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Influence of Jitter in ADC on Precision of Direction-Finding by Digital Antenna Arrays

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Abstract—Direction-finding methods by linear and row-column digital antenna arrays are synthesized. Approximate expressions for dispersions and expected value of angle of arrival estimate are obtained under assumption that jitter is small. Simulation results are presented.

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A desire to decrease the number of frequency conversions in a radio receiving circuitry of radars to increase the system's dynamic range and to decrease intrinsic noise of the receiver leads to higher signal frequency at the receiving circuit's output [1]. This leads to a situation when in digital antenna arrays (DAR), which are essentially multichannel analogue-to-digital conversion systems, the level of digital signal's noise caused by ADC's jitter during sampling increases. Due to this revision of expressions used to calculate precision of direction-finding is required.

Earlier in [2] using simulation of direction-finding by linear DAR by solving the likelihood equation (by enumeration) it was shown estimate's dispersion for the found direction depends on the sum of additive noise and ADC's jitter noise powers under assumption that jitter is small. A modified expression of the lower Kramer–Rao boundary (LKRB) was obtained in [3] for the problem of direction-finding by linear DAR under the presence of ADC's jitter, while in [4] a similar modified expression for LKRB of a planar equidistant row-column DAR is given.

It is more convenient to have analytical expression for direction to the signal source. Hence, when analyzing influence of ADC jitter on precision of direction-finding, in the present work such an expression is synthesized for the cases of linear and row-column arrays. Further using linearization of random variables function [5] approximate expressions are obtained that characterize dispersion and expected value of the synthesized estimates in the presence of ADC jitter.

ESTIMATES SYNTHESIS

To synthesize estimates we'll use ideas described in [6].

Let's consider a linear DAR consisting of N elements (Fig. 1) with element spacing d. Angle β indicating direction to the signal source will be calculated from the normal to the array. Let's assume that the signal with frequency F received by each element is converted to intermediate frequency (IF) f with simultaneous generation of analogue complex signal.

An expression for voltage at the output of nth receiving channel may be represented as

$$\dot{u}_n(t) = A\exp(j(\omega t - \Omega n d c^{-1} \sin\beta + \varphi)), \quad (1)$$

where n is the receiving channel number, A is signal's amplitude, $\omega = 2\pi f$ is circular intermediate frequency, $\Omega = 2\pi F$ is the frequency of received signal, c is the light velocity, φ is the initial phase of signal at the receiving channel's output.

Let's assume that signal at the output of receiving channels is sampled using synchronously clocked ADCs. Expressions for kth sample of co-phase and quadrature components at ADC outputs may be written down as