ISSN 0735-2727, Radioelectronics and Communications Systems, 2020, Vol. 63, No. 1, pp. 1–14. © Allerton Press, Inc., 2020.
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Antenna Array Calibration Algorithm without Access to Channel Signals

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Received August 17, 2019
Revised January 16, 2020
Accepted January 20, 2020

Abstract—This paper describes the algorithm of antenna array (AA) calibration, which estimates and compensates phase lags, caused by non-identical electrical characteristics of array channels. The algorithm does not require the access to the channel signals or the channels disabling. It uses only the array output power measurements under the specific channel phase perturbations. The algorithm accuracy equals the phase shifter quantization step, i.e. it is twice less than phase shifter accuracy itself and does not depend on the number of array channels. The algorithm accuracy is compared with two similar calibration algorithms, known from publications. The compared algorithms accuracy depends on the number of array channels and is much less than the proposed algorithm. Thus, the new algorithm can be widely used for the efficient AA calibration, signal source angular position estimation and tracking by a calibrated or a non-calibrated AA with any aperture shape: linear, flat or conformal, with an arbitrary distance between neighbor AA elements and with an arbitrary antenna selected as a reference one.

DOI: 10.3103/S073527272001001X

INTRODUCTION

Antenna Arrays (AA) are widely used in contemporary radioelectronic systems as directional antennas, thus enabling enhancement of a range of technical and live usage performance metrics of such systems. AAs provide non-mechanical steering of main lobe of radiation pattern (RP), better output SNR, suppression of directional interference sources, multi-beam capability and a number of other useful features [1–3].

There are some certain features while working with AAs in millimeter-wave band, such as short range due to significant wave attenuation [4]. Besides that, millimeter-wave devices have geometrical sizes comparable to wavelength. With this features and recent advancements in contemporary semiconductor technologies and micromechanics [5] it is now possible to integrate micropower transmitting and receiving array RF feeds and antennas into inexpensive and low-power devices named AoC (Antenna-on-Chip) and AiP (Antenna-in-Package), which already exist as a separate electronic components in integrated chip and micro assembly form-factors [6–11].

However, such AAs frequently require TX/RX lines calibration, which cannot be manually performed due to mechanical inaccessibility to array internal components, as it is done in arrays built using discrete components. In the case of AoC or AiP calibration can be performed by employing external control of pre-determined internal regulated parameters of such devices.

AA calibration means equalisation of feed lines electrical characteristics, resulting in electrical identity of channels, providing coherent signals summation at receiving phase AA (PAA) output [1]. Calibration is reached by gain coefficient absolute value equalisation and AA channels phase shifts compensation (equalisation).

To equalise channels gain coefficients, AA must contain discrete attenuators or variable gain amplifiers, controlled by digital or analog means. However, AAs rarely employ such devices. Attenuator usage lowers AA transmitted/received signals power, and microwave variable gain amplifiers are still complex devices [12]. Meanwhile, gain coefficient magnitude spread in ±1 dB range results in an insignificant RP shape distortion in main lobe and sidelobes [13].

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

ADDITIONAL INFORMATION

The initial version of this paper in Russian is published in the journal "Izvestiya Vysshikh Uchebnykh Zavedenii. Radioelektronika," ISSN 2307-6011 (Online), ISSN 0021-3470 (Print) on the link http://radio.kpi.ua/article/view/S002134702001001X with DOI: 10.20535/S002134702001001X.

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