Principles of Modern CDMA/MIMO/OFDM Wireless Communications

Prof. Aditya K. Jagannatham
Department of Electrical Engineering
Indian Institute of Technology, Kanpur

Lecture – 26
Introduction to Code Division Multiple Access (CDMA)

Welcome to another module in this Massive Open Online Course on the Principles of CDMA, MIMO and OFDM Wireless Communications. Today we are going to start looking at CDMA Wireless Communication Systems.

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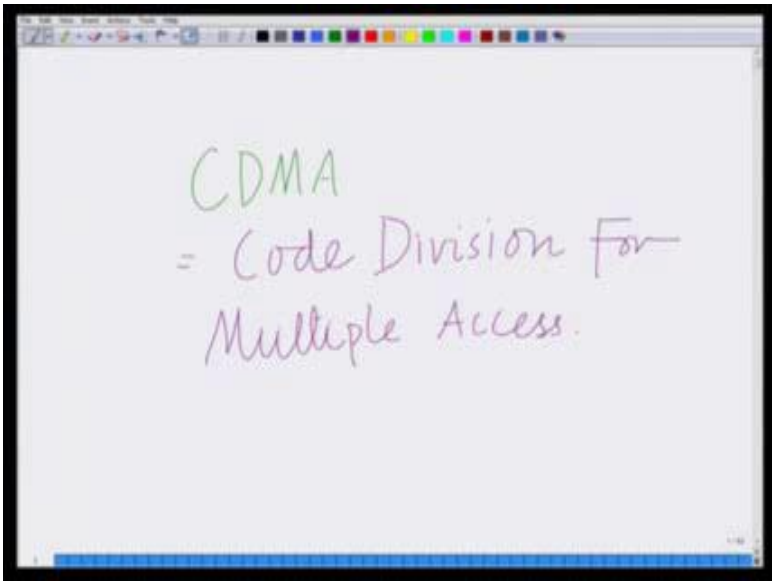

You want to start looking at CDMA and CDMA as we all know we have seen in the very first module its stand for Code Division for Multiple Access. That is the full form of CDMA as we have seen in the very first module itself and CDMA is a key technology which is used in several 3G wireless standards. For instance CDMA is used in wireless standard; such as WCDMA which is wide band Code Division Multiple Access.

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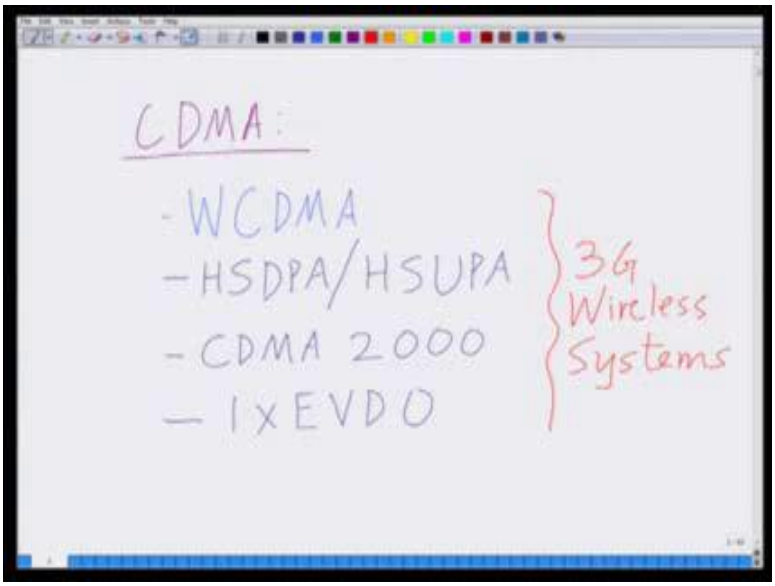

It is used in HSDPA and HSUPA systems it is used in CDMA. CDMA 2000 and 1 x EVDO and all of these as we have already seen. These are various 3G wireless systems. CDMA is used in WCDMA, HSDPA, HSUPA that is high speed downlink packet access, high speed uplink packet access. CDMA 2000, 1 x EVDO and these are several different 3G wireless systems was CDMA is a key technology.

Since it used in several 3G wireless communication system. It is a key technology and understanding, it is very important to understand the properties or some of the key technologies which have led to the progression of wireless communications right.

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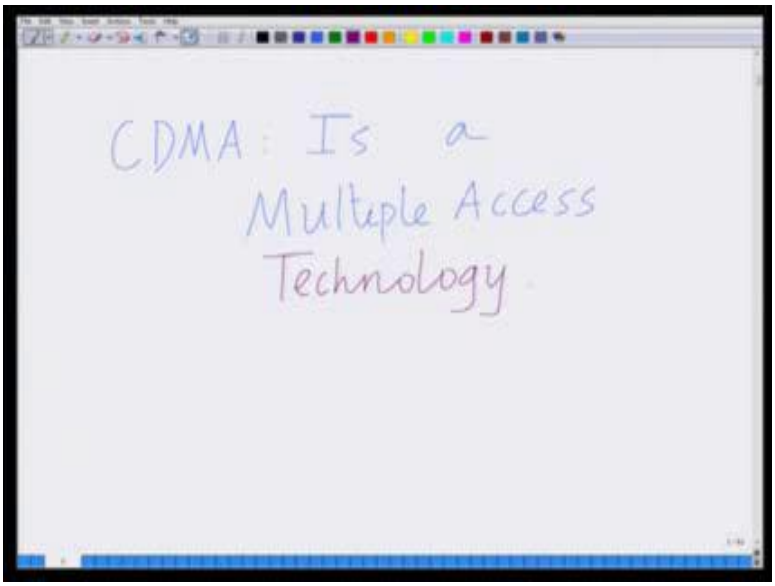

What is CDMA? At basically CDMA is a multiple access technology. CDMA is a technology for Multiple Access. Now what do we mean by multiple access. Multiple access is a very important component of any wireless communication system and it can be explained as follows for instance.

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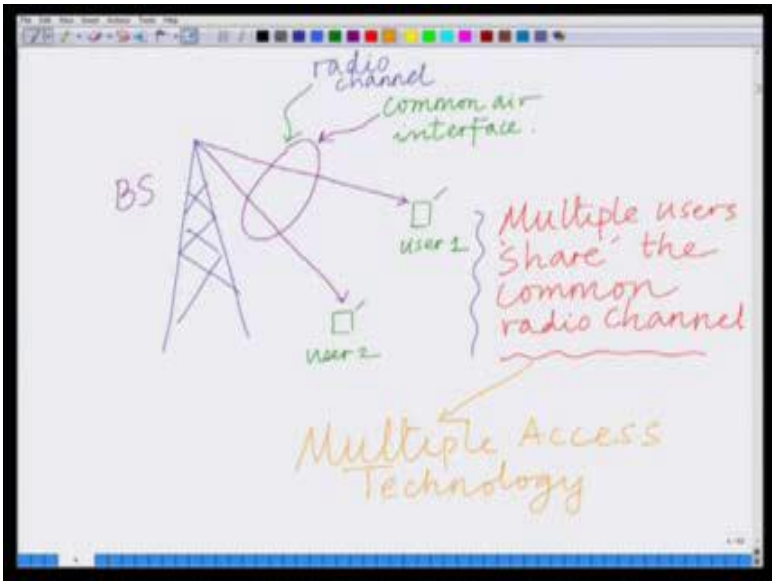

Let us say I have a Base Station, which I am representing by BS. Let us say its transmitting to 2 users let us take a simple example. Let us say this is user 1, let us say this is user 2 and the same Base Station and these 2 users are connected to the Base

Station over the common channel. Which is the air interface; this is the common radio channel or also the common air interface. You can also call this as the radio channel or the propagation.

The same Base Station is transmitting to multiple users. It is transmitting to user 1, as well as user 2. In fact, in practical scenario it is transmitting to several users, several 10s or even 100s of users simultaneously. These users with their mobile devices are beings are able to simultaneously access the Base Station over the common radio channel. That is unlike a wire line channel; in which there is a dedicated wire between the transmitter and receiver there is no dedicated channel between the transmitter and receiver. The several users are or these multiple users are simultaneously connecting to the Base Station over the common radio channel and therefore, these multiple users share the same radio channel.

What we have is basically, we have multiple users they share. Multiple users are sharing this common channel. There has to be a mechanism or there has to be a protocol to enable these multiple users to simultaneously share this radio channel and this technology is termed as the multiple access technology. At this mechanism through which multiple users share the common radio channel; this is termed as your Multiple Access Technology and CDMA is 1 such multiple access technologies. There are several multiple access technologies for instance you might have heard of TDMA, which is Time Division for Multiple Access which is used in GSM.

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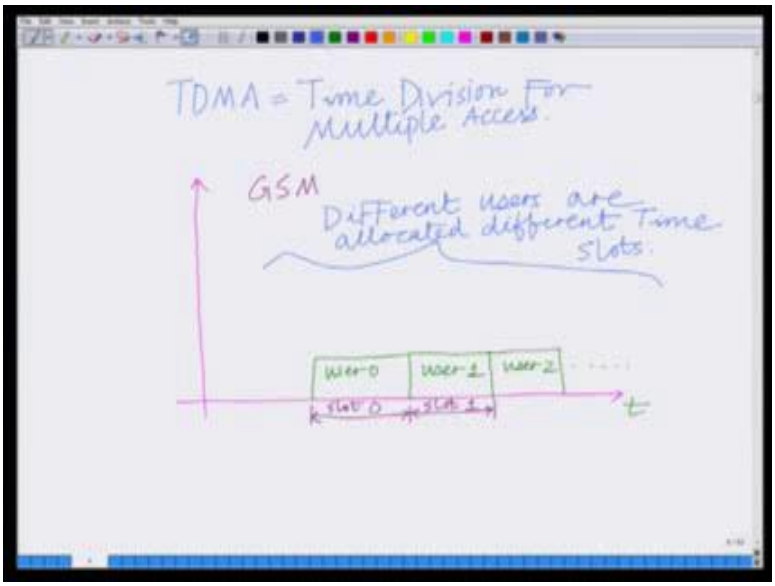

So, TDMA which is basically Time Division For Multiple Access which is used in our 2G wireless system, such as GSM which we have already seen in the first module that is the Global System for Mobile Communication. Where different users are allocated different time slots. So, this is user 0, user 1, and user 2 and so on. These are multiplexed or multiple users have different time slots.

This is the slot corresponding to user 0, slot 0, this is the slot corresponding to user 1. Different users are allocated different time slots for instance, this is used in GSM. That is the Global System for Mobile Communication. And the basic idea is that different users are allocated different. We have TDMA which is Time Division for Multiple Access in which multiple users connect to the Base Station in different time slots. This is known as TDMA that is Time Division for Multiple Access. Similarly the frequency domain analog of this is known as FDMA; which is frequency domain or Frequency Division Multiple Access, in which different users are assigned different frequency bands for transmission.

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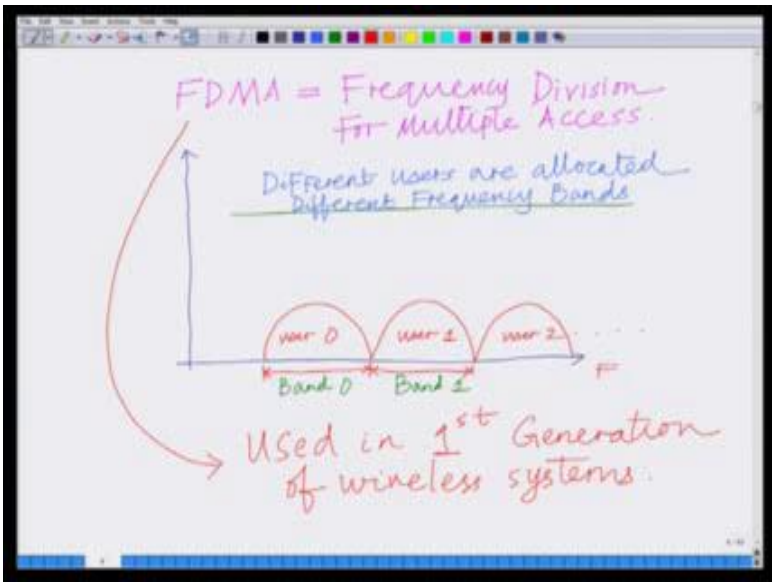

FDMA which historically is even prior to TDMA that it was used in first generation wireless communication systems in which different users. This is in the frequency domain, in which different users are allotted different frequency band. So, this is band 0 this is band 1. So, what we have is different users are allocated different frequency bands and this is termed as FDMA. Which stands for Frequency Division for Multiple Access and this is used in the first generation wireless communication systems and this technology FDMA is used in the very first generation of wireless communication systems.

What we have seen is TDMA which is Time Division for Multiple Access. In which the different users, mobile users are allocated different time slots and then we also have FDMA or Frequency Division for Multiple Access. In which the different users are allocated different bands in the frequency domain and each user transmits over his appropriate frequency bands and thereby multiple users are able to transmit simultaneously about the common radio channel and CDMA similarly is a Multiple Access Technology in which different users are allocated different codes. So, CDMA is also a Multiple Access Technology and the name itself.

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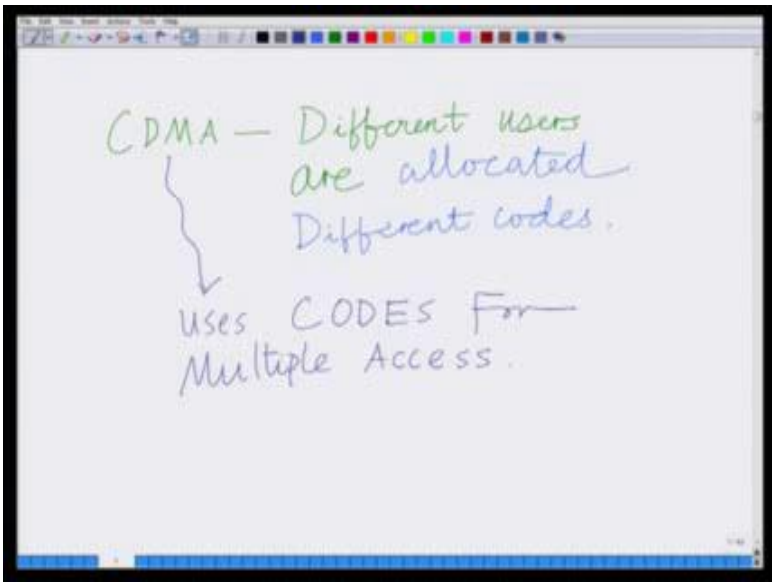

CDMA is Code Division Multiple Access in which different users are allocated different codes. It uses the concept of codes for multiple access.

CDMA uses codes for Multiple Access and different users are allocated different codes for transmission over the radio channel. And this can be explained with the aid of a simple example as follows for instance.

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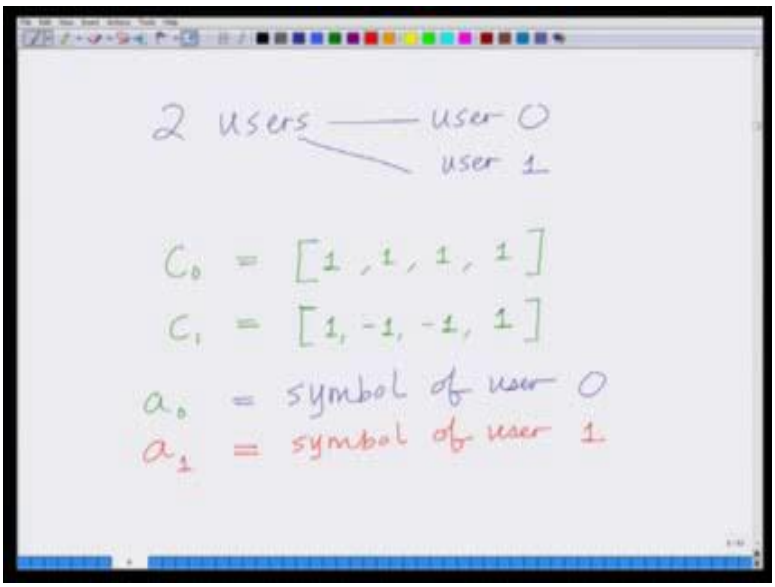

Let us take a 2 users scenario CDMA with 2 users. Let us call them user 0 and user 1 right. Now let us also allocate the following codes. So, code 0 for user 0, let us denote

this by this vector 1 1 1 1. So, it contains 4 elements these elements are also known as chips and code 1 of user 1 equals 1, - 1, - 1, 1. We have 2 users. We are considering a 2 user CDMA scenario with 2 codes c_0 and c_1,

c_0 is 1 1 1 1 and c_1 is 1, - 1, - 1, 1

Each code contains 4 elements and also now let a_0 denote the symbol of user 0. Therefore,

a_0 = symbol of user 0

a_1 = symbol of user 1

What we are going to now do is we are going to multiple the symbol of each user by the corresponding code and then we are going to add these 2 signals.

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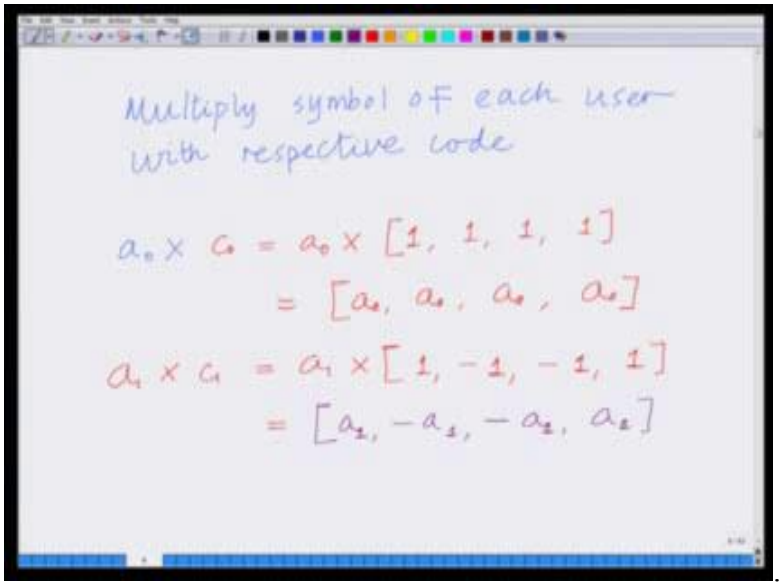

So, what we are going to do now is multiply symbol of each user with the respective code therefore, we have

a_0 x c_0 = a_0 x [1 1 1 1]

$= [a_0, a_0, a_0, a_0]$

$a_1 \text{ x } c_1 = a_1 \text{ x } [1 \text{ -1 -1 } 1]$

$= [a_1, -a_1, -a_1, a_1]$

Now, we are going to generate the sum signal or the combined signal at the Base Station and this is done by adding these 2 signals, this combined signal.

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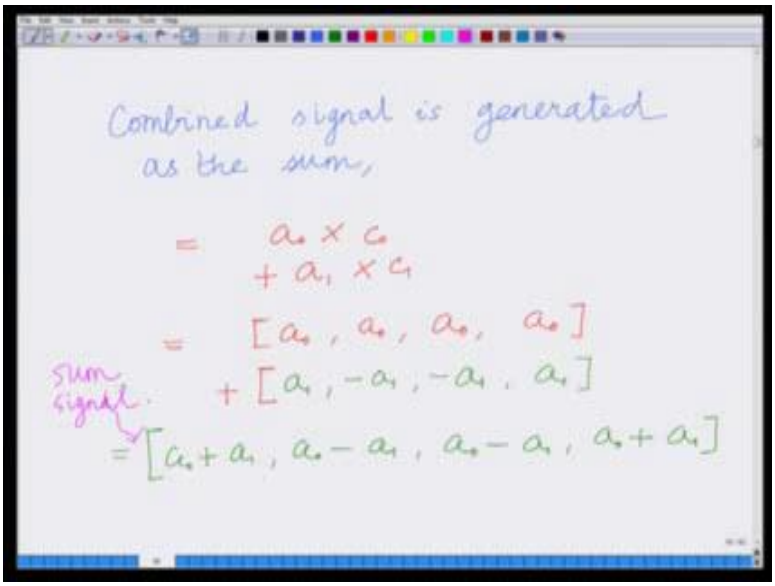

The combined signal is generated as the sum. We have the sum which is equal to

$= a_0 \text{ x } c_0 + a_1 \text{ x } c_1$

$= [a_0, a_0, a_0, a_0] + [a_1, -a_1, -a_1, a_1]$

$= [a_0 + a_1, a_0 - a_1, a_0 - a_1, a_0 + a_1]$

This is the combined signal. So, this is the sum signal what is this is the sum signal or the combined signal corresponding to the 2 users that is user 0 and user 1.

So, what have we done, we have multiplied symbol a_0 with c_0 of user 0. We have multiplied symbol a_1 with c_1 of user 1 and then we have performed the sum or we

have taken the sum of these 2 signals and the sum signal is transmitted over the common air interface or over the common radio channel.

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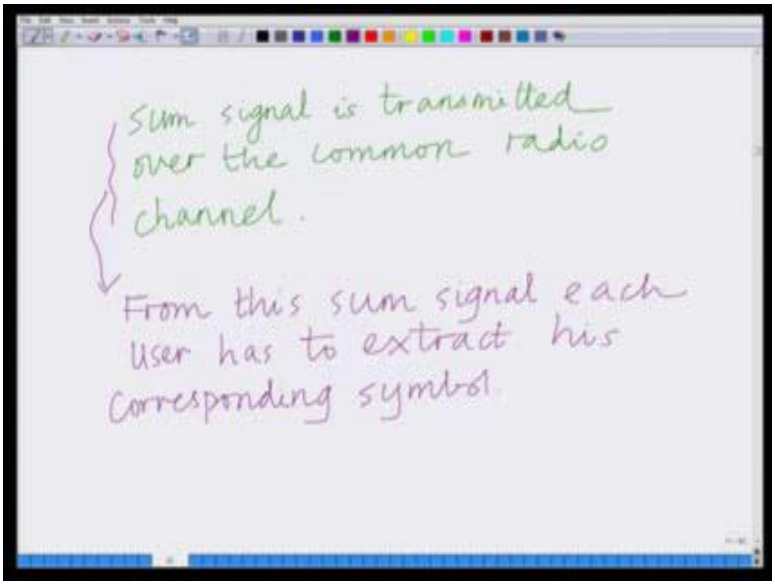

The sum signal is transmitted. The sum signal is transmitted over the common radio channel and from this sum signal each user has to extract his own symbol that is user 0 has to extract symbol a_0 and user 1 has to extract his symbol a_1.

From this common signal, from this sum signal each user that is both user 0 and user 1 each user has to extract his corresponding symbol. And let us see how this is done, each user correlates with his own code that is user 0 correlates with c_0; which means he multiplies each element of the signal with each corresponding element of the code and takes the sum.

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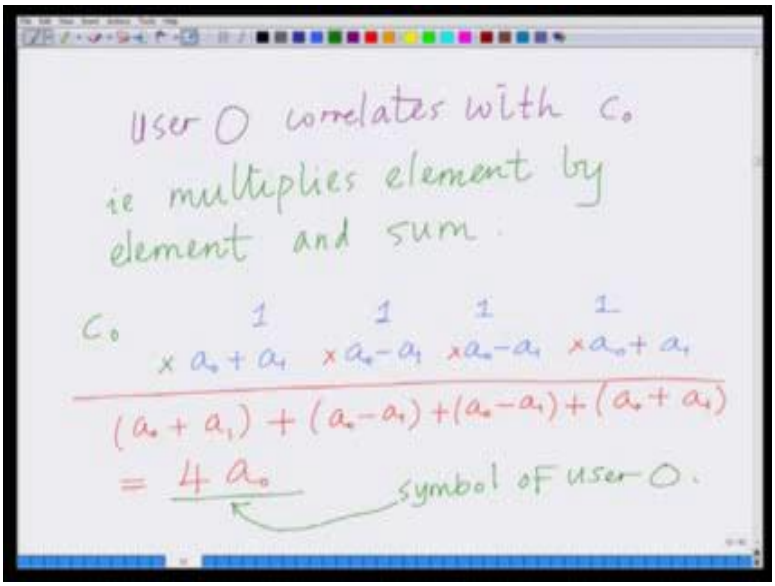

So, user 0 correlates with his code c_0, that is multiplies element by element, that is you multiply the received signal each element of the received signal with the corresponding element of the code and then take the sum.

For instance, the received signal is we have the element the code is c_0 is 1 1 1 1 and the received signal is basically, we have the received signal which is given as $a_0 + a_1$, $a_0 - a_1, a_0 - a_1, a_0 + a_1$ and therefore, we multiply each element of the code with the corresponding element of the signal and then we take the sum of all this.

$$1\,x\,(a_0 + a_1) + 1\,x\,(a_0 - a_1) + 1\,x\,(a_0 - a_1) + 1\,x\,(a_0 + a_1)$$

$$= 4\,a_0$$

By performing this correlation operation with c_0 which is the code of user 0 you are able to extract $4\,a_0$ which is basically nothing but it is a scaled version of the symbol a_0. So, user 0 is able to extract his symbol a_0 from this common signal that has been transmitted over the radio channel by performing this correlation this correlation is an element by element multiplication with the code followed by the sum. Similarly user 1 can now correlate with his code c_1. And similarly extract his symbol a_1.

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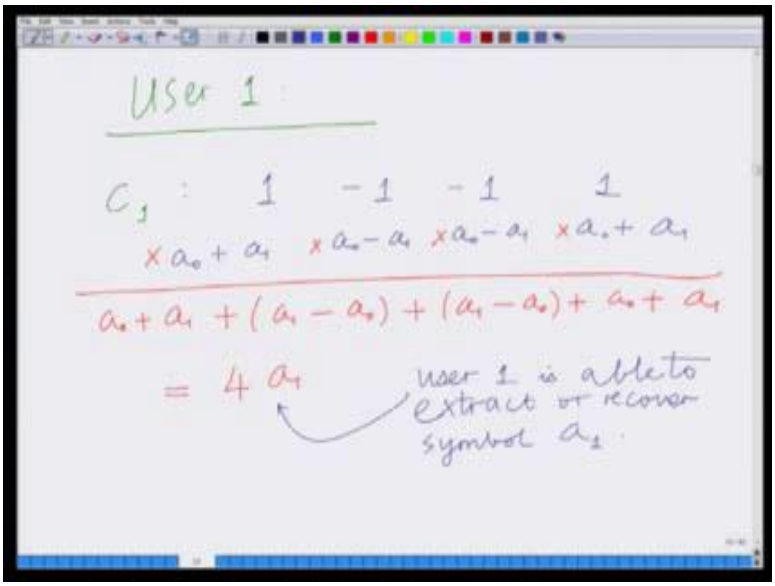

Let us look at for user 1, for user 1 his code is

c_1 is 1 -1 -1 1 and the received signal is basically, we have the received signal which is given as $a_0 + a_1, a_0 - a_1, a_0 - a_1, a_0 + a_1$ and therefore, we multiply each element of the code with the corresponding element of the signal and then we take the sum of all this.

$$1\,x\,(a_0 + a_1) - 1\,x\,(a_0 - a_1) - 1\,x\,(a_0 - a_1) + 1\,x\,(a_0 + a_1)$$

$$= 4\,a_1$$

which is nothing, but a scaled version of the symbol transmitted by user 1. And therefore, user 1 is able to extract or recover his symbol that is a_1.

So, what we have shown is the following thing; we have shown that the Base Station. You can multiply the symbol of each user with the corresponding code. That is symbol a_0 with c_0 of user 0, symbol a_1 with c_1 of user 1 then take the sum of these 2 signals and transmit this common signal over the air and each user can further correlate this received signal with the corresponding code of the user to extract his own received symbol thereby, multiple users are able to simultaneously access or simultaneously

connect to Base Station or simultaneously receive information symbols from the Base Station by using these codes; which are C_0, C_1 and so on for more user.

And therefore, this is Code Division for Multiple Access, where the codes are been used by these different users to simultaneously receive information symbols from the Base Station and this phenomenon of basically multiplication by the code and sum and transmitting the sum signal by the Base Station and correlation by the different users to recover their transmitted symbol system. This is the key principle behind CDMA which is Code Division for Multiple Access.

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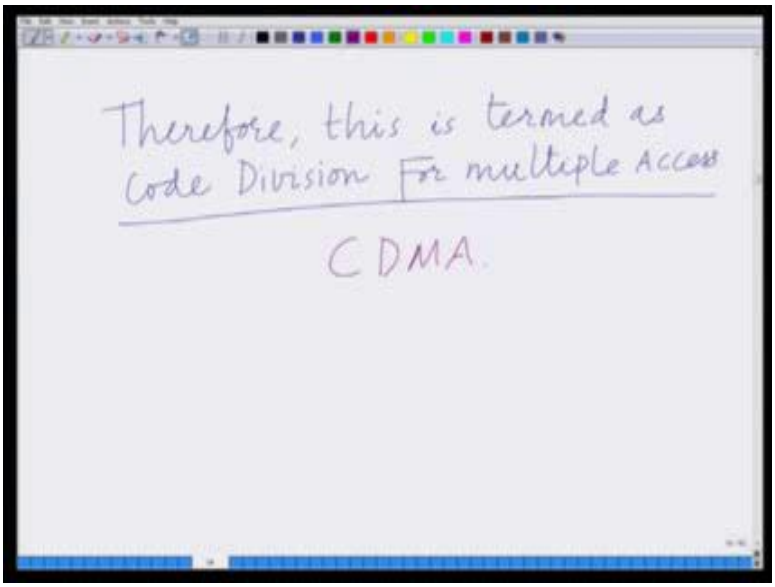

This is the key principle behind Code Division for Multiple Access. Therefore, this is termed as which is basically CDMA and this phenomenon, where different codes are being used by the Base Station to transmit the information symbols corresponding to the different users and the different users are able to simultaneously access the Base Station through their corresponding codes this is termed as Code Division for Multiple Access. This illustrates the principle behind CDMA.

And we will conclude this module here and continue with other aspects of CDMA in the subsequent modules.

Thank you very much.