Principles of Modern CDMA/MIMO/OFDM Wireless Communications

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Lecture – 27
Clip Time and Bandwidth Expansion in CDMA

Hello. Welcome to another module in this Massive Open Online Course on the Principles of CDMA, MIMO, and OFDM Wireless Communication System. Today let us look at another interesting aspect of CDMA communication system, previously what we said is that in a CDMA communication system each symbol is multiplied with a code.

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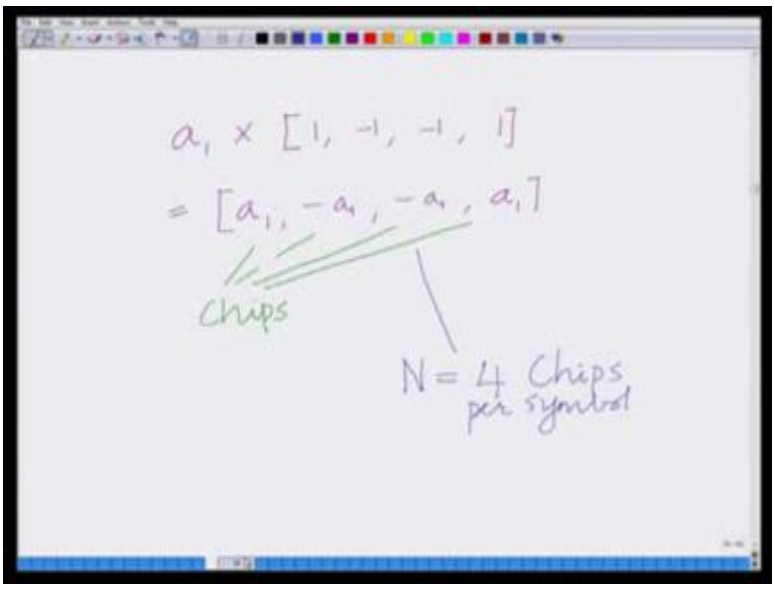

For instance, let us have a symbol a_1 of user 1 that is multiplied with the c_1 is 1, - 1, - 1, 1 to generate the samples $a_1, -a_1, -a_1, a_1$. These samples are also known as the Chips. In the context of CDMA, these samples are that have generate for each symbols, these are also known as Chips. Therefore what we are doing here is that, we are generating 4 chips that is n which is the length of the code equal to 4.

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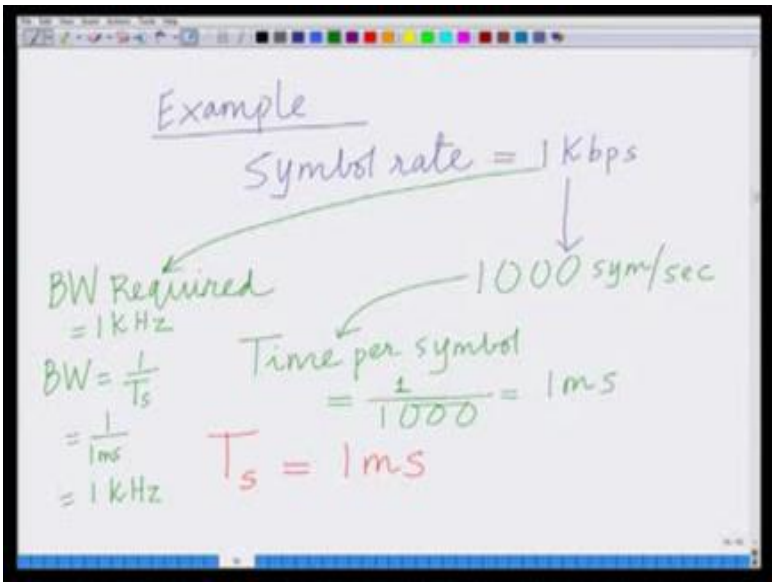

So, we are generating n equal to 4 chips per symbol. So, for in this simple example that we consider previously for each symbol, a_0 were generating 4 chips, first symbol a_1 were generating 4 chips, so a transmitting for chips per each symbol. Now consider a symbol example in which let same as symbol rate consider a simple example, in which the symbol rate equals 1 kilo bits per second, implies basically there are 1000 symbols per seconds.

So we have transmitting, let us say a thousand symbols every second the rate as 1 kilo symbols per second, we are transmitting 1 bit per every symbol, then it will be 1 kilo bit per second. Which implies that the time per symbols is equal to

$$T_s = \frac{1}{1000} = 1\text{ms}$$

since you are transmitting 1000 symbols per second, that time per symbol is equal to 1ms. So, our symbol time our T_s, which equal to symbol time is equal to 1 millisecond in this system. Also the symbol band width, the band width of the symbol since a symbol rate is 1 kilo bit per second, the symbol band width, the band width required for this system is equal to 1 kilo hertz. Since we have a symbol rate of 1 kilo bit per second or1 kilo symbol per second, the band width required for this system is one kilo hertz, this can

also be seen from the symbol time, and symbol time is 1 millisecond. Therefore band width is 1 over 1 millisecond, which is1 kilo hertz.

Therefore the bandwidth = $\frac{1}{T_s} = \frac{1}{1ms}$ = 1 kilo Hz.

So, the symbol time is 1 millisecond and bandwidth is 1 kilo hertz. Now in a CDMA system what we are doing is, we are transmitting n Chips or n is equals to 4 chips, in this specific example we a transmitting n equal to 4 chips per symbol. Which means if the symbol time T_s is equals to 1 millisecond, that Chip time T_c equals

$$T_c = \frac{T_s}{4} = \frac{1ms}{4} = 0.25\text{ms}$$

because we have to transmit for chips during the symbol time.

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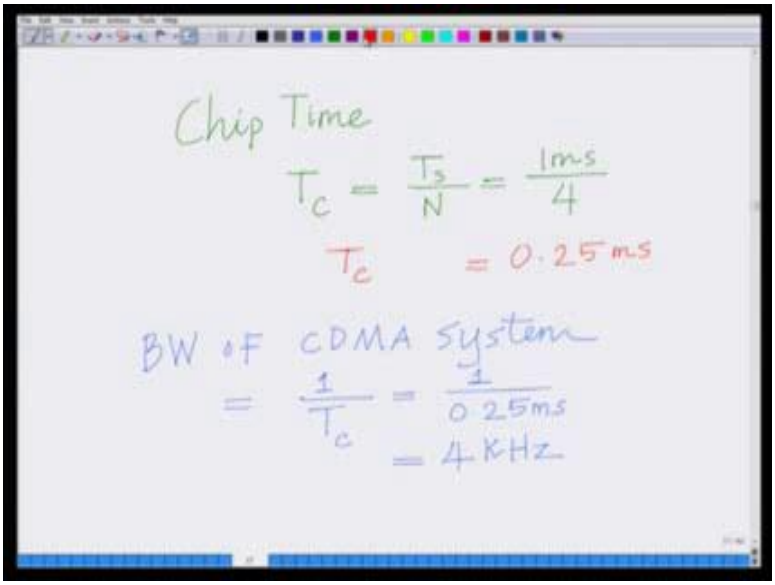

Therefore, the chip time T_c equals, symbol time T_s divided by n were n is the number of chips, which is

$$T_c = \frac{T_s}{n}$$

Since your transmitting n chips per each symbol, the chip time is symbol time divided by n or in other words for this examples 1 millisecond divided by 4 that is 0.25 millisecond. Now the new band width of the CDMA system is 1 over the chip time. Therefore band width of CDMA system is 1 over the chip time, which is 1 over 0.25 milli second is basically equal to 4 kilo hertz.

Therefore, the band width of the CDMA system is 4 kilo hertz, what we at seen previously is that, the band width of the system is 1 kilo hertz, now in the CDMA system because here transmitting more and more chips per each symbol, that band width as increase to 4 kilo hertz and therefore, the band width required for the CDMA system and this can be expressed pictorially as follows.

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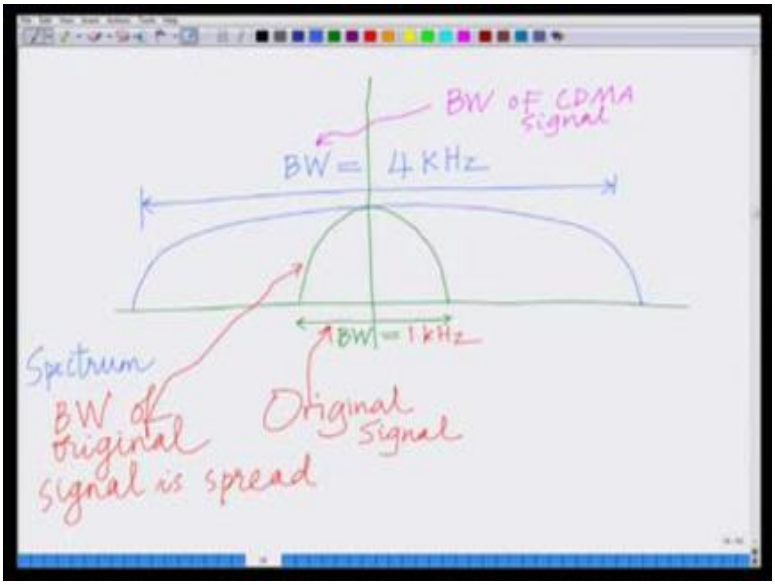

So, let us we have a original signal which as a band width, this is my bandwidth of the original signal which is 1 kilo hertz, this is the original signal, the band width of the new signal that is the CDMA signal is 4 kilo hertz, this is the band width, the band width as increased the band width of the CDMA signal equals 4 kilo hertz. So this is the band width of the CDMA signal.

So multiplying by the code as resulted in an increase in the band width of the CDMA signal or the bandwidth of the original signal is 1 kilo hertz, this bandwidth as been spread to 4 kilo hertz. So, the band width of the original signal is spread in a CDMA communication system. So what we are observing is that the bandwidth of the original

signal or the spectrum of the original signal; bandwidth or the spectrum this can also called as the “Spectrum’.

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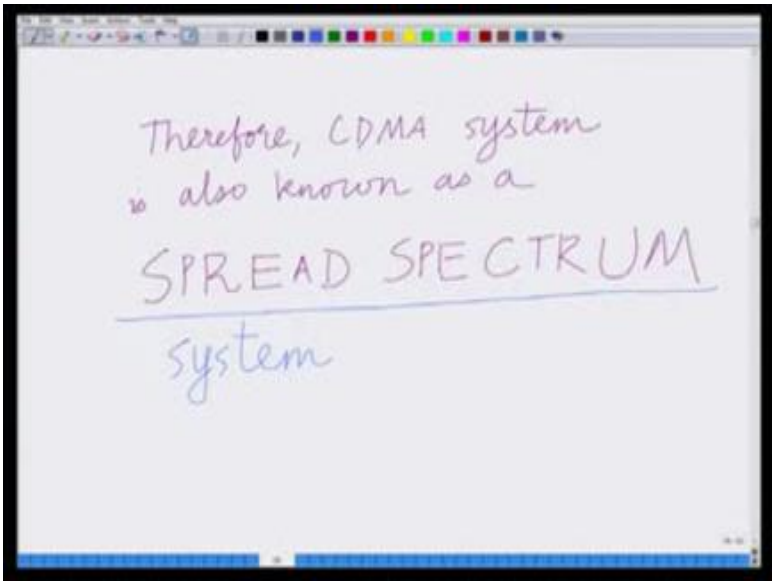

Spectrum of the original signal is spread in a CDMA system. Therefore CDMA system is also known as a “Spread CDMA System” and this is the key word. Because the band width of the original which is 1 kilo hertz, is spread by factor of n that is 4 times, to become 4 kilo hertz. In general if n is the length of the code the band width of the original signal is spread by factor of n.

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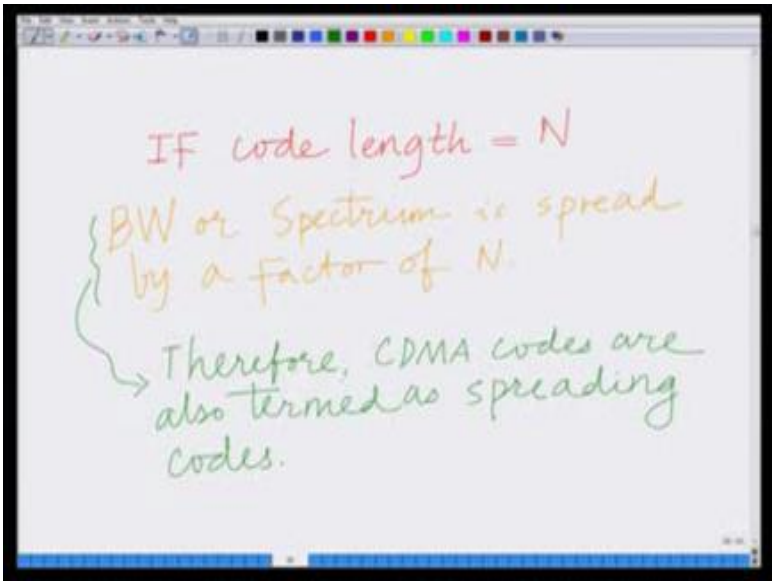

So, code length is N, then bandwidth or spectrum is spread by a factor of N. Therefore, the codes in CDMA system are also termed as a Spreading code. So, what we have seen is the following thing. Since, we are transmitting multiple chips per each symbol in a CDMA system.

This results in a spreading of the band width. The resulting band width of the system increases. Therefore CDMA is also known as Spread Spectrum System and these codes which spread the bandwidth of the signal in the CDMA system are also termed as the spreading code and this factor of n is also termed as the spreading factor.

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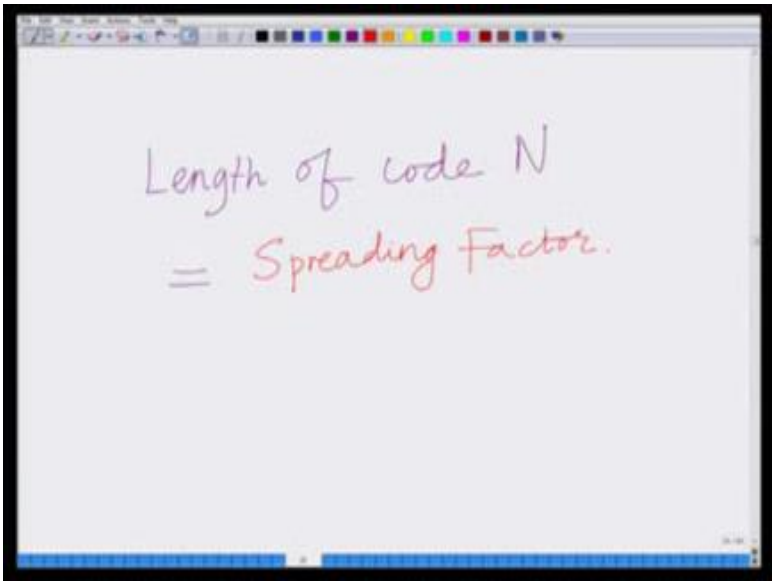

The length of the code N is equal to the spreading Factor in this Spread Spectrum CDMA system. So this module basically explains what is the reason behind calling CDMA as a Spread Spectrum System? What is the impact of the length of the spreading code on the CDMA system? We will stop this module here and we look at other aspects in the some sequent modules.

Thank you.