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Analysis of 3x4 Microstrip Patch Antenna Array for 94GHz Radar Applications

Mohammad Saber Niazy[1], Fahad Masood[2,]Badam Niazi[3,] Mashal Rokhan[4,] Riaz Ahmad[5]
[*]1,4Department of Computer Science, Khurasan University, Jalalabad, Nangarhar, Afghanistan
2Department of Computing and Technology, Abasyn University, Peshawar, Pakistan
3Department of Computer Science, Nangarhar University, Afghanistan
4Faculty of Engineering and Technology, Kardan University, Kabul, Afghanistan
**Corresponding Author: Mohammad Saber Niazy*

Abstract
In this research, the design and analysis of a 3x4 Microstrip patch antenna array for a 94GHz radar application have been done. Using CST and MATLAB the operating frequency is taken 94GHz which is the higher frequency range for radar applications, the array size is kept to be 3x4 i.e., 12 elements in the array. The Microstrip patch antenna is designed in CST software and the results are compared with the results obtained through MATLAB. The antenna array configuration is used for the rectangular arrays. Analysis has been done for four different parameters i.e., Resistance, reactance, S-parameter, and voltage standing wave ratio. The comparison shows that for rectangular array configuration, results are almost the same Resistance is between 90 and 92GHz while reactance is also between 90 and 92GHz bandwidth. The Scattering- parameter response is shown the threshold value is -10 dB it is seen that the maximum bandwidth for the s-parameter is between 9.0 and 9.2 GHz bandwidth. The minimum value for VSWR is 3V while the maximum value is 58V.
***Keywords**: Microstrip patch antennae, resonance frequency, impedance.*

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I. INTRODUCTION

Because of its many benefits such as lightweight, low volume, integrated circuit compatibility with the hard surface, and inexpensive costs, microstrip patch antennas are currently utilized more widely for a day. Microstrips Patch is designed for dual or circular polarization in dual and multi-band applications. These antennas are utilized by many portable communicators [1]. The microstrip patch antennas are the fastest developing structures inside the antenna sector in the current fifteen years. The researchers have earned a global inventive interest and several patents, papers, and books have been published. There have also been more than one symposium lesson and fast instructions. Consequently, MPAs have moved quickly from educational news to the commercial world, with packages in a big type of microwave structure [2].

The patch antenna of microstrip is a one-layer design, containing most of these four components patch, ground plane, substrates, and feeding. It is extremely easy using traditional microstrip line feed in construction. A patch can be supplied in any form, although the main application is rectangular and circular settings. Ground Plane may be finite or infinite by the model (transmission line, cavity model, complete wave model, or instant technique) used for dimensional analysis. Two key features for the substrate are relative permittance and height, which may be carried out in these methods, namely: Microstrip, coaxial sensor, aperture coupled, and feed closure linked. In the radio communication system, an antenna is an important component that both the transmitter and the receiver terminals require. In its manner, each form of antenna has various applications and features. The antenna patch array of Microstrip consists of two or more patch components. To obtain enhanced performance across one antenna, signals from individual patch elements are processed. The need for the addition of fields in the table components in the desired direction and cancelations in other directions is to get highly directed patterns. The feed mechanism excites the patch, which accumulates charges along the edge of the patch. The charges generate fields at the fringes of the antenna of the microstrip and result in the radiation of the microstrip antenna [3].

To ensure high efficiency, mobility, and reliability, modern wireless networks require lightweight, simple-to-build, high-performance, and low-profile antennas. Microstrip antennas are thus extremely popular due to their low visibility, ease of production, and feeding simplicity. In recent years, there have been a few microstrip-antenna models published in peer-reviewed journals. The authors of [4] created a WiMAX-based transmission device that operates at 5.8 GHz and evaluated the effectiveness of several dielectric materials. The best results were obtained using FR4 and Dupont-951 dielectric materials. The authors of [5] successfully tested a small microstrip-patch antenna at 28 GHz using simulation software. The researchers are tested on the sloped basic of the mm-wave microstrip patch series in [6].

The curved slope of the surface was found to be extremely efficient, whilst the curved slope was reported to have no impact. By creating a 4 x 4 Vivaldi antenna (SCVA) range system, the researchers in [7] achieved an overall gain of around 23 dBi in the 28 GHz and 38 GHz bandwidth range (25-40 GHz). The researchers created a lightweight flattened L-shaped antenna array with a U-slot in [8]. For UWB applications, the antenna worked at frequencies ranging from 4.8 to 7.8 GHz. The authors of [9] proposed an elevated broad patch antenna for a variety of applications including communication satellites, WiMAX, science and medical bands, and so on. The circular patch antenna has the disadvantage of having a symmetrical refractive index. Other structures are more difficult to investigate and need extensive computational simulations.

The Input impedance and Gain patterns, Distance, Radiation patterns, and Length of a microstrip line differentiate it. Microstrip patch array antennas provide several advantages over standard microwave antennas and hence have various applications across a wide frequency band ranging from 100MHz to 94GHz. Microstrip antennas are a single-layer design that consists primarily of the following four components: the Feeding part, the Substrate, the Ground plane, and the Patch. It is quite common to construct utilizing a standard microstrip line feed.

The patch can have any shape, although the most common shapes are circular and rectangular. Depending on the model (power transmission, cavity model, maximum wave model, or moment technique) chosen for dimension analysis [10], the Ground Plane might be nearly unlimited. A radio transmission device's amplifier is a critical component that is utilized for both receiving and sensing interfaces. Any form of antenna is useful in its own right, with a variety of features and applications. The patch antenna array is configured using two or three patch components. Signals from various patch components are handled to improve efficiency over a single antenna. To produce strong guiding patterns, the array elements' fields must be applied affirmatively in the desired direction and canceled in the opposite direction [11].

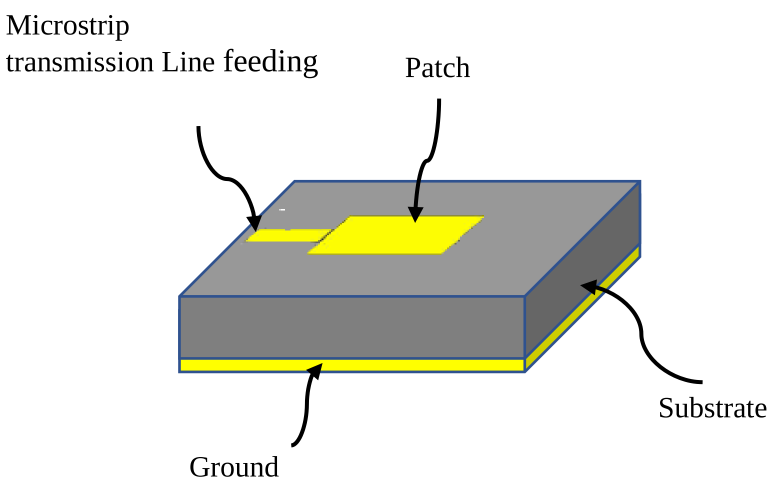

Figure 1: Model of microstrip patch antenna

1.1 APPLICATION

Microstrip antennas are widely recognized for their presentation, sturdy design, manufacturing, and wide use. The benefits of this Microstrip antenna outweigh the disadvantages such as ease of design, lightweight, and so on. The applications are many, including medical applications, satellites, and, of course, military systems such as rockets, airplanes, and missiles. The use of Microstrip antennas is growing rapidly in many disciplines and regions, and they are currently thriving commercially due to the inexpensive cost of the substrate material and production. It is also predicted that the rising use of patch antennas in a wide range would supplant the use of conventional antennas for the majority of applications. There are several uses for microstrip patch antennas. Some of these uses are explored in more detail below.

A. Application for mobile and satellite communication:

Small, low-cost, low-profile antennas are required for communication. All criteria are met by microstrip patch antennas, and several kinds of microstrip antennas have been created for use in mobile communication systems. Circularly polarized radiation patterns are necessary for satellite communication and may be produced using either a square or circular patch with one or two feed points.

B. Application of Radar

Radar can identify moving objects, such as people and cars. Microstrip antennas are an excellent alternative for low-profile, lightweight antenna systems. When compared to traditional antennas, the photolithography-based manufacturing technique allows for the mass manufacture of microstrip antennas with a reproducible performance at a cheaper cost and in a shorter time frame.

C. ApplicationsfortheGlobalLocationSystem

Microstrip patch antennas with high permittivity sintered substrates are being utilized in global positioning systems. Because of their location, these antennas are circularly polarized, very small, and highly costly. It is predicted that millions of GPS receivers will be used by the general public to correctly locate land vehicles, airplanes, and marine vessels.

D. Identification of Radio Frequency (RFID)

In several applications, RFID is employed, such as mobile communication, logistics, manufacturing, transportation and healthcare. Typically, RFID systems operate at frequencies of between 30 Hz to 5.8 GHz. An RFID system comprises of a tag or transmitter as well as a reader.

E. Rectenna Implementation

Rectenna is a corrective antenna that transforms microwave radiation to DC power immediately. Rectenna consists of four subsystems; an antenna, an ore filter, a recirculator and a filter for post-recurring. Rectenne antennas have to be built with exceptionally high directional characteristics to meet the requirements of long-range connections. The only method is to increase the electrical size of the antenna, because the aim is that the rectenna is used to transmit DC power over long distances using wireless connections.

F. Application of Telemedicine

The antenna operates at 2.45 GHz in the telemedical application. Wireless body area networks use wearable microstrip antennas (WBAN). The recommended antenna featured a larger front to back ratio compared to the other antennas. Apart from the half-directional pattern of radiation which is preferred over the all-round pattern in order to prevent the unwanted radiation to the user's body and fulfills the on-body and off-body applications criteria. It is suitable to have an antenna in telemedicine with a gain of 6.7 dB and a ratio of 11.7 dB resonant with 2.45 GHz[12].

II. RELATED WORKS

In this [13] article all antennas with CST- simulation software are examined and simulated. All antennas are compared to each other using the simulated results. Table 2 shows comparing simulated results, the antennas are offered 5 that are appropriate for 4–8 GHz broadband C-Band applications. The simulated findings are compared to existing documents from the literature study after the design and optimization of the suggested antennas. Table 3 shows the comparing simulated outcomes. For band space improvement, gain improvement, and decreased return losses are utilized to compute CPW-Fed. For simulation and design, we use a CST simulation tool, utilizing material ($\varepsilon r = 4.3$), and measuring 1.6 mm in height. For all purposes it is useful; it is between 3.20 GHz and 7.94 GHz.

The author in [14] analyzed many fundamental microwaves balanced bandpass filter designs and investigated alternate methods for constructing, modeling, and testing differentially fed microstrip BPFs the study included stepbystep designs of planar differentially regulated (BPFs) to help other researchers with the building procedure. Mixed-mode reflection parameters were developed in general, and this may be enhanced when a designer has a multi-port circuit to complete definition of differential controlled systems. Because balanced filters comprise a pair of differential ports or a couple of two single-ended ports which are short-circuited to the surface, authors offer a design method for the usage of mixed-mode s-parameter migration in variable filters.

In [15] A comparison of a rectangular patch antenna with a circular patch antenna was performed using simulation data received from CST Microwave studio. Both antenna designs perform well in terms of return loss, VSWR, gain, and radiation efficiency for Bluetooth spectrum applications. However, in terms of return loss and gain, the rectangular patch configuration outperforms the circular patch design, while the circular patch configuration outperforms the rectangular patch configuration in terms of bandwidth, radiation pattern, and sidelobe levels.

In [16] A microstrip patch antenna constructed in an array configuration with a varying number of patch components was studied. A larger number of patch antenna components results in a higher gain of the antenna array. At 5.8 GHz, 4x4 arrays have achieved a return loss of up to -43 dB. Increasing the number of patch components in the arrays improves bandwidth, directivity, and radiated power. In this case, 2x1, 2x2, and 4x4 patch arrays are inset fed, thus additional analysis would be performed by introducing coaxial feed into these arrays. These studied microstrip patch antenna arrays are helpful for WLAN/MIMO and 3G communication systems due to their tiny size, low weight, and conformal characteristics.

In [17] The antenna resonated at 2.4 GHz frequency, according to the Analysis of HFSS modeling program. The edge feed approach was utilized in this study to simulate a 2x1 Circular Patch Antenna array and 4x1 Circular Patch Antenna array, while the probe feed technique was used for Single Patch Antenna. The greatest achievable gain using the suggested simulation design was 8.2572 dB for a 4x1 array and 5.7414 dB for a 2x1 array.

[18] In the report. Two kinds of radar antennas are available for 77 GHz radar operation. Both types of antennas are coupled with various waveguides to micro-stream transitions in one single dielectric substratum structure. The initial 10x4 rectangular patch antennas, an antenna-type of 77 GHz and a first transitions-type are connected to a 19,8 dBi gain and 20,10, respectively, antenna structure. At 77 GHz, the second kind of antenna, 12x4 photovoltaic antennas, is connected to the second type, creating a 19.6 dBi and 19 livres per 11.6 per beam width antenna structure.Both forms of antenna work equally, according to the modeling findings. However, because of its simplicity and compactness, the first form of antenna is better than the second type.

In [19] This endeavor proposes and designs a tri-cell combination rectangular slotted 1x4 microstrip patch array antenna for WLAN applications. The functional properties of the proposed array antenna are studied, including return loss, gain, VSWR, and directivity. The suggested 1x4 array antenna resonates at 2.4GHz, with a return loss of -33.6878dB and a VSWR of 1.0233, respectively. The suggested array antenna has an overall dimension of 143mm x 71mm. As a result, it may be consolidated for WLAN applications.

In addition, blue structure is essential in wireless RF, MW, and mm-wave applications because the differential mode signal generated is then provided to other differential components, including filters, antennes and power amplifiers (PA)[20]. As a consequence, a novel pattern is given for the construction of differential flat BPF and balloon filters which include edge and linked couplings[20]. Edge- and linked connectors are used to construct differential flat BPF and balance filters concurrently using this technique. This combination exceeds the modeling methods of insert loss, CMRR and stop-band attenuation This combination is more effective than any previous modeling strategies.

The investigators reported in [21] an asymmetrical quasi-reflection-less approach for building of the new differential flat filter. The input and output terminals of the structure are linked to virtually absorbing resistantly ended filter strips. The unspecified input power of the stop band signal passes in this case to the resistor loads of the band stop terminals. This approach shows that high-order BPFs can lead to a severe rejection of the skirt and a greater standardized signal suppression by differential mode, using the same quantitative method.

A tiny, double-band balanced BPF microstrip based on closed-loop resonators in quadruple-mode is described in [22]. The dual differential band defense was generated by two types of step-impedance close-loop resonators. The admission ratio component of the step-by-step resonators was properly adjusted to eliminate conflicts of signal between common mode and differential mode. The input and output feeding ports were loaded on to two compact and contiguous transmission lines to increase the differential mode of signal roll-out skirts and to increase the attainment of common mode within the differential transmitted signal.

The IE3D software used in [23] for resonant frequency, bandwidth examination, and input impedance has a two-layer air thickness and inset location effect. Each design's microstrip patches should maintain spacing such that Fields in each patch overlap constructively to decrease scale. [24] proposed a frequency reconfigurable circular antenna design. At a center frequency of 10 GHz, a circular patch antenna with a circular slot was modeled and simulated using two pin diodes.

In [25] The simulation conclusions of a microstrip rectangular patch array are compared to those of a single patch antenna. The array outperforms a single patch antenna in terms of directivity, gain, efficiency, and bandwidth. It is critical to consider the effect of mutual coupling when constructing arrays for improved antenna performance. The results demonstrate that 4x1 arrays outperform 1x4 arrays in terms of performance. This is owing to the fact that the impact of mutual coupling in the E-plane is smaller than that in the H-plane. The linear array produced a gain of 12.3 dB and a bandwidth of 551.4 MHz. Linear antennas might be a suitable option when linear distance in a spacecraft or satellite is not an issue. Higher gains can be obtained with a greater number of components.

III. STUDY ANALYSIS

This paper has used the antenna toolbox in MATLAB and CST software to design the required antenna. This tool will analyze the performance assessment of the Microstrip patch antenna array for 94GHz using reactance behavior, resistance, S-parameter, and voltage standing wave ratio (VSWR). With better results, better performance facilities of light in weight, low volume, low-cost, low profile, little measurements, and manufacturing simplicity. Table 1 shows the detailed design parameters of the antenna.

Table 1: Design parameters of the antenna

S. No	Parameters	mm
1	Length	16
2	Width	23
3	Height	0.003
4	Ground place length	3.2
5	Ground place width	3.2
6	Frequency	88GHz-100GHz
7	Lg	2xL
8	Wg	2xw

Figure 2: shows the reactance behavior with both CST and MATLAB simulations. At the start, the amplitude is higher for both CST and MATLAB, but when the frequency increasing the amplitude is gradually decreasing. It is also noticed that it went to a negative value when the frequency reached between 90 and 94 GHz.

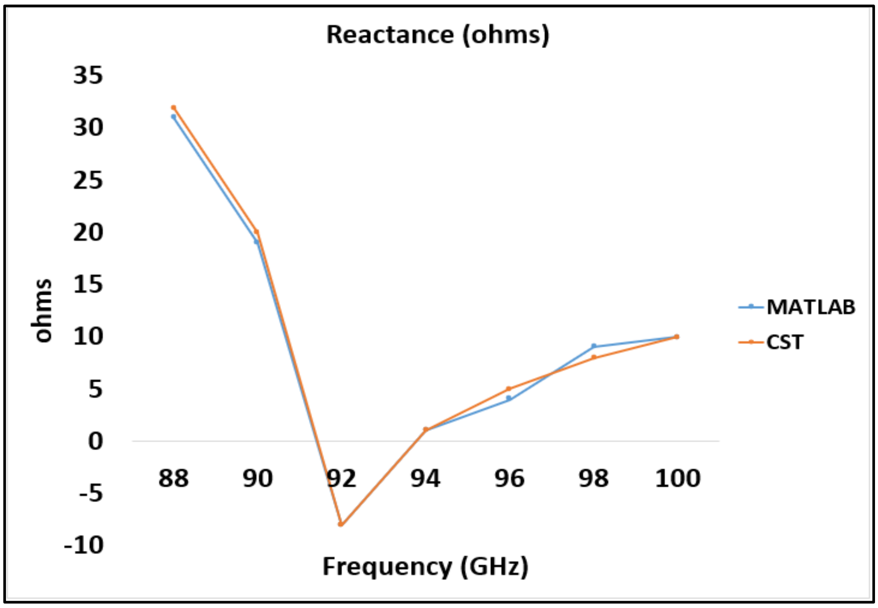

Figure 2: Shows Reactance

Figure 3: shows the resistance behavior with both CST and MATLAB simulations. It's noticed that at the start, the amplitude is higher for both CST and MATLAB. Still, when the frequency increases, the amplitude gradually decreases even at the last stage with a higher frequency. It reaches the lowest value.

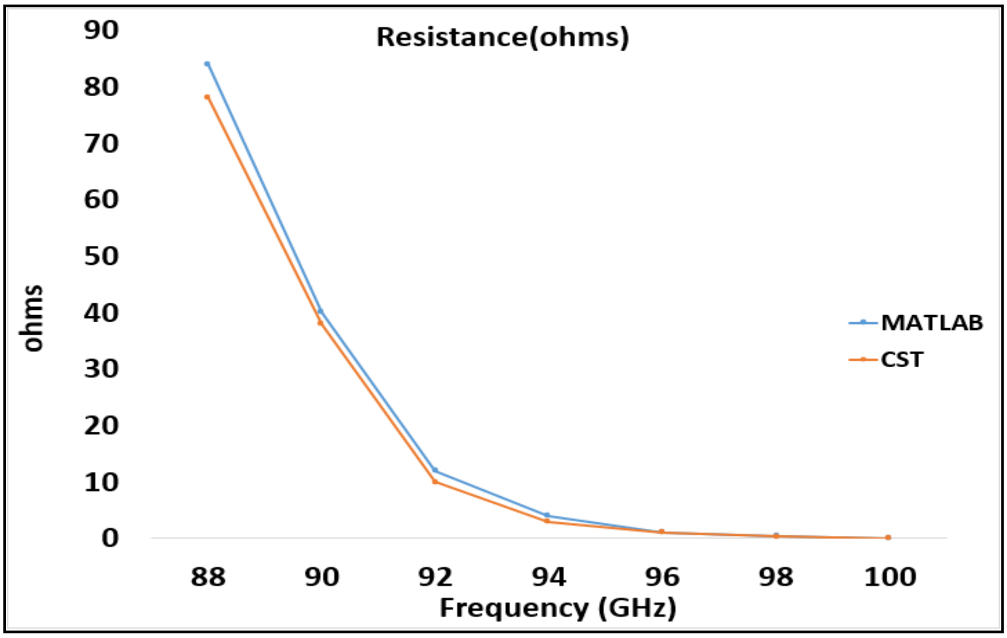

Figure 3: Shows Resistance (ohms)

Figure 4: shows the Scattering Parameters' behavior with both CST and MATLAB simulations. It noticed that starting the threshold is negative and dramatically goes to the lowest value until -14 for both CST and MATLAB. Still, when the frequency increases, the threshold value increases to the positive stage in MATLAB & CST tools.

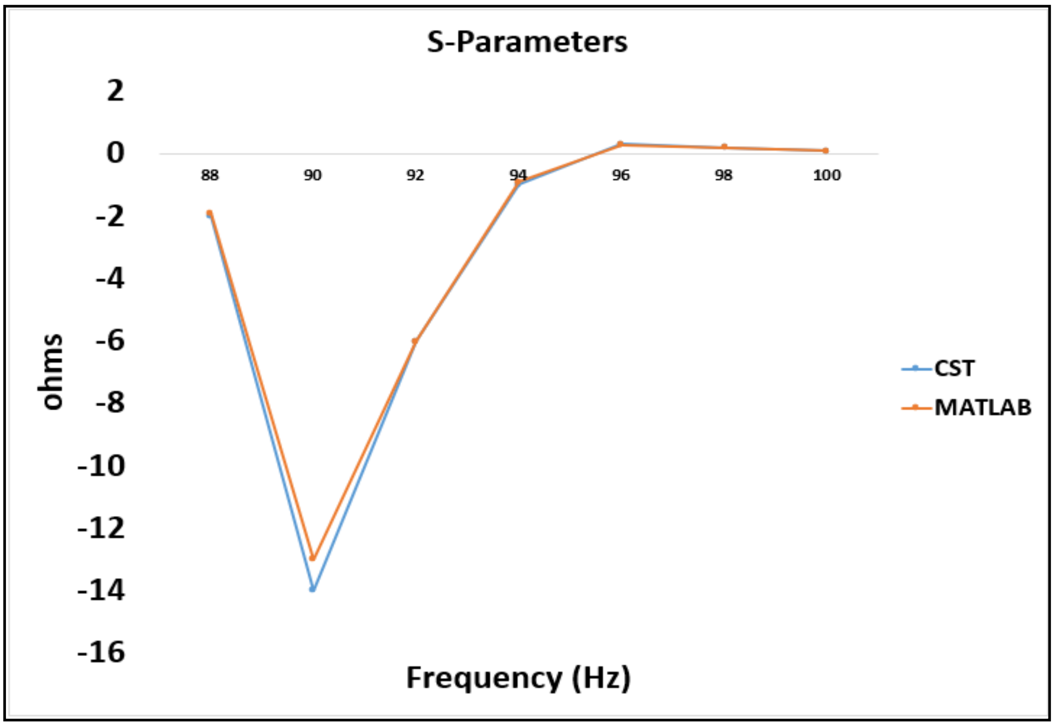

Figure 4: Shows S-Parameter

Figure 5: shows the Voltage Standing Wave Ratio (VSWR) behavior with both CST and MATLAB simulations. It was noticed that the amplitude is higher for both CST and MATLAB at the start, but when the frequency is increasing, the amplitude is gradually decreasing. Still, after the 94 GHz frequency, it is observed that the values are dramatically increasing.

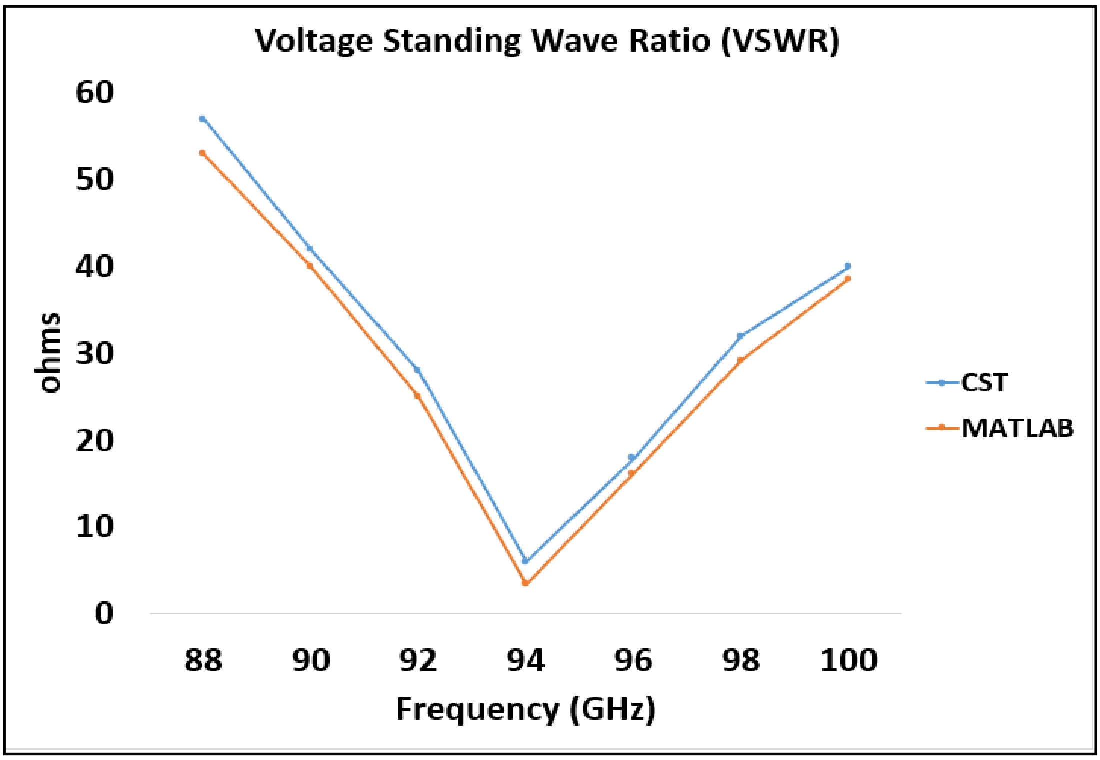

Figure 4: Shows voltage standing waveratio

IV. CONCLUSION

An effort has been made to analyze the Microstrip patch antenna array at 94GHz radar application at a higher frequency. In this research, the operating frequency is 94GHz which is the higher frequency range for radar application. The array element number is kept to be 3x4, i.e., 12 elements in the array. Different parameters, i.e., Resistance, reactance S-parameter, and voltage standing wave ratio (VSWR), are investigated through both CST and MATLAB simulation tools. All of the parameters are checked using CST and MATLAB, respectively. The results obtained from both tools show similar performance; however, the CST performs better than MATLAB.

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