CIRCULARLY POLARIZED ANTENNA ARRAY FOR ISM FREQUENCY BAND 24 GHz

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Abstract: In this paper, a circularly polarized antenna array [1] designed for operation at 45 GHz is redesigned to operate at 24 GHz. The antenna has a wide impedance bandwidth of 33 %, a 3 dB axial ratio bandwidth of 8.3 % and high gain performance. By using thicker substrates, the impedance bandwidth of the antenna was improved without changing its initial configuration. The antenna was designed in CST Microwave Studio.

Keywords: Circularly polarized antenna array, CST Microwave Studio, wideband antenna.

1 INTRODUCTION

At millimetre-wave frequencies, signals become more prone to faster, harder and longer degradation due to atmospheric conditions. These atmospheric conditions can also cause a change in phase or rotation of the signal and attenuate it. Linear polarization is greatly affected by these conditions compared to circular polarization. For this reason, among others such as less sensitivity to orientation of both transmitting and receiving antennas and the advantage of multipath effects, circularly polarized antennas are given preference for use in wireless communication systems such as GPS, radar, satellite systems and in fifth-generation (5G) communication systems [1], [2], [3], [4].

In this article, a 4x4 circularly polarized antenna array [1] designed to operate at 45 GHz is redesigned to operate at 24 GHz.

2 ANTENNA DESIGN

In [1], a novel planar antenna was designed on two substrates (see **Figure 1**). An antenna element comprising of four metallic patches is placed on the top substrate. On the bottom substrate, there is a microstrip feeder coupled to the antenna element by an aperture etched on the ground plane. Four metallic posts connect the patches to the ground. Two patches have L-shaped branches while the other two have truncated edges. These adjustments ensure that the conditions necessary for circular polarization to be attained are met [1].

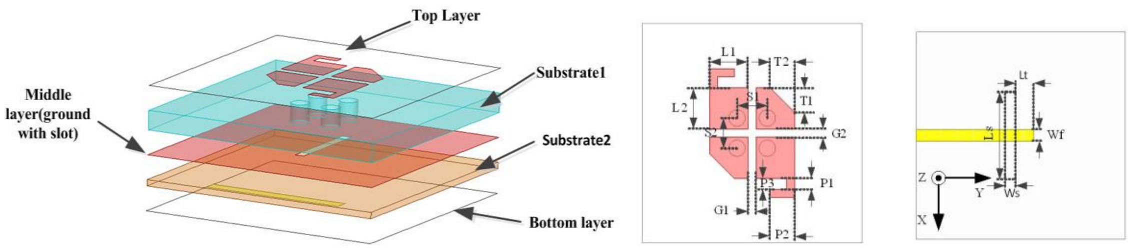


Figure 1: Configuration of planar antenna element. Adopted from [1].

3 ANTENNA ELEMENT SIMULATION

The antenna was designed in CST Microwave Studio using the microwave substrate CuClad 217 (ε_r = 2.17, tan δ = 0.0009) for both the top layer and the bottom one. The top substrate is 1.54 mm thick while the thickness of the bottom substrate is 0.254 mm. **Figure 2** shows the results of the antenna performance.

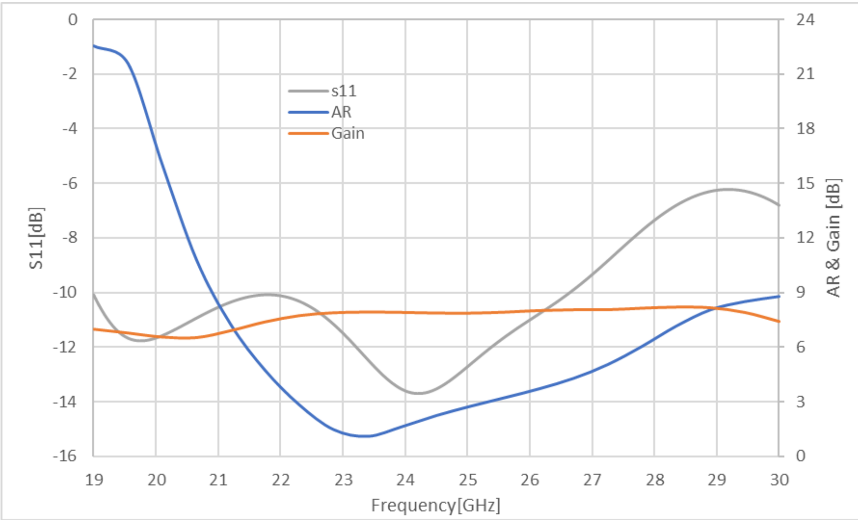
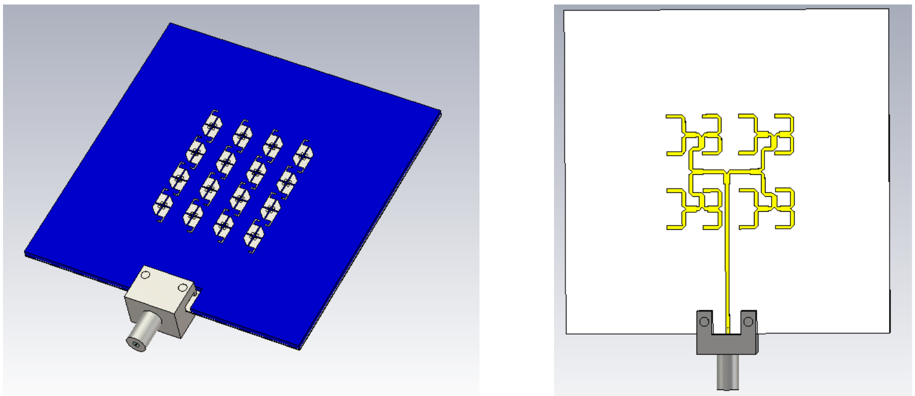


Figure 2: Frequency response of reflection coefficient (grey), axial ratio (blue) and gain (orange) of the antenna element in the 24 GHz ISM band.

The antenna element has a 3 dB axial ratio bandwidth of 13 %, an impedance bandwidth of 32 % from 19.0 GHz to 26.6 GHz and gain higher than 6 dBi for the frequency band 19 GHz to 30 GHz.

4 ANTENNA ARRAY SIMULATION

A 4x4 antenna array was designed with a compact corporate feed network (see **Figure 3**).



(a) (b)

Figure 3: Antenna array design in CST Microwave Studio:
(a) top view, (b) bottom view

Simulated frequency responses of |S11|, gain and axial ratio of the antenna array are shown in **Figure 4**. The impedance bandwidth is 33.0 % while the axial ratio bandwidth is 8.3 % (from 23 GHz to 25 GHz).Since both the impedance and axial ratio bandwidths are directly influenced by the separation distances between the individual antenna elements (mutual coupling) and improvement on one leads to an adverse effect on the other, a compromise was made during optimization which led to the axial ratio bandwidth of the antenna array being lower than that of a single antenna element. The simulated axial ratio bandwidth still sufficiently covers the 24 GHz ISM frequency band which ranges from 24 GHz to 24.25 GHz. The gain is above 16.5 dBi from 16.6 GHz to 30 GHz with the peak value of 18.9 dBi.

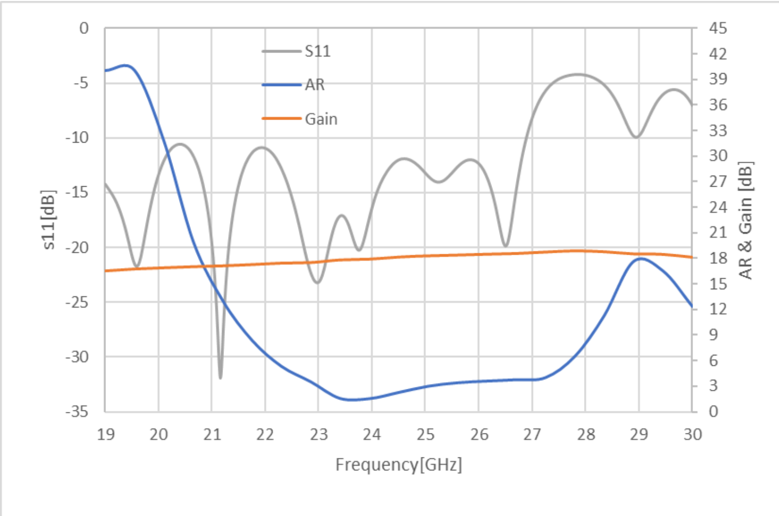


Figure 4: Frequency response of reflection coefficient (grey), axial ratio (blue) and gain (orange) of the 4x4 antenna array in the 24 GHz ISM band.

Radiation pattern of the 4x4 antenna array is depicted in **Figure 5**. The side lobe level equals to -9.9 dB and its low level as can be seen from **Figure 5** is mainly due to the spurious radiation of the microstrip feed network.

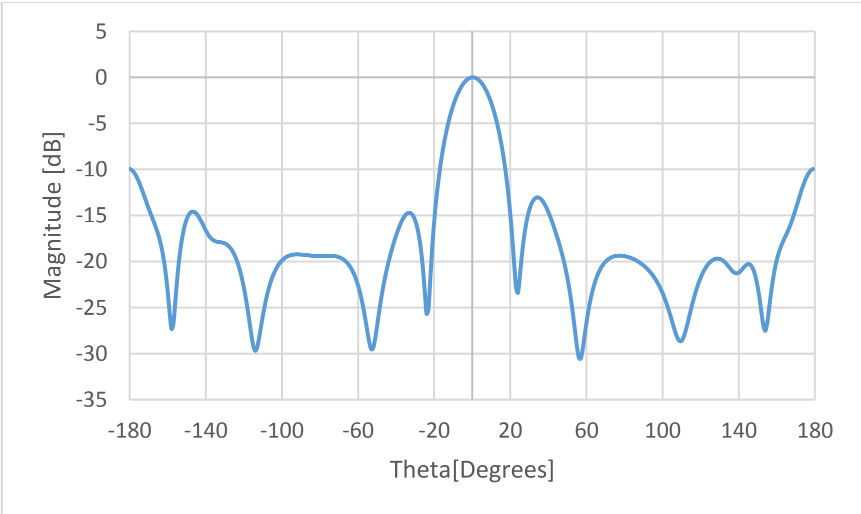


Figure 5: Normalized radiation pattern of the 4x4 antenna array at 24 GHz (Phi =90°).

5 CONCLUSION

In the paper, the 4x4 antenna array is described. The design of the original antenna was modified for the 24 GHz ISM band. The antenna was optimized and simulated.

The antenna has a very wide impedance bandwidth 33 % at frequencies 19.0 GHz to 26.9 GHz and a 3 dB axial ratio bandwidth of 8.3 % for frequencies 23 GHz to 25 GHz. The gain was 18.2 dBi at the operating frequency (24 GHz) and was above 16.5 dBi for the frequency band 19 GHz to 30 GHz.

Currently, experimental verification of antenna parameters is prepared.

ACKNOWLEDGEMENT

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