mmWave MIMO Systems for 5G Communications

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Abstract

The next generation 5g communications are used with baseband precoders and beam forming. The technology is needed to update the all the available characteristics in the present wireless communication system**.** In the mmWave MIMO system the number of antenna are increased to improve the spectral efficiency of the system.

Keywords:
mmWave, MIMO, 5G

1. Introduction

In cellular network (CN), a maritime communication, consider MIMO maritime BS with digital & analog pre-coding. In MIMO [1] systems a serious problem introduced with the number of antenna and number of different users. Due this problem was avoided by using pre-coders in system. Here we propose fully baseband pre-coder, which compares with the simulation results. Spectral efficiency is governed by Shannon's capacity for point-to-point transmission. Shannon capacity limit

$$\log_2\{1+\frac{received\ signal\ power}{interference\ power+noise\ power}\}\ \text{bits/s/Hz/user.}$$

2. System Model

MIMO base station with M antenna uplink/downlink with K [2] users channel coherence block S symbols. The over all spectral efficiency roughly limits to min $\left(M,K,\frac{S}{2}\right)$. MIMO in future with improve wide area coverage & handle super dense scenarios.

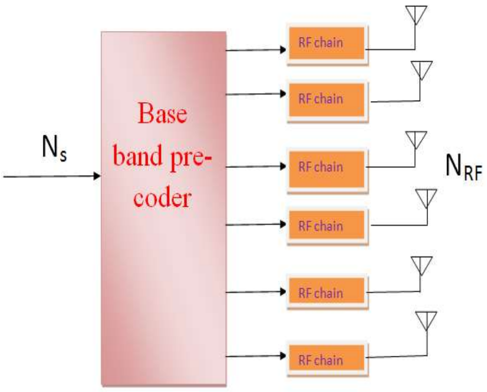

Fig1. Single user RF chain after pre-coding

Consider single user Hybrid mmWave MIMO every RF chain connected to antennas at transmitter with unit magnitude phase shifters. Single user Hybrid mmWave MIMO the baseband side as displayed in Fig.1. The DL baseband combiner as illustrated fig2. The DL [2] on the hybrid single user channel model as shown in Fig2. The transmit vector is given by

$$x = F_{BB}F_{RF}S$$
$$F = F_{BB}F_{RF}$$

$Then\ x = FS$

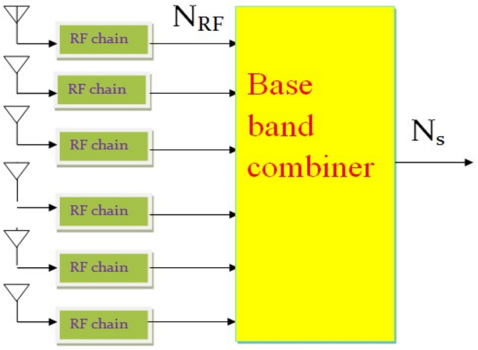

Fig2. Downlink base band combiner

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Where S=symbol vector, $N_s \le N_{RF} \le N_T$ *and* $N_s \le N_{RF} \le N_R$ *both the conditions are need to satisfies for the single user* [17].

$$s = N_s x 1$$
$$F_{BB} = N_{RF} x N_s$$
$$F^H = F_{BB}^H F_{RF}^H$$

The transmit symbol covariance as$E\{SS^H\} = \frac{1}{N_s} I$.
Here 1 specifies that unity.
I *is the identity matrix.* N_s *is number of trannsmitting equally distributed for all elements.*

$$\begin{aligned} E\{XX^H\} &= E\{(F_{BB}F_{RF}S)(F_{BB}F_{RF}S)^H\} \\ &= E\{SF_{BB}^H F_{RF}^H S^H F_{BB} F_{RF}\} \\ &= E\{SFF^H S^H\} \\ &= E\{Tr(SFF^H S^H\} \\ &= Tr[FF^H]E\{SS^H\} \\ &= \frac{1}{N_s} Tr[FF^H] \end{aligned}$$

$$y = \sqrt{p} W_{BB}^H W_{RF}^H H n F_{BB} F_{RF} + \breve{N}$$

Where the transmit power [3] put to equal to unity. i.e. $E\{XX^H\} = 1$. then $\frac{1}{N_s} Tr[FF^H] = 1. Tr[FF^H] = N_s$.

$$vec(y) = \sqrt{p}(F_{BB}F_{RF})^T \otimes W_{BB}^H W_{RF}^H . vec(H_n) + vec(\breve{N})$$

By using property$(A \times B)\ (C \times D) = AC \otimes BD$

$$vec(y) = \sqrt{p}\{(F_{BB}F_{RF})^T (A_T^H)^T \otimes W_{BB}^H W_{RF}^H A_R\} vec(H_n) + vec(\breve{N})$$

We cannot assume matrix should be known. Array with the transmitter array with receiver are not known.

$$Q_s = \left({F_{BB}}^T {F_{RF}}^T A_T^* \otimes W_{BB}^H W_{RF}^H A_R\right).$$

We do not know angle of arrival and angle of departure. Each angle have Transmitter array response vector.

$$vec(y) = \sqrt{p}\, Q_s vec(H_n) + vec(\breve{N})$$

Expanding a large set of possible angle of arrival and angle of departure [4]. So only some components of the value are equal to non-zero & large number of component of the value are equal to zero.

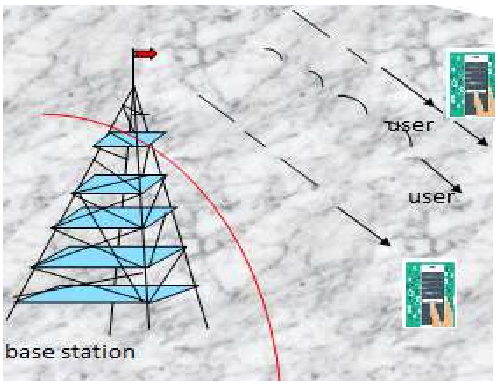

Fig 3. Base station overview

Now mmWave system

$$Y = HX + n$$

Digital, RF and antenna subsystem includes wideband power amplifiers massive MIMO antenna [5] arrays and adaptive algorithms. 5G operates at mm Wave requires new hybrid radio architecture to overcome higher propagation losses and channel impairments [6].

By Friss's equation the received power is

$$P_r = \frac{P_t G_t G_r \lambda^2}{L(4\pi d)^2}$$

where average Signal to Noise Ratio (SNR) is

$$SNR = \frac{P_r}{P_n}$$
$$SNR = \frac{P_t\ G_t G_r \lambda^2}{L(4\pi d)^2} \cdot \frac{1}{N_o B}$$

Where $N_o$is unilateral PSD.

mmWave system model is given by $minE\ \{\left\| \bar{S} - {W_{BB}}^H {W_{RF}}^H \bar{Y} \right\|^2\}$

$$= \boldsymbol{min} \left\| \boldsymbol{R}_{\boldsymbol{YY}}^{\frac{1}{2}} (\boldsymbol{W}_{\boldsymbol{MMSE}} - W_{RF}\, \boldsymbol{W}_{\boldsymbol{BB}}) \right\|^{\boldsymbol{2}}$$

The Received signal matrix Y is given by

$$Y = \sqrt{P}\ {W_{BB}}^H\ {W_{RF}}^H H\, n\, F_{RF} F_{BB} + \widetilde{N}$$

$\sqrt{P}$ is power constant.
${W_{BB}}^H$ *and* ${W_{RF}}^H$ Combiner.
F_{RF} *and* F_{BB} Are precoders and $\widetilde{N}$ is noise. Where RF chains=N_{RF}. $N_T^{Block} = \frac{N_T}{N_{RF}}$& $N_R^{Block} = \frac{N_R}{N_{RF}}$. For example N_T=**64,** N_{RF}=4 then N_T^{Block}=16.

3. Formation for Beam forming/ Combining

Bean forming is used for spatially signal transmission filtering with signal transmission and reception [7].

3.1. Zero Forcing:

Consider zero forcing MIMO channel model $y = Hx + n$. Where y is output system, H is channel; x is the input & n is the noise. The resulting receiver and cost function are important for the system. The cost function is given by $\widehat{x_{ZF}}$ = arg{min [$\|y - Hx\|^2$]} . $\|y - Hx\|^2 = (y - Hx)^H(y - Hx)$

$$\begin{aligned} &= (y^H - x^H H^H)(y - Hx) \\ &= y^H y - y^H Hx - x^H H^H y + x^H H^H Hx \end{aligned}$$

Take Gradient on function, According to the gradient rule$\nabla(.) = 0$. Then the function reduces to

$$\|y - Hx\|^2 = 0 - H^H y - H^H y + 2H^H Hx$$
$$= -2H^H y + 2H^H Hx$$

3.2. MMSE

Mean square error functions are basically two types i.e. Minimum Mean Square Error (MMSE) and LMMSE (Linear Minimum Mean Square Error).

3.2.1.MMSE channel estimation

Arranged pilot in frequency domain. The received vector for the R^th BS antenna, Q^th MS antenna

$$y^{RQ}(n) = [y_1{}^{RQ}(n), y_2{}^{RQ}(n), \dots y_N{}^{RQ}(n)]^T$$

$$y^{RQ}(n) = S^Q(n)h^{RQ}(n) + w^R(n)$$

MMSE channel estimation formulated

$$\widehat{h_{MMSE}} = R_{hy}R_{yy}^{-1}y^{RQ}(n)$$

3.2.1.LMMSE channel estimation:

Consider system model $y = Hx + n$. Then

$$\widehat{x_{LMMSE}} = m_x + \left(k_{xy}k_{yy}\right)^{-1} y + m_y$$

m_x is $E[x]$ & m_y is $E\,[y]$.

$k_{xy}$is cross covariance and k_{yy} is auto covariance.

$$k_{yy} = E\{(y - m_x)\left(y - m_y\right)^H\}$$

$$k_{xy} = E\{(x - m_x)\left(y - m_y\right)^H\}$$

$$x = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ . \\ . \\ x_{n-1} \\ x_n \end{bmatrix} n = \begin{bmatrix} n_1 \\ n_2 \\ n_3 \\ . \\ . \\ n_{r-2} \\ n_{r-1}. \\ n_r \end{bmatrix}$$

$$E\,[y] = E[xH + n]$$
$$= HE[x] + E[n]$$

$$k_{xy} = E[xy^H] = E\{x(Hx + n)^H\}$$

$$= E[xH^H x^H + xn^H]$$

$$k_{yy} = E[yy^H] = E\{(Hx + n)(Hx + n)^H\}$$
$$= E[(Hx + n)(H^H x^H + n^H)]$$
$$= E[HH^H xx^H + nH^H x^H + Hxn^H + nn^H]$$

$$= PHH^H + 0 + 0 + \sigma^2 I_r$$
$$= PHH^H + \sigma^2 I_r$$

Then

$$\left(k_{xy}k_{yy}\right)^{-1} y = PH^H(PHH^H + \sigma^2 I_r)^{-1} y$$

The functions are always invertible. Condition of invertible zero forcing rank min(r, t)[10].

3.2.3. Kalman filtering

Consider kalman base band precoding for MIMO, the system consisting of three single antenna terminals & one base station with M antennas. The BS is assumed perfect CSI. Three elements transmit the complex symbols x_1, x_2 & x_3 with transmit power P simultaneously in the same frequency band. Received signal strength at BS is $y = \sqrt{p}\,Hx + W$

$$y = \sqrt{p}.\,[h_1x_1 + \; h_2x_2 + \; h_3x_3]$$

h_1, h_2 & h_3 are independent $\mathbb{CN}\ (0, I_M)$.

4. Simulation results

The numbers of iterations are considering around 2000 iterations. The number of paths used 12. The Signal to Noise Ratio (SNR) ranges from -15 to 20 db. Hybrid precoding mmWave with low cost data transmission. The each antenna connected with RF precoding.

The simulation illustrates that single user, hybrid precoding and MMSE precoding as shown in fig4. In Fig5 shows that kalman & MSE precoding. The fig illustrates that response spectral efficiency with respect to SNR (db).

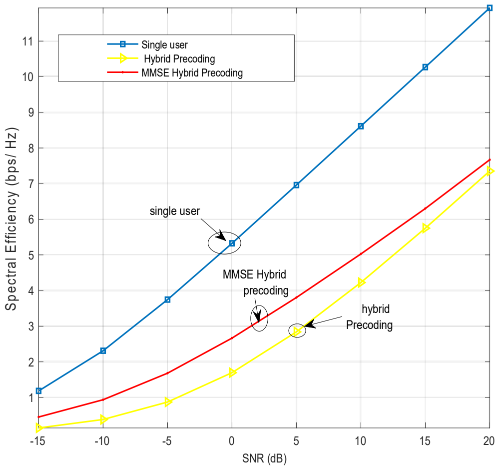

Fig 4. MMSE and Hybrid Precoding

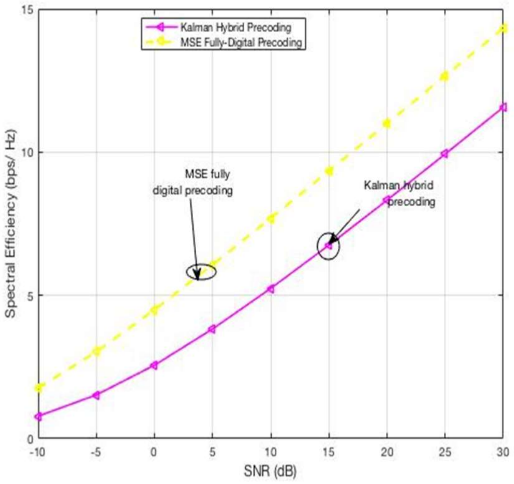

Fig5. Kalman and MSE precoding

5. Conclusions

The communication on 5G with required base band precoders then improve the transmission as well as compared with different existing algorithms & proposed algorithm improves the spectral efficiency.

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