Experimental Characterization of Channel Crosstalk in Interleaved Array Antennas for FMCW Radar

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Abstract— **The inter-channel isolation of an FMCW radar with interleaved transmit–receive array antennas is, for the first time, characterized by measurements on an operative system. Theoretical predictions, based on full-wave simulations, are compared to computations from the measured antenna scattering parameters. In both cases, the received signals are re-combined by using ideal equi-phase and equi-amplitude power distribution networks. Two 1 to 32 Wilkinson power dividers are then fabricated and the radar inter-channel isolation is measured directly between the input (transmit) port and the output (receive) port of the system, recording a crosstalk of -34 dB. The effects of the system non-idealities on the antenna isolation are discussed.**

I. Introduction

The performance of an interleaved solution combining, in a shared aperture, the transmit (T) and receive (R) antennas of a frequency-modulated, continuous-wave (FMCW) radar system was discussed in a number of recent publications [1], [2], [3]. The main arguments in favor of this architecture rely on the convenience, evident to every radar engineer, of employing one radiating aperture instead of two separated ones and on the phase noise suppression obtainable by means of exploiting the correlation effect, a phenomenon anticipated already in [4, pp. 14.5–14.6] and related to the homodyne demodulation of the received signals in FMCW radar [5]. The relevant reduction relaxes the stringency of the inter-system isolation requirement, a figure of merit that is of paramount importance for the application at hand. Nevertheless, even when this reduction is, effectively, obtained, the level of still needed inter-system isolation is significant, a feature that is, arguably, difficult to ensure in an interleaved array environment.

A preliminary study of the channel crosstalk in the case of an interleaved array for FMCW radar applications was discussed in [6]. Several solutions for mitigating the effect of the mutual coupling between the elementary radiators were discussed, with some preliminary computational and measurement results indicating the paths to be pursued for ensuring the system performance requirements.

The present contribution reports, for the first time, results concerning an operational T–R, interleaved, shared aperture, FMCW radar antenna system. The experiments are conducted on a test configuration employing a uniform 5×21 lattice (A) of cavity-backed, patch antennas that are directly and individually controllable and can be arbitrarily reconfigured into the needed T and R sub-arrays. The selection of the elements in each sub-array is achieved by resorting to the algorithm described in [6], by constantly enforcing the side-lobes level (SLL) that is demanded by the application at hand. The initial numerical investigations of the configurations of choice are then validated by a set of complex scattering parameters measurements on A and by involving both idealized power distribution networks (PDNs) and a physical implementation of them consisting of Wilkinson equi-amplitude, equi-phase power dividers [7] and coaxial cables. The observations derived in the course of these experiments provide useful handles for predicting the concrete modalities for reducing the inter-system crosstalk in a production mode variant of the advocated solution. The final goal of this study is to elucidate the feasibility of a shared aperture implementation for an FMCW radar antenna system.

II. Simulated vs measured A with ideal PDN

For assessing the expected inter-channel crosstalk in the case of the interleaved T–R array antenna architecture at hand, depicted in Fig. 1 (a), the structure is described, as shown in Fig. 1 (b), in a commercial, full-wave, finite-difference time-domain based electromagnetic (EM) solver and then analyzed numerically. The antenna aperture hosts $N_{\rm T} = 27$ transmitting elementary radiators and $N_{\rm R} = 27$ receiving ones, cast in a non-periodic manner on a 0.75×0.9 wavelengths uniform lattice with 5×21 elements, according to the algorithm described in [6]. The frequency sweep of the considered FMCW radar spans $50\,\mathrm{MHz}$ across the central frequency $f_{\rm c} = 9.4\,\mathrm{GHz}$. In the used EM solver, the signals can be fed to the elements of the T sub-array and recombined from the radiators of the R sub-array in such a way to emulate a lossless, equi-amplitude and equi-phase PDN, this result being displayed in Fig. 2. In order to assess the accuracy of the simulation reported in Fig. 2, the designed A is manufactured, and its layout is shown in Fig. 3. All the radiating elements of the A are equipped on the back with an SMA connector, which gives direct control over every single antenna of the array without any PDN behind the radiating aperture. This choice allows a direct validation of the numerical simulation above described and provides the