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Compact Multimode Antenna Arrays for High Spectral Efficiency MIMO-OFDM WLANs

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INTRODUCTION

In this work we propose space-multimode (SM-SCP-ULA) and space-multimode-polarization stacked circular patch uniform linear antenna arrays (SMP-SCP-ULA) for deployment in size-constrained access points, modems and end-user terminal equipments of IEEE 802.11n MIMO-OFDM WLAN systems at 5.8 GHz. The performance gain of higher-order modal SMP-SCP-ULA in terms of spatio-modal power correlations, ergodic spectral efficiencies and compactness gains are compared with dominant-mode operating circular patch antenna arrays (CP-ULA) and center-fed dipole arrays (DP-ULA).

In the concurrent and next-generation communication systems, the spectral efficiency and transmission quality can be vastly enhanced by multiple-input multiple-output (MIMO) communication techniques (Telatar,1999). In communication systems employing MIMO spatial-multiplexing, higher data rates can be achieved when there are a large number of scatterers between the transmit and receive antennas i.e. rich-scattering environment (Goldsmith, 2007; Biglieri, 2010). However, the spatial correlation between transmit and receive antenna ports that is dependent on antenna-specific parameters such as the radiation patterns, the distance between the antenna elements as well as the channel characteristics such as unfavourable spatial distribution of scatterers and angular spread severely degrades the capacity and quality achievable by MIMO spatial-multiplexing systems.

The space consumption of MIMO antennas is especially vital in applications such as access points, modems and end-user terminal equipments (laptops, PDAs etc.) of WLAN and WIMAX systems. When regularly spaced antenna elements are used in MIMO systems, the correlation between the antenna elements in a space diversity system and hence the channel capacity and transmission quality are dependent on the distance between antenna array elements, the number of antenna elements and the array geometry (Harshal, 2014). However, due to the physical constraints and the concerns on ergonomics and aesthetics, the distance between antenna elements in practice cannot be extended beyond a certain level which limits the use of space-only diversity MIMO spatial-multiplexing systems to achieve the desired spectral efficiencies and transmission qualities. As an alternative solution to achieve compactness in MIMO systems, the use of pattern diversity (Foschini, 1998; Forenza, 2006), multimode diversity (Sanchez, 2008; Svantesson, 2002), and polarization diversity (Mukherjee, 2007; Waldschmidt, 2003) techniques in conjunction with space diversity are proposed in the literature.

Besides polarization diversity that is well-known, multimode and pattern diversity techniques that are less addressed in antenna engineering community are achieved by using higher-order mode generation in antenna structures and in general microstrip, biconical, helical, spiral, sinuous and log-periodic antenna structures are amenable to higher-order mode generation (Yavanoglu, 2011). In this manner, the higher-order modes generated in a single antenna structure with

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directional radiation patterns resulting in low spatial correlation in angle space are used as diversity ports in a MIMO system within a compact space. In pattern diversity on the other hand that is slightly different than multimode diversity, orthogonal radiation patterns generated on distinct antennas that are co-located at the phase-centers are generated and used as diversity ports.

A multimode stacked circular microstrip patch antenna used in a uniform linear array structure (SCP-ULA) for MIMO-OFDM WLAN systems conforming to IEEE 802.11n standard is designed and the associated correlation, ergodic spectral efficiency and compactness with respect to omnidirectional dipole (DP-ULA) and circular microstrip uniform linear arrays (CP-ULA) operating in the dominant isotropic TM_{01} mode are analyzed in this work.

BACKGROUND

Recent developments in wireless communication systems in indoor environments require high data rates and high transmission qualities especially in wireless local area network systems (WLANs). In the recent years there has been intense work ongoing in increasing the capacity and quality in wireless communication systems. One of the main themes on these studies is the MIMO (Multiple-input Multiple-output) multiple-antenna systems that increase the capacity and quality without any additional bandwidth or power.

Last works have shown that the data rate that a MIMO system can support in a certain bandwidth with negligible amount of error is given by the minimum of the number of antennas used at the transmitter and receiver (Zelst, 2000). Besides the properties of antennas used to construct MIMO systems such as their physical structure play an important role in the performance of MIMO systems. In the design of MIMO systems one of the main limitations is the spatial complexity requirement that is defined by the area of the location where the multiplexed antennas are placed. Especially in wireless local area networks antennas has to be placed close due to space limitation and so the recieved signals at the antennas experience correlated fading. This leads to spatial diversity gain reduction and decreasses capacity and system quality. In this respect we propose and analyze a MIMO array consisting of higher-order space-multimode-polarization diversity stacked circular microstrip patch uniform linear arrays (SMP-SCP-ULAs) to exploit space-multimode and polarization diversity for use in WLAN systems. Using higher number of antenna ports in lower space and low cross-polar discrimination values between each transmit and recieve antenna, SMP-SCP-ULA yields higher multiplexing gain and satisfies more restrictive size constraints in space-limited MIMO systems (IEEE P802.11n, 2009).

The wireless local area network (WLAN) technology for medium-range indoor/outdoor wireless communications standardized by IEEE P802.11 working group has emerged from pre-802.11 standards towards spectrally-efficient and multipath-robust OFDM modulation based 802.11b and 802.11a/g with data rates increasing up to a maximum of 54 Mbps for 802.11a/g. These standards are limited to the use of single transmit and receive antenna at the access points and modems as well as laptops/PDAs in WLANs for end-users forming a SISO-OFDM (single-input single-output OFDM) channel.

In the last decade, with the proliferation of MIMO spatial-multiplexing technology using multiple transmit and receive antennas achieving much higher data rates without sacrificing either bandwidth or transmit power with respect to SISO systems, IEEE 802.11 standard is later extended with the version 802.11n incorporating MIMO capability with the first amendment published in 2009 proposing operation at lower and upper ISM bands of 2.4 GHz and 5.8 GHz with the corresponding bandwidths of 20 MHz and 40 Mhz respectively. By the use of MIMO spatial-multiplexing technology, higher-order 64/128/256-QAM modulations, a 40 MHz channel bandwidth at 5.8 GHz that is double that of legacy IEEE 802.11 a/b/g systems, a cyclic prefix of 400 ns that is half of legacy systems which reduces symbol time and hence increases data rates, more efficient OFDM structure with 52 subcarriers with respect to 48 subcarriers in legacy systems, and frame -aggregation/block-acknowledgement protocol with higher packet sizes at the MAC layer, IEEE 802.11n standard sets forth the basis for multimedia-enabling high-throughput next-generation Wi-Fi networks.

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