Chapter 9. Summary and Conclusions

A new reduced size axial mode helical antenna, named the Stub Loaded Helix (SLH), was introduced in this dissertation. This research lead to the development of an innovative new form of the helix antenna that features a significant size reduction with minimal compromises in performance. This chapter summarizes the results presented in this dissertation, details the contributions presented in this dissertation, and presents suggestions for future work to improve and enhance the performance of the new antenna.

9.1 Summary

The helical antenna dates back over 50 years and has seen a great deal of development and several geometry variations and modifications have been proposed during the intervening years. In Chapter 2, the historical development of the helical antenna was outlined along with a discussion of the how the helical structure supports traveling waves. Chapter 2 also discussed some of the many variations on the basic axial mode helix that have been developed over the years.

Chapter 3 explored the operation of the conventional axial mode helix as developed by Kraus. The theory of operation of the axial mode helix as expounded by Kraus and others was presented. Results of simulations using NEC were presented to explain the operation of the conventional axial mode helix in terms of current phase along the helix and how it relates to the Hansen-Woodyard condition for endfire operation.

Results of simulations of the gain of conventional helices were also presented in Chapter 3, along with discussions and comparisons of the simulation work of others and measured results. It was noted that comparisons of results between simulations, measurements and theory do not provide a satisfactory degree of agreement. While the discrepancies are not serious, they do suggest the need for additional work.

Chapter 4 introduced the geometry of the Stub Loaded Helix antenna and defined the important design parameters. Operation of the SLH was explored using NEC simulations of the currents along the helix winding. The operation of the SLH was presented using the same arguments utilizing the Hansen-Woodyard condition as in Chapter 3 in discussions of the conventional axial mode helix operation.

Chapter 5 presented numerical simulations results of the SLH to explore its operating characteristics. Using NEC models of 5- and 10-turn SLH antennas, the gain and axial ratio behavior of the antenna was explored. The results demonstrated that the axial ratio performance of the SLH is the limiting factor in determining its operating bandwidth. The simulations indicated a 3 dB axial ratio bandwidth of approximately 22% of the center frequency of operation. Using the simulation results for the 5- and 10-turn SLH models, the SLH provides reduction in circumference of 22-25% compared to a conventional helix and a length reduction of 50% or greater for the same number of turns.

In Chapter 6 results of parametric studies of the most important design parameters of the SLH were presented. Variations in helix pitch angle, α, stub depth, l_s, and the number of stubs-per-turn, N_s, were examined using NEC models to explore their effect on helix gain and axial ratio performance. Based on the results of these parametric studies, a set of 'optimum' design parameters were identified that maximized the gain and axial ratio bandwidth of the SLH.

Chapter 7 provided the results of some of the experimental verification tests we have conducted on this antenna geometry. Results of measurements made both at Virginia Tech and at Sandia Labs in New Mexico were presented. Measurements of gain and axial ratio performance as a function of frequency were presented for 10-, 15-, and 30-turn SLH prototype antennas. Measurement results showing a side-by-side comparison of pattern, gain, and axial ratio performance for a 15-turn SLH and a 15-turn conventional helix were also presented showing the SLH to perform comparable to the conventional helix, with only a slight reduction in gain, averaging 1-1.5 dB, and axial ratio bandwidth.

Details of an empirically derived matching technique to provide an adequate impedance match to 50Ω for the SLH was also presented in Chapter 7. Results of network analyzer measurements were presented to demonstrate that the tapered matching section presented can provide VSWR < 2:1 in a 50Ω system for the SLH.

Chapter 8 provided a comparison of the simulated results for the SLH antenna from Chapter 5 with the experimental results from Chapter 7. In Chapter 8 we also provided a suggested set of SLH design parameters for maximizing gain and bandwidth. These were based on the parameter studies presented in Chapter 6.

9.2 Contributions

A new helical antenna design was presented in this dissertation that offers a major improvement over classical axial mode helix antennas. This new design, the Stub Loaded Helix (SLH), provides gain and polarization performance comparable to the conventional axial mode helix, but in a significantly smaller size envelope. It accomplishes this through the use of a unique geometry. For a given helix diameter, the center frequency of operation of the SLH is approximately 25% lower than a full size helix. For the same number of turns, the SLH has one-half the axial length of a full size helix. Experimental results indicate the for an equal number of turns, the gain of the SLH is within 2 dB of a full size helix. The largest compromise of the SLH concept is its axial ratio performance. The typical 3 dB AR bandwidth of the SLH is on the order of 20-24% of the center frequency of operation. This is approximately one-half the operational bandwidth of a full size helix. However, most applications do not require a bandwidth greater than that of the SLH.

9.3 Commercialization

The SLH concept offers an antenna design that provides high performance in gain and polarization, but in a significantly smaller size than the conventional full size helix. In today's technology environment, smaller is always a desirable trait. The uniqueness and innovation of the SLH concept has been recognized by the issuance of a U.S. patent (#5,986,621) covering the concept. All rights to this invention are administered by Virginia Tech Intellectual Properties, Inc. (www.vtip.org), VTIP, a university affiliated, non-profit, private corporation.

VTIP has licensed the SLH technologies to Turbowave, Inc (www.turbowave.com) of Orem, UT for use in the area of application of wireless local area networks. Turbowave, working in conjunction with the Virginia Tech Antenna Group (VTAG), has developed a commercially produced version of the SLH antenna for use in the unlicensed 2.4 GHz

WLAN (wireless local area network) market. This antenna is currently being produced by FRC Corporation (www.frccorp.com) in Mason City, IA.

Additional information concerning licensing SLH technology for other applications can be found at VTIP's website at **http://vtip.org/licensing/disclosures/96-059.htm.**

9.4 Future Research Work

While we have spent several years exploring the SLH concept and developing a commercialized version of the antenna, there are still several areas which merit further investigation.

Improved matching/feed design - The matching section presented in Chapter 7 does an adequate job of providing a match to typical 50Ω system impedances. At microwave frequencies, the matching section is physically small and can be easily constructed from sheet brass or copper and is essentially self supporting. At lower frequencies, this matching section can become physically large and awkward. It becomes difficult to construct and support. At VHF/UHF frequencies, a discrete matching network should be more compact, although there may be issues related to bandwidth.

Variations of the SLH - As often happens, each new path reveals more paths. There may be variations on the SLH geometry that may yield improvements in gain, axial ratio bandwidth, or increased size reduction. Although not reported on here, we have briefly examined some variations without success. Possible variations that we have not examined include variable pitch angles, variable or tapered stub lengths, and variable stub placement. Alternative stub configurations may also be possible, but based on the theory of operation put forth in Chapter 4 and the parametric studies in Chapter 6, it is doubtful that significant variations would be feasible.

Verification of Helix Performance - As discussed in Chapter 3, there are discrepancies between the results for theory, simulation, and measurements reported in the literature for the conventional helix. A suggestion was made in Chapter 3 as to a potential source of the differences noted, namely the construction of the experimental test article used by King and Wong. It would be useful to repeat the work of King and Wong using helices with large planar reflectors for comparison with simulation and theoretical results. Or conversely, to construct accurate simulations of the cup reflector helix used by King and Wong and compare the simulation results to the measured ones in the literature. Similar work characterizing a family of SLH antennas would also provide useful verification of this work and provide designers with accurate performance data for design purposes.