

# Moving Target Indicator

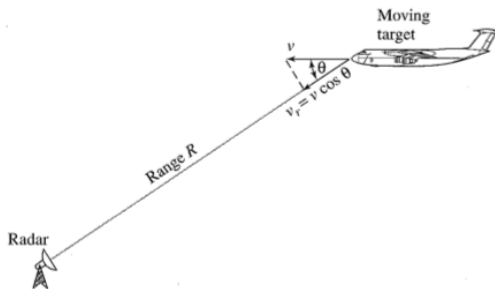
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April 25, 2014

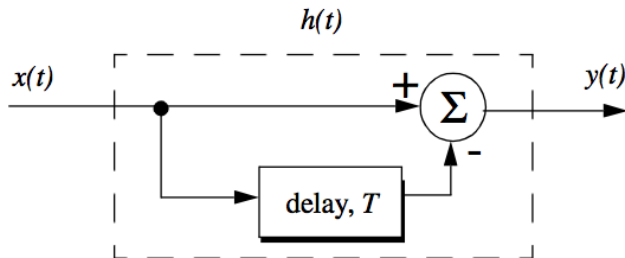
# Moving Target Indicator

- ▶ mode of operation of radar
- ▶ makes use of doppler effect



Source: Merrill I. Skolnik. *Introduction to Radar Systems*. McGraw-Hill, 2001.

# Single Delay Line Canceler



Source: Bassem R. Mahafza. *Radar Systems Analysis and Design Using MATLAB<sup>®</sup>*. Chapman & Hall/CRC, 2000.

# Single Delay Line Canceler

$$h(t) = \delta(t) - \delta(t - T)$$

$$H(\omega) = 1 - e^{-j\omega T}$$

$$\begin{aligned}|H(\omega)|^2 &= H(\omega)H^*(\omega) \\&= (1 - e^{-j\omega T})(1 - e^{j\omega T}) \\&= 2(1 - \cos\omega T) \\&= 4(\sin(\omega T/2))^2\end{aligned}$$

# Double Delay Line Canceler

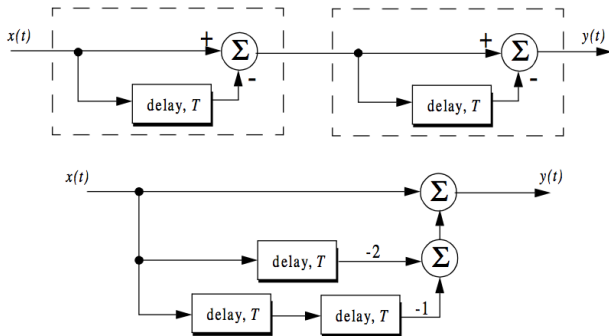


Figure: Two configurations for a double delay line canceler

# Double Delay Line Canceler

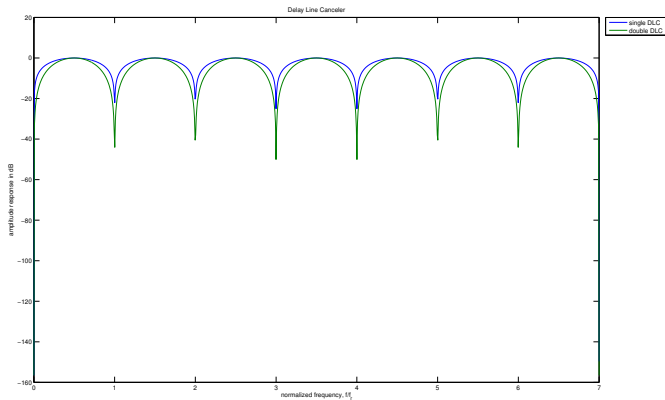
$$h(t) = \delta(t) - 2\delta(t - T) + \delta(t - 2T)$$

$$|H(\omega)|^2 = |H_1(\omega)|^2 |H_1(\omega)|^2$$

$$\text{where } |H_1(\omega)|^2 = 4(\sin(\omega T/2))^2$$

$$|H(\omega)|^2 = 16 \left( \sin \left( \omega \frac{T}{2} \right) \right)^4$$

# Delay Line Canceler



# Delay Lines with Feedback

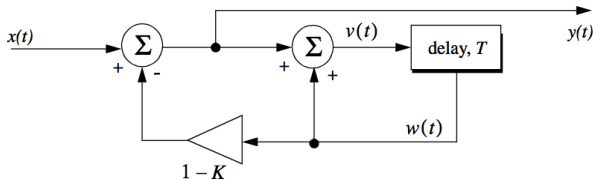


Figure: MTI recursive filter

Here,  $K$  is the gain factor.

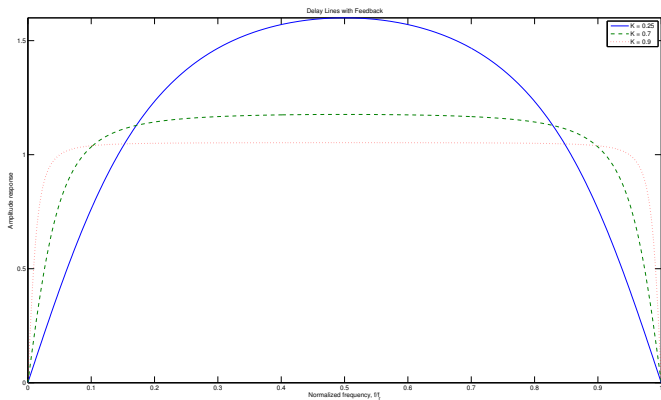
Source: Bassem R. Mahafza. *Radar Systems Analysis and Design Using MATLAB®*. Chapman & Hall/CRC, 2000.



# Delay Lines with Feedback

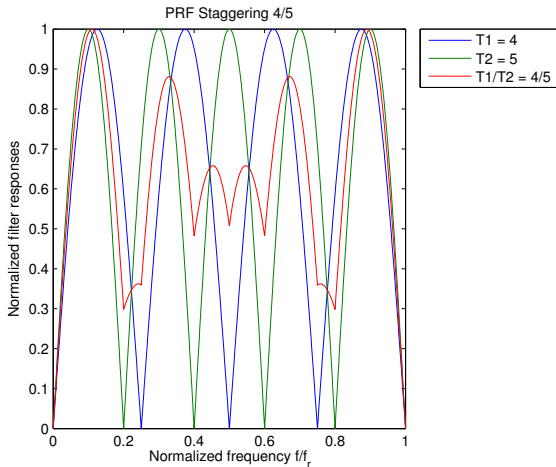
$$\begin{aligned}H(z) &= \frac{1 - z^{-1}}{1 - Kz^{-1}} \\|H(z)|^2 &= \frac{(1 - z^{-1})(1 - z)}{(1 - Kz^{-1})(1 - Kz)} \\&= \frac{2 - (z + z^{-1})}{(1 + K^2) - K(z + z^{-1})} \\|H(e^{j\omega T})|^2 &= \frac{2(1 - \cos\omega T)}{(1 + K^2) - 2K\cos(\omega T)}\end{aligned}$$

# Delay Lines with Feedback



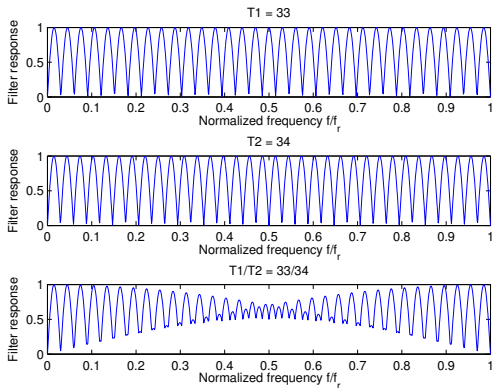
Source: Bassem R. Mahafza. *Radar Systems Analysis and Design Using MATLAB<sup>®</sup>*. Chapman & Hall/CRC, 2000.

# PRF Staggering 4/5



Source: Bassem R. Mahafza. *Radar Systems Analysis and Design Using MATLAB®*. Chapman & Hall/CRC, 2000.

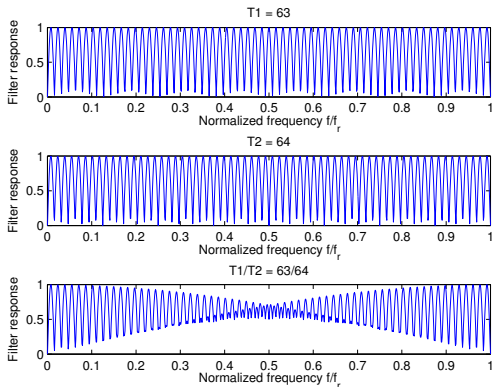
# PRF Staggering 33/34



Note: The dips in the upper two plots all touch  $y=0$  axis in reality. But since this is a digital plot with just 1000 samples from  $t=0$  to  $t=1$ , some of them did not get sampled.

Source: Bassem R. Mahafza. *Radar Systems Analysis and Design Using MATLAB®*. Chapman & Hall/CRC, 2000.

# PRF Staggering 63/64



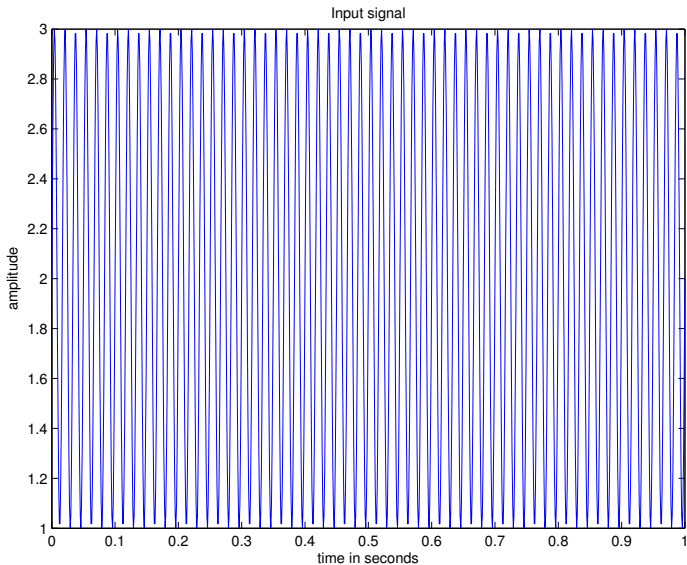
Note: The dips in the upper two plots all touch  $y=0$  axis in reality. But since this is a digital plot with just 1000 samples from  $t=0$  to  $t=1$ , some of them did not get sampled.

Source: Bassem R. Mahafza. *Radar Systems Analysis and Design Using MATLAB®*. Chapman & Hall/CRC, 2000.

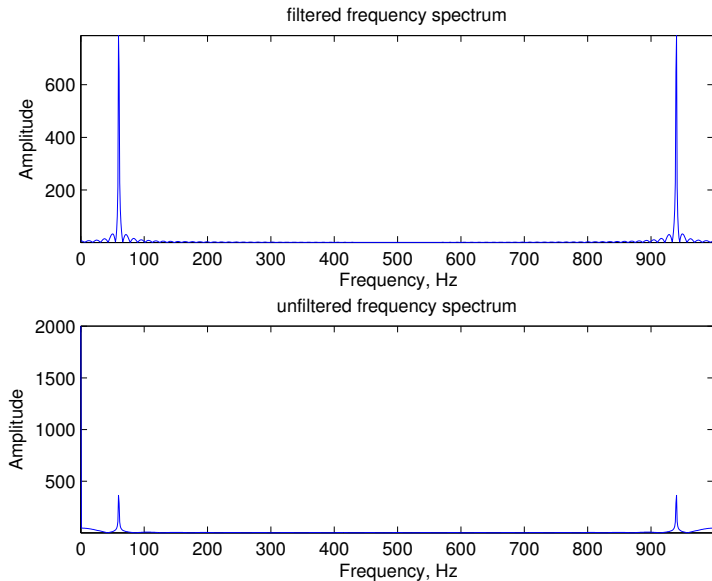
# First staggered blind speed

$$\frac{n_1}{T_1} = \frac{n_2}{T_2} = \dots = \frac{n_N}{T_N}$$
$$v_{blind} = \frac{n_1 + n_2 + \dots + n_N}{N} v_{blind1}$$

# 60Hz input

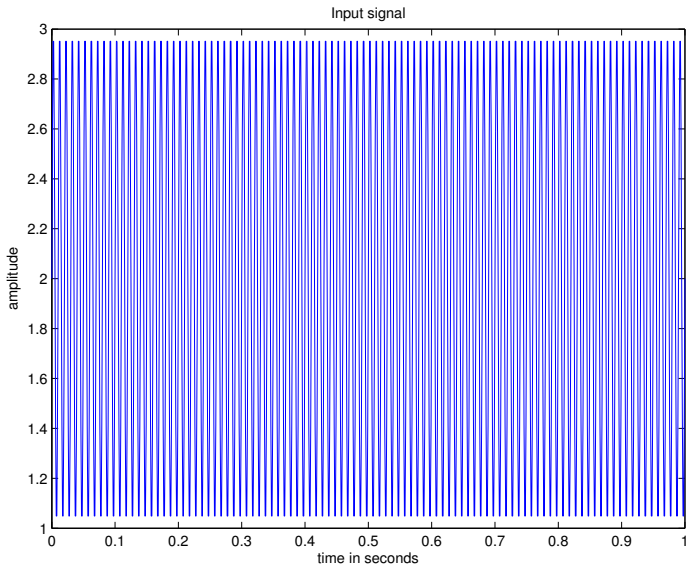


# Filtered spectrum of 60Hz input

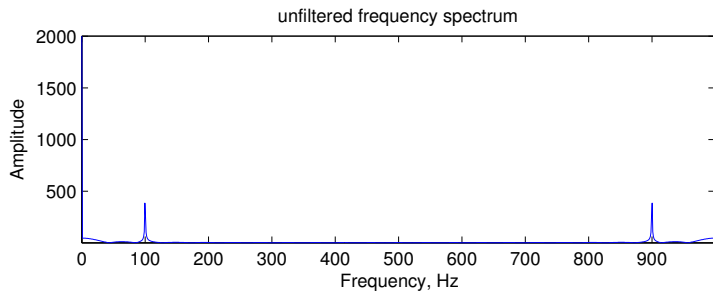
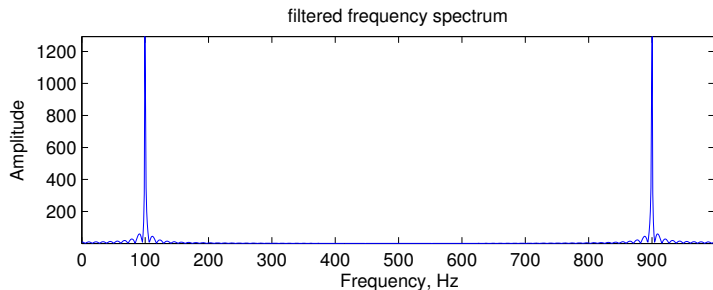




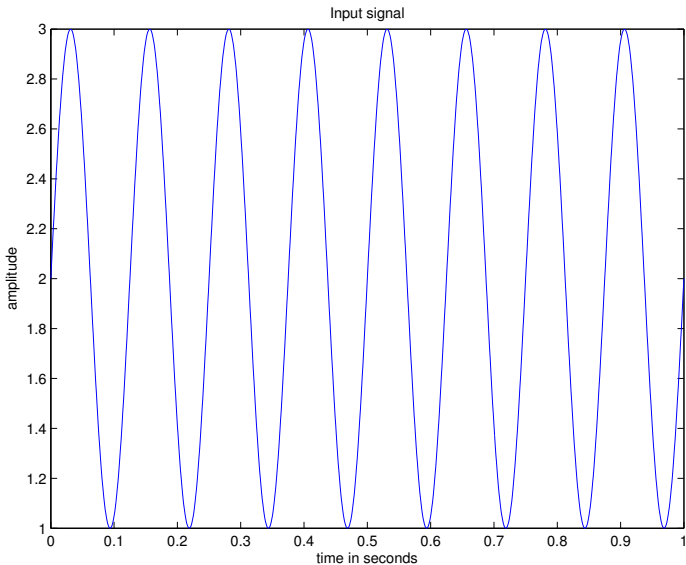
# 100Hz input



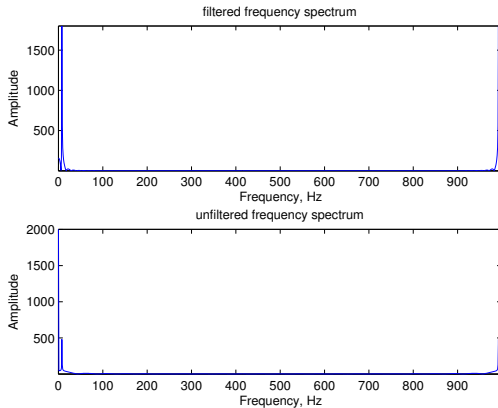
# Filtered spectrum of 100Hz input



# 1008Hz input



# Filtered spectrum of 1008Hz input

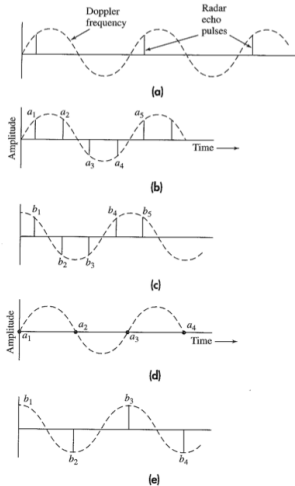


Here we are getting a non-zero filtered output because of aliasing happening due to limited sample rates possible. Ideally we should get a zero output at the frequency in which the blind speed occurs (1008Hz).

# Conclusion

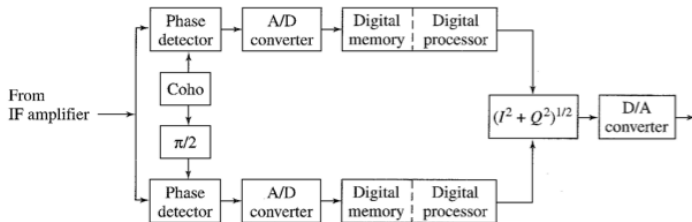
- ▶ Staggering PRFs is the best way to increase the blind speed.
- ▶ Using higher PRFs increases the blind speed, but it reduces the range of the radar too.
- ▶ Using staggering ratios like  $63/64$  gives us an actual first blind speed that is  $(63+64)/2$  or 63.5 times the lowest blind speed among the staggered PRFs.
- ▶ Similarly by making the staggering ratio closer to 1 and/or by using more than two staggered PRFs, we can get even higher blind speeds without reducing the range of the radar.

# Digital MTI (I and Q channels)



Source: Merrill I. Skolnik. *Introduction to Radar Systems*. McGraw-Hill, 2001.

# Digital MTI Processor



Source: Merrill I. Skolnik. *Introduction to Radar Systems*. McGraw-Hill, 2001.

# References

- ▶ Merrill I. Skolnik. *Introduction to Radar Systems*. McGraw-Hill, 2001.
- ▶ Bassem R. Mahafza. *Radar Systems Analysis and Design Using MATLAB®*. Chapman & Hall/CRC, 2000.
- ▶ [http://en.wikipedia.org/wiki/Moving\\_target\\_indication](http://en.wikipedia.org/wiki/Moving_target_indication)
- ▶ <http://www.radartutorial.eu/11.coherent/co13.en.html>



# Thank You