**W\_RF**

After the precoders are designed, the overall formula can be simplified similarly to calculate the RF combiner with a few quantities replaced; the inverse coefficient can be replaced by one over M in large MIMO systems. Then it can be calculated using algorithm 1 as well.

**W\_D**

Then the digital combiner is also calculated using MMSE. Now, the digital and RF precoder and combiner are all known, the performance of the system can be evaluated by its spectral efficiency which is calculated with matrices of precoders, combiners, and complex channel.

**Result 1**

This is the curve of spectral efficiency vs. SNR in a 64\*16 MIMO system assuming number of data streams and RF chains are equal. We can see that it’s almost linear and spectral efficiency increases with SNR, which is the same as in paper Fig. 2.

**Result 2**

These are the spectral efficiency curves for infinite resolution and 1-bit phase shifters, assuming a 10\*10 MIMO system and small equal number of data streams and RF chains. The performance of infinite resolution is better than that of 1-bit, which is the opposite from paper Fig. 3. The possible reason is that the project does not quantize the infinite resolution phase shifter after it is designed, while the paper does.

**Result 3 - 100**

Finally, we assume a 64\*16 MIMO system scenario with the number of RF chains is bigger than once but less than twice of the number of data streams. From the figures we can see that the performance of infinite resolution phase shifter is slightly better than that of 1-bit phase shifters, but 1-bit is catching up as the number of RF chains increases. This is in accordance with the paper Fig. 4.

**Result 3 – 1000**

Since the number of Monte Carlo trials is only 100, we can see the figures are rather unsmooth in the last page. After it’s changed to 1000, the figures more clearly shows the discovery that adding more RF chains to the system compensates the inaccuracy of phase shifters.

**Conclusion**

To sum up, this project implements the hybrid beamformer architecture proposed by the reference paper and evaluates its performance in different scenarios where the number of RF chains is equal or bigger than the number of data streams but smaller than twice of that. We came into the same conclusion with the paper that increasing the number of RF chains can trade off the inaccuracy of phase shifters in hybrid beamformer architectures to achieve a closer performance to that of fully digital ones.

**Thank you**

So here ends our project presentation. Thank you for listening.