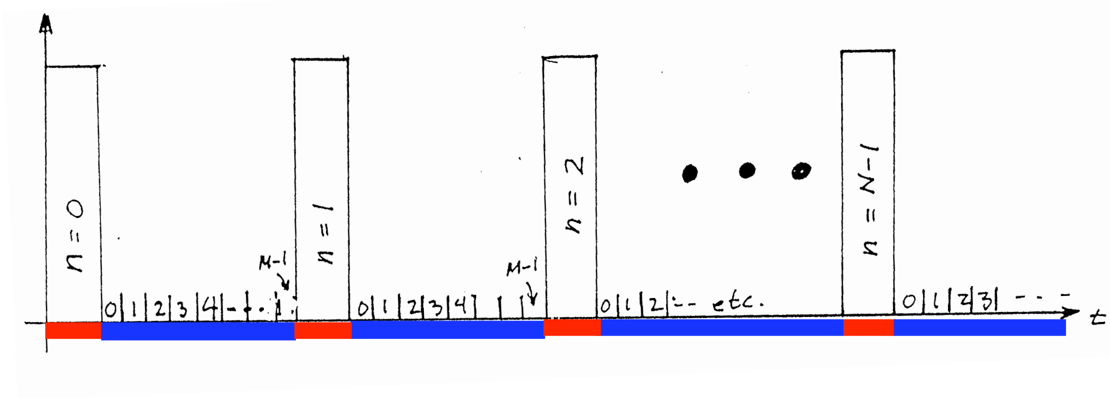
Session 32

The Pulse Waveform Delay-Doppler Processor

Recall...

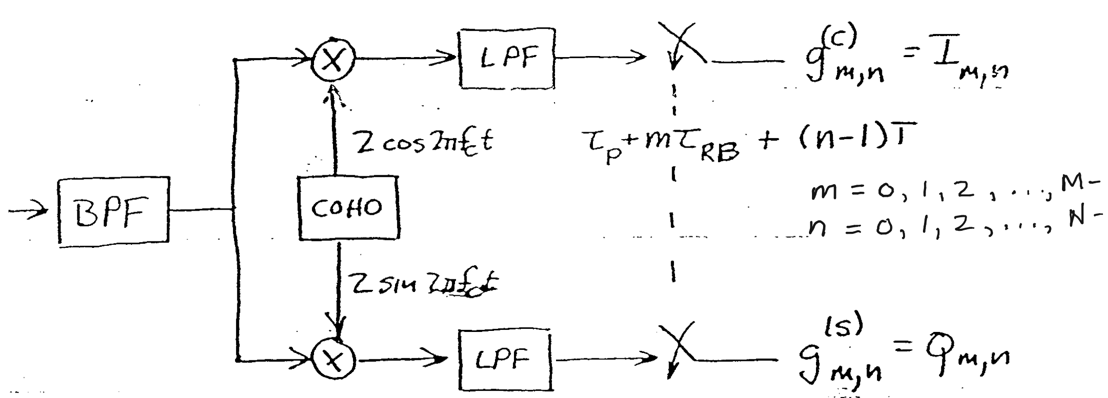
So we will divide the listening period into time bins of width τ_{RB} and sample the signal once per bin for each range bin of interest.

Label the range bins $0, 1, \ldots, M-1$.



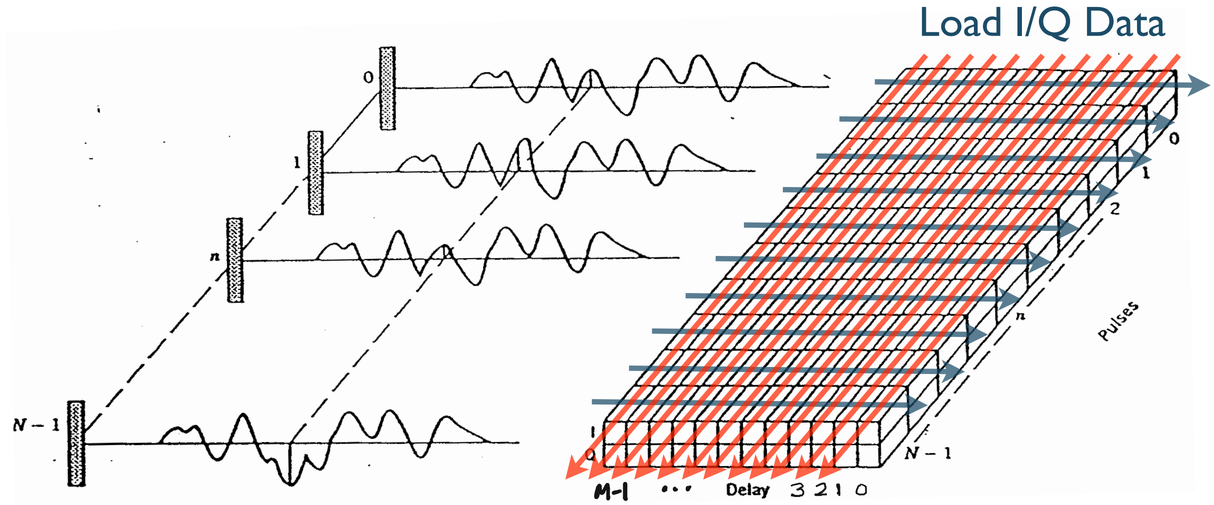
Recall...

We can get the sample returns from each of the range bins (both I and Q components to represent the complex baseband signal) by processing the received signal as follows:



n.b., τ_p is the transmitted pulse duration.

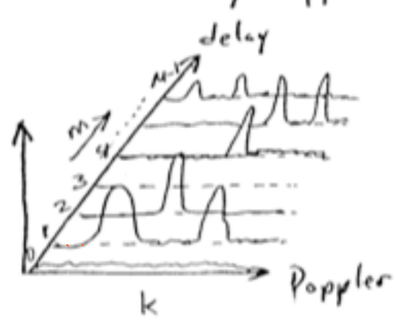
Recall...



Compute DFT for each range cell

Recall...

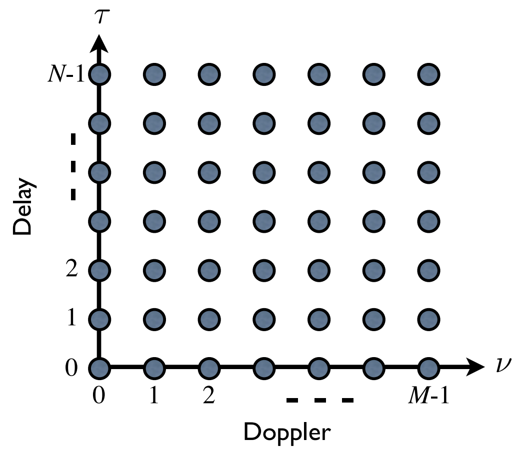
If we process in this way for each range cell (each m), we can construct a "Delay-Doppler* spectrum"

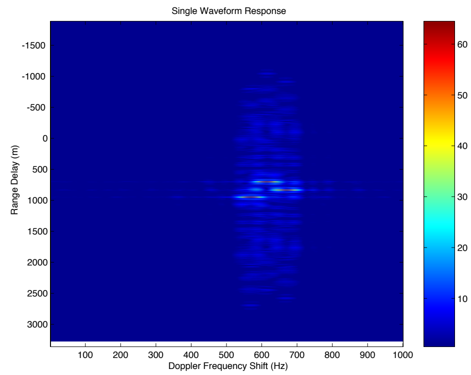


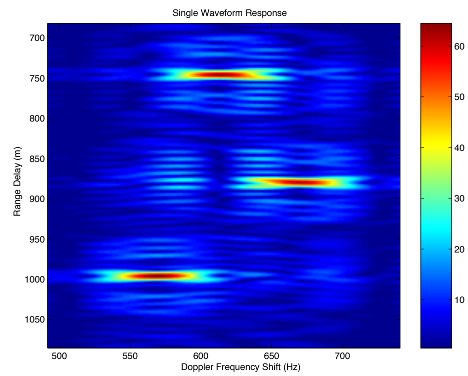
From such a Delay-Doppler image one can detect where the targets are in Delay and Doppler (τ and ν).

Recall...

Actually, because delay range bins are discrete and the Doppler response is computed using a DFT, we get a discrete map of delay-Doppler space:







Recall...

Of course the DFT response G_k will be maximum for a target Doppler f_D such that

$$f_D = \frac{k}{nT} + m \cdot \frac{1}{T}$$

however, for other $f_D \simeq \frac{k}{NT}$, DFT response will also be large.

<u>n.b</u> $G_k \equiv 0 \iff f_D = \frac{j}{NT}, \; j \neq k.$

It can be shown that the normalized response of the k-th Doppler filter G_k to a target with Doppler frequency f_D is

$$|\hat{G}_k(f_D)| = \frac{1}{N} \left| \frac{\sin[\pi N(f_D T - k/N)]}{\sin[\pi(f_D T - k/N)]} \right|$$

$$|\hat{G}_k(f_D)| = \frac{1}{N}\left|\frac{\sin[\pi N(f_D T - k/N)]}{\sin[\pi(f_D T - k/N)]}\right|$$

$|\hat{G}_{16}(f_D)|$ for $N=32$

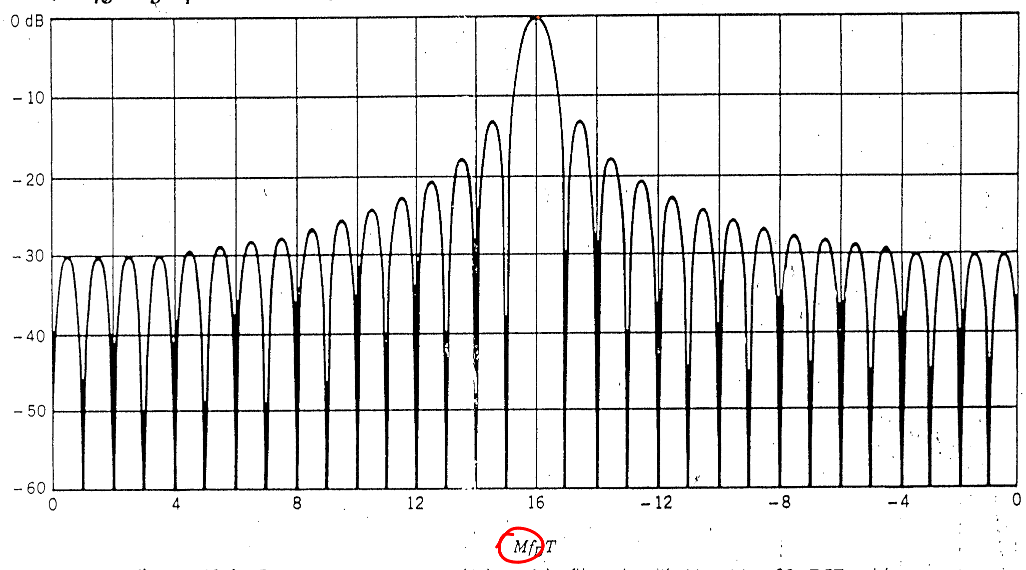


Figure 10.6 Frequency response of the 16th filter in an $N = M = 32$ DFT with a rectangular weighting.

$|\hat{G}_0(f_D)|$ for $N=32$

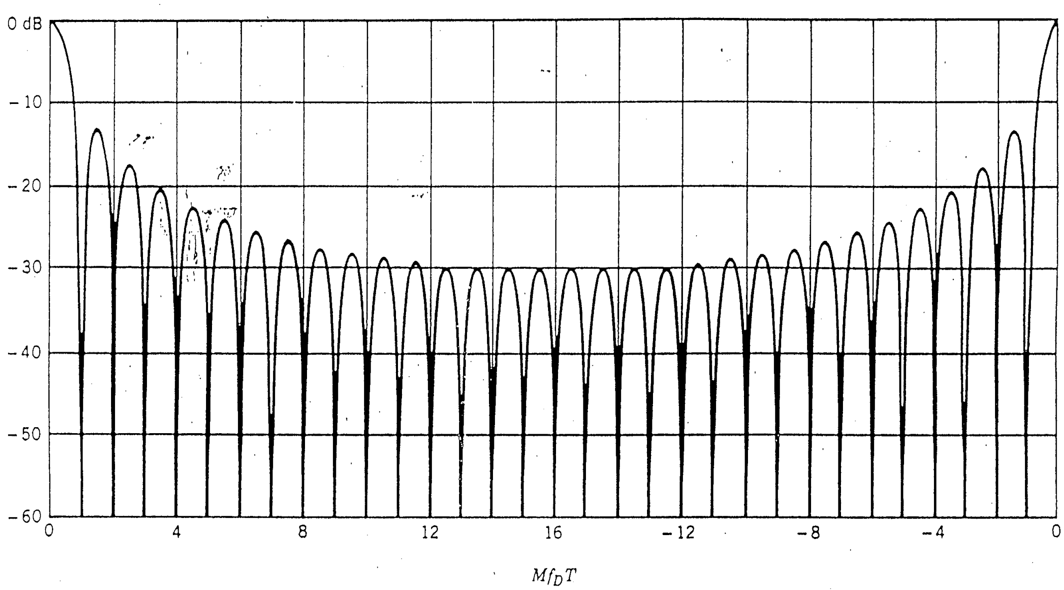


Figure 10.5 Frequency response of the zeroth filter in an $N = M = 32$ DFT with a rectangular weighting.

Sidelobes can be reduced with windowing before taking the DFT

$$\sum_{n=0}^{N-1} u_n \cdot w_n \, e^{-i\frac{2\pi n k}{N}}$$

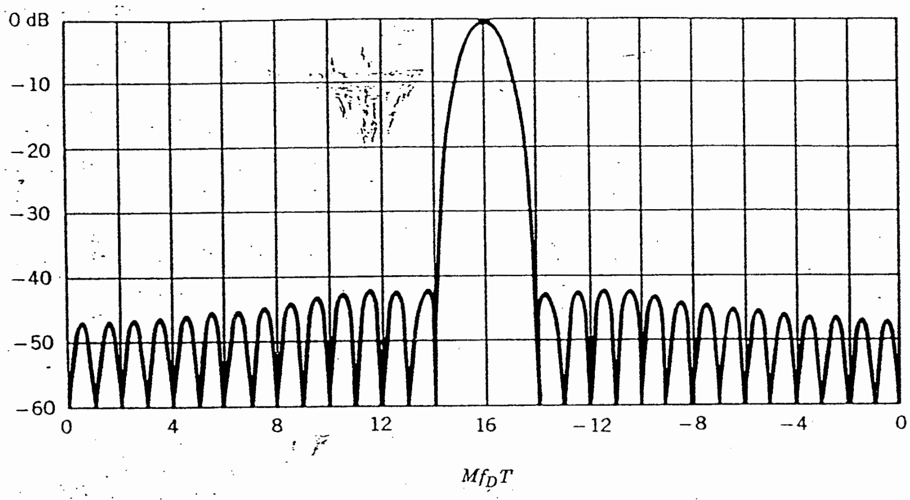


Figure 10.7 Frequency response of an $N = M = 32$ DFT, Hamming weighting.

Hamming Window: $W_n = a_0 - a_1 \cos\left(\frac{2\pi n}{N}\right)$

$a_0 = 0.53836$

$a_1 = 0.46164$

Sidelobes can be reduced with windowing before taking the DFT

Hann (Julius Von Hann) Window: Same as Hamming, but $a_0 = a_1 = 1/2$.

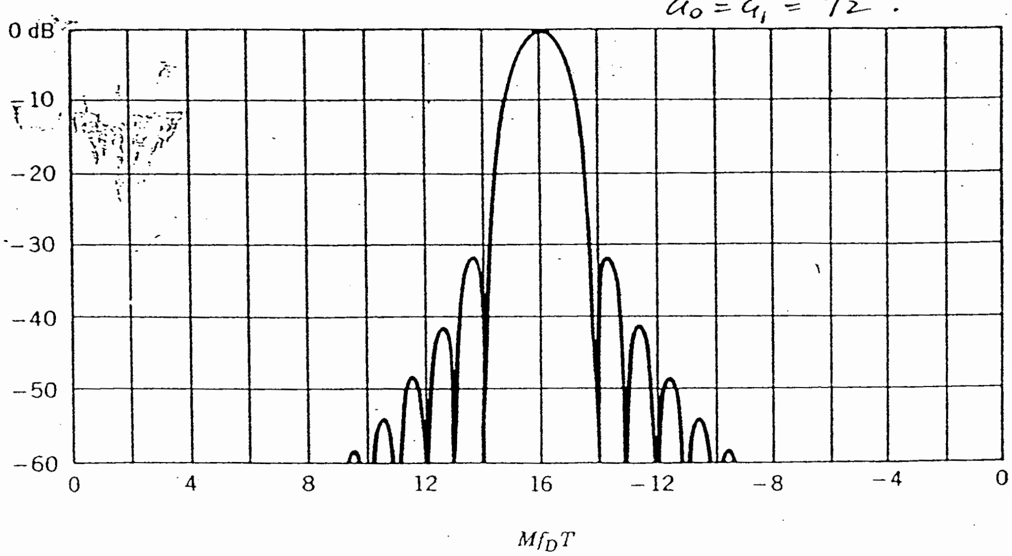


Figure 10.8 Frequency response of an $N = M = 32$ DFT, Hann weighting.

Comparison of Windows

$|\hat{G}_{16}(f_D)|$ for $N=32$

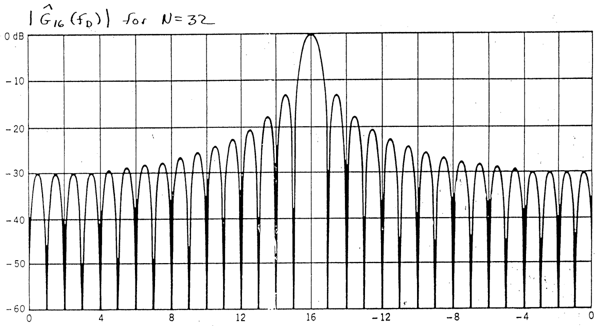


Figure 10.6 Frequency response of the 16th filter in an $N = M = 32$ DFT with a rectangular weighting.

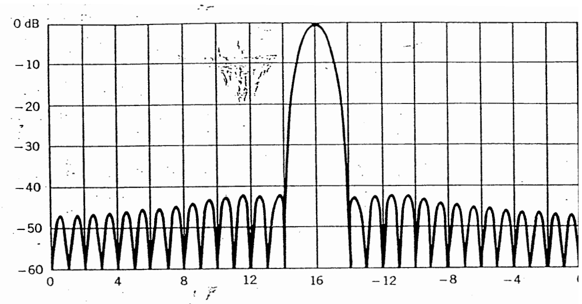


Figure 10.7 Frequency response of an $N = M = 32$ DFT, Hamming weighting.

Hamming Window: $w_n = a_0 - a_1 \cos\left(\frac{2\pi n}{N}\right)$

$a_0 = 0.53836$

$a_1 = 0.46164$

Hann (Julius Von Hann) Window: Same as Hamming, but $a_0 = a_1 = 1/2$.

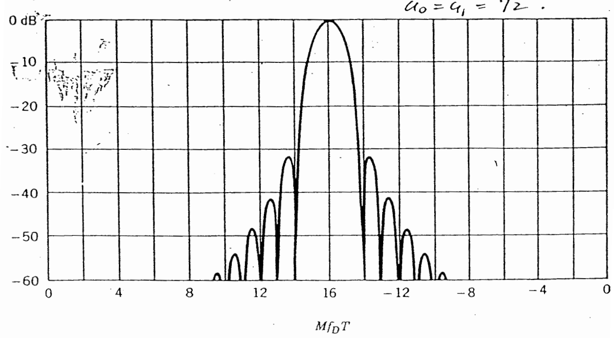
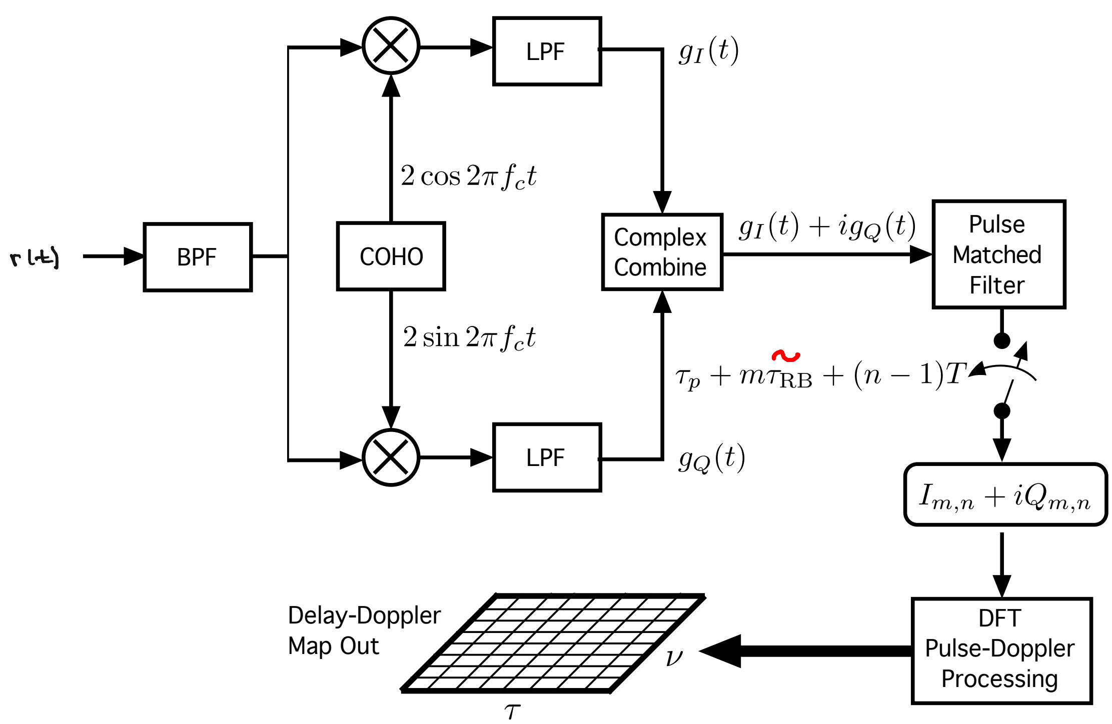


Figure 10.8 Frequency response of an $N = M = 32$ DFT, Hann weighting.

Including the Matched Filter



Coded Radar Signals

Reference: N. Levanon and E. Mozeson, ***Radar Signals***, Wiley, 2004 (ISBN 0-471-47378-2)

- We will consider coded radar "pulses" as opposed to pulse trains.
- We have already seen that modulation of a radar pulse (e.g. a "chirp") increases the range resolution of the signal through bandwidth expansion.
- Modulation of a radar pulse can significantly modify its ambiguity function (e.g. the "sheared" ambiguity function generated by a chirp)
- We want to consider intelligent approaches to modulating waveforms
- Coded waveforms provide a structured approach to designing waveforms.