Applied Optimization for Wireless, Machine Learning, Big Data
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Lecture - 50
Practical Application: Multiple Input Multiple Output (MIMO) Beamforming

***Keywords**: MIMO Beamforming*

Hello, welcome to another module in this massive open online course. So we are looking at various convex optimization problems and especially focusing on their practical applications. In this module, let us look at beamforming in MIMO systems.

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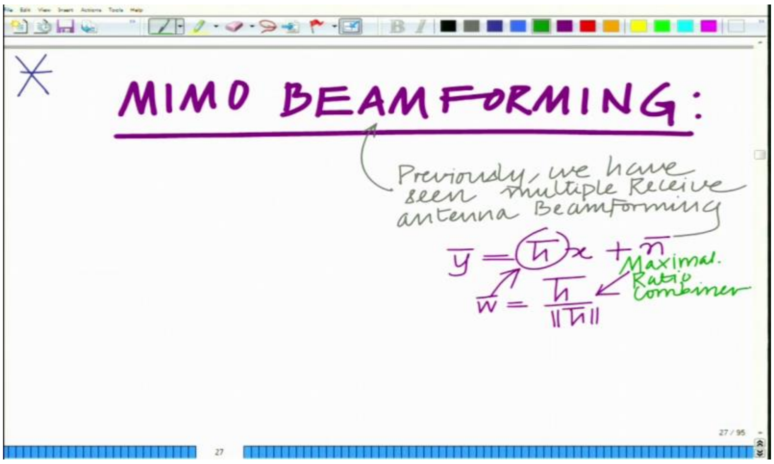

So previously we have seen a system modelled as $\bar{y} = \bar{h}x + \bar{n}$. The beamformer for this system is given by $\bar{w} = \frac{\bar{h}}{\left\|\bar{h}\right\|}$ and this is termed as the MRC or the maximal ratio combiner. Now, we want to extend this to a MIMO system which has not just multiple receiver antennas, but also multiple transmitter antennas. So that is why it is known as the MIMO system or the multiple input multiple output system.

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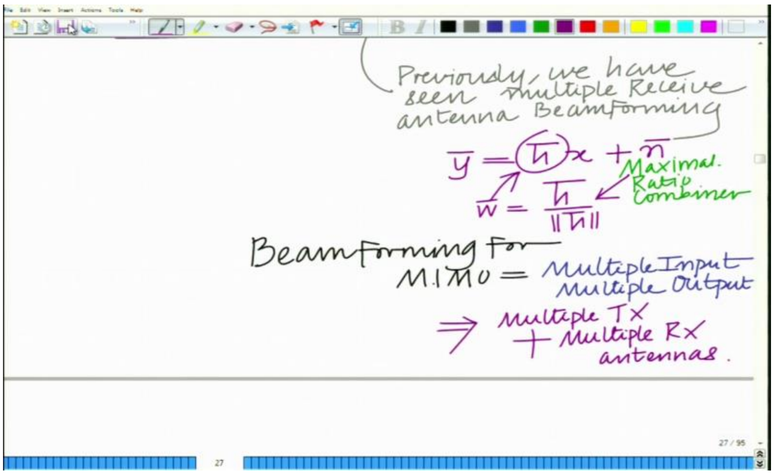

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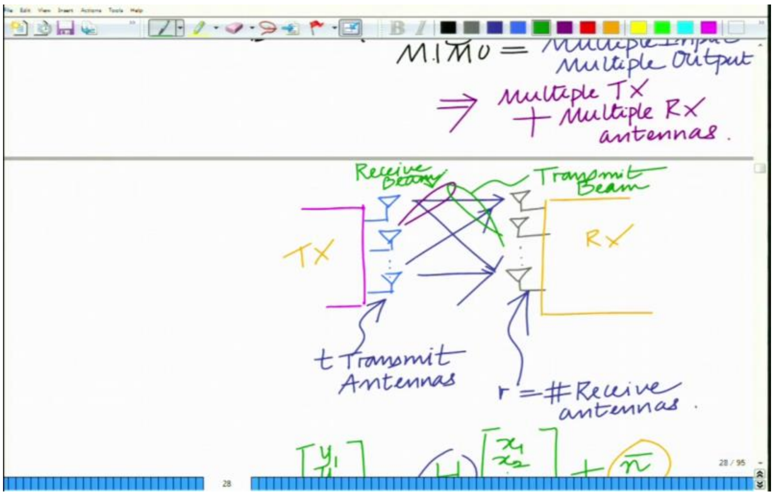

Now let there be t antennas at the transmitter and r antennas at the receiver.

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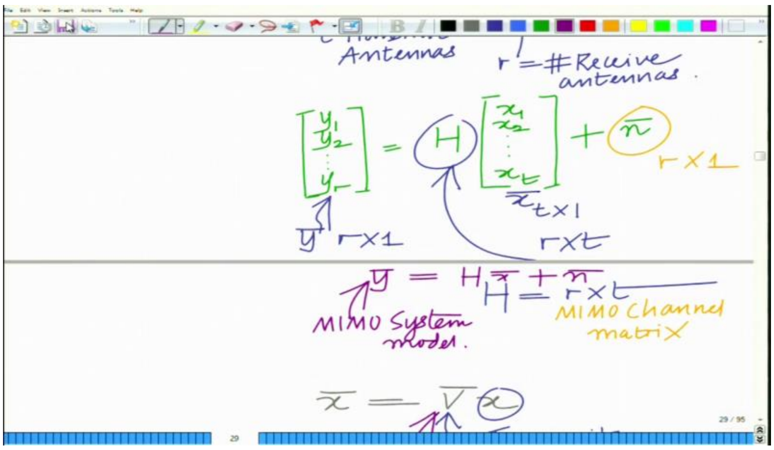

The system model can be represented as shown in slide, so we have $\bar{y} = H\bar{x} + \bar{n}$ where $\bar{y}$ is the $r \times 1$ received vector of symbols y_1, y_2 up to y_r, H is the $r \times t$ channel matrix, $\bar{x}$ is the $t \times 1$ transmit vector of symbols x_1, x_2 up to x_t and $\bar{n}$ is the $r \times 1$ noise vector. Now beamforming means transmitting in a particular direction, that is focusing the transmit power in the particular direction and receive beamforming means looking in a particular direction to receive the maximum amount of energy. So you have a transmit beam that is you are focusing the energy in the particular direction and you are have a received beam that is you are looking for the signal that is you are receiving the signal in a particular direction. In multiple antenna beam forming you are maximizing the signal to noise power ratio and by using only a particular direction, you can avoid the interference which is caused by the interfering users.

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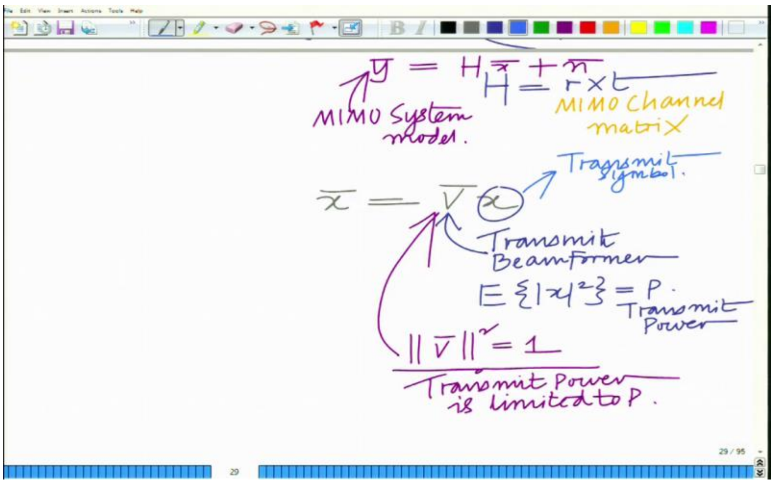

So let us say we want to transmit the vector $\bar{x}$, so we want to use a beamforming vector $\bar{v}$. And since you are doing this at the transmitter, this is also known as the transmit beamformer. So we have $\bar{x} = \bar{v}x$ where x is the transmitted symbol which is transmitted with the aid of this transmit beamformer. We can have the transmit power P and the beamformer simply focuses the signal, therefore it should not amplify or attenuate the signal. So we will fix the power of the beamformer that is $\|\bar{v}\|^2 = 1$. So this imposes a transmit power constraint. So we have this system model as $\bar{y} = H\bar{x} + \bar{n}$ and this is the MIMO system model.

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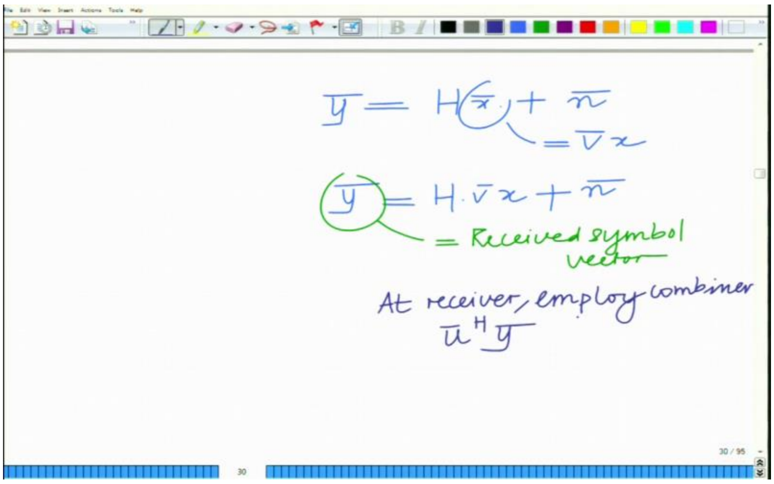

Now this $\bar{y} = H\bar{v}x + \bar{n}$, is the received symbol vector. At the receiver we employ a combiner which is of the form $\bar{u}^H\bar{y}$ and this is basically the receive beamformer.

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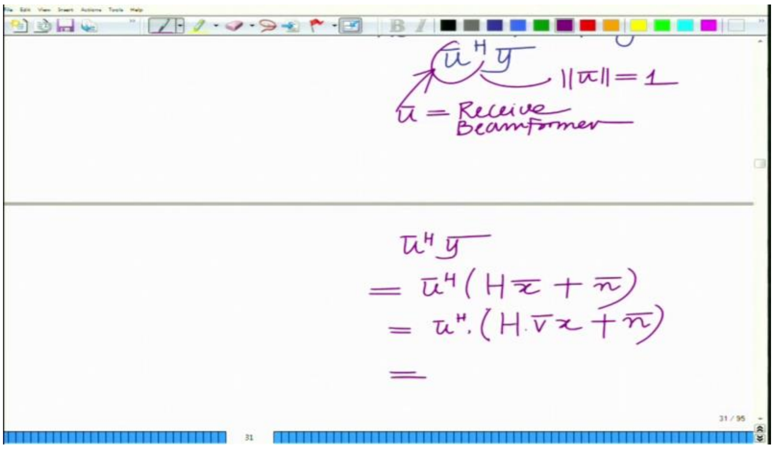

This becomes $\bar{u}^H\bar{y} = \bar{u}^H\left(H\bar{x} + \bar{n}\right) = \bar{u}^H\left(H\bar{v}x + \bar{n}\right)$.

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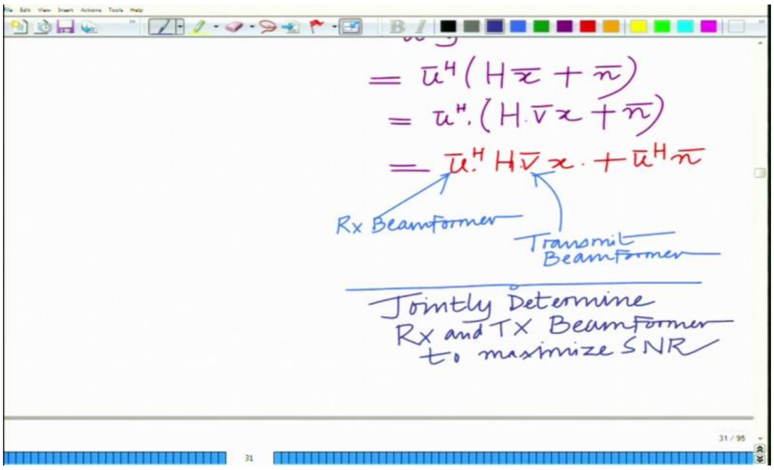

This becomes $\bar{u}^H H \bar{v} x + \bar{u}^H \bar{n}$. Now we have both the transmit and receive beamformers that is $\bar{v}$ and $\bar{u}$ respectively to maximize the SNR. We want to determine both of them and one has to determine both the optimal beamformers that maximize the SNR at the receiver and we will solve this in the subsequent module. Thank you very much.