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STACKED PATCH MIMO ANTENNA ARRAY FOR C-BAND APPLICATIONS

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Abstract- **Microstrip antenna arrays are one of the popular antenna configurations for nowadays wireless communication system. The paper proposes a compact novel design of multiple elements electromagnetically coupled stacked antenna array which operates in C-band. The antenna resonates at 6 GHz and shows bandwidth of 521 MHz with 5.84dBi gain. The proposed antenna shows the ECC to be 0.03 which indicated quite perfect behaviour for the MIMO antenna array system. The proposed MIMO system offers good capacity for data transfer. The simulated results of the antenna in terms of return loss, diversity gain and radiation pattern, capacity of the antenna system is presented in this paper. Simulations are carried out with CST MWS'14 and capacity plots are made using MATLAB R'11b**.

Keywords- **Stacked, Bandwidth, ECC, MIMO, Array, C-band, Return loss, Diversity gain, CST MWS'14, MATLAB R'11b.**

I. INTRODUCTION

The C-band is a widely used microwave frequency band in wireless communication systems including radars, satellite aircrafts, missiles, and in several space borne applications. The IEEE C-band (4 to 8 GHz) and its sub band frequencies are feasible also for modern wireless communication systems including Wi-Fi, Bluetooth, Wi-MAX, WLAN etc. With the increasing demand in the field of modern wireless systems there is a requirement for antennas with omni-directional radiation pattern, low profile, small size, and multiple frequency band operation. In order to satisfy the increasing demand of WLAN and C-band applications the antennas having small size are required. This encourages the usage of the microstrip antennas.

Microstrip patch antennas are appropriate radiating mechanism due to many unique features like compact in nature, light weight, easy manufacturing, low in -profile, ng [1].But it has one limitation of low bandwidth [2].Lot of researches are emphasised on increasing the impedance bandwidth [3]. Conventional antenna behaves like an open resonator having radiation losses. Thus, to achieve greater bandwidth different techniques can be employed. The most popular well known technique follows parasitic patches [5] U-slot technique [4], probe-feeding. One of the best ways to improve the bandwidth is adding parasitic elements which are electromagnetically coupled to the driven patch.

The demand for high spectral efficiency in wireless communication is ever increasing and can be overcome with MIMO system to some extent [6].MIMO system consists of multiple antennas at the transmitter and receiver which create multiple paths for the signal to travel. In a multipath wireless channel, using multiple antennas at both the ends ensures high data rate without an increase in the total transmission power. The capacity of the channel is said to grow linearly with the increasing number of antennas [7].The capacity of the MIMO system is dependent on the channel and the characteristics of antenna. By choosing appropriate array configuration [8] and proper design of antenna elements capacity of the system can be improved. Therefore it is obligatory to study how various array configurations are performing in the MIMO system. To employ stacked antenna in the MIMO systems coplanar patches are etched with both the driven as well as the parasitic patches.

Aim of this paper is to design a stacked antenna array for MIMO system that works in C-band. The paper is arranged as follows section II gives the brief about the MIMO system model. Section III describes the antenna geometry and specifications. Next sections are dedicated to the discussion of the simulated results and the conclusions.

II. SYSTEM MODEL

For this paper we have designed an antenna array that can be deployed at the receiver section. Consider a wireless communication scheme in which multiple antennas are present at the receiver and a single transmitting antenna at the source. An antenna is required at the TX as well as at the RX side for communication to be possible, more than one antenna at either of the two terminals leads to a configuration of a MIMO system.

The block diagram of our system is shown below:

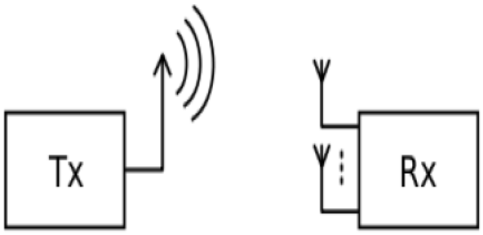

Fig 1. System Model

Mathematical model for this kind of a wireless communication scenario can be rewritten as:

$$y = Hx + n$$

Where H is the channel matrix, $h=[h_1,h_2.........h_{nr}]^T$. Here h_i (i=1,2…nr) represents channel gain between the transmitter and the receiver, n is the noise and x is the signal transmitted. The capacity of the system can be expressed as [9]:

$$C = log_2 \det[I + SNR * H'H]$$

I is Identity matrix of order n given by min (N,M) here M=1 which is the no of transmitting antennas & N=2 the no of receiving antennas. This kind of system is acceptable in many applications of C-band. To allow the antenna to be easily embedded inside the devices used for communication, a MSA is a good choice. The proposed antenna array for such systems is discussed in the next sections.

III. ANTENNA GEOMETRY AND SPECIFICATIONS

The antenna consists of two layers as shown in fig1. The lower substrate consists of array of two patches known as driven patches and the second layer consists of another substrate with two parasitic patches printed over it. The two driven patches are excited respectively with two ports 1 and 2 as shown below. Both substrates are made up of FR4 material having dielectric constant of 4.4 and loss tangent of 0.009.

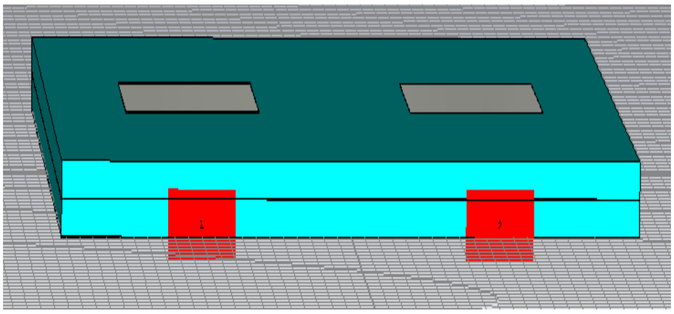

Fig2. Side View of Stacked Antenna

The dimensions of the patches were optimized so that four of the patches resonate at a centre frequency of 6 GHz. Values of the various parameters are calculated using transmission line equations [1].

TABLE 1: Calculated Parameters

Parameter	Calculated Value
Lower patches width	10 mm
Lower patches length	23 mm
Upper patches width	10 mm
Upper patches length	21.34 mm
Feedline width	2 mm
Resonant frequency	6 GHz

IV. RESULTS AND DISCUSSIONS

All the simulations related antenna array designs were carried out using CST MWS'14. All the four patches were optimized for the desired results. The results are presented in this section.

A. Return Loss of stacked antenna with two layers:

The return loss gives the information about how much power is reflected from the antenna and therefore it is called reflection coefficient. Figure 5 shows the return loss of a stacked antenna array. It covers an impedance bandwidth of 521MHz around 6GHz. The dimensions of the patch on the top substrate were optimised such that it covers a frequency close to the resonant frequency of lower patch. This way there is an increase in the bandwidth of the antenna.

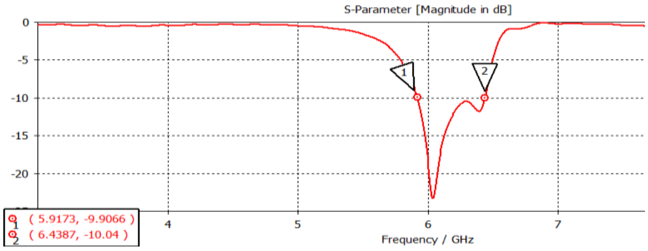

Fig 3. Return Loss (S_{11}) of Stacked Antenna Array

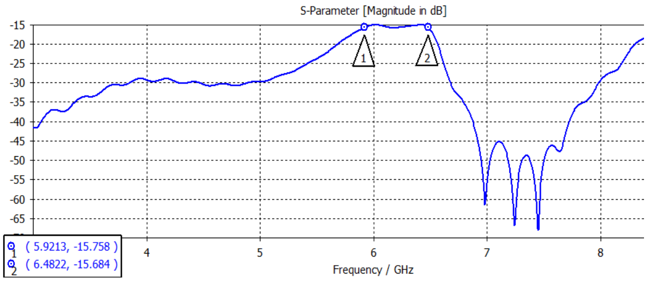

Fig 4. S_{12} of Stacked Antenna Array

S_{12}indicates the power transmitted from port 2 to port 1. From figure 4 it can be inferred that power transferred from port 2 to port 1 is -15dB in the desirable frequency band.

B. Radiation Pattern:

The radiation pattern of an antenna represents its radiation characteristics in a 3D plane. The antenna is energised by exciting the two ports. Fig 4 shows the gain of 5.684 dBi at port 1. And from graph 5 it can be inferred that proposed antenna shows the gain of 5.6dBi for port 2 excitation.

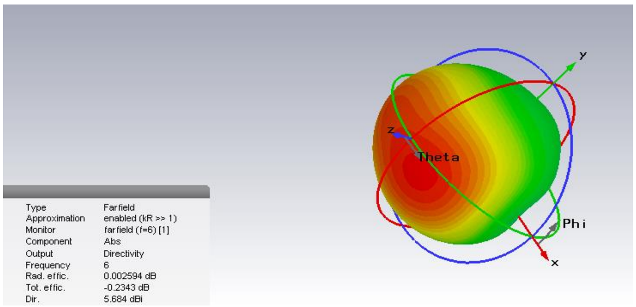

Fig 5. Radiation Pattern at Excitation 1

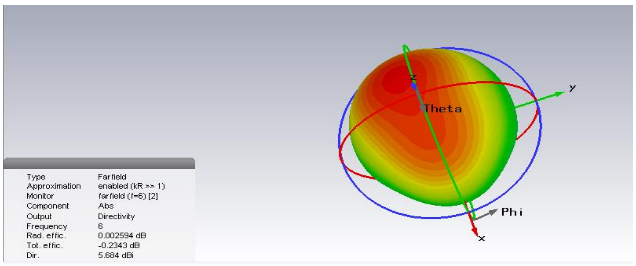

Fig 6. Radiation Pattern at Excitation 2

C. Envelope Correlation Coefficient:

The envelope correlation coefficient (ECC) estimates the correlation between the radiation patterns of MIMO receiving antenna pairs. In spite of good benefits offered by MIMO technology in modern wireless technology a major problem associated with it is deployment of the system in small wireless terminals. When antennas are oriented with less than half wavelength distance between them then mutual coupling takes place which affect the envelope correlation coefficient [10].

For any MIMO system ECC 'ρ' indicates the impact of various propagation paths of the RF signals reaching the antenna system [11]. Recent studies shows the ECC can be well explained by a straightforward closed form equation that associates the scattering parameters of the elements in an array configuration. For a system having two antenna elements the equation using the scattering parameters can be written as [11]:

$$\rho = \frac{|S_{11}^{*}S_{12}+S_{21}^{*}S_{22}|^2}{(1-|S_{11}|^2-|S_{21}|^2)(1-|S_{22}|^2-|S_{12}|^2)} \qquad (1)$$

The approximate value of the coefficient varies from 0 to 1. Quite perfect performance is attained when this parameter imprecise to zero. For MIMO system its value should be less than 0.4. Figure 7 shows the ECC of the array.

D. Diversity Gain:

Diversity gain explains the increased signal-to-interference ratio because of some diversity scheme, or how much the transmitted power can be lowered when a diversity scheme is introduced, without performance loss. Fig 8 shows diversity gain.

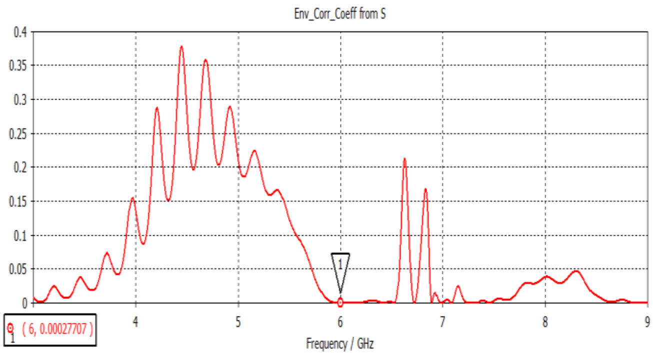

Fig 7. Envelope Correlation Coefficient

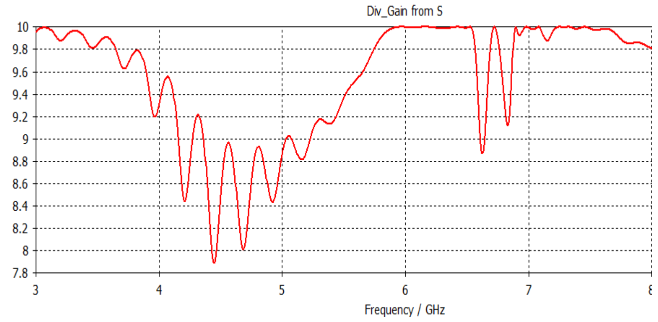

Fig 8. Diversity Gain

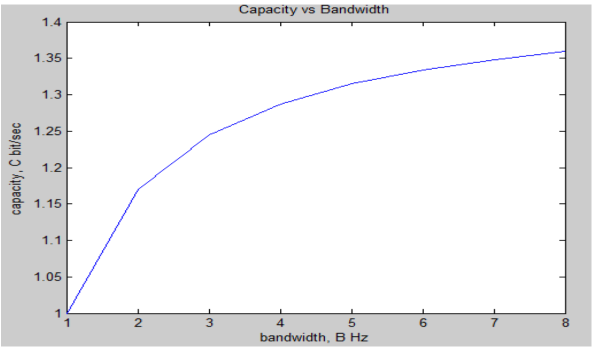

Fig 10. Capacity vs Bandwidth

V. PREDICTED DATA RATE of the PROPOSED ANTENNA SYSTEM

A. Capacity vs Power:

Increase in the signal power make us split the signal level into more number of levels while fortifying low probability of error. Hence increase signal power will conduct to more capacity. Figure 9 shows the plot of capacity vs power. Equation used for plotting the graph is given below:

$$C = B.^{*} \, log_2 \left(1 + \frac{P}{N_o{}^{*}B}\right) \quad (2)$$

B. Capacity vs Bandwidth:

More bandwidth means more number of transmissions per second, hence increase in the capacity.

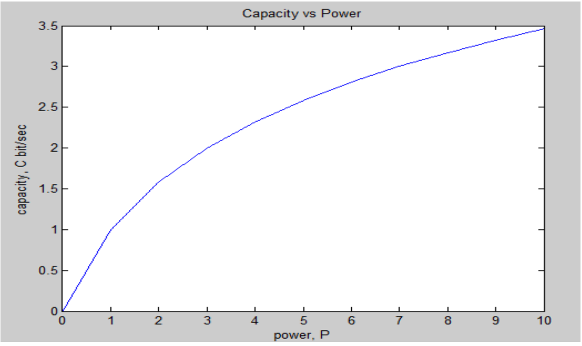

Fig 9. Capacity vs Power

VI. CONCLUSION

In the current paper a stacked antenna array is designed. This antenna has an impedance bandwidth of 521MHz. Thus stacking is proposed as an efficient method for increasing the performance of a microstrip antenna in terms of bandwidth. The array was also studied for ECC and diversity gain. Spacing between two coplanar antenna elements was optimized to get desirable ECC. The values of all the parameters were within the desirable bound of MIMO antenna system. Hence, the structure is suitable for C-band wireless application. Also the graph of capacity vs bandwidth and power were simulated using MATLAB R'11b.

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