Radio theory

- **Phase: Fraction** of one wavelength expressed in **degrees** from **000 - 360**
- **Cycle:** A complete series of values of a **periodical process**
- **Frequency:** Number of **oscillations/cycles** per **second** of an **electromagnetic** wave
- **Phase difference: ANGULAR difference** between two cycles of equal wavelength
- **Wavelength (λ) = Speed of light (m/s) ÷ frequency (Hz)**
- **SSB:** Used in **HF & VOLMET, AM**
- **Modulation:** Addition of a **low frequency** signal onto **high frequency carrier wave**
- **Phase** modulation**:** Used by **GPS, Helical** antennas as GPS have <u>circular polarization</u>
- **Pulse** modulation**: Radar**
- **NON A1A** modulation/**keying:** Interrupting carrier wave to break it into **dots & dashes** does **not change** frequency or amplitude
- **MSI: Modulation, signal, information**
- **Keying:** Interrupting the **carrier** wave to break it into **dots & dashes**

Antennae

- **Electrical** field **E same direction** as aerial
- **Magnetic** field **H perpendicular** to aerial
- **Antennae length = half wavelength (λ)**
- **POLARIZATION:** Orientation of the plane of oscillation of the **electrical** component **E**
- **AC** induced **parallel** to wire, but **remote** from it
- **First wire** radiates energy to **space, second wire** induces **AC**
- **Flat (Slotted) plate** eliminates/generates **less side lobes** than **parabolic**
- **Helical** antennae used by **GPS** due to **circular polarization**
- **Radar** uses **one** antenna for **both transmitting and receiving**
- **Directional** antennas: **Loop(ADF), parabolic, slotted planar, helical**
- **Dipole** antennas: Are the **simplest**. Needs the receiver & transmitter of **electrical field** on the **same planes**

Radio propagation

- **Electromagnetic** wave : **Sky** wave, **Radio** wave: **Space** wave
- **Absorption:** Energy **taken up** by atmosphere
- **Attenuation:**
  - **Weakening** of the **radio wave**.
  - <u>Lower **frequency, greater attenuation**</u>**. (RANGE)**
- **Diffraction:** Passing/bending over impenetrable **obstacles** with dimensions close to **wavelength**
- **Reflection:** Change in **direction** of radio wave after reaching a **boundary (**Used by **HF)**
- **Refraction:** Change in **direction/bending** due to a change in **speed**, as it passes area of different **electrical conductivity. (SKYWAVES) (**Used by **HF)**
- **Interference:** Superimposition of two radio waves of **same frequency**
- **Night effect/Fading:** Occurs at **night, Interference** of **ground wave** with <u>**sky wave,**</u> **Ionospheric reflection. HF** frequency should be **reduced** at **night, higher frequency** & **higher Ionospheric layer** = **larger skip distance**
- **ONLY HF** propagates via **SKYWAVE** for practical use and the ground wave is really small

Direction finding

- **Range = 1.23 x (√Transmitter + √Receiver)**
- **QUJ: True TO** station (To Juliet)
  QTE: True FROM station
  QDM: Magnetic TO station (To your Mom)
  QDR: Magnetic FROM station

- Provides **HOMING,** measures **RELATIVE TO/AT STATION.** Do **NOT BANK** when using
- Uses **METRIC** wavelengths, **VHF 118MHz – 136MHz,** Class **A: 2° B: 5° C: 10°**
- ATC must have at least **2** VDFs. Military uses **UHF**
- **Multi-path** error results in **bearing error**
- Uses **loop & sense** antenna
- Night effect: Fluctuating indications

<u>NDB/ADF</u>

- NDB **frequency: 190 - 1750 kHz, HECTOMETRIC/KILOMETRIC** wavelength
- **MH + RB = MB** (My hairy red balls make babies) [MB **to** station aka QDM]
- **Power new ÷ Power old = (Range new ÷ range old)^2**
- ADF/NDB **error: <u>+/-5 ° generally</u>**
- To **double range**, **power x 4**
- **Maintaining RB = maintaining CONSTANT TRACK**
- **RB** angle between where I'm **heading**(AC nose) to where ADF needle is **pointing**
- **True bearing** is **always** given **FROM** VDF station (**QTE**)
- **NDB/ADF** variations at **AIRCRAFT**
  VOR variations at the **STATION**
- Difference between **HOMING** & **TRACKING**
- **Range** of **NDB** determined by **power** & **surface** (land/water) **not affected** by aircraft **height**
  Land range = **2 √Power** in watts
  Sea range = **3 √Power** in watts
- **BFO circuit:** Makes **A1A** signal identifiable by Morse
- **LOCATERS:** Used for ILS, different from NDB in **operations** and **power**
- **EN-ROUTE: Long range**, **LF A1A**
- What does the arrow at the tip of the **RMI** indicate? **QDM**
- **ERRORS:**
  - **Mountain** effect: **<u>Reflection</u>** (For some reason)
  - **<u>Night effect</u>/Fluctuations/Fading: Interference** of **REQUIRED ground wave** with **sky wave, sky wave distortion** of null, max at **dusk** & **dawn,** sky wave **reflected** from **ionosphere (Only for NDB/ADFs)**
  - **Static interference: Thunderstorms** (Most significant)
  - **Coastal refraction: Higher ALT = Lesser error**
  - **Quadrantal: Refraction** of aircraft **fuselage**
  - **Absence of failure warning**
  - **Loop null error:** When plane of loop is at **right angles** to direction of transmitter

<u>VOR</u>

- **Phase** difference = **radial** from VOR
- **RADIAL: Magnetic** bearing of **aircraft FROM station**
- **NDB/ADF** variations at **AIRCRAFT**
  VOR variations at the **STATION**
- **CVOR signal**: Rotates at **30 times/second** giving characteristics of **30Hz AM**
- **DVOR:** Uses **frequency modulation (FM),** more accurate
- Using VOR **outside published range**, may cause **interference** from **other transmitters**
- **Quoted accuracy** applied at **all times**
- VOR **switches off** when there is **measured error** greater than **<u>1°</u>**
- VOR **frequency**: **108 – 117.95MHz (VHF frequency) , METRIC wavelengths**
- **VOT: Test** VOR
- **TVOR: Terminal** VOR, Even frequencies e.g. 108.**2**5, 108.**4**5… etc.
- 1 in 60: Angle **a = (Distance off track x 60) ÷ distance along track**
- **Same radial, different distance:** Reference & variable **both unequal**

Different radial, same distance: Reference **equal** & variable **unequal**
- **TO/FROM** indicator: Tells whether **track equal to selected bearing** will bring you to or away from VOR
- Questions on **CDI/OBS disregard magnetic heading,** questions on **HSI take into account magnetic heading**
- **ERRORS:**
  - **Scalloping (Only for VOR)**
  - **Uneven propagation** over irregular **ground surfaces**
  - **Compass stuck & RMI working: RB unavailable, radial available**
  - **RMI** stuck & ADF still working: **RB** still **available**

DME

- **UHF, 960 MHz – 1215 MHz,** approx. **max range = LOS 200NM, DECIMETRIC SSR**
- **108 – 112 MHz** for **terminal VOR/DME**
- **EPC: 50µs** delay to protect receiver from **reflected pulses, prevent self triggering**
- DME: Processes only **2700 PPS**
- Principle of **time** measurement between transmission & reception of radio pulses
- **More PPS** transmitted during **search** mode than **tracking** mode
- No lock-on during search mode, **PRF** reduces to **60** after **15000 PP** transmitted
- **PRF** transmitting **PP** of interrogators have own unique **rhythm**
- Time between PPS is at **random**
- Transmit & receive on two **different frequencies**, prevent self-triggering **63Mhz apart**
- **Irregular transmission sequence** to determine **from which aircraft** pulse pairs are received
- The **accuracy** of the DME, **decrease with increase in range**. But the **accuracy** of the **groundspeed function/reading/indication increase with increase in range** because the difference between ground range and the slant range gets bigger, **groundspeed less accurate near DME**
- **Co-located** VOR/DME: In **40s** DME **IDENT sounds** once at **1350 Hz (<u>Higher pitch</u>)**
  For **ENR: 600m/2000ft** apart, for **APP: <100ft**
- **DME/P : +/- 0.2NM**
  DME/N: 0.25NM + 1.25% of error
- Signal **interrupted**: Switch to **memory mode** for 10 - 15 s
- DME adjusts to **strongest** signals when saturated
- **LOP**: <u>**Ground distance**</u> on chart with DME at centre
- **Transponder** in **aircraft**, **interrogator** on the **ground**

ILS

- ILS: **Odd** tenths, Frequency **108.1 – 111.95 MHz**
- Principle of **difference in depth modulation [DDM]**
- ILS produces a **RADIATION PATTERN** which is **amplitude modulated [AM]**
- **Glide-slope** uses **UHF**
- **Localizer & marker beacons** uses **VHF**
- **LARD** – Left & above : mod frequency **90Hz** Right & down : mod frequency **150Hz**
- One dot **localiser = 0.5°,** one dot **glideslope = 0.14°**
- Max safe deviation for glideslope for approach : **Half scale deflection**
- **Within half scale deflection = Established**
- Localiser coverage**: 25NM** within **10°** and **17NM** within **35°**
- Glide-path coverage: **10NM** within **8°, intercepted** normally between **3 – 10NM**
- **0.45°** x glide path (**LOWER EDGE**); **1.75°** x glide path (**UPPER EDGE**).
- **Localiser transmitter** position **300m** behind end of **runway**
- **Glideslope transmitter** position **300m** behind **threshold**
- **False beams** found **above** correct glide path
- **1 in 60: [Glide slope x distance x 6080] ÷ 60**
- **ROD = 5 x GS** [For 3° glide slope]

Marker	Modulation	Distance	Colour	Morse
Outer	400Hz	4NM	Blue	Dashes
Middle	1300Hz	0.6NM	Amber	Dots & dashes
Inner	3000Hz	0.04 – 0.24NM	White	Dots

- **ILS markers** transmit at **75MHz, METRIC** wavelengths
- **Middle marker** marks **DH** for missed **CAT I** approach

CAT	Decision Height	Guidance	RVR
I	>200ft	200ft	550m
II	>100ft	50ft	300m
IIIA	<50ft or none	To runway	200m
IIIB	<50ft or none	To runway	>75m
IIIC	None	To runway	No limit

- **DDM : Doubles** as angular displacement **doubles**
- **Immune filter:** Make ILS **localiser (not glide-slope)** less susceptible to interference
- **Beam bends**: Slight curves caused by obstructions, can be followed by **large aircraft**
- **Scalloping:** Erroneous reading/hunting/rapid indications
- **Sensitive area** for vehicles/aircraft are active when **CAT I/II** operations in progress
- **DON'T** mix up **CDI** with a **flight director**, CDI glideslope horizontal bar above, decrease descent rate to recapture line/pitch up
- **Back course:** Align **CDI/HSI** needle so that it points to ILS **inbound** approach **course, OBI reverses** sensing, HSI is correct with **front course** set
- **ILS warning flag:** When **either** 90 or 150 Hz signal is **lost &** when the **percentage modulation** of either the 90 or 150 Hz signal reduced to **zero**

MLS
- **Time referenced scanning beam (TRSB)** using **SHF, CENTIMETRIC** wavelength
- **Principle** of **timing** the passage of **two scanning beams**
- **DME-P** used to obtain distance & **3D position**
- Azimuth: **+/- 40°** of runway centreline at a range of **20NM**
- Consists of **separate** azimuth & elevation transmitters, DME facility
- **200** available channels
- MLS with **no DME** = **ILS capabilities**
- **Multipath** error: Transmission **interrupted for terrain** reflection, **interference** are **insensitive** to MLS
- Aircraft receives **3** times **elevation** info compared to **azimuth** info

Pulse techniques
- Used by **ASMR,SSR,AWR & Approach radar**
- **PRF = 300000 ÷ [Range in Km x 2]**
- **PRF/PRR =** Pulses transmitted per second
- **PRF/PRR** determines **max range**
  Pulse width/length determines **minimum range; minimum useful range** requires **short pulses**
- **Short** pulses more useful for **primary radar, longer pulse length = more range**
- **Double range, power x16**
- To **discriminate** between targets in azimuth, **beam width** is a factor
- High **rotation** rate = target info **rapidly refreshed**

Ground radar
- **Primary search radar**
  Detects aircraft with **no transponder**
  - Displays aircraft **position only**

- Best scan picture = **<u>short pulse length & narrow beam</u>**
- **<u>Continuous waves</u>** for **short range** operation & **<u>eliminates min reception range</u>**
- Uses **<u>one</u>** directional aerial for **<u>both</u>** reception & transmission

* **MTI** erases & eliminates **stationary targets, echoes** that do not **move**
* **ASMR** operates in **SHF**, as EHF gets absorbed by **moisture**, rotates at **60 RPM**
* **Longer wavelength = better penetration**. Wavelength must be longer than precipitation/water droplets to be able to penetrate

<u>AWR</u>

- Frequency = **9375MHz, SHF CENTRIMETRIC** wavelength to detect **LARGE water droplets**
- Two modes:
  - **Pencil beam: Primary** mode, **3-5°, Range = >50-60NM,** more power, narrow
  - **Fan shape/cosecant beam**: Covers a large area, **independent of distance**
    Used in **MAP** mode, **80°, 50 – 60NM**
- **Stabilized** on **pitch** & **roll**
- **Hazardous** to personnel on the **ground**
- **ISO-ECHO**: **Detect** areas of possible **turbulence** in clouds
- **<u>Auto tilt:</u>** <u>Used when</u> **<u>changing altitude</u>**
- **Height ring:** Determines whether AWR is **working**
- **Map** mode: **Ground/terrain** indicated
- Turbulence **indicated** by **fingers, hooks, scallops**
- Increasing **range** = increasing radar **sensitivity** using the **GAIN** knob
- During **climb** tilt **decreased** and vice versa.
- **PWS**: Measures **horizontal** movement of precipitation. **OFF** during **take-off, ON** during **landings**
- **Single** very **bright line** indicates scanning of **cathode ray tube** is faulty
- **Height=[tilt-beam width/2] x range x 100ft**

<u>SSR</u>

- **Ground** transmitter **: 1030 MHz, Aircraft** transponder**: 1090 MHz,** separated by <u>60Mhz</u>
- Principle of transponder/interrogator, **echo return not used**
- **Two pulses** received plus additional **control** pulses **between** them
- **P2** pulse is used to distinguish between **side lobes**
- **P4** pulse: A pulse **after** pulse train, two types
  - **Short:** Mode S blocked, mode **A/C all call**
  - **Long:** Mode **A/C/S all call**
- Mode **S:**
  - **Data-link** &IDENT with **16 million** combinations
  - Mode S **Broadcast** for all **Mode S transponders**
  - Mode S **Selective =** Interrogate only **one** transponder.
  - **ACCURACY: 25 feet**
- Mode **A**: Sends **aircraft identification.** Interval between pulse 1 & 3 = **8µs**
- Mode **C**: Sends **pressure altitude** info in increments of **100ft**. Interval between pulse 1 & 3 = **21 µs**
- **SPI** pulse sent when pilot presses **IDENT,** a **special** pulse **after** normal response train
  And on **controller's** display it **flashes/fills in**
- **Operation:**
  1. **ALT** – Mode **A/C/S** transmitted
  2. **STDBY – Codes** are entered
- **4096** codes for A & C
- Parameters **basic**: **Position**, **squawk, FL, GS & callsign** <u>NO HEADING/SELECTED ALTITUDE</u>
  Parameters **enhanced: <u>SELECTED altitude</u>, Mach, roll angle, IAS, true track, mag heading and <u>no pitch, no temperature,</u>**

- **PSR** compared to SSR shows **only** **target range & bearing** but more **accurate**, however **SSR** consumes **less power**
- **2000**: Entering area where **SSR** operation **not required**
- **Errors:**
    1. **Garbling:** Replies of two or more aircraft in range of **less than 1.7NM,** same **direction/close proximity, overlap** , superposition
    2. **Fruiting:** Aeroplane at range responding to **other interrogations** from other **ATC stations.** **DEFRUITING: Removal** of **random** responses from the display

RNAV

- Method of navigation using a more **direct** flight path within coverage of **station navigation aids** or within limits of **self-contained aids(INS/IRS)** or a **combination** of these, within **any** airspace or flight path, **without** requiring to **fly over** ground facilities
- **Routes**: Segments/waypoints defined as positions **lat/long** based on WGS 84
- Waypoint (**Phantom station**), **valid VOR/DME signal** & **desired course**
- **RNP 1/ Precision** RNAV: Accuracy **+/- 1 NM 95%** of flight time. Aircraft can **compute** an **estimate** of its **position error**
- **RNP 5/ Basic** RNAV: Accuracy **+/- 5 NM 95%** of flight time
- **AR:** Authorization required
- **2D: Horizontal**
  3D: Horizontal & vertical
  4D: Horizontal, vertical & time
- **5 dot HSI:**
    - **En-route:** 1 dot = **1NM**
    - **Approach:** 1 dot = **0.25NM**
    - **VOR:** 1 dot = **2°**
    - **Localiser:** 1 dot = **0.5°**
    - **Glide slope:** 1 dot = **0.14°**
- **2 dot HSI:**
    - **En-route:** 1 dot = **2NM**
    - **Approach:** 1 dot = **0.5NM**

2D RNAV

- Uses navigation **computer** which solves basic sin/cosine **trigonometry,** calculates & uses **auto** computed values, **cross track error**, **distance** to go & **desired course** for **tracking** on **CDI/HSI**
- **Phantom station**: A waypoint defined by **radial & distance** of a **VOR/DME**
- VOR/DME **does not** have to be in range when **entered,** but must be when in use
- Errors: When in **limit range** at **low altitudes** (When near DME slant range error)

4D RNAV

- **Cross track distance** is distance between **actual** position & **great circle track** between active waypoints, displayed by **ND,CDU & HSI**
- Position of waypoints entered via **Lat/long, alphanumeric ICAO identifier** or **radial & distance**
- Selection/entering of the **flight plan** can only done **manually** by **pilot** using the **CDU**
- **Dead reckoning** mode inputs **TAS, heading & last computed W/V,** occurs when only **one VOR** information is used or when **radial** or **distance** information is **not received**
- **Wind vector** calculated from **heading** of **INS/IRS/compass system** & **TAS** from **ADC**
- **ETO: E**stimated **t**ime **o**ver significant point
- **Rho: DME, Theta: VOR**
- **Question tips:**

- Differentiate between **LATERAL** & **VERTICAL** functions
- Differentiate between **INPUTS** & **OUTPUTS** of 4D RNAV

FMS

- Total system error: **position error** in a **(NPA) non-precision approach = +/- 0.3NM** at **95%** probability for **final** approach section
- **GNSS updates** FMS position for drifting IRS
- **Symbol generator (SG)** generates **visual display** on EFIS
- **INPUTS:**
  - **DME distance & radials**
  - **TAS & altitude from ADC**
  - **Heading from heading system**
- **OUTPUTS:**
  - **Distance to waypoint**
  - **Estimated time overhead (ETO)**
  - **GS & TAS**
  - **Wind vector/true wind**
  - **Track error**
- **XTK – Cross track** is **abeam distance error** left or right of desired flight plan leg
  – Distance between **actual** position & **great circle line** between two active waypoints

FMS design

- **Weather/radar returns** can be displayed on **expanded VOR/ILS/NAV** & **MAP** modes
- **Colours:**
  - **Armed** or **CURRENT data and values = White (ArCu)**
  - **Engaged** or **SELECTED data and values = Green**
  - **Selected heading = Magenta**
  - **Active route / Active flight plan = Magenta**
  - **Aircraft symbol = White**
  - **Sky = Blue/Cyan**
  - **Caution = Yellow**
  - **Warning/system limits = Red**
  - **Turbulence = Magenta**
- Waypoint input formats: **Bearing/distance, bearing/bearing, ALONG track distance** & **latitude& longitude**
- **Failure** of VOR: **CRS, deviation bar & pointer** is **removed** from display
- **Kalman filtering:** Used in **FMS** & **NAVIGATION SYSTEM**

Satellites

Name	SATs	Planes	Height(Km)	Inclination(°)	Model	Orbit time(Hrs)
GLONASS	24	3	19 100	65	PZ – 90	11
GPS	24	6	20 200	55	WGS – 84 (**Ellipsoid**)	12
GALILEO	30	3	23 222	56		14

- Two **UHF** frequencies – L1: **C/A** & **P** codes at **1575MHz** for civilian use
  – L2: **P** codes at **1227MHz** for **military** use **only**
- **ICAO** accuracy limits: **95%, 13m or 9m horizontally, 15m vertically**
- **Phase modulation,** uses **helical antennas** for **circular polarization**
- **Principle** of **TIME**:

- **Distance/delay** between SAT & receiver = **time** x **speed of light**
- Information in the form of **spheres** (orbit **nearly circular**) with **satellite** at the **middle,**
- **Position line** can be obtained by **timing** period taken for **a** satellite transmission to reach receiver.
- Position **fix** uses more than one

- **Pseudo range**: Includes **clock error, clock bias** <u>**satellite**</u> **time** correction of **receiver clock (<u>By using 4 satellites</u>)**
- **PRN:** Code for **ident** of **one** satellite & **measurement** of **time** for signal to reach receiver, PSEUDO = fake, calculated range **includes** receiver clock error
- **Receiver** most suitable: **Multichannel**
- **Selective availability (S/A):** Degrades GPS by **manipulating/dithering** satellite signals
- **RAIM: Integrity monitoring** of satellites **within the receiver** to ensure **accurate navigation**, can **detect** & **identify** which satellite is **faulty.** If a GPS receiver is using **altitude augmentation** for RAIM, number of SAT can be **reduced by one**
- **Altitude** information when using GPS is **barometric altitude**
- **Mask angle** = **<u>5° or 7.5</u>°**, denies any receiver use of SAT **below mask angle**
- GPS most accurate with **3** SAT at **low elevation** in **120°** azimuth & one directly **overhead**
- "**All in view**": Tracking **more than 4** required satellites, all within receiver's **mask angle** & can easily replace any lost signal
- "**Search the sky**": Starts if there is **no stored** satellite data available. Approximately: **12.5 minutes**
- GPS has **4 clocks**: 2 **rubidium** & 2 **hydrogen** clocks**. NOT** identical & **NOT** synchronized to each other. However, clocks of the satellites **are synchronized** with clocks on the **ground** (control segment)
- **Aerial** installed on **top of fuselage** above **COG**
- **Galileo:**
  - Frequency: **1164-1215MHz, 1260-1300MHz, 1559-1591MHz**
  - Has a new method of **spectrum spread** signals
  - 3 sections: **Timing, signal generation & transmit**
- Number of satellites:
  - **3: 2D** fix
  - **4: 3D** fix & **correction** of **receiver clock error**
  - **5: 3D fix** with **RAIM** capability with **exclusion** of faulty SAT
  - **6: 3D fix** with **RAIM** capability with **no exclusion** of faulty SAT
- **Navigation message** includes 5 data:

1. **Almanac:**
   - For <u>**fast identification**</u> of received signals from visible satellites
   - Contains <u>**elevation** & **azimuth** data which will be **computed**</u> by the **receiver**
   - **Orbital data** of **all SAT**
2. **Ephemeris:**
   - **Position & orbit** of <u>**that**</u> satellite
3. **Satellite clock/UTC correction parameters:**
   - Difference between **UTC** & **GPS/satellite** time
   - Correction of <u>**SATELLITE**</u> **time only**
   - Offset of satellite clock **from UTC**
4. **Ionospheric model/delays:**
   - To **calculate** the **delay** of GPS signals
5. **Satellite health & status** data

- **Segments:**

1. **Control:**
   - Ensures transmitted data is **controlled & updated** from time to time
   - Sends new **ephemeris** & sat **clock error** data to GPS

- Consists of **master control stations**, **monitor stations** & **ground antennas**

2. **Space:**
   - **Transmits** signals to receivers to determine **time, position & velocity**
3. **User:**
   - **Auto selects** appropriate satellite,
   - **Track** signals & measure **time** taken by signals from satellite to reach the receiver
   - Determines **elevation & azimuth** data of satellite by **calculating** using **almanac** data in **nav message**

- **Errors:**
  1. **Ionospheric:** Minimised by **comparing L1 & L2,** reduced by using a **model of the ionosphere,** it is the **most significant** error
  2. **Ephemeris: Solar winds, gravity of sun/moon/planets**
  3. **Dilution of precision:** Loss of fix accuracy due to <u>**relative position**</u> of satellites
  4. GPS **not within accuracy limits**: Flight **continued by conventional navigation**
  5. **Shadowing**: Of aircraft e.g. **wing** prevents **reception** of signal
  6. **Path delay** is **proportional** to the **inverse** of the **carrier frequency squared**
  7. **Receiver clock error:** Corrected by using **four** satellites

<u>GBAS/LAAS/DGPS</u>

- **Frequency** is in **VHF band** of **ILS & VOR** systems
- Coverage: **30km, 15NM** from **threshold** within **35°** on **final approach** and **10°** between **20NM – 15NM**
- The **nearer/closer** the receiver is to a DGPS/LAAS **ground reference** station, the more **accurate** the position fix
- **Does NOT** account for **multipath** effects
- Sends **error corrections** for **Ionospheric** & **tropospheric** delays, **integrity data,** and **approach data** for **more than one** runway
- GBAS signal sent to **receiver** and modifies **vertical** & **horizontal guidance** corrections
- Does <u>**not**</u> transmit **receiver clock error**
- GLS more **precise navigation** within **airfield vicinity** than ILS
- **Services:**
  - **Precision approach** service: **Deviation** guidance for **final approach** segments
  - **Positioning** service: **Horizontal position** information to support **RNAV** operation in terminal areas

<u>SBAS/WAAS/WADGPS</u>

- Frequency **same** as **GNSS, UHF**
- **3 elements: Ground receiver** (**Measures signal errors** & transmits them to **satellites**), **receiver** in aircraft & **geostationary satellites (**These satellites are called **INMARSAT,** operate in **UHF** & can be used as **navigation** satellites with their own **PRN** codes**)**
- Pseudo **range** correction for certain satellite is split up into **ephemeris error** (Gravitational), satellite **clock error** (noise & clock drift) & **Ionospheric error** (atmosphere)
- Covers **more area** than GBAS
- Provides **approach** & **landing** operations with **vertical** guidance, for **precision approaches**
- **Improves** integrity by updating receiver within <u>**6 seconds**</u> instead of **3 hours**
- **WAAS: USA, EGNOS: Europe, GAGAN: India, MSAS: Japan**

<u>ABAS</u>

Includes **Aircraft autonomous integrity monitoring (AAIM)** which depends on **additional onboard** systems and on information from **GNSS** (To summarize: It doesn't use SAT provided altitude)

<u>Difference between SBAS & GBAS</u>

GBAS ground stations transmits corrections to **receiver**, SBAS ground stations transmits correction to **navigation satellites**

PBN

- RNP **is not sensor specific**
- Components: **navigational aid infrastructure, navigation specification & navigation application**
- Provides both **linear & angular lateral** guidance during **approach**
- Raw data: From **navigation aids & measured air data**
- Performance requirements: **Accuracy, integrity & accuracy**
- **Oceanic/remote, ENR, terminal phases** limited to operations with **linear lateral performance** requirements & **time** constraints
- Difference between **RNP** & **RNAV**: RNP includes on-board **performance** & **alerting**
- Aircraft approved for **more stringent** requirements may **not necessarily** meet requirements for **less stringent** navigation specification requirements
- **Fly-by**: Waypoint requiring **turn anticipation** to allow **tangential** interception of next segment
- **Fly-over:** Waypoint where **turn is initiated** to join next segment
- **RNP** to **LNAV** minima **only** is considered a **NPA**
- **RNAV 10** requires **2 long range navigation** systems, **INS, IRS/FMS** or **GNSS**
- IF there is **discrepancy** between **navigation database** & **procedures**, pilots must **NOT** fly RNP APCH

Type	Phase
RNP APCH/AR APCH	Approach
RNP 0.3	All except oceanic, remote & approaches
RNAV & RNP 1	Arrivals & departures (SIDs & STARs)
RNAV 2	En-route, arrival & departure
RNP 2	En-route, oceanic & remote
RNAV 5	En-route, arrival
RNAV 10 & RNP 4 (Extended by **updating)**	Oceanic & remote
A - RNP	Includes everything

Errors:

1. Path definition error **(PDE): Desired** path does **not correspond** to defined **RNAV path**
2. Flight technical error **(FTE): Accuracy** of the **crew** flying the path
3. Navigation system error **(NSE): Differences** between **estimated** & **true** position, **coordinates**
4. Total system error **(TSE): Sum** of **all errors**

Path terminators: Specific type of termination of **previous path**

- **IF:** Initial fix
- **TF:** Track fix
- **CF:** Course to fix
- **DF:** Direct to fix
- **FA:** Fix to altitude
- **CA:** Course to altitude
- **RF:** Radius to fix - curved terminal or **approach section** defined by a fix, radius and arc length
- **FRT:** Fixed **radius turn** for **en-route/approach** sections

Instrument	Wavelength	Frequency		Range
MLS (TRSB)	Centimetric	SHF	5.03-5.09GHz	+/- 40° & 20NM
AWR	Centimetric	SHF	9375MHz	Fan beam = 60NM, Pencil > 60NM
Aerodrome surface movement radar	Centimetric	SHF		6NM
Low altitude radio altimeter (FM)	Centimetric (2 aerials)	SHF	4200-4400MHz	2500ft
High altitude radio altimeter (FM)	Decimetric (2 aerials)	UHF	4200-4400MHz	5000ft
Aerodrome surveillance radar	Decimetric	UHF		25NM
Terminal area radar	Decimetric	UHF		80NM
Long range radar	Decimetric (1 aerial)	UHF		200 – 300NM [Power x16]
GPS/SBAS (Phase modulated)	Decimetric	UHF		
DME (Pulse modulated)	Decimetric	UHF	960-1125MHz	200NM
ILS glideslope (AM)	Decimetric	UHF	108-112MHz	10NM:8° (Captured at 3 – 10NM)
ILS localiser (AM)	Metric	VHF(Odd)	108-112MHz	25NM:10° 17NM:35°
GBAS	Metric	VHF	108-112MHz	30km
Marker Beacon	Metric	VHF	75MHz	OM:4NM/MM:0.6NM/IM:0.04NM
VHF radio/ VDF	Metric	VHF	118-136MHz	1.23 x ($\sqrt{T_{Height}}$ + $\sqrt{R_{Height}}$)
CVOR (AM)/ DVOR (FM)	Metric	VHF(Even)	108-118MHz	
HF communications/VOLMET (AM)	Hectometric	HF		Suitable for Polar areas
Locator	Hectometric/Kilometric	LF/MF		10 – 25NM
NDB/ADF [Power x4]	Hectometric/Kilometric	LF/MF	190-1750KHz	Land=2√Power Sea=3√Power