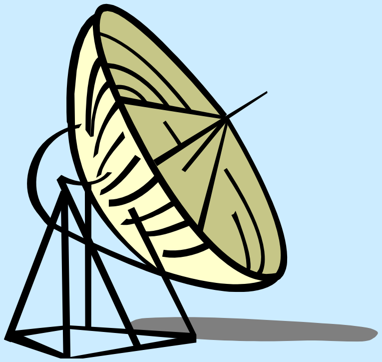
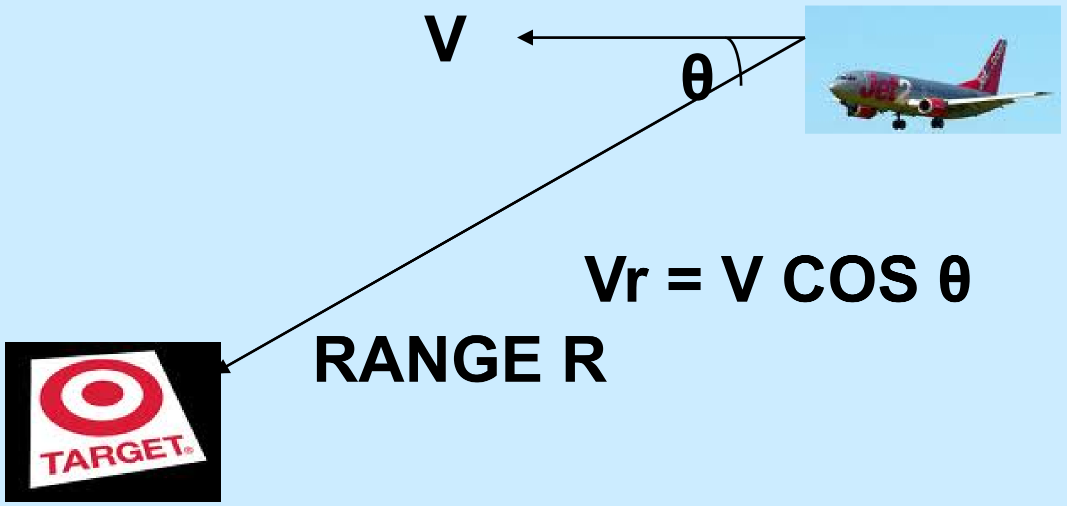
CW & Frequency Modulated Radar



DOPPLER EFFECT



$V_r = V \cos\theta$

RANGE R

RANGE TO TARGET = R

WAVE LENGTH = λ

NO. OF WAVELENGTHS TO TRAVEL 2R = $2R / \lambda$

TOTAL PHASE SHIFT $\Phi = 2\Pi X (2R / \lambda) = 4\Pi R / \lambda$

DOPPLER EFFECT

IF TARGET IS IN MOTION RELATIVE TO RADAR, R IS CHANGING. SO SHALL BE Φ

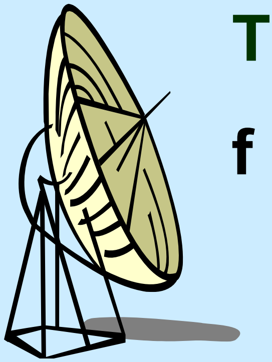
DIFFERENTIATING WE GET,

$\omega_d = d\Phi / dt = (4\pi / \lambda) \times (dR / dt) = 4\pi V_r / \lambda = 2\pi f_d$

$V_r = V \cos \Phi$

f_d = DOPPLER FREQUENCY

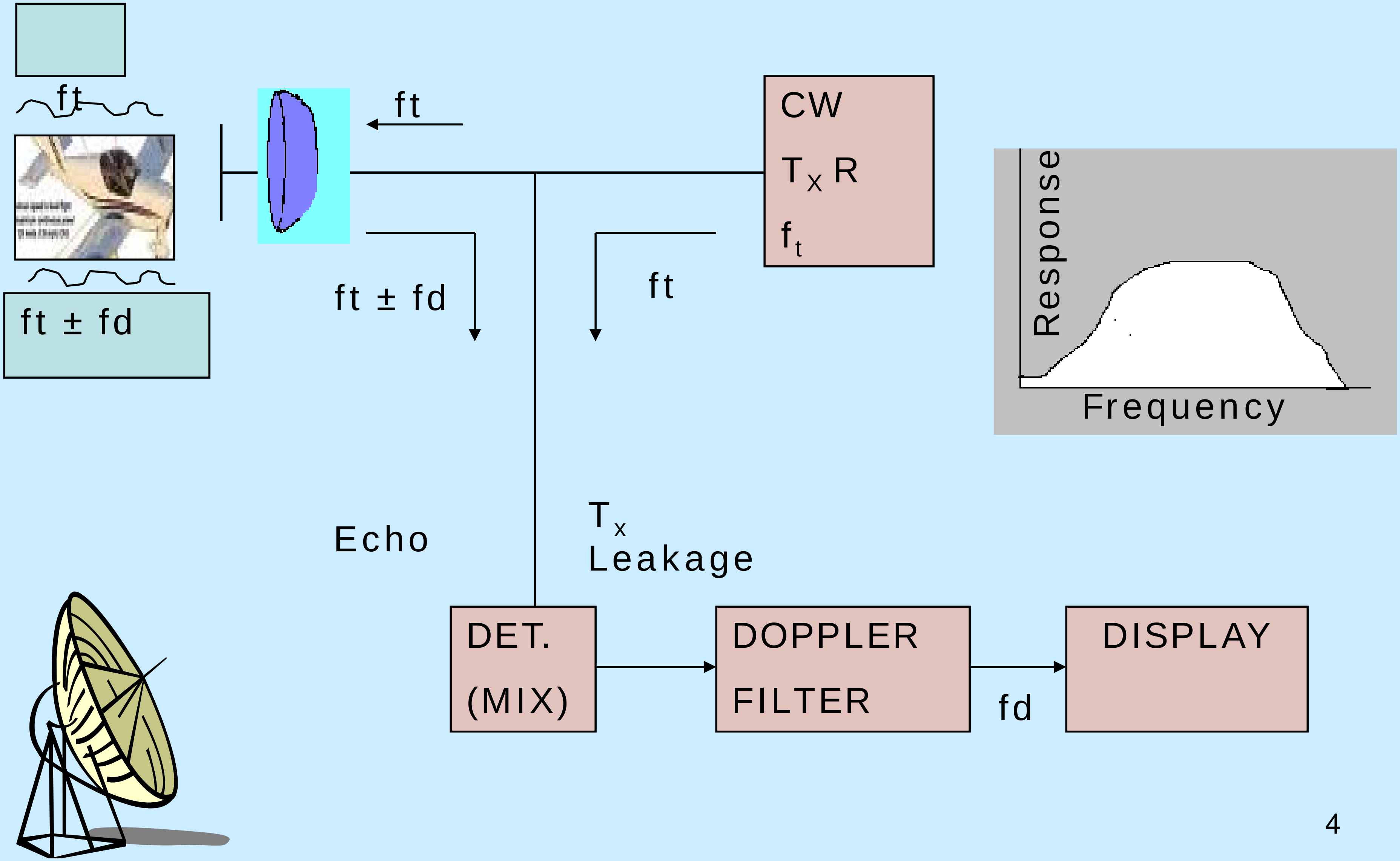
$\omega_d = 2\pi f_d$



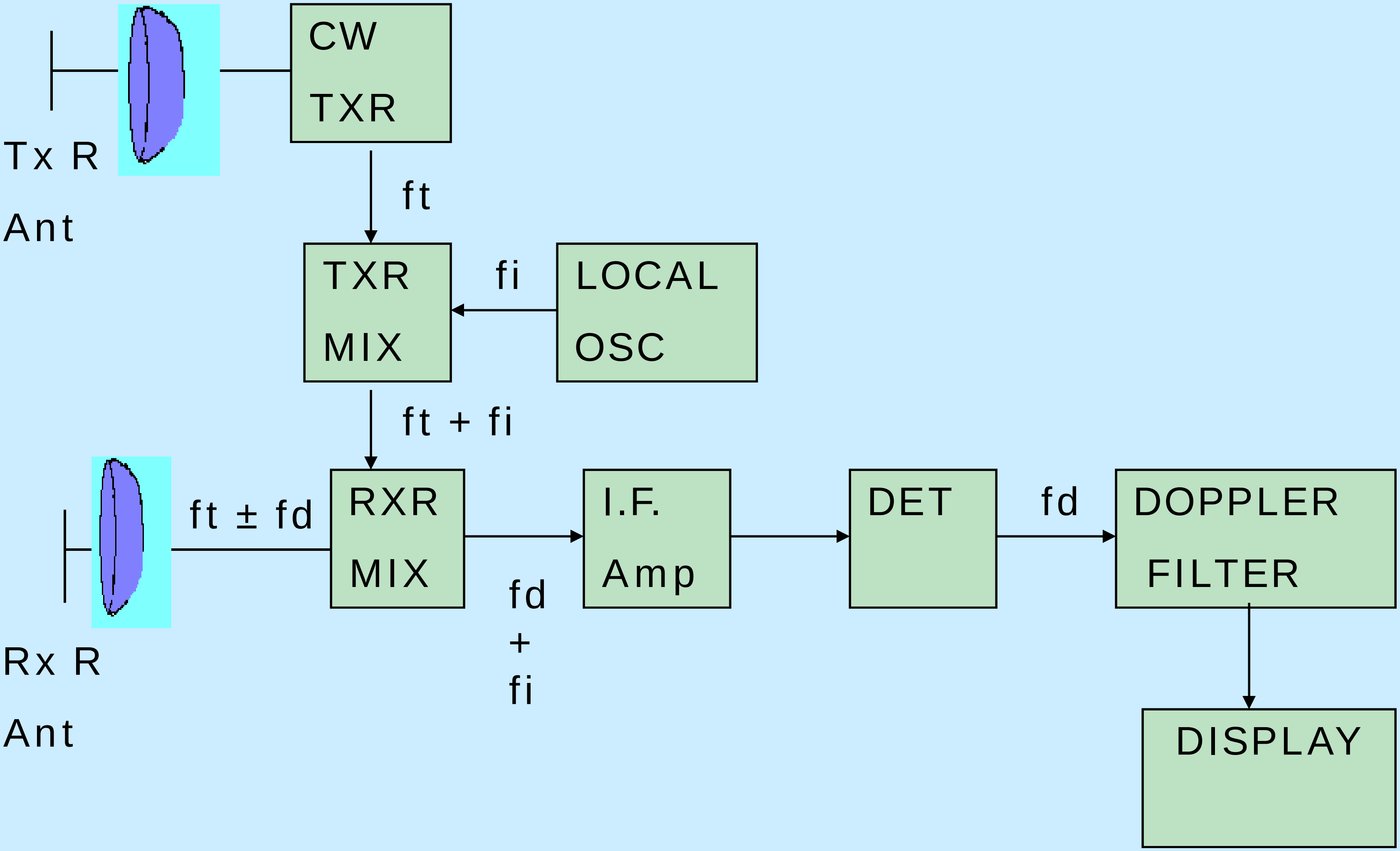
THEREFORE $2\pi f_d = 4\pi \times V_r / \lambda$

$f_d = 2 V_r / \lambda$

CW RADAR


ft
ft ± fd
ft
CW
T_X R
f_t
ft ± fd
ft
Response
Frequency
Echo
T_x
Leakage
DET.
(MIX)
DOPPLER
FILTER
fd
DISPLAY

CW DOPPLER RADAR WITH IF AMP



LIMITATIONS OF CW RADAR FOR LONG RANGE

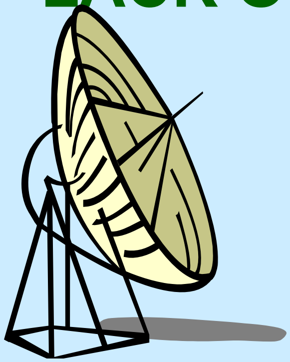
- LACK OF ISOLATION BETWEEN T_X r & R_X r
- FLICKER EFFECT NOISE – VACUUM TUBES

  PRODUCE NOISE α 1/ f
- HOMODYNE – SUPERHETRODYNE WITH O IF

  FREQUENCY.

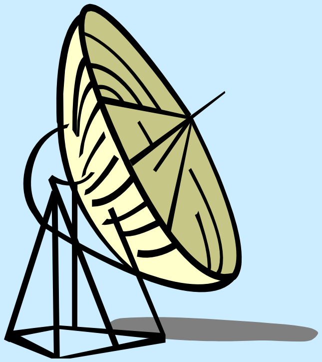
LACK OF MATCHED FILTER IN RECEIVER.

(MAX OUTPUT SIGNAL TO NOISE RATIO)



LIMITATIONS OF CW RADAR FOR LONG RANGE

- LACK OF KNOWLEDGE IF TARGET IS APPROACHING OR RECEDING .
- MORE CLUTTER AS COMPARED TO PULSE RADAR.
- NO RANGE INFORMATION.



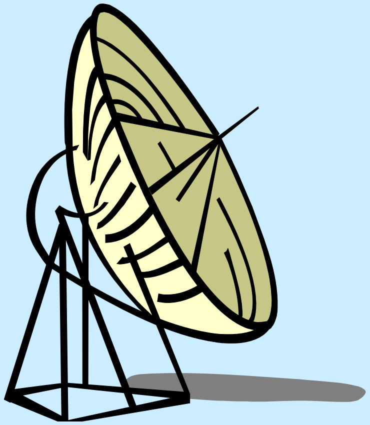
APPLICATIONS OF CW RADAR

a) POLICE SPEED METER .

b) SPEED GUN FOR BASEBALL & CRICKET.

c) ARTILLERY PROXIMITY FUSE.

d) ARTILLERY PROJECTILE MUZZLE VELOCITY RADAR.



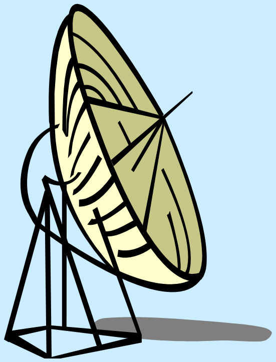
APPLICATIONS OF CW RADAR

e) **RADARS FOR DOCKING OF LARGE SHIPS.**

f) **AIRBORNE DOPPLER NAVIGATOR.**

g) **NON CONTACT MEASUREMENT OF VELOCITY.**

h) **VIBRATION MEASUREMENT, INTRUDER DETECTION, RESPIRATION RATE ETC.**

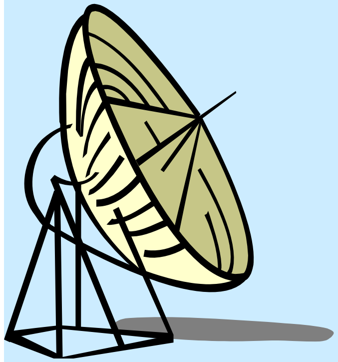


ISOLATION OF TRANSMITTER & RECEIVER

- USE OF TWO ANTENNAS.
- ABSORBING MATERIAL BETWEEN T_X & R_X .
- A MODERATE AMOUNT OF LEAKAGE FROM T_X SHALL ALWAYS ENTER R_X & SHALL NOT BE POSSIBLE TO ELIMINATE IT. IT SERVES AS A REFERENCE FOR DOPPLER SHIFT MEASUREMENT.
- AMOUNT OF ISOLATION REQUIRED DEPENDS UPON

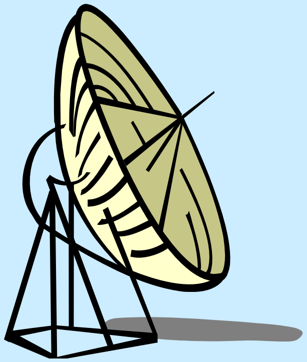
  a) TRANSMITTER POWER AND

  b) RUGGEDNESS & SENSITIVITY OF R_X r



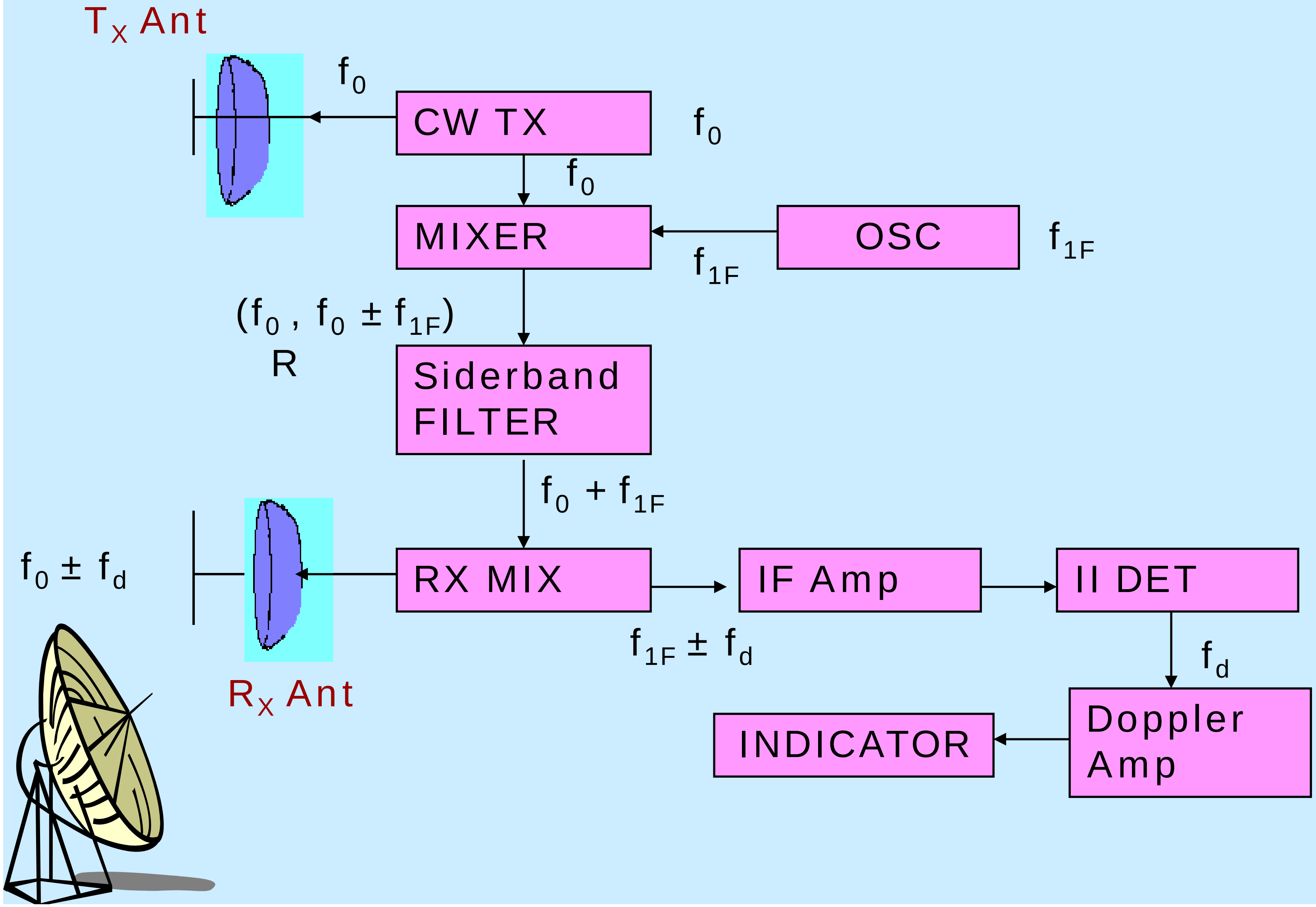
ISOLATION OF TRANSMITTER & RECEIVER

- IN CASE OF SINGLE ANTENNA , ISOLATION IS ACHIEVED BY:
  - (a) MAGIC T
  - (b) FERRITE ISOLATORS
  - (c) SEPARATE POLARISATION FOR T_X r & R_X r



REMOVAL OF FLICKER NOISE

CW RADAR WITH SUPERHYTRODYNE RECEIVER



T_X Ant

f_0

CW TX

f_0

f_0

MIXER

OSC

f_{1F}

f_{1F}

$(f_0 , f_0 \pm f_{1F})$

R

Siderband FILTER

$f_0 + f_{1F}$

$f_0 \pm f_d$

RX MIX

IF Amp

II DET

$f_{1F} \pm f_d$

f_d

R_X Ant

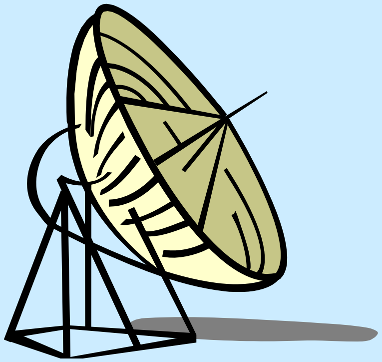
INDICATOR

Doppler Amp

REMOVAL OF FLICKER NOISE

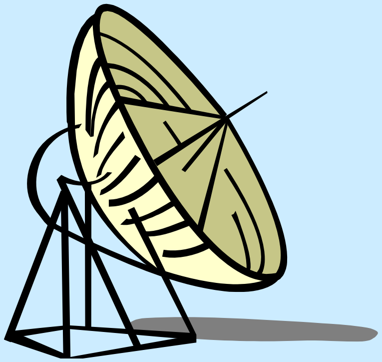
CW RADAR WITH SUPERHYTRODYNE RECEIVER

- FLICKER NOISE POWER α 1/ f^n .
- CAN BE REDUCED BY CHOOSING IF WHICH IS HIGH ENOUGH TO RENDER FLICKER NOISE SMALL AS COMPARED TO R_X r NOISE.



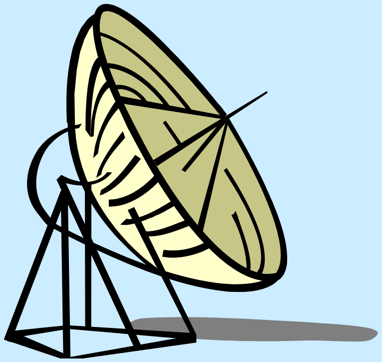
MATCHED FILTER

- DOPPLER FILTER USES A WIDE PASS BAND NOT A MATCHED FILTER.
- AN APPROXIMATION TO MATCHED FILTER IS WHOSE BAND WIDTH IS I / T_d WHEN T_d IS TIME DURATION OF SIGNAL PROCESSING.
- FILTER BAND IS PREFERRED.

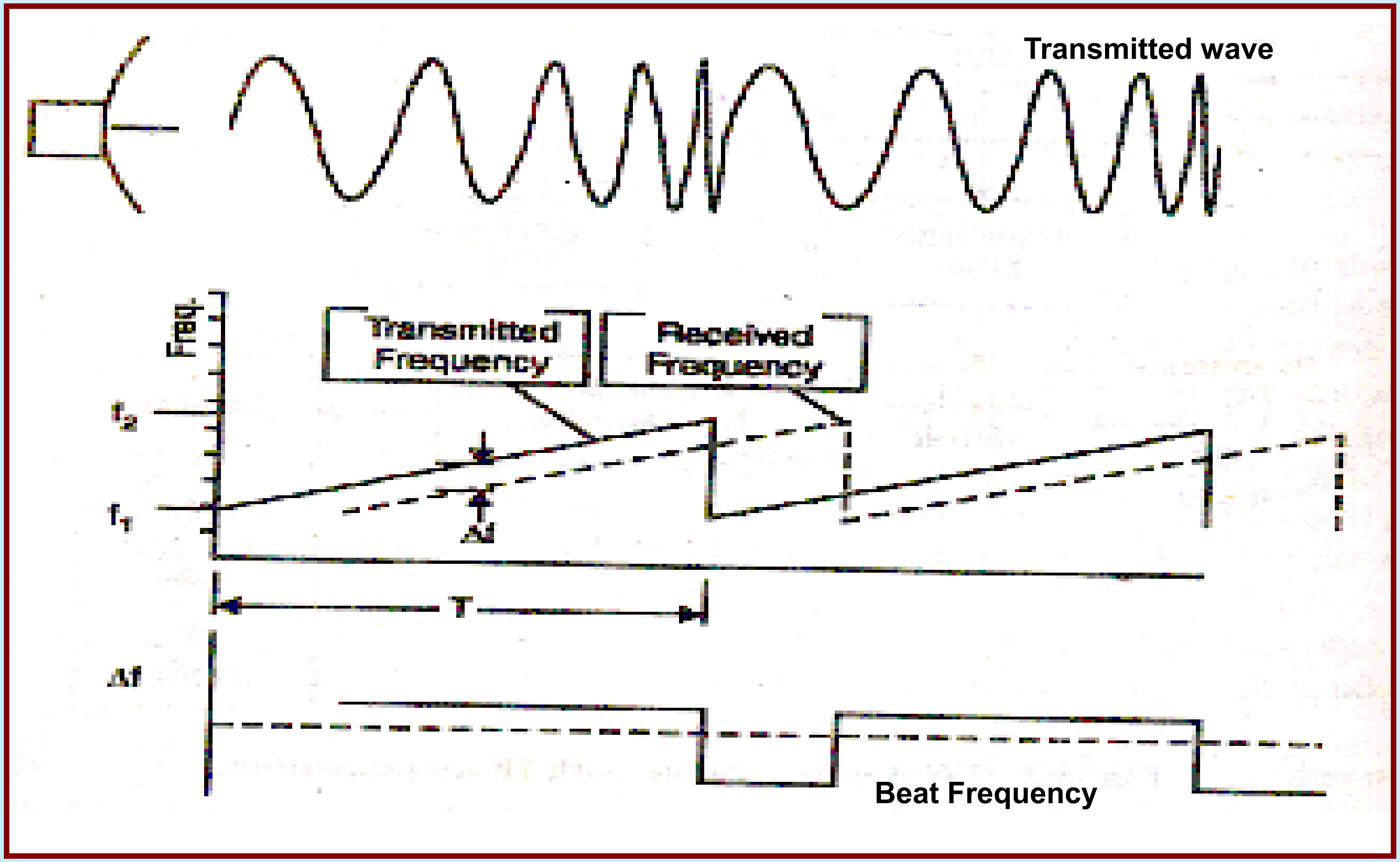


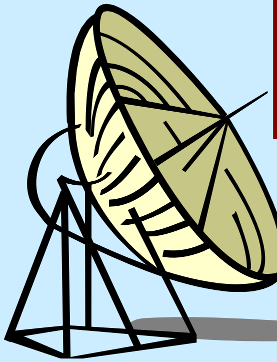
FM CW RADAR

- CW RADAR CANNOT MEASURE RANGE.
- SOME TIMING DEVICE NEEDS TO BE INCORPORATED.
- FREQUENCY MODULATION.



FM CW RADAR


Transmitted wave
Freq.
Transmitted Frequency
Received Frequency
f2
f1
Δf
T
Δf
Beat Frequency



FM CW RADAR

RATE OF FREQUENCY CHANGE = $(f_2 – f_1)$ / T

Δ f = INSTANTANEOUS DIFFERENCE BETWEEN

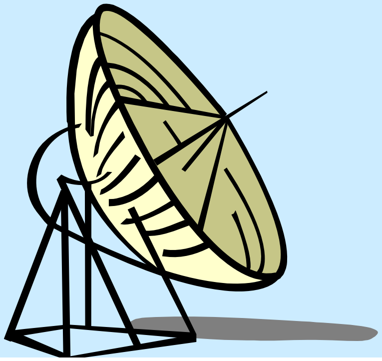
T_X & R_X FREQUENCY.

α TIME DELAY Δ t , WHICH IT TAKES TO REACH THE TARGET AND RETURN.

$\Delta t = T \times \Delta f / (f2 – f1)$

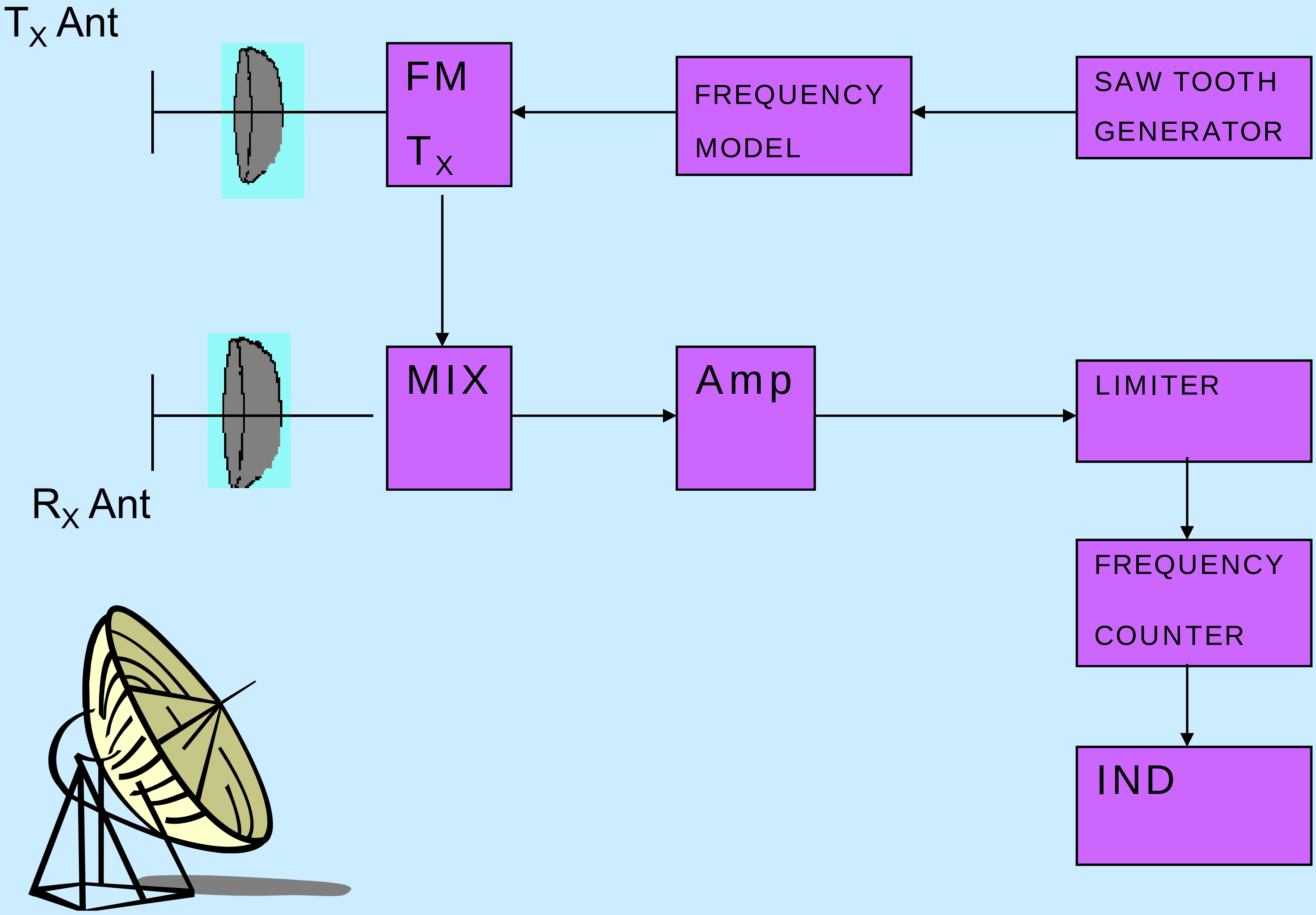
THEREFORE $R = C \times (\Delta t / 2)$

$= C / 2 \times (T_X \Delta f) / (f_2 – f_1)$



FM CW RADAR

BLOCK DIAGRAM



T_X Ant

FM T_X

FREQUENCY MODEL

SAW TOOTH GENERATOR

MIX

Amp

LIMITER

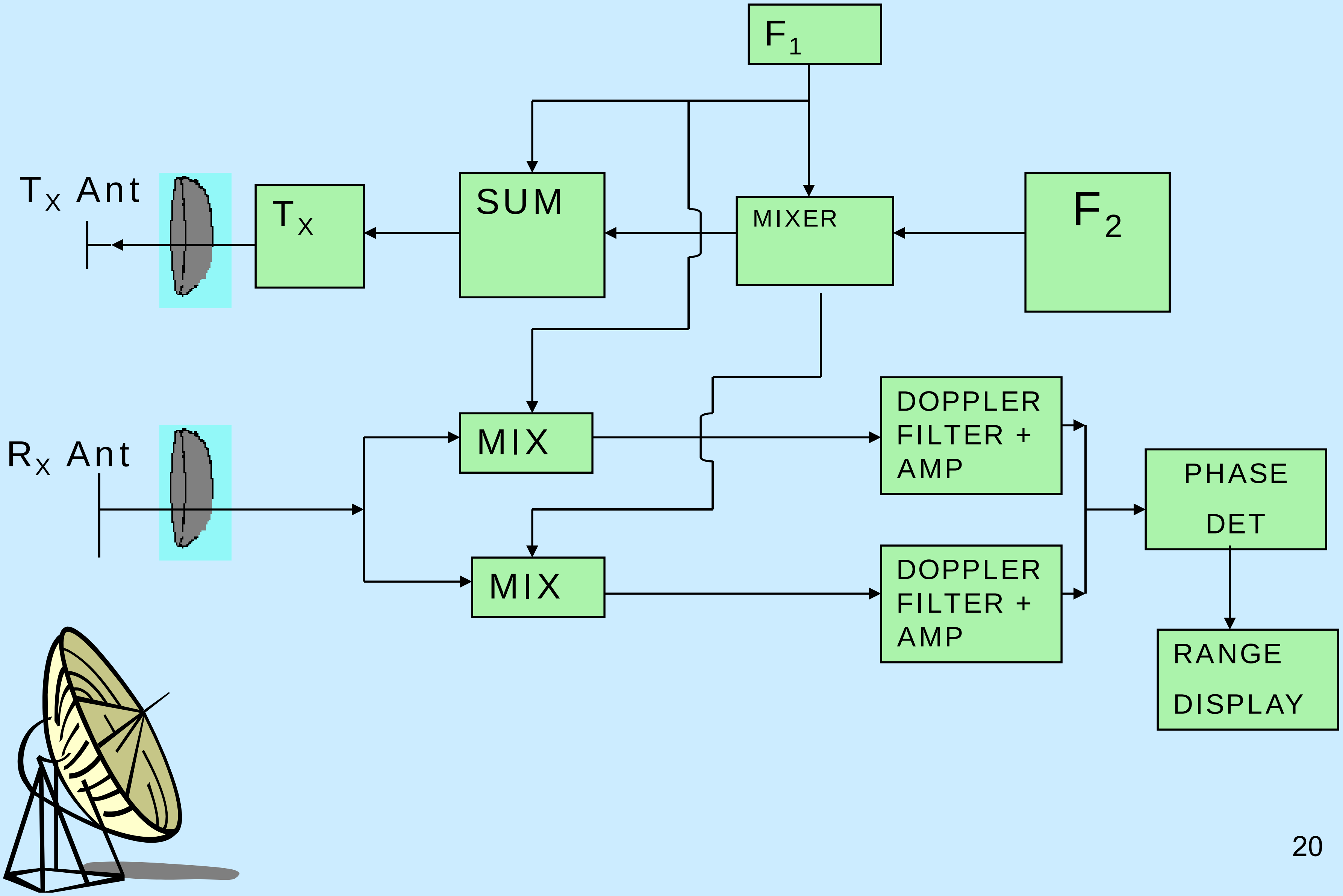
FREQUENCY COUNTER

IND

R_X Ant

WIDE AREA SURVEILLANCE RADARS

MULTIPLE FREQUENCY CW RADAR



F_1

T_X Ant

T_X

SUM

MIXER

F_2

R_X Ant

MIX

MIX

DOPPLER FILTER + AMP

DOPPLER FILTER + AMP

PHASE DET

RANGE DISPLAY

MULTIPLE FREQUENCY CW RADAR

TIME TAKEN FOR SIGNAL TO COME BACK = $2R/C$

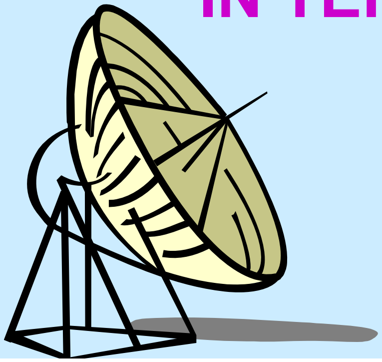
NO OF CYCLES = $(2R / C) \times f_t$

$\Delta\Phi$ = PHASE DIFFERENCE = $2R/C \times f_t \times 2\pi$

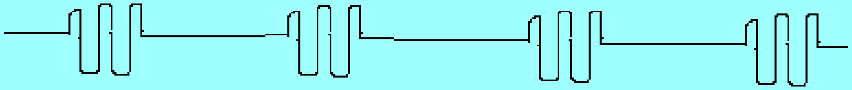
THEREFORE $R = (\Delta\Phi \times C) / 4\pi f_t$

IN TERMS OF λ , $\lambda = C / f_t$

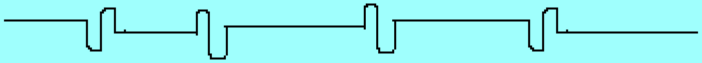
$$R = \Delta\Phi \times (\lambda / 4\pi)$$



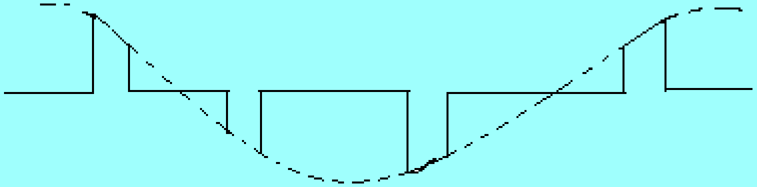
MULTIPLE FREQUENCY CW RADAR



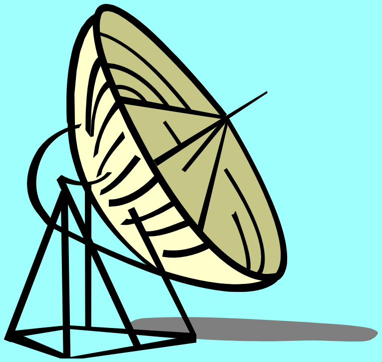
RF OR IF SIGNAL



VIDEO PULSE TRAIN

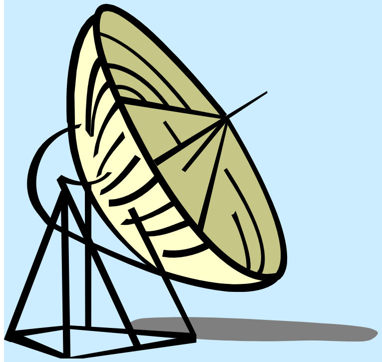


VIDEO PULSE TRAIN FOR $\boxed{f_d < 1 / T}$



TWO FREQUENCY CW RADAR

- **THE 2 FREQUENCIES CAN BE TRANSMITTED SIMULTANEOUSLY OR SEQUENTIALLY BY RAPIDLY SWITCHING A SIMPLE SOURCE.**
- **A LARGE DIFFERENCE IN FREQUENCY BETWEEN 2 TRANSMITTED SIGNALS IMPROVES THE RANGE MEASUREMENT ACCURACY SINCE A LARGE Δf IS EQVT TO A LARGE $\Delta\Phi$ FOR A GIVEN RANGE.**



- **HOWEVER $\Delta\Phi \leq 2\pi$ FOR RANGE TO BE UNAMBIGUOUS.**

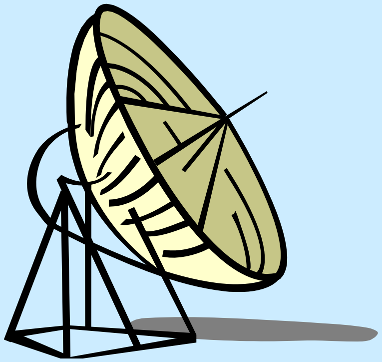
MAXIMUM UNAMBIGUOUS RANGE

$R_0 = C\Delta\Phi / 4\pi\Delta f$

PUT $\Delta\Phi = 2\pi$

$R_{UN} = C\,2\pi / 4\pi\Delta f = C / 2\Delta f$

OR $\Delta f \leq C / 2 R_{UN}$



MULTIPLE FREQUENCY CW RADAR

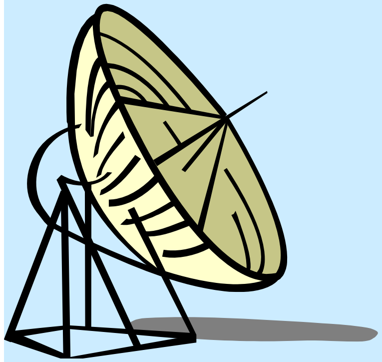
TWO FREQUENCY CW RADAR – FOR MEASURING RANGE

- IT IS POSSIBLE TO MEASURE RANGE BY MEASURING THE PHASE DIFFERENCE BETWEEN THE RECEIVED ECHO AND THE TRANSMITTED SIGNAL.
- **TRANSMITTED SIGNALS**

$$V_{1T} = \mathrm{SIN}\,(2\pi f_1 t + \Phi_1)$$

$$V_{2T} = \mathrm{SIN}\,(2\pi f_2 t + \Phi_2)$$

WHERE Φ_1 & Φ_2 ARE CONSTANT (ARBITRARY) PHASE ANGLES.



MULTIPLE FREQUENCY CW RADAR

ECHO SIGNALS :

$V_{1R} = \mathrm{SIN}\ [2\ \pi(f_1 \pm f_{d1})t - (4\ \pi\ f_1\ R_0 / C) + \Phi_1\ ]$

$V_{2R} = \mathrm{SIN}\ [2\ \pi(f_2 \pm f_{d2})t - (4\ \pi\ f_2\ R_0 / C\ ) + \Phi_2\ ]$

WHERE R_0 = RANGE AT TIME $t = t_0$

f_{d1} , f_{d2} = DOPPLER FREQUENCY wrt f_1 & f_2 RESPECTIVELY.

AS MING $f_{d1} = f_{d2} = f_d\ (f_2 - f_1 = \Delta\ f\ )$

MULTIPLE FREQUENCY CW RADAR

DOPPLER FREQUENCY COMPONENTS

$V_{1D} = SIN\ [\ \pm 2\ \pi\ f_{d1}t - (4\ \pi\ f_1\ R_0\ /\ C)\ ]$

$V_{2D} = SIN\ [\ \pm 2\ \pi\ f_{d2}t - (4\ \pi\ f_2\ R_0\ /\ C)\ ]$

$\Delta\Phi$ BETWEEN THESE TWO COMPONENTS

$= 4\ \pi\ (f_2 - f_2)\ R_0\ /\ C)$

$= 4\ \pi\ \Delta\ f\ R_0\ /\ C$ OR

$R_0 = C\ \Delta\Phi\ /\ 4\ \pi\ \Delta\ f$