5.35GHz and 5.72GHz-5.82GHz)[11], WiMAX(3.4GHz-3.69GHz and 5.25GHz-5.85GHz)[11] and IMT (2.3GHz-2.4GHz, 3.4GHz-4.2GHz and 4.4GHz-4.9GHz)[11] applications.

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