Design and Performance Analysis of Multiband Mimo Antenna for Wireless Applications

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Abstract: A novel compact two element multiband MIMO (Multiple Input Multiple Output) antenna system operating from 4–8 GHz is proposed for wireless applications. The experimental models are developed for the MIMO system consisting of two symmetrical radiating elements connected by a neutralisation line to cancel the reactive coupling. Using the proposed method, the return loss parameter value is reduced to around −46.85 dB. In addition the proposed system also has good impedance matching, isolation, and peak gain and radiation patterns.

***Index Terms*—Multiband, multiple-input–multiple-output (MIMO) antenna, peak gain, bandwidth.**

1.0 INTRODUCTION

Antennas are an indispensable part of any wireless communication system. In today's scenario, although, antenna as a device is not new to common man, but understanding the background concept involved in the working of this device will certainly help in designing new versatile antennas, in order to meet the stringent requirements of wireless communication engineers [1-5]. In any wireless communication system, after a radio frequency (RF) signal has been generated in a transmitter, some means must be used to radiate this signal through space to a receiver. The device that does this job is the antenna. The transmitter signal energy is sent into space by a transmitting antenna, the rf signal is then picked up from space by a receiving antenna. Microstrip Antenna (MSA) in its simplest configuration consists of a radiating patch on one side of a dielectric substrate, and has a ground plane on the other side. The patch conductors are normally of copper or gold. The advantages of these antennas include low weight, low cost, low profile, conformal, easy to fabricate and can be integrated with other microstrip components, easily mounted on missiles, rockets without any major alterations. For many practical designs, the advantages of MSA far outweigh their disadvantages. With continuous research and development, the microstrip antennas have been applied in many different and successful applications. Now a day it is the most popular antenna in the wireless communication market. MIMO stands for multiple input multiple output antenna employing multiple antennas at transmitter and receiver side. It is an antenna technology used mainly in wireless communications. It has become an essential element of wireless communication standards including IEEE802.11 (Wi-Fi), WiMAX (4G) and Long term evolution (4G). The antennas at each end are used to minimise errors and improve data rates [1-12]. This technology demands for antennas with wide bandwidth and good isolation characteristics. This technology improves speed of data exchange, reduces fading of signal, increases transmission capacity, does not require additional spectrum and does not consume much power.

Many methods have been proposed for reducing return loss, mutual coupling between the antennas. Various designs have been introduced to achieve low mutual coupling and return loss by changing shape of antenna.

In this paper we design microstrip MIMO antenna to further reduce the return loss parameter S_{11} (dB) and Mutual Coupling parameter S_{12} (dB) compared to original design. We also observe the experimental results.

2.0 MIMO

2.1 Basic Theoretical Concepts

2.1.1 Total Active Reflective Coefficient (TARC)

TARC is defined as the ratio of the square root of total reflected power divided by the square root of total incident power. The TARC for a 2x 2 antenna array can be directly calculated from the scattering matrix elements as follows [5]

$$TARC = \sqrt{\left|S_{11} + S_{12}e^{j\theta}\right|^2 + \left|S_{21} + S_{22}e^{j\theta}\right|^2} \Big/ \sqrt{2}$$

------------------ (2.1)

Where θ represents the phase from 0 to 2π

2.1.2 Correlation Coefficient

Previous work shows that the correlation coefficient, ρ, of a 2x2 antenna system can also be determined using s- parameters [9]

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

------------------- (2.2)

2.1.3 Channel Capacity

Based on the channel transfer matrix, H, the Shannon capacity, C for the MIMO system channel is

$$C = \log_2\left(\det\left(1+\frac{SNR}{M}HH'\right)\right) \quad \text{--- (2.3)}$$

Where H' is the Hermitian of the matrix H, M is the number of receivers and SNR is the estimated channel signal -to- noise ratio.

2.1.4 Capacity Loss

In case of high SNR, the capacity loss is given by [11]

$$C_{loss} = -\log_2 \det\left(\Psi^R\right) \quad \text{---- (2.4)}$$

Where Ψ^R is the receiving antenna correlation matrix

3.0 METHODOLOGY

A. Design of Multiband MIMO Antenna slot:

General Design of Patch Antennas

In this Paper Multiband MIMO Antenna is designed using CST software.

To design an antenna first we need to choose dielectric constant value and substrate height. They were choosen according to design frequency.

Substrate height is choosen as 1.52mm

B. Designing Parameters:

Calculation of the Width (W)

Calculation of Effective dielectric constant (ε_{ref})

Calculation of the Effective length (L_{eff})

Calculation of the length extension (ΔL)

Calculation of actual length of patch (L).

4.0 THEORITICAL CONSIDERATIONS

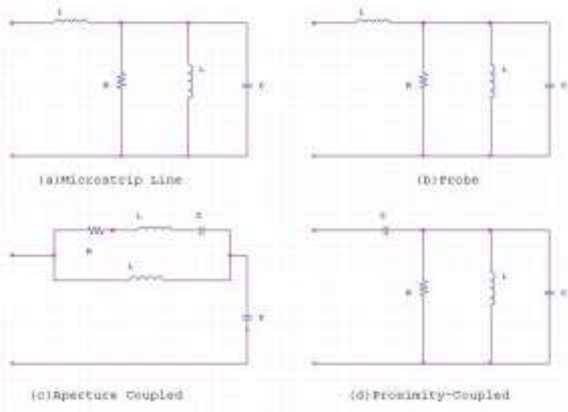

Figure 4.1 Equivalent circuits of typical feeding methods

5. 0 ANTENNA CONFIGURATION

The proposed antenna configuration is as shown in figure below. Dimensions of substrate are 320 mm x 150 mm. Dimensions of ground plane are they defined by using extrude function. By using these dimensions the proposed antenna is designed using CST software. In this design we give feeding with by using strip and assign ports.

Simulation Setup:

The antenna's resonant properties were predicted and optimized using CST 2014. The design procedure begins with determining the length, width and the type of dielectric substance for the given operating frequency. Then using the measurements obtained above simulation has been setup for the basic rectangular micro strip antenna and the parameters are optimized for the best impedance matching. This increases the gain of the antenna. Then dielectric substrate of dielectric constant of 1.0006 introduces to decrease the size of the antenna and to further enhance the bandwidth. At last the feeding is introduced for attaining a required bandwidth, resonating frequency and gain value.

Geometry of Antenna:

The geometry of the designed antenna is shown in the Figure4.1. The antenna is made of two patches on a single substrate. The patch has Wp x Lp dimension while the outer substrate has W x L dimension. Slots in this design are responsible for the excitation of next resonant mode.

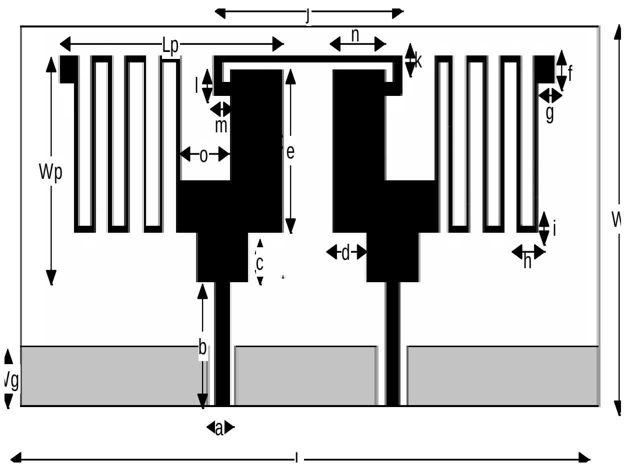

Fig 5.1: Geometry of proposed MIMO Antenna

The following table shows the values for the proposed Multiband MIMO Antenna design

Design parameters	Value(mm)
L	320
W	150
Lp	130
Wp	90
A	8
B	50
C	20
D	20
E	108
Wg	20
F	8
G	8
H	2
I	2
J	110
K	2
L	5
M	5
N	30
O	50

Table 1 : The values for the proposed Multiband MIMO Antenna design

The side view of the proposed antenna structure has been shown in Fig 5.2. The broad banding technique of stacked layers is used to improve the bandwidth. An air box of height 1 mm is inserted between substrate and the ground. The Rogers RO4350 of 1.52 mm thickness having relative permittivity of 3.66 and dielectric loss tangent of 0.004 has been used as substrate. The substrate and ground size has been considered as 320 mm x 150 mm. The antenna is probe feeded. The feeding method is easy to fabricate but difficult to model accurately and have low spurious radiation and narrow bandwidth of impedance matching. The location of the feed element with respect to the patch also plays a role in the antenna performance. The rectangular slots, in upper and lower edge of the patch have been introduced and rectangular slot strips symmetrical and parallel to the y-axis have been cut from the main patch. The slots are embedded at the two corners of the left and right edge of the patch. All these slots have been included in the design to achieve the desired antenna performance. The feed point is located at the ends of patches.

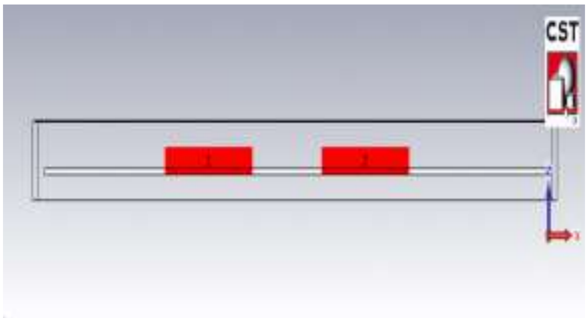

Fig 5.2: Perspective view of proposed antenna design

6.0 RESULTS AND DISCUSSION

The simulation results of proposed MIMO antenna with VSWR, S parameters, magnetic field, surface current distribution and far field patterns are shown below in figures. By using different types of approaches of design of microstrip MIMO antenna in references [1- 10], the return loss and mutual coupling parameters are compared with the proposed antenna design we get better results in terms of their antenna parameters as shown in figures 6.1, 6.2 & 6.3. Here we observed the VSWR is improved in this entire band it lies between 1.00 to 1.28. At a particular resonant frequency band of 6.453 GHz standing wave ratio value is around 1.009. The below fig 6.4 represents the far field results of proposed MIMO antenna.

The important parameters in the design of any MIMO system are channel capacity, correlation coefficient, Total Active Reflection coefficient (TARC) and channel capacity loss. These parameters are calculated by using the equations 2.1 to 2.4. The parameters of channel capacity 4.127 bits/s/Hz, capacity loss of 0.37 bits/s/Hz, TARC value is -18.23 dB and correlation coefficient is -38.57 dB.

By using different types of methods to reduce the mutual coupling between the MIMO antennas. Here a coplanar wave guide (CPW) is inserted between the two antennas to reduce the mutual coupling. Some of other methods [5-15] like EBG structure, Defected ground Structure and neutralization methods to reduce mutual coupling. Here the propose method got good result compared to other reference methods.

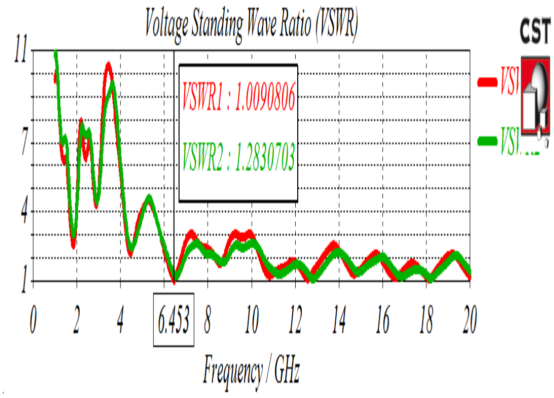

Fig 6.1: VSWR of the proposed MIMO Antenna

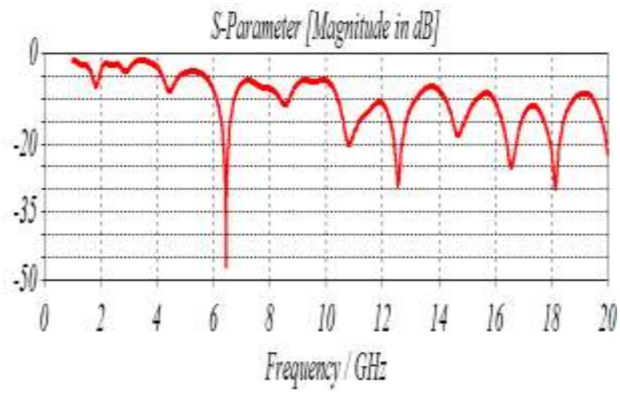

Fig 6.2: S parameters (S_{11}) of proposed MIMO Antenna

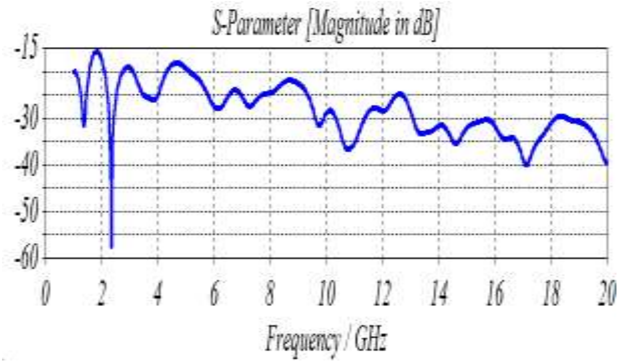

Fig 6.3: S parameters (S_{12}) of proposed Multiband MIMO Antenna

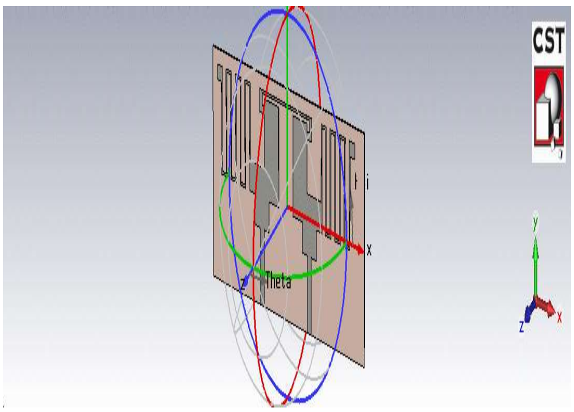

Fig 6.4: Far field results of proposed Multiband MIMO Antenna

7. 0 CONCLUSION

In this paper the proposed Multiband MIMO microstrip patch antenna without neutralisation line has been designed, simulated, optimised and analysed using CST 2014 software. A parametric study is presented with the results showing that the antenna can be operated at 4GHz - 8GHz frequency band. This result is an improvement to the original specification. Other parameters such as gain, directivity, VSWR, S_{11} and S_{12} also have been improved compared to the original design. This can be used in portable wireless applications.

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