PhD Thesis Description

ADVANCED USE OF A MULTI-ACCESS BROADBAND VECTOR ANTENNA FOR DIRECTION-FINDING AND PRECISE POSITIONING APPLICATIONS

1. Supervisors

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3. Description

3.1. Context

Direction-finding applications can be found in both the civilian and military sectors. The main applications include distress signal search, self-guided navigation, and radio spectrum monitoring. For the first two applications, the direction finder needs to be on-board. In this case, the sensor needs to be small to reduce its size and weight.

In the context of on-board antennas on small carriers such as small satellites or UAVs, for example, it is vital that the sensor takes up very little space. Conventional direction-finding is based on the principle of interferometry, requiring the use of a large antenna array to improve angular resolution. Another approach is based on the use of a vector antenna exploiting polarization diversity. This implies a smaller sensor with lower angular resolution performance. However, a broadband multi-access vector sensor benefits from additional degrees of freedom to improve performance through antenna processing techniques using frequency and radiation pattern diversity.

3.2. Objective(s)

The aim of this work is both to design a small-scale broadband vector sensor, and to develop innovative antenna processing that can exploit polarization, frequency and possibly time information to extend source localization (angle-of-arrival detection) to positioning (distance estimation).

3.3. Work Plan

The operating principle of a radio direction-finder is based on the reception of the RF signal on a particular geometrical arrangement of several sensors, in order to extract the direction of arrival of the signal by processing.

The system comprises three sub-elements: a multi-access antenna, an RF front-end based on a software define radio (SDR) and a signal processing algorithm.

At ENAC, several research projects have been focused on the development of vector sensors applied to the detection of emergency beacons at GSM band [1, 2] and for aircraft positioning at 5G bands [3]. These studies shown the capabilities of VA antenna for DoA estimation in 3D-space using small dimension antenna sensors. However, these first results use basic signal processing technics and some enhancement merit to be investigated in this point. It can be evaluated the gain using other kind of algorithms for accelerate the DoA processing. Moreover, polarization information can be evaluated, and frequency broad-band antenna characteristics can also be exploited. Besides, the measured VA antenna performances have been investigated in controlled environment by mean of a vector network analyzer (VNA). It can be interesting to test this kind of antenna in real environment by mean of a software defined radio device.

The planned program is as follows:

Task T1: Analysis of the state of the art

- T1.1: Literature review on algorithms applied to direction-finding using vector sensors.

- T1.2: Literature review on the benefits of vector sensors for direction-finding.

- T1.3: Literature review on frequency diversity and MIMO radar.

Task T2: Theoretical comparison of the performance of appropriate algorithms

- T2.1: Establish a numerical model of different sensors and estimation methods.

- T2.2: Compare performances according to the type of sensor and algorithm used (accuracy, computational load, implementation complexity, source discrimination, etc.).

- T2.3: Performance study of a vector sensor network

Task 3: Improvement of the selected DoA estimator

- T3.1: Specific study of incident field polarization estimation.

- T3.2: Specific study on the estimation of the number of sources.

- T3.3: Study of the use of additional synthesized diagrams.

- T3.4: Study of antenna bandwidth utilization.

Task 4: Implementation of an experimental bench based on a software receiver (SDR).

- T4.1: Measurement and processing of time series from vector sensors

- T4.2: Analysis of antenna performance associated with the signal processing technique used.

- T4.2: Analysis of sensor sensitivity to multipath.

Task 5: Drafting of thesis manuscript

3.4. Keywords

Direction of Arrival estimation, vector antenna, polarity diversity

3.5. References

[1] J. Lominé, C. Morlaas, C. Imbert and H. Aubert, "Dual-Band Vector Sensor for Direction of Arrival Estimation of Incoming Electromagnetic Waves," in IEEE Transactions on Antennas and Propagation, vol. 63, no. 8, pp. 3662-3671, Aug. 2015,
[2] J. Duplouy, C. Morlaas, H. Aubert, P. Potier, P. Pouliguen and C. Djoma, "Wideband and Reconfigurable Vector Antenna Using Radiation Pattern Diversity for 3-D Direction-of-Arrival Estimation," in IEEE Transactions on Antennas and Propagation, vol. 67, no. 6, pp. 3586-3596, June 2019.
[3] J. Duplouy, C. Morlaas, H. Aubert, P. Potier and P. Pouliguen, "Radiation-pattern reconfigurable and wideband vector antenna for 3-D direction finding," in URSI Radio Science Bulletin, vol. 2020, no. 373, pp. 56-62, June 2020.

4. Doctoral School

GEETS

5. Research Unit

ENAC

6. Proposed Funding (open options)

- CNES (full funding, 1st preselection phase succeeded, final phase needs an identified candidate)
- Other back-up options: AID, ENAC