Current Journal of Applied Science and Technology

22(2): 1-8, 2017; Article no.CJAST.34742
Previously known as British Journal of Applied Science & Technology
ISSN: 2231-0843, NLM ID: 101664541

Analysis of Wide Band Unequal Cone Angle Biconical Antenna

Subba Rao Chalasani[1*] and Sudhakar Alapati[2]

[1]Department of ECE, Prasad V Potluri Siddhartha Institute of Technology, Kanuru, Vijayawada, A.P, India.
[2]Department of ECE, RVR and JC College of Engineering, Chowdavaram, Guntur, A.P, India.

Authors' contributions

This work was carried out in collaboration between both authors. Author SRC has performed the design, modeling and simulations. Author SA has performed and presented the detailed analysis of the results. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/CJAST/2017/34742
Editor(s):
(1) Vyacheslav O. Vakhnenko, Division of Geodynamics of Explosion, Subbotin Institute of Geophysics, National Academy of Sciences of Ukrainian, Ukraine.
Reviewers:
(1) Wenbin Dou, Southeast University, China.
(2) Anwar Abdelrazzaq Hasan AL-Mofleh, Al-Balqa' Applied University, Jordan.
Complete Peer review History: http://www.sciencedomain.org/review-history/20023

Original Research Article

Received 8th June 2017
Accepted 1st July 2017
Published 13th July 2017

ABSTRACT

Radiation properties of biconical antenna of unequal cone angles have not been widely reported as compared to equal angle biconical antennas. Biconical antennas with cone of angle 90° have been widely reported. In this paper a compact biconical antenna with upper cone of 90° and lower cone of 120° angles are designed and analyzed for wide band applications from 1 GHz to 25 GHz. A finite biconical antenna has limited bandwidth due to its abrupt termination at its edges to free space. Biconical antenna of top cone of angle 90° and bottom cone of angle 120° with edges terminated in thick circular conductor is proposed. Radiation characteristics and return loss of the antenna are investigated. Unequal biconical antennas direct their maximum radiation to narrow space between two cone surfaces and provide wide base for support. The proposed antenna is suitable for modern wireless communications in L, S, C, X, Ku and K band frequencies.

Keywords: Biconical; wide band; loop; surface current.

**Corresponding author: E-mail: csr949@gmail.com;*

1. INTRODUCTION

For modern wirelesses communication wide band antennas are in demand. Antennas for VHF, UHF and UWB range have been well developed in recent times as identified in the literature. A wide range of microstrip antennas have been designed and reported for Ultra Wide Band (UWB) range. Antennas with wide band width for frequencies above UWB range are in demand for wireless communications. It is well known that antennas made with curved structure provide wide band width. A biconical antenna consists of two cones joined at the apex. An infinite biconical antenna provides wide band width as there are no reflections from the edges of its cones and the waves are traveling from source to the edges and there are no standing waves. But a finite biconical antenna is abruptly terminated at its edges and the current on the cones gets reflected from its edges and standing waves are formed that reduces its band width. An appropriate matching of the edges of the cones improves the band width of the biconical antenna. An expression for the radiation pattern from spherically capped conical antenna has been first proposed by C.H. Papas and R. King [1]. Conical antennas have been analyzed first by S. A. Schelkunoff. He proposed a finite biconical antenna enclosed in a sphere with the apexes of the cones at the center of a sphere [2]. He analyzed the radiation from the cones consisting of principal and complementary waves. Papas and R. King have analyzed a wide angle spherically capped biconical antenna for its input impedance properties [3]. It is reported that the input resistance produces damped oscillations around the characteristic resistance and similarly the input reactance starts at negative values and oscillates around zero ohms. S. S. Sandler and R.W.P. King have reported a spherically capped wide angle biconical antenna with wide band width up to 1 GHz. The edges of the cones are terminated in spherical caps with radius of 20 inches and the driving point impedance of the antenna for various heights and radii of the enclosing spherical cap are reported [2]. S.N. Samaddar and E.L. Mokole have reported the analysis of radiation properties of the biconical antenna of unequal cone angles of 106.2° and 140° [4].

It is proposed that the electric field vanishes on the terminating spherical cap and hence there is an improvement in the band width. The radiation pattern of electrically small wide-angle bicone is proportional to $\sin\theta$ and is same as that of a dipole and exhibits the capacitive impedance. It is reported that the input impedance and the radiated field for wide angle electrically small bicone depends on the cone angles of element [5]. Lu, et al. have presented top loaded biconical antenna for UWB indoor base station applications. But this antenna is complex to fabricate and is heavy. Radiation pattern and return loss characteristics exhibit oscillations [6]. Jacobs and others presented a truncated asymmetric conical dipole for wide band applications up to 17 GHz [7].

Biconical antennas were originally intended for use over the frequency range 20 MHz to 200 MHz. The first designs had a poor return loss, typically less than 4 dB over most of the frequency range. In present research a biconical antenna is developed with symmetric conical discs. To optimize the performances the design parameters such as the inner and outer radii of the cones are changed [8]. A tree-like biconical antenna with both conical and horizontal omni directional radiations is designed for UHF vehicle application. The antenna achieves both conical and horizontal omni directional radiations with the gains of 5–9 and 1.3–2.8 dBi over an impedance bandwidth of 41.1% from 560 to 850 MHz [9]. A compact symmetric discone antenna for the 3 GHz to 20 GHz frequency range is demonstrated. The antenna design is optimized for a good transient response with low angular dependency. Spherical mode analysis has successfully been applied in the design of an impulse radiating UWB antenna. Compared to a standard biconical antenna, the presented antenna shows far less frequency dependence of the radiation pattern [10]. A miniaturized biconical antenna loaded with two metal disks and cylinders is proposed for UWB application. By combining a biconical antenna and two magnetic dipoles, the antenna has wide impedance bandwidth from 200 to 965 MHz as well as stable radiation patterns and gain in the operating band [11].

In the paper the authors have proposed a new termination technique for the edges of the cones of the biconical antenna. The proposed technique enhances the band width and also simple as compared to the spherical cap termination technique.

2. DESIGN OF THE BICONICAL ANTENNA

The proposed antenna is designed considering 6 GHz as center frequency and the total height as half wave length equal to 25 mm. A circular ring of outer radius 12.5 mm which is equal to quarter wave length and thickness 1.5 mm is placed above the top cone and is fused to the cone top edge at a height of 13 mm. from the origin. Similarly the bottom cone angle is 120 degrees which corresponds to 21.55 mm radius. The terminating circular loop outer radius is also 21.55 mm and its thickness is 1.5 mm. the torus is placed at a height of -13mm and is fused to the bottom cone. The separation between the cones at the apices is 1 mm. After the fusion of the ring the edges of the cones are curved smoothly instead of sudden termination. All the design parameters are listed in the Table-1.

Table 1. Design parameters of the antenna

Parameter name	Dimensions (mm)
Upper radius of top cone	12.5
Bottom radius of top cone	0.9
Upper radius of bottom cone	0.9
Bottom radius of bottom cone	21.55
length of each cone	12.5
Separation between the cones	1
Outer radius of the terminating loop of top cone	12.5
Inner radius of the terminating loop top cone	10.5
Outer radius of the terminating loop of bottom cone	22
Inner radius of the terminating loop of bottom cone	20
Position of termination loop	±14.5
Cone Angle of top cone	90°
Cone Angle of bottom cone	120°

3. ANALYSIS OF THE ANTENNA

The current distribution on the cones of the antenna is mainly considered for analysis. The biconical antenna consists of two cones which are fed at the apices. Usually both the cones are of same in length and same cone angles. Such elements are equal cone angle antennas and have been analyzed and reported in the literature. Elements with two cones of different angles are also important in many applications especially for radiation in a narrow direction. Here the bottom cone is of wide angle than the top cone. It is established by earlier researchers that the radiation in a biconical antenna is confined to the space between the two cones. Ghosh and Sarkar have presented the radiation characteristics of spherically capped biconical antenna for wide band antennas [5]. It was reported that the surface current will be zero on the spherical cap which provides appropriate termination at its truncated edges.

3.1 The Structure of the Antenna

The surface current distributions on the cones with and without terminating loop at 6 GHz are shown in Fig. 1 and Fig. 2 respectively. Similarly the current distributions on the cones with and without edge termination at 25 GHz are shown in Fig. 3 and Fig. 4 respectively. S. N. Samaddar and E. L. Mokole have reported a spherically capped biconical antenna of unequal cone angles. The height of this antenna is 20 inches [3]. D. Ghosh and T. K. Sarkar have presented a spherically capped biconical antenna of height 5.6 cm with cone angles of 106° and 170° [4]. The proposed antenna in this paper is smallest in length 25 mm as compared to any other biconical element proposed earlier and the cone angle of upper cone is 90° and that of lower cone is 120°. The cone edges of both cones are terminated with a circular loop of thickness 1.5 mm.The outer radius of the circular loop is equal to the cone top radius and positioned at the top of the cone and fused to the top edge. Structurally this is simple than the spherical cap termination as it reduces weight. All design parameters are optimized to give wide band response. This proposed antenna is modeled in both CST and HFSS.

3.2 Surface Current

The current distribution on the surface of the cones is obtained by simulation of the element in CST at low and high frequencies such as 6 GHz and 25 GHz with and without the edge termination of the cones. The antenna is fed at the apices of the cones and the current at the apices of the cones is maximum and reduces to minimum gradually towards edges of the cones. Current on the cone surfaces without termination is not uniform and appears like irregular patches on the surface of the cones. This is due to sudden discontinuity at the edges and results in reflections from its edges. Whereas on the cone surface with termination the surface current appears uniform and follows regular paths. This is due to termination at the edges. The curved path at the end provides a smooth curved terminated path for the current and reduces reflections. Hence only traveling waves will exist. and this reduces the reflection coefficient and subsequently minimum return loss.

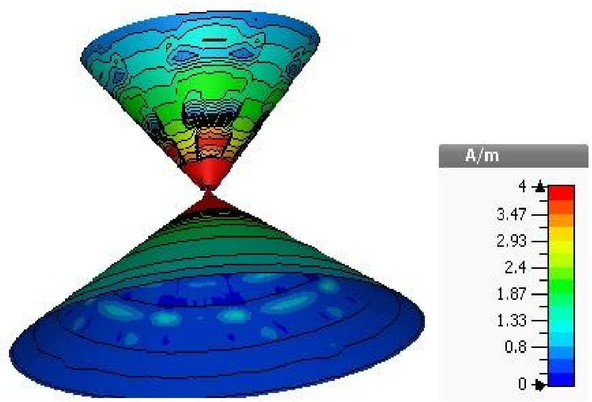

Fig. 1. Biconical Antenna without Edge Termination 6GHz

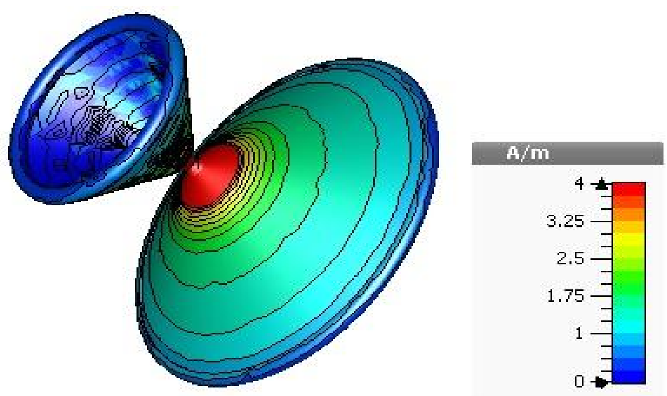

Fig. 2. Biconical Antenna with Edge Termination at 6GHz

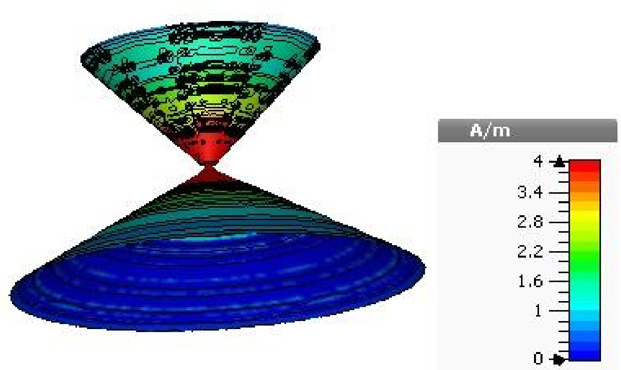

Fig. 3. Biconical Antenna without Edge Termination 25GHz

As we observe towards the edges the current density on the surface of the cones with edge termination appears to be uniform than perfect circular contours with gradually reduced amplitude values. On the terminating loop the current distribution is also uniform circular path. Each circular contour shows a particular amplitude value of the current density. Both the cones are of same length and the bottom cone is wide and the top one is small angle cone. Observing biconical antenna in Fig. 1 and Fig. 3 above current on top cone is non- uniform than on bottom cone even without termination and the reason is that the wide angle cones exhibit wide band width. The edge termination of the top cone shows much difference without termination for surface current. The current distribution on the cones without terminating loop is non-uniform. This antenna is modeled in CST and HFSS and is simulated using the same dimensions and the results are presented. Current is maximum at the apex of the cones in biconical antennas with and without edge termination. A finite biconical antenna is truncated at its edges abruptly and gives a sudden discontinuity for current flow. This results in reflections and formation of standing waves. As a result the antenna exhibits high reflection coefficient and subsequently high return loss.

3.3 Radiation Patterns

The three dimensional radiation patterns of the unequal cone angles are shown in Fig. 5 and Fig. 6 for frequencies 7 GHz and 25 GHz. The electromagnetic energy is concentrated in the space between the cones only. The pattern is omni directional in shape which is very useful in portable receiving systems. The respective two dimensional patterns in elevation plane simulated in CST and HFSS are shown in Fig. 7 and Fig. 8. It is observed that the radiation pattern is perfect omni directional from 1 GHz. The two dimensional patterns in horizontal plane are circular in shape and are omitted for brevity. The radiation pattern at 25 GHz exhibits ripples.

$$R(\theta,\omega)=\frac{E_{rad}^{\theta}(r,\theta,\omega)}{E_{rad}^{\theta}\left(r,\frac{\pi}{2},\omega\right)}=\frac{\sum_{n=1}^{\infty}\frac{i^{n-1}(2n+1)}{2n(n+1)}\frac{p^{1}(\cos\theta)g_n(\mu_1\mu_2)}{h_{n-1}^{(2)}(ka)-\frac{n}{ka}h_n^{(2)}(ka)}}{\sum_{n=1}^{\infty}\frac{i^{n-1}(2n+1)}{2n(n+1)}\frac{p^{1}(0)g_n(\mu_1\mu_2)}{h_{n-1}^{(2)}(ka)-\frac{n}{ka}h_n^{(2)}(ka)}} \tag{1}$$

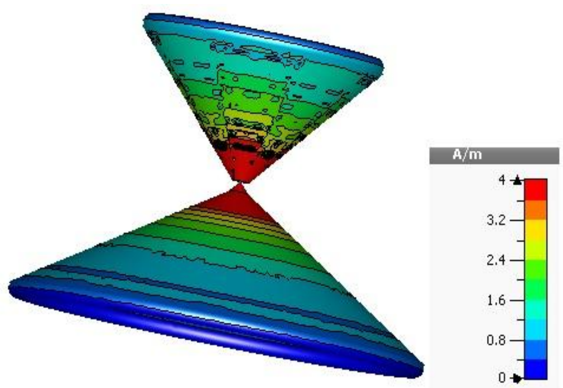

Fig. 4. Biconical Antenna with Edge Termination at 25GHz

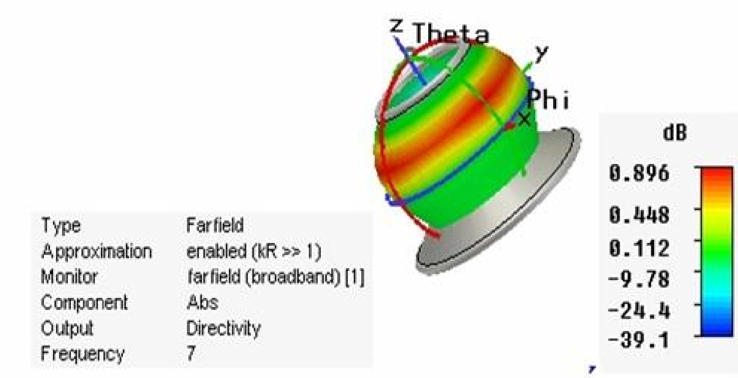

Fig. 5. Radiation Pattern 3D at 7GHz

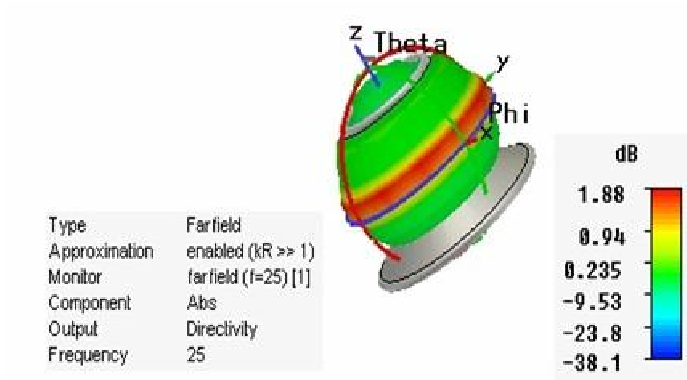

Fig. 6. Radiation Pattern 3D at 25GHz

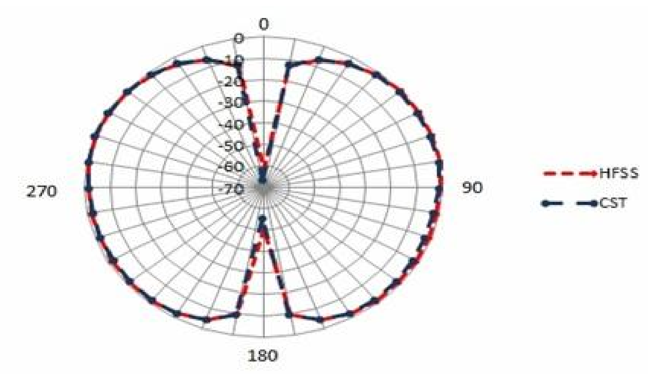

Fig. 7. Radiation Patten (Elevation) at 1 GHz

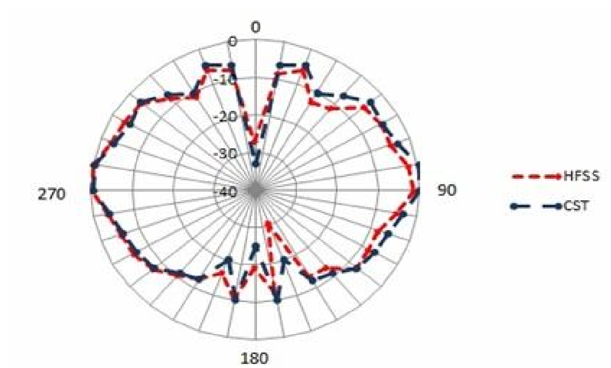

Fig. 8. Radiation Patten (Elevation) at 25 GHz

The Equation (1) shows the normalized radiation function of wide angle wide band biconical antenna. The E-plane pattern has been analyzed by Papas and King [1]. The expression for the normalized far-zone electric field at broad side is given in Equation (1). Where ‘k’ is the wave number and ‘a ‘is the height of the cone. μ_1 and μ_2 respectively the cone angles of upper and lower cones.

3.4 Return Loss

The band width of the antenna is determined by its return loss which depends on the reflection coefficient S_{11}. Reflection coefficient is negative and return loss is positive. The dimensions of the proposed antenna are optimized to realize the low return loss. Return loss for the biconical

Fig. 9. Frequency Vs .S- parameter without termination

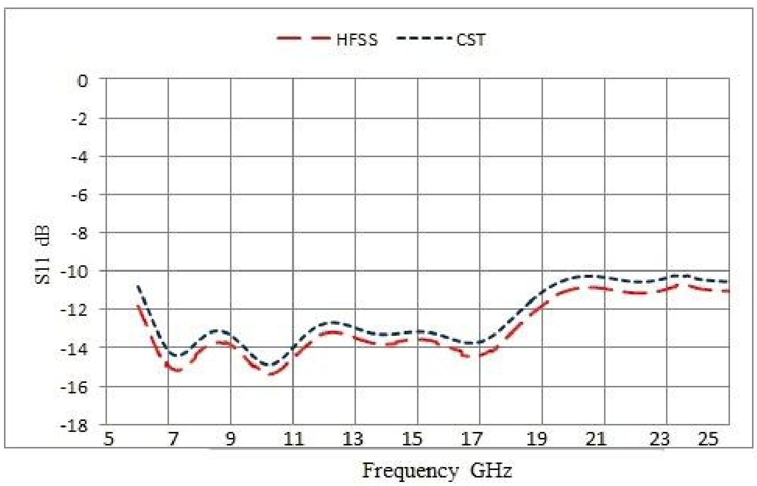

Fig. 10. Frequency Vs. S- parameter with termination

antenna has not been previously reported. At low frequencies this is not considered for analysis. But at microwave frequencies return loss must below 10 dB.

The reflection coefficients for biconical antenna with and without termination simulated in CST and HFSS are shown in Fig. 9 and Fig. 10 respectively. For many antennas the pattern band width will be wide but the return loss band width is limited. Reflection coefficient without termination shown in Fig. 9 is very high which is -0.025 dB at 5 GHz and -0.35 dB at 25 GHz. The corresponding return loss is also high. The reflection coefficient at 5 and 25 GHz is less than -10 dB.

Hence the corresponding return loss is also less than 10dB which is desired for any wide band antenna. For the antenna with terminated cones the reflection coefficient has reduced at each frequency to less than -10 dB. The reflection coefficient from 1 GHz to 5 GHz is around -5 dB which is not shown for brevity.

4. CONCLUSION

The proposed technique of terminating the edges of the cones of the biconical antenna has improved the band width of the unequal cone angle biconical antenna considerably. The simulated results of the reflection coefficient are less than -10 dB has extended the band width up to 20 GHz. The radiation pattern is omni directional from 1 GHz to 25 GHz except for the ripples of the pattern at high frequencies. This element is compact in size only 25 mm in length and is comparable to any microstrip antenna used today and is perfect fit for any portable device. This antenna provides coverage for C, X and Ku bands. If only radiation pattern band width is required then the proposed antenna covers L, S, C, X, Ku and K bands. The element is modeled and simulated in CST and HFSS to establish the performance for comparison. The results are coinciding without any major deviation. Hence the proposed element is compact and provides very wide band width.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Papas CH, King RWP. Radiation from wide-angle conical antennas fed by a coaxial line. Proc. IRE. 1951;39(1):49-51.
2. Schelkunoff SA. Theory of Antennas of Arbitrary size and Shape. Proceedings of the IEEE. 1964;72(9).
3. Sandler SS, King RWP. Compact conical antennas for wide-band coverage. IEEE Transactions on Antennas and Propagation. 1994;42(3).
4. Samaddar SN, Mokole EL. Biconical antennas with unequal cone angles. IEEE Transactions on Antennas and Propagation. 1998;46(2):181-193.
5. Ghosh D, Sarkar TK, Mokole EL. Design of a wide-angle biconical antenna for wideband communications. Progress in Electro magnetics Research B. 2009;16: 229-245.
6. Lu WJ, Weng YF, Cheung SW, Zhu HB. Compact top-loaded ultra wide band biconical antenna for indoor base-station applications. Microwave and Optical Technology Letters. 2010;52(11):2594-2598.
7. Jacobs OB, Odendaal JW, Joubert J. Analysis and design of a wide band omni directional antenna. Microwave and Optical Technology Letters. 2011;53(6):1352-1356.
8. Rakesh Kumar Yadav, Sushrut Das, Yadava RL. Parametric study of UWB biconical antenna for wide-band applications. Journal of Wireless Networking and Communications. 2012;2(5):117-125.
9. Zhang C, Liang X, et.al. An UHF tree-like biconical antenna with both conical and horizontal omni directional radiations. IEEE Antennas and Wireless Propagation Letters. 2015;14:187-189.
10. Narek Rostomyan, Arndt T. Ott, Marcel D. Blech, Robert Brem. A Balanced impulse radiating omni directional ultra wide band stacked biconical antenna. IEEE Transactions on Antennas and Propagation. 2015;63(1):59-68.
11. Shuai He, Lei Chang, Zhuang Zhi Chen. Design of a compact biconical antenna loaded with magnetic dipoles. IEEE Antennas and Wireless Propagation Letters. 2017;16:840-843.

Peer-review history:
The peer review history for this paper can be accessed here:
http://sciencedomain.org/review-history/20023