Chapter 1. Introduction

The helical antenna has a long history and has been the object of much study and development over the last half century since its invention in 1946 [Kraus, 1976]. It is an interesting antenna with unique characteristics, being capable of high gain, wide bandwidth, and circular polarization. As a result, it has been used in a wide range of applications including satellite communications, radio astronomy, and wireless networking. This dissertation presents a fundamental advancement of the basic axial mode helix design. This new form of helix antenna, called the Stub Loaded Helix (SLH) antenna, offers the advantage of a significant reduction in helix antenna size with only a relatively small corresponding reduction in performance. The performance reduction in many applications is not relevant and the application requirements are still satisfied. The result is a new antenna design that offers the performance characteristics and advantages of the conventional axial mode helix but in a much more compact physical size envelope.

The original aspects of the work described in this dissertation are covered by U.S. patent #5,986,621. All intellectual properties related to this patent are controlled and administered by Virginia Tech Intellectual Properties, Inc.

1.1 Motivation

The original motivation for this work came from the desire to develop a reduced size helix antenna for use in satellite communications links for both earth terminals and on space platforms. Although technological trends are toward the use of higher frequencies in the microwave and millimeter regions where greater bandwidths are available, there are still a number of satellite systems that utilize the VHF and UHF frequency bands. The most prominent of these is the U.S. Navy FLTSATCOM system which utilizes a network of geosynchronous satellites to provide worldwide coverage to bases, ships, and mobile ground forces.

At VHF and UHF frequencies, the physical dimensions of a conventional axial mode helix can be large enough to present difficulties, particularly for mobile forces and on the ever increasingly crowded top sides of today's naval ships. A typical helix for FLTSATCOM applications can have a helix diameter on the order of one foot (30.5 cm) and an axial length of 12 feet (4 meters) or greater with a groundplane on the order of 4 feet (1.3 meters). Mounting and pointing of such a large structure presents mechanical problems. Any reduction in antenna size without significantly impacting performance would be very desirable.

In every aspect of wireless communications today, there is a desire to minimize antenna size. The technological progress that has produced significant advances in the miniaturization of components and circuitry has not been mirrored by corresponding advancements in antenna miniaturization, for a very fundamental reason. Solid state components are only now approaching structure sizes that are comparable to the wavelength of an electron. Most antennas operate in the size regime where their physical dimensions are on the order of the wavelength of operation. Much theoretical work over the years, as well empirical results, indicate that antenna size reduction results in compromises of some key performance characteristics, most notably efficiency and bandwidth. It is the goal and art of engineering to minimize and optimize these compromises to provide a solution that meets the requirements of each specific application. It is hoped that the Stub Loaded Helix antenna has achieved an appropriate balance between performance and compromises in order to be considered a useful contribution.

1.2 Dissertation Overview

In Chapter 2, a historical perspective on the development of the helical antenna is presented. The early development of the axial mode helix antenna is predominately the story of John Kraus. The few pages devoted to its description here is a brief summary of an interesting story and fascinating man. For the definitive story of the development of the helix, the reader is directed to Kraus' own *Big Ear* [1976], and the many journal papers he authored or co-authored on the subject, some of which are listed in the bibliography. From the early work of Kraus, many variants of the helical antenna have evolved over the last fifty plus years, and an overview of some of these is also presented in Chapter 2.

Chapter 3 provides a discussion of the conventional axial mode helix as developed by Kraus and an exploration of its theory of operation. Results of the performance characteristics of conventional axial mode helices are discussed and compared with the results reported by others.

Chapter 4 introduces the Stub Loaded Helix (SLH), its geometry and operating principles. Building on the discussion of the theory of operation of the conventional helix in Chapter 3, the theory of operation of the SLH is presented using simulation results.

Chapter 5 presents the results of numerical modeling of the SLH's performance characteristics. Results using NEC (Numerical Electromagnetics Code) are presented and used as a tool to explore the behavior characteristics of the SLH. The SLH's capabilities for size reduction are presented through the results of these simulations.

In Chapter 6, the results of parametric studies of the major SLH design parameters is presented. Based on these parametric studies, we formulate a set of optimal design parameters to maximize the gain and axial ratio performance of the SLH.

Chapter 7 presents the experimental performance verification data of the SLH antenna. Measured results from several SLH prototypes, including gain and axial ratio performance behavior, are presented. A direct comparison between a full size helix and a comparable SLH is presented, demonstrating that the SLH antenna requires minimal compromises in performance while providing a significant reduction in size.

Chapter 8 examines the performance of the SLH with the full size helix based on results reported by others. In it we also compare our simulation results from Chapter 5 to the measured results from Chapter 7. Lastly, we present a suggested set of design parameters for the SLH to maximize gain and bandwidth.

Chapter 9 summarizes the results presented in this dissertation, outlines the contributions of this work and suggests avenues for future work and development of this unique antenna design.