CONTINUOUS WAVE RADAR

EEEN 567–SATELLITE ENGINEERING

Friday, September 19, 2025

WHERE ARE WE IN THE SYLLABUS?

ECE 514E – RADAR and SATELLITE ENGINEERING (3 Units)

Pre-requisites: ECE 328 - Principles of Communication Systems, ECE 416 - Digital Communication Systems

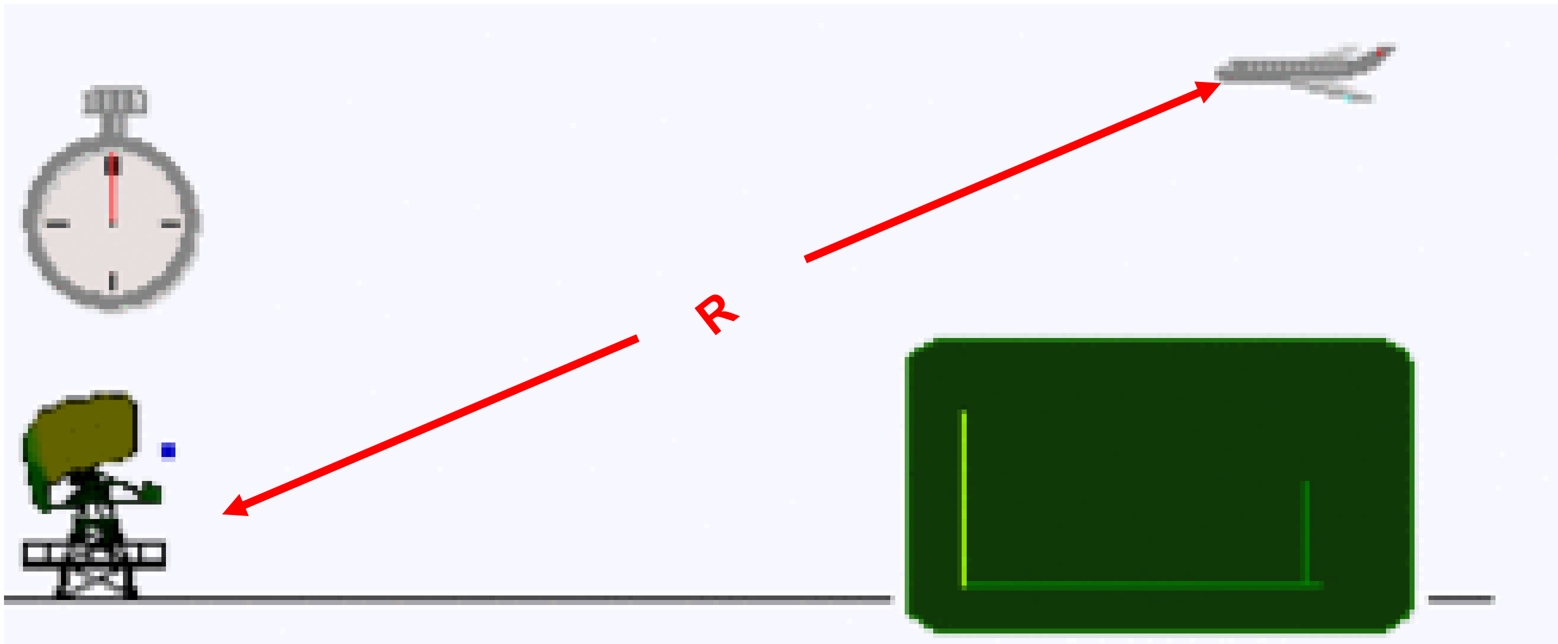
Course Purpose:
To enable students be familiarize with modern radar and navigation systems and principles of design radio-navigation and location systems, as well as radar systems

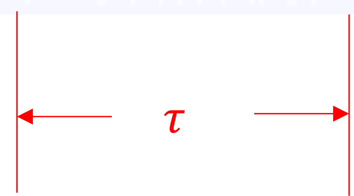
Expected Learning Outcomes:
Upon completion of this course, a student should be able to:

i. explain principles of operation of radar systems;
ii. apply theoretical and practical knowledge about principles, methods and applications of modern radar systems;
iii. measure and identify the parameters which determine the performance of radar systems;
iv. explain the function of satellite subsystems;
v. apply orbital mechanics formula and tools to spacecraft mission design;
vi. select appropriate launch systems and understand their effect on satellite and payload design and performance;
vii. design and analyse satellite links;
viii. evaluate satellite subsystem performance

Course Content:
Basic Principles of Radar, Antenna parameters, Radar equation. Performance parameters, target cross-section, MTI and Doppler radar: Doppler Effect, CW radar, FM CW, Delay line cancellers, Pulse Doppler Radar. Scanning, Duplexers and Radar receivers: Sequential lobbing, Conical Scanning, Monopulse Tracking RADAR, Tracking with surveillance RADAR, Acquisition, Radar receiver, Radar Displays; Duplexers.

RECALL: THE PULSE RADAR





$$2R = C\tau$$

$$R = \frac{c\tau}{2}$$

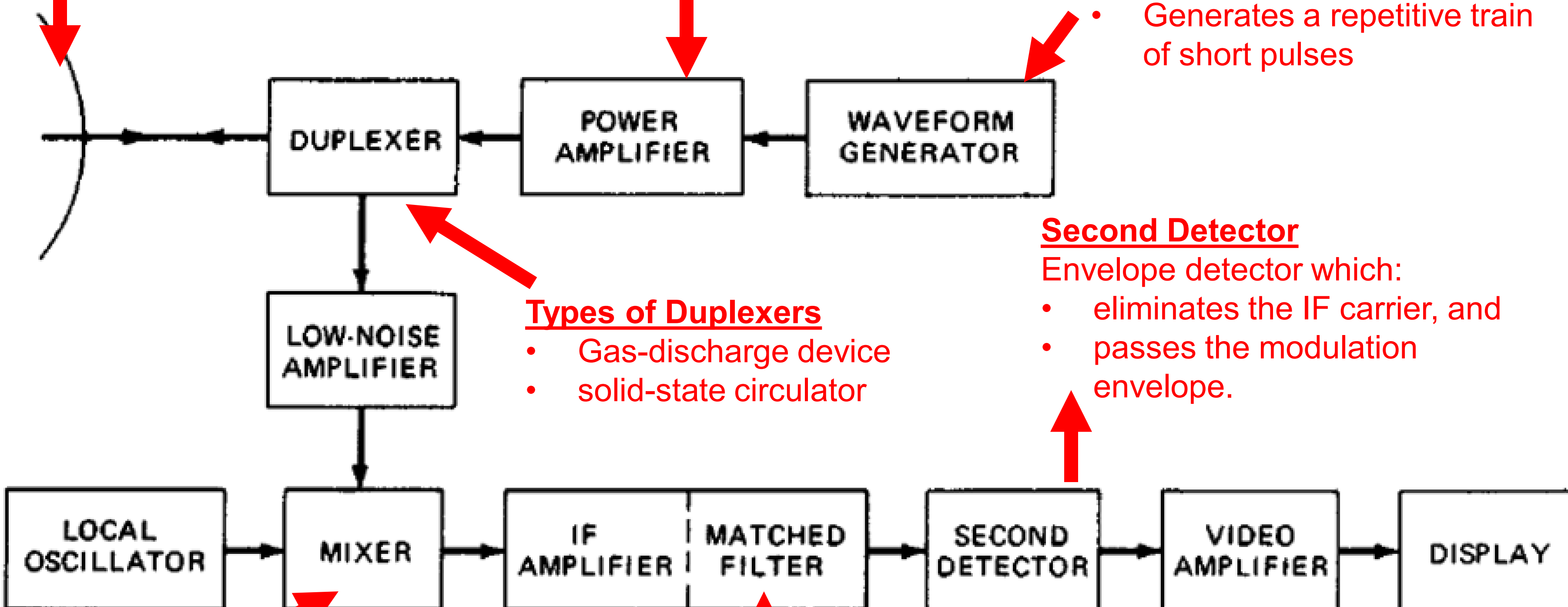
$$where\ c = 3 \times 10^{8}\ \mathrm{m/s}$$

PULSED RADAR SYSTEM (Textbook-Skolnik)

Types of Antennas
- Mechanically steered parabolic reflector antennas
- Planar phased arrays

Common Power Amplifiers
- Kystron,
- Traveling-Wave Tube (TWT),
- Crossed-field amplifier,
- Magnetron.

Waveform Generator
- Generates a repetitive train of short pulses



Types of Duplexers
- Gas-discharge device
- solid-state circulator

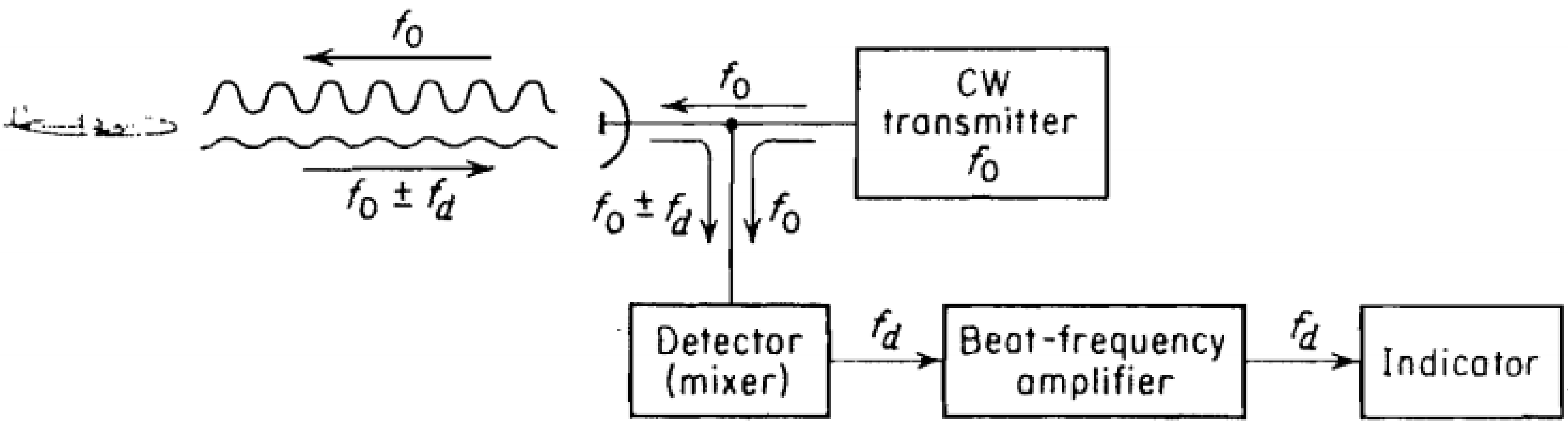
Second Detector
Envelope detector which:
- eliminates the IF carrier, and
- passes the modulation envelope.

MIXER
Translates the receiver RF signal to an intermediate frequency.

Matched Filter
- maximizes the output signal-to-noise ratio.

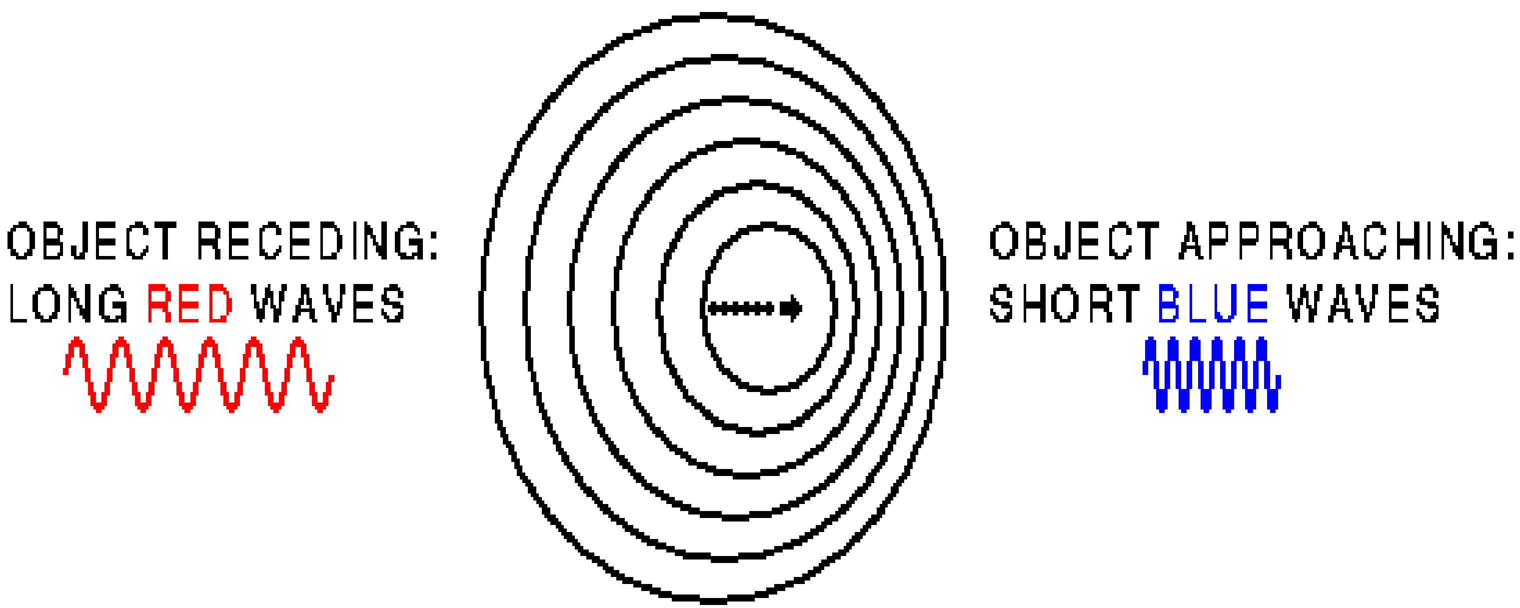
CONTINOUS WAVE RADAR

1. Unlike Pulsed radar, Continuous Wave (CW) radar systems emit electromagnetic radiation at all times.
2. Conventional CW radar are used to measure the instantaneous rate-of-change in the target's range, i.e target velocity, but a basic CW radar cannot measure range because there are no pulses and therefore no basis for the measurement of the time delay.



THE DOPPLER EFFECT

- It is well known in the fields of optics and acoustics that if either the source of oscillation or the observer of the oscillation is in motion, an apparent shift in frequency will result. This is the Doppler effect and is the basis of CW radar.



DOPPLER FREQUENCY

1. Let R be the distance from the radar to target'
2. The total number of wavelengths, L contained in the two-way path between the radar and the target is $\frac{2R}{\lambda}$
3. The total phase change, $\phi = 2\pi \frac{2R}{\lambda} = \frac{4\pi R}{\lambda}$ radians.
4. If the object is in motion then R and ϕ are constantly changing.
5. The Doppler angular frequency is given by:

$$\frac{d\varphi}{dt} = \frac{4\pi}{\lambda}\frac{dR}{dt} = \frac{4\pi v_r}{\lambda}$$ where v_r is the radial velocity

6. If f_d is the Doppler frequency shift, we can write:

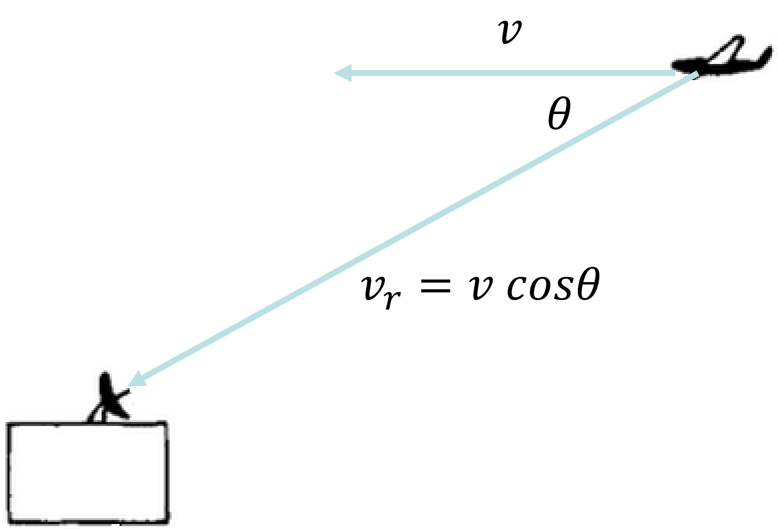
$$2\pi f_d = \frac{4\pi v_r}{\lambda} \quad \text{or} \quad f_d = \frac{2v_r}{\lambda}$$

where $c = 3 \times 10^8$,

7. Since $\lambda = \frac{c}{f}$

$$f_d = \frac{2 f v_r}{c}$$

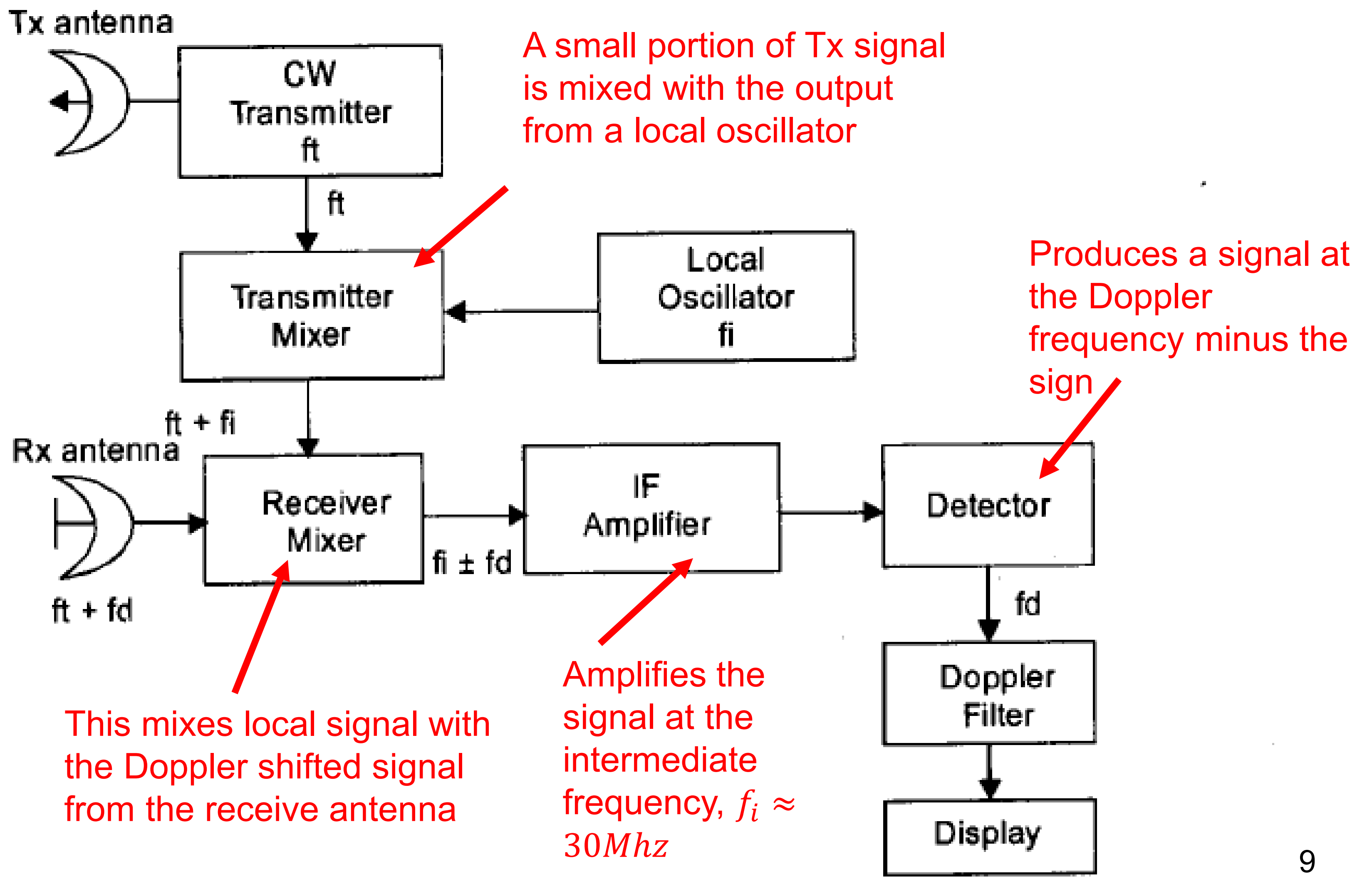
RADIAL VELOCITY Vs ACTUAL VELOCITY



- If the angle between the radar antenna is θ, and the target is moving at a speed v, then the radial velocity observed by the Doppler radar is:

$$v_r = v\,cos\theta$$

CW RADAR WITH INTERMEDIATE FREQUENCY (IF) STAGE



ADVANTAGES OF CW RADAR

1. its apparent simplicity which eases the handling of the received waveform, as minimum bandwidth is required in the IF circuitry.
2. Minimal spread in the transmitted spectrum which reduces the radio interference problem and simplifies all microwave preselection and filtering.
3. Ability to handle, without velocity ambiguity, targets at any range.
4. Less readily detectable by intercepting equipment since it generates its required average power with minimal peak power and may have extremely great frequency diversity.

APPLICATION OF CW RADARS

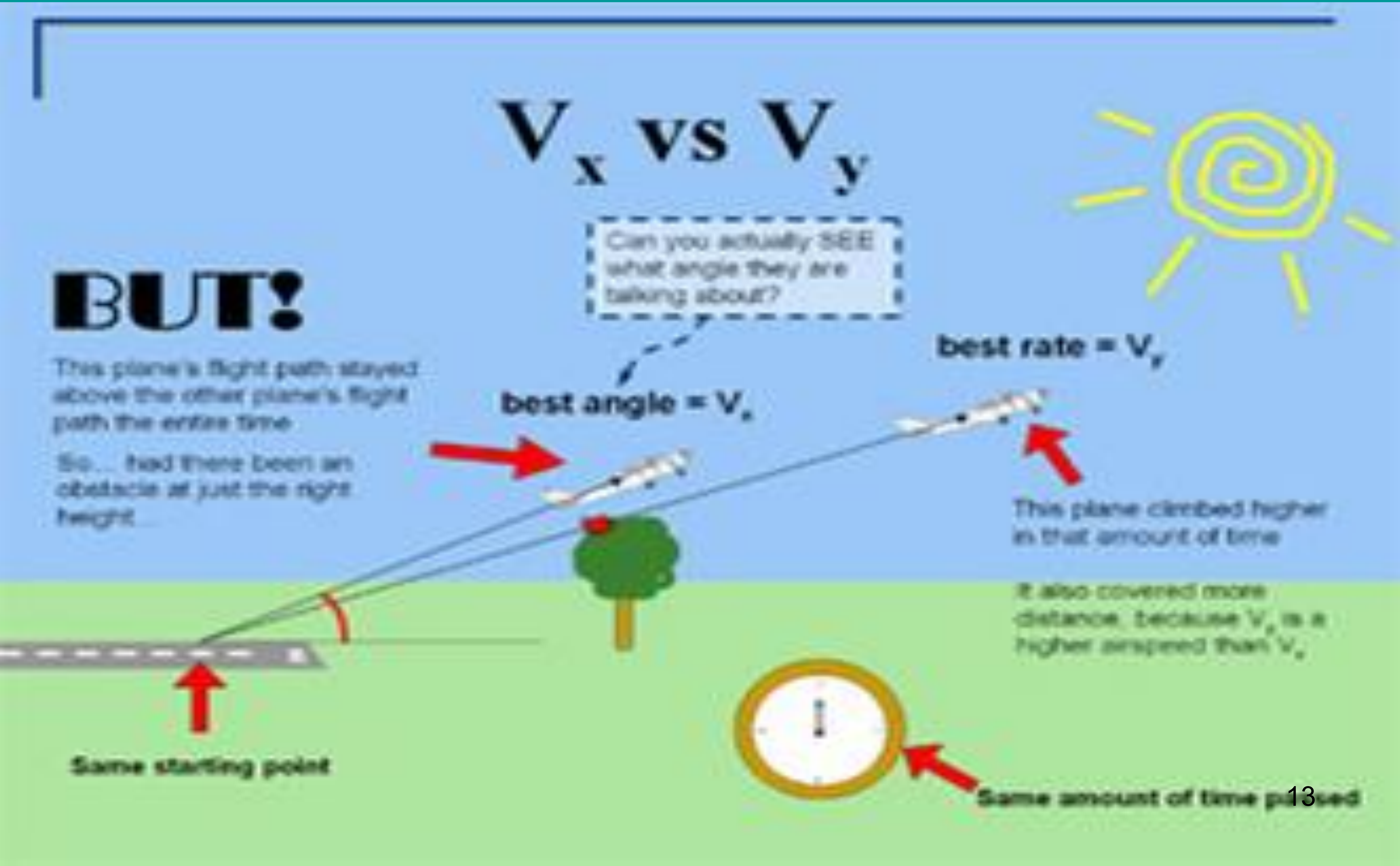
The main use of the simple, unmodulated CW radar is for measurement of the relative velocity of a moving target, as in

(a)the police speed monitor,

(b) Rate-of-climb meter for vertical-take-off aircraft, e.g. helicopter.

POLICE SPEED MONITOR

RATE OF CLIMB METER



RADAR APPLICATION IN MOTOR TRANSPORT

In support of motor vehicle traffic, CW radars can be used for:

a) Control of traffic lights, regulation of toll-booths,
b) Vehicle counting,
c) Replacement for the " fifth-wheel" speedometer in vehicle testing,
d) Sensor in antilock braking systems, and
e) Collision avoidance.

CW RADAR APPLICATION IN RAILWAYS

In railways, CW radar can be used as:

a) Radar speedometer to replace the conventional axle-driven tachometer. In such an application it would be unaffected by errors caused by wheelslip when accelerating or wheelslide when braking.

b) measurement of car velocity during humping operations in marshalling yards, and

c) as a detection device to give track maintenance personnel advance warning of approaching trains.

OTHER APPLICATIONS OF CW RADAR

In other applications, it used for:

a) intruder/Proximity alarms,
b) measurement of the velocity of missiles, ammunition, and baseballs.
c) monitoring of vibrations in the cables of suspension bridges.
d) Measurement of turbine-blade vibration.

CW RADAR EXAMPLE 1

1. A continuous wave (CW) radar transmitter operates at 5 GHz, what is the Doppler frequency displayed if the radial velocity is 100 Km/h?

SOLUTION

$$f = 5 \times 10^9 \text{ Hz}$$

$$v_r = \frac{100 \times 10^3}{60 \times 60} = 27.8 \frac{m}{s}$$

$$f_d = \frac{2v_r}{\lambda} = \frac{2\times27.8}{\left(\frac{3\times10^8}{5\times10^9}\right)} = \frac{2\times27.8}{0.06} = 926.7\ Hz$$

2. Assume a plane is approaching a CW radar radially at a relative velocity of 200 knots. If the radar transmits power at 5cm wavelength,

   a) Determine the Doppler frequency, f_d

   b) Determine Doppler f_d' frequency if the target changes course by 45^o.

Assume, 1 knot = 0.508 m/s

(a) SOLUTION

$$v_r = 200\ knots = 101.6\ m/s$$

$$\lambda = 5cm = 5 \times 10^{-2}\ m$$

$$f_d = \frac{2\ v_r}{\lambda} = \frac{2 \times 101.6}{5 \times 10^{-2}} = 4064\ Hz\ or\ 4.064\ KHz$$

(b) SOLUTION

If the target maintains the same speed but changes course by 45°, then the radial velocity becomes:

$$v_r = v\cos\theta = 101.6 \times \cos(45^o) = 101.6 \times 0.707 = 71.84\ m/s$$

The new Doppler frequency is therefore:

$$f_d = \frac{2\,v_r}{\lambda} = \frac{2 \times 71.84}{5 \times 10^{-2}} = 2{,}873\ Hz$$