Spread Spectrum Communications and Jamming
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Lecture – 56
Interference Handling by Smart Antenna

Hello students. In continuation of our discussion for controlling the interference or handling the interference mechanism in a CDMA network. Today we will discuss the smart antenna techniques. Smart antenna the antenna systems which are capable to automatically adapt their beam pattern or antenna characteristics to the reception condition.

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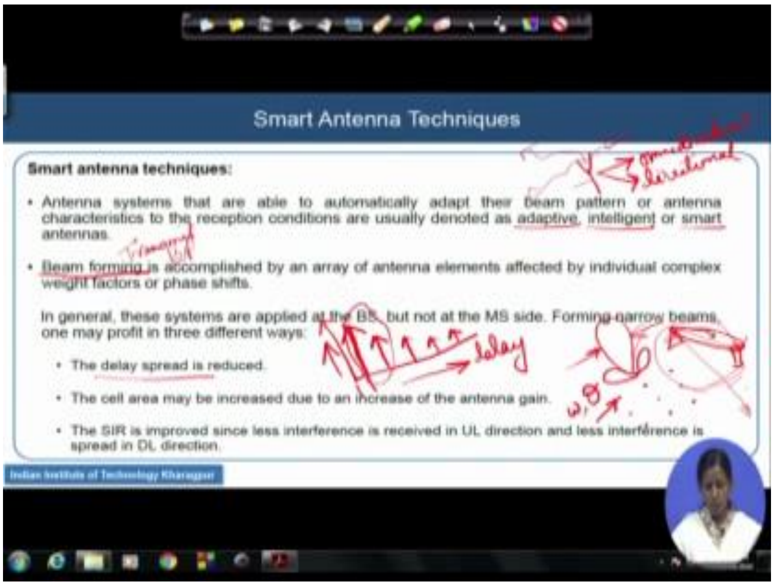

We will usually denote as an adaptive antenna or intelligent antenna or a smart antenna. So, usually in a communication system when we talk about an antenna, we usually think of an antenna which is omnidirectional. So, omnidirectional means the waves released from this, which is having no directivity and he will actually traverse the released beam, the released wave electromagnetic wave we can traverse on a 360 zone.

So, antenna also can be directional when the antennas are directional. So, in that situation we see that the electromagnetic waves are really focused to certain direction in the space and the total energy released in the earlier case unlike the omnidirectional case where, the total energy released is spread over 360 degree. The directional antennas the whole energy is heavily focused towards a certain direction. So, now, we are talking about a smart antennas who are basically able to automatically about their beams once we are actually talking about the directive antennas then, definitely we will have a typical beam pattern associated with this transmission. The beam, wherever the beam pattern is coming into picture the smart antennas are those antennas who can adaptively change this beam patterns and automatically adapt their beam patterns or they can change their antenna characteristics to such a way that the reception condition will be actually facilitated or they will be actually in terms of if it is our interest is signal to interference ratio such that the interference is reduced to that extent or the signal power is increased in other way.

So, the antenna of such capability who are adaptively changing their beam patterns and who are actually changing their antenna characteristics to facilitate the reception, to improve the signal to interference ratio we call them the adaptive antennas, which sometimes they are also called by the intelligent antenna or the smart antennas. So, this beam forming whenever we are talking about a beam or a beam pattern. So, then the some mechanism is going on inside the RF front end hardware architectured which actually is helping the antenna to form this beam pattern. We call it a beam forming.

So, this is accomplished by an array of the antenna elements and which are affected by the individual. So, all this antenna elements some elements are there for they form some architecture. There are several architecture there they can form all these elements they can form. So, for example, ULA or it is a linear circular architecture, circular array. The array may be actually uniform linear array or it can be a circular array. It can be a rectangular array actually this each and every element that you are seeing inside this array they will be actually fed with different kind of the complex wed vectors and some phase shifts they will have. So, based on the different wed vectors and the phase shifts jointly there is elements will form the beam.

So, when I am saying that you are changing the beam pattern. So, you are basically changing the wed vectors and the phase values of this antenna pattern to give a typical shape of this beam and even you are changing the direction of this beam. So, the totally the whole process, when you are changing the whole process of changing the beam pattern as well as the direction of the beams is called Beam forming. So, in general the systems are applied at the base stations because it is a transmit beam forming in the conventional ways. We see the beam forming is in that transmit beam forming because it involves lot of signal processing and the control in the hardware and the power consumption definitely involved. So, we initially we preferred to use this beam forming only in the base station. So, most of the beam forming that is deployed till today they are available today, they are the transmit beam forming but in tomorrow's communication system you will see that beam forming is also done in the mobile station and the handset in your receiver, which is a receiver as well as transmitter.

So, inside the mobile handset sometimes we use a beam forming architecture. Even for tomorrow then you will see that there is transmit as well as the receive beam forming. So, the array structure will be also involved inside the mobile station and jointly actually he will take part with the base station to maximize the gain and actually to heavily synchronize with the receiving antenna architecture that with the transmitting architecture. So, that the signal to receive signal to interference is maximized.

The actually this as we understand that this beam whenever we are giving some directivity, we are also narrowing down the width of the beam. We are varying actually the width of the beam. Actually if we feel, if we come to very narrow beams then we can get lot of facility from that narrow beams. What are they? Let us see. See the delay spread is reduced what is this delay spread? So, if I see the power delay profile of a channel, which is basically how the power of the different multi paths are spread over the delay axis. We understand that the multi paths that are coming to the receiver from much wireless channel they come like this. The direct line of site path approximately arrives almost at the, with some delay, with some initial delay from the transmitter because transmitting time and the reception time cannot be instantaneously same.

So, if this is a T equal to 0 with a initial transmit to receive delay after that time the line of site path will come from transmitter to receiver. Then the after fast reflection then immediate next path will come, then the third one will come, the fourth one will come and the fifth one will come like this. So, these are first reflection, second reflection, third reflection, fourth reflection like that actually one by one; one by one the different reflected rays are arriving in the receiver and over a certain delay you are going to expect the some part of the same signal it is getting repeated over the multiple paths.

So, we call it a power delay profile. This is a power value of those paths of the received signal we are saying. Now you see this is the situation of the case if you release the energy over 360 degree or 360 degree from the antenna. Then for this directional antenna cases we prefer to give actually we prefer to feed all the power to as a certain direction. So, in such that they it may happen that you are not going to get all the multi paths because power is not released to all the direction. So, there is a chance that you will get a reflection from all the direction of what necessary. You will receive the multi paths, but from certain direction. So, over the long delays are not actually there in your concern. It is the power is released in such a way it may happen that only two or three of the components you are getting as which are actually really involved in your consideration.

Hence, actually the delay spread of the signal that can be heavily reduced if I use a very narrow beam transmission. As we are focusing the power so you see as the power is more. So, all the power now earlier cases over this (Refer Time: 09:46) communication power most of the power is spread over the channel and over 360 degree zone and you cannot capture also all the power in the receiver. But if you are having a very focused power towards the directed to from the base station towards the mobile station after knowing your location it is all the power is heavily directed like this, then you can actually have a very high power reception inside that. So, received signal power compared to the interference plus noise will be very very high.

So, now what you can do is, you can increase the distance between the transmitter and the receiver and the mobile station more. So, in that sense actually earlier the cell size was say like this, when you are having the omnidirectional transmission and when we are having the directional transmission your cell area can be increased now. And signal to interference ratio is even if you are not doing that and if you are confined to the earlier cell area definitely actually your signal to interference ratio is heavily improved. So, the smart antenna technique and plays a very very nice role in controlling the interference of a CDMA network and it is a interesting technique actually though by means of which you can actually enhance the signal to interference ratio.

You can increase the cell radius; you can increase the data rate of the transmission because you are gaining in terms of the received signal power. So, it has huge advantage.

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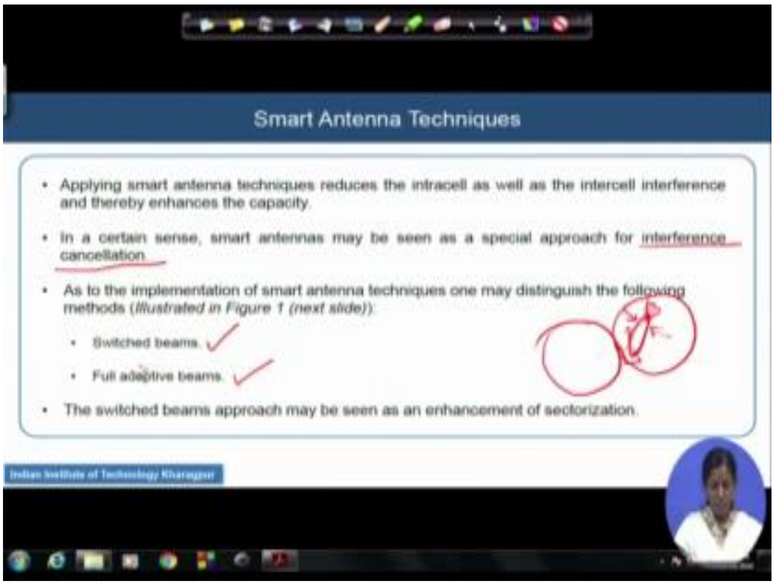

And if I use this smart antenna technique so that intra cell, inter cell interference that was our main concern when we were discussing the interference handling mechanism in the last module and also in the last two modules we were really very very concerned when we were doing the soft handover. We were really very very concerned about the cell users and the boundary and where actually their transmission power can go actually here and there all that.

So, if I apply the smart antenna so then, base station will be not releasing the energy in the omnidirectional area. So, it will be heavily focused if it is heavily focused. So, it can heavily reduce also the intra cell interference. The interference that are coming from the other users to this user and if I apply the transmitter I mean transmit beam forming capacity is also there in the mobile station. He can also focus the transmission towards the typical zone. So, he cannot actually give any interference to the neighbouring cell users and the base station and hence actually the intra cell, inter cell interference also can be handled.

So, smart antenna technique, when the smart antenna technique is applied over the base station he can control the intra cell interference and if it is applied in the mobile station then it can handle not only the intra cell it can also handle the inter cell interference. Same thing actually for the base station because from base station to base station also some interference may come in certain situation, but if you are focusing like this you are focusing the beam towards your direction where is your wanted direction then you can really control the inter cell interference also.

The smart antenna that is why we see, that the smart antenna technique is nothing, but an interference a very good approach for your interference cancellation and it is not handling its typically the interference cancellation directly. As to the implementation next one we will see the structure of this smart beam structure of these smart antenna techniques. So, there are two different ways to implement this smart antenna techniques; one is the switched beam techniques another is the full adaptive beam technique and the switch beam approach it may be seen as some enhancement of the sectorization we will see in the next.

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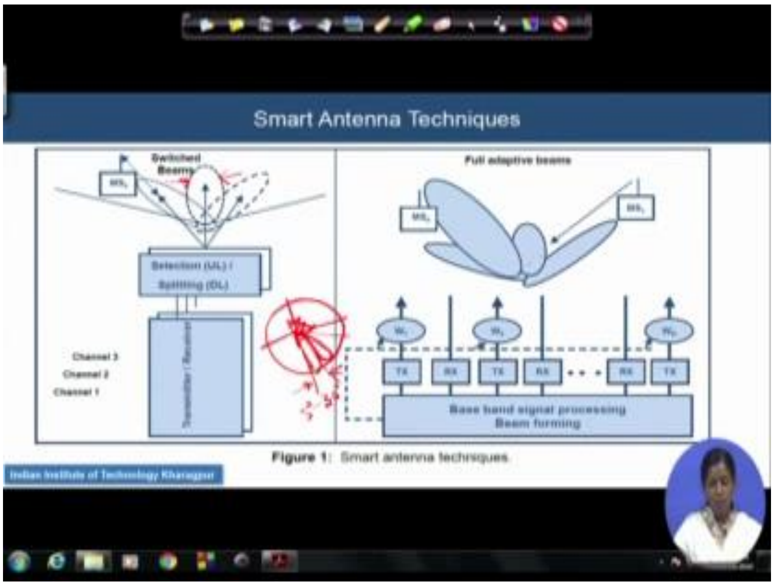

These are two mechanisms; one is a switched beam; in the left side is the switch beam and the right side is the full adaptive beams and remember this switched beam technique here, the fixed the beam width that is generated inside the transmitter or receiver architecture the width is fixed. And only the beam is moving from one to the next beam, to the third beam, to the fourth beam like this and what you are trying to do is suppose you had a cell which was sectored earlier and within this sectors, here is a base station setting and then actually his target is to actually target this sector and inside this sector he will now divide some sub sector.

That sub sector is actually a situation that base station knows there is no intimation actual sub section is there in practice, he is dividing this sub section and suppose a width of the sub section may be varying from 5 degree to 30 degree and this 5 degree to 30 degree width is basically the width of the beam that he will create. So, once actually he is creating a beam of 5 to 5 degree say, suppose it is 30 degree and it is 30 degree and he is focused towards this direction. So, he anybody actually within this zone of width of 30 degree and this direction; sub sector one direction then he will be receiving the signal from the base station. None of the users of the other sub sectors will be able to receive it.

Now, what will happen if the mobile moves from sub sector 1 to sub sector 2? Then he will simply switch the beam from sub sector 1 to sub sector 2 by changing the direction, but not changing the width of it. So, this way actually if the mobile station is moving he will simply keep on moving the beam. So, it is the switching the beam from sub sector to sub sector and even if the mobile is moving from the leaving this whole sector and entering into the next sector, the beam can move to that other sector also. So, this is a switched beam architecture, but remember whenever we are actually forming the beam there are some null spaces like this where, actually if the mobile station is here there may be a chance that there would be any coverage by the beams because there it is not a continuous beam, it is not like that that the when you are moving the beam is continuously moving with you.

It is beam width is switching from one to the next. So, next beam, third beam, fourth beam, fifth beam is continuously taking care of you. So, this is a structure of the switched beam. Whereas, in the full adaptive beams we are having a very complicated base band beam forming architecture associated with the RF front end where the wed vectors of the transmitting antenna array elements are continuously actually changing based on the which you have to track the location of the mobile station.

So, here not only the beam is formed, a single beam is formed and continuously actually it will trace the mobile station and it will form the beam in such a way that the SNR is maximized for the intendment receiver and the reception of the signal from the other mobile users actually will be the direction from where the mobile stations, other mobile station signal will be receiving they will be really closed to 0.

So, the interference level is assured to be very very less to the other neighbours as well as when you are moving the beam is continuously moving with you, but really frankly speaking is very hard to implement in practice because then you need to know the continuous channel condition and that update the complete channel vector information a priori should be we there with you, over the trajectory of your movement and based on that actually this wed vectors will be continuously applied and such that actually SINR can be maximized at your end. So, it is very hard to get the a priori information about the channel to do this implication and that is why the switch beams technique though, it has a lot of draw backs like this getting a null direction and gets a null space and null direction like that.

So, but switched beam is much more easy to for implementation and it is most popular and currently used in practise also.

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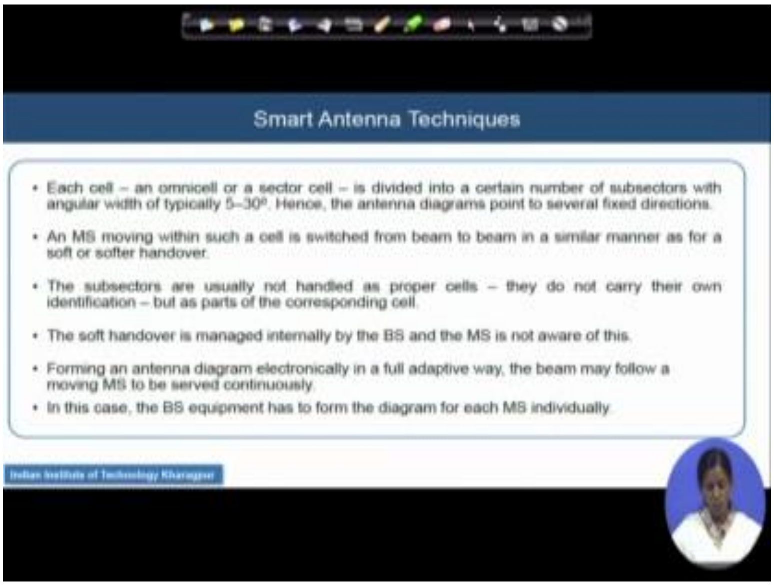

And this soft handover sometimes actually remember the sub sectors that I have already talked in the last one. The sub sectors and all there is no actual declaration of the sub sectors to the mobile users or in the network wherever. Only the base station divides it in such a way based on this hard work constraint and then he will actually do the control. It is a term complete control is there going on inside the base station if it is transmit beam forming. In case of my received in case of the uplink I mean the beam forming inside the receiver itself that is a completely different technique.

So, currently this sectorization and all and the sub sectorization of a sector itself is completely done and it is processed inside the base station. The soft handover is managed internally by the base station and the mobile station that is why is not at all aware of this. Like that the smart antenna technique is also inside the base station and mobile station is not aware of it. And as I already discussed that making a full adaptive way beam forming and full adaptive way controlling the beams for you, for a dedicated mobile station it will be very hard to control and then moving with the mobile station itself it needs lot of a priori information and hence we do not prefer to go ahead with that going by the complications.

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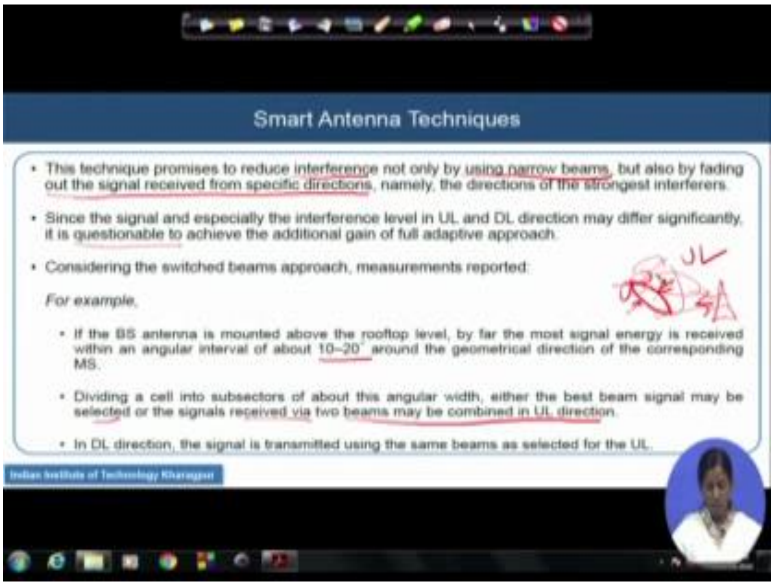

But now remember see the plus points of this techniques, smart antenna technique. It promises to reduce the interference. It is not only by using the narrow beams, but also by fading out the signal received from the specific direction. So, it is as if working as a special filter. So, he is not only maximising actually the interference, maximizing the signal power by focusing or saying or pouring maximum amount of the transmitted signal power inside a two (Refer Time: 21:04) specific direction, but also it is fading out all the signals that are coming out from the different directions.

So, the direction which are the strong interfering direction, if I have a priori indication or a priori information about that direction; so I can control the beaming width in such a way that the interference from those directions are not at all fall into the main beam width of my transmission and then hence actually I am totally get rid of that interference. Since the signal and the specially the interference level in the uplink as well as in the downlink they are actually having totally different kind of the interference pattern of the channel is having to a completely different kind of the interference pattern.

So, hence this technique is questionable to achieve the additional gain with the full adaptive algorithms. That is why the full adaptive algorithms are not so popular in practice. Let us have an example; if a base station antenna is mounted over the roof top level and where the most of the signal then you can receive there, over an angular spread of 10 degree to 20 degree around the geometrical direction of the corresponding MS. And now dividing this cell and the sub sectors into with this angular width either by the based beam signal, may be selected or the signals received by the two beams may be combined in the uplink direction. So, what is the situation is? Situation something like this the mobile station to the base station, that combination is giving you the maximum signal energy within a degree of 10 to 20 degree of the beam width.

So, if this is the situation then either I can select any one of the beam; maximum best beam signal that is coming or the signals that are received via the two different beams. May be the beam was switched here and then some other transmission was done, but in the sitting in the base station I have received both the beam powers and then I can do either select any one of them or I can do some combination of these two to have a choice of it. So, that is all in the uplink situation the wave I can go ahead with.

In downlink direction, the signal is transmitted using the same beams as selected by the uplink because uplink is more critical and remember once you are choosing the same beam for the downlink as you have chosen for the uplink, then you consider that the channel condition is not changing during the uplink and downlink which sometimes is too critical for the practical approach.

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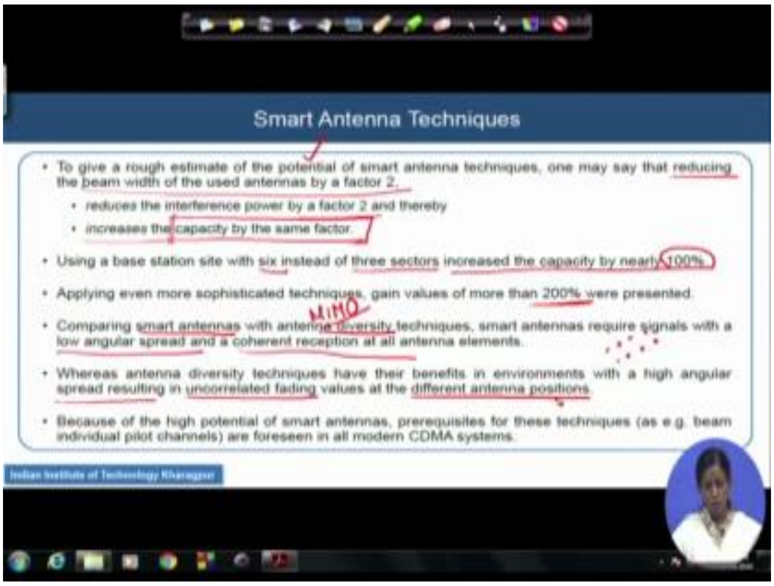

We do not get that kind of situation always truly. So, in order to give a very rough estimate, what is the potential of these smart antenna techniques? So let us take an example.

One may say, if I reduce the beam width of the used antenna by a factor of two say. I mean I had say 60 degree beam width I have reduced it to 30 degree. So, the antenna beam width this is to half. If I do that then it reduces the interference by a factor of 2, but it increases the capacity by the same factor of 2. So, as a interference is getting reduced also remember the signal power is getting more confined towards the within the beam width and your capacity we will be reduced by the same factor. There is a fast potential is very important potential of the smart antenna technique coming into picture and using a base station site with six. So, I mean six base stations are there and instead of the three sectors increase the capacity by nearly 100 percent this is a, from this result is from a practical measurement.

If we use the base station site with six instead of the three sectors, we could see that the capacity is nearly increasing by 100 times and applying even more sophisticated techniques this gain value that we are seeing that can be actually even increased by 200 percent. Now this comparing the smart antenna with the antenna diversity technique what we get via the MIMO architecture, MIMO antenna utilized for the antenna diversity, if I compare that with the smart antenna. So, where is the gain? Who is what?

Giving what? Then we will see that the smart antenna, they require the signals with the low angular spread and a coherent reception is heavily required at all the antenna elements and antenna elements are spaced in such a so that actually you can actually process the signal to get the maximized to process the signal to maximize a input SINR, but in the antenna diversity technique all the signals and the benefits comes from the environment with the high angular spread only.

So, here low angular spread and related coherent reception is giving you the gain and in case of the MIMO antenna with diversity techniques they with the long spreading angular spread because of which you would not get any relation uncorrelated fading you will get. So, that you can consider each and every path to be independent to each other that will give you the diversity gain.

So, that is why actually they are the different antenna positions are considered and we are getting the diversity gain on that. So, they are completely different approach one is the actually controlling, one is having the un-correlation of the fading because of which actually the gain is coming. Another is actually relying on the low angular spread and the coherent reception because of which actually the gain can be coming from and because of this high potential of this smart antenna. So, prerequisites for this techniques for example, the beam individual pilot channels they are forcing for this modern CDMA systems and we are actually in coming future we will be seeing as I have already discussed that, the current CDMA techniques and the current most of the current mobile communication techniques they prefer to use the transmit beam forming techniques.

But in near future we will be able to see that for the short range communications as well as for the outdoor mobile communications, for the 5 g both the transmit as well as a received antenna beam forming using the smart antennas will drive the communication system.