All-Band 2G+3G Radial Disc-Cone Antennas: Design, Construction and Measurements

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Abstract

We define as "All-Band 2G+3G" any band that includes all frequencies allocated to both 2G and 3G services. We define as "Radial Disc-Cone Antenna RDCA" any discone antenna with a structure of radial wires. The RDCA was theoretically analyzed and software simulated with the purpose of computationally design a broadband model of it. As an application, a broadband RDCA for operation from 800 to 3,000 MHz, which include all 2G and 3G frequencies, was designed and an experimental model was constructed and tested. In order to evaluate the agreement between theory and practice, mathematically expressed measurement error bounds were computed.

Introduction

In 1945, Kandoian invented the well-known discone antenna, that is a dipole made of a disc above a cone [1]. In 1953, Nail gave experimentally two naive relations for the discone dimensions [2].

In 1987, Rappaport designed discones using an N-type connector feed [3]. In 1993, Cooke studied a discone with a structure of radial wires [4]. In 2005, Kim et al. presented a double radial discone antenna for Ultra Wide-Band applications [5].

In this short paper we present an All-Band 2G+3G RDCA fed by an N—type/Female/50—Ohm connector.

Research

The RDCA was theoretically analyzed as a group of identical filamentary V-dipoles with unequal arms connected in parallel. The dipoles recline on equiangular vertical phi-planes around z-axis to form a disconical array. Fig.1A shows two such coplanar dipoles conformed with the apex angle a. Each V-dipole has a total length L equal to the sum of arm lengths r and s plus the gap g between its terminals.

The simulation was based on a suite of developed visual tools which are supported by a fully analyzed, corrected and redeveloped edition of the original thin-wire computer program by J.H. Richmond [6].

Two arithmetic criteria were adopted for the broadband characterization of a model:

(1) 50-Ohm VSWR lower than 2

(2) Normalized radiation intensity U/Umax lower than 3 dB on the horizontal plane.

A visual application program was specifically developed to design a broadband radial discone with bare wires of diameter d embedded in free space when the wire conductivity, the type of feeding connector and the frequency band are given.

The program uses the model of a radial discone fed by an N-type connector shown in Fig.2. Starting with an appropriate combination of the relations given by [2]-[4] the program computes by iteration in terms of wavelength λ, the geometric characteristics r, s, g, a, of the broadband model, just when the criteria are satisfied.

Fig.1B shows a Ground Plane Antenna GPA that was designed for reference and consists of equal number of cone radials s and a vertical monopole with height r.

As a practical application of the broadband design, the 2G+3G band from 800 to 2,500 MHz was selected to begin with and an experimental radial discone of copper wire fed by N-type connector was built, as shown in Fig.3.

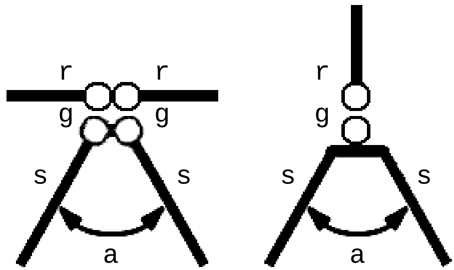

Fig.1: A — RDCA, B — GPA

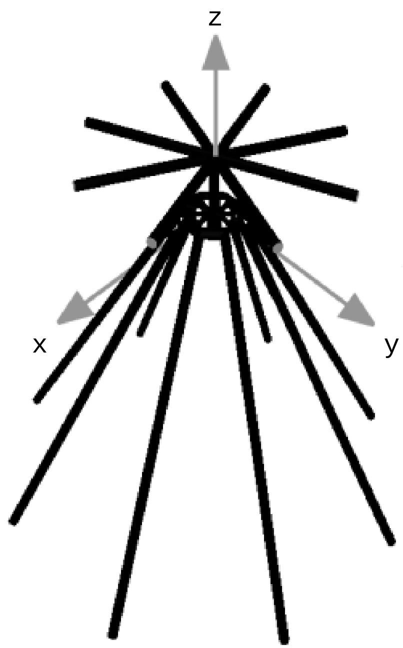

Fig.2: RDCA — Designed Model

In order to demonstrate the particular behavior of the experimental model, the 2G+3G band was divided as follows:

2G+3G Sub-Bands
800 MHz — 2,500 MHz

Sub-Band	MHz
I	806 — 960
II	1,429 — 1,513
III	1,710 — 1,900
IV	1,910 — 2,025
V	2,110 — 2,170
VI	2,400 — 2,499

Our measurement system consists of an EM anechoic chamber, a network analyzer, a number of support instruments, a set of standard loads of factory accuracy and a constructed antenna rotation mechanism with a built hardware control unit of its step motor. The combined characteristics of system parts specify a measurement band from 600 to 1300 MHz, which overlaps with the 2G+3G band. Developed control software synchronizes the system and collects data using the IEEE-488 protocol.

A developed general mathematical method expresses the measurement error bounds. Another set of developed software applications processes the collected data and computes the error bounds.

Results

The consideration of radial discone as an array of at least eight 8 V-dipoles produces a theta-polarized vector radiation pattern with magnitude a surface almost by revolution around z-axis. So the radial discone has indeed on the horizontal plane xOy the basic properties of a vertically polarized almost omni-directional antenna, that is a fact that encouraged the design of a broadband model by using simulation.

The application of the broadband criteria to 2G+3G band resulted to the design of a RDCA with the following geometrical characteristics:

All-Band 2G+3G RDCA
800 MHz — 3,000 MHz

Geometry		Units
d	1.5	[mm]
r	44	[mm]
g	6	[mm]
s	125	[mm]
a	60	[°]

The RDCA operates from 800 to 3,000 MHz, which exceeds that of 2G+3G band. The accordingly constructed experimental radial discone of Fig.3 should be implied with a constructional tolerance of ±0.5 mm and ±0.5°.

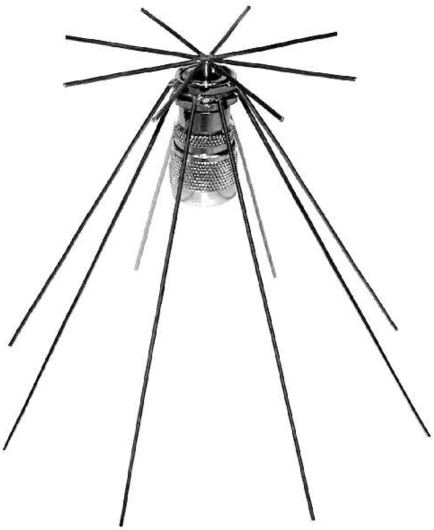

Fig.3: RDCA experimental model

The broadband model has a directivity from about –0.5 to 2.9 dBd with slope angle between –65° and +58°, but the directivity gain on horizontal plane stays very close to the desirable value of 0 dBi, since it changes from –1 to +1.7 dBi only. Fig.4 shows that the predicted horizontal normalized radiation intensity remains below 3 dB indeed, while it stays above 0 dB relative to the reference antenna in all 2G+3G subbands indicated by the vertical gray strips, when both are fed by the same 50-Ohm source.

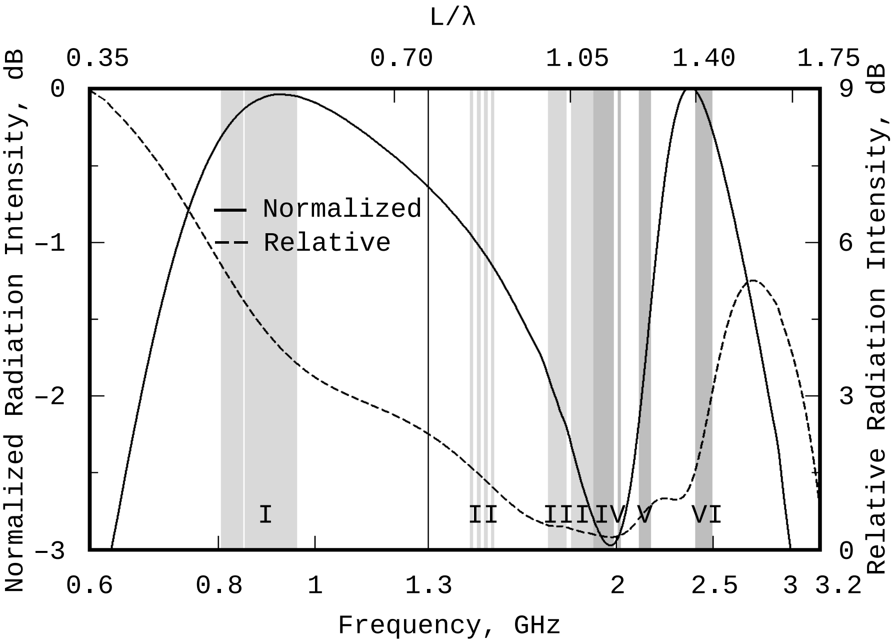

Fig.4: Predicted radiation intensity on horizontal plane.

Fig.5A shows the predicted normalized radiation patterns in dB at the center of each sub-band, which confirms the horizontal omni-directional radiation properties of the broadband model.

At the center frequency of 950 MHz of the measurement band, the predicted and measured radiation intensity on the three main cuts of the radiation pattern are in good agreement, as shown in Fig. 5B.

This is made clearer by the measurement error bounds on a vertical plane as shown in Fig.6.

Fig.7 shows that the 50-Ohm VSWR predicted results for the broadband discone are below 2 indeed and almost covered by the error bounds in the measurement band.

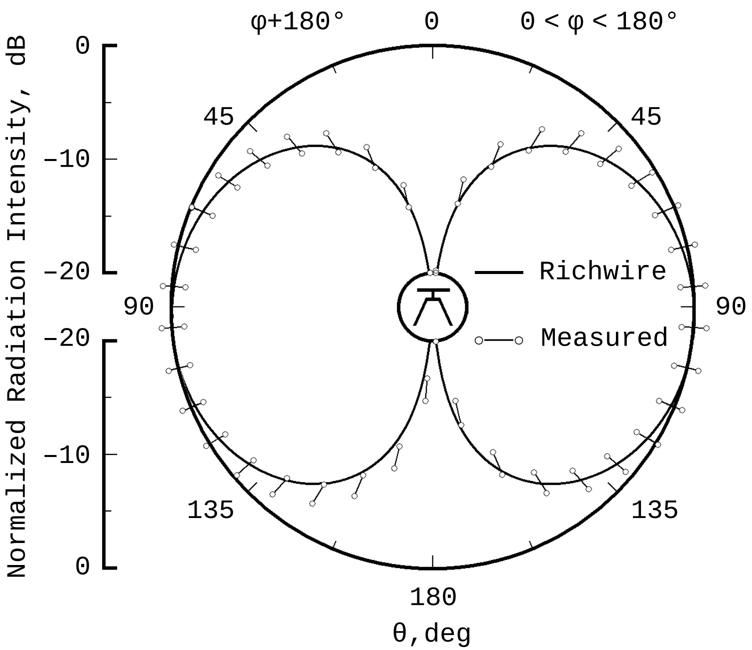

Fig.6: Measurement error bounds on a vertical plane

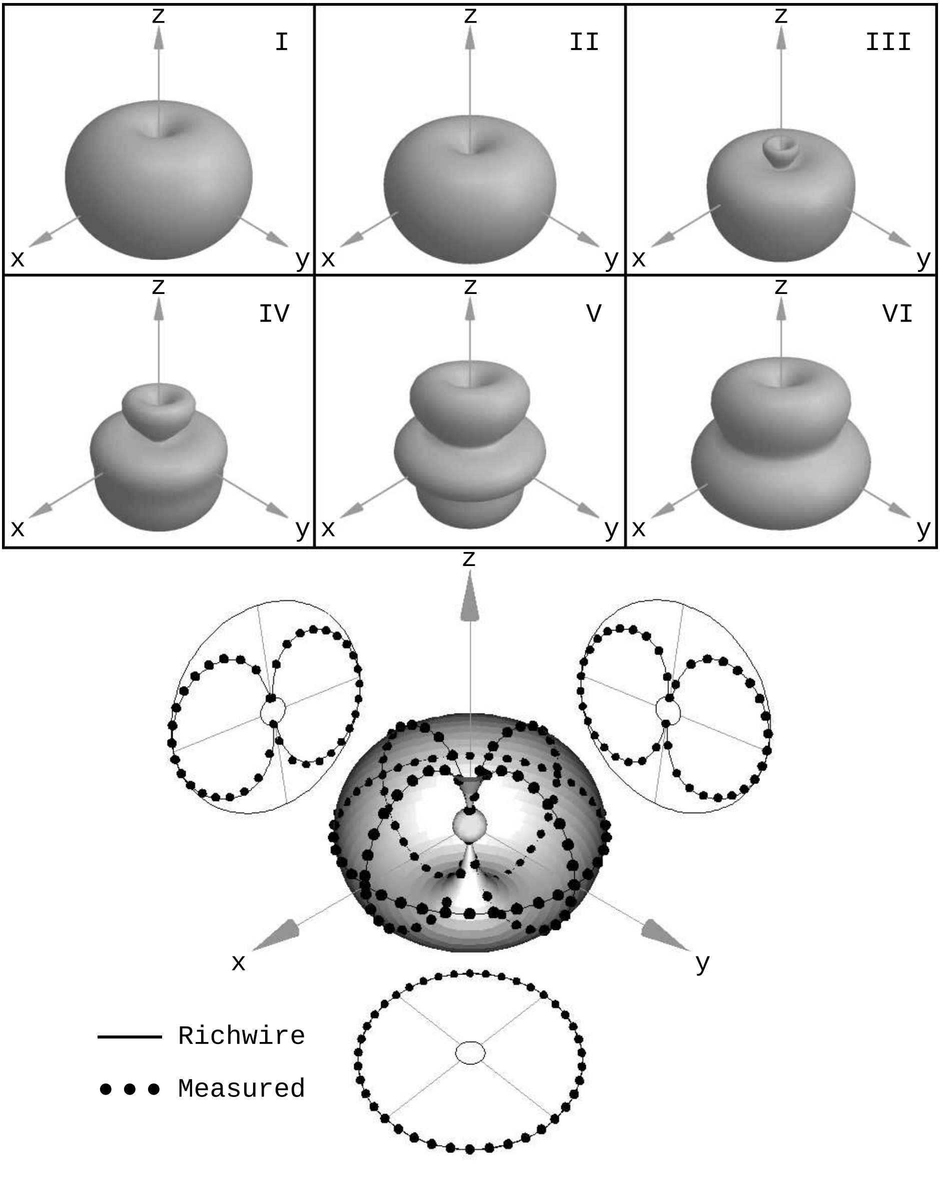

Fig.5: A (Up) Predicted normalized radiation intensity patterns at the center of each 2G+3G sub-band — B (Down) Normalized radiation intensity pattern at the center of measurements band

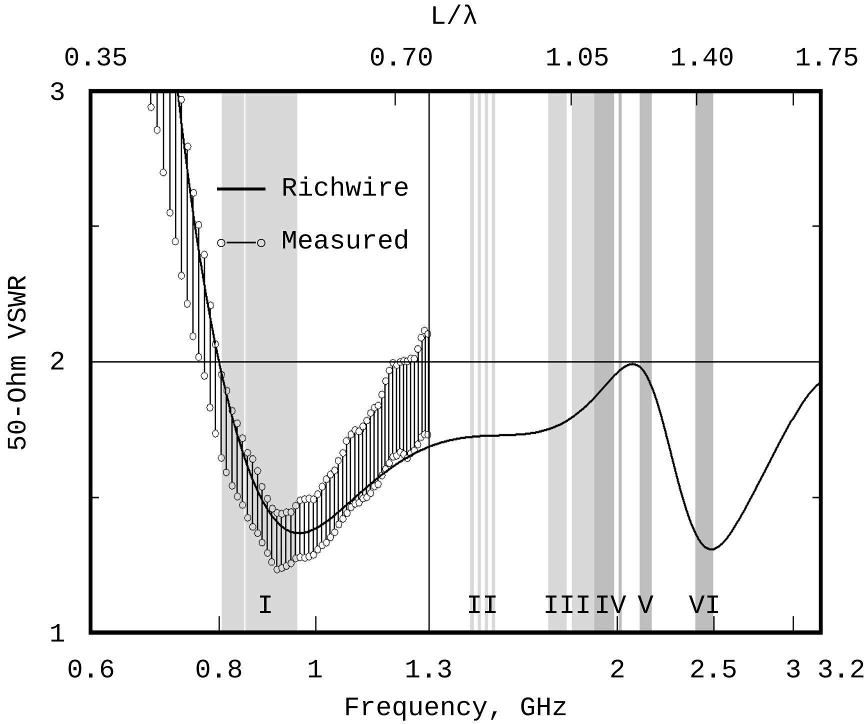

Fig.7: Standing wave ratio against frequency or ratio of total length to wavelength

Conclusion

Prediction and experimentation in the measurement band 600 MHz to 1,300 MHz proposes a successfully designed, constructed, and measured Radial Disk Cone Antenna RDCA capable to serve All-Band 2G+3G applications from 800 MHz to 3,000 MHz.

Credits

The authors acknowledge Adamantios Diamantidis, SV7FSF, a former member of Computer Center — Network Administration Center at Democritus University of Thrace, now Systems Engineer, Systems Administrator (honorary), Berlin, Germany, who motivated the study of Discone Antennas on behalf of FSF Free Software Foundation followers on the purpose to be openly supported in their Wi-Fi activities.

References

[1]Kandoian, A.G., "Three New Antenna Types and Their Applications", Proceedings of IRE, Vol. 34, February 1946, pp. 70W-75W

[2]Nail, J.J., "Designing Discone Antennas", Electronics, August 1953, pp. 167-169

[3]Rappaport, T.S., "Discone Design Using N-Connector Feed", IEEE Antennas and Propagation Society Newsletter, Vol. 30, February 1988, pp. 12-14

[4]Cooke, D.W., "The Skeleton Discone", The ARRL Antenna Compendium, Vol. 3, 1993, pp. 140-143

[5]Kim, K.H., Kim, J.U. and Park, S.O.: "An Ultrawide-Band Double Discone Antenna With the Tapered Cylindrical Wires", IEEE Transactions on Antennas and Propagation, Vol. 53, No. 10, October 2005, pp. 3403-3406

[6]Richmond, J.H., "Radiation and scattering by thin-wire structures in a homogeneous conducting medium", IEEE Transactions on Antennas and Propagation, Vol. 22, Issue 2, March 1974, p.365

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Follow-Up Research Paper

Not until now

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