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Novel Movement-Based Methods for the Calibration of Colocated Multiple-Input Multiple-Output Radars

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ABSTRACT It is well-known that the availability of transmit and receive arrays in colocated multiple-input multiple-output radar systems can be exploited to detect multiple targets, and estimate their range and angular coordinates. Unluckily, the accuracy achieved in the estimation of target parameters can be severely affected by hardware nonidealities. The impact of these nonidealities can be mitigated through the adoption of specific methods explicitly developed to estimate and compensate for them, i.e., briefly, of calibration methods. As far as we know, until now, most of the calibration techniques proposed in the technical literature for colocated multiple-input multiple-output radars are based on the idea of placing one or more reference targets in front of the considered radar device at perfectly known and fixed locations, and quantifying the difference between the expected radar image and the measured one. In this manuscript, two novel calibration methods are proposed. Both exploit the measurements captured by a colocated multiple-input multiple-output radar device at multiple positions; for this reason, the acquisition of such measurements involves the movement of the radar. Moreover, one of these methods does not require any knowledge about the number, position or radar cross section of the reference targets, provided that all these are in far-field. The other one, instead, requires the use of a single reference target in near-field conditions. The proposed methods are tested on a commercial radar device and compared with a traditional method for radar calibration.

INDEX TERMS Calibration, Multiple-Input Multiple-Output, Radar, Synthetic Aperture Radar.

I. INTRODUCTION

IN the last few years, an increasing attention has been paid by a number of researchers to colocated *multiple-input multiple-output* (MIMO) radars because of their potential applications in a number of fields. These devices, being equipped with *transmit* (TX) and *receive* (RX) antenna arrays, can detect multiple targets and, unlike their *single-input single-output* (SISO) counterparts, are able to measure not only their range, but also their angular coordinates (namely, their azimuth and elevation): such coordinates are estimated by assessing the *angle-of-arrival* (AoA) of the electromagnetic echoes that originate from the detected targets [1]. In commercially available colocated MIMO radars, the accuracy of AoA estimation is influenced by *hardware nonidealities*, that can make the structure of the acquired measurements significantly different from that described by standard math-

ematical models (e.g., see [2], [3]). Well-known nonidealities in the considered radar systems include: a) *array shape* and *antenna misplacements*, that lead to an AoA-dependent phase error in the received signal; b) mismatches in the distribution and in the length of antenna feed lines, and tolerances in hardware components, both introducing phase and frequency offsets independent of AoA; c) *TX-to-RX coupling*, that generates strong low frequency components in the baseband received signal; d) *RX-to-RX coupling*, that, being angle-dependent, affects AoA estimation accuracy. The impact of these nonidealities on radar performance can be mitigated by estimating the resulting signal distortions and compensating for them (when possible), i.e., briefly, by accomplishing *radar calibration* on the basis of a set of measurements acquired in a controlled propagation environment; this allows to reduce the difference between the behaviour of real hardware and that

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