Design and analysis of single and dual fed patch antenna array

Article · February 2018

3 authors, including:

Gazala Pravin
Barkatullah University

Alok Kumar Rastogi
Institute for Excellence in Higher Education, Bhopal

Design and Analysis of Single and Dual Fed Patch Antenna Array

Gazala Pravin[1], Alok Kumar Rastogi[2] (FIETE)
Research Scholar[1], Professor[2]
Department of Physics and Electronics, Barkatullah University Bhopal (M.P.), India[1]

Abstract— In many applications it is necessary to design antennas with very high gain to meet the demands of long distance communication. The gain or directivity of single antenna is less. To increase the gain and directivity the solution is antenna array. This can be done by increasing the size of antenna. Enlarging the dimensions of single antenna often leads to more directive characteristics. Another method is increasing the dimensions of antenna without increasing the size of individual element is antenna array. It is one of the common methods for combining the radiation from a group of similar antennas in which the phenomenon of wave interference is involved. In this paper analysis of single feed and dual feed microstrip patch antenna arrays is done, and results are compared.

Keywords— Microstrip patch, Array antenna, X-band, Rogers RT5880 Dielectric Substrate, wireless Communication.

I. INTRODUCTION

Modern wireless communication system requires low profile, light weight, high gain, and simple structure antennas to assure reliability, mobility, and high efficiency characteristics. Microstrip antenna satisfies such requirements. The key features of a microstrip antenna are relative ease of construction, light weight, low cost and either conformability to the mounting surface or, an extremely thin protrusion from the surface. This antenna provides all of the advantages of printed circuit technology. These advantages of microstrip antennas make them popular in many wireless communication applications such as satellite communication, radar, medical applications, etc [1]. The limitations of microstrip antennas are narrow frequency band and disability to operate at high power levels of waveguide, coaxial line or even strip line. Therefore, the challenge in microstrip antenna design is to increase the bandwidth and gain [2].

Different array configurations of microstrip antenna can give high gain and improved efficiency. The distribution of voltages among the elements of an array depends on feeding network. Suitable feeding network accumulates all of the induced voltages to feed into one point [3]. The proper impedance matching throughout the corporate and series feeding array configurations provides high efficiency microstrip antenna [4]. Power distribution among antenna elements can be modified by corporate feed network. The corporate feed network can steer beam by introducing phase change [5].

The choosing of design parameters (dielectric material, height and frequency, etc) is important because antenna performance depends on these parameters. Radiation performance can be improved by using proper design structures [6]. The use of high permittivity substrates can miniaturize microstrip antenna size [7]. Thick substrates with lower range of dielectric offer better efficiency, and wide bandwidth but it requires larger element size [8]. Microstrip antenna with superconducting patch on un axial substrate gives high radiation efficiency and gain in millimeter wave lengths [9].

Different radar systems such as Synthetic Aperture Radar (SAR), shuttle imaging radar, remote sensing radars, and other wireless communication systems operate in L, C and X bands. Microstrip antenna is the first option for this high frequency band such as X-band due to its low cost, light weight, and robustness [10]. This article provides a way to choose the design parameters of antennas to achieve the desired dimensions as well as the characteristics for the effective radiation efficiency. This paper also compares the characteristics of single feed and dual feed microstrip array antennas to get optimum feeding system. These designed antennas are potential candidate for the X-band and Wi-Max wireless applications due to the simplicity in structure, ease of fabrication and high gain and high efficiency.

The IEEE X-band is a portion of the electromagnetic spectrum in the microwave range of frequencies ranging from 8.0 to 12.0 GHz, which is followed by radar manufacturers and users. The X-band and its slight variations contain frequency ranges that are used for many satellite communication transmissions, some Wi-Fi devices, cordless telephones and weather radar systems [11].

Wi-Max (Worldwide Interoperability For Microwave Access) is a family of wireless communication standard based on the IEEE 802.16 and provides multiple physical layer and media access control option. In January 2003 IEEE approved the 802.16a standard which covers frequency band between 2GHz-11GHz [12].

III. MICROSTRIP ARRAY ANTENNAS AND FEED NETWORKS

Microstrip antennas are used not only as single element but also very popular in arrays. Main limitation of microstrip is that it radiate efficiently only over a narrow band of frequencies and they can't operate at the high power levels of waveguide, coaxial line, or even strip line [13]. This can be minimized with the help of various array configurations, feeding methods, dielectric materials and ground planes. Antenna arrays are used to scan the beam of an antenna system, to increase the directivity, gain and enhance various other functions which would be difficult with single element antenna. In the microstrip array, elements can be fed by a single line or multiple lines in a feed network arrangement [14].

A. Single Feed Patch Antenna Array

Popular microstrip antenna feeding system is the corporate feeding. This method has more control of the feed of each element and is ideal for scanning phased arrays, multi beam arrays. The phase of each element can be controlled using phase shifters while amplitude can be adjusted using either amplifiers or attenuators. The corporate feed network is used to provide power splits of 2n (i.e. n = 2; 4; 8; 16; etc.). Single feeding is the power at the first element. Here two successive patch elements are matched by using quarter wavelength transformer method [15]. The size of Patch Length (L) = 10.8mm, and Patch Width (W) = 4.8mm which is suitable for most wireless communication.

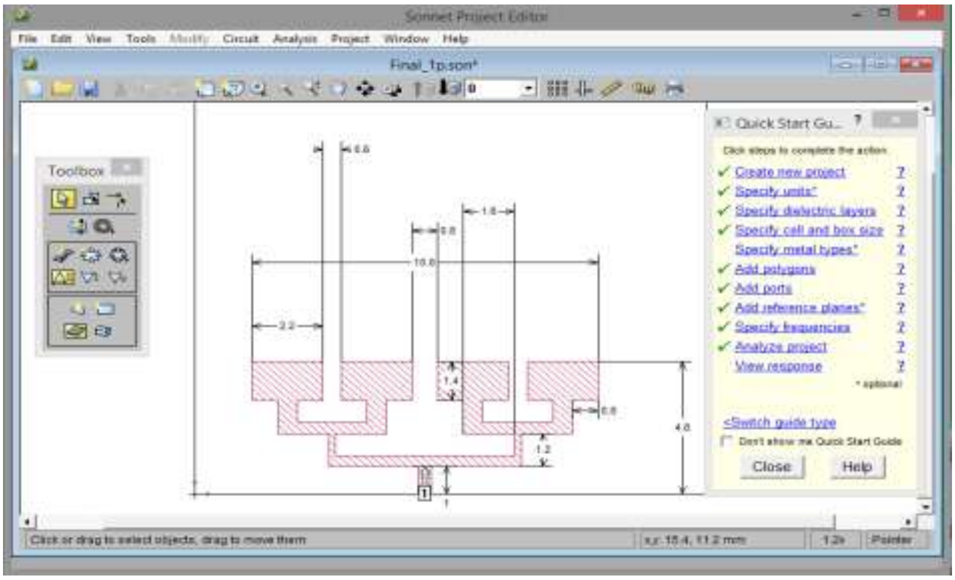

Fig.1.Geometry of Single Feed Patch Antenna Array

B. Dual Feed Patch Antenna Array

Dual feed arrays are general and versatile. This is accomplished by using either tapered lines or using quarter wavelength impedance transformers [16]. Here, the same array is fed with two feeds and hence two branch feeds are included with two feeds as demonstrated in the Fig. 7, the patch elements are connected by using the quarter wavelength impedance transformer method. The size of Patch Length (L) = 11mm, and Patch Width (W) = 3.5mm which is suitable for most wireless communication.

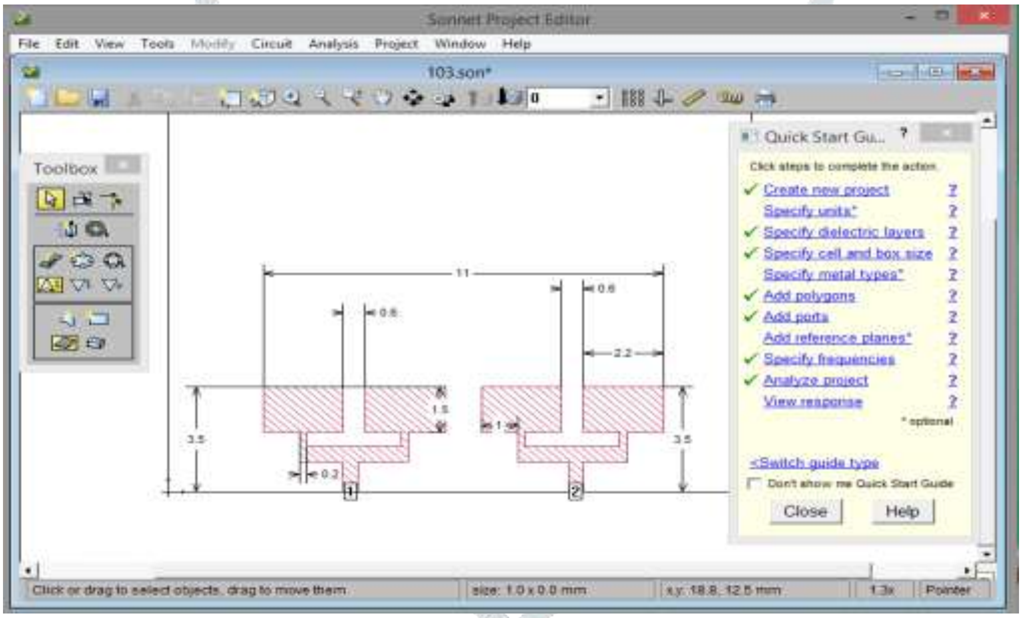

Fig.2.Geometry of Dual Feed Patch Antenna Array

IV. SIMULATION RESULT & DISCUSSION

A. Single Feed Patch Antenna Array

In this design, it is considered that the substrate permittivity of the antenna is 2.2 (Rogers RT5880), height is 1.5 mm and resonance frequency of the antenna is 11 GHz. Fig.3 shows the three dimensional structure designed on Sonnet software of the single feed microstrip patch antenna array. Fig. 4 illustrates the current distribution of 4-elements Single feed microstrip array antenna. It is apparent that current distribution is near about the same in each element. Fig. 5 shows that the return loss is -11.44dB at 11GHz. Fig. 6 and 7 shows simulated gain and radiation pattern of the antenna are 21.71dB at $\theta = 0$, $\varphi = 0$ for the operating frequency 11 GHz.

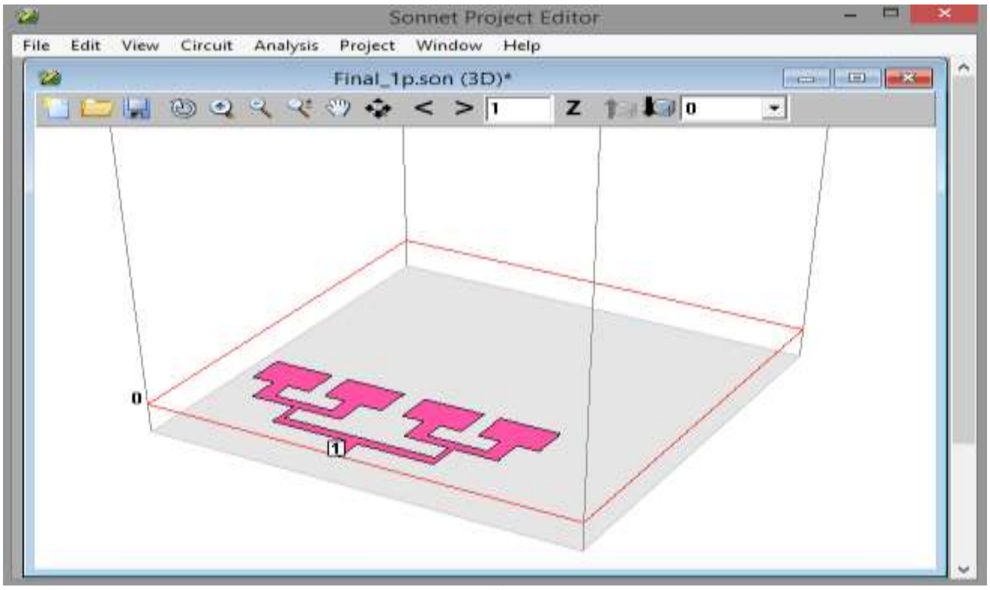

Fig.3.Three Dimension of Single Feed Patch Antenna Array

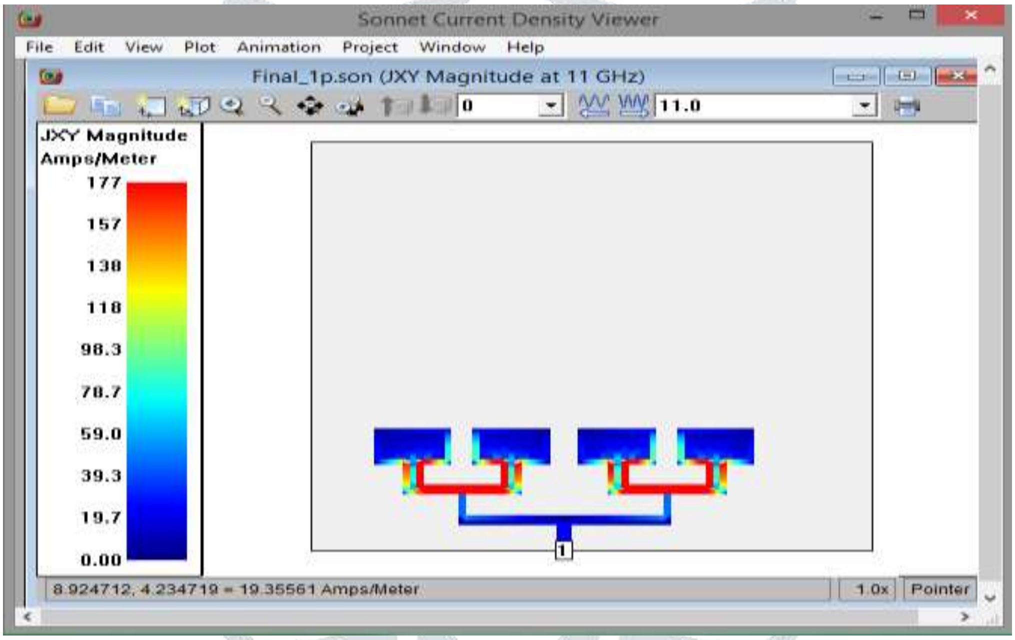

Fig.4. Current Density of Single Feed Patch Antenna Array

Fig.8 show the VSWR of the single feed patch antenna array, the VSWR circle is indicated by red circle where VSWR =2. VSWR input impedance of the antenna at the resonant frequency are found at VSWR = 1.7.

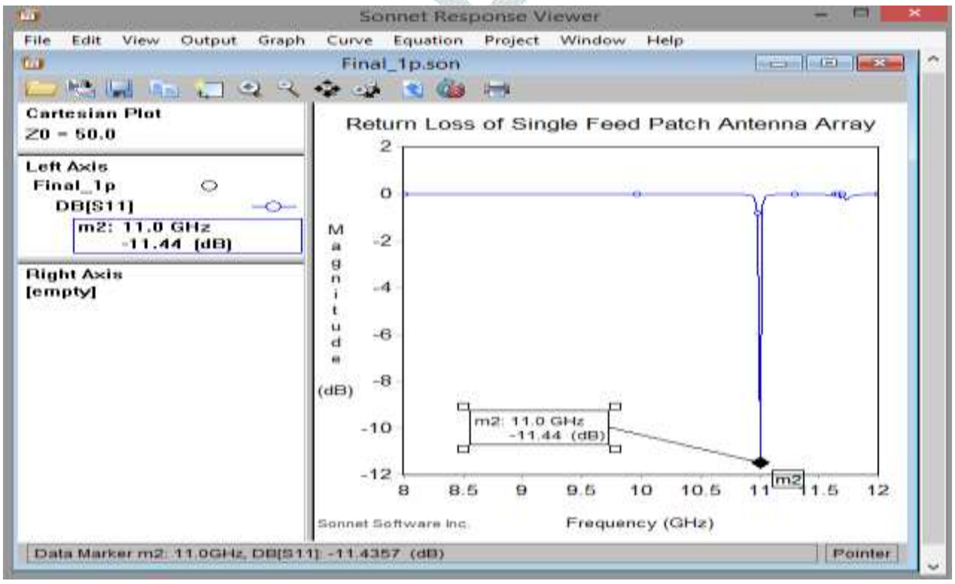

Fig.5. Return Loss [S11] of Single Feed Patch Antenna Array

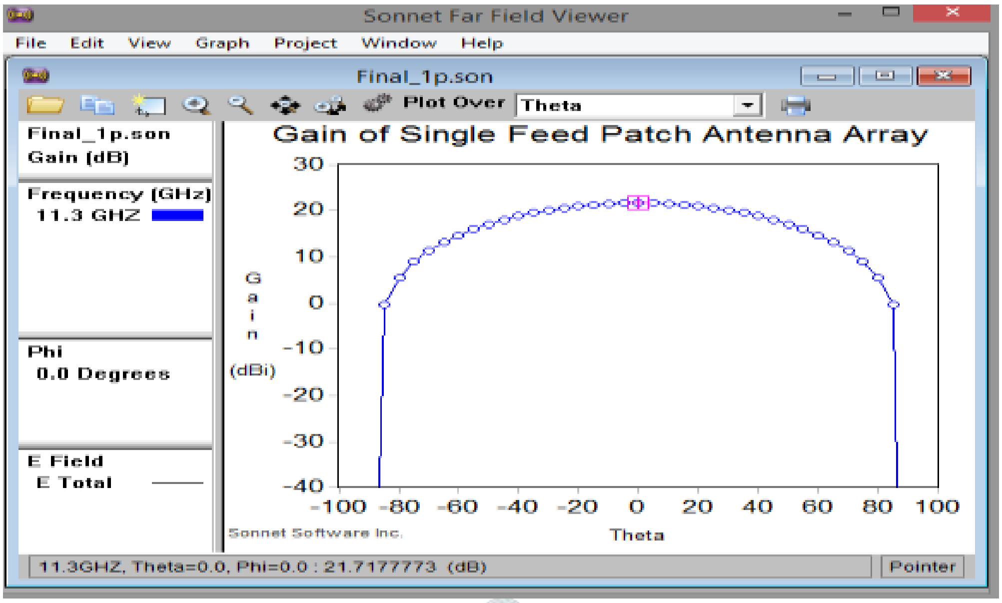

Fig.6. Gain of Single Feed Patch Antenna Array

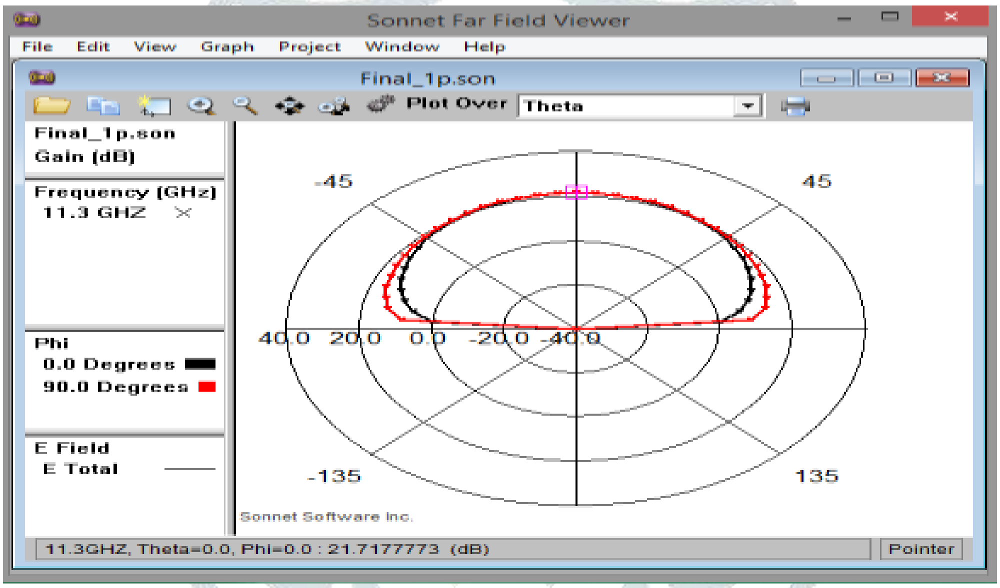

Fig.7. Radiation Pattern of Single Feed Patch Antenna Array

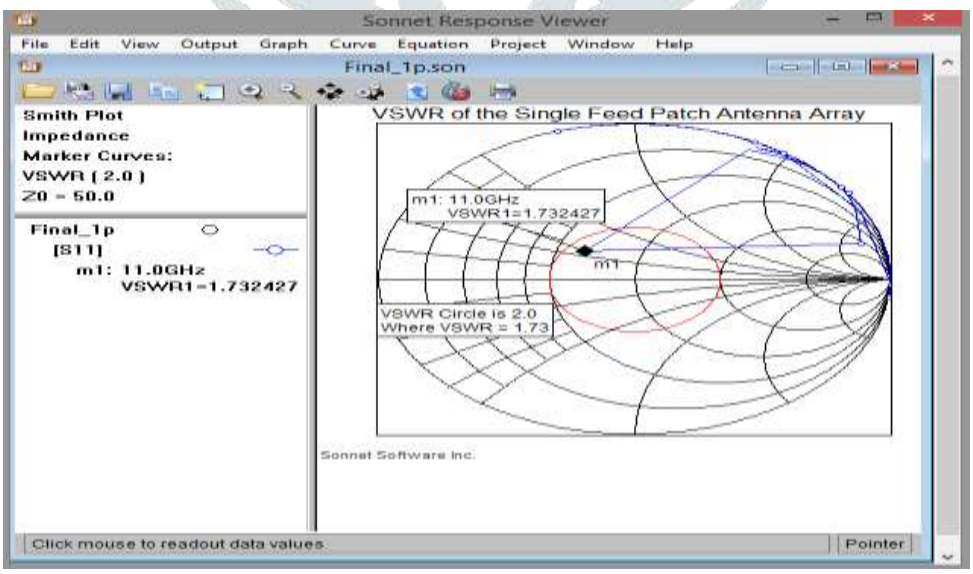

Fig.8.VSWR of Single Feed Patch Antenna Array

B. Dual Feed Patch Antenna Array

Fig.8 shows the three dimensional structure designed on Sonnet software of the dual feed microstrip patch antenna array. Fig. 9 illustrates the current distribution of 4-elements dual feed microstrip array antenna. Fig. 10 describes the current distribution of dual feed microstrip array antenna. In this array network, two successive patch elements as well as their corresponding transmission lines are matched by using quarter wavelength transformer method. Here, the substrate permittivity of the antenna is 2.2 (Rogers RT5880), height is 1.5 mm and resonance frequency of the antenna is 11GHz. Fig. 11 presents that the maximum return loss is -5.399dB at 11GHz. Return losses decrease than single feed patch antenna. Fig. 12 & 13 shows that the simulated gain and Radiation Pattern of the antenna are 3.26 and respectively at θ=00, φ=00 for the operating frequency 11GHz.

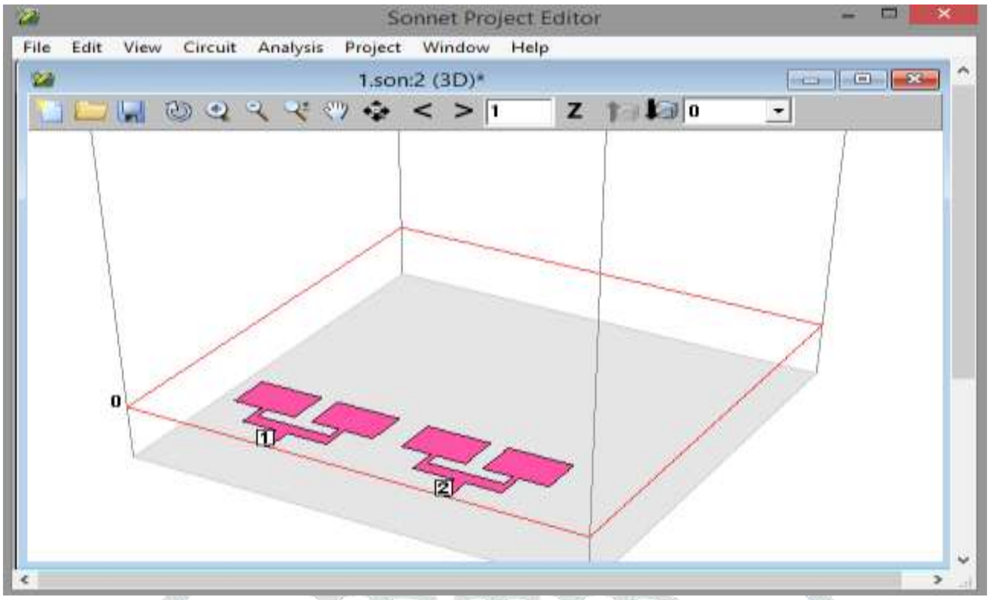

Fig.9. Three Dimension of Dual Feed Patch Antenna Array

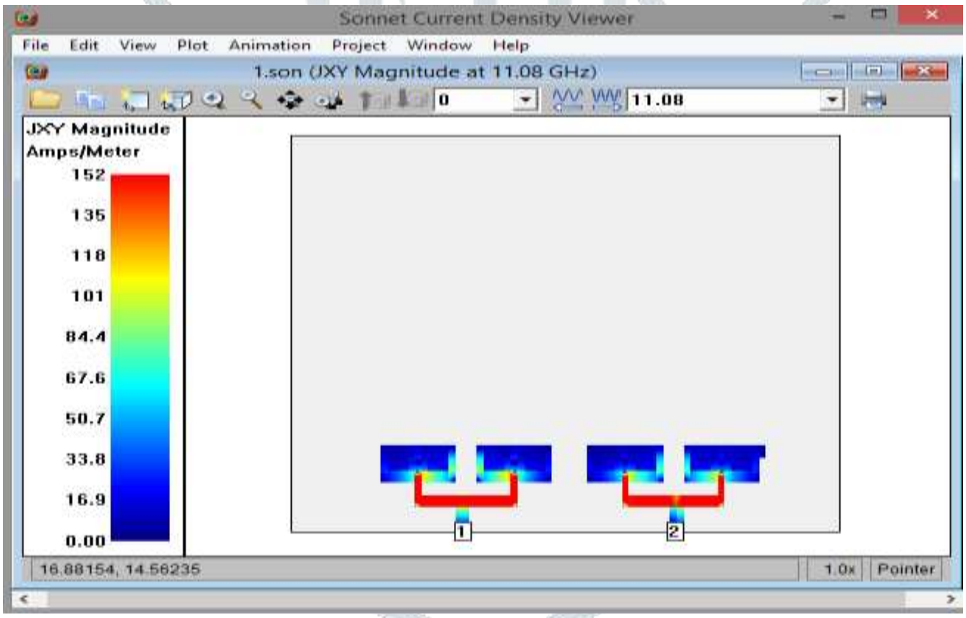

Fig.10. Current Density of Dual Feed Patch Antenna Array

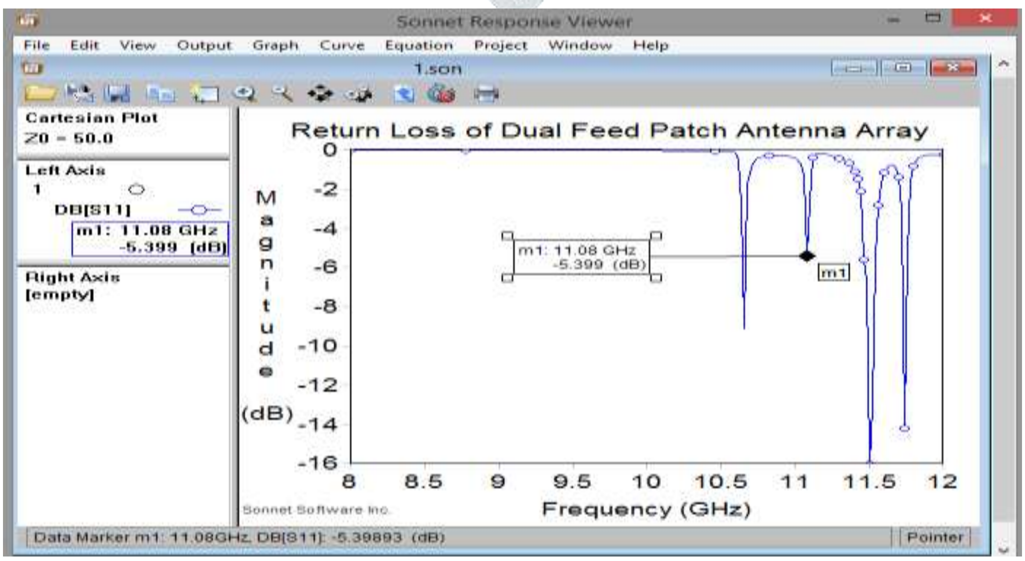

Fig.11.Return Loss [S11] of Dual Feed Patch Antenna Array

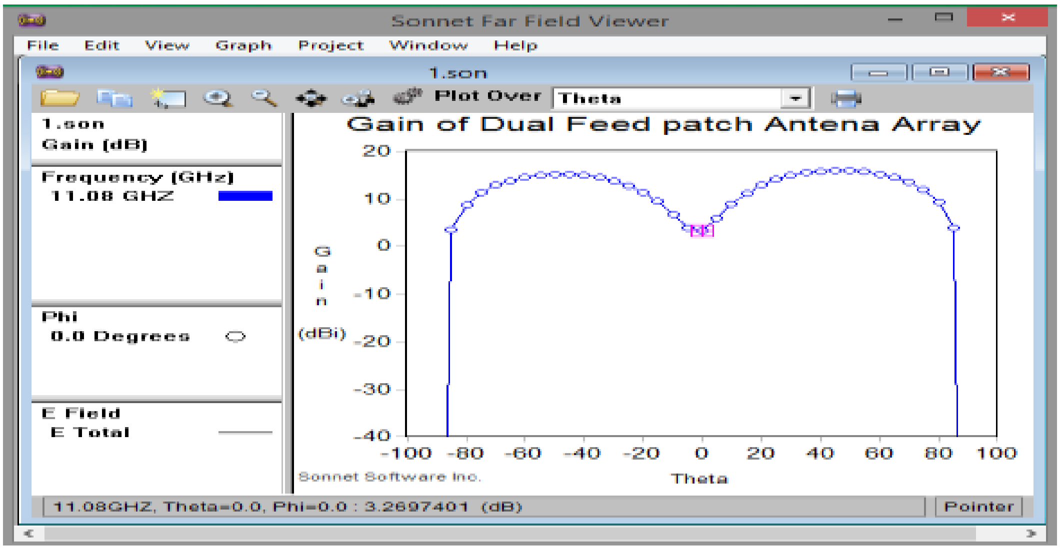

Fig.12. Gain of Dual Feed Patch Antenna Array

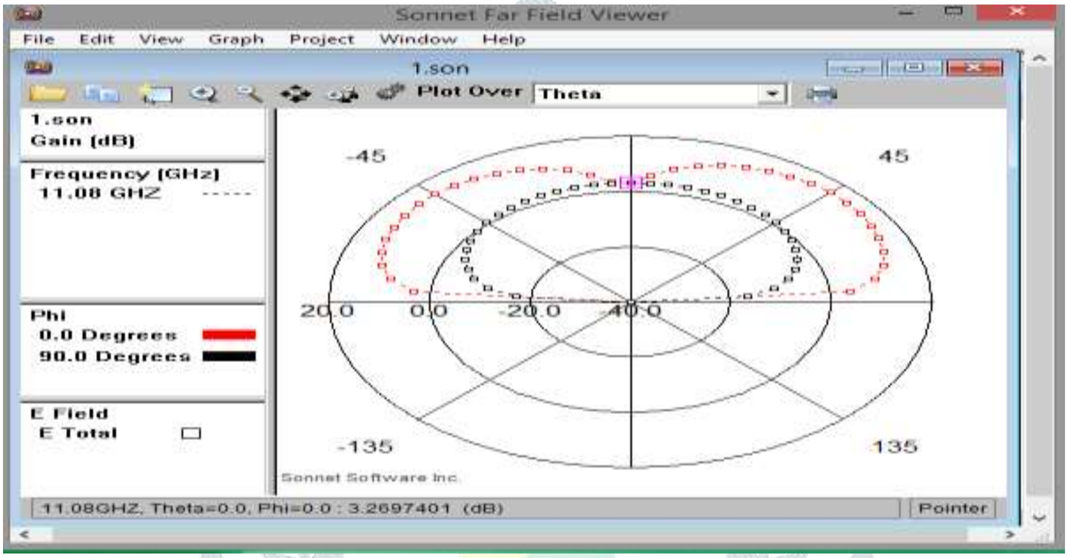

Fig.13. Radiation Pattern of Dual Feed Patch Antenna Array

Fig.14 show the VSWR of the dual feed patch antenna array, the VSWR circle is indicated by red circle where VSWR =3.5. VSWR input impedance of the antenna at the resonant frequency are found at VSWR = 3.3.

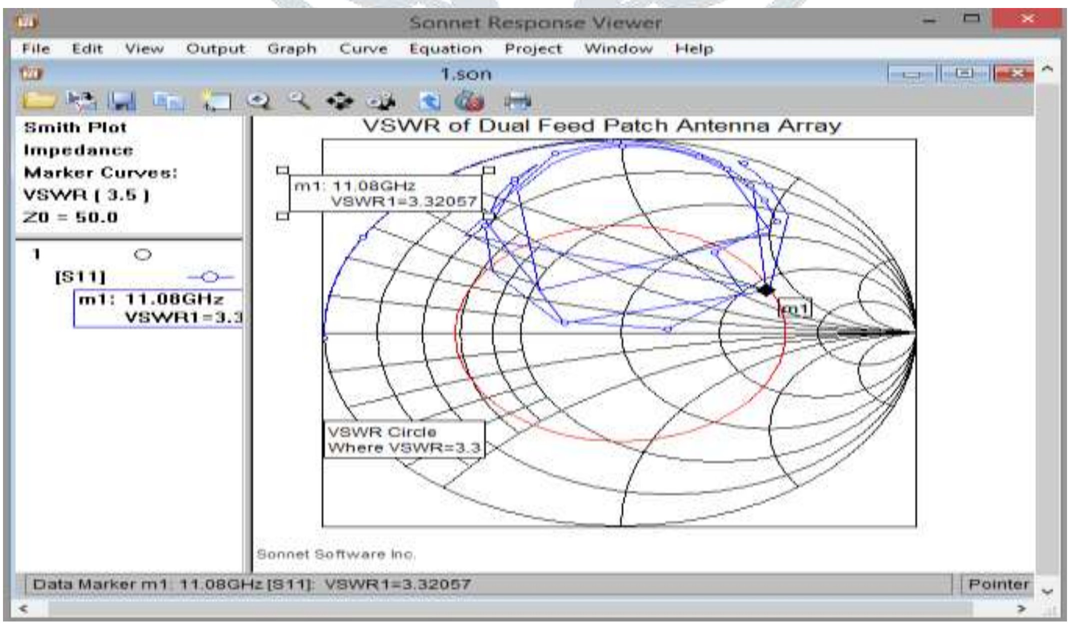

Fig.14. VSWR of Dual Feed Patch Antenna Array

Now compare both the antennas on the basis of VSWR and Return loss. Here Fig.51 shows comparison of return loss of both antennas. Return loss in dual fed patch antenna array is indicated by blue line and in single fed patch antenna array it is indicated by red line. Fig. 16 shows the comparison of VSWR of single and dual fed Patch Antenna array. It is clear from the Fig.15 that at the resonant frequency, the return loss of single patch antenna and dual fed patch antenna array are -5.399dB and -11.44dB and VSWR are 1.7 and 3.3 respectively. The return loss of single fed is decreased much more than dual fed patch antenna (as shown in the Fig.15) and VSWR of single is closer than dual Patch Antenna to 1(as shown in the Fig.16).

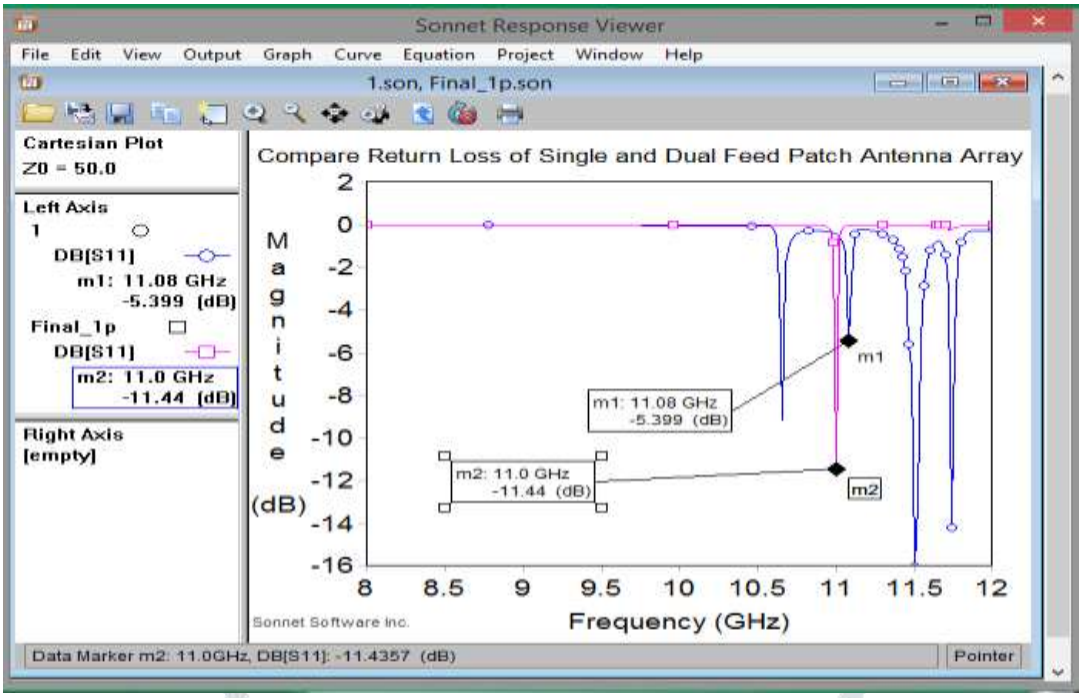

Fig.15. Comparison of return Loss [S11] of Single & Dual Feed Patch Antenna Array at Resonant Frequency (11 GHz)

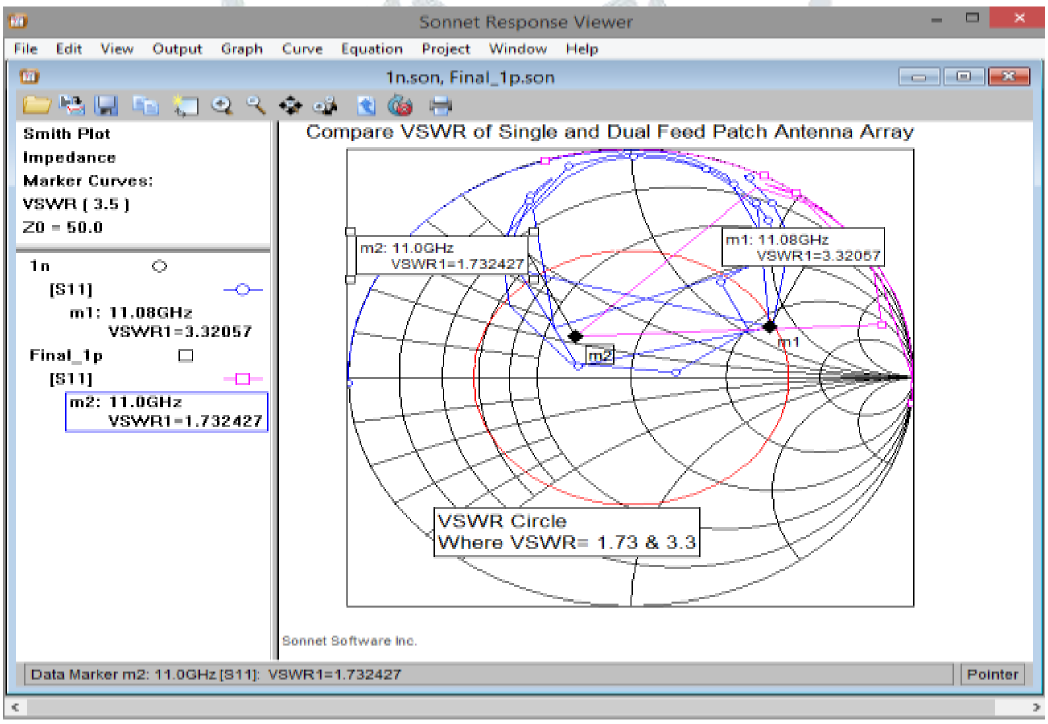

Fig.16. Comparison of return Loss of Single & Dual Feed Patch Antenna Array at Resonant Frequency (11GHz)

CONCLUSION

Finally, two different feed patch antennas are presented, simulated and discussed for wireless communications especially X-Band communication and Wimax at 11GHz and the simulated results compare between current density, S-parameter, Gain and VSWR [19]. Proposed single feed patch is better than any dual feed patch antenna at resonant frequency. The return loss of single feed is higher than dual feed patch antenna. Gain & radiation pattern are found 3.26 & 21.71 and the VSWR is found to be 3.3 and 1.7 at resonant frequencies of dual Feed patch and of single feed patch respectively. It was seen that current density, return loss and VSWR of single feed patch antenna is better than dual feed patch antenna. The antenna characteristics are applicable for X-Band communication and Wimax application

ACKNOWLEDGMENT

Authors would like to thank Maulana Azad National Fellowship (UGC) for financial support.

REFRENCES

[1] M. T. I. Huque, et al., "Design and Simulation of a Low-cost and High Gain Microstrip Patch Antenna Arrays for the X-band Applications," in International Conference on Network Communication and Computer – ICNCC 2011, New Delhi, India., March 21-23, 2011.

[2] R. Mailloux, et al., "Microstrip array technology," Antennas and Propagation, IEEE Transactions on, vol. 29, pp. 25-37, 1981.

[3] H. Cheng-Chi, et al., "An aperture-coupled linear microstrip leaky-wave antenna array with two-dimensional dual-beam scanning capability," Antennas and Propagation, IEEE Transactions on, vol. 48, pp. 909-913, 2000.

[4] K. Gi-Cho, et al., "Ku-band high efficiency antenna with corporateseries-fed microstrip array," in Antennas and Propagation Society International Symposium, IEEE, 2003, pp. 690-693 vol.4,2003.

[5] A. Abbaspour-Tamijani and K. Sarabandi, "An affordable millimeterwave beam-steerable antenna using interleaved planar subarrays," Antennas and Propagation, IEEE Transactions on, vol. 51, pp. 21932202, 2003.

[6] A. Boufrioua and A. Benghalia, "Effects of the resistive patch and the uniaxial anisotropic substrate on the resonant frequency and the scattering radar cross section of a rectangular microstrip antenna," Aerospace science and technology, vol. 10, pp. 217-221, 2006.

[7] K. C. Lo and Y. Hwang, "Microstrip antennas of very high permittivity for personal communications,", pp. 253-256 vol, 1997.

[8] J. M. Rathod, "Design Development of Antenna for TV Transmission for Connecting Outdoor Broadcasts Van to the Studio for Rural Areas," International Journal of Computer and Electrical Engineering, vol. 2, pp. 251-256, 2010.

[9] O. Barkat and A. Benghalia, "Radiation and resonant frequency of superconducting annular ring microstrip antenna on uniaxial anisotropic media," Journal of Infrared, Millimeter and Terahertz Waves, vol. 30, pp. 1053-1066, 2009.

[10]Ramesh Garg, Prakash Bhatia, Inder Bahal and Apisak Ittipiboon, "Microstrip Antenna Design Handbook", Artech House, 2001.

[11] M. F. Islam, et al., "Dual band microstrip patch antenna for SAR applications," Australian Journal of Basic and Applied Sciences, vol. 4, pp. 4585-4591, 2010.

[12] C. A. Balanis. Antenna, theory : analysis and design (3rd ed.) 2005..

[13] T. A. Milligan, et al. "Modern antenna design. Available",2005. http://dx.doi.org/10.1002/0471720615

[14] M. M. Alam, et al., "Design and performance analysis of microstrip array antenna," Session 5AP, p. 846.

[15] R. J. Mailloux, "Electronically Scanned Arrays," Synthesis Lectures on Antennas, vol. 2, pp. 1-82, 2007.

[16] G. Pravin A.K. Rastogi "A Double E-shaped Microstrip Patch Antenna for C-band RADAR Applications", One day nation conference on microwave Engineering, October 2016.