# A low-profile dual-band MIMO antenna design and measurement with AMC reflector

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MIMO is a method which uses a number of antennas as a receiver and a transmitter, and increases the capacity of the wireless channel because it transmits parallel information in an environment that is full of multipath effects by avoiding the need for extra power and bandwidth. We suggest a low-profile, dual-band (2.4-5.8 GHz) Multiple-Input Multiple-Output antenna; and use two identical L-shaped antennas that have high isolation. The dual-band Multiple-Input Multiple-Output antenna consists of a compact size of 82.50 x 40.0 mm². The parameters of the antenna ($s_{11}$, $s_{21}$) are measured by employing the FieldFox Network Analyzer. The dual-band MIMO antenna that has high isolation and that uses an Artificial Magnetic Conductor (AMC) is dealt with in the present manuscript. The computed loss of return is -21 dB for 2.4 GHz, and -12 dB for 5.8 GHz.

## 1. Introduction

In recent years, Multiple-Input Multiple-Output (MIMO) multiband antennas are used in a widespread manner as they are functional in wireless communication systems with the features that enable them to enhance the system efficacy by avoiding an increase in the bandwidth and power. MIMO enhances the capacity of the wireless channel because it transmits parallel information in a setting full of multipath effects by avoiding the need for extra power and bandwidth. When more than one antenna is positioned in a size-restriction terminal, the limitation in the separation of the antennas might be eliminated and the system performance remains the same. It is used by more than one antenna in the form of a transmitter-receiver to increase data transmission speed and to reduce multi-path fading [1-5].

This antenna system is supposed to have a low envelope correlation, compact size, isolation at a higher level and high efficiency in terms of radiation. MIMO technology has limited applications due to high coupling between two antenna objects since they have similarity to antenna elements. The success of the Multiple-Input Multiple-Output system might be influenced by these elements. Specific importance was given to decrease the interference that was mentioned above in a system that had more than one antenna, and by using various methods like neutralization line, slotting, parasite elements, and Electromagnetic Band Gap (EBG) [6-10].

The features that make AMC unique are a high-impedance feature and in-phase reflection in a definite frequency range. Artificial Magnetic Conductor surfaces might be employed for decreasing the size of the antenna and develop the performance of it in terms of bandwidth and radiation [11-16].

The dual-band MIMO antenna suggested here has a high-isolation feature as dual-band antenna is localized in a 90° rotation, and for this reason, the operating frequencies isolation here is below -20 dB. If back-up is used with PEC ground, the distance between PEC ground-radiating element becomes 28 mm, which is approximately one-fourth of the wavelength at 2.4 GHz. When Artificial Magnetic Conductor surface is employed, the antenna height could be decreased and the radiation properties could be enhanced. The air-gap becomes 8 mm if AMC is employed. The antenna suggested here has more gain (6,91 dB for 2,4 GHz; and 6,5 dB for 5,8 GHz) when compared with the microstrip antennas included in the literature.

In the present study, a newer system configuration is proposed, which is both prototyped and tested for confirmation purposes. The method of the study and the discussions involving the simulation and measurements are given below.

## 2. Antenna design

We propose an L-shaped MIMO antenna which comes to the forefront with its different resonance frequencies. The dielectric material was used by us to design the antenna. As given in Fig. 1, the L-shaped radiating elements are positioned on the top of the dielectric material printed on an 82.50 mm × 40.0 mm FR4 substrate with 1.6 mm thickness. The loss tangent is 0.02 and the relative dielectric constant is 4.4.

*Fig. 1. The size and geometry of the antenna that is proposed in the study*

When compared, FR4 has a higher dielectric constant. This causes that there appears a patch that is smaller in size, which is optimized with a simulation program. External dimensions of the antenna are 82.5 * 40 mm. The dimensions of the L arms are 33.0 mm long and 18.25 mm long. The two L arms are identical with each other. They are placed with 180 ° successive rotation angle relative to each other. The sequential fashion was used in placing the radiating elements, which yielded high isolation values for radiating elements. Furthermore, below the antenna, an artificial magnetic conductor reflector is placed.

## 3. Artificial Magnetic Conductor (AMC)

Artificial Magnetic Conductor (AMC) is also referred to as High Impedance Surface (HIS), and represents a reactive surface without any loss. It is realized as a printed circuit board. The Sievenpiper "mushroom" shape, which is the basic structure, has low-profile metallic inclusions that are put with periodical intervals on a grounded dielectric slab. In this way, the dimensions of the antenna are decreased and the high-impedance surface is forced to behave as a Perfect Magnetic Conductor (PMC). Such kind of a magnetic conductor does not exist in the natural environment. AMC is indicated by a reflection coefficient that has a magnitude of 1 and a 0° phase for design and analyses purposes. On the AMC, the reflection phase shows variations in a constant manner (between -180° and 180°). The result is zero at the resonance frequency. A high-impedance surface is yielded by AMC, which reflects the external electromagnetic waves (except for phase reversal). On the other hand, the Perfect Electric Conductor (PEC) yields a -1 reflectivity. It also owns out-of-phase electromagnetic waves with incident waves.

The main material used for the construction of it is the same for a dual-band antenna. The AMC unit cell owns a metal patch (26 mm × 26 mm), which has gaps of 1 mm. The grid of the AMC consists of 4 × 4 unit cells. The unit cell count was chosen for optimum performance with a small profile. To have an AMC characteristic in the specific frequency band, each of the cell dimensions and the gaps were optimized. The AMC antenna is given in Fig. 2 and Fig. 3.
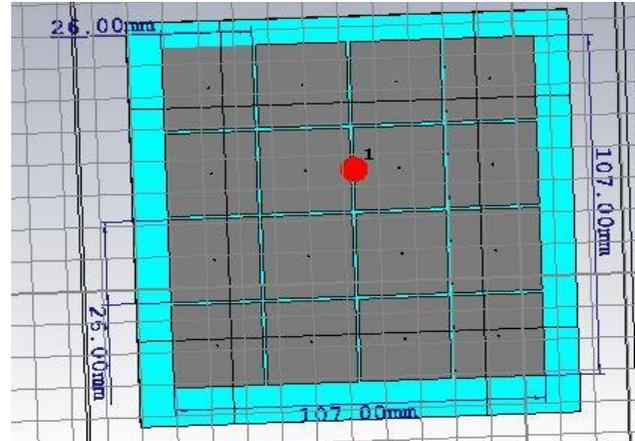


*Fig. 2. The structure of AMC*
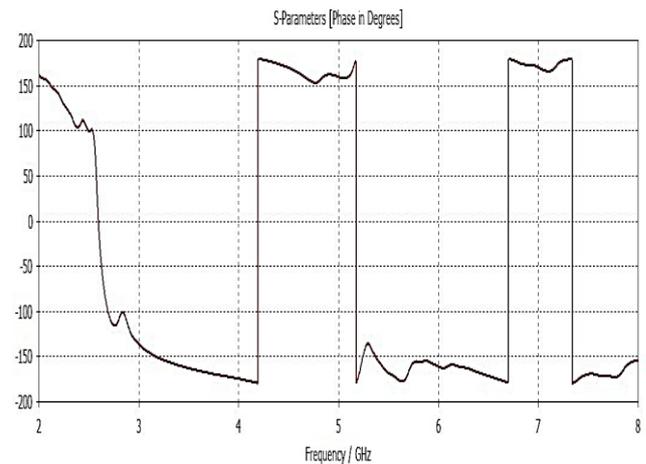


*Fig. 3. The simulated reflection phases for a normal-incident plane wave for AMC structure*

## 4. Simulation and measurement results

Several specific features are needed to design a dual-band microstrip patch antenna like antenna geometry, size, resonant frequency, and the type of the substrate. Once the design stage is over, a simulation is performed by employing CST Microwave Studio Software. Once the necessary parameters are achieved, the dual-band microstrip patch antenna is fabricated. The laboratory of Suleyman Demirel University was used to make the measurements and a FieldFox Network Analyzer was employed.

In the end, the obtained result was compared with the result of the simulation for the purpose of analyzing the performance of the antenna. The Matlab was employed to plot the result of the measurement in comparing and understanding the differences and similarities.

Farfield Realized Gain Abs (Phi=90)

—— farfield (f=2.4) [1]

Frequency = 2.4
Main lobe magnitude = 5.75 dB
Main lobe direction = -3.0 deg.
Angular width (3 dB) = 72.2 deg.
Side lobe level = -21.9 dB

Theta / Degree vs. dB

*Fig. 4. The radiation model of the antenna at 2.4 GHz with AMC reflector*

Farfield Directivity Abs (Phi=90)

—— farfield (f=5.8) [1]

Frequency = 5.8
Main lobe magnitude = 5.86 dBi
Main lobe direction = -35.0 deg.
Angular width (3 dB) = 105.7 deg.
Side lobe level = -19.0 dB

Theta / Degree vs. dBi
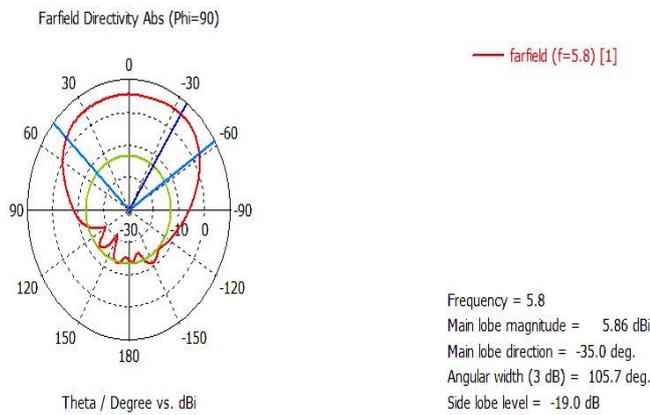
*Fig. 5. The radiation pattern of the antenna at 5.8 GHz with AMC reflector*

In Fig. 4 and 5, we can see the results of the simulation of the CST software program. Fig. 4, the simulation result of the radiation model of the antenna at 2.4 GHz with AMC reflector. Fig. 5, The radiation pattern of the antenna at 5.8 GHz with AMC reflector.

Realized Gain

—— Realized Gain [1]

1 (2.4045,6.9179)
2 (5.8693,6.5129)
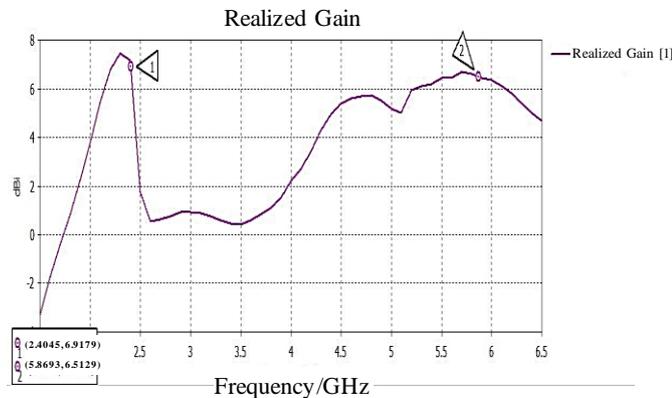
Frequency /GHz

*Fig. 6. Realized gain result of the antenna with AMC*

Fig. 6 shows the simulated gain of the antenna that is proposed. The gain is 6,91 dB at resonance frequency 2,4 GHz, and the gain is 6,5 dB at the other resonance frequency 5,8 GHz. These results are better than the microstrip antennas in the literature.
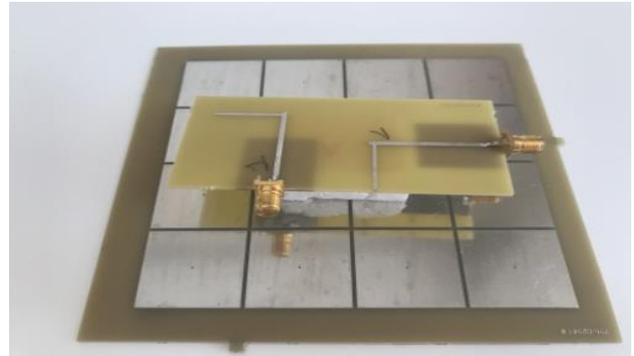


*Fig. 7. Fabricated dual-band MIMO antenna system with AMC reflector*
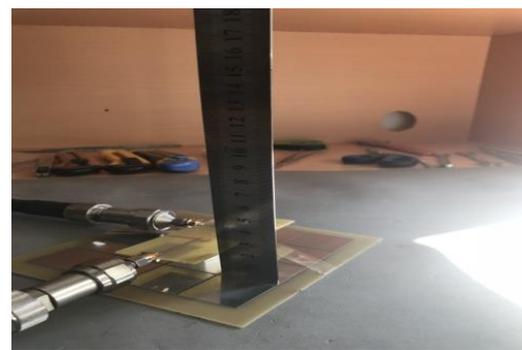




*Fig. 8. Antenna measurement system*

Fig. 7 and 8 show the use of the microstrip antenna designed with the AMC reflector. The air gap between the AMC reflector and the antenna is 8 mm, which is $\lambda / 6$ at approximately 5.8 GHz and $\lambda / 15$ at 2.4 GHz. During simulation and experimental measurements, the air gap was adjusted to 8 mm.
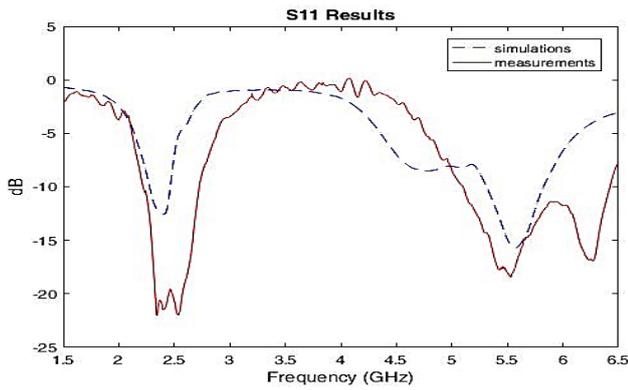
*Fig. 9. Return loss results*

Fig. 9 shows the result of the measurement and simulation of return losses (Our operating frequencies are 2.4 GHz and 5.8 GHz, the return loss is below -10 dB). In addition, results similar to the values obtained in the simulation are provided in the implementation of the antenna.
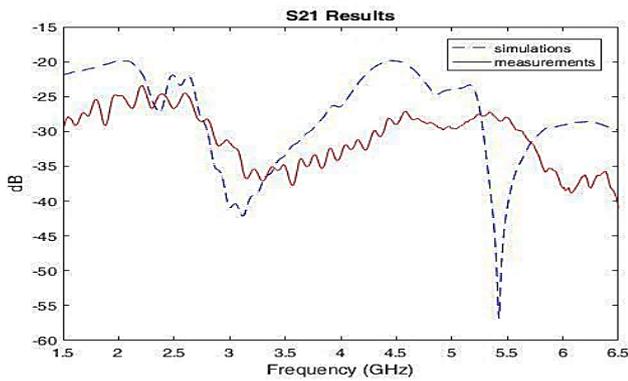


*Fig. 10. Insertion loss results*

The issue of isolation is one of the most crucial parameters for MIMO antenna. Fig. 10 shows the best performance with AMC. Superior isolation was achieved beyond 20 dB (at current distributions at 2.4 GHz and 5.8 GHz). Our isolation results are approximate -25 dB at 2.4 GHz and about -35 dB at 5.8 GHz. The values close to the simulation results can be obtained with the fabricated antenna.
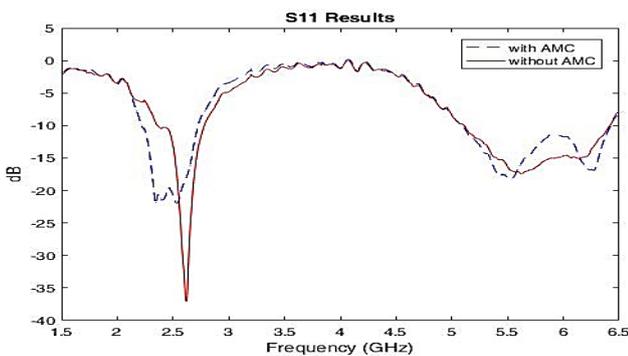


*Fig. 11. Measured result of return loss of antenna with and without AMC*

Fig. 11 shows the measured result of an antenna with and without AMC. Both of our operating frequencies are provided. In the case of AMC, the results are better.
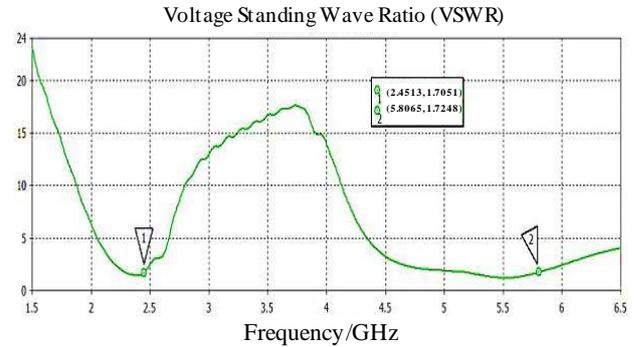


*Fig. 12. Simulation result of VSWR*

The frequency-standing wave ratio (VSWR) graph of the L microstrip antenna designed in Fig. 12 is given by the AMC reflector. The desired value for the standing wave ratio is less than 2, which is the operating frequency of the antenna at 2,45 GHz and 5,8 at 5,8 GHz, it has a value of 1.7.

*Table 1. Printed antenna results with and without AMC*

|  | 2,4 GHz | | | | 5,8 GHz | | | |
|---|---|---|---|---|---|---|---|---|
|  | $f_{min}$ (GHz) | $f_{max}$ (GHz) | BW (MHz) | $S_{11}$ (dB) | $f_{min}$ (GHz) | $f_{max}$ (GHz) | BW (MHz) | $S_{11}$ (dB) |
| With AMC | 2,2 | 2,7 | 500 | -22 (@2,3 GHz) | 5,2 | 6,3 | 1200 | -12 (@5,55 GHz) |
| With Out AMC | 2,4 | 2,7 | 300 | -10 (@2,6 GHz) | 5,2 | 6,3 | 1100 | -15 (@5,6 GHz) |

Table 1 shows the bandwidth information of with AMC reflector and without AMC in the operating frequencies of the fabricated antenna.

## 5. Conclusion

A dual-band Multiple-Input Multiple-Output antenna was suggested and realized in the present study by employing the CST Simulation Program. The simulation and measurement outcomes and the results of the measurement with and without AMC were compared by us. The air gap is 8 mm for AMC, and the length is roughly $\lambda/6$ at 5.8 GHz and $\lambda/15$ at 2.4 GHz.

In the light of the results obtained in the study, the dual-band MIMO antenna, which has high gain and good isolation, also has good radiation features. Many commercial WLAN appliances employ 2.4 GHz, 5.8 GHz

frequencies, and therefore, the solution suggested here was applied to this specific frequency. The designs suggested here may be integrated to the already-existing WLAN and WMAX appliances easily by replacing the antenna of these appliances. In this way, the proposed design brings flexibility for a wide variety of applications.

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