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HYBRID TECHNOLOGY PROVIDING CONCURRENT VEHICULAR SAFETY AND COMMUNICATION

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Abstract—Multi-carrier system has been fuelled by large demand on frequency allocation, resulting in a crowded spectrum as well as large number of users requiring simultaneous access. Existing wireless systems may be utilized single frequency, single antenna and pulse for carrier transmission and reception. Problems of such system is that in case of failure the total system will become non operational. So we established a distributed system in terms of multi-carrier, multi-antenna and coded pulse can provide a more suitable communication and sensor gives rise to DSSS-OFDM-MIMO based hybrid technology is the ultimate solution. This technology is a promising technique for high-data-rate broadband wireless communications and radar because it can reduce interference, multipath effect, jamming and higher target resolution as compared to conventional communication & radar etc. The proposed techniques improve the performance of OFDM, DSSS and MIMO based wireless communications and sensing for ITS and

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other applications. Finally this system can be implemented using Software defined Radio to get continuous connectivity of the system.

1. INTRODUCTION

All wireless technologies face the challenges of multipath signal fading (caused by destructive addition of multipath components), increasing interference from other users and limited spectrum. The major challenges in future wireless communications system design are increased spectral efficiency and improved link reliability. We resort to diversity to combat fading. Diversity provides the receiver with several (ideally independent) replicas of the transmitted signal and is therefore a powerful means to combat fading and interference and thereby improve link reliability. Common forms of diversity are time diversity (due to Doppler spread) and frequency diversity (due to delay spread) and in recent years the use of spatial (or antenna) diversity has become very popular, which is mostly due to the fact that it can be provided without loss in spectral efficiency. Receive diversity, that is, the use of multiple antennas on the receive side of a wireless link, is a well-studied subject [1].

The concept of MIMO was first introduced by Jack Winters [2] in 1987 for two basic communication systems. The first was for communication between multiple mobiles and a base station with multiple antennas and the second for communication between two mobiles each with multiple antennas. Subsequently, the papers of Foschini [3, 4] presented the analytical basis of MIMO systems and proposed two suitable architectures for its realisation known as vertical BLAST, and diagonal BLAST. The basic motive was to increase the data rate in a constrained spectrum.

The use of multiple antennas at both ends of a wireless link (multiple-input multiple-output) MIMO technology has recently been demonstrated to have the potential of achieving extraordinary data rates, without increasing the total transmission power or bandwidth [3–11] or the quality of target image will be more resolved for MIMO radar [12, 13], spectral efficiencies, allows longer range and supports backward-compatibility and simultaneous increase in range and reliability — All without consuming extra radio frequency. When perfect knowledge of the wireless channel conditions is available at the receiver, the capacity has been shown to grow linearly with the number of antennas. MIMO communication systems overcome the effect of fading in the wireless channel by transmitting redundant streams of data from several deco-related transmitters [14]. For independent fading paths, the receiver of a MIMO system enjoys the fact that the average (over all information streams) signal to noise ratio (SNR) is more or less constant, as the number of paths increases, whereas in conventional systems, which transmit all their energy over a single path, the received SNR varies considerably.

Digital communication using MIMO processing has emerged as a breakthrough for revolutionary wireless systems. It solves two of the toughest problems facing any wireless technology today: speed and range. The corresponding technology is known as spatial multiplexing [7, 8] or BLAST [7, 15] and yields an impressive increase in spectral efficiency. MIMO wireless has been restricted to narrowband systems. Besides spatial diversity broadband MIMO channels, however, offer higher capacity and frequency diversity due to delay spread. Orthogonal frequency division multiplexing (OFDM) [8, 9, 16, 17] significantly reduces receiver complexity in wireless broadband systems but in this case synchronization and channel estimation are very important. The use of MIMO technology in combination with OFDM, i.e., MIMO-OFDM [3, 5, 15, 18] is therefore seems to be an attractive solution for future broadband wireless systems. But this MIMO system having fast framing rate of the order of 1–2 μs will be polluted by ISI when operational in an environment having a typical time delay Spread of 200 μs. Thus an ISI value of $200/2 = 100$ is an undesirable multi-path effect for the real MIMO system. Therefore MIMO cannot achieve zero ISI and hence cannot be utilized alone. OFDM based multi-carrier approach may be enabler for the MIMO broadband operation So the fast frames are slowed down first and converted to several slow sub frames and modulated to multiple carriers of OFDM. OFDM-MIMO is, therefore, useful technology which can be explored both for communication and remote sensing (radar). The system efficiency will be further better if coding in the form of DSSS can be added to the OFDM resulting in a COFDM system [6]. This concept has been already proved in the field by NTT DoCoMo of Japan, where in the company tested such a system for outdoor use using a bandwidth of 100 MHz to achieve a throughput of 100 Mbps [19]. Thus hybrid technology will fulfill the goal of 4G Mobile communication towards achieving a data rate of 100 Mbps at user terminal.

2. OFDM-MIMO FOR WIRELESS COMMUNICATION

OFDM is a multicarrier transmission technique, which divides the available spectrum into many carriers, each one being modulated by a low data rate stream. Each sub-carrier is orthogonal to each other, meaning that cross-talk between the sub-channels is eliminated and inter-carrier guard bands are not required which significantly reduces the receiver complexity.

In current 802.11 systems without MIMO (Multiple Input Multiple Output) there is a single RF (Radio Frequency) chain on the wireless device. Multiple antennas use the same hardware to process the radio signal. So only one antenna can transmit or receive at a time as all radio signals need to go through the single RF chain. In MIMO there can be a separate RF chain for each antenna allowing multiple RF chains to coexist.

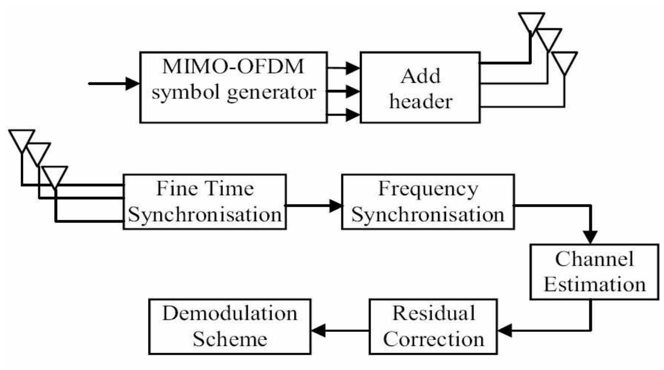

Figure 1. Simplified MIMO-OFDM system.

The various parameters on which the simulation followed by analysis are:

Modulation techniques: BPSK, QPSK, 8-PSK and 16-QAM.

Number of FFT points: 64, 128,256 and 512. (with and without interleaving), Convolution code rates: R1/2, R2/3 and R3/4,

Channel Models: AWGN, Rayleigh and Rician and Packet to simulate: 1000.

Systems: 1×1 (SISO), 1×2 (SIMO), 2×1 (MISO), 2×2 and 4×4 (MIMO). Subsystems: AWGN Gain (in dB) — 0, 10, 20 and 30; Rayleigh Gain Vector $-0.8\,$dB.

The performance analysis has been carried out broadly in two sections: OFDM-MIMO System and Sub-System Performance and OFDM-MIMO Channel estimation.

2.1. OFDM-MIMO System and Sub-system Performance

Performance analysis has been carried out for individual sub-system blocks and the system (MIMO-OFDM) as a whole. The individual subsystem blocks including OFDM subsystem block and Space-Time Coding subsystem block. A comparative study on the individual subsystem block with varying parameters has been done along with the overall performance of the OFDM-MIMO system as well based on MATLAB simulation. The experimental results have been verified using the simulation. The results of simulation have been verified with the various works being carried out in this area and the results conferred to be correct.

i) In comparison with three cases (SISO case, 2×2 & 4×4 MIMO), the performance of the MIMO system is profoundly better over other with respect to BER/PER. The performance of the uncoded systems seemed to be overlapping but we can make a clear distinction between the 1×2 (SIMO), 2×1 (MISO) and 2×2 (MIMO) by introducing codes before OFDM. Even the SIMO system performance shows great deal of improvement over other system, which is mainly due to it's receiving diversity technique being deployed as depicted in Figures 2 and 3.

ii) We are able to check that the performance of the MIMO systems improves drastically in the Rayleigh channel. Thus providing us the understanding for the need of deployment of multi-antenna systems or rather MIMO-OFDM systems for better performance as depicted in Figure 4.

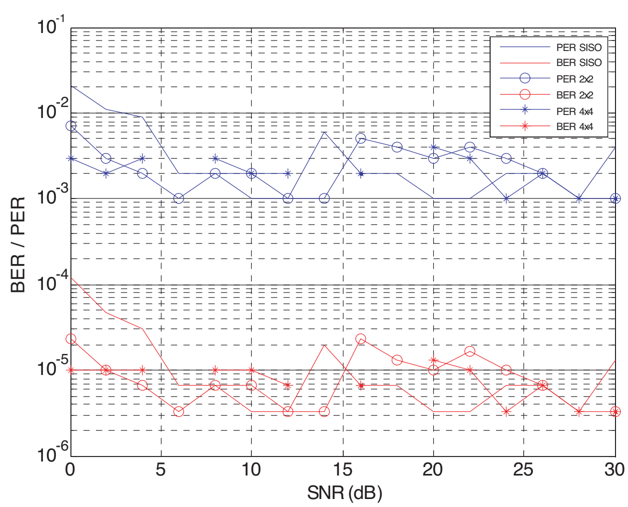

Figure 2. SISO vs. 2×2 vs. 4×4.
Parameters: No. off FFT points = 64; Modulation = BPSK; Convolution Code Rate = R1/2; Channel = AWGN.

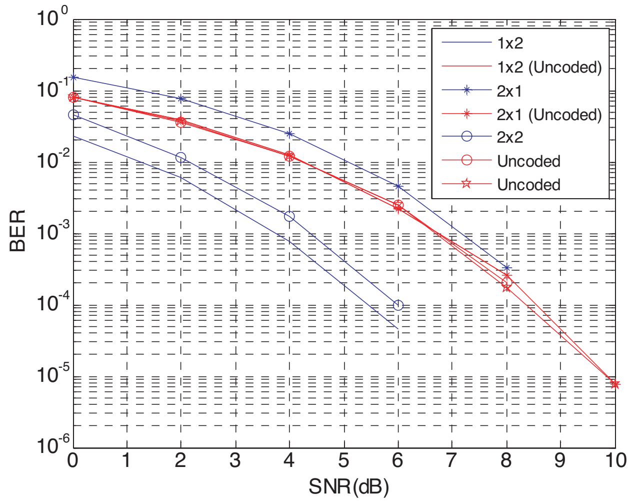

Figure 3. 1×2 vs 2×1 vs. 2×2 vs. 4×4 (AWGN). Parameters: No. off FFT points = 64; Modulation = BPSK; Convolution Code Rate = $R1/2$; Channel = AWGN.

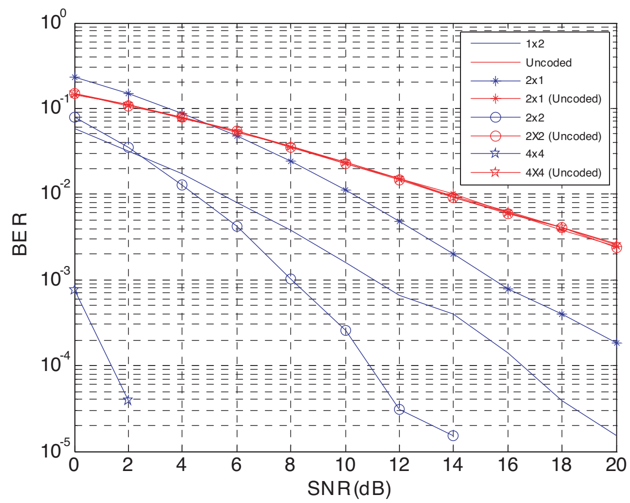

Figure 4. -1×2 vs 2×1 vs. 2×2 vs. 4×4 (Rayleigh). Parameters: No. off FFT points = 64; Modulation = BPSK; Convolution Code Rate = R1/2; Channel = Rayleigh.

iii) 2×2 MIMO performance alone may not be so satisfactory. Even it is slightly inferior to OFDM performance. But interestingly, the combined efforts of OFDM-MIMO are noteworthy and results in dramatic improvement of the total system. In this simulation other parameters are constant for the three systems as depicted in Figure 5.

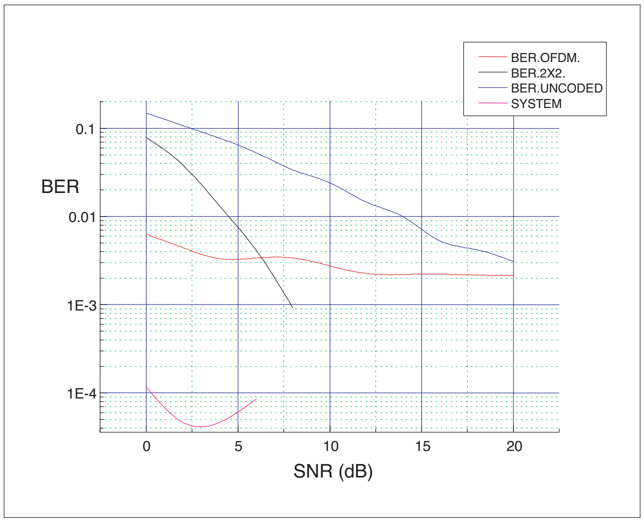

Figure 5. BER performance comparison between individual subsystem blocks and the total OFDM-MIMO Wi-Fi system.
Parameters: No. off FFT points = 64; Modulation = BPSK; Convolution Code Rate = R1/2; Channel = AWGN.

iv) The performance of a 2×2 MIMO system with various modulation techniques shows that the performance of QPSK is better than BPSK, 8-PSK better than QPSK and ultimately 16-QAM performing the best. 16-QAM modulation shows a phenomenal improvement over the increase in the value of the SNR as shown in Figure 6.

2.2. OFDM-MIMO Channel Estimation

i) The comparative performances of AWGN and Rayleigh channels under coded and uncoded conditions for a 2×2 MIMO case observation was interesting and useful. As practically observed Rayleigh channel conditions are worse than the AWGN case, and hence the simulation depicts a wide variation between the two in uncoded condition. But, interestingly when the channels are coded the margin of variation has reduced greatly as depicted in Figure 7.

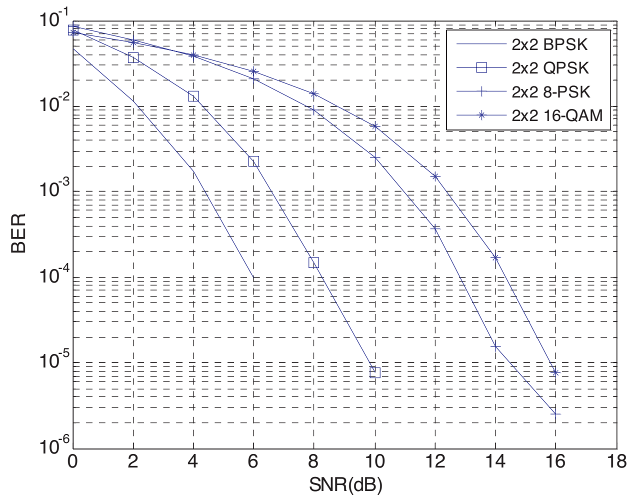

Figure 6. Performance of 2×2 MIMO system with various modulation techniques.
Parameters: No. off FFT points = 64; Convolution Code Rate = R1/2; Channel = AWGN; System = 2 × 2 MIMO.

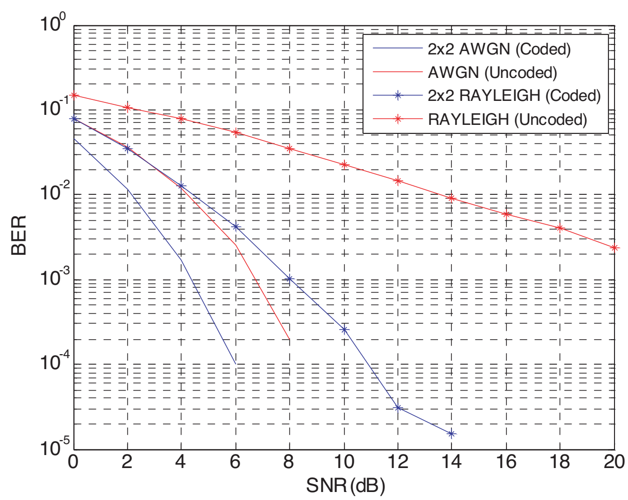

Figure 7. AWGN vs. Rayleigh (2 × 2 case).
Parameters: No. off FFT points = 64; Modulation = BPSK; Convolution Code Rate = R1/2; System = 2 × 2 (MIMO).

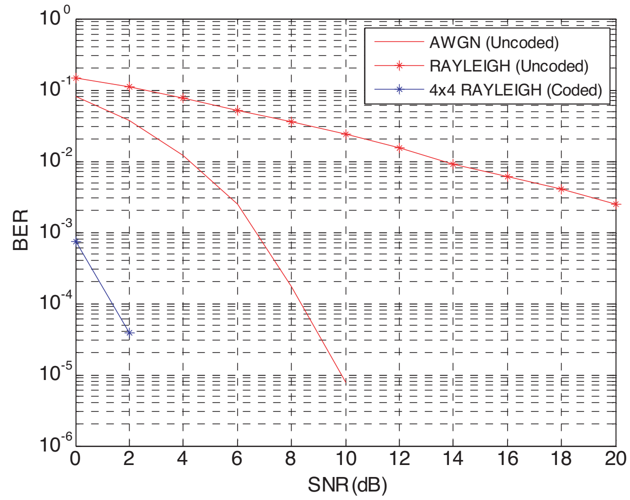

Figure 8. AWGN vs. Rayleigh (4 × 4 case).
Parameters: No. off FFT points = 64; Modulation = BPSK; Convolution Code Rate = R1/2; System = 4 × 4 (MIMO).

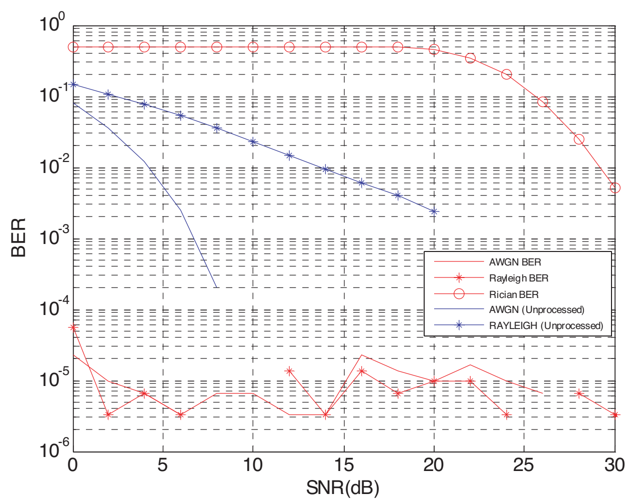

Figure 9. Processed vs Unprocessed (AWGN vs. Rayleigh vs. Rician [2 × 2]).
Parameters: No. off FFT points = 64; Modulation = BPSK; Convolution Code Rate = R1/2; System = 4 × 4 (MIMO).

ii) The comparative performances of AWGN and Rayleigh channels under coded and uncoded conditions for a 4×4 MIMO system. The performance of the coded channels has improved drastically as compared to the uncoded condition as depicted in Figure 8. Hence, proving the fact that the performance improves with the increasing number of antenna elements degrading the system simplicity.
iii) Rayleigh and Rician channels under processed and unprocessed conditions. The performance of the three channels in practical unprocessed condition varies with AWGN channel giving better performance over Rayleigh and Rician channels. Rician being the worst of the three. But an interesting finding is that when we are processing the signals all the three channels perform more-or-less equally. Hence, we can conclude that for a good communication system that has to operate in all types of environment need to be versatile. Hence, to obtain the versatility systems has to have a better channel coding (here given by OFDM) as shown in Figure 9.

3. WIRELESS SECURITY AT PHYSICAL LAYER/MAC LAYER

Spread spectrum modulation is a transmission technique, in which a pseudo noise code, independent of the information data, is employed as a modulation waveform to spread the signal energy over a bandwidth much greater than the signal information bandwidth. At the receiver the signal is dispread using a synchronized replica of the pseudo noise code, thus ensuring security at the physical layer.

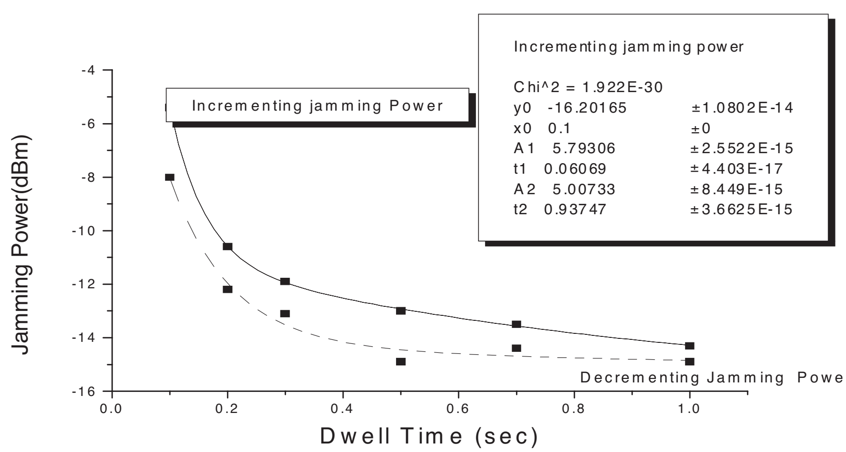

Figure 10. Dwell time vs. jamming power graph [21].

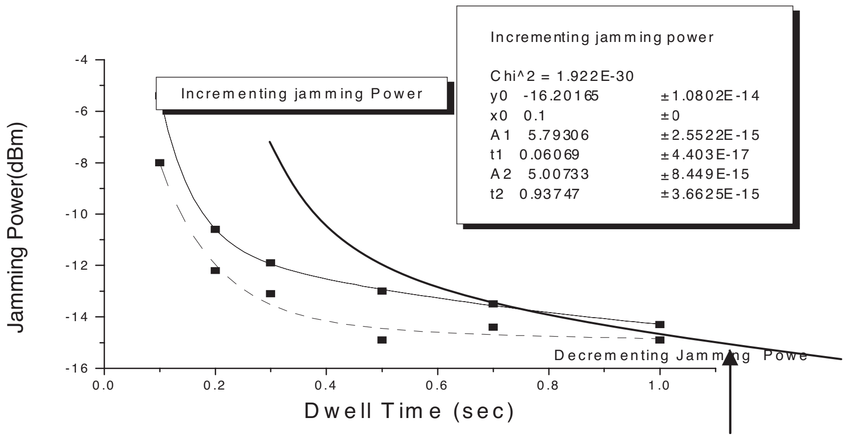

Figure 11. Offsetting jamming margin [21].

An interesting observation in this regard is already found out from an experiment utilising DSSS system. An exponential decay curve following an empirical relation is observed relating to jamming margin performance of the system. Two zones can be clearly marked .Below the curve any jamming power cannot interfere the system where as above the curve the zone is prone to interference as shown in Figures 10 and 11. So a DSSS system design can be thought of by rising this curve towards upper direction, thus making the system mostly interference free.

4. CONCLUSION

The performance of the system and sub-system of OFDM-MIMO system and DSSS was analyzed. Based on this our real SDR-based implementation will be parameterized properly, like the optimum number of FFT points, choice of code rates, number of antenna systems, type of modulation techniques, etc. for different environments.Thus a hybrid technology (DSSS-OFDM-MIMO) can be thought of and the performance of the system will be superb in terms of BER, channel capacity and security and interference rejection.

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