On the Development of a Self-Recoverable Antenna System

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Introduction

Antennas are used for tasks such as point-to-point communication, area coverage, or target tracking, to mention a few. If an element of an antenna system fails, it degrades the original radiation of the system, possibly severely. A service suffers such degraded characteristics until the antenna is replaced, which can bear high cost and a possible loss of service.

As the need for more reliable communications is growing, new solutions have been proposed such as diversity [1], to improve the reception of signals, or reconfigurable antennas, which are meant to reconfigure themselves in terms of parameters such as their operating frequency, polarization, or the radiation pattern [2-6]. Yet, *these approaches are based on the premise that all elements of the antenna are fully operational.* Traditional antenna-, and electronic- systems, have not been made to recover themselves if part of a system fails, possibly on a hard-to-reach location or at a critical moment, which can occur with broadcast towers, space stations, or at the battlefield, for example.

Our aim is to create a self-recoverable antenna (SRA) system in order to improve reliability and versatility to current solutions. To achieve it, we work on a system integration of advanced optimization algorithms with the Field-Programmable Gate Arrays (FPGA) [7].

This solution will be significant for all systems where intelligent operation and immediate response of an antenna to a sudden failure or to a change of conditions in the surrounding environment is sought. Such situations can readily appear in the critical fields of todays technology, such as broadcasting, transportation, defense, security, and the emerging field of telemedicine.

Failure Effects on the Radiation Pattern

Currently, there are *classical* antenna systems (e.g. terrestrial TV towers), smart antennas, and reconfigurable antennas present on the market. The *classical* systems do not change their radiation characteristics during the operation. Smart antennas, switched-beam or adaptive-beam, change their radiation pattern following some algorithm, while reconfigurable antennas will change some of their parameters such as the beam shape, if everything is operational.

The radiation pattern may easily get corrupted if any of the array elements get

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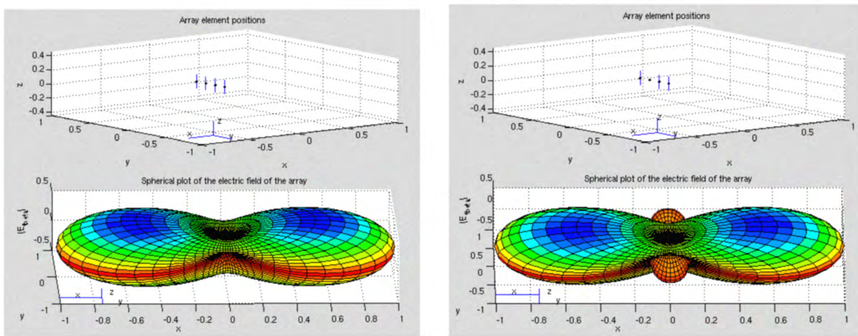
flawed, as shown in this simple example. Fig. 1(a) shows a fully operation array, illustrated by the dots and the lines crossing them (symbolizing dipoles), and the accompanying radiation pattern. Fig. 1(b) shows the same array, now with one flawed element, and the corresponding radiation pattern, which is now substantially affected.



(a) healthy array (b) flawed array

Figure 1: a) Example of a fully operational array and its radiation pattern. (b) The same array with a failed element and the corresponding radiation pattern.

One can easily imagine a variety of degraded beam shapes due to failure of one or more elements in the array, especially for the greater number of elements. Let us observe only three cases of element failures in a simple array, as indicated in Fig. 2 where "1" denotes a healthy element, while "0" denotes a flawed element.

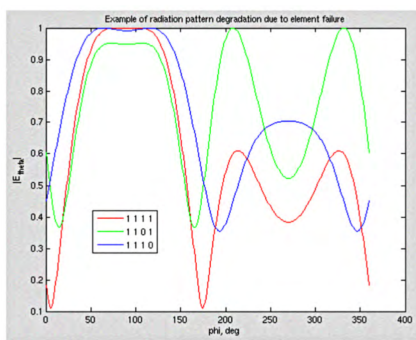


Figure 2: Samples of a small array failure cases.

Solution Development

Under this approach, we assume an n-element antenna array of any type, with adjustable magnitudes (A_i) and phases (α_i) that control the radiation pattern. We monitor the operation of each element by some indicator. When an array element fails, we compare the arrays new radiation characteristics with the original one. If it differs more than some tolerable amount, a self-recovery process of the system is started. Utilizing the genetic algorithm (GA) [8], we find A_i and α_i that will best recover the array with respect to a given failure. As the key advancement of the concept, we will employ the FPGA technology [8] to develop intelligent operation and control of the system as a system on a chip (SoC) (as it should later include additional algorithm modules for array optimization). The tuner, as in Fig. 3, receives from the SoC an optimal solution to the failure situation and sets new values of A_i and α_i to recover the operation of the SRA as much as possible. There is a feedback channel through which the client computer communicates with the SoC. This SRA would be capable of residing at a remote location and maintaining its communication with the client computer via some radio link.

The SoC occupies the central part of the system, communicating with the client computer, autonomously processing the information, making decisions, and generating proper signals to control the SRA. To reduce the response time, solutions to some number of premeditated failure cases are embedded in the SoC by means of a "look-up table." For unpredicted scenarios, GA executes in real-time to reach the solution.

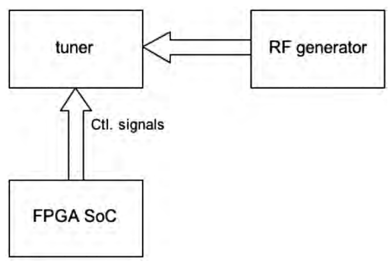


Figure 3: Signal conditioning principle.

The success of pattern recovery depends upon the array type and configuration (i.e. whether it is broadside, or end-fire, uniform or binomial, linear or planar) In this stage of the development, we work on the recovery algorithm(s) and its implementation within the FPGA controller. The example in Fig. 4 shows that a 4-element binomial broadside array pattern was recovered rather successfully after failure of one element. The algorithm was set to begin the self-recovery process if the mean error between the original pattern and the flawed pattern is 1.5 dB.

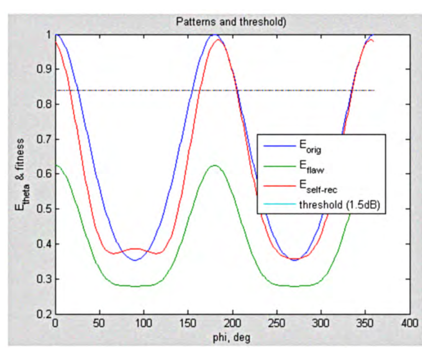


Figure 4: Recovery of the SRA pattern after an element failure.

Summary

We report on the initial stage of the development of a SRA system, whereas the complete system is meant to incorporate real-time computing, decision making, parameter optimization, and autonomous operation. When complete, the system could have a significant impact on smart communication systems in terms of their versatility and robustness of operation.

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