LETTER

Dynamic Hybrid Beamforming-Based HAP Massive MIMO with Statistical CSI

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SUMMARY In this letter, we study the dynamic antenna grouping and the hybrid beamforming for high altitude platform (HAP) massive multiple-input multiple-output (MIMO) systems. We first exploit the fact that the ergodic sum rate is only related to statistical channel state information (SCSI) in the large-scale array regime, and then we utilize it to perform the dynamic antenna grouping and design the RF beamformer. By applying the Gershgorin Circle Theorem, the dynamic antenna grouping is realized based on the novel statistical distance metric instead of the value of the instantaneous channels. The RF beamformer is designed according to the singular value decomposition of the statistical correlation matrix according to the obtained dynamic antenna group. Dynamic subarrays mean each RF chain is linked with a dynamic antenna sub-set. The baseband beamformer is derived by utilizing the zero forcing (ZF). Numerical results demonstrate the performance enhancement of our proposed dynamic hybrid precoding (DHP) algorithm.

key words: *high altitude platform, statistical CSI, hybrid beamforming, large-scale antenna array, dynamic connection*

1. Introduction

High altitude platforms (HAPs), terrestrial and satellite communication systems can be merged as a whole seamless telecommunication network [1]. HAP is equipped with massive multiple-input multiple-output (MIMO), which can substantially increase the spectrum efficiency. The energy consumption of the radio frequency (RF) chains takes the leading part in the total energy on HAP, while that of phase shifters (PSs) also has influence to some extent.

In [2] and [3], the fully digital beamforming scheme has been investigated, where the number of RF chains was equivalent to the number of antennas and it is unrealistic on hardware cost in the large scale antenna array. To further lower the number of RF chains and enhance the energy efficiency, the hybrid beamforming schemes have been proposed in [4]–[8], which can be composed of RF precoder and baseband precoder. In [4], an iterative algorithm has been proposed to get RF precoder from a discrete codebook according to the lower bound of the sum rate. In [5], [6], the RF precoder has been gotten by analyzing the signal-to-interference-and-noise ratio (SINR) and exploiting the phase of channel matrix. In [7], a successive algorithm has been proposed and a column of RF precoding matrix is correlated with all the former columns, which may result in some ineffective complexity. The instantaneous channel state information (ICSI) has been used in [2] and [4]–[8]. The acquisition of ICSI is unacceptable because of the high feedback overhead, especially for HAP systems. For HAP systems, the hybrid beamfoming scheme should be designed based on statistical channel state information (SCSI), that is the line-of-sight (LOS) component, as similarly used in [1] and [3].

Antenna grouping scheme was also proposed in [6]–[8]. In [6] and [7], the sub-connected hybrid precoding (SHP) scheme has been utilized by connecting the fixed set of transmit antennas with the given RF chain. The dynamically-connected hybrid precoding (DHP) scheme has been proposed in [8] by dynamically connecting the non-fixed set of transmit antennas with the optimal RF chain. The number of RF chains and PSs in DHP is the same as that in SHP. The dynamic connection in [8] has resulted in the higher energy efficiency and spectral efficiency than that of SHP in [6] and [7]. In [8], the phase of channel matrix, i.e. ICSI, was used to attain RF precoder, which is suitable for Rayleigh channel rather than Rician channel.

In this letter, we propose a dynamic hybrid beamforming algorithm for HAP massive MIMO systems. Firstly, we exploit the fact that the criterion of trace inverse of effective channel only has relationship with SCSI, where the RF precoder can be obtained. Next, we propose a novel statistical distance metric to measure the lower bound of trace inverse by utilizing the Gershgorin Circle Theorem. Then, the dynamic subarray scheme and the RF precoding matrix are designed at once based on the lower bound. The digital precoding matrix can be obtained by zero forcing (ZF). Simulation results show that the proposed dynamic hybrid precoding (DHP) algorithm outperforms the schemes in other references for stratospheric telecommunications.

2. System Model

We consider the downlink multiuser stratospheric massive MIMO system with K single-antenna users. The HAP is equipped with K RF chains and a uniform planar array (UPA) with N_T antennas consisting of M antennas in each column and N columns in the horizontal dimension ($N_T = M \times N$).

The received signal vector $\mathbf{y} \in \mathbb{C}^{K\times 1}$ is

$$\mathbf{y} = \mathbf{H}^H \mathbf{F}\mathbf{W}\mathbf{x} + \mathbf{z} \tag{1}$$

where the transmitted signal vector $\mathbf{x} \in \mathbb{C}^{K\times 1}$ satisfies $\mathrm{E}[\mathbf{x}\mathbf{x}^H] = \frac{P}{K}\mathbf{I}_K$, P denotes the total transmit power, $\mathbf{z} \sim$

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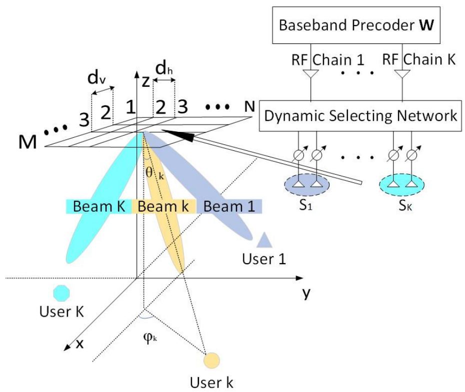


Fig. 1 DHP scheme for the HAP massive MIMO system.

$\mathcal{CN}(0, \sigma^2 \mathbf{I}_K)$ denotes the noise vector, σ^2 denotes the noise variance, $\mathbf{F} = [\mathbf{f}_1, \mathbf{f}_2, \cdots, \mathbf{f}_K] \in \mathbb{C}^{N_T \times K}$ denotes the RF precoder, $\mathbf{W} = [\mathbf{w}_1, \mathbf{w}_2, \cdots, \mathbf{w}_K] \in \mathbb{C}^{K \times K}$ denotes the baseband precoder. We set $\|\mathbf{FW}\|_F^2 = K$ to satisfy the power constraint.

As shown in Fig. 1, the dynamic selecting network is the process of antenna grouping and the implementation of the RF precoder $\mathbf{F}$. We partition the N_T antennas into K groups. Let S_g be the subset of antennas linked to the gth RF chain, such that $|S_g| \geq 1$, $S_i \cap S_j = \emptyset$ for $i \neq j$ and $\sum_{g=1}^{K} |S_g| = N_T$. The constraints on $\mathbf{f}_i$ can be represented as

$$\mathcal{F} = \left\{\mathbf{f}_i \middle| |\mathbf{f}_{i,j}| = 1/\sqrt{S_i}, \forall j \in S_i, \mathbf{f}_{i,j} = 0, \forall j \notin S_i\right\} \tag{2}$$

The channel matrix $\mathbf{H} = [\mathbf{h}_1, \mathbf{h}_2, \cdots, \mathbf{h}_K] \in \mathbb{C}^{N_T \times K}$. The channel vector at the kth user $\mathbf{h}_k$ is

$$\mathbf{h}_k = \sqrt{\alpha_k}\left(\sqrt{\frac{K_k}{1+K_k}}\widehat{\mathbf{h}}_k + \sqrt{\frac{1}{1+K_k}}\widetilde{\mathbf{h}}_k\right) \tag{3}$$

where large-scale fading $\alpha_k = (\frac{4\pi r_k}{\lambda})^{-2}$, r_k denotes the distance between the kth user and the HAP and λ denotes the carrier wavelength, K_k denotes the Rician factor, line-of-sight (LOS) component $\widehat{\mathbf{h}}_k$ is

$$\widehat{\mathbf{h}}_k = \mathbf{a}(M, d_1(k)) \otimes \mathbf{a}(N, d_2(k)) \tag{4}$$

where $\mathbf{a}(x, y) = [1, e^{y}, \cdots, e^{(x-1)y}]^T$, $d_1(k) = j2\pi \sin\theta_k \cos\varphi_k \frac{d_v}{\lambda}$, $d_2(k) = j2\pi \sin\theta_k \sin\varphi_k \frac{d_h}{\lambda}$, where $d_v = d_h = \lambda/2$ denote the antenna spacing in vertical and horizontal respectively, $\theta_k \in [0, \frac{\pi}{2})$ and $\varphi_k \in [-\pi, \pi]$ denote the angle of departure (AoD) of the kth user in vertical and horizontal.

Non-line-of-sight (NLOS) component $\widetilde{\mathbf{h}}_k = \sqrt{\widetilde{\mathbf{R}}_k}\mathbf{w}_k$, where $\mathbf{w}_k \in \mathbb{C}^{N_T \times 1} \sim \mathcal{CN}(\mathbf{0}, \mathbf{I})$ and $\widetilde{\mathbf{R}}_k \in \mathbb{C}^{N_T \times N_T}$ denote the correlation matrix of kth user.

$$\left[\widetilde{\mathbf{R}}_k\right]_{p,q} = \int_0^{\frac{\pi}{2}} \int_{-\pi}^{\pi} f(\varphi) f(\theta) e^{(p-q)(d_1+d_2)} d\varphi d\theta \tag{5}$$

where

$$f(\varphi) = e^{(\kappa \cos(\varphi - \mu_k))}/(2\pi I_0(\kappa)),$$
$$f(\theta) \propto e^{(-\sqrt{2}|\theta-\theta_0|/\delta)},$$

$I_0(\cdot)$ is the zeroth-order modified Bessel function of first kind, $\mu_k \in [-\pi, \pi]$ is the horizontal AoD of the kth user, κ controls the angular spread (AS), θ_0 and δ are the mean vertical AoD and AS.

We obtain the baseband precoding matrix $\mathbf{W}$ by ZF based on equivalent channel $\mathbf{H}_{eq} = \mathbf{H}^H\mathbf{F}$. Let $\bar{\mathbf{W}} = [\bar{\mathbf{w}}_1, \bar{\mathbf{w}}_2, \cdots, \bar{\mathbf{w}}_K] = \mathbf{H}_{eq}^H(\mathbf{H}_{eq}\mathbf{H}_{eq}^H)^{-1}$ and $\mathbf{w}_k = \frac{\bar{\mathbf{w}}_k}{\|\bar{\mathbf{w}}_k\|}$. The spectrum efficiency of this system is

$$R = \sum_{k=1}^{K} \log_2\left(1 + \frac{\frac{P}{K}\|\mathbf{h}_k^H \mathbf{F} \mathbf{w}_k\|^2}{\frac{P}{K}\sum_{i=1, i\neq k}^{K} \|\mathbf{h}_k^H \mathbf{F} \mathbf{w}_i\|^2 + \sigma^2}\right) \tag{6}$$

Then, the ergodic sum rate can be denoted as

$$\begin{aligned} \mathrm{R}_{\mathrm{sum}} &= \mathrm{E}[R] \\ &\overset{(a)}{\geq} \mathrm{E}[K \cdot \log_2(1 + \frac{P/\sigma^2}{\mathrm{tr}((\mathbf{H}_{eq}\mathbf{H}_{eq}^H)^{-1})})] \\ &\overset{(b)}{\geq} K \cdot \log_2(1 + \frac{P/\sigma^2}{\mathrm{E}[\mathrm{tr}((\mathbf{H}_{eq}\mathbf{H}_{eq}^H)^{-1})]}) \end{aligned} \tag{7}$$

where $\mathbf{H}_{eq} = \mathbf{H}^H\mathbf{F}$, (a) comes from the sum rate theorem in [4], and (b) comes from the fact that $\mathrm{E}(\log_2(1 + 1/x)) \geq \log_2(1 + 1/\mathrm{E}(x))$ for $x > 0$. We take the trace inverse of equivalent channel as the metric to measure the impact of antenna grouping on the stratospheric system similarly used in [4].

3. Antenna Grouping and Beamforming Design

We first exploit the fact that the HAP-MIMO channel is dominated by the LOS component, especially in the large scale array regime. Then we transform the metric of trace inverse into a novel statistical distance metric of the LOS component. The dynamic antenna grouping algorithm and hybrid beamforming scheme are jointly designed based on the Gershgorin Circle Theorem. The asymptotic setting $M, N \to \infty$ is considered throughout the paper.

The correlation matrix $\mathbf{R}$ of HAP-MIMO channel can be defined as

$$\begin{aligned} \mathbf{R} &\triangleq \lim_{M,N\to\infty} \mathrm{E}[\mathbf{H}\mathbf{H}^H] \\ &= \lim_{M,N\to\infty} MN\mathbf{U}^H \sum_{k=1}^{K} \mathrm{E}[\frac{1}{MN}\mathbf{U}\mathbf{h}_k\mathbf{h}_k^H\mathbf{U}^H]\mathbf{U} \\ &\overset{(c)}{=} \sum_{k=1}^{K} \frac{\alpha_k K_k}{(1+K_k)} \widehat{\mathbf{h}}_k \widehat{\mathbf{h}}_k^H \end{aligned} \tag{8}$$

where $\mathbf{U}$ is a Discrete Fourier Transform (DFT) matrix, which is a temporary unitary matrix and we do not need to define it detailedly, (c) comes from the NLOS theorem in [1], such as $\lim_{M,N\to\infty} \frac{1}{MN}\mathbf{U}\widetilde{\mathbf{R}}_k\mathbf{U}^H = \mathbf{0}$.

The novel statistical distance metric can be defined as

$$\zeta(p, q) \triangleq |\widehat{\mathbf{H}}_p * \widehat{\mathbf{H}}_q^H| = |[\mathbf{R}]_{p,q}| \tag{9}$$

where $\widehat{\mathbf{H}} = [\sqrt{\frac{\alpha_1 K_1}{(1+K_1)}}\widehat{\mathbf{h}}_1, \sqrt{\frac{\alpha_2 K_2}{(1+K_2)}}\widehat{\mathbf{h}}_2, \cdots, \sqrt{\frac{\alpha_K K_K}{(1+K_K)}}\widehat{\mathbf{h}}_K]$, $\widehat{\mathbf{H}}_p$ is the pth row of $\widehat{\mathbf{H}}$ and $p,q \in \{1,2,\cdots,N_T\}$. Let $\delta^{(g)}$ be the maximum of the sum of all $|S_g|$ statistical distances for group g, defined as

$$\delta^{(g)} = \max_{l \in S_g} \sum_{j=S_g^1}^{S_g^{|S_g|}} \zeta(l,j) \tag{10}$$

where S_g^j is the jth element of S_g and we propose the DHP algorithm in Algorithm 1.

Theorem 1: For the antenna grouping $\{S_1, S_2, \cdots, S_G\}$ with SCSI on $\widehat{\mathbf{H}}$, the metric of trace inverse in (7) for HAP-MIMO system is bounded as

$$\lim_{M,N\to\infty} \mathrm{E}[\mathrm{tr}((\mathbf{H}_{eq}\mathbf{H}_{eq}^H)^{-1})] \geq K^2 / \sum_{i=1}^{K} \delta^{(i)} \tag{11}$$

Proof: We let the RF precoding matrix $\mathbf{F} = [\mathbf{F}_{K-1} \ \ \mathbf{f}_K]$, where $\mathbf{F}_{K-1} \in \mathbb{C}^{N_T \times (K-1)}$ denotes the first $(K-1)$ columns of $\mathbf{F}$ and $\mathbf{f}_K$ denotes the Kth column of $\mathbf{F}$. Furthermore,

$$\begin{aligned}
&\lim_{M,N\to\infty} \mathrm{E}[\mathrm{tr}((\mathbf{H}_{eq}\mathbf{H}_{eq}^H)^{-1})] \\
&\overset{(d)}{\geq} \lim_{M,N\to\infty} \mathrm{E}[K^2/\mathrm{tr}(\mathbf{H}_{eq}\mathbf{H}_{eq}^H)] \\
&\overset{(e)}{\geq} \lim_{M,N\to\infty} K^2/\mathrm{E}[\mathrm{tr}(\mathbf{H}_{eq}\mathbf{H}_{eq}^H)] \\
&= K^2/\mathrm{tr}(\mathbf{F}^H\mathbf{R}\mathbf{F}) \\
&= K^2/\mathrm{tr}([\mathbf{F}_{K-1} \ \ \mathbf{f}_K]^H \mathbf{R} [\mathbf{F}_{K-1} \ \ \mathbf{f}_K]) \\
&= K^2/[\mathrm{tr}(\mathbf{F}_{K-1}^H\mathbf{R}\mathbf{F}_{K-1}) + \mathrm{tr}(\mathbf{f}_K^H\mathbf{R}\mathbf{f}_K)] \\
&\overset{(f)}{=} K^2/\sum_{i=1}^{K}\mathrm{tr}(\mathbf{f}_i^H\mathbf{R}\mathbf{f}_i) = K^2/\sum_{i=1}^{K}\mathrm{tr}(\bar{\mathbf{f}}_i^H\mathbf{R}_i\bar{\mathbf{f}}_i) \\
&\overset{(g)}{=} K^2/\sum_{i=1}^{K}\lambda_i^1
\end{aligned} \tag{12}$$

where (d) comes from Cauchy-Schwarz inequality, (e) comes from Mullen's inequality, (f) comes from the properties of trace, $\bar{\mathbf{f}}_i \in \mathbb{C}^{|S_i|\times 1}$ is the non-zero elements of $\mathbf{f}_i$, the constraints on $\bar{\mathbf{f}}_i$ is $\bar{\mathcal{F}} = \{\bar{\mathbf{f}}_i \,|\, |\bar{\mathbf{f}}_{i,j}| = 1/\sqrt{|S_i|}, \forall j\}$ based on (2), $\mathbf{R}_i \in \mathbb{C}^{|S_i|\times|S_i|}$ is the corresponding sub-matrix of $\mathbf{R}$ by keeping its S_i rows and S_i columns, λ_i^1 is the maximum eigenvalue of $\mathbf{R}_i$, (g) comes from the proposition derived in [7] and $\bar{\mathbf{f}}_i = \frac{1}{\sqrt{|S_k|}} e^{j\cdot\mathrm{angle}(\mathbf{v}_i^1)}$, where $\mathbf{v}_i^1$ is the corresponding eigenvector to the eigenvalue λ_i^1 of $\mathbf{R}_i$.

Applying the Gershgorin Circle Theorem, we know that each eigenvalue should be lower than the sum of absolute values of all elements in at least one row or column. Therefore, the maximum eigenvalue λ^1 of $\mathbf{R}$ satisfies $\lambda^1 \leq \max_{p\in\{1,2,\cdots,N_T\}} \sum_{q=1}^{N_T} \zeta(p,q)$. Similarly, the maximum eigenvalue λ_i^1 of $\mathbf{R}_i$ satisfies $\lambda_i^1 \leq \max_{l\in S_i} \sum_{j=S_i^1}^{S_i^{|S_i|}} \zeta(l,j) = \delta^{(i)}$. □

Algorithm 1 Proposed DHP algorithm

Input: The correlation matrix $\mathbf{R}$ and the antenna set $\mathcal{A} = \{1,2,\cdots,N_T\}$.
Output: S_k, $\forall k$ and $\mathbf{F}$.
1: *Initialization*: $\mathbf{F} = \mathbf{0}$, $S_k = \emptyset$ for $k = 1,2,\cdots,K$;
2: $\mathbf{C} \in \mathbb{C}^{N_T\times N_T}$, when $p \neq q$, $\mathbf{C}_{p,q} = \zeta(p,q)$, when $p = q$, $\mathbf{C}_{p,q} = 0$, where $\zeta(p,q)$ is obtained from (8);
3: Randomly select one element a from $\mathcal{A}$ and $S_1 = a$;
4: Let $\mathcal{A}^r = \mathcal{A}/a$ be the remaining antenna set;
5: Let $\mathcal{A}^h = a$ be the antenna head set;
6: **for** $k = 2,3\cdots,K$ **do**
7: $\quad j^* = \arg\max_{j\in\mathcal{A}^r} \mathbf{C}_{i,j}$, where $i \in \mathcal{A}^h$;
8: $\quad S_k = j^*$;
9: $\quad \mathcal{A}^h = \mathcal{A}^h \cup j^*$, $\mathcal{A}^r = \mathcal{A}^r/j^*$;
10: **end for**
11: **for** $i \in \mathcal{A}^r$ **do**
12: $\quad j^* = \arg\max_{j\in\mathcal{A}^h} \mathbf{C}_{i,j}$;
13: $\quad$Find j^* in group k^*, $S_{k^*} = S_{k^*} \cup i$.
14: **end for**
15: **for** $k = 1,2,\cdots,K$ **do**
16: $\quad$Obtain $\mathbf{R}_k = \mathbf{R}(S_k, S_k)$;
17: $\quad$Obtain the first eigenvector $\mathbf{v}_k^1$ of $\mathbf{R}_k$;
18: $\quad$Obtain the kth RF precoding vector $\mathbf{f}_k(S_k) = \frac{1}{\sqrt{|S_k|}} e^{j\cdot\mathrm{angle}(\mathbf{v}_k^1)}$.
19: **end for**

The ith RF precoding vector $\mathbf{f}_i$ has no relationship with the former $(i-1)$ RF precoding vector $\mathbf{F}_{i-1}$, which is not same with the process in [7]. The $\mathbf{f}_i$, i.e. $\bar{\mathbf{f}}_i$, can be obtained at the same time of the attainment of the ith antenna group S_i.

In order to maximize the lower bound of ergodic sum rate in (7), the trace inverse should be minimized at first. In light of Theorem 1, we provide a new criterion which maximizes the $\delta^{(g)}$ over all g such that

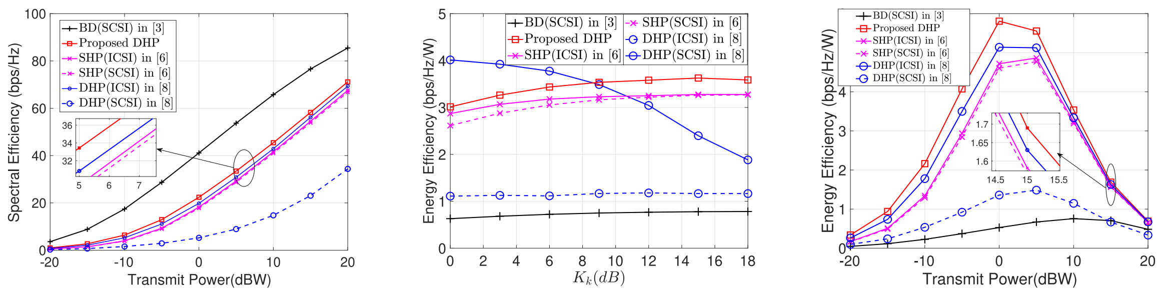
$$\{S_g^*\}_{1\leq g\leq K} = \arg_{\{S_g\}_{1\leq g\leq K}} \max \delta^{(g)} \tag{13}$$

The complexity of the proposed DHP algorithm is about $O(MN\frac{K(K+1)}{2} - \frac{K(K+1)(2K+1)}{6} + S\sum_i |S_i|^2 + 2KS)$, where the first eigenvector in step (18) is obtained through an iterative algorithm in [7], S is the iteration number and can be set as $S = 5$ [7]. The DHP algorithm in [8] has the complexity of $O(2MNK)$, but its feedback overhead is very high for HAP-MIMO system. We can simply utilize our proposed algorithm with the user grouping and power allocation algorithms in [1] and [6]. For the sake of innovation and limited space, user selection strategy is not considered in this letter.

4. Numerical Results and Analysis

In this section, the performance of the proposed DHP algorithm is evaluated. We assume the frequency, bandwidth and Rician factor to be 2.4 GHz, 10 MHz and 10 dB respectively. We set the height of HAP and the radius of users randomly distributed all as 20 km. The HAP is equipped with UPA ($\sqrt{N_T} = M = N$). We set κ, μ_{g_k}, θ_0 and δ as 5, 0^o, 30^o and 10^o. The noise variance is -169 dBm/Hz [3]. The Rician factor K_k is 10 dB.

The spectral efficiency performance of the proposed DHP scheme, BD scheme in [3], SHP scheme in [6] and DHP scheme in [8] with respect to different transmit power



(a) (b) (c)

Fig. 2 (a) Spectral efficiency performance versus transmit power ($M = N = 16, K = 8, K_k = 10\,dB$); (b) energy efficiency performance versus the Rician factor ($M = N = 16, P = 10\,dBW, K = 8$); (c) energy efficiency performance versus transmit power ($M = N = 16, K = 8, K_k = 10\,dB$).

is shown in Fig. 2(a). With the growth of transmit power, the spectral efficiency of the six curves are all faced with distinct increase. In [3], each RF chain is connected to one antenna and the number of RF chains is N_T. That's the reason that the BD scheme can achieve the best performance. The exploitation of the novel distance metric and singular value decomposition (SVD) make the proposed DHP algorithm under SCSI performs better than the SHP and DHP under ICSI. The sum rate of SHP and DHP under ICSI are higher than that under SCSI.

The energy efficiency ϵ is defined as

$$\epsilon = \frac{R_{sum}}{P + K \cdot P_{RF} + N_T \cdot P_{PS} + P_{BB}} \tag{14}$$

where R_{sum} is the sum rate, P_{RF}, P_{PS} and P_{BB} are the power consumption of RF chains, PS and baseband respectively. Let $P_{RF} = 300\,\text{mW}$, $P_{PS} = 1\,\text{mW}$ and $P_{BB} = 200\,\text{mW}$ [6]. Moreover, it is shown that RF components may consume up to 70% of the total transceiver energy consumption [6]. We do not consider the power consumption of other factors besides the above four.

Figure 2(b) and Fig. 2(c) depict the energy efficiency performance of the proposed DHP scheme, BD scheme in [3], SHP scheme in [6], DHP scheme in [8] as a function of the Rician factor and transmit power respectively. We can see that the performance of BD algorithm is the worst with the reason mentioned above. With the increase of the Rician factor K_k, all the six curves increase except the curve of the DHP scheme. The performance of DHP with SCSI is dramatically lower than that with ICSI and we can know that the DHP scheme in [8] is more suitable for the Rayleigh fading channel, rather than the HAP-MIMO system. When the Rician factor is high, the performance of the proposed DHP algorithm can outperform all the other schemes. According to Fig. 2(c), we can see that the performance of the proposed DHP algorithm is the best, resulted from the dynamic subarray architecture. At the point of $P = 0\,\text{dBW}$, the energy efficiency of the proposed achieves the peak and then it decreases, because P is in the denominator of (13).

5. Conclusion

In this letter, we have proposed a dynamic hybrid beamforming algorithm for HAP massive MIMO systems. Firstly, we have exploited the fact that the criterion of trace inverse of effective channel only has relationship with SCSI, where the RF precoder could be obtained. Next, we have proposed a novel statistical distance metric to measure the lower bound of trace inverse by utilizing the Gershgorin Circle Theorem. Then, the dynamic subarray scheme and the RF precoding matrix have been designed at once based on the lower bound. The digital precoding matrix could be obtained by ZF. Simulation results have shown that the enhanced performance of the proposed algorithm.

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