**ECE 233 Project Report**

**Hybrid Digital and Analog Beamforming Design**

**for Large-Scale Antenna Arrays**

**Ruoye Wang | 605625594**

**Yida Chen | 005852117**

**Abstract**

Abstract

**System Model**

This project implements a model proposed by the reference paper. This narrowband downlink single-cell multi-user MIMO system model has a two-stage hybrid digital and analog beamforming architecture at the base station (BS) and the user terminals. A picture containing diagram, plan, text, technical drawing

Description automatically generated

Figure : Block diagram of the model proposed by the paper

As the figure above shows, the BS has antennas and RF chains and serves users. Each user is equipped with antennas and RF chains, and requires data streams. The number of data streams required by each user; the total number of data streams .

A picture containing font, text, handwriting, typography

Description automatically generated

A picture containing font, text, white, typography

Description automatically generated

TODO explain x, y

This project assumes single-user scenario, i.e., . To simplify the notation while preserving the generality, it is assumed that . The project first implements the hybrid beamformer design for the case where to show that, according to Proposition 1, a fully digital beamformer architecture can be realized by a hybrid structure with at least RF chains using a proposed heuristic algorithm. Then the same algorithm is implemented for the case where .

The symbols represent the digital precoder at the BS (size ), the RF precoder at the BS (size ), the digital combiner at the user end (size ), and the RF combiner at the user end (size ). (size ) is the matrix of the complex channel gains from the transmit antennas of the BS to the user (note that since , all can be represented by a single ; the same can be applied to other user-specific quantities in the paper).

**Main Part**

This paper mainly focuses on maximizing the overall spectral efficiency with total transmit power constrained and fully known. This requires us to find the optimal solution for precoders at the transmitter end and the combiners at the receiver end, which can be represented by this formula:

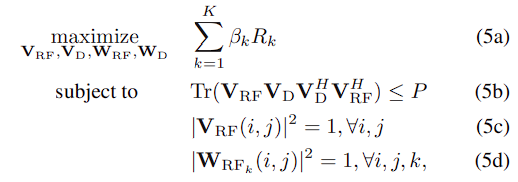


Figure : the formula representing the main problem (K=1, disregarding k)

This formula is calculated under the aforementioned cases and . It can be simplified for precoder design:

A picture containing text, font, line, white

Description automatically generated

Figure : Precoder design formula

When , can be calculated by:

A picture containing text, font, line, screenshot

Description automatically generated

Figure : RF precoder design formula

Which is a simplification of Figure. 3 assuming . It is summarized in Algorithm 1:

A picture containing text, screenshot, font, number

Description automatically generated

Figure : Algorithm 1 to calculate RF precoder

Then can be calculated by solving:

A picture containing text, font, handwriting, line

Description automatically generated

Figure : Digital precoder design formula

Where and .

We use a water-filling solution:

Where is the set of right singular vectors corresponding to the largest singular values of and is the diagonal matrix of allocated powers to each stream. (Reference: Ruifu Donar Li)

A picture containing diagram, line, technical drawing, rectangle

Description automatically generated

Figure : Water-filling solution

After have been obtained, the performance of the model can be evaluated by its spectral efficiency:

A picture containing text, font, handwriting, white

Description automatically generated

Figure : Formula of spectral efficiency

**Results and Discussion**

1. Plot the spectral efficiency vs. SNR in the range −10 dB to 6 dB, assuming a 64 × 16 MIMO system and .

A picture containing line, diagram, plot, parallel

Description automatically generated

TODO discussion

1. Plot the spectral efficiency vs. SNR in the range 0 dB to 30 dB, assuming a 10 × 10 MIMO system, , and phase shifters with 1-bit and infinite resolutions.

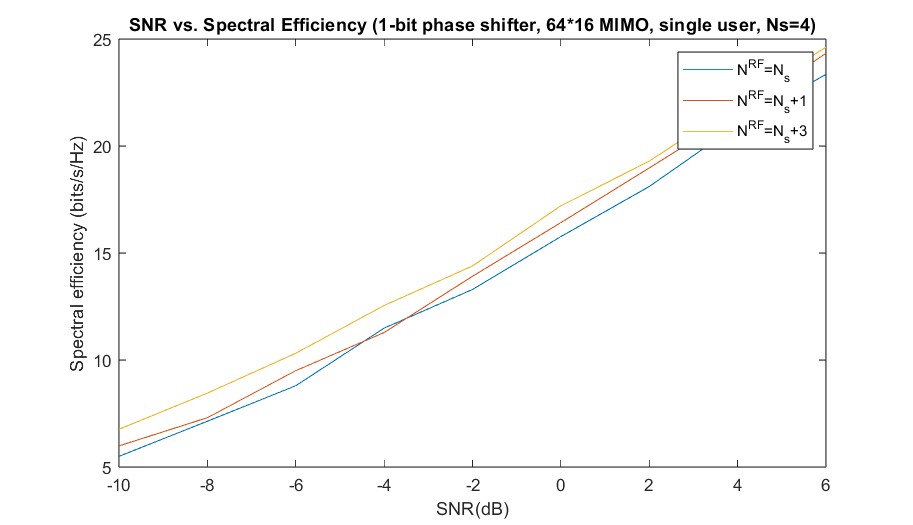
A picture containing line, text, plot, diagram

Description automatically generatedA picture containing line, plot, diagram, text

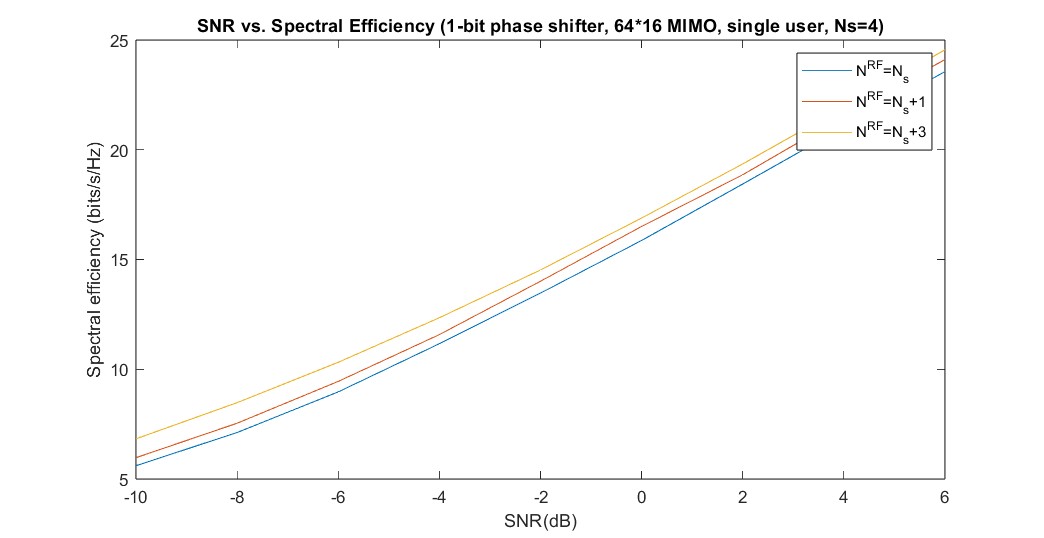
Description automatically generated

TODO discussion

1. Plot the spectral efficiency vs. SNR in the range −10 dB to 6 dB, assuming a 64 × 16 MIMO system, , and phase shifters with 1-bit and infinite resolutions.

A picture containing text, line, diagram, plot

Description automatically generated

TODO discussion

**Conclusion**

Conclusion