

The Project

The purpose of the project in the course TSKS05 Communication Systems CDIO has been to demonstrate the capabilities of Massive MIMO in an audio environment. Using the hardware built in a previous project we designed and implemented communication and Zero Forcing capabilities to the already existing system. The goal of the system is to be able to send two data streams to two different units simultaneously.

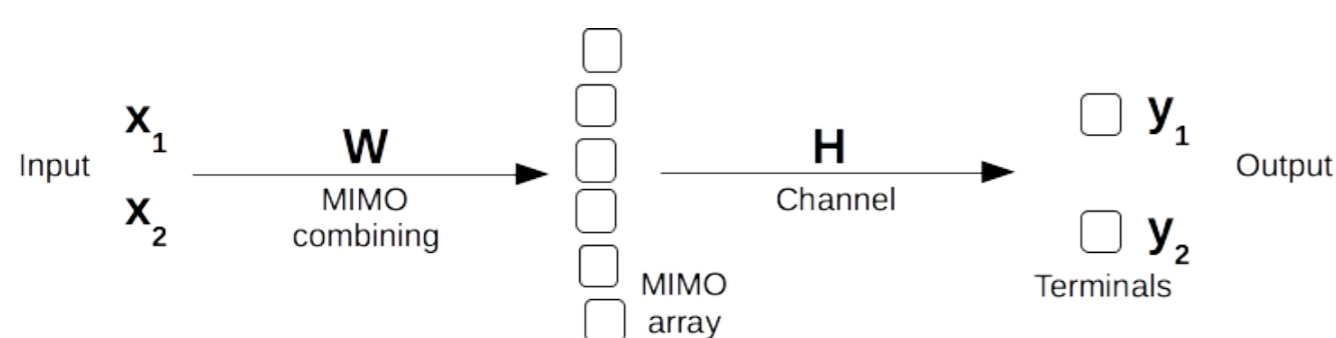
MIMO

Multiple Input Multiple Output (MIMO) is an essential element of wireless communication that uses multiple antennas at both the transmitter and receiver to enhance the capacity of the radio link by focusing signal energy into small regions of space.

Beamforming

Beamforming is an essential technique in a MIMO system. The concept is that signals from multiple antennas are transmitted in such a way that the signal energy gets focused at certain points in space. In the case of Zero Forcing beamforming, the signal energy is focused at the relevant user while the other users essentially receive no signal at all in order to reduce inter-user interference.

Zero Forcing



The figure above depicts an idealized case where we know the channel and there is no noise. We want the output, Y to equal the input X and that can be achieved by precoding the signal by multiplying the input with the inverse W of the channel matrix. Since the true channel state matrix H is not known we have to estimate it with \hat{H} .

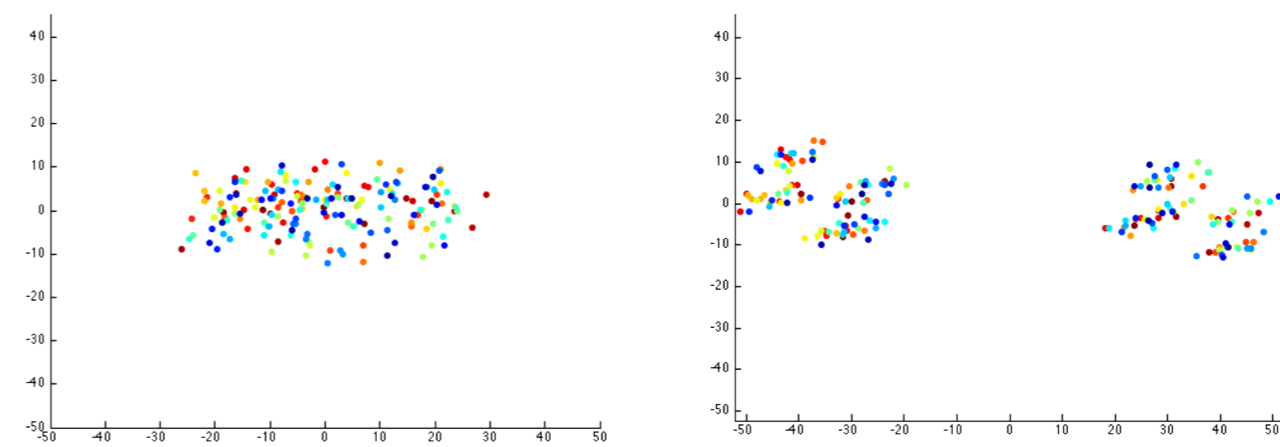
$$Y = HWX$$

$$W = \hat{H}^*(\hat{H}\hat{H}^*)^{-1}$$

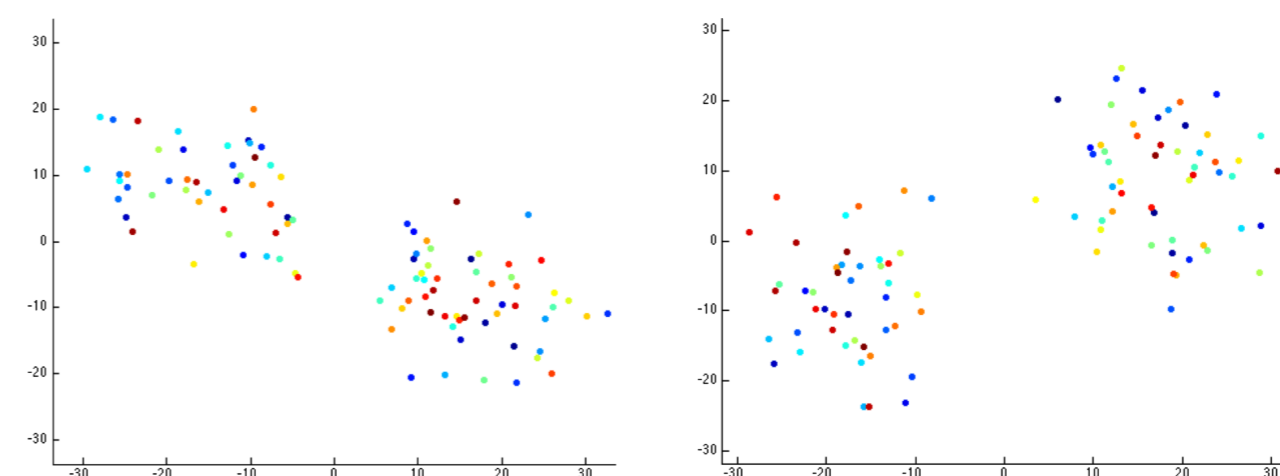
Results

The top figure shows the received symbols when one terminal is forced to zero while we are sending data to the other. The zero forcing technique clearly works but ideally the symbols for the terminal that is forced to zero should be more focused around the origin. In the bottom figure the received symbols are shown for the two terminals when data is sent simultaneously to both terminals. Note that the transmission is successful since the two clusters are distinguishable for both terminals. The slightly rotated symbol constellation is not a problem since we detect this phase using k-Mean clustering and compensate for it.

One terminal forced to zero while sending to the other



Sending simultaneously to two terminals



Maximum ratio combining (MRC) was also evaluated and showed slightly lower performance than Zero Forcing. Power control, however, gave a significant improvement, visible mainly in the scatter plots where the clusters become more separated.

Conclusion

- Successful demonstration of the Zero Forcing concept, by simultaneous error-free data transmission to two terminals, has been achieved.
- MRC and power control were evaluated, where the latter showed significant improvement.
- Hardware, sampling frequency in particular, is the main limiting factor of the performance.

Further Information

A full description of the system and the methods used are presented in a technical report which is available on the following webpage:

<http://www.isy.liu.se/edu/projekt/kommunikationssystem/2015/zf/>

