Development of Microstrip Antenna for Satellite Application at Ku/Ka Band

Farooq Al-Janabi[1], Mandeep Jit Singh[1], and Amar Partap Singh Pharwaha[2]

[1] Department of Electrical, Electronic and Systems Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

[2] Department of Electronics and Communication Engineering, Sant Longowal Institute of Engineering and Technology, Longowal 148106, Distt. Sangrur, Punjab, India

Email: p95307@siswa.ukm.edu.my; mandeep@ukm.edu.my; aps.aps67@gmail.com

Abstract—Antennas are the most important unit in almost all wireless communications, which played the key of transmitting the radiating electromagnetic waves after converting it from electrical signal. In this paper, designed an antenna that is capable to operate at frequencies between 12 GHz – 18 GHz for Ku band, and 26.5 GHz – 40 GHz for Ka band. This antenna was designed to overcome the narrow bandwidth, low gain, and large size of most satellite application antennas. By using a square shaped patch on a 4.3 dielectric constant substrate, modified and optimized the dimensions of the patch element, this antenna operated on dual-band frequencies between 12 GHz – 18 GHz and 26.5 GHz – 40 GHz, which satisfies the required bandwidth for satellite application. The antenna design was simulated using CST Microwave Studio software to analyze and evaluate the performance of the antenna design visibility.

Index Terms—Communication, satellite, antenna, Ku band, Ka band, 12 GHz – 18 GHz 26.5 GHz – 40 GHz, CST studio suite, design, simulation

I. INTRODUCTION

An antenna is an electrical conductor or a system of conductors or a combination of dielectric and conducting system which can radiate electromagnetic energy into space and receive electromagnetic radiation from space [1]. The recent years shows the amazing improvement made by researchers to enhance this field concerning lacks in antenna technology. Wireless communication has various applications like Global Position System (GPS), mobile phone, traffic radar, military, biomedical and aerospace area that antenna structure is the fundamental part of these systems [2]. At the same time a significant amount of usage is made into this field by various users as education systems, business, medicine, space, oil and gas companies and may more. Therefore, enhancement should be considered also upon the communication field and its infrastructure as its equally important. Considering the landline communication and equalize it with the size of planet and the various scattered human attentions, rural areas and industries, and massive ocean ships makes it nearly impossible to cover all that area and provide direct access among the different users. As a result, lot of companies made their way to the satellite communication to overcome the shortcuts that land infrastructure cannot cover and develop. The presence of the antenna in the satellite communication system is of great significance, and as such cannot be eliminated. The modern society has evolved and moved into the information age, and with this evolution, there are higher requirements for antenna. Thus, it becomes crucial to study multiband and miniaturized antennas [3]. Besides the many advantages of characteristic microstrip antennas, they additionally have three basic disadvantages: narrow bandwidth, low gain, and quite large size. These parameters are further degraded by the compact antenna configuration, as the reason of relationship between the antenna's bandwidth, size, and efficiency. Apart from that relationship, there is also a relationship between the gain and the antenna's size. Typically, the gain of electrically small antennas is lower than that of the large ones [4].

Modern consumer level markets are mostly serviced with cable and land line-based infrastructure for the delivery of two-way internet access. Due to the logistical and broadband limitations of this cable-based infrastructure the opportunity appears for the use of Underneath band (Ku-band) and if possible Above band (Ka-band) satellite infrastructure to deliver broadband communications to consumer level markets. As the absence of a cable network, and existing the satellite television infrastructure, the opportunity arises for the combination of a Ka-band uplink capability with the already existing Ku-band down link that currently assist the delivery of satellite television. As the antenna is widely available in different shapes sizes, with the same concept of electromagnetic operating principles. Modern technology growth led to cutting everything sizes as it is a key feature for world advancement. Thus, wireless communication network developers certify that they keep improvement a wireless communication component which makes the devices to be lighter and easy to navigate. Thats the reason why the radio communication antenna developers should make a small-sized antenna, as different frequencies handle different wireless communication system and utilize small telecom operators modern devices. In order to suit the rapid

improvement of compact modern wireless devices, applying miniaturizing techniques will accompanied by few limitations as limited bandwidth, and a reduction of gain and efficiency radiation [5]. Although increasing the thickness of the substrate to overcome the bandwidth, will increase the surface power besides decreasing the radiation power, which will lead to poor radiation efficiency. Also, satellite communication still challenging due to the requirements of the power and signal polarization when using Ku-band at 12 GHz – 18 GHz, and Ka-band at 26.5 GHz – 40 GHz [6].

One of the main used technologies today for high-speed satellite internet is the Ku-band. Ku-band which is a part of the electromagnetic spectrum, is the lower portion among the three NATO K bands that operate in ranging frequencies from 20 GHz to 40 GHz, as Ku-band operates from 12 GHz to 18 GHz. It is widely used in the satellite communications world. Reliable for the higher-powered satellite services used in digital TV to include news feeds, educational networks, teleconferences, sports, entertainment programming, and international programming. As well as, using it in Very Small Aperture Terminal (VSAT) systems on ships, for commercial aircraft, and by NASA in space. Some of the Ku-band advantages that the power of uplink and downlink can be increased as needed, it is frequently better over lower frequency microwave bands as that shorter wavelength can separate the signals of different communication satellites with smaller parabolic antenna, it offers the flexibility for the users with freedom from land operations making it easier to find a properly functioning dish site, and most importantly it is generally cheaper option [7].

The applications of Ka-band system involve two-way broadband internet, VSAT networks, enterprise applications, remote area communications, mobile backhaul, defense applications, satellite news gathering, and disaster management Since the commercial VSAT system operate in Ku-band; yet, a need for much wider bandwidth make Ka-band frequencies more outstanding for future commercial VSAT system. At higher frequencies the short wave has the lead of allowing compact terminals and antennas to support high bandwidth applications. Since the need for bandwidth, the up and down links have moved from the Ku-band to the Ka-band. There are a host of wide band systems being presented for Ka-band also, as Astrolink, Spaceway and Teledesic, which proposed to afford multimedia services to desktop computer-size terminals [8]. Narrow band and wide band systems are both reliable because they offer greatly higher capacity and low user costs compared to traditional systems. As the bandwidth need keep increasing, the carrier frequencies will keep moving to higher bands. The Ka-band so far still in various stages of development. Operating in the Ka- band offers more advantages over usual satellite networks operating Ku-band and lower frequencies, that because of the high gain antenna in Ka-band has comparing to lower frequencies.

Still, the disadvantages exist in Ka-band as the weather conditions impact the Ka-band more than at lower frequencies. Thus, appropriate planning is needed for the implementation of well-designed ground systems, network links reliability and resources to overcome the diverse weather effects [9].

As the antenna are wildly used due to the light weight, small profile, low cost, and ease of fabrication. It is much desirable to have a single antenna with a single feed point which cover dual frequency bands than several antennas for each frequency band [10]. Therefore, proposing a square shaped microstrip antenna for satellite application that operate at Ku and Ka band. The proposed dual band antenna is a well solution for high frequency applications, as it has a small compact size, and operate at both bands with a good return loss and good Voltage Standing Wave Ratio (VSWR). The requirement and the mechanism of the antenna been collected to realize the design specification, that included details of the antenna's geometrical parameters and the dielectric substrate. The antenna's design process been determined based on the specifications of the certain application of the antenna.

II. ANTENNA DESIGN METHODOLOGY

Satellite system is one of the supremely important application of microstrip antenna. Mobile communication needs small sized, low-cost, and low-profile antennas. Microstrip patch antenna has all these requirements and various types of microstrip antennas have been designed to be used in mobile communication systems. For satellite communication, circularly polarized radiation patterns are required and can be attained by using either square or circular patch with one or two feed points, due to the massive distance between the earth and satellite [11].

A microstrip patch antenna is used for generally narrowband applications. It has a wide-beam which is made by etching the design pattern on the metallic surface over a dielectric insulating base, a continuous metal layer in the opposite side of the strip forms a ground plane. Microstrip patch antennas can be found in many shapes, common shapes are regular like square, rectangular, circular, triangular etc. but in fact any irregular shape is possible. Regular shapes are generally chosen because of ease of analysis, ease of fabrication, attractive radiation characteristics and low cross radiation properties [12]. The radiation in microstrip patch antennas is due to the fringing fields between the edge of the patch and the ground plane. A thick substrate with a very low dielectric constant is suitable for good antenna performance since it provides a larger bandwidth, better efficiency, and better radiation. But in such a scenario, the antenna size increases. Thus, to reduce the size, high dielectric constants substrate must be used which have a narrow bandwidth and less efficient. Hence a proper trade-off must be done at the designing stage to realize antenna performance improvement at a particular operating frequency and constrained physical dimensions [13].

Microstrip antenna feed techniques can be categorized as two methods, the contacting and non-contacting. In the contacting method, the Radio Frequency (RF) Power is fed directly to the radiating patch using a connecting element such as a microstrip line. The microstrip line and the coaxial probe are examples of contacting method. In the non-contacting, electromagnetic field coupling will be implemented to transfer the power between the microstrip line and the radiating patch. Techniques that are in these non-contacting methods are aperture coupling and proximity coupling. The feed technique that will be used in this paper is microstrip line feed. Microstrip line feed is one of the easiest methods to fabricate, by conducting strip connecting to the patch and therefore can be consider as extension of patch. It is simple to model and easy to match by controlling the inset position. However, as the substrate thickness increases, surface waves and spurious feed radiation increase, which for practical designs limit the bandwidth and the introduction of coupling between the feeding line and the patch, which leads to spurious radiation and the required matching between the microstrip patch and the 50 Ω impedance feeding line [14].

The feed-lines and the radiating patch are usually photo-etched on the dielectric substrate. The substrate can be thick or thin, and must be chosen with permittivity between 2.2 and 12. Flame Retardant 4 (FR4) materials response to environment, such as moisture diffusivity and moisture concentration, can also impact the performance of the design. The electrical performance of advance materials is often compared to a standard FR4 baseline which consists of standard copper foil laminated to a core of woven E-glass reinforcement impregnated with unmodified FR4 epoxy resin. Therefore, the electrical performance of design using baseline of standard FR4 can be improved by changing one or more of its components.

The proposed microstrip patch antenna designed as a square shaped, while having an additional slot between the square shaped patch as shown in Fig. 1. The model been adjusted and optimized for the best results. That ensures the desirable qualities as better efficiency, larger bandwidth, and better radiation [15]. The first slot between the outer square and middle square has a width of 0.95 mm and length of 1.95 mm, second slot has a width of 0.325 mm and length of 0.625 mm, and third slot has a width of 0.425 mm and length of 0.325 mm, both of second and third slots are in between the middle square and the inner square. Furthermore, the antenna designed with 4.3 dielectric constant substrate and one feeder line, the design been operating at two frequencies where it been functioning between 12 GHz to 18 GHz frequency for Ku-band, and 26.5 GHz to 40 GHz frequency for Ka-band. As for the design procedure, the dimensions of the proposed antenna been calculated using basic equations, the width of the antenna patch can be obtained using Eq. (1) [16].

$$W = \frac{v_o}{2f_r}\sqrt{\frac{2}{\varepsilon_r + 1}} \tag{1}$$

where, W is the patch width, v_o is the free space velocity of light (3×10^8), f_r is the resonant frequency, and ε_r is the substrate dielectric constant. The length of the antenna patch can be found as shown in Eq. (2).

$$L = L_{eff} - 2\Delta L \tag{2}$$

where, L is the patch length, L_{eff} is the effective length, and ΔL is the extended length.

$$L_{eff} = \frac{c}{2f_r\sqrt{\varepsilon_{reff}}} \tag{3}$$

where, c is the free space speed of light (3×10^6), and ε_{reff} is the effective dielectric constant.

$$\varepsilon_{reff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-\frac{1}{2}} \tag{4}$$

where, h is the substrate height.

$$\Delta L = 0.412h\frac{(\varepsilon_{reff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{reff} - 0.258)(\frac{W}{h} + 0.8)} \tag{5}$$

The proposed antenna structure phases started by having a 5 mm × 5 mm square shaped patch, second phase has an outer square shaped patch with 0.3 mm width, third phase added a center square shaped patch with 2.5 mm width, fourth phase added a middle square shaped patch with 0.3 mm width, fifth phase added an inner square shaped patch with 1.25 mm width, sixth phase added a 1.95 mm × 1.95 mm slot between the outer square and middle square shaped patch, seventh phase added a 0.625 mm × 0.325 mm slot between the middle square and inner square shaped patch, the last phase were adding a 0.325 mm × 0.425 mm slot between the middle square and inner square shaped patch, both of second and third slots are in between the middle square and the inner square. This process is meant to reach the final results that aims to operate the antenna at dual satellite applications frequencies.

The antenna, which is useful for radio transmission and reception signals, its own electric energy can be converted to electromagnetic energy. The antenna can be represented as a transitional structure between free-space and a guiding device. It is the last element in the transmission side, when the first element is receiving side. Therefore, the antenna is considered as an integral part of all wireless communication systems. The final dimensions of the whole antenna structure are (10 mm × 10 mm) with thickness of 1 mm. The antenna is designed over Flame FR4 substrate with 0.025 dielectric loss tangent [17]. the square shaped patch having a dimension of (5 mm × 5 mm) with a microstrip feedline at a distance of 2.5 mm from patch. The antenna parameters measurements are shown in Table I.
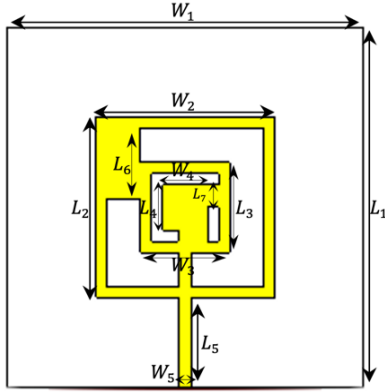
Fig. 1. Microstrip antenna geometry

TABLE I: ANTENNA PARAMETERS

Parameters	Description	Value (mm)
W_1	Ground and substrate width	10
W_2	Patch outer square width	5
W_3	Patch middle square width	2.5
W_4	Patch inner square width	1.25
W_5	Microstrip feed line width	0.4
L_1	Ground and substrate length	10
L_2	Patch outer square length	5
L_3	Patch middle square length	2.5
L_4	Patch inner square length	1.25
L_5	Microstrip feed line length	2.5
L_6	patch outer slot length	1.95
L_7	patch inner slot length	0.625

The parameters of the proposed square shaped patch antenna been optimized using CST studio suite software. The resulting dual band antenna is suitable for satellite communication systems, as result and discussion will show that it operated at the Ku-band (12 GHz – 18 GHz), and Ka-band (26.5 GHz – 40 GHz).

III. RESULTS AND DISCUSSION

The simulation results for the proposed antenna are presented, the investigation and analysis conducted about the satellite applications, especially for Ku frequencies that operate at 12 GHz to 18 GHz, and Ka frequencies that operate at 26.5 GHz to 40 GHz. The complete simulation and modeling for the designed dual band antenna conducted using CST software. The simulation process started from designing the proposed antenna based on the size required, followed with addition slots between the patch square shapes of the design. The square shape patch was used to operate on Ku and Ka band, were the additional slots was used to enhance the S_{11} and gain response of the antenna. The final operating frequencies were 14.832 GHz and 36.944 GHz, which are suitable for satellite application at Ku band and Ka band [18].

Reflection coefficient S_{11} shown in Fig. 2 shows the amount of power that is reflected back at the port of the antenna due to mismatch from transmission line, if $S_{11} < -10$ dB that means 90% of power excited been transmitted [19]. The response of the return loss S_{11} for

the proposed design, is measured from 10 GHz to 40 GHz frequency and 0 to -60 dB return loss parameter, at Ku band it has a return loss of -32.988 dB at 14.832 GHz, and Ka band has a return loss of -55.029 dB at 36.944 GHz. This good matching ensures a longer antenna radiating distance.

The bandwidth of the antenna is the range of frequencies within which the performance of the antenna, with respect to some characteristic, conforms to a specified standard. Impedance bandwidth from the impedance point of view identifies the range of frequencies, where more than 90% of the power applied to the input terminals of the antenna is accepted. The impedance bandwidth over a frequency range can be indicated in terms of return loss (S parameters). The proposed antenna has a wide band at both frequencies, which satisfies the requirements of the satellite applications [20]. The Ku band has bandwidth of 0.5055 GHz, which operates between 14.587 GHz and 15.093 GHz. The Ka band has a bandwidth of 3.028 GHz, that operates between 35.586 GHz and 38.615 GHz.
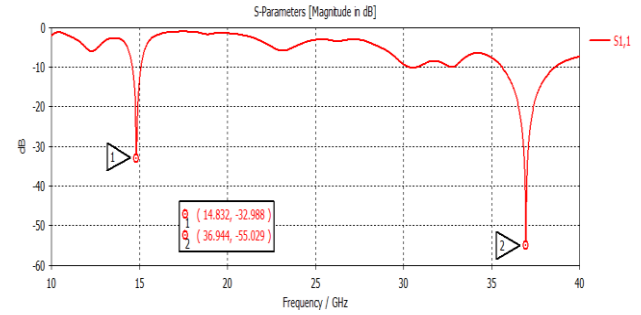

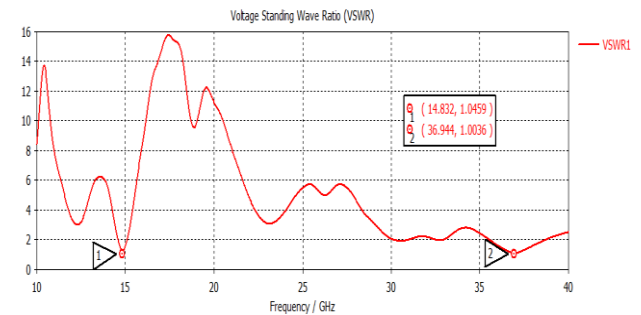Fig. 2. Antenna return loss at Ku and Ka band

Fig. 3. Antenna VSWR at Ku and Ka band

In wireless communications, the impedance bandwidth is defined as the range of frequencies over which the antenna return loss is greater than 10 dB or a VSWR of at most 2 dB [21]. The return loss of the antenna and the VSWR are dependent on the antenna reflection coefficient. The reflection coefficient can be defined as the ratio of the reflected wave to the incident wave. The VSWR of the conventional design is shown in Fig. 3. VSWR is a reflection of the S_{11} response, as the VSWR below 2 dB is suitable the most for antenna applications, which means that a good radiation pattern is possessed by the antenna if the VSWR is as low as possible [22]. The response of the antenna that is measured from 10 GHz to 40 GHz frequency and VSWR from 0 dB to 16 dB, it

shows that the antenna having a good match in terms of VSWR, as the proposed design had a good match of 1.0459 dB for Ku band, and Ka band had 1.0036 dB, were the maximum VSWR showed 16 dB. As both Ku and Ka bands has less than 2 dB, this design is satisfying the requirements for operating at dual band frequency of satellite applications.

Antenna gain is a significant parameter that can be used to describe the characteristics of the antenna's radiation, the gain of the antenna is described as the performance of an antenna, it is a measure that takes into count the efficiency of the antenna radiation and the directivity [23]. Furthermore, it is expressed as in a given direction, the ratio of the intensity to the radiation intensity that would be obtained when the power gets accepted by the isotopically radiated antenna. The response of the proposed antenna gain of the frequency is shown in Fig. 4, the response of the antenna that is measured from 10 GHz to 40 GHz frequency and gain from -2 dBi to 7 dBi, it has a peak gain of 2.3163 dBi at 14.832 GHz, and a peak gain of 4.8344 dBi at 36.944 GHz. The antenna frequency versus the gain, shows that the antenna has a reasonable gain at 14.832 GHz for Ku band and at 36.944 GHz for Ka band, also it shows a slight gain drop at K band, it furthermore shows that the maximum gain is about 6.2 dBi.
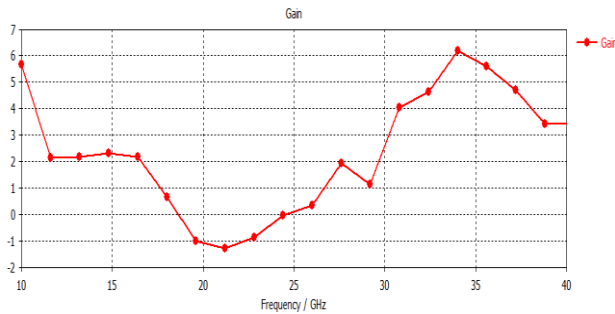

Fig. 4. Antenna gain vs frequency response

Summed up result of the single dimensional responses shows for Ku band at 14.832 GHz, the proposed antenna shows a return loss of -32.988 dB, wide Ku bandwidth of 0.5055 GHz at (14.587 GHz to 15.093 GHz), total gain of 2.3163 dBi, and a VSWR of a good match at 1.0459 dB. Furthermore, the Ka band at 36.944 GHz has a return loss of -55.029, wide Ka bandwidth of 3.028 GHz at (35.586 GHz to 38.615 GHz), total gain of 4.8344 dBi, and a good VSWR match at 1.0036 dB.

The antenna performance can be known by its gain, as it shows how good the antenna converts the input power into radio waves designed to transmit in the required direction [24]. Also, the positive gain is needed to reach a good wave propagation. As a performance parameter of the proposed antenna, the three-dimensional (3D) gain pattern are shown in the Fig. 5 were, (a) represent 3D gain plot at 14.832 GHz, and (b) represent it at 36.944 GHz.

The red areas represent the maximum gain of the beam pattern for the proposed antenna, while the blue color

represent the lowest gain of the beam pattern. The antenna radiation pattern can have a directional beam pattern radiation [25]. The gain for Ku band shows a positive value of 1.83 dBi while the far field of Ku band shows a radiation efficiency of -4.417 dB, total efficiency of -4.419 dB, and minimum gain of -24.2 dBi. At Ka band the gain shows a positive value of 4.95 dBi besides the far field of Ka band that shows the radiation efficiency of -2.444 dB, total efficiency of -4.445 dB, and minimum gain of -32.3 dBi, making the antenna successful to be used at the satellite applications.
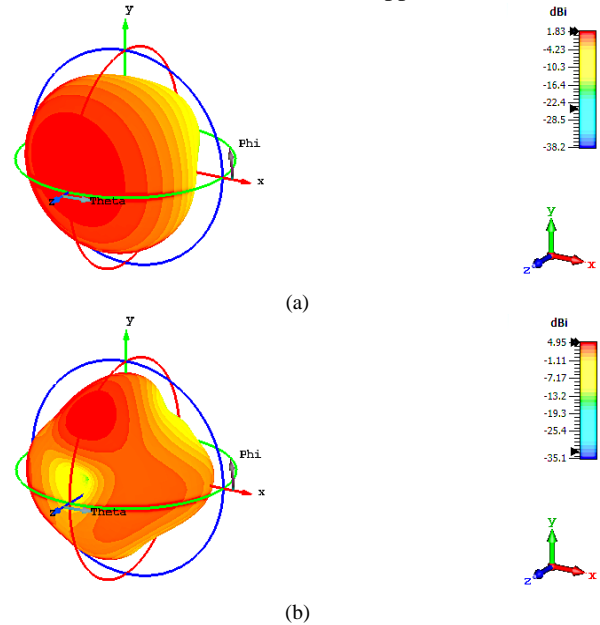

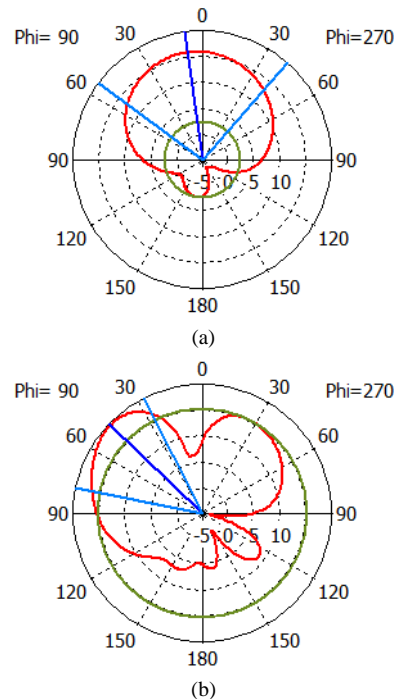Fig. 5. (a) 3D plot at 14.832 GHz (b) 3D plot at 36.944 GHz

Fig. 6. (a) E-Field at 14.832 GHz (b) E-Field at 36.944 GHz

The antenna's electromagnetic field observe the directional power radiated by the antenna. The radiation

pattern of the antenna can be represented as a two-dimensional (2D) or a 3D [26]. The 2D patterns can be given as slices through the 3D pattern. To define antenna radiation patterns, the spherical coordinate system is used. Considering the antenna is designed on yx-plane, The Electric Field (E-Field) and Magnetic Field (H-Field) can be observed by vertical polarized direction as E-plane having phi = 90 for yz-plane, or a horizontal polarized direction as H-plane having phi = 0 for xz-plane. Fig. 6 shows the E-Field at Ku and Ka bands, while Fig. 7 shows the H-Field at both bands.
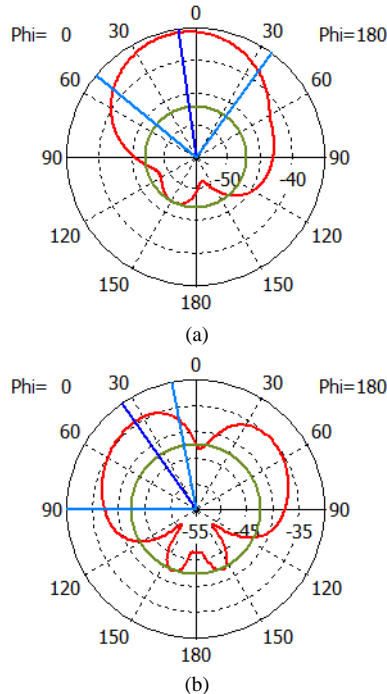

(a)

(b)

Fig. 7. (a) H-Field at 14.832 GHz (b) H-Field at 36.944 GHz

The E-plane and H-plane can define the performance of an antenna that is linearly polarized. While the electric-field vector together with the direction of maximum radiation are contained in the former, the latter contains the magnetic-field vector and direction of maximum radiation [27].

The polar coordinate that showing the antenna radiation pattern, can show that both frequencies having a directional pattern. The beam width of Ku band at E-Field were 94.5 degree, were Ka band has 51.3 degree. Also, at H-Field the beam width of Ku band was 86.8 degree, were Ka band has 78.5 degree.

The radiation pattern for E-field at 14.832 for Ku band, shows an omnidirectional co-polarization characteristic, the gain at the main lobe magnitude 1.83 dBi is evenly distributed.

The cross-polarization radiation pattern of E-field main lobe magnitude is 16 dBV/m, it has a maximum directivity at the main lobe direction of the E-filed radiation pattern 8.0 degree, with (3dB) angular beam width of 94.5 degree, and side lobe of -13.7 dB.

At 36.944 for Ka band, the characteristic of the radiation patter for E-field shows an omnidirectional co-

polarization, the gain that is evenly distributed has a main lobe magnitude of 4.95 dBi.

The E-field radiation pattern cross-polarization main lobe magnitude is 19.6 dBV/m, besides a maximum directivity at the main lobe direction of the E-filed radiation pattern 46.0 degree, were the (3dB) angular beam width is 51.3 degree, and -4.5 dB side lobe level.

H-field at 14.832 GHz for Ku band simulated results at co-polarization main lobe magnitude is -35.6 dBA/m, and main lobe directional is 8.0 degree.

The H-field cross-polarization radiation pattern wide angular beam width (3dB) is 86.8 degree, the level of the side lobe is -11.6 dB.

The co-polarization of H-field at 36.944 GHz for Ku band simulated results main lobe magnitude is -34.4 dBA/m, and main lobe directional is 35.0 degree.

The cross-polarization of H-field radiation pattern wide angular beam width (3dB) is 78.5 degree, were the side lobe level is -7.9 dB.

The plotted simulated radiation pattern results of the proposed antenna show the result for Ku band at 14.832 GHz were the direction angle is shifted to the left side by 35.0 degree for E-field and H-field. Were, the result for Ka band at 36.944 GHz shows the direction angle is shifted to the left side by 46.0 degree for E-field and 35.0 degree at H-field. The misalignment of axis in the measurement can cause a discrepancy which arise in return an inaccuracy in obtaining the measured data.

IV. CONCLUSION

In this paper, a dual band microstrip antenna for satellite application is presented and been simulated using CST studio suite, the proposed microstrip patch antenna designed as a square shaped, the square shaped patch design had an added slots among the outer, middle, and inner square shaped patches, the first slot between the outer square and middle square had a width and length of 0.95 mm × 1.95 mm, second slot had a width and length of 0.325 mm × 0.625 mm, and third slot had a width and length of 0.425 mm × 0.325 mm, both of second and third slots are in between the middle square and the inner square, the antenna has a total 10 mm^2 profile size and uses an FR4 substrate material, to provide the best simulation results aimed at the return loss, VSWR, gain, and radiation pattern. It is clear from all the results obtained that the proposed design is successfully operating at Ku band and Ka band for satellite applications with great results. The antenna is capable to operate at 14.832 GHz frequency for Ku band, and 36.944 GHz for Ka band. The simulated design showed a return loss of -32.988 dB at 14.832 GHz, with a wide Ku bandwidth of 0.5055 GHz at (14.587 GHz to 15.093 GHz), and total gain of 2.3163 dBi. The Ka band at 36.944 GHz had a return loss of -55.029, wide Ka bandwidth of 3.028 GHz at (35.586 GHz to 38.615 GHz), and a total gain of 4.8344 dBi. As the VSWR below 2 dB is suitable the most for antenna applications, Ku band had

a VSWR of a good match at 1.0459 dB, and Ka band had a good VSWR match at 1.0036 dB. As the positive gain is needed to reach a good wave propagation, the 3D gain pattern for Ku band showed a positive value of 1.83 dBi, were at Ka band the gain showed a positive value of 4.95 dBi. The width of the beam of Ku band at E-Field were 94.5 degree, were Ka band had 51.3 degree. Besides, at H-Field the beam width of Ku band was 86.8 degree, were Ka band had 78.5 degree. The designed antenna showed a good return loss, that covers the satellite applications frequencies as well as having a low cost, good gain, and small profile size.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Farooq Al-Janabi conducted the research, and analyzed the data; Mandeep Jit Singh simulated the proposed antenna, and conducted the results; Amar Partap Singh wrote the paper; all authors had approved the final version.

REFERENCES

[1] R. Garg, P. Bhartia, I. Bahl, and A. Ittipiboon, *Microstrip Antenna Design Handbook*, Artech House Publishers, Boston, London, 2001.

[2] R. Ludwing and P. Bretchko, *RF Circuit Design: Theory and Applications*, 2nd ed., 2009.

[3] I. J. Bahl and P. Bhartia, *Microstrip Antennas*, Artech House, 1980.

[4] C. G. Christodoulou and P. F. Wahid, *Fundamentals of Antennas: Concepts and Applications*, Prentice Hall of India, 2004.

[5] F. Yang and Y. Rahmat-Samii, *Electromagnetic Band Gap Structures in Antenna Engineering*, Cambridge Univeristy Press, 2009.

[6] K. F. Lee, K. M. Luk, and H. W. Lai, *Microstrip Patch Antennas*, World Scientific, 2017.

[7] B. S. Kumar, "Design and optimization of microstrip patch antenna for satellite applications," *International Journal of Research*, vol. 7, no. 9, pp. 369-373, 2018.

[8] A. Kandwal, "Compact dual band antenna design for Ku/Ka band applications," *Advanced Electromagnetics*, vol. 7, no. 4, pp. 1-5, 2017.

[9] S. C. Pavone, G. S. Mauro, L. D. Donato, and G. Sorbello, "Design of dual circularly polarized sequentially-fed patch antennas for satellite applications," *Applied Sciences*, vol. 10, no. 6, pp. 1-11, 2020.

[10] S. Viesse, S. Asadi, and M. K. Hedayati, "A novel compact defected ground structure and its application in mutual coupling reduction of a microstrip antenna," *Turkish Journal of Electrical Engineering and Computer Science*, vol. 24, pp. 3664-3670, 2016.

[11] K. Hati, N. Sabbar, A. El Hajjaji, and H. Asselman, "A novel multiband patch antenna array for satellite applications," in *Procedia Engineering*, 2017, pp. 496-502.

[12] W. H. Weedon and S. K. Cheung, "Ku-band low-profile and wideband satellite communication antenna (LPWSA)," in *Proc. IEEE International Symposium on Phased Array Systems and Technology (PAST)*, 2016, pp. 1-7.

[13] K. L. Wong, *Compact and Broadband Microstrip Antennas*, John Wiley & Sons, 2004.

[14] L. S. Chuan, S. Ru-Tian, and Y. P. Hon, "Ka-band satellite communications design analysis and optimisation," in *Defense Science and Technology Agency (DSATA) Horizons*, 2015, pp. 70-78.

[15] R. Deng, S. Xu, and F. Yang, "Design of a Ku/Ka quad-band reflectarray antenna for satellite communications," in *Proc. IEEE International Symposium on Antennas and Propagation (APSURSI)*, 2016, pp. 1217-1218.

[16] C. A. Balanis, *Antenna Theory: Analysis and Design*, Wiley, 2005.

[17] U. Ozkaya and L. Seyfi, "Dimension optimization of microstrip patch antenna in X/Ku band via artificial neural network," in *Procedia-Social and Behavioral Sciences*, 2015, pp. 2520-2526.

[18] M. Moniruzzaman, M. T. Islam, G. Muhammad, M. S. Singh, and M. Samsuzzaman, "Quad band metamaterial absorber based on asymmetric circular split ring resonator for multiband microwave applications" in *Results in Physics*, 2020, pp. 1-16.

[19] S. Malisuwan, J. Sivaraks, N. Madan, and N. Suriyakrai, "Design of microstrip patch antenna for Ku-band satellite communication applications," *International Journal of Computer and Communication Engineering*, vol. 3, no. 6, pp. 413-416, 2014.

[20] N. Fugo, R. Kaewon, and S. Sirivisoot, "A comparison of various patch sizes and feed point positions of graphene microstrip antenna for orthopedic implants," presented at 2015 Biomedical Engineering International Conference, 2015.

[21] N. Sanil, P. A. Venkat, and M. R. Ahmed, "Design and performance analysis of multiband microstrip antennas for IoT applications via satellite communication," in *Proc. Second International Conference on Green Computing and Internet of Things (ICGCIoT)*, Bangalore, India, 2018, pp. 60-63.

[22] Y. Liu and Y. H. Mary, "One dual-polarization 10-40 GHz planar array antenna for sattelite communication," in *Proc. IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting*, 2019, pp. 1213-1214.

[23] R. Shrestha, D. E. Anagnostou, S. J. Horst, and J. P. Hoffman, "Dual-frequency and dual-polarization antenna array for satellite deployment," in *Proc. IEEE Aerospace Conference*, 2016, pp. 1-6.

[24] E. Mutluer, B. Döken, and M. Kartal, "A dual-band frequency selective surface design for satellite applications," in *Proc. 18th Mediterranean Microwave Symposium (MMS)*, 2018, pp. 43-46.

[25] K. M. Ho and G. M. Rebeiz, "Dual-band circularly-polarized microstrip antenna for Ku/Ka band statellite communication arrays," in *Proc. IEEE Antennas and*

Propagation Society International Symposium (APSURSI), 2014, pp. 1831-1832.

[26] S. Dixit and S. Mahadik, "Design of multislot dual band patch antenna for satellite communications," *International Journal of Scientific Engineering and Applied Science (IJSEAS)*, vol. 1, no. 5, pp. 329-331, 2015.

[27] C. Chen, S. Xie, X. Zhang, and Z. Ren, "A new space and terrestrial integrated network architecture aggregated SDN," *Journal of China Academy of Electronics and Information Technology*, vol. 10, no. 5, pp. 450-454, 2015.

Farooq Al-Janabi was born in Basrah, Iraq, in 1994. He received the B.S. degree in Electronics Engineering from the Infrastructure University Kuala Lumpur (IUKL), Selangor, Malaysia, in 2017. He is currently pursuing the M.S. degree in Communication and Computer Engineering at Universiti Kebangsaan Malaysia (UKM), Selangor, Malaysia. His current research interest includes antenna and propagation, and wireless communication systems.

Mandeep Jit Singh was born in Malaysia in 1975. He is a Professor at the Department of Electrical, Electronic and Systems Engineering of the Universiti Kebangsaan Malaysia (UKM) and visiting Professor of Covenant University, Nigeria. He is author and co-author of more than 250 research articles in antenna and microwave RF. He is also the recipients of more than 50 research grants (national and international). Thus far, his publications have been cited 1480 times and his H-index is 21. His research interests include communication antenna design, radiowave propagation, satellite antennas, and IOT. Dr. Singh currently serves as the Editor-in-Chief for the Greener. Journal of Electronics and. Communication and Associate Editor for Journal of Electrical and Computer Engineering, Hindawi. He received several International and National Medal awards for his research and innovation. He currently the advisor of the Engineering Education Technical Division (E2TD), Institute of Engineers Malaysia.

Amar Partap Singh was born in Sangrur, Punjab in 1967 and received his BTech degree in ECE from GNDU, Amritsar in 1990. He received his MTech degree from REC, Kurukshetra in 1994 and PhD degree in 2005. Presently, he is a professor in ECE department at SLIET, Longowal. Dr Singh is credited with a professional experience of more than 24 years. He has guided seven PhD thesis and six more students are pursuing their PhD degrees under his supervision. He has published more than 180 research articles in various national and international journals/conferences and received various awards including IETE Students Journal Award in 2006 by IETE, New Delhi, Certificate of Merit in 2006, KF Anita Award in 2009, Sir Thomas Ward for the year 2010, and again KF Anita Award in 2014 by the Institution of Engineers (India).as born in Jiangsu Province, China, in 1978. He received the B.S. degree from the University of Science and Technology of China (USTC), Hefei, in 2001 and the M.S. degree from the University of Florida (UF), Gainesville, in 2003, both in electrical engineering. He is currently pursuing the Ph.D. degree with the Department of Electrical and Computer Engineering, UF. His research interests include spectral estimation, array signal processing, and information theory.