

CHAPTER 1

INTRODUCTION

1.1 HISTORY OF MICROWAVE ANTENNA

The demand for miniature antennas in wireless communication is ever increasing with the advances in the modern technologies. John Kraus et al (2010) mentioned that the first wireless communication was established by Hertz with a flat dipole and single turn loop followed by a demonstration of the same for practical application by Guglielmo Marconi. There were simple wires, dipoles and coils used for long years. Until World War II the parabolic structures were importantly used in all long distance and other wireless communications. The idea of using small antennas for civilian applications triggered investigators to develop various microwave and frequency independent antennas during the 1950s and 1960s. Later the microstrip integrated circuit (MIC) antennas slowly started getting developed in 1970s to meet out the demand for small antennas which were the most required components for secured military and reliable satellite applications. Gupta and Abdelaziz Benalla (1988) and Gupta et al (1996) had been the main contributors for MIC antennas. Also as the technological development has been in the ascending path, the necessity to categorize these antennas into narrowband and broadband has led investigators to contribute much for newer miniaturized antenna designs.

1.2 MICROSTRIP ANTENNA (MSA)

Dau-Chyrh Chang et al (2010) mentioned that the first MSA was proposed by Deschamps in 1953. Although appeared in the 1950's as stated by Randy Bancroft (2006) the MSAs drew notable attention of designers after two decades in the 1970's only. These MSAs possess low profile suitable for many aircraft, satellite and missile applications when the size, space occupancy, weight, robustness, ease of installation, mechanical reliability and manufacturing cost are considered important. MSAs are useful for applications above 500 MHz because their dimensions are wavelength dependent. However, the prime limitations of MSA are its narrow bandwidth and low gain. Stacked MSAs were the only possibility to increase the gain without compromising the size but at the cost of weight and space. Alternatively the improvements in the gain were tried with arrays of MSA but this increased the size, weight and space required which are against the low profile. Also there were many approaches made to improve the bandwidth such as use of additional substrates or increasing the substrate thickness so that dual band operation was made possible. However, this suffers from the thickness conformability to the surface to which it is mounted along with other circuitry.

1.3 FRACTAL ANTENNA (FA)

MSAs have everlasting attraction among antenna designers due to their low profile nature. However still more attraction gets added when the shape of the MSA is modified innovatively resulting in fractal structures. The French mathematician Mandelbrot (1983) first used the name fractal and fractal dimension in 1970. He stated "A fractal is a shape made of parts similar to the whole in some way" and defined "fractals as a rough and fragmented geometrical shape, which can be subdivided into parts each of which is a reduced copy of the whole". Understanding this concept Douglas

Werner and Suman Ganguly (2003) and many antenna investigators and designers started contributing much to the world of FA after knowing its advantages in the fields of microwaves and antennas. More specifically FAs are the outcomes of creative ideas made on metallic structures. Therefore the important and notable properties of a fractal shape are the space filling and self-similarity of structure resulting in some advantages towards the performance enhancement.

One can witness from the literature that fractals are being studied continuously for many years because of their interesting properties and some of such antennas are in use for a long time. However, investigations of different FAs are ever new on the scene because of the ‘creativity in the radiating structures’ leading to new shapes. The practical FA pioneer had been Nathan Cohen, a radio astronomer from Boston University. He had made experiments in 1988 with wire FAs called von Koch curves and arrays of planar FAs called Sierpinski triangles and proved fractal properties. There have been lot of contributions towards the development of FAs and the complications (Gianvittario and Rahmaat Samii 2000) with these structures are found in literatures. FAs are useful in cellular phones, laptops and many handheld wireless devices. In some applications requiring larger bandwidths or multiple resonances the FAs are more efficient when compared to the conventional MSAs.

1.4 METAMATERIAL (MTM) ANTENNA

In the recent years the applications of MTM are being interestingly investigated and populated in the literature. The MTMs are artificial dielectric media whose unusual properties are gained by artificially modifying the naturally existing substrate structures and not from addition of any chemical compositions to the substrates. More precisely, the MTMs are those materials with unusual medium properties such as negative permittivity, negative

permeability and negative refractive index which are not found in naturally occurring materials. These MTMs are also termed as double negative materials (DNG) and left handed metamaterials. However the materials with dominating negative permittivity or negative permeability are called single negative (SNG) MTMs/more specifically epsilon negative (ENG) or mu negative (MNG) materials respectively. All these DNG or SNG MTMs are used for improving the performance of MIC components such as antennas and filters. These materials are preferred mainly in MICs because they possess frequency selective property finding application in microstrip filters and provide size reduction ability, improved gain and radiation pattern for MSA designs. The analytical method outlined by Filiberto Bilotti et al (2007), for an MSRR, spiral resonator and labyrinth resonator based on square rings can be useful to prepare the frequency selective MTMs for many MSAs and filters.

The MTMs were first introduced theoretically by the Russian Scientist Victor Vesselago (1968). Later the applications of these materials in the field of MSAs have been under investigation vigorously after a silent gap of roughly around 32 years when the work on slip ring resonators proving the existence of negative μ and negative ϵ was reported by David Smith and Norman Kroll (2000).

1.5 IMPLANTABLE ANTENNA (IA)

The feasibility of implementation of IMDs in the human body for various diagnostic purposes is found increasing with the recent improvements in both the wireless technology and medical field. An IA is a device that is capable of being implanted inside the human body for various sensing applications such as monitoring blood pressure, heart beat, tissues characteristics, treating cancerous cells etc. This type of antenna should have the low return loss (≤ -10 dB) at resonances, high gain and large directivity.

This IA engineering is a relatively recent development and is an active area of research as the small size and multiband property of antennas make them attractive candidates for wireless communications to and from the body.

At the beginning the research activities on wireless antennas for microwave applications were mainly focused on obtaining low profile antennas. When the MSA is able to provide such low profile it suffers from certain disadvantages mentioned earlier and hence the research focus has been switched over in the directions of finding out possible improvements while retaining the low profile as unaltered as possible. In the investigation and development of IAs for the body-centric wireless communication, the study of interactions between human body and EM waves due to IA remains to be very important (Koichi Ito 2007). The SAR test is also needed to know the power deposited in the body due to EM waves (Bahrami and Cheldavi, 2010). Also, new research fields for improving the performances of such antennas have emerged because of the advancements in microwave technology and of the need for miniaturization of the systems as a whole in addition to antenna size.

1.6 ORGANIZATION OF THE CHAPTERS

This thesis reports the performances of some novel FA structures with multiple resonances, their improved performances in the presence of MTM substrates and proposes the suitability of application of such antennas in wireless and implantable applications.

Chapter 2 provides a detailed review of literatures on the FAs, MTM antennas, IAs, ANN based MSAs and ANN/MTM based LPF which had already been investigated by previous researchers. It also provides brief information on the usage of numerical CEM methods such as IE3D and HFSS.

Chapter 3 provides the design aspects of MSAs, FAs, MTMs and useful information on IAs. It provides details on the analytical design formulae with many useful guidelines of how the design, simulation, testing of MTM properties can be carried out.

Chapter 4 provides a novel method of combining the square and triangular edged meander fractal structure called Minkowski-Koch combined patch antenna using a rectangular MSA using microstrip as well as CPW feed systems. It also describes another design and simulation of meander type patch as well as thin FAs and presents the analysis of performance.

Chapter 5 presents the description on the design and simulation of a CPW fed new Hilbert curve FA (HCFA) created from the space-filling properties of fractals.

Chapter 6 proposes two modified HCFAs using microstrip and CPW feed systems. The simulations were carried out in air as well as body tissue environments in order to find out their suitability for implantable medical applications. The observed near and far-field radiation characteristics and the multi-resonant ability indicating their suitability for external body and in-body communications have been mentioned.

Chapter 7 provides the simulation of a compact CSRR type MTM loaded HCFA and experimental performances of the same in a large frequency range along with analyses reports.

Chapter 8 initially provides an algorithm for an innovative design of a SFA. It describes how the slots introduced in the SFA can improve the performance. The resonance behavior of the various stages of SFA is analyzed and some experimental results supporting it are provided. Next it describes the performances of SFA of two different sizes obtained from

iterations along with their experimental results in a large frequency sweep range. It also presents a report on the effects of using MSRR based MTM along with the SFA. It carries the verification of experimental results with the simulation in the discussions. Finally it provides an insight into the design optimization of SFA structures with analyses results of application of ANN linked with HFSS platform for obtaining enhanced performances.

Chapter 9 reports the use of ANN in a third order T section Chebyshev type microstrip LPF design. It helps in obtaining the optimized filter design. The performance of the filter simulated using the optimized results is also discussed. It provides a report on an extension of witnessing the benefits of MTM in a third order Pi section Chebyshev type microstrip LPF. An improved filter performance by embedding a newly proposed V shaped MTM structure is included.

Finally the Chapter 10 consolidates the newness and provides a concise summary of thesis contribution along with results achieved throughout this thesis work. Moreover it includes the future scope of directions of research.