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Design and Fabrication of a L-Probe Fed Inverted Patch Antenna for 3G/IMT-2000 Application

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Abstract: Enhancement bandwidth and improvement performance of a conventional patch antenna for 3G applications are presented in this paper. This novel antenna is designed for the (WARC 92) frequency range of 1.885 GHz to 2.200 GHz for IMT-2000 operations. The design adopts contemporary techniques such as: L-probe feeding, inverted patch structure with air- filled dielectric and slotted patch. The composite effect of integrating these techniques and by introducing the novel slotted EH-shape patch and novel L-probe fed with auxiliary pin, offer a small size, low profile, broadband impedance, high gain, low cross-polarization and compact antenna element. Simulation results show a satisfactory performance with an achievable impedance bandwidth (VSWR $\leq$ 1.5) of 17.56% at referenced to the center operating frequency at 2.05 GHz. Maximum achievable gain of about 9.26 dBi with 0.74 dB gain variation between the mentioned frequency range and cross-polarization level of about 50 dB below the main lobe level is obtained. Simulation and experimental results are in good agreement. The design is suitable for array applications with frequency range of 1.85 GHz to 2.30 GHz, especially for 3G/IMT-2000 base station smart antenna.

Key words: 3G base station smart antenna · L-probe fed · Inverted slotted patch

INTRODUCTION

The 1992 World Administrative Radio Conference (WARC 92) determined 230 MHz of spectrum at 1885 MHz to 2025 MHz and 2110 MHz to 2200 MHz for use by countries wishing to implement 3G systems. Advances in wireless and digital technologies have led to the development of Third Generation (3G) mobile wireless services, sometimes referred to as International Mobile Telecommunications for the Year 2000 (IMT-2000) [1].

The European proposal for IMT-2000 is known as the Universal Mobile Telecommunications System (UMTS). The third-generation systems aim to provide a seamless network that can provide users voice, data, multimedia and video services regardless of their location on the network: fixed, cordless, cellular, satellite and so on. The networks support global roaming while providing high-speed data and multimedia applications of up to 144 kbps on the move and up to 2 Mbps in a local area. The bearers for IMT-2000 are therefore defined as 384 kbps for full area coverage and 2 Mbps for local area coverage [2]. Thus, 3G systems by linking between digital mobile telecommunications technologies and systems for fixed and mobile wireless access systems, provide a solution for sharing a common antenna for various operators, this will also reduce the un-aesthetically or unpleasing base station sites. Base station antennas are generally Omni-directional or sectored. On the one hand, this is an efficient way to cover an area, on the other hand it can be considered as a waste of power, since most of the power is radiated in directions other than that towards the user. Additionally, other users can detect this unnecessarily radiated power as interference [3]. One of the main focuses of 3G is to develop an antenna system that can direct the antenna beam to the intended users while placing a null to the interferers in a dynamic fashion [4]. This can be accomplished by assembling multiple radiating elements in an electrical and geometrical configuration, forming an antenna array. Smart antenna consists of an array of antennas associated with it a base-band hardware and control unit (inclusive of the software algorithm) that have the capability to change its radiation pattern according to the direction of the user [5]. One of the main challenges for the base station antenna design is to come up with an antenna system with smart antenna capabilities covering 3G bandwidth and with facility for easy installation and maintenance in recent wireless applications. Patch antennas have found

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extensive application in wireless communication system owing to their advantages such as low-profile, small size, light weight and low-cost fabrication. They can also be made conformable and well suited to be integrated with MIC (microwave integrated circuit) and feed-networks. The bandwidth and the size of an antenna are generally mutually conflicting properties. In other words, improvement of one characteristic normally results in degradation of the other one [6]. Recently, several techniques have been proposed to enhance the 3G antenna characteristic and performance, for example: E-shape patch with probe fed, EH-shape slotted patch with L-probe fed, E-shape patch with L-probe fed and EH-shape patch with L-probe fed that reported respectively in [5-8]. However, these antennas are fabricated on thick substrates.

In this paper, a novel patch antenna is investigated for enhancing the gain, polarization and impedance bandwidth. The design employs contemporary techniques namely, the L-probe feeding, inverted patch and slotted patch techniques to meet the design requirement. The proposed antenna is suitable for array applications especially for 3G/IMT-2000 base station smart antenna. Included in the paper are simulations, fabrication, measurement and the results of the novel wideband patch antenna design. The advantage of the proposed antenna, in comparison to the previous models, is discussed in simulation results part.

Antenna Design and Fabrication: The application of superstrate with inverted radiating patch offers a gain enhancement and at the same time provides the necessary protections for the patch from the environmental effects as a radome [9]. Increasing the thickness of the patch antenna will increase the impedance bandwidth [10]. However, thicker substrate of the antenna will be used for longer coaxial probe and thus, more probe inductance will be introduced which limits the impedance bandwidth. Consequently, a patch antenna design that can counteract or reduce the probe inductance will enlarge the impedance bandwidth. The proposed patch antenna is fabricated on (Taconic TLY^{tm}) substrate. The rectangular patch with width (W) about λ/2 and length (L) about λ/4, is supported by the superstrate with dielectric permittivity (ε_r) equal to 2.2 and thickness (h_3) about λ/100. The λ is guided wavelength of the centre operating frequency. An air-filled substrate with dielectric permittivity (ε_0) and thickness (h_3) about λ/10 is sandwiched between the superstrate and a ground plane with thickness 1mm. A brass plate with dimensions of (180 mm × 200 mm) is used as a ground plane. The fabricated inverted patch and ground plane are assembled together by using the Teflon spacer and screws (with 6 mm diameter). The proposed patch antenna geometry is shown in Fig. 1.

The patch antenna integrates both the E-shape and H-shape patch on the same radiating element. For the E-shape, slots are embedded in parallel on the radiating edge of the patch and symmetrically with respect to the centerline (X-axis) of the patch; while for the H-shape, slots are embedded in serial on the non-radiating edge of the patch and symmetrically with respect to the centerline. Extra slot is embedded in the middle arm of the E-shape and symmetrically with respect to the centerline. The thick air-filled substrate is sandwiched between the ground plane and the inverted patch and prepares easy L-probe feeding for the patch. In addition, air-filled substrate thickness can be adjusted easily by varying the spacers height. It also eliminates the deformity problem of the foam material in the Strip Slot Foam Inverted Patch (SSFIP) antennas [9]. The patch is fed by a 50-Ù SMA connector with L-shape probe and auxiliary pin of cooper with diameters of 1.3 mm along the centerline on the top surface of the ground. The L-probe is connected to the feed network by SMA connector. It is located underneath the ground plane and its outer conductor body is soldered to the down surface of the ground plane. Fig. 2 shows the photograph of the fabricated antenna.

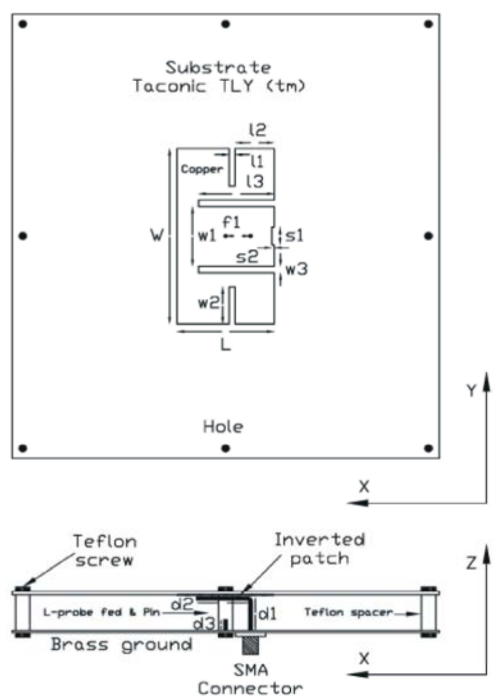


Fig. 1: Top view and side view of the proposed patch antenna

(a)

(b)

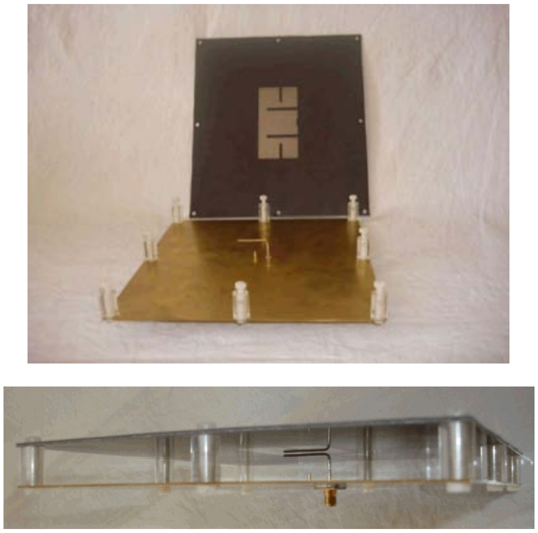


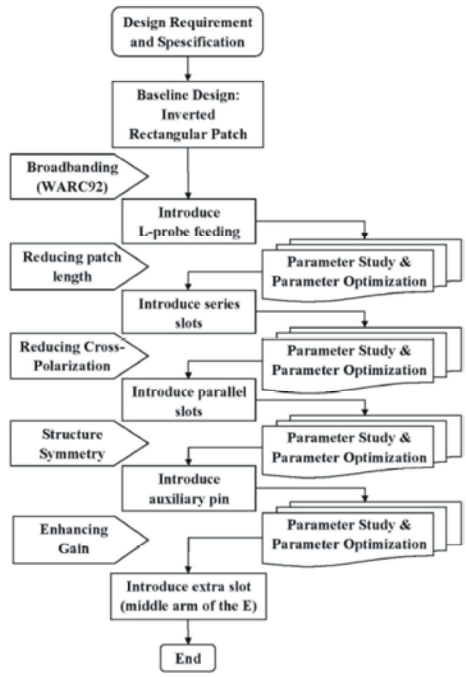
Fig. 2: The photograph of the proposed patch antenna: (a) inverted patch view and (b) side view

The L-probe system could be viewed as a capacitively loaded monopole electromagnetically coupled to the patch. Both the monopole and patch have their own resonances and if properly combined, give rise to a broadband behavior. Parametric simulation for the L-probe dimensions, defined the best values of the vertical part about 0.15λ and the horizontal part about 0.1λ. So, the complete length of the feeder is equal to λ/4 for the "monopole" length.

The simple L-probe fed structure suffers from currents flowing along the vertical part of the feeder and its effect develops mainly in the higher cross-polarization level in the H-plane [10]. If another wire is properly placed in a vertical position along the (X-axis) on the ground plate, the current on this auxiliary wire will partially cancel the current on the vertical part of the feeder and reduce the cross-polarization level in the H-plane. Moreover the additional wire by centered the electrical fields under the patch, helps to improve the gain of antenna. In circuit modeling for the proposed antenna, the interaction between the patch and the horizontal arm of the probe, introduce a capacitive coupling for the feed of antenna. The inductance of the vertical arm is an undesired factor that can be suppressed by effect of auxiliary wire. So this L-shape probe is an excellent feeding technique for a thick substrate patch antenna. This feeding technique also offers easy fabrication where soldering to the patch can be avoided and the probe can be bent easily. These advantages are very favorable especially in array structure.

Table 1: Design Parameters for the proposed patch antenna

Parameter = Value (mm)			
W = 79	L = 41	d1 = 15	s1 = 8
w1 = 27	l1 = 2.5	d2 = 23.5	s2 = 1
w2 =16.8	l2 = 16.5	d3 = 5	ha = 16
w3 = 2.9	l3 = 32	f1 = 10.5	hs = 1.57



The L-probe inverted E-shape patch antenna exhibits better cross-polarizations than the conventional L-probe inverted rectangular patch antenna. This is due to the reduction of current flow in H-plane direction introduced by the embedded parallel slots. Also by incorporating extra slots in the middle arm of the E-shape slot, the current flow is decreased to the H-plane direction in fed point and becomes effective in reducing the cross-polarization level. Without the series slots, the width (W) of the patch is obtained by ratio W/L and is approximately equal to 1.5 and can be achieved to maximum co-polar/cross-polar ratio [7]; While use of series slots reduces length (L) size of the patch and W/L is approximately equal to 2. Table 1 shows the design parameter obtained for the proposed patch antenna.

The design flow diagram is shown in Fig. 3, starting with a baseline design of the inverted rectangular patch with an air-filled dielectric, substrate with dielectric permittivity (ε_r) and the baseline parameters (W, L, h_3 and h_3) are determined at the center frequency. The L-probe introduced to feed the patch and its parameters are adjusted to achieve the broadband requirement. Next, the H-slot and E-slot are introduced on the patch with the initial parameters to reduce the patch size and cross-

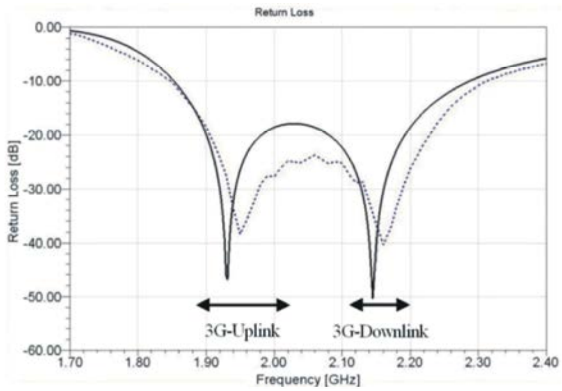


Fig. 4: Simulated and measured return loss result of the proposed antenna (-- Simulated, •••••• Measured)

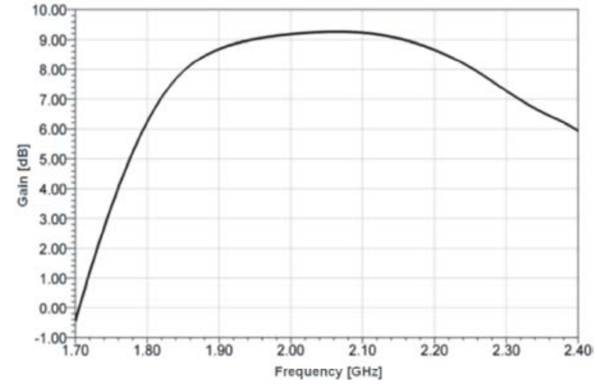


Fig. 5: Simulated gain of proposed patch antenna

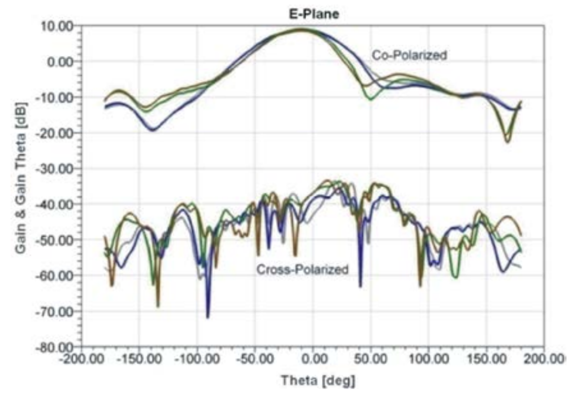


Fig. 6: E-plane simulated radiation pattern of the antenna at various frequencies (-- 1.88 GHz, -- 1.93 Ghz, -- 2.14 GHz, -- 2.20 GHz)

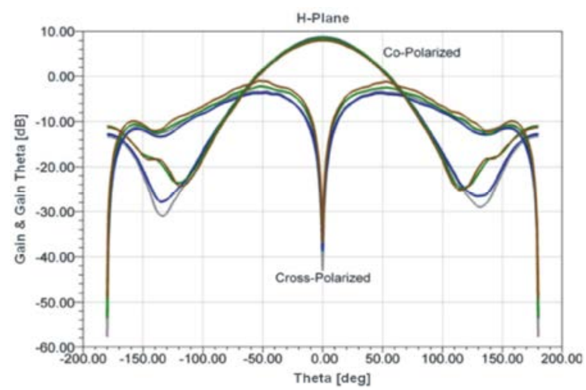


Fig. 7: H-plane simulated radiation pattern of the antenna at various frequencies (-- 1.88 GHz, -- 1.93 Ghz, -- 2.14 GHz, -- 2.20 GHz)

polarization level. The auxiliary pin used to reduce H-plane cross-polarization, is also effective for the improvement of structure symmetry. The extra slot in the middle arm of E-slot is used for gain improvement and cross- polarization reduction.

Simulation and Measurement Results: A commercial software package for calculating the electromagnetic behavior of a structure (Ansoft HFSS Version 11.0) is used for the design. The measurement and simulation results of the return loss of the antenna are shown in Fig. 4. The results are in good agreement. In the figure, the L-probe fed patch antenna, exhibits two closely resonance frequencies at 1.93 GHz and 2.14 GHz for the wideband characteristic. These resonance frequencies are achieved respectively at -47 dB and -50 dB in return loss curve.

The frequency range for (VSWR $\leq$ 1.5) covering 1.87 GHz to 2.23 GHz and achieves the impedance bandwidth of 17.56% with respect to the centre operating frequency at 2.05GHz. The frequency range for (VSWR $\leq$ 2) covering 1.85 GHz to 2.30 GHz and achieves the impedance bandwidth of 21.74%. These results are totally better than those reported by [4,6, 8].

Simulation gain for the patch antenna is shown in Fig. 5. The maximum achievable gain is 9.26 dBi at the frequency of 2.06 GHz. The 3-dB bandwidth covering 1.80 GHz to 2.37 GHz that is contains the (WARC 92) frequency range. The gain variation in this frequency range is about 0.73 dB. These results are better than those reported by [4, 6, 8].

Fig. 6 shows the simulated E-plane radiation patterns of the antenna at the beginning and the end of the (WARC 92) frequency range and two resonance frequencies. The 3-dB beam-width is about $60°$. The asymmetrical characteristics of the co-polarization pattern are clearly shown in the figure. This is due to the patch and fed structures of the design. The peak cross-polarization level of the antenna is observed to be 50 dB below the co-polarization level of the main lobe. The improvement in the cross-polarization characteristic of the patch is due to the embedded parallel slots which reduce

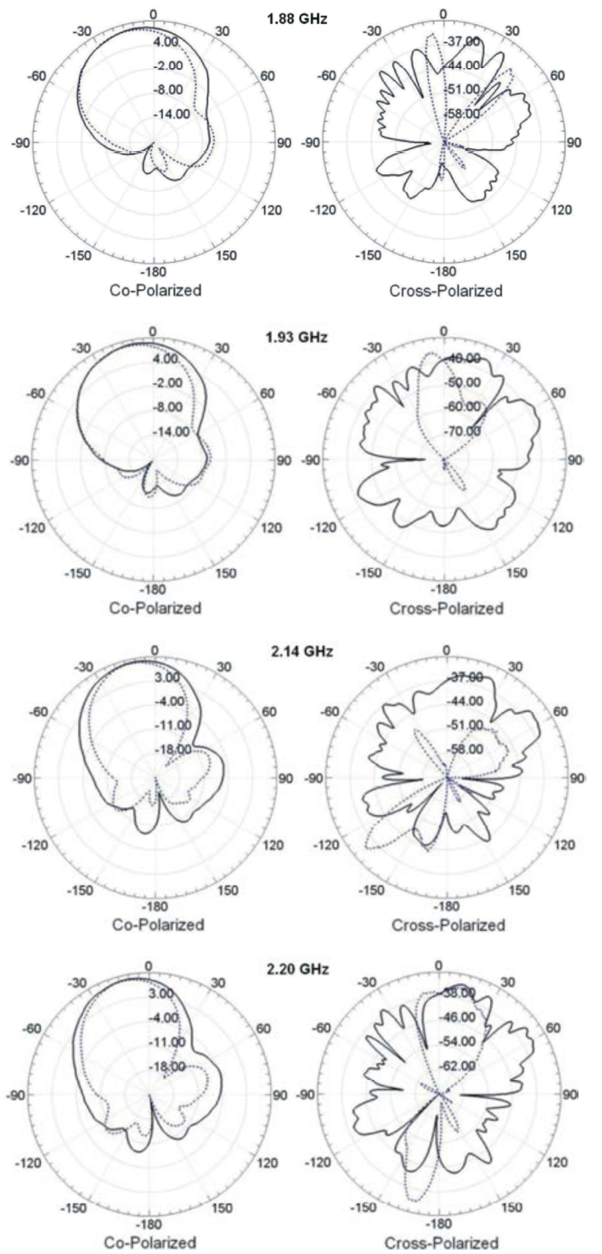


Fig. 8: The simulated and measured E-plane radiation patterns of the antenna at different frequencies (-- the antenna Simulated, •••••• Measured)

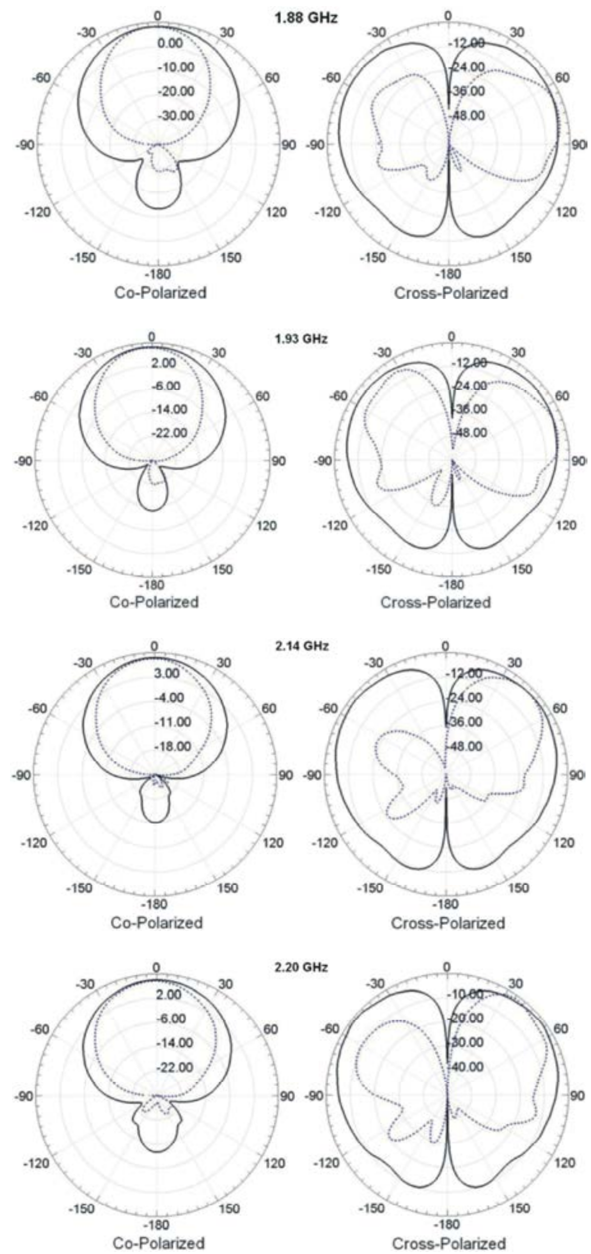


Fig. 9: The simulated and measured H-plane radiation patterns of the antenna at different frequencies (-- the antenna Simulated, •••••• Measured)

the current flow in H-plane direction. The simulated H-plane radiation patterns of antenna are presented in Fig. 7. The 3-dB beam-width is about 60°. Noted in this figure, the cross-polarization in the H-plane is considerably higher than the E–plane, difference with co-polarization and cross-polarization peak is about 12.38 dB and 10.81 dB, respectively at low and high resonance frequencies. Also the main lobe direction in the H-plane does not have its maximum at broadside direction because the structure is asymmetrical. But by employed the auxiliary wire on the ground plane, these results is better than those reported by [4, 6, 8].

The radiation patterns of the proposed patch antenna are measured in the far-field chamber located at the Khajenasir University of Technology antenna laboratory in Iran. The patterns are measured at the beginning and the end of the (WARC 92) frequency range (1.88 GHz and 2.20 GHz) and two resonance frequencies (1.93 GHz and 2.14 GHz). The simulated and measured radiation patterns are shown in Fig. 8-9. In the E-plane, the measured main lobe level is about 8.5 dBi and the 3-dB beam-width is about 58° In the H-plane, the measured main lobe level is about 8.3 dBi and the 3-dB beam-width is about 57°.

CONCLUSION

In proposed antenna, simulated and measured radiation pattern and impedance bandwidth results are in good agreement. The two closely excited resonant frequencies at 1.93 GHz and 2.14 GHz are achieved at -47 dB and -50 dB, respectively. The simulated impedance bandwidth (VSWR $\leq$ 1.5) of 17.56% from 1.87 GHz to 2.23 GHz is achieved. Impedance bandwidth (VSWR $\leq$ 2) of 21.74% from 1.85 GHz to 2.30 GHz is achieved.

In simulation, the maximum achievable gain is 9.26 dBi at the frequency of 2.06 GHz. The 3-dB bandwidth covering 1.80 GHz to 2.37 GHz that contains the (WARC 92) frequency range. In this frequency range, the gain variation is about 0.74 dB. Simulated curves for E-plane radiation pattern show that the 3-dB beam-width is about 60°. The peak cross-polarization level of the antenna is observed to be 50 dB below the co-polarization level of the main lobe. Simulated curves for H-plane radiation pattern show that the 3-dB beam-width is about 60°. Difference with co-polarization and cross-polarization peak is about 12.38 dB and 10.81 dB, respectively at low and high resonance frequencies. The design offers a small size, low profile, broadband impedance, high gain, low cross-polarization and compact antenna element suitable for array applications especially for 3G/IMT-2000 base station smart antenna.

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REFERENCES

1. Department of Defense IMT-2000 Technical Working Group, Investigation of the Technical Feasibility of Accommodating the International Mobile Telecommunications (IMT) 2000, 27 October 2000.
2. Lal, C., 2002. Godara: Handbook of Antennas in Wireless Communications, Cellular Systems, University of South Wales. by CRC Press LLC.
3. Walter Ruzzarin: Cellular network optimization based on mobile location, CELLO-WP2-MTCI-D02-008-Int.
4. Mohammad Tariqul Islam, Norbahiah Misran and Ng Kok Jiunn, 2007. A 4×1 L-probe fed Inverted Hybrid E-H Microstrip Patch Antenna Array for 3G Application, American J. Appl. Sci., 4(11): 897-901.
5. Norbahiah Misran, Mohammad Tariqul Islam and Ng Kok Jiunn, 2008. Design and Development of Broadband Inverted E-shaped Patch Microstrip Array Antenna For 3G Wireless Network', American J. Appl. Sci., 5(4): 427-434.
6. Mohammad Tariqul Islam, 2009. Broadband Microstrip Patch Antenna, European J. Scientific Research ISSN 1450-216X, 27(2): 174-180.
7. Zainol Abidin Abdul Rashid1 and Ng Kok Jiunn, 2005. Gain Enhanced Broadband L-probe Inverted E-shaped Microstrip Patch Antennas, J. Teknologi, 42(D): 83-94.
8. Zainol Abidin Abdul Rashid, Ng Kok Jiunn and Mohammad Tariqul Islam, 2005. Wideband L-probe Fed Inverted Hybrid E-h Microstrip Patch Antennas for Imt-2000 Band, Jurnal Teknologi, 42(D): 133-146.
9. Zurcher, J.F. and F.E. Gardiol, 1995. Broadband Patch Antennas-The SSFIP Principle, Norwood, MA: Artech House, 3(1-3): 46-51.
10. Girish Kumar, 2003. Broadband Microstrip Antennas', Artech House, 2(2): 45-61.