Tishk International University
Engineering Faculty
Aviation Engineering Department

AVIONICS SYSTEMS
AVE 402/V

TOPIC: Aircraft Navigation Systems

Week6_Lecture6

4th Grade- Fall Semester 2024-2025

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TO NAVIGATE A PILOT NEEDS TO KNOW THE FOLLOWING:

- Starting point (point of departure)
- Ending point (final destination)
- Direction of travel
- Distance to travel
- Aircraft speed
- Aircraft fuel capacity
- Aircraft weight & balance information

With this information flight planning can commence and the proper method of navigation can be put to use.

INTRODUCTION

AIRCRAFT NAVIGATION SYSTEMS INCLUDE –

- ✓ VHF OMNIDIRECTIONAL RANGE (VOR)
- ✓ INSTRUMENT LANDING SYSTEM (ILS)
- ✓ DISTANCE MEASURING EQUIPMENT (DME)
- ✓ AUTOMATIC DIRECTION FINDERS (ADF)
- ✓ DOPPLER NAVIGATION SYSTEM
- ✓ INERTIAL NAVIGATION SYSTEM
- ✓ RADIO ALTIMETER

VHF OMNIDIRECTIONAL RANGE (VOR)

WHAT IS VOR ?

- VOR, short for VHF Omnidirectional Radio Range, is a type of radio navigation system for aircraft, enabling them to find their position and stay on course by receiving radio signals emitted by a network of radio beacons.
- It uses frequencies in very high frequency (VHF) from 108 to 117.95 MHz.

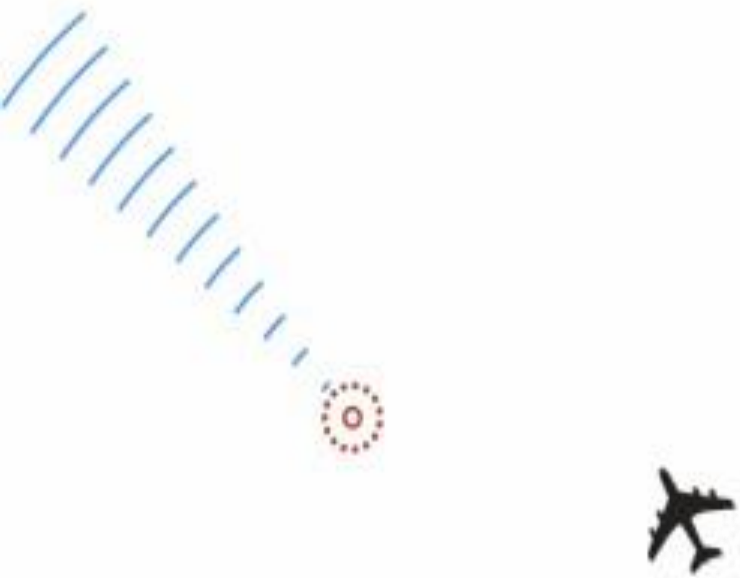
What is a VOR?

VHF Omni Directional Range

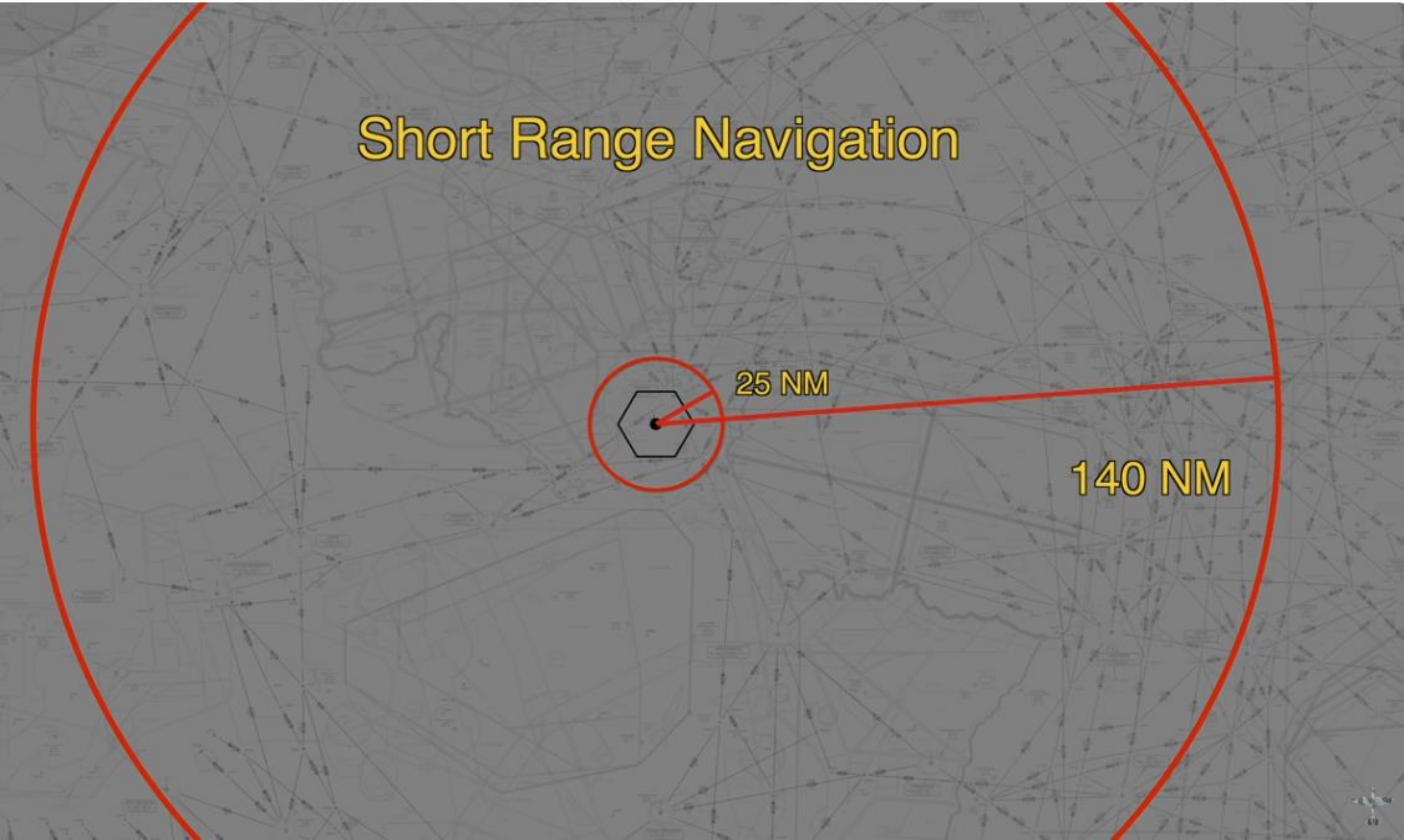
VHF OMNIRANGE SYSTEM (VOR)

- ✓ VOR, short for VHF Omnidirectional Radio Range, is a type of radio navigation system for aircraft, enabling them to find their position and stay on course by receiving radio signals emitted by a network of radio beacons.
- ✓ It uses frequencies in very high frequency (VHF) from 108 to 117.95 MHz.
- ✓ VHF Omnidirectional Radio Range (VOR), is an aircraft navigation system operating in the VHF band.
- ✓ VORs broadcast a VHF radio composite signal including the station's Morse Code identifier (and sometimes a voice identifier), and data that allows the airborne receiving equipment to derive the magnetic bearing from the station to the aircraft.
- ✓ This line of position is called the "radial". Alternatively, the VOR radial may be combined with magnetic heading from the aircraft compass to provide a bearing relative to the aircraft axis, which cn be used to home to the beacon. VOR beacons are frequently used as way-points on conventional Airway systems, or as the basis for a Non-Precision Approach.
- ✓ It produces 360 usable radials or courses ,any one of which is radial path connected to the station.

VOR Station



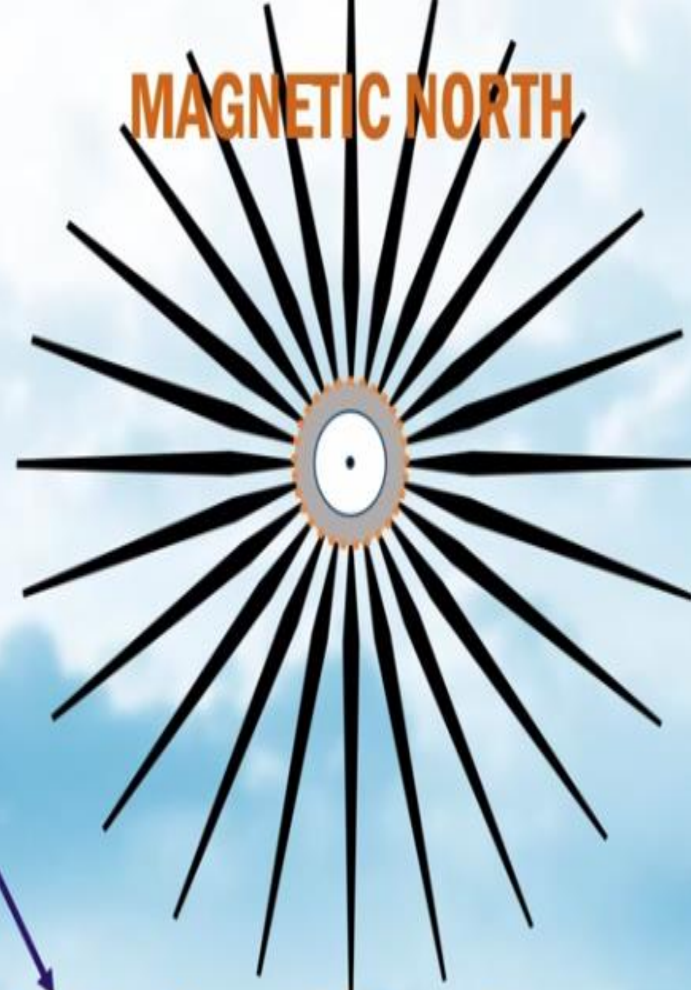
HOW THE VHF OMNIRANGE SYSTEM IS WORKING ?



How does VOR Function?

360 Radials

1^{o} Spacing



2 Signals

Reference Signal

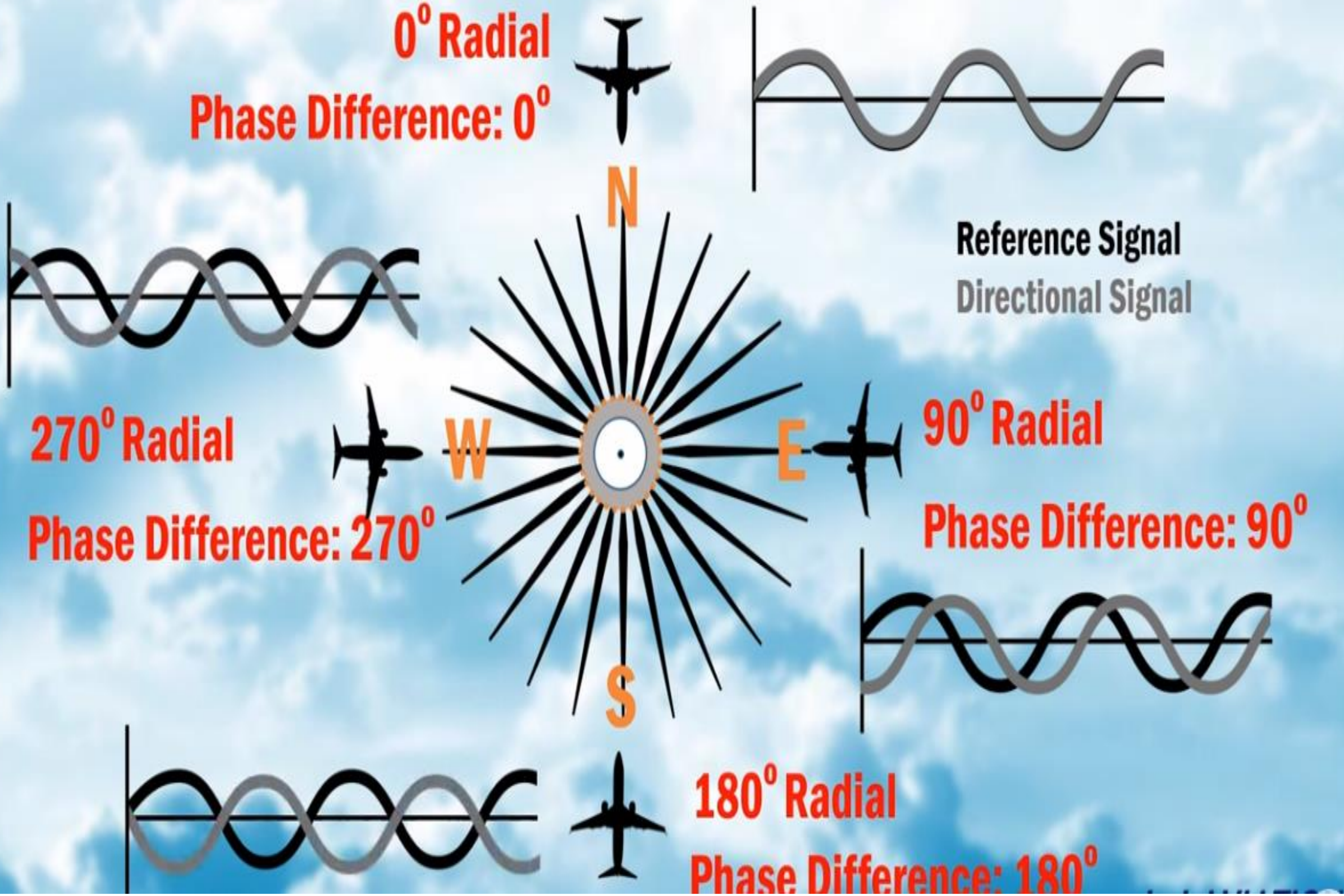
Frequency Modulated

Directional Signal

Amplitude Modulated

Phase Difference

How does VOR Function?

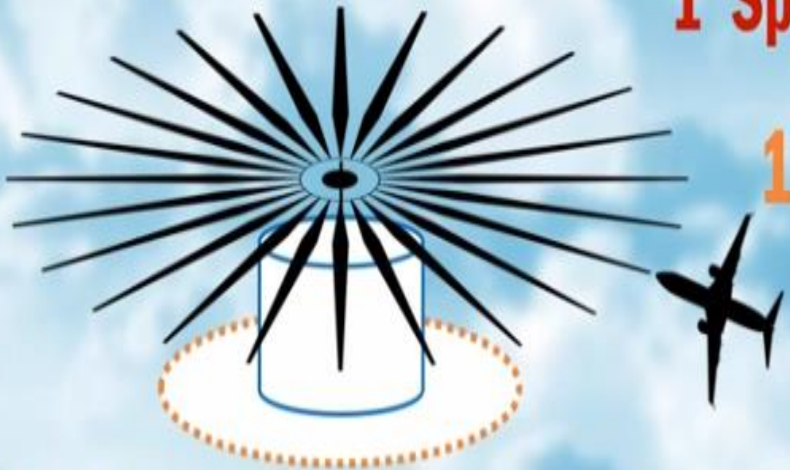


How does VOR Function?

Phase Difference = Corresponding Radial

360 Radials

1° Spacing



How does VOR Function?

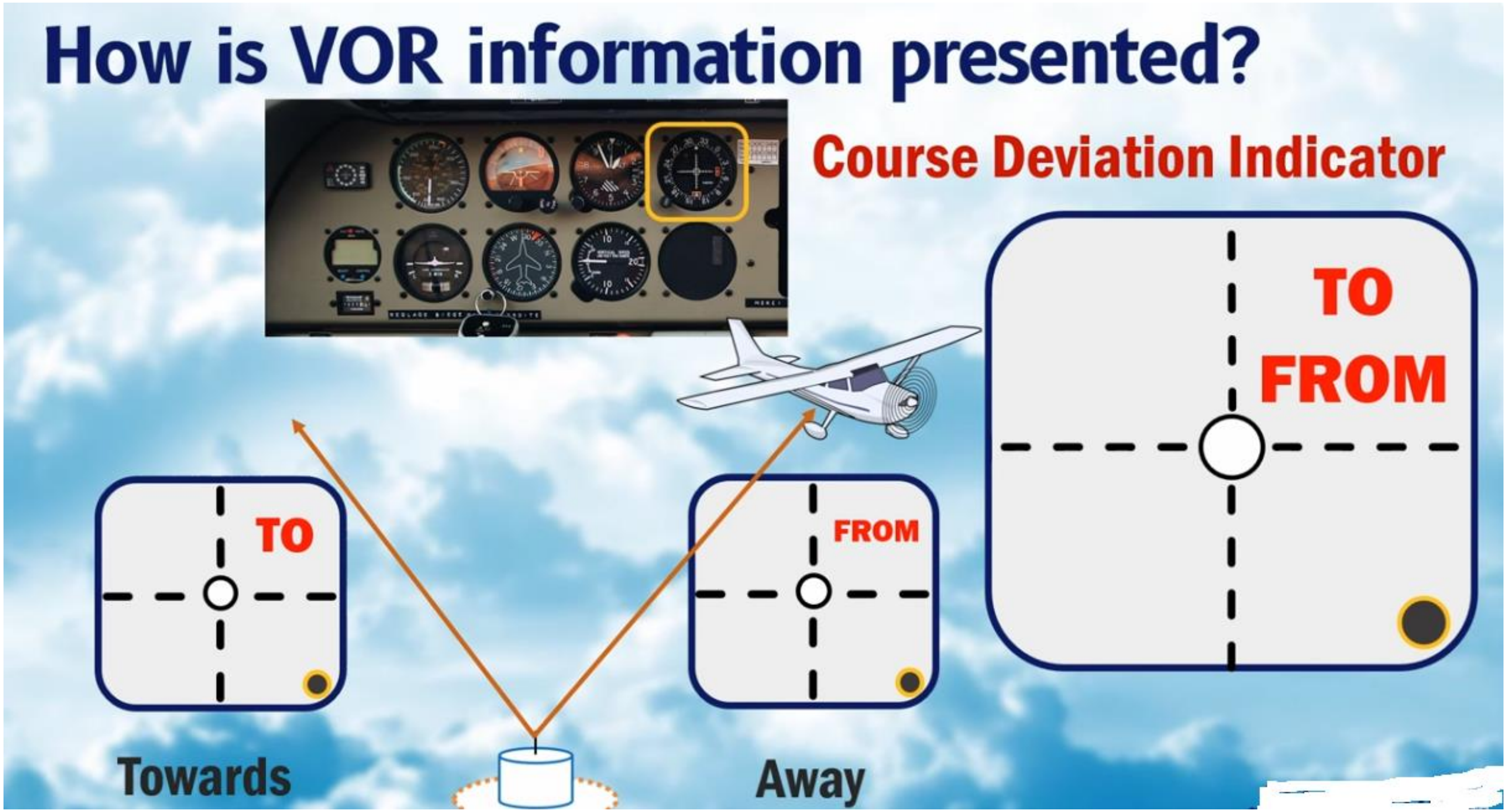
Phase Difference = Corresponding Radial

360 Radials

1^{o} Spacing

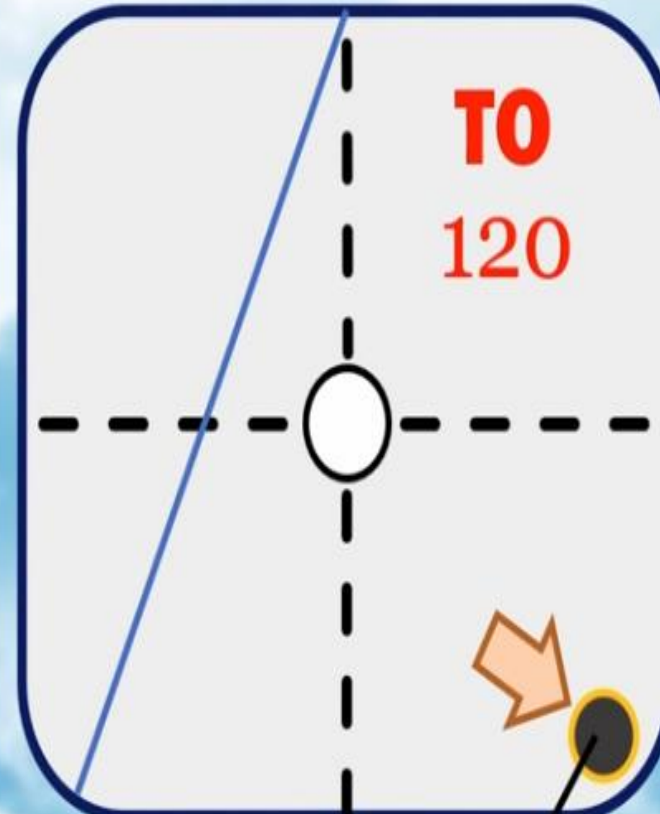
Towards or Away from?

https://www.youtube.com/watch?v=Mp2rP1RaUCc


How is VOR information presented?
Course Deviation Indicator
TO
FROM
TO
FROM
Towards
Away

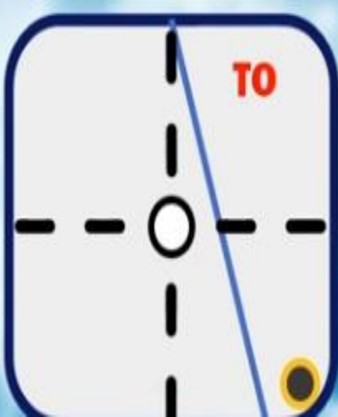
How is VOR information presented?

Navigation Radio



Position of Needle

Fly Right

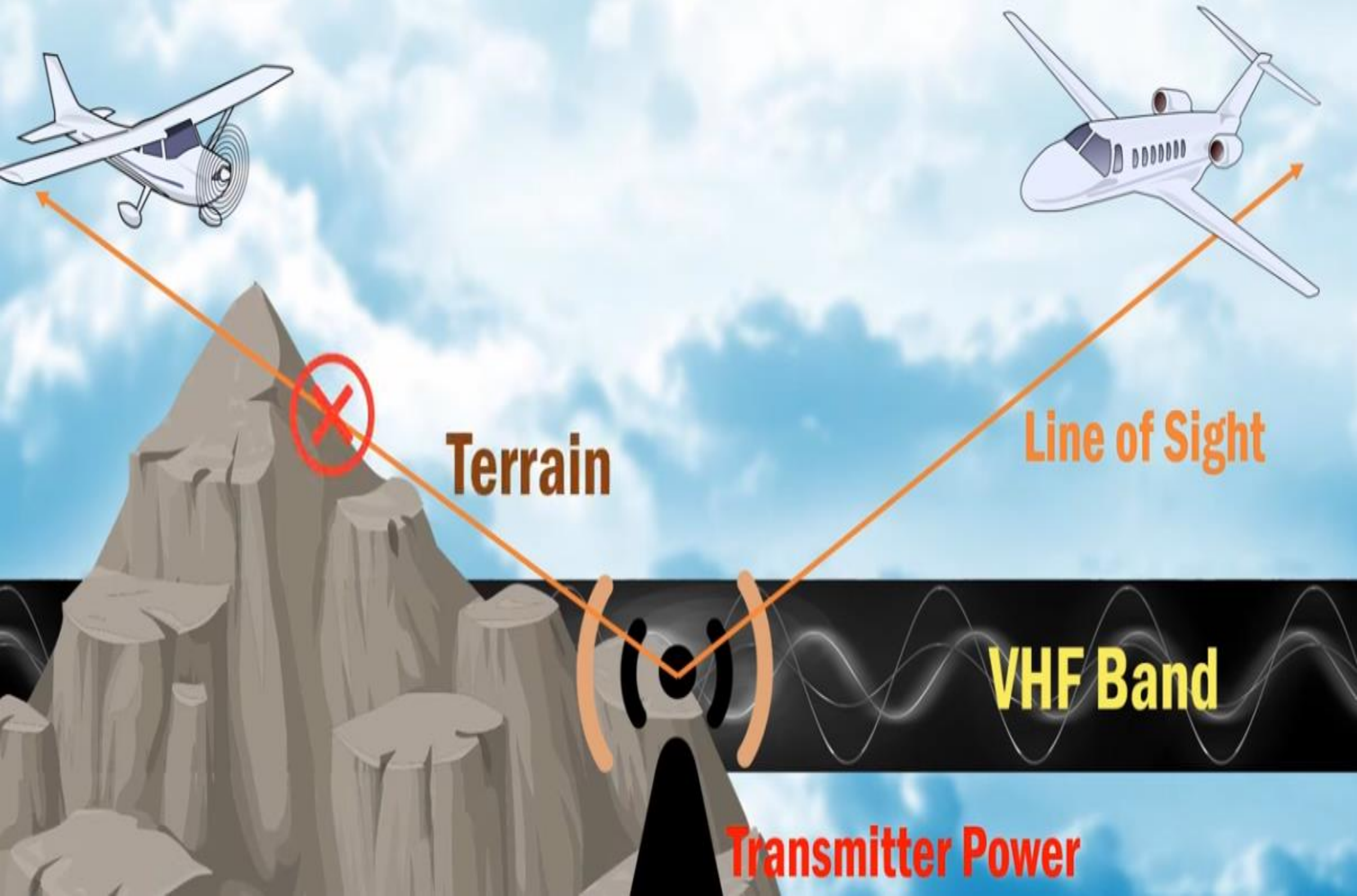


Fly Left

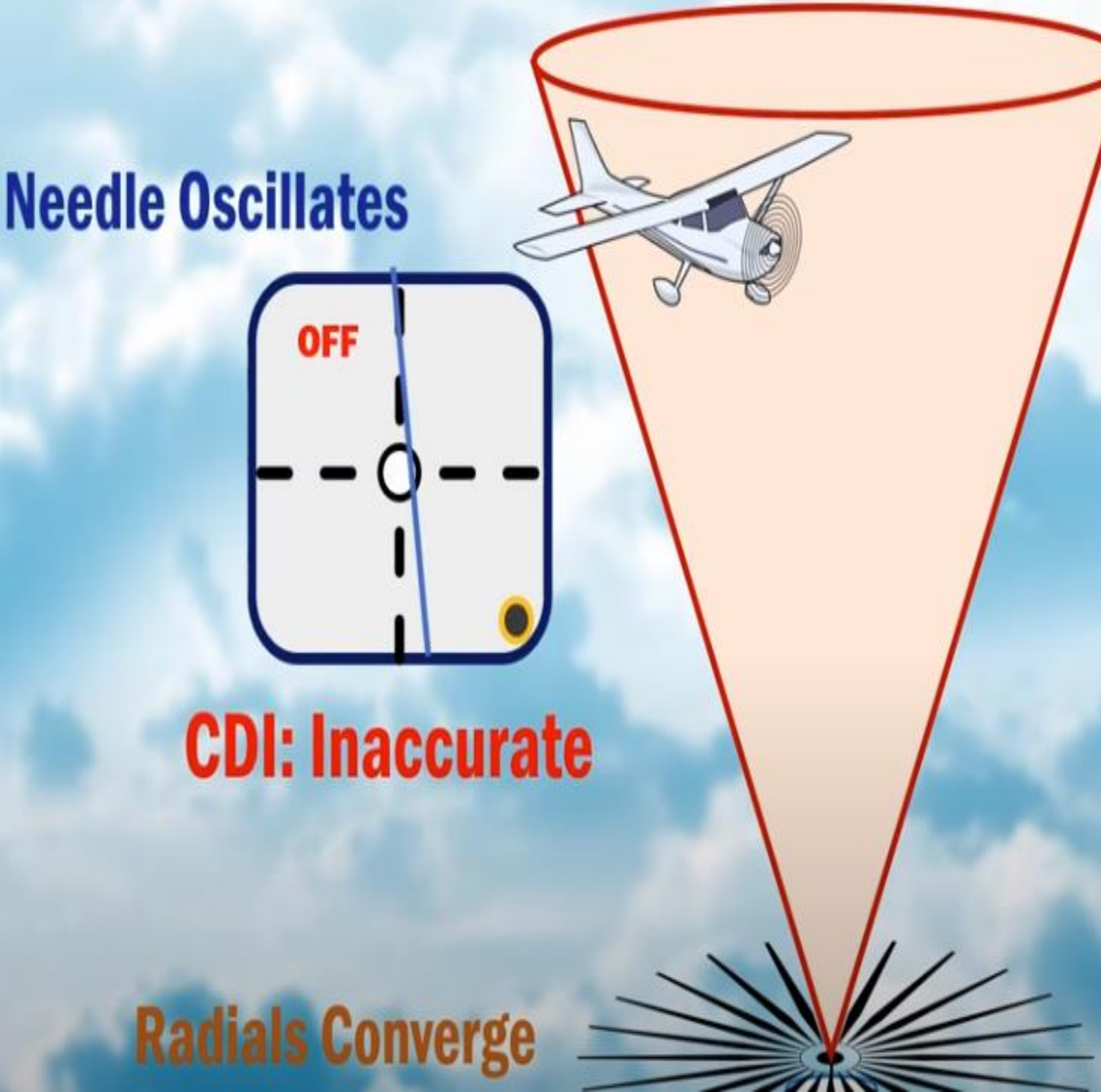
Select Bearing/Radial

Omni Bearing Selector

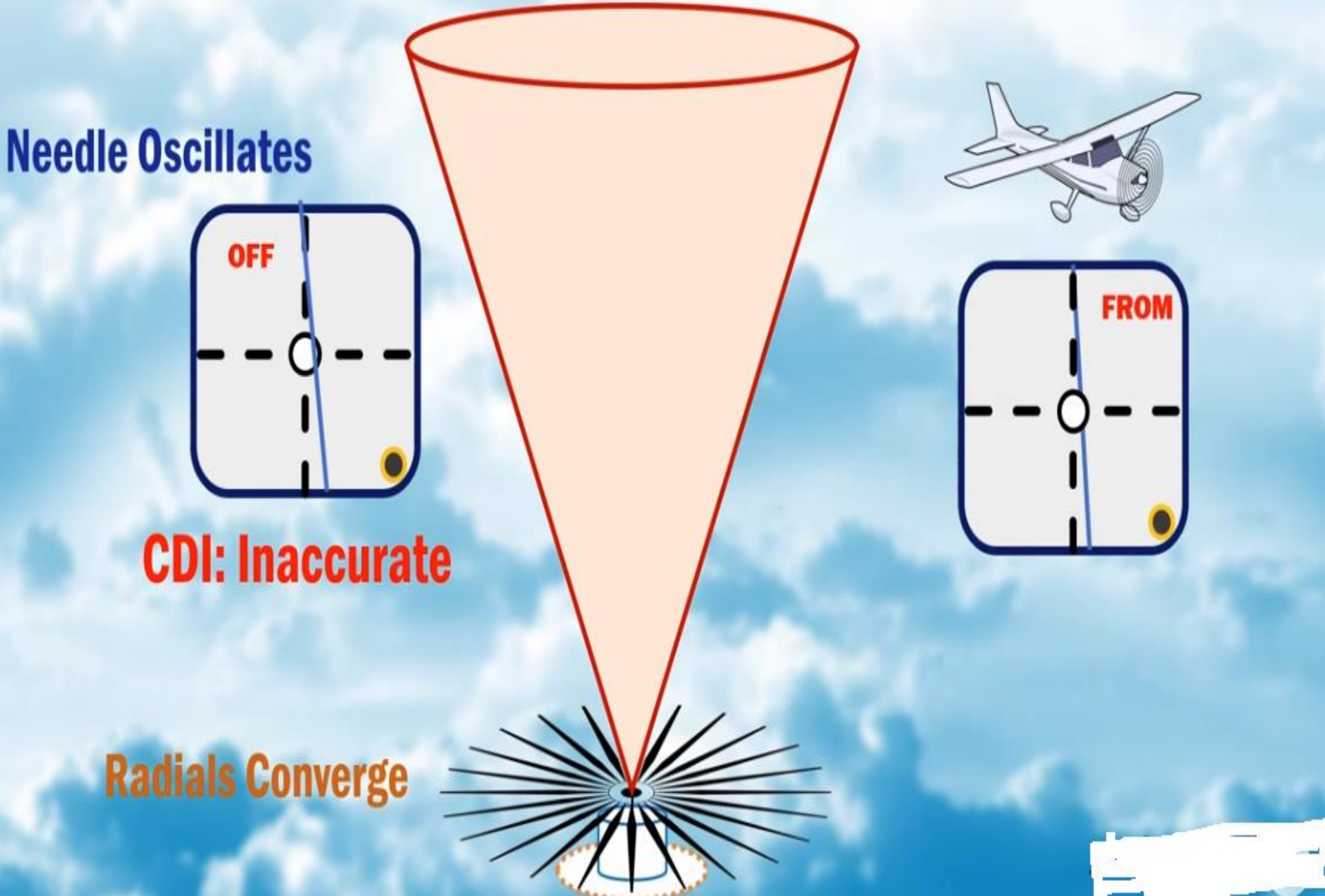
What Factors affect VOR transmission?



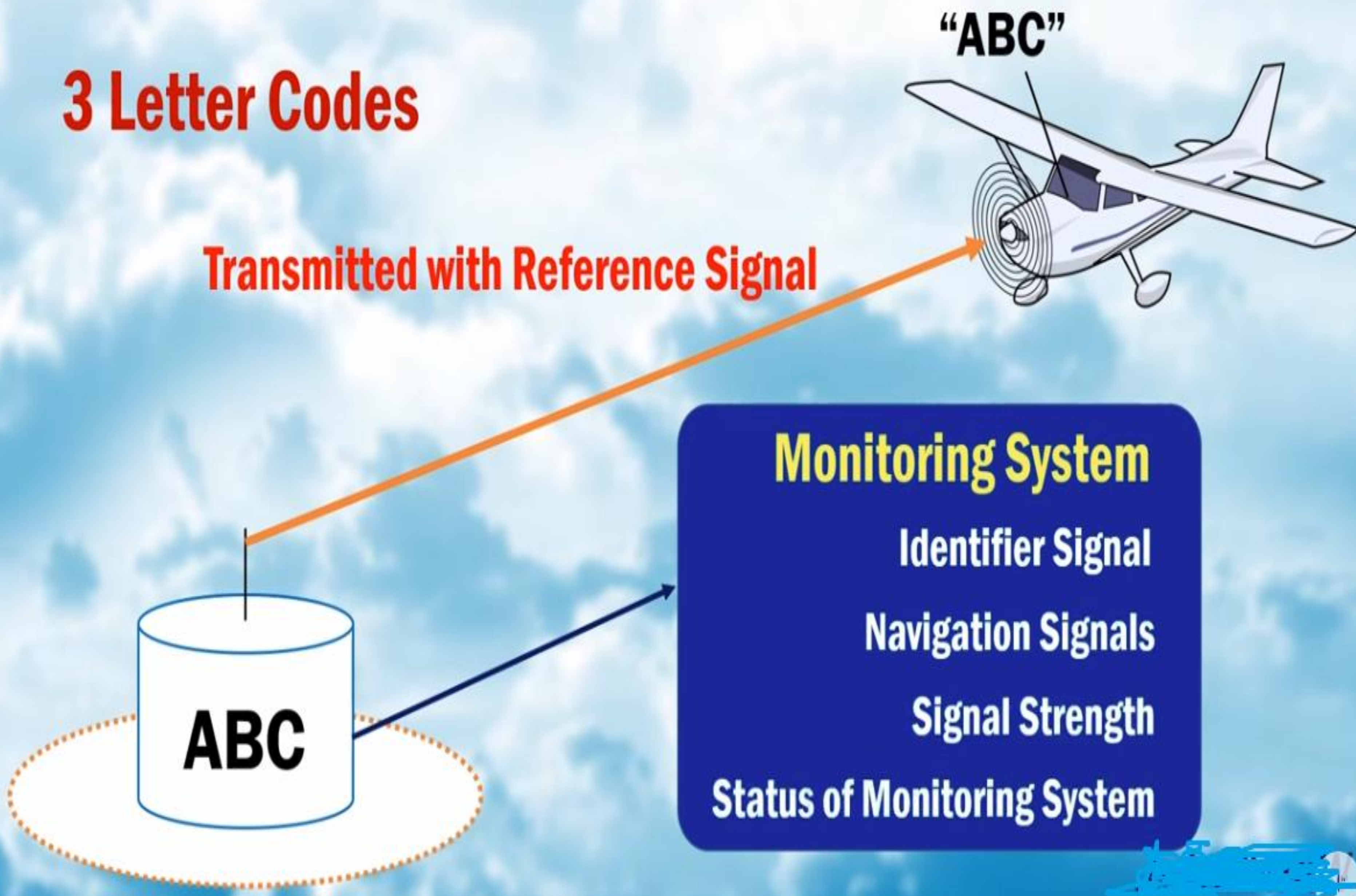
What is Cone of Ambiguity?



What is Cone of Ambiguity?



How to identify a VOR?

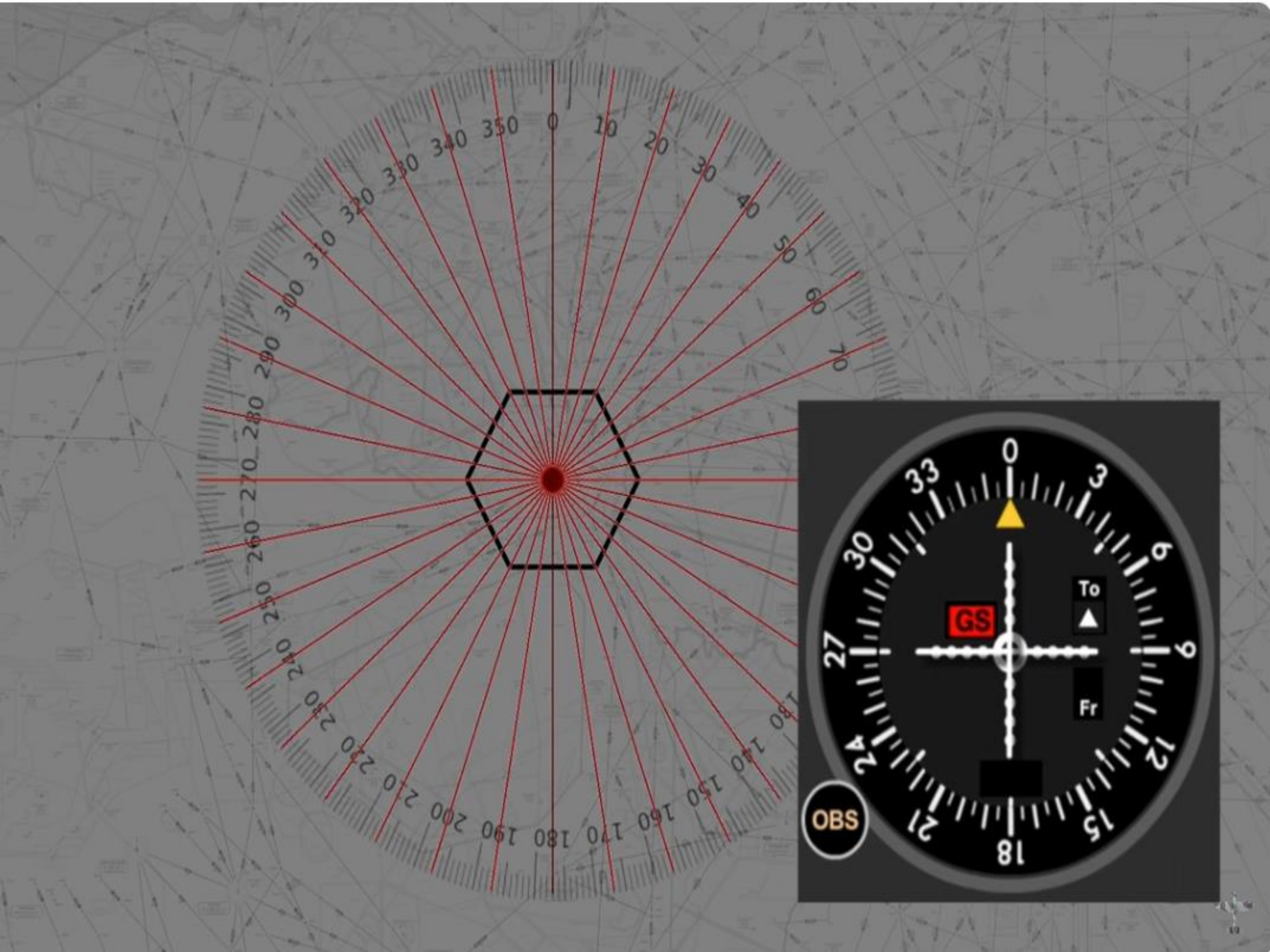


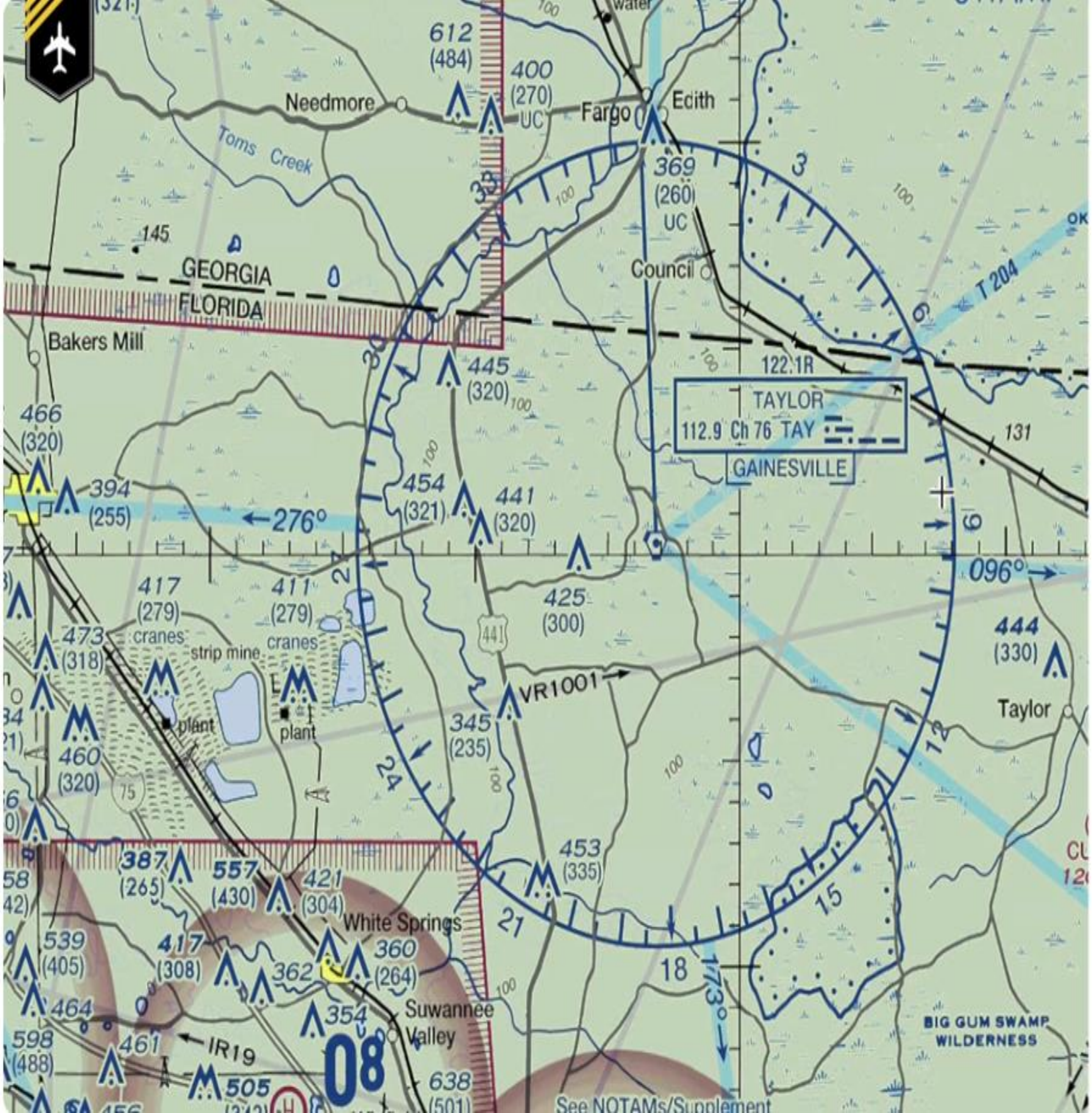
Uses of VOR

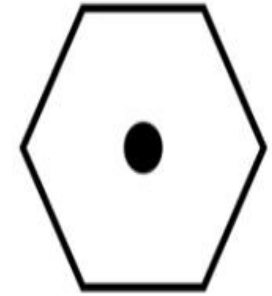
GPS

Primary Navaid

- Backup if GPS not available
- Marking Certain Airways
- Approach Procedures
- Holding Point


GS
To
Fr
OBS

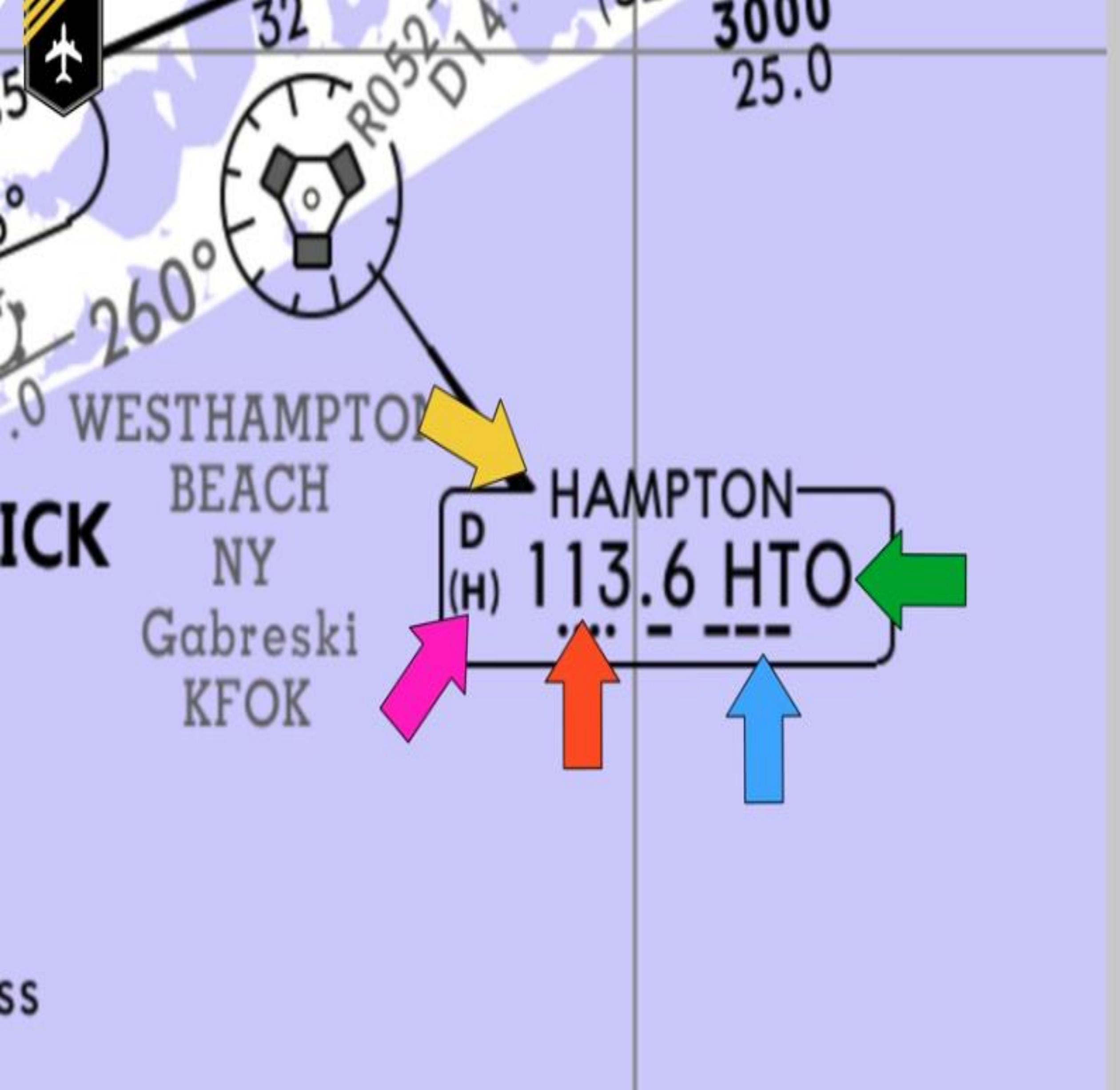




VOR

VOR/DME

TACAN



VOR Name
(Location)

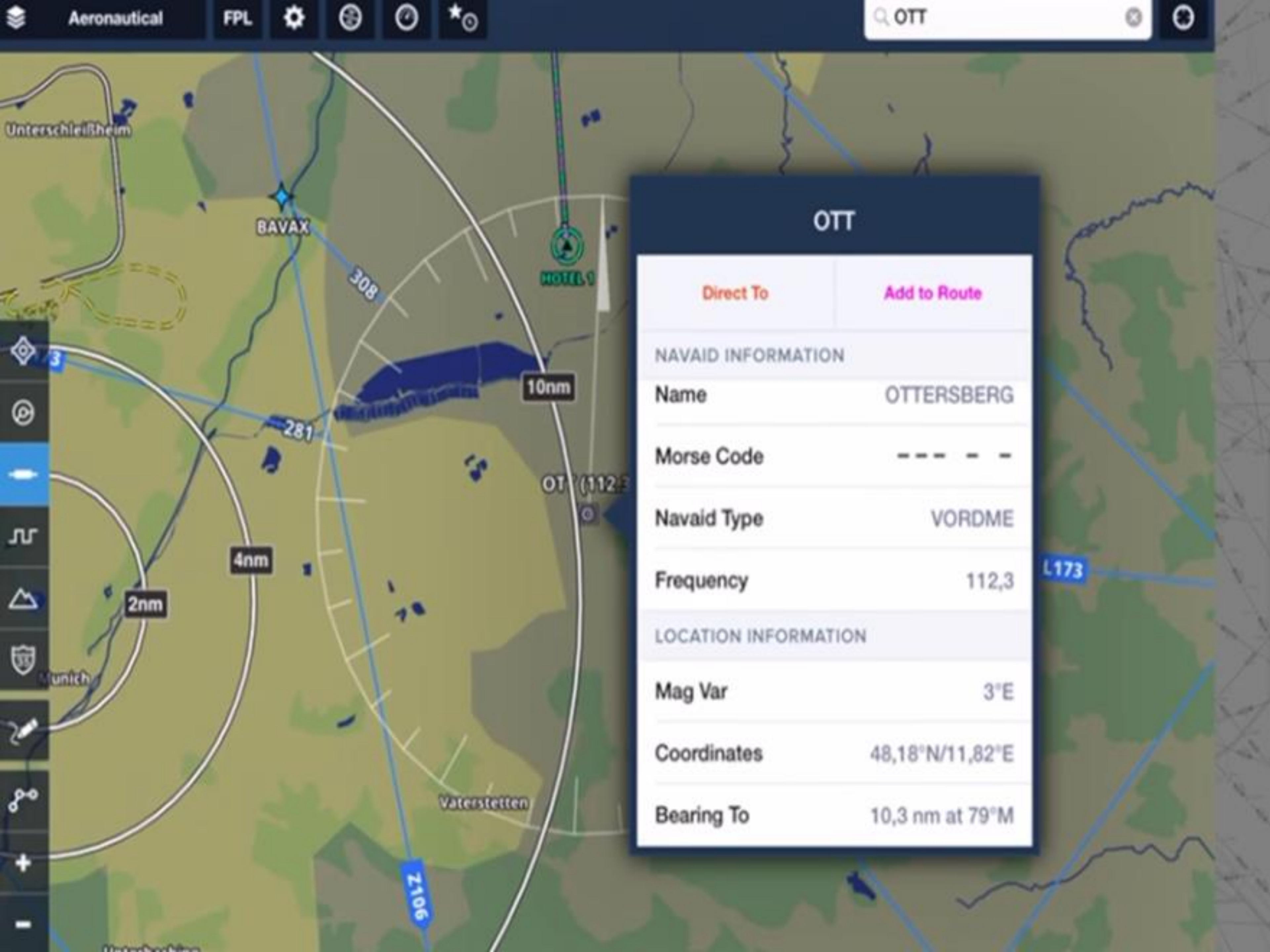
Frequency
Range 108.00 -117.95MHz
(50kHz spacing)

3 - Letter Identifier

Morse Code

Weather broadcasting facilities

https://www.youtube.com/watch?v=wuLTppemEgA

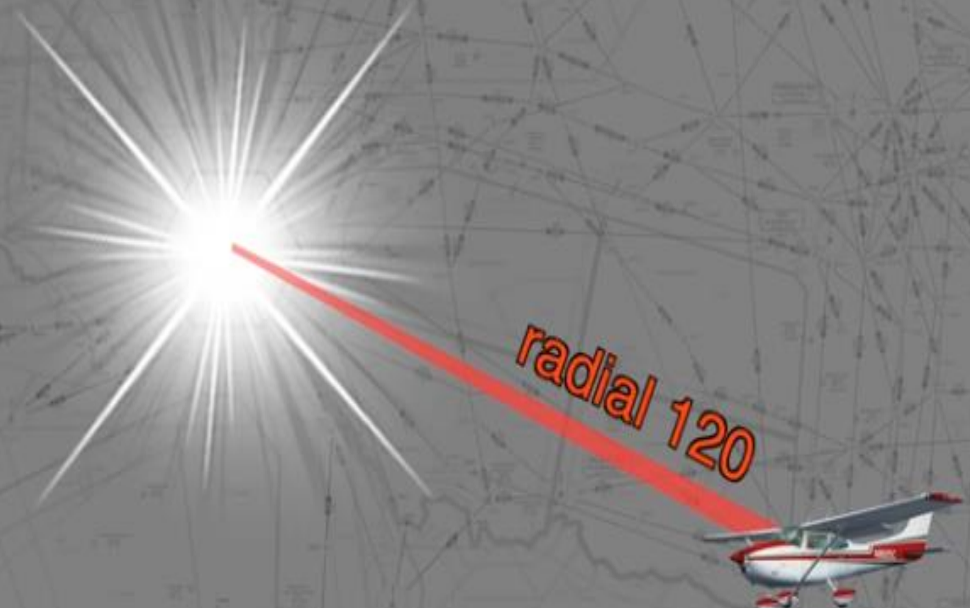

Aeronautical
FPL
OTT
Unterschleißheim
BAVAX
308
HOTEL 1
10nm
281
4nm
2nm
Munich
Vaterstetten
Z106
L173
OTT
Direct To
Add to Route
NAVAID INFORMATION
Name OTTERSBERG
Morse Code --- - -
Navaid Type VORDME
Frequency 112,3
LOCATION INFORMATION
Mag Var 3°E
Coordinates 48,18°N/11,82°E
Bearing To 10,3 nm at 79°M

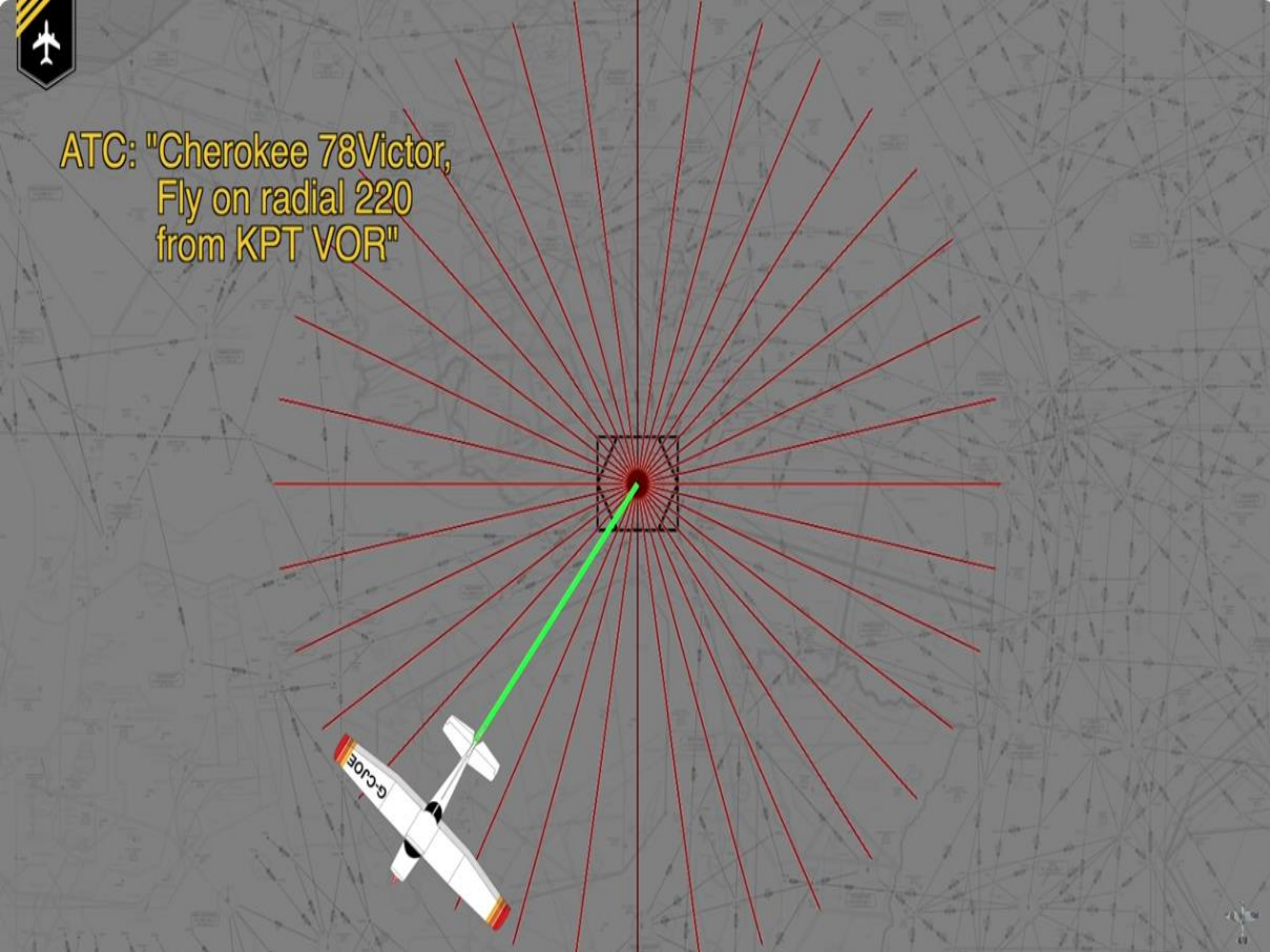
60 sec = 360°

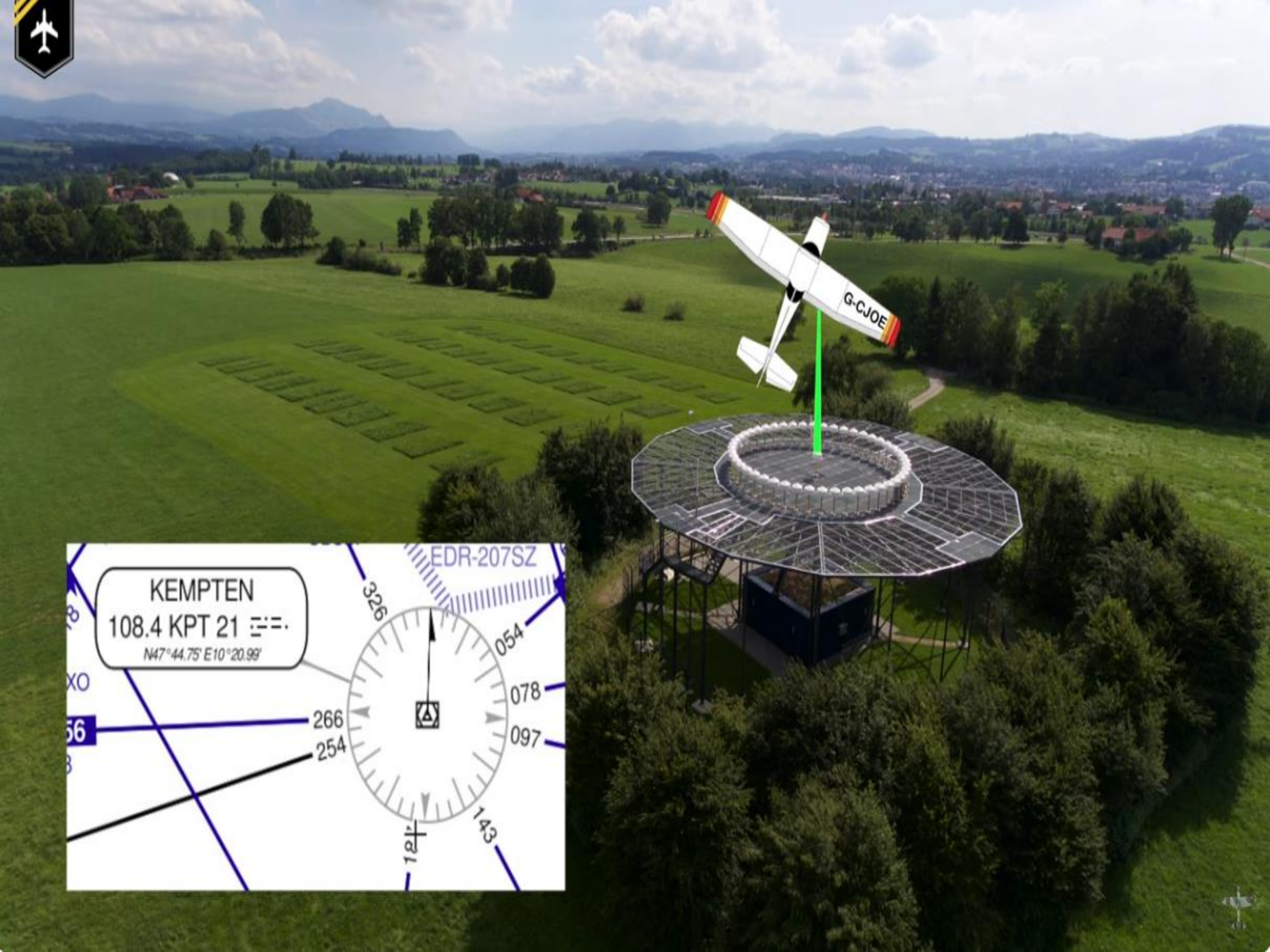
20 sec = ?°

$$\frac{20\ \cancel{\text{sec}} \times 360^\circ}{60\ \cancel{\text{sec}}}$$

$=120^\circ$




ATC: "Cherokee 78Victor,
Fly on radial 220
from KPT VOR"
G-CJOE


G-CJOE
EDR-207SZ
KEMPTEN
108.4 KPT 21
N47°44.75' E10°20.99'
326
054
078
097
143
266
254

CDI Instrument

OBS

Omni
Bearing
Selector

CDI Instrument

CDI

Course
Deviation
Indicator

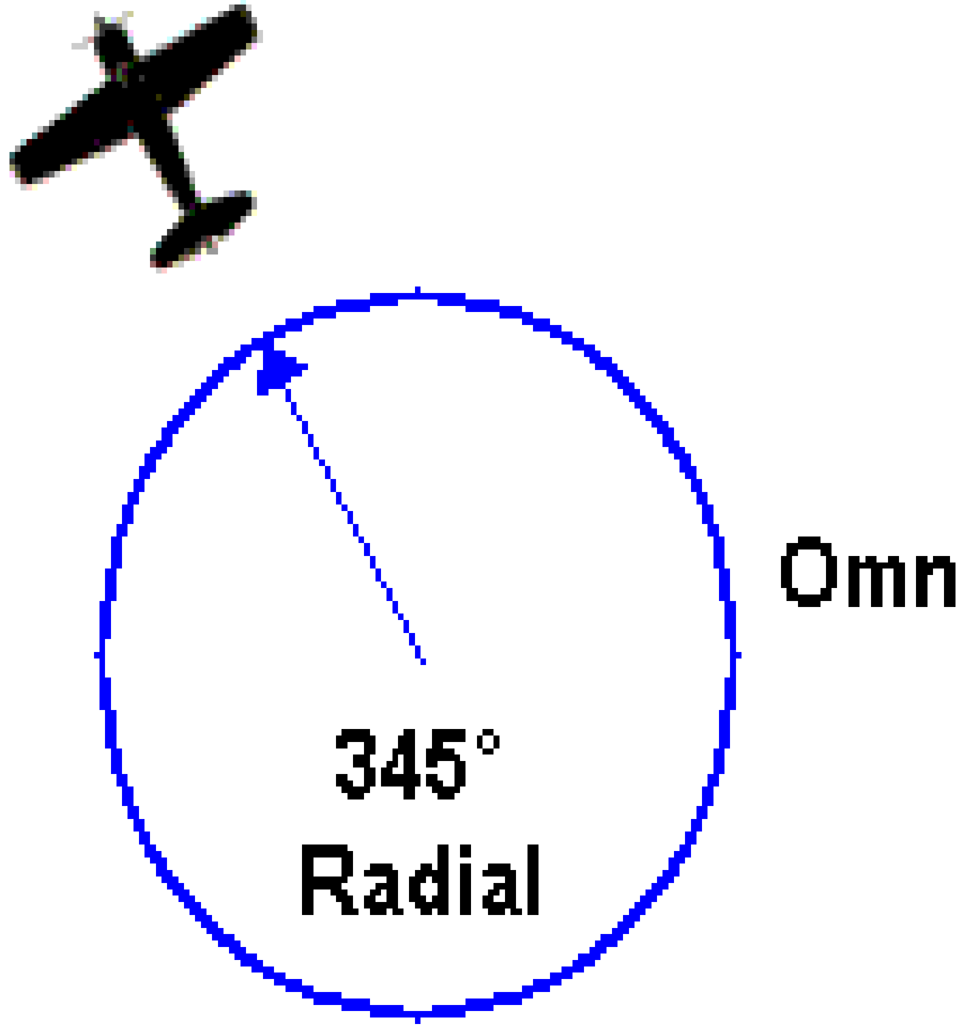
"The Needle"

❖ BENEFITES

- More accurate and precise flying
- Reliable
- Voice capable
- Reduces interference from atmosphere and precipitation

✓ Navigation info is visually displayed on an instrument in cockpit called the CDI (Course Deviation Indicator.)

VHF OMNIRANGE (V0R)



OBS (Omni-Bearing Selector).

CDI (Course Deviation Indicator.)

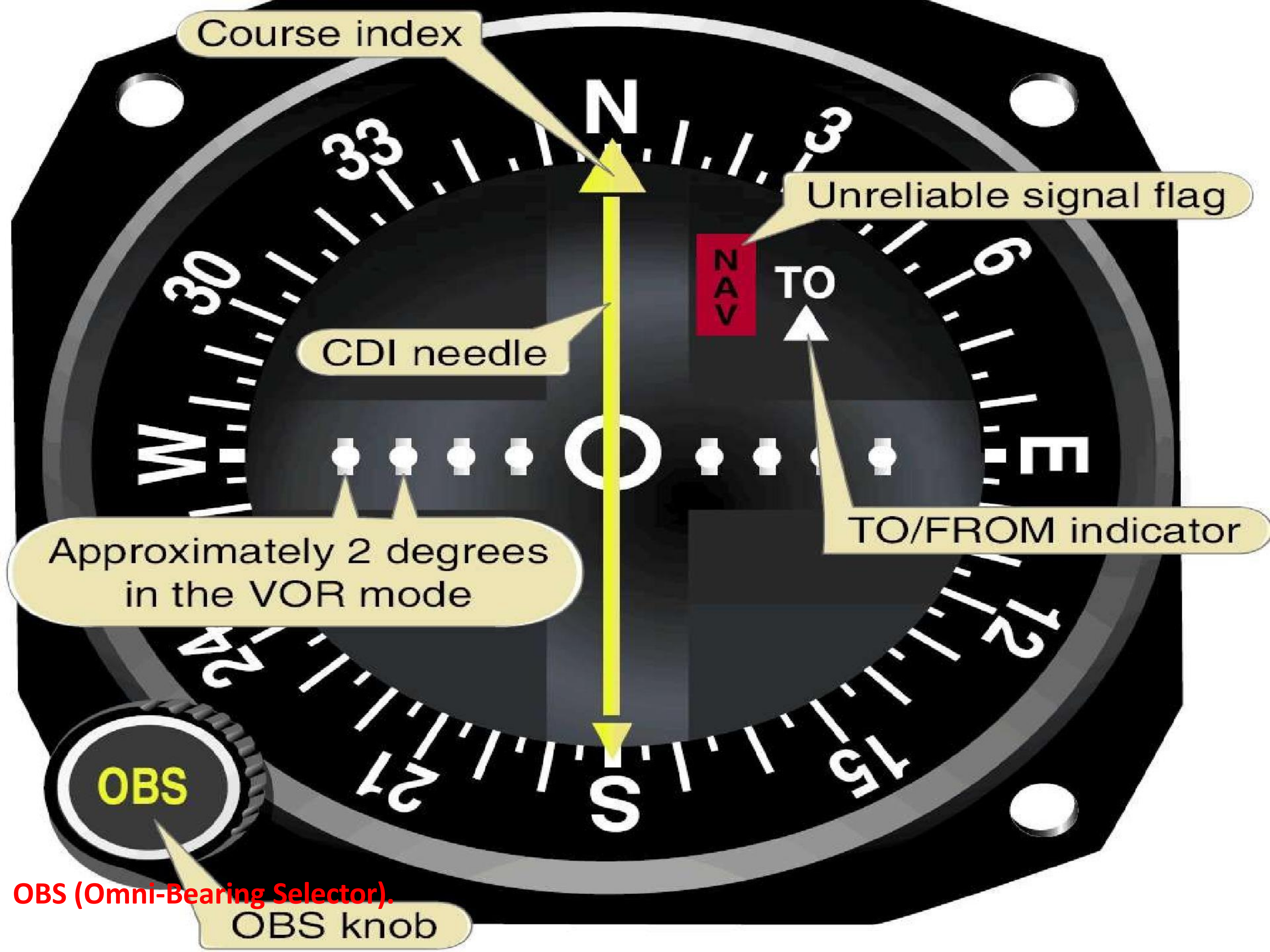
VOR RECEIVING SYSTEMS CONSIST OF ;

- ✓ A RECEIVER
- ✓ VISUAL INDICATOR
- ✓ ANTENNAS
- ✓ A POWER SUPPLY
- ✓ FREQUENCY SELECTOR: USED TO TUNE RECEIVER TO SELECTED VOR GROUND STATION

INFO FROM THE VOR RECEIVER IS DISPLAYED ON THE CDI (COURSE DEVIATION INDICATOR).

WORKING OF VOR

- ✓ Info from the VOR receiver is displayed on the CDI (Course Deviation Indicator).
- ✓ The vertical needle is used as the course indicator.
- ✓ Vertical needle also indicates when the aircraft deviates from the course and
- ✓ The direction of the aircraft must be turned to attain the desired course



OBS (Omni-Bearing Selector).


ASI
Mach
0.17
Kno
IAS
AI
ALT
TC
TURN COORDINATOR
2 MIN
NO PITCH INFORMATION
HI
VSI
UP
DN
VOR
GS
To
Fr
OBS
Omni
Bearing
Selector
– 5
OBS
000
CDI
Course
Deviatio
Indicato

WORKING OF VOR THROUGH CDI

- To-from indicator presents the direction to or from the station along the omni radial.
- When the localizer signals are selected on the receiver ,the indicator shows the position of the localizer beam relative to the aircraft and the direction the aircraft must be turned to intercept the localizer.
- During VOR operation the VOR radial to be used is selected by rotating the OBS (Omni-Bearing Selector).
- OBS is graduated in degrees from 0 to 360.

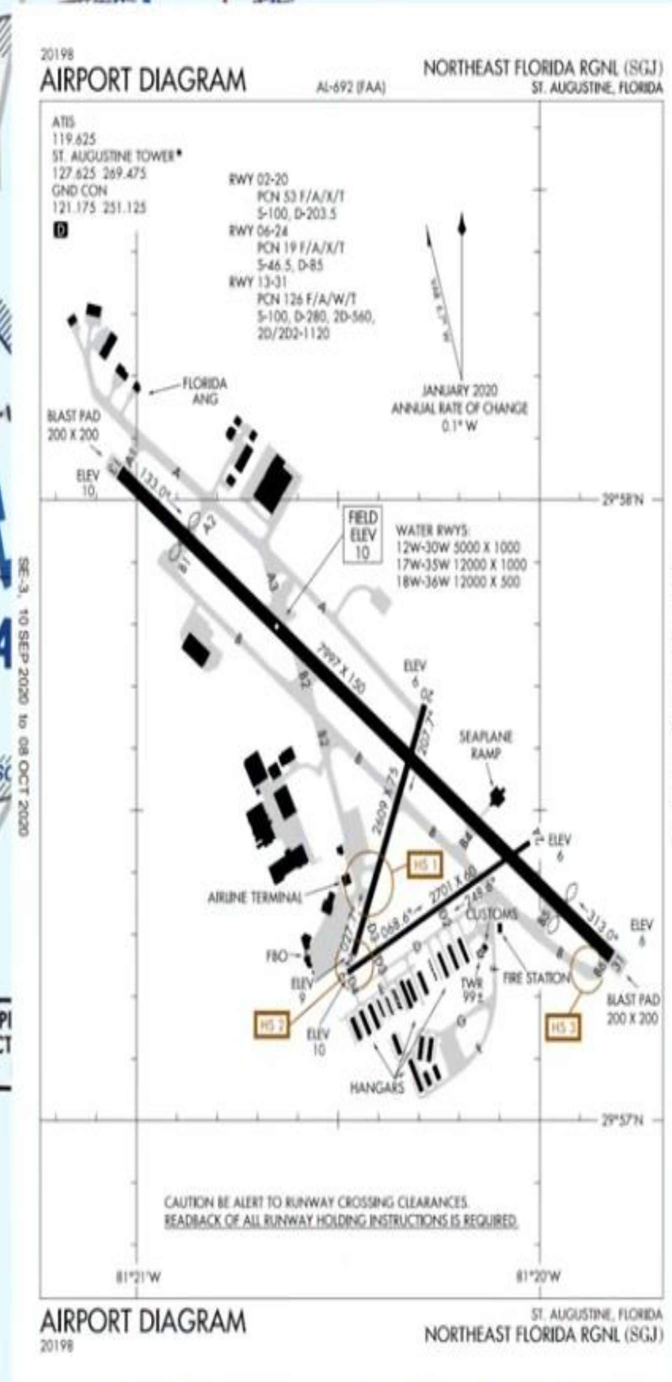
VOR SIMULATOR
VOR Navigation Made Easy + ADF & DME


VPAFY
W-136E
SPECIAL MILITARY ACTIVITY
CONTACT GAINESVILLE RADIO ON 122.2
FOR ACTIVITY STATUS
122.3
VOR-DME
ST AUGUSTINE
109.4 Ch 31 SGJ
GAINESVILLE
IR32
2700 MSL
W-137
See NOTAMs/Supplement
for Class D/E (sfc) eff hrs
NORTHEAST FLORIDA RGNL (SGJ)
CT - 127.625 ★ C
ATIS 119.625
10 *L 80
00 - 120
122.95
Vilano Beach
St. Augustine
ANASTASIA
ISLAND
St Augustine Beach
VR1040-1041
JETSO
SEBAG
VPBEC
CONTIGUOUS
Durbin
PONCE DE LEON
golf course
Penney Farms
WILLIAMS (Pvt)
REYNOLDS
338 RYD
HALLER (Pvt)
R-2903 D
PALATKA RCO
GAINESVILLE
Florahome
PALATKA-LARKIN (28J)
AWOS-3 119.925
TATER (Pvt)
Palatka
Elkton
VR1007
See NOTAMs/Supplement
for Class D/E (sfc) eff hrs


Horizontal Navigation
022°
203°
202°
To
From
30 Nm
Not to scale
Vertical Navigation
ASI
Mach
0.17
Knots
IAS
AI
ALT
29.92
TC
TURN COORDINATOR
2 MIN
NO PITCH INFORMATION
HI
HDG
017
VSI
UP
VERTICAL SPEED
FT/MIN
x1000
VOR
GS
To
Fr
OBS
022


Horizontal Navigation
020°
201°
200°
20
To
From
30 Nm
ASI
Mach
0.17
IAS
AI
ALT
29.92
TC
TURN COORDINATOR
2 MIN
NO PITCH INFORMATION
HI
HDG
VSI
UP
DN
VERTICAL SPEED
FT/MIN
x1000
VOR
GS
To
Fr
020


VFR Map
Hybrid VFR
JACKSONVILLE APP WITHIN
N 132.775 284.6 ABOVE 5000';
4 5000' & BELOW
CAUTION: HIGH DENSITY MILITARY TRAFFIC
CONTACT ATC FOR ADVISORIES
60
05 AGL
VPAFY
122.3
VOR-DME
ST AUGUSTINE
109.4 Ch 31 SGJ
GAINESVILLE
IR32
INSET
See NOTAMs/Supplement
for Class D/E (sfc) eff hrs
NORTHEAST FLORIDA RGNL (SGJ)
CT - 127.625 ★ C
ATIS 119.625
10 *L 80
00 - 120
122.95
Green Cove Springs
Penney Farms
REYNOLDS
338 RYD
(Pvt)
REYNOLDS
21 - 50
HALLER (Pvt)
75 - 26
Picolata
PRKKS
ST JOHNS RIVER
Vilano Beach
St. Augustine
ANASTASIA ISLAND
St Augustine Beach
West Tocoi
Tocoi
SEBAG
VPBEC
Crescent Beach
BYRD
21 - 26
Elkton
MATEO
HUTSON
50 - 24
Hastings
EARLE (Pvt)
25 - 23
Summer Haven
PALATKA RCO
GAINESVILLE
122.25
775 stack &
(695) cooling twrs
CARRA
Carraway
substation
PALATKA-LARKIN (28J)
AWOS-3 119.925
48 *L 60
122.8 C
Palatka
TATER (Pvt)
14 - 24
VPEGV
FRONTIER
street pattern
VR1007
VR1040-1041
IR20
SE-3, 10 SEP 2020 to 08 OCT 2020


20198
AIRPORT DIAGRAM
AL-692 (FAA)
NORTHEAST FLORIDA RGNL (SGJ)
ST. AUGUSTINE, FLORIDA
ATIS
119.625
ST. AUGUSTINE TOWER ★
127.625 269.475
GND CON
121.175 251.125
RWY 02-20
PCN 53 F/A/X/T
S-100, D-203.5
RWY 06-24
PCN 19 F/A/X/T
S-46.5, D-85
RWY 13-31
PCN 126 F/A/W/T
S-100, D-280, 2D-560,
2D/2D2-1120
JANUARY 2020
ANNUAL RATE OF CHANGE
0.1° W
FLORIDA ANG
BLAST PAD
200 X 200
ELEV
10
FIELD
ELEV
10
WATER RWYS:
12W-30W 5000 X 1000
17W-35W 12000 X 1000
18W-36W 12000 X 500
29°58'N
7997 X 150
2609 X 75
2701 X 60
SEAPLANE RAMP
AIRLINE TERMINAL
CUSTOMS
FBO
FIRE STATION
TWR
HS 1
HS 2
HS 3
HANGARS
29°57'N
CAUTION: BE ALERT TO RUNWAY CROSSING CLEARANCES.
READBACK OF ALL RUNWAY HOLDING INSTRUCTIONS IS REQUIRED.
81°21'W
81°20'W
AIRPORT DIAGRAM
20198
ST. AUGUSTINE, FLORIDA
NORTHEAST FLORIDA RGNL (SGJ)
SE-3, 10 SEP 2020 to 08 OCT 2020

https://www.youtube.com/watch?v=u_HJi58QhxI


CESSNA
ALTITUDE ENCODER EQUIPPED
ASXGS
ALT
CLOCK
VERTICAL SPEED
127.850 124.850
109.40 110.50
124.850 124.850
110.50 113.90
HOURS
WARNING
ADF
8 9 0
CABIN AIR
MIXTURE
THROTTLE
CARB HEAT


VFR MAP
FL60
SGJ
42J
KGNV
GN
ASXGS
ISOLINE MAP
GPS TRACKING


VFR MAP
FL03
FL60
SGJ
42J
KGNV
GN
ISOLINE MAP
GPS TRACKING
ALTITUDE ENCODER
EQUIPPED
ASXGS
ALT
CLOCK
VERTICAL SPEED
SUCTION
ADF
THROTTLE
MIXTURE
CARB HEAT
CABIN AIR


CESSNA
ASXGS

INSTRUMENT LANDING SYSTEM (ILS)

Automatic Landing Systems *(1)*

- Air carrier acft that are authorized for precision-approach below category II must have automatic landing (auto-land) system.

1. Guidance & control requirements by FAA
   - For category II: the coupled autopilot or crew hold the acft within the vertical error of +or- 12 ft at the 100ft height on a 3deg glide path
   - For category III: the demonstrated touchdown dispersions should be limited to 1500ft longtudinally & -or+ 27ft laterally

Automatic Landing Systems *(2)*

2. **Flare Guidance**
   - **During the final approach the glide-slope gain in the auto-land system is reduced in a programmed fashion. Supplementary sensors must supply the vertical guidance below 100ft**
3. **Lateral Guidance**
   - **Tracking of the localizer is aided by heading (or integral-of-roll), roll, or roll-rate signals supplied to the autopilot and by rate & acceleration data from on-board inertial system**

Instrument Landing System(ILS) (1)

- Is a collection of radio transmitting stations used to guide acft to a specific runway.
- In 1996 nearly 100 airports worldwide had at least one runway certified to Category III with ILS
- More than one ILS in high density airports
- About 1500 ILSs are in use at airports throughout the US

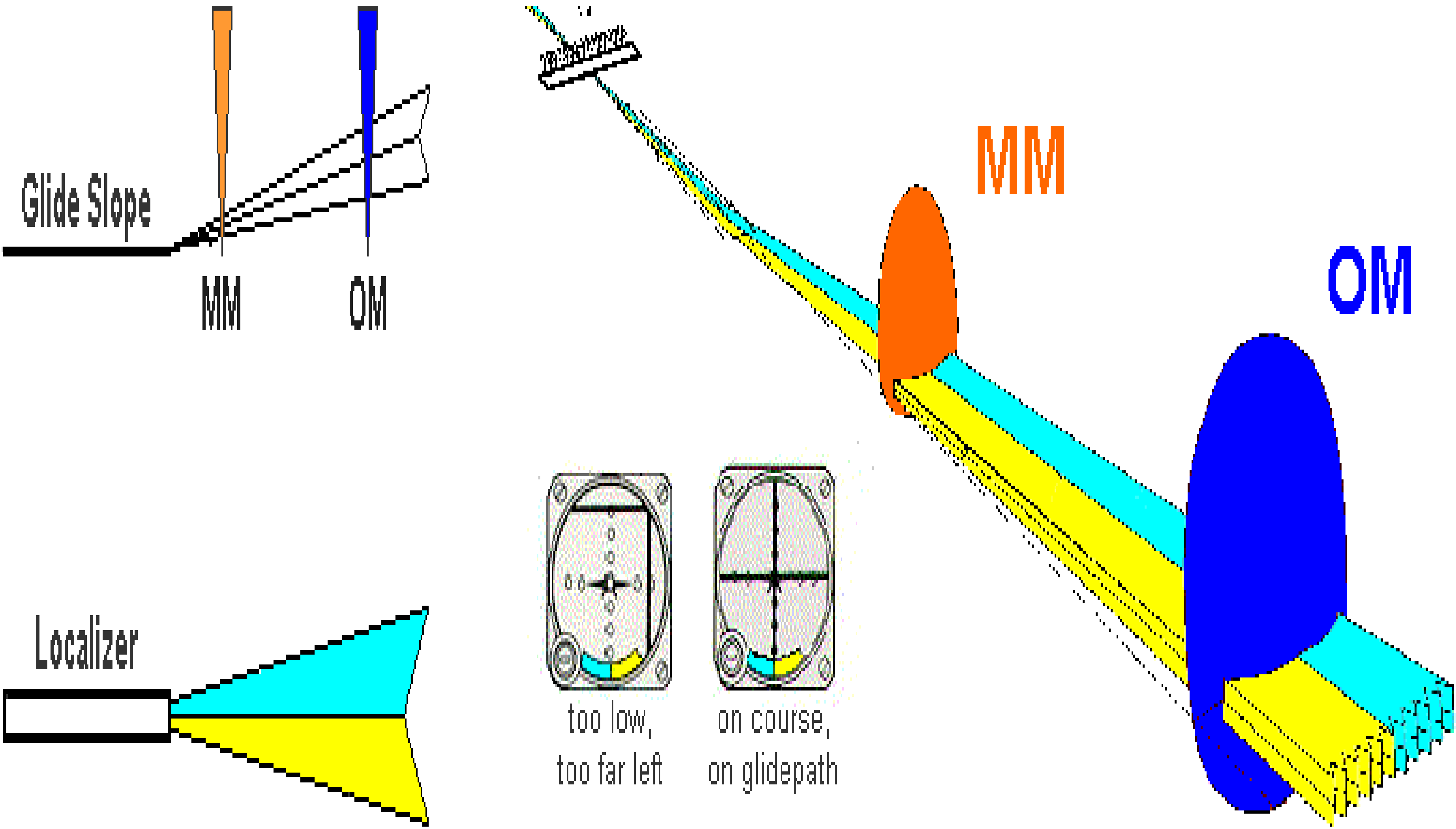
Instrument Landing System(ILS) *(2)*

- ILS typically includes:
  - The localizer antenna is centered on the runway beyond the stop end to provide lateral guidance
  - The glide slope antenna, located beside the runway near the threshold to provide vertical guidance
  - Marker beacons located at discrete positions along the approach path; to alert pilots of their progress along the glide-path
  - Radiation monitors that, in case of ILS failure alarm the control tower, may shut-down a Category I or II ILS, or switch a Category III ILS to backup transmitters

DEFINITION OF INSTRUMENT LANDING SYSTEM (ILS)

- ✓ In aviation, the instrument landing system (ILS) is a radio navigation system that provides short-range guidance to aircraft to allow them to approach a runway at night or in bad weather.
- ✓ It Operates in the VHF portion of the electromagnetic spectrum
- ✓ System consists of ;
  - a runaway localizer,
  - a glide slope signal, and
  - marker beacons for position location
- ✓ Localizer equipment produces a radio course aligned with the centre of an airport runaway.
  - ✓ The on course signals result from the equal reception of two signals;
- ✓ Blue sector(150 Hz) and yellow sector(90 Hz)

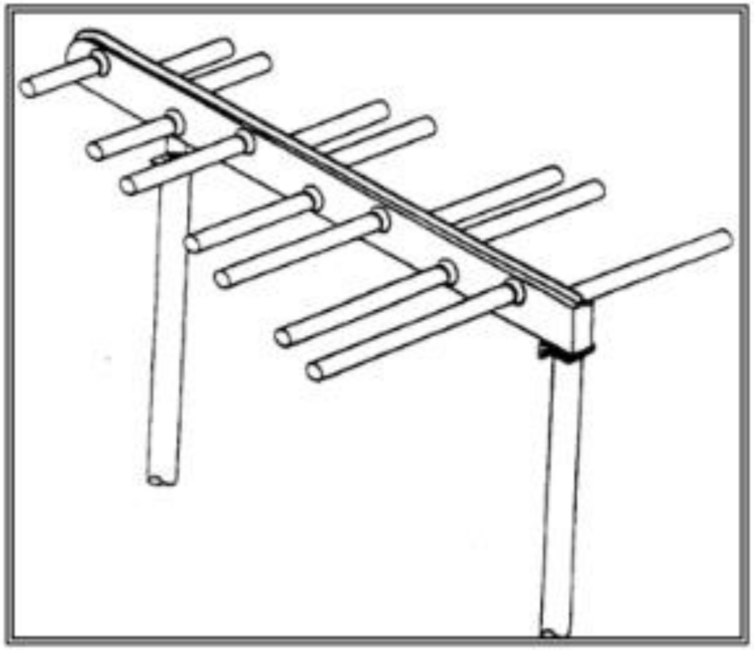
GLIDE SLOPE INFORMATION



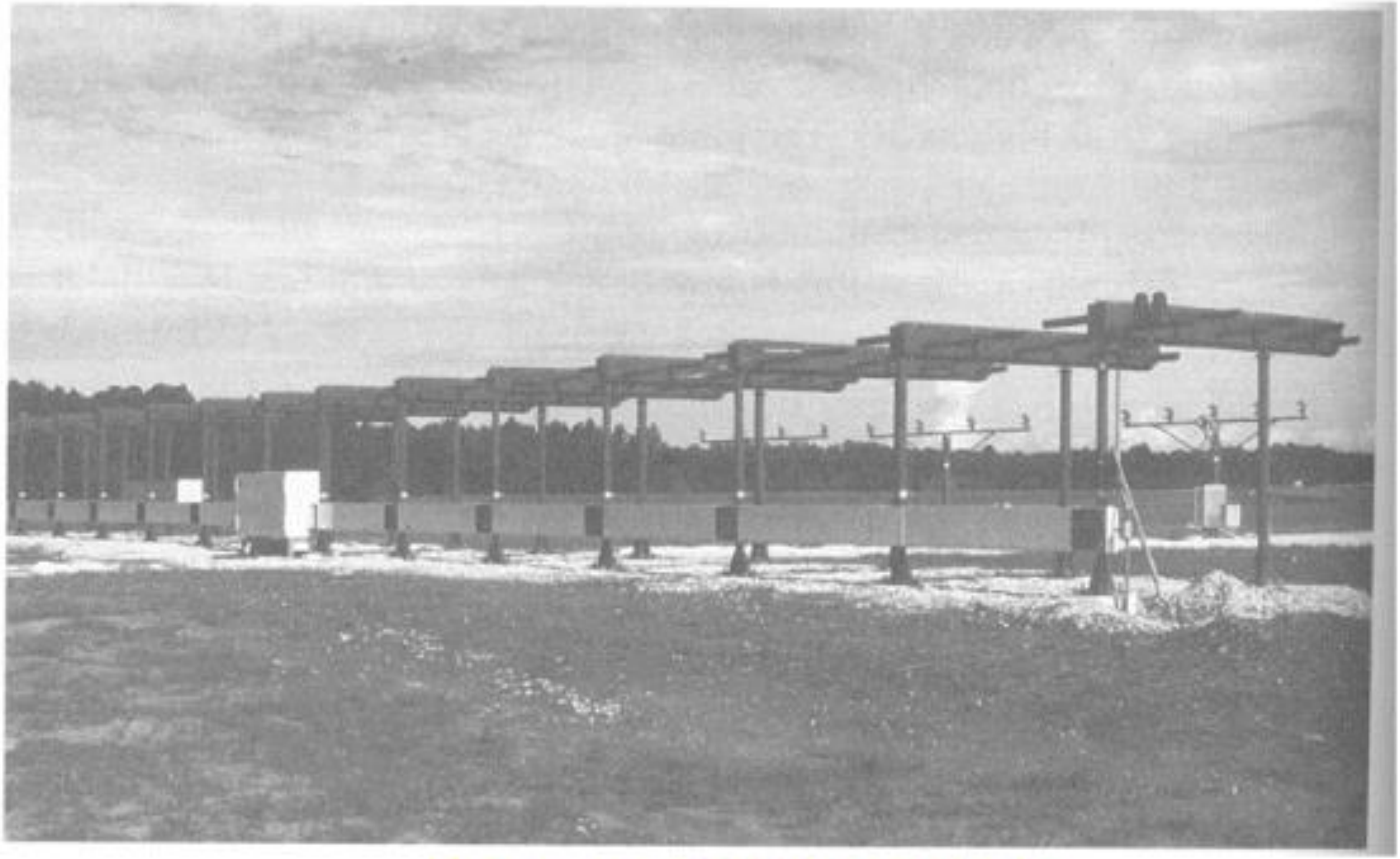
The Localizer *(1)*

- The typical localizer is an array usually located 600 to 1000 ft beyond the stop end antenna of the runway
- The array axis is perpendicular to the runway center line

Log-periodic dipole antenna used in many localizer arrays



The Localizer *(2)*



Category IIIB localizer

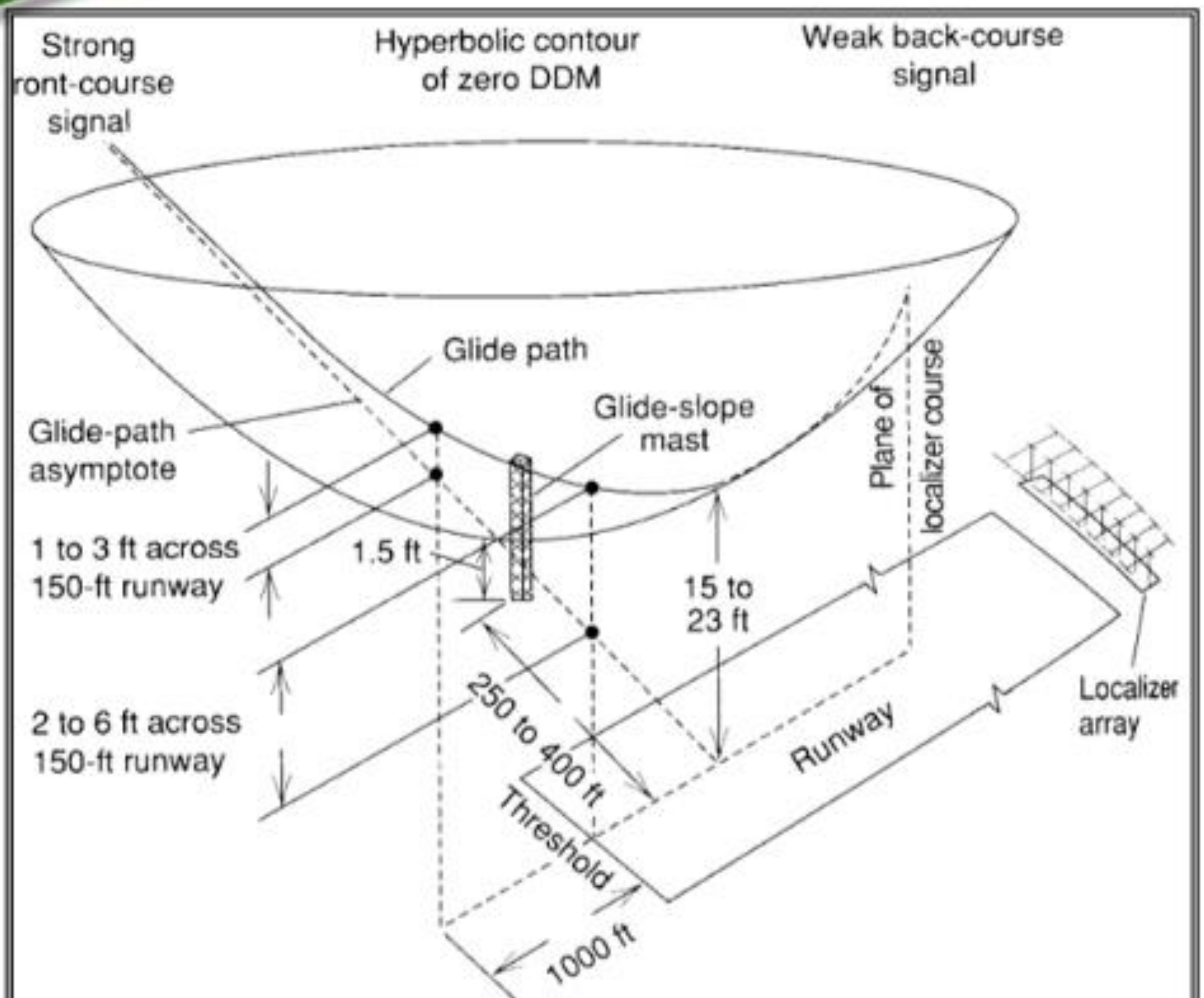
The Glide Slope *(1)*

- There are five different of glide-slope arrays in common use; three are image systems & two are not
- Image arrays depend on reflections from level ground in the direction of approaching acft to form the radiation pattern
  - The three image systems are *null-referenced* system, with two antennas supported on a vertical mast 14 & 28 ft above the ground plane
  - The *sideband-reference* system, with two antennas 7 and 22ft above the ground plane
  - The *capture-effect* system, with 3 antennas 14, 28, and 42 ft above the ground plane

The Glide Slope(2)

Category IIIB capture-effect glideslope & Tasker transmissometer

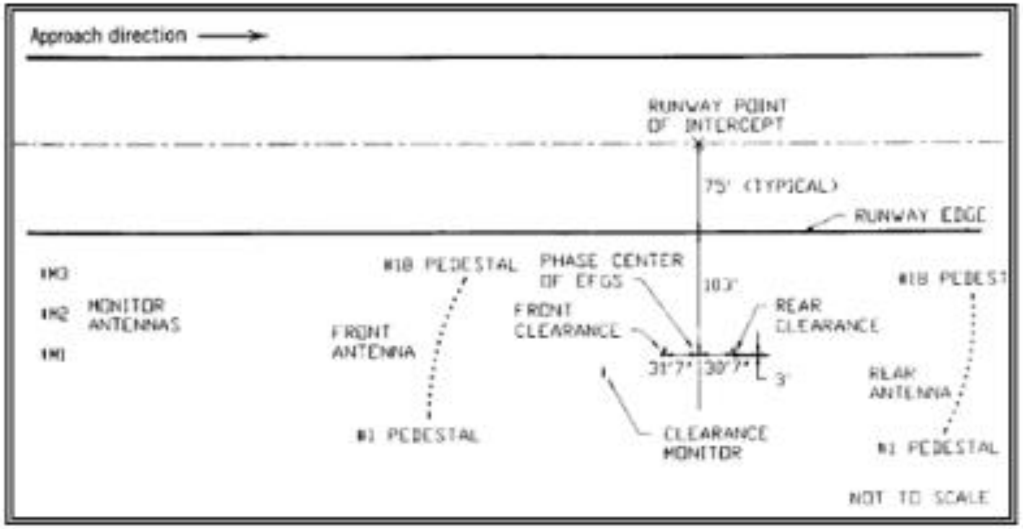
The Glide Slope *(3)*



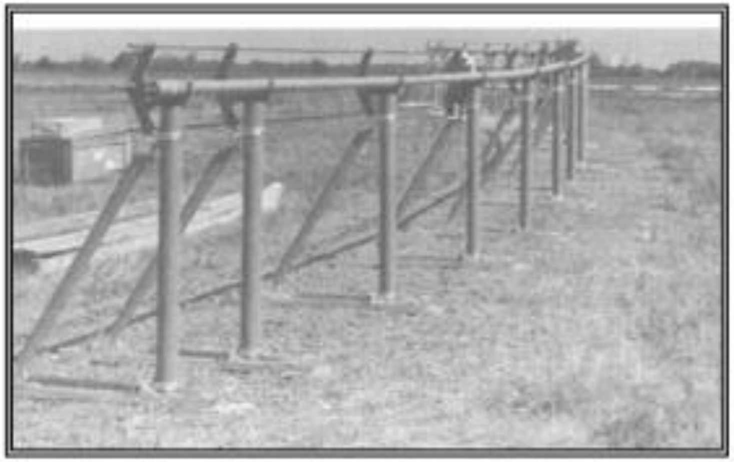
Glide-slope pattern near the runway. DDM counters are symmetrical around the vertical, but signal strength drops rapidly off course

The Glide Slope *(4)*

- The cable radiators of the end-fire array are installed on stands 40 in. high & are site alongside the runway near desired touchdown point
- Fig 13.10
- Fig 13.11



Standard end-fire glide-slope system layout



Front slotted-cable radiator of an end-fire glide slope

- ✓ The glide slope : assists pilot in making the correct angle of descent.

- ✓ Glide slope signals are radiated from two antennas located adjacent to the touchdown point of the runway.

- ✓ Info from both localizer and glide slope receivers is presented to the CDI;

THE COURSE DEVIATION INDICATOR ;

- ✓ The vertical needle: localizer information
- ✓ Horizontal needle : Glide slope information

When both needles are centered, the aircraft is on course and descending at the proper rate.

ILS Marker Beacons *(1)*

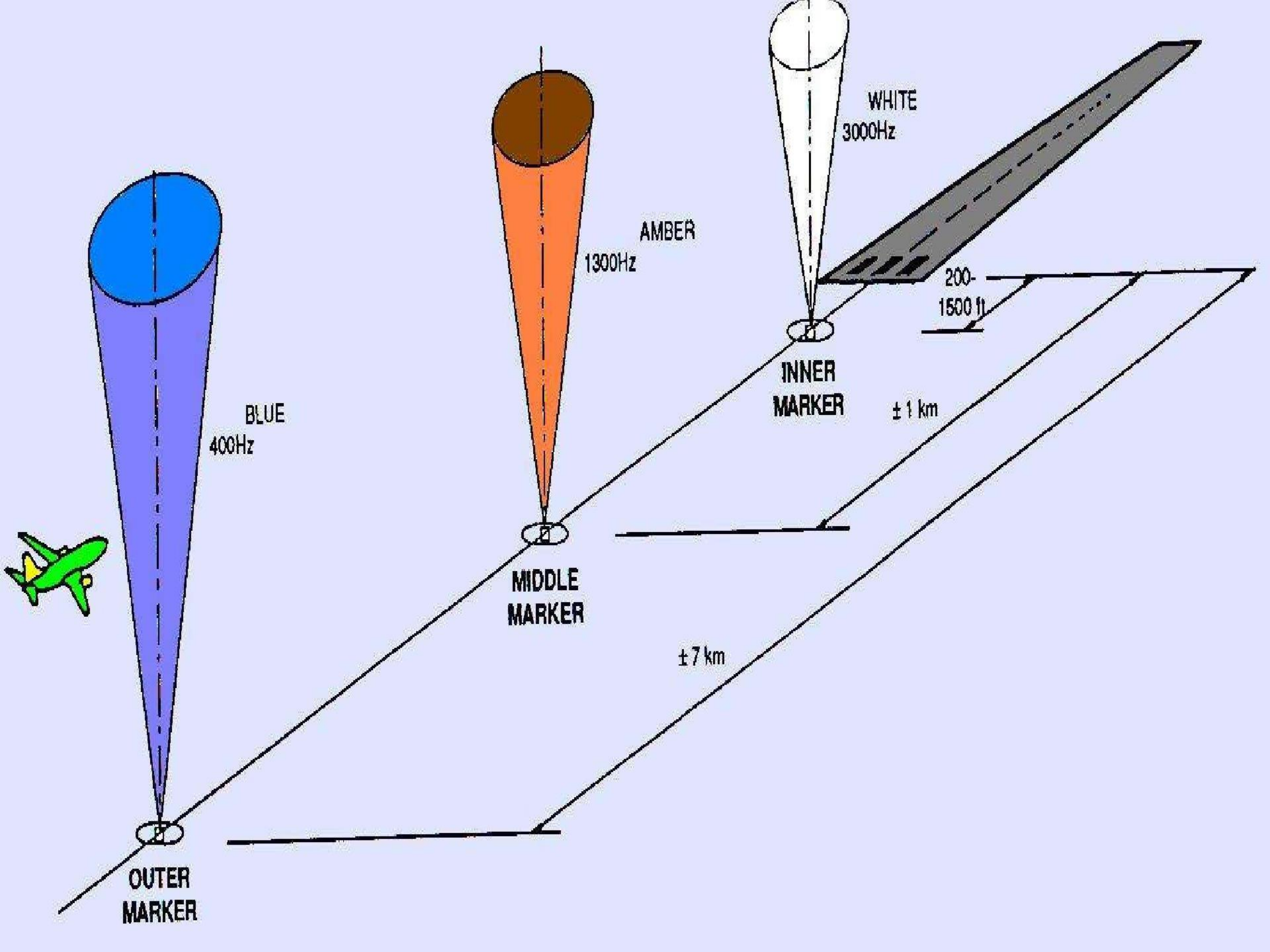
- Marker beacons provide pilot alerts along the approach path
- Each beacon radiates a fan-shaped vertical beam that is approximately +or- 40deg wide along the glide path by +-85deg wide perpendicular to the path
  - The outer marker(OM) is placed under the approach course near the point of glide-path intercept & it is modulated with two 400 Hz Morse-code dashed per second

MARKER BEACONS

- ✓ In connection with the instrument landing system, signals which indicate the position of the aircraft along the approach to the runway.

- ✓ Three markers are used in each installation:

- ➢ Outer marker - the beginning of the approach path
  is modulated by a 400 HZ signal, a tone keyed in long dashes, its position is ± 7km to to the beginning of the runway.
- ➢ Middle marker: 3500 ft from the end of the runway
  is modulated at 1300 Hz, a higher-pitched tone keyed with alternate dots and dashes. its position is
  ± 1km to to the beginning of the runway.
  Inner Marker is modulated at 3000 Hz , its position is
  1500feet to to the beginning of the runway.


WHITE
3000Hz
AMBER
1300Hz
BLUE
400Hz
200-
1500 ft
INNER
MARKER
± 1 km
MIDDLE
MARKER
± 7 km
OUTER
MARKER

DISTANCE MEASURING EQUIPMENT(DME)

- ✓ Constant visual indication of the distance the aircraft is from a ground station.

- ✓ NOT a true indication of point to point distance as measured over the ground.

- ✓ Indicates the slant range between the aircraft and the ground station.

WORKING OF DME

- ✓ Transceiver transmits a pair of spaced pulses to the ground station,
- ✓ Ground station responds with a pulse transmission on a separate frequency to send a reply to the aircraft,
- ✓ Time elapsed is time between the challenges and are measured;
- ✓ Time travel is the distance separating plane and station.
- ✓ Distance is indicated in ‘nautical miles’ by a cockpit instrument.

WORKING OF DME

✓ **Transmitting frequencies are in 2 groups**

- **962 MHz to 1024 MHz**
- **1151 MHz to 1212 MHz**

- **Receiving frequency is between 1025 to 1149 MHz**

Aircraft's DME transceiver is tuned to the selected DME ground station

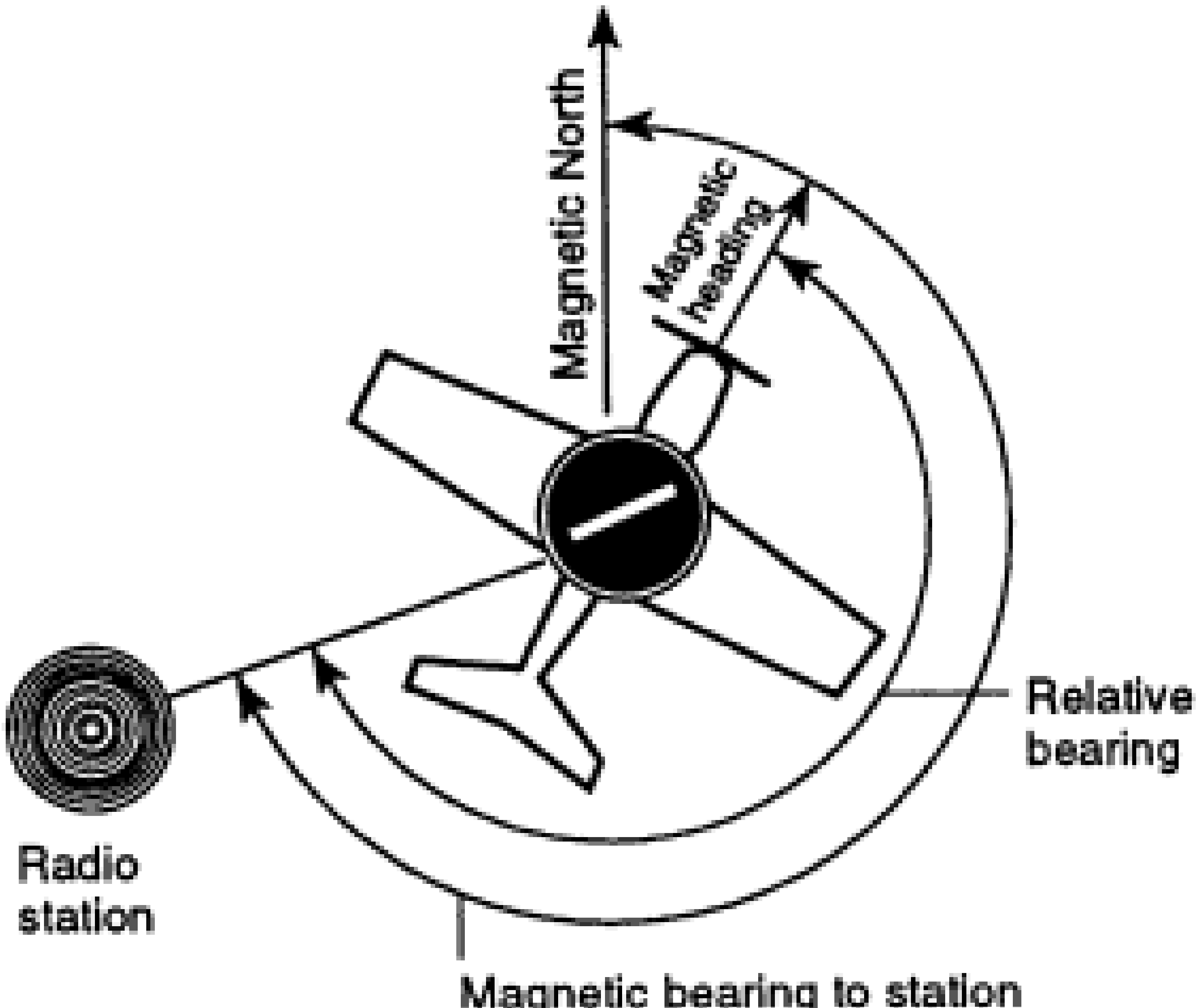
AUTOMATIC DIRECTION FINDERS ADF

- ✓ ADF (Automatic Direction Finder) is the radio signals in the low to medium frequency band of 190 KHz to 1750 KHz. It was widely used today. It has the major advantage over VOR navigation in the reception because it is not limited to line of sight distance.
- ✓ The ADF signals follow the curvature of the earth.
- ✓ The maximum of distance depends on the power of the beacon. The ADF can receives on both AM radio station and Non-Directional Beacon NDB .

Commercial AM radio stations broadcast on 540 to 1620 KHz.

Non- Directional Beacon NDB operates in the frequency band of 190 to 535 KHz.

AUTOMATIC DIRECTION FINDERS ADF



AUTOMATIC DIRECTION FINDERS ADF consists the following ;

- ✓ **Consists of**
  - **Receiver, Loop antenna,**
  - **Sense or non-directional antenna,**
  - **Indicator and control unit.**

- ✓ **Loop antenna rotates through 360 degrees.**

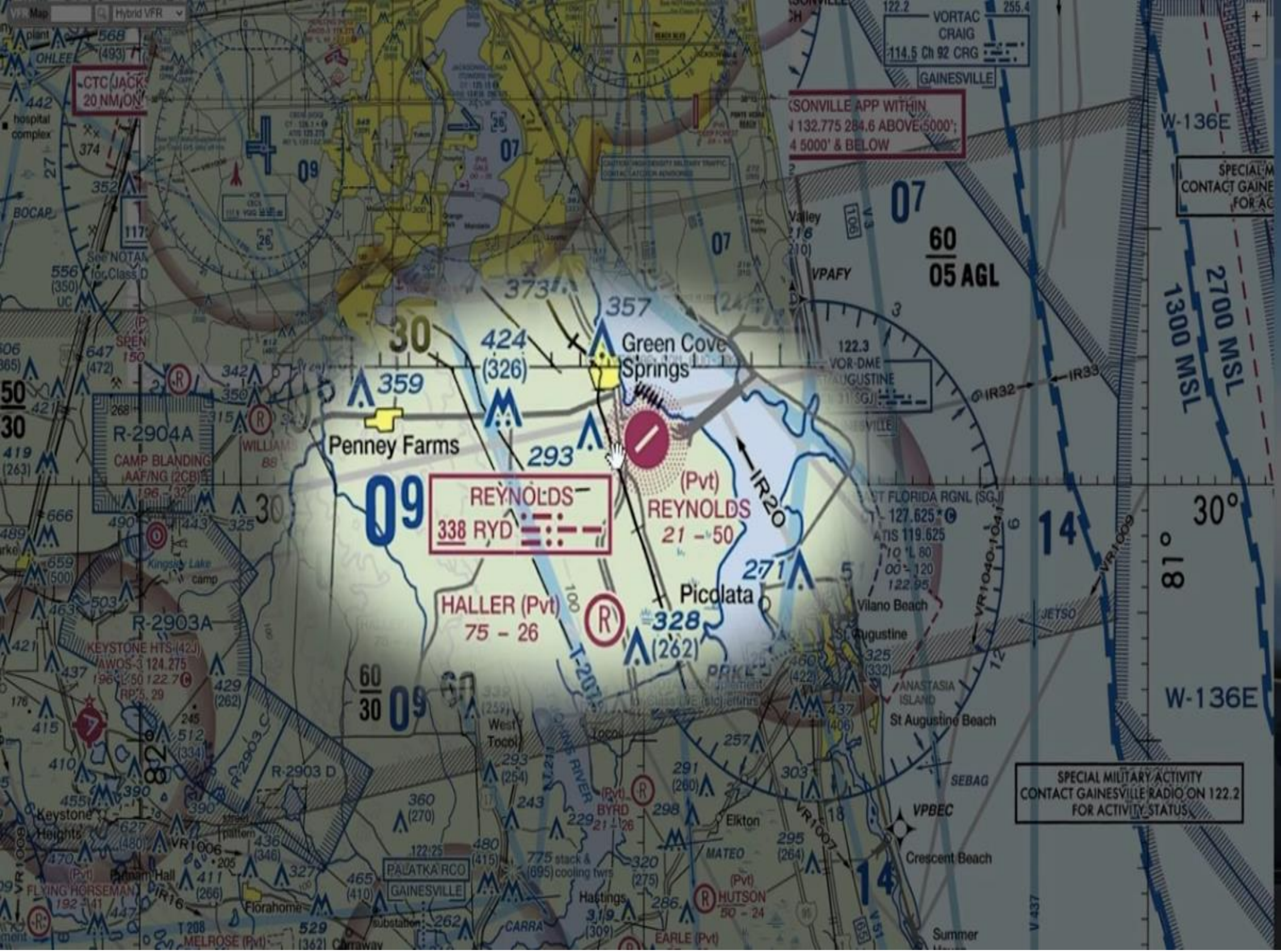
- ✓ **Receives <u>Max</u> signal strength: In parallel position with the direction of the transmitted signal.**

- ✓ **Reaches the <u>Min</u> when perpendicular to the transmitted signal position of the loop, is called the null position.**

Loop Antenna Indications

- ✓ Null position of the loop is used for direction finding.
- ✓ Two null positions exist (180 degrees apart).
- ✓ Loop antenna cannot differentiate, require sense antenna.
- ✓ Signal strength of the sense antenna is superimposed with the null antenna.
- ✓ Only one null position of the loop.

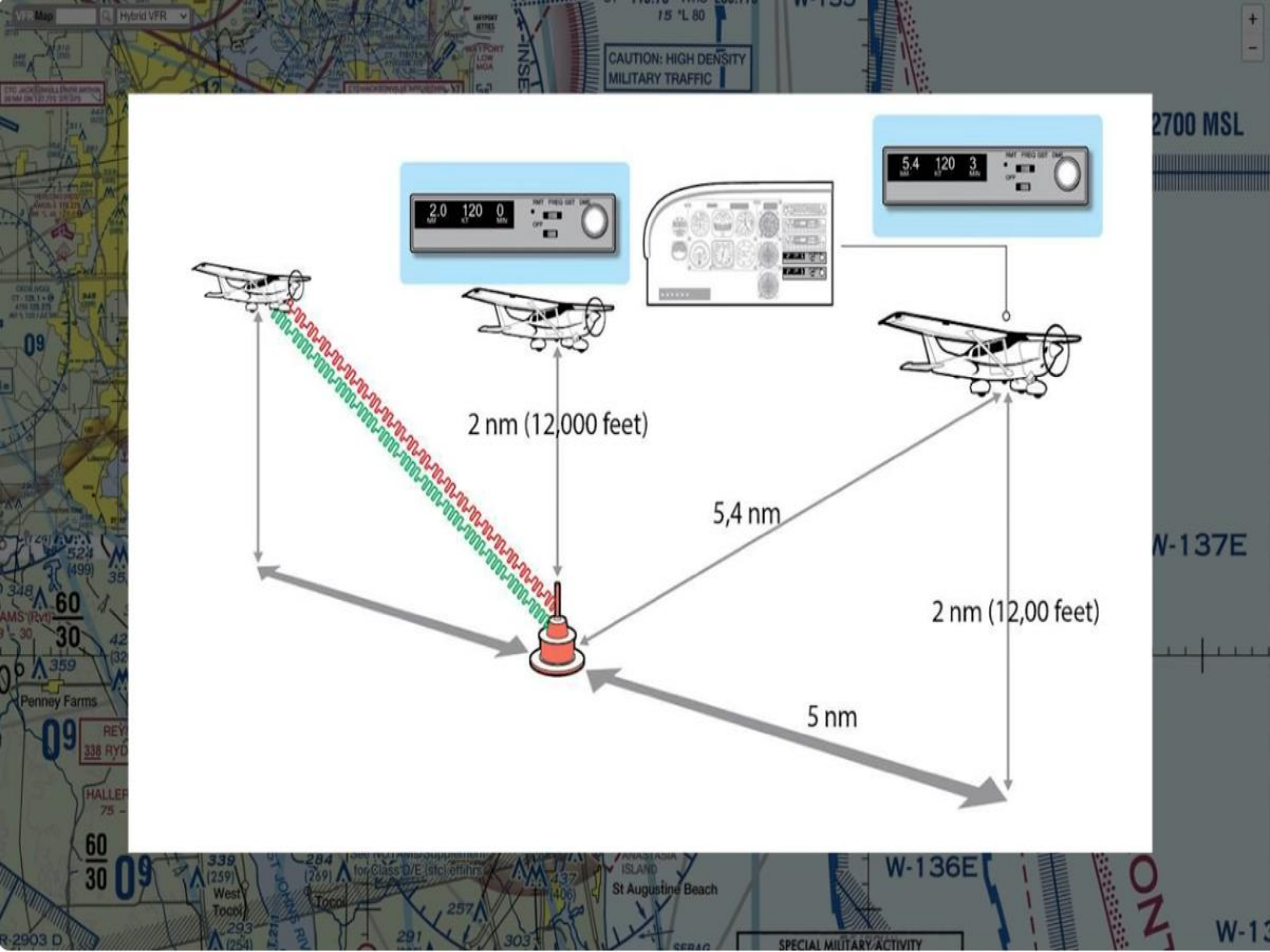
Horizontal Navigation
To
From
30 Nm
Not to scale
Vertical Navigation
ASI
Mach
0.17
Knots
IAS
AI
ALT
29.92
TC
TURN COORDINATOR
L
R
2 MIN
HI
VSI
UP
VERTICAL SPEED
FT/MIN
x1000
017
VOR
OBS



Hybrid VFR
VORTAC
CRAIG
114.5 Ch 92 CRG
GAINESVILLE
07
60
05 AGL
W-136E
1300 MSL
2700 MSL
30
373
357
424
(326)
359
Green Cove
Springs
Penney Farms
293
09
REYNOLDS
338 RYD
(Pvt)
REYNOLDS
21 – 50
IR20
IR32
IR33
122.3
271
Picolata
HALLER (Pvt)
75 – 26
328
(262)
30°
81°
14
R-2904A
CAMP BLANDING
R-2903A
R-2903 D
KEYSTONE HTS (42J)
Keystone
Heights
Vilano Beach
St. Augustine
ANASTASIA
ISLAND
St Augustine Beach
Crescent Beach
Elkton
Hastings
PALATKA RCO
GAINESVILLE
SPECIAL MILITARY ACTIVITY
CONTACT GAINESVILLE RADIO ON 122.2
FOR ACTIVITY STATUS
60
30
09


124.850 124.850
USE
STBY
COMM
116.20 110.50
USE
STBY
NAV
HOURS
HOURS
WARNING
ADF
3 3 8
REC
ADF
BFO
OFF
Test bearing reliability
ON
ALT
TST
IDENT
MIXTURE
LEAN
PULL
ON
OFF
FUEL IND
BCN PILOT
STROBE LTS
LDG LTS
FLAP
INST LTS
NAV DOME
1 2 3 4
RADIOS

CAUTION: HIGH DENSITY
MILITARY TRAFFIC
JACKSONVILLE EXEC
AT CRAIG (CRG)
CT - 132.1* C ATIS 125.4
41 *L 40 122.95
122.2
255.4
VORTAC
CRAIG
114.5 Ch 92 CRG
GAINESVILLE
2700 MSL
W-136E
SPECIAL MILITARY ACTIVITY
CONTACT GAINESVILLE RADIO ON 122.2
07
60
05 AGL
VPAFY
122.3
VOR-DME
ST AUGUSTINE
109.4 Ch 31 SGJ
GAINESVILLE
NORTHEAST FLORIDA RGNL (SGJ)
CT - 127.625* C
ATIS 119.625
See NOTAMs/Supplement
for Class D/E (sfc) eff hrs
30°
81°
14
REYNOLDS
338 RYD
Penney Farms
Green Cove Springs
Vilano Beach
St. Augustine
Picolata
INSET
7.8
NM
98
KT
5
MIN
DME



CAUTION: HIGH DENSITY
MILITARY TRAFFIC
2700 MSL
2.0 NM 120 KT 0 MIN
5.4 NM 120 KT 3 MIN
2 nm (12,000 feet)
5,4 nm
2 nm (12,00 feet)
5 nm
W-137E
Penney Farms
W-136E
St Augustine Beach
SPECIAL MILITARY ACTIVITY

DOPPLER NAVIGATION SYSTEM

- ✓Automatically and continuously computes and displays ground speed and drift angle of an aircraft without the aid of ground stations, wind estimates or true air speed data.

- ✓Does not sense direction as search radar does.

- ✓Uses continuous carrier wave transmission energy and determines the forward and lateral velocity component of the air craft by utilizing the principle known as

DOPPLER EFFECT

What is DOPPLER EFFECT ?

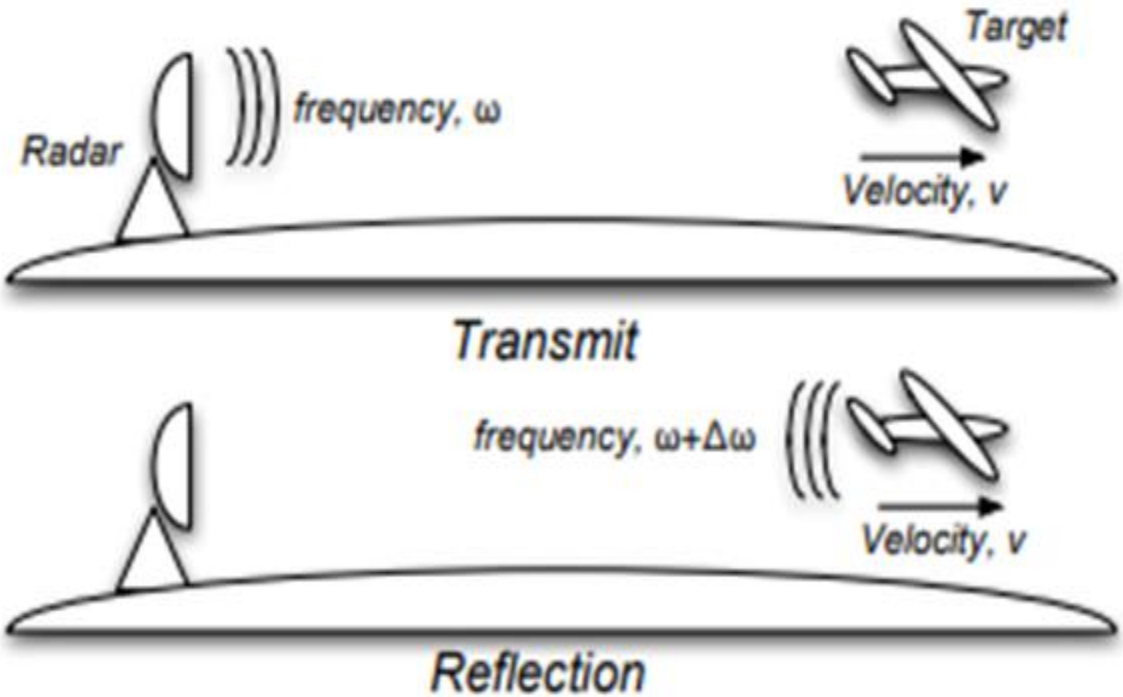
- Doppler effect implies that the frequency of a wave when transmitted by the source is not necessarily the same as the frequency of the transmitted wave when picked by the receiver.

- The received frequency depends upon the relative motion between the transmitter and receiver.
- If transmitter and receiver both are moving towards each other the received frequency higher, this is true even one is moving.
- If they are moving apart the received signal frequency decreases and if both are stationary, the frequency remains the same. This change in frequency is known as *Doppler shift.*
- Doppler shift depends upon the relative velocity between radar and target

- If R is the distance from the radar to target, the total number of wavelengths λ contained in the two-way path between the radar and the target are $2R/\lambda$.
- Each wavelength corresponds to a phase change of 2π radians. The total phase change in the two way propagation path is then

$$\phi = 2\pi * \frac{2R}{\lambda} = 4\pi R/\lambda$$

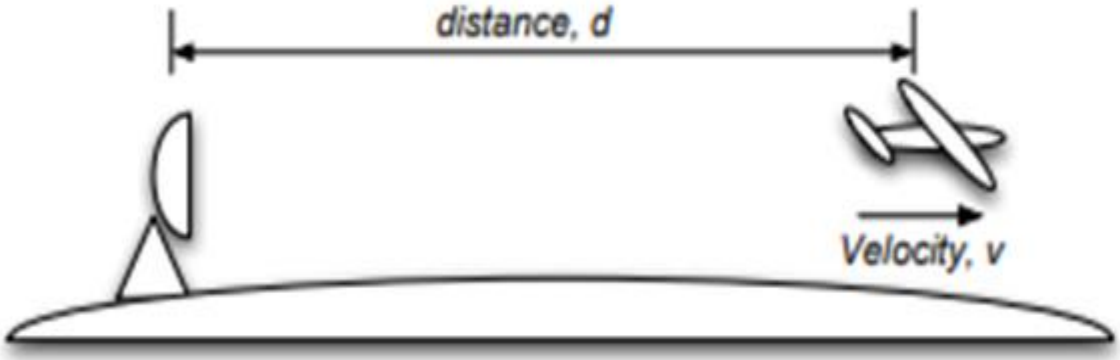
Basic Doppler Radar Idea



The target is moving.

The reflected RF pulse is shifted in frequency.

Doppler Shift



The target is a distance d from the antenna, moving at a velocity v.

The phase of the received signal is the total distance divided by the wavelength λ.

$$\phi = -2\pi \frac{2d}{\lambda}$$

The negative sign is due to the fact that the received signal is *delayed* in time.

The frequency of the signal is

$$\omega_d = \frac{d}{dt}\phi = \frac{d}{dt}\left(-2\pi\frac{2d}{\lambda}\right) = -2\pi\frac{2v}{\lambda}$$

The wavelength $\lambda = c/(\omega/2\pi) = 2\pi c/\omega_c$, where c is the speed of light, so

$$\omega_d = -2\pi\frac{2v}{2\pi c/\omega_c} = -\frac{2v}{c}\omega_c$$

or, dividing both sides by 2π, and using $f = \omega/2\pi$,

$$f_d = -\frac{2v}{c}f_c$$

For an airplane traveling 300 m/s (just below the speed of sound, 330 m/s), and a radar frequency of $f_c = 1\text{GHz}$, this gives

$$f_d = -\frac{(2)(3 \times 10^2 \text{ m/s})}{3 \times 10^8 \text{ m/s}}(1 \times 10^9 \text{ Hz}) = -2 \times 10^3 \text{ Hz} = -2 \text{ kHz}.$$

You also see a similar frequency shift in communications.

The shift is half of the radar doppler shift, since there is only the one-way path.

This shift is noticeable when you are decoding packets. The frequency will drift depending on the changing distance between you and the airplane.

It is even more of an issue with low earth orbit satellites, due to their very high speeds.

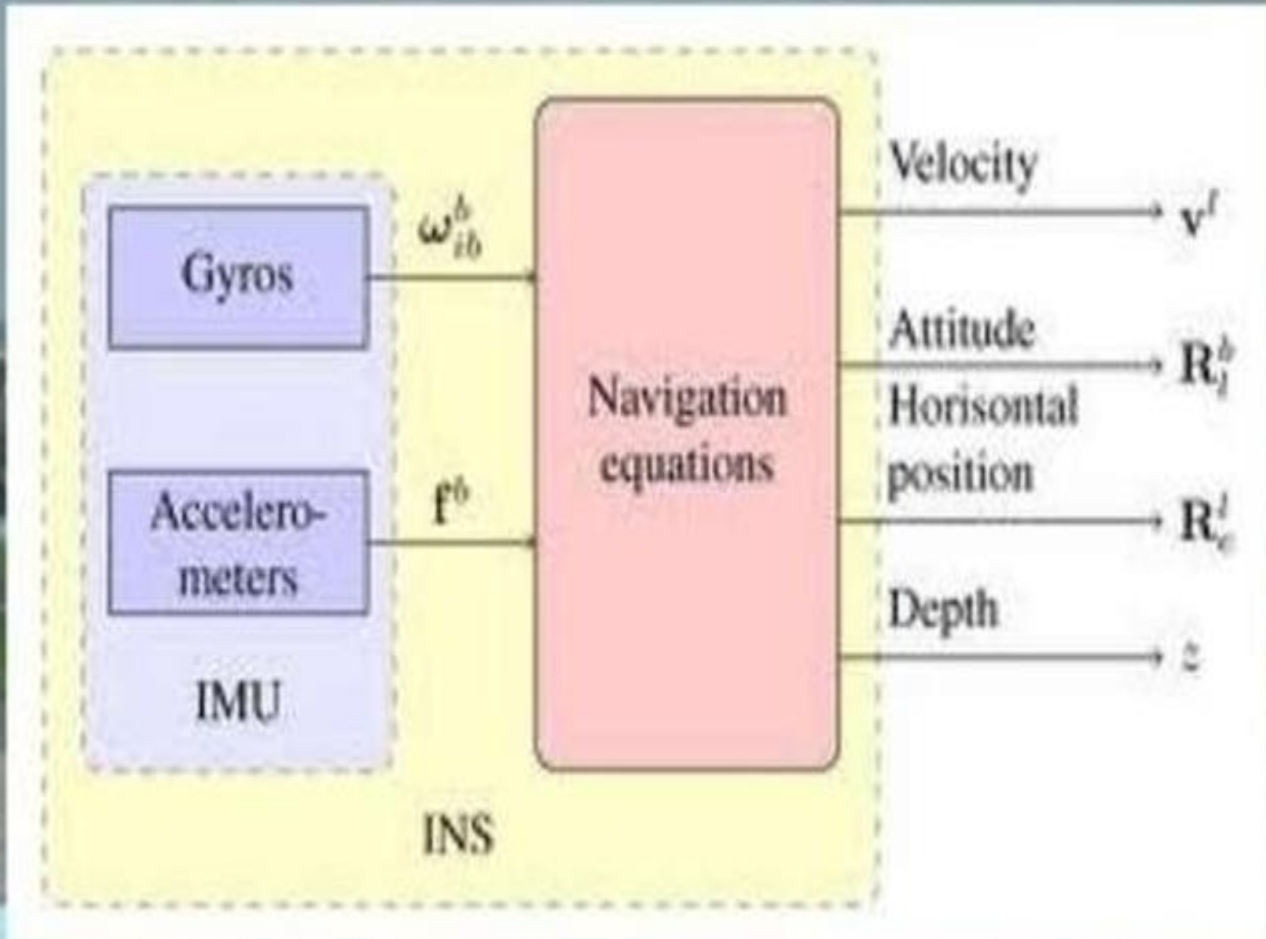
INERTIAL NAVIGATION SYSTEM

- ✓ Used on large aircraft as a long range navigation aid
- ✓ Self-contained system;
- ✓ <u>DOES NOT</u> require any signal inputs from ground navigational facilities.

- ✓ Derives <u>altitude</u>, <u>velocity</u>, and <u>heading information</u> from measurement of the aircraft's accelerations.
- ❖ Two accelerometers are required,
  one referenced towards east and other towards north.
- ✓ The accelerometers are mounted on a gyro stabilized unit, called the stable platform.

- ✓ Averts the introduction of errors resulting from the acceleration due to gravity.

INERTIAL NAVIGATION SYSTEM



INERTIAL NAVIGATION SYSTEM COMPONENTS

An inertial navigation system is a complex containing four basic components :-

- ✓ A stable platform which is oriented to maintain accelerometers horizontal to the earth's surface.
- ✓ Accelerometers arranged on the platform to supply specific components of acceleration.
- ✓ Integrators which receive the output from the accelerometers and furnish velocity and distance.
- ✓ A computer which receives signals from the integrators and changes distance travelled to position in selected coordinates.

RADIO ALTIMETER

Radio altimeters are based on the principle of reflection of electromagnetic wave pulses by the surface of the earth or sea. These waves fall within the radio spectrum range.

Electromagnetic waves travel at the speed of light and thus the calculation of the distance is effectively immediate. Although they are affected by surface irregularities generating deviations in the radio signal, radio altimeters provide a reliable and accurate method of measuring height.

✓ Measures the distance from the aircraft to the ground.

✓ Accomplished by transmitting radio frequency energy to the ground and receiving the reflected energy at the aircraft.

Pulse Type

- Altitude determined by measuring time required for transmitted pulse to hit ground and return.
- Indicating instrument gives true altitude of aircraft.
- Used during landing to determine decision whether to continue to land or execute climb-out.

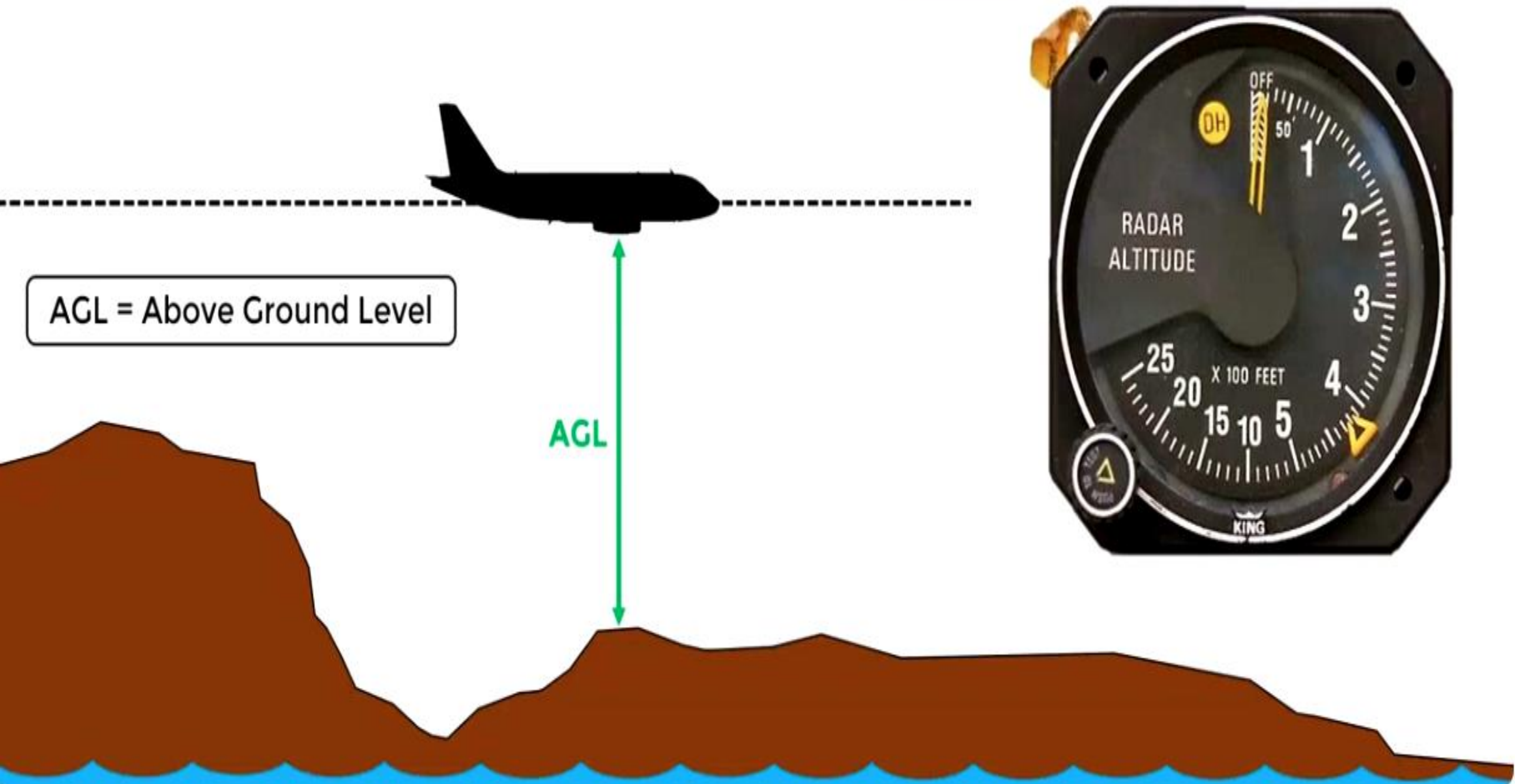
THE RADIO ALTIMETER

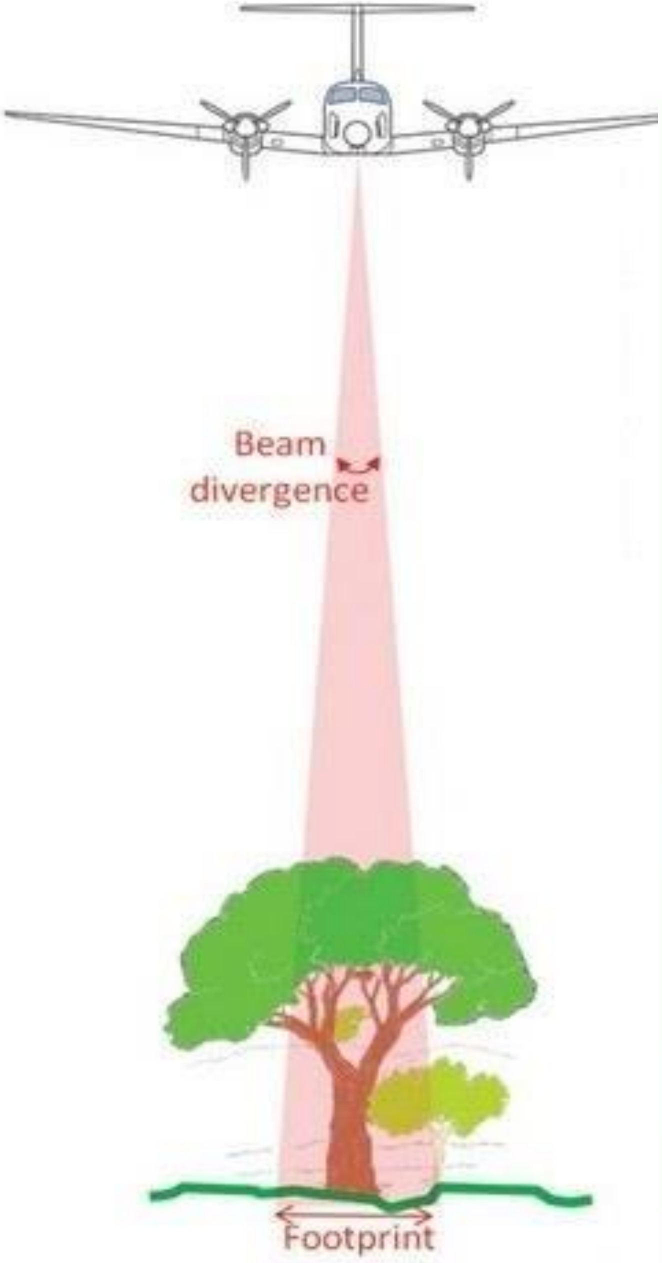
RADIO ALTIMETER ➡ Radar Altimeter

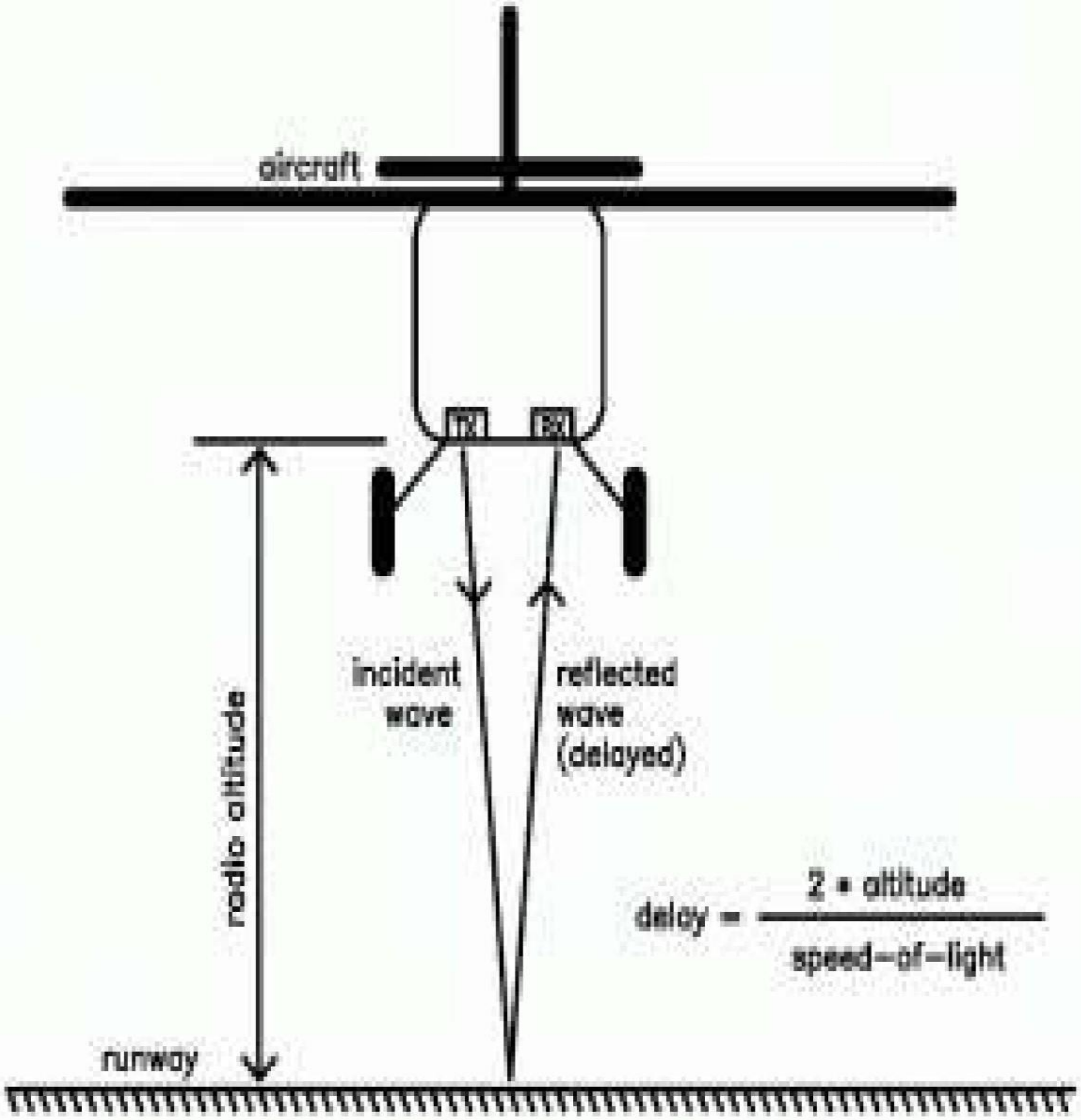
RA

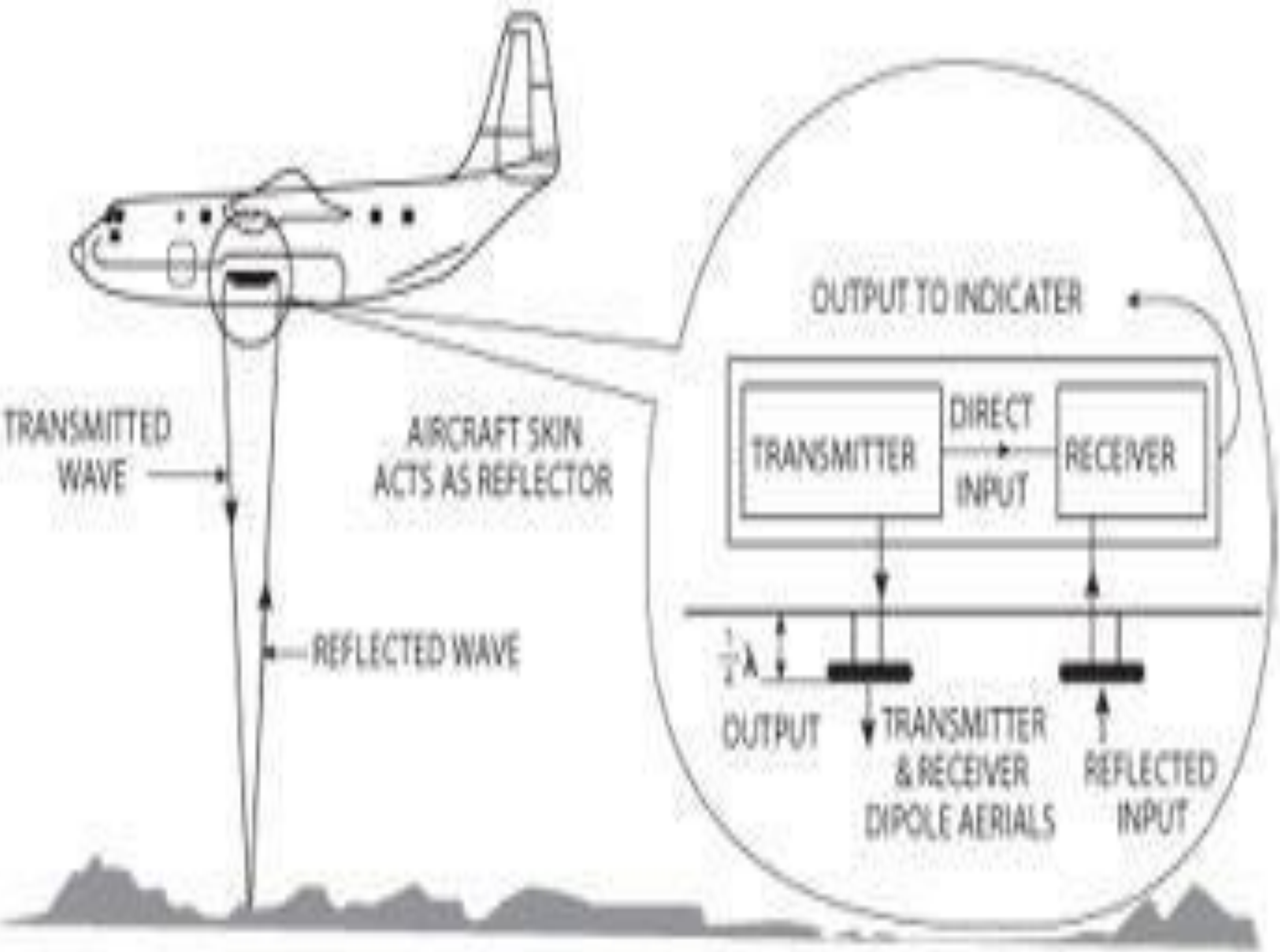
Instrument that indicates the height of the aircraft in relation to the ground immediately below it.

AGL




Beam
divergence
Footprint


aircraft
TX
RX
incident
wave
reflected
wave
(delayed)
radio altitude
delay = 2 * altitude / speed-of-light
runway



OUTPUT TO INDICATER
TRANSMITTED WAVE
AIRCRAFT SKIN ACTS AS REFLECTOR
TRANSMITTER
DIRECT INPUT
RECEIVER
REFLECTED WAVE
$\frac{1}{4}\lambda$
OUTPUT
TRANSMITTER & RECEIVER DIPOLE AERIALS
REFLECTED INPUT

Video Links

VOR

Hhttps://www.youtube.com/watch?v=u_HJi58QhxI

https://www.youtube.com/watch?v=wuLTppemEgA

ILS

https://www.youtube.com/watch?v=PziW3iKF5GI


Thank You!