

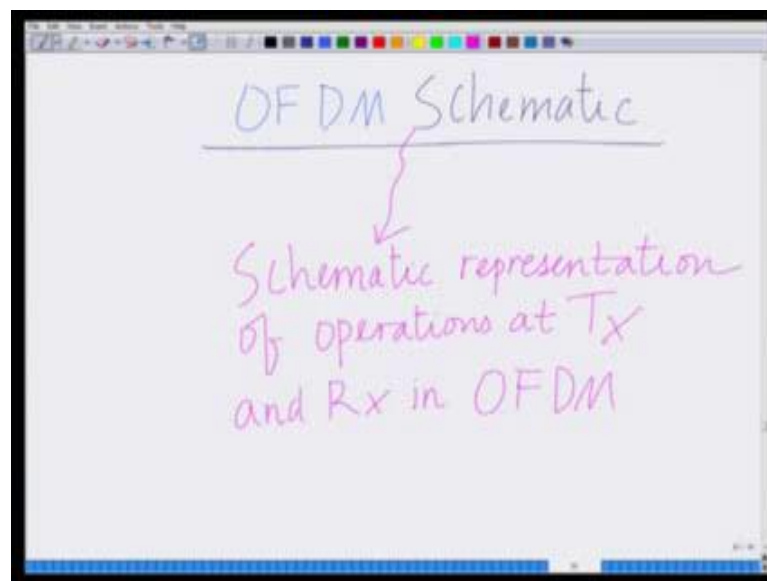
Principles of Modern CDMA/MIMO/OFDM Wireless Communications
Prof. Aditya K. Jagannatham
Department of Electrical Engineering
Indian Institute of Technology, Kanpur

Lecture – 49
Schematic Representation of OFDM Transmitter and Receiver

Welcome to another module in this massive open online course on the principles of CDMA, MIMO and OFDM Wireless Communication Systems. In the previous module we have seen how the IFFT operation with the transmitter, FFT operation at the receiver and addition of the prefix converts the OFDM system helps convert a frequency selective wireless channel into n parallel flat fading channels in an OFDM or orthogonal frequency division multiplexing system.

To summarize this entire process, let us now look at schematic diagrams for the operation operations at the transmitter and the receiver in an OFDM wireless system.

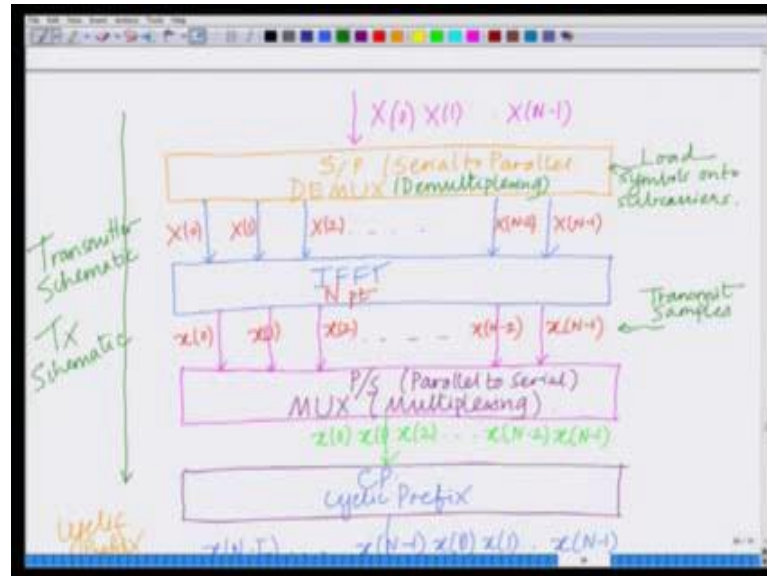
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So, what we are going to look at today is you are going to look at the OFDM schematic that is the schematic diagrams, a schematic representation that is what we are going to look at is schematic representation of operations at transmitter and receiver in OFDM. That is what is the sequence, that is what are operations and what is the sequence in which these operations are carried out in an OFDM system, at the OFDM transmitter and the OFDM receiver we are going to look at the various operations. The various

operations at the block level what are the inputs to these various blocks and what are the outputs from these various blocks.

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So, let us now look at the transmitter schematic in the transmitter we begin with to begin with we have a set of symbols these are $x(1), x(2), x(N-1)$ which are basically loaded on to the sub carriers. What do we have is, we have a serial symbol stream $x(1), x(2), x(N-1)$. We are going to convert this to a parallel stream; this is a serial to parallel, this is also known as a DE MUX or de multiplexing operation; which is basically to load the symbols onto the sub carriers to load symbols on to. We are starting with a serial to parallel operation; we have a serial symbol stream of the Xs that is $x(1), x(2), x(N-1)$. These symbol stream is converted into a set of parallel symbols $x(1), x(2), x(N-1)$ to load them onto the various sub carriers for the FFT for the IFFT operation this is also known as a serial to parallel conversion or a DE MUX or a de multiplexing operation. So, DE MUX stands for de multiplexing.

So, let me write this in brackets DE MUX stands for the (Demultiplexing) after this (Demultiplexing) or serial to parallel conversion. I now have these n symbols, which are loaded on to what I have is basically, these N symbols, which are loaded onto the N sub carriers. Here I have the various symbols and then I am going to take the IFFT of these symbols. This is an N point IFFT of the symbols, $x(0), x(1), x(2), x(N-1)$; I am

taking these symbols $x(0), x(1), x(2), \dots, x(N-1)$ I am loading them on to the sub carriers I am taking the IFFT, the inverse fast Fourier transform of these symbols to generate the transmit samples which are the $x(0), x(1), x(2), \dots, x(N-1)$ remember.

So, you can recall you might recall, the d is then generate the transmit samples may now generate the transmit samples; that is now, what we do is we generate the transmit samples. So, we generate the transmit samples which are $x(0), x(1), x(2), \dots, x(N-1)$

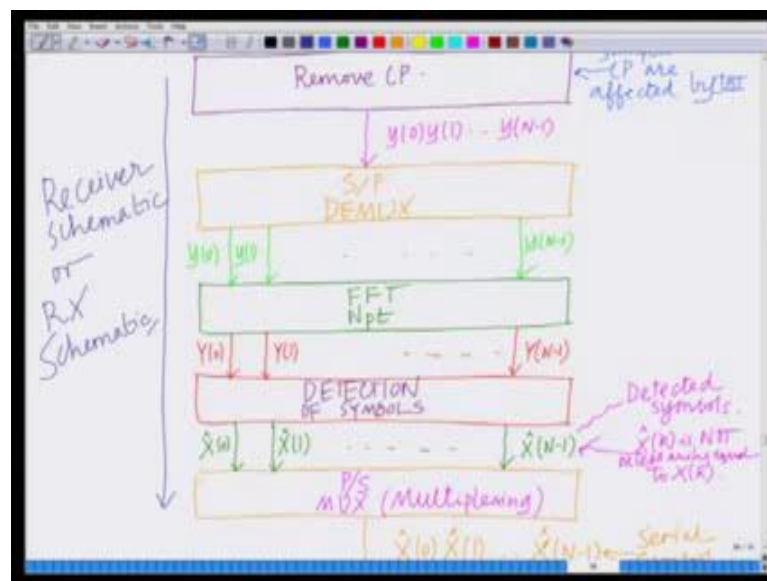
These are the samples or the transmit samples correct. Now, these are now again converted back to a serial stream that is P by S , use a Parallel to Serial converter and this operation is also known as this is the inverse of the de multiplexing operation. This is also known as a multiplexing operation. At after IFFT you have the samples the transmit samples $x(0), x(1), x(2), \dots, x(N-1)$, you pass these to a parallel to serial converter which is also known as a multiplexing operation or a MUX to generate the serial streams $x(0), x(1), x(2), \dots, x(N-1)$.

What you do here is you generate your serial transmit stream, so what I am doing here is I am generating my serial transmit stream, that is the $x(0), x(1), x(2), \dots, x(N-1)$ this operation is known as multiplexing. And now I am going to add the cyclic prefix that is cp or I am going to add the cyclic prefix to this. Once I add the cyclic prefix to this what I am going to have over here is am going to have $x(N-\bar{L})$; up to, $x(N-1)$; this is the cyclic prefix followed by $x(0), x(1), x(2), \dots, x(N-1)$; which is the original block and now these are; so this what I have over here this $x(N-\bar{L})$; to $x(N-1)$, this is the cyclic prefix and now what you are going to do is now these samples are transmitted over the channel.

So, what we have is we have our samples $x(0), x(1), x(2), \dots, x(N-1)$. We are going to add the cyclic prefix of \bar{L} samples that is $x(N-\bar{L})$; $x(N-\bar{L}+1)$, until $x(N-1)$. This is prefixed before the original block that is $x(0), x(1), x(2), \dots, x(N-1)$ and this is then transmitted over the wireless channel. This is basically after the addition of the cyclic prefix of length \bar{L} samples, Where \bar{L} is chosen appropriately, this is transmitted over the wireless channel this is the OFDM signal which is transmitted. This is also known as the transmitter schematic correct. This is basically the sequence of

operations which is carried out at the transmitter this is also known as the transmitter schematic. This part if you can look at this part, this whole part this is known as the Transmitter Schematic or the Tx schematic. The schematic representation of the operation or a sequential representation of the operations at the transmitter showing the various inputs and the outputs to the various blocks and the sequence of operations that is to be carried on at the transmitter.

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Let us now look at the corresponding operations at the receiver of this OFDM system. Let us look at the receiver schematic of this OFDM system. So, in the OFDM system I receive the samples from the channel. So, I receive samples from the wireless channels. **I have samples which are received from the wireless channel.** What I am going to do is first I am going to remove the cyclic prefix. So, this module is basically going to remove the cyclic prefix. Because remember the samples in the cyclic prefix are affected by the inter block interference. Samples in CP or a cyclic prefix are affected by inter block interference.

After we receive these samples at the receiver the first thing that we do is to remove the outputs corresponding to the cyclic prefix. Because these samples in the cyclic prefix they are affected by the inter block interference. We remove the **L** samples, output samples corresponding to the cyclic prefix and we take the rest of the samples that is 0 until N minus 1 corresponding to the original OFDM block all right. This avoids inter

block this is how we eliminate inter block interference at the receiver in this OFDM system. This is then followed by now; at this point we have our samples $y(0), y(1), y(2), y(N-1)$.

Now, what we do is again we carry out a serial to parallel operation. So, this is serial to parallel operation as we have already seen; this is also a DE MUX or a de multiplexing operation and at the output of the de multiplexer, what we are going to perform after the de multiplexing basically we are going to perform the FFT operation at the receiver and obviously this is your N point FFT operation. What you have as the input to the FFT are basically your samples received samples $y(0), y(1), y(2), y(N-1)$ you are performing the N point; that is these are the output of the de multiplexer, these are input to the FFT that is N point FFT block and then at the output of the FFT; obviously, what you are going to get is you are going to get on each sub carrier you get the output of the corresponding, that is the you get the $y(0), y(1), y(2), y(N-1)$, these are the FFT of the sequence received samples.

Now, what we are going to do to these samples is from these samples on each $y(k)$, we are going to detect. This is a detection module. Detection of symbols using each $y(k)$ we are going to detect the transmitted symbol and what we are going to having here is basically we are going to have the detection module and therefore, what we have at the output of our detection module is we have the symbols that are detected, these are the symbols that are detected; which is the $\hat{x}(0), \hat{x}(1), \hat{x}(2), \hat{x}(N-1)$, these are the detected symbols. These symbols are basically these are the detected symbols. And observe that $\hat{x}(k)$ is not necessarily equal. We are denoting the detected symbol by $\hat{x}(k)$ and not $x(k)$ that is $x(k)$ because the detected symbol $\hat{x}(k)$ need not be equal to the transmitted symbol $x(k)$. There can be errors in the detection and this is where we have bit errors in the OFDM system.

We are denoting the detected symbols by $\hat{x}(0), \hat{x}(1), \hat{x}(2), \hat{x}(N-1)$, where each $\hat{x}(k)$ is the symbol detected on the sub carrier k from the corresponding output of the FFT; that is $y(k)$ which is the kth FFT coefficient of the received output samples. And

now finally, once we have detected these symbols $\hat{x}(0), \hat{x}(1), \hat{x}(2), \hat{x}(N-1)$, all that is left is I have to do a parallel to serial conversion that is I have to do a MUX or a multiplexing operation to basically convert these back these are now converted back to my serial stream that is $\hat{x}(0), \hat{x}(1), \hat{x}(2), \hat{x}(N-1)$. So, this is my serial symbol stream. Which has been generated and what this is again, this is the sequence of operations that is carried out at the receiver therefore; this is the receiver schematic of the OFDM or also which we can call as RX the receiver Schematic.

So, what we are seeing in this receiver is basically, initially we start with the removal of the cyclic prefix followed by the serial to parallel de multiplexing operation; followed by the N point FFT; followed by the detection of the symbols on each sub carrier; followed by the parallel to serial multiplexing to generate the serial symbol stream $\hat{x}(0), \hat{x}(1), \hat{x}(2), \hat{x}(N-1)$, this is the schematic of the receiver of the OFDM receiver.

What we have seen in this module is we have basically seen the transmitter schematic. That is we have seen the sequence of operations the various modules in the transmitter, the input to each module, the output to each module, until the transmit stream that is the samples that are transmitted across the channel in this OFDM transmitter are generated. Subsequently we receive these samples at the receiver and at the receiver, we have also illustrated the receiver schematic; which is a block level system diagram of the various modules in the receiver.

The sequence of operation of these various operations at the receiver; the input to each module at the receiver and the output to each module, until we recover the transmitted serial symbol stream that is the $\hat{x}(0), \hat{x}(1), \hat{x}(2), \hat{x}(N-1)$. This basic, this schematic representation of transmit and receive operations in the OFDM system helps clarify a lot of this. They help succinctly summarize this various modules and the various operations in this OFDM wireless communication system. Thereby also giving you a convenient pictorial representation something that is easy to remember something that is easy to recollect with respect to this OFDM wireless system.

We will stop this module here; we will look at other module other aspects on the subsequent module.

Thank you very much.