A SMALL CAVITY-BACKED MICROWAVE SPIRAL ANTENNA COVERING 6-18 GHZ

TNC Wang
Yamada International Corp.
2350 Mission College Blvd.
Santa Clara, CA 95054, U.S.A.
K.K. Mei and Y.W. Liu
Electronics Research Laboratory
University of California at Berkeley
Berkeley, CA 94720, U.S.A.

I. Introduction

Spiral antennas radiate circularly polarized waves in a broadband frequency. Theory and practice of the two most popular types: Archimedian spiral and Log-spirals can be founded in many previous works [1-6]. General features of these antennas, without a cavity-backed are [1-2]:

- Radiates a circularly polarized wave over an octave bandwidth, with an axial ratio of about less than 2dB
- By-directional pattern, with a 3dB beamwidth about 80 to 90 degrees
- Input impedance equals to about 60π ohms

With a cavity-backed, the pattern then becomes unidirectional, and the 3dB beamwidth can be made wider dependent upon size and shape of cavity. The input impedance will be somewhat effected by the cavity (especially with dielectric loaded). When a balun is used, impedance-matching can be improved to match to a 50 ohm feed.

For some special system applications, it is requested to design and implement a physically small, cavity backed spiral antenna to cover a frequency range of 6 to 18 GHz, and to meet the following electrical specs: a 3dB beamwidth of unidirectional pattern equal or greater than 100 degree; axial ratio equal or less than 2dB; using a 50 ohm line feed with a input VSWR equal to less than 3:1. Physical size allowed for this spiral antenna is that: diameter for the spiral plane is about 2cm and its thickness is about 1cm (excluding the SMA connector). Because of smallness in size and much over one octave in bandwidth, it is not a straightforward task to design and implement a spiral antenna such as specified above. After some effort, we have developed and made a prototype spiral antenna, which met the above specs closely. This paper gives a brief description on our design and implementation of a prototype for the subjected small microwave spiral antenna.

II. Design Considerations

We used a type of two-arm spiral approach. To meet the radiation characteristics of this antenna (i.e.; circularly polarized waves with an axial ratio equal or less than 2dB, covering a frequency range from 6 to 18 GHz), it was found, after some analysis, that each arm should have at least, about 7 turns. Since the diameter

of spiral plane is limited to about 2cm, the equation for conventional equiangular or log-spirals can not be used here. This is because that two arms based on log-spirl expand too fast resulting only a few turns not sufficient for low-end frequency range of our interest. On the other hand, equation for conventional Archimedian spiral cannot be used here because it expands too slow leading to a situation that successive turns being too tightly spaced. This would result some phase cancellations so that an active loop with inphase region of one-wavelength perimeter may not be formed for the entire frequency range of interest. This effect becomes worst especially in the high-end frequencies of our interest.

In view of the above discussions, we used the following equation, a derivative or modification from conventional Archimedian equation:

$$r_1 = r_0 + a\phi^X \tag{1a}$$

$$r_2 = r_0 + a(\phi + \pi)^x$$
 (1b)

Where r_1 , r_2 are the polar radius of the two spiral arms, ϕ is the polar angle in radians, ro is the initial radius, and $a = 2(b - r_0)/\pi$, b is a constant of design parameter chosen to fit the size and practical implementation, and (b-ro) is related to the spacing between the successive spiral traces. The exponential parameter x (Note x should be equal or greater than one), determines the expansion rate for the spiral arms. For the case of x = 1, Equation (1) decuces to that of conventional two-arm Archimedian spiral. It is clear, based on Equation (1), the expansion rate for the spiral traces is faster than that of Archimedian spiral and slower that of Log-spiral, and that the value of x controls the expansion rate. A computer simulation results that x = 1.6 being the optimum choice for our present design. Using x = 1.6 in Equation (1), we have about 7 turns for each spiral arm with an adequate spacing between spiral traces suitable for implementation. The required diameter of the spiral-plane for this case is about 2.1cm, which meets our size requirement.

In consideration of the cavity for producing a unidirectional pattern as well as its contribution to the pattern factor, one can not, for this case, use a simple cylindrical shaped cavity spaced 1 cm back to the spiral plane. This is because that the simple cavity aforementioned is a narrowband structure. In line with our interest in the broadband of 6 to 18 GHz, we designed a cone-shaped cavity as shown in Figure 1. It is clear that, using this structure of cone-shaped cavity, one gets an effective cylindrical cavity, situated at a quarter wave length behind the spiral plane for each frequencies between 6 to 18GHz. Thus, this cone-shaped cavity can be considered as a broadband structure to fit our needs.

III. Prototype Development

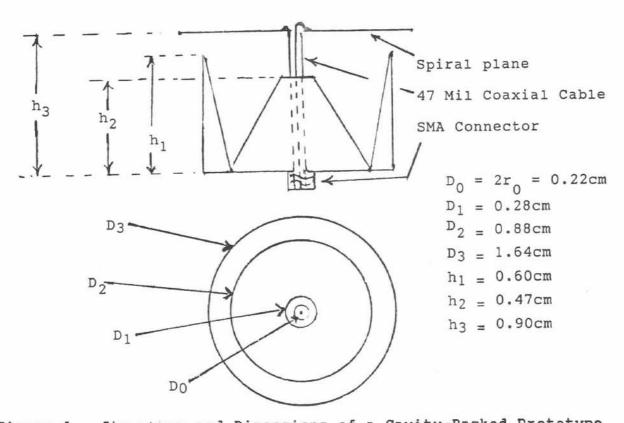
Based on the design considerations described above, we have constructed a prototype unit of such spiral antenna with its structure and dimensions indicated in Figure 1. Due to space limitations, a balun is not considered for impedance match. A 47 mils semi-rigid 50 ohm coaxial line together with a SMA connector is used for the feed. The input return loss was measured from frequency 6 to 18 GHz, as shown in Figure 2. It is seen that the worst case of return loss is about 5dB. Thus input VSWR for a 50 ohm feed of the prototype antenna is equal or less to about 3 to 1 ratio. We made a pattern measurement for a few frequencies at this time, observed the results that the 3dB beamwidth all greater than 100 degree, with an axial ratio less than about 2dB. Detail measured figures on pattern characteristics will be ready for presentation at the conference.

IV. Concluding Remarks

As a result of our study effort, we have deduced a somewhat generalized Archimedian spiral equation and designed an adequate broadband cavity. Based on our design concept and approach, we have achieved in construction of a physically small prototype spiral antenna reasonably met the desired specs. Some improvements on feeding 50 ohm line (e.g., a stripline or differnt diameter coaxial lines) together with the ways in connecting the arms, and/or using a balun can be made to further inhance impedance matching, and thus to reduce input VSWR ratio. These efforts are still being continued in our work.

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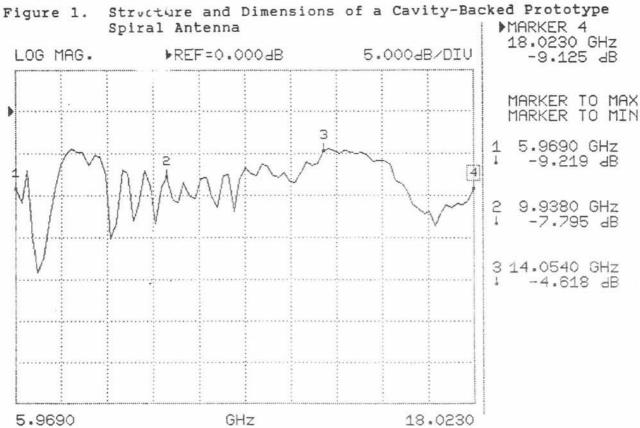


Figure 2. Return Loss for a 50 ohm Coaxial Feed