RADAR ENGINEERING AND NAVIGATIONAL AIDS

Unit - IV

Outline

- **Radar receivers:**

  Super regenerative, crystal video, TRF, Superheterodyne

- **Mixers:**

  Crystal, balanced, double balanced, product return, image enhanced, image recovery mixers.

- **Radar displays:**

  (I) Raw video :: (1)deflection mounted displays: A, A scope, J, M, O, N, K, R (2) Intensity modulated : B, C, D, E, H, RHI

  (II) Synthetic Video :: ADT : Digital computers, microprocessor, micro computers, mini computers, ARM processors

- **Receiver protectors:**

  Passive TR limiter, solid state limiter, ferrite limiters, circulator

Function of the radar receiver

- To detect desired echo signals in the presence of noise, interference, or clutter.
- Receiver must separate wanted from unwanted signals, to a level where target information can be displayed to an operator, or used in an automatic data processor.
- The design of a radar receiver will depends on

  type of waveform to be detected, nature of the noise interference and clutter echoes.

- Good radar receiver design is based on maximizing the output SNR,

  to maximize SNR, the receiver must be designed as a <u>matched filter</u>

- Receiver design must be consider

  sufficient gain, phase, amplitude stability, dynamic range, tuning ruggedness, and simplicity

- Protection must be provided against over load or saturation and burnout from near by interfering transmitter.

- Timing and reference signals are needed to properly extract target information

  eg: MTI radar, tracking radar.

- Super regenerative, crystal video, and TRF receiver .
- Which type of receiver is mostly preferred?
- The superhetrodyne receiver preferred for most of the application the reason is as they have good sensitivity, high gain, selectivity and reliability.
- No other receiver type has been competitive to the superhetrodyne receivers.

Mixers

Mixers ::

a) Broad Band Mixers :

Crystal Mixer

b) Narrow Band Mixers :

Balanced Mixer : Hybrid junctions, Magic Tee or an equivalent

Mixers :: a) Silicon point contact

b) Schottley barrior diodes : Si / GaAs

(Broad band)

Mixers

- ✓ Many super heterodyne type Radar receiver do not use a low-noise RF Amplifier. LNRFA
- ✓ The first stage is simply the mixer instead LNRFA

The Function of the mixer is to convert RF Energy to IF Energy with minimum loss and without spurious responses.

Mixers

- Silicon point-contact and Schottky-barrier diodes Mixers, Semiconductor contacts have been used as mixing element.
- Schottky-barrier diodes are made of either silicon or GaAs, with GaAs preferred for the higher MW frequencies
- Schottky-barrier have lower noise figure and lower flicker noise, than conventional point-contact diodes.

1. Conversion Loss
2. Noise Temperature Ratio.

Conversion Loss

- ✓ Conversion loss of the Mixer is defined as

  Lc = Available RF Power/Available IF Power.

- ✓ It is a measure of the efficiency of the mixer in converting RF signal into IF.

  Lc (Conversion Loss) varies from 5 to 6.5dB.

  Theoretical can never be < 3dB.

- ✓ A crystal mixer is called " broad band“ when the signal and image frequencies are both terminated in matched loads.

Conversion Loss cont…

- ✓ The image frequency is defined as that

  Frequency which is displaced from the local oscillator frequency f_{LO} by the IF Frequency, and which appear on the opposite of the L.O frequency as the signal frequency f_{RF}.

- ✓ Short -circuiting or open- circuiting the image frequency termination result in a narrowband mixer.

- ✓ The Conversion loss, Lc is less in the narrowband than is the broad band mixer about 2 db Lower

- ✓ broad band mixer has been simpler to achieve and less critical than a narrowband mixer.

2. NOISE-TEMPERATURE RATIO.

✓NOISE TEMPERATURE RATIO of a crystal mixer is defined as Tr = Actual available IF Noise power/ Available noise power from an equivalent resistance

$$T_r = \frac{F_c k T_0 B_n G_c}{k T_0 B_n} = F_c G_c = F_c / L_c$$

Fc= Crystal mixer noise figure ;

Lc= 1/Gc = Conversion loss.

BALANCED MIXER (Narrow Band Mixers)

Introduction

- Because of the non-linear action the mixer the LO signal can appear at the IF Frequency
- The LO Noise must be removed if receiver sensitivity is to maximized
- One method for eliminating LO noise that interferes with the desired signal is to insert a narrow-band pass RF Filter Between LO and the Mixer

Balanced mixer

- The Center Frequency of the filter is that of the LO, and its BW must be narrow so that LO noise at the signal and the image frequencies do not appear at the mixer
- A method of eliminating LO Noise with out the disadvantages of a narrow bandwidth filter is the balanced mixer
- A balanced mixer uses a hybrid junction, a magic T or an Equivalent.

There are four port junctions. Fig1 : illustrates magic T , in which the LO and RF signals are applied to two ports. Diode mixer are in each of the remaining two arms of the magic T.

At one end of diodes the sum of of RF and LO signals appears , at the other diode difference of the two obtained.

LO would be applied to H plane arm, and RF would be applied to E plane arm

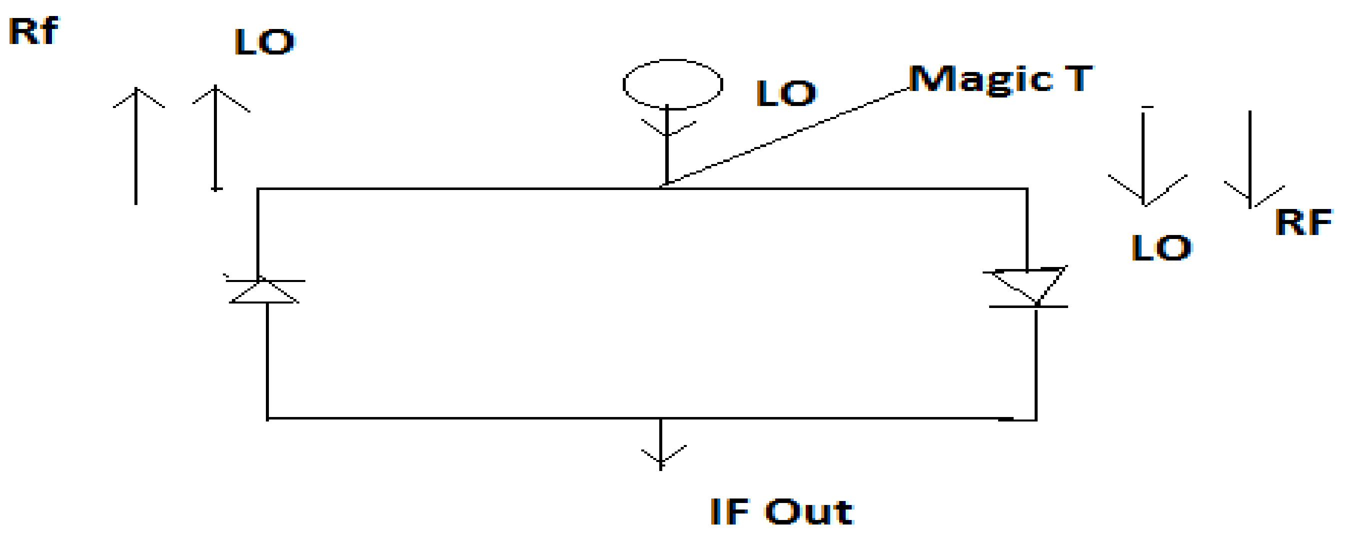


Fig: Principle of the Balanced mnixer based on Magic T

Receiver protectors

1. Passive TR limiter is widely used as a receiver protector
2. Solid state limiters
3. Ferrite limiters
4. Circulator and receiver protector
5. Duplexer protector :On transmission it protects a receiver from the damage (branch type and balanced duplexers)
6. PIN diode protectors may also be used to achieve additional sensitivity time control(STC)

Receiver protectors

- A receiver protector is a necessary in addition to the duplexer to limit the receiver input with in a nanosec, and fast acting PIN diodes are useful for purpose
- The TR is not usually energized when the radar is turned off,
- more power is needed to break down the TR than when it is energized

- Radiation from near by transmitters may therefore damage the receiver with out firing the TR
- To protect the receiver under these conditions
- A mechanical shutter can be used to short circuit the input to the receiver whenever the radar is not operating.

must be designed to attenuate a signal by 25 to 50dB

- TR is not perfect switch ; some transmitter power always leaks through the receiver
- The envelop of RF leakage might be shown in fig.

- The short duration, large amplitude “spike” at the leading edge of the leakage pulse is the result of the finite time required for the TR to ionize or breakdown order of 10 nsec
- After the gas in the TR tube is ionized , the power leakage through the tube is considerably reduced from peak value of the spike.
- This portion of the leakage pulse is termed the flat

- Damage to the receiver front end may result when either the energy contained with in the spike or the power in the flat portion of the pulse is too large
- Spike leakage of one erg or less

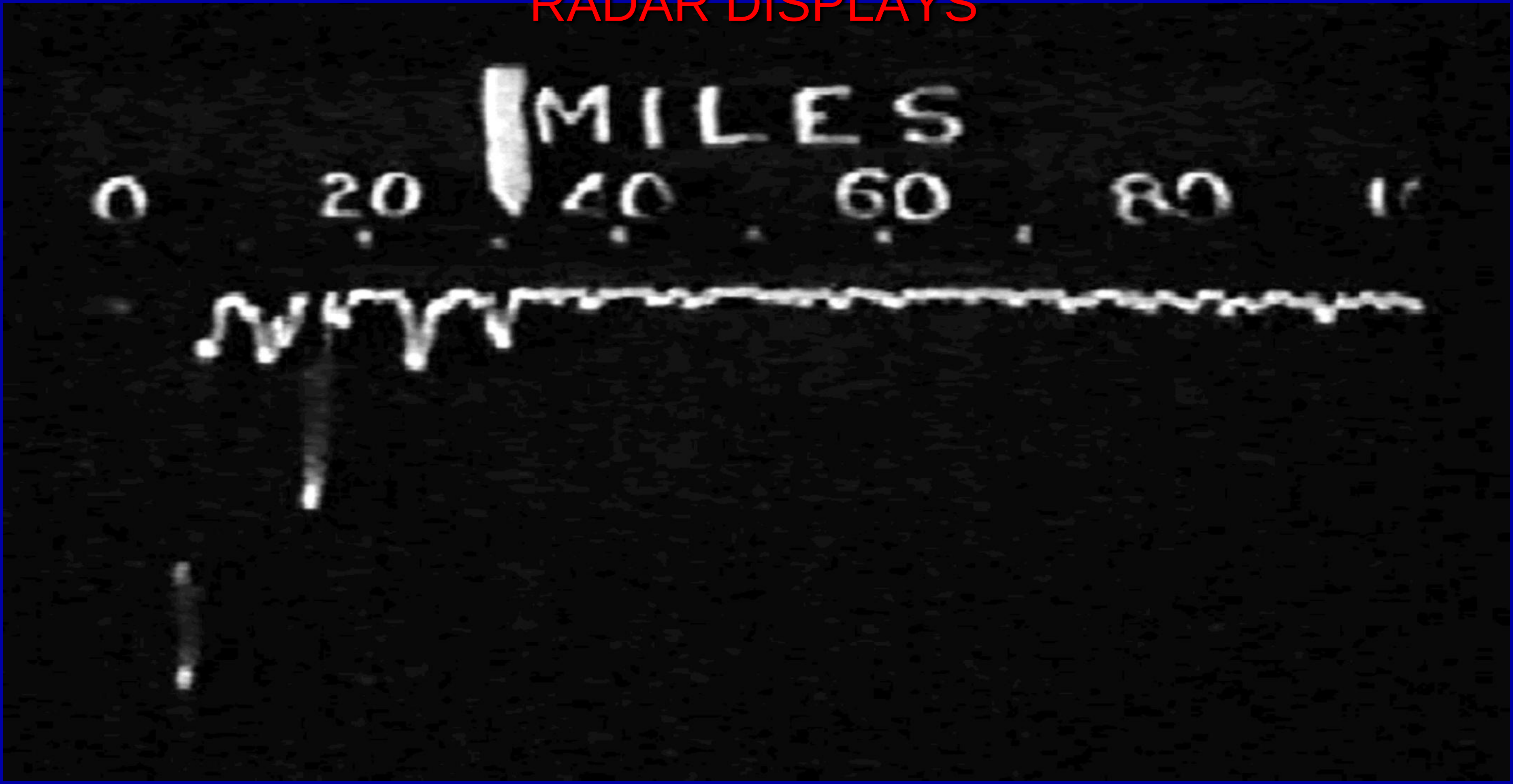
RADAR DISPLAYS

(I) Raw video : when displays connected directly to the video output of the receiver, the information displayed is called raw video

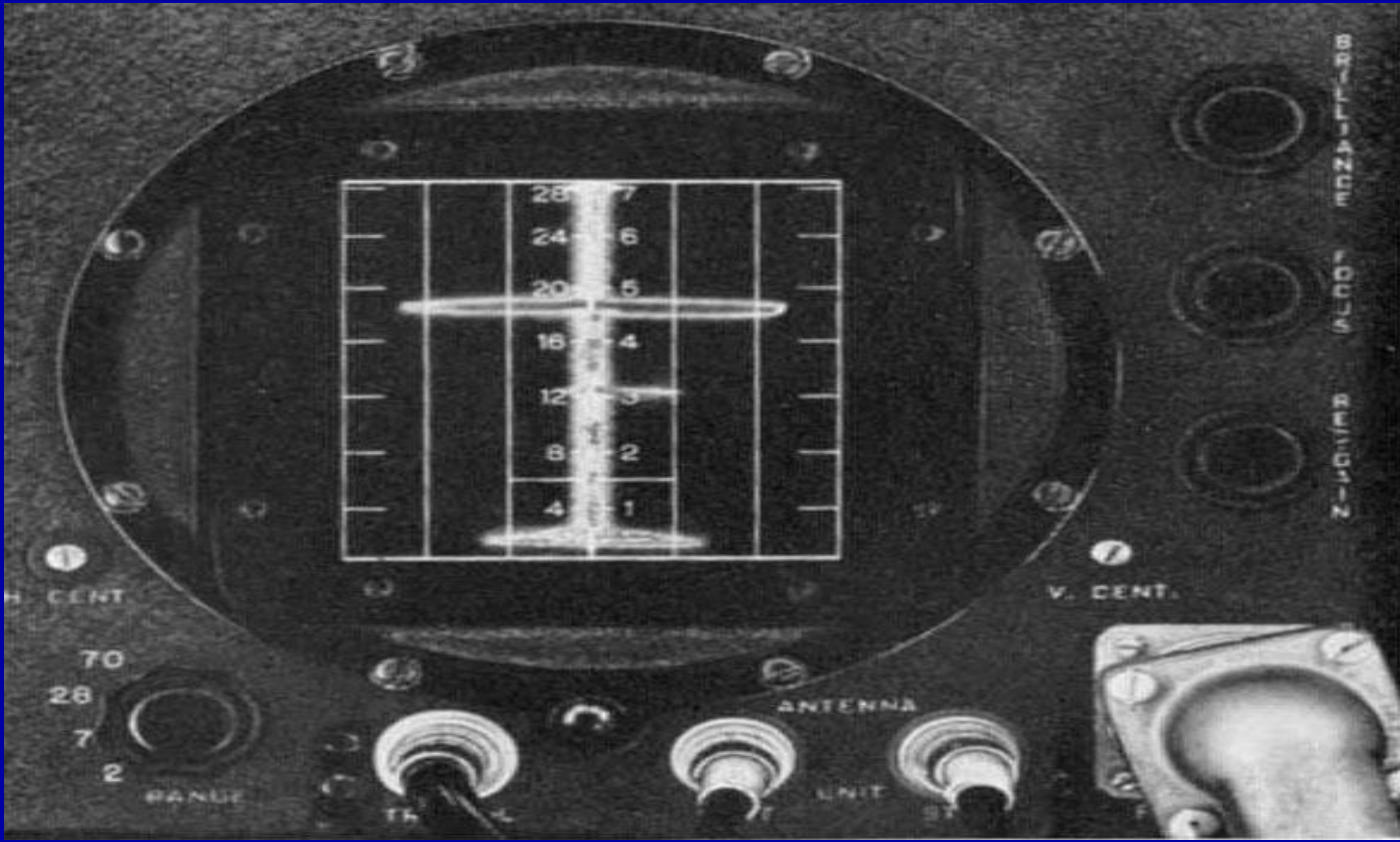
(II) Synthetic Video: when the receiver video output is first processed by an automatic detector or automatic detection and tracking processor(ADT), the output displayed is called synthetic video

1. CRT display : has been almost universally used as radar display
    1. Deflection modulated CRT
    2. Intensity modulated CRT

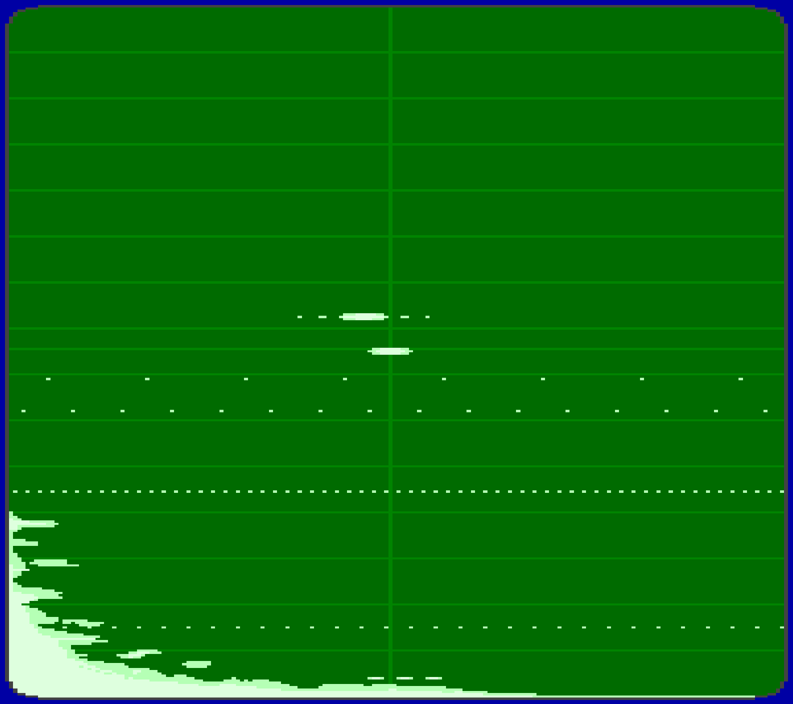
RADAR DISPLAYS

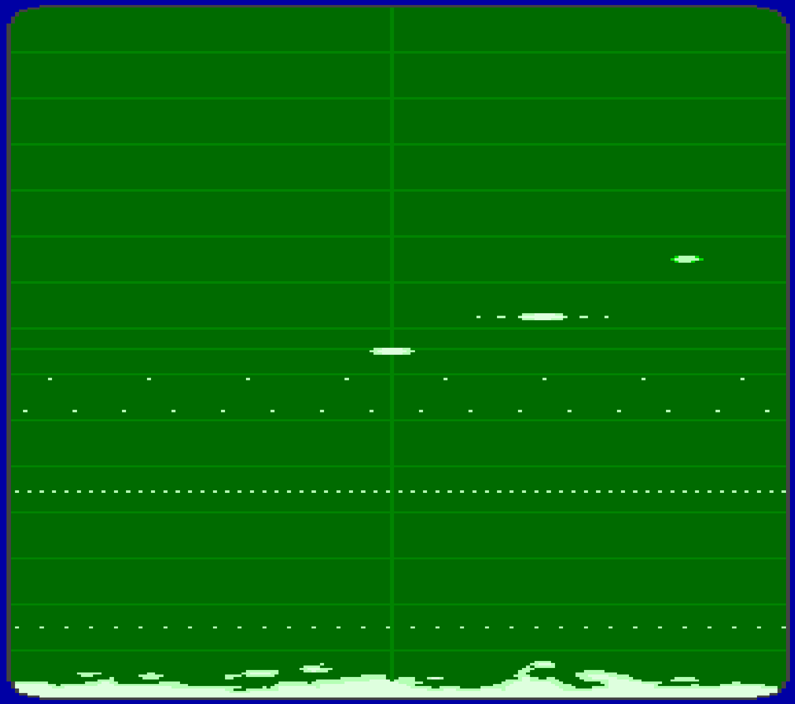


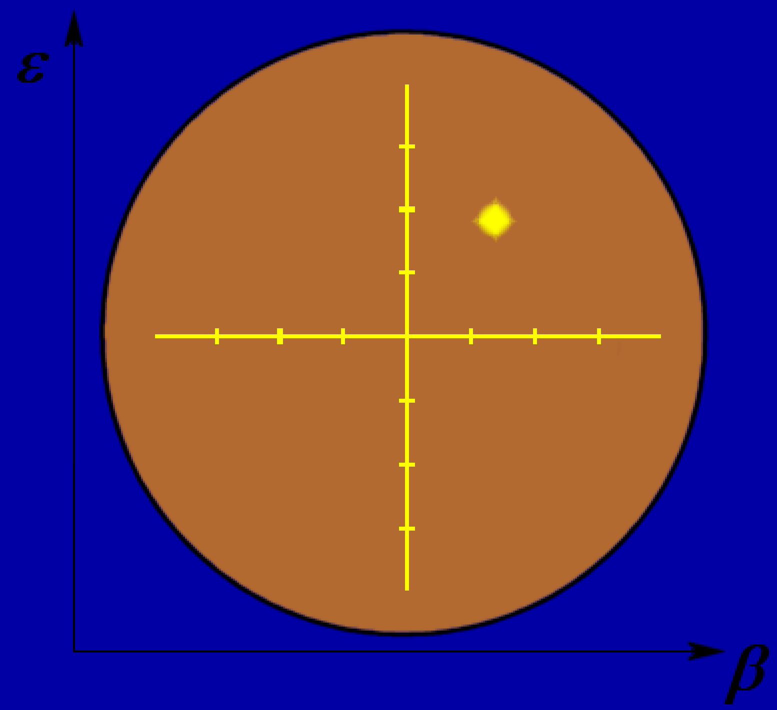
The original radar display, the **A-scope** or **A-display**, shows only the range, not the direction, to targets. Some people referred to these displays also as **R-scope** for *range scope*. A-scopes were used on the earliest radar systems during World War II,
This image shows several target "blips" at ranges between 15 and 30 miles from the station. The large blip on the far left is the leftover signal from the radar's own transmitter, targets in this area could not be seen. The signal is inverted to make measurement simpler.



The L-scope was basically two A-scopes placed side-by-side and rotated vertically. By comparing the signal strength from two antennas, the rough direction of the blip could be determined. In this case there are two blips, a large one roughly centred, and a smaller one far to the right.






ε
β

A **C-scope** displays a "bullseye" view of azimuth vs. elevation. The "blip" was displayed indicating the direction of the target off the centreline axis of the radar, or more commonly, the aircraft or gun it was attached to. They were also known as "moving spot indicators", the moving spot being the target blip.

Almost identical to the C-scope is the **G-scope**, which overlays a graphical representation of the range to the target.[1] This is typically represented by a horizontal line that "grows" out from the target indicator "blip" to form a wing-like diagram

The **PPI** display provides a 2-D "all round" display of the airspace around a radar site. The distance out from the center of the display indicates range, and the angle around the display is the azimuth to the target. The current position of the radar antenna is typically indicated by a line extending from the center to the outside of the display, which rotates along with the antenna in realtime.[1]

Radar displays:

Raw video ::

(I) (1)deflection mounted displays: A scope, J, M, O, N, K, R scopes

(II) (2) Intensity modulated : B, C, D, E, H,

RHI (Range Height Indicator) scopes

PPI (Plane Position Indicator also called P-scope)

Synthetic Video :: ADT : Digital computers, microprocessor, micro computers, mini computers, ARM processors

1. Synthetic video display:

Automatic detection and tracking(ADT)

Digital computers used as an ADT: to extract target information results in synthetic display

Air traffic control display

Ex: Air traffic control display in which such information as target identity and altitude is desired to be displayed

- The use of computer

  to generate the graphics and control the CRT display offers flexibility in the choice of such things as range scale

  physical map outlines

  grid displays

  airport runways

  raw video display of several successive radar scans

- In long range air traffic control radar located in busy area these might be more than a hundred target for display extracted

- ✓ The data on the synthetic display must be refreshed

  at a sufficiently high rate to obtain a high brightness and to avoid flicker

- ✓ When the no. of displays are used with the

  of singe radar,

  a dedicated mini computer can be used at

  display position for the refresh of data

Principle of direction finders

When the ship reached to the port

- ✓ Loop antenna used as a directional finder
- ✓ Radio direction finder are still widely employed in radio navigation in variety of forms.
- ✓ Direction of radio transmission from a port to aid the ship to reach port using directional antenna
- ✓ An aircraft approaching an airport needs greater precision in direction finding, for which specialized antenna is employed in the aircraft or at the airport

Principle of direction finders

- ✓ These directional finders are specially called homing systems or radio ranges
- ✓ All the directional finders, the determination of direction is made by utilizing the directional property of a loop antenna or modified form

Aircraft Homing and Instrument Landing System

- Homing
- Instrument landing system
- Instrument landing aids
- VHF Omnirange (VOR)

Instrument Landing System

1. Homing

The guidance of an aircraft towards an airport is called homing.

In busy airports, large number of aircrafts are scheduled to arrive simultaneously,

the pilot of each aircraft must know its own bearing in flying, with precision

other wise such a simultaneous approach to an airport by no. of aircrafts may lead to collision between adjacent aircrafts

Instrument Landing System

- Instrument Landing System (ILS)

  When the aircraft approaching closely to the airport the landing of an aircraft is often aided by radio aids called ILS.

  It is useful during poor visibility conditions and during night.

▪ Instrument Landing Aids (ILAs)

- ✓ Radio aids for landing of an aircraft to the airport are called Instrument Landing Aids.
- ✓ The Radio aids may be incorporated with in the aircraft operated and controlled by the pilot. These are called Instrument Landing Systems.
- ✓ GCA (Ground Control Approach) : Alternatively, it may be systems controlled from the ground when the pilot is to landing following instructions from the ground control operator obtained from the Ground Control Approach systems

- I.L. Systems enables blind landing of an aircraft under poor visibility conditions.
- The I.L. Systems guides the air craft both in elevation and azimuth supported by an aid called Radio Altimeter.
- Elevation guidance using radiation pattern
- Elevation guidance using lobe switching
- I. L. Systems is also called as the guide slope system in airports (UHF 339.3 - 335 MHz)

Radio Altimeter

- A Radio altimeter is designed to the altitude indication of an aircraft while it is landing phase is based on a FM-CW radar
- Due to the modulation the transmitted frequency will fallow the modulation
- Fig c The transmitted frequency at the instant 0,when the modulation wave from passes through a zero, with the carrier frequency fc

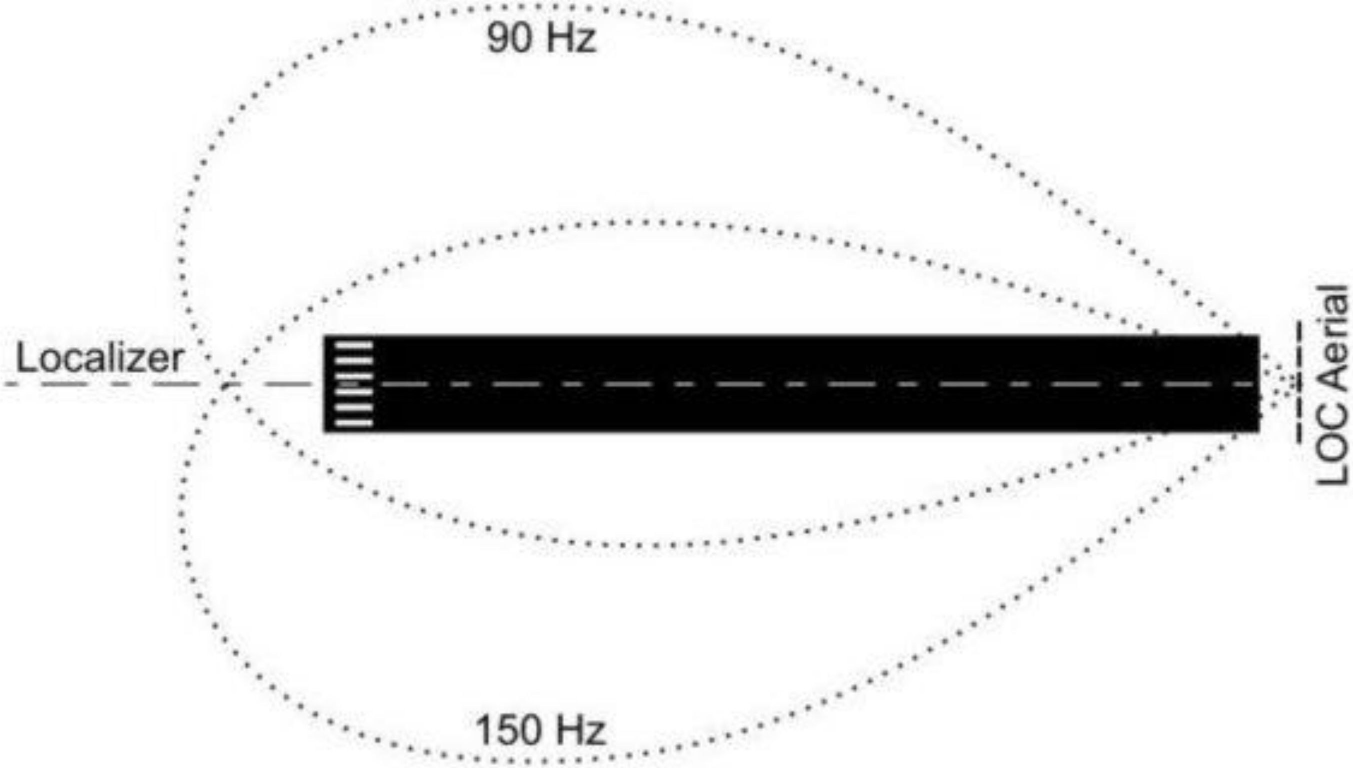
Radio Altimeter

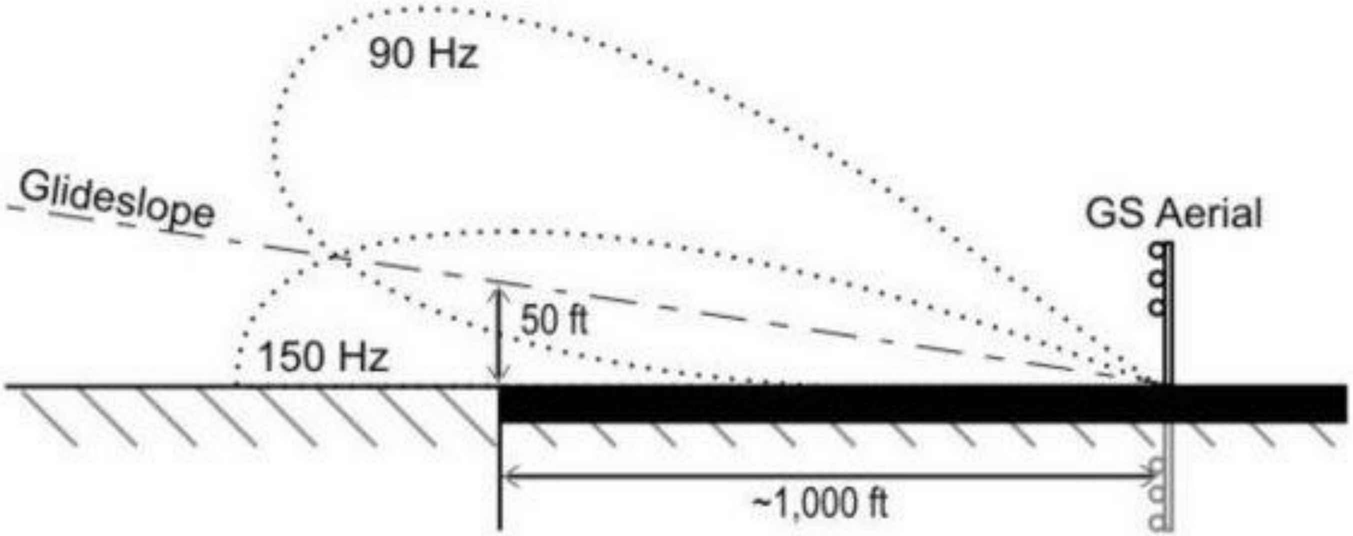
- This transmission will be received back the reflection at the ground after delay

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

- During the delta t the transmitted frequency is changed to a new value fc differing from fc by

$$f_b = f_c' - f_c$$


90 Hz
Localizer
LOC Aerial
150 Hz


90 Hz
Glideslope
GS Aerial
50 ft
150 Hz
~1,000 ft

LOCALIZER

- Localizers operate in the VHF range and provide horizontal course guidance to runway centerline.
- Transmitters are located on the centerline at the opposite end of the runway from the approach threshold.
- The signal transmitted consists of two fan shaped patterns that overlap at the centre. The overlap area provides the on-track signal.
- The angular width of the beam is between 3°and 6°. Normally width is 5°, resulting in full scale deflection at 2.5°.
- The width of the beam is adjusted to be 700 feet wide at runway threshold.
- beginning with X, aligned localizer identifiers begin with I.

- The localizer may be offset from runway centerline by up to 3°. Localizers offset more than 3° will have an identifier
- A cautionary note will be published in the CAP whenever localizer is offset more than 3°.
- Normal reliable coverage of localizers is 18nm within 10° of either side of course centerline and 10nm within 35°.
- Localizer installations provide back course information, and non-precision localizer back course approaches may be published.
- Caution: a localizer signal is transmitted differently than a VOR radial. Aircraft receivers are not supplied with azimuth information relative to magnetic or true north. It is simply a beam aligned with the runway centerline.

Glide Path

- Glide path information is paired with the associated localizer frequency.
- The glide path is normally adjusted to an angle of 3° (may be adjusted 2° to 4.5°) and a beam width of 1.4°(0.7° for full scale deflection).
- The antenna array is located approx. 1000ft from the approach end of the runway and offset approx. 400ft. (if glide path is followed to the pavement touchdown point will be at the 1000ft markers)
- In installations with an ILS serving both ends of a runway the systems are interlocked so only one can operate at a time.
- Note: on a standard 3° glide path 320ft/1nm can be used to verify.

RUNWAY LIGHTING AND TRANSMISSOMETERS

- The following must be fully serviceable to meet CAT II/III standards:
- Airport lighting:
  - approach lights
  - runway threshold lights
  - touchdown zone lights
  - centerline lights
  - runway edge lights
  - runway end lights
  - all stop bars and lead-on lights
  - essential taxiway lights
- ILS components:
  - localizer
  - glide path

- RVR equipment:
  - CAT II- two transmissometers- approach end, mid-field
  - CAT III- three transmissometers- approach end, mid-field, departure end
- Power source:
  - Airport emergency power as primary power source for all essential system elements.
  - Commercial power available within one second as a backup.

What is ILS ?!

- An **Instrument Landing System** (**ILS**) is a ground-based instrument approach system that provides precision guidance to an aircraft approaching and landing on a runway.
- It uses a combination of radio signals(VHF-UHF) and, in many cases, high-intensity lighting arrays to enable a safe landing.
- Concept: modified AM- Space Modulation

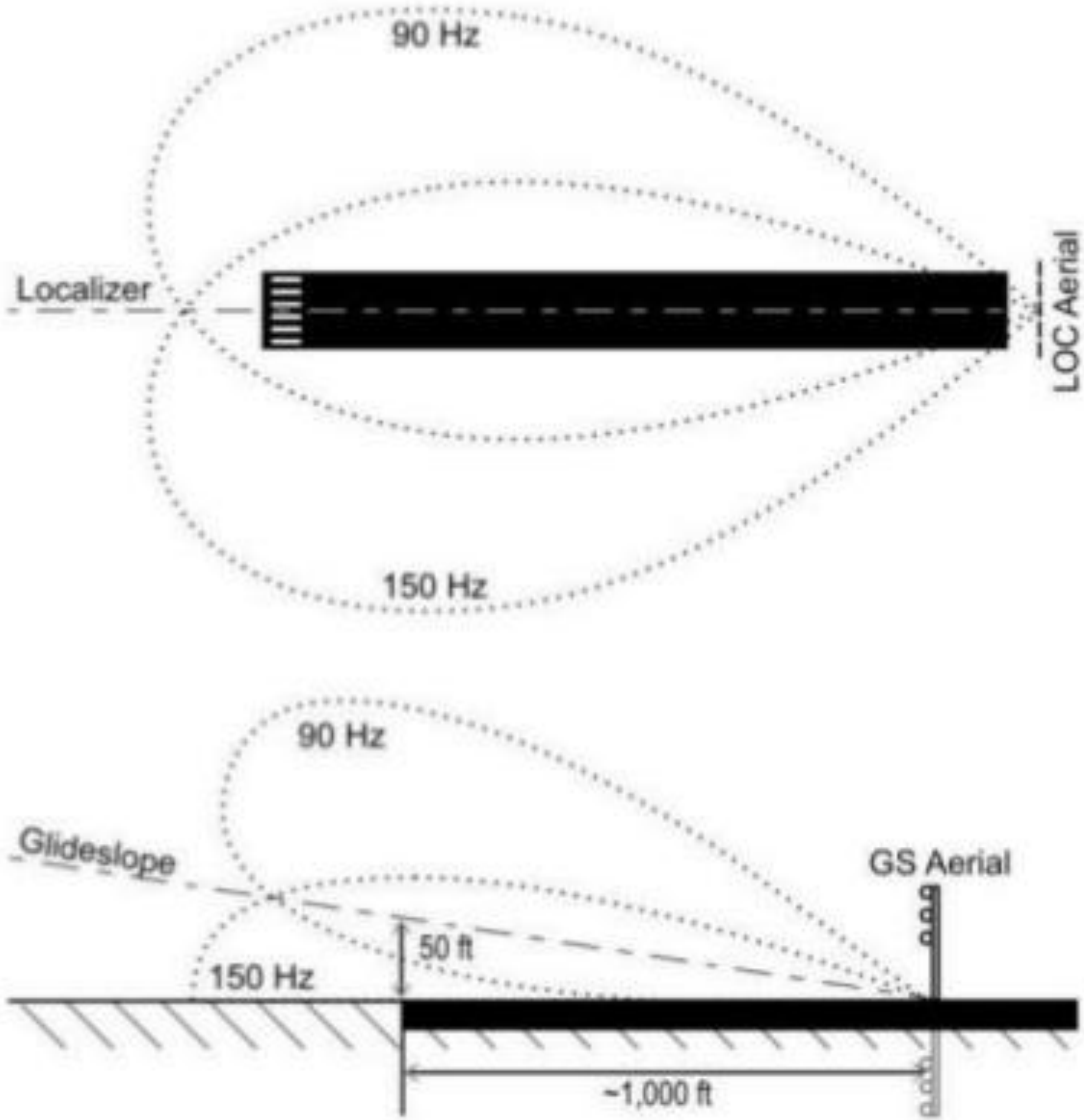
Why is it employed ?!

1. To enable safe landing during reduced visibility due to fog, rain, or snow.
2. If an Aircraft is considerably ‘heavy’ for a runway length, guidance to the exact ‘touch-down’ zone is required.
3. In order to enable ‘Auto-land’ in newer aircrafts, ILS signals are essential.

What is it comprised of ?

1. Localizer (LOC) : lateral guidance
2. Glide Slope (GS): vertical guidance
3. Marker Beacons

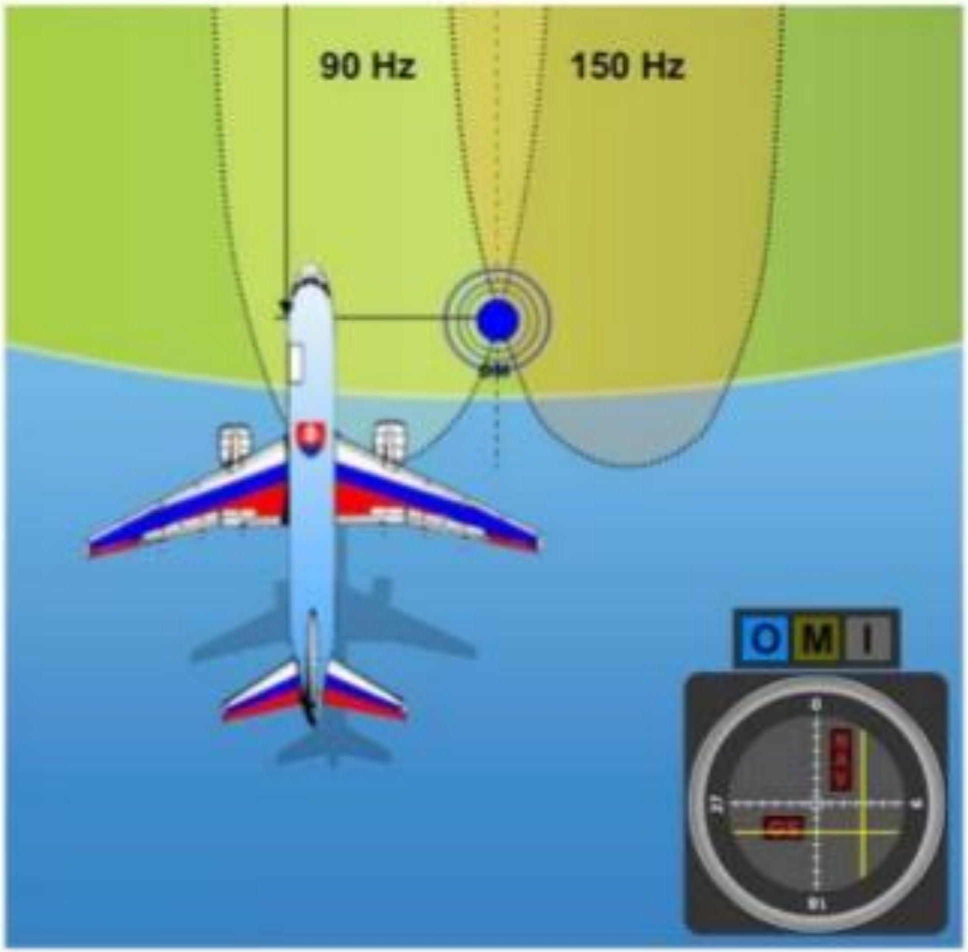
Illustration



1. How does LOC work ?!

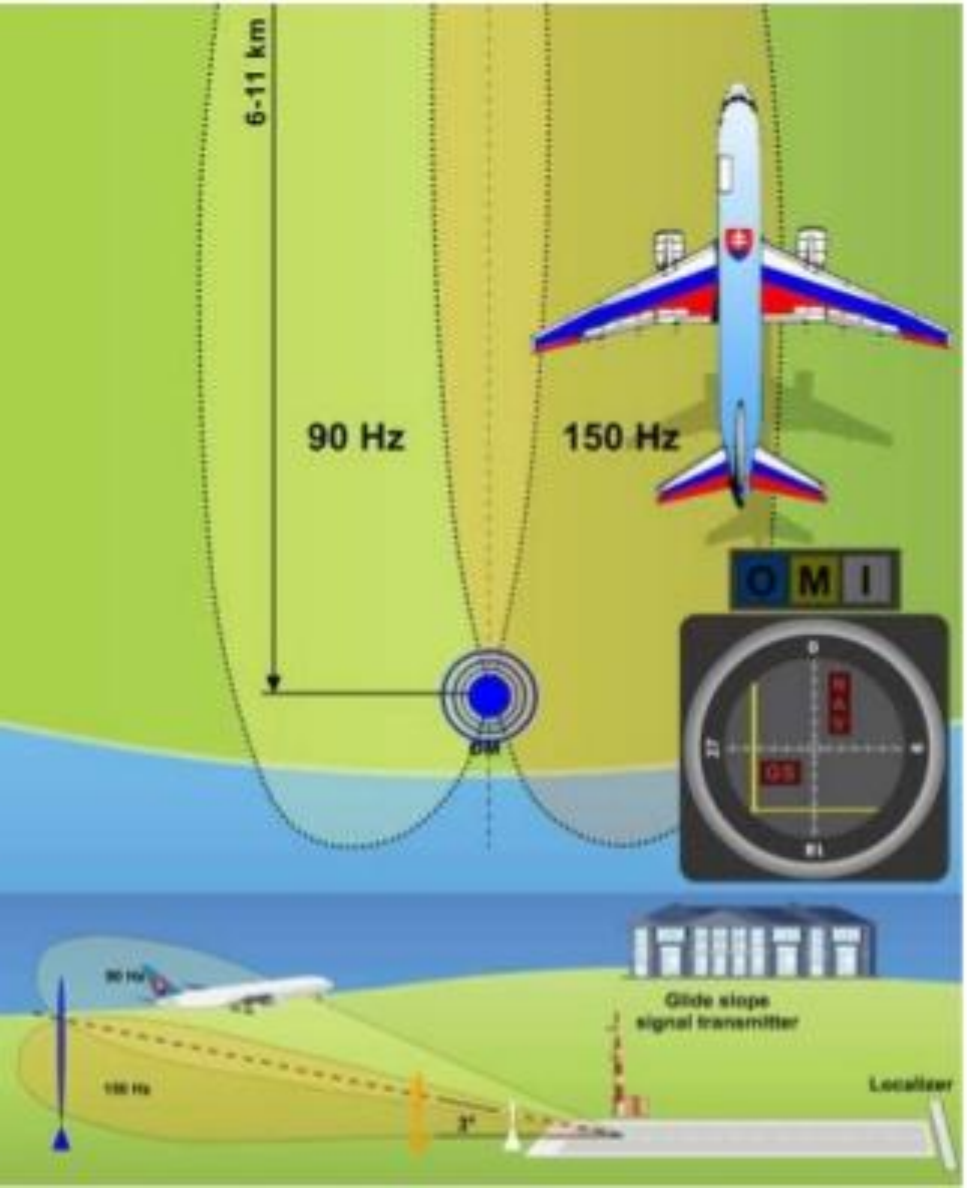
- Localizer transmit two signals which overlap at the centre.
- It operates in the **VHF** band: **108MHz to 117MHz**
- The left side has a 90 Hz modulation and the right has a 150 Hz modulation.
- The overlap area provides the on-track signal.
- For example, if an aircraft approaching the runway centre line **from the right, it** will **receive more of the 150 Hz modulation** than 90Hz modulation.
- Difference in **Depth of Modulation** will align the aircraft with the runway centre line.

Airplane Approaching to the left of runway center line.



Observe the yellow NAV vertical pointer line tracking the runway center line and moving towards right.

Airplane Approaching above 3˚ glide path



Observe the yellow GS horizontal pointer line tracking the 3˚ glide path and moving downwards.

3. What do Marker Beacons do?

They aid in indicating the distance of the aircraft from the runway.

1. **Outer Marker (OM)**

   The outer marker is normally located 7.2 to 10 km (4.5 to 6 mi) from the runway threshold. The cockpit indicator is a blue lamp that flashes in unison with the received audio code. The purpose of this beacon is to provide height, distance, and equipment functioning checks to aircraft on intermediate and final approach. On the aircraft, the signal is received by a 75 MHz marker receiver. The pilot hears a tone from the loudspeaker or headphones and a blue indicative bulb lights up.

2. **Middle Marker(MM)**

   The middle marker should be located so as to indicate, in low visibility conditions, the missed approach point, and the point that visual contact with the runway is imminent, ideally at a distance of approximately 3,500 ft (1,100 m) from the threshold. The cockpit indicator is an amber lamp that flashes in unison with the received audio code.

3. Inner Marker (IM)

The inner marker will be located so as to indicate in low visibility conditions the imminence of arrival at the runway threshold. This is typically the position of an aircraft on the ILS as it reaches Category II minima. Ideally at a distance of approximately 1,000 ft (300 m) from the threshold. The cockpit indicator is a white lamp that flashes in unison with the received audio code.

CATEGORIES OF ILS

APPROACH CATEGORY	DECISION HEIGHT OR ALERT HEIGHT (MINIMUM HEIGHT ABOVE RUNWAY THRESHOLD OR TOUCHDOWN ZONE)	RUNWAY VISUAL RANGE("RVR")	VISIBILITY MINIMUM
I	200 feet (61 m)	550 m or 2400 ft (1200 ft is approved at some airports), increased to 800 m for single crew operations	800 m (1600 ft or 1200 ft in Canada)
II	100 feet (30 m)	300 m or 1000 ft	N/A
IIIa	50 ft < DH < 100 feet (30 m)	200 meters (660 ft)	N/A
IIIb	0 < DH < 50 feet (15 m)	75 meters (246 ft) (JAA)< RVR < 200 meters (660 ft)	N/A
IIIc	No DH	No RVR	N/A

Microwave Landing System

- MLS is an all-weather, precision landing system originally intended to replace or supplement ILS installations
- MLS has a number of operational advantages-

i. wide selection of channels to avoid interference with other nearby airports,
ii. excellent performance in all weather,
iii. wide vertical and horizontal ‘capture’ angles.

MLS facts

- Uses a carrier of 5GHz or more
- GS Signal can be caught at an altitude of 5km !
- Used by Space Shuttles- angle of descent-19^{o}
- Accuracy – 4cm !
- Prevalent in European countries
- Phased out from American airports in 2009

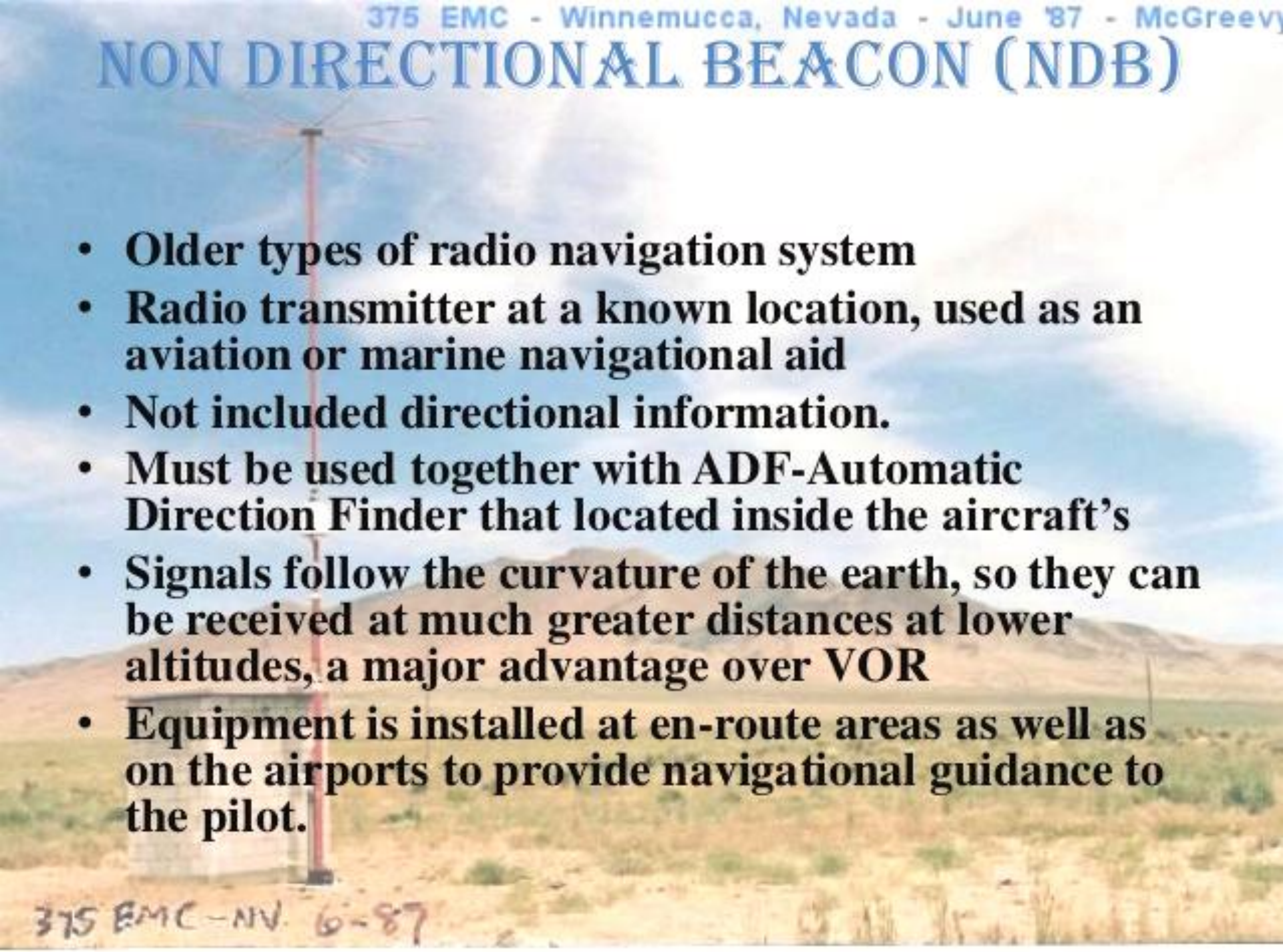
2. How does the GS work ?!

- **GS** operates in **UHF** band: **329 to 335 MHz**
- Glide path antenna produces two signals in the vertical plane.
- The upper has a 90 Hz modulation and the bottom has a 150 Hz modulation.
- For example, if an aircraft approaching the runway too high, it will receive more of the 90 Hz modulation than 150Hz modulation.
- Difference in Depth of Modulation will align the aircraft with the **3º glide path**.

INTRODUCTION

NAVIGATIONAL EQUIPMENT

- **NDB (Non Directional Beacon)**
- **ADF (Automatic Direction Finder)**
- **VOR (VHF Omni-directional Range)**
- **DME (Distance Measuring Equipment)**
- **ILS (Instrument Landing System)**
- Marker Beacons
- Area Radar, Approach Radar
- **GPS (Global Positioning System)**
- **Approach Lighting**



NON DIRECTIONAL BEACON (NDB)

- **Older types of radio navigation system**
- **Radio transmitter at a known location, used as an aviation or marine navigational aid**
- **Not included directional information.**
- **Must be used together with ADF-Automatic Direction Finder that located inside the aircraft's**
- **Signals follow the curvature of the earth, so they can be received at much greater distances at lower altitudes, a major advantage over VOR**
- **Equipment is installed at en-route areas as well as on the airports to provide navigational guidance to the pilot.**

AUTOMATIC DIRECTION FINDER(ADF)

- **Operate in a low or medium frequency band of 200 to 415 kHz.**
- **It is used for identifying positions, receiving low and medium frequency voice communications, homing, tracking, and for navigation on instrument approach procedures**
- **Major advantage over VOR navigation in the reception is not limited to line of sight distance**
- **The ADF can receives on both AM radio station and NDB (Non-Directional Beacon)**
- **Widely used today**

VOR (VHF OMNI-DIRECTIONAL RANGE)

- **Broadcasts a VHF radio composite signal including the station's identifier, voice (if equipped), and navigation signal. The identifier is Morse code.**
- **Located along air routes and airport to ensure continuity of guidance.**
- **When military tactical air navigation (TACAN) equipment is installed with the VOR, it is known as a VORTAC.**
- **Primary navigational aid (NAVAID) used by civil aviation in the National Airspace System (NAS).**

DISTANCE MEASURING EQUIPMENT

- Transponder-based radio navigation technology that measures distance by timing the propagation delay of VHF or UHF radio signals.
- Provide continuous and accurate indication of the slant range distance (expressed in nautical miles) of an equipped ground reference point
- composed of a UHF transmitter/receiver (interrogator) in the aircraft and a UHF receiver/transmitter (transponder) on the ground.
- also can be co-located with an ILS glide slope or localizer where it provides an accurate distance function.

INSTRUMENT LANDING SYSTEM

- Ground-based instrument approach system that provides precision guidance to an aircraft approaching and landing on a runway, using a combination of radio signals and, in many cases, to enable a safe landing
- Guide the pilot during the approach and landing.It is very helpful when visibility is limited and the pilot cannot see the airport and runway.To provide an aircraft with a **precision final approach.**

Consists of Ground Installations and Airborne Equipments

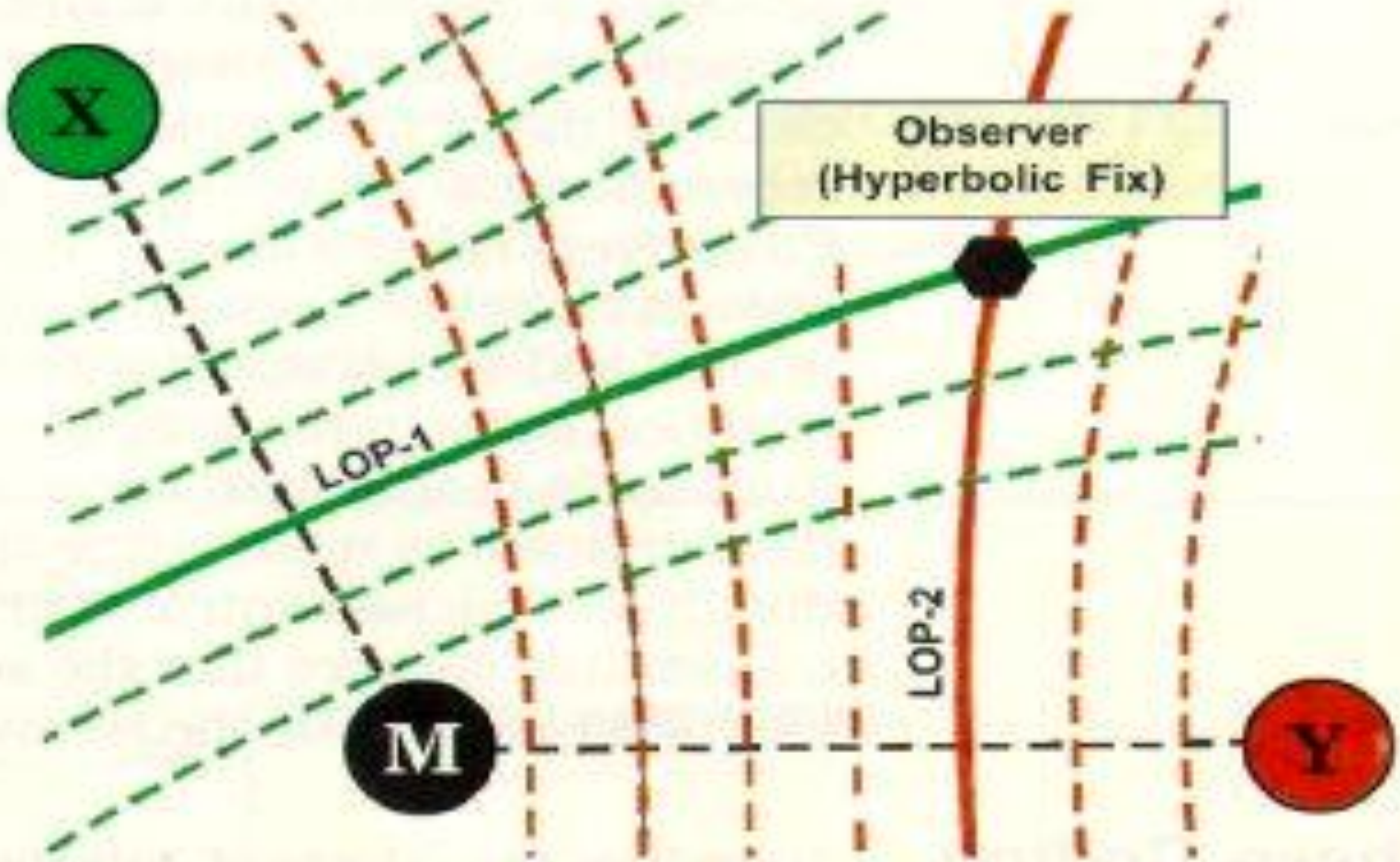
- **Ground Installations** – Localizer, Glide path, Marker Beacons
- **Airborne Equipments** - ILS indicator , Localizer and Glide Path

TRAFFIC COLISION AVOIDANCE SYSTEM

- Designed to reduce the incidence of mid-air collisions between aircraft.
- Warns pilots of the presence of other transponder-equipped aircraft which may present a threat of mid-air collision
- Consists of hardware and software that together provide a set of electronic eyes so the pilot can "see" the traffic situation in the vicinity of the aircraft

GLOBAL POSITIONING SYSTEM

- Official name are **Navigational Satellite Timing And Ranging** Global Positioning System (NAVSTAR GPS)
- Provides accurate reliable location and time information in all weather and at all times and anywhere on or near the Earth when and where there is an unobstructed line of sight to four or more GPS satellites
- Freely accessible by anyone with a GPS receiver
- Provides three-dimensional location (latitude, longitude, and altitude) plus the time
- USERS :
  Aircraft Navigation,Civilian(individual),Military Railroad System,Marine ,Weather Prediction, Automobile ,Sports(sky diving)



LOP - The locus of all positions where the observed time difference between the arrival of signals from two stations are constant.

The LOP forms a hyperbola which gives rise to the designation of Loran-C as a hyperbolic radionavigation system.

Graphics: Orbler Technologies AB

Hyperbolic Navigational systems

- LORAN-A
- LORAN- C
- OMEGA

DECCA navigator company :

- DELRAC
- Inland Shipping aids

- VOR (VHF Omni range)

LORAN-A and LORAN-C

- LORAN : Long rang aid to navigation
- Principle
- Operating frequency
- Range
- Transmitted power

OMEGA

- OMEGA was the first truly global navigation system for aircraft. it enabled ships and aircraft to determine their position by receiving VLF radio signal transmitted by a network of fixed terrestrial radio beacons, using a receiver unit.
- Principle: Omega is a phase difference system similar to DECCA

✓ but operating at lower frequency in the VLF band around 10 kHz at which the reliable ground wave courage may be increased to a few thousand kilometers with,

✓ base line lengths of several thousand kilometers