AN APPROACH FOR BTS ANTENNA SYSTEM FOR 3G AND 4G

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Abstract **-** In this paper, a BTS antenna system using conventional adaptive array antennas with transmit diversity is presented. Beam forming is constructed not only by an adaptive algorithm but also using a MIMO strategy. The performance of the suggested antenna system is compared to normal adaptive array antenna.

Keyword: MIMO, DOA, adaptive array, LMS.

I. INTRODUCTION

BTS is short for base transceiver station. It is an important part of a cellular mobile radio network. With its position in the network the BTS can be connected with all the mobile units within a given cell depending on the particular frequency planning. In the past, BTS antenna of the first generation had omni-directional patterns whereas the second generation had sectorization patterns. This kind of antenna was presented by W. C. Y. Lee [1]. With the development of 3G, the need for adaptive beam forming or smart antenna arised [2]. In addition, with 4G, designers have to combine existing BTS antenna systems and the MIMO strategy [3]. This is the main purpose of this paper.

This paper is organized as follows. The conventional BTS antenna structure is presented in section II. An approach for a BTS antenna system for 3G and 4G is proposed in section III. The operation of new antenna system is discussed in section IV. Section V concludes the paper.

II. BTS ANTENNA STRUCTURE

A conventional BTS antenna system is placed on the sides of an equilateral triangle (Fig. 1). In general, the antenna on each side supports one sector, covering three sectors. If the beamwidth of each antenna is about 120 degrees, this BTS antenna system will serve nearly 360 degrees of azimuthal plane. As in [1], we can use one transmitting antenna (Tx_1) and two receiving antennas (Rx_1, Rx_2) on each side.

If a linear antenna array is used for Tx_1, the array factor, AF, can be expressed as

$$AF = \frac{\sin\left(N\frac{\varphi}{2}\right)}{N\sin\frac{\varphi}{2}} \qquad (1)$$

where

$$\varphi = \frac{1}{2}\beta d\cos\Delta \qquad (2)$$

and where N is the number of elements in the array, d is the distance between two elements, β is the propagation constant, and Δ

is the angle between the incoming signal and the side of the array.

If a vertical dipole is used for each element, the element factor, *EF*, is given by

$$EF = \sin\theta \qquad (3)$$

The total electric field of Tx_1 is then

$$E = AF \cdot EF = \frac{\sin\left(N\frac{\varphi}{2}\right)}{N\sin\frac{\varphi}{2}}\sin\theta \qquad (4)$$

Two receiver antennas (Rx_1, Rx_2) are used for direction of arrival (DOA) estimation.

III. NEW ANTENNA STRUCTURE

The transmitting antenna is still placed on the three sides of an equilateral triangle. However for 4G, two transmitting antennas (Tx_1, Tx_2) are used as compared to one transmitter antenna (Tx_1) for 3G.

An antenna system without phase center is used for all receiving antennas. This antenna is placed on top of the triangle (Fig. 2). The structure of the receiving antenna consists of two antennas. The first antenna is a monopole (Rx_1). The second antenna has no phase center and is constructed from two vertical dipoles couples. These couples are perpendicular to each other and one is phase shifted by 90 degrees from the other. Further information about this type of antenna, called a turnstile antenna, can be found in [4].

IV. OPERATION

Transmitting strategy

For the transmitting strategy, we assume that a transmitted symbol is constant during the sampling period *T*. At moment *t*, symbol S_0 is transmitted by Tx_1 and symbol S_1 is transmitted by Tx_2. At next moment ($t + T$), symbol $-S_1^*$ and S_0^* are transmitted correspondingly. This MIMO strategy was introduced in [3].

The complex transmitted symbols are given by

$$X = \begin{bmatrix} S_0 & -S_1^* \\ \underbrace{S_1}_{t} & \underbrace{S_0^*}_{t+T} \end{bmatrix} \begin{matrix} Anten1 \\ Anten2 \end{matrix} \qquad (5)$$

In reality, only real symbols are transmitted.

The real transmitted symbols are given by

$$X = \begin{bmatrix} S_0 & -S_1 \\ \underbrace{S_1}_{t} & \underbrace{S_0}_{t+T} \end{bmatrix} \begin{matrix} Anten1 \\ Anten2 \end{matrix} \qquad (6)$$

When this simple transmitting diversity applied for adaptive antenna, the transmitted symbols become

$$X = \begin{bmatrix} S_0 W_0 & -S_1 W_1 \\ \underbrace{S_1 W_0}_{t} & \underbrace{S_0 W_1}_{t+T} \end{bmatrix} \begin{matrix} Anten1 \\ Anten2 \end{matrix} \qquad (7)$$

It is clear that if $W_0 = W_1 = 1$ the formula (7) will be the same as the formula (6) without loss of the generality.

DOA estimation

By using an antenna system without phase center and the MUSIC algorithm, the DOA can be estimated accurately.

Given the incoming signal $S(t)$, the output of the array can be expressed as

$$U(t) = AS(t) + W(t) \qquad (8)$$

where

$$A(\theta) = [a(\theta_1), a(\theta_2), \ldots, a(\theta_{n-1})] \qquad (9)$$

is the array manifold. $a(\theta)$ is the steering vector and $W(t)$ is a zero mean white Gaussian noise.

The autocorrelation matrix of the output signal is given by

$$R_{\mathbf{uu}} = E\{\mathbf{uu}^H\} \quad (10)$$

where **u** is the vector of output samples.

Let

$$V_n = \{q_i | i = D, ..., N - 1\} \quad (11)$$

where q_i are eigenvalues corresponding to eigenvectors of $R_{\mathbf{uu}}$.

Applying the MUSIC algorithm we get the power spectrum function

$$P(\theta) = \frac{1}{a_m^H(\theta) V_n V_n^H a_m(\theta)} \quad (12)$$

where

$$a_m(\theta) = (1, \exp(-j\varphi_B(\theta)) \quad (13)$$

$$\varphi_A(\theta) = C \quad (14)$$

is the phase pattern of the first receiving antenna and

$$\varphi_B(\theta) = \theta \quad (15)$$

is the phase pattern of the second receiving antenna.

Beam forming

We assume that the LMS algorithm is used and DOA is given by the DOA estimation process.

The weight vector is given by

$$W^T(n) = [w_1(n), w_2(n), \dots w_M(n)] \quad (16)$$

The vector of output samples can be expressed as

$$u^T(n) = [u_1(n), \dots\dots\dots\dots u(n - M + 1)] \quad (17)$$

The error vector is formed as follows

$$e(n) = d(n) - w^H(n) \,.\, u(n) \quad (18)$$

With d(n) is desired respond (It contains DOA and synchronization informations).

Therefore the objective function denoted as

$$J(n) = E\,[e(n)^2] \quad (19)$$

Thus

$$J(n) = E\,[(d(n) - W^H u(n))(d^*(n) - u^H(n)\, w)] \quad (20)$$

We rewrite J(n) as

$$J(n) = \delta_d^2 - w^H(n)\, p - p^H w(n) + w^H R w \quad (21)$$

Where

$$\delta_d^2 = E\,[d(n) d^*(n)] \quad (22)$$

$$p = u(n) d^*(n) \quad (23)$$

$$R = u(n)\, u^H(n) \quad (24)$$

To minimize the objective function gradient vector is calculated as

$$\nabla(n) = -2p(n) + 2R(n)\, w(n) \quad (25)$$

or

$$\nabla(n) = -2u(n) d^*(n) + 2\, u(n)\, u^H(n)\, w(n) \quad (26)$$

Interactive process can be executed as

$$w(n+1) = w(n) + \mu\, u(n)\, [d^*(n) - u^H(n) w(n)] \quad (27)$$

The weight vector can be written more simpler as

$$w(n+1) = w(n) + \mu\, u(n)\, e^*(n) \quad (28)$$

After some interaction processes, the optimum weight vector is obtained. Consequently, the main beam will point towards the direction of communications while nulls will be placed in the directions of noise sources.

Evaluation

Using the suggested BTS antenna structure, we exploited not only the adaptive antenna concept, but also the diversity transmitting strategy. The capacity of cellular mobile networks can be increased by the number of transmitted antenna to satisfy the demands of 3G and 4G [3]. Furthermore, using an antenna system without phase center, the DOA estimation process can be more accurate [4] and the number of receiving antennas reduced compared to the conventional approach.

The adaptive beam forming is done by using LMS algorithm to ensure that signal processing processes can be performed as quick enough for real time applications.

V. CONCLUSION

An approach for BTS antenna system was presented. Its benefits were pointed out. It is an important step in telecommunications research towards applications for next generation wireless networks.

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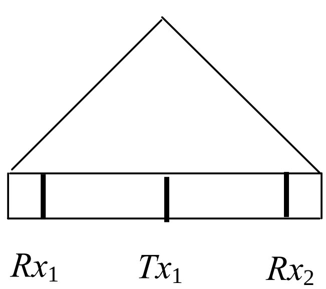

Fig. 1: Conventional antenna structure.

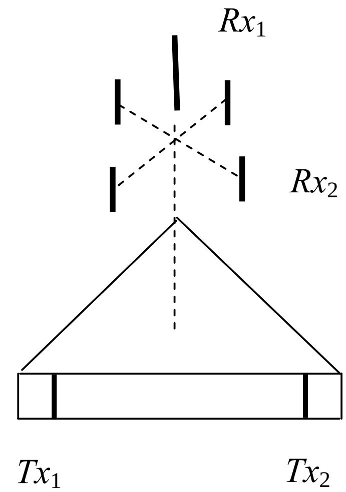

Fig. 2: New antenna structure.