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HIGH-RESOLUTION DIRECTION FINDING USING A SWITCHED PARASITIC ANTENNA

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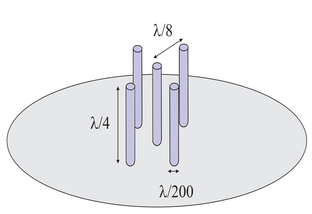
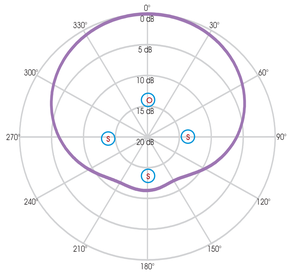
Introduction

- Direction finding is of great importance in applications such as radar, sonar, communications, and personal locating services
- Often, the Direction Of Arrival (DOA) is estimated based on the fact that an incident wave will arrive at each element of an antenna array at different time instants
- Employing many elements is expensive and DOA estimation requires accurate calibration
- An interesting alternative is to exploit the directional radiation patterns of a Switched Parasitic Antenna (SPA)
- By employing switchable passive (parasite) elements, several different radiation patterns can be obtained using only a single radio receiver connected to a center element
- These different radiation patterns can be used for high-resolution direction finding applications

Switched Parasitic Antenna





- The far-field radiation patterns $F(\phi)$ can be altered by short-circuiting the parasitic elements (PEs) on and off via switching of pin diodes
- The PEs become reflectors when shorted to ground and thus directs the radiated energy in one direction
- There are no switches in the RF-path since the center element always is connected to the receiver
- Obtain several signal samples by switching through M patterns and sample coherently (spatio-temporal oversampling)
- Switching time of pin diodes of the order of ns

Data Model

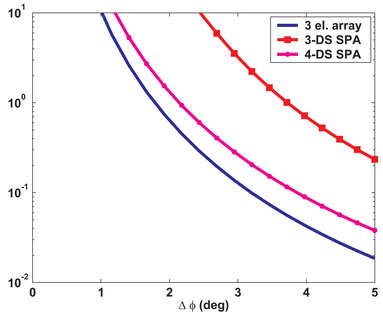
- Model for the measured voltages: $\mathbf{x}(t) = \mathbf{A}(\boldsymbol{\phi})\mathbf{s}(t) + \mathbf{e}(t)$

$$\mathbf{A}(\phi) = \begin{bmatrix} F(\phi_1) & F(\phi_2) & \cdots & F(\phi_p) \\ F(\phi_1 + 2\pi/M) & F(\phi_2 + 2\pi/M) & \cdots & F(\phi_p + 2\pi/M) \\ \vdots & \vdots & \vdots & \vdots \\ F(\phi_1 + (M-1)2\pi/M) & F(\phi_2 + (M-1)2\pi/M) & \cdots & F(\phi_p + (M-1)2\pi/M) \end{bmatrix}$$

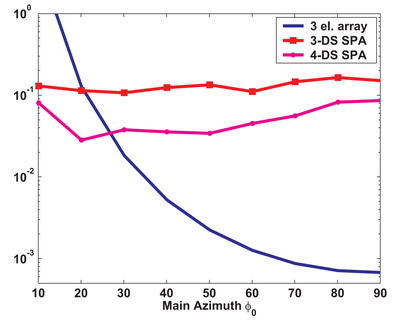
- Assumptions:
  - –The steering matrix $\mathbf{A}(\phi)$ $(M \times p)$ has full rank
  - –The noise is circularly Gaussian distributed $\mathbf{e}(t) \in \mathcal{N}(0, \sigma^2\mathbf{I})$
  - –The signal is also circularly Gaussian distributed $\mathbf{s}(t) \in \mathcal{N}(0, \mathbf{S})$

Direction Finding Performance

- A common performance measure in direction finding is the variance of the DOA estimates since most methods give unbiased estimates
- Examine the direction finding potential of the switched parasitic antenna by calculating a lower bound on the variance, the Cramèr-Rao Bound (CRB)



The square root of the CRB for several different configurations when two waves are incident from (30°,30°+Δ) with SNR=10dB and 1000 samples.



The square root of the CRB for several different configurations when two waves are incident from (ϕ_0,ϕ_0+5) with SNR=10dB and 1000 samples.

- Better performance for an array for most DOAs except for end-fire, however the SPA requires only a single radio receiver
- More robust performance of the SPA since CRB similar for all DOA
- Performance increases with more parasites (or directional symmetries)
- High-resolution direction finding possible using the SPA

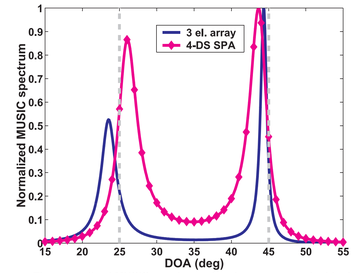
Estimation Methods

- In principle, all DOA estimation schemes that are derived for a general antenna array can also be applied to the SPA
- The data model is still the same, the only difference is a new steering matrix
- Additional DOA estimation methods can also be developed that simply compares the received magnitude for each radiation pattern

Estimation Example:

MUSIC Method

- Performance of MUSIC similar for the SPA with four parasites and a three element array (l/2)
- For uncorrelated signals, MUSIC is unbiased and asymptotically efficient



The normalized MUSIC spectrum when two waves are incident from 25° and 45° upon a 4-DS parasitic antenna and a three element array with SNR=10dB and 1000 samples.

Conclusions

- By employing passive elements (parasites) that can be shorted to ground via pin diodes, directional radiation patterns is obtained that successfully can be used to estimate DOAs.
- Since the Switched Parasitic Antenna (SPA) only requires a single radio receiver, it offers DOA estimation at a low cost
- The SPA also offers a more compact antenna than an array
- A data model for the SPA was derived and the direction finding performance was examined by calculating the CRB and the MUSIC estimator for several different cases.
- It was found that the SPA offers high-resolution direction finding possibilities using only a single radio receiver
- Exploiting parasitic elements for DOA estimation is an interesting alternative that offers several advantages over traditional arrays.