Question 2

Write an essay (max 5 pages) on the role of signal processing in an engineering application of your choice. Your essay must be fully referenced.

Solution

SIGNAL PROCESSING IN RADAR SYSTEMS

Introduction

The word "radar" was coined from "radio detection and ranging" can be seen in the fundamental concept of its operation. A radar sends out electromagnetic energy in form of waves and when this waves hit an object, they are reflected back to the radar antenna. The nature of the returned signal or waves gives information about the object. This object is referred to as the target. The location and velocity of the target can be computed from the signal returned. Thus, a radar system in simple terms transmits signals and receives a reflection of the signal and performs signal analysis to determine the target parameters based on the distinct reflection it receives. This process can be summed up as transmitting signal for detection, tracking the signal for signal processing and imaging.



Figure 1, Simple block diagram of a Radar System (O'Donnell 2010).

There are various types of radar systems such as Pulse Compression, CW and FM, Moving Target Indication, Pulse Doppler, Tracking, Height finding and 3D, Synthetic Aperture, Meteorological, HF Over-the-Horizon, Bistatic and a host of other radar types. These are used across different fields like air traffic control, weather prediction, tactical battlefield surveillance, satellite communication, space surveillance, air defence systems and the likes.

It will interest one to know that of all the types and various fields of application, radars operate on the same principle but different technologies or platforms based on the signal processing type applied.

Signal Processing

One of the first and most important things a good radar system does is detection. Detection of target can be a challenge in the presence of noise; noise from the system itself, noise from the background, noise from the atmosphere and intentional noise(counter signal). Signal processing becomes very crucial in filtering and conditioning the required signal. The knowledge and understanding of signal transformation using fundamental spectral analysis tools such as Discrete Fourier Transforms (DFT) and Fast Fourier Transforms (FFT) is really appreciated here. Let's take a quick look at the processing of radar signal as outlined in the figure below.



Figure 2, An example of a generic radar signal processor flow of operations (Richards, 2013).

The process flow may vary with the different radar systems and the point at which the signal is digitized may also not be the same. Signal conditioning, noise removal or suppression, tracking, detection and imaging all depend on the heavy application of spectral analysis tools like DFT/FFT and sampling techniques. The design of efficient and effective signal processors for filtering and cleaning the signal also depends on these tools.



Figure 3, (*a*) Linear FM waveform modulation function, (*b*) Output of the matched filter for the LFM waveform of (*a*), (Richards, 2013).

Figure 3a above shows the output of the matched filter corresponding to the LFM pulse while 3b is for the response.

These days, digital signal processors are becoming the order of the day in signal processing. Various design techniques and filter implementation are done very often especially with the help of FFT algorithm and its various forms. Some of these filters built on fast convolution filter implementation platform are: dual pipeline FFT matched filter, single forward FFT matched filter, single inverse FFT matched filter, reconfigurable FFT matched filter and so on.

Other application in radar processes that utilize these tools are Doppler processing which involves the removal of clutter from the signal in order to reveal moving targets. Cancellers and other techniques as Delong Hotstetter techniques also use FFT/DFT algorithms.

Conclusion

In conclusion, this little write up discusses a brief overview of the role signal processing plays in modern day radar systems as seen in the application of signal processing techniques in radar technology. Most of today's designs, modelling and implementation of filters and signal conditioners are based on DFT/FFT technique for filtering, analysing and imaging of signals.