Analysis And Design of Microstrip Patch Antenna at 60 GHz For Automotive Radar

Thesis submitted in partial fulfillment of the

Requirements for the Degree of

MASTER OF TECHNOLOGY

By

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UNDER THE GUIDANCE OF

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WAKNAGHAT, SOLAN, H.P.

MAY-2018

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DECLARATION

I hereby declare that the work reported in the M-Tech dissertation entitled **"Analysis and Design of Microstrip patch antenna at 60Ghz for automotive radar"** submitted at **Jaypee University of Information Technology, Waknaghat, India,** is an authentic record of my work carried out under the supervision of **Dr. Ashwani Sharma and Dr. Vikas Baghel**. I have not submitted this work elsewhere for any other degree or diploma.

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CERTIFICATE

This is to certify that the work reported in the M-Tech. dissertation entitled "**Analysis and Design of patch antenna at 60Ghz for automotive radar application**", submitted by **Nikita Sharma** at **Jaypee University of Information Technology, Waknaghat**, **India,** is a bonafide record of her original work carried out under my supervision. This work has not been submitted elsewhere for any other degree or diploma.

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Nikita Sharma

Date:

ABSTRACT

The automotive radar antenna array analysis and design have been presented for use in 60GHz short range automotive collision avoidance radar. Today's automation needs to have the efficient antenna devices so that road safety can be improved to a large extent.

The first portion of the thesis gives the basic idea behind the selection of 60 GHz radio band for short range automotive radar and the basics of the automotive radar technology.

The second d part comprises of the detailed explanation of the microstrip patch antennas their design procedure and the considerations. It includes the information of patch antenna array for improving the gain in the automotive radar.

CST studio suit is employed for all the design and the performance analysis of the microstrip antenna as well as for array of elements.

In the end thesis shows the simulation results or the single microstrip patch antenna as well as the results of the array with different spacing among them varying between half of the resonance wavelength and one third of the resonance wavelength and steering is performed by giving the progressive phase shift. It also shows the improvements in the main lobe magnitude while jumping from a single patch to the array but at the same time some other output parameters get degraded.

LIST OF ABBREVIATIONS

GHz	Gigahertz
NTP	National transport plant
PCB	Printed circuit board
GPS	Global positioning system
FCC	Federal communication commission
SLL	Side lobe level
UWB	Ultra-wide band
NB	Narrow band
CP	circular polarization
MRR	Medium range radar
LRR	Long range radar
SRR	Short range radar

LIST OF FIGURES

CHAPTER-1

INTRODUCTION

Automotive radar antennas have become a very essential part of the automotive industry for road safety like lane change assists, autonomous emergency braking, backing out of parking area and to avoid collision with other vehicles indication of stopping the vehicle, all these driver assistance systems work via automotive radar, among these adaptive cruise control is handled by LRR(long range radar), lane change and cross traffic are Handled by MRR (medium range radar), whereas the object detection and the parking aid are the part of SRR(short range radar). Automotive radar determines the relative velocity range and angle of the distant objects by sending the radio waves. Automotive radar antenna designs are preferred at millimeter wave range because at these frequencies antennas not only provide us with large channel capacity and high data rates but also at millimeter wave range targets can even be detected in bad weather conditions like fog, rain showers, hails, snow, thunder storms and lightning.

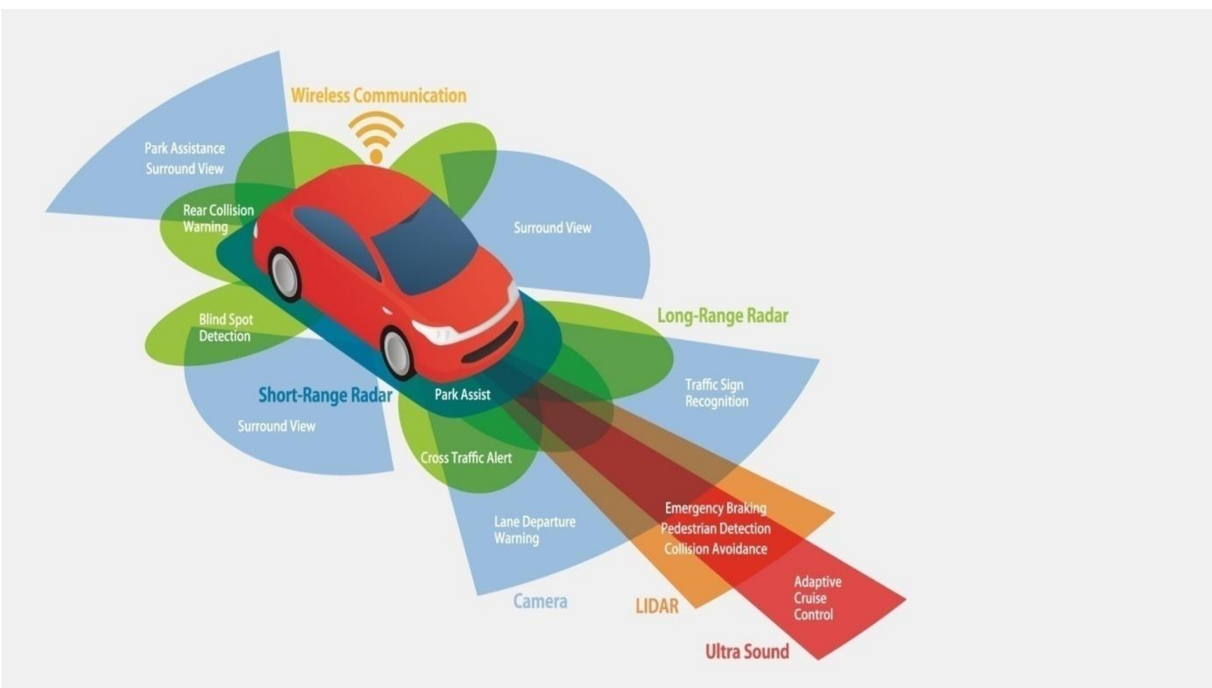

Figure 1.1: Various road safety sensors.

The antenna arrays have become an integral part of radar communication because they provide sufficiently high gain, beam forming and also antenna arrays designed at millimeter wave range is low profile thus they don't affect the appearance of vehicle. 60 GHz is widely used in practical because it is an unlicensed frequency band but this frequency range is specifically preferred for the short range applications that are of distance less than 1Km due to the high atmospheric attenuation at this particular frequency.

By the year 2020 UWB production will be discontinued because of spectrum regulations and standard developed by FCC and ETSI in US and Europe. Thus high range frequencies would be available for automotive radar and thus bandwidth would be more as compared to UWB.

Resolution and accuracy of the distance measurements are the factors which requires serious attention, frequency modulated continuous wave radar transmits a "chirp signal" which is nothing but the frequency sweep and transmitted over the system bandwidth and the objects those comes in the way of the signal, reflects this chirp or ramp back to the transmitter and the distance of the object from the transmitter can be obtained by calculating the frequency difference of the transmitted chirp and the chirp which is reflected back from the object because this difference is linearly related to the distance measurements.

The Phase difference between the transmitted signal and the signal which is at the receiver can be utilized to measure the relative velocity of an object. With the decrease in the wavelength or as we keep on increasing the frequency resolution and accuracy increases. Therefore millimeter range frequency has been considered to be better than UWB.

1.1 Problem statement

While designing any vehicle automotive safety must be given the prime importance rather than other vehicular luxuries so as to reduce the road accidents and their consequences although the automakers have reduced the rate of consequences of road accidents to some extent, by introducing seatbelts and airbag system but still some more immense advancements need to done in this field to avoid the road accidents to a large extent and this can be made possible only when more and more Automotive safety will be introduced in the vehicles by the automaker. Although there are many safety technologies which are incorporated in the vehicles but their microelectronic signal processing have the high delay time besides this the implementation of these technologies is very expensive which prevents automakers from including these in vehicles hence road safety is not considered.

According to current survey in year 2017 the figures of road accident killed in India came down by 3% i.e.by 4560 among 1.51 which is the result of safety technologies incorporated in the vehicle sand it needs to be further reduced this reduction can be achieved by only by incorporating safety techniques. According to the, 2014-2023 national transport plan (NTP) target is that by 2024 fatalities and severe injuries shouldn't be more than 500. There are four layes of this plan which includes vision zero, targets for the particular time span, indicator targets and its measures, where vision zero means that no one should be severely injured or killed. Vision zero is the basis for the all safety technologies and it is based upon the idea of long term, careful system and fixed amount of work in this field.

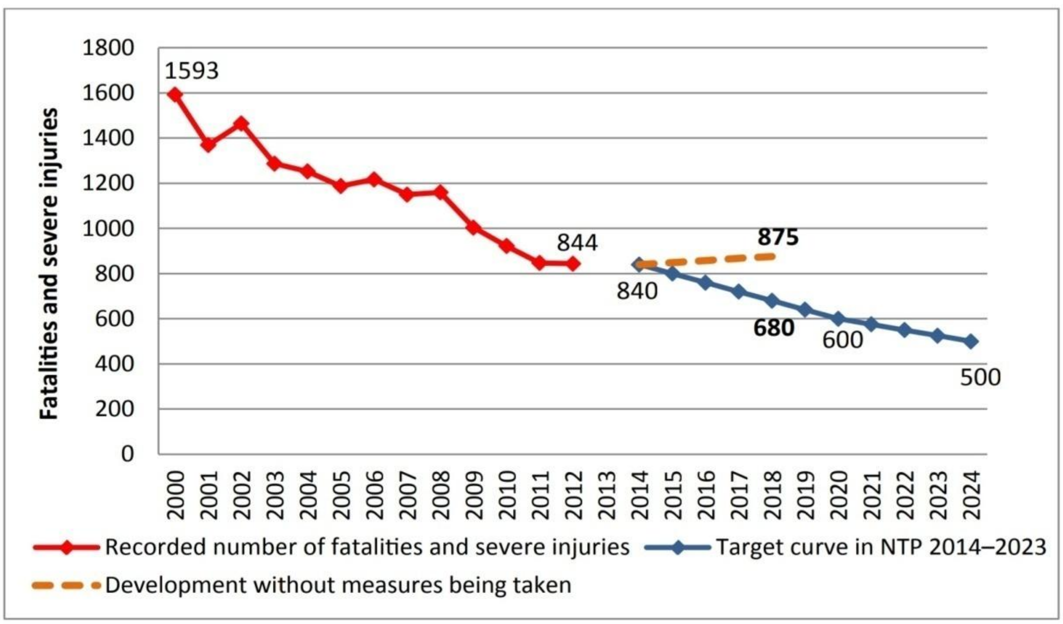

Figure 1.2: Expected reduction in the road accidents by NTP

For achieving this scenario the every vehicle must incorporate all the possible road safety technologies and this would be possible only when the devices of the automotive radar won' be too expensive and the design of the low cost, low profile antenna can make automakers to incorporate all these safety technologies in almost all the vehicles the safety technologies must be mandatory for every vehicle design. Use of short range radar at 60GHz unlicensed band is the low cost and very effective design for forward collision warning within the short range.

1.2 60 GHz millimeter wave band for short range automotive radar

This microwave band provides the favorable circumstance to have orders of magnitude which eventually gives reliable gbps data rates that are higher than UWB and other lower frequency ranges. There are some desirable features of the millimeter range over the traditional microwave bands due to which millimeter wave range automotive radar are preferred over others.

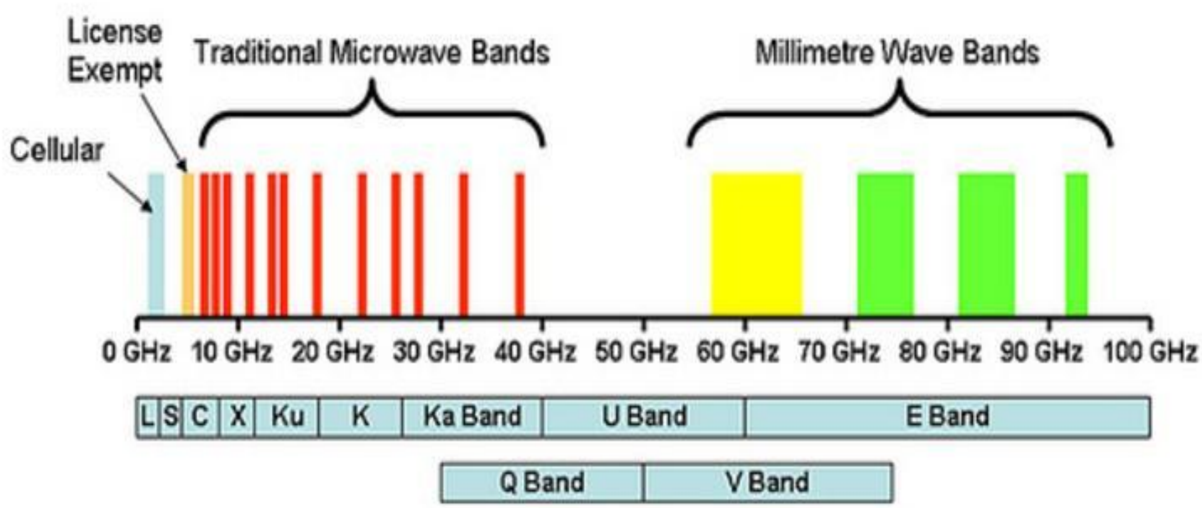

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Figure 1.3: The location of the traditional microwave band and millimeter wave band in the spectrum.

Bandwidth, power and data rates all three of them are directly proportional to each other. Large bandwidth allows transmitting more power and we can get higher data rates. In 60 GHz band enough spectrums has been allocated which helps in getting wireless connections.

The federal communications commission (FCC) in year 2001 made the 7 GHz block unlicensed spectrum between 57 ~ 65 GHz which is much higher as compared to the 1.5GHz block of the UWB and 660 MHz of the 802.11n. Besides total available spectrum 60GHz band is also having 2500 MHz of bandwidth whereas in UWB the bandwidth of 520 MHz and in 802.11n bandwidth of 40 MHz is available.

The 7 GHz of license exempt spectrum has its availability worldwide. This is a continuous spectrum, thus antennas operating in this range doesn't have to face difficulty in regulatory.

Table 1.1 Performance comparisons of 60GHz with traditional microwave band.

	Channel bandwidth	Max. possible data rate	Effective transmit power
802.11n	40 MHz	1,100 Mbps	160 mW
UWB	520 MHz	80 Mbps	0.4 mW
60 GHz	2500 MHz	25,000 Mbps	10,000 mW

10's and 100's of watts of equivalent isotropic radiated power are provided for the wireless transmission in the 60GHz band due to its oxygen absorption characteristics and because of this high power transmission capability along with wide bandwidth helps in achieving the high data rate transmission. Also the 60 GHz band does not require the complex modulation technique.

There is oxygen absorption at 60 GHz which attenuates signals that travel long distances and this oxygen absorption property is not present in other radio bands this limit has an advantage of security and also in mitigating the interference since the radiation from any 60 GHz link can be immediately lower down to a level, which won't interfere the other neighboring 60 GHz links, thus more devices can be operated simultaneously with minimal interference to each other. Furthermore since 60 GHz radios are allowed to transmit high power the antennas are very directional as compared to the traditional radio waves and directivity of any antenna tells how well is the focus of antenna in the desired direction. Narrow beam widths avoid the interference between the various 60 GHz signals. To get the information about the signal a receiver which is lined up on identical trajectory need to be located that too in the vicinity of transmitter which is not a easy task to do, and this characteristic makes the 60 GHz highly protected as compared to the traditional lower range radios.

According to friss's law, as operating frequency changes from a lower value to the higher, antenna effective area reduce. The Friss equation of path loss is reason for the high antenna gains especially at 60 GHz. This concludes that an antenna which is having a gain of 25dBi for 60GHz will be having area equivalent to one square inch although the gain for the same area in case of 5GHz would be only 3dBi. Due to this property 60 GHz and other millimeter radio have the capability to transmit more power with more speed over the links and this makes the 60 GHz antenna penetrate the objects in spite of attenuation due to oxygen absorption.
Thus 60GHz radio band is an appropriate choice for automobile short range antenna applications.

1.3 Planar antenna for short range automotive radar

For spreading all over the angular range of object for covering it fully for the scanning we need to have beams which are intersecting with each other at their 3dB points. Radar target's angular positon can be determined by monopulse technique, according to this technique angular position determination of the distant object can be done by taking the ratio of the amplitudes of the received signals in the radar beams which are adjacent Beam width of antenna is limited by the availability of the mounting space on the bumper and beam width further depends upon the antenna's aperture size.

Although monopulse technique for determining angular position of antennas have played very important role in automotive radars but there are some advancements in the technique i.e. complex monopulse which is specially for multi target situation and there are high resolution algorithms as well. If compromise with the accuracy is acceptable for getting faster determination of the angular position, it can be achieved by increasing the beams and target angle should be determined in a highest.

CHAPTER-2

OVERVIEW OF MICROSTRIP PATCH ANTENNA

This chapter comprises of the literature study of the microstrip antenna which includes the performance characteristics, properties, analysis, basic theory, which are significant for the ultimate design of microstrip patch antenna array for target detection in automotive radar. In 1972 Bob Munson invented microstrip antennas, although earlier work was done in 1953 by Dchamps but it got popular in 1970's.

2.1 Basic structure of microstrip patch antenna

Microstrip antennas are undoubtedly most preferred and extremely versatile antennas at microwave frequencies. These antennas are nothing but a metal "patch" on the top surface of the dielectric substrate which is on the ground, and that's the reason it is also referred to as a "patch antenna". This patch could be of either planar or non planar geometry and it's a narrow band antenna. Microstrip antennas are mostly employed in microwave frequencies and they excellent radiators at the high frequencies which are relevant for antenna technologies. Microstrip antennas are very versatile, which typically includes compactness, wide bandwidth for reliable ubiquitous links connectivity, compatibility with PCB technology which makes its manufacturing easy in both ways either as single element radiator or as an array of radiating elements and these benefits of the patch radiator makes it appropriate choice for various vehicular applications like automotive radar satellite link antennas based on vehicles GPS (global positioning system).

Despite of numerous benefits moicrostrip antennas have some demerits as well, which includes their high Q which sometimes exceeds 100, poor polarization purity, its narrow bandwidth which sometimes can be advantageous for some systems where high security is the need, they have meager efficiency, but it can be ameliorated, by increasing the dielectric substrates height although there is a consequences of increasing the height of the substrate which includes the travelling surface waves which affects the performance parameters of the antenna like radiation pattern and the polarization characteristics but there are so many techniques to eliminate this shortcoming of travelling surface waves generation like using stacking and cavity. If we go for the large arrays this needs to be accepted that both bandwidth and scan volume can't be achieved at the same time, in this matter we need to face tradeoff. According to the design of the microstrip antenna mostly the maxima of the radiation pattern of the antenna is perpendicular or normal to the metallic patch and can be referred to as broadside radiator although the maxima can also be in the sane axis of the antenna elements and this is done by choosing the proper mode here which is nothing but the field configuration of excitation in the lower part of the patch.

The substrates those employed in the designing of the antenna have their dielectric constants lying between 2.2<= Ɛr <=12. The most wished substrates for getting high performance parameter are those which are having lower dielectric constants and higher thicknesses because they have better performance in terms of bandwidth and efficiency whereas if we want to reduce undesired coupling and the radiation losses then we need to go for the substrates which are having higher dielectric constant and lesser thickness.

Microstrip antenna is a radiator which can be of various shapes, because of the fabrication and analysis ease rectangular circular dipole and square shapes are most widely employed.

Microstrip antennas are mostly employed in microwave frequencies and they are resourceful radiators at the high frequencies which are essential for microstrip antenna technologies. Microstrip antennas are very versatility, which typically includes compactness and wide bandwidth for reliable ubiquitous connectivity. There are two important parameters of antenna, first parameter is the length of the patch, the dimensions of the length must lie between λ/2 to λ/3, so that patch should be able to transmit operating frequency corresponding to wavelength (λ), thus it can be concluded that frequency of operation is affected by the length of the patch and length can be varied to get exact operating frequency. Second important parameter is width of the patch and width of the patch further controls three performance parameters those are input impedance bandwidth and radiation pattern where width is inversely proportional to input impedance we could increase input impedance by decreasing the width of the patch and vice versa, whereas, bandwidth is having direct relation with the width of the antenna. Input impedance of patch antenna is considered to be 300Ω and the transmission line through which the patch is fed is of 50Ω impedance, which constitutes a high impedance mismatch between transmission line and the antenna, so to combat frequency mismatch careful monitoring of the width is very important, the width of the antenna can be increased or decreased to match the antenna with transmission line.

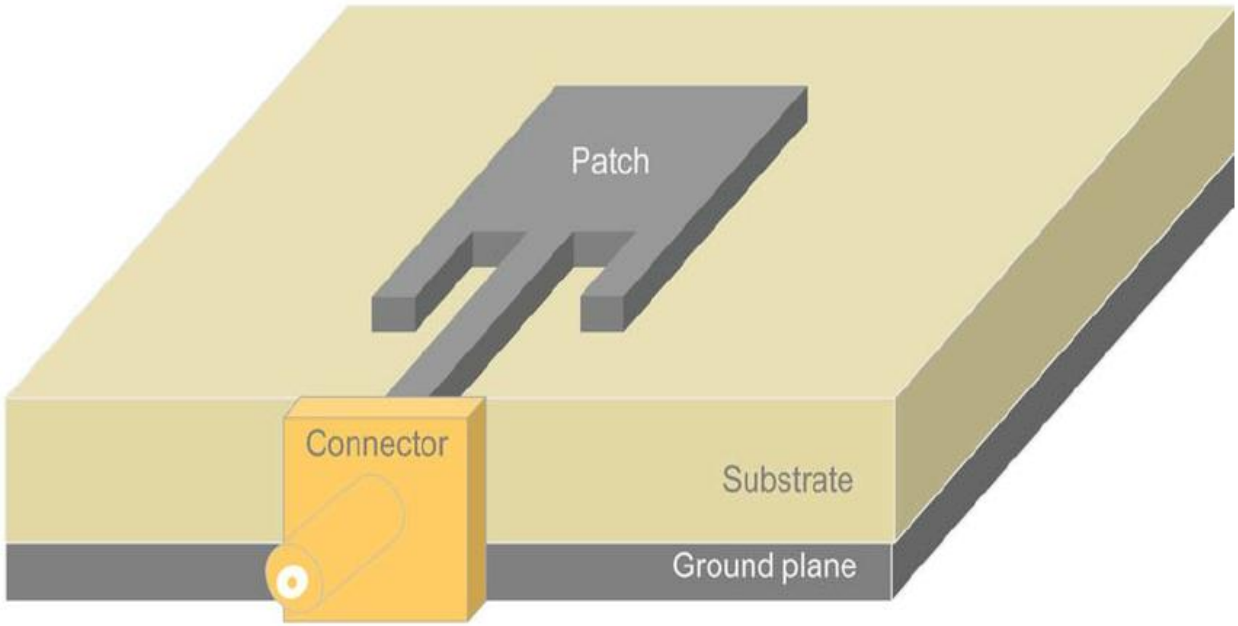


Figure 2.1: Placement of different objects on microstrip patch antenna.

Microstrip antenna acts as a resonant cavity, where patch is comparable with the cavity top Whereas bottom of the cavity can be compared with the ground of a microstrip antenna and the edges of the patch are similar to the left and right surfaces of the cavity and can behave as open circuited- boundary conditions and as a result of this, with perfect conductor on both upper and lower surfaces patch radiator works as a cavity and like a flawless "magnetic conductor".

Metallic radiating patch can be of various different shapes but the most frequently employed shapes are rectangular square elliptical circular triangular and circular ring as shown in the figure: in this thesis rectangular radiating patch has been considered due to its excellent impedance bandwidth in comparison to the other shapes of the patch radiator.

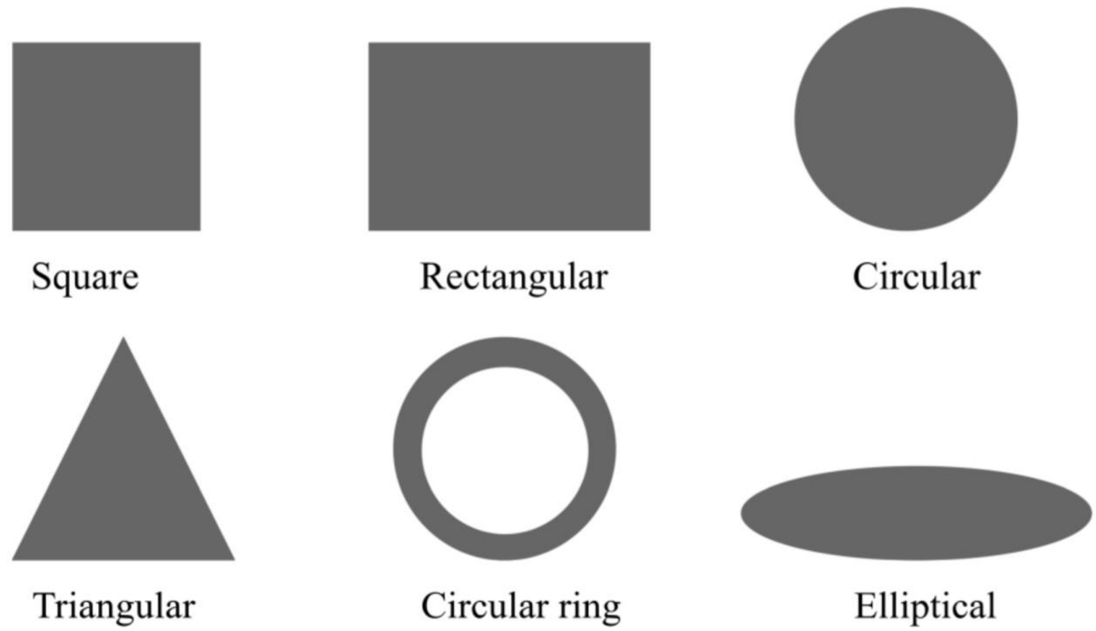


Figure 2.1.1: Various geometrical shapes of the patch of the antenna

2.2 Basic principle of operation

The reason behind the radiation of the electromagnetic waves from the patch is the “Fringing field Effect”, and this effect lies between the ground of the radiating patch and the patch edges although there exists many methodologies of analyzing microstrip patch radiator but transmission line model is the most suitable and commonly used model for the analysis due to its simplicity, but at the same time, the compromise with the accuracy of the analysis is the issue with this transmission model approach whereas cavity model offers much precise analysis of the patch radiator, in case of full wave model is considered it is distinctly multi skilled with high precision and can handle arbitrary geometry elements , finite as well as infinite arrays, stacked and single elements, and this full wave model is best suitable as compared to two above explained models because they give excellent insight but are too complex.

2.2.1 Transmission line model

In transmission line model microstrip patch radiator can be served as two slots having some width (w) and the height (h), the two lines of length (l) and this arrangement looks like a transmission line with hollow between two lines. Microstrip is a heterogeneous line of two dielectrics which are air and substrate so, majority of the dielectric field lines remains in the substrate and the little part of the electric field lines goes in the environment (air), which can be seen in the figure and this is the reason why smooth TEM transmission mode can't be supported by this transmission line since there would be phase velocity discontinuities in the two different mediums (air and substrate). As a substitute quasi-TEM mode would be propagating dominated mode. Hence to provide satisfactory explanation for the propagation of wave in the line and fringing effect an "effective dielectric constant" must be attained.

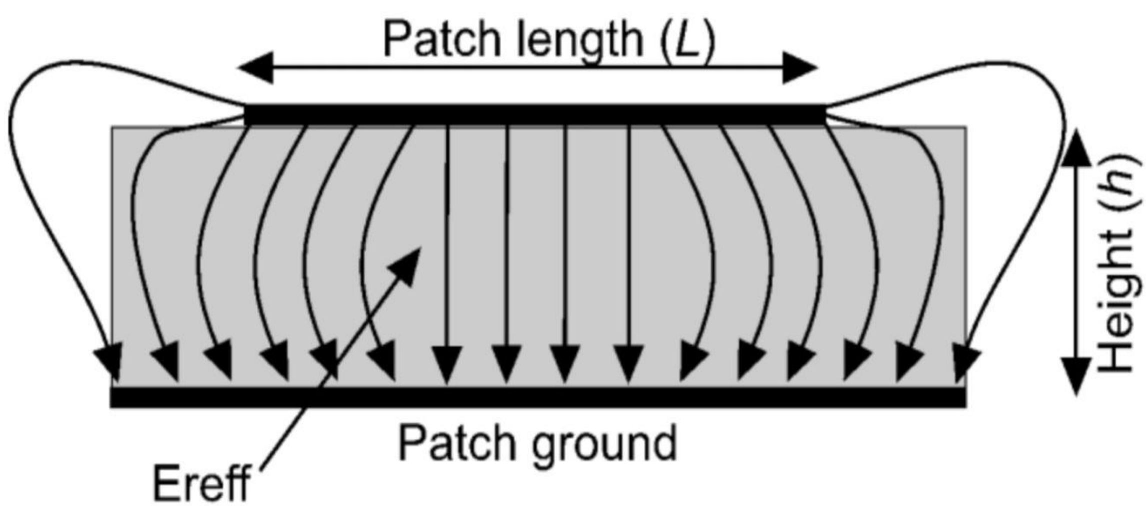


Figure 2.2.1: Fringing field effect in the patch edges.

The fringing field doesn't remains in the surrounding of the radiating patch instead they are expanded in the air , because of this the value of effective dielectric constant is usually less in contrast to dielectric constant. According to the coordinate system arrangement length is on the x-axis whereas width is measured in the y-axis and height id depicted along z-axis.

Radiating Patch length must be little shorter than λ/2 For operating in the TM10 mode which is essentially a fundamental mode, here wavelength in the dielectric is 'λ' and is equivalent to λ0/√Ɛreff), here λ0 can be defined as free space wavelength. According to fundamental TM10

Mode along the length fringing field varies along the all over length as one λ/2 cycle whereas width of radiating patch remains the constant there is no changes in the width of radiating patch .microstrip patch antenna comprises of the two radiating slots which are separated by two parallel lines open circuited from both the ends and have some length L can be seen as transmission line, at both the ends of the transmission line voltage is large whereas current is minimum because both the ends of the parallel transmission line is open. Fields at the edges of the microstrip antenna can be found as tangential and the normal components corresponding to the ground plane.

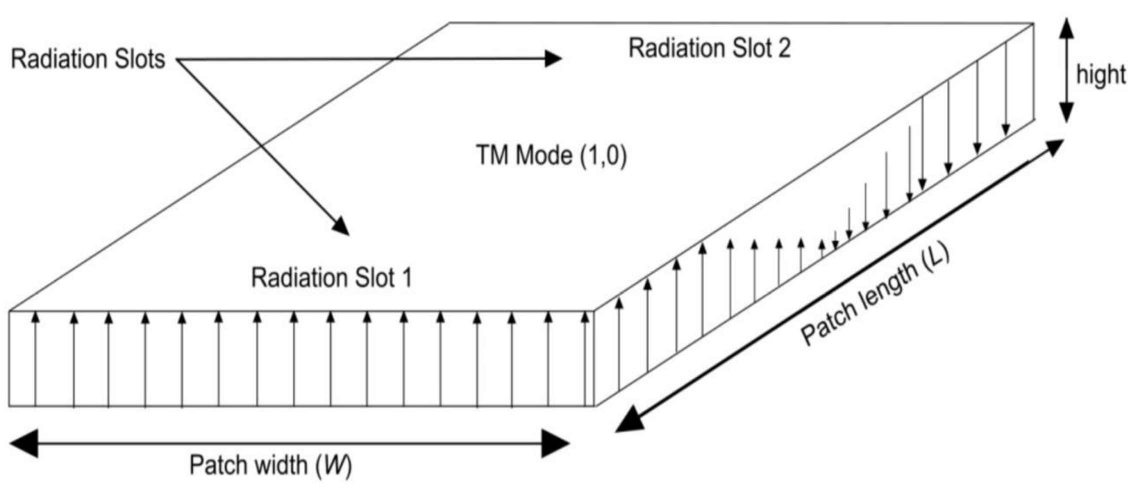


Figure 2.2.2: Radiating slots of microstrip patch antenna

2.2.2 Cavity model:

Cavity model was given by Lo in 1970'S. Although the implementation is quite complicated than the traditional transmission line model but it provides higher degree of precision in this approach inside region is not empty, throughout area in the periphery is surrounded by the magnetic walls.

When patch radiator is given power The charges are spread on patch's both upper and lower surfaces as shown above fig: two types of mechanisms can be employed for controlling the distribution of charges on the patch levels .they are namely attractive and repulsive mechanism

In the bottom part of the cavity between the opposite charges there exists an attractive mechanism which keeps the charge concentration untouched in the bottom of radiating patch whereas repulsive mechanism does the opposite job by pushing the charges from patch bottom to the top surface and by this charge moving current flow in both top and bottom surfaces of the antenna

The core of this assumption for thin substrate ($h<<\lambda$) is based upon following observations:

Fields do not vary to large in the z direction or the normal to the patch extend the interior region because the substrate is thin.

Electric field only points in the z direction and magnetic field only comprises of transverse components which are Hx and Hy in the region which is patch metallization bounded and ground plane. Here the observation gives the walls at the both upper and lower surfaces.

The cavity walls and the material are lossless due to this reason cavity won't be able t radiate and input impedance would also be completely reactive. Loss resistance RL and thE radiation resistance RR need to be introduced to see the effect of radiation and cavity would take into account loss mechanisms.

While doing the thin substrate approximation inside the cavity magnetic field can be given as:

$$\underline{H} = -\frac{1}{j\omega\mu}\nabla\times\underline{E}$$
$$= -\frac{1}{j\omega\mu}\nabla\times\left(\underline{\hat{z}}E_z\left(x,y\right)\right)$$
$$= -\frac{1}{j\omega\mu}\left(-\underline{\hat{z}}\times\nabla E_z\left(x,y\right)\right)$$

$$\underline{H}\left(x,y\right) = \frac{1}{j\omega\mu}\left(\underline{\hat{z}}\times\nabla E_z\left(x,y\right)\right)$$

There is a width Restriction for a Rectangular Patch and that is given by:

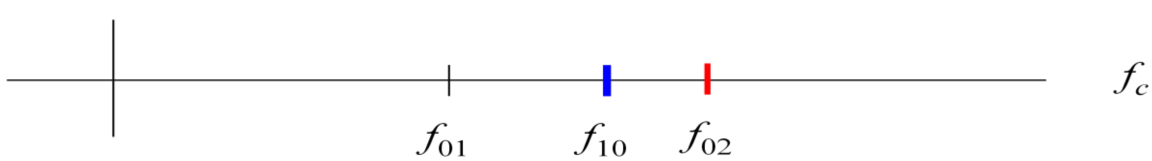
$W < 2L$, where w is typpically considered as

$W = 1.5\,L$

$$f_{mn} = \frac{c}{2\pi\sqrt{\varepsilon_r}}\sqrt{\left(\frac{m\pi}{L}\right)^2 + \left(\frac{n\pi}{W}\right)^2}$$

$$f_{01} = \frac{c}{2\sqrt{\varepsilon_r}}\left(\frac{1}{W}\right) \qquad f_{10} = \frac{c}{2\sqrt{\varepsilon_r}}\left(\frac{1}{L}\right) \qquad f_{02} = \frac{c}{2\sqrt{\varepsilon_r}}\left(\frac{2}{W}\right)$$

$$f_{02} - f_{01} = \frac{c}{\sqrt{\varepsilon_r}}\left(\frac{1}{W} - \frac{1}{2L}\right)$$



Resonant Input Resistance The resonant input resistance is fairly independent of the substrate thickness *h* unless *h* gets small (the variation is then mainly due to dielectric and conductor loss).

CHAPTER-3

DESIGN AND ANALYSIS OF THE 60GHz PATCH ANTENNA

3.1 Analysis of the input parameters of patch antenna

A 60GHz microstrip antenna is simulated as seen from the figure: 3.1. The patch of "ht" height having a dielectric permittivity "ϵ_r" and dielectric height "hs" is chosen. This patch is mounted over Rogers RT5880 (lossy) substrate of dielectric permittivity of *2.2* and having a loss tangent as 0.0009 of dimension 3.180×3.886×0.127 mm^3, this dielectric is further placed on ground plane. The patch is excited by microstrip line of width 'w' and "ht" height.

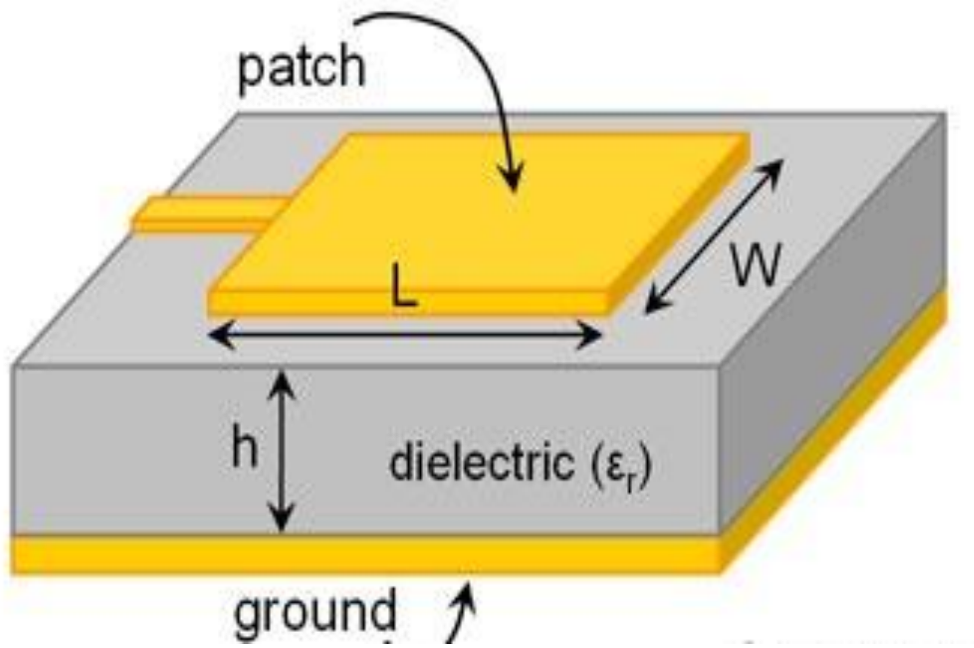


Figure 3.1: Structure microstrip patch antenna having single element as radiator.

Table 3.1: Simulation parameters of the proposed Patch antenna.

l (millimeter)	W (mm)	Lg (mm)	wg (mm)	wf (mm)	fi	gpf	wl (mm)	ht (mm)	hs (mm)
1.590	1.943	3.180	3.886	0.3657	0.542	0.08	1.684	0.035	0.127

To yield better impedance matching the slot depth fi and the microstrip line width is optimized. The results of the patch antenna are simulated using CST Studio suit (student edition), which is a commercial simulator and it is based on the finite integration techniques. We have used the transient solver have been used for the design, and the results of the patch are carried out by the adaptive refinement of the mesh.

3.2 Results

The length of the microstrip feed line and the slot depth and width between the microstrip line and the patch are chosen to obtain operating frequency and excellent antenna performance. The width of the microstrip line is set to 0.3657mm. These 2 parameters are optimized with the help of CST studio suit (student version). First, the variation of the microstrip feed line width is considered by setting the slot width as 0.08mm.

The depth of the slot of the patch is fixed to 0.542mm and the length of the strip line is also optimized to get the impedance matching. It is observed that by optimizing the various parameter of the patch best impedance matching is obtained at 60GHz frequency (S_{11} < -60dB) for 1.943mm width and 1.590mm length of the patch, i.e., length and width of the patch are optimized to yield the exact operating frequency. After computing and optimizing all the parameters, Designing is done to yield S-parameters directivity and gain of the design microstrip antenna. It is noticed that the designed microstrip patch antenna to operate at 60GHz frequency and -10 dB bandwidth is calculated to be 1.67 GHz as seen from Fig. 3.2

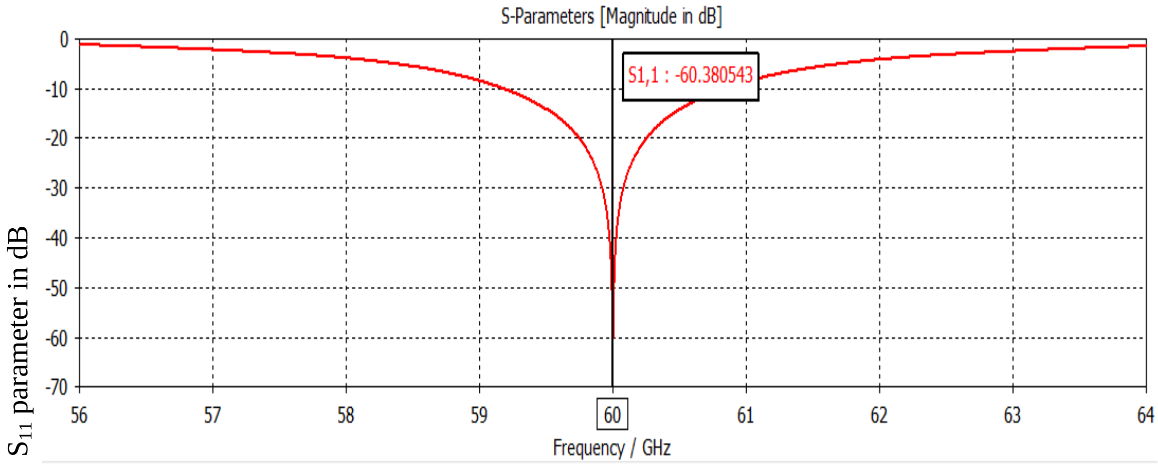


Figure 3.2: S_{11} parameter of the proposed patch antenna.

At the 60GHz operating frequency, main parameter which is directivity in came out to be 8.23dBi as shown in Figure 3.3(a), and side lobe level of -17.0 dB is obtained in the major lobe is along 0˚ direction, angular width at 3dB is 68.8˚, as seen from fig 3.2.1(a)

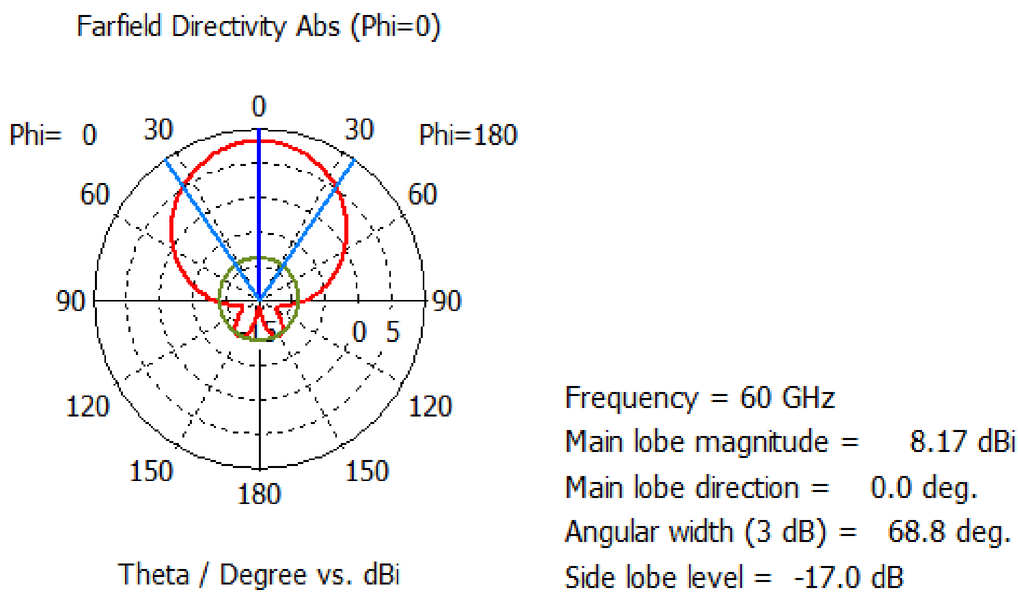


Figure 3.2.1(a): far field abs polar plot of the single patch (phi=180)

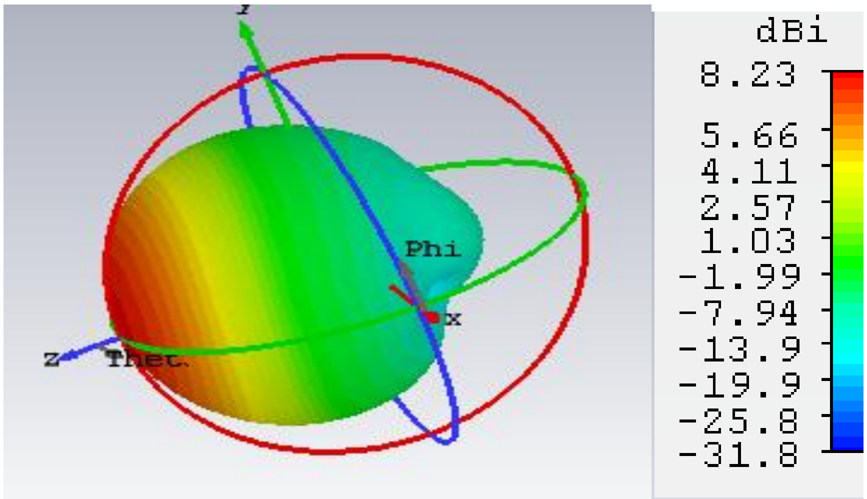


Figure 3.2.2(b): 3-D radiation characteristics (directivity) of the proposed antenna.

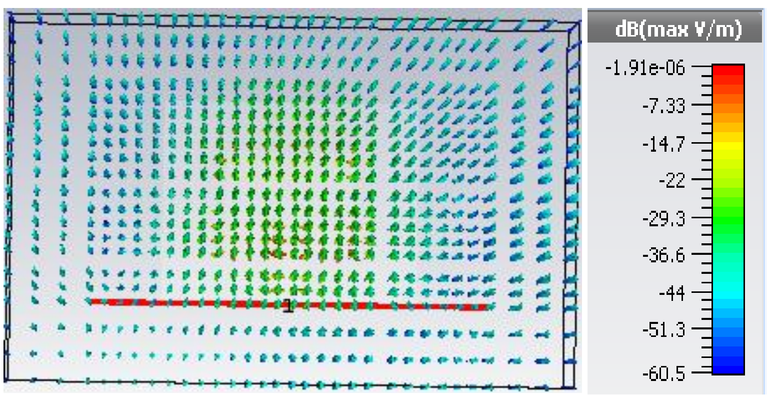


Figure 3.2.2(c): E-Field pattern of the microstrip patch antenna dB (max V/m)

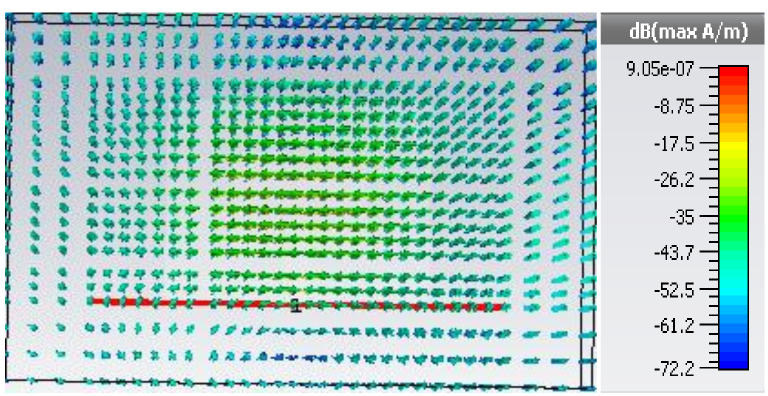


Figure 3.2.2(d): H-Field pattern of the microstrip patch antenna dB (max A/m)

3.3 Conclusion

Microstrip patch antenna at 60GHz of resonace frequency plays a indicative role in short range automotive radar by providing narrow bandwidth which avoids the other 60GHz frequencies from the interfering with each other and also helps in providing high directivity. The parameter analysis of the microstrip patch antenna is computed for 60 GHz resonant frequency. A narrow band of 1.67 GHz with a resonance dip at 60GHz. At 60GHz directivity of 8.23dBi is achieved.

The length of the microstrip feed line and the slot depth and width between the microstrip line and the patch are chosen to be same as in the previous chapter of single patch antenna element

The spacing between the 5 antenna elements is kept constant to obtain operating frequency and to have enhanced antenna performance. Width of the microstrip line is set to 0.3657mm. These 2 parameters have been optimized using CST studio suit (student version) 2017. First, the variation of the microstrip feed line width is considered by setting the slot width as 0.08mm.

The depth of the slot of the patch is fixed to 0.542mm and the length of the stripline is also optimized to get the impedance matching. It is observed that by optimizing the various parameter of the patch best impedance matching is obtained at 60GHz frequency (S_{11} < -60dB) for 1.943mm width and 1.590mm length of the patch, i.e., length and width of the patch are optimized to yield the exact operating frequency. After computing and optimizing all the parameters, this new design is simulated for getting better S-parameter, directivity and gain of the proposed microstrip antenna. It is noticed that the designed microstrip patch antenna operates at 60GHz frequency and -11 dB impedance bandwidth of 1.67 GHz is obtained.

CHAPTER 4

DESIGN OF LINEAR PATCH ANTENNA ARRAY OF 5 ELEMEMTS

In this chapter, design of microstrip patch antenna array is presented the results of the patch antenna array for 5 equally spaced elements for different spacing among them and different progressive phase shift has been employed and then various output parameters and beam steering for different situations are analyzed. Equally spaced microstrip antenna elements are simulated using CST Studio suit (student edition), which is a commercial simulator and it's working is on the finite integration techniques. Transient solver have been used for the design, and the results of the patch are carried out by the adaptive refinement of the mesh.

Patch array here helps in enhancing the gain, of the automotive sensor. An array of the microstrip antenna is presented and implemention is done using an elaborated parametric analysis.

4.1 5×1 Configuration of Linear Array of 5 elemets

In the patch array designing, an array of 5×1 is designed. The transient study of the array design is done. The major beam of antenna is made steerable at $\phi = 0°$ and $0° \leq \theta \leq 60°$ and the side lobe level < -11dB is obtained in case of uniform current distribution.

Figure 4.1: linear array of 5 elements.

4.2 Results:

In array with spacing less than half of the wave gives the better results as shown below:

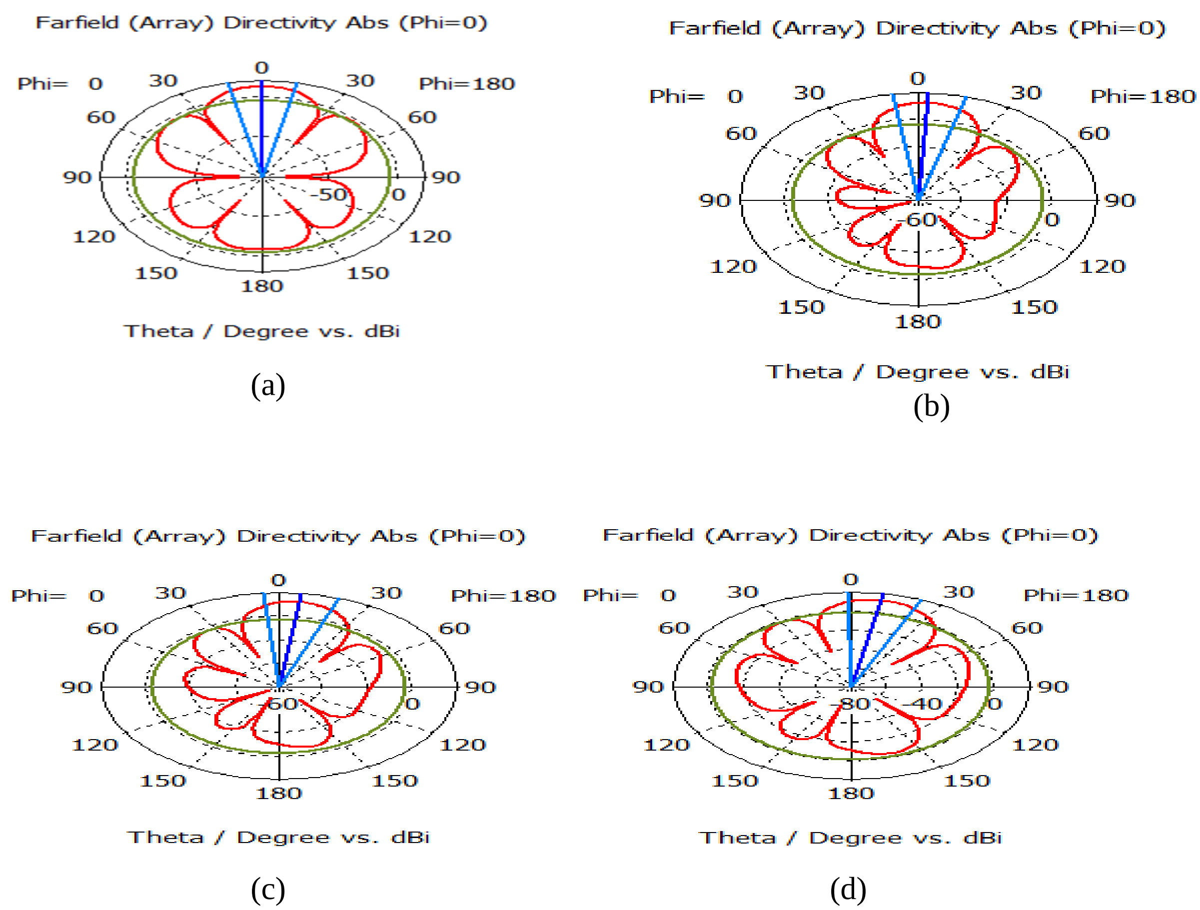


Figure4.2(a)(b)(c)(d): Far-field plots of proposed antenna array at different progressive phase shifts 0º,10º,20º,30º, respectively.

Table4.2: Phase shift in x-direction with spacing between antenna elements of 2mm for uniform distribution.

Progressive Phase shift (deg)	Main lobe magnitude (dBi)	Main lobe direction (deg)	Angular width (3dB) (Deg)	Side-lobe level (dB)
0	12.5	0	24.3	-16.9
10	12.5	3	24.4	-15.9
20	12.5	7	24.5	-15.0
30	12.5	10	24.6	-14.0

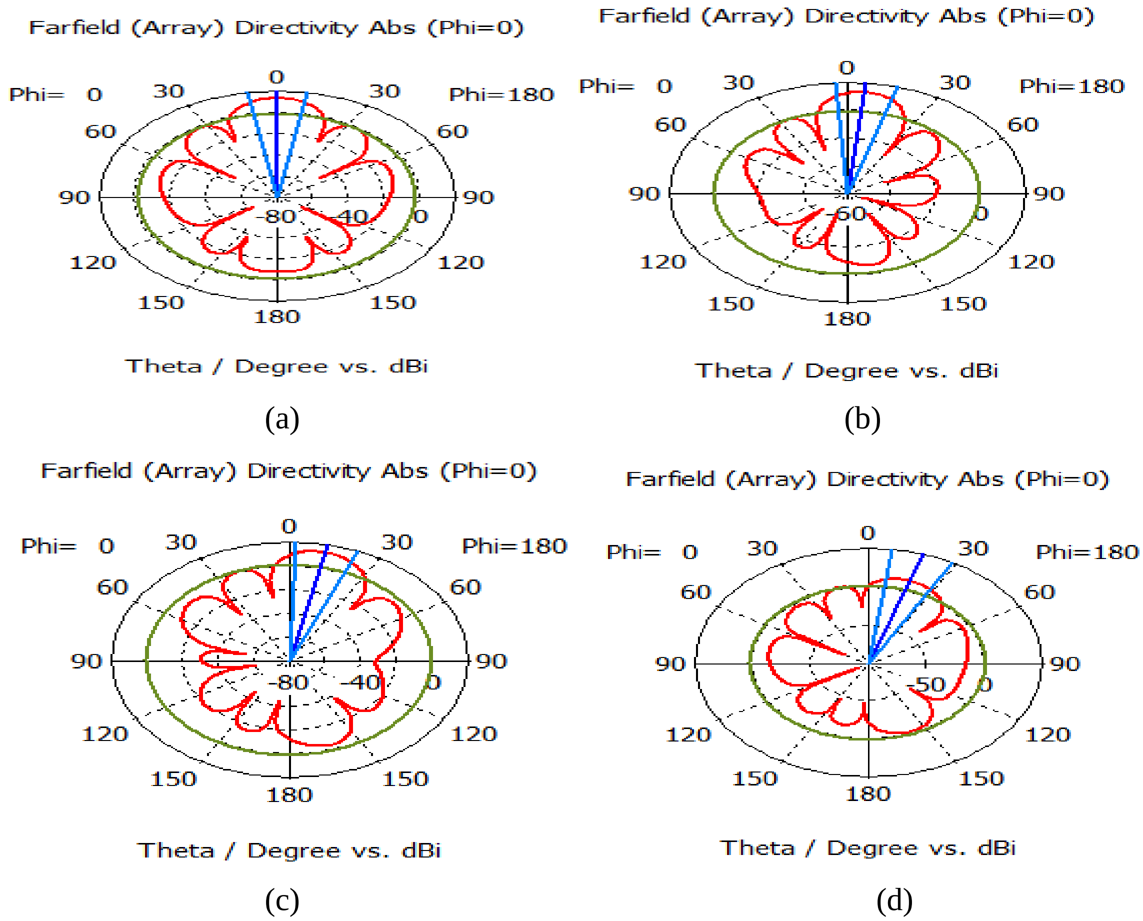


Figure 4.3(a)(b)(c)(d): Far-field plots of proposed antenna array at different progressive phase shifts 0º,20º,40º,60º, respectively.

Table4.3: Phase shift in x-direction with spacing between antenna elements of 2.5mm for uniform distribution.

Progressive Phase shift (deg)	Main lobe magnitude (dB)	Main lobe direction (deg)	Angular width (dB)	Side-lobe level (dB)
0	13.4	0	19.9	-15.1
20	13.3	6	20.0	-13.9
40	13.3	12	20.2	-12.8
60	10.4	18	24.6	-11.7

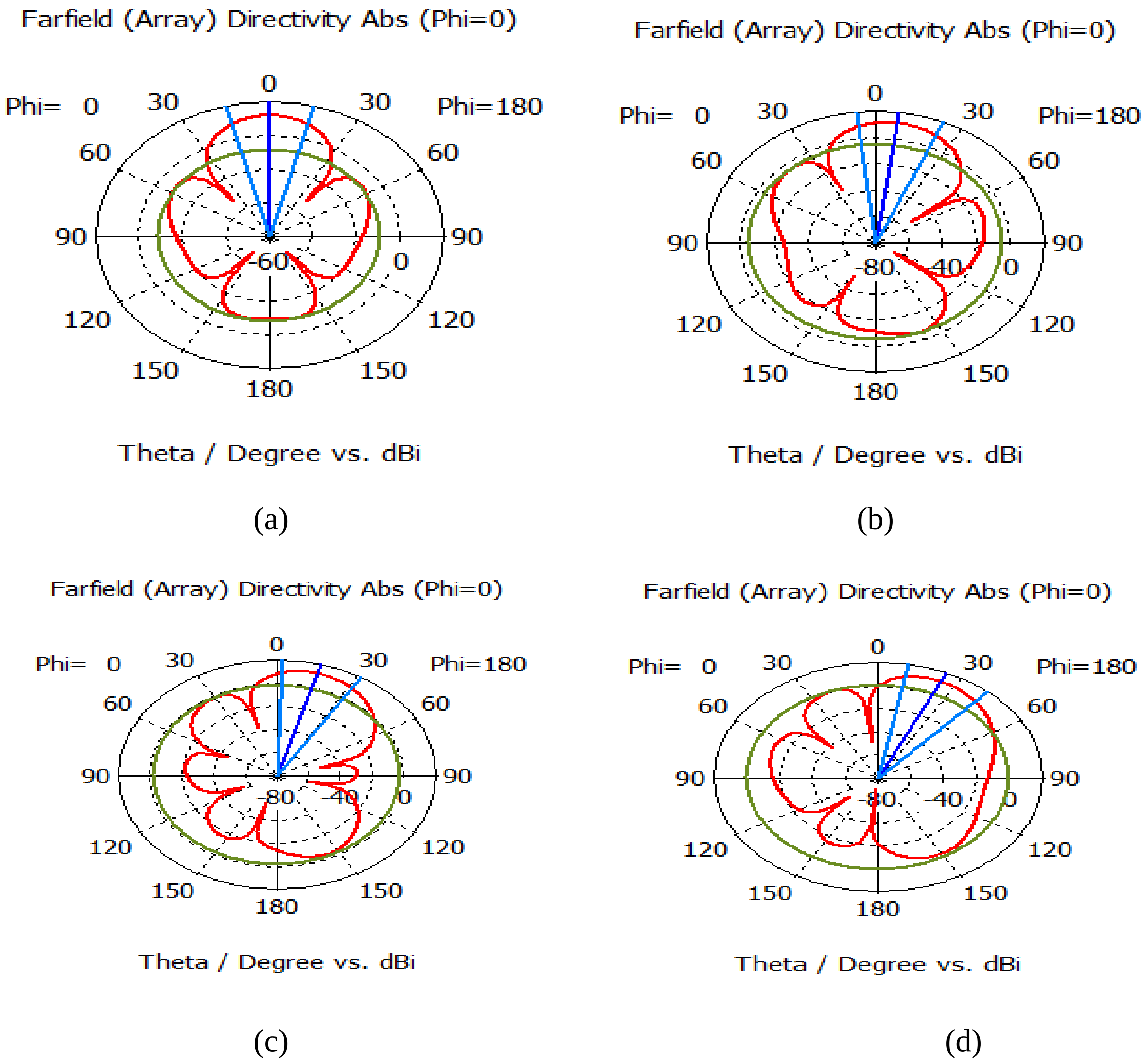


Figure 4.4(a)(b)(c)(d): Far-field plots of proposed antenna array at different progressive phase shifts 0º,20º,40º,60º, respectively.

Table4.3: Phase shift in x-direction with spacing between antenna elements of 1.6mm for uniform distribution.

Progressive Phase shift (deg)	Main lobe magnitude (dB)	Main lobe direction (deg)	Angular width (dB)	Side-lobe level (dB)
0	11.7	0	29.5	-20.1
20	11.7	8.0	29.7	-16.7
40	11.6	16.0	30.2	-13.9
60	11.5	24.0	31.1	-11.3

CHAPTER 4

CONCLUSION AND FUTURE WORK

The millimeter wave regime in the electromagnetic spectrum is an excellent choice to be employed in the automation industry. Automotive safety is no more a demand these days but it has became the necessity the demand n, so low profile devices need to designed for the vehicles in order to reduce the road extent. Further, The potential issues that is related to the high atmospheric attenuation at this frequency prevents this unlicensed band to be used for ling and medium range radars The high gain and directivity antennas play an essential role in the implementation of GHz radar links.

In Chapter 2, a simple patch antenna design is presented which resonant at 60GHz frequencies and bandwidth of 1.67 GHz is obtained with directivity of 8.23dBi. In Chapter 3. The results have shown for the, beam steering with the different spacing and by providing the constant phase difference which is progressive and the output is analyzed. The gain and directivity is increased by adding more no. of elements, but due to beam steering other parameters got degraded like side lobe level got increased

The major challenges in the future work of this would be complexity in designing the feed network for large number of antenna array and providing impedance matching at each junction of complex configuration.

High antenna gain/directivity is essential because at 60 GHz because at this frequency there is already high atmospheric interference . In this chapter, the concept of beam-forming by a linear array is introduced for a 60GHz microwave band for short range radar. The array configuration helps in enhancing the gain of the system; therefore a linear array design is implemented.

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