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DESIGN AND SIMULATION OF AN ARRAY ANTENNA FOR 5G BASE STATION

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ABSTRACT: *A modified T-shaped antenna array design is presented for V-band applications. A prototype of 1x4 T-shaped antenna array is designed. The single element of the array comprises of a T-shaped patch. The array antenna presented in this paper are optimized to minimize the cost and complexity. It is observed that the proposed antenna offers V band characteristics from 53.78GHz to 62.17GHz. The measured results of the 1x4 array antenna shows the low return loss of (s11=-24.1024dB) and a high gain of 5.1760e+000. The proposed antenna is promising for a number of applications ranging from WiGig, 5G communications, Satellite communications and so on.*

Keywords: *Array antennas, Insert feed, WiGig applications, 5G mobile communication*

I. INTRODUCTION

Electromagnetic spectrum is one of the natural resources available for human use and the antenna has been using this resource. Antennas are used to transmit and receive electromagnetic energy. In recent days the wireless communications has developed rapidly and this evolution leads to the need of more efficient communication system .According to the new generation 5G, it requires more advancement in the design of antennas which gives high bandwidth, gain and efficiency. In this project we proposed a design of the array antenna for fifth generation (5G) wireless communication. In this proposed design, microstrip array antenna is designed using insert feed. In [1] the 2x1 and 4x1 array antennas are designed to operate at 28 GHz and covers the millimeter- wave band. From the presented configurations, the authors achieved a return loss of -23dB, directivity of 7.77dB and a gain of 4.30dB for 2x1 array antenna and for 4x1 array antenna, the authors achieved a return loss of having a 35dB, directivity of 12.87dB and a gain of 6.18dB. Microstrip patch antennas are now widely used due to their light weight and reduced footprint which have a narrow band width and moderate gain.

In [2] Full-Duplex Phased Array Front-End is designed using two cross- polarized Arrays and a Canceller. It mainly focus on the nonlinearities and noise in the TX and RX arrays are experimentally analyzed to demonstrate that the proposed cross-polarized arrays have enough isolation to achieve suppression to the level of the RX noise floor. In this paper the author achieves a Full Duplexed phased-array system having more than 95-dB isolation and RX noise floor at 28.5−29.5 GHz.

In [3] a 1x2 taper slot antenna array is designed with flip-chip interconnect via glass-IPD technology for 60 ghz radar sensors applications. The antenna is designed with a dimension of 5 × 7.4 mm2 , the prototype achieves a measured 10 dB impedance bandwidth from 47.2 to 67 GHz. The calculated antenna gain is higher than 6.5 dBi for 60GHz. Modified planar rectangular antenna array is designed for wideband 5G MIMO applications in [4]. In this paper, the single element of the array comprises of a modified rectangular patch fed using a 50Ω microstrip feed line, and a partial ground plane with a rectangular notch. From that proposed antenna, the authors observed the wide band characteristics from 26.88 GHz to 61.17 GHz and the author achieves an average gain and efficiency of 5 dBi and 93%, respectively.

In [5] three-dimensional microfabricated broadband patch antenna is designed for WiGig applications. In this proposed antenna, the patch metallization is deposited on top of this 3-D structure.

Whereas the main role of the structure made out of SU-8 material is to provide a mechanical support for the patch metallization, the antenna takes advantage of the air cavities underneath, thus resulting in an antenna substrate with a very low loss which in turn, improves the overall antenna performances. In this paper, the author achieves an gain of 6.4dB in a broadside direction over the entire WiGig band.

In [6] a Cavity-Backed Aperture-Coupled Microstrip Patch Antenna Arrays using Substrate Integrated Waveguide Fed at 60 GHz. In this paper, the author achieved a gain up to 30.1 dBi with a 3-dB gain bandwidth of 16.1%, an impedance bandwidth of 15.3% for SWR < 2, and symmetrically broadside radiation patterns with −40 dB.

In [7] a cavity-backed shorted annular patch (SAP) array antenna is designed for mid-range V-Band backhauling applications. In this paper, the parasitic patch is included to maximize the gain of the proposed antenna. In this paper a 4 × 4 array which presents a reflection coefficient bandwidth covering the frequencies from 58.7 to 63.25 GHz (7.6% at 60 GHz). The experimental array gain is equal to 18 dBi corresponding to 37.9% of aperture efficiency. In [8] a compact monopulse antenna array is designed using substrate integrated waveguide based on microstrip feed. In this paper, the author mainly concentrates on the performance of the array and the measured gain reaches 16.4dBi, and the null depth is 33.8dB.

In [9] dual polarized array antennas are designed for millimetre wave applications. In [10] the antenna is designed for wide band applications and in [11] microstrip patch antennaa is designed using parasitic patch for the bandwidth enhancement

II. PROPOSED ANTENNA

The patch antenna consists of a ground plane and a dielectric substrate with a T-shaped radiant metallic motif on the top surface. A 50Ω microstrip feed line based modified rectangular patch is designed on top side of FR4 substrate having εr = 4.4, h =1.6 mm using insert feed method.

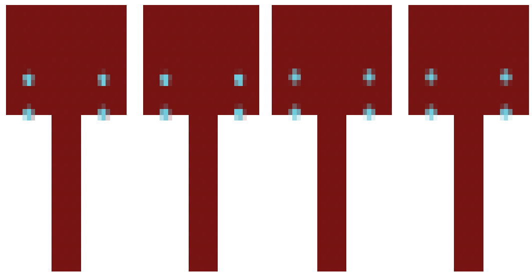

Fig 1. T-shaped Microstrip array antenna with four elements

4 x 1 microstrip patch antenna array with rectangular patch elements having the same shape as the single element rectangular microstrip patch antenna. Furthermore, these elements have the same dielectric substrate and dimensions.

The specifications of the structure of the antenna are

- No of patches=4
- Impedance of the line feeding=50 Ω
- Length of the patch= 1.57mm
- Width of the patch=3.17mm
- Length of the feed line= 3.590600
- Width of the feed line= 0.972119

PATCH ANTENNA DESIGN PARAMETERS

The width of the patch will be calculated from the following equation

$$W = \frac{C}{2f_0\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \qquad (1)$$

W is the width of the patch, ε_r is the dielectric constant, C is the velocity of light, f_0 is the resonant frequency

The length of the patch can be calculated from the following equation

$$L = L_{eff} - 2\Delta L \qquad (2)$$

$$L_{eff} = \frac{C}{2f_0\sqrt{\varepsilon_{reff}}} \qquad (3)$$

$$\Delta L = 0.414h\frac{(\varepsilon_{reff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)} \quad (4)$$

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-\frac{1}{2}} \quad (5)$$

L is the length of the patch , ΔL is the change in length, h is the height of the substrate, ε_r is the dielectric constant and ε_{reff} is the effective dielectric constant.

III. RESULTS AND DISCUSSIONS

The proposed 1x4 array antenna array is optimized and measured. Fig 2. represents the design of 1x4 array antenna in HFSS software. The simulated S11 for the whole antenna is -24.88 dB. The simulated antenna bandwidth covers the frequencies from 53.95 GHz to 62.56 GHz which corresponds to the impedence band width and gain of 14.7% GHz. and 5.1760e+000 respectively. The radiation pattern obtained for the proposed array antenna is omni-directional in nature. The gain of the antenna can be measured with the help of the isotrophic antenna

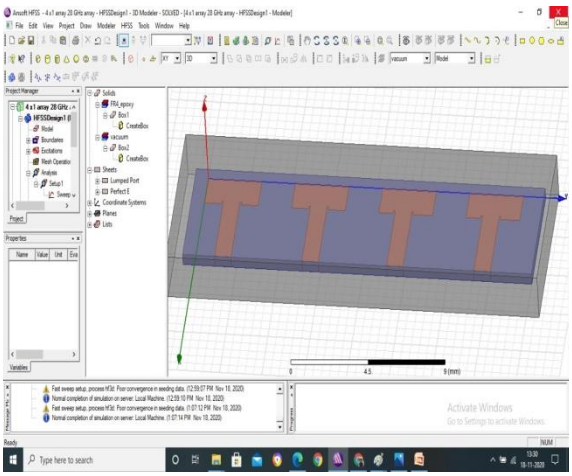

Fig 2. Design of antenna array in HFSS software

RETURN LOSS

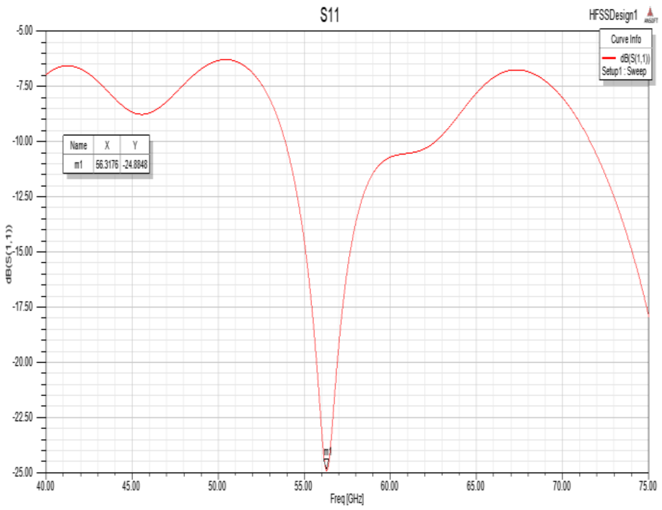

Fig 3. Return loss plot

Fig 3. Depicts the return loss characteristics of the proposed 1x4 array antenna. From the figure, it is observed that the array antenna has a wide response in the range of 56.31GHz for V band applications.

BANDWIDTH

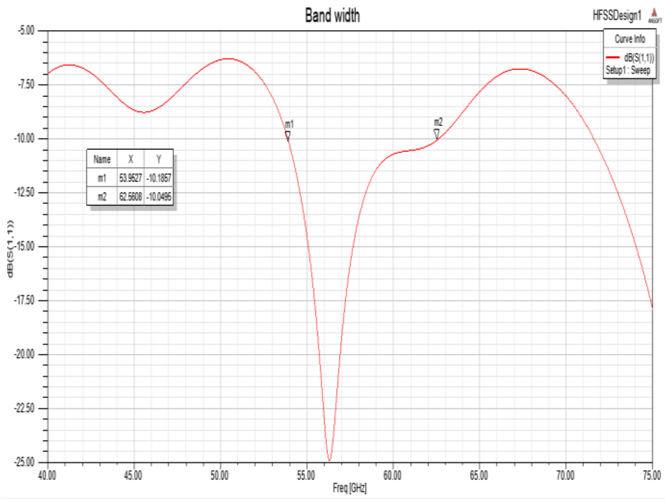

Fig 4. Bandwidth plot

From this fig 4. It is inferred that the impedance bandwidth of the array elements is >53 GHz. The ratio of the difference between two frequencies and the resonant frequency obtains the impedance bandwidth in GHz. The proposed antenna has the impedance bandwidth of 14.7% GHz.

GAIN

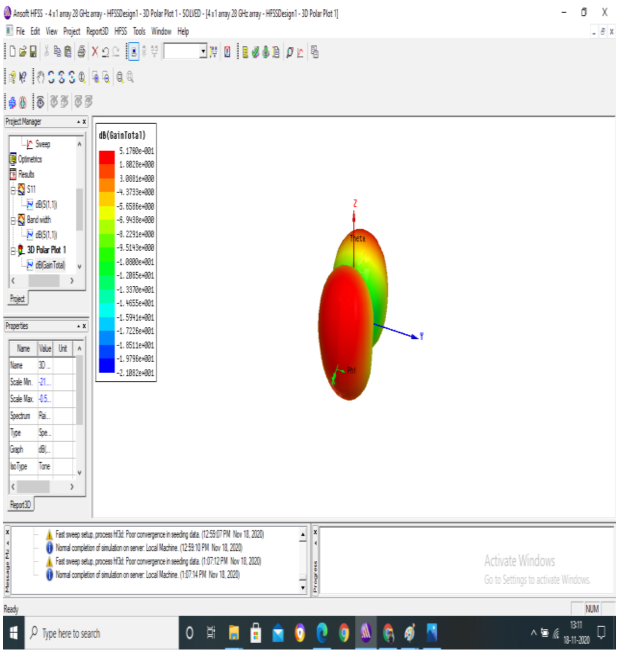

Fig 5. Gain plot

Gain can be calculated by using the parameters such as directivity, loss of the transition and the loss of the radiating patch with the help of reference antenna. The gain of the antenna is propotional to the directivity of the antenna. From the Fig 5 it is observed that the proposed array antenna has the increased gain which improves the performance of the antenna.

BEAMWIDTH

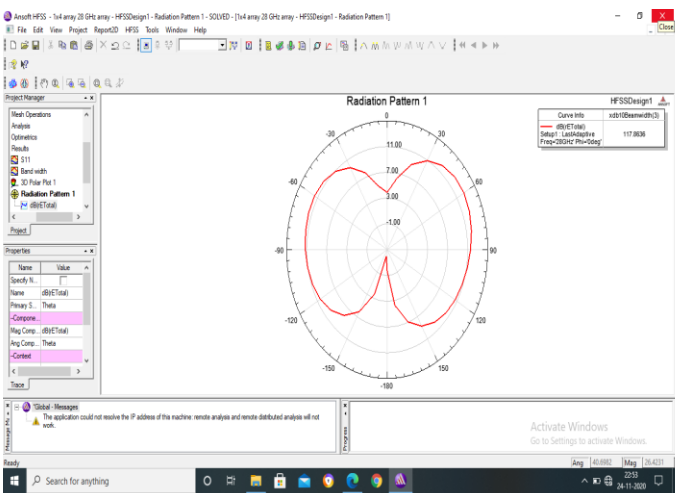

Fig 6. Beamwidth plot

In this Fig 6 it is observed that the proposed antenna radiates in the omni-direction.This radiation pattern depends on the relative field strength of the radio waves emmited by the proposed antenna at different angles.

IV. CONCLUSION

A modified T-shaped array antenna is presented for 5G base stations. The proposed array antenna design consists of a modified T-shaped patch with ground and substrate. It is described that the proposed array antenna characteristics posses V band characteristics in a frequency range of 53.95 GHz to 62.56 GHz. It is also described that the proposed array antenna design offers a hign gain and beamwidth of 5.1760e+000 dBi and 117.86. Further more, the four element array antenna is designed to evaluate the performance of the proposed antenna for the 5G base station, satellite communications, WiGig applications and so on. From the presented results, the proposed antenna is well suited for 5G applications.

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Biographies

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