Low Cost Planar Array Antenna for 60 GHz Millimeter Wave Band Applications

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Abstract— **-** Now a day, new emerging technology operates at millimeter wave frequencies for higher data rates of multiple gigabits per second. This paper presents a novel, planar 12-elements array antenna for 60 GHz application band. The antenna is designed on a thin substrate having substrate height is 0.3mm and dielectric constant of Ɛr = 4.4. This planar antenna array provides larger gain by connecting more number of antenna elements. The proposed antenna consists of 12 elements, where three series rectangular microstrip patch elements in a single array antenna, such four antennas are connected with series–corporate novel feed. This feeding techniques gives a good impedance matching at inputs of the radiating elements.. The antenna presents a wide bandwidth of 2.65 GHz and satisfies all performance parameters. It has return loss of -32 dB at the resonance frequency of 60GHz (S11< -10dB). The antenna is low cost, less weight and low profile with radiation efficiency of 75%. The 60GHz unlicensed band is used for radar, sensing and wireless indoor communication. The antenna is designed, analyzed and optimized on IE3D Zeland software version 15.30

Keywords*- Planar antenna array , series rectangular microstrip patch, series–corporate feed.*

I. INTRODUCTION

In the recent years, the wireless communications technology developed very rapidly, so the interest to design a compact and wideband antenna, is one of the important part of any wireless system [1][2]. Millimeter (mm)Wave band is between 30GHz to 300GHz, which corresponds to wavelengths from 10mm to 1mm.The millimeter wave technology was introduced before many decades, still it is undeveloped. In 2001, Federal Communications Commission (FCC) released the unlicensed millimeter-wave band around the 60 GHz frequency [3] and is from 57GHz-64GHz. 60 GHz frequency band is considered for Wireless Personal Area Networks (WPANs) in IEEE 802.15 standard body . This band is universal unlicensed spectrum around 60 GHz for short-range communication systems such as high speed internet, mobile distributed computing, uncompressed high-definition video streaming , wireless gaming and multimedia applications, and wireless personal area networks, Intelligent Transport Systems (ITS) and so on [4] . The millimeter (mm) wave systems have mainly been deployed for military applications and low-cost integration solutions.

Generally, a horn antenna is used due to its high performances at millimeter-wave frequency. But it is heavy, bulky and expensive too. It also requires comparatively high power and has additional losses [5]. Therefore, for 60 GHz wireless applications, microstrip patch antenna has been chosen due to their small size, light weight, low cost and ease of fabrication and integration with complex circuitry. However, the conventional microstrip patch antenna inherently has a narrow bandwidth and low gain [6]. Many broadband patch antennas can be found in the literature that proposed various techniques for bandwidth improvement. Some of the designs include patch with Substrate Integrated Waveguide (SIW), multi-layer and multi-patch designs, and different shape with multi slotted patch and so on [7][8]. However, various shapes of slotted antenna are frequently used to enhance the antenna performances because of their structural simplicity.

When the free propagation loss is high, communication at 60-GHz band may get affected. In order to compensate this problem antennas are required to be high in gain. The planar elements can easily form an array structures by combining small and simple elements, of microstrip patches. Also conformal and phased arrays can be built. Therefore for front ends of mm-wave, uses the planar antennas.

Array of patches design concept has been made in this paper which is presented for 60-GHz applications. Antenna elements are mounted inside the patch and they are feed with series–corporate novel feed. This design is fabricated on a single layered substrate for achieving higher output characteristics.

Antennas for communication systems at 60 GHz are expected to be broadband to achieve high data rate [7] and should have a high gain due to the high path loss at these frequencies [8]. Moreover, high gain antenna provides wide area coverage for data exchange.

In this paper, we present a novel planar 3-element series feed array antenna and 12-elements series–corporate feed array antenna for 60 GHz application band. The antenna is designed on a thin substrate having substrate height is 0.3mm and dielectric constant of Ɛr = 4.4. This planar antenna array provides larger gain by connecting more number of antenna elements. The proposed antenna consists of 12 elements, where three series rectangular microstrip patch elements in a single array antenna, such four antennas are connected with series–corporate novel feed. This feeding technique gives a good impedance matching at inputs of the radiating elements.. The antenna presents a wide bandwidth of 2.65 GHz and satisfies all performance parameters. It has return loss of -32 dB at the resonance frequency of 60GHz (S11< -10dB). The antenna is low cost, less weight and low profile with radiation efficiency of 75%. The 60GHz unlicensed band is used for radar, sensing and wireless indoor communication. The antenna is designed, analyzed and optimized on IE3D Zeland software version 15.30

The proposed antenna configuration and antenna geometry design are described in Sections II. Simulated results of return loss, VSWR leads to reach for design of proposed antenna are discussed in section III. Comparative Simulated results of all other parameters of the proposed both antennae with different feed are presented in Section IV, followed by a conclusion and discussion of this design is in section V. In this proposed paper the square patch is chosen because of its simplicity in design and analysis performance.

II .PROPOSED ANTENNA CONFIGURATION AND DESIGN

The series feeding technique consists of a continuous transmission line from which small amount of energy is coupled into the individual element along the line

The single patch geometry of proposed microstrip antenna consists of three patches connected in series with each other having same length and different widths. The dimensions of top patch is 2.125mm X1.25mm , while middle patch is 2.125mm X1.775mm and lower patch is 2.125mmX1.3mm as shown in following Figure 1. The separation between top and middle is 1.125mm and that of middle and lower patch is 1.075mm, with strip line feed for proper impedance matching as shown in Figure 1.

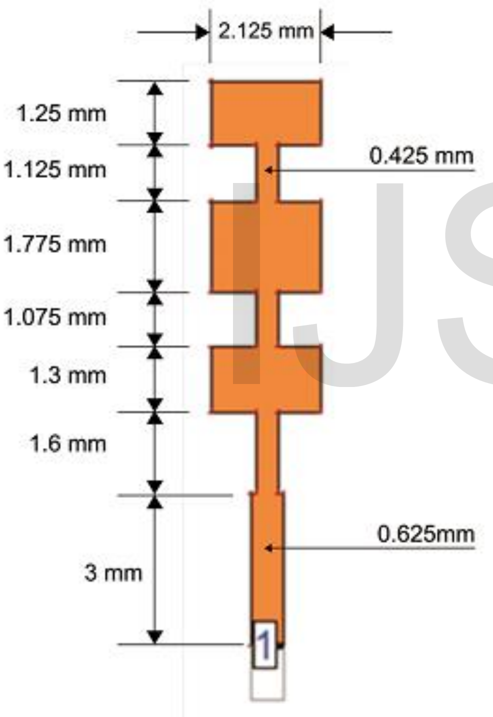


Figure1. The series feed Single Patch Geometry antenna

The proposed first internal antenna has compact dimensions of 2.125 X 11.125 mm^2. It is mounted on the top portion of a dielectric substrate having height h=0.3mm and relative permittivity Ɛr=4.4, and loss tangent 0.025 for radiating purpose to which antenna elements are mounted on it with for exciting the antenna elements. The system ground plane studied here is chosen to have dimensions with length 2.125 mm and width 11.125 mm, a series feed is employed to excite the antenna.

The corporate feed widely uses parallel feed configuration. The power is equally split at each junction[10]. However different power divider ratios can be selected, for power distribution across the array. The disadvantages of this type of feed is that it requires long transmission lines between radiating elements and the input port, hence reducing the overall efficiency of the array[9] .

The proposed high gain planar antenna has compact dimensions of 11.125 X 11.15 mm^2 as shown in Figure 2. It is mounted on the top portion of a dielectric substrate having same height, h=0.3mm and relative permittivity Ɛr=4.4, and loss tangent of 0.025 for radiating purpose to which antenna elements are mounted on it for exciting the antenna elements. The series-corporate feed is being discussed for this 4x3 array of microstrip patch antenna to achieve, higher gain, input impedance and better bandwidth of the antenna array. Because single antenna is not enough to achieve high gain ,as it has limited gain.

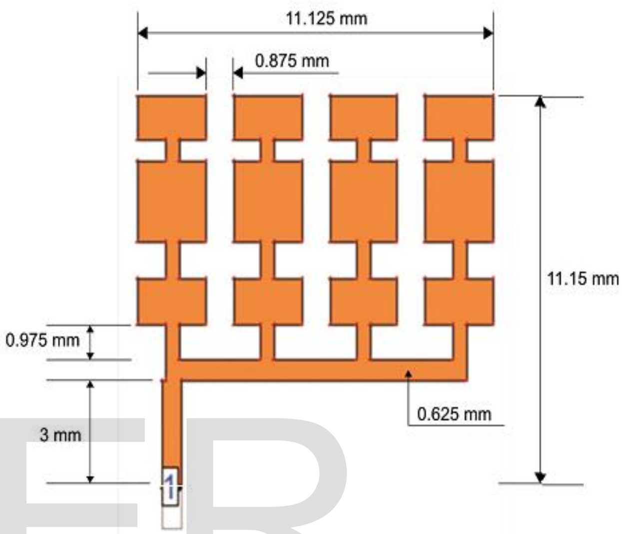


Figure2. The series -corporate feed Array antenna Geometry

III. PARAMETRIC STUDY

Parametric study of the proposed antennae is carried in the presence of the coupling strip structure. Figure 3 shows the simulated return loss, Figure 4 as VSWR of the proposed series feed antenna. This antenna gives the excellent return loss curve in the specified frequency range of 58.55GHz to 61.9GHz . The curve has deep and wide dips at frequency 60 GHz. The return loss obtained at that frequency is -32 dB. A bandwidth of 3.35GHz which correspond to 5.587% is achieved from the current design.

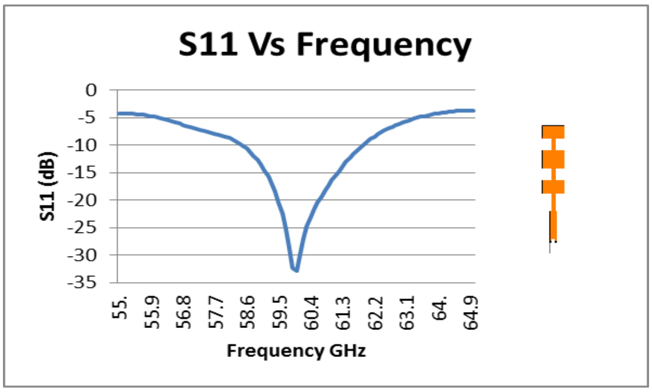


Figure 3. Simulated return loss for the series feed antenna

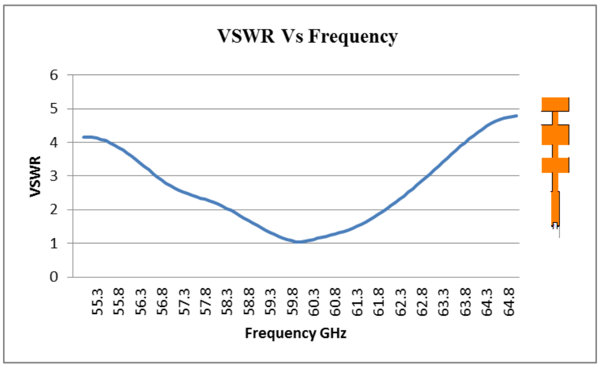


Figure 4.Simulated VSWR of series feed antenna

Figure 5 shows the simulated return loss, Figure 6 as VSWR of the proposed series-corporate feed antenna. This antenna gives the excellent return loss curve in the specified frequency range of 57.9GHz to 60.55GHz . The curve has deep and wide dips at frequency 60 GHz. The return loss obtained at that frequency is -32dB. A bandwidth of 2.61GHz which correspond to 4.35% is achieved from the current design.

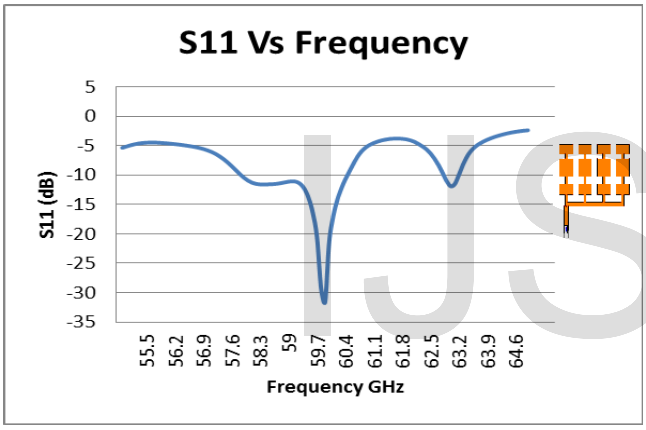


Figure 5. Simulated return loss for the series -corporate feed array antenna

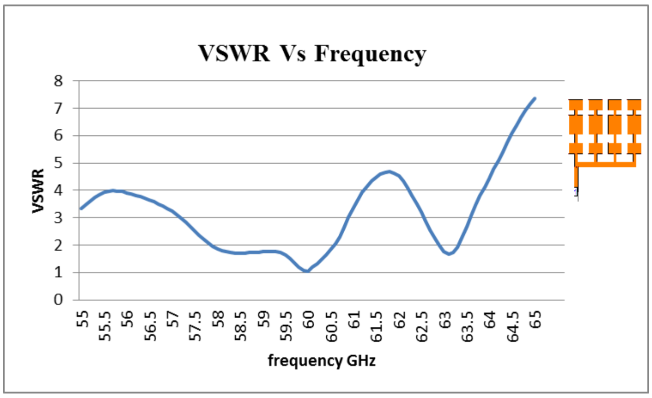


Figure 6.Simulated VSWR of series -corporate feed array antenna

In the design, 2:1 VSWR is used as the impedance matching bandwidth, which is generally acceptable for practical mobile phone antennas [2] as shown in Figure 4 and Figure 6.

2D Radiation Pattern at 60GHz is as shown in Figure 7. For series feed antenna.

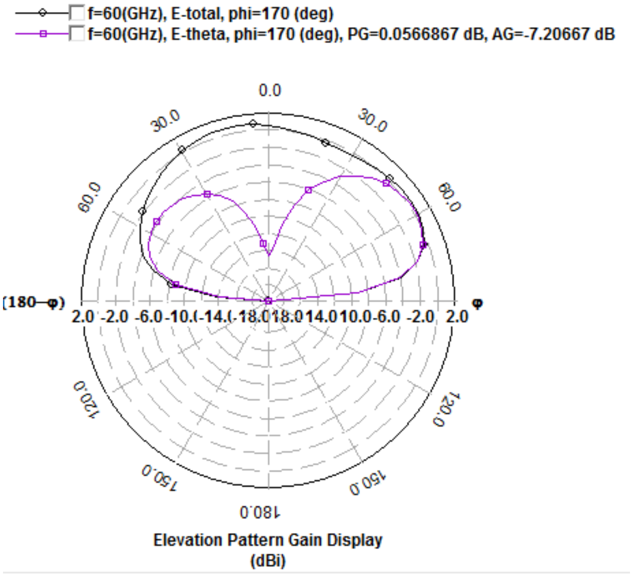


Figure 7.Simulated Radiation Pattern of series feed antenna

2D Radiation Pattern at 60GHz is as shown in Figure 8. For series-corporate feed antenna

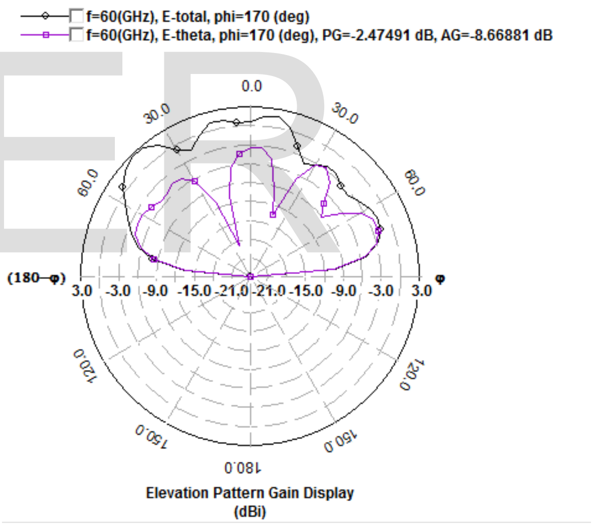
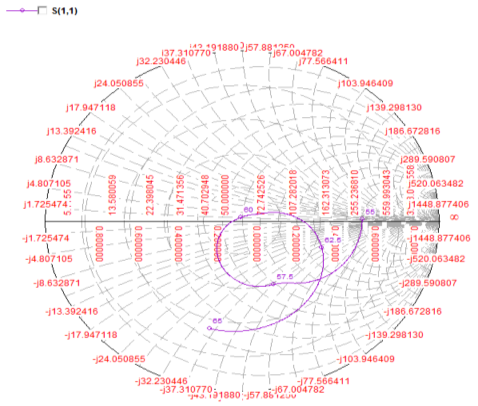


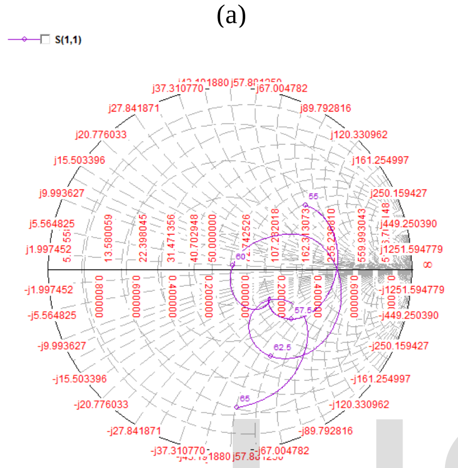
Figure 8. Simulated Radiation Pattern of series-corporate feed array antenna

The radiation pattern of the arrays is shown in Figure 7 and Figure 8. It clearly indicates that by increasing the number of elements in the array, the directivity and gain increases with decrease in the beam width and increasing number of array elements. The 4x3 array has a maximum gain of 9 dBi and directivity of 12 dBi 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 3x6 array and 3x8 array with similar design concepts.

Input impedance smith charts for series and series-corporate feed are as shown in Figure 9 (a) and (b) respectively.



(a)



(b)

Figure 9. Input impedance smith charts

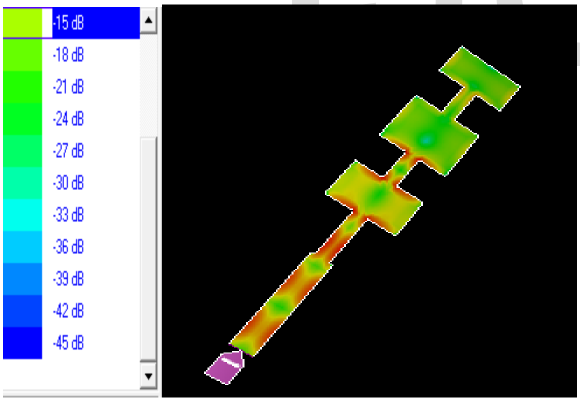


Figure 10.Simulated current distribution of series feed antenna

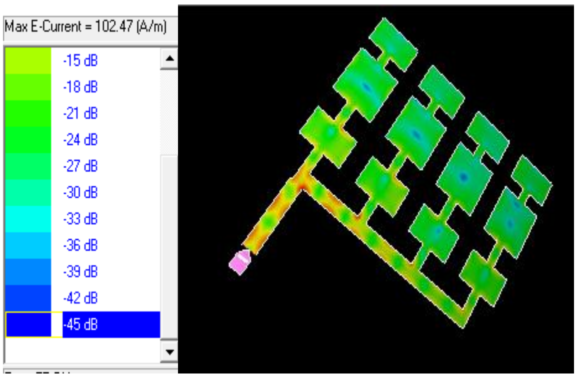


Figure 11.Simulated current distribution of series-corporate feed array antenna

The simulated surface current distributions on the printed metal portion of the proposed antenna are as shown in Figure10 for series feed while Figure 11 shows for series-corporate feed array antenna. The relatively strong current distributions are observed on the coupling strip. The proposed planar antenna structure is formed by, the radiating strips (feeding strip, coupling strip) and the system ground plane. The whole antenna configuration makes an effective radiating system to cover wide bands of 3.35GHz and 2.61GHz for series feed and series-corporate feed respectively.

IV. SIMULATED RESULTS AND DISCUSSION

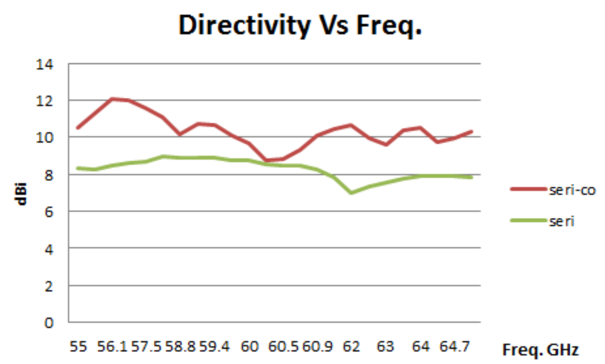
The proposed antenna is fabricated. Figure 12 shows photos of the fabricated printed antenna. The simulated results are obtained by IE3D15.30

(a) top side

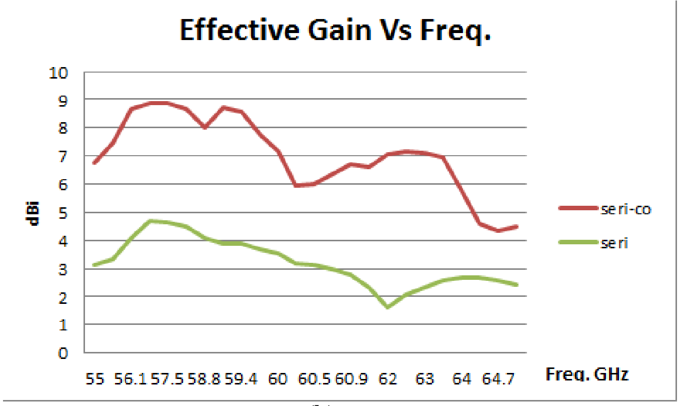
(b)back side.

Figure 12. Photos of the manufactured printed series-corporate feed array antenna

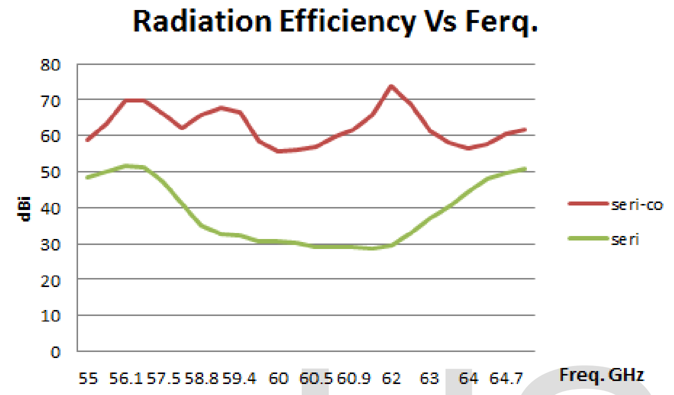
Several main parameters, in this design, are also studied.



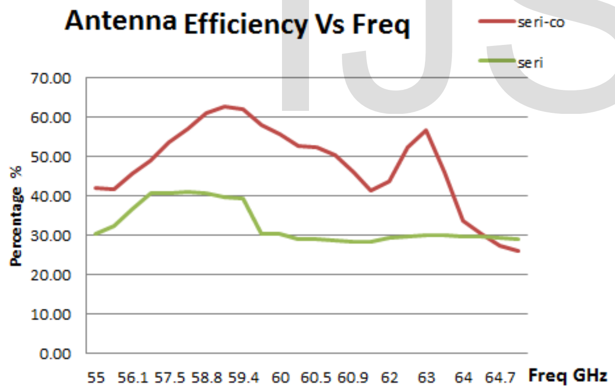
(a)



(b)



(c)



(d)

Figure 13.Simulated results of series and series-corporate feed array antenna

Proposed antenna with the presence of wideband features and good radiation efficiency higher than 70% which is about 75% over the desired operating band is as shows in Figure 13. The antenna efficiency is also about to 65%. This is the good feature for universal unlicensed spectrum around 60 GHz for short-range communication systems.

V. CONCLUSION AND DISCUSSION

The paper proposed two antenna designs with series feed and series–corporate feed techniques. The measured parameters, including radiation patterns, return loss, VSWR, radiation efficiency and antenna efficiency are given to validate the proposed antenna for the universal unlicensed spectrum around 60 GHz for short-range communication systems. The radiation efficiency higher than 70% is achieved over the desired operating bands, for the communication system applications. They achieve higher gain of 9dBi and better bandwidth of 2.61GHz centered at 60 GHz. We observed from the above results that the increase in the number of elements of an array technique with series-corporate feed had increased the impedance bandwidth,gain and directivity of 12dBi is obtained.

Millimeter wave microstrip antenna are smaller in size and lower in cost. This structure is very simple and easy to fabricate , but it required some highly precise fabrication, for such a small size antenna.

Therefore this antenna can be considered as a good candidate for indoor application and short distant speedy communications at 60 GHz.

All experimental results indicate that a high-performance antenna array is obtained by simply using the proposed series-corporate feed technique.

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