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# Design and Testing of Biconical Antenna

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***Abstract*—Major objective of this paper is to design, assemble, and test Biconical Antenna with the methods for measuring gain. These types of antennas are widely used for Electronic Support Measures (ESM) applications. An omni directional Biconical Antenna has been designed for the interception of electromagnetic waves in the frequency band of 0.5-18GHz.The omni directional pattern helps in achieving almost 360 degrees of azimuth coverage along with some degree of coverage in elevation plane. Such antenna can be used to ensure 100% probability of intercept (POI) of enemy targets.**

**Index Terms—Omni directional Antenna,Azimuth and Elevation plane, CST.**

## I. INTRODUCTION

Electronic Warfare (EW) is any action involving the use of the electromagnetic spectrum or directed energy to control the spectrum, attack of an enemy, or impede enemy assaults via the spectrum. In modern warfare, electronically guided weapon systems have a kill probability close to unity while command, control and communication systems ensure effective co-ordination of the available resources. This makes undefended vital installations easy targets for destruction. Improper operation of the electronic circuits would make the weapon system as well as the command, control and communication infrastructure totally ineffective. It is hence, seen that if counter-electronic systems are used to reduce the effectiveness of the electronic circuits, the end result of the battle could be different.

Effective use of Electronic Warfare is only possible if sufficient knowledge of the electronic equipment used by the enemy is available. BEL has the know-how for designing and developing Electronic Warfare Systems in the areas of Signal Intelligence, Electronic Counter Measure and Electronic Support Measure. EW is the science of manipulation and control of EM environment for its own survivability but denies or limits it to the adversary. EW technology extracts essential information from the EM environment. This information is then exploited to influence adversary's capability to coordinate its activities, to restrict its communication media, to deny the use of radar for weapon launching or guiding. EW enhances the survivability of own forces by denying the use of EM spectrum by the enemy. Armed forces use radar for both defensive and offensive weapon systems. Reflected RF echoes of the target, are used to measure target range, bearing and elevation and determine target location. Radar uses RF transmission ranging from high frequency (HF) to millimeter waves (30 MHz - 95 GHz). RF can be pulsed or continuous wave (CW). Radar function includes target detection, identification, acquisition, tracking and navigation. Radar extracts range, bearing and speed of a target. Radar information is used for launch and control of a weapon like missile, air defense gun etc. Modern advancements include Phase Array Antennas, Complex modulation on the radar pulse, Low probability of Intercept Radars, improved signal processing to extract data from highly corrupted echo signal etc.

### 1.1. Functionality Classification

EW is classified based on functionality into three groups.
(i).Electronic Support (ES)
(ii).Electronic Attack (EA)
(iii).Electronic Self Protection (EP).

**(i).Electronic Support (ES)**
ES also is known by ESM (Electronic Support Measure). ES involves search, intercept, locate, record and analyze radiated EM energy for the purpose of exploiting 'the radiation information either for formulating EOB (Electronic Order of Battle) or to provide the real time information to EA system. ES provides surveillance and warning information derived from intercepted EM environment emissions.

**(ii).Electronic Attack (EA)**
EA also is known name ECM (Electronic Counter Measure). EA involves action taken to prevent or reduce enemy's effective use of EM spectrum. It can be active like Jammers, or it can be passive like chaff.

**(iii).Electronic Self Protection (EP)**
EP also is known by old name ECCM (Electronic Counter Counter Measures). EP involves actions taken to ensure friendly use of EM spectrum despite the use of ECM. EP protects own platform against EA by the adversary.

## II.BICONICAL DIPOLES

Biconical dipoles are defined as two conical conductors that are symmetrical about an axis and vertex. An example of a biconical dipole can be seen in Figure 2.1.

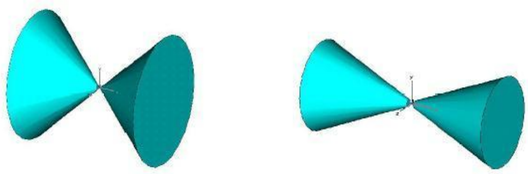


**Figure 2.1.Biconical Dipole**

Biconical dipoles are considered as a part of broadband dipole, being able to operate at a wide range of frequencies. The dipole feed is located at the center where both the cones meet. The antenna radiation pattern is similar to that of a regular dipole and the only real difference is the allowable bandwidth of this antenna is considerably higher than the dipole and can commonly achieve bandwidths of four to one . Sometimes these cones are made out of a solid metal conductor which can be heavy and costly.

## III. BICONICAL ANTENNA

A Biconical Antenna is a broad-bandwidth antenna made of two conical conductive objects, nearly touching at their vertices. Biconical antennas are broadband dipole antennas, typically exhibiting a bandwidth of three octaves or more. A common subtype is the bowtie antenna, essentially a two-dimensional version of the bi-conical design which is often used for short-range UHF television reception. These are also sometimes referred to as butterfly antennas. The biconical antenna has a broad bandwidth because it is an example of a travelling wave structure; the analysis for a theoretical infinite antenna resembles that of a transmission line. For an infinite antenna, the characteristic impedance at the point of connection is a function of the cone angle only and is independent of the frequency. Practical antennas have finite length and a definite resonant frequency. A simple conical monopole antenna is a wire approximation of the solid bi-conical antenna and has increased bandwidth (over a simple monopole).

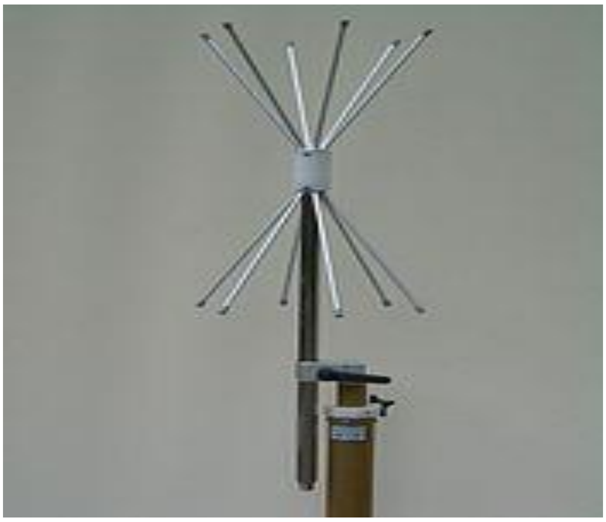


**Figure 3.1. Model Antenna**

Biconical (or "bicon") antennas are often used in Electro Magnetic Interference (EMI) testing either for immunity testing, or emissions testing. While the bi-con is very broadband, it exhibits poor efficiency at low frequencies, resulting in low field strengths when compared to the input power. Log periodic dipole arrays, Yagi-Uda antennas, and reverberation chambers have shown to achieve much higher field strengths for the power input than a simple bi-conical antenna in an anechoic chamber. However, reverberation chambers, especially, are poor choices when the goal is to fully characterize a modulated or impulse signal rather than merely measuring peak and average spectrum energy content.

## IV. DESIGN

### 4.1. Physical Description

A Bi-conical antenna has been designed and simulated to operate in 0.5-18 GHz frequency range with maximum VSWR 2.5:1 and Omni-directional pattern in Azimuth plane. The important parameters of a bi-conical antenna are cone angle (α), radius of the cone (r), gap between the cones (g) and the conical length (l). These parameters were taken as variables and optimized to obtain the desired results.

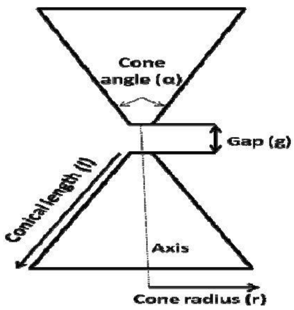



**Fig:4.1. Biconical Antenna Geometry**

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. The antenna shown in Figure is composed of two symmetric cone-like structures. The design parameter like outer and inner radius of the cone are 10cm and 0.51cm respectively, while the height of the cone is 6.5cm.There is a port between the two cone whose gap is 0.5cm and width is also 0.5cm.

| Parameter | Optimized value |
|---|---|
| Gap(g) | 2.5mm |
| Conical length(l) | 12cm |
| Cone outer radius(r) | 10cm |
| Angle(α) | $53^0$ |
| Cone Height (h) | 6.5cm |

**Table 4.1 Antenna Parameters**

The parameters like conical length(l) or cone angle (α) can be derived from each other if other parameters like cone height (h) and cone radius (r) are defined. Based on the trigonometry, a relationship between cone height (h), cone angle (α) and cone radius (r) is given as:

$$\tan(\alpha/2) = r/h$$

The other important design parameters have been optimized and their final values are given in Table for reference. Based on the optimized design parameters, a bi-conical antenna has been modelled in CST Microwave Studio. The modelled Bi-conical antenna is excited by a 50Ω coaxial connector. It shows that the two metallic cones are separated from each other with the help of connector dielectric which maintains the gap. The conic sections are hollow and have a thickness of 1 mm.

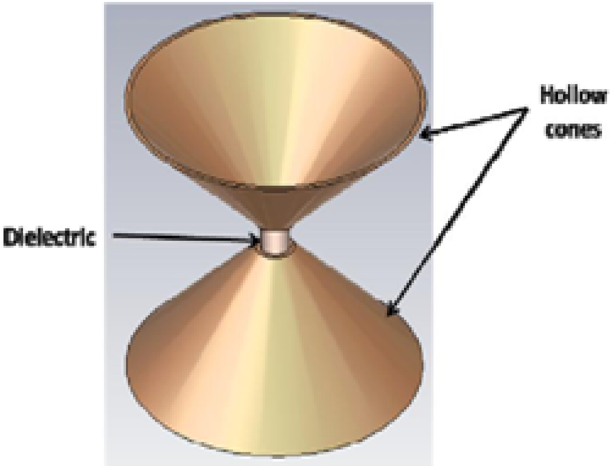



**Fig:4.2. Biconical Cones**

The modelled antenna has been analysed for obtaining the electrical performance parameters like return loss, VSWR, radiation Pattern and gain of the designed Bi-conical antenna.

## V. SIMULATION TECHNOLOGY

One approach is to discretize the space in terms of grids (both orthogonal, and non-orthogonal) and solving Maxwell's equations at each point in the grid. Discretization consumes computer memory, and solving the equations takes significant time. Large-scale Computational electromagnetics (CEM) problems face memory and CPU limitations. As of 2007, CEM problems require super computers, high performance clusters, vector processors or parallelism. Typical formulations involve either time-stepping through the equations over the whole domain for each time instant or through banded matrix inversion to calculate the weights of basis functions, when modeled by finite element methods or matrix products when using transfer matrix methods or calculating integrals when using method of moments or using fast fourier transforms, and time iterations when calculating by the split-step method or by business process modeling (BPM).Choosing the right technique for solving a problem is important, as choosing the wrong one can either result in incorrect results, or results which take excessively long to compute. However, the name of a technique does not always tell one how it is implemented, especially for commercial tools, which will often have more than one solver.

### 5.1. Method of Moments (MOM) or Boundary Element Method (BEM)

The method of moments or boundary element method is a numerical computational method of solving linear partial differential equations which have been formulated as integral equations (i.e. in boundary integral form). It can be applied in many areas of engineering and science including fluid mechanics, acoustics, electromagnetics, fracture mechanics, and plasticity.MOM has become more popular since the 1980s. Because it requires calculating only boundary values, rather than values throughout the space, it is significantly more efficient in terms of computational resources for problems with a small surface or volume ratio. Conceptually, it works by constructing a "mesh" over the modeled surface. However, for many problems, BEM is significantly computationally less efficient than volume-discretization methods (finite element method, finite difference method, finite volume method).

Boundary element formulations typically give rise to fully populated matrices. This means that the storage requirements and computational time will tend to grow according to the square of the problem size. By contrast, finite element matrices are typically banded (elements are only locally connected) and the storage requirements for the system matrices typically grow linearly with the problem size. Compression techniques (e.g. multi-pole expansions or adaptive cross approximation or hierarchical matrices) can be used to ameliorate these problems, though at the cost of added complexity and with a success-rate that depends heavily on the nature and geometry of the problem.BEM is applicable to problems for which Green's functions can be calculated. These usually involve fields in linear homogeneous media. This places considerable restrictions on the range and generality of problems suitable for boundary elements. Nonlinearities can be included in the formulation, although they generally introduce volume integrals which require the volume to be discretized before solution, removing an oft-cited advantage of BEM.

### 5.2. Finite-Difference Time-Domain (FDTD)

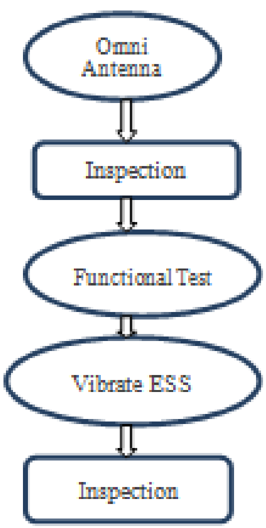
Finite-difference time-domain (FDTD) is a popular computational electromagnetic technique. It is easy to understand. It has an exceptionally simple implementation for a full wave solver. It is at least an order of magnitude less work to implement a basic FDTD solver than either an FEM or MOM solver. FDTD is the only technique where one person can realistically implement oneself in a reasonable time frame, but even then, this will be for a quite specific problem.

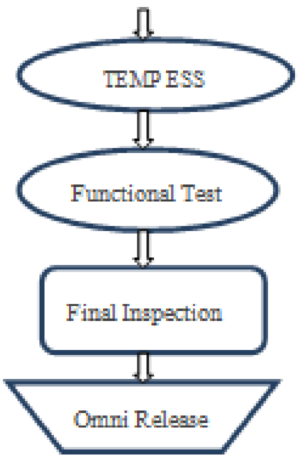
Since it is a time-domain method, solutions can cover a wide frequency range with a single simulation run, provided the time step is small enough to satisfy the Nyquist–Shannon sampling theorem for the desired highest frequency.FDTD belongs in the general class of grid-based differential time-domain numerical modeling methods. Maxwell's equations (in partial differential form) are modified to central-difference equations, discretized, and implemented in software. The equations are solved in a cyclic manner: the electric field is solved at a given instant in time, then the magnetic field is solved at the next instant in time, and the process is repeated over and over again.

### 5.3. Finite Element Method (FEM)

The Finite element method is used to find approximate solution of partial differential equations (PDE) and integral equations. The solution approach is based either on eliminating the time derivatives completely (steady state problems), or rendering the PDE into an equivalent ordinary differential equation, which is then solved using standard techniques such as finite differences, etc.In solving partial differential equations, the primary challenge is to create an equation which approximates the equation to be studied, but which is numerically stable, meaning that errors in the input data and intermediate calculations do not accumulate and destroy the meaning of the resulting output. There are many ways of doing this, with various advantages and disadvantages. The Finite Element Method is a good choice for solving partial differential equations over complex domains or when the desired precision varies over the entire domain. With the growing incidence of computer modeling and simulation, the scope of simulation domain must be extended to include much more than traditional optimization techniques. The most widely used optimization techniques that can be effectively integrated with a simulation model is described.

## VI.TEST SEQUENCE




**Flow Chart 6.1 Antenna testing Flowchart**

Antenna testing sequence refers to the testing of antennas in a sequential manner to ensure that the antenna meets specifications or simply to characterize it. The step by step testing process follows as shown in the figure 6.1. The need to perform antenna testing is to ensure quality and reliability is undisputed. The methods to achieve an efficient and capable screening process can employ many forms. The fault spectrum of modern electronic assemblies has shifted from component related defects to assembly related defects. The nature of environmental stress screening programs must ensure that they properly stimulate the types of defects that are expected to be found in production and in the field.

From many studies and the availability of stress screen equations, we are aware of the benefits of thermal cycling over all other forms of environmental stress. We are also aware of the need to subject the products in the screen to high thermal rates of change to quickly and cost effectively stimulates latent defects to patent defects. In addition, the combined environments of thermal cycling with random vibration provide the highest probability of precipitating the most common defect types. To minimize facility costs and operating costs, the use of two zone air-to-air chambers are an attractive choice for average rates of change between 20°C/minute to 30°C/minute. Performing power cycling during the thermal screen allows additional fault modes to be exercised and is more effective than performing the same screens in tandem.

## VII.RESULTS

### 7.1. Gain Measurement

The gain of antenna can be known using the formula. Gain of Antenna Under Test (AUT) = Power radiated by AUT - Isotropic radiated power. Isotropic radiated power is the difference between power of standard horn antenna and gain of standard horn antenna. Gain Calculation of Antenna for Different Frequencies.

| Frequency (GHz) | Std Horn Pr H(dB) | Antenna Under Test Pr A(dB) | Difference Pr Level Pr H-Pr A | Std Horn Gain (dBi) | Gain A.U.T (dBi) |
|---|---|---|---|---|---|
| | B | A | A-B | C | (A-B)+C |
| 0.5 | -39.86 | -55.5 | -15.64 | 5.6 | -10.04 |
| 1 | -39.3 | -53.39 | -14.09 | 9.7 | -4.39 |
| 2 | -36.25 | -53.25 | -17 | 15.62 | -1.38 |
| 3 | -38.06 | -53.65 | -15.59 | 18.04 | 2.45 |
| 4 | -38.22 | -51.54 | -13.32 | 17.2 | 3.88 |
| 5 | -38.34 | -53.57 | -15.23 | 18.72 | 3.49 |
| 6 | -3.03 | 19.73 | -16.7 | 21.82 | 5.12 |
| 7 | -1.71 | -18.62 | -16.91 | 22.46 | 5.55 |
| 8 | -1.66 | -17.93 | -16.27 | 22.78 | 6.51 |
| 9 | -6.11 | -22.62 | -16.51 | 21.9 | 5.39 |
| 10 | -4.26 | -21.01 | -16.75 | 22.3 | 5.55 |
| 11 | -5.2 | -22.15 | -16.95 | 22.6 | 5.65 |
| 12 | -8.4 | -24.76 | -16.36 | 22.8 | 6.44 |
| 13 | -9.47 | -28.61 | -19.14 | 23.75 | 4.61 |
| 14 | -9.7 | -29.49 | -19.79 | 24.15 | 4.36 |
| 15 | -9.04 | -26.33 | -17.29 | 24.46 | 7.17 |
| 16 | -11.11 | -28.85 | -17.74 | 24.2 | 6.98 |
| 17 | -14.81 | -34.35 | -19.54 | 24.9 | 5.36 |
| 18 | -18.07 | -36.41 | -18.34 | 25 | 6.66 |

**Table 7.1 Gain Measurements**

Pr H – power radiated by horn antenna

Pr A – power radiated by Antenna Under Test

AUT- Antenna Under Test.

**VIII.CONCLUSION**

In this paper, Biconical Antenna design and testing sequence is proposed. The antenna consists of two conical conductive objects, nearly touching at their vertices. The proposed antenna is designed in Electromagnetic Simulation software CST Studio suite. After simulation antenna gain is observed to be -10.04dBi at 0.5GHz and 6.66dBi at 18GHZ.Wide band performance is the other characteristic of this new antenna with return loss less than 13 dB.

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