Chapter 1. *Introduction*
1.1 Background

Indian scientist Sir Jagadish Chandra Bose worked on quasi-optic millimeter wave in the year 1895. He developed an elegant millimeter wave spark transmitter, self recovering coherer detector, wire grid polariser, cylindrical diffraction grating, dielectric lens and prism, rectangular waveguide, horn antenna and microwave absorber, for the studies of reflection, refraction, absorption and polarisation of millimeter waves and its application to wireless remote control for firing a gun. All these pioneering activities indicate that he was well ahead of his time and prompted us to call him the father of Radio Science [1]. Bose's invention of the "mercury coherer with a telephone” which Marconi used was published in the Proceedings of the Royal Society, London, on April 27, 1899, two years prior to Marconi's first wireless communication on December 12, 1901, from New Foundland, now in Canada.

It is the demand and appetite for innovations which is driving the overall rapid growth of wireless technology and literally changing people’s lives in all sorts of useful ways. Telecommunication industry is not the only market that benefits from the advances in wireless technology; healthcare, medical diagnosis, treatment and monitoring systems, automotive production and industrial remote monitoring systems have also considerably gained from improvement of the wireless systems. There is a vast opportunity for wearable and logistic applications in security systems and these are just a few applications among many others. What is really interesting is the fact that it appears that there will be further developments in due course that will challenge the understanding of wireless technology.

Software defined radio, (SDR), and cognitive radio, (CR), are two new concepts in wireless communications that will in the foreseeable future, have significant effects on antenna requirements in a host of applications from mobile phones to satellite communications. Software defined radio was first described by Mitola [2], as a system in which majority of the functionality is defined by software algorithms. A cognitive radio (CR) is a wireless transponder that can sense the environment where it wishes to operate and can adapt itself to optimize its operation. Thus, it offers much promise to increase spectrum usage efficiency to users in a wide variety of applications, covering commercial, military and space communications. Software defined radio is seen as an enabling technology for cognitive radio. Both terms, since
their first description, have attracted increasing interest and driven significant worldwide research.

Among the current driving forces in wireless communications, there is a need for wideband antennas or multi-band antennas receiving much attention to fulfill different applications in just a single terminal. Single terminals or devices could have many applications such as, GPS, GSM, WLAN, Bluetooth, etc. In some instances, particularly long-distance applications, radiators with directive, high-gain characteristics are necessary. The other important parameters that need to be achieved are compact size, efficiency and cost.

1.2 Motivation

Antennas are necessary and critical components of communication and radar systems. Arguably, nine different types of antennas have proliferated during the past 50 years in both wireless communication and radar systems. These nine varieties include dipoles/monopoles, loop antennas, slot/horn antennas, reflector antennas, microstrip antennas, log periodic antennas, helical antennas, dielectric/lens antennas, and frequency-independent antennas [3]. Each category possesses inherent benefits and detriments that make them more or less suitable for particular applications. When faced with a new system design, engineers change and adapt these basic antennas, using theoretical knowledge and general design guidelines as starting points to develop new structures that often produce acceptable results.

The gain and bandwidth are important parameters of antenna. The essential requirements for almost all the applications of the antenna are higher gain and larger bandwidth. Scientists, engineers and research scholars are struggling to enhance the gain and bandwidth of antenna so that multiple antennas used in aircrafts, satellites and other applications can be replaced by a single antenna, or at least the number of antennas can be reduced. Enhancement of both gain and bandwidth is quite challenging because the product of gain and bandwidth will remain constant, as improvement in gain will degrade the bandwidth and vice versa.
A modern aircraft has many antennas protruding from its structure, for navigation, various communication systems, instrument landing systems, radar altimeter, and so on. There can be as many as 20 different antennas or more, up to 70 antennas on a typical military aircraft has been quoted [4], causing considerable drag and increased fuel consumption. Integrating these antennas into the aircraft skin is highly desirable. Preferably, some of the antenna functions should be combined in the same unit if the design can be made broadband enough. The need for conformal antennas is even more pronounced for the large-sized apertures that are necessary for functions like satellite communication and military airborne surveillance radars.

The primary motivation of this thesis is to enhance gain as well as bandwidth of antenna so that multiple antennas in any specific application can be replaced by a single antenna or at least the number of antenna can be reduced. The antenna size is an important parameter to make it conformal. The conformal antenna is an antenna that conforms to a surface whose shape is determined by considerations other than electromagnetic; for example, aerodynamic or hydrodynamic.

### 1.3 Objectives

The main objectives for this research are to develop:

- Antenna solution for gain as well as bandwidth enhancement
- Conformal antenna with miniaturised size
- Antenna solution for high power handling
- Antenna solution apart from the conventional antenna design concepts.

1.4 Layout of the Thesis

The thesis is organized as follows: Chapter 2 is dedicated to a brief review of antenna design parameters and elements. Chapter 2 begins with the IEEE definition of antenna and antenna as a transition device. The helix is a fundamental form of antenna of which loops and straight wires are limiting cases. The helix geometry and axial and normal radiation modes are discussed in this chapter.

Chapter 3 reviews the helical antenna for bandwidth and gain enhancement, size reduction and conformability issues. The review found that the challenge is the gain and bandwidth enhancement with conformability and size reduction of antenna.

A single turn triple band helical antenna for centre frequencies 2.4 GHz, 3.6 GHz, and 5.4 GHz is introduced in Chapter 4. The gain and bandwidth of a single turn triple band helical antenna compared with three different single turn helical antenna of similar geometry for respective frequencies. The maximum gain enhancement of triple band single turn helical antenna is 7 dB as compared with a single turn helical antenna. The selection of single turn helical antenna is for size reduction but this antenna does not satisfy the conformability issue.

The length of the helix and size of ground plane is the predominant obstacle in making helical antenna compact and conformal. The helix enclosed in a highly conductive shield of circular cross section results in helical loaded cavity backed antenna. A 1.64 turns of helical loaded cavity backed antenna is discussed in Chapter 5, which mainly addresses the conformability and size reduction issues. Loading the helix in the cavity changes the antenna radiation pattern from normal mode radiation to axial mode radiation.

Chapter 6 introduces five different partial metallic wall cavity configurations under a finite square ground plane. A 1½ turn helical antenna is loaded in a single metallic wall, double wall pi-shape, double wall L-shape, triple wall U-shaped and four wall complete cavity has been investigated. Different parametric variation such as the feed
pin height variation and helix diameter variation is done for optimization of antenna design. These cavity configurations enhance the gain and bandwidth of the antenna with conformability and reduction in size.

The antenna characteristics such as radiation pattern, gain and bandwidth can be improved by building an array of the radiating elements placed such that the radiation pattern is additive. Chapter 7 introduces a cylindrical cavity loaded helical antenna in array of 2x2 and Chapter 8 introduces array of 4-element rectangular cavity loaded helical antenna. The design and fabrication of both the arrays is for 2.4 GHz frequency.

Finally, Chapter 9 draws conclusion of the work. The primary objectives are reviewed and the significant achievements are highlighted. Furthermore, this chapter presents the challenges, which continue to remain and which are worthwhile to investigate as future research topics.