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DESIGN AND ANALYSIS OF HIGH GAIN MILLIMETER WAVE MICROSTRIP ANTENNA ARRAY FOR WIRELESS APPLICATIONS

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ABSTRACT

The design of a millimeter wave n x n array antenna at 60 GHz with corporate feed network printed on the same side of the substrate is presented. The antenna is designed using transmission line model and simulated using IE3D software. Simulation and measured results were in good agreement. Analyses were carried out for 2x2, 4x4, 8x8 arrays. The gain and beam width of 8x8 microstrip array is 18.48 dBi and 10.49 deg. The 10 dB return loss bandwidth spans from 59 GHz to about 61 GHz. The proposed array can be integrated with the existing MMIC's or wireless equipment with suitable selection of the substrate.

Keywords - *Corporate feed, Microstrip antenna, 60 GHz band.*

1. INTRODUCTION

The existing and emerging wireless system such as WLAN, WPAN, UWB and Bluetooth operate below 11 GHz which is likely to be congested in near future due to the lack of wide bandwidth [1] [2]. Broad frequency bands can be easily obtained at higher frequency. This broad band not only satisfies the requirement of more channels but can also provide simultaneous service of data, voice and video transmission at high data rates. Hence the need arises to move towards the millimeter wave frequency(>30 GHz) which also avoids the interference between wireless systems[3]. Millimeter wave band has many advantages such as large spectral capacity, compact antenna structure, light equipment, etc. More attention is concentrated at 60 GHz that as 7 GHz unlicensed spectrum which fulfills all the wireless system requirements. In 60 GHz band the signals are attenuated (10-15 dB/km) due to oxygen absorption. This attenuation restricts the use of wireless link for long distance communication (>2km)[4]. Short wavelength and wide bandwidth at 60 GHz makes antenna structure compact and excludes co-channel interference in a dense point to point wireless link within indoor environment.

Microstrip antennas are suited for this application because of their conformal and low profile structure. It allows all the advantages of printed circuit technology and ease integration with millimeter wave circuits. At 60 GHz the form factor of the antenna is very small which results in low gain. So arrays with high gain and directivity are preferred for efficient and reliable communication [5]. Due to the oxygen absorption at 60 GHz, FCC allows 40 dBm equivalent isotropic radiated power (EIRP) [4] for transmission which is comparatively higher than the other wireless standards in lower GHz band. This highly allowable transmit power along with the wide bandwidth allows multi- Gigabits/sec transmission over a typical indoor distances (~10m). The transmit power and the antenna gain should be so chosen that it lies within the allowable limit. This means that for a transmit power of 16 dBm, the antenna gain should be 24 dBi. Commercial power amplifiers are now available that can produce 16 dBm of power with good linearity[6]. So the proposed antenna array with high gain is well suited for integrating with existing MMIC's for wireless video home link (1.7 Gbps), wireless LAN bridges -1Gbps and other wireless multimedia applications such as wireless Embedded systems(0.01 Mbps), Remote control (TV, lighting, door/window lock)- 0.01 Mbps, wireless video phones-1.5 Mbps wireless video conferencing- 10-100 Mbps.

2. METHODOLOGY

Fig.1 shows the geometry of the proposed 8x8 antenna array fed by corporate feed network connected to a 50 ohm feed line on one side of the FR4 substrate of thickness 0.15mm, a dielectric constant of 4.4 and the ground on the other side of the substrate. Corporate feed network is used for power division between antenna element. The amount of power delivered to each patch element is controlled by altering the width of the line and maintaining the length equal. Width of the transmission lines are calculated based on the line impedance. Corporate feed network can also introduce phase change that required for beam steering [7]. Here the corporate feed network is designed for power division.

The antenna proposed for this array is the inset fed microstrip antenna. The inset impedance for the antenna is chosen in such a way that it is less than the radiation resistance of the antenna and also it overcomes the practical difficulty of fabrication[8].

Theoretical design of antenna was done using transmission line model method [9][10]. Analyses were carried out for the 4x4 and 2x2 array also and the geometry is shown in Fig.2 and Fig.3. The substrate thickness of 0.15 mm is chosen so that it can be integrated with the MMIC's. The antenna dimension remains the same for all the three arrays. The dimensions of the radiating element are 1.0128 mm and 1.5215 mm for resonant frequency of 60 GHz. The spacing between the radiating structures is 0.64λ. The inset impedance of the antenna is chosen as 200 ohms for constructing corporate feed network. The dimensions of the transmission lines used in 8x8 array are of widths 0.0085mm, 0.0425mm, 0.1327mm and 0.2861mm and length 0.5 mm, 0.7478mm, 0.72mm and 12.86mm for 200 ohm, 141.4 ohm, 100 ohm and 50 ohm transmission lines. The 50 ohm feed can be microstrip transmission line feed or coaxial feed based on its application. In this paper we have chosen microstrip transmission line feed for integrating with millimeter wave receiver circuits [11]. The designed array structure was simulated using IE3D software and tested using Network Analyzer.

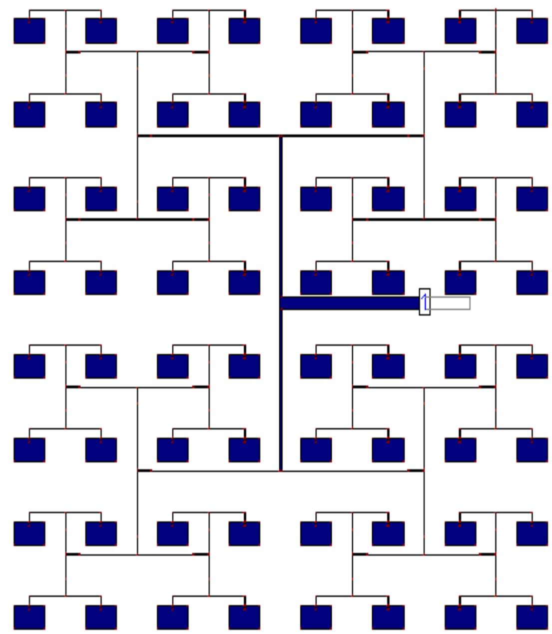

Figure 1. Geometry of 8x8 Microstrip antenna array with corporate feed network

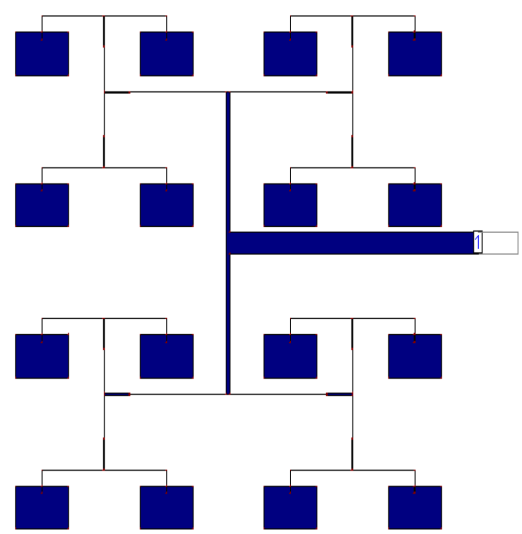

Figure 2. Geometry of 4x4 Microstrip antenna array with corporate feed network

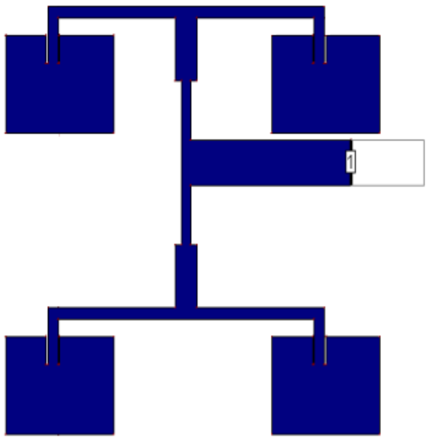

Figure 3. Geometry of 2x2 Microstrip antenna array with corporate feed network

Table 1. Design parameters of 2x2, 4x4 and 8x8 Microstrip antenna array for frequency 60 GHz, dielectric constant 4.4 and substrate thickness 0.15mm.

Array/ Dimension	2x2	4x4	8x8
Length of the patch	1.0128 mm	1.0128 mm	1.0128 mm
Width of the patch	1.5215 mm	1.5215 mm	1.5215 mm
Inset feed impedance	200 ohms	200 ohms	200 ohms
No.of Antennas	4	16	64
Substrate dimension	25.72x25.7 mm^2	12.92x12.9 mm^2	6.52x6.52m m^2
Feeding Technique	Corporate	Corporate	Corporate
Width of the 50 ohm line	0.2861 mm	0.2861 mm	0.2861 mm
Length of the 50 ohm	12.86mm	6.46mm	3.26mm

3. RESULTS AND DISCUSSION

The proposed geometry is simulated using IE3D. The performance parameter of the 2x2 , 4x4 and 8x8 Microstrip array antenna are compared in Fig.4 and simulation results listed in Table 1. The radiation pattern of the arrays are shown in Fig. 5. It clearly depicts that by increasing the number of elements in the array, the gain and directivity increases with decrease in the beam width. The 8x8 array as a maximum gain of 18.43 dBi and directivity of 22.4 dBi. and beam width of 10.49 deg which satisfies the requirement for short range indoor wireless applications. Because of its compactness, it can also be integrated with the existing MMIC's. If further enhancement in gain and beam width is required, we can go for 16x16 array and 32x32 array with similar design concepts.

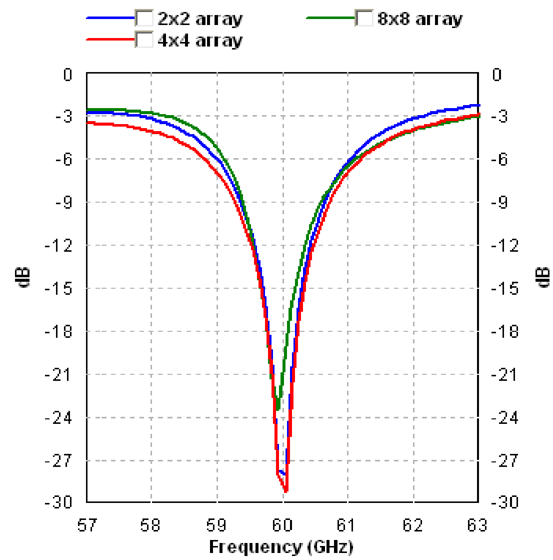

Figure 4a. Return Loss Characteristics of 2x2, 4x4 and 8x8 Microstrip antenna array

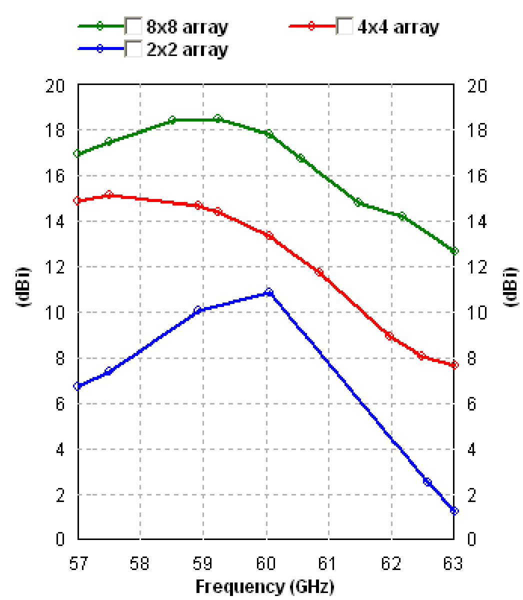

Figure 4b. Gain Vs Frequency of 2x2, 4x4 and 8x8 Microstrip antenna array

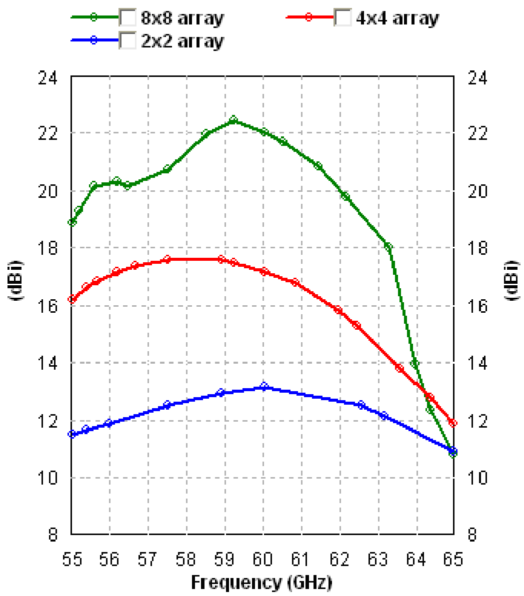

Figure 4c. Directivity Vs Frequency of 2x2, 4x4 and 8x8 Microstrip antenna array

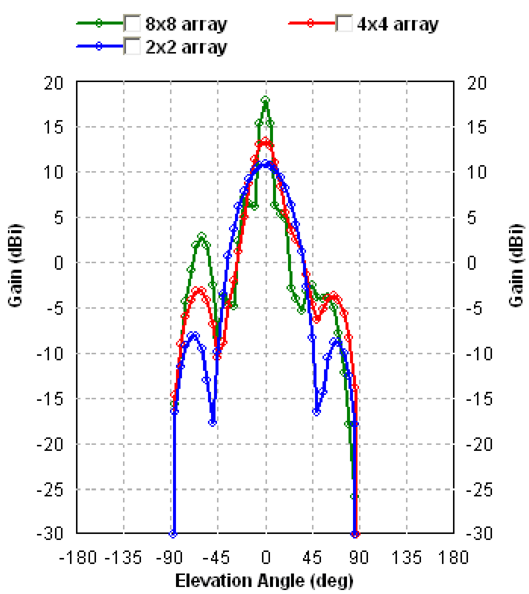

Figure 4d. Elevation angle Vs Gain of 2x2, 4x4 and 8x8 Microstrip antenna array.

Figure 4. Comparison of 2x2, 4x4 and 8x8 Microstrip antenna array performance parameter.

Table 2 . Simulated results of 2x2, 4x4 and 8x8 Microstrip antenna array.

Arrays/ parameters	2x2 array	4x4 array	8x8 array
Return loss	-27.98 dB	-29.24 dB	-23.48 dB
Return Loss Bandwidth	1.268 GHz	1.468 GHz	2.066 GHz
Gain	10.78 dBi	14.81 dBi	18.43 dBi
Directivity	13.15 dBi	17.566 dBi	22.44 dBi
3dB Beam width	40.48 deg	23.11 deg	10.49 deg

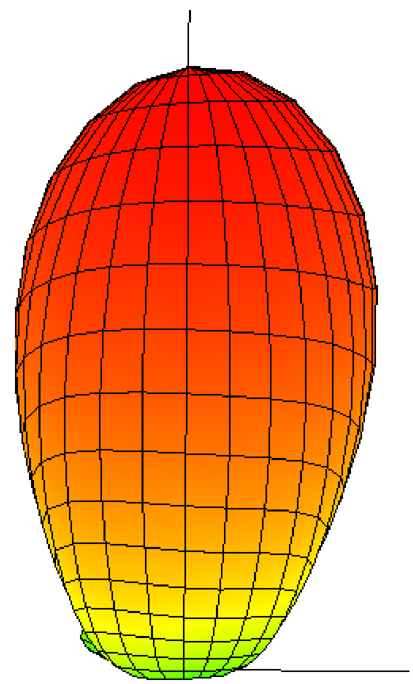

Figure 5a. Radiation pattern of 2x2 array Beam width 40.48 deg

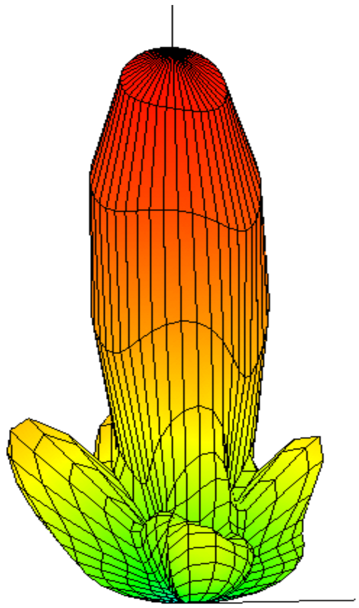

Figure 5b. Radiation pattern of 4x4 array. Beam width 23.11 deg

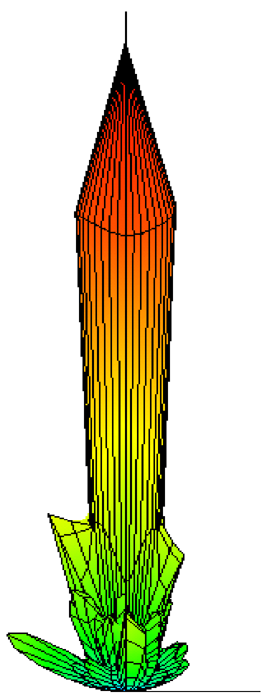

Figure 5c. Radiation pattern of 8x8 array. Beam width 10.49 deg

In view of the non availability of the testing facility at 60 GHz in our laboratory, we have designed same structure at 10 GHz and verified the design with the fabricated one. The dimension of each antenna element of a 2x2 array at 10 GHz on a FR4 substrate of thickness 1.6 mm and relative dielectric constant 4.4 is 4.98mm x 9.13mm . Inset feed impedance of the antenna is 100 ohms. The transmission lines used in the corporate feed network are of widths 1.416mm, 3.235mm and 3.05mm for 100 ohms, 70.7 ohms and 50 ohm line. The return loss is measured using an Agilent N5230A Network Analyzer. The simulated and measured return loss Characteristic of the 2x2 array which are in good agreement is shown in Fig. 6 and performance parameters are tabulated in Table.3.

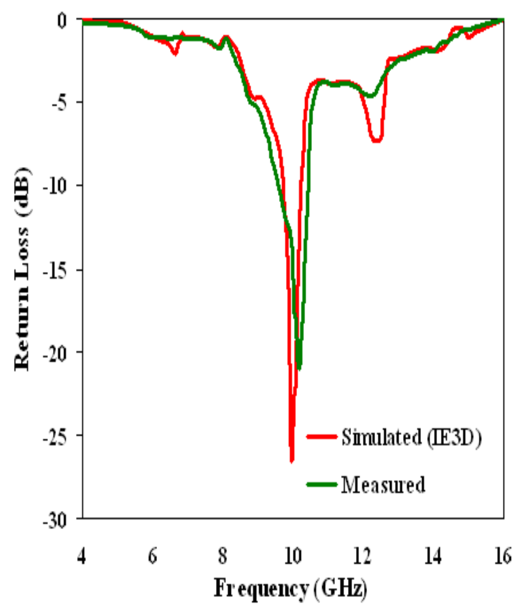

Figure 6. Comparison of measured and simulated Return Loss Characteristics of 2x2 array.

Table 3. Measured and simulated results of 2x2 array.

Antenna parameters	Simulated	Measured
Return Loss	-26.98 dB	-21.025dB
Resonant frequency	10 GHz	10.152 GHz
Return Loss Bandwidth	1.268 GHz	1.463 GHz

4. CONCLUSION

A millimeter wave planar antenna array with high gain and narrow beam width that can be integrated with millimeter wave circuits is presented in this paper. The measured results show wide bandwidth in the frequency band of interest. It can be positioned on the top of MMIC's or other wireless equipment for short range application. Because of compactness and ease of fabrication the proposed antenna is suitable for commercial applications.

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