`

A Wideband Magneto-Electric Dipole Antenna with Improved Feeding Structure

Neetu Marwah[1], Ganga P. Pandey[2], Vivekanand N. Tiwari[1], Sarabjot S. Marwah[3]

[1]Department of Electronics and Communication, Manipal University Jaipur, Jaipur, India
[2]Department of Electronics and Communication, Maharaja Agrasen Institute of Technology, Delhi, India
[3]Department of Computer Science, GTBPI, Delhi, India
*corresponding author, E-mail: neetu03@rediffmail.com

Abstract

An improved feeding structure in magneto-electric dipole antenna is proposed and analyzed, which is simpler in design and costruction and better in performance than previous designs, involving differential feeding. Due to this improved feeding structure, the antenna has achieved an impedance bandwidth of 133.3% (0.5 GHz – 2.5 GHz, resulting into an ultra-wide band antenna. The maximum broadside gain 6.5dBi with unidirectional radiation pattern has also been reported for the entire the range of operation. Symmetry in E-plane and H-plane radiation patterns has been observed due to the symmetry in structure and excitation of antenna.

1. Introduction

Differential circuits have been able to achieve popularity in radio frequency integrated circuits (RFICs) and microwave monolithic integrated circuits (MMICs) because of their good performance characteristics like common mode rejection, low mutual coupling, less noise, great harmonic suppression and high linearity. But most of these antennas have been designed for single-ended circuits. Baluns are required for the transition between differential signals and single ended signals, when they are to be integrated with differential signals. The use of differentially fed antenna is to remove the bulky off-chip baluns, for size reduction and to remove the insertion loss of baluns. Besides this, differentially fed antennas introduce a cancellation mechanism that helps to suppress some higher-order modes and unwanted radiation from vertical feeding structures (e.g. a feeding probe), to reduce the cross polarization radiation and thus enhance the polarization purity [1-5].

Recently a new wideband "Magneto Electric Dipole Antenna" has been proposed by K.M.Luk et al [6-7], and it has been originated from the researches made in the designs of complimentary antenna. A vertically oriented quarter-wave shorted patch has been used as magnetic dipole and a planar dipole is used as an electric dipole. The antenna possesses many advantages like, simple structure, equal E-plane and H-plane radiation pattern, low cross polarization level, wide impedance bandwidth and constant gain within the range of operating frequency. The antenna has gained popularity especially in wireless base station system and many more wireless communication applications.

Initially, magneto-electric dipole antenna was designed for single-ended applications. With different feeding structures, the antennas were able to achieve impedance bandwidth of more than 60% [8, 9]. Recently a differentially fed magneto-electric dipole antenna has been reported by [10,11], to achieve an impedance bandwidth of 114% from 2.95GHz-10.73 GHz. In spite of having stable gain and identical E-plane and H-plane radiation patterns in the entire range of operation, this UWB antenna is very complex in structure. A simple structured differentially fed antenna has also been designed by [12] with 92% impedance bandwidth.

In this paper a differentially fed magneto-electric dipole antenna has been designed, fabricated and discussed. The antenna has a big advantage of having simple structure. The proposed antenna has achieved an impedance bandwidth of 133.3 % for 0.5 GHz to 2.5 GHz for a differential refection coefficient of less than -10dB. A peak gain of 6.5dBi has also been reported. Almost Identical radiation pattern for E-plane and H-plane has also been observed due to the proposed feeding structure.

2. Electrical Parameters of Differentially Fed Antenna

The differential input impedance, Z_d, of a symmetric differentially fed antenna is defined in [12] as

$$Z_d = Z_{11}-Z_{12}-Z_{21}+Z_{22} \quad (1)$$

Where Z_{11}, Z_{12}, Z_{21}, Z_{22} are the Z parameters of a two ports network, considering differential port of the antenna as two ports network. Differential reflection coefficient S_{dd11} can be derived from Equation (1), which is

$$S_{dd11} = 0.5(S_{11}-S_{12}-S_{21}+S_{22}) \quad (2)$$

S_{dd11} is equivalent to the reflection coefficient measured from input port of balun. S_{11}, S_{12}, S_{21} and S_{22} are the S parameters of two ports network.

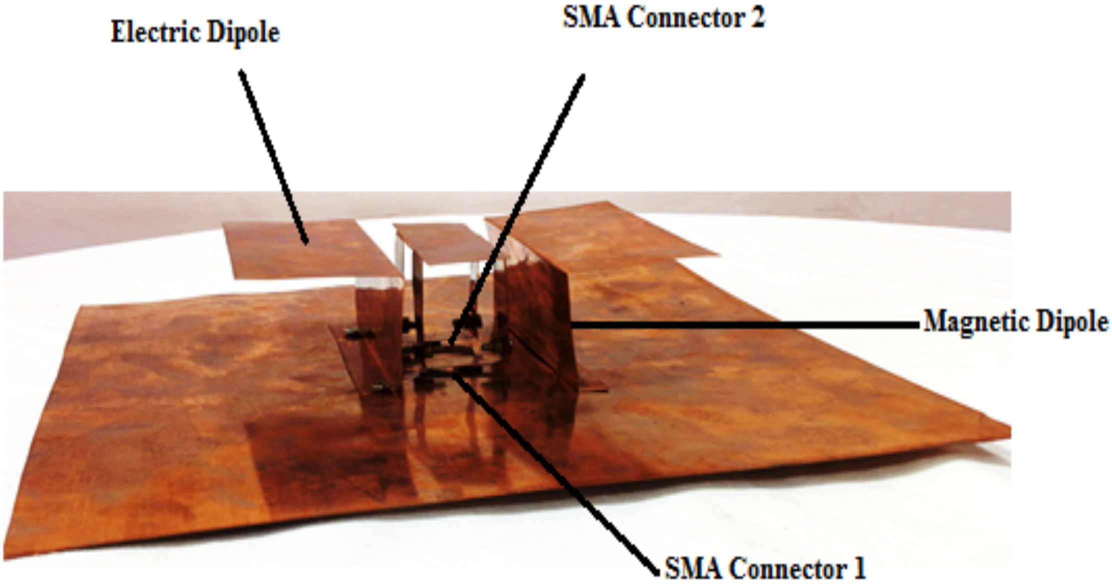

Figure 1a. Prototype of proposed antenna with side view of feed

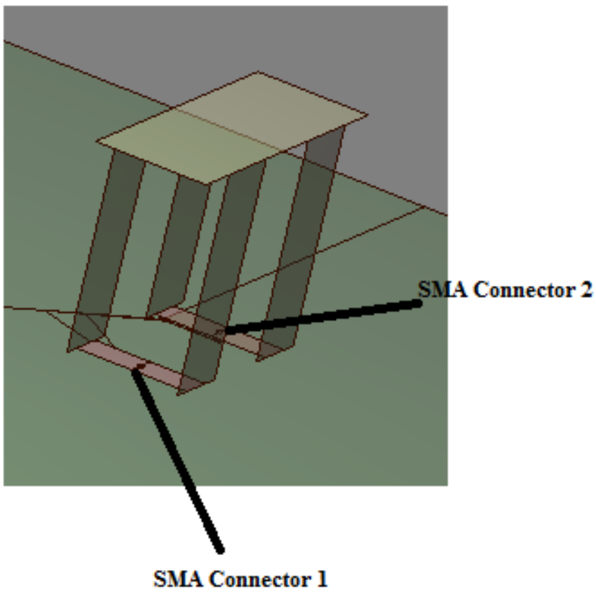

Figure 1b. 3-D view of proposed feed design

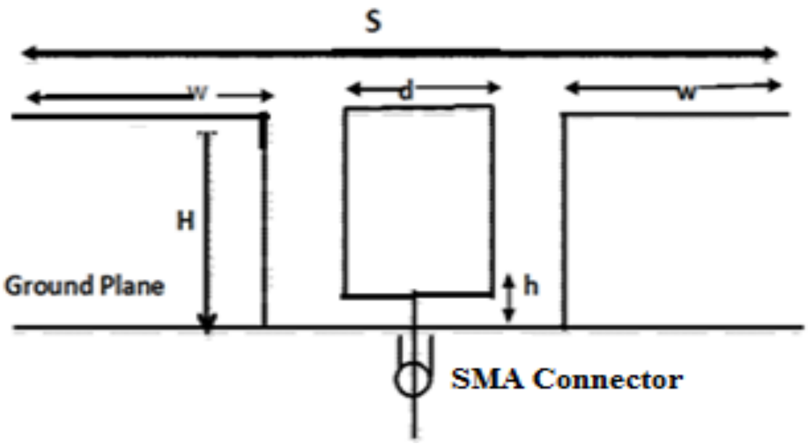

Figure 2a. Side view of the proposed antenna

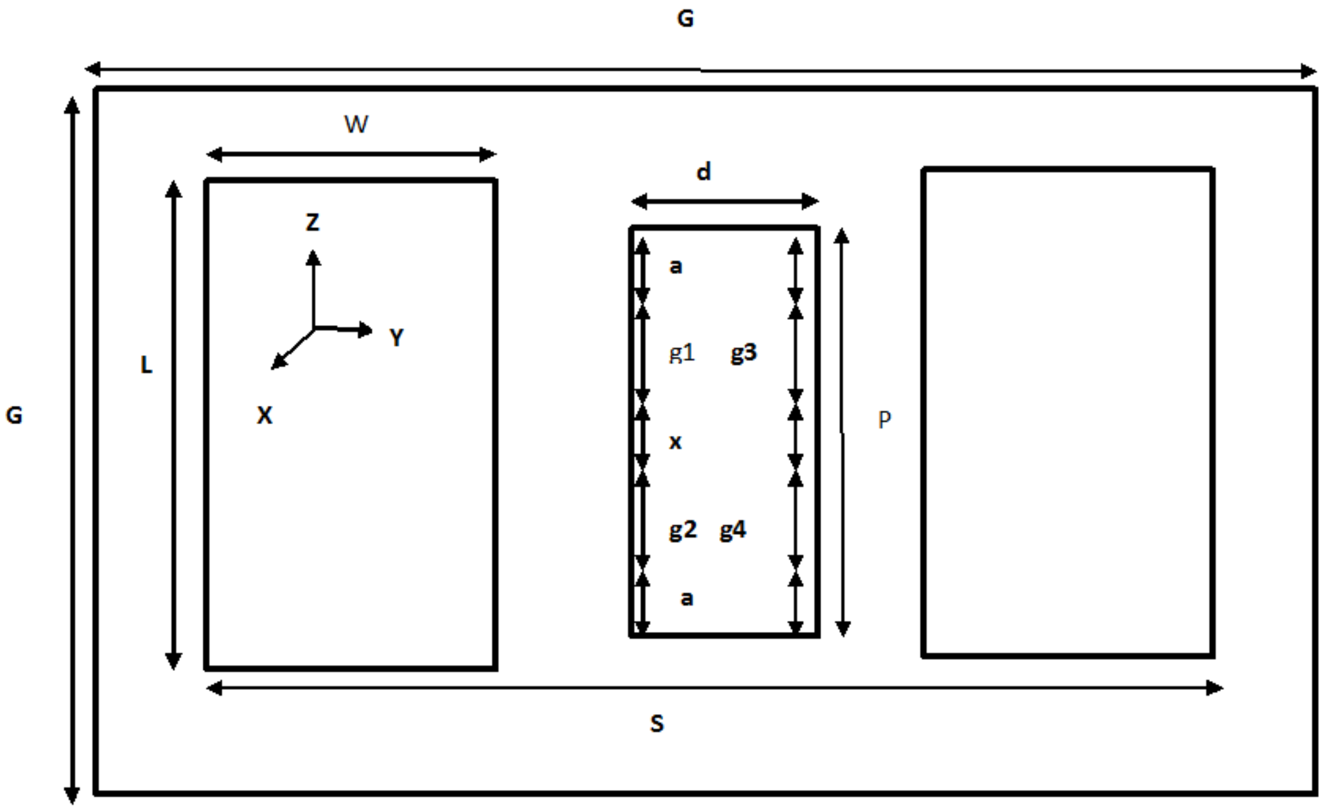

Figure 2b. Top view of the proposed antenna

Table 1. The optimized geometrical parameters of proposed antenna

Parameter	G	S	W	d	P	g1=g2=g3=g4	H	h	L	x	a
Value (mm)	270	145	50	26	72	16	50	2	110	20	10

3. Design and Simulation

Figure 1.represents the photograph of fabricated and proposed differentially fed magneto-electric dipole antenna along with 3-D geometry of proposed feed. The geometry of proposed differentially fed magneto-electric dipole antenna is given in Figure 2. The geometry is symmetric about X-Z and Y-Z planes. The proposed antenna has been designed for a center frequency f_0= 1.5GHz. The antenna has mainly three parts- radiation structure, a feeding structure and a ground plane. The radiation structure is vertically oriented quarter wave shorted patch as magnetic dipole and a planar dipole as an electric dipole. The feeding structure has been designed to provide equal excitation to magnetic and electric dipoles, for broadband impedance matching. It has four vertical parallel strips hanging on two sides of horizontal plate to form two pairs of strips -front and back. The two front vertical strips are connected via a 9mm wide horizontal copper strip, 2mm above the ground plane and a 50 ohms SMA connector is placed at the center to make first port. The same process is repeated for both back vertical strips to form second port. These sets of front and back parallel strips act as balanced transmission line. The main functioning of horizontal plate is to couple the differential signal to the radiating structure. The two SMA ports together have been designated as differential input port. This differential port consists of port 1^+, where SMA connector 1 has been connected and port1^-, where SMA connector 2 is connected. Ground plane and all the parts of the proposed antenna has been made of copper with 0.3mm thickness. The radius of each of the SMA probe is 0.635mm and the length over the ground plane has been chosen as h= 2mm. The designed antenna has been optimized and simulated on MOM based IE3D software. The purpose of optimization was to maximize the impedance and gain bandwidth and also to maintain unidirectional as well as stable radiation pattern in the range of operation. Table.1 gives the optimized geometrical parameters of the proposed antenna.

4. Results and Discussion

The single ended S parameters-S_{11}, S_{12}, S_{21} and S_{22}; of the proposed antenna were measured with vector network analyzer as a single ended two ports network. From Equation 2, differential reflection coefficient S_{dd11} has been calculated from single ended S parameters. Similar way, single ended Z parameters are calculated and using Equation 1, differential input impedance Z_d is calculated.

An antenna measurement system is used to measure the broadside gain and radiation pattern of the proposed antenna. An 180^o hybrid coupler is used to transform single ended operation into differential operation. The difference port of the hybrid coupler was connected to signal source and the sum port was terminated by 50 Ω load, for the purpose of measurement. The output ports of the hybrid coupler were connected to the differential input port of the antenna. Figure 3. shows the predicted differential reflection coefficient, $S_{dd1,}$ of the proposed antenna. The simulated impedance bandwidth of the antenna was 133.3% from 0.5GHz to 2.5GHz. There is a shift between measured and simulated result at about 800 MHz, which may be due to imperfection in design (which includes screws used to make antenna stand on ground plane, soldering etc) or measurement mismatch. The gain of the antenna at broadside is 6.5dBi, which is given in Figure 4. The gain of antenna reduces at higher frequency range due to low antenna efficiency. Figure 5.depicts the simulated input impedance of the proposed differentially fed antenna. The resonant frequency has been defined as the frequency where the reactive part of input impedance is zero. It is observed that the reactive part of impedance is zero at 0.75 GHz and remains near to zero between 1.45GHz and 2.0 GHz, that means multiple resonance (where reactance part is 0) have occurred in the range of antenna operation, which has ultimately resulted into wide impedance bandwidth. The drift at 800MHz is not apparent because the reflection coefficient depends upon real as well as imaginary parts of input impedance. Even if imaginary part matches, real part may mismatch due to which dip is shifted. The simulated radiation patterns at 1GHz, 1.5GHz, 2GHz and 2.5GHz have been indicated by Figure 6, which shows a unidirectional and stable radiation pattern over the band of frequencies. As the structure and excitation are symmetrical, E-plane and H-plane radiation patterns are also almost symmetrical. Figure 7 indicates the effectiveness of antenna showing antenna efficiency and radiation efficiency. From the figure it is cleared that radiation efficiency is greater than 90% whereas antenna efficiency is greater than 60% in the entire range of frequency operation. A comparison table, Table 2 has also been added to indicate the improved performance of proposed antenna.

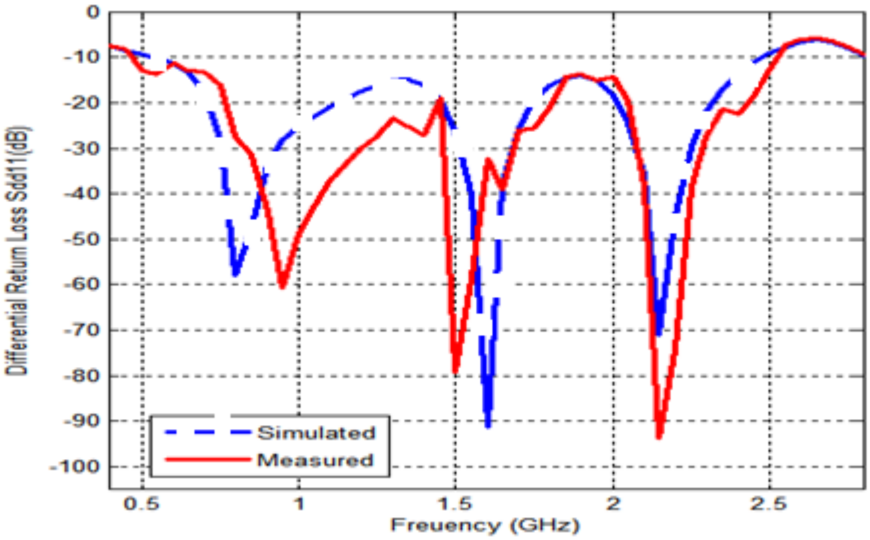

Figure 3. The simulated and measured differential return loss, S_{dd11}

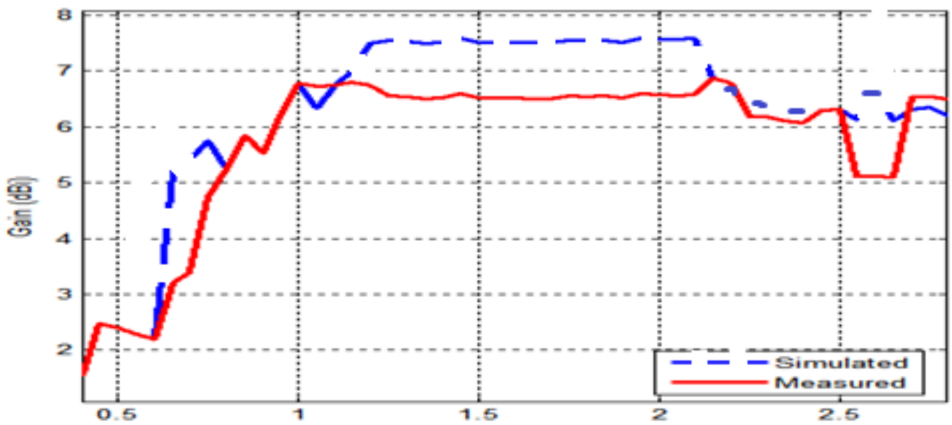

Figure 4. The simulated and measured gain of proposed antenna

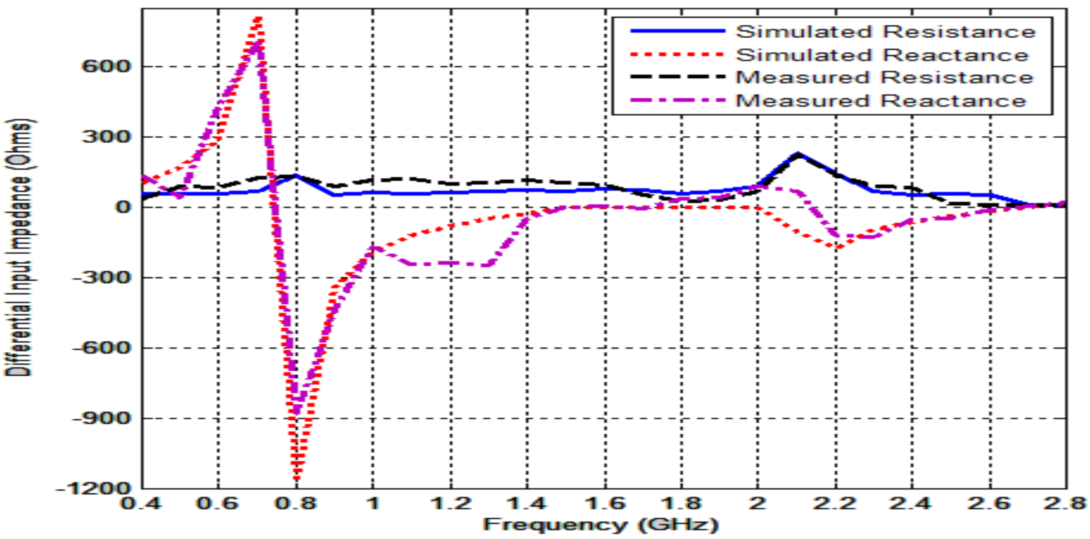

Figure 5. The simulated and measured differential input impedance

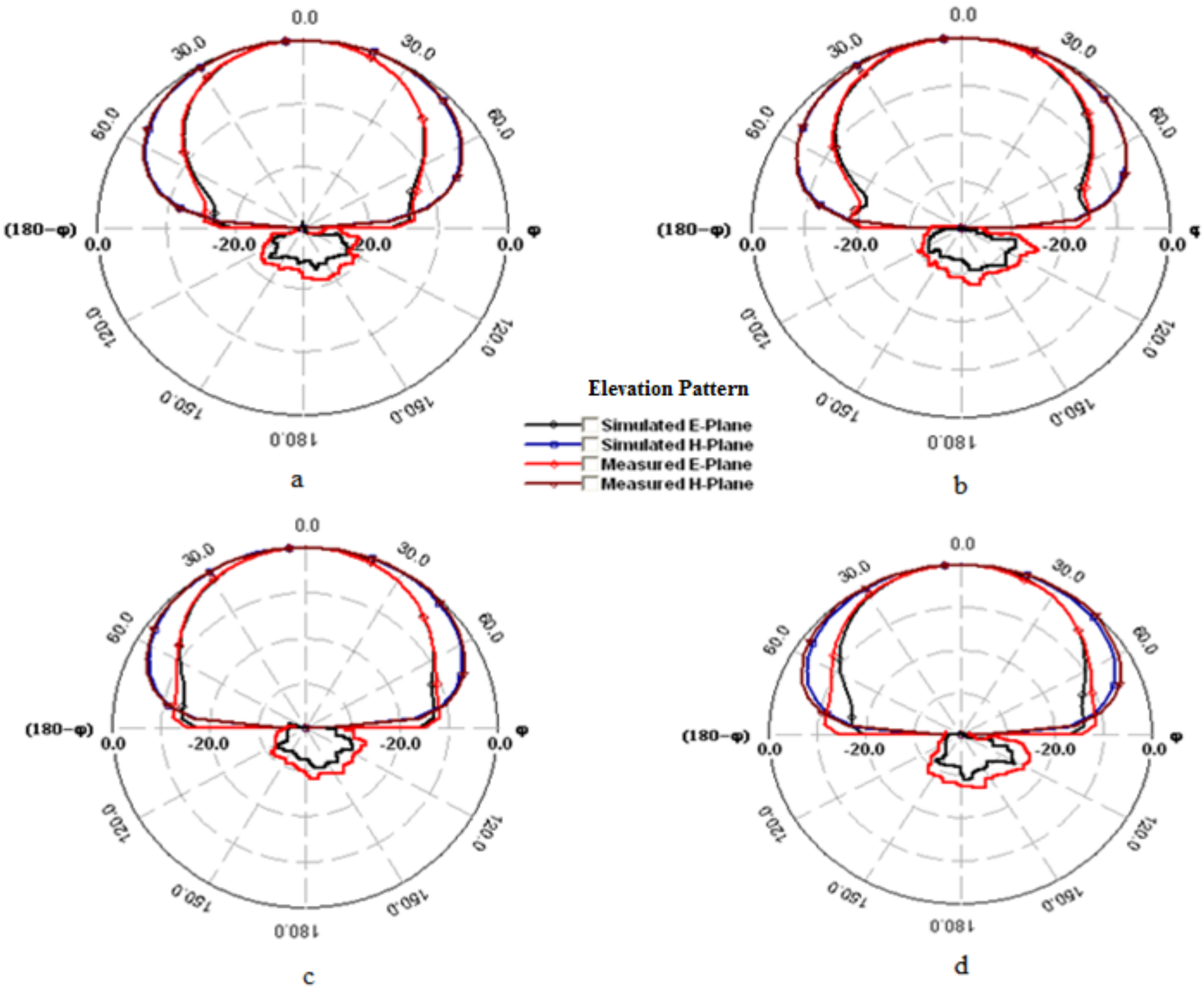

Figure 6. Simulated and measured E-plane and H-plane radiation patterns at: a-1GHz, b-1.5GHz, c- 2GHz, d-2.5GHz

Table 2

Reference No.	Frequency Range (GHz)	Material Used for Feed Design	Impedance Bandwidth(%)	Simulated Gain (dBi)	Antenna Circuitary
[11]	2.95-10.73	Duroid 5870	114	8.2±1.0	Complex
[12]	0.80-2.16	Copper	92	7.7	Simple
Proposed	0.5-2.5	Copper	133	7.5	Simple

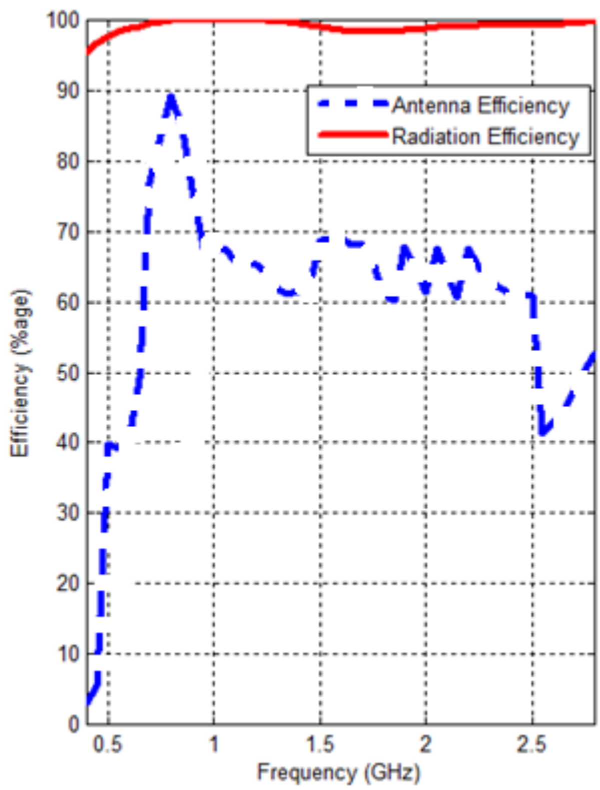

Figure 7. Simulated antenna efficiency and radiation efficiency of proposed antenna

5. Conclusion

A simple and easy to design differentially fed magneto-electric dipole antenna has been designed and fabricated. The measured results indicate that it possess wide impedance bandwidth, which is 133.3% from 0.5GHz-2.5GHz. A stable unidirectional radiation pattern has also been observed. It is also concluded that because of symmetry in antenna structure and excitation, almost equal E-plane and H-plane radiation patterns are observed. A peak gain of 6.5dBi has also been reported. It is also concluded that compared to previous differentially fed antenna, designed by counterparts, this design is much simpler and better. Due to its good electrical characteristics, the antenna is suitable for differential microwave/ RF front ends for various wireless communications.

References

[1] S. W. Liao, Q. Xue, and J. H. Xu, "Parallel Plate Transmission Line and L- Plate Feeding Differentially-Driven H –Slot Patch Antenna," *IEEE Antennas and Wireless Propagation Letters,* 11, 2012, pp.640-644.

[2] C. H. Chin, Q. Xue and H. Wong, "Broadband Patch Antenna with a Folded Plate Pair as a Differential Feeding Scheme," *IEEE Transactions on Antennas and Propagation*, AP-55, 9 September 2007, pp. 2461-2467.

[3] Y.P. Zhang, "Design and Experiment on Differentially Driven Microstrip Antennas," *IEEE Transactions on Antennas and Propagation*, AP-55, 10, October 2007, pp.2701-2708.

[4] Y.P. Zhang and J.J.Wang, "Theory and Analysis of Differentially Driven Microstrip Antennas," *IEEE Transactions on Antennas and Propagation*, AP-54, 4, April 2006, pp. 1092-1099.

[5] Q. Xue, and X.Y. Zhang and C. H. K. Chin, "A Novel Differentially Fed Patch Antenna," *IEEE Antennas and Wireless Propagation Letters,*5, 2006, pp.471-473.

[6] Bi Qun Wu and Kwai-Man Luk, "A Broadband Dual - Polarized Magneto-Electric Dipole Antenna with Simple Feeds," *IEEE Transactions on Antennas and Propagation*, vol.8, pp.60-63, Apr.2009.

[7] Lei Ge and Kwai-Man Luk, "A Wideband Magneto-Electric Dipole Antenna," *IEEE Transactions on Antennas and Propagation*, vol.60, pp.4987-4991, Nov.2012.

[8] K. M. Luk and H. Wong, *A Complimentary Wideband Antenna*, US Patent No. US7843389B2, November 30, 2010.

[9] Z. N. Chen, K. M. Luk, *Antennas for Base Stations in Wireless Communications,* New York, McGraw- Hill, 2009, pp. 219-237.

[10] M.J. Li and K. M. Luk, "A Differentially- Fed Magneto- Electric Dipole Antenna for UWB Applications," Asia-Pacific Microwave Conference, Melbourne, December, 2011, pp.1953-1956.

[11] M.J. Li and K. M. Luk, "A Differentially- Fed Magneto- Electric Dipole Antenna for UWB Applications," *IEEE Transactions on Antennas and Propagation*, vol.61, No.1, pp.92-99, Jan.2013.

[12] S. W. Liao, Q. Xue, and J. H. Xu, "Differentially Fed Magneto-Electric Dipole Antenna with a Simple Structure," *IEEE Antennas and Propagation Magazine*, vol.55, No.5, pp.74-84, October 2013.