Design of a Dual Band 2.45 GHz and 5.2 GHz Microstrip MIMO Antenna with T-Geometry based on AMC Reflector

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Abstract: - Multiple input-multiple output (MIMO) is one of the important applications of WLAN wireless communication technology. In wireless communication systems, especially with the developing services, an increase in data speed and access quality is required in indoor WLAN systems for multi-media data transmission. In new-generation wireless communication systems, high transmission performance and high data rates can be achieved with MIMO systems that use multiple antennas in the sender and receiver. In the MIMO system, parallel data transmission can be made over multiple antennas at the same time and frequency by using the spatial domain. In this study, a MIMO dual-band microstrip antenna with artificial magnetic conductive surface T geometry operating at 2.45 GHz and 5.2 GHz was designed. CST simulation program was used in the designs. To increase the efficiency of antenna parameters; an artificial magnetic conductor design (AMC) was made and used as a reflector for the antenna. The designed dual-band MIMO microstrip antennas; parameters such as reflection coefficient, radiation diagrams, and gain were examined.

Key-Words: - Multiple Input-Multiple Output (MIMO); 2.45-5.2 GHz; Microstrip Antenna; AMC structure; Performance Analysis; Wi-Fi.

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1 Introduction

MIMO communication systems act as a savior due to the increasing number of users and data communication traffic in recent years. The most important feature of MIMO technology is that it can increase channel capacity and reliability without requiring additional power or bandwidth, [1]. For this reason, it has played a major and critical role in communication systems with 4G communication. MIMO systems are based on the use of multiple channels on both the transmitter and receiver side. In this way, it is possible to increase a limited capacity by using multiple channels. Additionally, diversity gain is achieved thanks to multiple antennas used in both the transmitter and receiver.

In MIMO systems, signal attenuation is overcome by using transmitter and receiver antennas thanks to diversity methods, [2]. Multiple input-multiple outputs (MIMO) technology, which attracted the attention of researchers to eliminate many problems such as limited channel capacity that emerged in the 4th generation technology, has become the focus of attention of researchers with 5G. The most important reason why MIMO technology has become the center of attention with 5G is that it has multiple communication channels, and the channel capacity can be easily increased, as well as having important features such as broadband, high data rate, high gain and low energy consumption, [3], [4].

In the antenna structures of 5G technology, traditional microstrip patch antennas are one of the most preferred antenna structures due to their features such as simple structure, easy use, and wide variety. Despite these advantages, the most important problem in the use of microstrip patch antennas is their limited operating performance (bandwidth, gain, etc.). With 5G, the use of MIMO structures is at the forefront to increase the operating performance of microstrip patch antennas, [5], [6], [7], [8]. With MIMO antenna structures, important parameters of the antenna such as bandwidth, radiation, and gain can be improved, [9].

Artificial magnetic conductor (AMC), for a specified frequency band is a type of electromagnetic band gap material or artificially designed material with a magnetic conductive surface. AMC is also known as a high-impedance surface and has received significant attention in recent years. The high impedance feature and phase reflection within a certain frequency range make AMC surfaces unique. Such surfaces can be used to increase the bandwidth and radiation performance of an antenna and reduce its size, [10], [11], [12].

AMC benefits from both the suppression of surface waves and the unusual reflection phase. This can be applied to a variety of antenna designs, including patch antennas, which are often affected by the effects of surface waves. AMC surfaces have very high surface impedance in a certain limited frequency range where the tangential magnetic field is small even with a large electric field across the surface, [13]. The AMC surface can serve as a new ground plane for low-profile wire antennas, which is desirable in many wireless communications. Thus, to reduce antenna size, the high-impedance surface structure acts as a perfect magnetic conductor (PMC), which does not exist in nature. Since its structure is artificially designed, it is called an artificial magnetic conductor. The AMC or PMC state is characterized by the frequency or frequencies at which the magnitude of the reflection coefficient is 1. The surface impedance (Z_s) is high and reflects external electromagnetic waves without phase reversal. AMC can also be used as a metallic plate, such as a ground plane, to direct back radiation and provide protection for antennas, [14].

In this study, a MIMO dual-band microstrip antenna with artificial magnetic conductive surface T geometry operating at 2.45 GHz and 5.2 GHz will be designed.

2 Simulation Program and Material Used

For the design of the dual-band microstrip antenna, features such as the type of material to be used, antenna geometry, dimensions, and operating frequencies were determined. After these features were decided, a T geometry antenna working in a microstrip dual band was designed using the CST Microwave Studio simulation program. The material used for the microstrip antenna is FR4. Table 1 shows the properties of FR4 material.

Table 1. Properties of FR4 material

Material	Dielectric constant	Lost tangent	Dielectric thickness	Copper thickness
FR4	4.6	0, 0035	1, 6 mm	1µm

3 Artificial Magnetic Conductor Design

In this study, the artificial magnetic conductive surface was designed for the 2.4 GHz – 5.2 GHz frequency bands, which are the operating frequencies of the T microstrip antenna, and it shows magnetic conductive surface properties in these band ranges. Here, an artificial magnetic conductor was used as the reflective surface. Since artificial magnetic conductive surfaces have high resistance 180° phase difference is observed in the reflected wave. For this reason, there is no need to leave a distance of $\lambda/4$ between the radiating elements and the reflector. The gap in this design; The distance up to $\lambda/6$ for 5.8 GHz and $\lambda/15$ for 2.45 GHz is 8 mm. For the T microstrip antenna, each cell is 26*26 mm² in size and there is a 1 mm gap between them. AMC grid structure consists of 3*3 unit cells.

AMC reflector simulation pictures are shown in Figure 1. The number of unit cells was chosen to give the best performance with a small profile. The AMC was then placed under the MIMO microstrip antenna as a reflector.

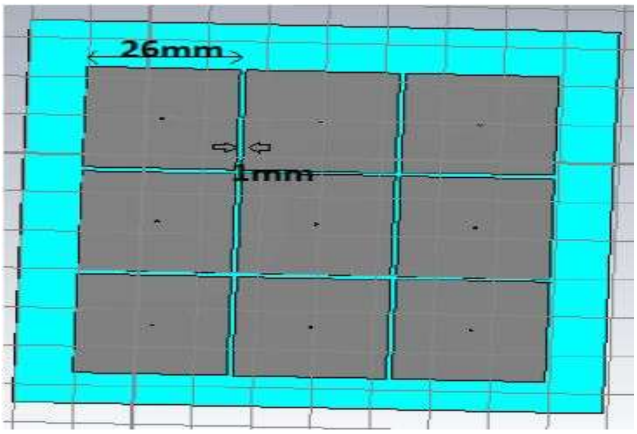

Fig. 1: AMC reflector simulation image for T microstrip antenna

The reflection phases graph of the AMC reflector is shown in Figure 2.

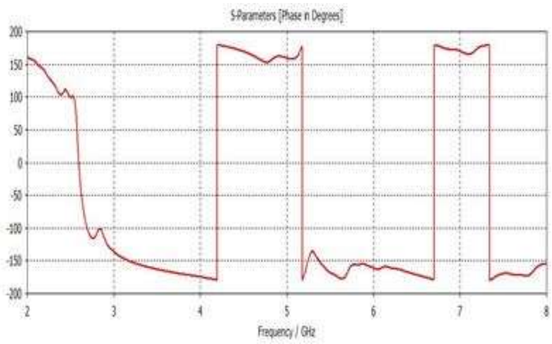

Fig. 2: Simulated reflection phases graph for AMC reflector structure

4 T Geometry Microstrip Antenna Design

A high-isolation microstrip MIMO antenna with T geometry dual-band operating at 2.45 GHz and 5.2 GHz resonance frequencies is proposed. There are T-shaped emitter elements on the upper side of the dielectric material, as shown in Figure 3. The long arm of the T shape is 17 mm, this value is a quarter wavelength of 2.4 GHz frequency; The short arm length of the T shape is about 4.8 mm, at this value the quarter wavelength of 5.2 GHz is the square root ratio of the dielectric constant of 4.5, taking into account the effect of the dielectric material on the length. Radiating elements are placed in sequential rotation. This type of arrangement creates high insulation between elements.

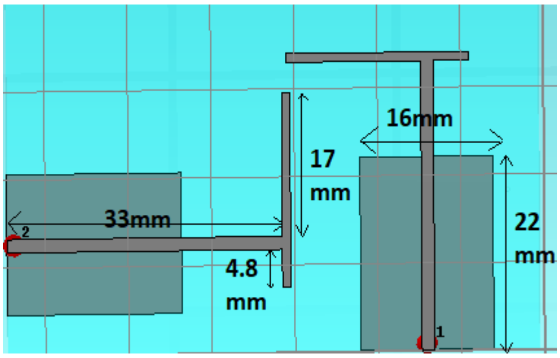

Fig. 3: Simulation image and dimensions of the T antenna

The dimensions of the antenna were designed so that the long side of the T is 4.8 mm and the short side is 17 mm. In this way, it is possible to operate at two different frequencies. The dimensions of the bottom layer of the microstrip antenna are designed to be 16 * 22 mm. When the antenna is supported by a PEC ground, the distance between the PEC ground and the irradiating element is 28 mm, which is a quarter wavelength at 2.4 GHz. With the AMC surface, the air gap of the antenna can reduce the height and the radiation characteristics can be improved.

Figure 4 shows the antenna printed circuit. There is an AMC reflector under the antenna. This air gap is 8 mm, which is approximately λ/8 at 5.2 GHz and λ/15 at 2.4 GHz. Two identical T antennas are placed at a rotation angle of 90° relative to each other. This method has been optimized with the CST simulation program to have high insulation without using the method mentioned above.

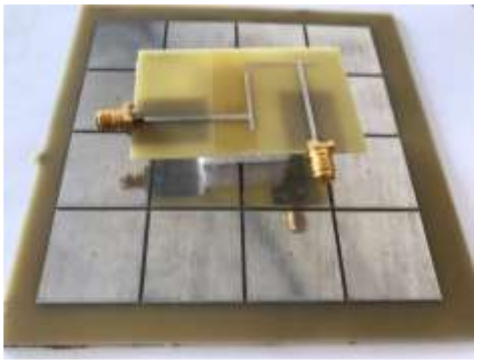

Fig. 4: Printed circuit of the T-geometry microstrip antenna operating at 2.45 GHz and 5.2 GHz with AMC reflector

5 T Geometry Microstrip Antenna Simulation Results

Simulation results of the designed T-geometry microstrip dual-band MIMO antenna are given. For the designed T geometry antenna; The reflection coefficient (S_{11}) and isolation parameter (S_{21}) simulation results of the antennas used with different reflectors were compared graphically. In Figure 5, it is observed that the simulation results of the parameter S_{11} which is the reflection coefficient of the T geometry antenna with AMC reflectors, are -15 dB for 2.45 GHz and -18 dB for 5.2 GHz. Since they are below the value of -10 dB, these are the operating frequencies.

Fig. 5: S_{11} simulation result of AMC reflector antenna

In Figure 6, the graph of the simulation results of the S_{11} parameter of the antenna is given comparatively for different reflectors. The red line shows the results of the AMC antenna, the pink line shows the results of the microstrip antenna, and the brown line shows the results of the PEC antenna. These values are -15 dB for 2.45 GHz, -17 dB for 5.2 GHz with the AMC reflector; in the case of PEC structure -11 dB for 2.45 GHz, -14 dB for 5.2 GHz; In the case without the reflector, it is -12 dB for 2.45 GHz and -15 dB for 5.2 GHz.

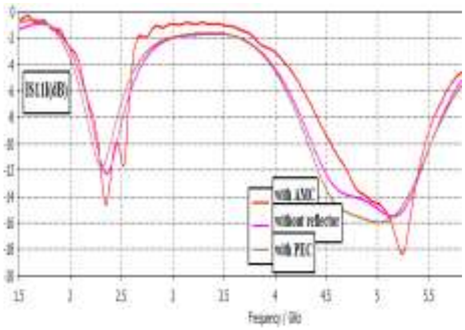

Fig. 6: S_{11} simulation results of the antenna with different reflectors

Figure 7 shows the insulation results of the antenna with different reflectors. In the case of a PEC reflector, it is -20 dB for 2.45 GHz and 5.2 GHz, and for an antenna without reflector, it is -20 dB for 2.45 GHz and 5.2 GHz. MIMO antennas must have good isolation. For good isolation, the S_{21} parameter should be above -20 dB. According to this graph, the AMC antenna shows a better isolation performance than other antennas. In the case of the AMC reflector, it is -24 dB for 2.45 GHz and -23 for 5.2 GHz. Since the S_{21} isolation value is below -20 dB at resonance frequencies, it is understood that the isolation between MIMO antenna elements is good. The important factor in this value is that two identical T antennas are placed at a 90° angle relative to each other.

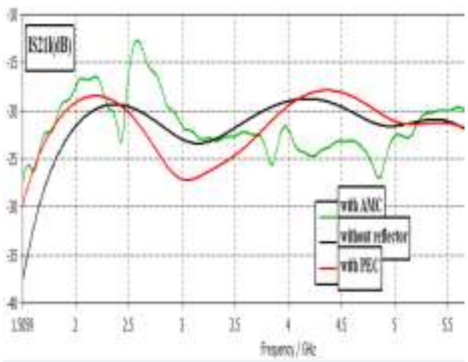

Fig. 7: S_{21} simulation results of the antenna with different reflectors, green line AMC antenna, black line microstrip antenna, red line PEC antenna

Figure 8 shows the frequency-standing wave ratio change graph of the T microstrip antenna with the AMC reflector. Standing wave ratio; It occurs when the outgoing and reflected signals meet, and its disadvantage is that it causes power loss on the antenna. Therefore, a value below two is the desired value. As can be seen from the graph, the resonance frequencies of the antenna have values of 1.5 at 2.45 GHz and 1.1 at 5.2 GHz.

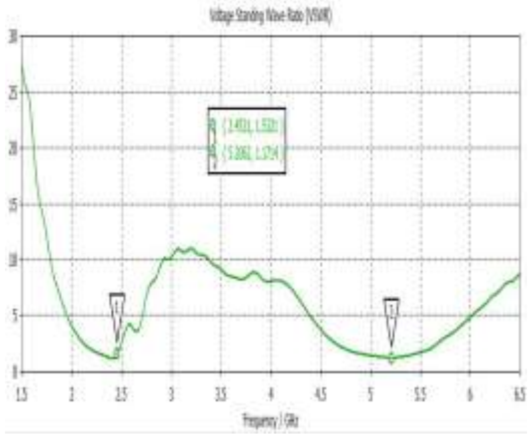

Fig. 8: Frequency-standing wave ratio graph of T microstrip antenna with AMC

Figure 9 and Figure 10 in Appendix show the 2D far field pattern results for the T microstrip antenna. As seen in Figure 9 (Appendix), for 2.45 GHz, the maximum radiation angle of port 1 is 23° and the signal level is 8.3 dBi; The signal level of port 2 is 8.08 dBi and its maximum radiation angle is 15°. From Figure 10 (Appendix), for 5.2 GHz, the signal level of port 1 is 8 dBi and its main lobe radiates in the 17° direction, the main lobe of port 2 radiates in the 21° direction and the signal level is 8.8 dBi.

Figure 11 (Appendix) shows the directivity and gain values of the T microstrip antenna. Directivity values for 2.4 GHz are 8.5 dBi in port 1 and 8.1 dBi in port 2; for 5.2 GHz, it is 7.9 dBi in port 1 and 8.8 dBi in port 2. When the gain results are examined, for 2.4 GHz, 6.9 dB in port 1 and 6.9 dB in port 2; for 5.2 GHz, port 1 is 6.8 dB and port 2 is 7.8 dB. When compared to the literature, it is understood that the gain and directivity values give very good results for microstrip antennas.

6 Conclusions

In this study, MIMO microstrip dual-band antennas were designed using the CST simulation program, and all designed antennas and AMC reflector structures were produced with a printed circuit. Antenna design and simulation with AMC substrate formed the basis of this study. When the designed antennas are compared with literature values; they have high gain (6.5-7 dB per antenna) and good isolation (values above -20 dB per antenna). Compared to existing classical dual-band MIMO microstrip antennas; by using AMC substrates, an antenna system with higher performance, higher directionality and improved parameters has been obtained. Achieving the desired insulation values was made possible by the position of the antenna elements relative to each other. The proposed designs can be easily integrated into existing WLAN/WIMAX receivers by simply changing the antenna. Thus, it provides great flexibility for a wide range of applications.

Target specifications and international standards (WHO, FCC, etc.) are met with the designed antennas. Multiple input multiple output technology is a technology that enables increased communication performance by using more than one antenna in both the receiver and transmitter. MIMO technology has attracted great attention because it increases transmission speed and quality without requiring more power or bandwidth. This; increasingly high efficiency is achieved by line application and reduced damping. Because of these features, MIMO is the most important topic of current wireless communication research.

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Contribution of individual authors to the creation of a scientific article (ghostwriting policy)

The authors contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflicts of Interest

The author(s) declare no potential conflicts of interest concerning the research, authorship, or publication of this article.

APPENDIX

Port 1 Port 2

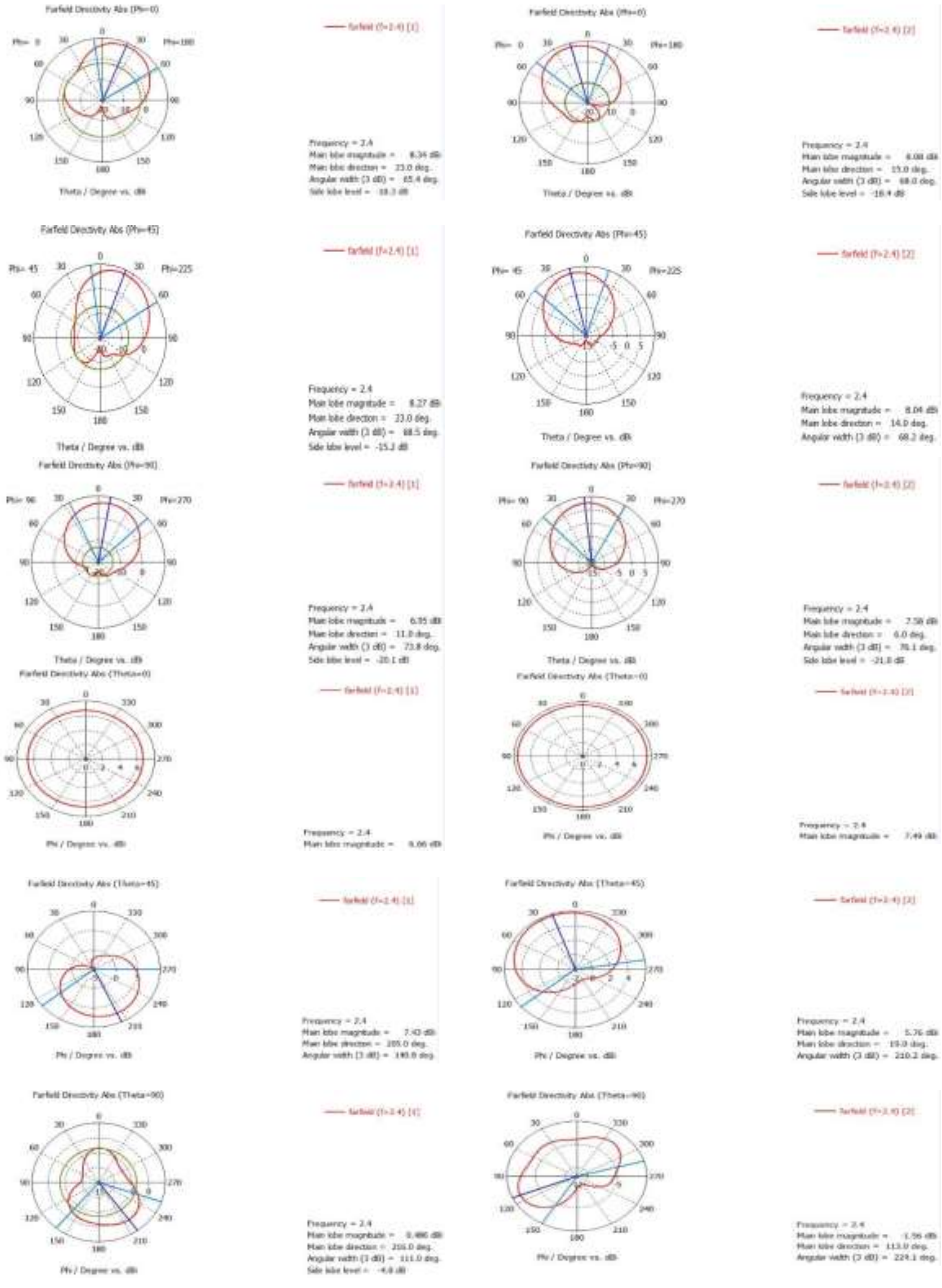

Fig. 9: Far-field pattern results of T microstrip antenna for 2.45 GHz

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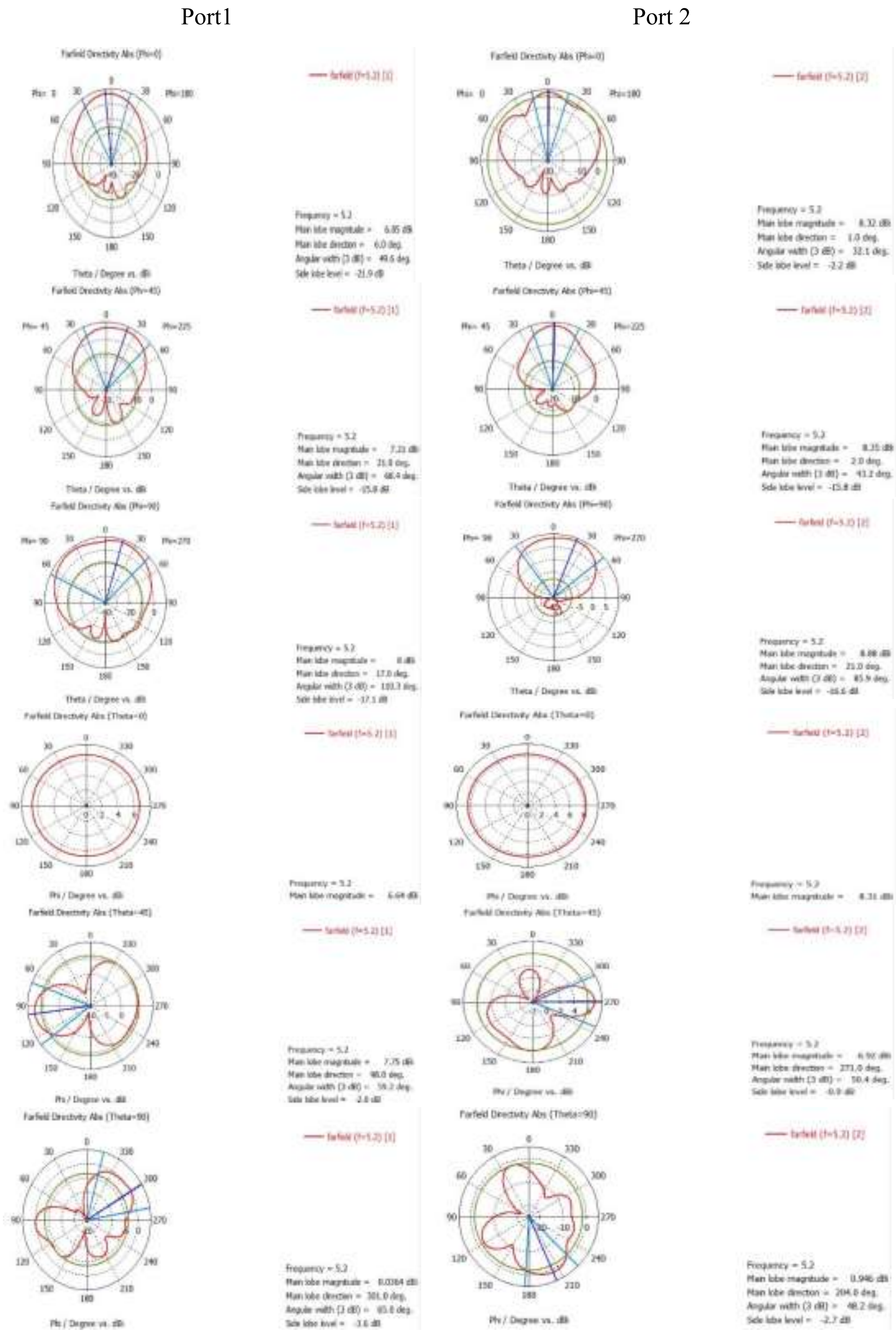

Fig. 10: Far-field pattern results of T microstrip antenna for 5.2 GHz

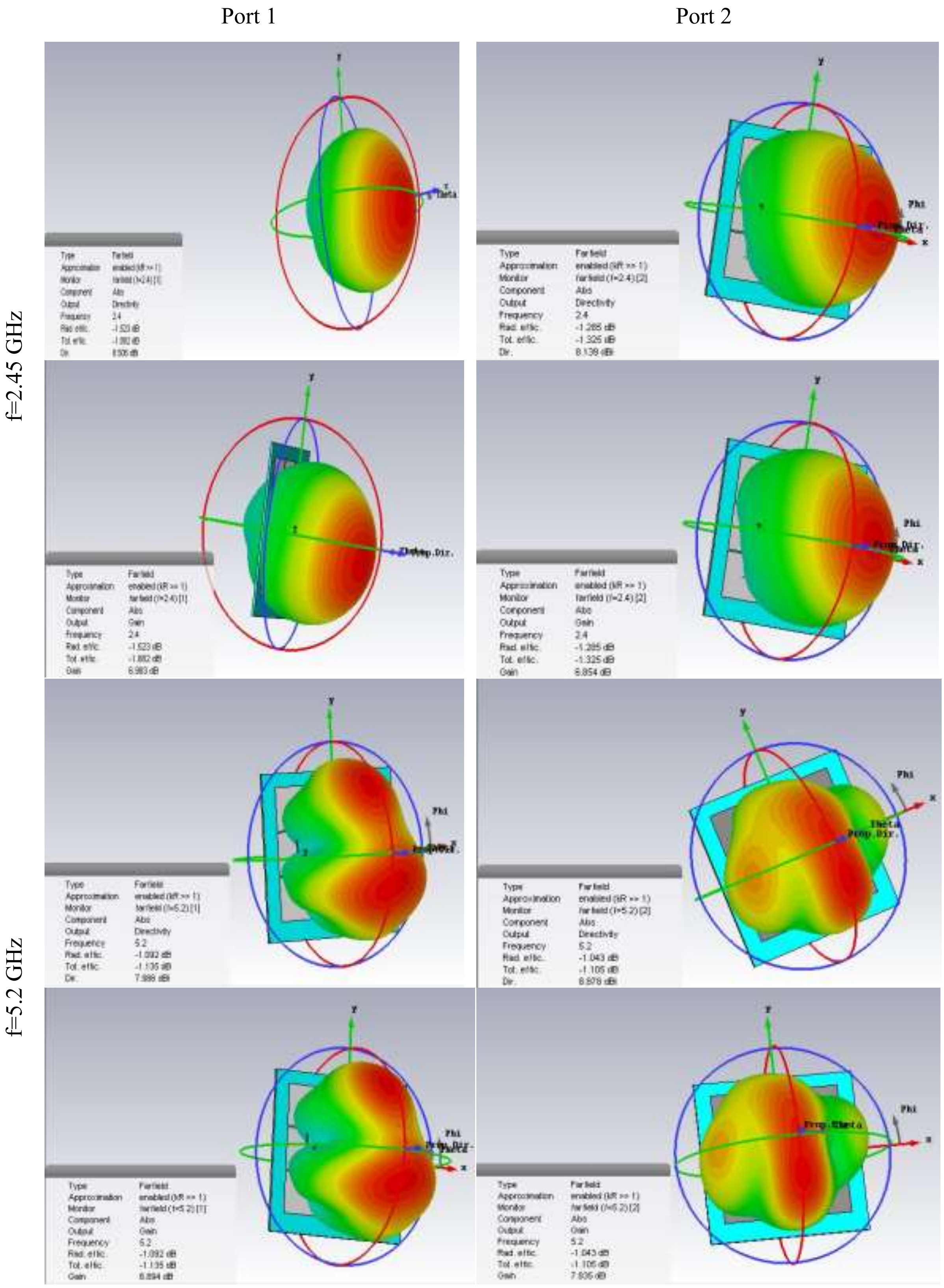

Fig. 11: T microstrip antenna directivity and ga