ADVANCED WIRELESS TECHNOLOGIES

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Hello. Welcome to another module on wireless communications in this MOOC massive open online course.

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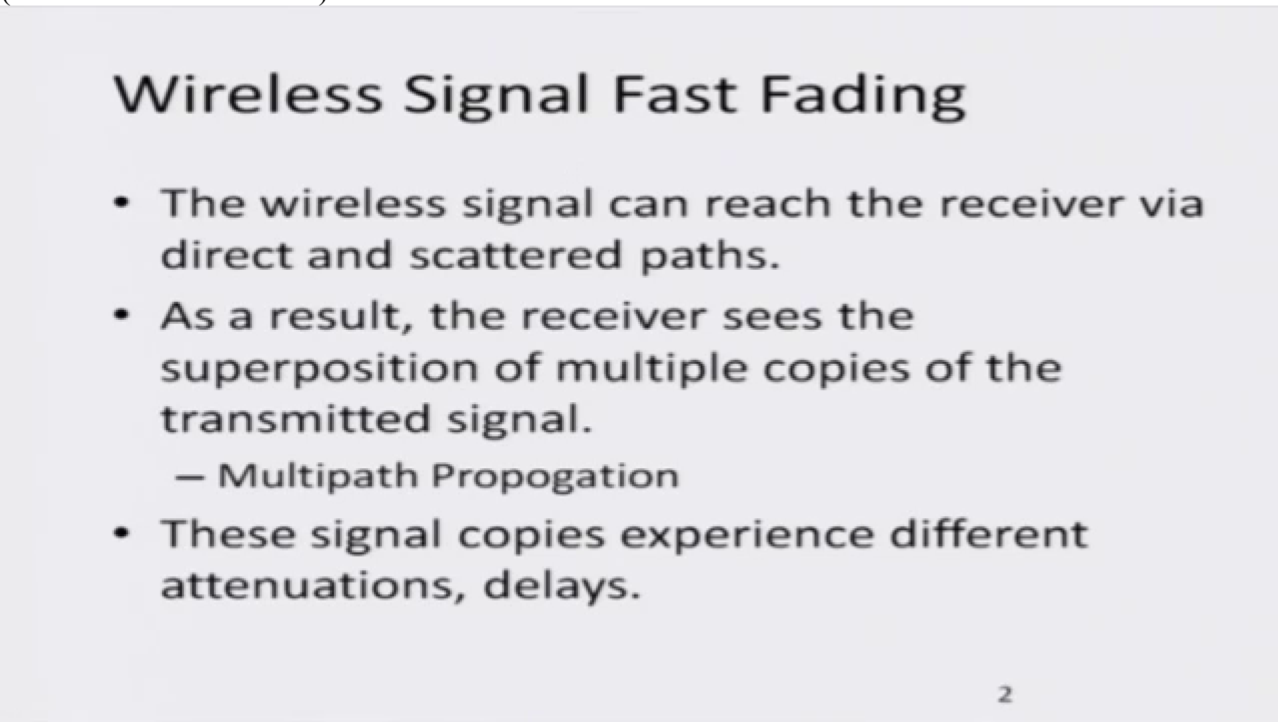

And in this module let us look at some of the advanced aspects of technology that make a wireless communication possible, the high data rates possible in current wireless communication systems when you talk about 3G or 4G wireless communication system. As we already seen in the very first module the wireless communication environment is a very tricky and a challenging environment because there's no dedicated channel or there's no wire between the transmitter and receiver, so the signal can reach the receiver from the transmitter via a several paths. As a result what the receiver sees is really a superposition of these several signals and we know from physics that when these signals superpose they can end up cancelling each other or sometimes even adding up to enhance the signal strength. So what you see is really is a variation of the signal strength and occasionally the signal also dips severely below an acceptable signal strength.

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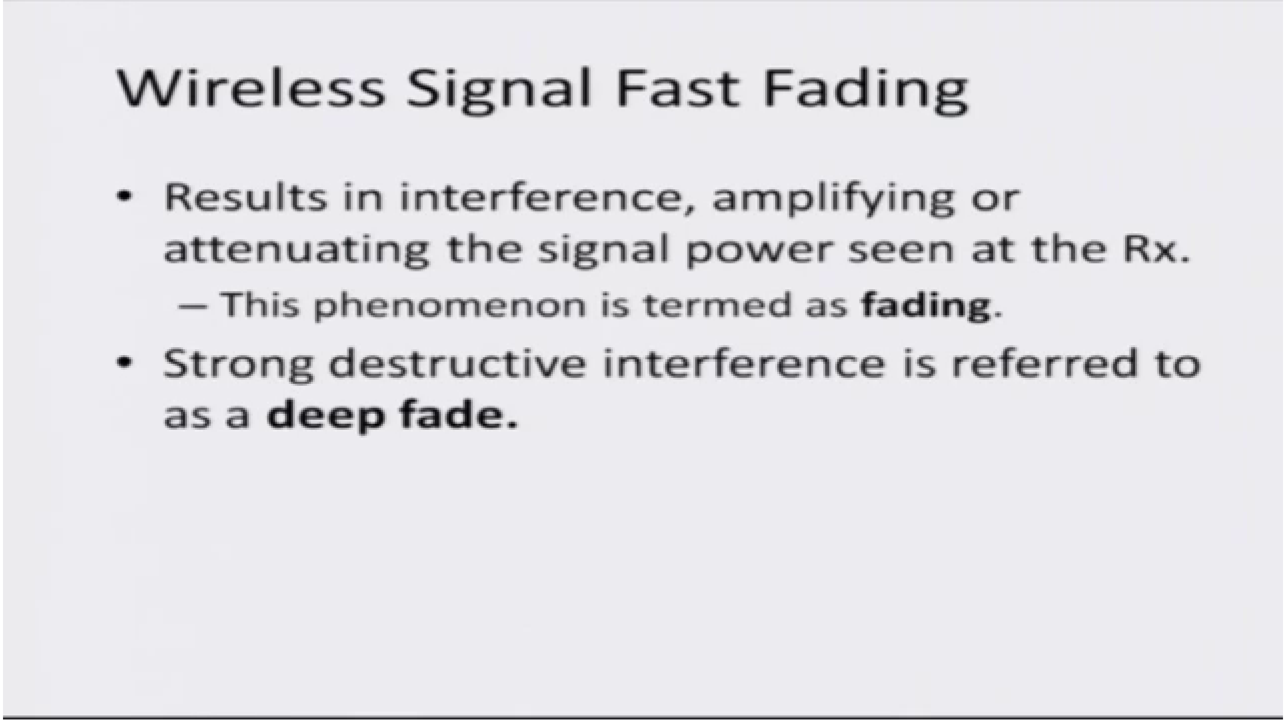

And therefore what we need is we need mechanisms to basically overcome. Then this process is known as fading and therefore we need mechanisms which overcome this sort of fading effect of the wireless channel and sort of ensure service or good quality of services irrespective of or ensure good quality of service even in scenarios where the signal strength is not so favorable because of the fading aspect.

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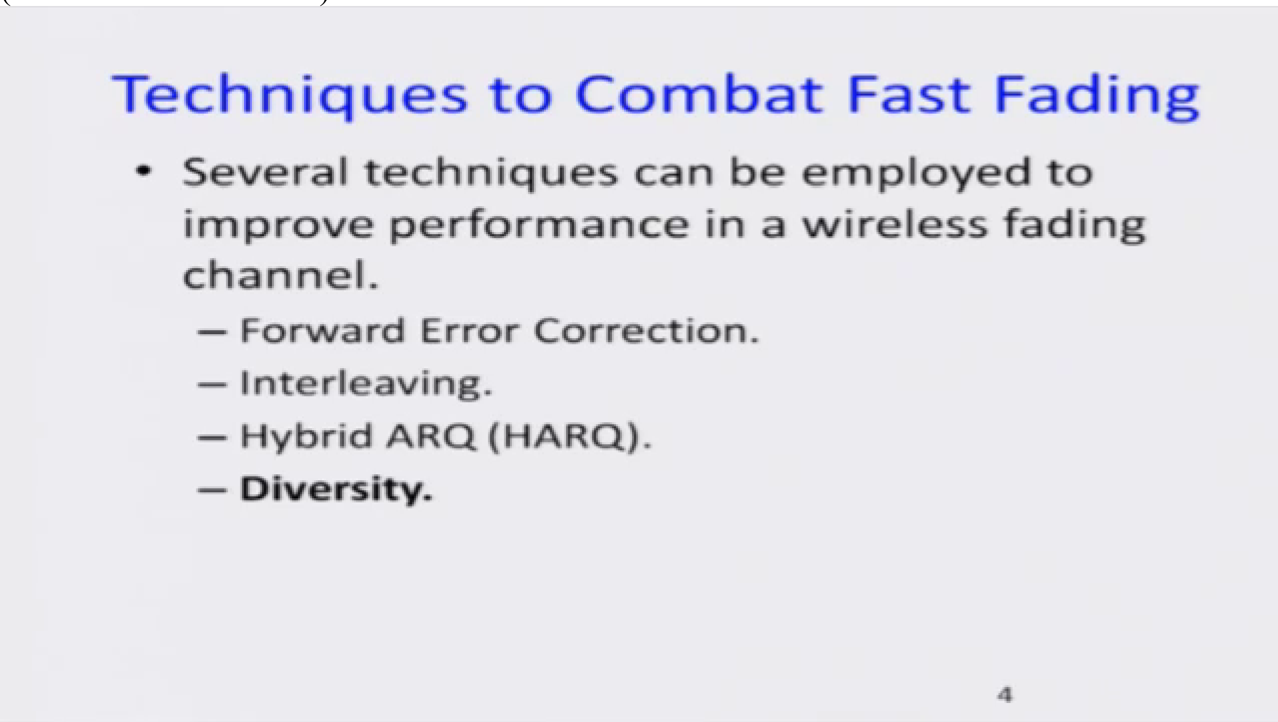

And there are several ways to ensure reliability of wireless transmission, some of these techniques are listed here such as forward error correction, interleaving, hybrid ERQ, diversity, we will go over some of these aspects sort of superficially to give you an high-level overview.

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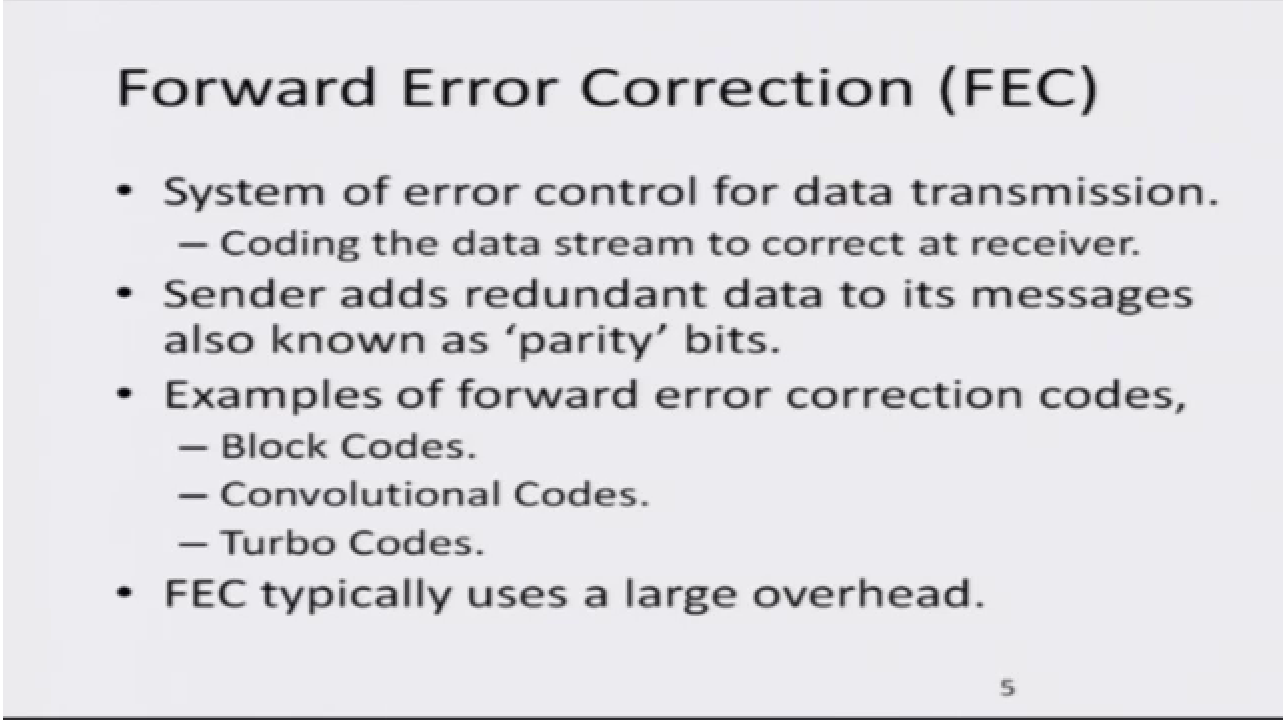

Forward error correction is basically enhancing the reliability or basically enhancing the quality of transmission by enhancing the accuracy of the transmitted data bits by coding them. This is known as forward error correction. There are a large number of advanced codes that have been developed in recent years such as block codes, convolutional codes, turbo codes. And forward error correction typically causes a large overhead. So it increases the overhead and communication but also ensures reliability and accuracy of transmission of bits.

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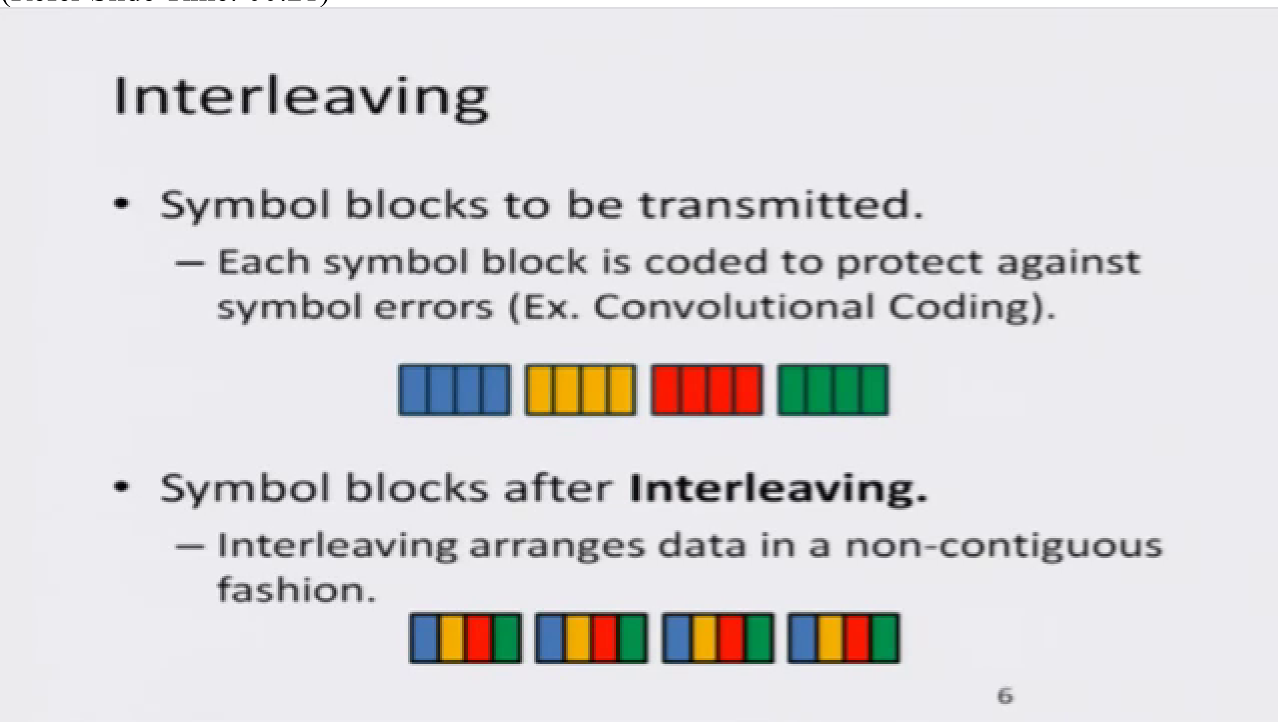

The other aspect is interleaving where these different transmitted bits in a block are sort of transmitted in a jumbled fashion and that sort of -- and these jumbled bits have been transmitted over the air.

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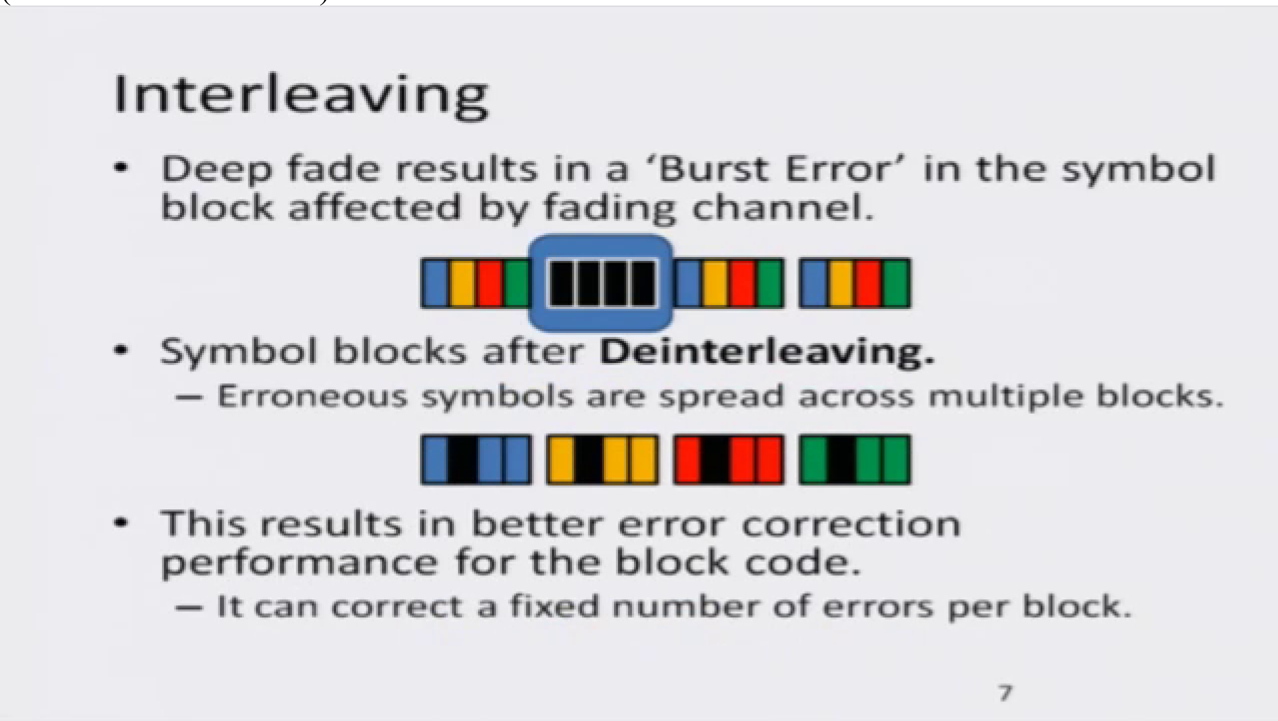

And that is known as interleaving at the receiver they are D interleaved and sort of arranged in an orderly fashion and that sort of protects against continuous stream of bits being lost over the channel. This feature is known as interleaving.

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Hybrid Automatic Repeat ReQuest or HARQ is another error control method this is basically actually to increase the reliability by repeated retransmission because of the wireless channel

is highly error prone so there are several packets which are either dropped or which are received in error. So what we need is a fast mechanism for retransmission and so that these packets can be transmitted over and over again until they are accurately received and this is known as HARQ or Hybrid Air Q and that significantly enhances the reliability of the link.
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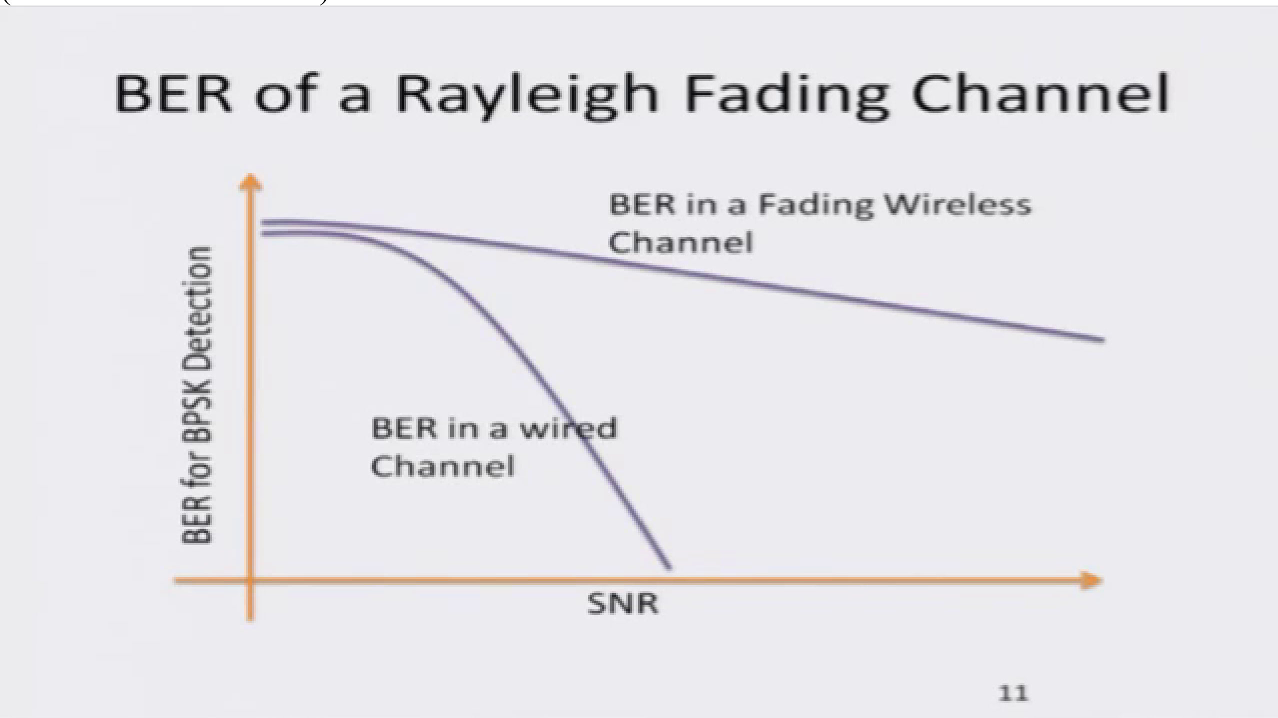

And if you look at the error rate performance of a fading wireless channel you will see that the fading wireless channel has a significantly high error rate that is caused by as I said because of the fading nature of the signal or the varying nature or the unreliability of the signal strength at the receiver because of the interference caused by this multiple signal copies.
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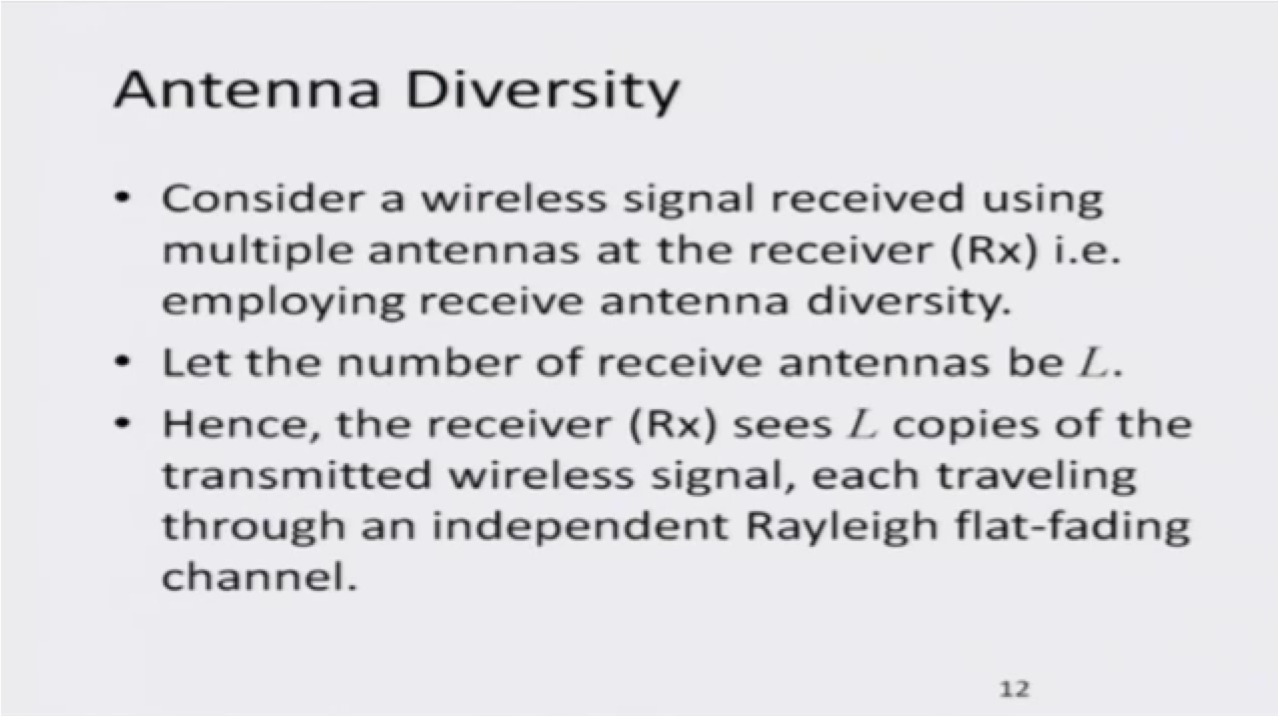

And therefore one has to explore or a challenge is to come up with techniques or smart strategies to enhance the signal strength and the receiver and diversity or in particular antenna diversity is one such technique which simply put is to use multiple antennas.

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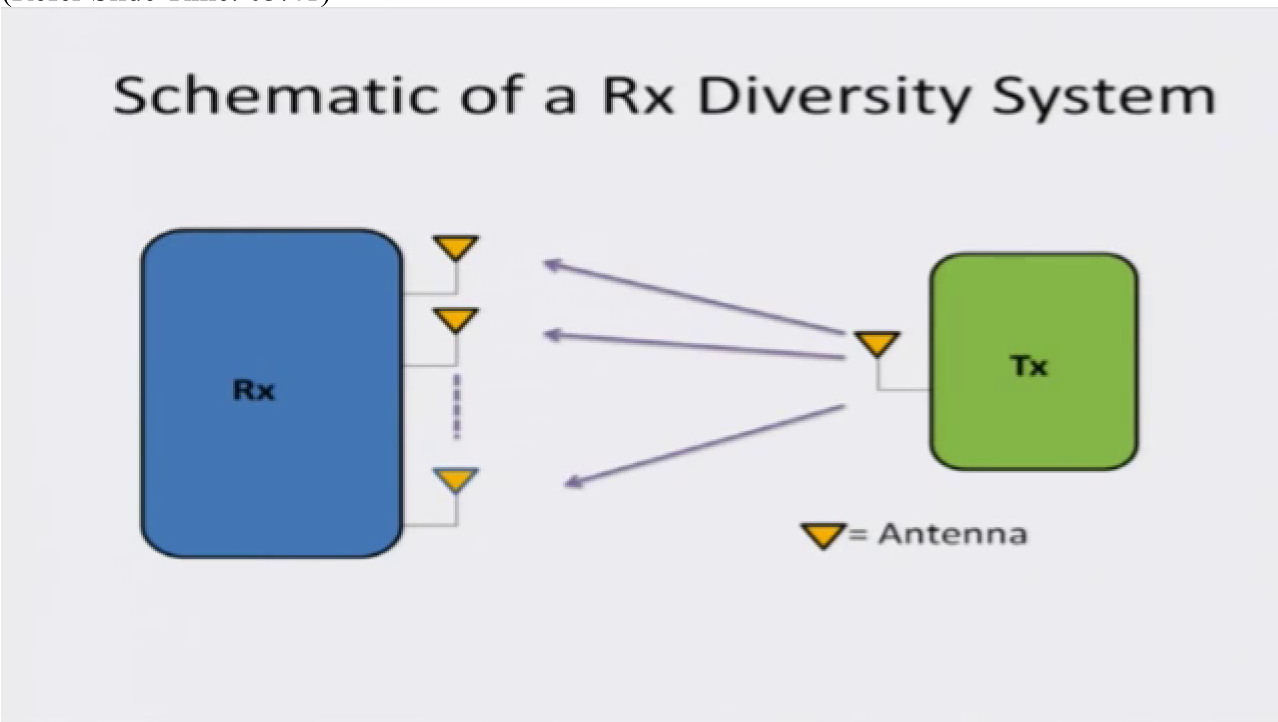

Now these multiple antennas for example at the receiver receive multiple signal copies and then they sort of combine these signal copies so as to enhance the signal length strength. That is known as diversity.

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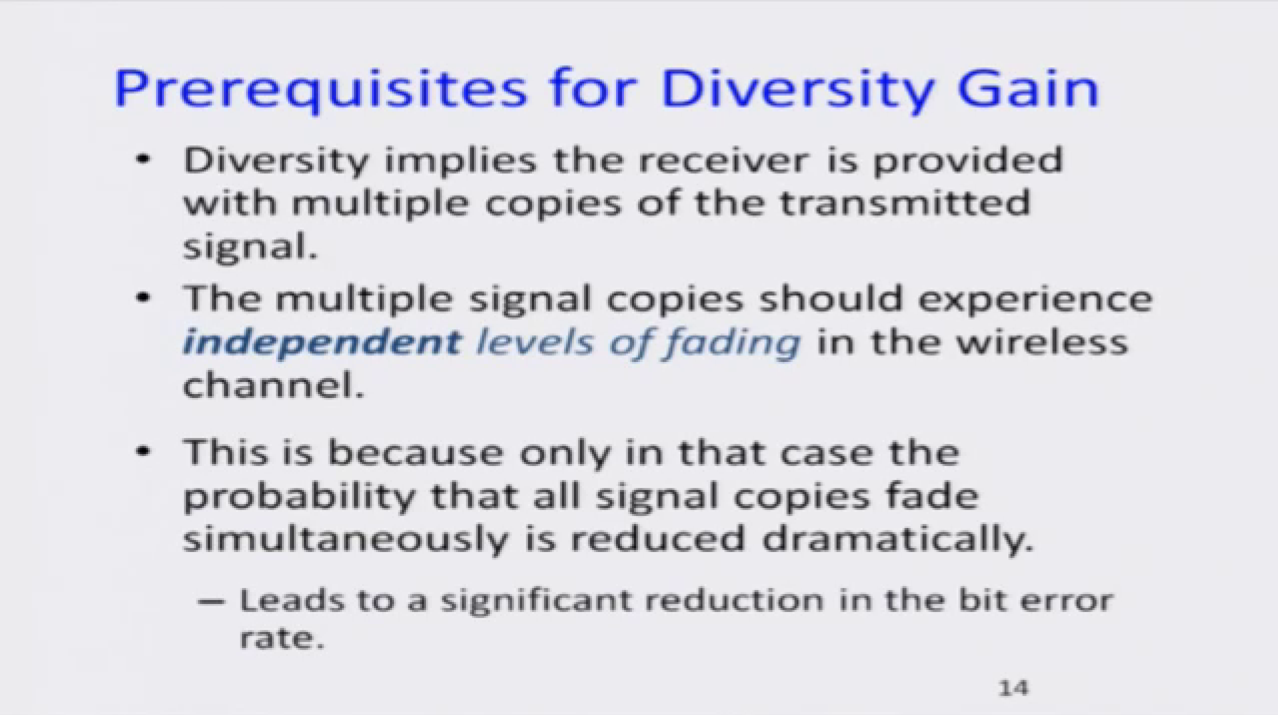

There are various forms of diversity.

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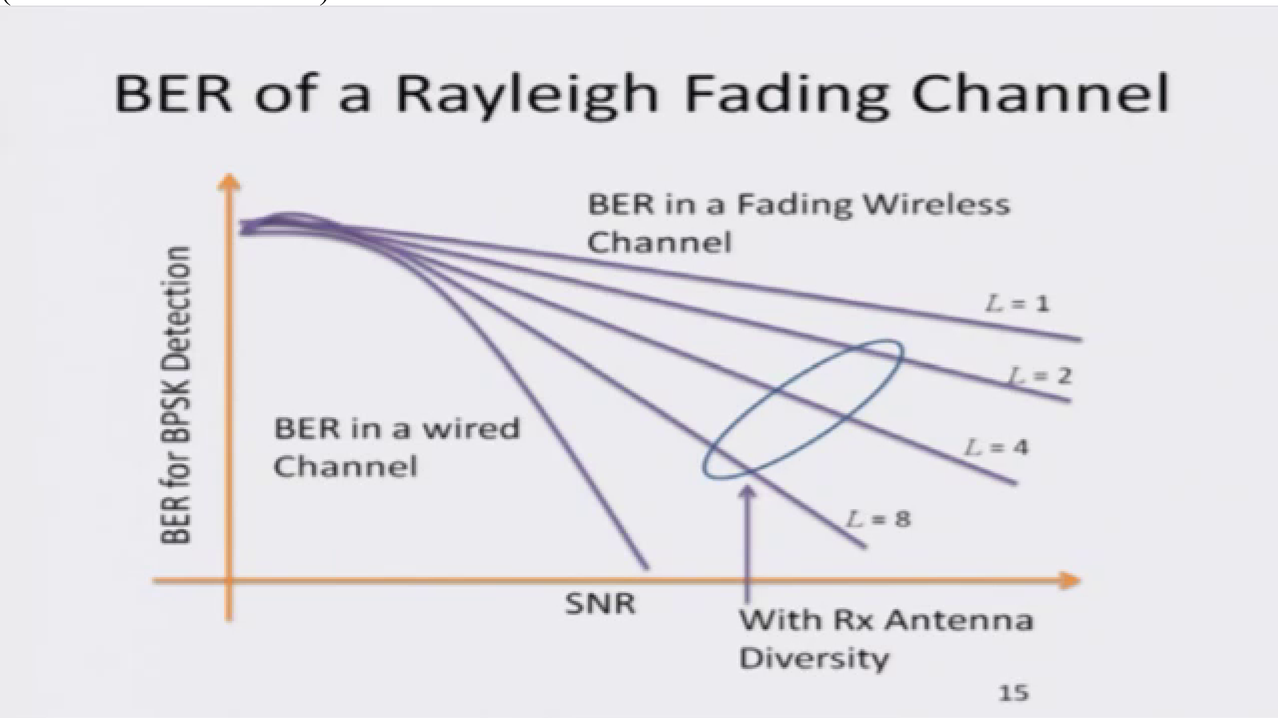

And as you can see as the number of antennas increases for instance here you have the beta rate for L equal to one or one antennas number of antennas increases two, the beta rate decreases significantly 4, 8 and so on. You can see the beta rate progressively keeps on decreasing which means as the error rate is decreasing the link or the quality of bit transmission is progressively improving.

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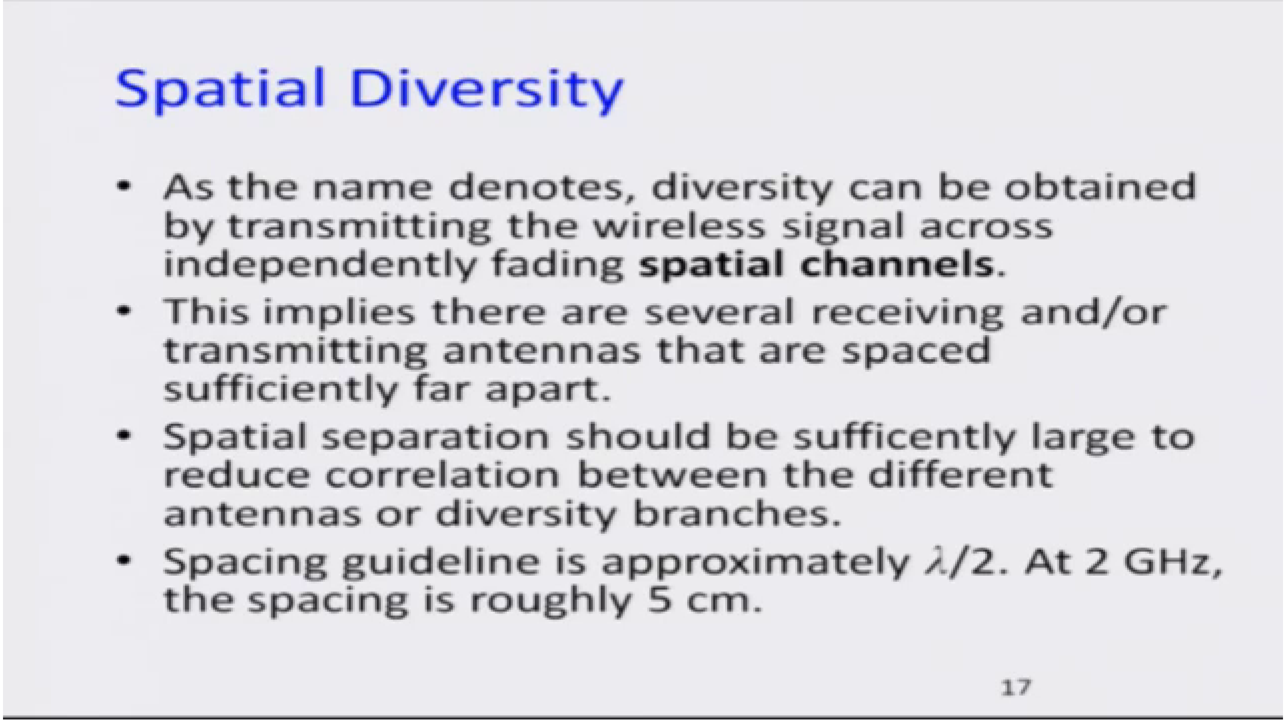

There are several methods to achieve this diversity or to get this multiple signal copies and increase the signal strength by adding them up constructively, one is through spatial diversity that is something that we've already seen also antenna diversity that is you have multiple antennas. You see multiple signals from these multiple antennas across space, you add them up constructively to enhance the signal strength.

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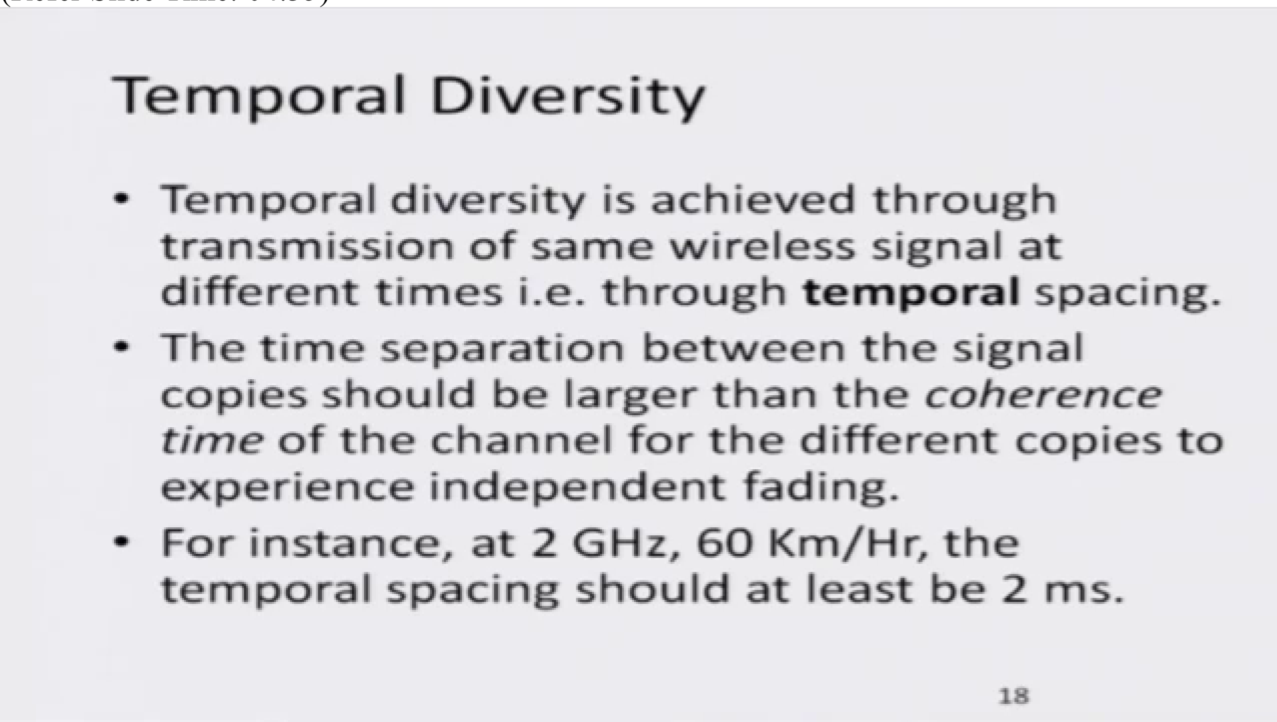

Temporal diversity that is you receive signals through at multiple instants of time or multiple temporal slots. You add these signals up to again increase the reliability of the signal.

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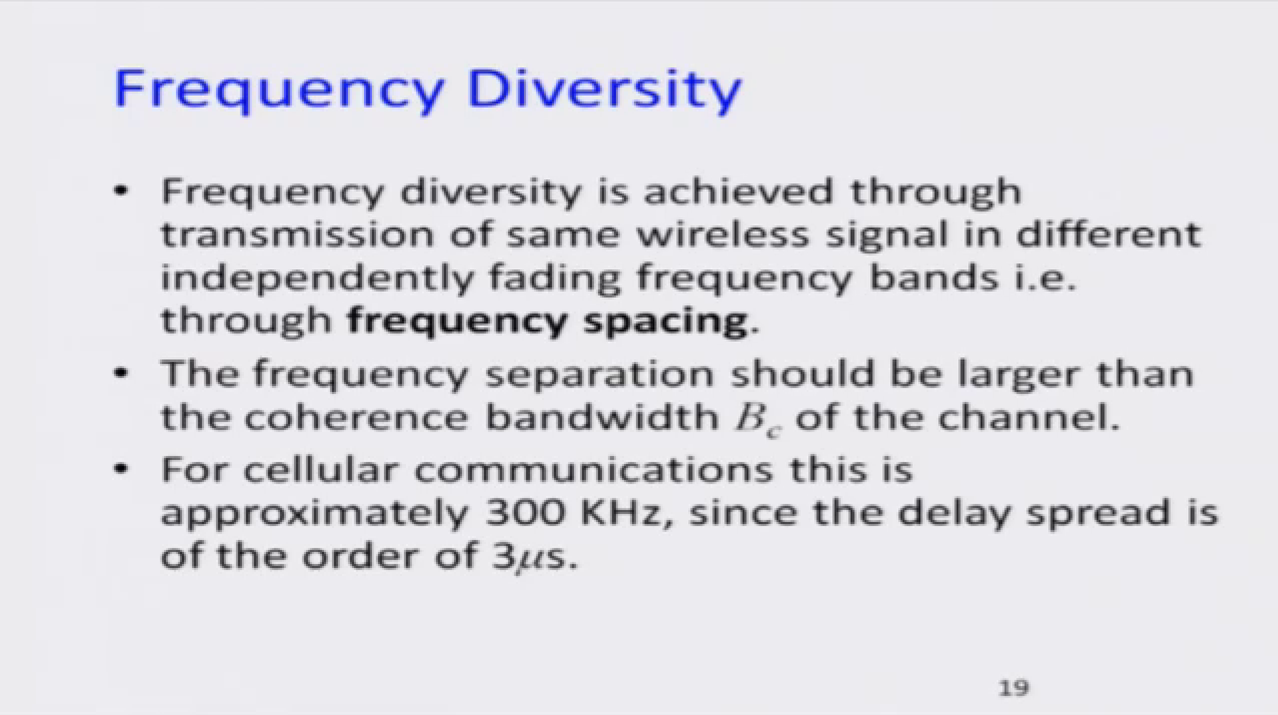

A frequency diversity where you receive signals in multiple frequency bands such as OFDM which has possible transmission which enables transmission through multiple frequency bands, you combine these signals and again enhance the signal strength.

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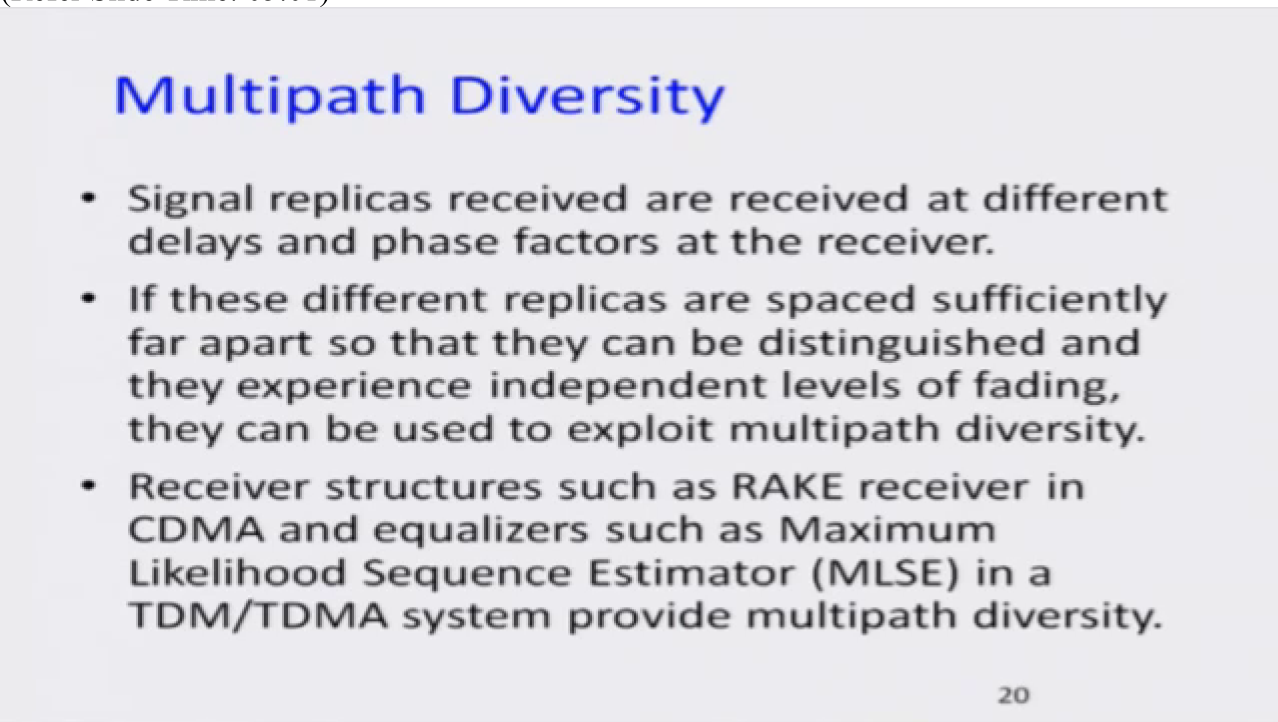

Multipath diversity for instance is something that can be seen in CDMA where you have different signal, signal copies coming from different paths and because of the nature of CDMA because of the nature of the spreading codes used in CDMA you can actually use, pick these different signal components and combine them rather than interfering you can combine them constructively or coherently to enhance the signal strength through mechanism known as the RAKE receiver et cetera and that significantly enhances the quality of the signal.

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Another important technology which makes high data rates possible in 3G and 4G wireless communication systems or what is known as multiple-input multiple-output systems.

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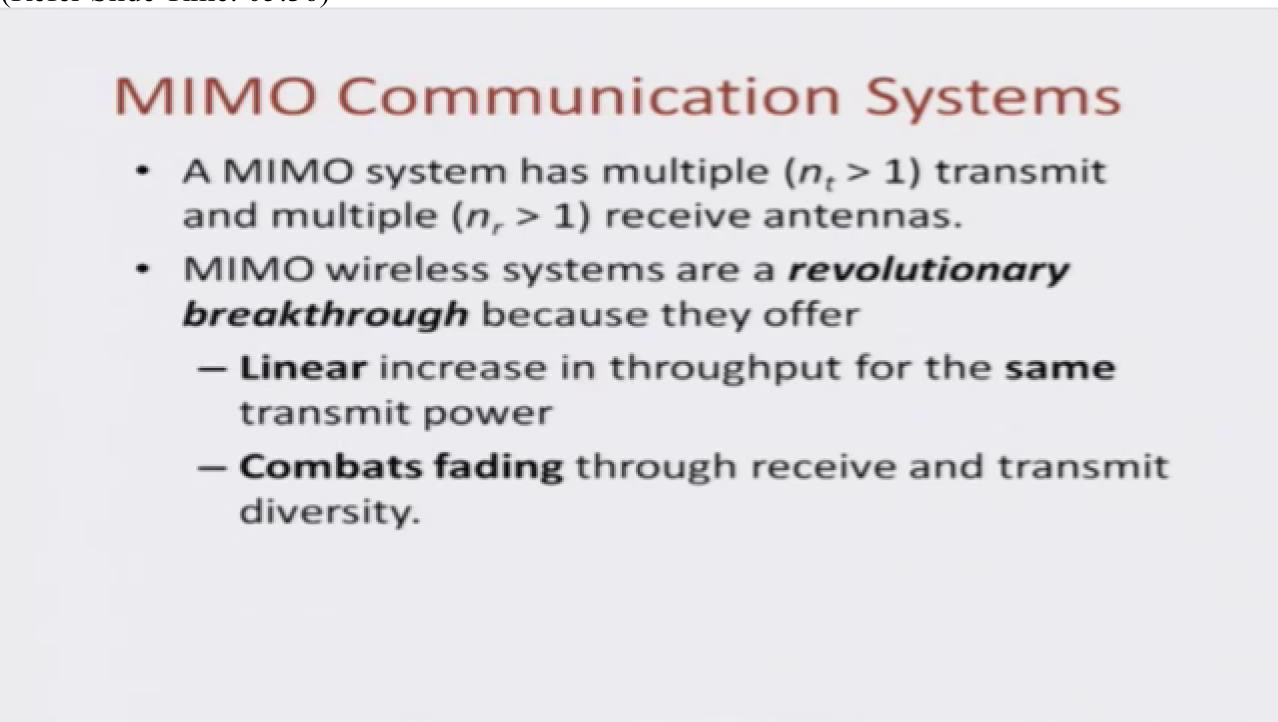

A simply put these are having multiple antennas at the transmitter and multiple antennas at the receiver.

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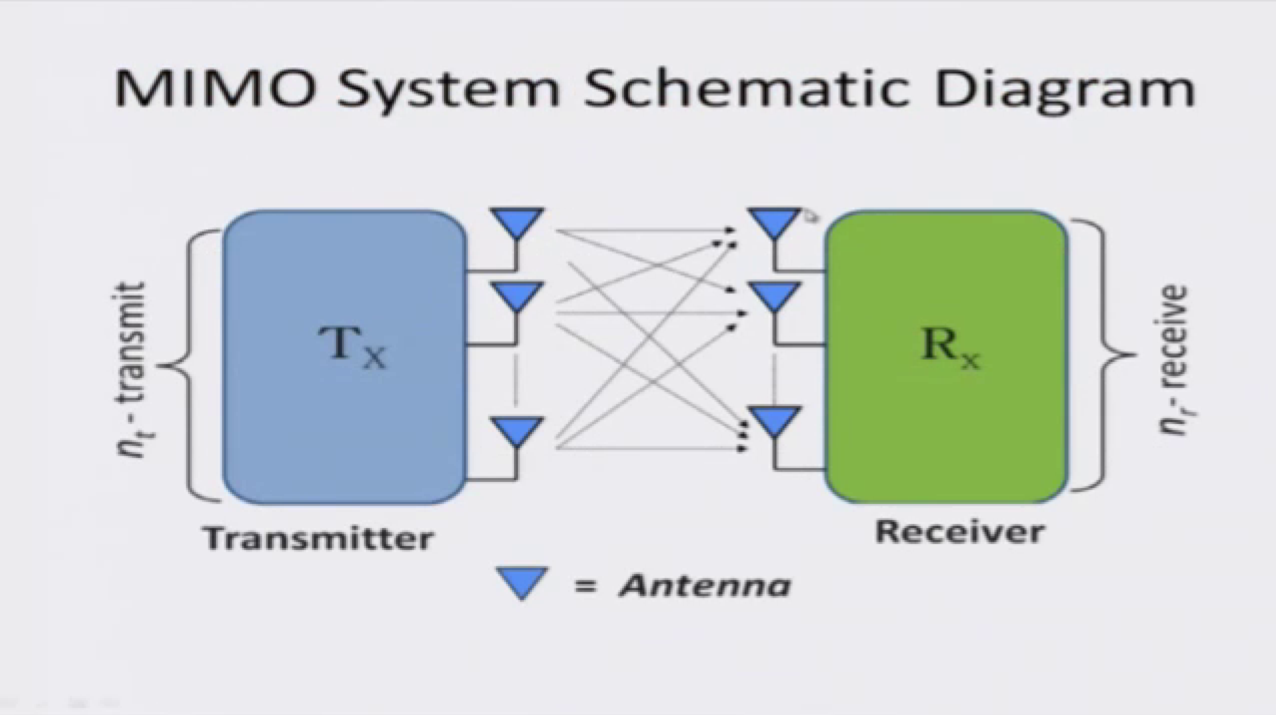

And it can be shown that when you have multiple antennas at the transmitter and multiple antennas at the receiver as shown in this slide over here you create a large number of pathways or a large number of independent spatial channels or additional spatial channels to transmit multiple information streams between the transmitter and receiver.

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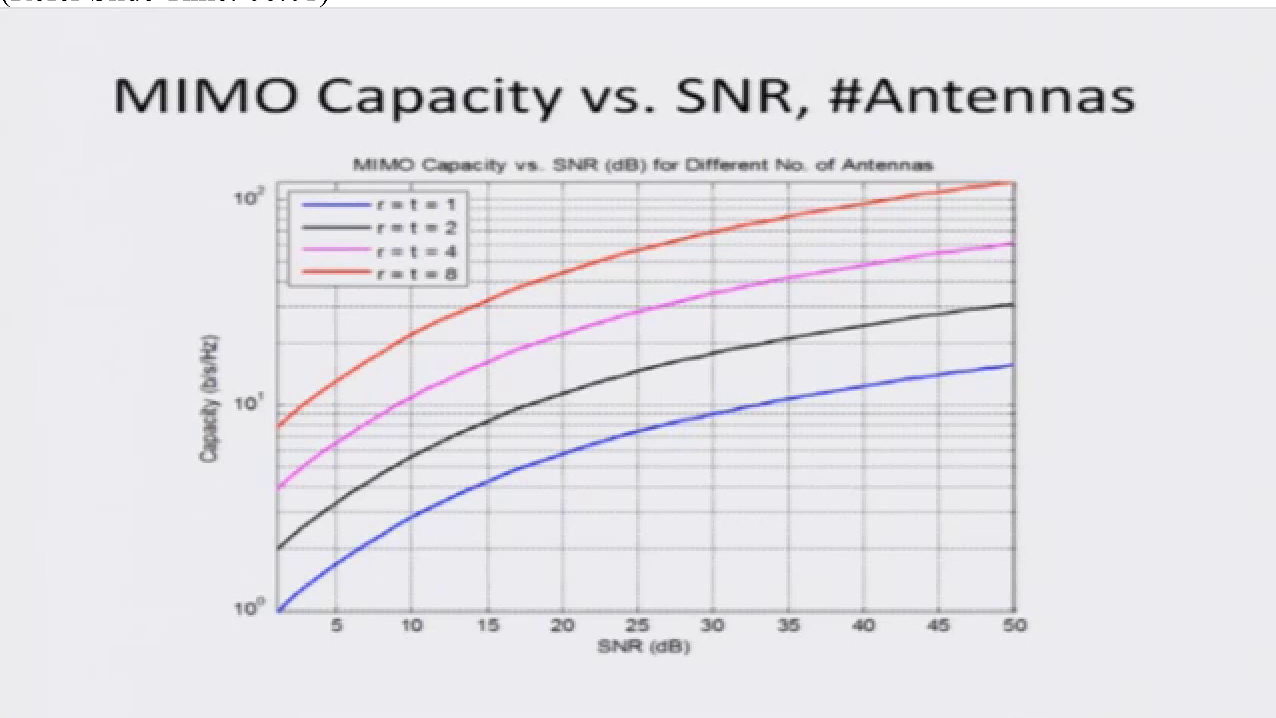

As a result what you have is you can pump data at a much higher rate between the transmitter and receiver. For instance the blue curve here shows the data rate when you have a single transmitter and receiver. When you increase the number of transmit and receive antennas two you have a significant bump almost twice an increase in the data rate. And progressively as you increase the number f receive and transmit antennas without an increase in the transmit power or without an increase in the bandwidth you have a progressive increase in the capacity or in the number of bits that can be remits, that can be transmitted at the same power at the same bandwidth and therefore that significantly increases the data rate in wireless links and therefore MIMO or Multiple-Input Multiple-Output system are one of the Technology enables in 3G and also in fact more importantly in 4G or four generation wireless communication systems.

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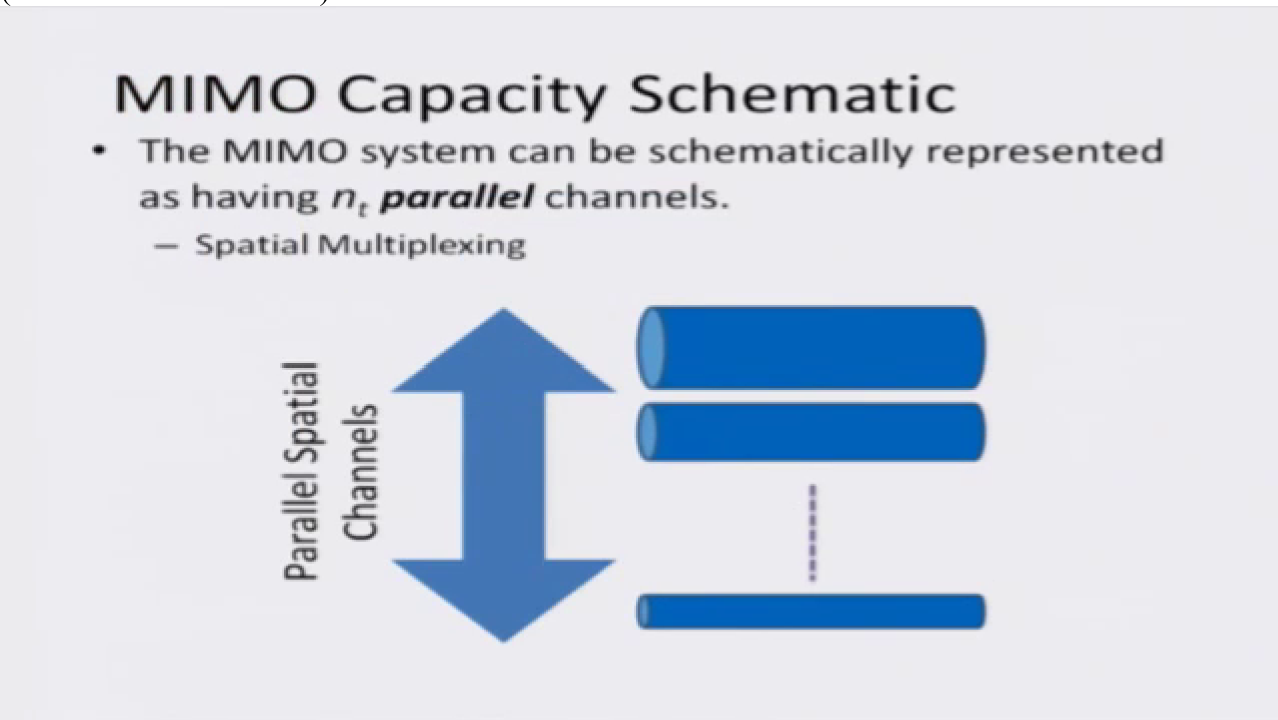

And that is done through what is known as spatial multiplexing where you have because of this multiple antennas you at the transmitter and receiver you create multiple modes or multiple spatial pathways, parallel spatial pathways between the transmitter and receiver to simultaneously transmit multiple streams of information. This is known as spatial multiplexing.

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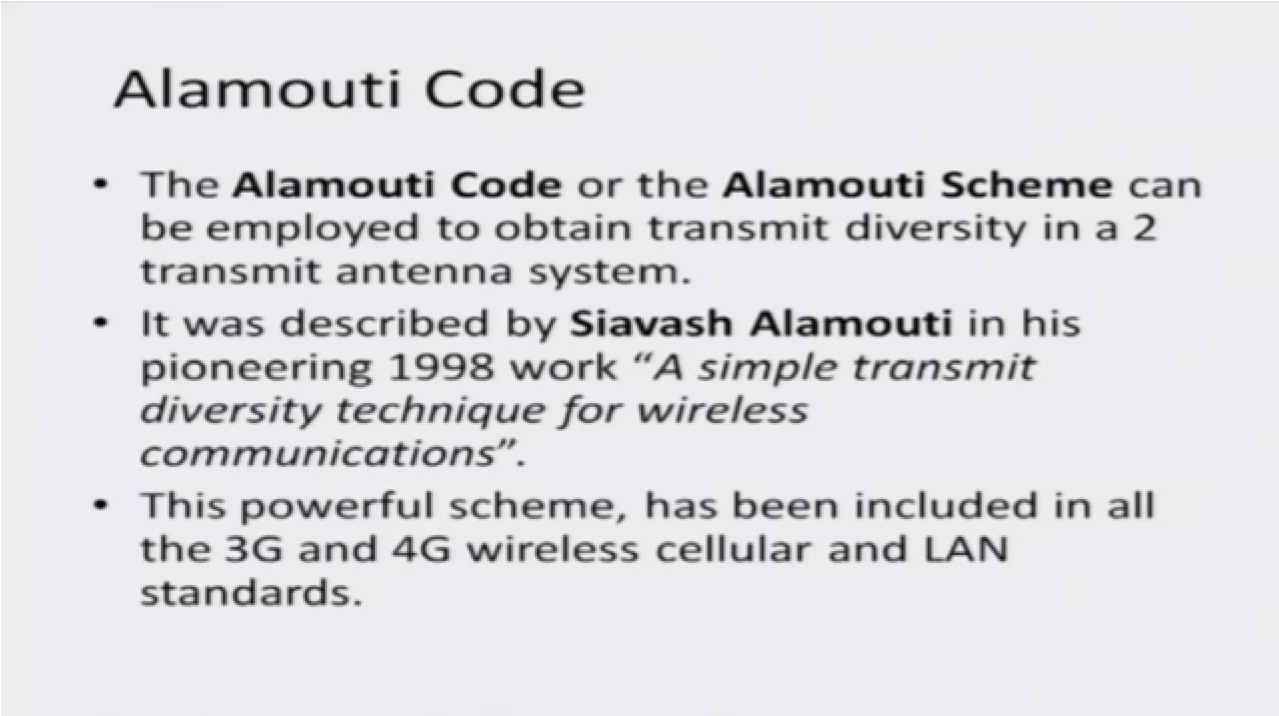

Another feature advanced feature of 3G 4G wireless systems is using what is known as space time block codes that is coding across the space and time dimensions. This technique was pioneered by Siavash Alamouti, the initial paper a simple transmit diversity technique for wireless communications are proposed around 1998. And this is a revolutionary scheme which sort of enhances, significantly enhances the reliability and the reliability of bit or transmission of bits over the wireless link.

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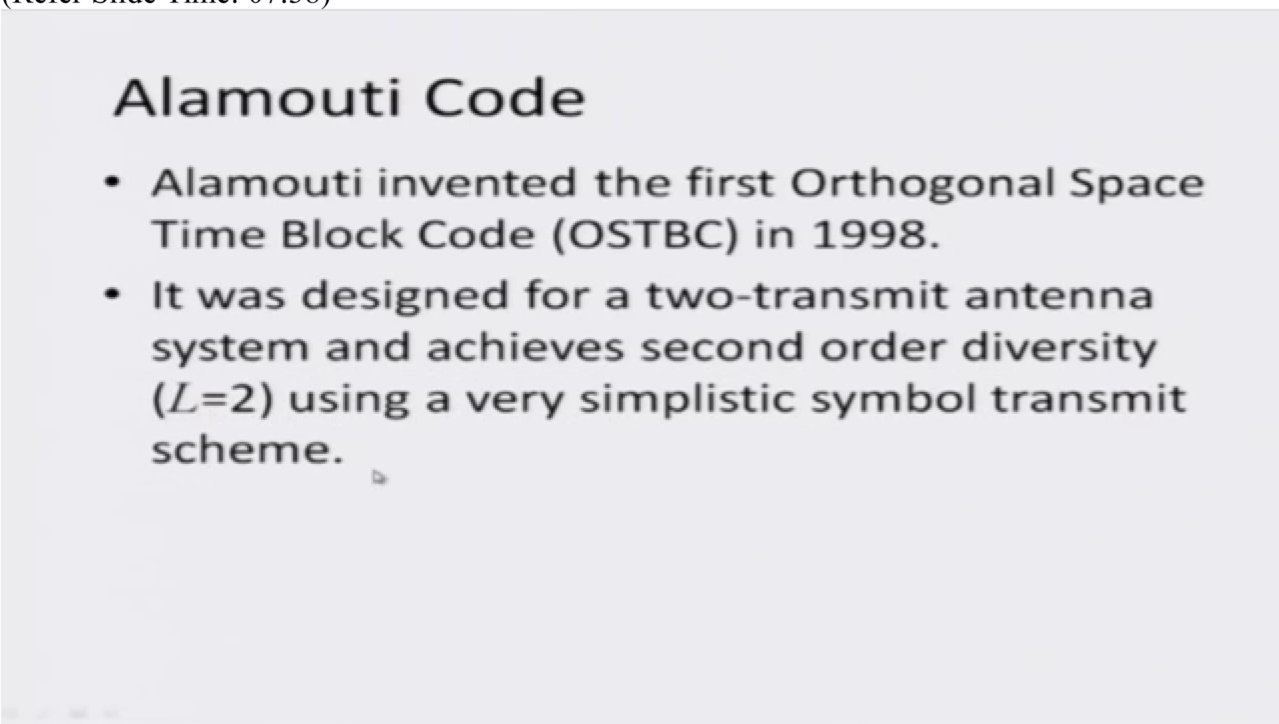

This mechanism is known as space time block codes or orthogonal space time block codes and originally was proposed for two antennas by an Alamouti and later extended for other systems. And so all these mechanisms put together the MIMO the multiple antennas, the diversity, the HARQ, the space time block codes et cetera. These are the key technological advances in wireless communications or wireless key technology advances in wireless signal transmission in the past decade or so which have enabled, which are exploding an explosion of the bandwidth or which I mean able transmission of higher data rates with the lower power at lower bandwidth and over wireless link thereby enabling broadband access significantly improving the efficiency of wireless data transmission and simply improving the data rates possible in wireless communication system which in turn enhances the richness of the services that can be supported in wireless communications systems. For instance in 2G where you can support only voice, to 3G where you can support voice along with video telephony with to 4G where you can support a large number of services such as video streaming, high-definition online gaming et cetera and several other applications. Thank you.