DUAL POLARIZED MICROSTRIP PATCH ANTENNA FOR KU-BAND APPLICATION

[1]Rezaul Azim, [2]Mohammad Tariqul Islam and [3]Norbahiah Misran

[1,3]Department of Electrical, Electronic and Systems Engineering
[2,3]Institute of Space Science (ANGKASA), Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, Selangor, Malaysia.

Key words: Dual-polarization, microstrip patch antenna, Ku-band, high-isolation.

Abstract: A dual polarized microstrip patch antenna is proposed for Ku-band applications. The corner chopped square patch with four bent slots is adopted in this design. The antenna has a compact structure and the total size is 15 mm × 15 mm. The result shows that the impedance bandwidth (VSWR ≤ 2) of the proposed antenna is 950 MHz (7.76%). The antenna with reduced size is also able to achieve the stable radiation performance with a maximum gain of 7.6 dBi in the operating band of 11.76 GHz to 12.71 GHz and the gain variation is about 0.8 dBi. The present design provides a maximum of -26 dB isolation level between the two ports and a stable low cross polarization level for both E- and H-planes. Details of the proposed antenna design and results are presented and discussed. The patch shows a high matching level in Ku-band and isolation elements that makes it suitable for wireless and satellite communication.

Dvojno polarizirana mikrostrip antena za Ku-frekvenčni pas

Kjučne besede: dvojna polarizacija, mikrotrakasta antena, Ku-frekvenčni pas, visoka izolacija

Izvleček: V prispevku opišemo mikrotrakasto anteno z dvojno polarizacijo za uporabo na Ku-frekvenčnem pasu. Antena ima kompaktno strukturo in je velika 15 mm x 15 mm. Rezultati kažejo pasovno širino (VSWR ≤ 2) 950 MHz (7.76%). Tako zmanjšana antena zmore stabilno sevanje z maksimalno ojačitvijo 7.6 dBi znotraj pasovne širine med 11.76 GHz do 12.71 GHz in stabilnostjo ojačitve znotraj 0.8 dBi. Trenutna zasnova omogoča maksimalno izolacijo med stopnjama -26dB in stabilno nizko križno polarizacijo med E in H ravnijo. V članku so opisane podrobnosti in rezultati predlagane zasnove antene.

1. Introduction

Dual polarized microstrip patch antennas excite two orthogonal modes, which generate vertically polarized electric field and horizontally polarized electric field. Therefore, dual polarized antennas added information by providing two co-polarizations and two cross-polarizations. These antennas reduce side effects of multi-path fading and increase channel capacity per frequency in many applications. Microstrip patch antennas have good potential for making dual-polarized antennas due to their several attractive features including low profile, light weight, low cost and compatibility with integrated circuit technology. Microstrip patch antennas have been widely used in high performance satellite and wireless communication. Several works have been reported to overcome drawbacks of the conventional microstrip antenna such as low efficiency and narrow bandwidth. The main problem of the dual polarized antenna is that two input ports may be coupled to each other to an undesired level. This coupling affects the performance of the antenna and may reduce the impedance bandwidth and deteriorate the radiation patterns for each polarization. The task is more complicated when it is required to achieve wide bandwidth with highly isolated dually polarized antennas. Several solutions have been proposed to achieve the dual polarized antenna with wide bandwidth, high isolation, and low cross polarization level. One of the most common solutions consists of using off-set slots /1-2/. Other solutions using two feeding points in one or two slots and crossing slots /3/ or having crossing slots and lines in different layers /4/ have been reported. The various feeding techniques include mixture of the aperture coupled feed and capacitive coupled probe feed /5-7/, proximity coupled feed /8/ and L-shape probe feed without shorted patch /9-10/, all of which have been proposed to improve the isolation of the dual-polarized antenna with wide bandwidth. Chiou *et al.* demonstrated a high isolation patch antenna at L-band by utilizing two in-phase aperture-coupled feeds at port 1 and two out-of-phase gap-coupled probe feeds at port 2. Chiou and Wong /6/ demonstrated an isolation of 40 dB between the two ports. Haneishi *et al.* presented better than 30 dB port isolation performances at 5 GHz using dog-bone slots /11/. The antenna proposed by Mariano Barba /12/ achieved a bandwidth of 24% with a port isolation of 36 dB. Despite the excellent performances, however, these structures require multi-layer structures which increase the complexity. In this work, a simple feeding structure for a planar patch antenna is presented by employing a coaxial probe feed.

In general, the design of a patch having high isolation results in antennas with narrow bands or high values for return losses (RL). For example, the antennas presented by Ghorbani and Waterhouse /4/ shows high values of matching level (RL< -10dB) and isolation. This matching level is useful for many applications such as wireless communication and airborne-based synthetic aperture radar. Besides, the solution proposed in /4/ uses two layers for the input signals, while the antenna has the input lines in the same layer of the same board. The use of two layers increases the complexity and mainly the cost since, it is know, RF substrates and etching drive to ones of the most important contributions in the antenna cost.

In this paper, we demonstrate that a slot-loaded microstrip patch antenna with a group of four symmetrical bent slots can perform excellent dual-polarized radiation, while the antenna size is signi cantly reduced. The four symmetrical triangular slots are aligned in parallel with the patch's diagonal for obtaining 0^0 and 90^0 polarizations, and the two polarizations are excited by using two probe feeds. Due to the perturbation of the bent slots, the excited patch surface current paths are meandered, which results in the same lowering of the operating frequencies for the two polarizations. That is, dual-polarized radiation can be obtained with a reduced antenna size at a xed operating frequency. The square patch is chosen due to its simplicity of fabrication. The coaxial probe feed is used because it is easy to match impedance and has low spurious radiation.

2. Antenna design

The geometry of the proposed dual polarized bent slot corner chopped square microstrip patch antenna is shown in fig.1.

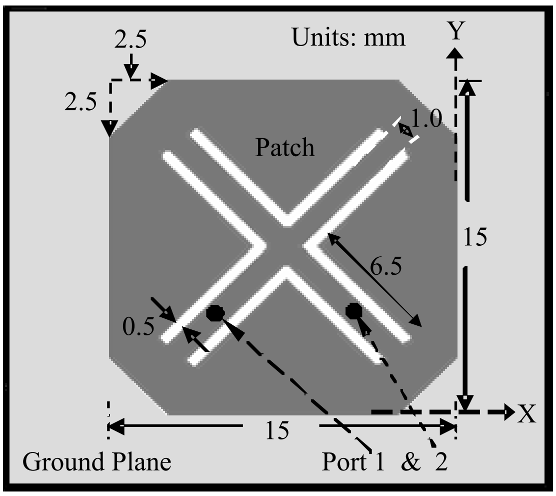

Fig.1: Geometry of the proposed antenna

The design procedure starts with the determination of sidelength of the patch using the classical equations /13/:

$$W = \frac{c}{2f_o}\sqrt{\frac{\varepsilon_r + 1}{2}} \tag{1}$$

$$L = \frac{c}{2f_o\sqrt{\varepsilon_e}} - 2\Delta l \tag{2}$$

where W is the width and L is the length of the patch, f_o is the center target frequency, c is the speed of light in vacuum. The effective dielectric constant can be calculated by the equation

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

where ε_r is the relative dielectric constant and h is the thickness of the substrate. Due to the fringing field around the periphery of the patch, the antenna electrically looks larger than its physical dimensions. The increment to the length, Δl due to fringing field can be express as:

$$\Delta l = 0.412h\frac{(\varepsilon_e + 0.3)\left[\frac{w}{h} + 0.8\right]}{(\varepsilon_e - 0.258)\left[\frac{w}{h} + 0.8\right]} \tag{4}$$

Considering the requirements of design such as bandwidth and dielectric constant, the antenna is initially designed to operate in Ku band and consequently optimized to obtain the most efficient size of the patch using method of moments based full wave electromagnetic simulator IE3D.

The whole radiating element of the proposed dual-polarized corner chopped square patch microstrip antenna is centered on the top of a ground plane of 40mm × 40mm. The patch has a side length of 15mm and is directly printed on RT 5880 microwave substrate material of thickness 1.5748mm, relative permittivity 2.2 and tangent loss 0.009 to reduce the cost. The radiating patch is truncated with a truncation of 2.5 mm × 2.5 mm at each corner to enhance the bandwidth. The truncated patch produces additional degenerating modes necessary for widening the bandwidth. Since a dual polarized with the same requirements is sought, the patches are squared. The four bent slots have the same dimensions and have a narrow width of 0.5mm with a length 6.5mm is parallel to the patch's diagonal. The spacing between two adjacent bent slots is 1mm. The two copper coaxial probe feeds with radius 0.2 mm for the two feeding ports are located at a distance of 6.0 mm from the patch centre and radiates ± 45^0 slanted linearly polarized waves.

The above specific shape patch for the bent slots and corner chopped square shaped patch configuration allow us to obtain a satisfactory 50 Ω impedance matching across the frequency band of interest.

3. Results

The performance of the proposed antenna has been analyzed and optimized by using commercially available method of moments based full wave electromagnetic simulator IE3D package version 12.0/14/. The simulated return loss of the proposed antenna is shown in Fig. 2. From the plot, it can be observed that the return loss of the proposed antenna is less than -10dB over frequency ranges of 11.76 -12.71

GHz (7.76%), which is in the Ku-band region. The above impedance bandwidth of 950 MHz is obtained due to proper matching and introduction of four bent slots on the design, which is higher than corresponding dual polarized microstrip antennas /15/. It resonates at 12.2 GHz. Fig. 3 shows the isolation of the proposed antenna. From the figure it is seen that, the minimum isolation is about -22.6 dB and the isolation is better than -33 dB at 13.3 GHz. At the resonance frequency of 12.2 GHz the isolation is about -22.6 dB. It can be observed that at lower and higher frequencies, the isolation is higher but the isolation at middle frequencies has a little degradation. However, throughout the frequency range from 11.76 to 12.71 GHz, the isolation is still better than -22.6 dB. The return loss and high port isolation characteristics of this dual-polarized patch antenna are very suitable for being used in many practical applications such as wireless communication.

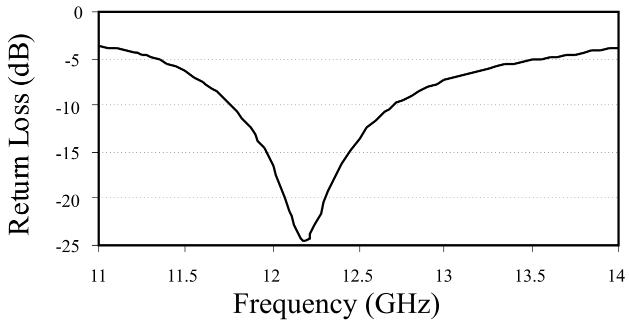

Fig.2: Return loss of the proposed antenna

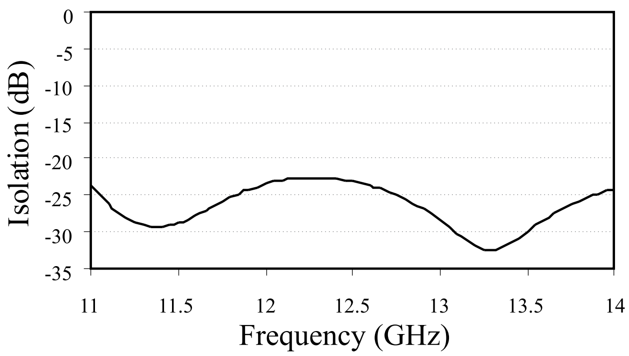

Fig.3: Port isolation of the proposed antenna

The maximum gain and maximum directivity of the antenna are shown in the fig. 4 and fig. 5 respectively. The antenna exhibits the gain of more than 6.15 dB_i over the band of 11.76-12.71 GHz with a peak gain of 7.6 dB_i at 12 GHz. At resonance frequency of 12.2 GHz the observed gain is 7.58 dB_i and the gain variation across the operating band is about 0.8 dBi. Although the size of proposed antenna is reduced by 75%, the gain is remain higher compared to that of the corresponding unslotted dual polarized antennas.

The directivity of the proposed antenna varies from 7.78 to 9.36 dB_i which has a value of 9.32 dB_i at the center frequency of 12.5 GHz.

Figure 6a and b show the radiation pattern for E-plane and H-plane of the proposed antenna at resonance frequency of

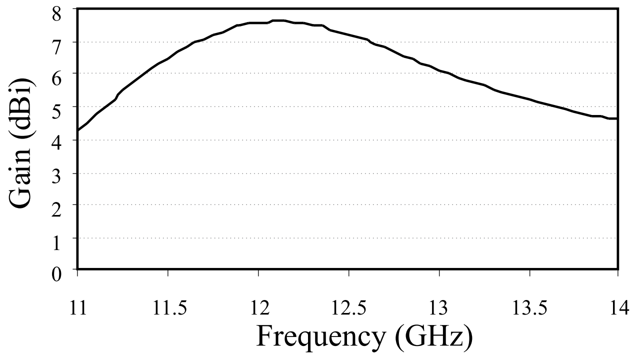

Fig. 4: Gain of the proposed antenna

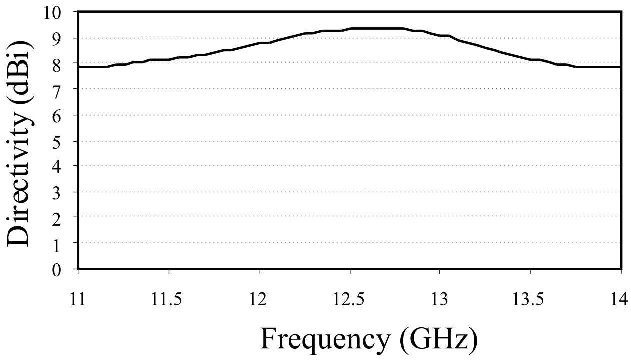

Fig. 5: Directivity of the proposed antenna

12.2 GHz. The co-polarization patterns are symmetric and the cross-polarization levels in E- and H-plane are better than -12 dB and -18 dB respectively. Broad beam width is observed in the main beam of co-polarization (E-Plane). The beamwidth of 3-dB is more than 65^0. It can be easily observed from the radiation pattern that the designed antenna produces bidirectional radiation and almost stable radiation pattern throughout the whole operating band with low cross polarization. There are some significant advantages if a patch antenna has a stable and symmetrical radiation pattern. One of the major advantages is that during construction of an antenna array, the radiation pattern would be more stable across the operating bandwidth.

The current distribution on the patch at resonance frequency of 12.2 GHz is depicted in fig.7. Arrow sign indicates the direction of current. From the current distribution display, it is observed that the electric current strongly flows at the edge of the bent slots especially near the feeding probes of the patch. This indicates that the slots dominate the antenna performance. The current flow is restricted due to the bent slots which leads the reduction of cross-polarization level. However, the current distribution at different part of the patch is almost regular.

4. Conclusions

Dual polarized microstrip patch antenna coupled to a coaxial probe feed has been demonstrated in this paper. The corner chopped square patch with bent slots and dual feeding technique makes it possible to have a bandwidth

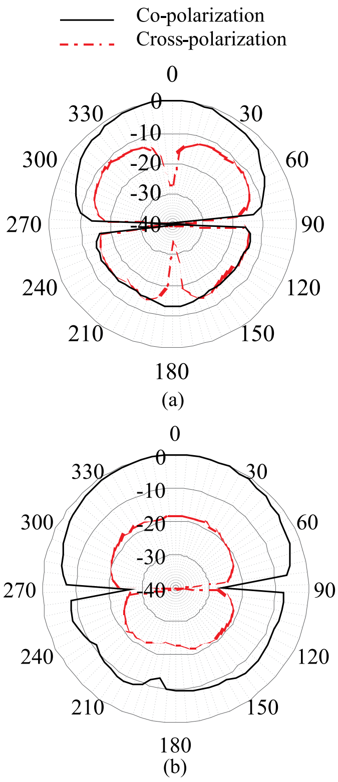

Fig.6: Radiation pattern of the proposed antenna at 12.2 GHz (a) E-plane (b) H-plane.

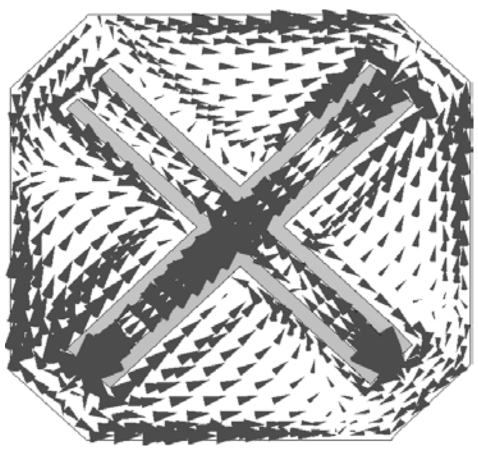

Fig.7: Current distribution on the patch surface at 12.2 GHz.

of 950 MHz (7.76 %) and radiation pattern at Ku-band. It covers the frequency ranges from 11.76 GHz to 12.71 GHz and provides a good isolation level between the two ports with low cross polarization levels. This antenna can be easily fabricated on substrate material due to its small size and thickness. The dual polarized patch antenna can be used for wireless and satellite communication.

Acknowledgment

The authors would like to thank the Institute of Space Science (ANGKASA), Universiti Kebangsaan Malaysia for sponsoring this work.

References

/1/ Gao, S. C., Li, L. Wei., Leong, M. S., and Yeo, T. S., 2003. Dual-polarized slot- coupled planar antenna with wide bandwidth. IEEE Trans. Antennas Propag., 51(3): 441–448.

/2/ Padhi, S. D., Kamakar, N. C. Law, C. L. and Aditya, S., 2003. A dual polarized aperture coupled circular patch antenna using a C-shaped coupling slot. IEEE Trans. Antennas Propag., 51(12),3295–3298.

/3/ LindMark, B., 1997. A novel dual polarized aperture coupled patch element with a single layer feed network and high isolation. in Proc. IEEE Antennas Propag. Soc. Int. Symp., 4: 2190–2193.

/4/ Ghorbani, K. And Waterhouse, R. B., 2004. Dual polarized wideband aperture stacked patch antennas. IEEE Trans. Antennas Propag., 52(8): 2171– 2174.

/5/ Chiou ,T. W., Tung , H.C., and Wong, K.L., 2000. A dual-polarization wideband circular patch antenna with hybrid feeds. Microwave and Optical Technology Letters, 26(1): 37-39.

/6/ Chiou, T.W. and Wong, K.L., 2002. Broadband Dual-Polarized Single Microstrip Patch Antenna With High Isolation and Low Cross Polarization. IEEE Trans. Antennas Propagat., 50: 399-401.

/7/ Wong, K.L. and Chiou, T.W., 2002. Broad-Band Dual-Polarized Patch Antennas Fed by Capacitively Coupled Feed and Slot-Coupled Feed. IEEE Trans. Antennas Propagat., 50(3): 346-351.

/8/ Gao, S. and Sambell, A., 2005. Broadband dual-polarized proximity coupled circular patch antenna. Microwave and Optical letters, 47(3): 298-302.

/9/ Wong, H., Lau, K.L. and Luk, K.M., 2004. Design of Dual Polarized L- Probe Patch Antenna Arrays With High Isolation. IEEE Trans. Antennas Propagat., 52(1): 45-52.

/10/ Guo, Y.X., Khoo, K.W., and Ong, L.C., 2007. Wideband Dual-Polarized Patch Antenna With Broadband Baluns. IEEE Trans. Antennas Propagat., 55(1): 78-83.

/11/ Hanseishi, M. and Konno, M., 2006. Dual-polarized planar antenna fed by dog-bone slots. IEICE Transactions on Electronics, E89-C(9): 1345-1347.

/12/ Barba, Mariano, 2008. A High-Isolation, Wideband and Dual-Linear Polarization Patch antenna. IEEE Trans. Antennas Propagat., 56(5): 78-83.

/13/ Garg, R., Bhartia, P., Bahl, I. and Ittipiboon, A., 2001. Microstrip Antenna Design Handbook. Boston - London: Artech House, Inc. ISBN 0-89006-513-6.

/14/ IE3D version 12, 2006. Zeland Software, Inc., Fremont, CA, USA.

/15/ Row, J.-S., Yeh, S.-H. and Wong, K.–L., 2000. Compact Dual-Polarized Microstrip Antennas. Microwave and Optical Technol. Lett., 27(4): 284-287.

[1]Rezaul Azim, [2]Mohammad Tariqul Islam and [3]Norbahiah Misran

[1,3]Department of Electrical, Electronic and Systems Engineering
[2,3]Institute of Space Science (ANGKASA)
Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, 43600 UKM, Bangi, Selangor, Malaysia.
[1]rezaulazim@yahoo.com

Prispelo: 02.03.2010 *Sprejeto: 24.06.2011*