MIMO with Constant Envelope Modulation (CEM) - For Better Circuit Design

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Abstract - **The wireless communication networks are expected to handle higher data rates capacity with flexible spectra allocation i.e., optimum usage of available frequency bands and also with minimum power utilization. In this process various wireless standards evolved *viz.,* 2G,3G & 4G,etc. The Multiple Input Multiple Output (MIMO) wireless communication systems, one of the promising technology, increased the spectral efficiency and exploited the power utilization. MIMO increases throughput reliability and coverage without increasing power and bandwidth. In this paper the system of MIMO, with its limitations are presented. The MIMO with OFDM has a few disadvantages which are overcome by Constant Envelope Modulation method for improving power utilization optimally is also presented.**

Index Terms - **BER, Constant Envelope Modulation, MIMO, Rayleigh Distribution.**

I. INTRODUCTION

We have Wireless Communication Standards *viz*., 2G, 3G & 4G. In 2G we have GSM, CDMA, GPRS & EDGE Technologies. In 3G we have WCDMA/UMTS, CDMA2000, HSDPA/HSUDPA & 1xEVDO technologies. In 4G we have LTE & WiMAX technologies. The evolution developed from using 10s of Kbps to 100s of Mbps. The major criterion for development of Wireless Communication system are (i) utilization of available bands of frequencies width and (ii) minimum power utilization.

Manuscript received Feb, 2014.
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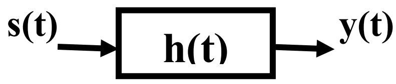
The wired communication has the advantage of utilizing maximum power and all the available band of frequencies.

But the physical limitation plays the major role for optimum utilization. This physical limitation is surpassed in wireless communication system. The efficiency is further increased by multipath propagation. The performance of wireless system is easily understood by the parameter Bit Error Rate, BER.

The wireless propagation environment is modeled as



where s(t) is the input to the wireless channel, h(t) is the impulse response of the wireless channel and y(t) is the input to the receiver in wireless environment.

The wireless signal is modeled by

a. The input as

$$\mathbf{s(t) = Re\,\{S_b(t)e^{j2\pi f_c t}\}} \qquad \ldots(1)$$

where $S_b(t)$ is the baseband or passband representation.

b.The channel as

$$\mathbf{h(t)} = \sum_{i=0}^{L-1} a_i\, \delta(t-\tau_i) \qquad \ldots(2)$$

as fading coefficient with L multiple paths in wireless environment, a_i as attenuation factor of the i^{th} path.

The net signal thus obtained is by convolution

$$\mathbf{y(t) = s(t) * h(t)} \qquad \ldots(3)$$

$$\mathbf{y(t)}=\mathrm{Re}\{\sum_{i=0}^{L-1} a_i\, S_b\,(t-\tau_i)e^{j2\pi f_c(t-\tau_i)}\} \qquad \ldots(4)$$

with $t-\tau_i$ is the delay in i^{th} path.

Thus it is challenging to provide Quality of Service(QoS) over multipath fading channels in presence of noise.The term Fading is defined as the variation in signal power at the receiver. When no power is received at the receiver then its Deep Fading.

We can better adjudge a wireless system if we have a better understanding of the fading coefficient h(t).

II. DEFINITIONS

A. RAYLEIGH MODEL

The Rayleigh model distribution of the attenuation factor 'a' is given by

$$\mathbf{2ae^{-a^2}} \quad \text{for } 0 \le a \le \infty \qquad \ldots(5)$$

and the phase is

$$\frac{1}{2\pi} \qquad \text{for } -\pi \le \phi \le \pi \qquad \ldots(6)$$

B. BIT ERROR RATE (BER)

BER is the probability of the rate at which the bits are received in error. The BER of a wireless channel is

$$\mathbf{Q}\left(\sqrt{\mathbf{a^2}\,\frac{\mathbf{P}}{\sigma_n^2}}\right) \qquad \ldots(7)$$

where 'a' is Rayleigh distributed magnitude and 'P' is power of the signal and 'σ_n^2' is noise power.[1]

The average BER in Rayleigh fading channels decreases with increased Signal to Noise Ratio power.[2]

C SIGNAL TO NOISE RATIO (SNR)

The received SNR of a wireless communication system is $\mathbf{a^2}\,\frac{\mathbf{P}}{\sigma_n^2}$

The relation between BER and SNR of wireless channel is

$$\mathbf{BER} = \frac{1}{2}\left(\mathbf{1} - \sqrt{\frac{\mathbf{SNR}}{\mathbf{2+SNR}}}\right) \qquad \ldots(8)$$

At high SNR, BER $\approx 1 / 2$SNR.

This indicates that the SNR power is to be increased to achieve a very low BER. In this condition the received power by the receiver is less than noise power and is the deep fade event.

Hence the limitation of 'increasing power' for better communication, is an undesirable case in the wireless communication system.

III. DIVERSITY

The performance of wireless system can be improved by Diversity in which there are number of diverse links between transmitter and the receiver. The diversity establishes link between the transmitter and the receiver in noisy environment i.e., incase of deep fade event.

To obtain low BER with minimal power a diversity technique of multiple antenna system leading to MIMO is used.

In this multiple antenna system, we rely on spatial diversity techniques for reliability and range in wireless systems. This reliability is achieved by sending or receiving independent multiple copies of information in parallel along different spatial paths between the transmitter and receiver.

A. SPATIAL DIVERSITY

In spatial diversity, the antennas are kept sufficiently apart. For independent channels across receiving antennas the spacing required is half-wavelength ($\lambda/2$) of the carrier frequency. [3]

For example lets consider the 4G system with carrier frequency f_c = 2.3 GHz the λ=13.04 cm and the distance required between multiple antennas is 6.5 cm.

The spatial diversity is measured in diversity order'd'. The diversity order is given by

$$\boldsymbol{d} = -\lim_{SNR \to \infty} \frac{\log P_e(SNR)}{\log SNR} \qquad \ldots(9)$$

with P_e(SNR) is BER.

The system model for multiple antenna system is

$$\bar{\boldsymbol{y}} = \bar{\boldsymbol{h}}\boldsymbol{x} + \bar{\boldsymbol{n}} \qquad \ldots(10)$$

where $\bar{y} = [\ y_1\ \ y_2\ \ y_3\ \ldots\ldots\ \ y_L]^T$ is receive vector,

$\bar{h} = [\ h_1\ h_2\ h_3\ \ldots\ldots\ h_L]^T$ is fading coefficient vector &

$\bar{n} = [\ n_1\ \ n_2\ \ n_3\ \ldots\ldots\ \ n_L]^T$ is noise vector and the suffixes 1 to L stand for respective transmitter and receiver antenna.

IV.MULTIPLE INPUT MULTIPLE OUTPUT (MIMO)

The MIMO model by equation (10) is

$$\begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ . \\ . \\ y_r \end{bmatrix} = \begin{bmatrix} h_{11} & \cdots & h_{1t} \\ \vdots & \ddots & \vdots \\ h_{r1} & \cdots & h_{rt} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ . \\ . \\ x_r \end{bmatrix} + \begin{bmatrix} n_1 \\ n_2 \\ n_3 \\ . \\ . \\ n_r \end{bmatrix}$$

where 't' subscript stands for transmitter antenna number and 'r' stands for receiver antenna number.

The MIMO is a promising technology providing increased throughput, extended range and improved reliability.[2]

V.CONSTANT ENVELOPE RECEIVER (CEM)

The CEM comprises of Phase Modulated signal at the transmitter. This improves the power efficiency of a power amplifier as the amplitude is constant in PM signal and the signal can be converted into frequency domain.

In general dynamic transfer characteristic is not a straight line. Nonlinearity arises as static output characteristics are not equidistant straight lines for constant input increments. Distortion of this type is nonlinear or amplitude distortion. The different types of power amplifiers are Class A, Class B, Class AB and Class c. The conversion efficiency is a measure of the ability of an active device to convert the dc power of the supply into ac signal power delivered to the load. This is also known as collector circuit efficiency.

$$\eta \equiv \frac{signal\ \ power\ \ delivered\ \ to\ load}{dc\ power\ \ supplied\ \ to\ output\ \ circuit} \times 100$$

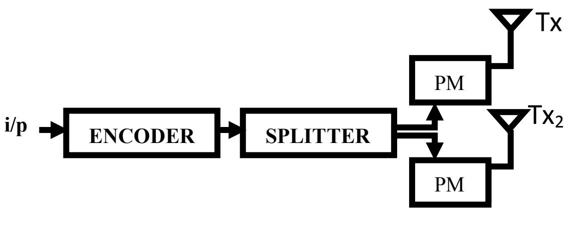
For Class A power amplifier, η = 25 % which is a poor choice for power amplification. For Class B push-pull power amplifier η = 78.5%. But Class C power amplifier is useful since one can operate at the transistor's peak current rating. When FM signal or any signal in which the information is not contained in amplitude, is to be amplified, linear amplifier such as Class C is good choice.[4] Now the power amplifier stage can be designed for improved linearity and power efficiency. At the receiver, CEM power consumption is greatly reduced and is simple circuit without the need for Automatic Gain Control (AGC). Hence the CEM can be extended for MIMO.

The OFDM in MIMO has the disadvantages of exhibiting noise like statistics with high PAPR, consumption of high power at RF and ADC(Analog to Digital Convertor) stages and linear power inefficient power amplifier stage.

A. MIMO-CEM

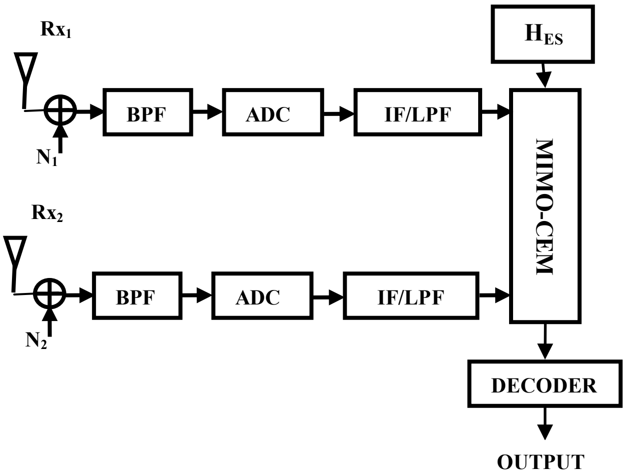
To overcome the disadvantages of OFDM-MIMO transceiver, MIMO-CEM transceiver can be used.

The Transmitter diagram is



It is allowed to use nonlinear Power Amplifier at the transmitter to reduce spurious transmissions.

The Receiver diagram is



In the transmitter binary data is encoded by encoder to enhance BER. Then this encoded data is split into the number equal to multiple transmitting antennas, two in our example. CEM PM modulator results in constant envelope of the encoded signal.

At the receiver, the received signal(Rx_1 or Rx_2) is Rayleigh Fading multipath signal with Noise added (N_1 or N_2). The Band Pass Filter (BPF), increases SNR for IF band. The analog data is converted into digital format by ADC. The LPF stage can be a Hard Limiter or Signum function.

The received signal after LPF can be expressed as

$$\mathbf{y} = \mathbf{f}\left(\sum_{\mathbf{i=1}}^{\mathbf{Tx_t}} \mathbf{H}\,\mathbf{x_i} + \mathbf{N_i}\right) \qquad \ldots(11)$$

Where $\mathbf{Tx_t}$ is number of transmitting antennas, which can be derived from equation 10. The **H** is the Channel estimation matrix.[5]

VI. CONCLUSION

In this paper the case of Wireless Communication system is presented in comparison with Wired Channel leading to diversity models to Multiple Input Multiple Output (MIMO). The method of Constant Envelope Modulation is also presented as an efficient method for improving performance of MIMO systems. Further there are numerous dynamic methods for increasing performance of MIMO systems.

The presented system can be modified by decision directed channel tracking method, adaptive channel estimation, pilot assisted linear interpolation method and various power allocation methods for improving MIMO performance.

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