International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 02 | Feb-2016 www.irjet.net p-ISSN: 2395-0072

# Multiuser-MIMO Broadcast Channel techniques

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**Abstract** – *The main objective of this paper is to provide a review of the broadcast channel techniques for the multiuser multiple input multiple output (MU-MIMO) communication system.Block Diagonalization(BD), Dirty Paper Coding(DPC) and Zero forcing Channel Inversion(CI) are the broadcast channel techniques. The chief objective of these techniques is to rebuild the original signal with help of filtration or any other methods and take away the effect of interference so that the reliability of data transmission is maintained. By these above techniques multiuser interference, known interference at transmitter side and ISI can be eliminated respectively.*

***Keywords*** – MU-MIMO, Interference, DPC, ISI, BD

## 1. INTRODUCTION

The number of telecommunications users, as well as their capacity demands, have been increasing rapidly, bringing more and more technical challenges to the academia, industry and regulatory bodies.So recently, everybody has been talking about the MU-MIMO.

The main idea behind MIMO [1][2] is to exploit the multipath environment in a way that every possible combination of one transmitter and one receiver element is actually one possible propagation path, thus creating a lot of possibilities for achieving better quality of service (QoS), higher reliability and higher bit rates. That is why MIMO has found its way into every modern wireless standard.

Traditional MIMO wireless system uses antenna arrays at both transmitter and receiver, thus connecting the base station (BS) with one user (single user MIMO, SU-MIMO). However, the concept of MIMO [3]-[8] has evolved since into a system able to connect several separate transmitters with different users (multiuser MIMO, MU-MIMO), with several key advantages compared SU-MIMO. The concept of MU-MIMO has raised a lot of interest in the last few years, as a promising candidate for achieving true MIMO potential for improving capacity in future wireless systems.

The main benefit of MU MIMO[9] comes from its ability to solve the problem of de-correlation. To achieve MIMO full benefits sub-channels should be independent or ideally uncorrelated. This way a full-rank MIMO channel matrix is achieved and maximum capacity can be gained. To accomplish this antenna elements should be adequately distanced-typically at least half a wavelength.

In MU-MIMO broadcast (downlink) channels, transmit antenna arrays can be used to simultaneously transmit data streams to receivers and thus considerably improve throughput. Dirty Paper Coding (DPC) is a capacity achieving for the MIMO broadcast channel [11], but this technique has a very high level of complexity. Zero Forcing (ZF) and Block Diagonalization (BD) [12][13] have low complexity than DPC.

## 2. BLOCK DIAGONALIZATION

Block Diagonalization is a linear precodingtechnique for the multiple antenna broadcast (downlink) channel that involves transmission of multiple data streams to each receiver such that no multiuser interference is experienced at any of the receiver. This low complexity scheme operates only a few dB away from capacity but does require extremely precise channel knowledge at the transmitter, which can be quite hard to acquire in fading scenarios. We consider a limited feedback system where each receiver knows its channel perfectly, but the transmitter is only provided with a finite number of channel feedback bits from each receiver.

The block Diagonalization strategy when perfect CSI is available at the transmitter involves precoding the signals to be transmitted in order to suppress interference at each user due to all other users (but not due to different antennas for the same user). If $S_i \in C^{N\times 1}$ contains the N complex symbols intended for the $i^{th}$ ($1< i < K$) users and $V_i \in C^{M\times N}$ is the precoding matrix , then the transmitted vector is given by:

$$x = \sqrt{\frac{P}{K}} \sum_{i=1}^{K} V_i s_i \tag{1}$$

And the received signal at the $i^{th}$ user is given by:

$$V_i^H V_i = I_N \tag{2}$$

It is assumed that a uniform power allocation strategy among user is employed (due to absence of channel magnitude information at the transmitter). Furthermore, in order to maintain the power constrain it is assumed that $V_i^H V_i = I_N$ And E[||$s_i$||$^2$]< 1.

Following the BD strategy, each $V_i$ is chosen such that $H_i^H V_i$ is 0, $\forall\, i \neq$j. this amounts to determining an orthonormal basis for the null space of the matrix formed by stacking all $H_j,\ j \neq i$ matrices together. This reduces the interference terms in equation (2) to zero at each user. This is different from zero forcing where each complex symbol to be transmitted to the $m^{th}$ antenna (among N antenna) of the $i^{th}$ user is precoded by a vector that is orthogonal to all the column of $H_{j=i}$ as well as orthogonal to all but the $m^{th}$ column of $H_i$.
However, perfect knowledge of the $H_i$ 's at the transmitter is required for zero interference.

## 3. DIRTY PAPER CODING

We have now consider a new non linear technique in line with the concept of "writing on dirty paper"presented by Costa [14]. In that paper, the traditional additive Gaussian noise channel is modified to include an additive interference term that is known at the transmitter:

Received signal = transmitted signal +interference+ noise

The most convenient action to take in this circumstance would be to set the transmitted signal equal to desired data minus the interference, nevertheless such an tactic demands increased power. Costa proved this amazing consequence that the capacity of this channel is the same as if the interference was not present; no more power is needed to cancel the interference than is used in a nominal additive Gaussian noise channel. To work with Costa's analogy, writing on paper is information theoretically equivalent to writing on clean paper when one knows in advance where the dirt is. Costa's strategy theoretical, even so, and does not provide a practical technique for approaching capacity.

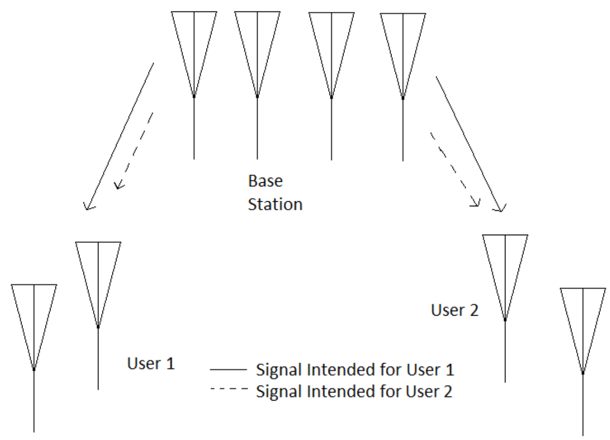


**Fig-1***:* An illustration of a MU-MIMO downlink. Each user often receives data intended to other user

The application of this principle to downlink Transmission in multi-user MIMO channels was proposed in [15]. Because the transmitter in Fig. 1 has CSI, it knows what interference user 1's signal will produce at user 2, and hence can design a signal for user 2 that avoids the known interference. This idea has been utilized to characterize the sum-capacity and capacity region of the multi-antenna multi-user channel [16].
The principal client of this system sees no interference from other users; its signal might be picked without respect for alternate users. The second user sees interference only from the first user; this interference is known and thus may be overcome using dirty paper coding. Subsequent users are dealt with in a similar manner.
Another methodology applies dirty paper techniques directly, rather than for individual users. A vital difference between the MU-MIMO channel and the interference channels for which dirty paper techniques are composed is that the interference reliesupon the signal being designed. In the past segment, the interference for any specific user depends only on the interference created by previous users. DPC is then applied to cancel this interference. A substitute method is to design all the signals jointly; this is themethodology taken in [17], where matrix algebra is used to solve for the signal to be transmitted. The simple dirty paper technique of applying a modulo operation to the transmitted and received data is shown to operate close to the sum capacity.
Figure 2 shows this procedure, referred to as vector precoding. It can be seen as a modification of channel inversion, where the desired signal dis offset by a vector *l*

of integer values chosen to minimize the power in the transmitted signal,

$$x = H^{-1}(d + \tau l)$$

$$l = \arg\min_{l'} \| H^{-1}(d + \tau l^{-1}) \|$$

where t is chosen in the same way as for the successive algorithm described above. As with basic channel inversion, this encoding results in the $k^{th}$ receiver seeing an additive Gaussian channel $y_k = d_k + tl_k + w_k$. The integer offset $l_k$ is removed by applying a modulo function at the receiver, resulting in a signal that looks very much like an additive noise channel:

$$(y_k) \bmod \tau = (d_k + \tau l_k + w_k) \bmod \tau$$
$$= (d_k + w_k) \bmod \tau$$

## 4. ZERO-FORCINGLINEAR CHANNEL INVERSION(LCI)

A block Diagonalization (BD) is an attractive method which operatesonly a few dB away from the sum capacity. This scheme isa generalization of the zero-forcing channel inversion to thecase where each receiver is equipped with multiple antennas.One of the limitation of the BD is that the sum rate doesnot grow linearly with the number of users due to the noiseenhancement.

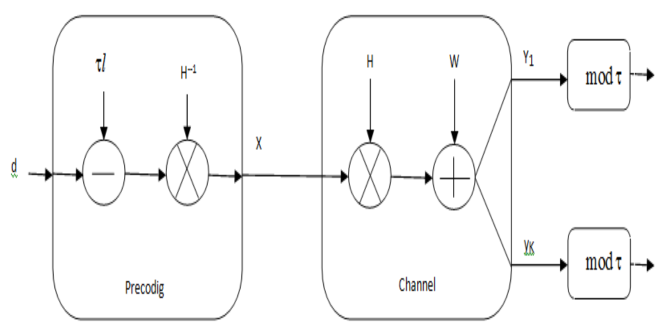


**Fig-2:** A modulo precoding technique. A vector chosen to minimize the signal power is added to the data to be transmitted

We consider a down-link transmission system with $n_T$ $T_X$ antennas at the BS and $m_R$ receive antennas which can belong to one MT or to $m_R$ decentralized MTs with one Rx antenna each. We limit ourselvesto the case of $(n_T \geq m_R)$ *oth*erwise interference free pre-codingis not applicable. The BS has perfect channel state information (CSI)prior to the transmission which can be obtained for TDD systemsby feedback or by a channel measurement into the opposite linkdirection under the assumption of channel reciprocity. Each of theMTs is supplied with an individual data stream and the signal tonoise plus interference ratio requirements (SINR) are set to the samelevel for all MTs. The transmit signal coming from all transmit antennas is givenby ***x*** and the transmission channel from the BS to the $k^{th}$ MT is described by the channel vector $H_k^T$.

We assume a flat block fading channel $h_K$ for all antennas and ani.i.d. additive white Gaussian noise vector *n*with noise variance &.The transmission equation in compact form reads

$$\boldsymbol{y} = \boldsymbol{H}\,\boldsymbol{x} + \boldsymbol{n}$$

where **y** is the receive signal vector over all Rx antennas, **H** $=[h_1, \ldots, h_{mR}]^T \in C^{n_T \times m_R}$ is the overall channel matrix and the precodedand transmitted signals from all $T_X$ antennas are collected in ***x*** = $x = [x_1, \ldots, x_{n_T}]^T$ is the noise at the $k^{th}$ Rx antenna with noise variance &,. The transmission block isshown in principle inFig.3. With the assumption that *rank(H)*= $\min(n_T, m_R)$ = *m,* data transmission can be performed over *m* parallel sub-channels.

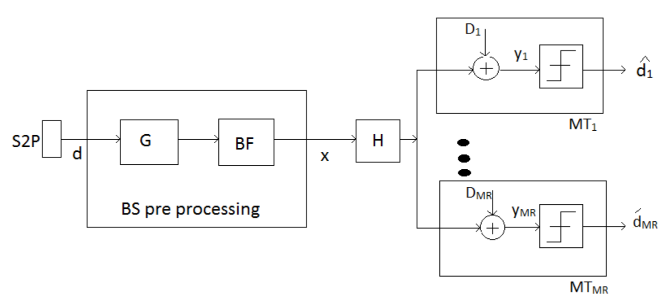


*Figure 3 Block diagram of joint Tx pre-processing for all data streams. d is the parallelized data vector, z the sent transmission signal, G is the diagonal power allocation matrix and BF is the unitary beam forming matrix.*

## 5. CONCLUSION

Interference is one of the obstacles for accomplishing reliable high speed data transmission over wireless media. The above mentioned broadcast channel techniques are used to remove the interference in the communication system. Block Diagonalization (BD) is used to remove multiuser interference at the receiver side. Dirty Paper Coding (DPC) is used to eliminate known interference at the transmitter side and Zero forcing Channel Inversion (CI) is used to remove ISI at receiver side. Dirty papercoding (DPC) is capacity achieving for the MIMO broadcast channel, but this technique has a very high level of complexity. ZeroForcing (ZF) and Block Diagonalization (BD) are alternative low-complexity transmission techniques

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