1. Introduction

Electrical communications plays a vitally important role in the human society. Speech, music, pictures, computer data, and other forms of information transmitted by means of electrical signals enable human beings to communicate no matter where they are, on the earth or in space. Following the first demonstration of radio wave communication by Guglielmo Marconi in 1897, wireless communication has evolved in many directions, developed to unimaginable levels of sophistication, and expanded to many different applications. In particular, the past two decades have witnessed an explosion of wireless communication technology and market growth and an upsurge of research activities in this area.

An essential part of any radio wave communication link is an antenna, which facilitates radiation of electrical signals into space when used as a transmitter or detection of radiated signals when used as a receiver. Antennas assume many different shapes and configurations depending upon performance requirements and other factors such as cost, size, and maintenance. The antenna of particular interest in this work is that of a helical geometry which is easy to construct and exhibits radiation properties such as circular polarization, wide bandwidth, and relatively high gain that are highly desirable in many communication applications.

The conventional helical antenna, consisting of a wire wound around a cylinder and fed by a coaxial cable, was first introduced by Kraus [1]. This antenna has been the subject of extensive experimental and theoretical investigations during the past five decades. Of particular importance are research studies aimed at improving the radiation characteristics of helical antennas. Various modifications to the conventional cylindrical helix have been proposed for the purpose of increasing the gain and bandwidth as well as reducing the axial ratio and the voltage standing-wave ratio. A brief survey of these modifications is presented in Chapter 2 of the thesis.

Recently, a novel helical antenna referred to as “spherical helix” was introduced at Virginia Tech. This antenna consists of a winding on a spherical surface with a constant spacing between the turns. It is fed by a coaxial cable and is backed by a conducting ground plane. The investigation of spherical helix revealed some unique properties. In particular, it has been shown that the spherical helix provides circular polarization over a broad beamwidth [2-4]. This is in contrast to the conventional cylindrical helix that provides circular polarization only over a rather narrow beamwidth about the axis of the helix. The compact geometry of the spherical helix is also an important advantage, particularly in situations where size limitations need be observed. While the initial investigation of spherical helix was very revealing, a more in-depth study of this antenna is required in order to understand the effects of the antenna parameters on the radiation characteristics. This study identified improved designs that provide better electrical performance (e.g., higher gain, lower axial ratio, etc.) and/or require smaller antenna size.

Previous studies have largely been limited to full spherical helices with a square ground plane. This thesis expands on the investigation to truncated helices, particularly to the hemispherical geometry that seems to be very promising. Also, arrays of spherical helices, for the purpose of increasing the gain, are examined. Both experimental and numerical investigations are carried out. Numerical results for the radiation properties of spherical helix are obtained using the electromagnetic code ESP (Electromagnetics Surface Patch Code). The ESP code, developed at the Ohio State University, is a powerful numerical method based upon the method of moments. Antenna characteristics such as current distribution, input impedance, radiation efficiency, and far-field patterns are calculated directly by ESP. The output data are used to obtain other important properties such as axial ratio and directivity.

A literature survey of helical antennas is presented in Chapter 2. Chapter 3 reviews the geometry and radiation properties of the spherical helix. Chapter 4 presents the numerical results for radiation properties of several truncated spherical helices. Emphasis will be placed on cases with circular polarization. Results for far-field patterns, directivity, axial ratio, and input impedance are presented. The influences of antenna parameters on radiation properties are addressed. A discussion of experimental results and comparison with the numerical results are presented in Chapter 5. Chapter 6 summarizes the main conclusions of this work and points out the contribution of the thesis. The appendices contain a listing of computer programs developed for studying radiation properties of the spherical helix not directly provided by the ESP, as well as computed and measured radiation patterns for the cases not presented in Chapters 4 and 5.