THE BEAMFORMING AT BS AND MS WITH RAKE FINGERS USING MIMO SYSTEM AND SPACE-TIME TECHNIQUE

BỨC XẠ TẠI BS VÀ MS VỚI CÁC NGÓN TAY RAKE SỬ DỤNG HỆ THỐNG MIMO VÀ KỸ THUẬT KHÔNG GIAN - THỜI GIAN

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Abstract:

The Rake receiver performs a multi-path signal gathering function and combines them into a signal of good strength. However, in order to serve the large capacity needs of users, Multiple Input - Multiple Output (MIMO) multi-antenna system incorporates the space-time coding technique used in combination with the Rake receiver. In a cellular network, the Mobile Station (MS) may have to receive multiple signals from different Base Stations (BSs) of which one base station desired and the rest are the affecting stations. The problem posed when using MIMO in combination with the Rake receiver, we need to make sure that the beam generated at the receiver will have the receiving direction related to the affecting base stations will have a gain of nearly zero. The paper concentrates on build these types of beam, and also proves the Signal to Interference and Noise Ratio (SINR) to be higher than the traditional case without using anti-inteference radiation from other BS stations.

Keywords:

Rake finger, MIMO, SINR, beam, multipath, space - time coding.

Tóm tắt:

Máy thu Rake thực hiện chức năng thu tín hiệu đa đường và kết hợp chúng thành một tín hiệu có cường độ tốt. Tuy nhiên, để phục vụ được nhu cầu dung lượng lớn cho người dùng, hệ thống đa anten vào - đa anten ra MIMO kết hợp kỹ thuật mã hóa không gian - thời gian được sử dụng với máy thu Rake. Trong một mạng di động, máy di động có thể phải thu nhận nhiều các tín hiệu từ các trạm di động khác nhau trong đó thường một trạm gốc mong muốn còn lại là các trạm ảnh hưởng. Bài toán đặt ra khi sử dụng MIMO kết hợp bộ thu Rake, chúng ta cần đảm bảo bức xạ được tạo ra ở máy thu sẽ có hướng nhận liên quan đến các trạm gốc ảnh hưởng sẽ có độ lợi gần bằng không. Bài báo tập trung xây dựng các bức xạ dạng này, hơn nữa còn chứng minh được tỷ số tín hiệu trên nhiễu và tạp âm (SINR) cao hơn so với trường hợp truyền thống không sử dụng bức xạ chống nhiễu từ các trạm BS khác.

Từ khóa:

Ngón tay Rake, MIMO, SINR, bức xạ, đa đường, mã hóa không gian - thời gian.

1. INTRODUCTION

The Rake receiver is the best function block with anti-interference capability. Each receiver is used to process a transmission path. Paper [1] describes in details the operating principle of a Rake receiver using the correlation matched filter (MF) measuring channel estimates. The output symbols from the RAKE fingers are multiplied by the complex conjugate of this channel estimation and aggregated using the combined maximum ratio diversity (MRC) technique. The paper [2] likewise, aims to maximize the signal to noise ratio (SNR) signal ratio by selecting the best multi-path signals and combining them to get the best signal out. The papers [3] [4] provide the method of selecting the best Rake receivers at the same time with the best SNR criteria. The paper [5] applies Bayesian method to calculate channel estimation, but this method is quite complicated in calculating channel parameters. The paper [6] shows a combination of Rake receiver and adaptive antennas. In the paper [6], the algorithm used for path estimation is blind which does not require channel estimation but needs to update the link weight continuously. In this paper, the combination of Rake receiver and adaptive antennas is investigated. This combination still has the goal of making the SNR the largest, but there is a channel status information feedback from the receiver to the transmitter. Information channel status does not change much because it is the spatial characteristics for the physical transmission path.

2. CHANNEL MODEL

This section assumes multiple BS transmitters and a MS receiver, with a special emphasis on the use of the spread spectrum codes $c_i, i = 1 \to M_s$ for M_s BSs (the space-time technique). The transmitter and receiver are introduced below:

- The transmitter: using the Q beams patterns.
- The receiver: using the P beam patterns the H_a elements correspondingly. This is called a 2D (two - dimensional) Rake.

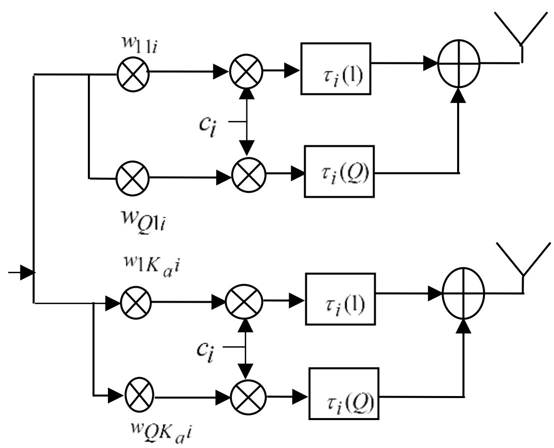

Figure 1. Transmitter using adaptive antennas

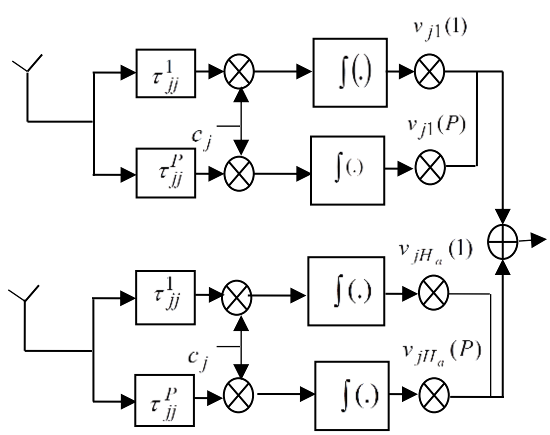

Figure 2. Receiver using adaptive antennas

In this section, the j th mobile experiences interference from the other M_s base stations where each base station has the Q beam patterns as reported in Figure 1. This mobile also uses the P beam patterns as described in Figure 2. For this mobile, a received signal is expressed as:

$$x_j^p(t) = \sum_{i=1}^{M_s}\sum_{q=1}^{Q}\sum_{l=1}^{L_{ji}} \sqrt{\tilde{P}_i\, G_{ij}^l \alpha_{ij}^l}\, \mathbf{w}_i^H(q)\mathbf{at}_{ij}^l \mathbf{ar}_{ij}^l$$
$$\sum_{k=-N_s}^{N_s} b_i(n-k) g\left(t - nT_b - qT_c - \tau_{ij}^l - \tau_{jj}^p - \tau_i(q)\right) + n_j^p \quad (1)$$

where $\tilde{P}_i$ is the transmit power of the i th base station.

G_{ij}^l is the gain between the i th base station and the j th mobile.

α_{ji}^l is the fading between the i th base station and the j th mobile.

$\mathbf{w}_i^H(q)$ is the q th transmit eigenvector of the i th base station and is expressed as:

$$\mathbf{w}_i(t) = \sum_q \mathbf{w}_i(q) g(t - qT_c) \quad (2)$$

$g(t)$ is the pulse shaping function, recall that $\mathbf{w}_j(t)$ is the beam vector at the time t and can be obtained by the space-time technique. $\mathbf{at}_{ij}^l$, $\mathbf{ar}_{ij}^l$ are the array responses at base station i and mobile j respectively and are defined as:

$$\mathbf{at}_{ij}^l = \begin{bmatrix} 1 \\ e^{-j\frac{2\pi}{\lambda} s_T \sin\varphi_{ij}^l} \\ \cdots \\ e^{-j\frac{2\pi}{\lambda} s_T \sin\varphi_{ij}^l (K_a - 1)} \end{bmatrix}$$

$$\mathbf{ar}_{ij}^l = \begin{bmatrix} 1 \\ e^{-j\frac{2\pi}{\lambda} s_R \sin\theta_{ij}^l} \\ \cdots \\ e^{-j\frac{2\pi}{\lambda} s_R \sin\theta_{ij}^l (H_a - 1)} \end{bmatrix}$$

where K_a is the number of elements at the transmit antenna.

H_a is the number of elements of the receive antenna.

$b_i(k)$ is the k th binary of massage sequence at the i th base station.

τ_{jj}^p is the delay of the p th finger at the j th mobile.

τ_{ij}^l is the delay of the l th path between the i th base station and the j th mobile.

$\tau_i(q)$ is the delay of the q th beam pattern of the i th base station.

$n_i^p(k)$ is the noise at the output of the p th finger at the i th mobile of the transmit k th binary.

T_b is the period of the one transmit bit.

$2N_s + 1$ is the length of the one symbol.

L_{ji} is number of paths between the the i th base station and the j th mobile.

At the sampler of the mobile, the output signal at the p th finger after sampling with an interval of pT_c (chips) is expressed as:

$$z_{j,h}^p(k) = \sum_{i=1}^{M_s}\sum_{q=1}^{Q}\sum_{l=1}^{L_{ji}} \sqrt{\tilde{P}_i\, G_{ij} \alpha_{ij}^l}\, \mathbf{w}_i^H(q)\mathbf{at}_{ij}^l \mathbf{ar}_{ij}^l(h) \quad (3)$$
$$b_i(k) r((p-q)T_c - \tau_{jj}^p - \tau_{ij}^l - \tau_i(q)) + n_i^p(k)$$

where $r(\tau)$ is the convolutional function of $g(t): r(\tau) = \int g(t-\tau) g(t) dt$.

When considering the response function between the BS and MS offered by the (3), this function is defined as:

$$\mathbf{h}_{ij,h}(k) = \sum_{l=1}^{L_{ji}} \sqrt{G_{ij}\alpha_{ij}^{l}}\,\mathbf{at}_{ij}^{l}\mathbf{ar}_{ij}^{l}(h)\, r(kT_c - \tau_{jj} - \tau_{ij}^{l} - \tau) \quad (4)$$

when it is assumed that $\tau_{jj}^{p} = \tau_{jj}, \tau_i(q) = \tau$

Hence, the function $z_{j,h}^{p}(k)$ can be rewritten as:

$$z_{j,h}^{p}(k) = \sum_{i=1}^{M_s}\sum_{q=1}^{Q}\sqrt{\tilde{P}_j}\,\mathbf{w}_i^{H}(q)\mathbf{h}_{ij,h}(p-q)b_i(k) + n_j^{p}(k) \quad (5)$$

Therefore, the output signal at of the combiner is expressed as:

$$y_j(n) = \sum_{h=1}^{H_a}\sum_{p=1}^{P} v_{jh}(p) z_{j,h}^{p}(n) = \sum_{h=1}^{H_a}\sum_{j=1}^{M_s}\sum_{q=1}^{Q}\sum_{p=1}^{P}\sqrt{\tilde{P}_i}\,\mathbf{w}_i^{H}(q)\mathbf{h}_{ij,h}(p-q) v_{jh}(p) b_i(k) + n_{jh_a}^{p}(k) \quad (6)$$

Where

$$\mathbf{H}_{ij}(p-q) = \left[\mathbf{h}_{ij,1}(p-q), \mathbf{h}_{ij,2}(p-q), \ldots, \mathbf{h}_{ij,H_a}(p-q)\right]$$

and $\mathbf{v}_j^{(p)} = \begin{bmatrix} v_{j1}(p) \\ v_{j2}(p) \\ \ldots \\ v_{jH_a}(p) \end{bmatrix}$, the function $y_j(n)$ is rewritten as:

$$y_j(k) = \sum_{h=1}^{H_a}\sum_{p=1}^{P} v_{jh}(p) z_{j,h}^{p}(k) \sum_{i=1}^{M_s}\sum_{q=1}^{Q}\sqrt{\tilde{P}_i}\,\mathbf{w}_i^{H}(q) \sum_{p=1}^{P}\left(\mathbf{H}_{ij}^{(p-q)}\mathbf{v}_j^{(p)} b_i(k) + \sum_{p=1}^{P}\sum_{h=1}^{H_a} n_{jh}^{p}(k) v_{jh}(p)\right) \quad (7)$$

It is assumed that:

$$\mathbf{F}_{ij} = \left[\mathbf{H}_{ij}(1-q), \mathbf{H}_{ij}(2-q), \ldots, \mathbf{H}_{ij}(P-q)\right]$$

$\mathbf{v}_j = [\mathbf{v}_j^{(1)}; \mathbf{v}_j^{(2)}; \ldots; \mathbf{v}_j^{(P)}]$ so that $y_j(k)$ is rewritten as:

$$y_j(k) = \sum_{i=1}^{M_s}\sum_{q=1}^{Q}\sqrt{\tilde{P}_i}\,\mathbf{w}_i^{H}(q)\mathbf{F}_{ij}(q)\mathbf{v}^{j} b_i(k) + \mathbf{N}_j(k)\mathbf{v}^{j} \quad (8)$$

where

$$\mathbf{N}_j(k) = \left[n_{j1}^{1}(k) \;\ldots\; n_{jH_a}^{1}(k) \;\ldots\; n_{j1}^{P}(k) \ldots\; n_{jH_a}^{P}(k)\right]$$

When the beam vector $\mathbf{w}_i(t) = \sum_q \mathbf{w}_i(q) g(t - qT_c)$, i.e., when the beam $\mathbf{w}_i(q)$ is available at the time $t = qT_c$, then the *SINR* that can be expressed as below for the j_d th desired mobile at the i_d th desired base station with the beam $\mathbf{w}_{i_d}^{H}(q)$ can be expressed as:

$$SINR\,(qT_c) = \frac{P_{i_d}^{n-1}\left|\mathbf{w}_{i_d}^{H}\mathbf{F}_{i_d j_d}(q)\mathbf{v}_{j_d}^{n-1}\right|^2}{\sum_{j=1, j\neq j_d}^{Z} P_j^{n-1}\left(\left|\mathbf{w}_{i_d}^{H}(q)\mathbf{F}_{ij}(q)\mathbf{v}_j^{n-1}\right| + \mathbf{N}_j\left|\mathbf{v}_j^{n-1}\right|^2\right)} \quad (9)$$

where Z is number of mobiles.

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In the case where the strongest eigenvector is utilized, given optimum beam is achievable when this vector $\mathbf{w}_{i_d s}^H(q)$ is the eigenvector corresponding to the largest eigenvalue of matrix $(\mathbf{F}_{i_d j_d}(q)\mathbf{F}_{i_d j_d}(q)^H)$.

Another method to increase the $SINR$ is using invariant dimensions. The eigenvector $\mathbf{w}_{i_d}^H(q)$ can be separated by the L_{ji_d} invariant eigenvectors $\mathbf{w}_{i_d}^H(q,l)$ where L_{ji_d} is the number of the physical paths between the i_dth desired base station and the jth mobile. When considering the $SINR$ offered by these dimensions, it is defined as:

$$SINR\ (qT_c) = \sum_{l=1}^{L_{ji_d}} \frac{P_{i_d}^{n-1}\left|\mathbf{w}_{i_d}^H(q,l)\mathbf{F}_{i_d j_d}(q,l)\mathbf{v}_j^{n-1}\right|^2}{\sum_{j=1, j\neq j_d}^{Z}\sum_{l=1}^{L_{ji_d}} P_{i_d}^{n-1}\left(\left|\mathbf{w}_{i_d}^H(q,l)\mathbf{F}_{i_d j}(q,l)\mathbf{v}_j^{n-1}\right|^2 + \mathbf{N}_j\left|\mathbf{v}_j^{n-1}\right|\right)} \quad (10)$$

where:

$$\mathbf{F}_{ij}(q,l) = \left[\mathbf{H}_{ij}(1-q,l) \quad \mathbf{H}_{ij}(2-q,l) \quad \ldots \quad \mathbf{H}_{ij}(P-q,l)\right]$$

$$\mathbf{H}_{ij}(p-q,l) = \left[\mathbf{h}_{ij,1}(p-q,l), \ldots, \mathbf{h}_{ij,H-1}(p-q), l\right]$$

$$\mathbf{h}_{ij,h}(k,l) = \sqrt{G_{ij}\alpha_{ij}^l}\,\mathbf{at}_{ij}^l\mathbf{ar}_{ij}^l(h)r(kT_c - \tau_{jj} - \tau_{ij}^l - \tau)$$

The solution is known from the above $SINR$ in which the vector $\mathbf{w}_{i_d}^H(q)$ is separated independently from the vectors $\mathbf{w}_{i_d}^H(q,l)$ defined as eigenvector corresponding to the largest eigenvalue of

$$\mathbf{F}_{i_d j_d}(q,l)\mathbf{F}_{i_d j_d}(q,l)^H\left(\sum_{j=1, j\neq j_d}^{M_s}\sum_{l=1}^{L_{ji_d}} \mathbf{F}_{i_d j}(q,l)\mathbf{F}_{i_d j}(q,l)^H\right)$$

3. SIMULATION

We simulate and compare capacity in the three cases: case 1 does not use beamforming, meaning that the radiation is omni- directional and the power is distributed equally to these radiation. Case 2 is using component vectors $\mathbf{w}_{i_d}^H(q,l)$. Transmission environment includes $M_s = 3$ base stations (1 desired BS and 2 interfering BSs) and one cellphone of interest. Determining the number of paths for each base station interfering to the mobile is 2 with the angle to the mobile is $\left[15^o \quad 60^o \quad 75^o \quad 90^o\right]$. The signal wavelength $\lambda = 0.1$ m. The distance between the transmitting and receiving antennas is $s_T = s_R = 0.1$. The transmission-time delays are 0. Figure 3 depicts the signal to interference and noise ratio of the two cases in different transmit directions.

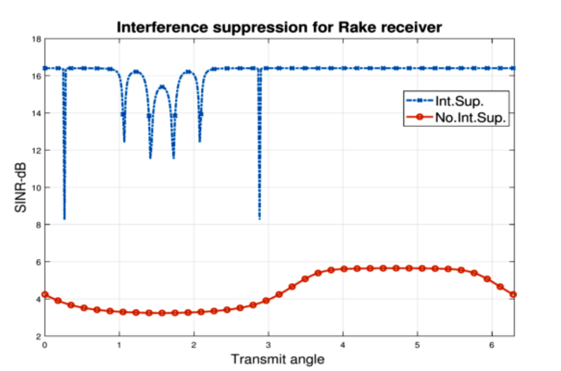

Figure 3. SINR with interference suppression

As shown in Figure 3, we see that case 2 has some low gain directions to ensure that the reception of signals from the two interferers will not be large. In addition, the signal ratio in case 2 is always greater than case 1.

4. CONCLUSION

The paper has given an anti-interference algorithm in the environment of many affecting base stations. The paper has also simulated and demonstrated a higher beam gain than in the case having none anti-interference algorithms. At the same time, the beam directions coming from interfering base stations based on the proposed algorithm will have the beam gain near zero.

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Bioagraphy

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