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Generation of Orthogonal Waveforms for RADARS

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Abstract- *Recently, the concept of MIMO (multiple-input-multiple-output) radars has drawn considerable attention. In traditional SIMO (single-input-multiple-output) radar, the transmitters emit coherent waveforms to form a focused beam. In MIMO radar, the transmitters emit orthogonal (or incoherent) waveforms to increase the spatial resolution. In the MIMO radar, since many transmitting waveforms are involved, their cross-ambiguity functions enter into the signal design problem. Hence, the successful design of orthogonal code sets with low auto correlation and cross-correlation is crucial for implementing mimo radar systems. In this project, pseudo-random code sequences are used to generate orthogonal MIMO radar waveforms. the waveforms generated are Linear Frequency Modulation Waveforms and Frequency Hopping waveforms. Their auto-correlation and Cross-correlation functions are then determined and compared.*

Keywords- *Radar, MIMO, SIMO, Linear Frequency Modulation, Frequency hopping, Pseudo-random sequence, auto correlation, cross correlation.*

INTRODUCTION

Radar is a system that uses electromagnetic waves to detect, locate and measure the speed of reflecting objects such as aircraft, ships, spacecraft, vehicles, people, weather formations, and terrain. It transmits the electromagnetic waves into space and receives the echo signal reflected from objects. By applying signal processing algorithms on the reflected waveform, the reflecting objects can be detected. Furthermore, the location and the speed of the objects can also be estimated. Recently, the concept of MIMO radar has been proposed. The MIMO radar is a multiple antenna radar system which is capable of transmitting arbitrary waveform from each antenna element. In the traditional phased array radar, the transmitting antennas are limited to transmit scaled versions of the same waveform. However the MIMO radar allows the multiple antennas to transmit arbitrary waveforms. Several advantages of MIMO radar have been discovered such as increased diversity of the target information, excellent interference rejection capability, improved parameter identifiability, and enhanced flexibility.

The radar systems can be categorized into monostatic and bistatic. The transmitter and the receiver of a monostatic radar are located in the same location while the transmitter and receiver of the bistatic radar are far apart relative to the wavelength used in the radar. According to the characteristics of the transmitted signals, the radar systems can be further categorized into continuous waveform radar and pulse radar. The continuous waveform radar transmits a single continuous waveform while the pulse radar transmits multiple short pulses. Most of the modern radars are monostatic pulsed radars.

Detection and Ranging

Detection is the most fundamental function of a radar system. After emitting the electromagnetic waveform, the radar receives the reflected signal. To detect the target, it is necessary to distinguish the signal reflected from the target, from the signal containing only noise. After detecting the target, one can further calculate the range.

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Consider a monostatic radar system with one antenna as shown in Fig. 1.1. The radar emits a waveform u(t) into the space. The waveform hits the target located in range r and comes back to the antenna. After demodulation, the received signal can be expressed as

$$\alpha u(t - \frac{2r}{c}) + v(t),$$

where c is the speed of wave propagation, r is the range of the target, v(t) is the additive noise, and α denotes the amplitude response of the target. The amplitude response is determined by the radar cross section (RCS) of the target, the range r of the target, the beam pattern of the antenna, and the angle of the target.

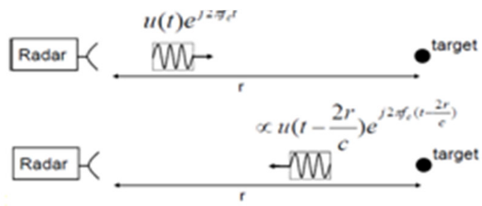


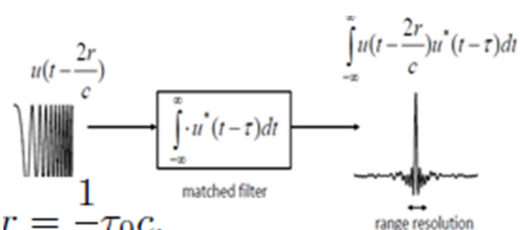
Figure 1.1: Basic radar for detection and ranging

The receiver, a matched filter is usually applied to enhance the signal to-noise ratio (SNR). The matched filter output can be expressed as

$$y(\tau) = \int_{-\infty}^{\infty} \alpha u(t - \frac{2r}{c}) u^*(t-\tau) dt + \int_{-\infty}^{\infty} v(t) u^*(t-\tau) dt$$

$$r_{uu}(\tau) = \int_{-\infty}^{\infty} u(t) u^*(t-\tau) d\tau$$

Where is the autocorrelation function of u(t). The relation is illustrated in Fig 1.2. To determine whether there is a target, the matched filter output signal is checked at a specific time instant. If the auto-correlation function is greater than the predefined threshold, then the radar system reports that it has found a target.



$$r = \frac{1}{2} \tau_0 c,$$

After detecting the target, one can further determine the range of the target. For a simple point target, the range of the target can be obtained by where τo is the time instant at which the matched filter output exceeds the threshold. For the case of multiple targets, the matched filter output signal can be expressed as

$$y(\tau) = \sum_{i=0}^{N_t - 1} \alpha_i r_{uu}(\tau - \frac{2r_i}{c}) + \int_{-\infty}^{\infty} v(t) u^*(t-\tau) dt,$$

where Nt is the number of targets,Ri is the range of the ith target, and αi is the amplitude response of the ith target. To be able to distinguish these targets, the autocorrelation function has to be a narrow pulse in order to reduce the interferences coming from other targets. A narrow pulse in time-domain has a widely spread energy in its Fourer transform and vice versa. Therefore to obtain a narrow pulse one can choose the waveform u(t) so that the energy of the Fourier transform of the autocorrelation function is widely spread. Fourier transform of the autocorrelation function is expressed as

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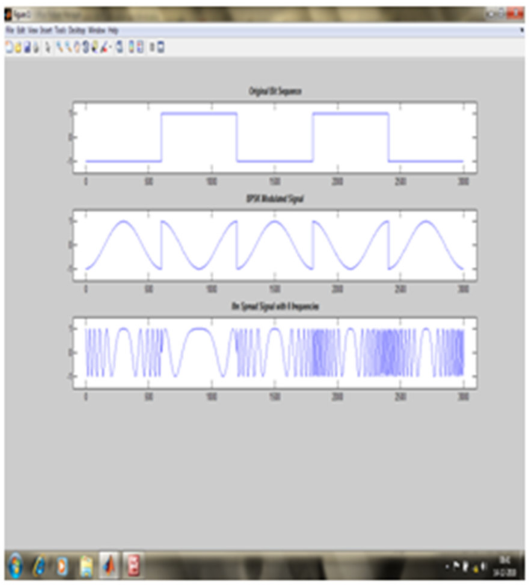
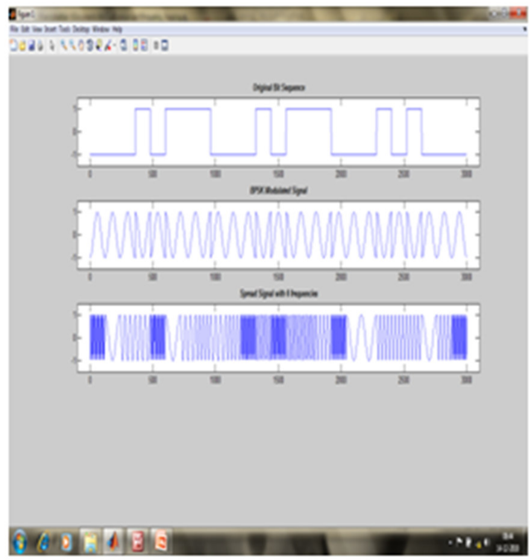
$$S_{uu}(j\omega) = |U(j\omega)|^2$$

where U(jω) is the Fourier transform of the waveform u(t). Therefore, one can choose u(t) so that its energy is widely spread over different frequency components. Another very important desirable property of the transmitted waveform is the constant modulus property. The constant modulus property allows the antenna to always work at the same power. This avoids the use of expensive amplifiers, and the nonlinear effect of the amplifiers. One good candidate that has widely spread energy in the frequency domain and also satisfies the constant modulus property is the linear frequency modulated (LFM) waveform. It is also called the chirp waveform.

Results



Real part of LFM waveforms



Frequency hopping Waveforms

Conclusion and Future Scope

In this paper, orthogonal waveforms are generated for MIMO radars. Their auto-correlation and cross correlation values are determined and tabulated. The code sequences are taken from literature. Use of orthogonal waveforms for MIMO radars, ensure there is no interference. Hence, they find applications in detecting slow moving targets in a cluttered environment and fast moving targets in clear air. Orthogonal waveforms can also be used for enabling multiple transmitters to share a single code division multiplexed (CDM) or code division multiple access (CDMA) channel. The requirement for optimizing the code sequences- used for generating orthogonal waveforms -to achieve good aperiodic auto-correlation and cross correlation properties is the major area of study for the future. Use of polyphase codes instead of binary or frequency hopping codes ensure better optimization and hence efforts to design polyphase codes with various configurations forms the scope for the future.

References

1. O Liu, Zishu He, Qian He, "Optimization of Orthogonal Discrete Frequency-Coding Waveform Based on Modified Genetic Algorithm for MIMO Radar," IEEE international conference on Communications, Circuits and Systems, 2007, pp. 966 – 970.
2. Chun-Yang Chen and P. P. Vaidyanathan, "MIMO Radar Ambiguity Optimization Using Frequency-Hopping Waveforms," IEEE international conference on Signals, Systems and Computers, 2007, pp. 192 – 196.
3. Bo Liu, Zishu He, lun Li, "Mitigation of Autocorrelation Side lobe Peaks of Orthogonal Discrete Frequency-Coding Waveform for MIMO Radar," IEEE international conference on Radars, 2008, pp. 1-6.

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