Preface

Wireless communication systems have become an integral part of humans' everyday life. Wireless communication technologies enable consumers to have access to a wide range of services comfortably at any time from any place. The limitations imposed on the people's communication by geographical locations are eliminated with the introduction of wireless mobile access points. The Internet allowed people to access and share information in a much faster way. Satellite TV and radio are one of the sources for peoples entertainment. Wired devices have been replaced with cordless devices. Wireless networking technologies such as Bluetooth, wireless fidelity (Wi-fi), and wireless personal area networks (WPAN) enhanced the way portable devices stay interconnected. The demand for high speed, high capacity, and secure wireless communications is increasing day by day to keep up with the ever increasing needs of the humans.

The upper limit on the capacity or data rate attainable in an additive white Gaussian noise (AWGN) channel characterized as band-limited ideally is given by Shannon-Nyquist Criterion [1, 2]. The increment in transmission rate of data is possible either by raising the transmission power level or extending the occupied bandwidth. The channel capacity increases logarithmically as the signal-to-noise (SNR) increases. Existing wireless systems operate at fixed frequencies and bandwidth with strict regulations imposed by Federal Communication Commission (FCC). Higher speeds are attainable with raising the transmission signal power. A large number of portable devices use battery as a source of power which limits the transmitted power. Apart from that a higher transmitted power leads to the potential interference with nearby communication systems, as wireless system is interference limited. Consequently, a large spectral bandwidth is the best possible solution to achieve higher data rates. However, the spectrum is scares and comes under the strict regulations of FCC.

In order to achieve higher data rates with the limited available resources and imposed constraints, wireless communication technology needs to be pushed beyond the physical limits of the propagation channel. To address the issue, two promising technologies have been evolved in the past decade. One is the ultra-wideband (UWB) communication and the other one is multiple-input-multiple-output (MIMO) communication system. The approach to achieve higher data rate over Shannon's limit using these technology is different from one another. The former technology takes the advantage of short time-domain un-modulated pulse transmission, whereas the later takes the advantage of multipath propagation characteristics of wireless channel to achieve a higher data rate. These technologies can coexist with existing narrowband communication standards without any interruption/interference.

In February 2002, a wide 7.5 GHz spectrum beginning at 3.1 GHz and ending at 10.6 GHz was released by Federal Communications Commission (FCC) for unlicensed use permitting the implementation of ultra-wideband (UWB) technology for commercial purposes [3]. UWB technology has drawn significant attention with this new spectrum allocation. UWB technology offers a promising solution to the high data rate transmission and RF spectrum drought. Ultra-wideband communications are a game changing wireless technology with many inherent merits. In UWB technology, large amounts of digital data are transmitted over a short range over a large portion of the frequency spectrum utilizing low powered, short pulse radio signals. UWB technology is capable of delivering performance not attainable by conventional narrow band wireless technologies. Some advantages of UWB technology include high data rate are consumption of less average power, better immunity to multipath cancellation, higher range measurement accuracy, and range resolution, low cost [4]. By using very low powered, short pulse, broad spectrum radio signals, the interference caused when compared to the other narrow band systems is very less, and hence coexistence with already existing other narrowband conventional wireless technologies which include wireless local area network (WLAN), wireless fidelity (Wi-fi), and Bluetooth is possible. These features of UWB technology make it suitable for applications such as covert communication links, surveillance, Internet with very high-speed broadband accession in short range, ground-penetrating radar with high resolution, through-wall imaging, precision navigation, RF tracking and positioning, and high bit rate WPAN [5].

Antenna is a crucial part of any system because ultimately any wireless system needs to use an antenna to convert the signal to electromagnetic waves for propagation in free space and the received electromagnetic waves back to signal. The performance of UWB systems is highly dependent upon antenna characteristics. A high performance in terms of wideband impedance matching, linear phase response, and stable radiation pattern over wideband is essential for the successful transmission and reception of UWB pulses. Many researchers have reported various antenna solutions for UWB communication [6, 7]. Still there is a need of novel antenna solution for pulse transmission. A time-domain analysis is required to compare the performance of these antennas.

Recent research has shown that by using multiple antenna elements at the transmitter and receiver ends known as MIMO system (multiple-input-multiple-output), the channel capacity can be increased without the need of increasing the channel bandwidth or transmitted power level. The limits on data rates have been pushed up by introducing another dimension to mobile communication technology, i.e., spatial diversity, having multiple antenna elements at both receiver and the transmitter ends, the channel capacity increases linearly with the number of antennas in comparison to a conventional single-input-single-output (SISO) system [8]. This system with array of antennas at both transmitter and receiver ends is called the MIMO system. The channel capacity over fading channels having antenna arrays at both the ends was first published by Winters in 1987 [9]. The tremendous potential of MIMO systems was appreciated more than ten years later when they were reinvented by Foschini and Gans [10], and Telatar [11]. Since then, efforts have been put in to overcome challenges of MIMO systems.

Earlier most of the research on MIMO systems focused on the channel properties as well as the signal processing algorithms. The derivations on maximum achievable channel capacity of MIMO systems were based on assuming zero correlation between the signals on different antennas. The new major parameters of focus are the propagation channel and the antenna design keeping in view that signal processing and channel characteristics are equally important. MIMO systems performance improves with lower correlation between the signals on different antennas [12]. Antenna parameters such as (1) array configuration, (2) polarization of antenna, (3) radiation pattern, and (4) mutual coupling between signals impact the correlation.

It is very difficult to accommodate several antennas maintaining low correlation in the small dimensions of the mobile terminal. At the base station, low correlation can be achieved by placing the antennas at appropriate distances ideally half wavelength apart as there is no restriction of space. This is known as spatial diversity. At the mobile terminal, the space is limited so antennas cannot be placed far apart which results in high correlation and, therefore, degrades the MIMO performance. Using diversity techniques such as pattern diversity and polarization diversity, uncorrelated signals can be obtained in a multipath environment by having orthogonal signal patterns. The entire work done in the present book is broadly categorized in two parts, i.e., (1) design and analysis of compact UWB antennas for high data rate communication, and (2) design and analysis of compact MIMO antennas for space crunch applications.

Overall, during the course of the research work, according to the defined problem statement, compact antenna solution has been presented for UWB and MIMO systems to achieve high data rate communication. All above mention issues are presented in Chaps. 1–7 of this book. An introduction of the entire work followed by the motivation behind it and objective of the research is presented in Chap. 1. It also presents the scope of the overall work. Chapter 2 presents a comprehensive review on previous published literature on antenna solution for UWB and MIMO communication systems. The research gap and the problem formulation have been presented. Chapter 3 deals with time-domain analysis of ultra-wideband antennas with notch techniques. In the first section, UWB antenna with single notch has been discussed. In second section, UWB antenna with dual band-notch characteristics has been discussed. In the above two sections, the realized notch is static type notch which cannot be altered in real time. Sometimes, it is required that the notch to be tuned so that a particular target frequency can be rejected. So in third section, UWB antenna with tunable band-notch characteristics has been presented. To mitigate interference with existing narrow band communication systems, UWB antenna with various band-notch techniques has been explored by various researchers in literatures. These techniques result a similar kind of frequency domain notch characteristics, i.e., notch bandwidth and notch strength. However, time-domain performance may get affected differently by different band-notch techniques. A time-domain comparison of band-notch techniques has been discussed in Chap. 4. In Chap. 5, compact MIMO antenna solution utilizing pattern diversity has been discussed for space crunch mobile terminals. The first antenna utilizes a omnidirectional type pattern diversity, whereas the second antenna shows a combined pattern and polarization diversity. In an environment where multiple scattering elements and depolarizing elements are common, use of a circularly polarized antenna gives excellent performance over linearly polarized antenna. Again using a circular polarization diversity MIMO antenna, the channel capacity can be increased. Novel antenna solution for MIMO system utilizing polarization diversity has been designed and analyzed for a compact terminal has been presented in Chap. 6. Finally, Chap. 7 summarizes the contributions made in this book and the scope for the future work is outlined. In summary, this book contributes toward the development of compact antennas for high data rate communications. Wideband antennas for pulse transmission and compact MIMO antennas have been designed, analyzed, and presented in this book.

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