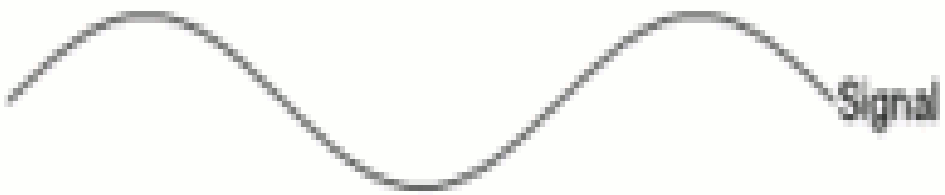
FREQUENCY MODULATED CONTINUOUS WAVE RADAR

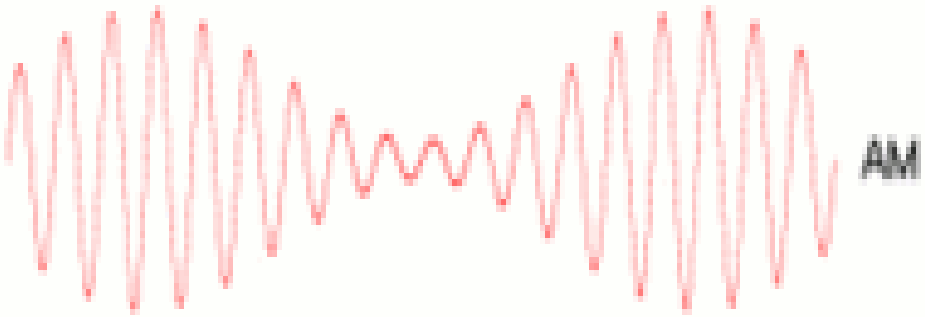
ECE 521E-RADAR & SATELLITE ENGINEERING

Monday, 28 September 2026

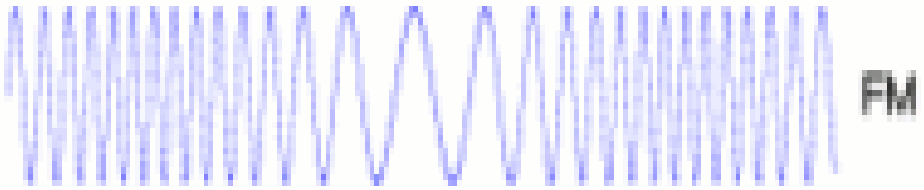
FM/AM REVISION



Modulating Signal

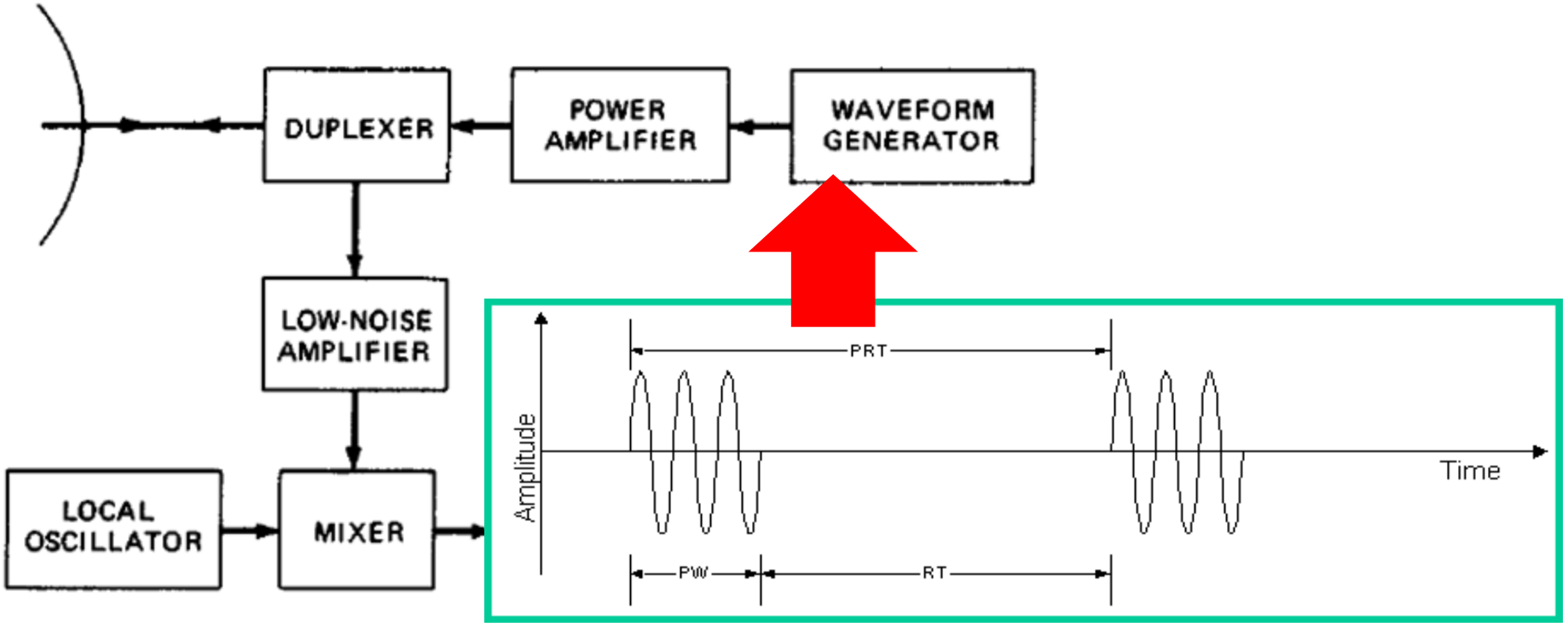


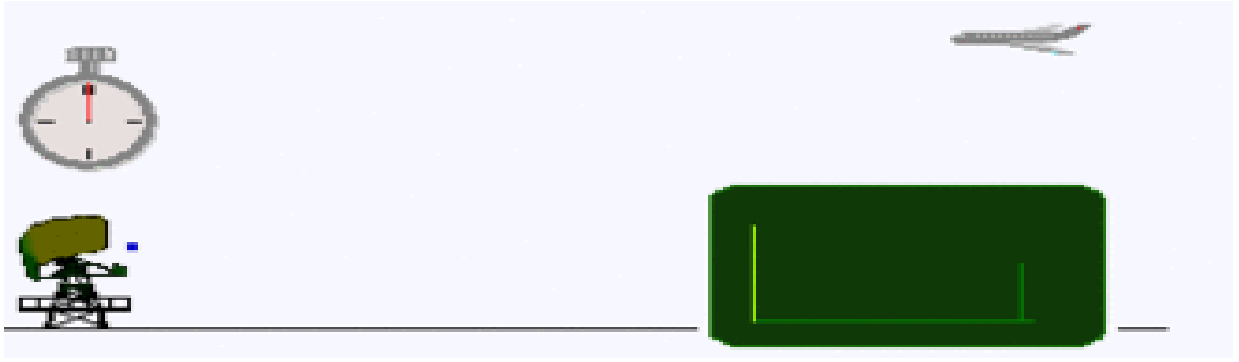
Carrier amplitude varies in accordance with the modulating signal



Carrier frequency varies in accordance with the amplitude of the modulating signal

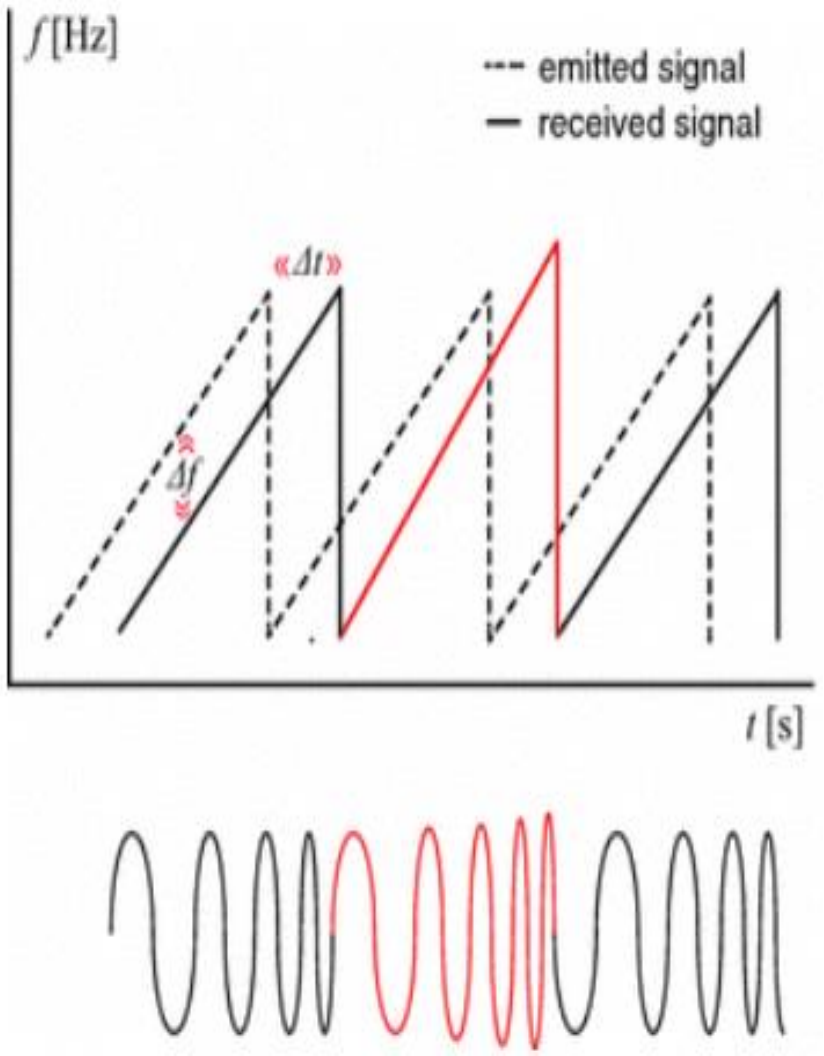
RECAP: PULSE RADAR USES PULSE AMPLITUDE MODULATION





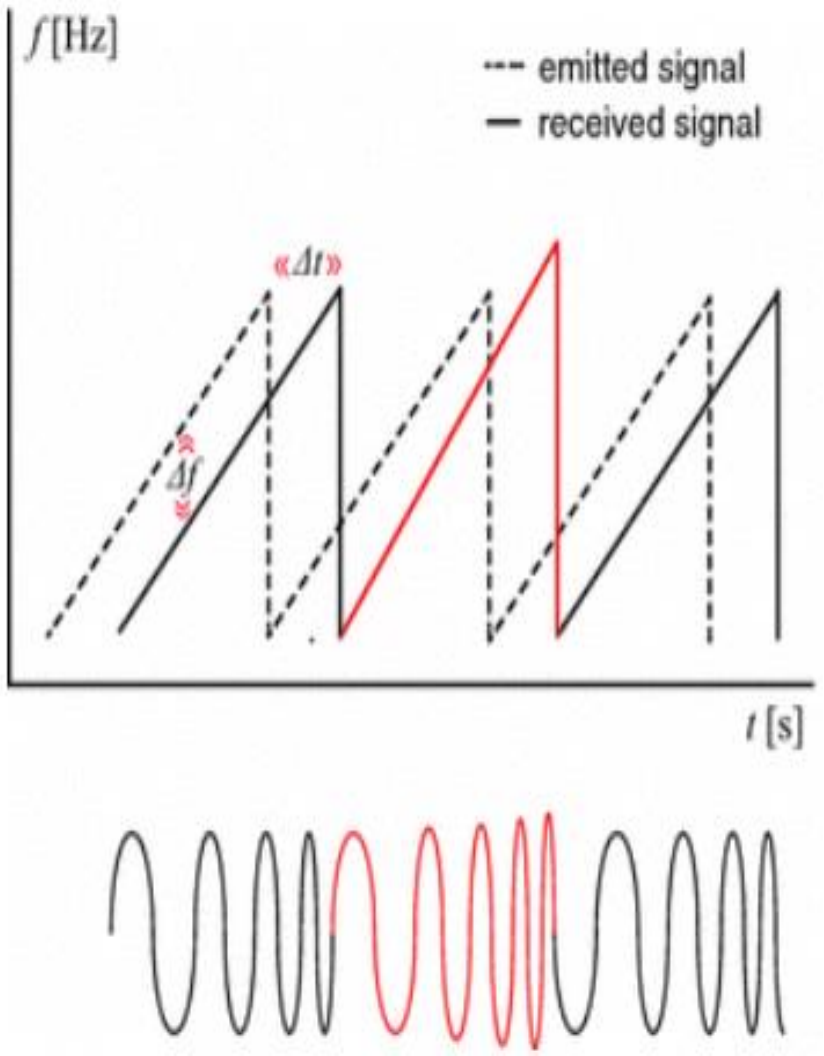
WHAT IS FMCW RADAR?

1. **F**requency-**M**odulated **C**ontinuous **W**ave **R**adar (**FMCW**) is a type of radar which radiates continuous transmission power like a simple continuous wave radar (CW-Radar) but changes its operating frequency in a known manner during the measurement.
2. The changes in frequency make it possible to estimate the time delay of the echo signal and hence the range.

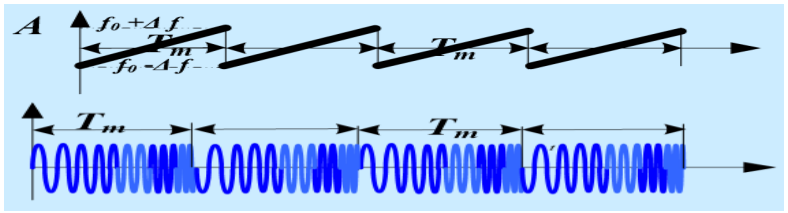


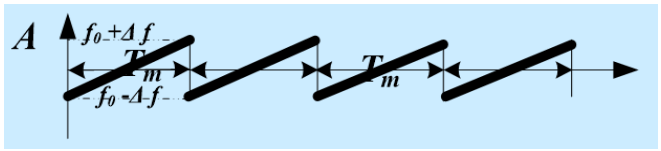
FMCW RADAR PRINCIPLES (1)

1. The transmitter of a CW radar has no timing marks. Therefore, it cannot:
   (a) provide range of target, or
   (b) Establish the particular cycle being received
2. **If the CW radar frequency is altered to be a function of time in a known manner, then the transition marks can be used to determine the range**.
3. A CW radar that is modified in such a manner is called a **Frequency Modulated Continuous Wave (FMCW) radar.**



BLOCK DIAGRAM OF SAWTOOTH MODULATED FMCW RADAR





Tx Antenna

FM Transmitter

Frequency Modulator

Voltage-controlled Oscillator

Saw Tooth Generator

Mixer

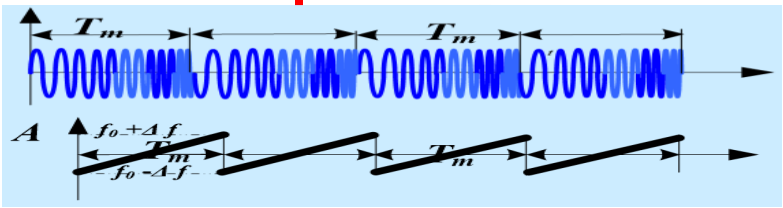
Amplifier

Limiter

Processor

Indicator

Rx Antenna

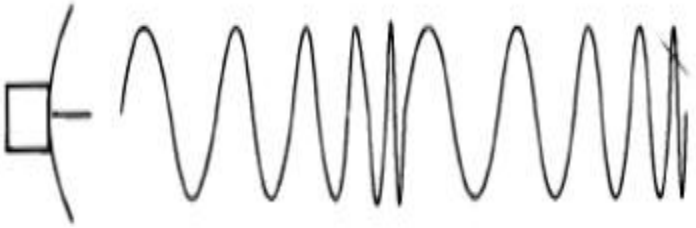


Echo is ramp frequency modulated with doppler shift f_d but delayed by Δt

Display shows:
(a)Velocity (b) Rage

FMCW RADAR RANGE COMPUTATION (1)

1. FMCW radar measures the instantaneous difference between transmitted and received frequencies (doppler frequency shift), Δf which is directly proportional to the time delay Δt.

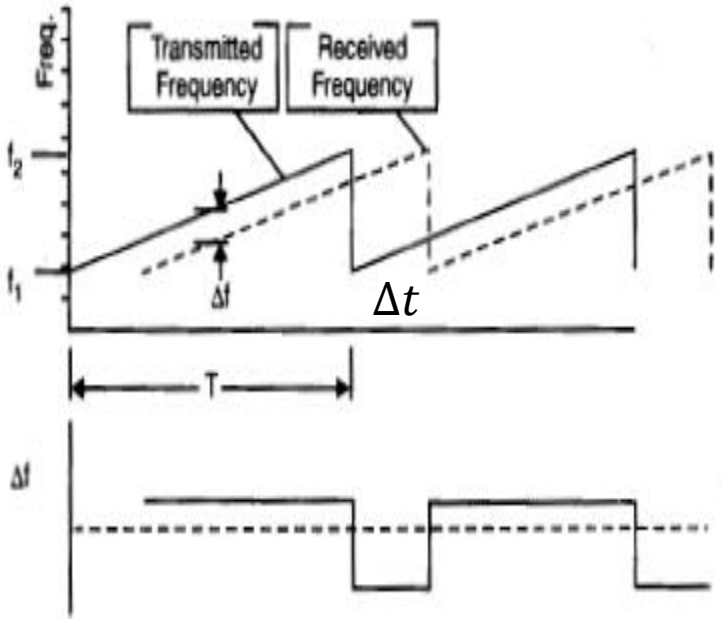


2. Range can then be computed using proportions as:

$$\frac{\Delta t}{T} = \frac{\Delta f}{f_2 - f_1}$$

or

$$\Delta t = \frac{T\Delta f}{f_2 - f_1}$$



Where

f_2 = maximum frequency

f_1 = minimum frequency

.

FMCW RADAR RANGE COMPUTATION (2)

1. Just like the Pulse Radar, FM-CW Radar range can be computed as

$$R = c\frac{\Delta t}{2}$$

Substituting

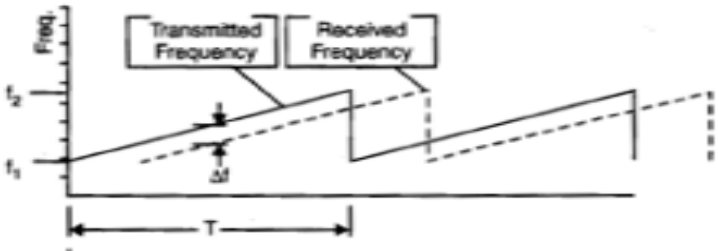
$$\Delta t = \frac{T\Delta f}{f_2 - f_1}$$

We get

$$\mathrm{R} = \frac{cT\Delta f}{2(f_2 - f_1)}$$

2. The unambiguous range is limited by the duration of the sweep and is given by:

$$R_{Unamb} = c\frac{T}{2}$$

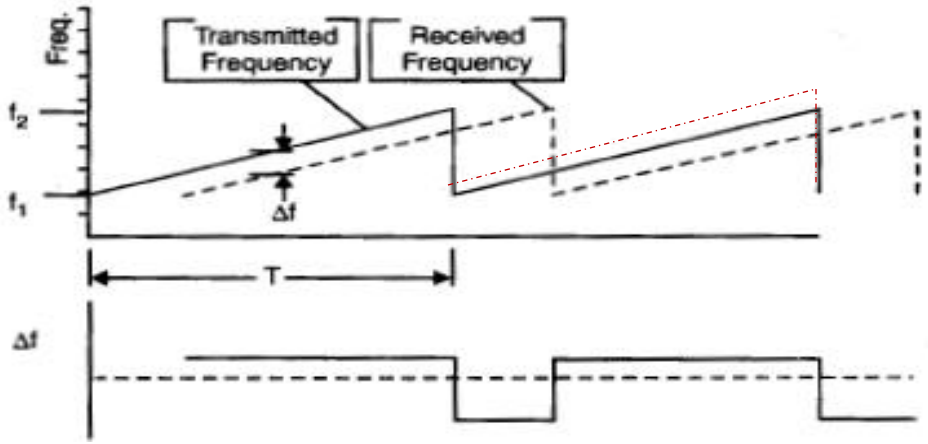


EXAMPLE

1. A frequency modulated radar sweeps from 400Hz to 800Hz in 10μsec. What is the maximum unambiguous range which can be measured by the radar?

SOLUTION



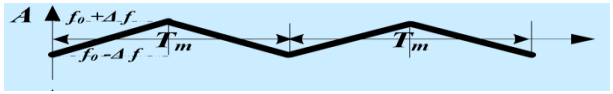


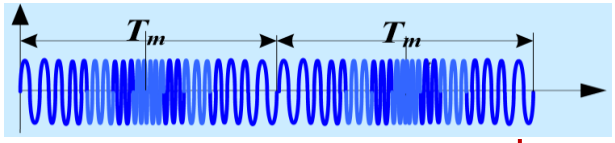
Solution:

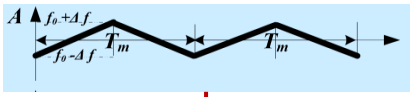
$$R_{Unamb} = c\frac{T}{2}$$

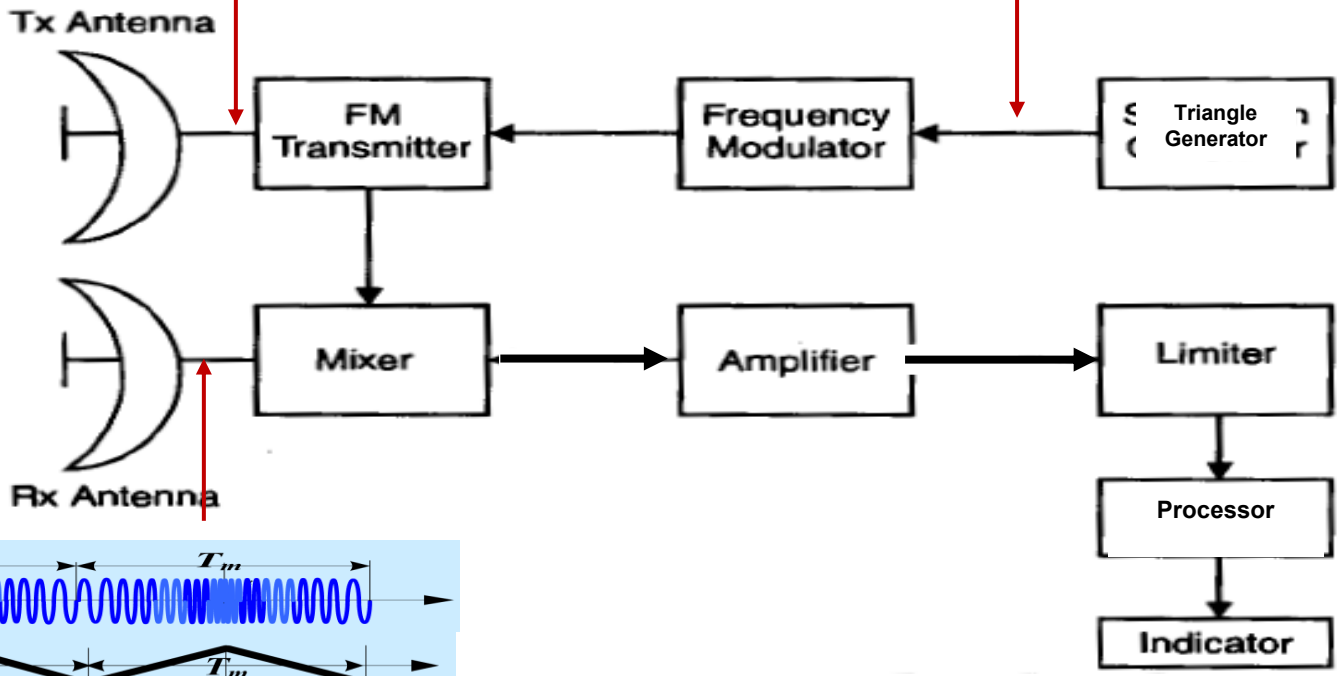
$$R_{\max=} = R_{Unamb} = \frac{(3x10^{8})x(10x10^{-6})}{2} = 1500m$$

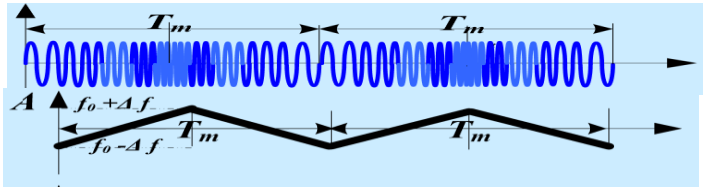
TRIANGLE MODULATED FMCW RADAR(1)







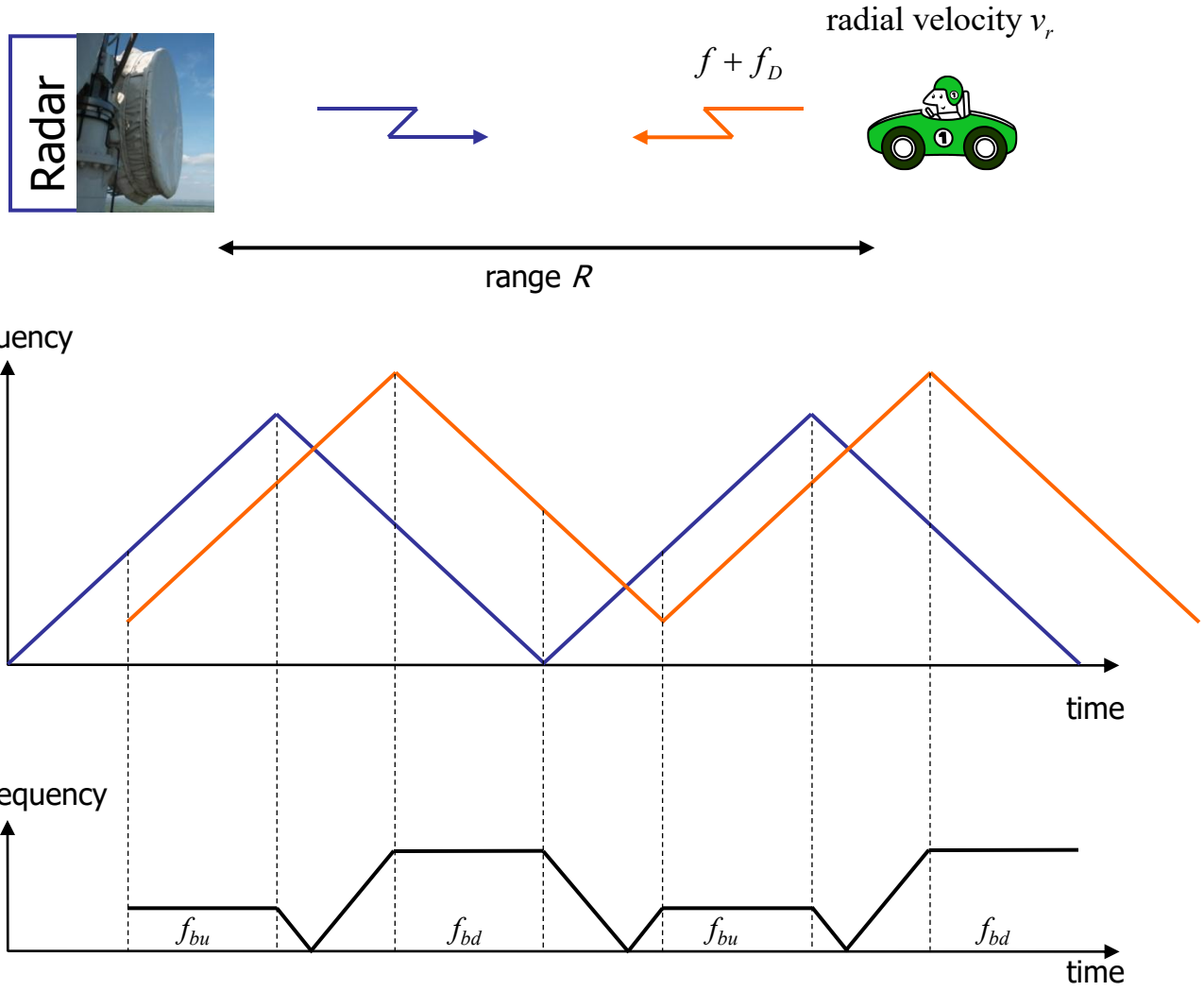




Echo is triangle frequency modulated with doppler shift f_d but delayed by Δt

Display shows:
(a)Velocity (b) Rage

TRIANGLE MODULATED FMCW RADAR(2)



Beat frequency components due to range and Doppler frequency shift:

$$f_b = \frac{B_{sweep}}{T_s} \cdot \frac{2R}{c}$$

$$f_D = \frac{2v_r}{\lambda}$$

that are superimposed as

$$f_{bu} = f_b - f_d$$

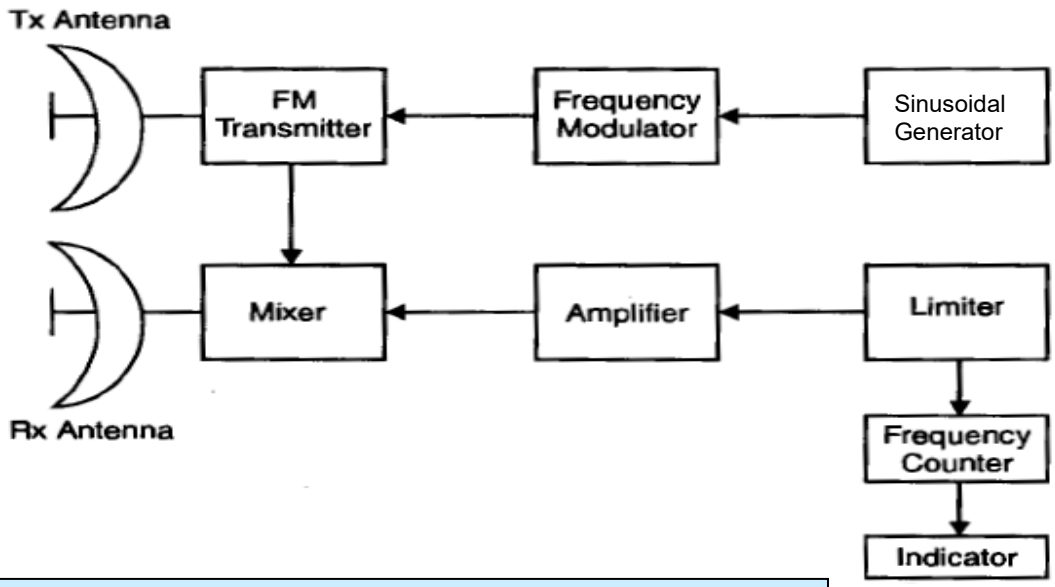
$$f_{bd} = f_b + f_d$$

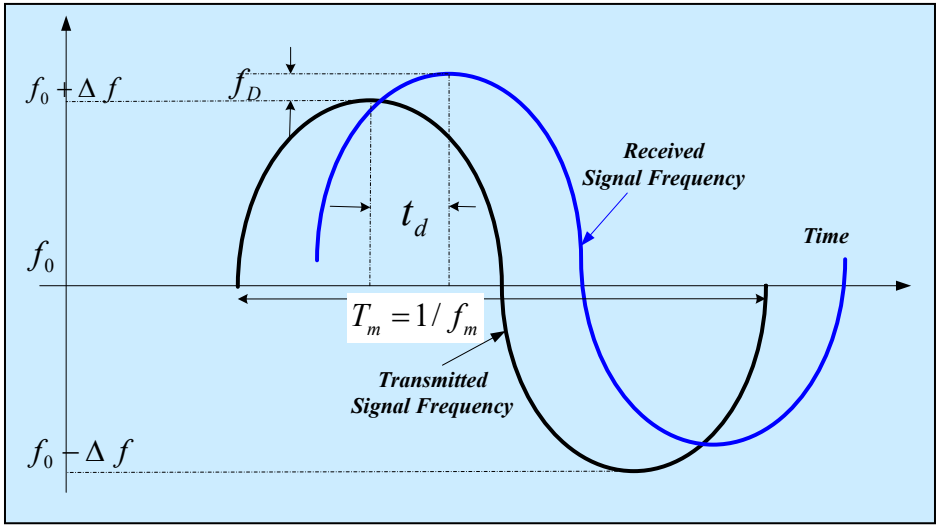
so range and radial velocity can be obtained as

$$R = \frac{cT_s}{4B_{sweep}}\left(f_{bd} + f_{bu}\right)$$

$$v_r = \frac{\lambda}{4}\left(f_{bd} - f_{bu}\right)$$

SINUSOIDAL FMCW RADAR





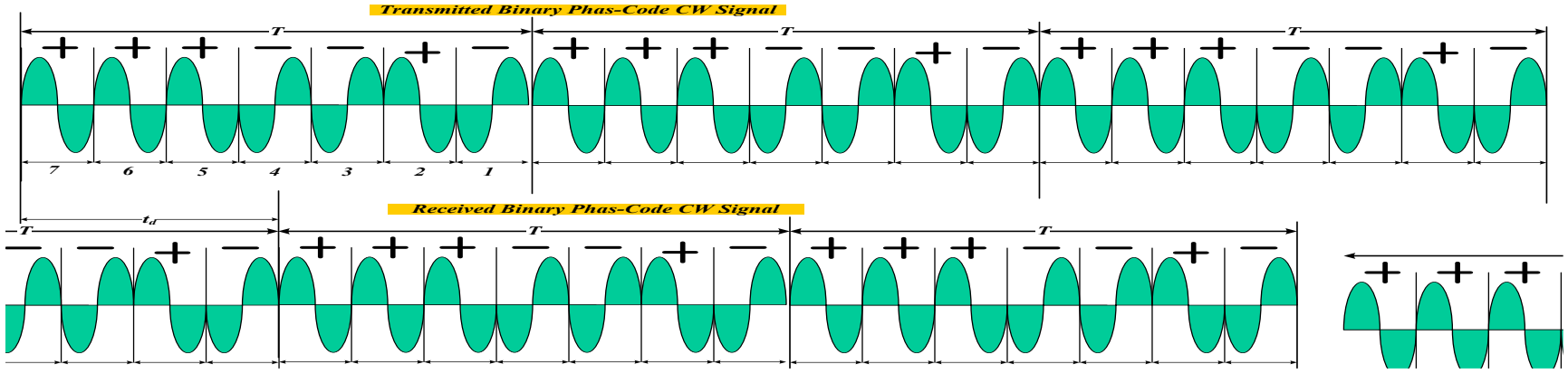
PHASE MODULATED CW RADAR

1. **PMCW radar** measures target range by applying a discrete phase shift every T seconds to the transmitted CW signal, producing a phase-code waveform.

2. The returning waveform is correlated with a stored version of the transmitted waveform.

3. The correlation process gives a maximum when we have a match.

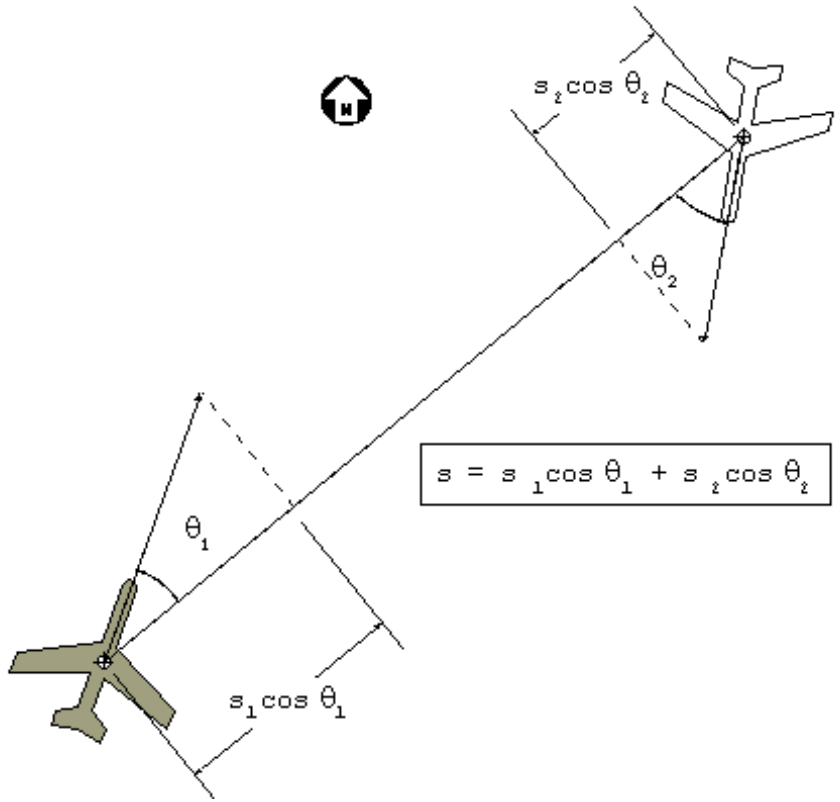
4. The time to achieve this match is the time-delay between transmitted and receiving signals and provides the required target range.



LINE OF SIGHT SPEED

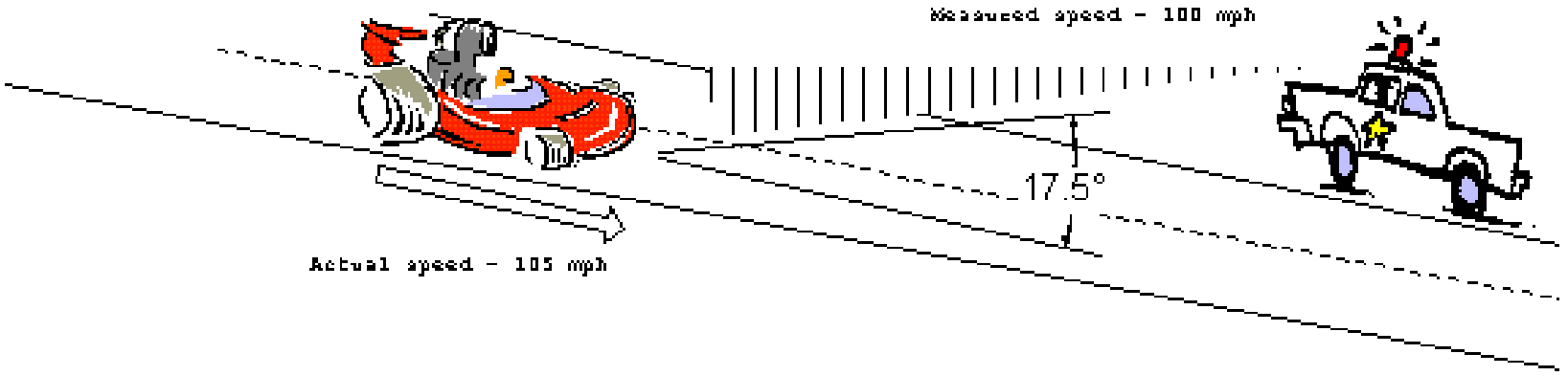
If two planes are moving in opposite directions but not on a line of sight, the speed will be detected by onboard CW radar as:

$$s = s_1 \cos\theta_1 + s_2 \cos\theta_2 .$$



USE OF CW RADAR FOR LAW ENFORCEMENT

1. CW radars are used by the law enforcement agencies to measure the speed of vehicles.
2. What is actually measured is the fraction of the total speed which is towards the radar.
3. There is always an error if there is difference between the direction of motion and the line-of-sight,
4. Fortunately for speeders, the measured speed is always lower than the actual.



ULTRASOUND DOPPLER FLOW METERS

- What is actually measured is the fraction of the total speed which is towards the radar.
- There is always an error if there is difference between the direction of motion and the line-of-sight,

