BROADBAND LOG-PERIODIC NORMAL MODE HELICAL ANTENNA[1]

Jorge Salazar-Cerreño*, Rafael A. Rodríguez-Solís, Ph.D.
Department of electrical and Computer Engineering
University of Puerto Rico
Mayagüez, PR 00681-9042
jorges@ece.uprm.edu, rafaelr@ece.uprm,edu

I. Introduction

The normal mode helical antenna (NMHA) is a common antenna used on transceivers for wireless communications due to its omnidirectional radiation pattern, large bandwidth and small physical size. Applications such as Ground Penetrating Radar (GPR) and Croswell Radar Tomography (CRT) require ranges of frequency in the order of 4 MHz to 1 GHz and can benefit from the use of NMHA. In this work, a scale model of a NMHA operating from 0.2 GHz to 10 GHz is developed for a CRT system at Northeastern University. Normal-mode helical antennas usually have a very small bandwidth, while axial-mode helical antennas can be designed to operate with wide bandwidths. In [1], the bandwidth of the helical antenna is improved by improving the input matching of the antenna. This is accomplished by providing a transition between the feed point and the first turn of the helix. Parasitic monopoles were located around a helix in [2] to increase the bandwidth of a normal-mode helix. In addition, the diameter of the helix is tapered in [3] to increase the bandwidth of an axial mode helical antenna. Nevertheless, the bandwidth improvement is not enough for the requirements of this project. In this work, the antenna must operate in a frequency range from 0.2 GHz to 10 GHz, with an omnidirectional radiation pattern and less than 0.01m in diameter. To increase the bandwidth, a new methodology was introduced which combines a NMHA and the properties of a log-periodic array antenna. The final results of the VSWR obtained with a log-periodic NMHA (LP-NMHA) prototype were satisfactory for one 90% of the frequency range required. The normal mode operations of this antenna was verified with several radiation pattern measurements.

II. Design and Results

The NMHA was selected because this antenna fits well with the research requirements (Omnidirectional radiation pattern and small physical size). In addition, this antenna has several design parameters that can be scaled using the log-periodic principle to improve the impedance bandwidth [4]. The design premise was to change the separation between turns (S) in a log-periodic fashion in a helical antenna, to maintain its normal mode operation for a wide bandwidth.

Before introducing the log-periodic properties in a NMHA, the authors performed several studies to consider which factors enhance the NMHA bandwidth. The first study consisted in optimizing four of its parameters (number of (*N*), separation between turns (*S*), diameter of the conductor (*dw*) and height of the feeder (*fh*)). Based on design of experiments (DOE) and statistical techniques (2^K factorial design) [5], 27 antennas were fabricated and measured. Eleven mathematical equations were obtained and optimized to obtain the desirable parameters for a

[1] This work was sponsored by the Center for Subsurface Sensing and Imaging Systems, NSF grant NSF00-137s

0-7803-7846-6/03/$17.00 ©2003 IEEE

VSWR<3. The second study consisted in substituting the cylindrical conductor by a tape conductor. The width of the conductor used was found using the equivalent radius defined by Balanis in [6] and the results of the design of experiment mentioned before. The results are shown in Figure 1. Note that the VSWR is enhanced significantly when the tape conductor is used. The third study was carried out with the purpose of knowing if the support material used in the NMHA affects the bandwidth of this antenna. Three available materials with different relative permittivities were employed for this study: glass ($\varepsilon r=7$), delrin ($\varepsilon r=3.6$) and wood ($\varepsilon r=2.1$). The results of the VSWR in the Figure 4 show that for the material with of lower relative permittivity the VSWR is lower. The material selected for this work was Delrin, this material is homogeneous and it does not present changes in its electrical properties with the environment as wood does.

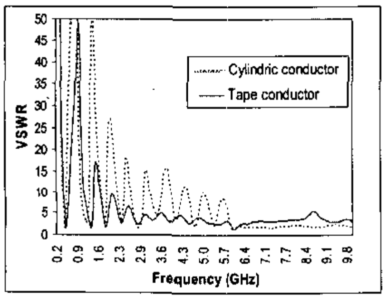

Figure 1. VSWR of NMHA for different material support

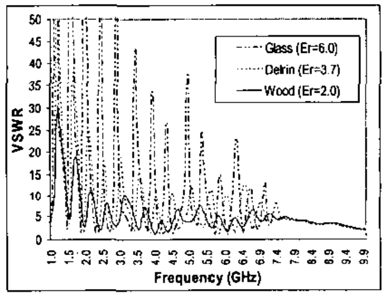

Figure 2. VSWR for different type of conductor

The parameter selected to apply the log-periodic principle was the separation between turns (S). The diameter of the helical antenna (D) was not considered because it has to be smaller than 0.01 m, according with the design specifications. Nor was it considered the width of conductor (W) due to the limitations presented in the fabrication of the antenna geometry.

Based on the previous considerations, the LP-NMHA was designed considering the following steps: 1) Calculate the wavelength in function of the highest frequency in the range of required frequency (10 GHz). 2) Assume one initial scale factor (τ_o) between 0.76 to 0.98. 3) Considering the second of Kraus' criteria ($S<0.01\lambda$) the first value of S was obtained. 4) Determine the value of S for every turn dividing the previous S between the initial scale factor (τ_o). 4) Verify that the three Kraus' criteria to guarantee the correct operation of the helix antenna in normal mode [7] for the entire frequency range. The scale factor is modified until all Kraus' criteria are met for the entire frequency range. The number of turns for the antenna is then given by the scale factor. This is shown in Figure 4. This plot gives the number of turns required to guarantee the normal mode operation of this antenna for W=0.003m, D=0.01m and fh=0.003m.

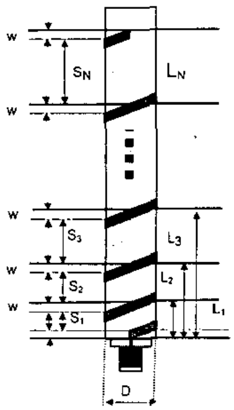

Figure 3. Geometry of LP-NMHA

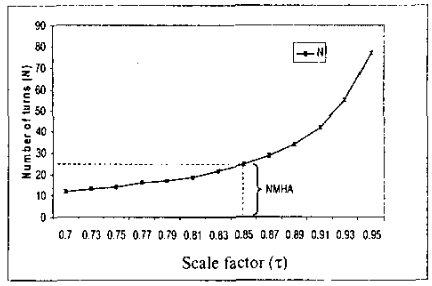

Figure 4. Number of turns vs. scale factor τ

Two LP-NMHA for two different scale factors τ=0.805 and τ=0.850 using the before procedure were performed at the UPRM Radiation Laboratory. The results of the VSWR that are showed in the Figure 5 are satisfactory for a frequency range from 2.7 GHz to 12 GHz. To verify the normal mode operation of these antennas, several pattern measurements were performed at the UPRM Radiation Laboratory. These are shown in Figure 6 for the antenna with a scale factor of 0.805.

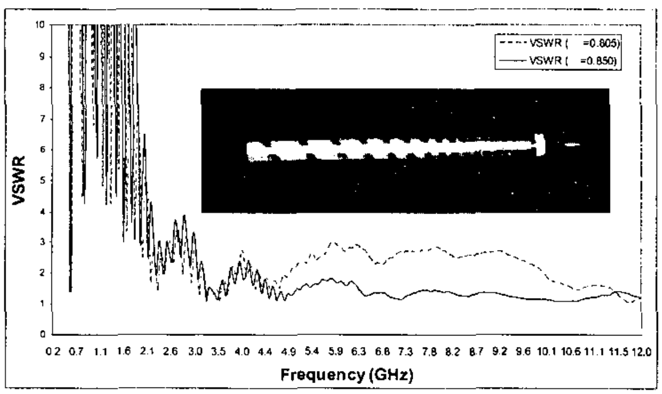

Figure 5. VSWR of the LP-NMHA for τ =0.850 and τ =0.805

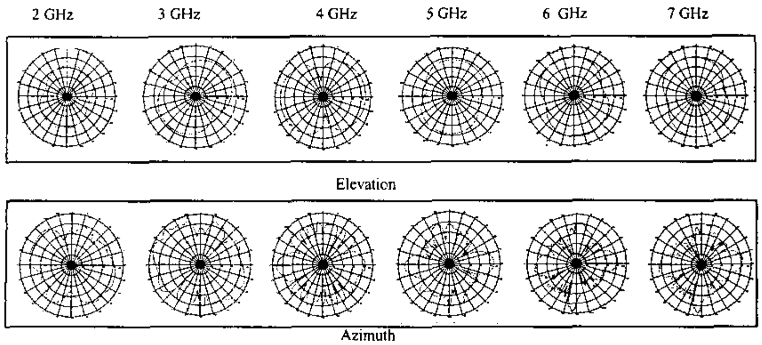

Figure 6. Measured radiation pattern of the LP-NMHA ($\tau = 0.805$)

III. Conclusions

A new methodology and procedure to enhance the bandwidth of the NMHA was presented. The log-periodic principle was applied to the separation between turns (S) of the NMHA; the bandwidth of this antenna is increased considerably. This technique was based on the three Kraus' criteria to guarantee the helical normal mode operation.

Several LP-NMHA antennas were designed and built and tested using this technique and the bandwidth is significantly improved for each of them. The frequency range of operation obtained covered from 2.7 GHz to 12 GHz. To verify the normal mode operation, several pattern measurements were performed.

IV. References

[1] B. Atkins, Antennas and Feed Lines, McGraw-Hill Book Co., New York, Chap. 9, 1985.
[2] S. D. Rogers, J. C. Young, C. M. Butler "Bandwidth Enhanced Normal Mode Helical Antennas", Digest 1998 USNC/URSI National Radio Science Meeting, Atlanta, GA. p 293, June 1998.
[3] J.L.Wong, H.E. King, "Broadband-Taper Helical Antennas", IEEE Transactions on Antennas and Propagation, AP-27(1), January 1979.
[4] P. E. Mayes, Frequency-Independent Antennas and Broad-Band Derivates Thereof, Proceeding of IEEE, Vol.80, No. 1, January 1992.
[5] D.C. Montgomery, Analysis and Experimental Design, Limusa Wiley, New York, Chap. 9, 2002.
[6] J.D. Kraus, Antennas, McGraw-Hill Book Co., New York, Chap.7, 1988.
[7] C. A. Balanis, Antenna Theory, John Wiley & Sons, Toronto Inc., Chap.10, 1997.