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Non-Orthogonal Multiple Access (NOMA) With Beamforming

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Abstract;- **Non-Orthogonal Multiple Access(NOMA) is one of the promising radio access techniques for performance enhancement in next-generation cellular communications. NOMA offers a set of desirable benefits including high spectral efficiency. Beamforming (BF) is a signal processing technique used in various wireless systems for directional communications. The integration of both NOMA with multiuser BF(NOMA-BF) has the potential to capture the benefits of both NOMA and BF. NOMA with beamforming can exploit the power domain as well as spatial domain to increase spectral efficiency. NOMA-BF system improves the sum capacity, compared to conventional multiuser beamforming system. Due to beamforming, signals from one cluster to the other are suppressed. This paper discusses the performance of NOMA when it is integrated with beamforming techniques**

Keywords;- **Beamforming, NOMA, Spectral Efficiency, Sum capacity**

I. INTRODUCTION

Non-Orthogonal Multiple Access (NOMA) is an essential enabling technology for 5G wireless networks to meet the heterogeneous demands on low latency, high reliability, massive connectivity, and high throughput. The key idea of NOMA is to use the power domain for multiple access, whereas the previous generations of mobile networks have been relying on the time/frequency/code domain. Take the conventional Orthogonal Frequency-Division Multiple Access (OFDMA) used by 3GPP-LTE as an example. A main issue with this Orthogonal Multiple Access (OMA) technique is that its spectral efficiency is low when some bandwidth resources, such as subcarrier channels, are allocated to users with poor channel conditions.

Traditional base station antennas in existing systems are either omni-directional or sectorised. There is a waste of resources since the majority of transmitted signal power radiates in directions other than toward the desired user. In addition, signal power radiated throughout the cell area will be experienced as interference by any other user than the desired one. Concurrently the base station receives interference emanating from the individual users within the system. Smart Antennas offer a relief by transmitting /receiving the power only to/from the desired directions.Smart Antennas can be used to achieve different benefits. The most important is higher network Capacity.It provides better range or coverage by focusing the energy sent out into the cell, multi-path rejection by minimizing fading and other undesirable effects of multi-path propagation.

Adaptive antenna can be used to achieve different benefits. By providing higher network capacity, it increases revenues of network operators and gives customers less probability of blocked or dropped calls. An adaptive antenna consists of number of elements whose signals are processed adaptively in order to exploit the spatial dimension of the mobile radio channel .All elements of the adaptive antenna array have to be combined in order to adapt to the current channel and user characteristics. This weight adaptation is the "smart" part of the adaptive antenna. The adaptive antenna systems approach communication between a user and base station in a different way, in effect adding a dimension of space. By adjusting to an RF environment as it changes, adaptive antenna technology can dynamically alter the signal patterns to near infinity to optimize the performance of the wireless system. Adaptive arrays utilize sophisticated signal-processing algorithms to continuously distinguish between desired signals, multipath, and interfering signals as well as calculate their directions of arrival. This approach continuously updates its transmit strategy based on changes in both the desired and interfering signal locations. Adaptive Beam forming is a technique in which an array of antennas is exploited to achieve maximum reception in a specified direction by estimating the signal arrival from a desired direction while signals of the same frequency from other directions are rejected. This is achieved by varying the weights of each of the antennas used in the array. It basically uses the idea that, though the signals emanating from different transmitters occupy the same frequency channel, they still arrive from different directions. This

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spatial separation is exploited to separate the desired signal from the interfering signals.

Beamforming is a signal processing technique used in sensor arrays for directional signal transmission or reception. This spatial selectivity is achieved by using adaptive or fixed receive/transmit beam patterns. The beam pattern is formed by adjusting complex weights of the antenna elements so that the beam is directed in the direction of interest. When receiving, the information from different sensors is combined in such a way that, the expected pattern of radiation is preferentially observed. Thus Receive Beamforming increases the sensitivity in the direction of desired user than that of interferences., A beamformer controls the phase and relative amplitude of the signal at each transmitter when transmitting and produces a high directional beam in the direction of desired user and null in the direction of interferences, thereby increasing SINR of the desired user and reducing the wastage of transmitted power in the undesired direction. The reception beamforming is achieved independently at each receiver while in the transmit beamforming, the transmitter has to consider the all receivers to optimize the beamformer output. This paper presents three methods of beamformer design namely the phase shift beamformer, the Minimum Variance Distortionless Response (MVDR) beamformer, and the Linearly Constrained Minimum Variance (LCMV) beamformer.

II.NON-ORTHOGONALMULTIPLE ACCESS (NOMA)

The use of NOMA enables each user to have access to all the subcarrier channels, and hence the bandwidth resources allocated to the users with poor channel conditions can still be accessed by the users with strong channel conditions, which significantly improves the spectral efficiency. Furthermore, compared to conventional opportunistic user scheduling which only serves the users with strong channel conditions, NOMA strikes a good balance between system throughput and user fairness. In other words, NOMA can serve users with different channel conditions in a timely manner, which provides the possibility to meet the demanding 5G requirements of ultra-low latency and ultra-high connectivity. Considering the combination of NOMA and Multiple-Input Multiple-Output (MIMO) technologies. Various MIMO-NOMA designs will be introduced to achieve different tradeoffs between reception reliability and data rates, since spatial degrees of freedom can be used to improve either the receive Signal-to-Noise Ratio (SNR) or the system throughput. The concept of cooperative NOMA will then be described, where employing user cooperation in NOMA is a natural choice since some users in NOMA systems know the information sent to the others and hence can be used as relays. In addition, cooperative NOMA has the potential to exploit the heterogeneous nature of future mobile networks, in which some users might have better capabilities, e.g., more antennas, than the others. Therefore, the reception reliability of users with poor capabilities can be improved by requesting the ones with strong capabilities to act as relays.

III. NOMA WITH BEAM FORMING

NOMA with Beam Forming (NOMA-BF) can exploit the power domain as well as the spatial domain to increase the spectral efficiency by improving the SINR. To see this, consider a system of four users as shown in Fig.1, There are two clusters of users. User 1 and User 3 belong to cluster 1, while User 2 and User 4 belong to cluster 2. In each cluster, the users spatial channels should be highly correlated so that one beam can be used to transmit signals to the users in the cluster.

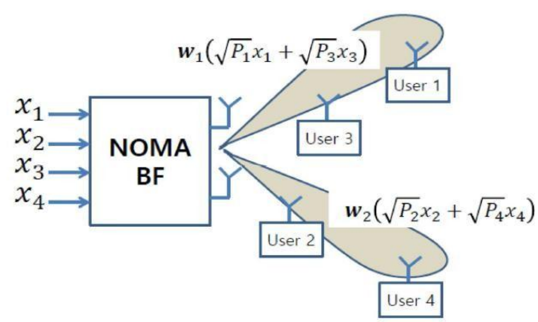

Fig1: An illustration of NOMA with beam forming.

Due to beam forming, the signals from one cluster to the other are suppressed. Thus, at a user in cluster 1, the received signal would be a superposition of $x1$ and $x3$,

while a user in cluster 2 receives a superposition of $x2$ and $x4$, where xk is the signal to user k. As shown in Fig1, if User 3 is closer to the BS than User 1, User 3 would first decode $x1$ and subtract it to decode $x3$ using SIC. User1 decodes $x1$with the interference, $x3$. Clearly, conventional NOMA of two users can be applied in each cluster. This approach is studied to support 2N users in the same frequency and time slot with N beams that are obtained by Zero-Forcing (ZF) beam forming to suppress the inter-cluster interference. A two-stage beam forming approach is proposed using the notion of multicast beamforming . It is assumed that the users have multiple receive antennas. Thus, receive beam forming can be exploited at the users to suppress the inter-cluster interference. In this case, the BS can employ a less restrictive beam forming approach than ZF beam forming.

IV. SIMULATION RESULTS:

A.Phase Shift Beamformer:

A beamformer can be considered a spatial filter that suppresses the signal from all directions, except the desired ones. A conventional beamformer simply delays the received signal at each antenna so that the signals are aligned as if they arrive at all the antennas at the same time. In the narrowband case, this is equivalent to multiplying the signal received at each antenna by a phase factor.

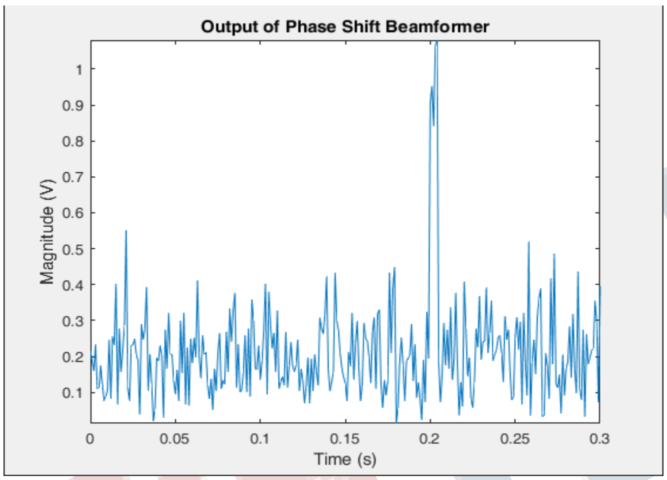

Fig2: Output of Phase Shift Beamformer

From the fig2, it is observed that the signal becomes much stronger compared to the noise. The output SNR is approximately 10 times stronger than that of the received signal on a single antenna, because a 10-element array produces an array gain of 10. Next, use the beamformer to enhance the received signal under interference conditions. In the presence of strong interference, the target signal may be masked by the interference signal. For example, interference from a nearby radio tower can blind the antenna array in that direction. If the radio signal is strong enough, it can blind the radar in multiple directions, especially when the desired signal is received by a sidelobe. Such scenarios are very challenging for phase shift beamformer, and therefore, adaptive beamformers are introduced to address this problem. To overcome the interference problem, the MVDR beamformer is used.

B.MVDR Beamformer:

The MVDR beamformer preserves the signal arriving along a desired direction, while trying to suppress signals coming from other directions. In this case, the desired signal is at the direction 45 degrees in azimuth. MVDR beamformer pointing to the target signal direction and apply the MVDR beamformer to the received signal

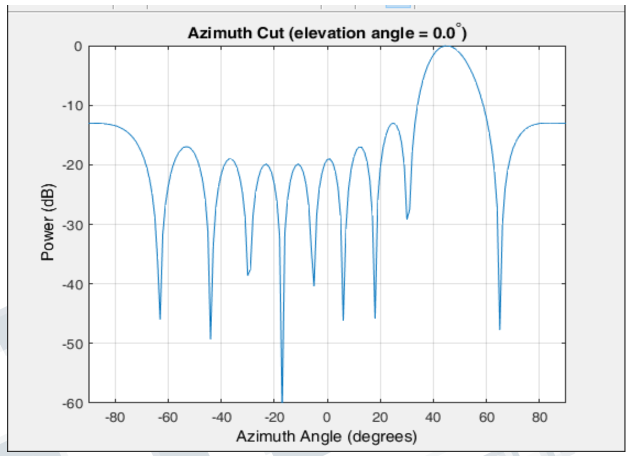

Fig3: Plot array response with weighting

the main beam of the beamformer is pointing in the desired direction (45 degrees), as expected. Next, we use the beamformer to enhance the received signal under interference conditions. In the presence of strong interference, the target signal may be masked by the interference signal.

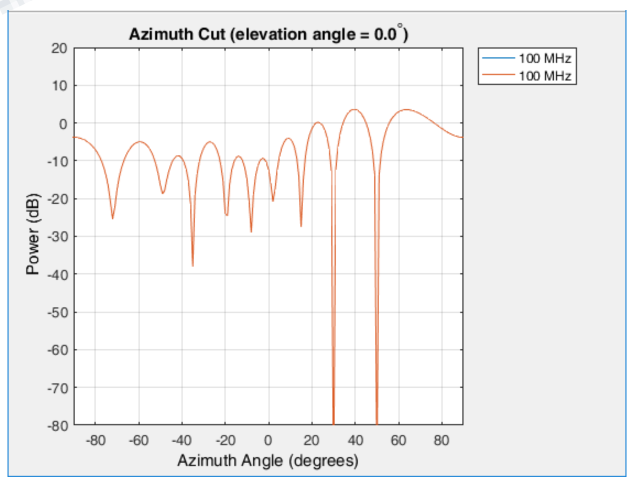

Fig4: Plot array response with interference

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C. LCMV Beamformer:

To prevent signal self-nulling LCMV beamformer can be used, which allows us to put multiple constraints along the target direction. It reduces the chance that the target signal will be suppressed when it arrives at a slightly different angle from the desired direction .The plot below shows that the target signal can be detected again even though there is the mismatch between the desired and the true signal arriving direction.

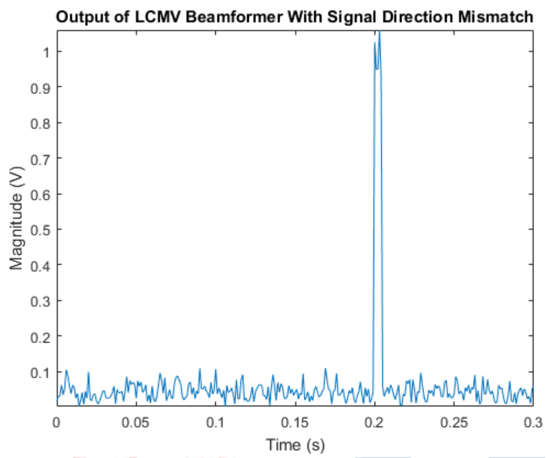

Fig5:Output of LCMV Beam former

The LCMV response pattern shows that the beamformer puts the constraints along the specified directions, while nulling the interference signals along 30 º and 50 º. Here only show the pattern between 0 º and 90 º degrees in azimuth so that we can see the behavior of the response pattern at the signal and interference directions better.

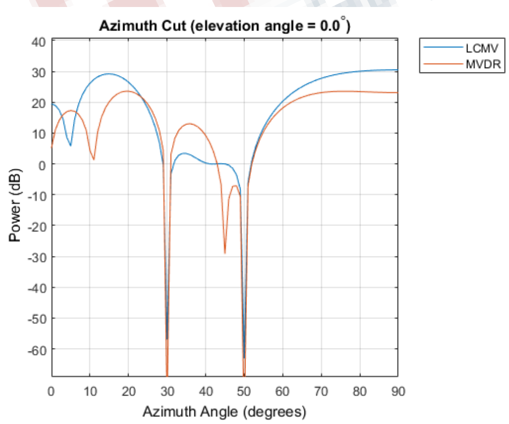

Fig6: Beamformer response with inteference

The effect of constraints can be better seen when comparing the LCMV beamformer's response pattern to the MVDR beamformer's response pattern. The LCMV beamformer is able to maintain a flat response region around the 45 º in azimuth, while the MVDR beamformer creates a null.

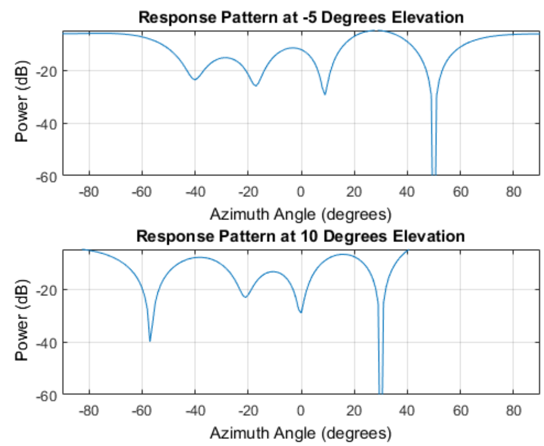

Fig7:Response at -5ºand10º Elevation

CONCLUSION

Beamforming is a signal processing technique used in various wireless systems for directional communications.. This paper presents three techniques such as Phase Shift Beamformer, the Minimum Variance Distortionless Response (MVDR) and Linear Constraint Minimum Variance (LCMV). Based on application requirements one of the beamforming algorithms is selected. Using MVDR algorithm is better from LCMV algorithm.Thus beamforming has proved its benefits for mobile system and plays a vital role in next generation mobile networks..Beamforming is a good candidate which fulfils user demands with efficient spectrum utilization when it is integrated with NOMA.

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