Stepped-Frequency Continuous Wave Radar Based on Compressive Sensing

Lingyun Ren * (1), Haofei Wang (1), (2), Vinh Dang (3), Ozlem Kilic (3), and Aly E. Fathy (1)
(1) University of Tennessee, Knoxville, TN, 37996, USA
(2) Beijing Institute of Technology, Beijing 100081, China
(3) The Catholic University of America, Washington D.C., USA

Usually, UWB radar systems can operate either in time domain or in frequency domain. The time domain UWB systems are able to achieve high range resolution by transmitting a single very short pulse. This kind of time domain UWB radar consumes much less power and has a simple transmitter architecture. However, it presents a considerable challenge to digitize the short-duration pulses. The required high speed ADCs to record the short-duration pulses are usually either very expensive or commercially unavailable.

Alternatively, the stepped-frequency continuous wave (SFCW) radar, transmits a series of discrete tones in a stepwise fashion to attain a large effective bandwidth. As the instantaneous bandwidth of SFCW radar is relatively very narrow, a low-speed ADC can be used to digitize the received baseband signal and the hardware requirements for the receiver become less stringent. Besides, the narrow-bandwidth receiver would result in a narrow noise bandwidth and a higher signal-to-noise ratio (SNR). The only drawback that discourages the practical application of SFCW radar system is its long data acquisition time because it is necessary to receive all the frequency points before any processing is initiated.

Based on compressive sensing (CS) theory, a sparse signal can be recovered exactly by using only a few measurements below the Nyquist rate. During the last few years, CS has been successfully applied in many radar specific tasks, such as synthetic aperture radar (M.A. Herman and T. Strohmer, IEEE Trans. Signal Process, 57, 6, 2275-2284), ground penetrating radar (A.C. Gurbuz, J.H. McClellan, and W.R. Scott, IEEE Trans. Signal Process., 57, 7, 2640-2650), and through-the-wall imaging radar (Q. Huang, L. Qu, B. Wu, and G. Fang, IEEE Trans. Geosci. Remote Sens., 48, 3, 1408-1415).

In this paper, we introduce a novel data measurement scheme for SFCW radar. Instead of measuring all the frequencies in a frame of stepped-frequency signal, only a random subset of frequencies is measured, and a CS based algorithm is utilized to reconstruct the target high resolution range profile (HRRP). Real measured radar data has been obtained and our experimental results demonstrate that the HRRP of the target can be recovered very well even when only 20% of the total frequencies are used.