Initial Direction of Arrival Estimation for Direction Lock Loop in DS/CDMA

Nenad Denić[1], Nenad Milošević[2], Zorica Nikolić[3]

Abstract – **In this paper, an algorithm for initial direction of arrival estimation is proposed. The proposed algorithm is made for model of the mobile receiver having three antennas. Tree antennas system is divided into tree separate systems in a very small time interval pointed in different direction. It is shown that the algorithm is able to estimate azimuth of arriving signal.**

Keywords – **Direction of arrival (DOA), Direction lock loop (DiLL), DOA tracking, estimation matrices, smart antenna, shifted angle, locking range...**

I. Introduction

World's first cellular network based on analog radio transmission technologies was put in service in early 1980's [1]. The first network reached high number of subscribers within the first few years. On the other side, subscribers had demand for higher capacity.

The first CDMA network was commercially launched in 1995, and provided ten times more capacity then analog network. Since 1995, CDMA network evaluated and whole system is demonstrated in theory as well as in practice. CDMA system based on the direct sequence (DS) spreading technique can in fact offer a higher bandwidth efficiency than its predecessors, such as the frequency division multiple access (FDMA) and TDMA techniques [1].lessen

High capacity DS/CDMA system demands clear signal without interference with other signals. In urban area multipath signals are common. Multipath signal decreases bit rate capacity. To reduce multipath influence on system capacity, many different techniques are used. One of the most important and most promising methods is space-division multiple-access (SDMA), implemented by using smart antenna systems and spatial filtering interference reduction. In recent years, smart antenna systems based on direction-of-arrival (DOA) have been developed to effectively suppress undesired signals from other directions by forming a beam pattern [2].

Eigen structure methods such as MUltiple SIgnal Classification-MUSIC and Estimation of Signal Parameters using Rotation Invariance Techniques-ESPRIT [3], [4]. However, these methods demand a lot of processing power and are not suitable for moving sources.

Subspace tracking algorithms have been proposed, such as projection approximation subspace tracking with deflation algorithm (PASTd) [5]. This algorithm tracks a signal subspace recursively. The computational requirement can be reduced in DS/CDMA systems with the assumption that a signal power is much stronger than that of the multiple access interference (MAI) after despreading [6].

In [7], tree dimensional DOA tracking scheme for DS/CDMA systems is proposed. The algorithm can track both azimuth and elevation if the initial values of these angles are within a certain range which is referred to as, the locking range. An error signal for the DOA tracking is generated from the spatial correlation of an input signal and the array response vectors whose directions are shifted from the current DOA tracking value. This error signal is used to iteratively update DOA tracking value. The DiLL may be implemented in both coherent and noncoherent modes. System for DOA estimation and tracking can work properly if the initial system direction is in locking range.

Initial direction of arrival for azimuth in DiLL algorithm is proposed in this paper. The algorithm is able to estimate azimuth of the incoming signal. As shown in [8], DiLL may be coherent or noncoherent.

II. System Model

The system model is the same as in [7]. Mobile receiver has one antenna at top, one at bottom and one antenna at its side. Having in mind Fig. 1, the mobile receiver has length of $2d$, and width of $2h$. In [7] it was shown that three antenna system can track both azimuth and elevation if is initial direction in certain locking range. To estimate initial value of azimuth the tree antenna system is divided in tree two antenna systems shifted for certain angle in space. Dipoles on Fig.1. are marked with numbers 1 to 3.

Let consider a two antenna array. Array response for this system, with the dipoles marked as n and m, is:

$$F_{n-m}(\theta) = A_n \exp\big(j(0)\big) + A_m \exp\big(j(kd\sin(\theta) - kd\sin(\theta_n))\big) \quad (1)$$

Where $A_1 = A_2 = A$, $k = 2\pi/\lambda$, θ is the angle of arrival, θ_n is the angle of antenna system direction, d represents distance between dipoles n and m. For dipoles 1 to 3, the Eq. 1 can be represented as following:

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$$F_{1-2}(\theta) = A(1+\exp\left(j(kd_1\sin(\theta) - kd_1\sin(\theta_0))\right)$$
$$F_{2-3}(\theta) = A(1+\exp\left(j(kd_1\sin(\theta) - kd_1\sin(\theta_1))\right) \quad (2)$$
$$F_{3-1}(\theta) = A(1+\exp\left(j(kd\sin(\theta) - kd\sin(\pi/2))\right)$$

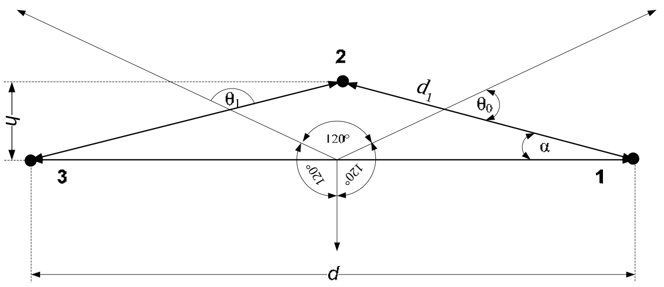


Fig. 1. A model of the antenna system

Fig.1 shows that there are tree two antenna systems 1–2, 2–3, 3–1. System 1–2 must have pattern pointed at angle θ_0, and 2-3 at angle θ_1. Two antenna system 3-1 represents a reference system and its pattern is pointed at 270° direction.

Angle θ_0 can be calculated from:

$$\tan(\alpha) = \frac{h}{d/2} \quad (3)$$

$$\alpha = \arctan(\frac{h}{d/2}) \quad (4)$$

Using simple operations, θ_0 can be represented as:

$$\theta_0 = 30 + \alpha = 30 + \arctan(\frac{h}{d/2}) \quad (5)$$

From Eq. 5, θ_1 is calculated as:

$$\theta_1 = 150 - \arctan(\frac{h}{d/2}) \quad (6)$$

III. Initial Direction of Arrival Estimation

In this section, the principle for the initial direction of arrival estimation will be described.

Basic idea of this system is to measure signal power in each of two antenna system. In the beginning, radiating pattern of two antenna system 1-2 is pointed at angle θ_0 as shown in Fig 2.a, and the signal power is measured and saved. After Δt period of time, system 2-3 pattern is pointed at angle θ_1, Fig. 2.b, and again the signal power is measured and saved. The same is repeated for system 3-1, shown in Fig. 2c, and pattern is pointing at angle 270°.

Received signal power values make power array:

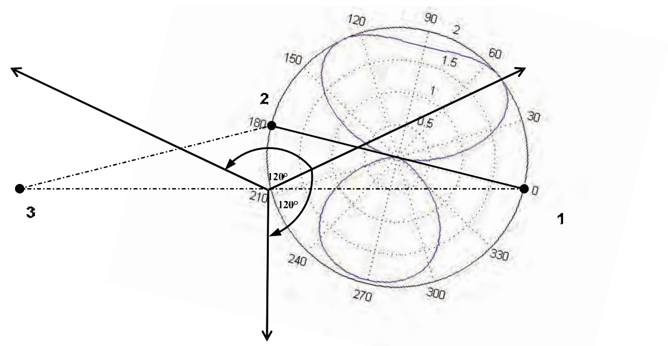
$$P(\theta_e) = [P_{1-2}(\theta_e), P_{2-3}(\theta_e), P_{3-1}(\theta_e)] \quad (7)$$

Where $P_{n-m}(\theta)$ represents the power received by two antenna system *n-m*. $P_{n-m}(\theta)$ can be written as:

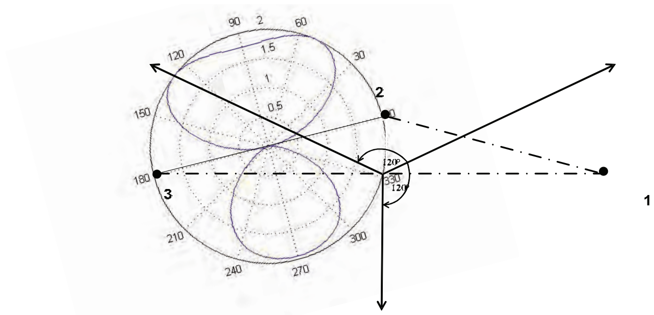
$$P_{n-m}(\theta_e) = F_{n-m}(\theta_e)P_s \quad (8)$$

where P_s represents signal power at the input of *n-m* system.

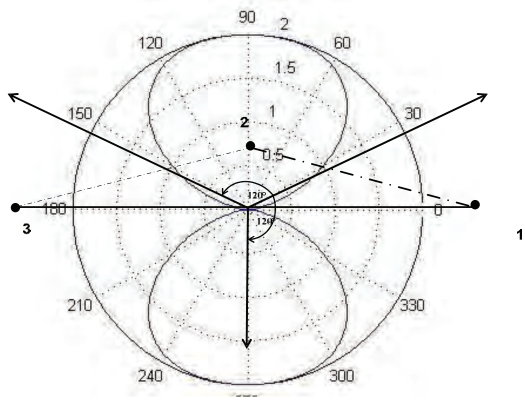
For each two antenna system array response has to be measured and saved.



a)



b)



c)

Fig. 2. Array response for two antenna systems,
a) $F_{1-2}(\theta)$, b) $F_{2-3}(\theta)$, c) $F_{3-1}(\theta)$

To put in same reference system 3-1, the other two array responses must be reordered, i.e. array $F_{1-2}(\theta)$ has to be shifted shifted for θ_0 and $F_{2-3}(\theta)$ for θ_1. So

$$F^*_{1-2}(\theta) = F_{1-2}(\theta - \theta_0) \quad (9)$$

$$F^*_{2-3}(\theta) = F_{2-3}(\theta - \theta_1) \quad (10)$$

Estimation matrix can be represented as:

$$F^*(\theta) = [F^*_{1-2}(\theta), F^*_{2-3}(\theta), F^*_{3-1}(\theta)] \quad (11)$$

Using Eq. (8) in (7), the received signal power array is

$$P(\theta) = [F_{1-2}(\theta_e)P_s, F_{2-3}(\theta_e)P_s, F_{3-1}(\theta_e)P_s] \quad (12)$$

The algorithm used for angle of signal arrival estimation is shown in Fig. 3.

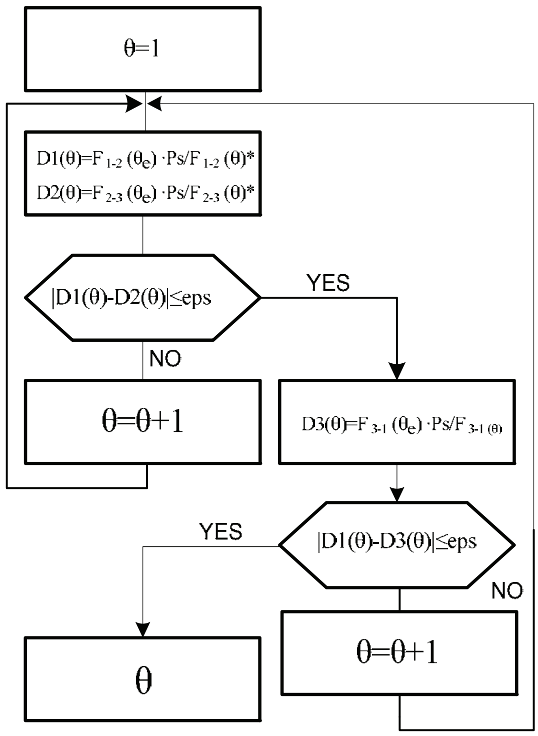


Fig.3 Algorithm for initial DOA estimation

Fig. 3 represents mathematical algorithm for initial DOA angle form estimation matrices and power array. Power value of first two antenna system is divided with estimation matrices value for certain angle. Next step is subtraction of values D1(θ) and D2(θ). If absolute difference is not smaller or equal than *eps* (threshold), angle value is changed for +1. If difference is smaller than *eps* algorithm will check the difference between D1(θ) and D3(θ). If their difference match criteria angle θ is DOA angle θ_e.

IV. Simulation Results

In this section, an example of initial DOA estimation will be shown. Simulation is performed in Matlab. It was chosen $d = \lambda / 2$ and $h = \lambda / 10$, f = 1800 MHz, P_s = 0.5W, and angle of signal arrival is 72°.

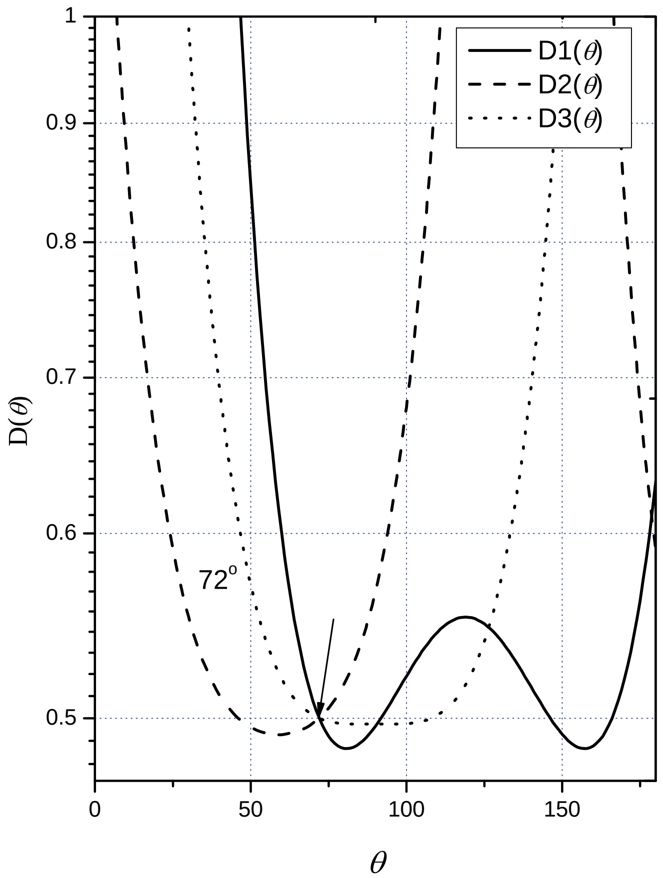


Fig.4 DOA final results

Fig.4. shows functions D1, D2 and D3 as a function of estimated angle θ. It can be seen that all curves intersect at angle θ = 72°. Therefore, the direction of arrival is determined correctly.

V. Conclusion

In this paper, an algorithm for s initial direction of arrival estimation is proposed. The algorithm is able to estimate elevation by forming the estimation matrices and a power array. It was shown that the proposed algorithm can estimate the direction of arrival of the incoming signal. System for the three dimensional DOA estimation and way how to solve problem for initial elevation estimation will be the subject of the authors' future work.

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