Beamforming Based Mobile User Tracking

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ABSTRACT - One way to increase system capacity in the future telecommunication systems is to employ adaptive antennas at the base station. They enable reception and transmission utilizing narrow beams which can dramatically reduce interference for other users. In this paper we propose a fast multi-user tracking system based on the spatial domain beamforming concept. The simulation results show that the proposed tracking system reacts fast and gives small tracking errors.

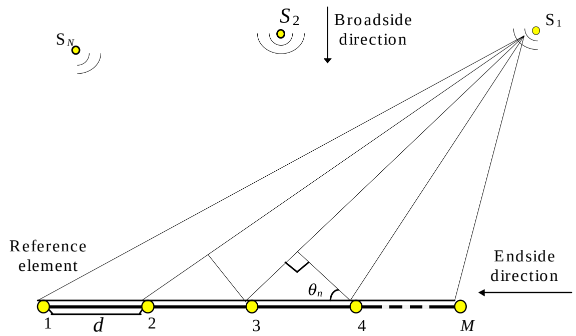

Figure 1 Adaptive antenna array receiver.

1. INTRODUCTION

The target tracking problem arises in numerous applications, e.g., mobile communications where for each moving user appropriate beamforming based connections have to be established and maintained. Target tracking methods in this context enable continuous locating of mobile terminals as they move around in the cell. For this aim, efficient and robust mobile user tracking system is needed. The location and tracking problem of multiple moving targets could be solved by utilizing numerous different beamforming methods like MUltiple SIgnal Classification (MUSIC) or Maximum Likelihood (ML) methods [1]. However, continual application of these kinds of algorithms is prohibited from the computational complexity point of view. Furthermore, they also introduce the data association problem, i.e., the beamformer has no way to associate location estimates to different mobile users. In this paper we employ the method which can track multiple moving sources efficiently by using a conventional beamforming strategy without any greater performance losses in the case of Direction-of-Arrival (DOA) pointing errors [2]. The tracking system is enhanced by introducing an adaptive control strategy [3].

2. TRACKING MODEL

The tracking model for the antenna array used in the simulations will be developed in this section. The adaptive antenna configuration is illustrated in Figure 1, where the antenna array receiver with *M* elements at the base station and *N* surrounding mobile users are shown. The communication signals S_n (n=1, …, N) are crude modeled as a zero-mean Gaussian distributed processes [4]. The additive noise process is also drawn from a Gaussian distribution. Furthermore, it is assumed that samples from the signal and noise process do not correlate with each other. The beamforming concept is based on the antenna steering vector which represents the azimuth θ_n response of the antenna array for each source. The beamforming operation forms the beams for each source and extracts the desired communication signals. The tracking problem becomes to that of continuous location estimation as the mobile users move around the base station.

Figure 2 shows the components of the tracking system. The communication signals impinged on the antenna array are downconverted and digitized in the receiver frontend. The baseband user signals are estimated in the beamforming unit by using the conventional block beamforming strategy. In the tracking unit the steering vectors are updated based on the received sample block which reflect new locations for mobile users. The updating rule can be derived by minimizing all the interference signal and noise components orthogonal to desired user signal component [5]. In the model fitting unit the new azimuth tracking angles for each user are determined by projecting the steering vector

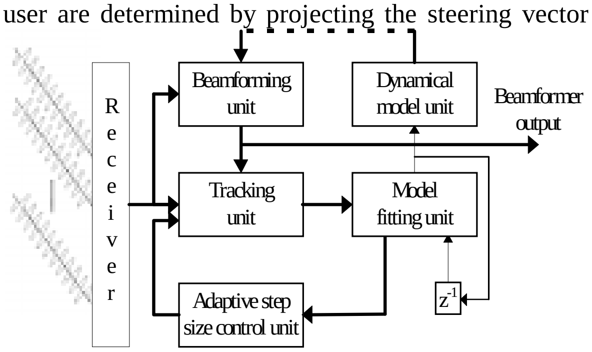

Figure 2 Tracking system.

back to the array manifold. The dynamical model unit takes care of the quality of the location estimates. As the mobile users in the crossing stage are in the resolution range of the antenna array the location estimates become worse and the beamformer may start to follow wrong mobile user. This problem can be avoided by switching to an appropriate location estimation method, like linear regression on the past estimated location values. Adaptive Step (AS) size control unit enhances the adaptation speed by adjusting the step size suitably. Large tracking errors are introduced by using too large step size. On the other hand too small step size can not react in the nonstationary environment.

3. SIMULATION RESULTS

The antenna array receiver consists of M=8 uniformly distributed antenna elements with $\lambda/2$ spacing. Two Gaussian distributed sources with equal variance with SNR=10 dB are at the initial azimuth locations of 10° and 40°. The pointing errors of 5° are introduced to the location estimates of both sources so that the convergence behavior can be inspected. Figure 3 shows the simulation results for the dynamical signal scenario case. Figure 3a) illustrates the target tracking curves. The moving sources are under the constant speed of 0.25 Deg/sample. Figure 3b) shows the tracking error behavior for both Least Mean Square (LMS) and AS methods. As can be seen the AS method can easily outperform any fixed step size method. Finally Figure 3c) confirms the steady behavior for the step size.

4. CONCLUSIONS

The proposed adaptive method gives good results in terms of low misadjustment and fast convergence. This is advantageous especially for users following curvaceous trajectories.

ACKNOWLEDGEMENTS

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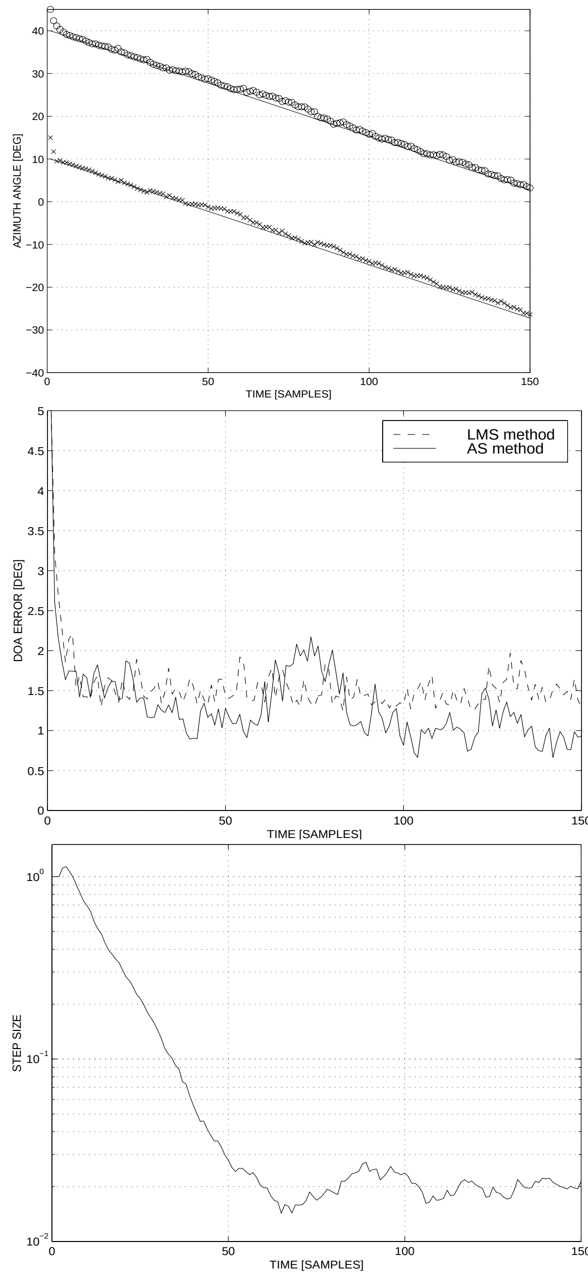

Figure 3 Dynamical signal scenario. a) Illustration of tracking of moving sources b) DOA error as a function of time by using LMS with the fixed step size 0.1 and AS method. c) Step size behavior for AS method.

REFERENCES

[1] P. S. Unnikrishna, *Array Signal Processing*. New York, NY: Springer-Verlag, 1988.

[2] R. T. Compton, *Adaptive Antennas*, Englewood Cliffs: Prentice Hall, 1988, pp. 448.

[3] P. T. Karttunen, T. I. Laakso and J. Lilleberg, “Tracking of Mobile Users in a Mobile Communications System Using Adaptive Convergence Parameter”, PIMRC’97, Helsinki, Finland, Sep 1-4, 1997, pp. 989-993.

[4] C. W. Therrien, *Discrete Random Signals and Statistical Signal Processing*, Englewood Cliffs: Prentice Hall, 1992, pp. 727.

[5] S. Affes, S. Gazor and Yves Grenier, “An algorithm for multisource beamforming and multitarget tracking”, *IEEE Trans. on Signal Processing*, Vol. 44, No. 6, June, 1996, pp. 1512-1522.