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High Gain Circular Sector Microstrip Patch Antenna for Millimeter Wave WLAN Applications

Dibin Mary George, VA Libimol, S Sreenath, P S Sreekala and C K Aanandan

Department of Electronics, Cochin University of Science and Technology, Cochin, India
dibinmary@gmail.com

ABSTRACT

Radiation Characteristics of a circular sector micro strip antenna (CSMA) designed for the 60 GHz millimeter-wave band an application is presented in this paper. The proposed antenna consists of a circular patch with sector slot excited by micro strip feeding technique. Substrate material chosen here is the Kapton which is a polyimide used in high performance flexible printed circuit and thermal blankets on satellites, and various space instruments. Parametric studies have been performed for optimizing the different parameters such as slot angle, Feed point etc. for the best possible results. The proposed antenna configuration resulted in a bandwidth of 1.47 GHz covering the frequency range from 59.26 to 60.73 GHz, with a gain of 8.0334 dB at the 60 GHz resonance frequency. The CSMA proposed is characterized by its ease of manufacture, its miniature dimensions and its simple design. The presence of slot makes impedance variations along the circumference so that the antenna can be fed using a micro strip line.

Key words: Micro strip patch antenna, antenna with sector slot, 60 GHz, millimeter wave, micro strip feed, WLAN

INTRODUCTION

In recent years, the transmission of multimedia content using Wi-Fi has become widespread, with an ever increasing demand from users to send and receive data, audio and video content, wirelessly between devices in their homes and offices. The current Wi-Fi standards operate at 2.4 and 5 GHz which allow a maximum data transfer of 54Mbps which is sufficient for audio and low quality video. With increasing technological advances such as High Definition and 3D Television, these bandwidths offered by the current Wi-Fi standards are not adequate and there is a data 'bottle neck'. This has resulted in a new standard (IEEE 802.11ad) which specifies an operating frequency of 60 GHz and allows at least a 50 fold increase in the available bandwidth.

Operating at 60 GHz poses a number of challenges due to the very small wavelength of electromagnetic waves at this frequency. The effect of this is that objects in a room, have a much greater effect on the propagation of the electromagnetic waves, reflecting and absorbing the signal in a very complicated manner. Because of this the new standard requires that the system antennas are directional and can be focused towards the device with which they are communicating. This reduces interference and allows faster data rates. The rapid development of wireless technology increased the interest to design a compact antenna, which is an important part of any wireless system [1]–[5]. Traditionally, horn, reflector, and lens antennas have been used in mm wave devices. These antennas have high gain and efficiency but they are not suitable for low-cost commercial devices because they are expensive, heavy, bulky, and they cannot be integrated with solid-state devices [6]. Micro strip slot and rod antennas are popular in millimeter wave applications, but planar antennas that are printed on top of a dielectric substrate are lightweight, low-profile, compact, and easy to integrate with MMICs. The use of planar integrated antennas can also greatly reduce interconnection losses and wireless transceiver costs. The use of PCB fabrication will allow complete systems to be fabricated on a single multilayer printed circuit board, combining the low frequency signal processing and control elements with high frequency microwave and antenna arrays. This will greatly reduce the cost of a complete system and make mass produced 60GHz communications a possibility. The conventional microstrip patch antenna inherently has a narrow bandwidth and low gain [7]-[8]. A sector antenna reduces multipath blurring and interference in broadband wireless communications [9]-[10]. The 60 GHz circular patch without sector has less bandwidth and gain for the 60 GHz operation [11].A circular patch antenna with a sector slot suitable for operating in the 60GHz band is proposed in this paper.

60 GHZ CIRCULAR SECTOR MICRO STRIP ANTENNA DESIGN GEOMETRY

The 60 GHz circular sector micro strip patch antenna geometry is shown in Fig.1. It consists of a circular patch of radius r, with a sectoral slot of angle (θ) is introduced. The structure is fabricated on a thin substrate of thickness h (h<<λ) and relative substrate permittivity ε_r. The Introduction of slot produces an impedance variation along the circumference so that it can be easily excited using a microstrip feed. The microstrip feed line is positioned at an angle ϕ as shown in the fig.1. Comparison of the properties of the antenna of our present work with previous work [11] is given in Table-1.The parameters of the antenna are optimized using HFSS to get the response as shown in fig.2.

Table-1 Comparison of Current Work with Previous Work

Properties of the Antenna	Previous Work[11]	Current Work
Bandwidth(GHz)	1.2	1.47
Gain (dB)	5.78	8.03
Size or Diameter(mm)	1.8	1.6

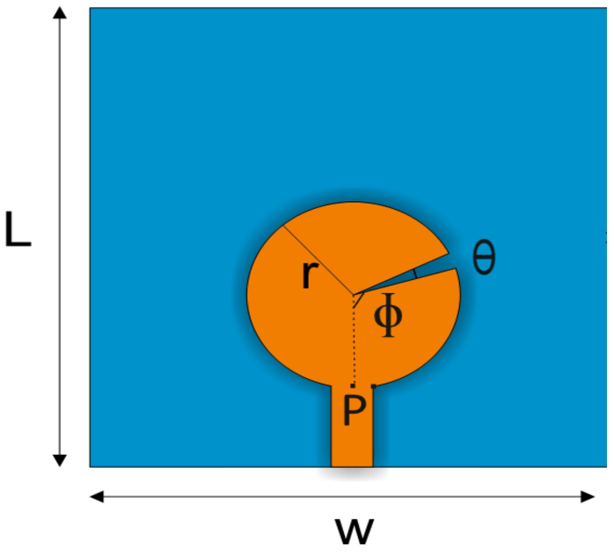


Fig.1 Circular Sector Slot Microstrip Antenna

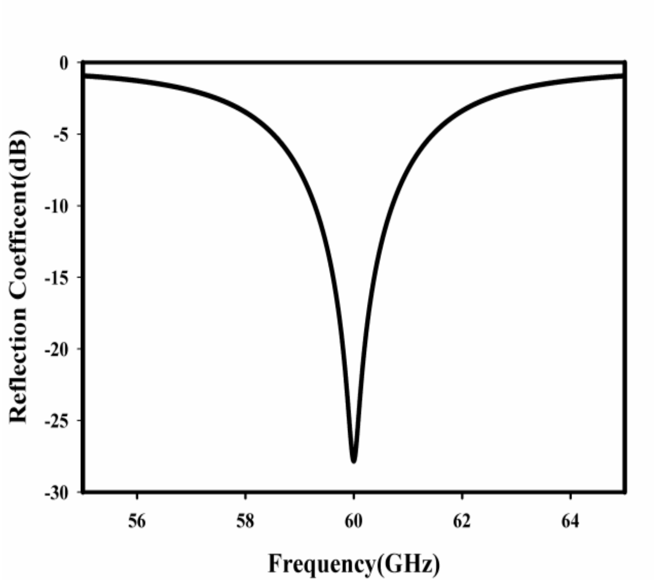


Fig.2 Return Loss of the Antenna with Optimized Parameters (r=0.8mm, θ =11.3 ^{0}, H=0.125mm, ϕ=99.3^0, ε_r=2.9, W=4mm.L=4mm)

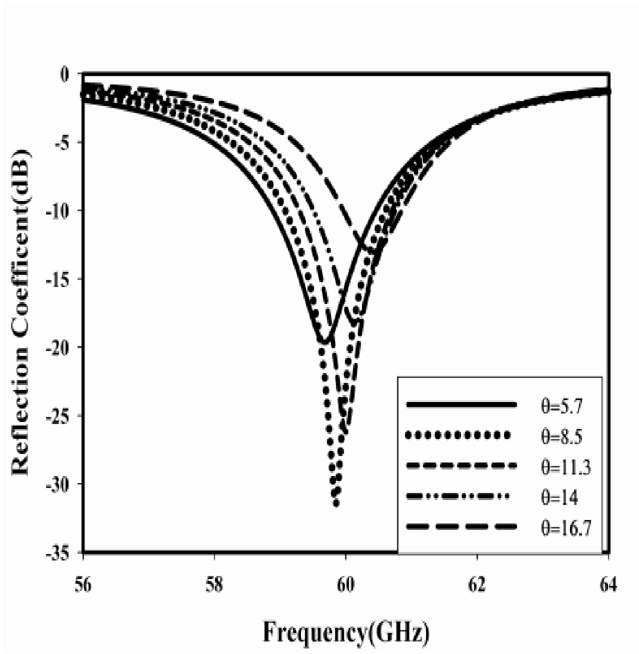


Fig.3 Variation of Reflection Coefficient with Slot Angle

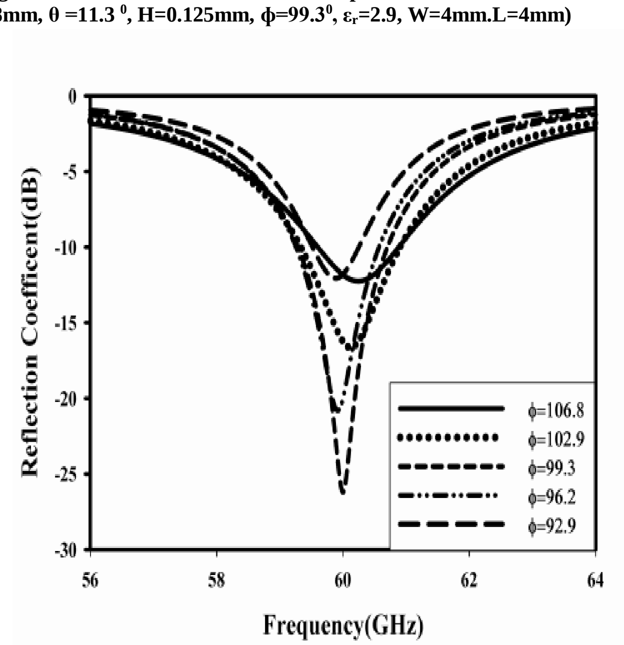


Fig. 4 Variation of Reflection Coefficient with Feed Point

STUDY OF THE ANTENNA PARAMETERS

Effect of Slot Angle

The introduction of the slot reduces the resonant frequency by increasing the overall resonating length. More importantly the presence of slot produces an impedance variation along the circumference so that a microstrip line can be used to excite the patch. The effect of slot angle on the resonant frequency, band width and return loss of the antenna is shown in fig.3. Increasing the slot angle increases the resonant frequency as the overall resonating length is decreased. As the slot angle is varied, the angular position of the feed also is to be shifted for matching and the results are shown in the fig.3.

Effect of Feed Point Position

In this section, the variation of the return loss with different feed position of the antenna is studied and shown in fig.4. The feed position is indicated in terms of angle ϕ as shown in figure.

RESULTS AND DISCUSSIONS

The surface current distribution in vector frames at 60 GHz is appeared in Fig.5. The maximum surface current density can be seen at the centre of the circular patch and minimum is approximately at the edge near the slot and opposite edge of the slot. The gain verses frequency graph is shown in fig.6. The maximum gain obtained is approximately 8.0334 dB around 60GHz and it is stable over the operating band. However, the gain can be further enhanced by making a compact array of this small antenna configuration. The combination of the enhanced configuration parameters along the circular sector slot micro strip antenna size enhanced the antenna performances. The directivity verses frequency graph is shown in fig.7. The directivity of the proposed antenna at 60GHz is 7.6317dB.

Radiation Characteristics of the Optimized Antenna

Fig.8 demonstrates the radiation Characteristics of the antenna at 60 GHz. The pure line represents the co-polarization whereas the dashed line represents the cross-polarization pattern. In the E-plane and H-plane the co-polarization level is higher than the cross-polarization while slightly higher but difference below –20 dB.

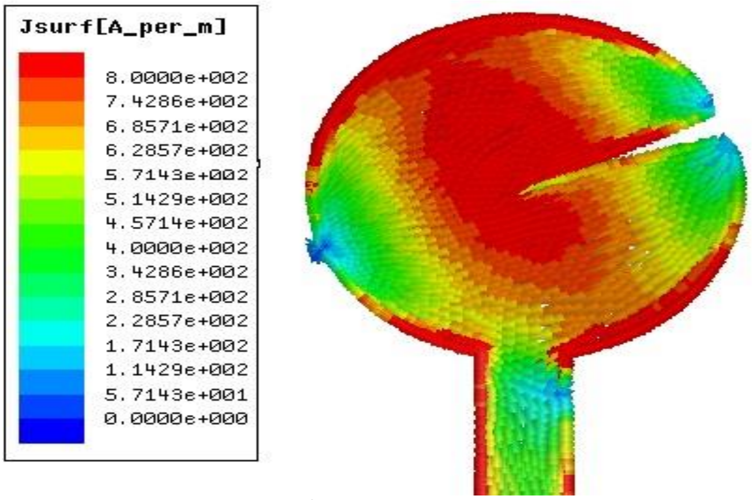


Fig. 5 Surface Current Distribution

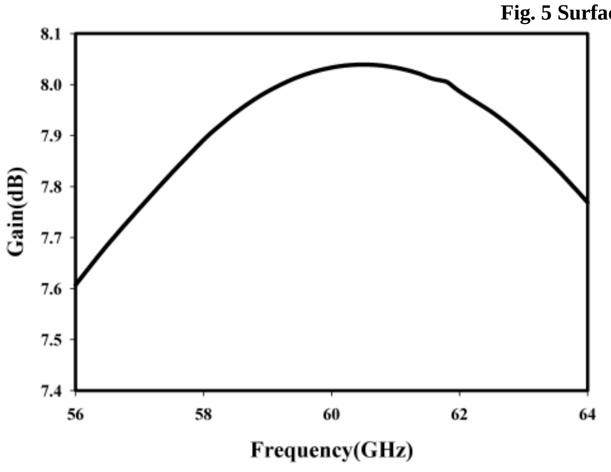


Fig.6 Gain verses Frequency

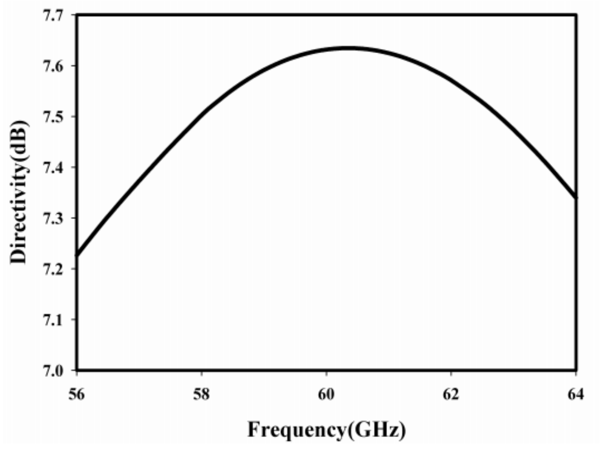
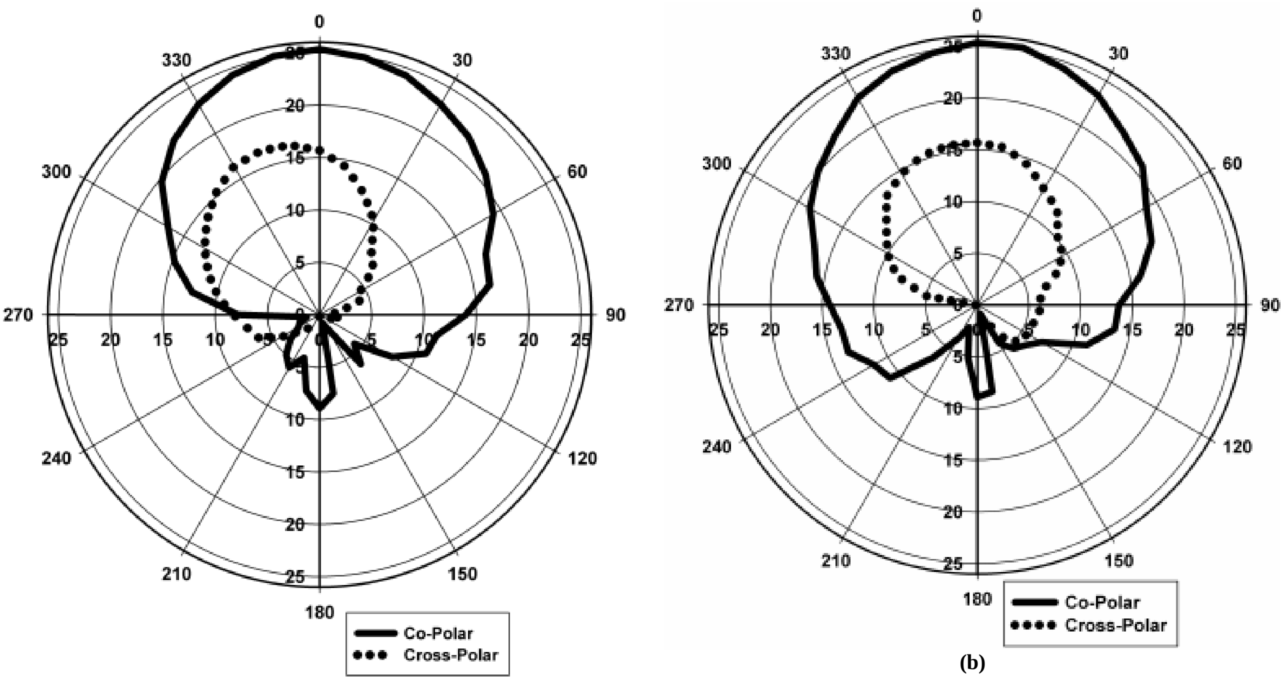


Fig.7 Directivity verses Frequency



(a)

Fig.8 2D radiation pattern for (a) E-Plane and (b) H-plane

CONCLUSION

In this paper, the design of a circular micro strip antenna with sectoral slot that provides a high gain radiation pattern at 60 GHz band is presented. The design is been proposed for short range high-speed wireless applications at 60 GHz. Parametric studies have been performed to optimized the performance. This structure is very simple and easy to fabricate.

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