Hybrid Beamforming

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I. Abstract

II. Introduction

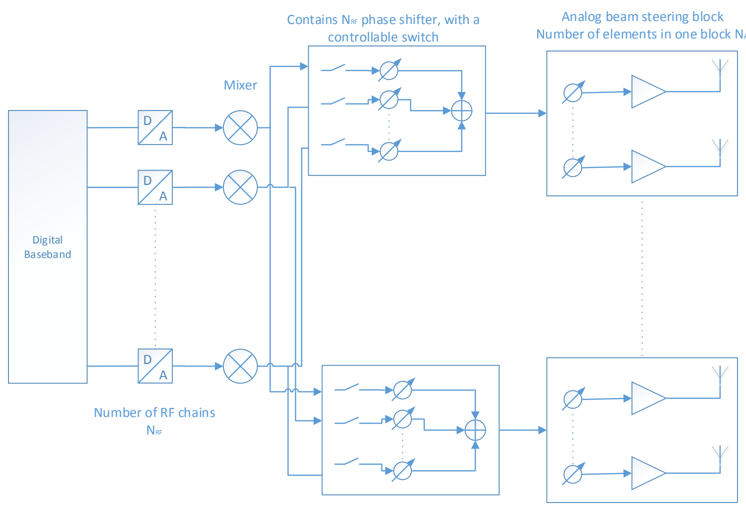

Fig. 1. System architecture.

$\mathrm{N_A}$ is the number of antennas in a single analog beam steering blocks.

Total number of transmit antennas is $\mathrm{N_A} \times \mathrm{N_{RF}}$

Number of baseband chains at the transmitter is $\mathrm{N_{RF}}$. This is also equal to the number of analog beam steering blocks.

Number of receive antennas is $\mathrm{N_R}$

W is the DFT matrix

$\mathrm{E_F}$ is the analog precoder matrix in the frequency domain and E is the analog precoder matrix in the time domain.

P is the digital precoder matrix

H is the received channel matrix of dimensions $\mathrm{N_R} \times (\mathrm{N_A} \times \mathrm{N_{RF}})$

X is the transmitted data.

y is the received signal and n is AWGN noise

$$y = \mathrm{H}\mathrm{E_F}\mathrm{P}\mathrm{X} + n. \tag{1}$$

Matrix E can be represented as a product of two matrices, a block diagonal and a square matrix. The block diagonal one represents the configuration of the analog beam sterring blocks and the square matrix represents the cross connections of the hybrid beamforming system.

$$\mathrm{E_F} = \mathrm{W} \times \mathrm{E} \tag{2}$$

$$\mathrm{E} = \mathrm{E_{BD}} \times \mathrm{E_S} \tag{3}$$

$$\mathrm{E_{BD}} = \begin{bmatrix} \begin{bmatrix} e^{j\phi_{1,1}} \\ e^{j\phi_{2,1}} \\ \vdots \\ e^{j\phi_{\mathrm{N_A},1}} \end{bmatrix} & \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} & \cdots & \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} \\ \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} & \begin{bmatrix} e^{j\phi_{1,2}} \\ e^{j\phi_{2,2}} \\ \vdots \\ e^{j\phi_{\mathrm{N_A},2}} \end{bmatrix} & \cdots & \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} \\ \vdots & \vdots & \ddots & \vdots \\ \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} & \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \end{bmatrix} & \cdots & \begin{bmatrix} e^{j\phi_{1,\mathrm{N_{RF}}}} \\ e^{j\phi_{2,\mathrm{N_{RF}}}} \\ \vdots \\ e^{j\phi_{\mathrm{N_A},\mathrm{N_{RF}}}} \end{bmatrix} \end{bmatrix} \tag{4}$$

$$\mathrm{E_S} = \begin{bmatrix} \mathrm{A}_{1,1} e^{j\theta_{1,1}} & \cdots & \mathrm{A}_{1,\mathrm{N_{RF}}} e^{j\theta_{1,\mathrm{N_{RF}}}} \\ \mathrm{A}_{2,1} e^{j\theta_{2,1}} & \cdots & \mathrm{A}_{2,\mathrm{N_{RF}}} e^{j\theta_{2,\mathrm{N_{RF}}}} \\ & \ddots & \\ \mathrm{A}_{\mathrm{N_{RF}},\mathrm{N_{RF}}} e^{j\theta_{\mathrm{N_{RF}},\mathrm{N_{RF}}}} & \cdots & \mathrm{A}_{\mathrm{N_{RF}},\mathrm{N_{RF}}} e^{j\theta_{\mathrm{N_{RF}},\mathrm{N_{RF}}}} \end{bmatrix} \tag{5}$$

$e^{j\phi_{m,n}}$ represents the phase shift provided by the m_{th} phase shifter in the n_{th} analog beam steering block. $\mathrm{A}_{p,n}$ and $\theta_{p,n}$ are respectively the gain and phase shift provided to the p_{th} time domain data stream which is being transmitted by the n_{th} analog beam steering block.

Things to find out

1) For a given E matrix, a P matrix which maximizes the sum rate,
2) Study the following topologies of $\mathrm{E_S}$
   a) A binary diagonal matrix,
   b) binary bidiagonal matrix,
   c) binary triangular matrix,
   d) diagonal matrix,
   e) bidiagonal matrix,

f) triangular matrix,

g) a fully connected matrix,

III. System Model

IV. Numerical Results

V. Conclusions