Multiple Antenna Techniques

MIMO systems :-

(Multiple Input Multiple Output)

MIMO means both transmitter and receiver have multiple antennas.

→ It uses multiple inputs & multiple outputs from a single channel.

→ MIMO is defined by Spatial Diversity & Spatial Multiplexing.

By using MIMO :-

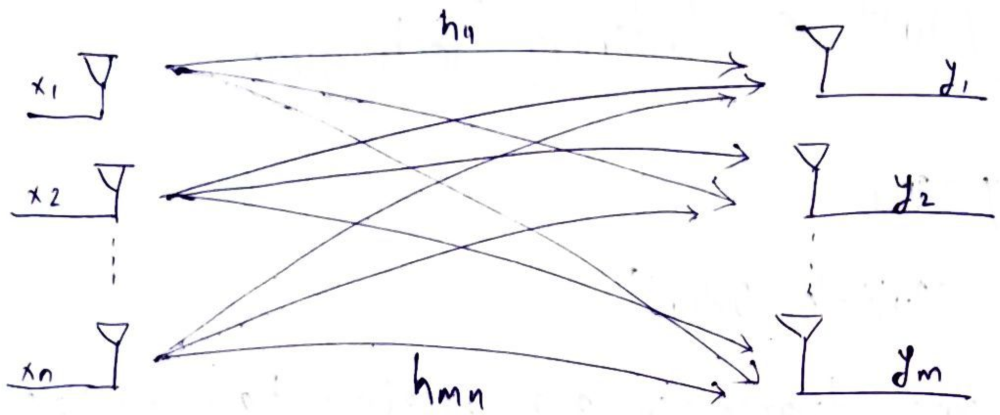
- Diversity gain mitigates the fading & increases coverage & improves QoS.
- Multiplexing gain increases capacity & spectral efficiency with no additional power or bandwidth expenditure.
- Spatial Diversity & Spatial Multiplexing can be conflicting goals

Spatial Diversity :-

- Signal copies are transferred from multiple antennas or received at more than one antenna.
- redundancy is provided by employing an array of elements, with a minimum separation of $\lambda/2$ b/w neighbouring antennas.

Spatial Multiplexing :-

- the system is able to carry more than one data stream over one frequency, simultaneously.



$$\begin{bmatrix} y_1 \\ \vdots \\ y_m \end{bmatrix} = \begin{bmatrix} h_{11} & \cdots & h_{1n} \\ \vdots & & \\ h_{m1} & \cdots & h_{mn} \end{bmatrix} \begin{bmatrix} x_1 \\ \vdots \\ x_n \end{bmatrix} + \begin{bmatrix} N_1 \\ \vdots \\ N_m \end{bmatrix}$$

or simply as

$$y = Hx + N$$

Channel matrix H consists of zero mean complex circular Gaussian random variables. So power spectral density of channel noise is calculated by $\sigma^2 I_m$.

$$\sigma^2 = E|n_i^2| = \frac{N_0}{2}$$

$$\frac{P}{\sigma^2} = \rho$$

$$\sum_{i=1}^{n} E|x_i x_i^*| = P$$

$$T_r(R_x) = \rho$$

$$R_x = E[x x^*]$$

Important parameters in MIMO system:-

CSIT - Channel Side Information at Transmitter

CSIR - Channel Side Information at Receiver

The CSI describes how a signal propagates from transmitter to the receiver & represents the combined effect at, for example, scattering, fading & power delay with distance etc..

Capacity of a MIMO system over fading channel

Shannon coding theorem proved that, high data rate close to capacity with less BER

$$C = B\log_2\left(1 + \frac{P}{N_0 B}\right)$$

→ Shannon capacity of a MIMO channel, which equals the maximum data rate that can be transmitted over the channel will arbitrary small error probability.

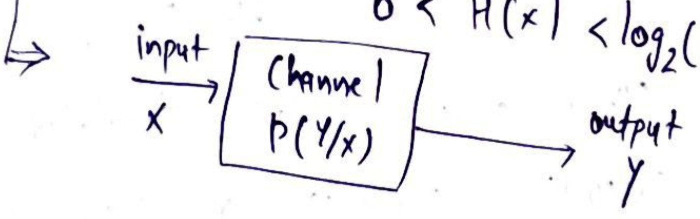
$$C = B\log_2(1 + \gamma)$$

Entropy (The average amount of information per symbol is called Entropy)

$$I(X:Y) = H(Y) - H(Y/X)$$

$$H(x) = -\sum_{x \in X} p(x)\log_2 p(x)$$

$$0 \leq H(x) < \log_2(N)$$



$$C = \max_{p(x)} I(X;Y)$$

The information capacity C is obtained by maximizing this mutual information taken over all possible input distribution p(x).

MIMO Flat fading Channel Model :-

$$y = Hx + n$$

where y = Received response from channel - dimension $(N_r \times 1)$

H = Complex channel matrix of dimension

x = Vector representing transmitted signal - dimension $(N_t \times 1)$

N_t = No of transmit antennas

N_r = No. of receive antennas

n = Complex baseband

$$C = \log_2\left[\det\left[I_{N_t} + \frac{1}{\sigma_n^2} H K_x H^H\right]\right]$$

→ Two types of capacity possible in flat fading MIMO systems are :

⇒ Ergodic [Shannon Capacity] ⇒ statistical average of mutual information, where the expectation is taken over H

$$C = E\left[\log_2\left[\det\left[I_{N_t} + \frac{1}{\sigma_n^2} H K_x H^H\right]\right]\right]$$

⇒ Outage Capacity :- Defined as information rate below which the instantaneous mutual information falls below a prescribed value of probability expressed as percentage - q

$$P\left(E\left(\left[\log_2\left[\det\left[I_{N_t} + \frac{1}{\sigma_n^2} H K_x H^H\right]\right]\right]\right) < C_{out, q\%} = q\%\right.$$

Beam Forming ⇒

Precoding is a generalization of beamforming to support multi-stream transmission in multi-antenna wireless communications.

A transmit strategy where the input covariance matrix has unit rank is called beamforming.

→ In beamforming method, same symbol weighted by a complex scale factor is sending over each transmit antenna so that input covariance matrix has unit rank.

→ Beamforming is the combination of radio signals from a set of small non-directional antennas in order to simulate a large directional antenna. Aligning the transmit signal in direction of transmit antenna array pattern is called transmit Beamforming.

→ Wireless InSite currently supports two methods for beamforming:

- Maximum Ratio Transmission (MRT): maximizies the beam b/w T_x & R_x points
- Precoding Tables: Allows a user to define tabulated beams, supporting a number of approaches that allow for selection from predefined beams.

$$\bar{Y} = U^H H x + U^H n$$

$\bar{x}_t$ - Input, $\bar{y}_t$ - Output, $\bar{n}_t$ - Noise, $\bar{\sigma}_i$ - Channel gain & $\bar{y}_i$ - Weight

$$\sigma_i = \sigma_{max}$$

$$SNR = Y = \sigma_{max}^2 \rho \Rightarrow C = B \log_2 (1 + \sigma_{max}^2 \rho)$$

Spatial Multiplexing ⇒

It defines the system is able to carry more than one data stream over one frequency, simultaneously.

Spatial multiplexing needs MIMO antenna configuration. A signal placed at high rate splits into lower rate streams in multiples & each stream is transferred from different transmitting antennas in a similar frequency channel.

→ In case for MIMO spatial multiplexing the no. of receive antennas must be equal to or greater than the number of transmit antennas.

$$r_1 = h_{11} t_1 + h_{21} t_2 + h_{31} t_3$$
$$r_2 = h_{12} t_1 + h_{22} t_2 + h_{32} t_3$$
$$r_3 = h_{13} t_1 + h_{23} t_2 + h_{33} t_3$$

where r_1 is a signal received at antenna 1 . . . .

$$[R] = [H] \times [T]$$

Spatial Diversity ⇒

Techniques :-

- Signal copies are transfered from multiple antennas or received at more than one antenna.
- Redundancy is provided by employing an array of antennas with a minimum separation of $\lambda/2$ between neighbouring antennas.

- It has goal of decreasing error rates compared to single - antennas stream.

Receive Diversity :- One transmitting antenna & many receiving antennas are used. Here the desired message is transmitted by using single transmitting antenna & received by multiple antennas.

N_r different antennas approximately separated are deployed at the receiver to combine the uncorrelated fading signals. It is also called space diversity.

Types of Space Diversity :-

1. Selection Diversity
2. feedback diversity
3. Maximum Ratio Combining
4. Equal Gain Diversity

Transmit Diversity : Multiple antenna elements are required at the transmitter & one antenna element at the receiver & provide better performance.

Types of transmit Diversity:

1. Transmitter Diversity with Channel State Information (Closed loop Transmit Diversity)
2. Transmitter Diversity without Channel State Information (Open loop Transmit Diversity)

Thank you

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