Radar Signal Synchronization by Multi-Layer Modularization Implementation of Phase Shifters in the Beamforming Network of Phased Array of Antennas

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Phased array of antennas is widely used in radar system for beam steering to detect targets. In operation, the system sends a sequence of periodic radar signals to illuminate targets. These signals require proper synchronization in order to enhance the target's illumination strength and therefore reduce detection ambiguity. Conventional implementation of single-layer beamforming network (BFN) by embedding phase shifters (PSs) right behind antenna elements may result in synchronization insufficiency because the characteristics of PSs are generally narrow-banded. In particular, digital phase shifters (DPSs) may only provide a maximum time delay by a wavelength at the center frequency of carrier, which is not sufficient to compensate the time delay arising from the spatial difference of antenna elements' locations at wide-angle beam steering. Besides, the quantization of DPSs may also result in synchronization dispersion of received signals.

This paper presents a hierarchical BFN architecture to incorporate DPSs and investigate the modularization of DPS subarrays in radar signal synchronization. The goal is to develop DPS subarray modularization technique in providing sufficient time-delay compensation for wide-angle beam signal in radar applications while in the meantime reducing the BFN complexity. Thus at each layer each module is formed by an identical format of subarray elements at a lower layer such that the modules at this layer can be controlled by the same micro-control unit (MCU). Based on this hierarchical construction, the time delays provided by the DPSs at each layer can be accumulated to produce sufficient net time delay for wide-angle beam steering. In this case, the number of DPSs retains same in comparison to the original BFN architecture. Furthermore, optimization technique genetic algorithm (GA) will be employed to optimize the signal synchronization by selecting proper phase states to produce the time delays.

To demonstrate the concept, we will consider linear frequency modulated (LFM) signals to numerically simulate the system scenario. The basic mathematic model is formulated to illustrate the modulation procedure and basic phenomena. This LFM signals will be applied to the modularization procedure to examine its effectiveness. Comparison between the proposed BFN and the conventional implementation will be presented to validate the concept.