Transmitted Beampattern Synthesis with Waveform Diverse Arrays Based on Arctangent Function

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Abstract
In this paper, we apply a nonlinear frequency modulation scheme based on arctangent function to waveform diverse array systems to design a transmitted beam pattern at a specific position. Distinct from most of the existing methodologies, the proposed method overcomes the constraint that the focusing performance of the signal power will decrease when considering the propagation process of the transmitted signal. As a result, the transmitted signal power can be focused at a desired position and be limited by the power transmission rate.

Introduction
On account of the ability to provide a range-angle dependent beamformer [1], frequency diverse arrays (FDA) techniques possess potential technical support for various power transmission system, radar-based security system or some other application-specific system. Therefore, some efforts have been dedicated to using FDA technology to design transmit beam patterns to focus signal power at a specific position. However, it is difficult to keep the focusing position unchanged after the signal power has been focused. Initially, the research on FDA technology focused on the study of linear frequency offset. Some methodologies based on linear frequency offset have been proposed in [2-6]. Some of the nonlinear frequency offset can be applied in [7] to design a range-angle dependent beamformer. However, the desired focusing position has been changed; the transmit weight coefficients used to be recalculated. Some nonlinear offset (e.g., harmonic offset frequency, random frequency offset) based methodologies have been proposed in [8-12] to design a beamformer with a single maximum. However, the focusing position system will become the desired position even in constant. In these cases, the focusing performance of the signal power will decrease when considering the propagation process of the transmitted signal. Moreover, the nonlinear frequency modulation with multiplexing because of the unassigned angle dimension coupling. FDA systems consist of multiple sub-arrays with optimal weight transmit weight matrix has been proposed in [7] to design a range-angle dependent beamformer. However, the desired focusing position has been changed, the transmit weight coefficients used to be recalculated.

Radar array structure
Figure 1: A uniformly-spaced linear array with 20+41 elements.

Transmitted signal model
The simulation results of the proposed methodology are reported and discussed in detail. The array system parameters are set to $f_0 = 3000\mathrm{MHz}$, $\theta_0 = 0.1\mathrm{deg}$, $T = 1\mathrm{~ns}$, $N = 6$ and $\Delta f = 2\mathrm{MHz}$. The simulation time step is $\Delta t = 0.1\mathrm{~ns}$.

Simulations
The study of the proposed methodology is reported and discussed in detail. The array system parameters are set to $f_0 = 3000\mathrm{MHz}$, $\theta_0 = 0.1\mathrm{deg}$, $T = 1\mathrm{~ns}$, $N = 6$ and $\Delta f = 2\mathrm{MHz}$. The simulation time step is $\Delta t = 0.1\mathrm{~ns}$. The simulation results are reported and discussed in detail. The array system parameters are set to $f_0 = 3000\mathrm{MHz}$, $\theta_0 = 0.1\mathrm{deg}$, $T = 1\mathrm{~ns}$, $N = 6$ and $\Delta f = 2\mathrm{MHz}$. The simulation time step is $\Delta t = 0.1\mathrm{~ns}$.

Conclusion
In this paper, a new transmitted beampattern synthesis methodology for waveform diverse array radar system has been proposed to solve the problem. The new methodology incorporates a nonlinear frequency modulation scheme based on an arctangent function with a uniform frequency offset. More specifically, the non-uniform frequency offset is capable to make the transmitted beampattern angle-depending; and the nonlinear frequency modulation based on an arctangent function is appropriate to make the beampattern range-dependent. Different from those existing schemes, due to the non-linear frequency modulation, the focusing performance of each signal varies from greater than the carrier frequency to less than the carrier frequency. The closer the signal frequency is to the carrier frequency, the faster the signal frequency changes. Therefore, this feature makes the transmitted signal power at any one location except the desired position becomes very small. Besides, this paper reports a meaningful approximation for the different propagation processes of the transmitted signal which has been ignored when deriving the array pattern (in [13]). It makes the focusing performance of the transmitted signal power degrading. And the proposed scheme has considered the propagation process of the transmitted signal. As a result, the proposed scheme can focus the signal power at the desired position for a long period of time. Furthermore, the proposed array radar system is capable to transmit a series of pulse signal because all the elements start to transmit signal at the same time. In addition, a pulse radar signal with the same pulse repetition period will be observed at the desired position.

Authors Biographies
Zhonghan Wang was born in Nanjing, China, in 1993. He received the B.E. degree in telecommunication engineering from Xidian University in 2015 and is currently studying for the Ph.D. degree in Nanjing University of Science and Technology, Nanjing, China.

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Figure 2: Normalized power pattern at $(\theta, r)$. The work was supported in part by the National Natural Science Foundation of China under Grant 61371124 and in part by the National Natural Science Foundation of China under Grant 61301229.