1 Introduction

In this report a micro radar system is utilized for surface classification. Specifically, a radar sensor is placed on the inside of a robot facing downwards, with the objective of distinguishing if the surface below is made of grass and dirt or not.

2 Radar system overview

The radar system used for this project is a 60 GHz radar developed by Acconeer AB.

An antenna transmits a wavelet signal towards an object of interest. After a brief period of time a second wavelet signal is generated and *mixed* with data from a recieving antenna. This procedure is repeated, every time slightly delaying the generation of the second wavelet and thus mixing with a different section of the incoming pulse.

Throgh this methodology we can effectively produce

2.1 The radar principle

The radar principle is at its core simple. A wavelet pulse $x_T(t)$ with some carrier frequency Ω is transmitted towards an object of interest.

etc etc..

2.2 Matched filter

something something desired frequency response of the recieving antenna.

In any radar system a good Signal-to-Noise Ratio (SNR) is a highly desired property. Finding a reciever frequency response which maximizes SNR is thus an important topic. Denoting the reciever output as $y(t)$ and the incoming waveform as $x(t)$ the output spectrum will be a convolution of $x(t)$ and the system impulse response $h(t)$, or conversely a multiplication in the frequency domain $Y(\Omega) = X(\Omega)H(\Omega)$. If we seek to maximize SNR at some arbitrary point in time T_M the power at that very instant is

$$|y(T_M)|^2 = |\frac{1}{2\pi}\int X(\Omega)H(\Omega)e^{j\Omega T_M}d\Omega|^2. \tag{1}$$

Now we consider interference in the form of spectrally flat noise with power spectral density σ^2 W/Hz. The SNR ξ measured at time T_M can then be described as the ratio between the total signal power and the total noise power

$$\xi = \frac{|y(T_M)|^2}{(1/2\pi)\int |\sigma H(\Omega)|^2 d\Omega} = \frac{|(1/2\pi)\int X(\Omega)H(\Omega)e^{j\Omega T_M}d\Omega|^2}{(\sigma^2/2\pi)\int |H(\Omega)|^2 d\Omega} \tag{2}$$

which clearly depends on which reciever response is used. It can from above expression be shown [reference] that the maximum ξ is obtained when

$$H(\Omega) = \alpha X * (\Omega) e^{j\Omega T_M}, \text{ or} \tag{3}$$

$$h(t) = \alpha x^*(T_M - t) \tag{4}$$

where α is an arbitrary constant which has no impact on the resulting SNR. Examining $h(t)$ above we see that the optimal filter for maximizing SNR is when the coefficients consist of the transmitted waveform conjugated and time-reversed. This filter is called a *matched filter* due to the symmetrical relationship between waveform and impulse response.

One way of interpreting the matched filter is by viewing the filtering as a correlation. If we denote $\bar{x}(t)$ as the sum of both target and noise components the output $y(t)$ is given by

$$y(t) = \int \bar{x}(s)h(t-s)ds = \alpha \int \bar{x}(s)x^*(s + T_M - t)ds \tag{5}$$

which is recognized as the cross-correlation between noisy signal $\bar{x}(t)$ and transmitted waveform $x(t)$ evaluated at lag $T_M - t$. By shifting the constant lag T_M we then can obtain the full cross-correlation

2.3 IQ demodulation

3 Feature selection

4 Classification

5 Discussion