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Introduction

Modern communication systems attract the interest of researchers in order to provide reliable wireless transmission between computers, portable personal wireless devices and small electronic gadgets in wireless personal area network (WPAN). These devices transfer stream of audio as well as video data. In order to accommodate all these devices in WPAN, it requires large operational bandwidth. Moreover, there is a requirement of such devices which can transfer high data rate at very low power consumption compared to current wireless technology. Any communication system has an antenna at its front end. Hence, it must have compact dimensions in order to easily integrate it with the system. Traditional antennas operate at multiple frequency bands. Hence, different antennas are required for these multiple frequency bands, which in turn lead to large system size. In order to overcome this problem, multiband antennas should be replaced with a single wideband antenna. Therefore, ultrawideband (UWB) technology gets the attention of researchers because of its wide operational bandwidth and high data transmission capacity at low power. At the same time, it imposes great design challenges to the antenna designers to achieve the desired antenna characteristics in a given compact dimension. Compactness in the design helps to integrate the antenna with UWB system in a given small area. It also helps to reduce the overall cost of UWB systems.

1.1 Motivation

The concept of fractal geometry can be applied to design various types of antennas (e.g. Patch antenna, Planner antenna, etc.). The application of fractal geometry in antenna design helps to achieve compactness and wide impedance bandwidth with optimized antenna characteristics. Fractals geometries have infinite complexity, which may be utilized to reduce the antenna size. Therefore, low profile antennas can be easily designed by using fractal geometry. The self-similarity concepts of fractals lead to (1) multiple frequency bands due to similarity of different parts of the geometry to each other at different scales, and (2) obtain wider operational bandwidth by combining these multiple frequency bands. Fractals have several bends and curves in the design and are the cause for change in the current path, which in turn leads to enhance the radiation characteristics of the designed antenna. Hence, the application of fractals in antenna design helps to achieve desired miniaturization and wideband phenomena.

1.2 Objectives

The purpose of the proposed work is to design and development of compact and wideband antenna with enhanced radiation characteristics using fractal geometry. The objectives of the present work are as follows:

- Application of space filling property of fractals in antenna design to achieve the desired miniaturization.
- Use of self-similar characteristics of fractals, which leads to multiple resonance phenomena to obtain wide impedance bandwidth.

- Development of UWB antenna with stable radiation pattern and good gain.
- Design of compact UWB antenna in order to integrate it with UWB systems.

1.3 Author's Contributions

The introduction of fractal geometry concept in antenna design for different UWB applications has been studied extensively and can be further divided into five parts. The first part deals with a number of novel antennas generated using Minkowski-like, Minkowski, Sierpinski and Koch fractal geometries and their characteristics are investigated. In addition, an analytical mathematical formula is presented to show the miniaturization concepts of the antenna. Furthermore, a comparative study among different fractal antennas in terms of bandwidth, gain and fidelity factor is also carried out.

In the second part, compact UWB antennas with band rejection characteristics are presented. An UWB system operates in wide frequency range from 3.1-10.6 GHz. In this spectrum range, many other narrowband systems also operate and cause the interferences with UWB systems. In order to achieve the band rejection characteristics, fractal as well as non-fractal C-shaped slots are being used in the design. These prototypes are fabricated and measured to validate the proposed concept.

In part three, reconfigurability is introduced in antenna design in order to utilize the spectrum efficiently. In the design process, reconfigurability is introduced in terms of band rejection as well as operating bandwidth using p-i-n diodes, capacitors and resistors in fractal UWB antenna design.

The fourth part reviews the compact UWB multiple-input-multiple-output (MIMO) antennas designed using Minkowski and Koch fractal geometry. UWB systems also face severe challenges such as multipath fading and interferences due to other narrowband systems. It is demonstrated that application of fractals in UWB MIMO antenna design helps to achieve the desired miniaturization and enhanced radiation characteristics.

Finally, the operating behavior of fractal UWB antenna and fractal UWB MIMO antenna are studied, in the proximity of the human body, in the context of on-body and off-body Wireless Body Area Network (WBAN) applications. The performance evaluation of these antenna are carried out in terms of S-parameters and radiation patterns at different body parts (near forehead, heart and abdomen) to receive healthcare data for different scenarios.

1.4 Outline of the Thesis

The thesis is organized in the form of 8 chapters. Following this chapter, remaining part of the thesis is organized as: Chapter 2 presents the literature review of the previous works in the context of the study. It highlights the research gaps of the previous studies carried out and the need for the contribution of the present study. Chapter 3 presents numerous UWB antennas designed using different fractal geometries to achieve the miniaturization and wideband phenomena with enhanced radiation characteristics. Chapter 4 reviews the band rejection phenomena in UWB antenna design. The objective is achieved by fractal or non-fractal C-shaped slot in the design. Chapter 5 introduces the concept of reconfigurability in the fractal UWB antenna. Reconfigurable multiple band notch and reconfigurable bandwidth concepts are studied to utilize the spectrum efficiently. Chapter 6 covers the application of fractals in UWB MIMO antenna design. Chapter 7 gives an insight into the practical application of fractal UWB antenna and fractal UWB MIMO antenna, in the proximity of human body, in the context of on-body and off-body WBAN applications. Finally, chapter 8 summarizes and concludes the research work and provides inputs for future developments.

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