Md SAMSUZZAMAN[1], M. Tariqul ISLAM[2], BAHARUDIN YATIM[2], M. A. MOHD ALI[2]

Universiti Kebangsaan Malaysia (1,2)

Dual Frequency Triangular Slotted Microstrip Patch Antenna for Ku Band Applications

***Abstract**. A single feed, compact, new shaped, dual band microstrip patch antenna has presented in this paper. Here three equilateral triangular slots are introduced in the three edges of the patch and a small feed line has used another edge of the patch to obtain the dual band. The antenna has a condensed structure where patch dimension is about 8.5mm by 7.96mm by 1.905mm leading to good bandwidths covering 13.15 GHz to 13.72 GHz and 16.04 GHz to 16.58GHz. The return loss of -19.00dB is achieved at the first resonant frequency at 13.61 GHz and -28.69dB is at second resonance frequency at 16.33GHz. Stable average peak gain that is observed across the operating band in both lower and higher frequency is almost 3.53dB and 5.562dB respectively .The radiation patterns are nearly omnidirectional with moderate gain in both these operating bands. Good results have been established in dual frequencies at 13.62GHz as downlink and 16.33GHz as uplink. This low profile nature and simple configuration of the proposed antenna show the way to easy fabrication and make it adaptable for the application in wireless and satellite communication*

***Streszczenie.** W artykule przedstawiono dwupasmową prostokątną antenę mikropaskową o jednym doprowadzeniu i nowym kształcie. W trzech rogach znajdują się trzy szczeliny w kształcie trójkąta równobocznego, a w czwartym doprowadzenie linii. Antena posiada pasmo 13,15-13,72GHz oraz 16,04-16,58GHz. Niski profil oraz prosta konfiguracja wskazują na łatwą metodę produkcji oraz możliwość zastosowania w aplikacjach bezprzewodowych i komunikacji satelitarnej. (**Dwuczęstotliwościowa antena mikropaskowa z trójkątnymi szczelinami w zastosowaniu do pasma Ku**).*

Keywords: Dual band**,** Satellite, microstrip patch antenna, Ku band.
Słowa kluczowe: podwójna częstotliwość, prostokątna antena mikropaskowa, pasmo Ku.

Introduction

Now a days in radar and space satellite communication applications, microstrip patch antennas have great demand due to their low profile, mechanically robust, compatible with MMIC designs, relatively compact and light in weight and dual frequency operation. They are easy and inexpensive to manufacture and can be conformable in planar and non-planar planes. But, unfortunately they have some limitations and disadvantages such as relatively low efficiency and low power, spurious feed radiation, narrow frequency bandwidth and relatively high level of cross polarization radiation[1-2].To overcome these limitations and demerits, researchers have been proposed and investigated many techniques such as slotted patch antennas, microstrip patch antennas on electrically thick substrate, probe feed stack antenna and the uses of various feeding and impedance matching techniques, the uses of multiple resonators [3-11]. Presently, wider bandwidth is required for the increasing demand of modern wireless communication system applications. Generally each antenna performs its function at a single frequency, so different antennas that are needed for different applications will cause a limited space and place problem. Researchers think that multiband band antennas provide solutions to relief from this problem where one single multiband antenna can operate at many frequencies for different applications. By applying fractal shape technique into antenna geometrics, multiband antenna can be constructed [12-13]. Besides, by using multilayer stacked patch [14] and single layer microstrip antenna [15] has been paid to little attention for achieving dual band. In [16] dual frequency is achieved by cutting a square slot in the middle of a rectangular patch where they achieved both compactness and dual frequency operation. Dual frequency with tuneable frequency ratio can be attained by loading a pair of narrow slots parallel and close to the radiating edges of a bow tie patch [17].The satellite spacecraft’s antenna [18][18.] which is dual frequency, slotted, circularly polarized square patch to operate as the telemetry, telecommand and control (TT &C). Pre factual geometry and two short circuits in patch are used to achieve compact dual band circular polarization antenna [19]. In [20], they have proposed a rectangular shaped with complex slot cutting dual band microstrip antenna for Ku band application but their average gain is not good. Besides multilayer stacked patch and multi resonator antennas [21-25] are used for obtaining dual frequency but these structures have some disadvantages such as very complex ,large, costly, thick substrate and difficult for manufacturing. On the other hand, using single feed antennas can diminish complication and high cost of the receiver front-end. For the increasing use of broadband communication system to make available high capacity and omnipresent communications , a demand for low profile and lightweight antenna with a small foot print has been obligatory where antennas are installed on land moving vehicle’s and aircrafts.Advances in wireless communications have introduced tremendous demands in the antenna technology. It's also the paved the way for wide usage of mobile phones in modern society resulting in mounting concerns surrounding its harmful radiation [26-27].Antenna technology for satellite communication is steadily more interesting in commercial market for mobile satellite terminals.Different types of applications like land application; aeronautical or maritime navigation must be able to receive satellite broadcasting services with moving. Ku band is considered in this study for automotive tracking applications with the possibility of realizing compact cost effective small antenna [28]. Here the target is to shrink the size of the antenna and high gain as well as to enhance the operating bandwidth. In this paper, we have proposed a new microstrip triangular slotted radiating patch that achieves dual band high gain compared to others and medium operating frequency for aircraft, space craft and satellite based communication system.

Antenna Modelling and Design

The initial dimension of the proposed antenna for obtaining desired resonance frequency, the geometry of the patch was first designing and implementing the equations from the transmission line model (TEM) approximation in which patch radiating element is viewed as a transmission line resonator with no transverse field variations. In the reported literature [29], the approximation states that the width and length of the patch antenna can be modelled according to the specified central frequency by following equations:

(1) $$W=\frac{c}{2f_0}\sqrt{\frac{\varepsilon_r+1}{2}}$$

(2) $$L=\frac{c}{2f_0\sqrt{\varepsilon_e}}-2\Delta l$$

where *L* is the length of the patch, *W* is the width of the patch, f_o is target resonance frequency, c is the speed of light in a vacuum and the effective dielectric constant can be calculated by the equation:

(3) $$\varepsilon_e=\frac{\varepsilon_r+1}{2}+\frac{\varepsilon_r+1}{2}\sqrt{1+\frac{10h}{W}}$$

where *h* is the thickness of the substrate and ε_r is the dielectric constant of the substrate. Because of the fringing field around the periphery of the patch, electrically the antenna looks larger than its physical dimensions. Δl takes this effect in account and can be expressed as:

(4) $$\Delta l=0.412h\frac{(\varepsilon_r+0.3)\left(\frac{W}{h}+0.264\right)}{(\varepsilon_e-0.258)\left(\frac{W}{h}+0.8\right)}$$

As the antenna is fed with the probe feed, the length of the probe feed is also calculated. The input impedance of the antenna must be matched to the probe feed line by choosing the correct position for the feeding point.After taking into account the design requirements such as bandwidth and dielectric constant, the antenna is initially designed to operate in dual frequency at Ku-band and consequently optimized to obtain the most preferable size of the patch using Ansoft's 3D full wave electromagnetic simulator HFSS .

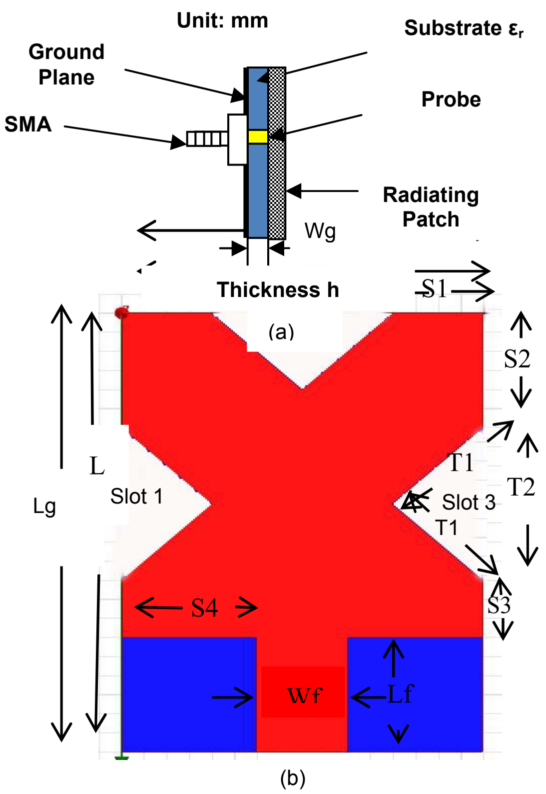


Fig. 1: Configuration of the proposed patch antenna (a) Side view (b) Top View

The geometry of the proposed patch slotted antenna is shown in Figure 1(a) Side view and Top view (b). It is printed on Rogers RT/Duroid 6010 substrate of thickness h=1.905 and relative permittivity ε_r=10.2, loss tangent tanδ =0.0023. About 50 ohm probes feed a microstrip line, etched on the left side of the radiating patched with dimension of L_f and W_f. The antenna has a compact structure and total dimension is about 11.50 mm by 7.96mm by 1.905mm but radiating dimension is 8.5mm X 7.96mm X1.905mm. Actually the radiating patch is a rectangular structure with three triangular slots. The area and the position of these three triangular slots are responsible for varying resonance frequency. Each triangular slot has two arms equal and third arm's length is twice than others. Because of these three triangular slots, current lines are changed. The current is to flow around the patch. So the effective length of the current lines becomes longer and the antenna size becomes miniature. In order to achieve good impedance matching and symmetrical excitement, proposed shaped antennas feeding is selected to the centred at the midpoint of y axis length of the antenna. Equilateral slots are applied to achieve the two band performances with sufficient -10dB impedance bandwidth. In table 1, all the exhaustive parameters of the proposed shape antenna are abridged.

Table 1. Parameters of the proposed antenna (Units: mm)

Parameter	Value(mm)	Description
L	8.5	Length of the Patch
W	7.96	Width of the path
L_g	4.5	Length of the Ground Plane
W_g	7.96	Width of the Ground Plane
L_f	3	Length of the Microstrip feed line
W_f	2	Width of the Microstrip feed line
S_1	1.98	Patches different side length after using slot
S_2	3	
S_3	1.5	
S_4	2.98	
T_1	2.82	Triangular side length
T_2	4.0	Triangular another side length
h	1.905	Substrate Thickness

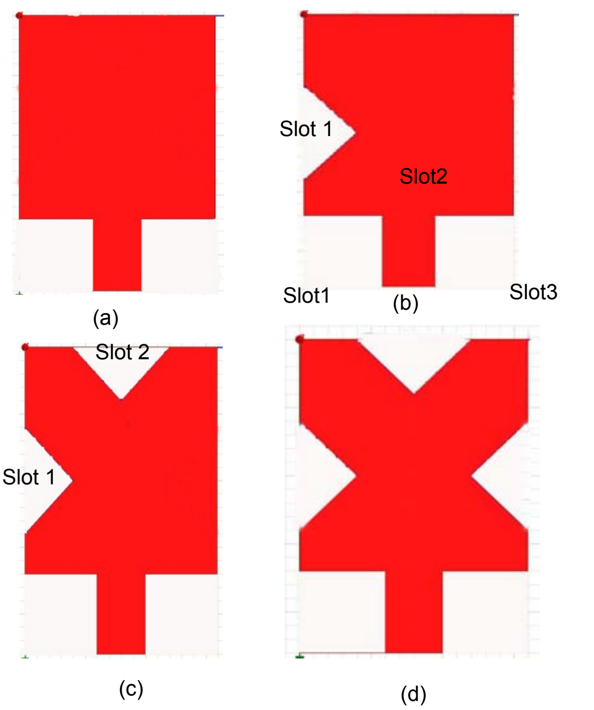


Fig. 2: Geometry of a) Without slot antenna b) one equilateral triangular slot antenna c) Two equilateral triangular slot antenna d) Proposed shape antenna

In order to inspect the effects of the triangular slots in radiating patch, we simulated four archetypes. The first one without any slot is called the without slotted antenna as shown in fig 2(a). The second one with left triangular slot in figure 2(b) , third one is left and upper triangular slot in figure 2(c) and finally our proposed shape with three triangular slot in left, upper and right is shown in figure 2(d).

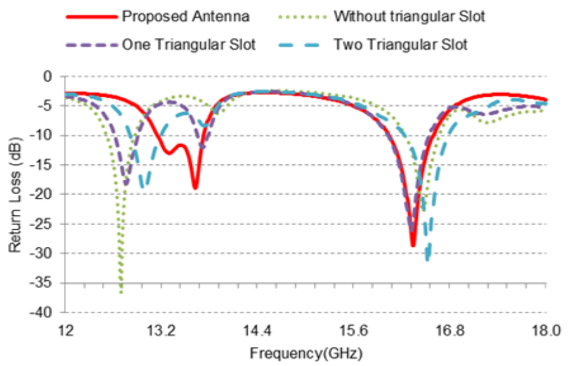


Fig. 3. Simulated S11 of the four types of antenna

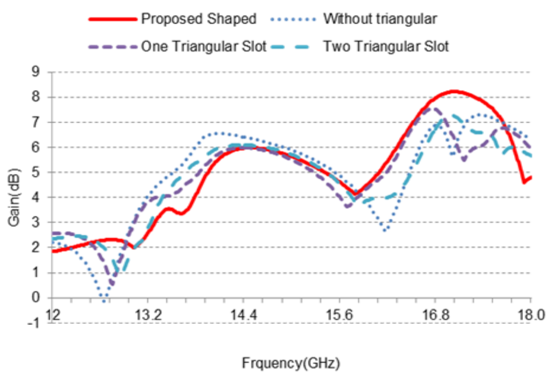


Fig. 4. Simulated Gain of four types of antenna

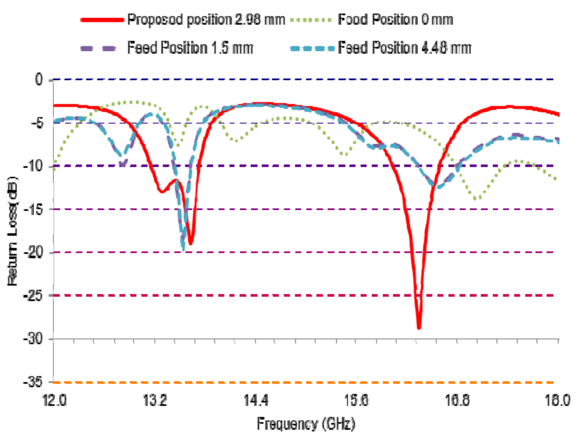


Fig. 5 S_{11} with different feed position

Figure 3 and 4 demonstrates, how the existence of slots impacts the reflection co efficient S_{11} and gain of the different shapes of antenna. From Figure 3, we can see that the conventional rectangular antenna without any slot demonstrates a broadband design with the bandwidth of 336MHz and 408MHz at centre frequency12.96GHz and 16.46MHz respectively .From Figure 4 average peak gain in those band is about .292dB and 4.89dB.When cutting a equilateral triangular slot at the left edge, the second antenna type of antenna excites its gain in both band but bandwidth in high band. The band width is 276MHz, average peak gain .652dB and 504MHz , average peak gain 5.61dB. Antenna type 3 is formed by cutting two triangular slots in left and upper edge of the patch. Which has dual band characteristics but band width and gain are 360MHz, 1.90dB and 528MHz, and 5.19dB respectively. Adjusting the values S_1, S_2 , S_3, S_4,W_f and L_f antenna 4 has obtained , which exhibits the S_{11} and gain better than -10dB over the bandwidths of the two operation band of 576MHz and 540MHz . These two bands are works in Ku band applications. Lower band works for sender antenna and higher band works for receiver antenna. Table 2 depicts the detailed dimension as well as performance of the four antennas.

Table 2: Slot and performances of the four antennas

Serial	Antenna Type	f_{c1} (GHz)	BW_1 (GHz)	Average $gain_1$(dB)
(a)	Without Triangle Slot	12.696	0.336	0.292
(b)	One Triangular Slot	12.756	0.276	0.652
(c)	Two Triangular Slot	12.984	0.360	1.790
(d)	Proposed Shaped	13.620	0.576	3.363

Serial	Antenna Type	f_{c2} (GHz)	BW_2 (GHz)	Average $gain_2$(dB)
(a)	Without Triangle Slot	16.464	0.408	4.899
(b)	One Triangular Slot	16.308	0.504	5.611
(c)	Two Triangular Slot	16.536	0.528	5.195
(d)	Proposed Shaped	16.332	0.540	6.084

Fig. 5 shows the simulated S_{11} with different feed position. Among four, proposed position is the best among than others according to reflection coefficient.

Result and Discussion:

The different characteristics of the proposed shape antenna is investigated and optimized by commercially available finite element based software HFSS 13.0.2. The reflection coefficient results are shown in Figure 6. In that Figure the low operating frequency is 576MHz from 13.152GHz to 13.728 GHz and high one is 540MHz from 16.044GHz to 16.584GHz where return loss is achieved less than -10dB. The resonance frequency of this region is 13.62GHz and where maximum returns loss -19.00dB.

As shown in figure 7, the average peak gain of the proposed antenna for low band is almost 3.53dB and for high band is 5.56dB. It is marked from the return loss and gain curve that the proposed shape antenna is utterly capable of transmitting and receiving in desired Ku band of 13.62 and 16.33GHz, respectively with a peak gain characteristics than others [30-34].

The radiation pattern for E plane and H-plane of the proposed antenna at cut off frequency depicts in figure 8 (a) and (b). The co–polarization is symmetric and omnidirectional. Broad Beam width is observed in the main beam of co-polarization (E-plane). From the radiation pattern, it can be easily says that the designed antenna produces omnidirectional radiation and almost stable radiation pattern throughout the whole operating band with low cross polarization.

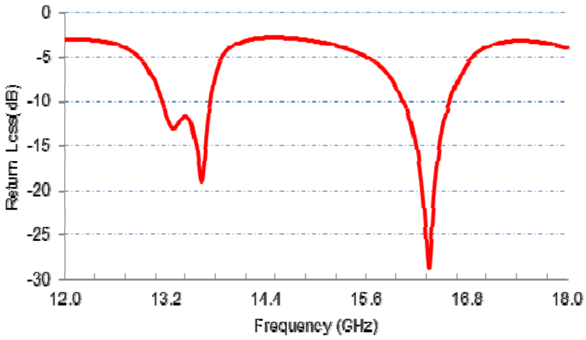


Fig. 6. Return loss of the proposed shape

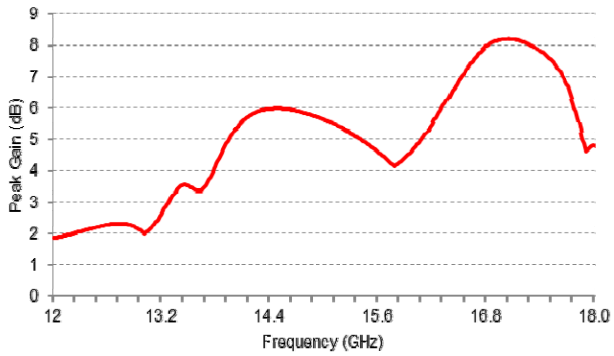
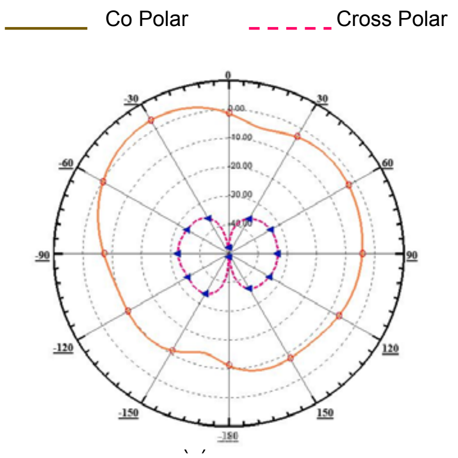
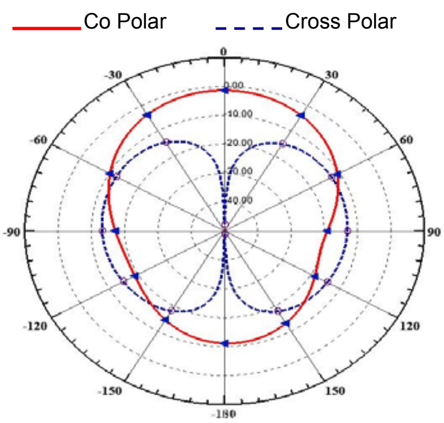


Fig 7. Peak Gain of the proposed shaped

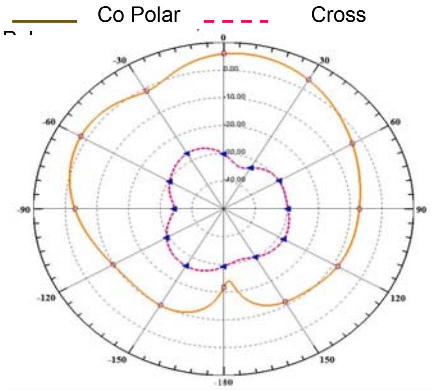


E-Plane

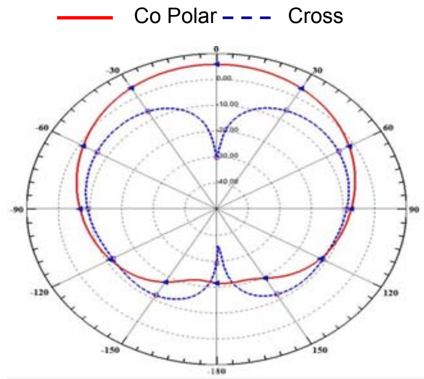


(b) H-Plane

Fig. 8 Radiation pattern of the proposed antenna at 13.62 GHz

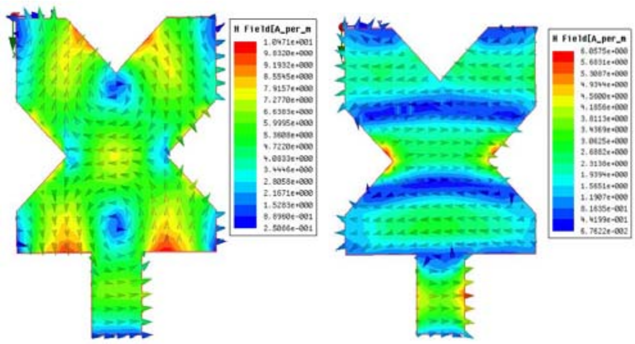


(a) E-Plane



(b): H-Plane

Fig. 9 Radiation pattern of the proposed Antenna at 16.33 GHz



(a) (b)

Fig. 10 Current distribution of the radiating patch at a) 13.62 GHz b) 16.33GHz

Figure 10 depicts the current distribution on the patch at resonance frequency 13.62GHz and 16.33GHz. The direction of current is indicated by arrow sign. It is clearly observed from the current distribution display that the electric current strongly flows at the edge of the triangular slot, especially near the feeding probes of the patch. So, we can say that the slots dominate the antenna performance. Due to the triangular slot, the current flow is controlled which leads the lessening of cross polarization level. At different part of the patch, the current distribution is almost regular.

Conclusion

In this paper, a single feed, single slayer compact triple equalitarian triangular slot microstrip antenna has been proposed. It is shown that proposed new shaped antenna can operate in Ku band. Triple equalitarian triangular slot reduced the size of the antenna and increase the bandwidth. An optimization with size reduction, bandwidth enhancement and high gain also maintained in this work. Since the radiation pattern is omnidirectional, so it is suitable for satellite application which require instantaneous transmit/receive functionality at broadly separated antennas.

REFERENCES

[1.] Garg.R., Bhartia.P.,Bahl I.and Ittipiboon A."Microstrip Antenna Design Handbook"Artech House Norwood 2001.

[2.] Wong, K. L. "Compact and Broadband Microstrip Antennas". NewYork: J. Wiley and Sons, 2002.

[3.] Islam, Shakib, and Misran, "Broadband E-H shaped microstrip patch Antenna for Wireless Systems", Progress In Electromagnetics Research, PIER 98, 163-173, 2009.

[4.] Mobashsher, A.T., Islam, M.T., Misran, N., " A novel high-gain dual-band antenna for RFID reader applications," IEEE Antennas and Wireless Propagation Letters 9 , art. no. 5499148 , pp. 653-656, 2010

[5.] Zhang, L., Y. C. Jiao, G. Zhao, Y. Song, X. M. Wang, and F.-S. Zhang, "A novel CPW-FED monopole antenna for multiband operation," Journal of Electromagnetic Waves and Applications, Vol. 22, No. 5-6, 741-747, 2008.

[6.] Naghshvarian-Jahromi, M. and N. Komjani, "Novel fractal monopole wideband antenna," Journal of Electromagnetic Waves and Applications, Vol. 22, No. 2-3, 195-205, 2008.

[7.] Islam, M.T., Shakib, M.N., Misran, N.," Multi-slotted microstrip patch antenna for wireless communication," Progress In Electromagnetics Research Letters 10 , pp. 11-18, 2009

[8.] Abbas-Azimi, M., F. Arazm, J. R. Mohassel, and R. Faraji-Dana, "Design and optimization of a new 18GHz double ridged guide horn antenna," Journal of Electromagnetic Wave and Applications, Vol. 21, No. 4, 501-516, 2007.

[9.] Azim, R., Islam, M.T., Misran, N., "Ground modified double-sided printed compact UWB antenna," Electronics Letters 47 (1) , pp. 9-11, 2011

[10.] Elsadek, H. and D. Nashaat, "Quad band compact size trapezoidal PIFA antenna," Journal of Electromagnetic Waves and Applications, Vol. 21, No. 7, 865-876, 2007.

[11.] Shakib, M.N., Islam, M.T., Misran, N., "Stacked patch antenna with folded patch feed for ultra-wideband application," IET Microwaves, Antennas and Propagation 4 (10) , pp. 1456-1461, 2010.

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

[13.] Randy Bancrof , Microstrip and Printed Antenna Design, 2008

[14.] Azeri, A. and J. Rowan, "Ultra wideband fractal micro strip antenna design," Progress In Electromagnetic Research C, Vol. 2, 7-12, 2008.

[15.] Salmasi, M. P., F. H. Kashani, and M. N. Azarmanesh, "A novel broadband fractal Sierpinski shaped micro strip antenna," Progress In Electromagnetic Research C, Vol. 4, 179-190, 2008.

[16.] Azim, R., Islam, M.T., Misran, N., "A planar monopole antenna for UWB applications," International Review of Electrical Engineering 5 (4) , pp. 1848-1852, 2010.

[17.] Lai, T. F., W. N. L. Mahadi, and N. Soin, "Circular patch micro strip array antenna for KU-band," World Academy of Science, Engineering and Technology, 48, 2008.

[18.] Saidatul, N. A., A. A. H. Azremi, R. B. Ahmad, P. J. Soh, and F. M. Malek, "Multiband fractal planar inverted antenna (F-PIFA) for mobile phone application," Progress In Electromagnetic Research B, Vol. 14, 127-148, 2009.

[19.] Liang, J., et al., CPW-fed circular disc monopole antenna for UWB application,"IEEE In-ternational Workshop on Antenna and Technology: Small Antennas and Novel Met materials,"505-508, Marina Mandarin, Singapore, and March 7-9, 2005.

[20.] M.T. Islam, N. Misran and A.T. Mobashsher. "Compact Dual Band Microstrip Antenna for Ku-Band Application". *Information Technology Journal,Vol. 9 ,Issue 2,: 354-358.* , 2010

[21.] S.-C. Pan and K.-L. Wong, "Dual-frequency triangular microstrip antenna with a shorting pins,"IEEE Trans. Antennas Propag., vol. 45, no.12, pp. 1889–1891, Dec. 1997.

[22.] J. Wang, R. Fralich, C. Wu, and J. Litva, "Multifunctional aperture-coupled stacked antenna,"Electron. Lett., vol. 26, no. 25, pp. 2067–2068,1990.

[23.] M. Pozar and S. D. Targonski, "A shared-aperture dual-band dual polarized microstrip array," IEEE Trans. Antennas Propag., vol. 49, pp. 150–157, Feb. 2001.

[24.] R. Pokuls, J. Uher, and D. M. Pozar, "Dual-frequency and dual polarization microstrip antennas for SAR applications,"IEEE Trans. Antennas Propag., vol. 46, no. 9, pp. 1289–1296, Sep. 1998.

[25.] L. Shafai, W. Chamma, M. Barakat, C. Strickland, and G. Seguin, "Dual-band dual-polarized perforated microstrip antennas for SAR applications,"IEEE Trans. Antennas Propag., vol. 48, no. 1, pp. 58–66, Jan. 2000

[26.] Faruque, M.R.I., Islam, M.T., Misran, N., "Effect of human head shapes for mobile phone exposure on electromagnetic absorption," Informacije MIDEM 40 (3) , pp. 232-237, 2010

[27.] Faruque, M.R.I., Islam, M.T., Misran, N., "Evaluation of specific absorption rate (SAR) reduction for PIFA antenna using metamaterials," Frequenz 64 (7-8) , pp. 144-149, 2010

[28.] M. Habib Ullah, M. T. Islam, "Design Of A Modified W-Shaped Patch Antenna On Al_2 O_3 Ceramic Material Substrate For Ku-Band," Chalcogenide Letters Vol. 9, No. 2, p. 61 – 66, 2012,.

[29.] Garg, R., R. Bhartia, P. Ittipiboon, A. and I. Bahl,. Microstrip Antenna Design Handbook. Artech House, Boston, London. 1980

[30.] Chen, C. and E. Yung. Dual-band dual-sense circularly-polarized cpw-fed slot antenna with two spiral slots loaded. IEEE Trans. Antennas Propag. 57: 1829-1833, 2009.

[31.] R. Azim, M. T. Islam and N. Misran, "Dual Polarized Microstrip Patch Antenna For ,Ku-Band Application", Informacije MIDEM, 41(2), 114-117 ,Ljubljana

[32.] He, Q.Q., Wang, B.Z. and J. He, 2008. "Wideband and dual-band design of a printed dipole antenna. IEEE Antennas Wireless Propag. Lett., 7: 1-4.

[33.] Nguyen, T.K., B. Kim, H. Choo and I. Park, Multiband dual spiral stripline-loaded monopole antenna. IEEE Antennas Wireless Propag. Lett., 8: 57-59. 2009.

[34.] Pongchompoo, R., V. Santitewagul and D. Eungdamrong,. A modified design of slot ring using E-shape. Int. Conf. Adv. Commun. Technol., 1: 196-199. 2009.

Author: [1]Md Samsuzzaman, Faculty of Engineering and Built Environment, E-mail:sobuzcse@eng.ukm.my; [2]Prof. Dr. Tariqul Islam, Institute of Space Science (ANGKASA),E-mail: tariqul@ukm.my. [2]Prof. Dato' Dr. Baharudin Yatim ,Institute of Space Science (ANGKASA),E-mail: email :baha@ukm.my; [3]Prof. Dr. Mohd. Alauddin Mohd. Ali, , Institute of Space Science (ANGKASA),Email:mama@vlsi.eng.ukm.my.