NOVEL ULTRA-WIDEBAND DISCONE ANTENNA

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ABSTRACT: A double-discone antenna for an ultra-wideband frequency scan is presented. An exquisite assembly of two inverse-feeding discone antennas shows a 30:1 broad bandwidth with VSWR below 2.5 and an omnidirectional radiation pattern. These features make the proposed antenna very suitable for both the UWB system antenna and the wideband scan antenna. © 2004 Wiley Periodicals, Inc. Microwave Opt Technol Lett 42: 113–115, 2004; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.20224

Key words: discone antenna; ultra-wideband

1. INTRODUCTION

A discone antenna is usually used to monitor the wide-frequency band. Generally, the discone antenna shows a 1:8 (low-cutoff frequency: high-cutoff frequency) bandwidth ratio for the UHF band. The critical matching factor for broad bandwidth is the gap height between the disk and the cone skirt. Another factor is disk size. If the finite size of the disk is three times larger than the discone’s skirt length, then the ground-plane dimension of the tear-drop antenna affects not only the bandwidth but also the antenna’s radiation pattern [1]. However, in the case of a fixed disk radius, the low cutoff frequency depends on the discone’s skirt dimension of a quarter wavelength ($\lambda/4$). Also, the high-frequency limit is due to fixing the face of an adaptor for coaxial feeding, and, as a result, the antenna skirt’s apex must be truncated. The truncated section width $W$ in Figure 1(a) is inversely proportional to the bandwidth of the discone antenna [2]. Such a discone antenna’s feeding structure can be overcome by using a small ball-type skirt without any truncation to create the tear-drop antenna [3]. However, the tear-drop antenna is used for the high-frequency band above 2 GHz because of the weight and dimension of the conical ball. Another untruncated structure is the skeletal biconical antenna. The skeletal biconical antennas for EMC applications are fed by a balun without any truncation of the cone’s apex [4]. However, if the structure is applied to the discone antenna, the dimensional advantage will vanish. So, we need to consider utilizing the unavoidable truncation of the feeding part of cone. This paper presents the design and realization of a new type of discone antenna (the double-discone antenna), which shows ultra-wideband frequency characteristics and utilizes two discone shapes.

2. DESIGN AND OPTIMIZATION OF THE DOUBLE-DISCONE ANTENNA

In order to utilize the upper flat region causing the frequency-bandwidth limitation, we consider the other discone antenna with a higher-frequency band. Then, the two antennas are united upside down with a shared feeding point. The proposed antenna consists of two different dimensional discone antennas, with opposite feeding directions. The conventional large-discone antenna is designed to cover from 300 MHz to 2.4 GHz, as shown in Figure 1(a), while the small-discone antenna’s skirt angle $\Phi$ and height $h_1$ are optimized to cover the high-frequency area from 2.4 to 9 GHz [Fig. 1(b)]. In Figure 1(c), the optimized dimensions of the large discone antenna are the skirt’s angle $\theta = 30^\circ$, the 230-mm height (about $\lambda/4$ at 300 MHz), and the disk radius $D = 145$ mm. For the small discone antenna, the radius $W/2$, which becomes the small discone antenna’s disk radius, is fixed at 35 mm. The reversed small discone antenna’s skirt angle $\Phi$ and height $h_1$ are tuned to maximize the bandwidth ratio and gain. From the optimized result using the computer simulation, good performance is obtained at the angle $\Phi = 50^\circ$ and height $h_1 = 25$ mm. The small discone antenna’s skirt and the large one’s disk are placed by a nut that does not affect the antenna’s electric performance. The feed cable...
is a coaxial line, and the coaxial line is joined to the small discone’s skirt by a coaxial jack adaptor. Figure 1(c) shows that the conventional discone and small discone antennas are reversely connected to each other.

### 3. THE EXPERIMENTAL RESULTS

This proposed antenna is designed by using a commercial program based on the FEM method and measured using an Agilent 8510C Network Analyzer. The parameters of the proposed antenna are described in Figure 1(c), and the optimized parameters of this antenna are listed in Table 1. The geometric dimensions are: overall height 260 mm, lower cone’s base radius 172.5 mm, $\theta = 30^\circ$, small discone skirt angle $\Phi = 50^\circ$, and disk radius 145 mm.

Figure 2 shows the measured and simulated VSWR. As shown in Figure 2, the calculated and measured VSWR patterns seem to be in good agreement with each other. But, there are some discrepancies between these results, due to mechanical inaccuracies and the feeding problem from the jack adaptor, which were not considered in the simulation. This antenna shows a 30:1 bandwidth from 282 MHz to 8.93 GHz (VSWR < 2.5). The radiation patterns of the measured and simulated results are shown in Figure 3, at 0.5, 2, and 5 GHz, respectively, and good agreement is found between both results. This antenna radiates maximum power in the direction from 100° to 140°. A three-antenna technique is used to measure the radiation gain. The simulated and measured gains are shown in Figure 4. The measured-gain error is within ±0.5-dBi accuracy. The small discrepancies between the simulated and measured gains are due to the dielectric loss and the inexactness calculated feeding structure.

### 4. CONCLUSION

This paper has demonstrated the double-discone antenna, which is reversely connected with two different discone antennas within a single discone-antenna dimension. The performances were validated by the measured results of the prototype. This structure exhibited an omnidirectional radiation pattern, 30:1 bandwidth,
ABSTRACT: A new coaxial waveguide-port algorithm is developed and tested for the time-domain finite-element method. The electric field is modeled by edge elements and, for part of a coaxial cable or a similar transmission line, the full Maxwell’s equations are reduced to the one-dimensional transmission-line equation through the use of macro elements, which represent the dominant waveguide mode. The port algorithm converges quadratically with the cell size for geometries with smooth boundaries, which is demonstrated by tests on a coaxial cable with a short-circuit termination. The port algorithm is proven to be stable up to the Courant limit of the explicit scheme used for the transmission-line equation, without any added artificial dissipation. The proposed port algorithm preserves, by construction, the reciprocity of Maxwell’s equations. For a $2 \times 2$ array of patch antennas, computation of the coupling of the antenna elements demonstrates that the scattering matrix is symmetric or, equivalently, that the proposed algorithm preserves reciprocity. © 2004 Wiley Periodicals, Inc. Microwave Opt Technol Lett 42: 115–119, 2004; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.20225

Key words: waveguide port; finite-element method; finite-difference time-domain; stability; explicit-implicit time stepping

1. INTRODUCTION

Coaxial cables and similar transmission lines are widely used in microwave applications. Numerical treatment of devices fed by coaxial cables (for example) is challenging and the difficulties stem mainly from the large differences in the length scales involved. The cross section of the coaxial cable has relatively small dimensions compared to the waveguide wavelength, the typical size of the driven apparatus, and the free-space wavelength. To provide a challenging example, an accurate computation of the input impedance of wideband antennas often requires a precise and detailed model of the entire feeding structure. For such problems, time-domain computations are particularly attractive, since one simulation provides the response in a broad frequency band.

The finite-difference time-domain (FDTD) scheme [1, 2] is very popular for computational analysis of microwave devices in the time domain. A number of reduced FDTD models have been developed for coaxial cables; one approach involves voltage-gap sources [3–6]. An alternative solution is to use an aperture field [6], which can be interpreted as a magnetic frill. Maloney, Shlager, and Smith [7, 8] coupled a voltage-gap source, placed at the feeding point in the three-dimensional FDTD grid, to a one-dimensional FDTD discretization of the transmission line equation for the transverse electromagnetic mode of the coaxial cable. Further, a body-of-revolution formulation of the FDTD scheme applied to a monopole on a ground plane was used by Maloney, Smith, and Scott [9] to discretize (in detail) a part of the coaxial cable, which was truncated by a boundary condition for the dominant mode. Hertel and Smith [10] compared the most common FDTD feed models using convergence studies. The finite-element method (FEM) allows for local mesh refinement, which is appropriate for small features of feeding structures (see [11] for an account of the FEM). However, port algorithms for the FEM are typically formulated for computations in the frequency domain (see [11] for a compilation of techniques and [12, 13] for examples of port algorithms based on the dominant waveguide mode).

In this paper, we develop a coaxial waveguide port algorithm for accurate and broad frequency-band analysis by the time-domain FEM. The proposed technique allows for an accurate and unbiased three-dimensional representation of the entire feeding structure, including the part of the transmission line where higher-order waveguide modes are expected. We apply Galerkin’s method to the self-adjoint Maxwell’s equations, where the electric field is modeled by the curl-conforming edge elements [14]. For the part of the coaxial cable where higher-order modes can be neglected, the port algorithm uses macro elements to restrict the fully three-dimensional representation of the electric field to a one-dimensional voltage wave governed by the transmission-line equation. We rigorously prove that the proposed scheme is stable up to the Courant condition of the explicitly time-stepped transmission-line equation, which is combined temporally with implicit time stepping for the finite elements used for the three-dimensional field representation. Altogether, the development of the proposed coaxial waveguide-port algorithm conforms with the construction of