A SPHERICALLY-CAPPED DISCONE ANTENNA FOR ULTRA-WIDEBAND OPERATION

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ABSTRACT

The wide-angle discone antenna terminated by a truncated spherical cap is investigated. The antenna is simulated in both the time and the frequency domains. The radiation pattern has been observed for various values of ka signifying all the ranges of operation of the antenna. It is seen that for large values of ka the radiation pattern is limited within an angular sector determined by the cone angles of the bicone. The transient radiated and received responses of the antenna for wideband operation have been obtained. The waveshapes of the transient fields bear a certain relationship with the shape of the input pulse.

1. INTRODUCTION

This paper analyzes the wide angle discone antenna terminated by a truncated spherical cap. This antenna is suitable for operation over a wide band of frequencies. The truncated spherical cap reduces the reflections from the antenna structure by preventing the sudden termination of the cones. The biconical antenna has been previously analyzed by Schelkunoff [1], Smith [2], Papas and King [3-4], and more recently by Sandler and King [5] and Samaddar and Mokole [6]. Various exact and approximate analytical expressions for the driving impedance, the effective height and the radiated field of the bicone have been derived in ref. [1-6]. In this paper the biconical antenna has been modeled and simulated in frequency domain using a program that utilizes the Electric Field Integral Equation (EFIE) to evaluate the currents on the structures [7]. The antenna structure is shown in Fig 1. It is axially symmetric and it has wide cone angles with the half cone angle exceeding $40°$. The half cone angles of ψ_1 and ψ_2 satisfy $0 < \psi_1 < \pi/2$ and $0 < \psi_2 \le \pi - \psi_1$. The cones are excited symmetrically at the apices. In this paper the bicone is considered to have $\psi_1 = 53.1°$ and $\psi_2 = 90°$ as in Fig 2.

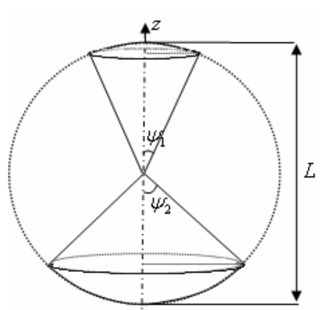

Fig 1. Model of Spherically-Capped Biconical Antenna

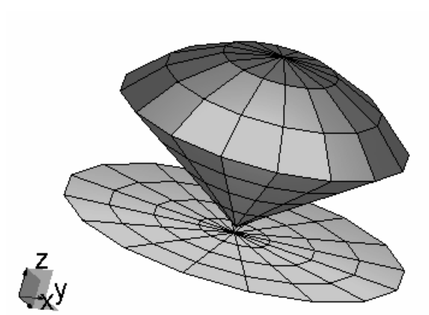

Fig 2. Structure of the Spherically-Capped Discone Antenna

2. RADIATION PATTERNS OF DISCONE ANTENNA

A bicone with $\psi_1 = 53.1^\circ$ and $\psi_2 = 90^\circ$ and a total length of 0.112 m is shown in Fig 2. This is a special case of unequal cone angles of the spherically-capped bicone antenna. So this antenna is similar to a discone antenna with spherical caps. The antenna has a feed wire of length 4 mm and radius 0.1 mm connecting the tips of the two cones. The antenna is excited symmetrically through the feed wire. Due to azimuthal symmetry of the structure one needs two dimensions only for representing the radiation pattern.

The radiation pattern of the antenna for different values of ka is shown in Fig 3. Two dotted lines are shown in Fig 3, one of which represents the angular value of $\psi_1 = 53.1^\circ$ whereas the other represents $\psi_2 = 90^\circ$, the angles being measured from the vertical axis of the structure as shown in Fig 1. In the case of an electrically small structure where $ka \ll 1$ the pattern is similar to that of a short dipole pattern approximated by $\sin\theta$ as shown in Figs 3a. As ka increases the radiation pattern is limited within an angular area determined by the two dotted lines representing the two conical edges of the antenna. These simulations verify the statement in [6] that for $ka \gg 1$ most of the energy is concentrated in the triangular area outlined by the cone angles of the bicone. In this case all the energy is concentrated in the upper half of the plane for $ka \gg 1$ as shown in Fig 3c.

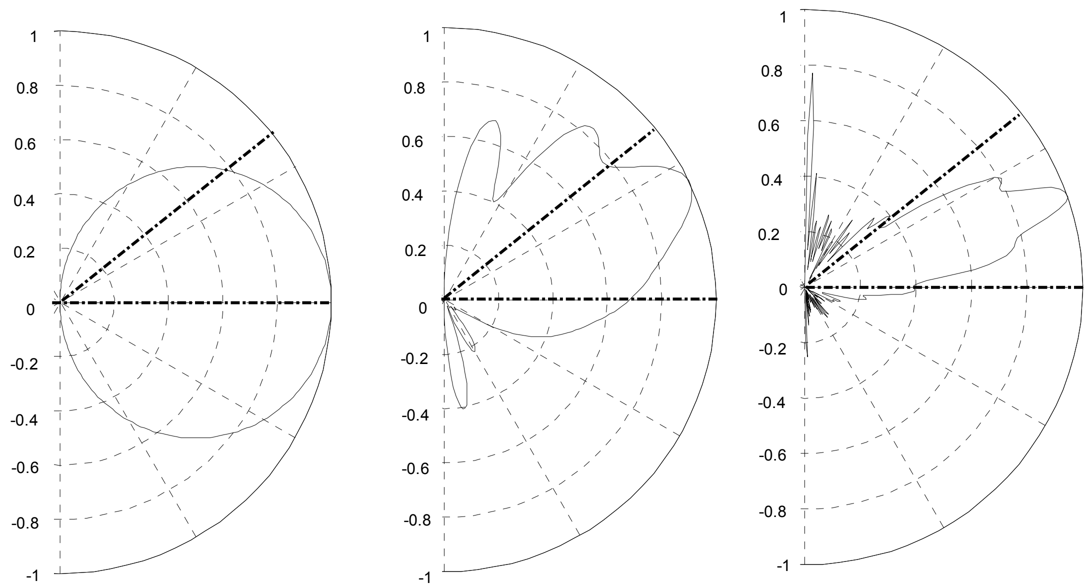

Fig 3a. $ka = 0.0106$ Fig 3d. $ka = 10.6395$ Fig 3e. $ka = 60.99$

Fig 3. The Normalized E-plane Radiation Pattern for Different Values of ka for a Spherically-Capped Discone Antenna

3. TRANSIENT RADIATED AND RECEIVED FIELDS OF A DISCONE ANTENNA

Next we obtain the transient radiated and received fields of the antenna. The antenna is simulated over a very wide band of frequencies ranging from 300MHz to 26GHz such that the antenna is suitable for ultra wideband operation. We consider the input pulse as a monocycle pulse given by

$$\vec{E}^{inc}(t) = \vec{u}_i \frac{E_0}{\sigma\sqrt{\pi}} \frac{d}{dt}\left\{\exp\left(-\frac{\left(t - t_0 - \vec{r}\bullet\vec{k}\right)^2}{\sigma^2}\right)\right\},$$

where $\vec{u}_i$ is the unit vector that defines the polarization of the incoming plane wave, E_0 is the amplitude of the incoming wave (chosen to be 377 V/m), σ controls the width of the pulse, t_0 is the delay that is used to ensure the pulse rises smoothly from 0 at the initial time to its value at time t, $\vec{r}$ is the position of an arbitrary point in space, and $\vec{k}$ is the unit wave vector defining the direction of arrival of the incident pulse. The usefulness of the monocycle pulse is evident from the paper by Ghosh, et al [8] where the monocycle has been successfully used as input to various UWB antennas.

The radiated field is shown in Fig 4a and when the bicone is used as receiver the induced current is shown in Fig 4b. The radiation pattern of an electrically large biconical antenna is very similar to that of a long dipole antenna. In the case of an infinitely long antenna, the transmit transfer function is almost flat with respect to frequency [9]. So if the antenna is an approximation to an infinitely long antenna, the radiated field should be a close replica of the driving point voltage. Again Kanda has shown that the transmitting transient response is proportional to the time derivative of the receiving transient response [10]. So, it follows that the induced current will be an integral of the incident field. This statement is verified by Fig 4a where the radiated field is a close replica of the monocycle input voltage and by Fig 4b where the received field is an integral of the monocycle incident wave.

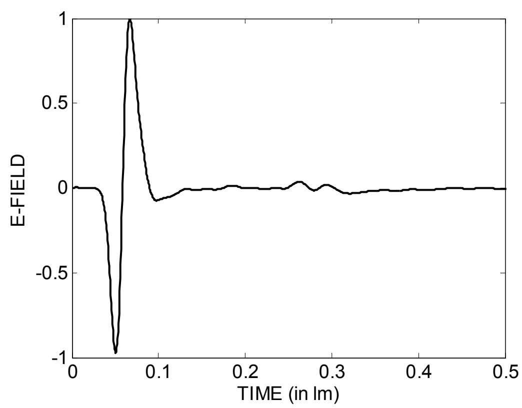

Fig 4a. Radiated Field for a Bicone Antenna

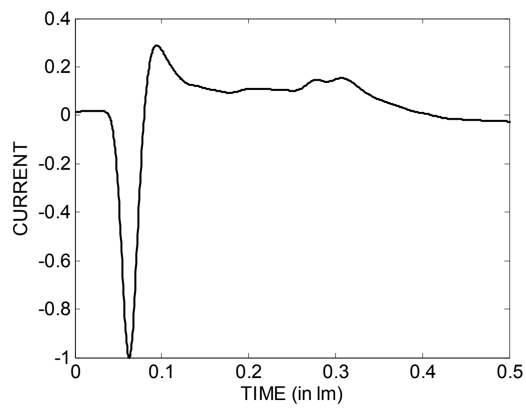

Fig 4b. Received Field on a Bicone Antenna

But the radiated field also contains reflections due to finite nature of the antenna as evident by the presence of a reflected pulse at around 0.26 lm in Fig 4. It should be noted that as the length of the antenna is 0.112 m, the reflected pulse should arrive after approximately $\left(2\times 0.112\right) = 0.224$ lm after the input pulse which has a delay of 0.0575 lm. In many UWB applications, it is desired that the antennas radiate most of the energy along the direction where the pulse is most similar to the exciting waveform or its derivative. For achieving this we need to reduce the dispersion from the antennas. Loading the antenna with a predetermined resistive profile reduces the dispersion from the antenna. Application of the loading profile on the bicone antenna has been illustrated in [8].

4. CONCLUSIONS

The spherically capped discone antenna has been studied in this paper. An investigation of the radiation pattern of the antenna shows that for $ka \ll 1$ the radiation pattern can be approximated by $\sin\theta$ whereas for $ka \gg 1$ the pattern lies within an angular area determined by the cone angles of the antenna. Thus we can limit the radiation energy in the upper half of the E-plane within an angular region of 36.9° by choosing $\psi_1 = 53.1°$ and $\psi_2 = 90°$. The transient response of the antenna has also been investigated for both radiation and reception. Observation of the output wave shapes from the antennas gives us important information about their transmitting and receiving properties and relationships are obtained between the input and output wave shapes.

5. REFERENCES

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