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A measurement based feasibility study of Space-Frequency MIMO detection and decoding techniques for next generation Wireless LANs

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Abstract— **This article presents a performance evaluation of various multi-antenna concepts based on OFDM for Wireless LANs. The studies are based on state-of-the-art measured channel data. The studies aim to assess the MIMO concepts for future high speed W-LANs.**

Keywords— **MIMO, WLAN, Space-time, OFDM.**

I. Introduction

THE current generation of high data rate wireless local area network (WLAN) standards, such as IEEE802.11a, provide data rates of up to 54 Mbit/s. However, the ever-increasing demand for even higher data rate services, such as internet, video and multi-media, have created a need for improved bandwidth efficiency from next generation wireless LAN consumer products. The current IEEE802.11a standard employs the bandwidth efficient scheme of Orthogonal Frequency Division Multiplex (OFDM) and adaptive modulation and demodulation. The systems were designed as single-input single-output (SISO) systems, essentially employing a single transmit and receive antenna at each end of the link. Within ETSI BRAN some provision for mutiple antennas or sectorised antennas has been investigated for improved diversity gain and thus link robustness.

Until recently considerable effort was put into designing systems so as to mitigate for the perceived detrimental effects of multipath propagation, especially prevalent in indoor wireless LAN environments. However, recent work [1] has shown that by utilising multiple antenna architectures at both the transmitter and receiver, so-called muliple-input multiple-output (MIMO) architectures, vastly increased channel capacities are possible, limited only by the amount of multipath activity in the propagation environment and the number of transmit/receive antennas employed.

The ideas behind space-time trellis coded modulation (STTCM) were first presented in [2]. By adopting relatively simple coding and decoding strategies, across both the spatial and temporal domains, capacities within 2.5dB of the theoretical outage capacity were obtained. Recent attention has turned to the adoption of space-time coding techniques to wideband channels, and in particular their usage in OFDM-based systems where coding is performed in the space-frequency domain.

The technique of space-frequency coding for OFDM-based systems is of interest for future enhancements to consumer electronic WLAN products. Performance gains, in terms of capacity and/or link robustness, can be achieved at relatively small cost. The major cost component is borne by the need for multiple transmit and receive antennas, whilst signal processing relies upon well established methods (Viterbi maximum likelihood sequence estimation, interference suppression etc.).

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II. Space-frequency techniques in MIMO-OFDM

Practically all techniques that have been developed for single carrier MIMO systems can by utilised in MIMO-OFDM. The only difference is that the MIMO channel, typically described by a mixing matrix $\mathbf{H}$, is not constant. This is equivalent to fast fading single carrier MIMO systems.

A. Space-frequency trellis coded OFDM

When STTCM is applied to OFDM systems the coding takes place across frequency and space rather than time and space. In the time domain the amount of available diversity is related to the Doppler phenomenon. Conversely, the delay spread in the radio channel gives rise to diversity in the frequency domain. It is expected that WLAN systems will operate in environments ranging from frequency flat to frequency selective. Hence, the diversity may be available in both the space and frequency domain. Reference [3] presents studies of STTCM with OFDM over measured channels.

B. Spatially multiplexed OFDM

As primarily a diversity technique, the constructions of STTCM-OFDM typically do not exceed a configuration of

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2Tx by 3Rx. Spatial multiplexing (known also as BLAST [4]) represents a direct exploitation of the available space-time resources. In spatial multiplexing for OFDM, independent codewords are sent on each sub-carrier. The decoding as a mirror operation is performed independently on all sub-carriers, which simplifies the detection. However, this also impairs the system performance since no frequency diversity is utilised. This situation can be ameliorated if the system uses outer channel coding with interleaving to recover frequency diversity. Another solution is a hybrid of Space-frequency coding and spatial multiplexing.

C. *Combined spatial multiplexing and space-frequency coding*

Combining both approaches can be achieved using *Group Interference Suppression* (GIS) [5]. Here, a modified version of the GIS receiver suitable for Space-Frequency coded OFDM is presented. A schematic of this idea is depicted in figure 1. Such architecture can also be viewed as the Spatial multiplexing system, where each stream of data is protected by G individual Space-frequency codes (SFC). An optimal receiver would perform a systematic search over all possible codewords generated by the whole set of component codes. Such an approach however results in prohibitively high complexity. The component codes can be decoded separately, using the receive antenna array as a spatial processor to suppress other component codes - GIS.

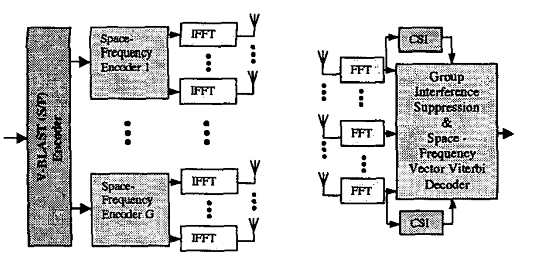

Fig. 1. A combination of Spatial Multiplexing and Space-frequency Coding.

III. Wideband MIMO channel measurements

The wideband MIMO measurements utilised in this work have been taken using a customised Medav RUSK BRI vector channel sounder operating in the 5.2 GHz band with 120 MHz of bandwidth. Each complete MIMO (8 Tx by 8 Rx) channel snapshot of takes 102.4 ms. The measurements were taken in an open plan office with approximate dimensions of 30L x 20W x 4H (m). The Mobile Terminal (MT) antenna array comprises of 4 dual polarised patch antennas. The antennas were located in the corners of a dielectric plane with dimensions similar to that of a typical laptop computer cover. The Access Point (AP) utilises a circular array of printed dipoles. The measurements locations were chosen to emulate a wireless LANs operational scenario.

IV. Numerical Example

Figure 2 depicts the frame error rate of the Spatial multiplexing Space-frequency coding concatenation for the 8×8 case. Each SFC encoder uses the same 32 state 4-PSK component code. It can be observed that the difference between measured and synthetic channels is $\approx 5 - 6$dB. The difference is predominantly due to the larger amount of frequency diversity available in the simulated channels case. An additional 2dB (approx.) of SNR per receive antenna is needed to compensate for the lack of ideal CSI.

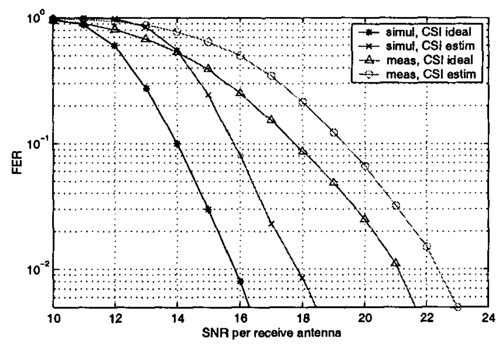

Fig. 2. Performance of Spatial multiplexing Space-frequency Coding concatenation over simulated and measured channels.

V. Conclusions

This article investigates space-frequency concepts for MIMO-OFDM. In this context Space-frequency coding and spatial multiplexing for OFDM has been studied. The two approaches have been combined to mutually exploit the benefits of both schemes. Performance results confirm the increased system robustness, indicating a vast potential for future OFDM based WLAN standards.

Acknowledgments

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