HIGH-RESOLUTION DIRECTION FINDING USING A SWITCHED PARASITIC ANTENNA

Thomas Svantesson
Department of Signals and Systems
Chalmers University of Technology
SE-412 96 Göteborg, Sweden
email: tomaso@e2.chalmers.se

Mattias Wennström
Signals and Systems Group
Uppsala University
SE-751 20 Uppsala, Sweden
email: mw@signal.uu.se

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

Data Model
- Model for the measured voltages: \( x(t) = A(\phi)t + e(t) \)
  \[
  A(\phi) = \begin{bmatrix}
  F(\phi_1) \\
  F(\phi_1 + 2\pi/M) \\
  \vdots \\
  F(\phi_1 + (M-1)2\pi/M)
  \end{bmatrix}
  \]
- Assumptions:
  - The steering vector \( A(\phi) \) has full rank
  - The noise is circularly Gaussian distributed \( e(t) \in \mathcal{N}(0,M) \)
  - The signal is also circularly Gaussian distributed \( x(t) \in \mathcal{N}(0,S) \)

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)

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 (22)
  - For uncorrelated signals, MUSIC is unbiased and asymptotically efficient

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.

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 direct 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