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EDITORIAL PREFACE

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Performance Analysis of MIMO-OFDM System Using QOSTBC Code Structure for M-PSK

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Abstract

MIMO-OFDM system has been currently recognized as one of the most competitive technology for 4G mobile wireless systems. MIMO-OFDM system can compensate for the lacks of MIMO systems and give play to the advantages of OFDM system. In this paper, a general Quasi orthogonal space time block code (QOSTBC) structure is proposed for multiple-input multiple-output–orthogonal frequency-division multiplexing (MIMO-OFDM) systems for 4X4 antenna configuration. The signal detection technology used in this paper for MIMO-OFDM system is Zero-Forcing Equalization (linear detection technique).

In this paper the analysis of high level of modulations (i.e. M-PSK for different values of M) on MIMO-OFDM system is presented. Here AWGN and Rayleigh channels have been used for analysis purpose and their effect on BER for high data rates have been presented. The proposed MIMO-OFDM system with QOSTBC using 4X4 antenna configuration has better performance in terms of BER vs SNR than the other systems.

Keywords: MIMO, OFDM, QOSTBC, M-PSK

1. INTRODUCTION

As the demand for high-data rate multimedia grows, several approaches such as increasing modulation order or employing multiple antennas at both transmitter and receiver have been studied to enhance the spectral efficiency. [1][2] In today's communication systems Orthogonal Frequency Division Multiplexing (OFDM) is a widespread modulation technique. Its benefits are high spectral efficiency, robustness against inter-symbol interference, ease of implementation using the fast Fourier transform (FFT) and simple equalization techniques. Recently, there have been a lot of interests in combining the OFDM systems with the multiple-input multiple-output (MIMO) technique. These systems are known as MIMO OFDM systems.

Spatially multiplexed MIMO is known to boost the throughput, on the other hand, when much higher throughputs are aimed at, the multipath character of the environment causes the MIMO channel to be frequency-selective. OFDM can transform such a frequency-selective MIMO channel into a set of parallel frequency-flat MIMO channels and also increase the frequency efficiency. Therefore, MIMO-OFM technology has been researched as the infrastructure for next generation wireless networks. [3]

Therefore, MIMO-OFDM, produced by employing multiple transmit and receive antennas in an OFDM system has becoming a practical alternative to single carrier and Single Input Single Output (SISO) transmission.[4] However, channel estimation becomes computationally more complex compared to the SISO systems due to the increased number of channels to be estimated. This complexity problem is further compounded when the channel from the i_{th} transmit antenna to the m_{th} receive antenna is frequency-selective. Using OFDM, information symbols are transmitted over several parallel independent sub-carriers using the computationally efficient IFFT/FFT modulation/demodulation vectors. [5]-[8]

These MIMO wireless systems, combined with OFDM, have allowed for the easy transmission of symbols in time, space and frequency. In order to extract diversity from the channel, different coding schemes have been developed. The seminal example is the Alamouti Space Time Block (STB) code [9] which could extract spatial and temporal diversity. Many other codes have also been proposed [10]–[12] which have been able to achieve some or all of the available diversity in the channel at various transmission rates.

In open-loop schemes, there are generally two approaches to implement MIMO systems. One is to increase the spatial transmit diversity (STD) by means of space-time coding and space-frequency coding. Another is to raise the channel capacity by employing spatial division multiplexing (SDM) that simultaneously transmits independent data symbols through multiple transmit antennas. STD mitigates impairments of channel fading and noise, whereas SDM increases the spectral efficiency. [13][14]

In section 2, general theory of OFDM and the necessary condition for orthogonality is discussed. In section 2.1, the signal model of OFDM system with SISO configuration is discussed in detail with the help of block diagram. In section 2.2, M-PSK (M-Phase Shift Keying) modulation technique is discussed in detail. In section 2.3, different channels used for analyses purpose are discussed namely AWGN and Rayleigh channel. In section 3, general theory about the MIMO system is presented. In section 4, MIMO-OFDM system with QOSTBC is discussed. In section 4.1, general theory about QOSTBC and the proposed QOSTBC code structure for 8x8 antenna configuration is presented. In section 4.2, idea about the linear detection technique i.e. Zero Forcing equalization for MIMO-OFDM system is presented. Finally in section 5, the simulated results based on the performance of MIMO-OFDM system in AWGN and Rayleigh channels have been shown in the form of plots of BER vs SNR for M-PSK modulation and for different antenna configurations.

2. ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM)

OFDM is a multi-carrier modulation technique where data symbols modulate a sub-carrier which is taken from orthogonally separated sub-carriers with a separation of 'f_k' within each sub-carrier. Here, the spectra of sub-carrier is overlapping; but the sub-carrier signals are mutually orthogonal, which is utilizing the bandwidth very efficiently. To maintain the orthogonality, the minimum separation between the sub-carriers should be 'f_k' to avoid ICI (Inter Carrier Interference).

By choosing the sub-carrier spacing properly in relation to the channel coherence bandwidth, OFDM can be used to convert a frequency selective channel into a parallel collection of frequency flat sub-channels. Techniques that are appropriate for flat fading channels can then be applied in a straight forward fashion .

2.1 OFDM Signal Model

Figure.1 shows the block diagram of a OFDM system with SISO configuration. Denote X_l ($l = 0,1,2,....,N-1$) as the modulated symbols on the l_{th} transmitting subcarrier of OFDM symbol at transmitter, which are assumed independent, zero-mean random variables, with average power σ_X^2.

The complex baseband OFDM signal at output of the IFFT can be written as:

$$x_n = \frac{1}{\sqrt{N}} \sum_{l=0}^{N-1} X_l \, e^{j\frac{2\pi}{N}nl} \qquad (1)$$

where N is the total number of subcarriers and the OFDM symbol duration is T seconds.

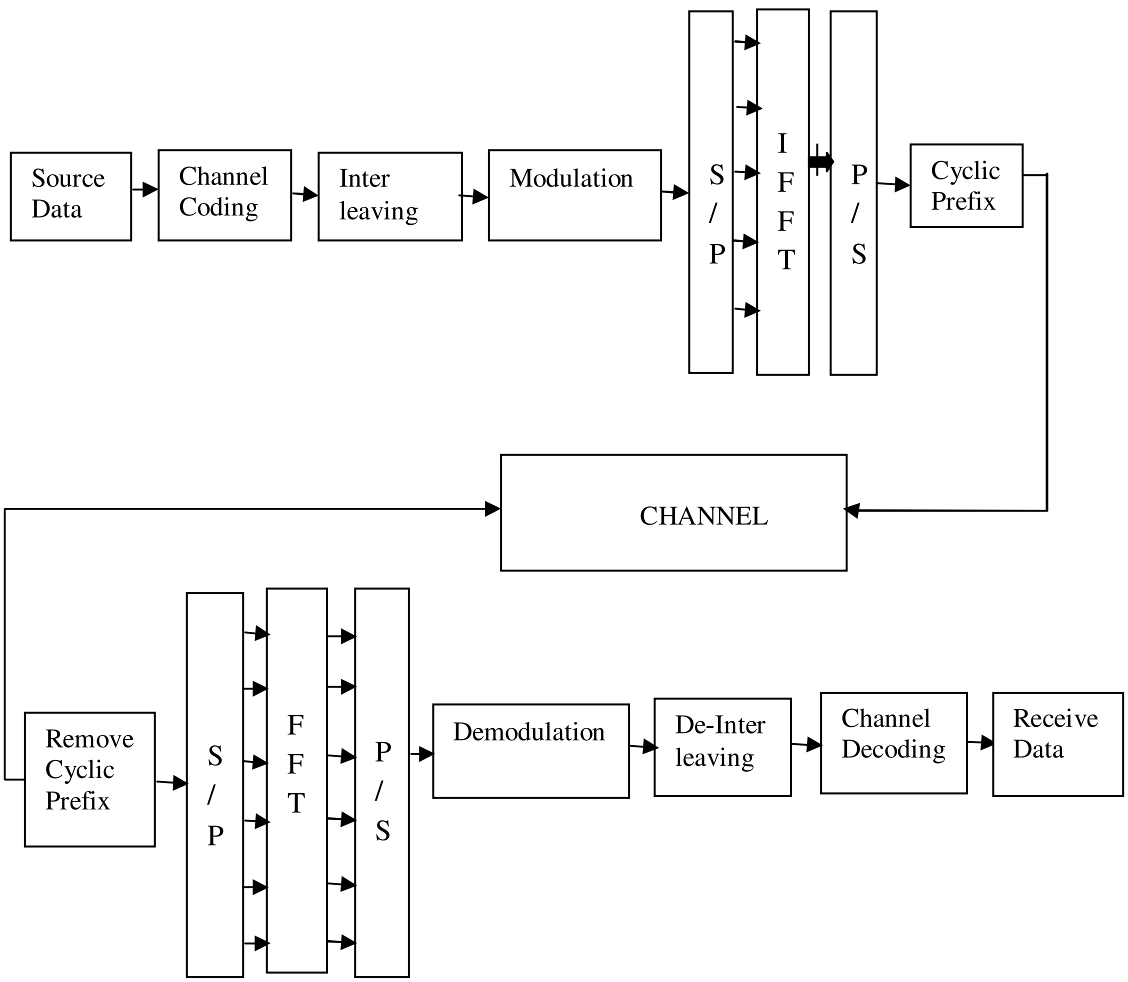

FIGURE 1: Block Diagram of OFDM system

At the receiver, the received OFDM signal is mixed with local oscillator signal, with the frequency offset deviated from Δf the carrier frequency of the received signal owing to frequency estimation error or Doppler velocity, the received signal is given by:

$$\hat{x}_n = (x_n \otimes h_n) \; e^{j\frac{2\pi}{N}n\Delta fT} + z_n \qquad (2)$$

where h_n, $e^{j\frac{2\pi}{N}n\Delta fT}$, and z_n represent the channel impulse response, the corresponding frequency offset of received signal at the sampling instants: $\Delta f\ T$ is the frequency offset to subcarrier frequency spacing ratio, and the AWGN respectively, while $\otimes$ denotes the circular convolution.

Assuming that a cyclic prefix is employed; the receiver have a perfect time synchronization. Note that a discrete Fourier transform (DFT) of the convolution of two signals in time domain is equivalent to the multiplication of the corresponding signals in the frequency domain.

Then the output of the FFT in frequency domain signal on the k_{th} receiving subcarrier becomes:

$$\hat{X}_k = \sum_{l=0}^{N-1} X_l H_l Y_{l-k} + Z_k, \qquad k=0,....,N-1$$

$$= X_k H_k U_0 + \sum_{l=0, l\neq k}^{N-1} X_l H_l Y_{l-k} + Z_k \qquad (3)$$

The first term of (3) is a desired transmitted data symbol X_k. The second term represents the ICI from the undesired data symbols on other subcarriers in OFDM symbol. H_k is the channel frequency response and Z_k denotes the frequency domain of z_n. The term Y_{l-k} is the coefficient of FFT (IFFT), is given by:

$$Y_{l-k} = \frac{1}{N}\sum_{m=0}^{N-1} e^{j\frac{2\pi}{N}n(l-k+\Delta fT)} \qquad (4)$$

when the channel is flat, Y_{l-k} can be considered as a complex weighting function of the transmitted data symbols in frequency domain. [15]

2.2 Different Modulations Techniques Used in OFDM System

Modulation is the process of mapping the digital information to analog form so it can be transmitted over the channel. Consequently every digital communication system has a modulator that performs this task. Closely related to modulation is the inverse process, called demodulation, done by the receiver to recover the transmitted digital information. [16]

Modulation of a signal changes binary bits into an analog waveform. Modulation can be done by changing the amplitude, phase, and frequency of a sinusoidal carrier. There are several digital modulation techniques used for data transmission. The nature of OFDM only allows the signal to modulate in amplitude and phase.

There can be coherent or non-coherent modulation techniques. Unlike non-coherent modulation, coherent modulation uses a reference phase between the transmitter and the receiver which brings accurate demodulation together with receiver complexity. [17]

2.2.1 Phase Shift Keying

Phase-shift keying (M-PSK) for which the signal set is:

$$S_i(t)=\sqrt{\frac{2E_s}{T_s}} *(\cos(2\pi * f_c + 2\frac{(i-1)}{M})) \qquad (5)$$

$$i=1,2,.....M \ \& \ 0 < t < T_s$$

where E_s the signal energy per symbol T_s is the symbol duration, and f_c is the carrier frequency.

This phase of the carrier takes on one of the M possible values, namely

$$\theta_i = 2(i\text{-}1)^{\pi/M} \qquad \text{where } i=1,2,\ldots,M$$

An example of signal-space diagram for 8-PSK is shown in figure 2

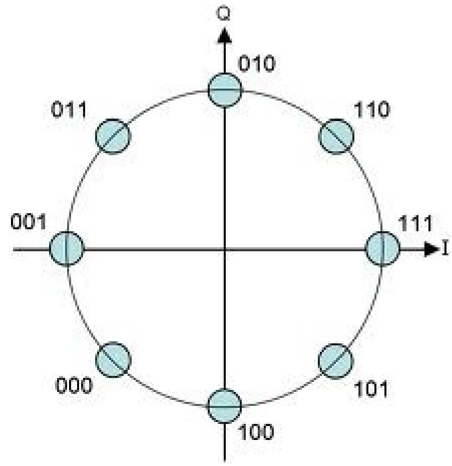

FIGURE 2 : Signal-space diagram for 8-PSK

2.3 CHANNELS

Wireless transmission uses air or space for its transmission medium. The radio propagation is not as smooth as in wire transmission since the received signal is not only coming directly from the transmitter, but the combination of reflected, diffracted, and scattered copies of the transmitted signal.

Reflection occurs when the signal hits a surface where partial energy is reflected and the remaining is transmitted into the surface. Reflection coefficient, the coefficient that determines the ratio of reflection and transmission, depends on the material properties.

Diffraction occurs when the signal is obstructed by a sharp object which derives secondary waves. Scattering occurs when the signal impinges upon rough surfaces, or small objects. Received signal is sometimes stronger than the reflected and diffracted signal since scattering spreads out the energy in all directions and consequently provides additional energy for the receiver which can receive more than one copies of the signal in multiple paths with different phases and powers. Reflection, diffraction and scattering in combination give birth to multipath fading. [18]

2.3.1 AWGN Channel

Additive white Gaussian noise (AWGN) channel is a universal channel model for analyzing modulation schemes. In this model, the channel does nothing but add a white Gaussian noise to the signal passing through it. This implies that the channel's amplitude frequency response is flat (thus with unlimited or infinite bandwidth) and phase frequency response is linear for all frequencies so that modulated signals pass through it without any amplitude loss and phase distortion of frequency components. Fading does not exist. The only distortion is introduced by the AWGN. AWGN channel is a theoretical channel used for analysis purpose only.
The received signal is simplified to:

$$\mathrm{r(t)} = \mathrm{s(t)} + \mathrm{n(t)} \tag{6}$$

where $\mathrm{n(t)}$ is the additive white Gaussian noise. [18]

2.3.2 Rayleigh Fading Channel

Constructive and destructive nature of multipath components in flat fading channels can be approximated by Rayleigh distribution if there is no line of sight which means when there is no direct path between transmitter and receiver. The received signal can be simplified to:

$$r(t) = s(t)*h(t) + n(t) \quad (7)$$

where $h(t)$ is the random channel matrix having Rayleigh distribution and $n(t)$ is the additive white Gaussian noise. The Rayleigh distribution is basically the magnitude of the sum of two equal independent orthogonal Gaussian random variables and the probability density function (pdf) given by:

$$p(r) = \frac{r}{\sigma^2} e^{-\frac{r^2}{2\sigma^2}} \qquad 0 \leq r \leq \infty \quad (8)$$

where σ^2 is the time-average power of the received signal. [19][20]

3. MULTI INPUT MULTI OUTPUT (MIMO) SYSTEMS

Multi-antenna systems can be classified into three main categories. Multiple antennas at the transmitter side are usually applicable for beam forming purposes. Transmitter or receiver side multiple antennas for realizing different (frequency, space) diversity schemes. The third class includes systems with multiple transmitter and receiver antennas realizing spatial multiplexing (often referred as MIMO by itself).

In radio communications MIMO means multiple antennas both on transmitter and receiver side of a specific radio link. In case of spatial multiplexing different data symbols are transmitted on the radio link by different antennas on the same frequency within the same time interval. Multipath propagation is assumed in order to ensure the correct operation of spatial multiplexing, since MIMO is performing better in terms of channel capacity in a rich scatter multipath environment than in case of environment with LOS (line of sight). This fact was spectacularly shown in [21]. MIMO transmission can be characterized by the time variant channel matrix:

$$H(\tau, T) = \begin{pmatrix} h_{1,1}(\tau,t) & h_{1,2}(\tau,t) & \cdots & h_{1,N_R}(\tau,t) \\ h_{2,1}(\tau,t) & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ h_{N_T,1}(\tau,t) & \cdots & \cdots & h_{N_T,N_R}(\tau,t) \end{pmatrix} \quad (9)$$

where the general element, $h_{nt,nr}(\tau, t)$ represents the complex time-variant channel transfer function at the path between the $n_{t\text{-}th}$ transmitter antenna and the $n_{r\text{-}th}$ receiver antenna. N_T and N_R represent the number of transmitter and receiver antennas respectively.

Derived from Shannon's law, for the capacity of MIMO channel the following expression was proven in [21] and [22]:

$$C = \max_{tr(R_{ss}) \leq p} log_2 \left(\det\left(I + H\, R_{ss}\, H^H\right)\right) \quad (10)$$

where H denotes the channel matrix and H^H its transpose conjugate, I represents the identity matrix and R_{ss} the covariance matrix of the transmitted signal s.

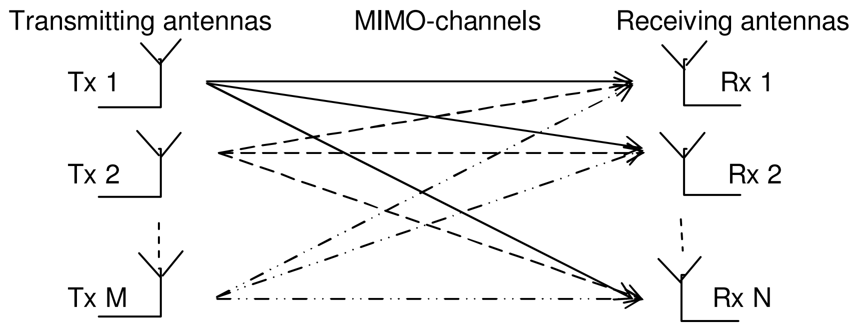

FIGURE 3: Block Diagram of a generic MIMO system with M transmitters and N receivers

4. MIMO-OFDM WITH QUASSI ORTHOGONAL SPACE TIME BLOCK CODING (QOSTBC)

MIMO-OFDM systems with orthogonal space–time block coding (O-STBC) [12] are particularly attractive due to the fact that they require a relatively simple linear decoding scheme while still providing full diversity gain . Unfortunately, they suffer from a lower code rate when a complex signal constellation and the complexity that more than two transmit antennas are used. To overcome the disadvantages of O-STBC, quasi-orthogonal space–time block coding (QO-STBC) was proposed in the literature [23]-[24] and the existing works have shown that QO-STBC offers a higher data rate and partial diversity gain.

To design a QO-STBC with full diversity gain, an improved QO-STBC through constellation rotation was proposed in [25] and [26].Maximum-likelihood (ML) decoding in QO-STBC works with pairs of transmitted symbols, leading to an increase in decoding complexity with modulation level M2. This subsequently increases transmission delay when a high-level modulation scheme or multiple antennas are employed. Sung et al. [27] proposed a method to improve the QO-STBC performance with iterative decoding, which of course achieves higher reliability but increases decoding complexity. In [28]–[32], some new decoding methods were proposed to reduce the computational complexity.

4.1 Quassi Orthogonal Space Time Block Codes

Consider a system with eight transmit antennas (i.e. M = 4) and 4 receive antennas (i.e. N=4). In what follows, assume that perfect channel state information (CSI) is available at the receiver but unavailable at the transmitter. Also assume that the channel is quasi-static, i.e. the channel coefficients are constant within one block of code transmission and independently realized from block to block. Let A_{12} and A_{34} be Alamouti code as in [9]

$$A_{12} = \begin{bmatrix} s_1 & s_2 \\ -s_2^* & s_1^* \end{bmatrix} \text{ and } A_{34} = \begin{bmatrix} s_3 & s_4 \\ -s_4^* & s_3^* \end{bmatrix}$$

Here the subscript 12 and 34 are used to represent the indeterminate s_1, s_2, s_3 and s_4 in the transmission matrix. Now consider the space time block code for M and N equals to 4 according the method given in [24], the matrix for 4X4 antenna configuration can also be constructed as follows :

$$B = \begin{bmatrix} A_{12} & A_{34} \\ -A_{34}^* & A_{12}^* \end{bmatrix} = \begin{bmatrix} s_1 & s_2 & s_3 & s_4 \\ -s_2^* & s_1^* & -s_4^* & s_3^* \\ -s_3^* & -s_4^* & s_1^* & s_2^* \\ s_4 & -s_3 & -s_2 & s_1 \end{bmatrix} \quad (11)$$

Note that it has been proven in [33] maximum diversity of the order of 4*N for a rate one code is impossible in this case. Now, suppose V_i, i = 1 ,2…..4 as the i_{th} column of Q, it is easy to see that

$$\langle V_1, V_2\rangle = 0 \qquad \langle V_2, V_4\rangle = 0$$
$$\langle V_1, V_3\rangle = 0 \qquad \langle V_3, V_4\rangle = 0 \tag{12}$$

Where $\langle V_i, V_j\rangle = \sum_{l=1}^{4} (V_i)_l \ (V_j)_l^*$ is the inner product of vectors V_i and V_j . Therefore, the subspace created by V_1 and V_4 is orthogonal to the subspace created by V_2 and V_3 , and similar is true for other columns as given by equation(11).

4.2 Signal Detection of Mimo-ofdm System

Signal detection of MIMO-OFDM system can be carried out by various sub-carrier channel signal detection. Although the whole channel is a frequency-selective fading, but various sub-carriers channel divided can be regarded as flat fading, so the flat fading MIMO signal detection algorithm for MIMO-OFDM system can be directly into the detection of all sub-channels, and signal detection algorithm of the corresponding MIMO-OFDM system can be obtained. Similarly, the other optimization algorithms used in flat fading MIMO signal detection can also be leaded into the MIMO-OFDM system. MIMO-OFDM detection methods consist of linear and nonlinear detection test.

4.2.1 Zero Forcing Algorithm [34]

Zero Forcing algorithm is regard the signal of each transmitting antenna output as the desired signal, and regard the remaining part as a disturbance, so the mutual interference between the various transmitting antennas can be completely neglected. The specific algorithm is as follows:
For k = 0, 1, 2,………….,K-1, so that,

$$R(k) = [R_1(k),R_2(k),……………,R_N(k)]^T \tag{13}$$

$$S(k) = [S_1(k),S_2(k),……………,S_M(k)]^T \tag{14}$$

$$N(k) = [N_1(k),N_2(k),……………,N_N(k)]^T \tag{15}$$

$$H(k) = \begin{bmatrix} H(k)_{11} & H(k)_{12} & \cdots & H(k)_{1M} \\ H(k)_{21} & H(k)_{22} & \cdots & H(k)_{2M} \\ \vdots & \vdots & \ddots & \vdots \\ H(k)_{N1} & H(k)_{N2} & \cdots & H(k)_{NM} \end{bmatrix} \tag{16}$$

Here $R(k)$, $S(k)$, $N(k)$ respectively express output signal, the input signal and noise vector of the k sub-channels in MIMO-OFDM system, for M transmitting antennas and N receiving antennas, $H(k)$ expresses channel matrix of the k sub-channels, mathematical expression of sub-channel in the MIMO-OFDM system is as follows:

$$R(k) = H(k)S(k) + N(k) \tag{17}$$

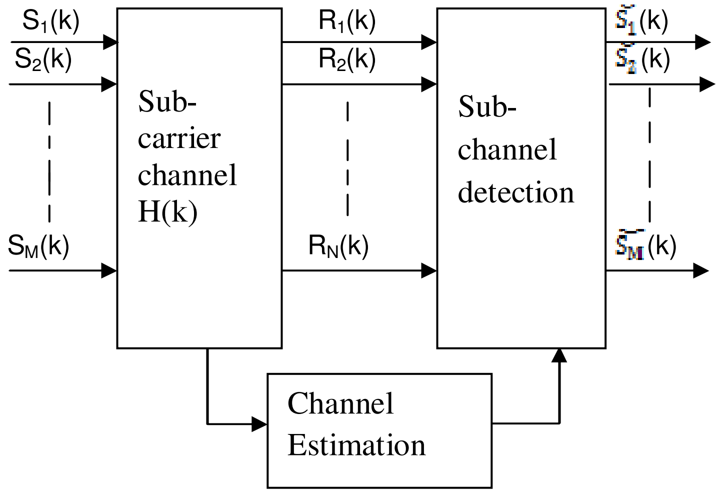

FIGURE 4: Baseband block diagram of k subcarrier channel in MIMO-OFDM system

There is a linear relationship between input signal $S(k)$ and output signal $R(k)$, that is similar to the flat fading channel for each subcarrier channel in MIMO-OFDM system. Its equivalent block diagram is shown in Figure 4. Therefore, signal detection can be transformed into K sub-channels in their signal detection to complete in MIMO-OFDM system and each sub-channel detection of the above can be used flat fading MIMO channel to achieve the detection algorithm.

Zero-forcing (ZF) detection algorithm for MIMO detection algorithm is the most simple and basic algorithms, and the basic idea of zero forcing algorithm is get rid of MIMO-channel interference by multiplying received signal and the inverse matrix of channel matrix. Zero-Forcing solution of MIMO-OFDM system is as follows:

$$S_{ZF} = H^{-1} R = S + H^{-1} N \tag{18}$$

In which H^{-1} is the channel matrix for the generalized inverse matrix, the type is obtained for hard-decision demodulation after that to be the source signal estimates:

$$\hat{S}_{ZF} = E(S_{ZF}) \tag{19}$$

5. SIMULATION RESULTS DISCUSSIONS

The system discussed above has been designed and results are shown in the form of SNR vs BER plot for different modulations and different channels. Here different antenna configurations such as 1x1, 2x2 are used to show the advantage in term of SNR of using 4X4 antenna configuration over the other configurations. The analyses have been done for three channels AWGN and Rayleigh channel.

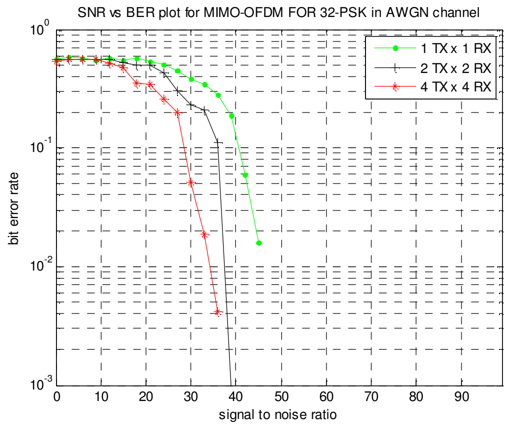

FIGURE 5: (a)

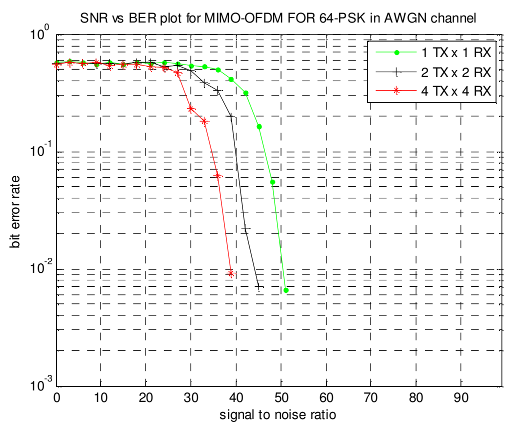

FIGURE 5: (b)

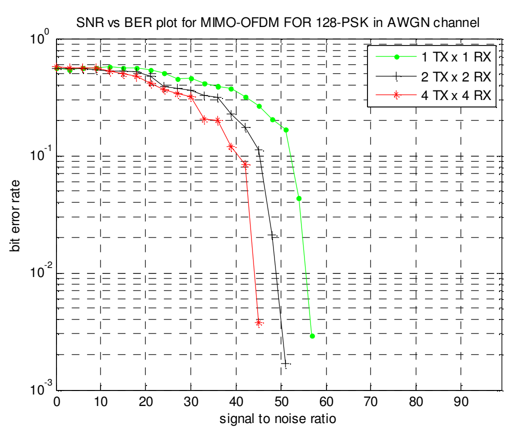

FIGURE 5: (c)

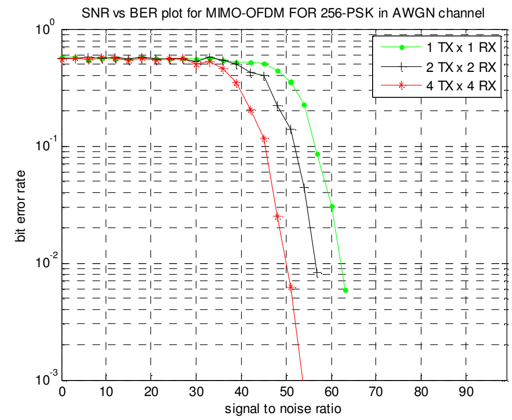

FIGURE 5: (d)

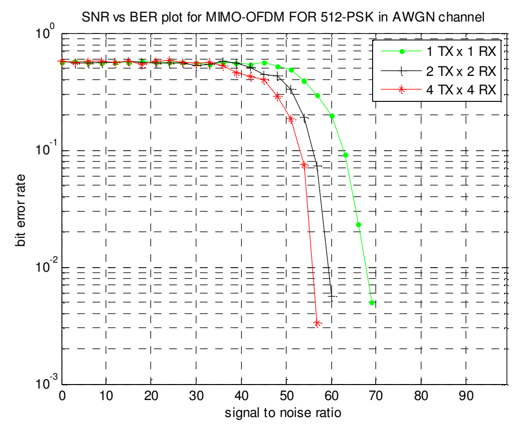

FIGURE 5: (e)

Figure 5 (a)-(e): SNR vs BER plots for PSK over AWGN channel for MIMO-OFDM system employing different antenna configurations (a) 32-PSK (b) 64-PSK (c) 128-PSK (d) 256-PSK (e) 512-PSK.

SNR vs BER plots for M-PSK over AWGN channel for MIMO-OFDM system employing different antenna configurations are presented in Figure 5. Here the graph depicts that in MIMO-OFDM system as we goes on increasing the no. of Transmitters and Recievers the BER keeps on decreasing due to space diversity and the proposed system provide better BER performance as compared to the other antenna configurations.

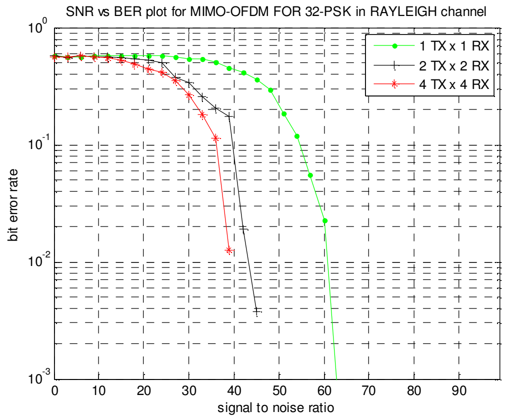

FIGURE 6: (a)

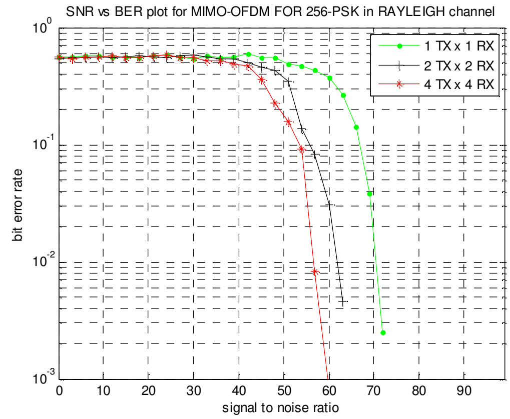

FIGURE 6: (d)

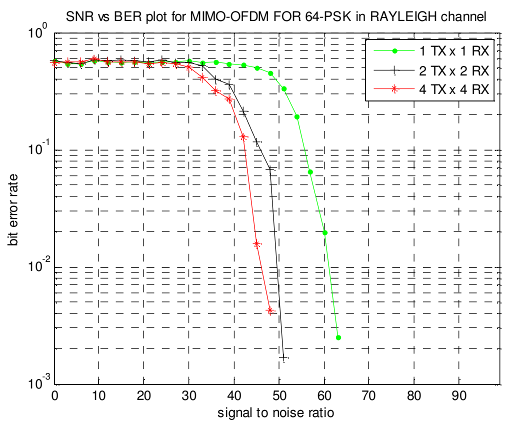

FIGURE 6: (b)

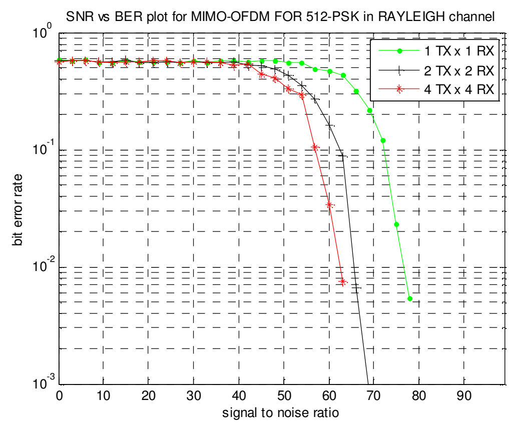

FIGURE 6: (e)

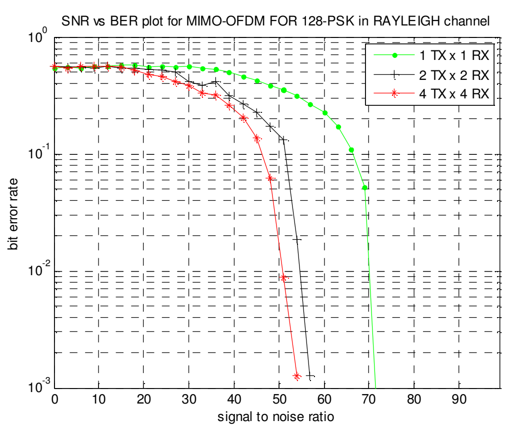

FIGURE 6
(c)

Figure 6 (a)-(e): SNR vs BER plots for PSK over Rayleigh channel for MIMO-OFDM system employing different antenna configurations (a) 32-PSK (b) 64-PSK (c) 128-PSK (d) 256-PSK (e) 512-PSK.

In Figure 6 SNR vs BER plots for M-PSK over Rayleigh channel for MIMO-OFDM system employing different antenna configurations are presented. It can be concluded from the graphs that in MIMO-OFDM system as we goes on increasing the no. of Transmitters and Recievers the BER keeps on decreasing due to space diversity and the proposed system provide better BER performance as compared to the other antenna configurations. But here BER is greater than the AWGN channel.

Table 1 shows the improvement in terms of decibels shown by proposed system employing QOSTBC code structure for 4X4 antenna configuration over the system employing QOSTBC code structure for 2X2 antenna configuration for different modulation schemes over different environments (channels).

Different Modulations	**For AWGN Channel**	**For Rayleigh Channel**
32-PSK	3.22 dB	3.85 dB
64-PSK	5.02 dB	3.42 dB
128-PSK	4.75 dB	3.88 dB
256-PSK	6.5 dB	4.98 dB
512-PSK	3.42 dB	3.05 dB

TABLE 1: Table showing the improvement in terms of dB, by using the proposed QOSTBC code structure (for 4X4 antenna configuration) for different Modulations and for different Channels.

7. CONCLUSION

In this paper, an idea about the performance of the MIMO-OFDM systems at higher modulation levels and for different antenna configurations is presented. MIMO-OFDM system can be implemented using higher order modulations to achieve large data capacity. But there is a problem of BER (bit error rate) which increases as the order of the modulation increases. The solution to this problem is to increase the value of the SNR so, that the effect of the distortions introduced by the channel will also goes on decreasing, as a result of this, the BER will also decreases at higher values of the SNR for high order modulations.
The motive of using high order antenna configuration (4X4) is to increase the space diversity, which will automatically lower the BER at given SNR as compared to lower order Antenna configuration (1x1, 2x2). By doing so, higher data capacity at any given SNR can be achieved. The proposed MIMO-OFDM system with 4X4 antenna configuration provides better performance in terms of SNR as compared to the MIMO-OFDM system with 2X2 antenna configuration at a BER of 10^{-2}.

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Coded OFDM in Fiber-Optics Communication Systems With Optimum biasing of Laser

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Abstract

A novel high spectral efficiency all-optical sampling orthogonal frequency-division multiplexing scheme is proposed using space frequency Block coding (SFBC) techniques and nonlinear behavior of vertical-cavity surface-emitting laser diodes is exploited by relative intensity to noise (RIN).We show that in long-haul fiber optics communications, SFBC-coded OFDM increases spectral efficiency and reduces the influence of chromatic dispersion in optical-OFDM system if RIN is adjusted to -155 dB/Hz

Keywords: Orthogonal Frequency Division Multiplexing (OFDM), Relative Intensity to Noise Ratio (RIN), Space Time Block Coding (STBC).

1. INTRODUCTION

Space-time block coded orthogonal frequency-division multiplexing (STBC-OFDM) schemes have garnered much attention as a simple transmit diversity technique in combating frequency selective fading channels [1], [2]. Although STBC-OFDM using Alamouti code can improve the performance of OFDM, its second-order diversity gain is still insufficient for communication requiring high reliability over fading channels. Thus, recent works have considered STBCOFDM schemes aimed at achieving fourth-order diversity gain [3], [4].STBC-OFDM using *G*4 code with 1/2 rate and *H*4 code with 3/4 rate are the conventional schemes being employed to provide fourth-order diversity gain [5]–[7]. However, problems arise when the conventional schemes described in [6] and [7] are used in spatially transmit correlated fading channels. These conventional schemes have been designed without taking spatial transmit correlation in consideration, although it occurs in many practical applications. The spatial transmit correlation causes a deficiency of randomness and independence in channel [8], [9]. Therefore, increasing the spatial transmit correlation results in bit-error-probability (BEP) performance degradation for STBC-OFDM schemes targeting a fourth-order diversity gain [10].Space-frequency coded OFDM (SFC-OFDM) schemes have been proposed to exploit both spatial and frequency diversity [11]–[13]. The authors of [12] proposed a type of SFC-OFDM without permutation from a simple mapping process using STBC. As with STBC-OFDM schemes, however, the SFC-OFDM design described in [12] fails to consider spatial transmit correlation, so that it suffers from spatially correlated channels. By precoding the incoming information symbol across OFDM subcarriers, the SFC-OFDM with permutation proposed in [13] attains both full transmission rate and frequency diversity over independent channels. However, exploiting the frequency diversity with this approach also limits the BEP performance in spatially correlated channels and requires high decoding complexity. This is because the SFC-OFDM described in [13] uses the precoding method instead of STBC for the full transmission rate. Therefore, a new STBC-based scheme using frequency diversity that can improve the performance in spatially correlated channels is still needed. Later on STBC-based transmit diversity scheme using frequency diversity was introduced that is more robust against spatial correlation than the STBC-OFDM schemes and the SFC-OFDM schemes, and which achieves fourth-order diversity gain. From the upper bound of BEP performance over spatially transmit-correlated channels, it was shown that performance can be improved by increasing the determinant of the channel correlation matrix. In order to exploit both frequency and spatial diversity and thereby increase the determinant, attempt was made to design an STBC-based transmit diversity scheme. The merged determinant condition for robustness is derived from detailed analysis of the determinant.

In this paper, the proper biasing conditions of Laser are proposed for 1Tx-1Rx, coded Optical-OFDM system that yields better BEP performance than the STBC-OFDM schemes and the SFCOFDM schemes. We have carried out the simulative analysis for averaging out the optimal value of RIN for better performance in high bit rate coded optical-OFDM direct transmission link. The impact of linewidth and its limiting value is investigated for optimal performance.

2. THEORY

The output of semiconductor laser exhibit fluctuations in its intensity, phase and frequency even when the laser is biased at constant current with negligible current fluctuations. The two fundamental noise mechanisms are spontaneous emission and electron hole recombination. Noise in semiconductor lasers is dominated by spontaneous emission. Each spontaneously emitted photon adds a small field component to the coherent field (established by stimulation emission), which is random in nature and thus perturbs the both amplitude and phase in a random manner. The occurrence rate of such a spontaneously emitted random field is about 10^{12} s^{-1}. Because of which intensity and phase of emitted light exhibit fluctuations over a time scale as short as 100ps. Intensity fluctuations lead to the limited signal to noise ratio (SNR) where as phase fluctuations leads to the finite spectral linewidth when semiconductor lasers are operated at constant current. Clearly such fluctuations lead to the degradation of system performance, therefore it is important to estimate their magnitude. Amplitude fluctuations are characterized by a factor called as Relative Intensity to Noise ratio (RIN).

3. SYSTEM DESCRIPTION

The transmitter and receiver configurations of an Optical-OFDM system with direct detection and the system set up for optical-OFDM system are shown in Figures 1a–c, respectively. On the transmitter side, the information-bearing streams at 10 Gb/s are encoded using identical SFBC codes. The outputs of these SFBC encoders are demultiplexed and parsed into groups of B bits corresponding to one OFDM frame. The B bits in each OFDM frame are subdivided into K subchannels with the ith subcarrier carrying b_i bits.The bi bits from the i_{th} subchannel are mapped into a complex-valued signal from a $2b_i$-point signal constellation such as M-ary QAM and M-ary PSK. For example, b_i = 2 for QPSK and bi = 4 for 16-QAM. The complex-valued signal points from sub channels are considered to be the values of the FFT of a multi carrier OFDM signal. By selecting the number of sub channels K sufficiently large, the OFDM symbol interval can be made significantly larger than the dispersed pulse width of an equivalent single-carrier system, resulting in ISI reduction.

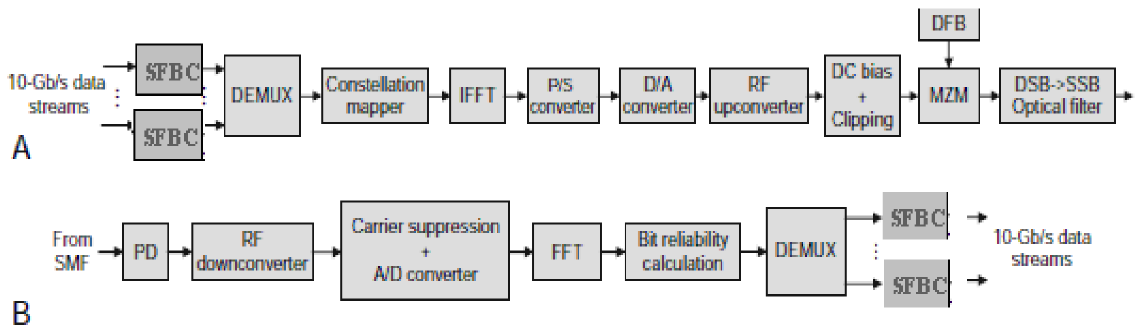


FIGURE 1: (a) Transmitter configuration **(b)** receiver configuration

The simulation set-up for optical-OFDM system is shown in **Figure 1c**.

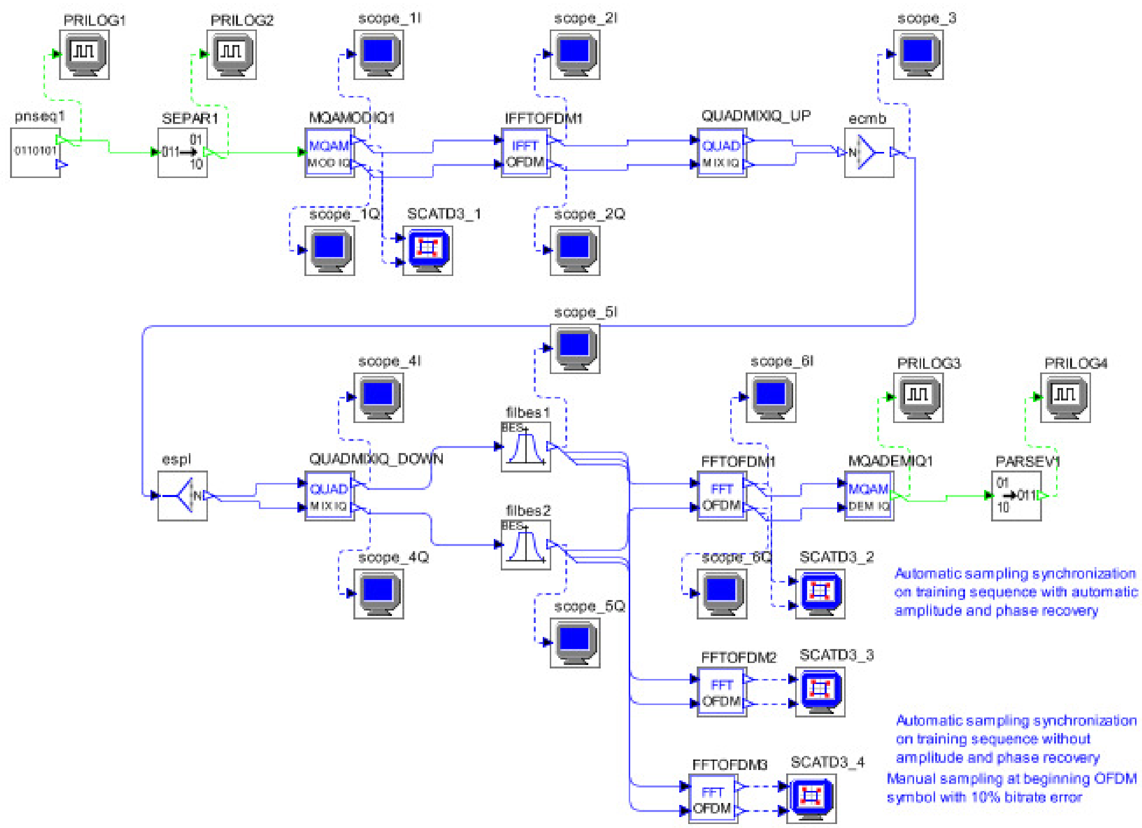


FIGURE 1: (c) system setup for Direct detection Optical-OFDM sytem

N_G nonzero samples are inserted to create the guard interval, and the OFDM symbol is multiplied by the window function. The purpose of cyclic extension is to preserve the orthogonally among subcarriers even when the neighboring OFDM symbols partially overlap due to dispersion, and the role of windowing is to reduce the out-of-band spectrum. For efficient chromatic dispersion and PMD compensation, the length of the cyclically extended guard interval should be longer than the delay spread due to chromatic dispersion and PMD. After D/A conversion and RF up-conversion, the RF signal can be mapped to the optical domain using one of two options: (1) The OFDM signal can directly modulate a DFB laser, or (2) the OFDM signal can be used as the RF input of a Mach–Zehnder modulator (MZM). A DC bias component is added to the OFDM signal to enable recovery of the incoherent QAM symbols.

4. PERFORMANCE ASSESSMENT OF CODED OFDM FIBER-OPTICS COMMUNICATIONS

A pseudo random sequence length of bits taken one bit per symbol is used to obtain realistic output values at the receiver. Firstly, to observe the impact of RIN upon system performance, simulation results are obtained for linewidth. It is investigated that it causes a sudden fall in optical power with gradual increase in the linewidth for the pulse. It was observed that increase in linewidth causes degradation of system performance as BER, timing jitter and Q values degraded drastically. Output electric power correlated with linewidth and results are shown in Figure 2. The output electrical power remains almost constant up to linewidth value of 6-7MHz but as the linewidth value is increased further and approaches14 MHz, there is a loss of optical power measuring 50% and even more.

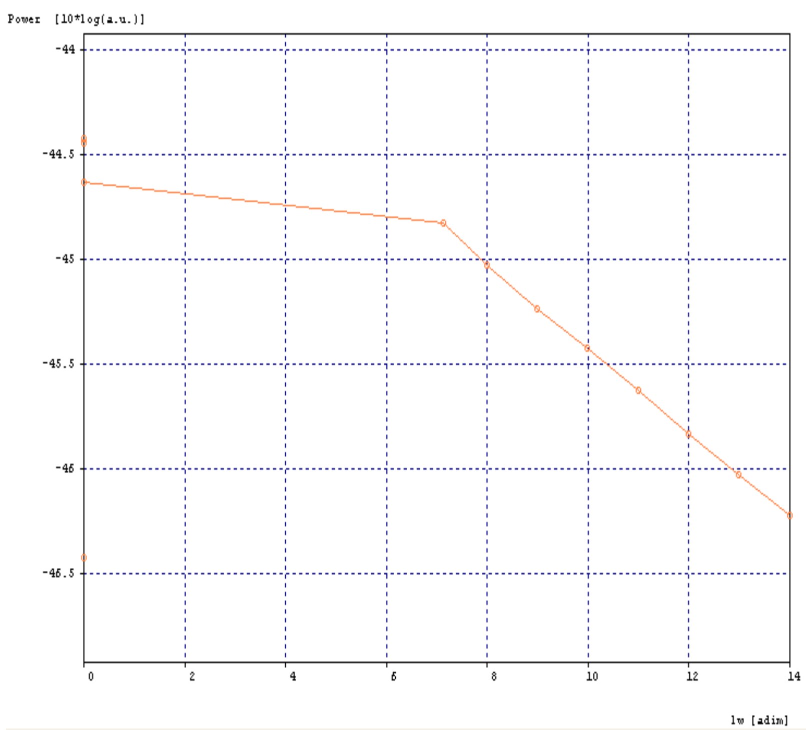


FIGURE 2: Response of electrical Power w.r.t linewidth

For positive values of RIN, Q value is found to be very less as compared with the negative values of RIN. In this paper we have iterated the values of RIN from 10dB/Hz to -180 dB/Hz and different parameters are observed. We found that Q value remains constant for negative values of RIN up to around -120 dB/Hz with further decrease in its value Q value decreases and again tends to be constant up to -160.dB/Hz.

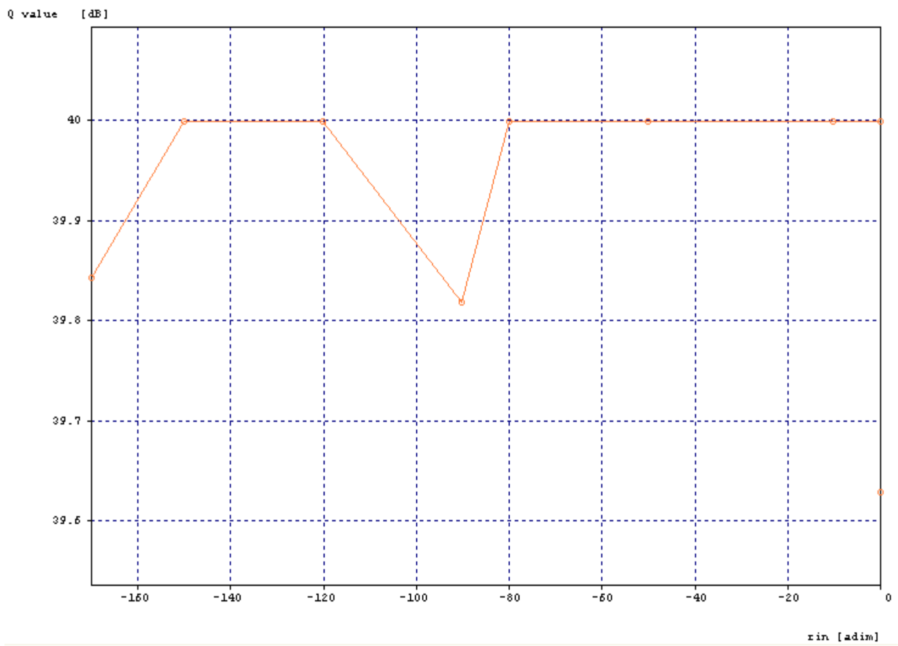


FIGURE 3: Response of Q-value w.r.t RIN

OFDM is suitable for long-haul transmission for three main reasons: (1) improvement of spectral efficiency, (2) simplification of the chromatic dispersion compensation engineering, and (3) PMD compensation. We have shown that Optical-OFDM provides the best power efficiency–BER performance compromise, and as such it is adopted here.

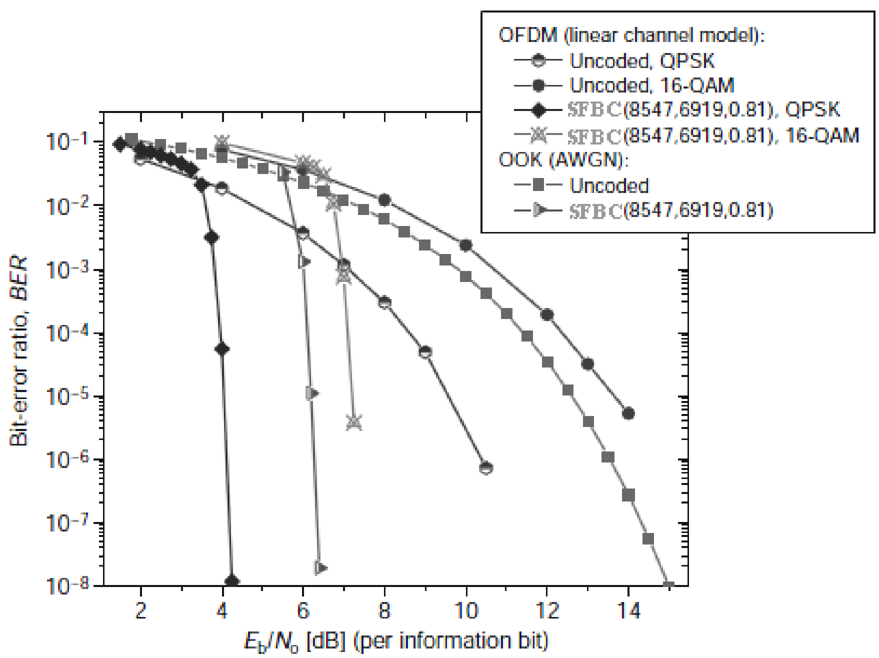
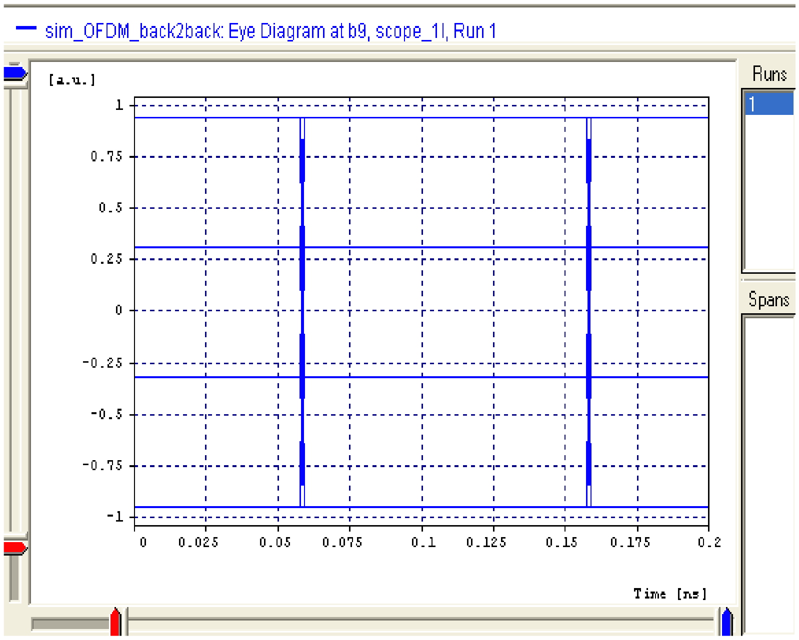


FIGURE 4: BER Performance for the system

The BER performance of this scheme (with an aggregate data rate of 40 Gb/s) against the conventional SFBC-coded RZ-OOK scheme (operating at 40 Gb/s) is given in Figure 4 for the thermal noise-dominated scenario. The SFBC-coded QPSK U-OFDM provides more than 2dB coding gain improvement over uncoded RZ-OOK at a BER of 10^{-8} . We have shown that SFBC-coded OFDM provides much higher spectral efficiency than SFBC-coded RZ-OOK.



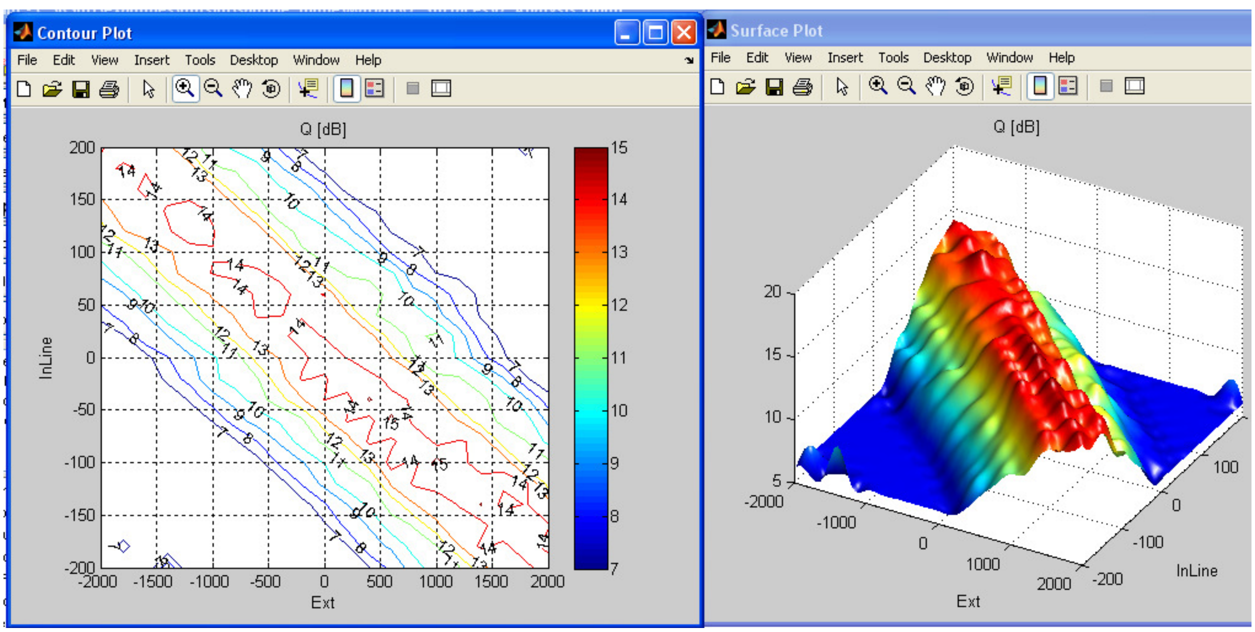


FIGURE 5: Dispersion map under study.

For the dispersion map described in Figure 5, the BER curves for the uncoded 100 Gb/s OFDM transmission using BPSK are shown in Figure 6, and fiber parameters are given in **Table 1**.

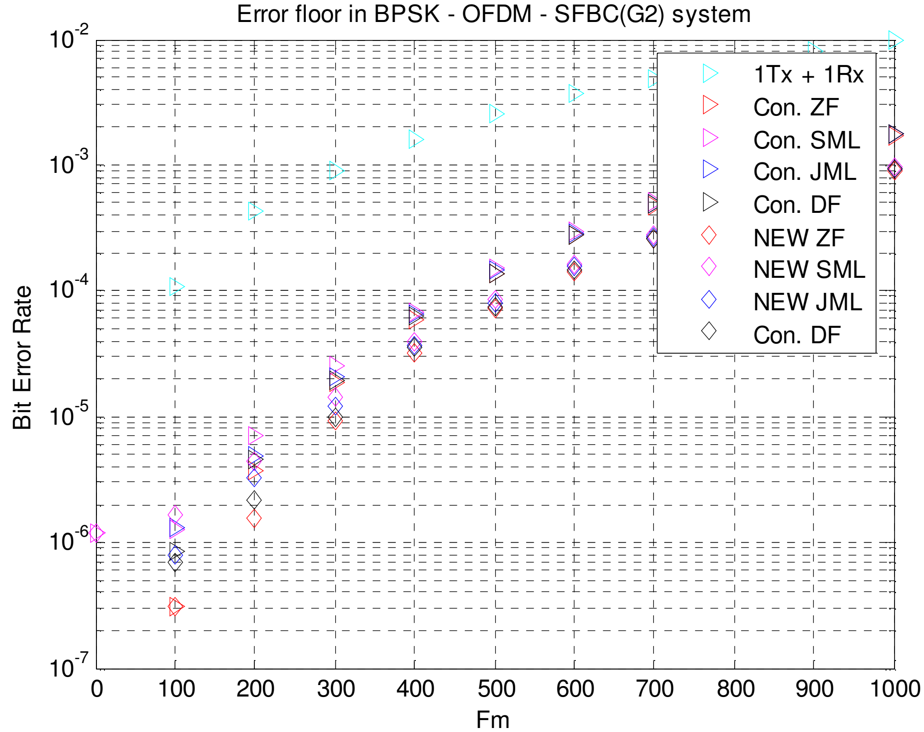
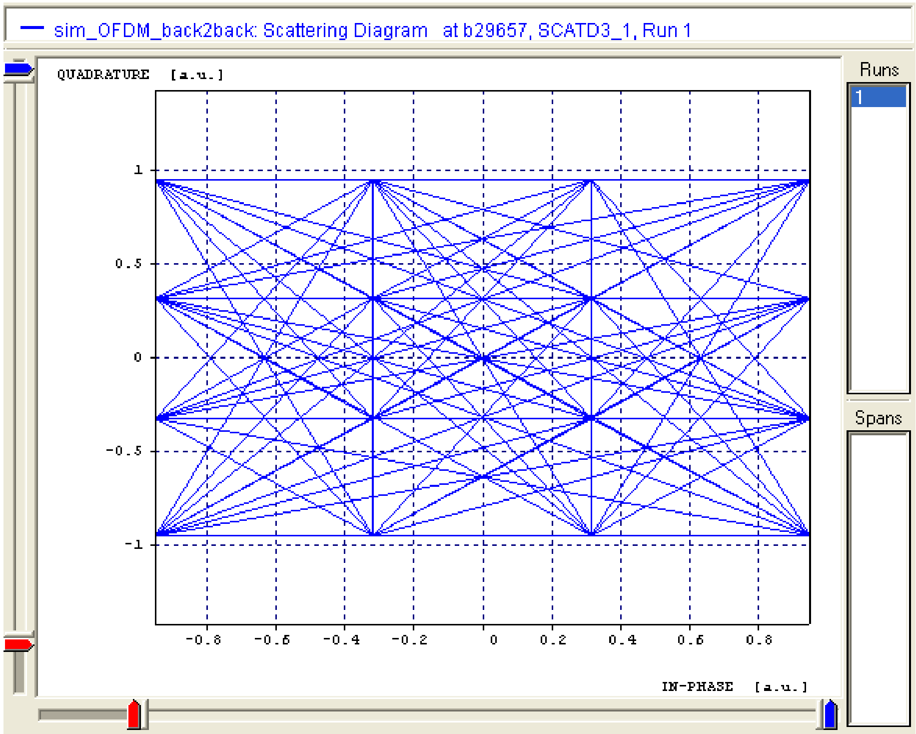


FIGURE 6: BER curves for BPSK-OFDM –SFBC system

The dispersion map is composed of N spans of length L=120 km, consisting of 2 L/3 km of D_ fiber followed by L/3 km of D_ fiber, with precompensation of -1600 ps/nm and corresponding postcompensation. The propagation of a signal through the transmission media is modeled by a nonlinear Schro¨dinger equation (NLSE).

	D_+ Fiber	D_ Fiber
Dispersion (ps/(nm km))	20	−40
Dispersion slope (ps/(nm^2 km))	0.06	−0.12
Effective cross-sectional area [μm^2]	110	50
Nonlinear refractive index (m^2/W)	$2.6 \cdot 10^{-20}$	$2.6 \cdot 10^{-20}$
Attenuation coefficient (dB/km)	0.19	0.25

TABLE1: Parameters for the system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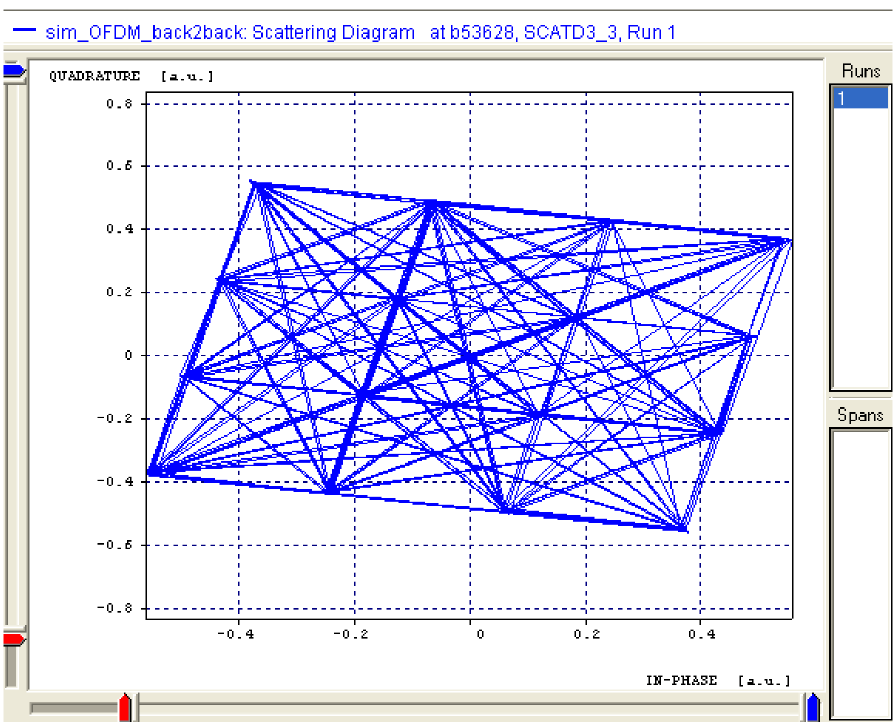
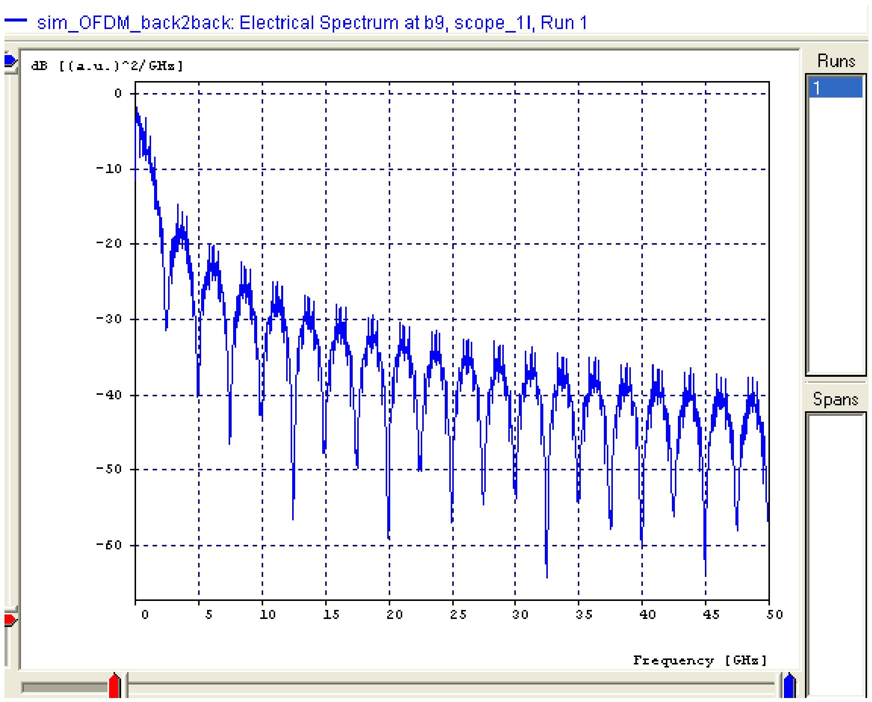
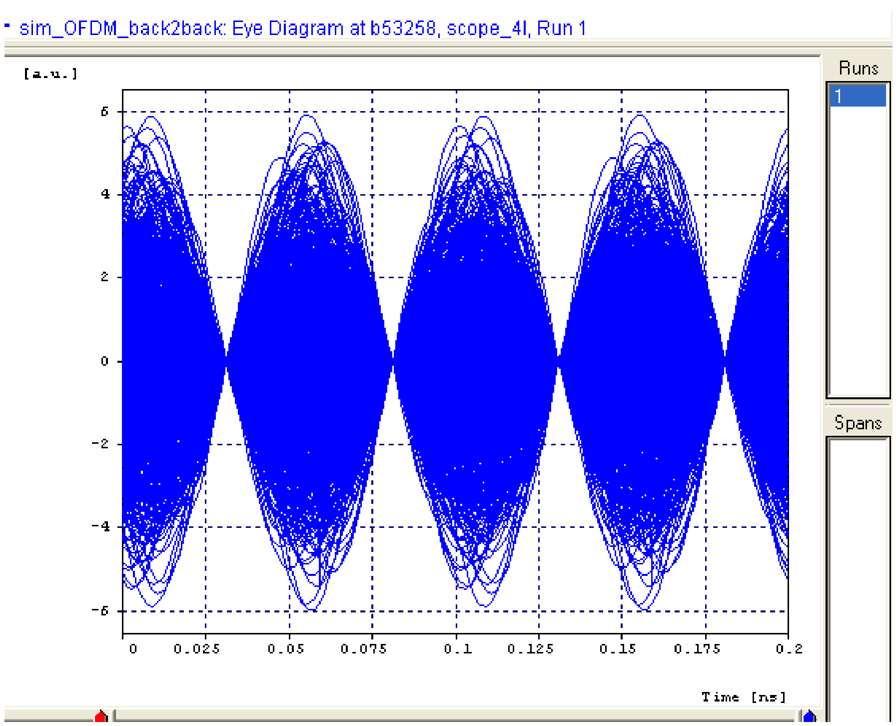
(a)


sim_OFDM_back2back: Scattering Diagram at b53628, SCATD3_3, Run 1
QUADRATURE [a.u.]
IN-PHASE [a.u.]
Runs
Spans

(b)



(c)



(d)

FIGURE 7: (a), (b) Signal scattering (c) Electrical spectrum (d) Eye diagrams

The signal scattering, electrical Spectrum and eye diagrams, are shown in Figure 7 before and after applying the channel estimation, for coded Optical-OFDM system with optimum biasing of laser. They correspond to the worst-case scenario (k = 1/2) and 10 Gb/s aggregate data rate. Therefore, the channel estimation-based OFDM is able to compensate for DGD of 1600 ps.

5. RESULTS AND DISCUSSION

The results of PMD simulations for Optical-OFDM and thermal noise-dominated scenario are shown in Figure 7 for different DGDs and the worst-case scenario (k = 1/2), assuming that the channel state information is known on a receiver side. The OFDM signal bandwidth is set to BW = 0.25 B (where B is the aggregate bit rate set to 10 Gb/s), the number of subchannels is set to NQAM = 64, FFT/IFFT is calculated in NFFT =128 points, the RF carrier frequency is set to 0.75 B, the bandwidth of optical filter for SSB transmission is set to 2 B, and the total averaged launched power is set to 0 dBm. The guard interval is obtained by cyclic extension of NG= 2*16 samples. The Blackman–Harris windowing function is applied. The 16-QAM OFDM with and without channel estimation is observed in simulations.The effect of PMD is reduced by (1) using a sufficient number of subcarriers so that the OFDM symbol rate is significantly lower than the aggregate bit rate and (2) using the training sequence to estimate the PMD distortion. For DGD of 1/BW, the RZ-OOK threshold receiver is not able to operate properly because it enters the BER error floor. Note that 16-QAM OFDM without channel estimation enters the BER floor, and even advanced FEC cannot help much in reducing the BER.

We investigated the optimal values for linewidth and RIN for a coded optical-OFDM system for its better performance. The limiting value of linewidth should be 6.5MHz up to which optical power remains almost constant and RIN value corresponding to this linewidth is measured to be -155 dB/Hz. and the average value of RIN is measured to be -125 dB/Hz.

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pComparison of Energy Detection Based Spectrum Sensing Methods Over Fading Channels in Cognitive Radio

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Abstract

With the advance of wireless communications, the problem of bandwidth scarcity has become more prominent. Cognitive radio technology has come out as a way to solve this problem by allowing the unlicensed users to use the licensed bands opportunistically. To sense the existence of licensed users, many spectrum sensing techniques have been devised. This paper presents the energy detection based spectrum sensing technique. In the present work, the comparison of ROC curves has been done for various wireless fading channels using squaring and cubing operation. The cubing operation shows an improvement of up to 0.6 times as compared to the squaring operation for AWGN channel. For Rayleigh channel, the improvement achieved is up to 0.4 times as we move from squaring to cubing operation in an energy detector.

Keywords: Cognitive Radio, Spectrum Sensing, Probability of Detection.

1. INTRODUCTION

The progressive growth of the wireless communications, has led to under-utilization of the spectrum. It has also been observed that major portion of the spectrum is rarely used as it is reserved only for the licensed users while other is heavily used. Federal Communications Commission (FCC) proposed the solution to this problem by allowing the unlicensed users to use the licensed bands opportunistically and named it as Cognitive Radio (CR) [1]. Cognitive Radio is a sophisticated wireless system that gathers the information about the surrounding environment and adapts its transmission parameters accordingly [2]. There are two main characteristics of Cognitive Radio: Cognitive Capability (i.e. gathering the information about the environment) and reconfigurability (i.e. adapting its transmission parameters according to the gathered information) [3]. Since the unlicensed secondary (users) are allowed to utilize a licensed band only when they do not cause interference to the licensed (primary) users, spectrum sensing is considered as one of the most important elements of the Cognitive Radio. Spectrum sensing aims at monitoring the usage and the characteristics of the covered spectral band(s) and is thus required by the secondary users both before and during the use of licensed spectral bands [1].

Energy detector based approach, also known as radiometry or periodogram, is one of the popular methods for spectrum sensing as it is of non-coherent type and has low implementation complexity. In addition, it is more generic as receivers do not require any prior knowledge about the primary user's signal [4]. In this method, the received signal's energy is measured and compared against a pre-defined threshold to determine the presence or absence of primary user's signal. Moreover, energy detector is widely used in ultra wideband (UWB) communications to borrow an idle channel from licensed user. Detection probability (P_d), False alarm probability (P_f) and missed detection probability ($P_m = 1 - P_d$) are the key measurement metrics that are used to analyze the performance of an energy detector. The performance of an energy detector is illustrated by the receiver operating characteristics (ROC) curve which is a plot of P_d versus P_f or P_m versus P_f [5].

This paper is organized as follows: Section 2 describes the performance analysis of energy detector. Section 2.1 illustrates test statistic for energy detection using squaring operation. Section 2.2 and 2.3 describe the expressions for probability of detection using squaring operation for AWGN and Rayleigh channel respectively. Simulation Results for squaring operation and cubing operation are presented in Section 2.4 followed by conclusions in section 2.5.

2. PERFORMANCE ANALYSIS OF ENERGY DETECTOR

Energy detector is composed of four main blocks [6]:
1) Pre-filter.
2) A/D Converter (Analog to Digital Converter).
3) Squaring Device.
4) Integrator.

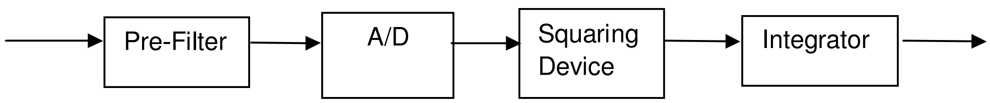

FIGURE 1: Block Diagram of Energy Detector [6].

The output that comes out of the integrator is energy of the filtered received signal over the time interval T and this output is considered as the test statistic to test the two hypotheses H_0 and H_1 [7].
H_0 : corresponds to the absence of the signal and presence of only noise.
H_1 : corresponds to the presence of both signal and noise.

2.1 Test Statistic Using Squaring Operation

Considering the following notations:

$x(t)$ is the transmitted signal waveform, $y(t)$ is the received signal waveform, $w_i(t)$ is in-phase noise component, $w_q(t)$ is quadrature phase component, B_N is noise bandwidth, N_0 is power-spectral density (two-sided), N is power spectral density (one-sided), T is the sampling interval, E_s is the signal energy, Λ is decision threshold.

The received signal $y(t)$ is filtered by a pre-filter which is a band-pass filter. The filtered signal is then passed through A/D converter i.e. converted to samples. Now, if noise $w(t)$ is a band-pass random process, its sample function can be written as [8, Eq. (5.4)]:

$$w(t) = w_i(t)cosw_c t - w_q(t)sinw_c t \tag{1}$$

where w_c is angular frequency. If $w(t)$ is confined to a bandwidth of B_N and has a power-spectral density N_0, then $w_i(t)$ and $w_q(t)$ can be considered as two low-pass processes with bandwidth less than $B_N/2$ and power spectral density of each equal to $2N_0$. Now, if a sample function has Bandwidth B and duration T, then it can be described approximately by a set of sample values $2BT$ or degrees of freedom will be $2BT$. Thus, $w_i(t)$ and $w_q(t)$ each will have degrees of freedom, *d* equal to $B_N T$ [7]. Also, using approximation as in [9, Eq. (2.1-21)]**:**

$$\int_0^T w^2(t)dt = \frac{1}{2}\int_0^T [w_i^2(t) + w_q^2(t)]dt \tag{2}$$

As $w_i(t)$ and $w_q(t)$ are considered as low-pass processes, therefore according to sampling theorem, $w_i(t)$ can be written as [10]:

$$w_i(t) = \sum_{k=-\infty}^{+\infty} c_{ik} sinc(B_N t - k) \tag{3}$$

where $sincx = \frac{\sin\pi x}{\pi x}$ and $c_{ik} = w_i(\frac{k}{B_N})$ is a Gaussian random variable with zero mean and variance $\sigma_k^{\,2} = 2N_0B_N, \forall k$.

Now, using the fact as in [7],

$$\int_{-\infty}^{\infty} sinc(B_N t - k) sinc(B_N t - m) dt = \begin{cases} \frac{1}{B_N}, & k = m \\ 0, & k \neq m \end{cases} \quad (4)$$

Therefore using (3) and (4), we obtain:

$$\int_{-\infty}^{\infty} \mathrm{w_i}^2(\mathrm{t})\,\mathrm{dt} = \frac{1}{\mathrm{B_N}} \sum_{\mathrm{k}=-\infty}^{+\infty} \mathrm{c_{ik}}^2 \quad (5)$$

As $w_i(t)$ has $B_N T$ degrees of freedom over the interval $(0, T)$ [7], therefore

$$w_i(t) = \sum_{k=1}^{B_N T} c_{ik} sinc(B_N t - k), \qquad 0 < t < T \quad (6)$$

And the integral $\int_{-\infty}^{\infty} w_i^{\,2}(t)\,dt$ over the interval $(0, T)$ can be written as

$$\int_0^T w_i^{\,2}(t)\,dt = \frac{1}{B_N} \sum_{k=1}^{B_N T} c_{ik}^{\,2} \quad (7)$$

Similarly,

$$\int_0^T w_q^{\,2}(t)\,dt = \frac{1}{B_N} \sum_{k=1}^{B_N T} c_{qk}^{\,2} \quad (8)$$

Substituting $\frac{c_{ik}}{\sqrt{2B_N N_0}} = d_{ik}$ and $\frac{c_{qk}}{\sqrt{2B_N N_0}} = d_{qk}$ in (7) and (8), and using (2), we arrive at [7]:

$$\int_0^T w^2(t)\,dt = \left[\sum_{k=1}^{B_N T} d_{ik}^{\,2} + \sum_{k=1}^{B_N T} d_{qk}^{\,2} \right] . N_0 \quad (9)$$

Similarly, considering transmitted signal $x(t)$ as a band-pass process [8], we have

$$\int_0^T x^2(t)\,dt = \left[\sum_{k=1}^{B_N T} b_{ik}^{\,2} + \sum_{k=1}^{B_N T} b_{qk}^{\,2} \right] . N_0 \quad (10)$$

or,

$$\sum_{k=1}^{B_N T} (b_{ik}^{\,2} + b_{qk}^{\,2}) = \frac{E_s}{N_0} \quad (11)$$

where $b_{ik} = \frac{x_i(\frac{k}{B_N})}{\sqrt{2B_N N_0}}$, $b_{qk} = \frac{x_q(\frac{k}{B_N})}{\sqrt{2B_N N_0}}$ and $E_s = \int_0^T x^2(t)\,dt$ is the signal energy.

The output of the integrator is $Y = \frac{1}{T}\int_0^T y^2(t)\,dt$.Test statistic can be Y or any quantity monotonic with Y. Taking Y' as the test statistic [7]:

$$Y' = \frac{1}{N_0}\int_0^T y^2(t)\,dt \quad (12)$$

Now, Under Hypothesis H_0, the received signal is only noise i.e. $y(t) = w(t)$, therefore using (9) test statistic Y' can be written as:

$$Y' = \sum_{k=1}^{B_N T}({d_{ik}}^2 + {d_{qk}}^2) \tag{13}$$

Thus, Test statistic Y'under H_0 is chi-square distributed [9] with $2B_N T$ degrees of freedom or $Y' \sim \chi^2_{2d}$ [11] .

Under Hypothesis H_1, received signal is the sum of signal and noise i.e. $y(t) = w(t) + x(t)$. Again considering $y(t)$ as a band-limited process [8], using equations (2-10), we arrive at [7]:

$$\int_0^T y^2(t)dt = \left[\sum_{k=1}^{B_N T}(d_{ik} + b_{ik})^2 + \sum_{k=1}^{B_N T}(d_{qk} + b_{qk})^2\right]. N_0 \tag{14}$$

Then, using (12) and (14), test statistic Y' can be written as:

$$Y' = \left[\sum_{k=1}^{B_N T}(d_{ik} + b_{ik})^2 + \sum_{k=1}^{B_N T}(d_{qk} + b_{qk})^2\right] \tag{15}$$

Thus, test statistic Y'under H_1 has a non-central chi-square distribution [9] with $2B_N T$ degrees of freedom and a non-centrality parameter λ given by $\frac{E_s}{N_0}$ [7]. Now, Defining Signal to Noise Ratio, γ in terms of non-centrality parameter as in [11]:

$$\gamma = \frac{E_s}{N} = \frac{E_s}{2N_0} = \frac{\lambda}{2} \tag{16}$$

Thus, test statistic Y' under H_1: $Y' \sim \chi^2_{2d}(\lambda)$ [11]. Also, probability density function of Y' can be expressed as [9, Eq. (2.3-21) & Eq. (2.3-29)]**:**

$$f_{Y'}(y) = \begin{cases} \frac{1}{2^d \Gamma(u)} y^{d-1} e^{-\left(\frac{y}{2}\right)}, & H_0 \\ \frac{1}{2}\left(\frac{y}{\lambda}\right)^{\frac{d-1}{2}} e^{-\left(\frac{\lambda+y}{2}\right)} I_{d-1}(\sqrt{\lambda y}), & H_1 \end{cases} \tag{17}$$

2.2 Probability Of Detection And False Alarm For AWGN Channel

Probability of detection P_d and false alarm P_f can be evaluated respectively by [11]:

$$P_d = P(Y' > \Lambda | H_1) \tag{18}$$

$$P_f = P(Y' > \Lambda | H_0) \tag{19}$$

where Λ is the decision threshold. Also, P_f can be written in terms of probability density function as:[12, Eq. (4-16) & Eq. (4-22)]

$$P_f = \int_\Lambda^\infty f_{Y'}(y)\, dy \tag{20}$$

Using (19),

$$P_f = \frac{1}{2^d \Gamma(d)} \int_\Lambda^\infty y^{d-1} e^{-\left(\frac{y}{2}\right)} dy \tag{21}$$

Dividing and multiplying the R.H.S. of above equation by 2^{d-1}, we get

$$P_f = \frac{1}{2\Gamma(d)} \int_\Lambda^\infty \left(\frac{y}{2}\right)^{d-1} e^{-\left(\frac{y}{2}\right)} dy \tag{22}$$

Substituting $\frac{y}{2} = t$, $\frac{dy}{2} = dt$ and changing the limits of integration to $(\frac{\Lambda}{2}, \infty)$, we get

$$P_f = \frac{1}{\Gamma(d)} \int_{\Lambda/2}^\infty (t)^{d-1} e^{-(t)} dt \tag{23}$$

or,

$$P_f = \frac{\Gamma(d, \Lambda/2)}{\Gamma(d)} \tag{24}$$

where $\Gamma(.)$ is the incomplete gamma function [13]. Now, Probability of detection can be written by making use of the cumulative distribution function [12, Eq. (4.22)].

$$P_d = 1 - F_{Y'}(\Lambda) \tag{25}$$

The cumulative distribution function (CDF) of Y' can be obtained (for an even number of degrees of freedom which is $2d$ in our case) as [9, Eq. (2.1-124)]:

$$F_{Y'}(y) = 1 - Q_d(\sqrt{\lambda}, \sqrt{y}) \tag{26}$$

Therefore, using (25) and (26), probability of detection P_d for AWGN channel is [11]:

$$P_d = Q_d(\sqrt{\lambda}, \sqrt{\Lambda}) \tag{27}$$

Using (16),

$$P_d = Q_d(\sqrt{2\gamma}, \sqrt{\Lambda}) \tag{28}$$

2.3 Probability Of Detection And False Alarm For Rayleigh Channel

Probability density function for Rayleigh channel is [12, Eq. (4-44)]:

$$f(\gamma) = \frac{1}{\bar{\gamma}} exp\left(\frac{-\gamma}{\bar{\gamma}}\right) \qquad ; \gamma \geq 0 \tag{29}$$

The Probability of detection for Rayleigh Channels is obtained by averaging their probability density function over probability of detection for AWGN Channel [11]:

$$P_{d,R} = \int_0^{\infty} P_d\, f(\gamma)\, d\gamma \tag{30}$$

where $P_{d,R}$ is the probability of detection for Rayleigh channel.
With (28) and (29), (30) becomes

$$P_{d,R} = \frac{1}{\bar{\gamma}} \int_0^{\infty} Q_d(\sqrt{2\gamma}, \sqrt{\Lambda})\, exp\left(\frac{-\gamma}{\bar{\gamma}}\right) d\gamma \tag{31}$$

Now, substituting $\sqrt{\gamma} = x$, $\gamma = x^2, d\gamma = 2xdx$ in (31), we get

$$P_{d,R} = \frac{2}{\bar{\gamma}} \int_0^{\infty} x.\, Q_d(\sqrt{2}x, \sqrt{\Lambda})\, exp\left(\frac{-x^2}{\bar{\gamma}}\right) dx \tag{32}$$

Considering the result [14]

$$\int_0^{\infty} dx.\, x.\, exp\left(\frac{-p^2x^2}{2}\right) Q_M(ax, b) = \frac{1}{p^2}.\, exp\left(-\frac{b^2}{2}\right).\left\{\left(\frac{p^2+a^2}{a^2}\right)^{M-1}\left[exp\left(\frac{b^2}{2}.\frac{a^2}{p^2+a^2}\right) - \sum_{n=0}^{M-2}\frac{1}{n!}\left(\frac{b^2}{2}.\frac{a^2}{p^2+a^2}\right)^n\right] + \sum_{n=0}^{M-2}\frac{1}{n!}\left(\frac{b^2}{2}\right)^n\right\} \tag{33}$$

Comparing (32) and (33), $p^2 = \frac{2}{\bar{\gamma}}$, $a = \sqrt{2}$, $b = \sqrt{\Lambda}$, $M = d$

Thus, using (33), Probability of detection for Rayleigh channel can be expressed as [11]:

$$P_{d,R} = e^{(-\Lambda/2)} \sum_{n=0}^{d-2}\frac{1}{n!}\left(\frac{\Lambda}{2}\right)^n + \left(\frac{1+\bar{\gamma}}{\bar{\gamma}}\right)^{d-1}\left[\exp\left(-\frac{\Lambda}{2(1+\bar{\gamma})}\right) - \exp\left(-\frac{\Lambda}{2}\right)\sum_{n=0}^{d-2}\frac{1}{n!}\left(\frac{\Lambda\bar{\gamma}}{2(1+\bar{\gamma})}\right)^n\right] \tag{34}$$

2.4 Simulation Results

The performance of energy detector is analysed using ROC (Receiver operating characteristics) curves for fading channels. Monte-Carlo method is used for simulation. It can be seen in the following figures that with increase in SNR (Signal to Noise Ratio), the performance of energy detection improves. FIGURE 2 and FIGURE 4 illustrates the ROC curves using squaring operation for AWGN and Rayleigh channel respectively. FIGURE 3 and FIGURE 5 depicts improvement in the performance of energy detector using cubing operation over AWGN and Rayleigh channel respectively. We assume time-bandwidth product=5.

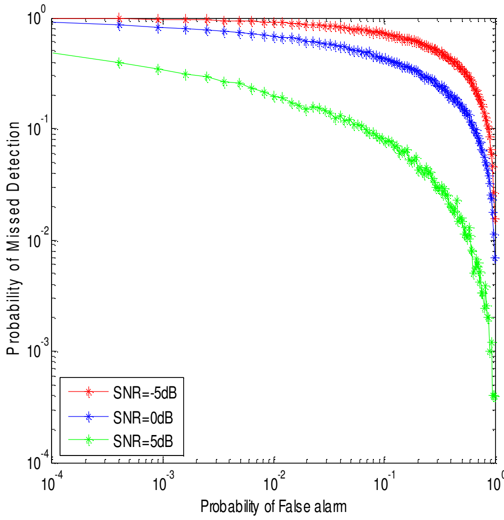

FIGURE 2: Complementary ROC Curves for AWGN using Squaring operation.

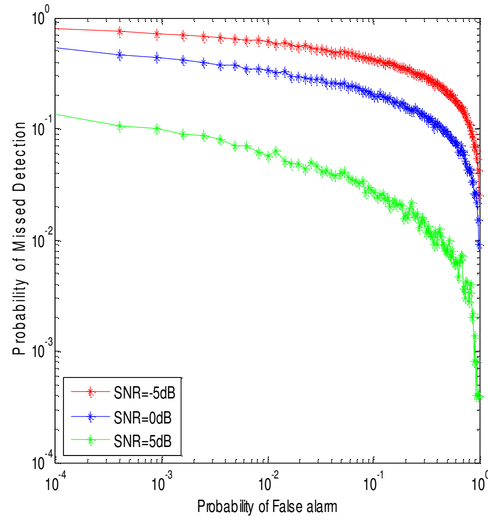

FIGURE 3: Complementary ROC Curves for AWGN using Cubing operation.

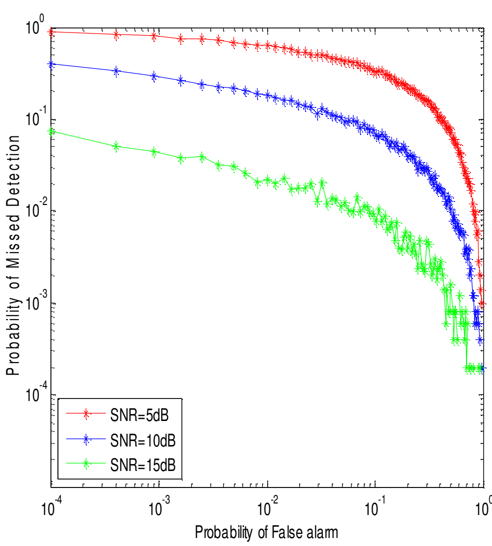

FIGURE 4: Complementary ROC for Rayleigh using Squaring operation.

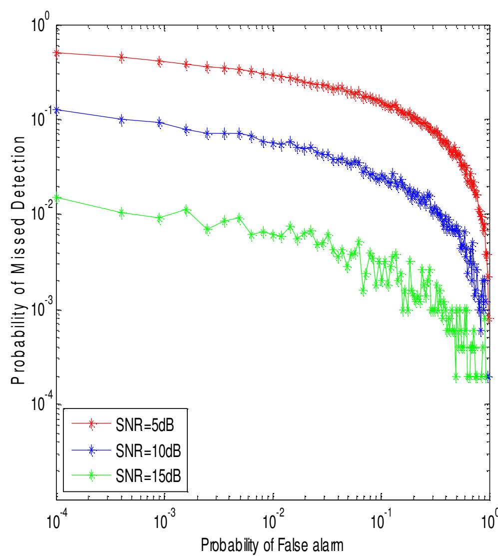

FIGURE 5: Complementary ROC for Rayleigh using Cubing operation.

The results obtained using cubing operation show an improvement of roughly one order of magnitude as compared to the energy detection method illustrated in [11]. The results obtained are quantified as shown in TABLE 1 and TABLE 2. These results illustrate improvement in probability of detection using cubing operation. This improvement has gone up to 0.4 times for Rayleigh Channel and 0.6 times for AWGN Channel. We assume time-bandwidth product=5 and Average SNR=5dB.

Probability of False Alarm	Probability of detection for AWGN Channel (Squaring Device)	Probability of detection for AWGN Channel (Cubing Device)	Improvement (times)
0.0001	0.5372	0.8656	0.6113
0.0441	0.8792	0.9594	0.0912
0.1681	0.9390	0.9758	0.0392
0.3721	0.9748	0.9862	0.0117
0.6561	0.9938	0.9952	0.0014

TABLE 1: Improvement using cubing operation for AWGN channel.

Probability of False Alarm	Probability of detection for Rayleigh Channel (Squaring Device)	Probability of detection for Rayleigh Channel (Cubing Device)	Improvement (times)
0.0001	0.6516	0.9746	0.4957
0.0441	0.4096	0.9982	0.0146
0.1681	0.9976	0.9996	0.0020
0.3721	0.9998	1.000	0.0002
0.6561	1.000	1.000	0

TABLE 2: Improvement using cubing operation for Rayleigh channel.

2.5 Conclusions

In the present work, the performance of energy detector is analysed. Closed form expressions for Probability of detection and false alarm over AWGN and Rayleigh channels are described. Using ROC Curves, it is shown that the Probability of detection is improved if cubing operation is used instead of squaring operation. Energy detection has the advantage of low implementation and computational complexities.

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Wavelet Based Noise Robust Features for Speaker Recognition

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Abstract

Extraction and selection of the best parametric representation of acoustic signal is the most important task in designing any speaker recognition system. A wide range of possibilities exists for parametrically representing the speech signal such as Linear Prediction Coding (LPC) ,Mel frequency Cepstrum coefficients (MFCC) and others. MFCC are currently the most popular choice for any speaker recognition system, though one of the shortcomings of MFCC is that the signal is assumed to be stationary within the given time frame and is therefore unable to analyze the non-stationary signal. Therefore it is not suitable for noisy speech signals. To overcome this problem several researchers used different types of AM-FM modulation/demodulation techniques for extracting features from speech signal. In some approaches it is proposed to use the wavelet filterbanks for extracting the features. In this paper a technique for extracting the features by combining the above mentioned approaches is proposed. Features are extracted from the envelope of the signal and then passed through wavelet filterbank. It is found that the proposed method outperforms the existing feature extraction techniques.

Keywords: Speaker Recognition, Mel Frequency Cepstral Coefficients (MFCC), Amplitude Modulation (AM) Wavelet Filterbank.

1. INTRODUCTION

Speaker recognition is the process of automatically recognizing who is speaking on the basis of the information extracted from the speech signal. This technique is used to verify the identity of a person with the help of speaker's voice. There are many application areas that are using Speaker recognition for controlling access to services such as voice dialing, voice mail, banking by telephone, telephone shopping, database access service, security control for confidential information etc.

The first speaker recognition system was introduced by Pruzansky [1] in 1960. In his work he used filter banks and spectrogram correlators for speaker recognition. Li et. al. [2] further developed it by using linear discriminators. In some of the approaches the speaker specific features are extracted by using the statistical or predictive parameters. A wide range of possibilities exists for parametrically representing the speech signal such as instantaneous spectra covariance matrix [3], spectrum and fundamental frequency histograms [4], Linear Prediction coefficients (LPC) [5], Mel frequency Cepstrum Coefficients (MFCC) [6] and others. Among all the approaches mentioned above MFCC are the most popular choice for any speaker recognition system, though one of the shortcomings of MFCC is that the signal is assumed to be stationary within the given time frame and is therefore unable to analyze the non-stationary signal. There exist two different approaches to deal with this problem.
In first approach researchers used different types of AM-FM modulation/demodulation techniques for extracting features from speech signal. Qifeng Zhu and Abeer Alwan considerd AM

modulation for speech recognition [7] [8]. They used the Harmonic demodulation methods in computing MFCC. Different from previous studies Petros Maragos, and Alexandros Potamianos proposed AM-FM modulation model to represent the speech signal [9]. Using AM-FM model Dimitrios Dimitrriadis et.al. proposed robust AM-FM features for speech recognition[10],[11] . It has been found in the above proposed methods that the AM and FM modulation features characterize the very fine structure of speech and they improve noise robust speech recognition efficiency.

In second approach wavelet transform based methods are used for feature extraction. In particular, in feature extraction schemes designed for the purpose of speaker and speech recognition, wavelets have been used as an effective decorrelator instead of Discrete Cosine Transform in the feature extraction stage [12]. In [13] wavelet coefficients with high energy are taken as features but such methods suffer from shift variance. T. Kinnunen proposed use of wavelet subband energies instead of Mel filterbank subband energies [14]. Later, Sarikaya et.al. [15] ,[16] Farooq and dutta [17] proposed wavelet filterbanks that are close approximation of Mel filter bank.

But all these existing speaker recognition systems discussed above performs well only under clean speech conditions. Their recognition efficiency decreases in noisy and real time speech conditions. This noise is additive in nature and can be removed from the noise corrupted features. But this requires noise estimation which increases the processing and time complexity. This noise estimation can be avoided by extracting noise robust features. In this paper a noise robust speaker recognition system is proposed which extracts noise robust features by extracting the vocal tract transfer function (VTTF) and then passing this through wavelet filterbank. The extraction of VTTF avoids the spectral mismatch produced by noise at low signal to noise ratio areas are avoided and wavelet filterbank avoids the loss of energy in side lobes. Following will be the organization of the paper: Section 2, critically analyses popular feature extraction technique MFCC and discuss existing modifications of MFCC by using AM demodulation and wavelet filterbank. Section 3 discusses proposed algorithm. Section 4 gives the performance evaluation and comparison of proposed algorithm with existing algorithms. Section 5 concludes the algorithm.

2. FEATURE EXTRACTION TECHNIQUES FOR SPEAKER RECOGNITION

The purpose of feature extraction is to convert speech waveform, to a set of features for further processing. These features can be used to generate a pattern and then classification can be done by the degree of correlation. Few other techniques use the numerical values of the features coupled to statistical classification method. Different approaches for feature extraction that have been successfully used include, Linear discriminator bases [2], Linear predictive coding (LPC) [5] Mel-frequency cepstrum coefficients (MFCC) [6]. Among them MFCC is the most popular technique for feature extraction. In this section MFCC feature extraction technique is discussed with its limitations and then some existing modifications of MFCC are outlined.

2.1 MFCC

Mel-frequency cepstrum coefficients (MFCC) [6] are well known features used to describe speech signal. They are based on the known variation of human ear's critical bandwidths with frequency. In MFCC feature extraction filters are spaced linearly at low frequencies and logarithmically at high frequencies as the information carried by low frequency components are more important for human perception than high frequency components. Figure 1. shows the feature extraction technique using MFCC.

In MFCC feature extraction first step is windowing. The window used for MFCC feature extraction is the hamming window given by the equation (assuming a window that is L frames long):

hamming $w[n] = 0.54 - 0.46\cos(2\pi n/L); \quad 0 \le n \le L-1$

; otherwise

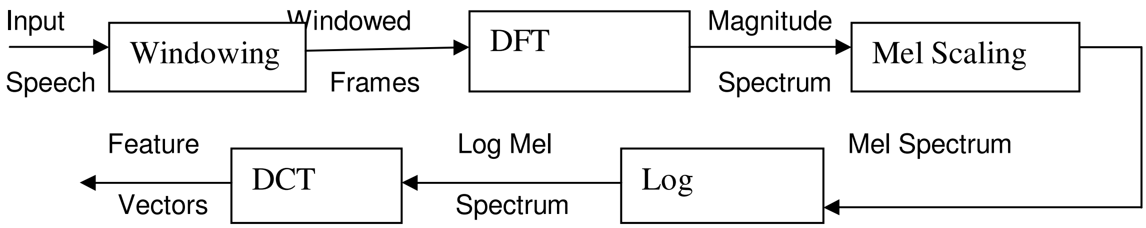


Figure1: Feature extraction using MFCC

The spectral information from the windowed signal is calculated by using DFT. The result after this step is often referred to as *spectrum* or *periodogram* and gives the information about the amount of energy at each frequency band. Since Human hearing is not equally sensitive at all frequency bands therefore the form of the model used in MFCCs is to warp the frequencies output by the DFT onto the Mel scale. The mapping between frequency in Hertz and the Mel scale is linear below 1000 Hz and the logarithmic above 1000 Hz. The Mel frequency m can be computed from the raw acoustic frequency as follows:

$$Mel(f) = 1127\ln(1 + (f/700))$$

A bank of filters is created which collect energy from each frequency band, with 10 filters spaced linearly below 1000 Hz, and the remaining 10 filters are spread logarithmically above 1000 Hz [6]. This filter bank has a triangular band pass frequency response, and the spacing as well as the bandwidth is determined by a constant Mel frequency interval. Then Log of the Mel spectrum is taken to incorporate the logarithmic human response to signal level. A set of Mel-frequency cepstrum coefficients is computed by taking discrete cosine transform of the logarithm of the short-term power spectrum expressed on a Mel-frequency scale.

MFCC is perhaps the best known and most popular feature extraction technique though it has somelimitations. In MFCC the signal is assumed to be stationary within a given time frame and may therefore lack the ability to analyze localized events accurately. Secondly a triangular filter bank is used whose frequency response is not smooth and therefore it may not be suitable for noisy speech data.

Some modifications are proposed by researchers to overcome the limitations of MFCC. In some approaches it is proposed to modify the signal under consideration before calculating MFCC [7] [8] [10] [18] [19]. In other approaches the MFCC is modified by using wavelet transform methods [13] [14] [15] [16] [17] [21]. These two approaches are discussed in section 2.2 and 2.3 respectively.

2.2 Feature Extraction Using Demodulated Speech Signal

The feature extraction using AM demodulation of speech signal was proposed by Zhu et. al.[8] in the year 2000. In [8] Zhu and Alwan performed the envelope detection of speech spectrum in frequency domain by performing the linear convolution between the speech spectrum and the characteristics of low pass filter. After extracting the envelope of the speech signal MFCC features are calculated from this envelope.

In [18] Fan-Gang Zeng, Kaibao Nie and others found that although AM from a limited number of spectral bands may be sufficient for speech recognition but FM significantly enhances speech recognition in noise, as well as speaker and tone recognition. Additional speech reception threshold measures revealed that FM is particularly critical for speech recognition with a competing voice and is independent of spectral resolution and similarity. These results suggest that AM and FM provide independent yet complementary contributions to support robust speech recognition under realistic listening situations.

In [19],Maragos, Kaiser and Quatieri proposed AM and FM models to represent time varying amplitude and frequency patterns in speech resonance and the total speech signal is superposition of such AM-FM signals. To demodulate a signal resonance, Energy separation algorithm (ESA) is used by Maragos, Kaiser and Quatieri [10] using the nonlinear energy-tracking operator. The ESA estimates the instantaneous frequency and amplitude of the signals.

The energy separation methodology has led to several classes of algorithms for demodulating AM–FM signals. Dimitrios Dimitriadis et. al. proposed to extract speech features inspired by the AM-FM model [11]. The proposed features measure instantaneous amplitude and frequency model and these features when combined with the MFCC are robust to noise.

2.3 Feature Extraction Using Wavelet Transform Methods

Wavelet transform is a multi resolution transform that has a capability to process the non stationary signal as well. Recently this transform has been used to extract features for the purpose of speech and speaker recognition. Another advantage of using the wavelet transform is its compact support which avoids spilling of the energy of the side lobes. In particular, in feature extraction schemes designed for the purpose of speech and speaker recognition, wavelets have been used twofold. The first approach uses wavelet transform as an effective decorrelator instead of Discrete Cosine Transform in the feature extraction stage [21]. According to the second approach, wavelet transform is applied directly on the speech signal. In this case, either wavelet coefficients with high energy are taken as features [13], or wavelet subband energies are used instead of the Mel filter-bank subband energies. In particular, in the speech recognition area, the wavelet packet transform, employed for the computation of the spectrum, was first proposed in [14]. Later, wavelet packet bases were used by SBCC of Sarikaya & Hansen [15], WPP of Sarikaya & Hansen [16] , WPF of Farooq and dutta [17]. In these approaches a wavelet packet tree/filter that is close approximation of Mel frequency division is used i.e. low to mid frequencies more subbands are assigned so that their decomposition preserves a log like distribution of subband. Then the subband energy for each subband is calculated.

3. PROPOSED METHOD USING AM DEMODULATION AND WAVELET FILTERS

The feature extraction techniques discussed in section 2 performs well for the clean speech signals. In real time conditions, the speech data is noisy due to sensor, environment and channel conditions. This reduces the signal to noise ratio and therefore degrades the performance of speaker recognition system. Hence an efficient method is required which can consider non-stationarity of the speech signal and can enhance signal to noise ratio. In this paper a hybrid noise robust speaker recognition system is proposed which utilizes advantages of both AM demodulation techniques (discussed in section 2.1) as well as wavelet filterbank (discussed in section 2.2). It is proposed to extract noise robust features from the AM demodulated envelop of real time signal and avoids loss of energy in sidelobes by using wavelet filterbank to improve signal to noise ratio. The proposed training system architecture used for noise robust speaker recognition system is shown in figure 2. It consists of three stages Pre-Processing, Feature extraction and Speaker modeling. In the preprocessing stage pre-emphasis and framing operations are performed. Feature extraction stage is modified by taking the features from the envelop of the speech signal instead of complete signal thereby reducing the noise effects. This is performed by AM demodulation of the signal in the frequency domain. This AM demodulated signal is then passed through a wavelet filterbank that is a close approximation of Mel filter bank. Since wavelet transforms avoids spilling of energy of the side lobes and this helps in selecting a non overlapping window. Speech features are then obtained by taking the Log and discrete cosine transform of the signal at the output of the filterbank. The speech features thus obtained are then modeled by using vector quantization. Each stage is described in detail in following section:

3.1 Preprocessing

Pre-emphasis-Pre-emphasis is done to boost the amount of energy in the high frequencies. In spectrum for voiced signals there is more energy at the lower frequencies than the higher frequencies. Boosting the high frequency energy makes information from these higher formants more available to the acoustic model.

Framing- Spectral features are extracted from a small window of speech assuming that the signal is stationary within this region. The window used in feature extraction is the Hamming window, which shrinks the values of the signal toward zero at the window boundaries, avoiding discontinuities. The equation or the window is given as

$$w[n] = \begin{cases} 0.54 - 0.46\cos(2\Pi n/L) & ; \; 0 \le n \le L-1 \\ 0 & ; \; \text{otherwise} \end{cases}$$

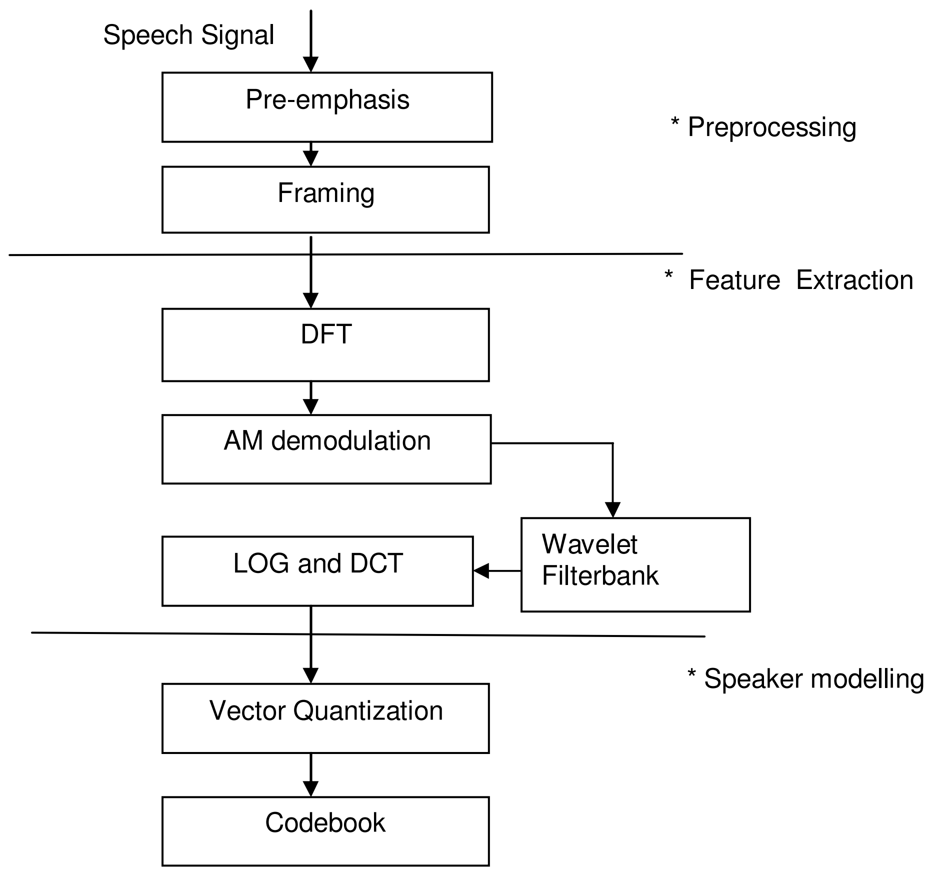


FIGURE 2: Training using proposed Algorithm.

3.2 Feature Extraction

In feature extraction stage it is proposed to extract the features from amplitude demodulated signal. Zhu et.al.[8] proposed that in frequency domain the speech signal is AM modulated signal with excitation spectrum as the carrier and Vocal tract transfer function (VTTF) as the modulating signal. They considered the speech waveform as the result of convolution between the excitation signal (which is either quasi –periodic, noise like, or a combination of the two) and the impulse response of the vocal tract transfer function (VTTF) as proposed by Fant [22]. Therefore in frequency domain the speech signal is obtained by multiplying the excitation spectrum (source spectrum) and the VTTF as shown in figure 3. If excitation spectrum is taken as the carrier and vocal tract transfer function as a modulating signal then by amplitude modulating the carrier with respect to the modulating signal in the frequency domain will give the results as shown in figure 3.

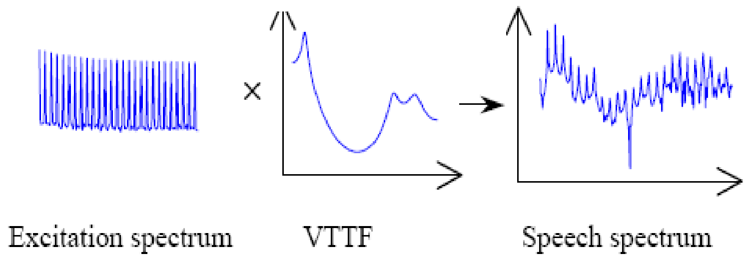


FIGURE 3: The linear source-filter model of speech production in the frequency domain. The x-axis is frequency [7].

Therefore in the proposed method, to AM demodulate the signal first the speech signal is transformed from time domain to frequency domain by using Discrete Fourier Transform (DFT). Then this signal is AM demodulated by using either Harmonic demodulation [8] or square law demodulator figure 4.

In Square law demodulator initially the signal is passed through the squarelaw device. Output of this is then passed through a low pass filter and then MFCC features are extracted. In this paper squarelaw demodulator is used for extracting the envelope.

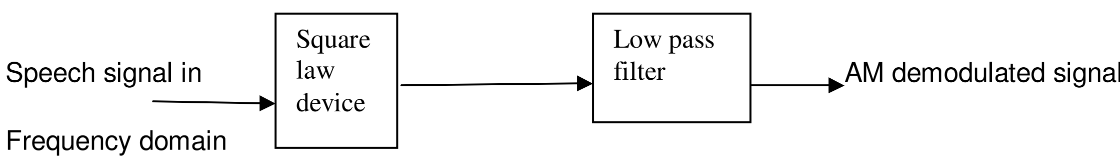
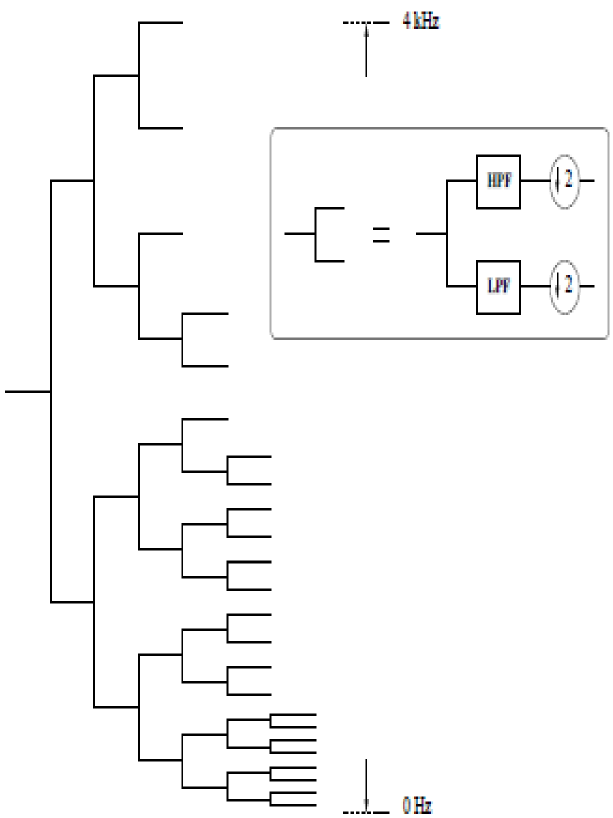


FIGURE 4: Block diagram of the square law demodulator

After extracting the envelop, instead of passing the signal through Mel filterbank, the speech signal is passed through the wavelet filterbank . For this filterbank suggested in [15] and given in figure 5 is used. Sarikaya & Hansen [15] performed a wavelet packet decomposition of the frequency range [0, 4] kHz such that the 24 frequency subbands obtained follow the Mel scale for the task of monophone recognition problem. The proposed analysis emphasizes low to mid frequencies assigning more subbands in these bands; overall, their decomposition preserves approximately a log-like distribution of the subbands across frequency. The wavelet packet decomposition is performed by using Daubechies'-32 wavelet filter. Finally, the log of each of the sub-band values is taken. In general the human response to signal level is logarithmic; humans are less sensitive to slight differences in amplitude at high amplitudes than at low amplitudes. In addition, using a log makes the feature estimates less sensitive to variations in input (for example power variations due to the speaker's mouth moving closer or further from the microphone). The last step in feature extraction is the computation of the Discrete cosine Transform. The outputs of the DCT stage are extracted features.

3.3 Speaker Modeling

The acoustic vectors extracted from input speech of each speaker provide a set of training vectors for that speaker. For each speaker there is a very large amount of data to store. The next step is therefore to condense this data. For clustering this data vector quantization is used. For that an algorithm, namely LBG algorithm [21], for clustering a set of *L* training vectors into a set of *M* codebook vectors is used. By using this LBG algorithm a set of vectors or codewords is created for each speaker. The codewords for a given speaker are then stored together in a codebook for that speaker. Each speaker's codebook is then stored together in a master codebook which is compared to the test samples during the testing phase.



Filter	SBCC central	MFCC
1	31	28
2	94	89
3	156	154
4	219	224
5	281	300
6	344	383
7	406	472
8	469	569
9	563	674
10	688	787
11	813	910
12	938	1043
13	1063	1187
14	1188	1343
15	1313	1512
16	1438	1694
17	1563	1892
18	1688	2106
19	1875	2338
20	2125	2589
21	2375	2860
22	2750	3154
23	3250	3472
24	3750	3817

FIGURE 5: 24-subband wavelet packet tree [15]

In the recognition phase, for making decision, features are extracted from an input utterance of an unknown voice using the proposed algorithm. The extracted features are then "vector-quantized". The *total VQ distortion* between each trained codebook and testing codebook is computed using Euclidean distance defined as

$$d(x,y_i) = \sqrt{\sum_{j=1}^{k}(x_j - y_{ij})^2}$$

where x_j is the jth component of the input vector, and y_{ij} is the jth is component of the codeword y_i. The speaker corresponding to the VQ codebook with smallest total distortion is identified as the speaker of the input utterance. The process is given in figure 6.

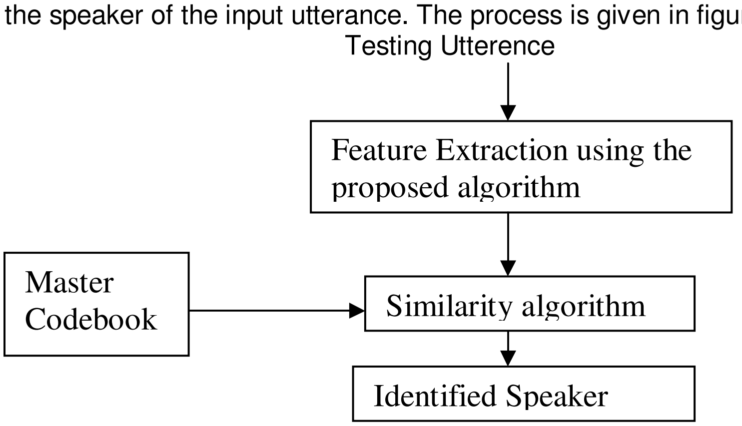


FIGURE 6: Testing using proposed Algorithm

4. RESULTS AND DISCUSSIONS

Performance of the proposed hybrid method is compared with feature extraction techniques using AM demodulation proposed by Zhu et.al. [8] [9] and named as HDMFCC, techniques using wavelet filterbank SBCC[15] , WPF [17] and with MFCC[6]. All these algorithms are implemented using MATLAB 7.4. These algorithms are tested for Hindi digits from 0 to 9 spoken by 80 male and 70 female speakers. The speech input is recorded at a sampling rate above 10000 Hz so that sampled signals covers all frequencies in human speech signal. Frame size of 30 millisecond is taken with 50% overlapping. DFT is performed by using 1024 point radix-2 FFT. A wavelet filterbank with 24 filters is used. The wavelet packet decomposition is performed by using Daubechies'-32 wavelet filter. A codebook of 64 codewords is used for performing vector quantization. The results obtained when tested for this real time data are given in Table 1 and figure 7.

Feature Extraction Technique Used	**% Recognition Efficiency**
MFCC [6]	63%
HDMFCC[7] [8]	65%
WPF [17]	68%
SBCC [15]	73%
Proposed Hybrid method	78%

TABLE 1: Recognition rates for MFCC, HDMFCC, SBCC, WPF, and AM-SBCC
Results: For Hindi digits from 0 to 9 spoken by 80 male and 70 female speakers

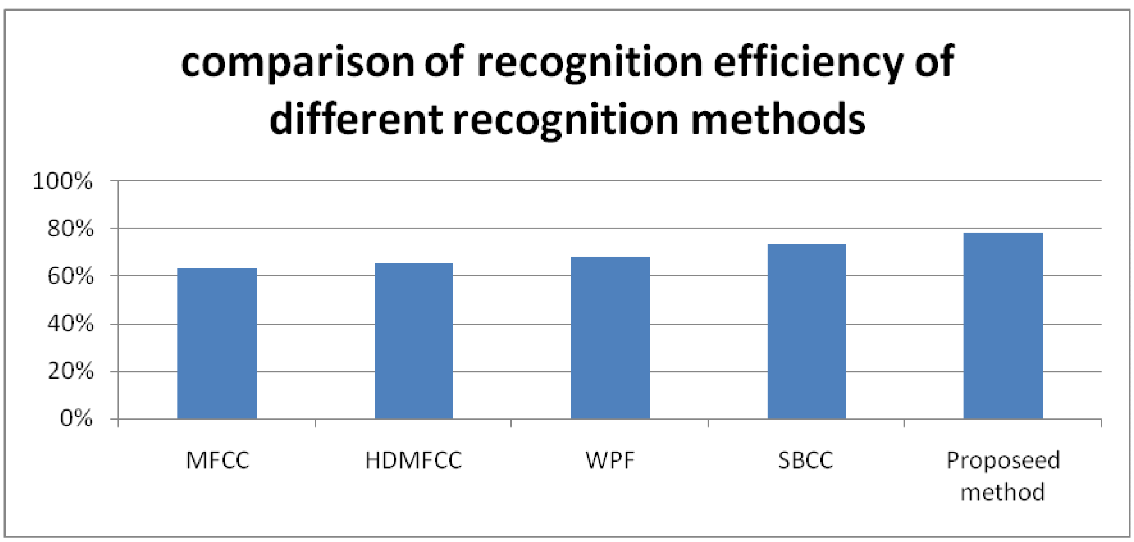
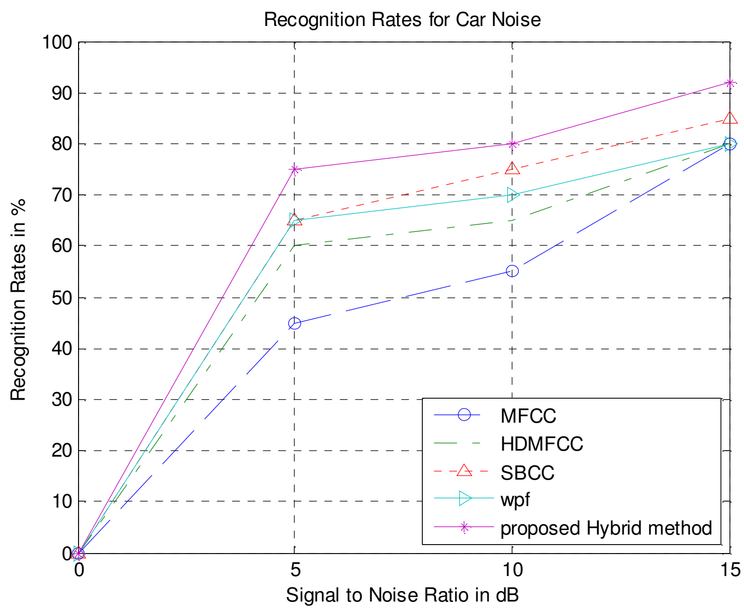


FIGURE 7: Comparison of recognition Efficiency of different recognition methods.

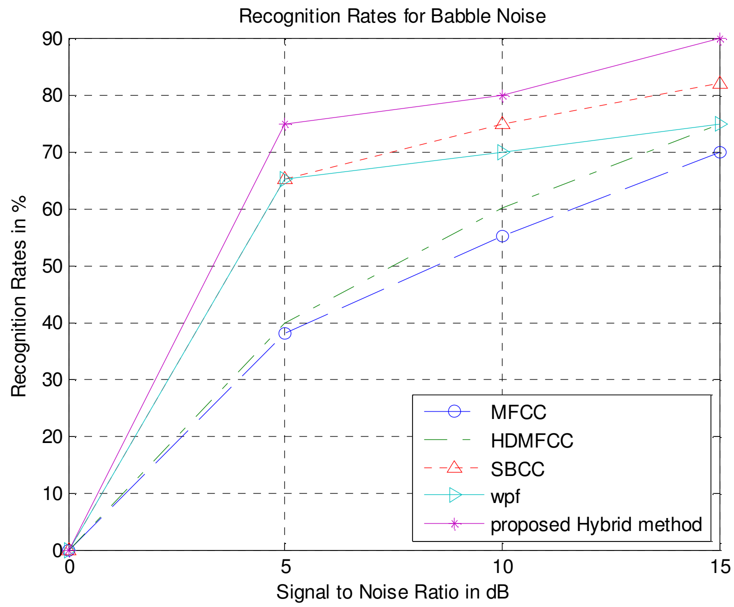
The results shows that the proposed hybrid method gives a recognition efficiency of 78% as compared to the 63% of MFCC for real time data. Compared with other methods also the recognition efficiency of the proposed method is higher. It gives improvement of 5 % as compared to SBCC[15] , improvement by 10 % as compared to WPF[17] and 13% when compared with HDMFCC[7] [8].

Experiments are also conducted by training the system with clean speech and testing their performance at different noise levels. Noisy speech corpus (NOIZEUS) is used [22]. For the experiments. This corpus is available to researchers freely and can be downloaded at http://www.utdallas.edu/~loizou/speech/noizeus/. In this speech corpora noise is artificially added to the speech signals. Noise signals were taken from the AURORA database [23] and included the recordings from different places such as Babble (crowd of people), Car, Street, and Train. The noise signals were added to the speech signals at Signal to noise ratio of 0dB, 5dB, 10dB, and 15dB.

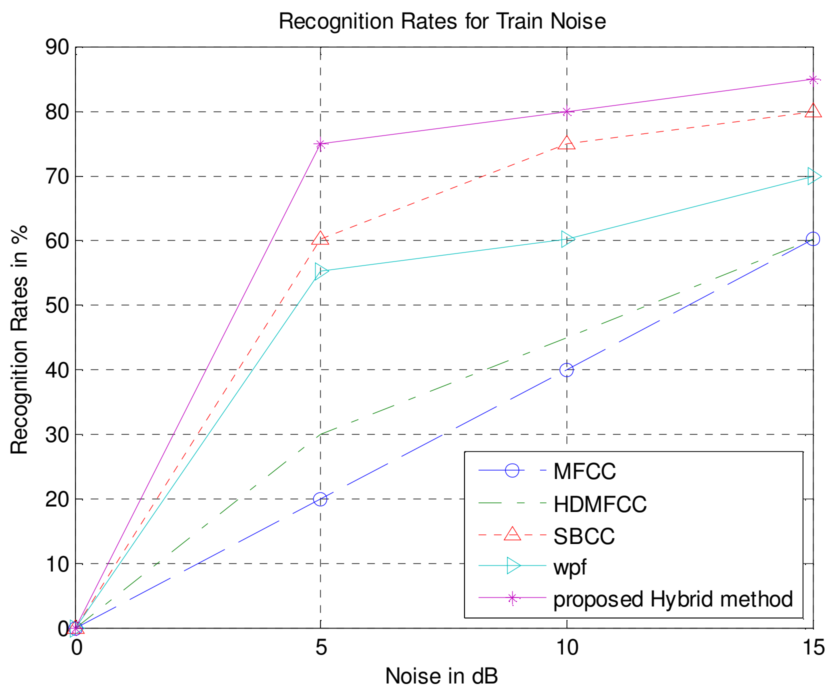
In the experiments the system under test is trained with the clean speech signal. During testing for recognition performance the same signal corrupted by different types of noise such as Car noise , Babble Noise , Street Noise and Train noise . The performance of the at signal to noise level of 0dB, 5dB, 10 dB, and 15 dB are plotted. The results obtained for the MFCC[6] HDMFCC[7] [8] , SBCC[15] , WPF [17] and proposed Hybrid method are given in figure 8. From the figure it is clear that recognition performance improves with the increase in signal to noise ratio for all the methods discussed. From the results it can be shown that proposed Hybrid method gives better recognition efficiency compared to other methods discussed at all signal to noise ratio .



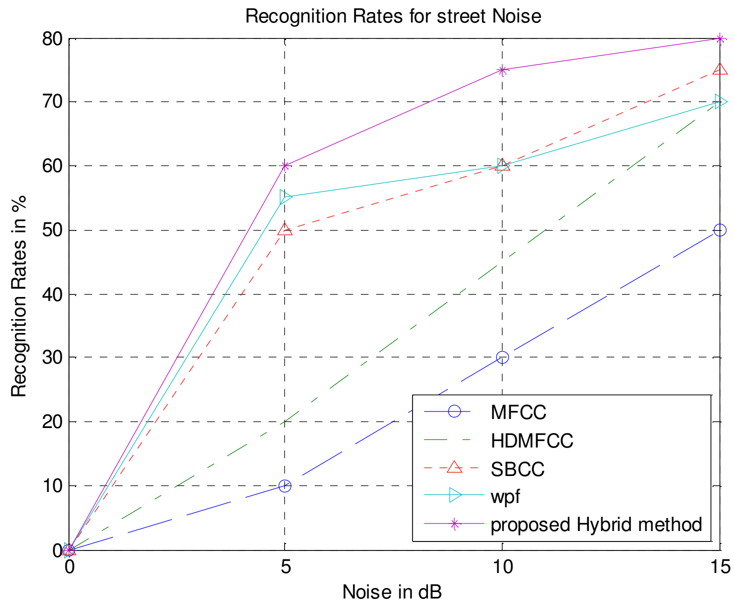
(a) Recognition Rates for Car noise



(b) Recognition Rates for Babble noise



(c) Recognition Rates for Train noise



(d) Recognition Rates for Street noise

FIGURE 8: Comparison of MFCC, HDMFCC, SBCC, WPF and, proposed method at different noise levels

5. CONCLUSION

The first drawback of MFCC is that the signal is assumed to be stationary within a given time frame and may therefore lack the ability to analyze localized events accurately. Hence it is proposed to extract the envelope of the signal. From results it is observed that the features extracted from envelope of the signal are more noise robust. The second limitation is, in MFCC triangular filterbank is used and frequency response of triangular filterbank is not smooth. Therefore it is proposed to use wavelet filterbank. Experimental results show that the proposed algorithm gives better recognition efficiency as compared to the other methods discussed. In future we will try to incorporate the Frequency modulation parameters for improving the speaker recognition performance

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The Electronic Eyes of the Social Capital

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Abstract

The video camera symbolizes an intelligible system that seeks to replace mechanically the human eye, in this paper, entitled “electronic eyes”. People’s reaction when realize that they are being observed through the lens of the “electronic eye” are in a variety of ways. Some people get shy, others show themselves off spontaneously, and many of them try to avoid the electronic lens. Can a mechanical eye influence people's behavior? This article examines not only this issue, but it goes further. Considering the increasing number of cameras installed in public and private places, the question is: may this fact cause any change in social relationships? The main purpose of this paper is to analyze the electronic eye’s influence on the concept of social capital. A qualitative exploratory study was performed conducted by semi-structured interviews. The results show that the electronic eye influences on peoples’ idea, on the social relationships, and on the social capital concept. Although changing peoples’ behavior and attitudes, the electronic eye does not replace the human eye, it only complements it. Coined by the authors, the term “electronic eyes”, is a contribution of this study to the Social Capital, conceptually supported by the social philosophy.

Keywords: Electronic Eye, Social Capital, Cameras

1. INTRODUCTION

It is essential to start the article highlighting some key aspects of the discussion about society in order to understand the concept of Social Capital. In this sense, supported by the social philosophy, it has been sought a contribution to the reflection about interpersonal relations on the cameras systems, that function as real electronic eyes, understood here as an attempt to reproduce mechanically the human organ through the system of video cameras. According to the Cambridge Dictionary of Philosophy (1999) the social philosophy and, in general, the philosophy of society, encompassing the philosophy of social sciences - with emphasis on economics and history - political philosophy, ethics and philosophy of law. In spite of this statement, two narrower directions are indicated: first, the society conceptual theory, considering the main part of all these mentioned studies and second, the normative study or the part of moral philosophy, which deals with the social activity and the individual participation in a society.

In a narrower sense, the task of social philosophy is to articulate the correct notion of the society concept. Distinguished thus between “narrow” and “large” society conceptions. The first one identifies the minimum aspects about society, in other words, the interaction of people whose actions affect the behavior of their peers. The other one adds other elements such as community rules, goals, customs and ideals.

At this point begins the dissent. Within one's own social descriptive philosophy, according to the Cambridge Dictionary of Philosophy (1999), there will be points of view that tend to join a social science, for example, the individualistic point of view to the economy, and the holistic to sociology. The main methodological controversy concerns to the holism versus the individualism. The first one holds that at least some social groups should be studied as irreducible units to its members and that it is not possible to understand a society including only the actions and motivations of its members. On the other hand, the individualism denies that societies are organisms and it declares that a society can be known only in this way.

Some German classical sociologists like Weber (1947), have distinguished between Gesellschaft whose paradigm is the voluntary association, such as join a club, where the coordinated actions by individuals who associate with the same goals, and the Gemeinschaft whose members find their identity in this group. Weber (1947) affirms that people can put their nation above all, for example, Brazilians which, whether or not join a group of people that shares the same opinion to form Brazilian society, are Brazilian above all. To the holism a society is considered a Gemeinschaft. They agree on the existence of such associations, however, they deny that these association lack of collective explanation. In this case, to comprehend Brazilians, it is necessary to understand how particular individuals behave compared to those of other societies.

The advent of sociobiology is considered by the Cambridge Dictionary of Philosophy (1999) as a source of explanation to the social phenomena. The normative philosophy tends to disappear in politics or ethics, especially the part of ethics which deals with how people should treat others, particularly in large groups, in relation to social institutions or social structures.

The core of this debate results in implications to the current concept of social capital. Individualists argued that the goodness of a society must be examined from the viewpoint of the goodness of its individual members. Organicist philosophers like Hegel (1979) declares that there is another way: the State or nation is superior to the individual. Subordinate to it, the individuals have fundamental obligations towards groups that they are members. On the other extreme, there are the libertarians, who defended the right to individual liberty as fundamental to society and no institution could ignore this law. Social Darwinism supported the survival of what is socially fair and it was sometimes confused as libertarian.

Standardized points of view have resulted from these currents of thought and, as they arise, they combine elements of both individualism and holism. From this perspective of multivariate views emerges the notion of social capital. Recognizing this concept, this article, has analyzed how the members of a society behave observed by the lens of the electronic eyes. To this end, a theoretical framework has been sought; the methodology has been defined followed by the data analysis and results as well as the final considerations.

2. THEORETICAL BACKGROUND

2.1 The Electronic Eye

St. Augustine, in his book “The Greatness of the Soul”, debates with Evodio about the sensitivity throughout the body. Particular emphasis is given to the sense of sight. Here is part of the debate:

> “August. - But what the eyes see, they feel.
>
> Ev. -I would not say it at all, because, who sees the pain, which the eyes often feel? (...)
>
> August. - But if you see, you feel, if you feel there is reaction; there can be any reaction where you're not, but you see where I am, so, react where I am. But if where I am, you are not; I do not know how you dare to say that I am seeing by you.
> Ev. - By vision, I say, led to the place where you are, I see where you are; but I recognize that I am not there. Though, as if I touched you with a stick, I certainly would feel and touch you, yet, I would not be where I have touched you. So, because I say that I see with my sight, although, I'm not there, I still don’t have to admit that it is not me who is seeing you.
>
> August. - Then you don’t agree on anything rashly, because your eyes can also defend itself in this way: the view is like a stick of the eyes, as you say, and this conclusion is not absurd, or that your eyes can see where they are. Or, are you of another opinion?
>
> Ev. - In fact, this is how you're saying, because I realized now that if the eyes could see where they are, they would see themselves as well.
>
> (...)
> August. - (...) So, when the eye of the mind, which we call reason, are projected onto something, and they see it, it is called science; but when they don’t see it, although it directs the eye, it is called lack of science or ignorance” (Agostinho, 2008).

The advance of science is unquestionably fast and surprising every day. When the “eye of mind” is opened to reality many creations and inventions that make human life easier on the planet are noticed. Even in living systems and self-creating entities. According to Senge (1999) the prospect of living systems emerged from the sciences: quantum physics, ecology, mathematics of complexity and chaos theory. In these living systems the world is interconnected, pulsating and changing constantly, quick interactions relationships, and order emerges naturally from chaos without being controlled.

Many of these “wonders” created by the human knowledge became true from the science fiction, which were seen, initially, in the big movie screens. In this “dark cave” images of a not true reality are projected, but it may become reality in the material world. Any similarity established here with Plato’s Cave Myth, is not mere coincidence. In this perspective, Plato conceived that the image preceded the materiality. Contrary, the image was a mere shadow of the reality that was taking place behind the cave’s prisoners, between the great light and the angle of view of those prisoners in chains.

Drawing a parallel, it is conceived here the image as a material prediction of a reality conceived through the great light of the intellect, or St. Augustine’s words, the view of the mind and its real existence. The movie is the metaphor that better represents this conception. From the movie screen it is possible to recognize the materialization of St. Augustine’s discussion with Evodio about the eye. A look that goes further. Images, though often unreal, arouse all kinds of reactions, intellectual, emotional, imaginary. In the book A Educação do Olhar (The Education of the Eye) (Brazil, 1998), there is a quote showing that the body of symbols dominates the mass culture:

> By definition, the contemporary world is considered to be dominated by mass culture, that means there is a body of symbols, myths and images concerning to

> the practical and imaginary life, with a system of projections and specific identifications associated to the images and sounds, which we capture by the means of mass communication (Brasil, 1998, 165).

This image culture is always associated to the sight, the perceived human organ to such sensory input. This happens because of the creative evolution that also has been reproduced from the living systems pointed out by Senge (1999). The video camera represents this intelligible system that seeks to replace mechanically the human eye. It reproduces almost exactly the same images that the human eye is able to capture. Besides it, this "mechanical eye" has the capacity to record images that can later be reproduced with precision.

2.2 The Eye That Transforms

The vision of the human being has been transformed over the years and it changes the perception of one's reality.

> How many things men are not added to the seductions of view, with the range of gears and work with their hands, on clothes, shoes, vases and objects of all genres and also in painting and other reproductions, going beyond the need limits (Augustine, 1984, 288).

Apart from utilitarian reflection, it has been noticed that the human eye in the statement of Augustine (p. 354-430), through the seductions of the sight, was transformed and changed the reality. Such changes do not stop there. The human eye intrigues and instigates the human being; it invites one to look further, to seek meaning, to reconstruct the panorama of the sight. The Professional Engineering Review (2009) states that retinal implant activates electrodes to pass visual messages to brain via optic nerves. Researchers and engineers from the Massachusetts Institute of Technology are working on a retinal implant that could help blind people regain a useful level of vision. In this case, patients who received the implant would wear a pair of glasses with a camera that sends images to a microchip attached to the eyeball. This is an attempt to mechanical reproduction of the human organ to replace exactly the eye.

In this perspective Heung Cho et al. (2008) declares that the human eye is a remarkable imaging device, with many attractive design features. On a experience, the engineers try to reproduce all the characteristics of the human cornea:

> […] we introduce a means of producing curvilinear optoelectronics and electronic eye imagers that uses well-established electronic materials and planar processing approaches to create optoelectronic systems on flat, two dimensional surfaces in unusual designs that tolerate compression and stretching to large levels of strain (50 per cent or more). Conceptually this feature enables planar layouts to be geometrically transformed (that is conformably wrapped) to nearly arbitrary curvilinear shapes. […] we use a hemispherical, elastomeric transfer element to accomplish this transformation with an electrically interconnected array of single-crystalline silicon photodiodes and current-blocking p–n junction diodes assembled in a passive matrix layout. The resulting hemispherical focal plane arrays, when combined with imaging optics and hemispherical housings, yield electronic cameras that have overall sizes and shapes comparable to the human eye. Experimental demonstrations and theoretical analyses reveal the key aspects of the optics and mechanics of these systems (Heung Cho et al., 748, 2008).

A deeper analysis reveals that with the introduction of this "electronic eye" a society keeps on changing. The probable reason for this transformation is the people's behaviors that have their attitudes deeply and stately modified when facing the "mechanical eye". An external body reaction of a person, for example, is immediately changed upon receiving the focus of a camera lens. Likewise, the increasing intensification on the use of "electronic eyes" is transforming the social relations once established on another prism.

The first amended concept is the notion of religion. From a God who was able to see everything to a God-man who is able to see and record "everything" that interests to him. According to Marcondes Filho (2009) this is a process of virtualization and replication of the world where a world without people is created, but with biological clones and virtual images. In this society, the author continues, “the man relieving himself, all the society becoming “pure energy”, moving to its final solution, [...] the project Disappearance as a technical project of virtuality, would be the most radical achievement of the metaphysical desire (being God): it is not about the place, but it can see everything” (Marcondes Filho, 2009, 64).

Another transformation takes place in the field of the individuality. The relationships that once were person-to-person, now in the “virtual mechanical” time goes through the network and through the “virtual eye”. In this way, the human being presents itself more by the “electronic eye” than by the real mediations.

> Before the mediation electric-electronics, the public sphere constructed places and situations that facilitated the approaches of all kinds. [...] The transformation that occurs today is of the complete or nearly complete path from the personal relationship forms to those that are mediated by electronic systems. They are no longer talks, chats on the network. It is the development of therapeutic forms of aid and transposition to the screen of demarcation social rituals, like marriage, to the virtual world (marcondes Filho, 2009, 41).

As a consequence of individual exchange, the family also suffers from its impacts. Starting with residential structure that owns now reduced and individualized rooms, with technologies like computer, TV, DVD, etc. Such devices have direct influenced on the residents behavior. In this context, the family becomes the “fixed point of reference” once represented by the living space whose emotional ties were paramount.

This new dimension exerts influence in all relationships that the individual establishes with its surroundings. At school, at work, at the club, everything changes having as a trust orientation the relationship itself established by the individual with their virtual counterparts. This confidence decreases or increase as a person defines its own sincere relationship with and through the “electronic eyes”.

2.3 Changing the Way of Thinking

Mankind has been conditioned over the centuries, to look unilaterally. It is very hard to turn away from the laws of view accepted by Western culture and realize, even intellectually, that this is not the only method of seeing things. The optical result was the development from a linear perspective, which created a revolution in how people perceive the objects around them. As a consequence, it emerged the “vision”, usually represented by a lane bordered by trees or a symmetrical street. >From this vision came out the “vista”, the limiting of the view held by an object of interest, often a facade symmetric elaborately to a certain distance. All other views were, consciously or unconsciously, considered erroneous: “From this place is that one must look” (Tyrwhitt, in Carpenter and McLuhan, 1968, 115-116).

The “electronic eye” breaks up with the unilateral perspective of seeing and of perceiving reality, to open up to endless possibilities. From the paradigm “from this place is that one must look” it makes room for “the place where one is that one should look”. The electronic eye permits to see many places from a single point. Without leaving the place, and from all sites, the various eyes spread around the world can be accessed. The entrepreneur does not need to go to the company to see what is going there. Before leaving for the summer holidays, you can see the traffic situation of the roads. The surgeon’s eye can reach the tiny pieces of the human body which before they were not able to be seeing.

According to Cascio (2009) the emerging technology, called “Augmented Reality” – AR, enables users to see location-specific data superimposed over their surroundings.

> With AR applications such as Layar, the smart phone displays what its camera sees, with information about nearby buildings and shops, travel directions, even notes and “tags” left by other users in that location. Although AR now relies on handheld devices, electronics makers like Sony are working on systems that

> you wear like sunglasses, making augmented vision more immersive (Cascio, 2009, 34).

People's behavior forced by changing habits and attitudes to new technology leads to a paradigm shift. This leads to the transformation of mentality and thinking. Thinking makes the epistemology that serves as the basis for new creations and new compositions of humanity. This dynamo almost infinite casts new light on the bases of the individual and society to draw from them elements not seen before, but it now becomes possible through the “Augmented Reality”.

2.4 Electronic Eyes and Individuality

A simple stroll through the city streets, parks, forests, galleries, sidewalks and avenues could be considered trivial and eminently personal and individual, by the end of last century. Walking aimlessly, meet friends in these areas, enjoy the shop windows, shopping at the mall, at the supermarket or at the bakery, it was considered very ordinary, moments that should remain intact in the sphere of private life. Nowadays, take the same leisurely walk may expose the image of each individual to the aware and vigilant eyes of hundreds of cameras

> 7 million eyes ... It is the estimate of how many closed-circuit cameras watch public places in the world. The account does not include the private spaces. Only in England, the surveillance country champion, there are 4.2 million cameras. Every resident of London is caught at least 300 times a day for these artifacts (Rosa, 2006, 32)

The relationship between individuality, holy value to the civilized world, and technology, desired and in high development, leads the human being to live a paradox, where each step in the exercise of his individuality, less privacy he gets. Privacy is partly a form of self-possession – custody of the facts of one’s life, from strings of digits to tastes and preferences. This version of privacy considers everything we know about ourselves and wish to control but that the continuous capture of our digital existence makes increasingly uncontrollable (Mccreary, 2008).

George Orwell, in 1948, wrote the book entitled “1984”, which portrayed a world without privacy, where government authorities monitored the activities of citizens taking advantage of a vast technological apparatus. A secure world, where individuality has been conceded by an absolute power domain, a world without freedom, where the expression “Big Brother” has been emerged, which could see and know everything. The loss of privacy shapes society, allowing the government to exercise control over all aspects of individual lives.

People still may not be aware that the guarded and monitored society, observed by Orwell at that time, it is the same society which people live nowadays. According to the article, Learning to live with Big Brother (2009), that might occur because of electronic surveillance has not yet had a big impact on most people's lives, other than (usually) making it easier to deal with officialdom.

Electronic eyes installed in most places reveal the people’s behavior. Walking on the streets, people are under the focus of monitoring cameras, revealing their attitudes and gestures. The fact is that everybody is vulnerable to the electronic eyes increasingly sophisticated, disguised, tiny and imperceptible to most of citizens who pay less attention.

2.5 Electronic Eyes and Society

The desire to observe, without being noticed, has always been irresistible and wrong for not being ethical. But times have changed and in modern society, due to the advancement of violence and technology, the license to spy rose from obscurity and got the status of need. And so, little by little, people get used and feel safer when monitored by an electronic eye.

Monitoring systems by cameras have expanded significantly over the past twenty years, representing a change in the forms of social organization to the extent that these systems show two facets: surveillance and social control. On the one hand, these monitoring systems seek to reduce risks to the administration of the population (Botello, 2006).

People living within a society still did not realize they are more exposed than ever. On the streets, in a bank, at a party, in a restaurant, inside of a lift, a bus or a shop, the fact is that people are increasingly involved in a web of technology so widespread that they have not stopped to think that the most common habits of their daily lives are constantly captured by powerful and vigilant lenses.

A major benefit of the monitoring systems by cameras is the enhancement of police action, helping the city become a safer environment. However it can result in an abandonment of police from the streets and from the contact with people. Society, in general, needs the police presence to convey the feeling of a safe place. In addition, often the presence of cameras may increase the feeling of that the place is unsafe. Conversely, places that do not have this type of monitoring may transmit the sensation of being unsafe (Paoli, 2005).

The future of a society belongs to the electronic eye, vigilantes and alert 24 hours a day, able to catch everything, everyone, and record images that can be used by public authorities and it is a major breakthrough in combating the high crime rates as assaults, robberies, kidnappings and murders. This look can also create true living organisms, knowing better the impulses of buyers than the buyers themselves. The electronic eye transcends even smart cards or marketing databases. The buyer is captured in the act, at the click of the mouse, without even to notice a shop window.

Many U.S. companies have made large investments on new video technologies, surveillance systems to protect products and promote a safe working environment (Nieto, 1997). The fact is that the monitoring system by cameras has being increasing and its use is becoming standard rule of many organizations.

With the development of these new technologies, new questions arise: How many professionals complain about this compulsory exhibition? What implications would the use of these technologies have on a daily work of a professional? Do people want to work for a company that reportedly monitors its employees? And, going further, for what purpose do the hierarchical superiors use the information?

2.6 Social Capital "a New Look"

As individuals, people have two sources of personal competitive advantage: human capital and social capital. Human capital, which includes intellect, talent, charisma, and formal authority, is essential for success, but frequently beyond our direct control. Social capital, on the other hand, drives from people's relationships (Shih, 2009).

Many authors, including Bourdieu, Coleman e Putnam, define the concept of social capital. According to Bordieu (1977, 503) social capital is a capital of social relationships which provide, when necessary, useful supports: a capital of honorability and respectability which is usually indispensable if one desires to catch the attention of clients in socially important positions, and which may serve as currency, for example in a political career.

Putnam (1993, 169) has defined capital social as features of social organization, such as trust, norms, and networks, that can improve the efficiency of society by facilitating coordinated actions. According to Coleman (1994, 302) social capital is defined by its function. It is not a single entity, but an assortment of different entities having two similar characteristics: they both consist of some aspect of a social structure, and they also facilitate certain actions of individuals who are within the structure. Shih (2009) states that individuals with greater social capital close more deals, are better respected, and get higher-ranking job.

The concept of social capital has increased and now covers several areas of knowledge, "it has taken off like a bushfire in the social sciences, it has started to catch on in policy circles, and it has also flared up from time to time in the mass media" (Field, 2003, p.1). In this perspective, a "new look" on social capital may arise from the integration of technology tools that influence people's behavior and their relationships.

2.7 Relationship Between Electronic Eye and Social Capital

In her work "The Death and Life of Great American Cities", Jane Jacobs (1992) describes what makes streets safe or unsafe, what a neighborhood constitutes of, and what function it serves within the larger organism of the city, plus, why some neighborhoods remain impoverished while others regenerate themselves. The author describes an event that occurred in Manhattan when she observed a man trying to drag a youngster off the sidewalk and the girl contested. In the account of the author, eyes came from all sides, the windows of nearby buildings were opened, people came out of shops, grocery stores, bars, butcher shop, and the like, nobody would let that a little girl was spanked. The man who was dragging the girl off the sidewalk was her father.

This community eye is an expression of the social capital contained in a society. The eye of an individual is complemented by the extension of another individual, as members of this community that help each other. This look, in turn, is part of an informal agreement that occurs between individuals, firms and governments. Its development can result from the interaction between tradition, previous experiences, among others. Whenever the cooperative agents are not able to monitor the actions of each other, without the expenditure of effort, problems of particular interest arise.

It is understood that two or more agents work together when they are engaged in relationships with common purposes. The Dictionary of Social Thought (1996) states that in general, cooperation is present in most human endeavors, from market transactions to international relations, from industrial production to education, involving even competitive relationship.

When monitoring is difficult, it becomes necessary alternative solutions for this dimension of social capital, it comes into play the "electronic eyes". These eyes come in disguised form of technological monitoring cameras in businesses, buildings, parks, libraries, classrooms, airports, shopping malls, residences, and the like. However, this new look can change people's behavior, and may even introduce a new meaning to the concept of social capital.

2.8 Trust

Trust is a key pillar underpinning the concept of social capital. Trust exist when one part has confidence in an exchange partner's integrity and reliability, and it creates a general expectation by an individual, that one's word can be taken as true. In addition, trust increases commitment and loyalty to the relationship. Trust is central to all relational exchanges (Morgan; Hunt, 1994).
Trust in other people is quite different from trust institutions or political authorities. One could easy trust one's neighbor and distrust city hall, or vice versa (Putnam, 2000). Beugelsdijk (2009) points out two levels of trust: (i) micro and (ii) macro. These levels are used to analyze the concepts of trust and networks, and their measurement, and the acquired insights are used to offer avenues for future multilevel research of social capital.

Micro trust is defined as a property of individuals or as characteristic of interpersonal relationships (Beugelsdijk, 2009). People who trust others are all-round good citizens, and those more engaged in community life are both more trusting and more trustworthy. On the other hand, the civic disengaged believe themselves to be surrounded by miscreants and feel less constrained to be honest themselves (Putnam, 2000).

Broadly speaking, at the macro level, there are two streams of research in economics and management which study the sources and consequences of trust. Trust is studied at the aggregate level in relation to the economic success of nations or regions. A core element in these approaches is the concept of generalized reciprocity (Beugelsdijk, 2009). A society that relies on generalized reciprocity is more efficient than a distrustful society (Putnam, 2000), so trust exists and it reduces transaction costs, thereby promoting growth (BeugelSdijk, 2009).

3. METHODOLOGY

The exploratory study was the chosen method for this research which, according to Collis and Hussey (2003) aims to find patterns, ideas or hypotheses, rather than testing or confirming a hypothesis. Malhotra (1996) adds that the exploratory research is characterized by flexibility and versatility with respect to the methods.

The research approach was qualitative. This approach is widely used in the development of research in social, economic, marketing, communication, management, representing generally a way to ensure accurate results, thereby avoiding distortions of analysis and interpretations (Oliveira, 1999; Raupp and Beuren, 2003).

Semi-structured interviews were carried out as a technique for data collection which, according to Hair Jr. et al. (2005, 163), allows the interviewer to add questions related to the topic that were not previously imagined or were not originally included in the script, enabling the emergence of unexpected and enlightening information, thereby improving the findings. The open structure allows that unexpected events or attitudes can be easily explored (Aaker; Kumar; Day, 2004).

The content analysis has been chosen for the information analysis, in which words were classified into semantic categories (Bardin, 2004). According to Aaker, Kumar and Day (2004, 223) it is an objective systematic and quantitative description of the manifest content of a communication unit. This technique allows examining the frequency with the words and major themes occur, and it identifies the contents and characteristics of information existing in the text (Hair Jr. et al., 2005). The unit of analysis can be words, characters, themes, measures of time and space, or topics (Aaker, Kumar and Day, 2004).

4. DATA ANALYSIS AND RESULTS

From the interviews, it was considered four topics of analysis, industry, commerce, business services and city streets (downtown). Some illustrative passages from the interviews are presented with the most relevant information. The names of the researched companies and respondents are identified by using fictitious names within their segments.

4.1 Electronic Eye in the Industry

The research has shown that the main reasons for installing electronic cameras were: property security and valuables, theft of equipment, monitoring products, warehouse and finished goods control, vandalism, and even as a tool in solving problems relating to lack of communication within organizations.

Some of the benefits provided for the electronic eyes are pointed out as a security measure that allows the reduction of incidents an theft, they protect the company's assets from intrusion and theft as well as make a contribution to the customer satisfaction, as it states the security manager of one of the largest metal mechanic segment industries in Brazil, Kevin, "[...] since the final good is stored on the patio, in case of its components been stolen, it may delay the delivery of goods to the customer." Moreover, the dissatisfaction and discomfort of some employees were the main disadvantages highlighted.

Investigated on the agreement of the company's decision to implant the cameras, the respondents were unanimous in saying that they agree with such determination. Sharon, a coworker of one of the researched industries, says: "you cannot take care of a place 24 hours a day." It was observed that the employees' attitudes at the beginning of the cameras implementation process were distrust, resistance, uncertainty but in the long run, it became part of the regular work routine, "it seems to have nothing", says Kevin. On the other hand, some employees feel uncomfortable, "you know that you are being monitored, you know that, if they (the managers) see anything through the cameras, they come to talk to us," assures Sharon.

Trust, a major component of social capital (Putnam, 2000), when brought up in the survey, it was recognized as indifferent to the electronic eyes. According to the respondents, these eyes do not interfere in the formation of trust between people within the organization. The employee Mathew says "trust we must have on people, with or without camera [...], the trust of a colleague comes from being together". For Kevin, there is a growth of trust in the teamwork provided by the security of the monitoring system. May this "security" be called trust? According to (Putman, 2000), trust is established among people. Can anyone trust an electronic device the same way they would trust another person?

Kevin says that the cameras do not interfere in the productivity, however, in a unit of the same company he works for, based in a country where terrorism makes many victims, the monitoring system positively affects the outcome of the work, because the employees feel safer and protected from terrorism.

The research examined whether the electronic eyes could replace the human eye. According to respondents, they do not replace it. The machine is cold and does not provide the human contact. In Sharon's words, "nothing replaces the person" and in Kevin's expression, "people make the difference, plus the managers' relationship with the employees make all the difference". Besides not replacing the human eye, the electronic eyes are not decisive for building consistent relationships.

4.2 Electronic Eye in the Commerce

The survey results show that car theft and the monitoring of events in traffic were the main reasons, according to the traders, for fixing electronic cameras on the streets. According to them, the control of traffic flow helps to prevent probable accidents and the pedestrian safety when crossing the streets are the major benefits of this "eye". Traders do not pose any disadvantage to using such equipment.

Owners of shops, bookstores and other commercial establishments assume that most of the time people do not realize that there are cameras fixed downtown, and even those who notice such a presence, do not exhibit any different behavior or inhibit themselves because of this fact. "The electronic eye is something that has become normal, ordinary" states Mary Elen, who owns a clothing shop, located downtown.

Most of the respondents believe there is no link between the use of electronic cameras and trust, as Paul points out "where trust does not exist, it is not equipment that will solve it." Furthermore, they state that these electronic devices, in spite of their perfection, they are not able to replace the human eye.

4.3 Electronic Eye in Public Places

The research results identify the mutual disrespect between pedestrians and drivers when crossing the streets, plus, crowded places such as malls, city bus terminals, airports, and shoplifting were the main reasons for the implementation of this electronic eye in public places. For Antony, an owner of a shoes shop, "the cameras were installed in the main city streets especially because of the lack of policing". Christian, one of the Shopkeepers City Chamber (CDL) directors declares:

> It was through an authorities of trade request (CDL, Sindilojas and Sindigêneros), demanding the military brigade and the municipal government, to provide a more efficient condition to those responsible for policing, using more modern techniques, such as a monitoring system. And since the state did not provide money, the system started from the trade entities and the local community (Chistian, 2010).

He adds that statistics available by the city Military Brigade were observed for placing the cameras. "After installing the monitoring system by cameras, there was a 70 per cent reduction on the crimes occurred in the city".

The main benefits mentioned by the implementation of the cameras are: the crime and vandalism control in the city's businesses and properties, the traffic control, and the police investigations. Antony says that "the main advantage of the monitoring system is the increase of prevention. Crime prevention reduces the incidence of transgression, police anticipates the criminal fact and inhibits the action of the delinquents, and it also decreases the level of violence downtown".

The main highlighted disadvantage by the respondents in using such equipment was the fact that too much confidence on the camera system can reduce the effective proper policing on the streets, in addition, often human and technical failures occur on the monitoring which forbids the system to observe the latest occurred facts.

The agreement to use the system was cited as indifferent by the respondents, that because people do not know or do not realize the cameras. Those questioned said that the presence of this eye does not influence people attitude, because they continue behaving as they always behaved. Although, when people know they are being filmed, they behave themselves better, acting seriously, and sometimes they feel embarrassed and shy, because they know that any carelessness can be considered something serious.

When addressing the issue of trust the opinions diverge. A portion of respondents consider that there is no trust in public places and these equipments do not provide it. On the other hand, some respondents believe that people become more confident, once the cameras provide a safer city. Anthony states that the system can increase confidence and "through a system of monitoring only one man can handle 20 times more an environment, so there is an increase in productivity."

The researched people do not consider the possibility of the electronic eye replace the human eye. Ms. Marie, who works as a doughnut vendor, for more than 10 years on the same street site, refers to violence like this: "it is different here when there is a policeman". Antony, declares that the "electronic eyes extend the condition of the human eye and it has a multiplier effect. The electronic eye records everything while the human eye just watches it".

4.4 Electronic Eye in the Service Companies

The safety of both, employees and customers, was the main reason pointed out by service companies for the installation of electronic cameras. In some researched companies, the camera-monitoring system is already considered standard for safety reasons.

Better security for employees and customers, security for the internal and external aspects of organizations and the reduction of frauds, were observed as major benefits of electronic eye into companies. According to Michael, service manager of a credit union, "there are no disadvantages on the installation of cameras, because it will only feel embarrassed people who want to do something wrong." On a personal side it can be sustained, but when it extends to the group, in certain situations, what is right and what is wrong? Who defines it? For a company, for example, on the factory floor, is it wrong to talk to the co-worker? When it comes to society as a whole, it approaches to the concept of Gesellschaft (Weber, 1947) but, what happens when it comes to a small ruling group, the direction of a large company, for example? No intention to enter deeply into the subject that involves the notion of right and wrong, it is relevant to mention that it has the conceptual principle of "right action", in modern ethics, more closely related to a conception of law. Such action has as its study the theory of duty, which is divided into two parts: systematic exposition of moral code that defines the obligations of citizens, and their justification. The first one presents comprehensive formulations about the fundamental principles of right and wrong and it shows how they produce all moral duties. The second one establishes the principles' authority; consequently, it validates the code. The moral philosophy of Kant (1724-1804) with the categorical imperative: "Act in such way that the maxim of your action can become a principle of universal legislation", it represents the effort by the theory on a single and general moral obligation (Reale; Antiseri, 1990).

Requested about the agreement on the company's decision of implanting monitoring cameras, the respondents believe that these cameras are important for security, work and investigation of fraud and theft. Thus, according to Rose, a bank manager, “[...] in case of fraud or suspicious attitudes, when people deny something, the cameras can help to obtain evidences, and thus to make the disclosure to the other units”.

When the respondents were asked about the relationship of trust and electronic eye, they indicated that, as the cameras have already been part of everyone day-to-day life; both employees and customers declare that there is a growth of trust. Michael complements “[...] the electronic eye can facilitate any investigation”.

The respondents believe that there is a positive influence related to the use of cameras and the result of the work, once the work becomes more productive and the employees work safer. Some companies measure the result of their work by the attitude of their employees, according to Rose “[...] through the cameras we can observe if the service employee is being productive and if customers are being well served”.

Finally, in order to investigate whether the electronic eye replaces the human eye, the result is unanimity, they all believe the human eye is irreplaceable. “The electronic eye does not replace the human eye, it only complements the human eyes, and it is a support used by man”, states Michael.

4.5 Comparison of the Results With literature Review

Electronic Eyes – literature review					
To transform	**To think**	**Individualty**	**Society**	**Social Capital**	**Trust**
Arts, working, object, necessity (AGOSTINHO, 1984). Reproduction of the cornea (HEUNG CHO et al., 2008). Reality virtualization, the notion of God - duplication of reality (MARCONDES FILHO, 2009). Relation person to person, person to network (MARCONDES FILHO, 2009). Family	Sided view (TYRWHITT, 1968). Endless Possibilities. Augmented Reality (CASCIO, 2009).	Private life x eyes of the cameras (ROSA, 2006). Self-possession X continuous capture digital (MCCREARY, 2008). Governments control (ORWELL, 1948).	Obscurity X necessity. Surveillance and social control (BOTELLO, 2006). Security (PAOLI, 2005). Prevention (NIETO, 1997). Social Control (ORWELL, 1948).	Transactions of personal relationships (Shih, 2009). Honor and respectability (BOURDIEU, 197 7). Confidence, norms and coordinated networks (PUTNAM, 1993). Function, action on the structure (COLEMAN, 1994). Social sciences, political circles, mass media (FIELD, 2003).	Community eye (JACOBS, 1992). Cooperation (DPS, 1996). Alternative: Electronic eye? People x Institutions (PUTNAM, 2000). Relational exchanges (MORGAN; HUNT, 1994). Individual ownership and interpersonal relationship (BEUGELSDIJK, 2009). Micro/macro (BEUGELSDIJK, 2009).
Comparison of results					
Industry. Commerce. Services companies. City streets. Communications. Reduction of	Unanimity installation. Prevention. Police investigations . Productivity.	Vandalism. Discomfort, privacy. Perception. Inhibits infraction.	Security. Customer satisfaction. Warehouse control. Traffic control. Prevention.	Resistance at first, routine. Robberies, thefts, frauds. Control of city property. Too much	Indifference among people. Feeling of security in the system. It does not replace human. Police reduction.

crimes. Behavior while being filmed.			Police disability.	confidence in the system when people deny something	Suspicious attitudes.

TABLE 1: Results X literature review

5. FINAL CONSIDERATIONS

From the results of this study it is worth to point out the transformation that the electronic eye plays on the individual, on the social relations and on the concept of social capital. The individual modifies its behavior from the sense of safety or discomfort caused by the mechanic eye. Afterward, the relationships between people change the way of social organization resulting from the difference in the trust level among them.

It has been observed that the trust, as part of social capital, differs across all surveyed sectors. In the industry, there is no consensus between the vision of management and staff. On one hand, it is observed that the managers consider existing an increasing of the trust level, because of the security provided by the equipments, on the other hand, it has been observed that the equipment does not interfere on trust relationship among the employees; trust exists or not, with or without the cameras presence. In this sense, the concept of trust means that a machine does not supply the other part of the human element necessary for the formation of social capital.

The commerce and services differ in opinions about trust. For the first sector there is no direct relationship between trust and the presence of cameras, because the equipment does not supply the level of trust existing among people. For the service sector, however, there is a plus in this relation since the electronic eye enables the verification of events occurring in business between individuals. The same contradiction observed in the commerce and services is repeated in public places.

The research revealed security as a determinant to the decision of implementing a monitoring system by cameras. The feeling of security interferes on the attitudes of human beings. The transformation that the electronic eye performs on a person's life pushes his way of seeing the reality. When placing a system of cameras people desire to complement their eye, and even to overcome the deficiencies of the human eye.

However, keeping in mind that the social relations among people within a community, whether or not influenced by the electronic eye, though this eye does not replace the human one, they are components of the social capital concept. For that reason this paper arises a question: Does the electronic eye modify the level of social capital in a community?

6. RESEARCH LIMITATIONS AND FUTURE STUDIES

Because of its exploratory nature, this research has some limitations such as: lack of literature that relates the relationship between electronic eyes and social capital; and the sample could be extended to other fields of society.

The researchers have as futures purposes to analyze the relationship between electronic eyes and employees' productivity. The perceptible people indifference related to the cameras over the time, and its consequences for the social capital.

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