

RATTLE-1 : A COMPACT, BROADBAND DIRECTIONAL UHF COMMUNICATION ANTENNA

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1. Introduction

This paper describes a compact, high power, directional antenna for use at ultra-high frequencies (UHF). The antenna design was subject to the user-specified physical constraints on the antenna installation and operation. The RATTLE-1 antenna is a 14-turn, two-arm conical Archimedean spiral antenna backed by a half-sphere cavity. This particular configuration evolved from dimension restrictions and the performance requirements of broadband frequency coverage, directionality, and power handling.

2. Design Restrictions and Requirements

The antenna placement and mode of operation is illustrated in Figure 1. The antenna is stored inside a cylinder of height H and diameter D , and is deployed to the top of this cylinder when in operation. The antenna is pointed along the horizon and rotates in azimuth.

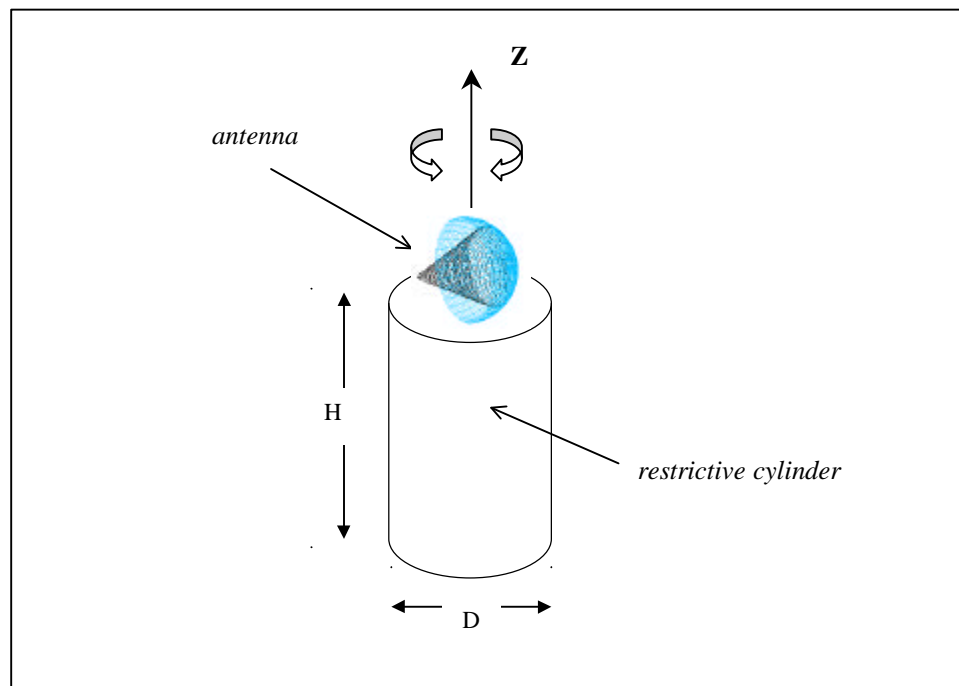


Figure 1 –Operational Description

The dimensional constraints imposed by the cylinder that houses the antenna are referred to as the physical restrictions (PR):

- (PR-1) the cylinder diameter is 47 cm; and
- (PR-2) the cylinder height is 90 cm.

The antenna operational requirements (OR) are:

- (OR-1) 300 MHz to 3GHz bandwidth;
- (OR-2) circular polarization;
- (OR-3) the voltage standing wave ratio (VSWR) is less than 3 over the operational bandwidth;
- (OR-4) 1kW power handling capability;
- (OR-5) maximum directivity, subject to volume constraints and bandwidth requirements.

3. The RATTLE-1 Development

RATTLE-1 antenna was derived from a conventional two-arm, cavity-backed spiral antenna (CBS) [4, 5, 6,7]. The CBS model is shown in Figure 2, where the cavity is represented by a wire grid [8]. The cavity provides uni-directional radiation and a typical wideband, low-loss design utilizes a metallic cone inside the cavity to maintain constant electrical distance between the antenna conductors and the cavity, as required for broadband operation.

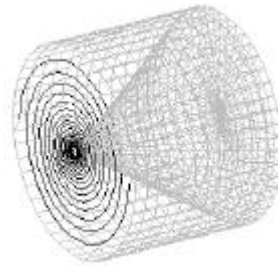


Figure 2 – Cavity-Backed Spiral Antenna (CBS)

The RATTLE-1 antenna, whose prototype is presented in Figure 3, differs from a conventional wideband, low-loss, cavity-backed spiral (Figure 2) in the following:

- the spiral is conical rather than flat, resulting in a unidirectional radiation pattern with a smaller beamwidth
- the conical spiral is backed by a hemispherical cavity rather than a cylindrical cavity which, for a given maximum diameter of the spiral, extends the bandwidth to lower frequencies.

The Archimedean spiral was selected over the logarithmic spiral because of a smaller variation of the antenna efficiency with frequency.

In order to arrive at an optimum antenna design for the particular application, more than 100 different antennas were simulated using the GNEC computer code [1]. GNEC, based on NEC4.1, uses the well-known Method of Moments [2,3] for wire and wire-grid model antenna simulations. A new technique, referred to as the Antenna Comparison Technique (ACT), was devised to optimize RATTLE-1. The ACT assigns “weights” to the antenna performance data derived from GNEC simulations, such as the antenna overall efficiency, upper and lower cutoff frequencies, and standard deviation of the overall antenna efficiency. The ACT allows the antenna user to establish the order of importance of various operational parameters (such as frequency range, efficiency, and so on) and the antenna designer to quantify and compare the performance of different antennas in a systematic manner.

4. The RATTLE-1 Specifications and Performance

RATTLE-1 (Figure 3) has the following dimensions:

- half-sphere cavity diameter of 47 cm;
- conical spiral length of 37.6 cm;
- conical spiral maximum diameter of 37 cm; and
- conical spiral minimum diameter of 2 cm.

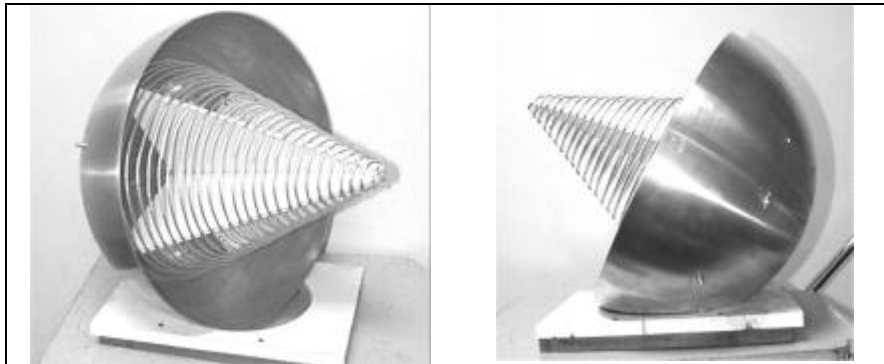


Figure 3 – The RATTLE-1 Antenna

The Rattle-1 prototype was built using 1673A Belden™ coaxial cable. This coax cable has 3.5mm outer diameter, 0.138 mm inner conductor diameter, teflon dielectric, and 50Ω nominal characteristic impedance. Laboratory measurements of the VSWR (Figure 4a) and the input impedance (Figure 4b) show that the antenna meets the VSWR lower than 3 requirement for the entire UHF band. The measurements were performed using an HP8510 network analyzer.

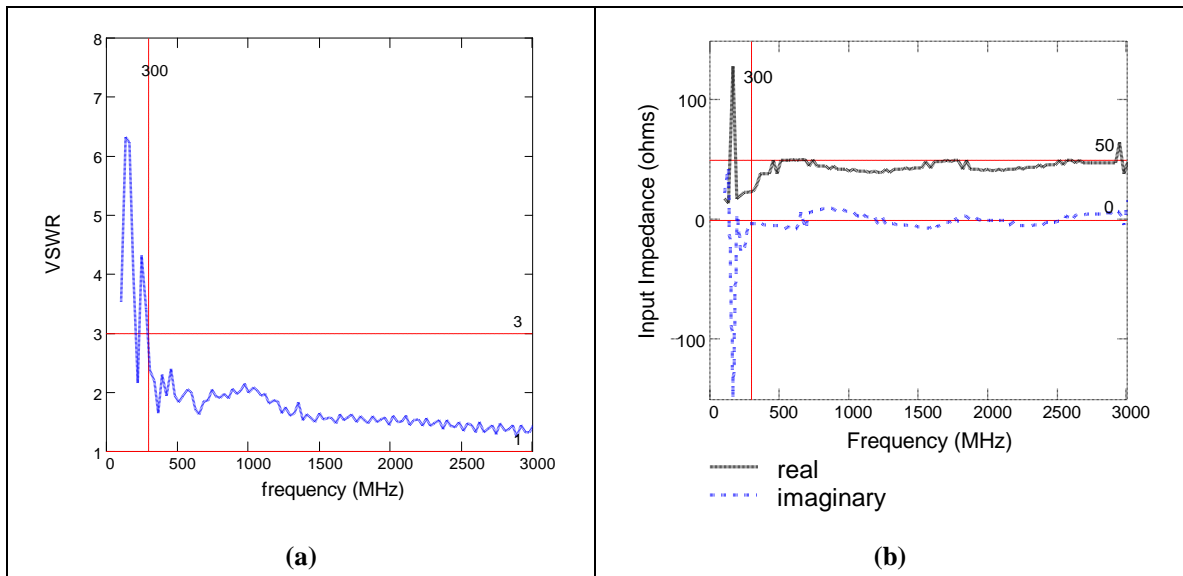


Figure 4 – Laboratory Measurements of the Rattle-1: (a) VSWR, and (b) Input Impedance

Representative radiation patterns normalized to maximum gain at four frequencies in the UHF band are shown in Figures 5 (horizontal plane) and 6 (vertical plane). These patterns were obtained from GNEC simulations. The patterns exhibit the expected symmetry with respect to the antenna axis. The half power beamwidth is approximately $\pm 30^\circ$ in both azimuth and elevation planes.

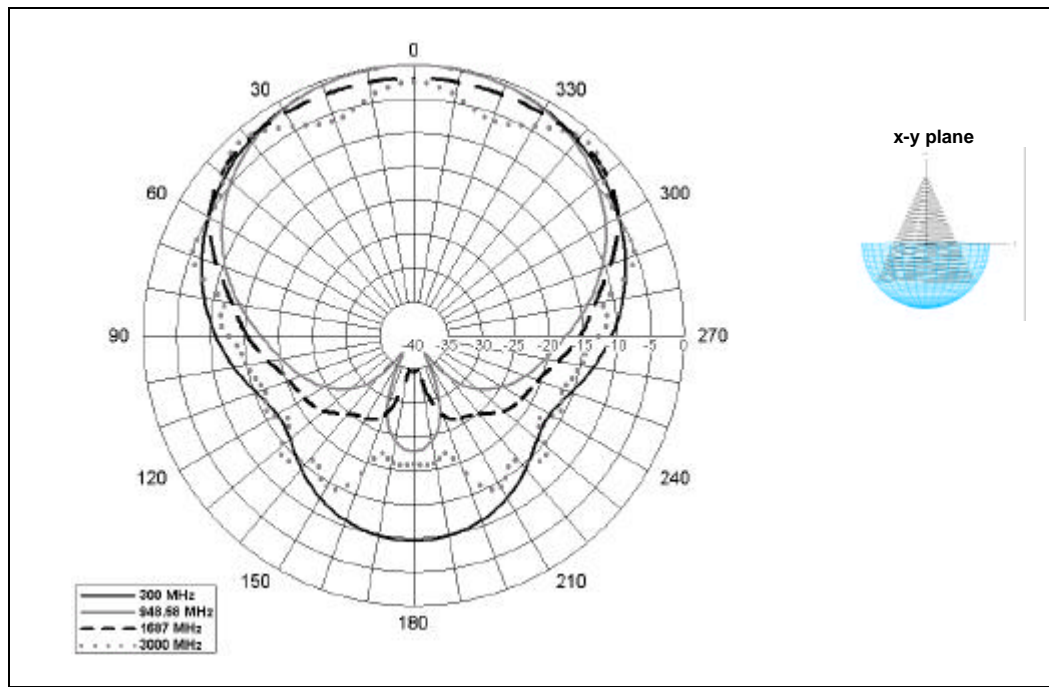


Figure 5 – Radiation Pattern of the RATTLE-1 Antenna (Horizontal Plane)

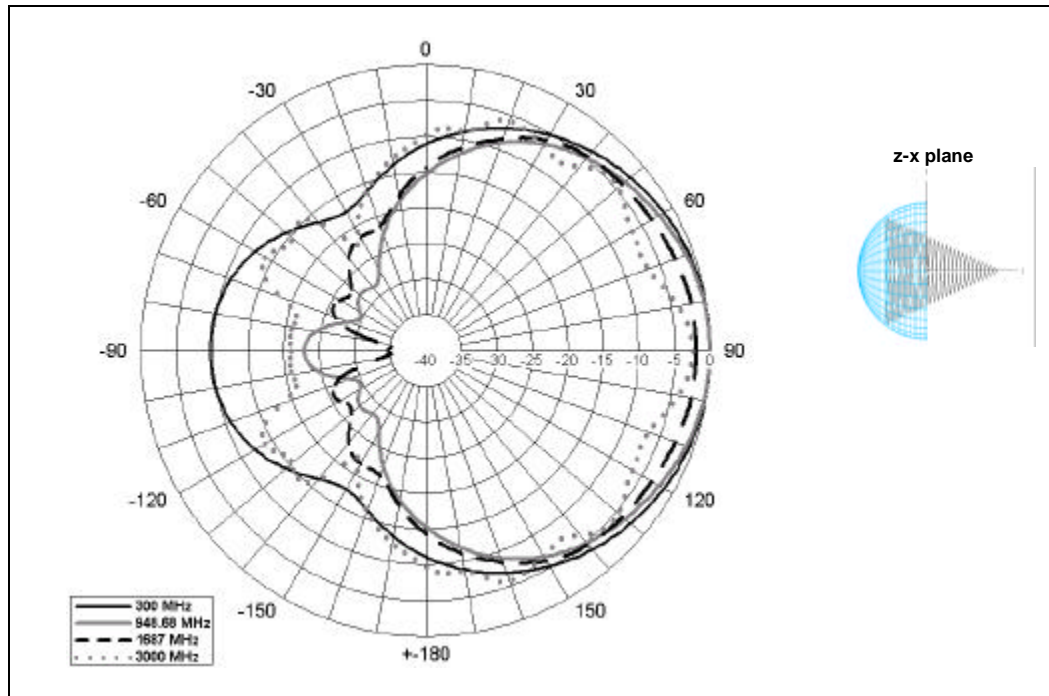


Figure 6 – Radiation Pattern of the RATTLE-1 Antenna (Vertical Plane)

5. Conclusion

The RATTLE-1 antenna is the result of a systematic approach to designing a broadband, circularly polarized, directional antenna under a given set of physical size and shape constraints. The antenna development is ongoing, including fabrication of the second prototype, maximizing power capability, simulation of the effect of electromagnetic coupling to the storage cylinder, the effects of the operational environment, and the possible use of dielectric materials to improve the performance at frequencies below 300 MHz.

6. References

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