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Research Article

DESIGN AND DEVELOPMENT OF A HIGH GAIN DISCONE ANTENNA FOR 4G LTE APPLICATIONS

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ABSTRACT

This study offers the design and realization procedure of a broadband monopole antenna for use in communication applications between 670 MHz-2750 MHz. the proposed monopole antenna comprises a low-cost discone antenna which has a relatively high gain value over a wide operation band. Firstly, the performance of the antenna is studied by changing the value of design parameters. Effect of each design parameter on return loss (S_{11}) and gain characteristic of the antenna design is observed and the optimal design parameters are taken. Both simulation and measurement results of the proposed antenna design show a matched bandwidth and a return loss of less than -10 dB in the desired operation band of 670 MHz and 2750 MHz. as it can be seen from both simulation and experimental results, the proposed discone antenna design is a suitable solution for broad-band wireless communication applications.
Keywords: Planar monopole antenna, low profile, airborne, EM simulation, VSWR, discone antenna.

1. INTRODUCTION

Newer communication applications, for optimum use, require single wideband antennas that can cover a range of frequencies. Recently many techniques had been presented for the design of high performance antenna for communication systems such as usage of Substrate Integrated Waveguide structures in antenna designs [1-5], application of Frequency Selective Surfaces for performance enhancement of antenna designs [6-9], usage of defected Ground Structures [10]. One of the latest antennas to fulfil this need is the planar monopole antenna [11]. This kind of antenna is adaptable and possesses remarkable features that make it suitable for use in communication applications. The main features that these applications require from the antenna that can be employed for wideband applications include radiation pattern stability and impedance bandwidth with low VSWR. Linear phase response and optimum radiation efficiency are two other important factors. Application of planar monopole antennas result in a linear phase response (constant group delay) on a wide band since they have a constant phase center on a wide band of frequencies [12].

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Their designs can be modified for optimum use to cover unusually wide impedance band width with maximum radiation efficiency and a steady omnidirectional radiation pattern.

These antennas boast of other appealing characteristics such as their conveniently small size and weight. They are relatively inexpensive to produce and have a simple planar acceptable structure in accordance with prevailing standards.

Ultra-wide-band (UWB) technology has a great demand in communications in both, civil as well as military, applications. This is due to the inherent advantages this wide-band technology possesses such as high-speed data transmission, low interference, relatively low cost, and low power density [12]. The commonly used wide-band antennas are discone, log-periodic, double-ridge waveguide horn, and biconical antennas [13-16]. Discone antenna is more popular than the other antennas mentioned here. This is because of its superior wide-band performance and omnidirectional radiation that is suitable for UWB systems. Discone antenna has been in use since 1945 when its optimal performance in wide frequency bands was noticed. Its simple design and structure combined with a low production cost and superior performance encouraged its use in various communication systems such as wide-band scan antennas, EMC applications, and UWB systems.

A suggestion for a double discone antenna with tapering wires that can function at a frequency of 180 MHz to 18 GHz and a VSWR under the value of 2.5 has been made [17]. It resulted in an omnidirectional radiation pattern that was mostly satisfactory except when it reached around 12 GHz. Another double discone antenna was developed for a UWB frequency scan and resulted in a 30:1 broad bandwidth with a VSWR under the value of 2.5 [18].

The forerunner of the discone antenna is the biconical antenna. One of the cones in the biconical antenna is substituted by a disc, hence the name. The wide-band characteristics of discone antennas remain the same as those of biconical antennas. These antennas were widely applied in the fields of radio and television broadcasting as well as avionic systems due to their unique radiation features. More modifications were made to these antennas in order to make them more suitable for UWB applications.

One of these modified antennas can be seen in [19] where it operates with an almost omnidirectional feature in a wide range from 180 MHz to 18 GHz. Another compact modified version is presented in [20] where it functions optimally in a frequency band between 400 MHz and 16 GHz. These antennas are created minimally so the bare structure is far cheaper and lighter than the normally used design.

The disc and the cone are regarded as two monopoles. This results in a considerably lower characteristic impedance of the antenna when compared to a normal dipole one. In combination with an appropriate design and frequency, the input impedance of the two monopoles gives different results.

Herein, design of a high performance broadband monopole antenna consist of a low-cost discone antenna had been studied. The proposed antenna designed had been aimed to operate at 670-2750 MHz for wireless communication applications. The parametric analysis of the antennas design parameters over the performance criteria such as S_{11} and gain had been studied to obtain the optimal design parameters. Then, for justification of the simulation results the antenna design had been prototyped and measured. In the next section the design, simulation and prototyping of the discone antenna are presented. After that, the measurement results of the discone are investigated, finally paper ends with conclusion section.

2. DESIGN PROCEDURE of DISCONE ANTENNA

This study makes some important modifications by introducing a short circuit loading method and alters the surface profile into a broken line. Traditionally, the discone antenna direction figure bandwidth is extremely narrow and the diameter of the disc should be raised in order to get a good directional diagram characteristic. But the drawback of this method is that the low frequency standing wave is reduced. In order to acquire index requirements, the size of the antenna must be increased. However, this puts constraints on the applications it can be used for. Hence it necessitates the changes mentioned earlier so the incongruity between the antenna technology index and the dimensional needs can be resolved optimally. The dimensions of the proposed discone antenna (Figs. 1-2) are given in table I, alongside of the simulated gain and VSWR results in Figs 3-4 and table II.

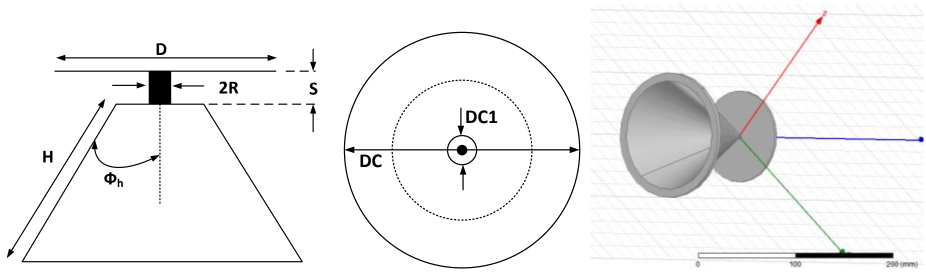


Figure 1. Dimensional views of design and its 3D model views of design HFSS

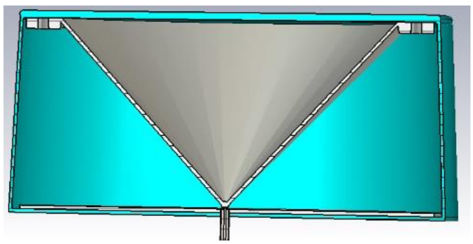
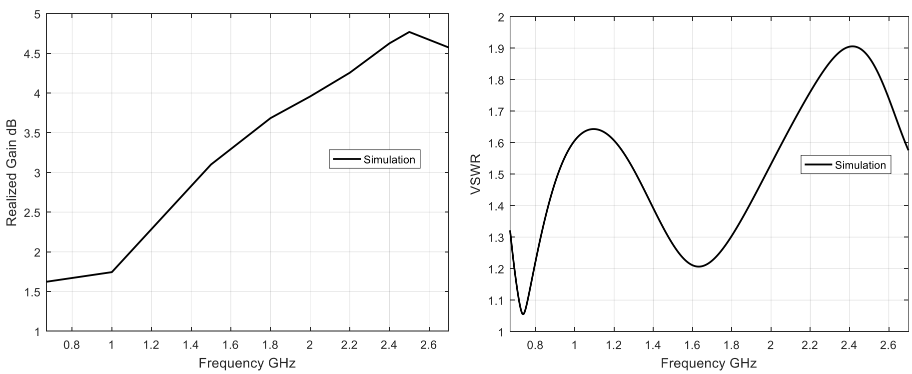


Figure 2. Three-Dimensional Simulation Model

Table 1. Design Parameters of the Proposed Antenna

D	95	S	2
R	1.4	DC	120
H	130	DC1	6.30
Φ_h		30^0	



(a) (b)

Figure 3. (a) Realized gain (b) VSWR

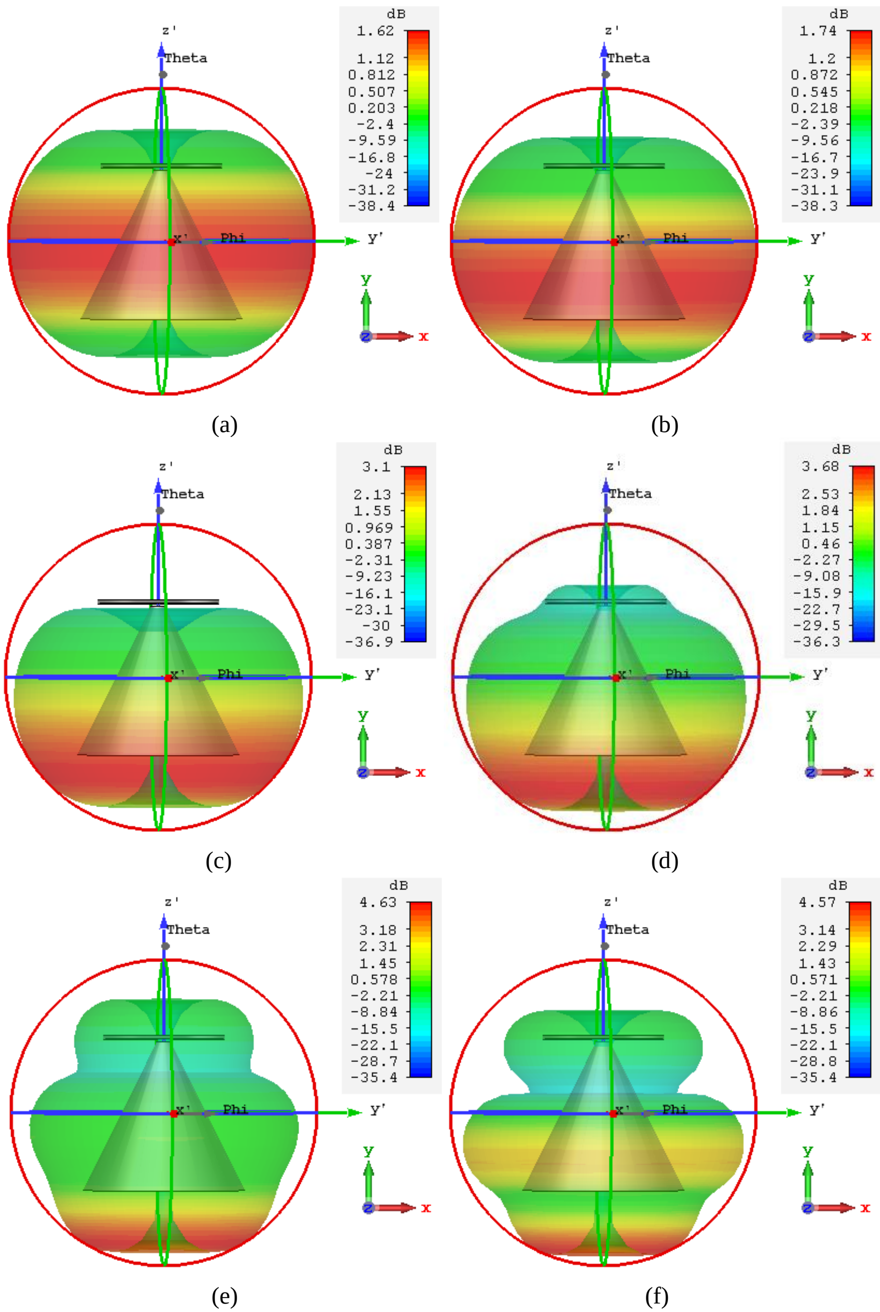


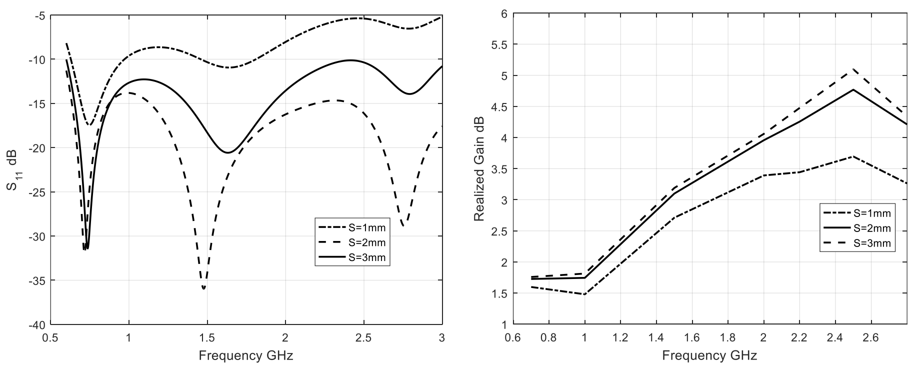
Figure 4. Realized Gain 3D at (a)670MHz (b)900MHz (c)1500MHz (d)1800MHz (e)2400MHz (f)2750MHz

Table 2. Simulated Radiation pattern at $\Phi=90^0$

Frequency (MHz)	Main lob Magnitude (dB)	Main Direction (degree)	3dB angular width (degree)
670	1.67	94	90.7
900	1.75	108	87.3
1500	3.1	129	68.2
1800	3.7	137	59.4
2400	4.63	149	34.9
2750	4.58	154	28.4

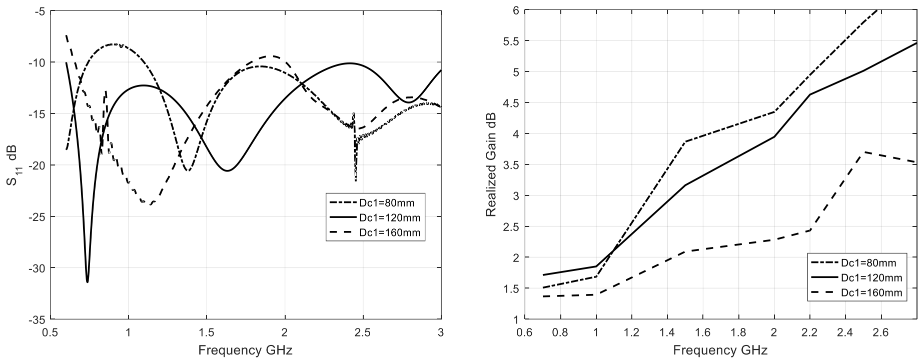
The radius of the disc and the height of the cone in a discone antenna play the most vital role in its operation. They are closely associated with the minimum frequency of the antenna operation. The disc should be around 0.7 times the height of the antenna and the height of the cone should be nearly a quarter-wave length of the minimum working frequency of the antenna. The space between the disc and the cone combined with the smallest surface on the cone, its base, regulates the input impedance of the antenna. The combination has a bearing on the maximum operational frequency as well. At the outset, approximations were made in order to achieve the best possible match at the required frequency. These estimates were then refined with EM stimulation and the process led to optimal results between 670 MHz and 2750 MHz. The signal pin of an SMA connector is fused with the cone and its flange screwed to the disc so as to feed the antenna.

Certain facets need to be kept in mind for the optimal functioning of the antenna. The dimensions of the antenna need to be lowered if a higher operating frequency is desired. Amplifying the flare angle will lessen the waves in the reflection coefficient. The ideal flare angle is 30 degrees. A significant change in the pattern can be noticed above a bandwidth ratio of 3:1. However, a wider band of 10:1 results in superior impedance characteristics. Adjusting the flare angle will impact the input impedance; increasing the angle will lower the impedance and vice versa. Enlarging the diameter of the disc will increase the low frequency input impedance and decreasing the diameter will lower it. It should be kept in mind that the diameter of the disc should be at about 70% of the maximum diameter of the cone. Reducing the feed gap and minimum cone diameter results in an augmented high frequency input impedance property. In Figs 5-8 the variation of gain and S_{11} performances of the discone antenna design due to its design parameters are studied. As it can be seen from the Figs. 5-8, each of the design variables has a considerable effect on the performance measures of the antenna design. The design parameter values given in Table 1 had been taken as the optimal design values for the prototyping of the proposed antenna that has a simulated performance achievements of gain level of 4.6 dBi and S_{11} value of less than -10 dB at 2.4 GHz.



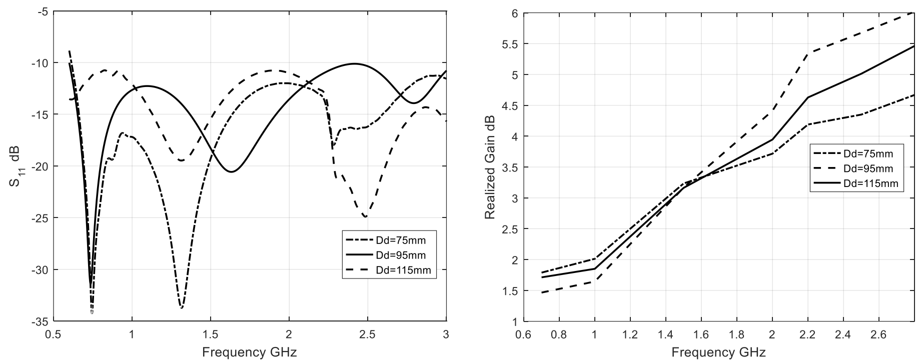
(a) (b)

Figure 5. (a) Reflection Coefficient (b) Realized Gain simulated result (parameter sweep, discone gap between 1mm to 3mm, step width: 1mm)



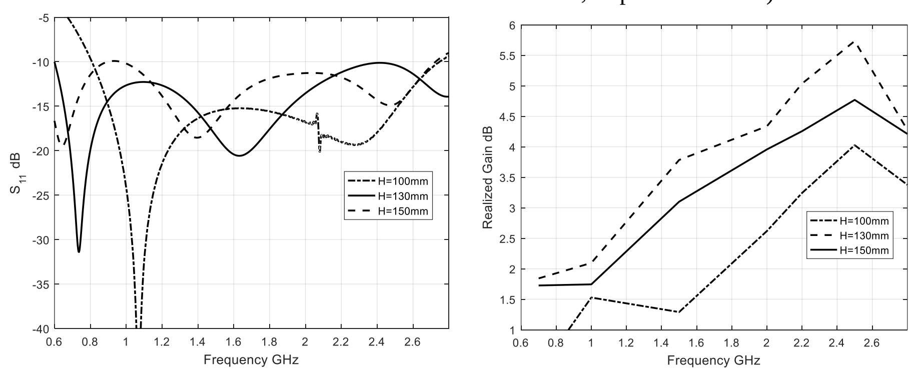
(a) (b)

Figure 6. Reflection (a) Reflection Coefficient (b)Realized Gain simulated result (parameter sweep, discone diameter maximum between 100mm to 140mm, step width:10mm)



(a) (b)

Figure 7. (a) Reflection Coefficient (b) Realized Gain simulated result (parameter sweep, disc diameter maximum between 75mm to 115mm, step width: 10mm)



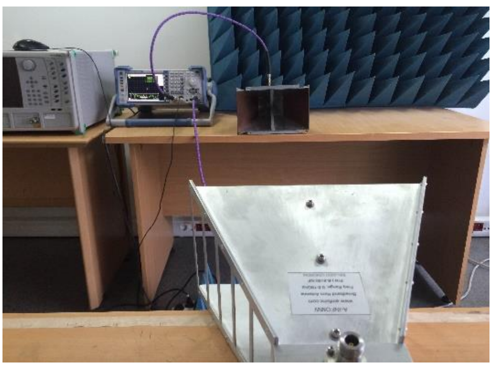
(a) (b)

Figure 8. (a) Reflection Coefficient (b) Realized Gain simulated result (parameter sweep, cone height between 100mm to 150mm, step width: 10mm)

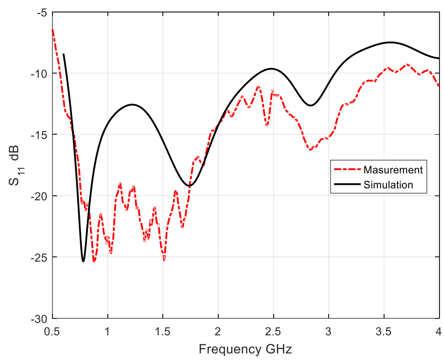
3. EXPERIMENTAL RESULTS

This section of the paper uses two identical antennas as reference antennas to gauge the radiation patterns, the maximum far field gains, and the divergence and transmission characteristics of the proposed modules [21]. In Figs. 9-10 the measurement setup and the prototyped Discone antenna are given. The return loss characteristics and maximum gain are shown in Fig. 9 and Table III respectively. Both simulation and measurement results of the proposed antenna design show a matched bandwidth and a return loss of less than -10 dB in the desired operation band of 670 MHz and 2750 MHz. as it can be seen from both simulation and experimental results, the proposed discone antenna design is a suitable solution for digital TV receiving and transmitting system and any indoor application.

Figure 9. Fabricated Antenna.



(a)



(b)

Figure 10. (a) Measurement setup for maximum far field gain [9] (b) Measurement and Simulation Comparison for Return loss

Table 3. Comparison between Discone Simulation and Measurement

	Frequency (MHz)	Simulated	Measured
Gain (dBi)	670	1.6	---*
	900	1.7	1.1
	1500	3.2	3.8
	1800	3.7	3.1
	2400	4.6	3.9
	2750	4.2	4.4

*can not be measured due to the limitation of reference antenna

Table 4. Comparison Literature

	Size (mm)	Operation Frequency GHz	S_{11} dB	VSWR	Max Gain dBi
[22]	368x368x377	0.12-18	---	<2.5	8
[23]	26x26x20	3.1-4.1	<-10	<2	2
[24]	144x144x165	0.38-3	<-10	---	1.8
[25]	40x40x18.5	2.15-7	<-10	---	5.3
[26]	55.2x55.2x22	1.7-2.7	<-10	---	3.6
This Study	120x120x110	0.67-2.75	<-12	---	4.4

4. CONCLUSION

Herein, a simple and low-cost design and realization of a discone antenna with a high gain and low-cost for use in 670 MHZ-2750 MHz microwave applications had been proposed. For this purpose, the operating principles of the antenna were studied by plotting the variation of S_{11} and Gain characteristics of the antenna design due to the change in design parameters. After the parametric analysis of the antenna design the optimal design values are taken to make an experimental model of the proposed antenna. Then both simulation and experimental results showed a high gain and good return loss characteristic. Form the measurement results it can be concluded that the proposed antenna is a suitable model for indoor application use in 670-2750 MHz band applications. The cost of manufacturing these antennas may come down in the future by employing 3D printing technology. Regardless of the manufacturing mode, the antennas will result in a high performance.

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