SAE 1201 AVIONICS

UNIT - I DISPLAYS TECHNOLOGY

Avionics are the electronic systems used on aircraft, artificial satellites, and spacecraft. Avionic systems include communications, navigation, the display and management of multiple systems, and the hundreds of systems that are fitted to aircraft to perform individual functions.

AIRCRAFT AVIONICS

Communications

Communications connect the flight deck to the ground and the flight deck to the passengers. On-board communications are provided by public-address systems and aircraft intercoms.

The VHF aviation communication system works on the airband of 118.000 MHz to 136.975 MHz. Each channel is spaced from the adjacent ones by 8.33 kHz in Europe, 25 kHz elsewhere. VHF is also used for line of sight communication such as aircraft-to-aircraft and aircraft-to-ATC. Amplitude modulation (AM) is used, and the conversation is performed in simplex mode. Aircraft communication can also take place using HF (especially for trans-oceanic flights) or satellite communication.

Navigation

Navigation is the determination of position and direction on or above the surface of the Earth. Avionics can use satellite-based systems (such as GPS and WAAS), ground-based systems (such as VOR or LORAN), or any combination thereof. Navigation systems calculate the position automatically and display it to the flight crew on moving map displays. Older avionics required a pilot or navigator to plot the intersection of signals on a paper map to determine an aircraft's location; modern systems calculate the position automatically and display it to the flight crew on moving map displays.

Monitoring

The Airbus A380 glass cockpit featuring pull-out keyboards and two wide computer screens on the sides for pilots.

The first hints of glass cockpits emerged in the 1970s when flight-worthy cathode ray tubes (CRT) screens began to replace electromechanical displays, gauges and instruments. A "glass" cockpit refers to the use of computer monitors instead of gauges and other analog displays. Aircraft were getting progressively more displays, dials and information dashboards that eventually competed for space and pilot attention. In the 1970s, the average aircraft had more than 100 cockpit instruments and controls.

Aircraft flight-control systems

Aircraft have means of automatically controlling flight. Autopilot was first invented by Lawrence Sperry during World War I to fly bomber planes steady enough to hit precision targets from 25,000 feet. When it was first adopted by the U.S. military, a Honeywell engineer sat in the back seat with bolt cutters to disconnect the autopilot in case of emergency. Nowadays most commercial planes are equipped with aircraft flight control systems in order to reduce pilot error and workload at landing or takeoff.

The first simple commercial auto-pilots were used to control heading and altitude and had limited authority on things like thrust and flight control surfaces. In helicopters, auto-stabilization was used in a similar way. The first systems were electromechanical. The advent of fly by wire and electro-actuated flight surfaces (rather than the traditional hydraulic) has increased safety. As with displays and instruments, critical devices that were electro-mechanical had a finite life. With safety critical systems, the software is very strictly tested.

Collision-avoidance systems

To supplement air traffic control, most large transport aircraft and many smaller ones use a traffic alert and collision avoidance system (TCAS), which can detect the location of nearby aircraft, and provide instructions for avoiding a midair collision. Smaller aircraft may use simpler traffic alerting systems such as TPAS, which are passive (they do not actively interrogate the transponders of other aircraft) and do not provide advisories for conflict resolution.

To help avoid controlled flight into terrain (CFIT), aircraft use systems such as ground-proximity warning systems (GPWS), which use radar altimeters as a key element. One of the major weaknesses of GPWS is the lack of "look-ahead" information, because it only provides altitude above terrain "look-down". In order to overcome this weakness, modern aircraft use a terrain awareness warning system (TAWS).

Black BoxeS

Commercial aircraft cockpit data recorders, commonly known as a "black box", store flight information and audio from the cockpit. They are often recovered from a plane after a crash to determine control settings and other parameters during the incident.

Weather systemS

Weather systems such as weather radar (typically Arinc 708 on commercial aircraft) and lightning detectors are important for aircraft flying at night or in instrument meteorological conditions, where it is not possible for pilots to see the weather ahead. Heavy precipitation (as sensed by radar) or severe turbulence (as sensed by lightning activity) are both indications of strong convective activity and severe turbulence, and weather systems allow pilots to deviate around these areas.

Lightning detectors like the Stormscope or Strikefinder have become inexpensive enough that they are practical for light aircraft. In addition to radar and lightning detection, observations and extended radar pictures (such as NEXRAD) are now available through satellite data connections, allowing pilots to see weather conditions far beyond the range of their own in-flight systems. Modern displays allow weather information to be integrated with moving maps, terrain, and traffic onto a single screen, greatly simplifying navigation.

Modern weather systems also include wind shear and turbulence detection and terrain and traffic warning systems. In-plane weather avionics are especially popular in Africa,India, and other countries where air-travel is a growing market, but ground support is not as well developed.

Aircraft management systemS

There has been a progression towards centralized control of the multiple complex systems fitted to aircraft, including engine monitoring and management. Health and usage monitoring systems (HUMS) are integrated with aircraft management computers to give maintainers early warnings of parts that will need replacement.

The integrated modular avionics concept proposes an integrated architecture with application software portable across an assembly of common hardware modules. It has been used in fourth generation jet fighters and the latest generation of airliners.

Gyroscopic instruments

Gyroscope

- An apparatus composed of a wheel which spins inside of a frame and causes the balancing of the frame in any direction or position.
- Basically, any spinning disc takes on the properties of a gyroscope.

  - This includes the spinning propeller in front of our airplane

What properties do spinning discs (gyroscopes) have?

Rigidity in Space

- Principle that a gyroscope remains in a fixed position in the plane in which it is spinning
- By mounting this wheel, or gyroscope, on a set of Gimbal rings, the gyro is able to rotate freely in any direction.
  - If the gimbal rings are tilted, twisted, or otherwise moved, the gyro remains in the plane in which it was originally.
  - Think of the gyro as being aligned with the horizon, and the airplane rotates around it.
- Stability increases if the rotor has great mass and speed
  - Approximately 15,000 rpm for the attitude indicator and 10,000 rpm for the heading indicator.

Gyroscopic Precession

- Whenever a force attempts to tilt the plane of rotation, the force is applied 90 degrees ahead of, and in the direction of rotation
  - Inversely proportional to the speed of the rotor and proportional to the deflective force

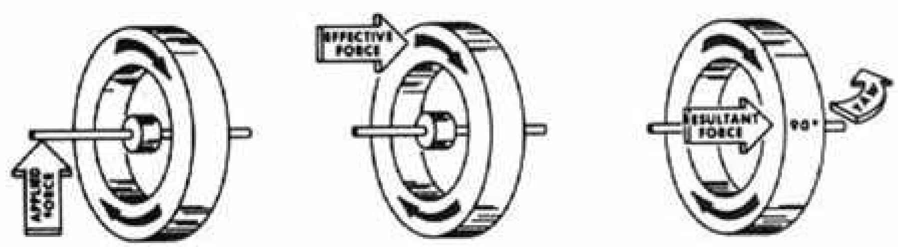
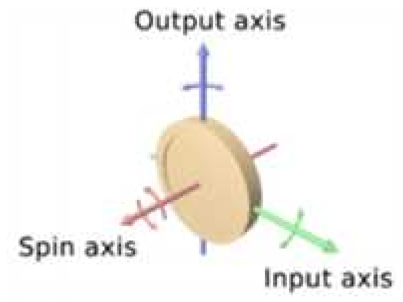
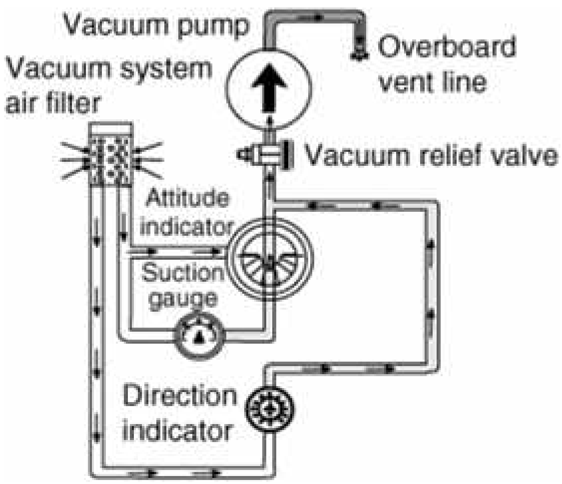


Figure 17–44 Gyroscopic Precession



Power Sources



Vacuum System

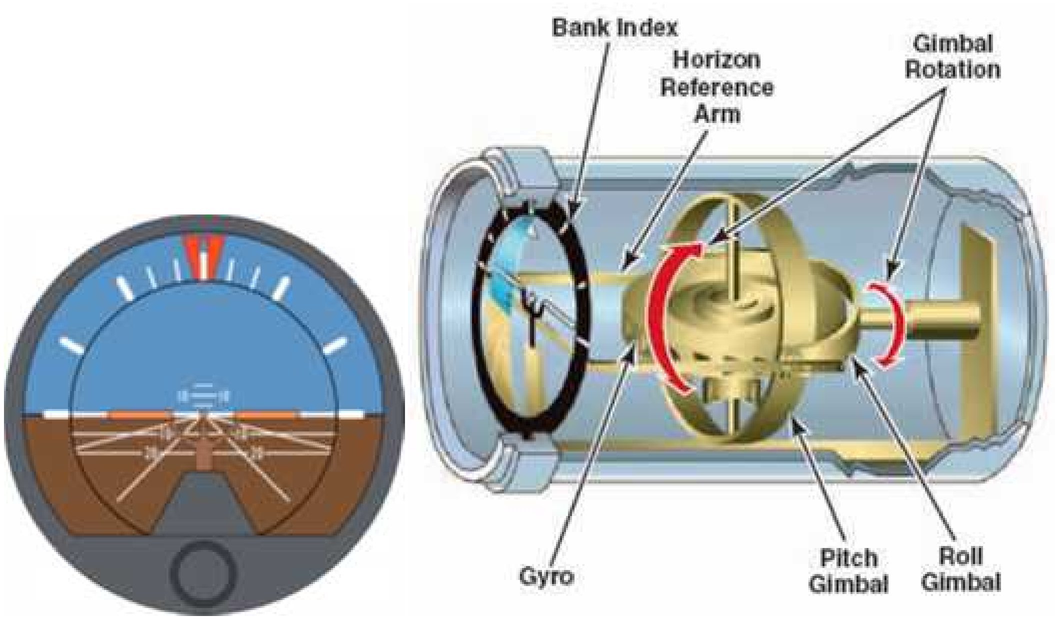
- Runs the Attitude Indicator and Heading Indicator
  - Engine Driven Pump creates suction through system
  - Air sucked through system is diverted over "buckets" in gyroscope walls to turn gyros
  - Semi-frictionless design

Electrical System

- The turn coordinator uses an electrical gyro so that in the event of a vacuum system failure, the pilot still has one working gyroscopic instrument

Gyroscopic Instruments

Attitude Indicator



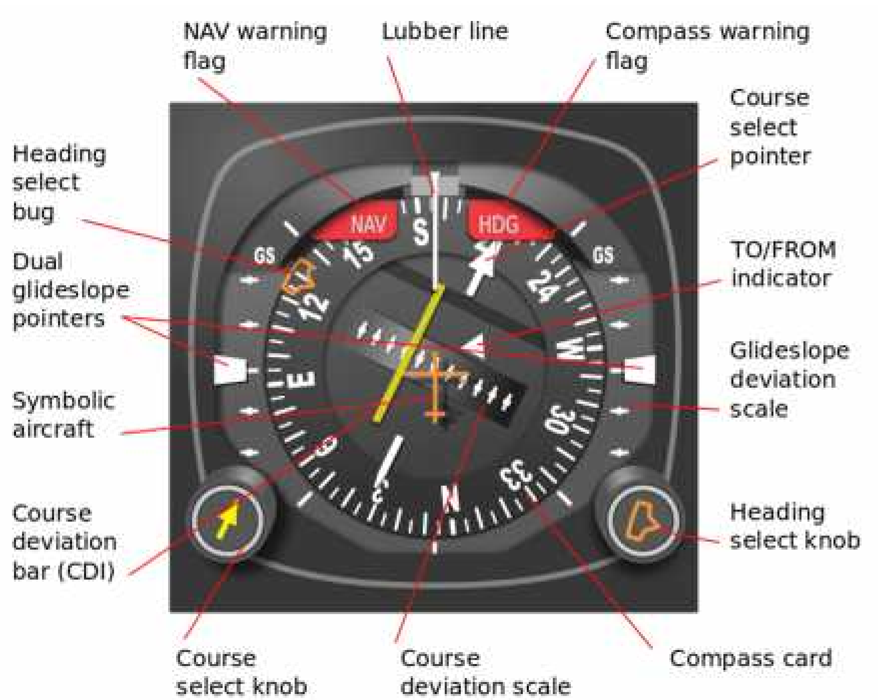
- Provides an artificial horizon (not AOA!) to the pilot to display information about both pitch and bank
- Gyroscope has two gimballs that the aircraft can rotate about for pitch and bank
- 10,20,30,60,90 degree markings for bank
- Pitch angle is indicated by a series of lines, each representing 5° or 10° of pitch
- Pilot can set where the miniature airplane meets the horizon before takeoff

Errors

- Turn Error
  - During a normal coordinated turn, centrifugal force causes the gyro to precess toward the inside of the turn.
  - This precession increases as the bank steepens; therefore, it is greatest during the actual turn
  - Error disappears as the aircraft rolls out at the end of a 180 degrees turn at a normal rollout rate.
- Acceleration Error
  - As the aircraft accelerates, gyro precession causes the horizon bar to move down, indicating a slight pitch up attitude.
- Deceleration Error
  - Deceleration causes the horizon bar to move up, indicating a false pitch down attitude

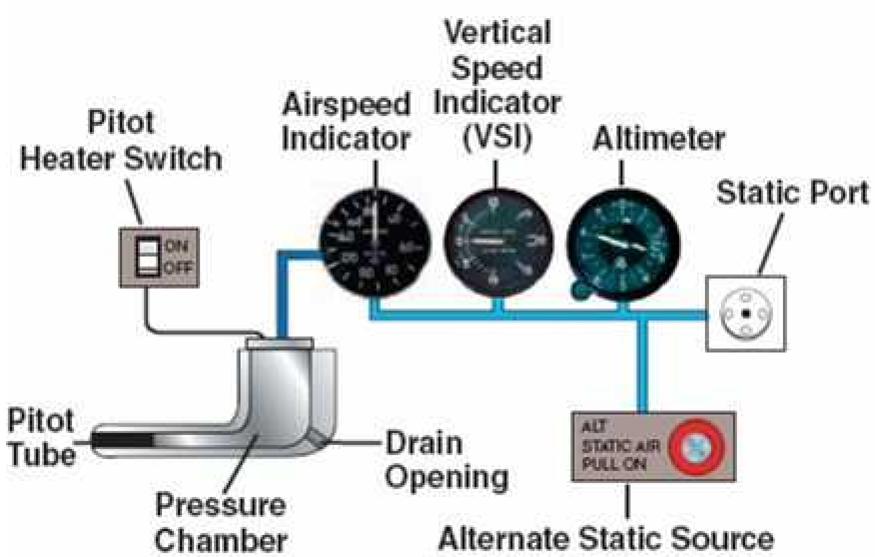
Horizontal situation indicator

- The heading indicator (also known as the directional gyro, or DG) displays the aircraft's heading with respect to magnetic north when set with a compass. Bearing friction causes drift errors from precession, which must be periodically corrected by calibrating the instrument to the magnetic compass.[1]:3-19 to 3-20 In many advanced aircraft (including almost all jet aircraft), the heading indicator is replaced by a horizontal situation indicator (HSI) which provides the same heading information, but also assists with navigation.

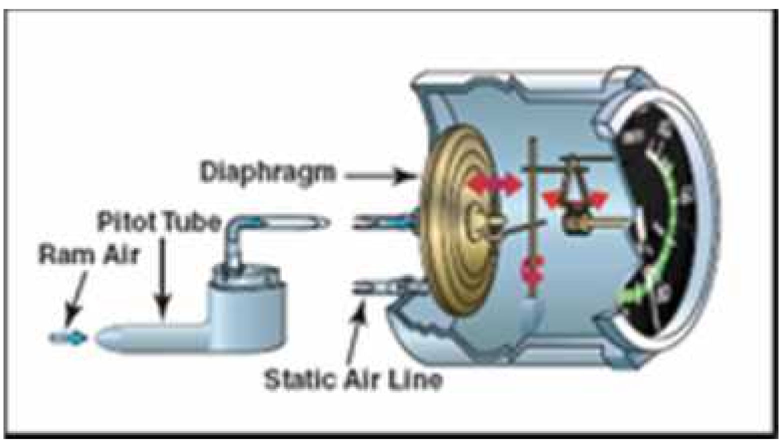


Pitot static instruments

The pitot-static system obtains pressures for interpretation by the pitot-static instruments. While the explanations below explain traditional, mechanical instruments, many modern aircraft use an air data computer (ADC) to calculate airspeed, rate of climb, altitude and Mach number. In some aircraft, two ADCs receive total and static pressure from independent pitot tubes and static ports, and the aircraft's flight data computer compares the information from both computers and checks one against the other. There are also "standby instruments", which are back-up pneumatic instruments employed in the case of problems with the primary instruments.



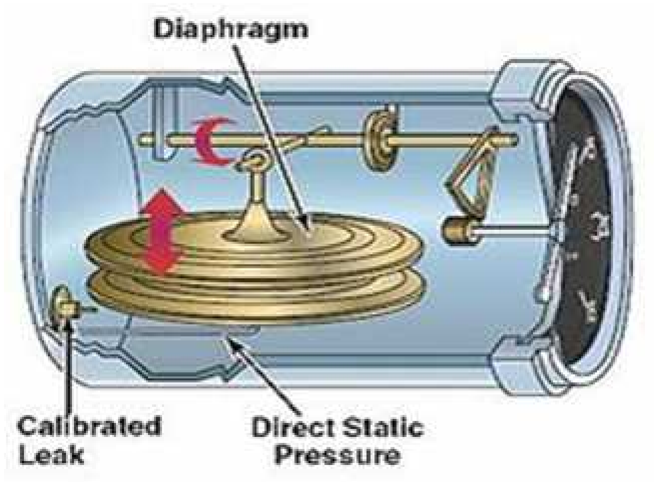
Airspeed indicator



The airspeed indicator is connected to both the pitot and static pressure sources. The difference between the pitot pressure and the static pressure is called dynamic pressure. The greater the dynamic pressure, the higher the airspeed reported. A traditional mechanical airspeed indicator contains a pressure diaphragm that is connected to the pitot tube. The case around the diaphragm is airtight and is vented to the static port. The higher the speed, the higher the ram pressure, the more pressure exerted on the diaphragm, and the larger the needle movement through the mechanical linkage.

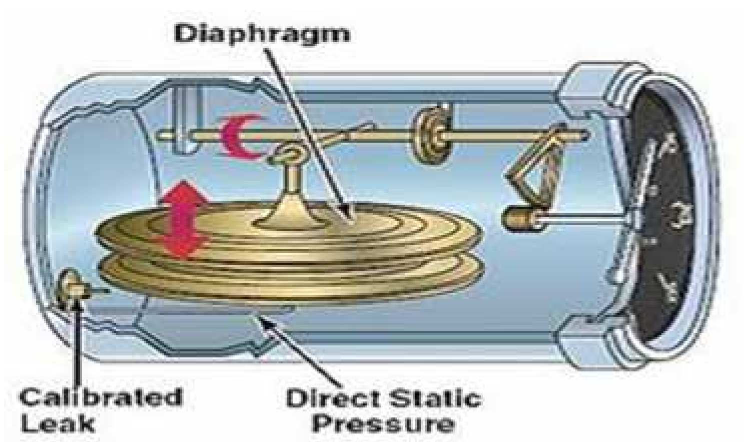
Altimeter

The pressure altimeter, also known as the barometric altimeter, is used to determine changes in air pressure that occur as the aircraft's altitude changes.[4] Pressure altimeters must be calibrated prior to flight to register the pressure as an altitude above sea level. The instrument case of the altimeter is airtight and has a vent to the static port. Inside the instrument, there is a sealed aneroid barometer. As pressure in the case decreases, the internal barometer expands, which is mechanically translated into a determination of altitude. The reverse is true when descending from higher to lower altitudes.



Main errors produced in altimeter!! 1) Blockage error 2)Lag error 3)Instruments error 4)Position error 5)Temperature error 6)Barometric error 7)Transonic Jump

Vertical speed indicator



The variometer, also known as the vertical speed indicator (VSI) or the vertical velocity indicator (VVI), is the pitot-static instrument used to determine whether or not an aircraft is flying in level flight.[5] The vertical speed specifically shows the rate of climb or the rate of descent, which is measured in feet per minute or meters per second.The vertical speed is measured through a mechanical linkage to a diaphragm located within the instrument. The area surrounding the diaphragm is vented to the static port through a calibrated leak (which also may be known as a "restricted diffuser"). When the aircraft begins to increase altitude, the diaphragm will begin to contract at a rate faster than that of the calibrated leak, causing the needle to show a positive vertical speed. The reverse of this situation is true when an aircraft is descending. The calibrated leak varies from model to model, but the average time for the diaphragm to equalize pressure is between 6 and 9 seconds.

C.R.T – Cathode Ray Tube

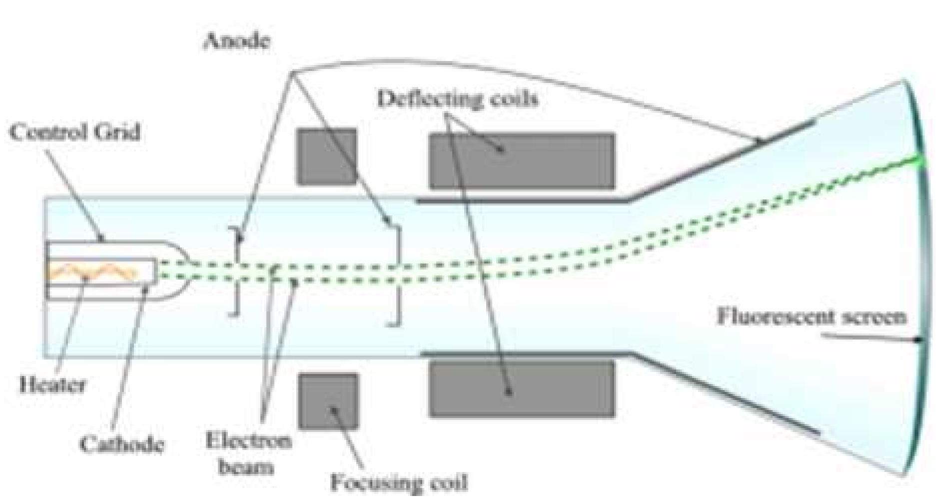
1).A beam of Cathode rays discharged by an Electron gun moves through some deflection systems.

2).So these deflection systems which direct the beam towards a described specified position on the Screen.

3).This Screen is Phosphor coated, and this Phosphor discharges a mark of light at each position where it is contacted by the Electron beam

4).To maintain the screen picture we need some process, as the light discharged by the phosphor fades with very high speed.

5).That method we require is “To keep up the phosphor glowing is to draw up again (redraw) the picture repeatedly by quickly directing this electron beam back on to the same points which were resulted in first time path. This kind of Display is called “Refresh CRT”



Working:

Electron Gun Components:

i).Heated Metal Cathode

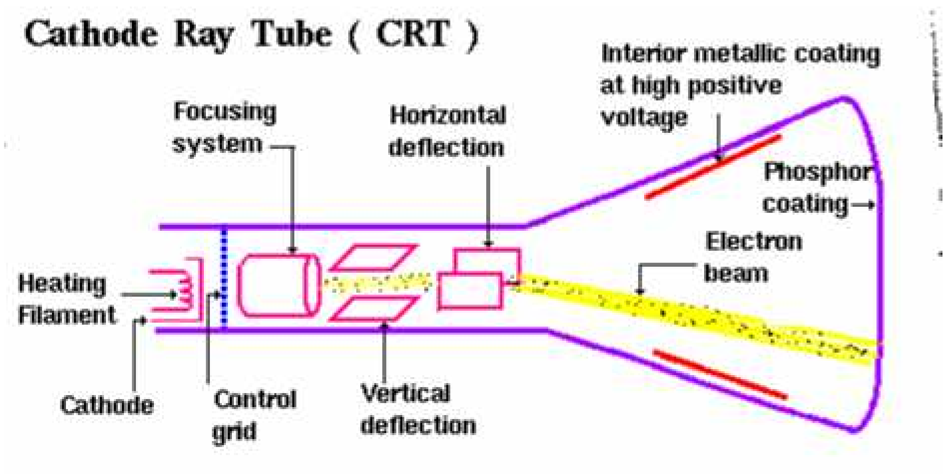
ii).Control Grid

1).Cathode gets heated by directing “Current” using wire coil, which is also called Filament

2).So obviously this causes electrons to be boiled off the very hot cathode surface. In the Cathode ray tube vaccum, already negative charged electrons are then accelerated towards the Coating by positive voltage

3).Accelerating voltage will be generated with a positively charged metal which is coated on the inside o the CRT envelope near the Phosphor screen

4).On the Phosphor screen, various marks or spots of light are produced on the screen by the transfer of CRT beam energy to screen



5).So soon after electrons in the beam collide with the phosphor coating, they are stopped. Now kinetic energy (K.E) is absorbed by the Phosphor. And some part of the beam energy is converted to heat energy because of Friction takes place. And the remaining energy causes electrons in the phosphor atoms to move up to the various higher of its quantum energy levels.

6).After some time, the excited phosphor electrons come back to their previous stable ground state.

7).Make note of this, the Frequency of the light emitted by the Phosphor is directly proportional to the energy difference between “excited quantum state” and “the Ground previous state”.

UNIT II - AVIONICS TECHNOLOGY

ARINC 429

ARINC 429 is a data transfer standard for aircraft avionics. It uses a self-clocking, self-synchronizing data bus protocol (Tx and Rx are on separate ports). The physical connection wires are twisted pairs carrying balanced differential signaling.

Bit numbering, Transmission Order, and Bit Significance

The ARINC 429 unit of transmission is a fixed-length 32-bit frame, which the standard refers to as a ’word’. The bits within an ARINC 429 word are serially identified from Bit Number 1 to Bit Number 32 or simply Bit 1 to Bit 32. The fields and data structures of the ARINC 429 word are defined in terms of this numbering.

While it is common to illustrate serial protocol frames progressing in time from right to left, a reversed ordering is commonly practiced within the ARINC standard. Even though ARINC 429 word transmission begins with Bit 1 and ends with Bit 32, it is common to diagram and describe ARINC 429 words in the order from Bit 32 to Bit 1. In simplest terms, while the transmission order of bits (from the first transmitted bit to the last transmitted bit) is conventionally diagramed as

First bit > 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, ... 29, 30, 31, 32 < Last bit,

this sequence is often diagrammed in ARINC 429 publications in the opposite direction as

Last bit > 32, 31, 30, 29, ... 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1 < First bit.

Word format

Each ARINC 429 word is a 32-bit sequence that contains five fields:

Bit 32 is the parity bit, and is used to verify that the word was not damaged or garbled during transmission. Every ARINC 429 channel typically uses "odd" parity - there must be an odd number of "1" bits in the word. This bit is set to 0 or 1 to ensure that the correct number of bits are set to 1 in the word.

Bits 30 to 31 are the Sign/Status Matrix (SSM) - these bits may have various encodings dependent on the particular data representation applied to a given word:

- In all cases using the SSM, these bits may be encoded to indicate:

Normal Operation (NO) - Indicates the data in this word is considered to be correct data.

Functional Test (FT) - Indicates that the data is being provided by a test source.

Failure Warning (FW) - Indicates a failure which causes the data to be suspect or missing.

No Computed Data (NCD) - Indicates that the data is missing or inaccurate for some reason other than a failure. For example, autopilot commands will show as NCD when the autopilot is not turned on.

- In the case of Binary Coded Decimal (BCD) representation, the SSM may also indicate the Sign (+/-) of the data or some information analogous to sign, like an orientation (North/South; East/West). When so indicating sign, the SSM is also considered to be indicating Normal Operation.
- In the case of two's-complement representation of signed binary numbers (BNR), Bit 29 represents the number's sign; that is, sign indication is delegated to Bit 29 in this case.
- In the case of discrete data representation (e.g., bit-fields), the SSM has a different, signless encoding.

The ARINC 629 is a bus system, i.e. a system used for data transmission in the field of avionics. This is a term used for all the electronic instruments in an aircraft - excluding the cabin. Here, the data transmission takes place at exactly specified time intervals and via a two-wire line that may be either optical or electrical. For this procedure, two different protocols are available with the ARINC 629.

- One is the basic protocol - this is a kind of protocol for which three different time intervals have been specified for sending and receiving data. On the one hand, there is the sending interval, which is also called the "transmitting interval". This protocol of the ARINC 629 has busses of the same lengths for all terminals, and it is initialized as soon as transmission starts on this technical data bus. A device can start to transmit again only when the transmitting interval has finished with the transmission of the data. The second protocol is the synchronization in which, just like the transmission interval, the terminals of a bus always have the same length. However, the synchronization is shorter than the transmitting interval and it starts just at the moment when no data are being transmitted on the bus (binary unit system). If, during the synchronization, another device switches on in the data transmission, the timer is then set back to the initial state. Finally, with the basic protocol, there is also device recognition, Here, in a way that differs from the first two basic protocols that have been described, the terminals all have a different length. As such, this protocol type of the ARINC 629 determines the process of the other protocols, as device recognition only starts when the synchronization has ended and no other device is still transmitting via the bus. Also, the timer is reset when a device starts to transmit data before device recognition has ended.

- The combined protocol (there are three different levels here as well) regulates the data transmission within the ARINC 629. The “combined protocol” is used especially for processing events that do not take place in a specified period. The periodic data is on the first level, which is also called level 1. This is also are transmitted in a specified order and with the same length, in the same way as the basic protocol. The short events and the more frequent nonperiodic events are especially transmitted on the second level. Also, when a deterministic cycle exists, the data are exchanged with each other at the end of the process. In the combined protocol, level 3 is then responsible for longer events and nonperiodic, infrequent events. At the end of the second level, if there is remaining cycle time, there is an exchange between these data results. Protocol levels 2 and 3 cannot be used together.

ARINC 629 - the decisive link in modern aircraft

ARINC 629 has become indispensable in avionics, as thanks to several improvements, it now reliably ensures safety and problem-free functionality of the devices in an aircraft. The high standard of this protocol is exemplified in the diversity of the place of use, even though it is naturally designed specifically for the Boeing 777 and speed. As such, data are transmitted at a rate of 2 Mbps. Based on the ARINC 429, the ARINC 629 presents itself as a high performance-oriented specification. The special feature when using an ARINC protocol is the fact that in the standard, there is no essential difference between the civilian and the military version.

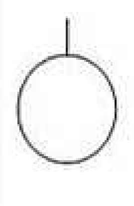
Fault tree analysis

(FTA) is a top down, deductive failure analysis in which an undesired state of a system is analyzed using Boolean logic to combine a series of lower-level events. This analysis method is mainly used in the fields of safety engineering and reliability engineering to understand how systems can fail, to identify the best ways to reduce risk or to determine (or get a feeling for) event rates of a safety accident or a particular system level (functional) failure. FTA is used in the aerospace, nuclear power, chemical and process, pharmaceutical,petrochemical and other high-hazard industries; but is also used in fields as diverse as risk factor identification relating to social service system failure. FTA is also used in software engineering for debugging purposes and is closely related to cause-elimination technique used to detect bugs.

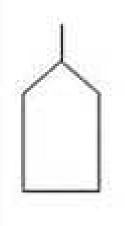
In aerospace, the more general term "system Failure Condition" is used for the "undesired state" / Top event of the fault tree. These conditions are classified by the severity of their effects. The most severe conditions require the most extensive fault tree analysis. These "system Failure Conditions" and their classification are often previously determined in the functional Hazard analysis.

Event Symbols

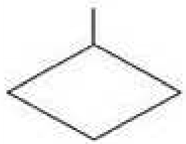
Event symbols are used for primary events and intermediate events. Primary events are not further developed on the fault tree. Intermediate events are found at the output of a gate. The event symbols are shown below:



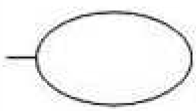
Basic event



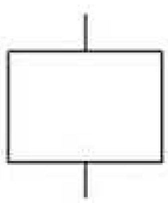
External event



Undeveloped event



Conditioning event



Intermediate event

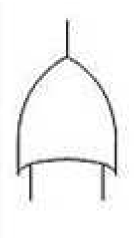
The primary event symbols are typically used as follows:

- **Basic event** - failure or error in a system component or element (example: switch stuck in open position)
- **External event** - normally expected to occur (not of itself a fault)
- **Undeveloped event** - an event about which insufficient information is available, or which is of no consequence
- **Conditioning event** - conditions that restrict or affect logic gates (example: mode of operation in effect)

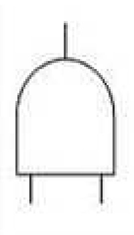
An intermediate event gate can be used immediately above a primary event to provide more room to type the event description. FTA is top to bottom approach.

Gate Symbols

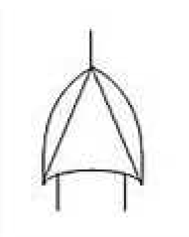
Gate symbols describe the relationship between input and output events. The symbols are derived from Boolean logic symbols:



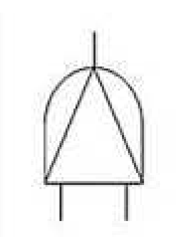
OR gate



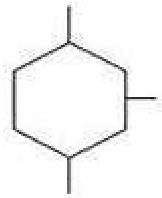
AND gate



Exclusive OR gate



Priority AND gate



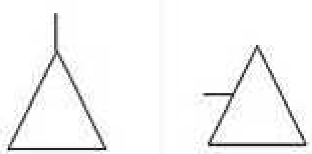
Inhibit gate

The gates work as follows:

- **OR gate** - the output occurs if any input occurs
- **AND gate** - the output occurs only if all inputs occur (inputs are independent)
- **Exclusive OR gate** - the output occurs if exactly one input occurs
- **Priority AND gate** - the output occurs if the inputs occur in a specific sequence specified by a conditioning event
- **Inhibit gate** - the output occurs if the input occurs under an enabling condition specified by a conditioning event

Transfer Symbols

Transfer symbols are used to connect the inputs and outputs of related fault trees, such as the fault tree of a subsystem to its system. NASA prepared a complete document about FTA through practical incidents.



Transfer in Transfer out

Failure mode and effects analysis (**FMEA**)

It was developed by reliability engineers in the late 1950s to study problems that might arise from malfunctions of military systems. An FMEA is often the first step of a system reliability study. It involves reviewing as many components, assemblies, and subsystems as possible to identify failure modes, and their causes and effects. For each component, the failure modes and their resulting effects on the rest of the system are recorded in a specific FMEA worksheet. There are numerous variations of such worksheets. An FMEA can be a qualitative analysis, but may be put on a quantitative basis when mathematical failure rate models are combined with a statistical failure mode ratio database.

A few different types of FMEA analyses exist, such as

- Functional
- Design
- Process FMEA.

Sometimes FMEA is extended to FMECA (Failure mode, effects, and criticality analysis) to indicate that criticality analysis is performed too.

FMEA is an inductive reasoning (forward logic) single point of failure analysis and is a core task in reliability engineering, safety engineering and quality engineering. Quality engineering is specially concerned with the "Process" (Manufacturing and Assembly) type of FMEA.

A successful FMEA activity helps to identify potential failure modes based on experience with similar products and processes - or based on common physics of failure logic. It is widely used in development and manufacturing industries in various phases of the product life cycle. Effects analysis refers to studying the consequences of those failures on different system levels.

Functional analyses are needed as an input to determine correct failure modes, at all system levels, both for functional FMEA or Piece-Part (hardware) FMEA. An FMEA is used to structure Mitigation for Risk reduction based on either failure (mode) effect severity reduction or based on lowering the probability of failure or both. The FMEA is in principle a full inductive (forward logic) analysis, however the failure probability can only be estimated or reduced by understanding the failure mechanism. Ideally this probability shall be lowered to "impossible to occur" by eliminating the (root) causes. It is therefore important to include in the FMEA an appropriate depth of information on the causes of failure (deductive analysis).

Failure

The loss of a function under stated conditions.

Failure mode

The specific manner or way by which a failure occurs in terms of failure of the item (being a part or (sub) system) function under investigation; it may generally describe the way the failure occurs. It shall at least clearly describe a (end) failure state of the item (or function in case of a Functional FMEA) under consideration. It is the result of the failure mechanism (cause of the failure mode). For example; a fully fractured axle, a deformed axle or a fully open or fully closed electrical contact are each a separate failure mode.

Failure cause and/or mechanism

Defects in requirements, design, process, quality control, handling or part application, which are the underlying cause or sequence of causes that initiate a process (mechanism) that leads to a failure mode over a certain time. A failure mode may have more causes. For example; "fatigue or corrosion of a structural beam" or "fretting corrosion in an electrical contact" is a failure mechanism and in itself (likely) not a failure mode. The related failure mode (end state) is a "full fracture of structural beam" or "an open electrical contact". The initial cause might have been "Improper application of corrosion protection layer (paint)" and /or "(abnormal) vibration input from another (possibly failed) system".

Failure effect

Immediate consequences of a failure on operation, function or functionality, or status of some item.

Indenture levels (bill of material or functional breakdown)

An identifier for system level and thereby item complexity. Complexity increases as levels are closer to one.

Local effect

The failure effect as it applies to the item under analysis.

Next higher level effect

The failure effect as it applies at the next higher indenture level.

End effect

The failure effect at the highest indenture level or total system.

Detection

The means of detection of the failure mode by maintainer, operator or built in detection system, including estimated dormancy period (if applicable)

Probability

The likelihood of the failure occurring.

Risk Priority Number (RPN)

Severity (of the event) * Probability (of the event occurring) * Detection (Probability that the event would not be detected before the user was aware of it)

Severity

The consequences of a failure mode. Severity considers the worst potential consequence of a failure, determined by the degree of injury, property damage, system damage and/or time lost to repair the failure.

Remarks / mitigation / actions

Additional info, including the proposed mitigation or actions used to lower a risk or justify a risk level or scenario.

UNIT III - SENSORS

AIR DATA

An air data computer (ADC) is an essential avionics component found in modern glass cockpits. This computer, rather than individual instruments, can determine the calibrated airspeed, Mach number, altitude, and altitude trend data from an aircraft's pitot-static system.

AIR DATA INERTIAL REFERENCE UNIT (ADIRU)

An air data inertial reference unit (ADIRU) is a key component of the integrated air data inertial reference system (ADIRS), which supplies air data (airspeed, angle of attack and altitude) and inertial reference (position and attitude) information to the pilots' electronic flight instrument system displays as well as other systems on the aircraft such as the engines, autopilot, aircraft flight control system and landing gear systems.[1] An ADIRU acts as a single, fault tolerant source of navigational data for both pilots of an aircraft.[2] It may be complemented by a secondary attitude air data reference unit (SAARU), as in the Boeing 777 design.

AIR DATA REFERENCE

The air data reference (ADR) component of an ADIRU provides airspeed, Mach number, angle of attack, temperature and barometric altitude data. Ram air pressure and static pressures used in calculating airspeed are measured by small ADMs located as close as possible to the respective pitot and static pressure sensors. ADMs transmit their pressures to the ADIRUs through ARINC 429 data buses.

INERTIAL REFERENCE

The IR component of an ADIRU gives attitude, flight path vector, ground speed and positional data.[1] The ring laser gyroscope is a core enabling technology in the system, and is used together with accelerometers, GPS and other sensors to provide raw data. The primary benefits of a ring laser over older mechanical gyroscopes are that there are no moving parts, it is rugged and lightweight, frictionless and does not resist a change in precession.

Magnetic Heading Reference System (MHRS) or Remote-Indicating Compass

Main Features of MHRS

- Flux detector element senses the horizontal component of Earth's magnetic field
- The signals from the flux detector element are "slaved" to or "drives" a gyro-stabilized system.

Advantages of MHRS

• No drift error because gyro is “slaved” to the flux detector

• No turn error and acceleration error because gyro senses maneuvers

• No deviation error because flux detector is mounted at tail or wing, far away from interference

• No dip error because flux detector instead of magnet is used to sense magnetic field

• Contains the strengths of the direct indicating compass and the DGI and eliminates the errors Higher accuracy of both.

1.Navigation systems

1 .Non-directional beacons and automatic direction finders A non-directional beacon (NDB) is a beacon on the ground, sending a signal in all directions. To use it, we need to equip our aircraft with an automatic direction finder (ADF). This ADF has two types of antennas.

• The loop antenna has the shape of a loop with two arms AB and CD. When the loop is aligned with the direction of the signal, the arms AB and CD will get the same excitation: nothing happens. This is the null position of the loop antenna. On the other hand, when the loop is placed facing the signal, then AB gets a (for example) positive current, while CD gets a negative. Thus, a voltage is created in the loop. This voltage has maximal value Vmax when the loop exactly faces the direction of the signal.

• The sense antenna is a lot simpler. It is omni-directional. It always measures the maximum voltage Vmax.

The loop antenna alone can’t detect the direction: it has a 180◦ ambiguity. But, by adding up the loop antenna voltage V1 and the sense antenna voltage V2, we get a cardioid pattern. Now, the ADF can find the direction of the beacon. The ADF thus yields a bearing to an NDB ground station.

2.VHF omnidirectional range

A VHF omnidirectional range (VOR) beacon gives three types of informations: a voice (for example, to carry wheather information), the identity of the VOR beacon and the radial on which the aircraft is positioned, relative to the beacon. This means that a lot of data is put on one wave. In fact, we first take a sub-carrier wave of 30Hz. This wave is frequency-modulated with the data signal. Then, we use this wave to amplitudemodulate the actual carrier wave of 9960Hz. Think this is complex? The working of the VOR itself isn't very easy either.

To explain the working principle of the VOR, we examine a 'lighthouse' with two 'lights'. Light 1 is always on, but the direction in which it shines varies. In fact, the light beam rotates at 30 RPM. Light 2 is only on when light 1 shines North. At this moment, light 2 shines in all directions. At every other time, light 2 is off. The result of this is a repeating pattern with a period of T = 1/30s. To find the radial, we can now use the equation

$$(t_{light\ 1\ on} - t_{light\ 2\ on} / T)360^{\circ}$$

In reality, we don't have two lights. Instead, we use a special limacon antenna. This antenna sends signals in a limacon pattern: some sides get a strong signal, while other sides get a weak signal. And the limacon antenna is also rotating at 30 RPS.

This results in another modulation: a 30Hz amplitude modulation. The signal that is sent thus contains two 30Hz signals. By measuring the phase difference between them, we can find our radial θ with respect to the beacon. VORs have been around for quite a while. In fact, they were used when defining airways. When following an airway, you usually keep on flying from one VOR to the next, until you have reached your destination.

3 Distance measuring equipment

A distance measuring equipment (DME) system is based on two-way communication. First, an airborne DME interrogator sends out a UHF pulse. (This is done about 150 times each second.) The ground-based DME transponder receives the signal, waits exactly 50µs, and then sends a signal back. The difference between the frequency of the incoming signal and the frequency of the replied signal is always 63MHz. The airborne equipment now computes the slant range d, being the line-of-sight distance. (So, if you're flying directly above a DME transponder, the slant range is not zero, but h.) This slant range is given by

$$d = 1/2\ c\ (\Delta T - 50\mu s).$$

One downside of the DME system is its relatively low accuracy. The accuracy is only 1 4NM + 0.0125R. Another downside is that it requires active communication. A DME beacon can only send out a limited amount of signals. This means that at most 50 to 100 aircraft can make use of a beacon simultaneously. But, with 50 aircraft using a beacon, how do we know which signal is meant for us? A first suggestion to solve this problem might be to just look at multiple intervals. Let's suppose that, every time we send the signal, we get a response a fixed amount of time Δt later.

Then this will probably be the reply to our signal! Sadly, if all aircraft send their signals at regular intervals, this trick doesn't work. But the solution to this problem is jitter. Instead of sending out our signal at constant intervals, we apply very small variations in our interval length. (Of up to 10µs only.) Now, the trick that we just described does work: there's only one signal with a constant time difference Δt.

4 Long range navigation system

The long range navigation (LORAN) system is, surprisingly, used for long range navigation. It's especially useful for oceanic regions or other remote places where no other beacons are present. LORAN makes use of ground waves for navigation. It thus uses LF signals.

The LORAN system consists of transmitting stations (beacons) put together in groups known as chains. Every group has one master station and at least two (but often more) secondary (slave) stations. This is because at least three beacons are needed for a position fix. All beacons in a LORAN chain send out pulses in all directions. This is done at a regular pattern. (This pattern can even be used to identify the LORAN chain.) A receiver, listening to the LORAN stations, measures the time differences between receiving the pulses. The receiver also knows the time difference between the sending of the pulses. Based on this, he can calculate the difference in distance with respect to the beacons. If he does this for multiple pairs of beacons, he can derive his own position. The accuracy of the LORAN system varies with position (GDOP). The accuracy is best when the receiver is on the baseline: the line between two beacons. Furthermore, the accuracy decreases as the distance from the beacons increases. Up to 350NM, the accuracy is roughly 130m. Up to 1000NM, it is about 550m. Starting from 1500NM, multipath effects due to sky waves start to play a role. The accuracy then drops to over 10NM.

ANTENNAS

Antennas are basic components of any electrical circuit as they provide interconnecting links between transmitter and free space or between free space and receiver. Before we discuss about antenna types, there are a few properties that need to be understood. Apart from these properties, we also cover about different types of antennas used in communication system in detail.

Properties of Antennas

- Antenna Gain
- Aperture
- Directivity and bandwidth
- Polarization

- Effective length
- Polar diagram

Types of Antennas

Log Periodic Antennas

- Bow Tie Antennas
- Log-Periodic Dipole Array

Wire Antennas

- Short Dipole Antenna
- Dipole Antenna
- Monopole Antenna
- Loop Antenna

Travelling Wave Antennas

- Helical Antennas
- Yagi-Uda Antennas

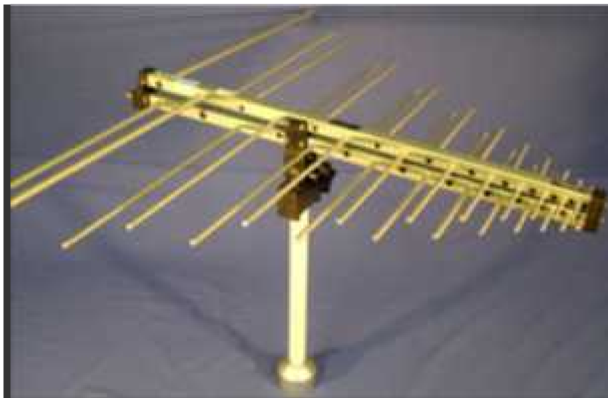
Microwave Antennas

- Rectangular Micro strip Antennas
- Planar Inverted-F Antennas

Reflector Antennas

- Corner Reflector
- Parabolic Reflector

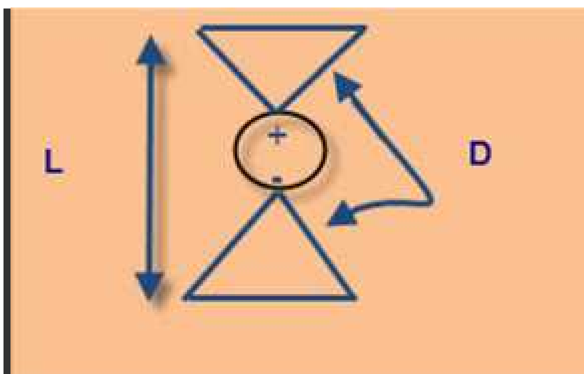
1. Log-Periodic Antennas



Log Periodic Antenna

A log-periodic antenna is also named as a log periodic array. It is a multi-element, directional narrow beam antenna that works on a wide range of frequencies. This antenna is made of a series of dipoles placed along the antenna axis at different space intervals of time followed by a logarithmic function of frequency. Log-periodic antenna is used in a wide range of applications where variable bandwidth is required along with antenna gain and directivity.

Bow-Tie Antennas

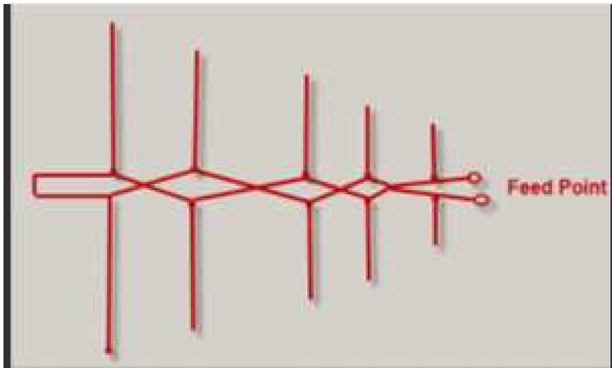


Bow Tie Antenna

A bow-tie antenna is also known as Biconical antenna or Butterfly antenna. Biconical antenna is an omnidirectional wide-band antenna. According to the size of this antenna, it has low- frequency response, and acts as a high-pass filter. As the frequency goes to higher limits, away from the design frequency, the radiation pattern of the antenna gets distorted and spreads.

Most of the bow-tie antennas are derivatives of biconical antennas. The discone is as a type of half-biconical antenna. The bow-tie antenna is planar, and therefore, directional antenna.

Log-Periodic Dipole Array

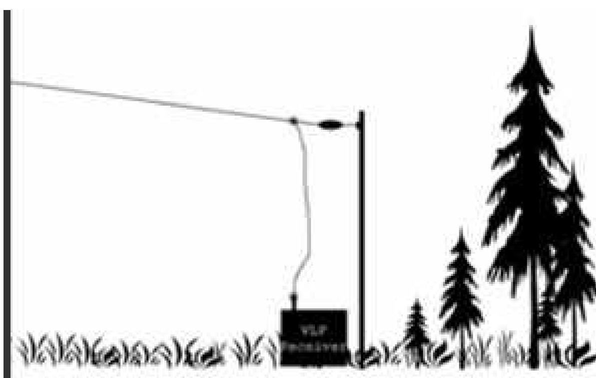


Log Periodic Dipole Antenna

The most common type of antenna used in wireless communication technology is a log-periodic dipole array fundamentally comprises a number of dipole elements. These dipole-array antennas reduce in size from the back end to the front end. The leading beam of this RF antenna comes from the smaller front end.

The element at the back end of the array is large in size with the half wavelength operating in a low-frequency range. The spacing of the element gets reduced towards the front end of the array wherein the smallest arrays are placed. During this operation, as the frequency varies, a smooth transition takes place along the array of the elements, which leads to form an active region.

2. Wire Antennas

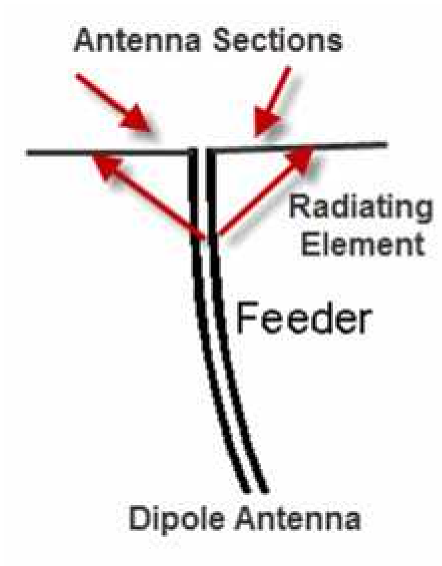


Wire Antenna

Wire antennas are also known as linear or curved antennas.These antennas are very simple, cheap and are used in a wide range of applications.These antennas are further subdivided into four as explained below.

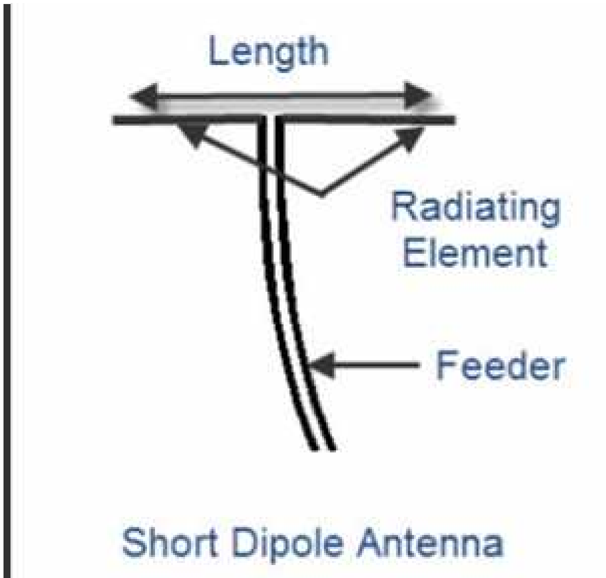
Dipole Antenna

A dipole antenna is one of the most straightforward antenna alignments. This dipole antenna consists of two thin metal rods with a sinusoidal voltage difference between them. The length of the rods is chosen in such a way that they have quarter length of the wavelength at operational frequencies. These antennas are used in designing their own antennas or other antennas. They are very simple to construct and use.



The dipole antenna consists of two metallic rods through which current and frequency flow. This current and voltage flow makes an electromagnetic wave and the radio signals get radiated. The antenna consists of a radiating element that splits the rods and make current flow through the center by using a feeder at the transmitter out that takes from the receiver.The different types of dipole antennas used as RF antennas include half wave, multiple, folded, non-resonant, and so on.

Short-Dipole Antenna:



Short Dipole Antenna

It is the simplest of all types of antennas. This antenna is an open circuited wire in which short denotes " relative to a wavelength" so this antenna gives priority to the size of the wire relative to the wavelength of the frequency of operation. It does take any consideration about the absolute size of the dipole antenna. The short dipole antenna is made up of two co-linear conductors that are placed end to end, with a small gap between conductors by a feeder. A Dipole is considered as short if the length of the radiating element is less than a tenth of the wavelength.

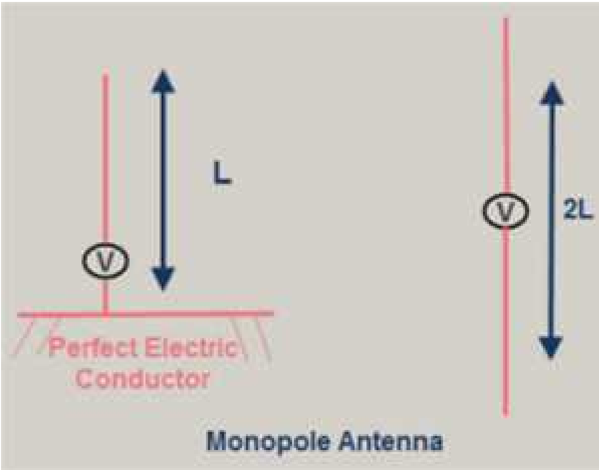
$L<\lambda/10$

The short dipole antenna is made of two co-linear conductors that are placed end to end, with a small gap between conductors by a feeder.

The short dipole antenna is infrequently satisfactory from an efficiency viewpoint because most of the power entering this antenna is dissipated as heat and resistive losses also become gradually high.

Monopole Antenna

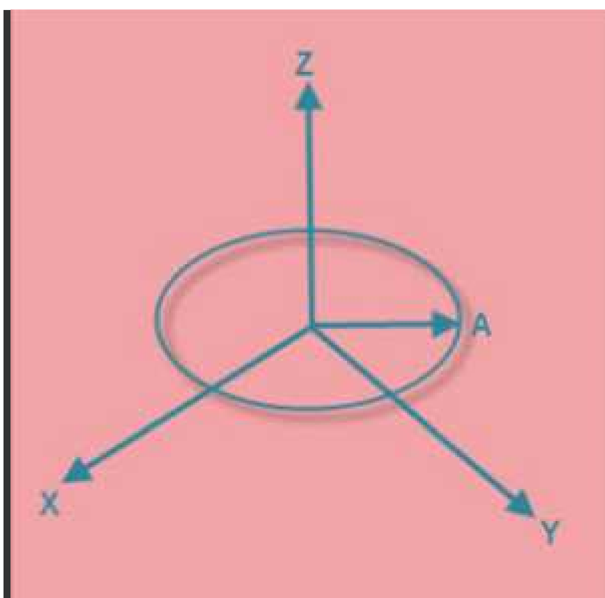
A monopole antenna is half of a simple dipole antenna located over a grounded plane as shown in the figure below.



The radiation pattern above the grounded plane will be same as the half wave dipole antenna, however, the total power radiated is half that of a dipole; the field gets radiated only in the upper hemisphere region. The directivity of these antennas become double compared to the dipole antennas.

The monopole antennas are also used as vehicle mounted antennas as they provide the required ground plane for the antennas mounted above the earth.

Loop Antenna



Loop Antenna

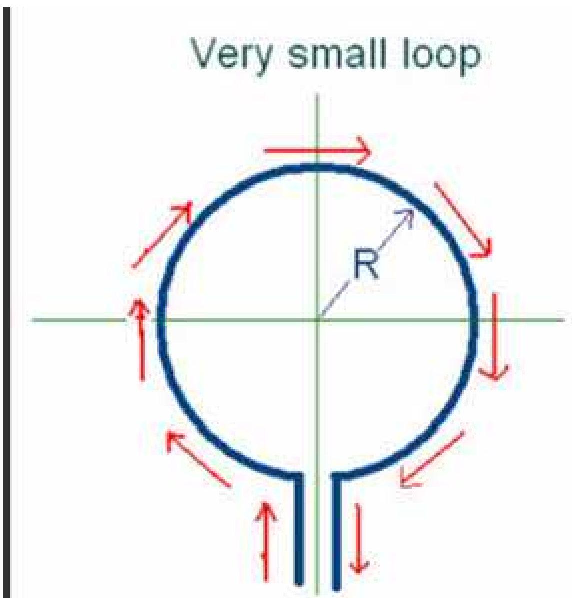
Loop antennas share similar characteristics with both dipole and monopole antennas because they are simple and easy to construct. Loop antennas are available in different shapes like circular, elliptical, rectangular, etc. The fundamental characteristics of the loop antenna are independent of its shape. They are widely used in communication links with the frequency of around 3 GHz. These antennas can also be used as electromagnetic field probes in the microwave bands.

The circumference of the loop antenna determines the efficiency of the antenna as similar to that of dipole and monopole antennas. These antennas are further classified into two types: electrically small and electrically large based on the circumference of the loop.

Electrically small loop antenna———> Circumference≤λ/10

Electrically large loop antenna ———> Circumference≈λ

Electrically small loops of a single turn have small radiation resistance compared to their loss resistance. The radiation resistance of small loop antennas can be improved by adding more turns. Multi-turn loops have better radiation resistance even if they have less efficiency.



Small Loop Antenna

Due to this, the small loop antenna are mostly used as receiving antennas where losses are not mandatory. Small loops are not used as transmitting antennas due to their low efficiency.

Resonant loop antennas are relatively large, and are directed by the operation of wavelength .They are also known as large loop antennas as they are used at higher frequencies, such as VHF and UHF, wherein their size is convenient. They can be viewed as folded-dipole antenna and deformed into different shapes like spherical, square, etc., and have similar characteristics such as high-radiation efficiency.

3. Travelling Wave Antennas

Helical Antennas

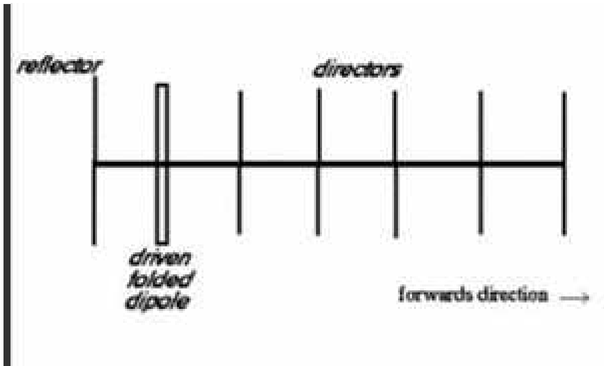
Helical antennas are also known as helix antennas. They have relatively simple structures with one, two or more wires each wound to form a helix, usually backed by a ground plane or shaped reflector and driven by an appropriate feed. The most common design is a single wire backed by the ground and fed with a coaxial line.

In General, the radiation properties of a helical antenna are associated with this specification: the electrical size of the structure, wherein the input impedance is more sensitive to the pitch and wire size.

Helical Antenna

Helical antennas have two predominate radiation modes: the normal mode and the axial mode. The axial mode is used in a wide range of applications. In the normal mode, the dimensions of the helix are small compared to its wavelength. This antenna acts as the short dipole or monopole antenna. In the axial mode, the dimensions of the helix are same compared to its wavelength. This antenna works as directional antenna.

Yagi-Uda Antenna



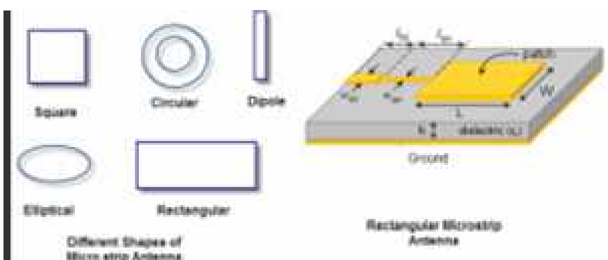
Yagi-Uda Antenna

Another antenna that makes use of passive elements is the Yagi-Uda antenna. This type of antenna is inexpensive and effective. It can be constructed with one or more reflector elements and one or more director elements. Yagi antennas can be made by using an antenna with one reflector, a driven folded-dipole active element, and directors, mounted for horizontal polarization in the forward direction.

4. Microwave Antennas

The antennas operating at microwave frequencies are known as microwave antennas. These antennas are used in a wide range of applications.

Rectangular Micro strip Antennas



Rectangular Micro strip Antennas

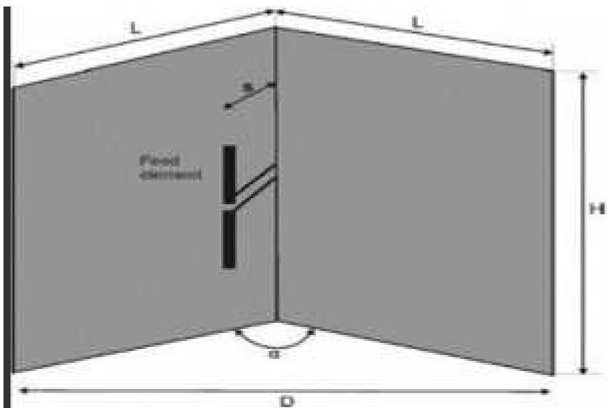
For spacecraft or aircraft applications – based on the specifications such as size, weight, cost, performance, ease of installation, etc. – low profile antennas are preferred. These antennas are known as rectangular microstrip antennas or patch antennas; they only require space for the feed line which is normally placed behind the ground plane. The major disadvantage of using these antennas is their inefficient and very narrow bandwidth, which is typically a fraction of a percent or, at the most, a few percent.

Planar Inverted-F Antennas

A Planar Inverted-F Antenna can be considered as a type of linear Inverted F antenna (IFA) in which the wire radiating element is replaced by a plate to increase the bandwidth. The advantage of these antennas is that they can be hidden into the housing of the mobile when compared to different types of antennas like a whip, rod or helical antennas, etc. The other advantage is that they can reduce the backward radiation towards the top of the antenna by absorbing power, which enhances the efficiency. They provides high gain in both horizontal and vertical states. This feature is most important for any kind of antennas used in wireless communications.

5. Reflector Antennas

Corner Reflector Antenna

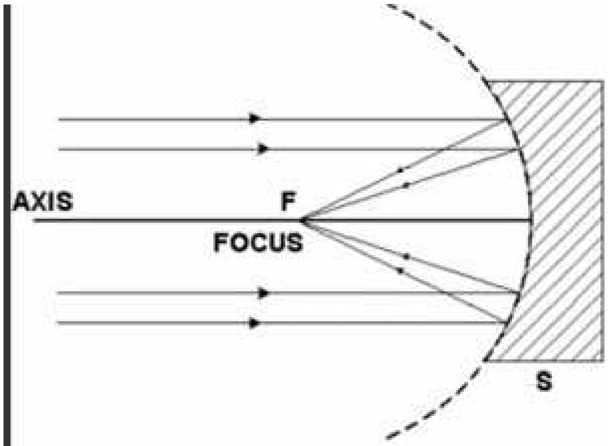


Corner Reflector Antenna

The antenna that comprises one or more dipole elements placed in front of a corner reflector, is known as corner-reflector antenna.The directivity of any antenna can be increased by using reflectors. In case of a wire antenna, a conducting sheet is used behind the antenna for directing the radiation in the forward direction.

Parabolic-Reflector Antenna

The radiating surface of a parabolic antenna has very large dimensions compared to its wavelength. The geometrical optics, which depend upon rays and wavefronts, are used to know about certain features of these antennas. Certain important properties of these antennas can be studied by using ray optics, and of other antennas by using electromagnetic field theory.



Parabolic Antenna

One of the useful properties of this antenna is the conversion of a diverging spherical wavefront into parallel wave front that produces a narrow beam of the antenna. The various types of feeds that use this parabolic reflector include horn feeds, Cartesian feeds and dipole feed.

In this article, you have studied about the different types of antennas and their applications in wireless communications and the usage of Antennas in transmitting and receiving data. For any help regarding this article, contact us by commenting in the comment section below.

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RADAR

The electronic principle on which radar operates is very similar to the principle of sound-wave reflection. If you shout in the direction of a sound-reflecting object (like a rocky canyon or cave), you will hear an echo. If you know the speed of sound in air, you can then estimate the distance and general direction of the object. The time required for an echo to return can be roughly converted to distance if the speed of sound is known.

Radar uses electromagnetic energy pulses in much the same way, as shown in Figure 1. The radio-frequency (rf) energy is transmitted to and reflected from the reflecting object. A small portion of the reflected energy returns to the radar set. This returned energy is called an ECHO, just as it is in sound terminology. Radar sets use the echo to determine the directionand distance of the reflecting object.

The term RADAR is an acronym made up of the words:

RAdio (Aim) **D**etecting **A**nd **R**anging

The term “RADAR” was officially coined as an acronym by U.S. Navy Lieutenant Commander Samuel M. Tucker and F. R. Furth in November 1940. The acronym was by agreement adopted in 1943 by the Allied powers of World War II and thereafter received general international acceptance. [1]

It refers to electronic equipment that detects the presence of objects by using reflected electromagnetic energy. Under some conditions a radar system can measure the direction, height, distance, course and speed of these objects. The frequency of electromagnetic energy used for radar is unaffected by darkness and also penetrates fog and clouds. This permits radar systems to determine the position of airplanes, ships, or other obstacles that are invisible to the naked eye because of distance, darkness, or weather.

Modern radar can extract widely more information from a target’s echo signal than its range. But the calculating of the range by measuring the delay time is one of its most important functions.

Basic design of a radar system

The following figure shows the operating principle of a primary radar set. The radar antenna illuminates the target with a microwave signal, which is then reflected and picked up by a receiving device. The electrical signal picked up by the receiving antenna is called echo or return. The radar signal is generated by a powerful transmitter and received by a highly sensitive receiver.

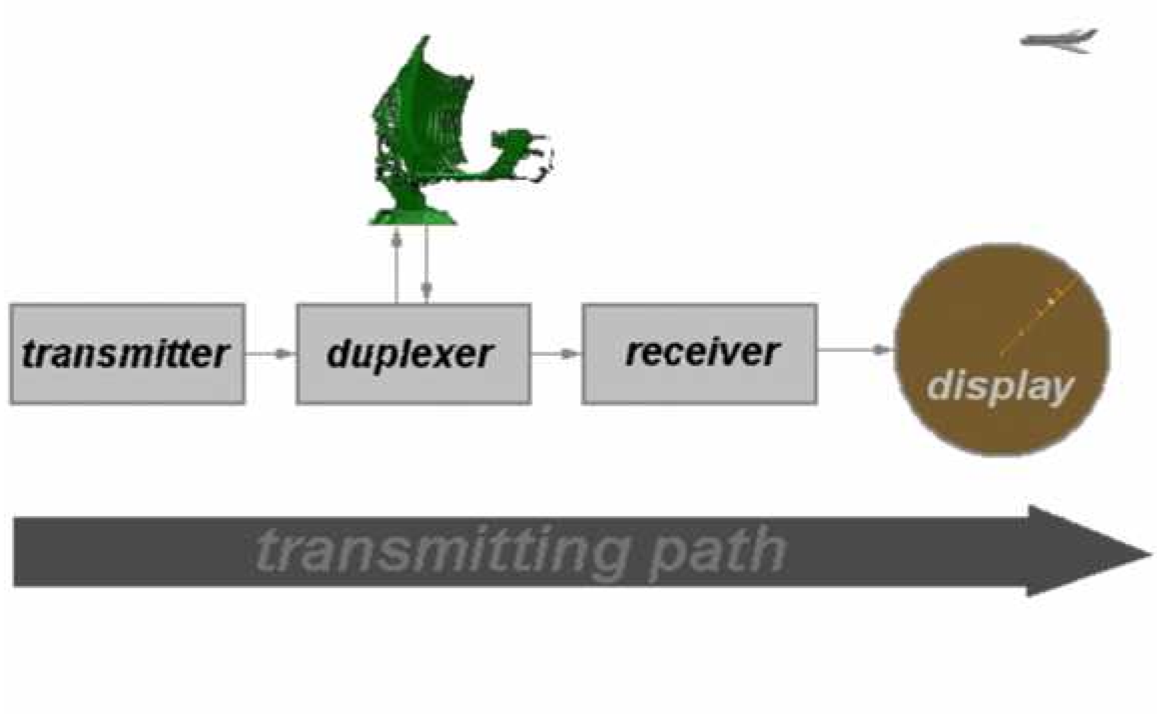


Figure 2: Block diagram of a primary radar (interactive picture)

All targets produce a diffuse reflection i.e. it is reflected in a wide number of directions. The reflected signal is also called scattering. **Backscatter** is the term given to reflections in the opposite direction to the incident rays.

Radar signals can be displayed on the traditional plan position indicator (PPI) or other more advanced radar display systems. A PPI has a rotating vector with the radar at the origin, which indicates the pointing direction of the antenna and hence the bearing of targets.

- **Transmitter**
  The radar transmitter produces the short duration high-power rf pulses of energy that are into space by the antenna.
- **Duplexer**
  The duplexer alternately switches the antenna between the transmitter and receiver so that only one antenna need be used. This switching is necessary because the high-power pulses of the transmitter would destroy the receiver if energy were allowed to enter the receiver.
- **Receiver**
  The receivers amplify and demodulate the received RF-signals. The receiver provides video signals on the output.
- **Radar Antenna**

The Antenna transfers the transmitter energy to signals in space with the required distribution and efficiency. This process is applied in an identical way on reception.

- **Indicator**

The indicator should present to the observer a continuous, easily understandable, graphic picture of the relative position of radar targets. The radar screen (in this case a PPI-scope) displays the produced from the echo signals bright blibs. The longer the pulses were delayed by the runtime, the further away from the center of this radar scope they are displayed. The direction of the deflection on this screen is that in which the antenna is currently pointing.

UNIT- IV NAVIGATION AND LANDING AIDS

satellite navigation

A satellite navigation or satnav system is a system of satellites that provide autonomous geo-spatial positioning with global coverage. It allows small electronic receivers to determine their location (longitude, latitude, and altitude/elevation) to high precision (within a few metres) using time signals transmitted along a line of sight by radio fromsatellites. The signals also allow the electronic receiver to calculate the current local time to high precision, which allows time synchronisation. A satellite navigation system with global coverage may be termed a global navigation satellite system (GNSS). The system can be used for navigation or for tracking the position of something fitted with a receiver (satellite tracking).

As of April 2013 only the United States NAVSTAR Global Positioning System (GPS) and the Russian GLONASS are global operational GNSSs. China is in the process of expanding its regional BeiDou Navigation Satellite System into the global Compass navigation system by 2020.[1] The European Union's Galileo is a global GNSS in initial deployment phase, scheduled to be fully operational by 2020 at the earliest.[2] India currently has satellite-based augmentation system, GPS Aided GEO Augmented Navigation(GAGAN), which enhances the accuracy of NAVSTAR GPS and GLONASS positions. India has already launched the IRNSS, with an operational name NAVIC (Navigation with Indian Constellation), a constellation of satellites for navigation in and around the Indian Subcontinent. It is expected to be fully operational by June 2016. France and Japan are in the process of developing regional navigation systems as well.

Global coverage for each system is generally achieved by a satellite constellation of 20–30 medium Earth orbit (MEO) satellites spread between several orbital planes. The actual systems vary, but use orbital inclinations of >50°

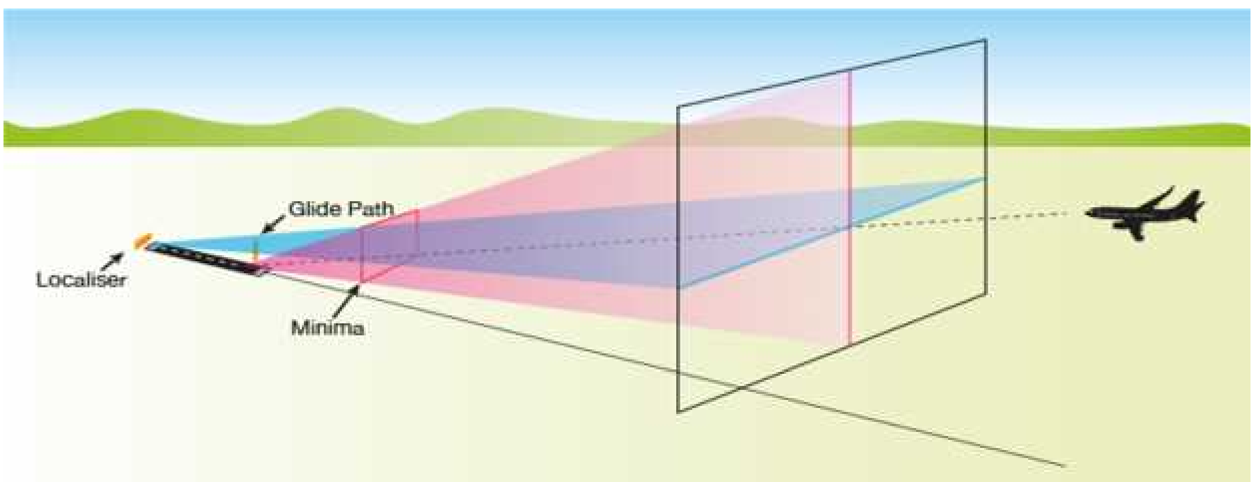
and orbital periods of roughly twelve hours (at an altitude of about 20,000 kilometres or 12,000 miles).

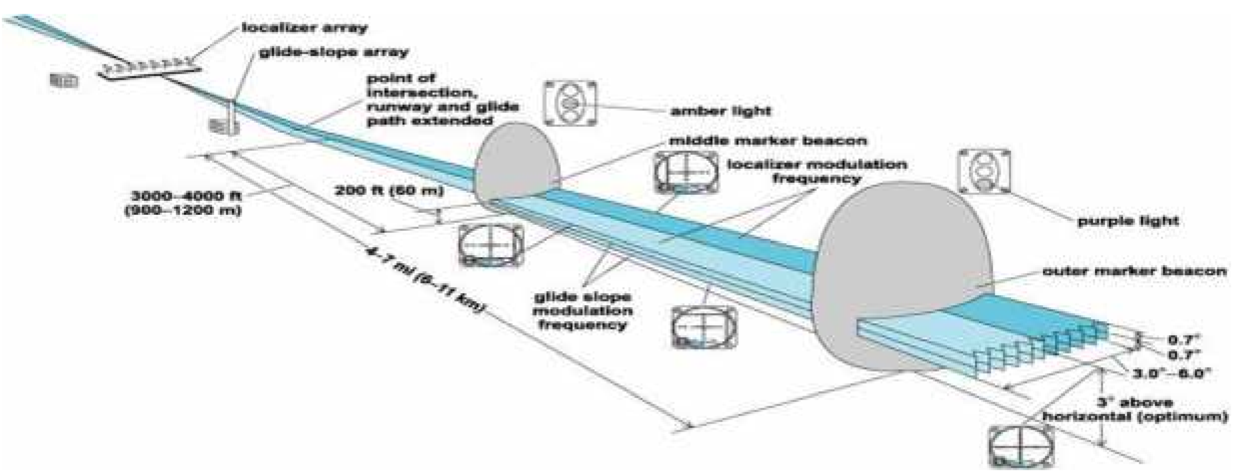
Satellite navigation systems that provide enhanced accuracy and integrity monitoring usable for civil navigation are classified as follows:

- **GNSS-1** is the first generation system and is the combination of existing satellite navigation systems (GPS and GLONASS), with Satellite Based Augmentation Systems (SBAS) or Ground Based Augmentation Systems (GBAS). In the United States, the satellite based component is the Wide Area Augmentation System (WAAS), in Europe it is the European Geostationary Navigation Overlay Service (EGNOS), and in Japan it is the Multi-Functional Satellite Augmentation System (MSAS). Ground based augmentation is provided by systems like the Local Area Augmentation System (LAAS). **GNSS-** 2 is the second generation of systems that independently provides a full civilian satellite navigation system, exemplified by the European Galileo positioning system. These systems will provide the accuracy and integrity monitoring necessary for civil navigation; including aircraft. This system consists of L1 and L2 frequencies (in the L band of the radio spectrum) for civil use and L5 for system integrity. Development is also in progress to provide GPS with civil use L2 and L5 frequencies, making it a GNSS-2 system.
- Core Satellite navigation systems, currently GPS (United States), GLONASS (Russian Federation), Galileo (European Union) and Compass (China).
- Global Satellite Based Augmentation Systems (SBAS) such as Omnistar and StarFire.
- Regional SBAS including WAAS (US), EGNOS (EU), MSAS (Japan) and GAGAN (India).
- Regional Satellite Navigation Systems such as China's Beidou, India's NAVIC, and Japan's proposed QZSS.
- Continental scale Ground Based Augmentation Systems (GBAS) for example the Australian GRAS and the US Department of Transportation National Differential GPS (DGPS) service.
- Regional scale GBAS such as CORS networks.
- Local GBAS typified by a single GPS reference station operating Real Time Kinematic (RTK) corrections.

INSTRUMENT LANDING SYSTEM

- An ILS is a highly accurate radio signal navigation aid used by pilots landing at an airport when there is poor weather and/or low visibility. It consists of two antennas which transmit signals to receivers in the aircraft cockpit—a glide path tower located next to the runway at the northern end and a localiser antenna at the southern end. These antennas provide the pilot with vertical and horizontal guidance when landing in low visibility.
- An ILS may be used outside these conditions as a preferred approach particularly for international operators. It may also be used by some aircraft at night and there will be occasions where aircraft and airlines require the ILS approach for licensing and training requirements.



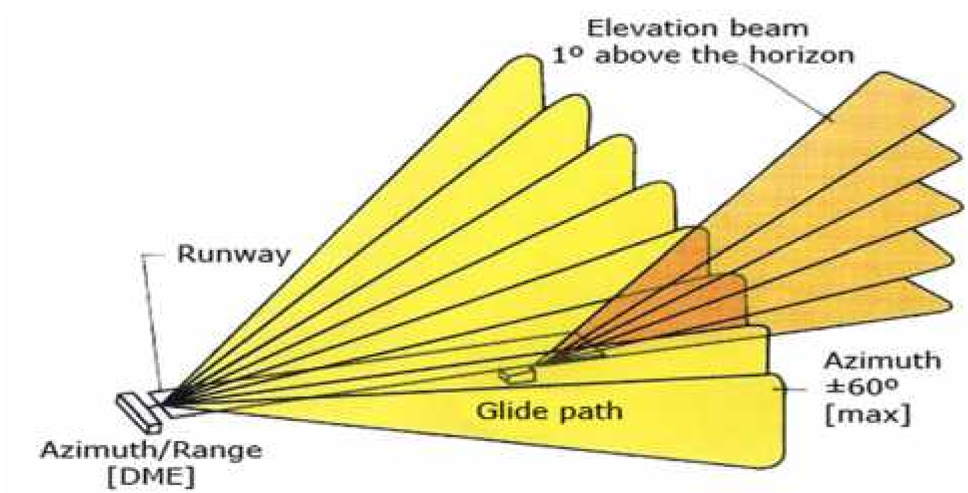


The ILS system is nowadays the primary system for instrumental approach for category I.-III-Aconditions of operation minimums and it provides the horizontal as well as the vertical guidance necessary for an accurate landing approach in IFR (Instrument Flight Rules) conditions, thus in conditions of limited or reduced visibility.The accurate landing approach is a procedure of permitted descent with the use of navigational equipment coaxial with the trajectory and given information about the angle of descent.

The equipment that provides a pilot instant information about the distance to the point of reach is not a part of the ILS system and therefore is for the discontinuous indication used a set of two or three marker beacons directly integrated into the system. The system of marker beacons can however be complemented for a continuous measurement of distances with the DME system (Distance measuring equipment), while the ground part of this UKV distance meter is located co-operatively with the descent beacon that forms the glide slope. It can also be supplemented with a VOR system by which means the integrated navigational-landing complex ILS/VOR/DME is formed.

MICROWAVE LANDING SYSTEM

The MLS is a system of precission approach for landing by instruments and constitutes a kind of an alternative to the ILS system. It provides information about the azimuth, optimal angle of descent and the distance, as well as data about the reverse course in case of an unsuccessful approach. It has several advantages compared to the ILS, for example a greater number of possible executed approaches, a more compact ground equipment, and a potential to use more complicated approach trajectories. However for certain reasons, in particular the advancement of the GPS satelite navigation, was the installation of new devices halted and finally in 1994 completely canceled by the FAA organization. On european airports we can rather seldom come across an MLS.



The MLS provides an accurate landing approach for an aircraft in the area of the final approach, where the path of the final approach isn't identical with the enlonged runway's axis. The system works with a microwave beam that is transmitted towards the sector of approach and scans the sector both in the horizontal as well as the verical plane. An aircraft in the approach sector receives the signal and with the help of this beam evaluates it's location in space. The aircraft's position is therefore determined both in the horizontal direction of approach and the vertical plane, in whatever point of reach of the scanning beam. Because the microwave technology is radiated into the space of approach in a given time and it's not spread out over different directions, no signal interruption results from various obstacles or terrain protrusions as it was with the ILS system. The MLS system can thus be situated also in developed areas, where an ILS system couldn't be set up. An onboard computer enables to solve the approach manoeuvre from a random direction, for variously oriented runways, even along a curved of bend landing trajectory. The MLS system is approved by the ICAO for every three categories of an accurate landing approach.

The MLS system is comprised of ground pieces of equipment that are divided into the protractor components, rangefinder components, and the onboard hardware. The information about the angles of the approach course, descent, flare and the course of an unsuccessful approach are aquired through an onboard antenna or the aircraft itself by measuring the time between two passages of an oscillating lobe of a high frequency signal . The distance is determined with the help of an ancillary device, the DME rangefinder. The MLS system further sends with the help of phase modulation and time-division multiplexing additional data, as identification, system status and so on. The ground equipment consists in the basic configuration of an Azimuth Transmitter (AZ) with an added DME rangefinder, perhaps even a more precise DME/P, in close distance of a course transmitter and near an elevation transmitter, see Fig. 1. A scaled up configuration is supplemented with a course transmitter for an unsuccessful approach and a flare transmitter.round Distance Measuring Equipment (DME)

The rangefinder unit presents a DME which is positioned together with the course transmitter. In connection with requirements of accuracy of the MLS system arose a demand to refine the DME system, which was accomplished with the accurate DME/P rangefinder (along with the DME/W and DME/N). Hence the function of the DME is to provide a pilot information about the distance from a specific point which is essential for pinpoint calculation of the plane's position in the three-dimensional space.Ground protractor components

The ground principle of both protractor parts of the MLS system for horizontal and vertical homing of an aircraft is to create levelled emiting diagrams, oscillating at a constant speed in directions „TO" and „FROM", and to measure the elapsed time between two passages of an oscillating plane lobe through an onboard MLS antenna.

UNIT V - COMMUNICATIONS AND NAVIGATION AIDS

TRAFFIC COLLISION AVOIDANCE SYSTEM OR TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM

A traffic collision avoidance system or traffic alert and collision avoidance system (both abbreviated as TCAS, and pronounced tee-kas) is an aircraft collision avoidance system designed to reduce the incidence of mid-air collisions between aircraft. It monitors the airspace around an aircraft for other aircraft equipped with a corresponding active transponder, independent of air traffic control, and warns pilots of the presence of other transponder-equipped aircraft which may present a threat of mid-air collision(MAC). It is a type of airborne collision avoidance system mandated by the International Civil Aviation Organization to be fitted to all aircraft with a maximum take-off mass (MTOM) of over 5,700 kg (12,600 lb) or authorized to carry more than 19 passengers. CFR 14, Ch I, part 135 requires that TCAS I is installed for aircraft with 10-30 passengers and TCAS II for aircraft with more than 30 passengers.

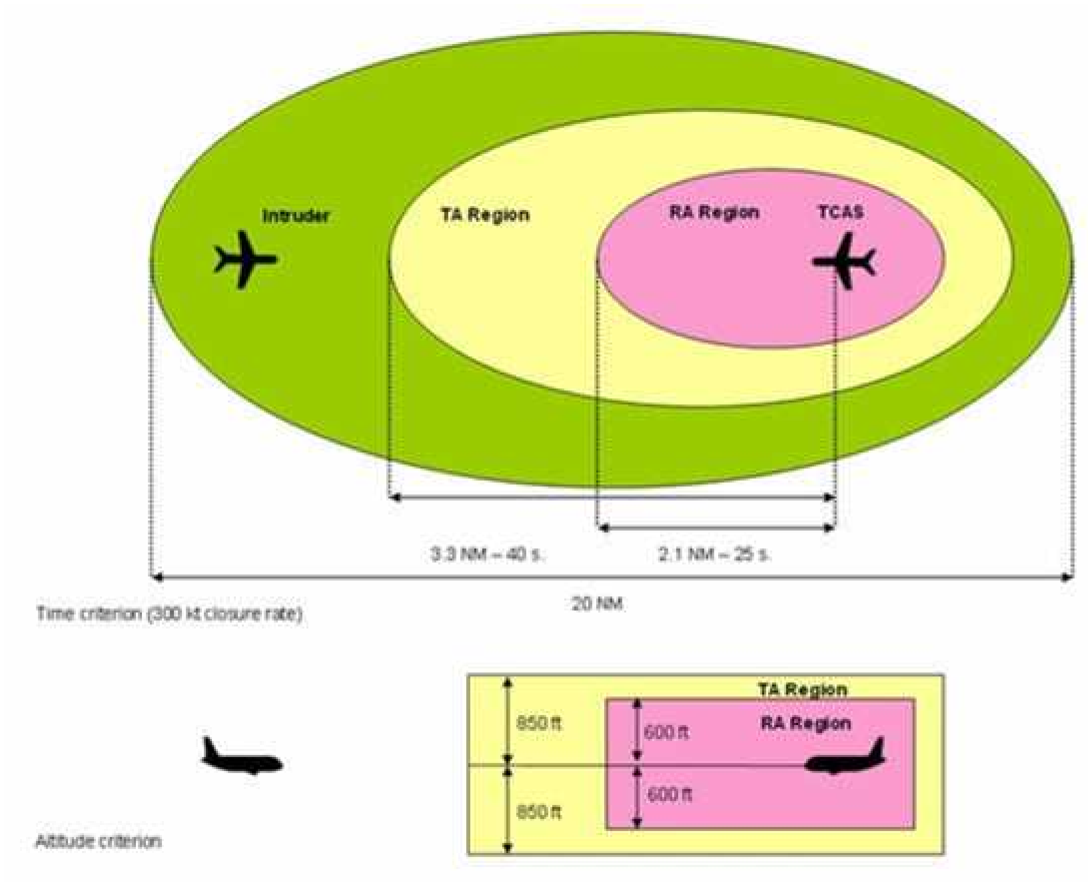
ACAS / TCAS is based on secondary surveillance radar (SSR) transponder signals, but operates independently of ground-based equipment to provide advice to the pilot on potential conflicting aircraft.

In modern glass cockpit aircraft, the TCAS display may be integrated in the Navigation Display (ND) or Electronic Horizontal Situation Indicator (EHSI); in older glass cockpit aircraft and those with mechanical instrumentation, such an integrated TCAS display may replace the mechanical Vertical Speed Indicator (which indicates the rate with which the aircraft is descending or climbing).

System description

TCAS involves communication between all aircraft equipped with an appropriate transponder (provided the transponder is enabled and set up properly). Each TCAS-equipped aircraft interrogates all other aircraft in a determined range about their position (via the 1.03 GHz radio frequency), and all other aircraft reply to other interrogations (via 1.09 GHz). This interrogation-and-response cycle may occur several times per second.

The TCAS system builds a three dimensional map of aircraft in the airspace, incorporating their range (garnered from the interrogation and response round trip time), altitude (as reported by the interrogated aircraft), and bearing (by the directional antenna from the response). Then, by extrapolating current range and altitude difference to anticipated future values, it determines if a potential collision threat exists.



Example of ACAS Protection Volume between 5000 and 10000 feet

TCAS and its variants are only able to interact with aircraft that have a correctly operating mode C or mode S transponder. A unique 24-bit identifier is assigned to each aircraft that has a mode S transponder.

The next step beyond identifying potential collisions is automatically negotiating a mutual avoidance manoeuver (currently, manoeuvers are restricted to changes in altitude and modification of climb/sink rates) between the two (or more) conflicting aircraft. These avoidance manoeuvers are communicated to the flight crew by a cockpit display and by synthesized voice instructions.

A protected volume of airspace surrounds each TCAS equipped aircraft. The size of the protected volume depends on the altitude, speed, and heading of the aircraft involved in the encounter. The illustration below gives an example of a typical TCAS protection volume.

System components

A TCAS installation consists of the following components:

TCAS computer unit

Performs airspace surveillance, intruder tracking, its own aircraft altitude tracking, threat detection, resolution advisory (RA) manoeuvre determination and selection, and generation of advisories. The TCAS Processor uses pressure altitude, radar altitude, and discrete aircraft status inputs from its own aircraft to control the collision avoidance logic parameters that determine the protection volume around the TCAS aircraft.

Antennas

The antennas used by TCAS II include a directional antenna that is mounted on the top of the aircraft and either an omnidirectional or a directional antenna mounted on the bottom of the aircraft. Most installations use the optional directional antenna on the bottom of the aircraft. In addition to the two TCAS antennas, two antennas are also required for the Mode S transponder. One antenna is mounted on the top of the aircraft while the other is mounted on the bottom. These antennas enable the Mode S transponder to receive interrogations at 1030 MHz and reply to the received interrogations at 1090 MHz.

Cockpit presentation

The TCAS interface with the pilots is provided by two displays: the traffic display and the RA display. These two displays can be implemented in a number of ways, including displays that incorporate both displays into a single, physical unit. Regardless of the implementation, the information displayed is identical. The standards for both the traffic display and the RA display are defined in DO-185A.

Operation modes

TCAS II can be currently operated in the following modes:

Stand-by

Power is applied to the TCAS Processor and the mode S transponder, but TCAS does not issue any interrogations and the transponder will reply to only discrete interrogations.

Transponder

The mode S transponder is fully operational and will reply to all appropriate ground and TCAS interrogations. TCAS remains in stand-by.

Traffic advisories only

The mode S transponder is fully operational. TCAS will operate normally and issue the appropriate interrogations and perform all tracking functions. However, TCAS will only issue traffic advisories (TA), and the resolution advisories (RA) will be inhibited.

Automatic (traffic/resolution advisories)

The mode S transponder is fully operational. TCAS will operate normally and issue the appropriate interrogations and perform all tracking functions. TCAS will issue traffic advisories (TA) and resolution advisories (RA), when appropriate.

TCAS works in a coordinated manner, so when an RA is issued to conflicting aircraft, a required action (i.e., *Climb. Climb.*) has to be immediately performed by one of the aircraft, while the other one receives a similar RA in the opposite direction (i.e., *Descend. Descend.*).

Alert

TCAS II issues the following types of aural annunciations:

- Traffic advisory (TA)
- Resolution advisory (RA)
- Clear of conflict

When a TA is issued, pilots are instructed to initiate a visual search for the traffic causing the TA. If the traffic is visually acquired, pilots are instructed to maintain visual separation from the traffic. Training programs also indicate that no horizontal maneuvers are to be made based solely on information shown on the traffic display. Slight adjustments in vertical speed while climbing or descending, or slight adjustments in airspeed while still complying with the ATC clearance are acceptable.

When an RA is issued, pilots are expected to respond immediately to the RA unless doing so would jeopardize the safe operation of the flight. This means that aircraft will at times have to manoeuver contrary to ATC instructions or disregard ATC instructions. In these cases, the controller is no longer responsible for separation of the aircraft involved in the RA until the conflict is terminated.

On the other hand, ATC can potentially interfere with a pilot's response to RAs. If a conflicting ATC instruction coincides with an RA, a pilot may assume that ATC is fully aware of the situation and is providing the better resolution. But in reality, ATC is not aware of the RA until the RA is reported by the pilot. Once the RA is reported by the pilot, ATC is required not to attempt to modify the flight path of the aircraft involved in the encounter. Hence, the pilot is expected to "follow the RA" but in practice this does not always happen.

Some countries have implemented "RA downlink" which provides air traffic controllers with information about RAs posted in the cockpit. Currently, there are no ICAO provisions concerning the use of RA downlink by air traffic controllers.

The following points receive emphasis during pilot training:

- Do not manoeuver in a direction opposite to that indicated by the RA because this may result in a collision.
- Inform the controller of the RA as soon as permitted by flight crew workload after responding to the RA. There is no requirement to make this notification prior to initiating the RA response.
- Be alert for the removal of RAs or the weakening of RAs so that deviations from a cleared altitude are minimized.
- If possible, comply with the controller’s clearance, e.g. turn to intercept an airway or localizer, at the same time as responding to an RA.
- When the RA event is completed, promptly return to the previous ATC clearance or instruction or comply with a revised ATC clearance or instruction.

ELECTRONIC WARFARE

Electronic warfare (**EW**) is any action involving the use of the electromagnetic spectrum or directed energy to control the spectrum, attack of an enemy, or impede enemy assaults via the spectrum. The purpose of electronic warfare is to deny the opponent the advantage of, and ensure friendly unimpeded access to, the EM spectrum. EW can be applied from air, sea, land, and space by manned and unmanned systems, and can target humans, communications, radar, or other assets.

Electronic attack (EA)

Electronic attack (EA) (previously known as Electronic Counter Measures (ECM)) involves the use of EM energy, directed energy, or anti-radiation weapons to attack personnel, facilities, or equipment with the intent of degrading, neutralizing, or destroying enemy combat capability. In the case of EM energy, this action is referred to as jamming and can be performed on communications systems (see Radio jamming) or radar systems (see Radar jamming and deception).

Electronic Protection (EP)

Electronic Protection (EP) (previously known as electronic protective measures (EPM) or electronic counter countermeasures (ECCM)) involves actions taken to protect personnel, facilities, and equipment from any effects of friendly or enemy use of the electromagnetic spectrum that degrade, neutralize, or destroy friendly combat capability. Jamming is not part of EP, it is an EA measure.

The use of flare rejection logic on an Infrared homing missile to counter an adversary's use of flares is EP. While defensive EA actions and EP both protect personnel, facilities, capabilities, and equipment, EP protects from the effects of EA (friendly and/or adversary). Other examples of EP include spread spectrum technologies, use of Joint Restricted Frequency List (JRFL), emissions control (EMCON), and low observability or "stealth".

An Electronic Warfare Self Protection (EWSP) is a suite of countermeasure systems fitted primarily to aircraft for the purpose of protecting the aircraft from weapons fire and can include among others: DIRCM (protects against IR missiles), Infrared countermeasures (protects against IR missiles), Chaff (protects against RADAR guided missiles), DRFM Decoys (Protects against Radar guided missiles), Flare(protects against IR missiles).

An Electronic Warfare Tactics Range (EWTR) is a practice range which provides for the training of aircrew in electronic warfare. There are two such ranges in Europe; one at RAF Spadeadam in the United Kingdom and the POLYGON range in Germany and France. EWTRs are equipped with ground-based equipment to simulate electronic warfare threats that aircrew might encounter on missions.

Antifragile EW is a step beyond standard EP, occurring when a communications link being jammed actually increases in capability as a result of a jamming attack, although this is only possible under certain circumstances such as reactive forms of jamming.

Electronic warfare support (ES)

Electronic Warfare Support (ES), is the subdivision of EW involving actions tasked by, or under direct control of, an operational commander to search for, intercept, identify, and locate or localize sources of intentional and unintentional radiated electromagnetic (EM) energy for the purpose of immediate threat recognition, targeting, planning, and conduct of future operations.[1] These measures begin with systems designed and operators trained to make Electronic Intercepts (ELINT) and then classification and analysis broadly known as Signals intelligence from such detection to return information and perhaps actionable intelligence (e.g. a ship's identification from unique characteristics of a specific radar) to the commander.

The overlapping discipline, signals intelligence (SIGINT) is the related process of analyzing and identifying the intercepted frequencies (e.g. as a mobile phone or radar). SIGINT is broken into three categories: ELINT, COMINT, and FISINT. the parameters of intercepted txn are-: communication equipment-: freq, bandwidth, modulation, polarisation etc. The distinction between intelligence and electronic warfare support (ES) is determined by who tasks or controls the collection assets, what they are tasked to provide, and for what purpose they are tasked. Electronic warfare support is achieved by assets tasked or controlled by an operational commander. The purpose of ES tasking is immediate threat recognition, targeting, planning and conduct of future operations, and other tactical actions such as threat avoidance and homing. However, the same assets and resources that are tasked with ES can simultaneously collect intelligence that meets other collection requirements.[1]

Where these activities are under the control of an operational commander and being applied for the purpose of situational awareness, threat recognition, or EM targeting, they also serve the purpose of Electronic Warfare surveillance (ES).

Multifunctional EW system

In February 2015 the Russian army received their first set of the multifunctional electronic warfare system, known as Borisoglebsk 2. After some months of testing, it has been used in Ukraine. Svenska Dagbladet claimed its initial usage caused concern within NATO.

A Russian blog describes Borisoglebsk 2 as "The 'Borisoglebsk-2' when compared to its predecessors has better technical characteristics: wider frequency bandwidth for conducting radar collection and jamming, faster scanning times of the frequency spectrum, and higher precision when identifying the location and source of radar emissions, and increased capacity for suppression."

AIR TRAFFIC CONTROL

Air traffic control (ATC) is a service provided by ground-based controllers who direct aircraft on the ground and through controlledairspace, and can provide advisory services to aircraft in non-controlled airspace. The primary purpose of ATC worldwide is to prevent collisions, organize and expedite the flow of air traffic, and provide information and other support for pilots. In some countries, ATC plays a security or defensive role, or is operated by the military.

To prevent collisions, ATC enforces traffic separation rules, which ensure each aircraft maintains a minimum amount of empty space around it at all times. Many aircraft also have collision avoidance systems, which provide additional safety by warning pilots when other aircraft get too close.

In many countries, ATC provides services to all private, military, and commercial aircraft operating within its airspace. Depending on the type of flight and the class of airspace, ATC may issue instructions that pilots are required to obey, or advisories (known as flight information in some countries) that pilots may, at their discretion, disregard. The pilot in command is the final authority for the safe operation of the aircraft and may, in an emergency, deviate from ATC instructions to the extent required to maintain safe operation of their aircraft.

Ground control

Ground Control (sometimes known as Ground Movement Control) is responsible for the airport "movement" areas, as well as areas not released to the airlines or other users. This generally includes all taxiways, inactive runways, holding areas, and some transitional aprons or intersections where aircraft arrive, having vacated the runway or departure gate. Exact areas and control responsibilities are clearly defined in local documents and agreements at each airport. Any aircraft, vehicle, or person walking or working in these areas is required to have clearance from Ground Control. This is normally done via VHF/UHF radio, but there may be special cases where other procedures are used. Aircraft or vehicles without radios must respond to ATC instructions via aviation light signals or else be led by vehicles with radios. People working on the airport surface normally have a communications link through which they can communicate with Ground Control, commonly either by handheld radio or even cell phone. Ground Control is vital to the smooth operation of the airport, because this position impacts the sequencing of departure aircraft, affecting the safety and efficiency of the airport's operation.

Some busier airports have Surface Movement Radar (SMR), such as, ASDE-3, AMASS or ASDE-X, designed to display aircraft and vehicles on the ground. These are used by Ground Control as an additional tool to control ground traffic, particularly at night or in poor visibility. There are a wide range of capabilities on these systems as they are being modernized. Older systems will display a map of the airport and the target. Newer systems include the capability to display higher quality mapping, radar target, data blocks, and safety alerts, and to interface with other systems such as digital flight strips.

Local control or air control

Local Control (known to pilots as "Tower" or "Tower Control") is responsible for the active runway surfaces. Local Control clears aircraft for takeoff or landing, ensuring that prescribed runway separation will exist at all times. If Local Control detects any unsafe condition, a landing aircraft may be told to "go-around" and be re-sequenced into the landing pattern by the approach or terminal area controller.

Within the tower, a highly disciplined communications process between Local Control and Ground Control is an absolute necessity. Ground Control must request and gain approval from Local Control to cross any active runway with any aircraft or vehicle. Likewise, Local Control must ensure that Ground Control is aware of any operations that will impact the taxiways, and work with the approach radar controllers to create "holes" or "gaps" in the arrival traffic to allow taxiing traffic to cross runways and to allow departing aircraft to take off.Crew Resource Management (CRM) procedures are often used to ensure this communication process is efficient and clear, although this is not as prevalent as CRM for pilots.

Flight data and clearance delivery

Clearance Delivery is the position that issues route clearances to aircraft, typically before they commence taxiing. These contain details of the route that the aircraft is expected to fly after departure. Clearance Delivery or, at busy airports, the Traffic Management Coordinator (TMC) will, if necessary, coordinate with the en route center and national command center or flow control to obtain releases for aircraft. Often, however, such releases are given automatically or are controlled by local agreements allowing "free-flow" departures. When weather or extremely high demand for a certain airport or airspace becomes a factor, there may be ground "stops" (or "slot delays") or re-routes may be necessary to ensure the system does not get overloaded. The primary responsibility of Clearance Delivery is to ensure that the aircraft have the proper route and slot time. This information is also coordinated with the en route center and Ground Control in order to ensure that the aircraft reaches the runway in time to meet the slot time provided by the command center. At some airports, Clearance Delivery also plans aircraft push-backs and engine starts, in which case it is known as the Ground Movement Planner (GMP): this position is particularly important at heavily congested airports to prevent taxiway and apron gridlock.

Flight Data (which is routinely combined with Clearance Delivery) is the position that is responsible for ensuring that both controllers and pilots have the most current information: pertinent weather changes, outages, airport ground delays/ground stops, runway closures, etc. Flight Data may inform the pilots using a recorded continuous loop on a specific frequency known as the Automatic Terminal Information Service (ATIS).

Approach and terminal control

Many airports have a radar control facility that is associated with the airport. In most countries, this is referred to as Terminal Control; in the U.S., it is referred to as a TRACON (Terminal Radar Approach Control). While every airport varies, terminal controllers usually handle traffic in a 30-to-50-nautical-mile (56 to 93 km) radius from the airport. Where there are many busy airports close together, one consolidated Terminal Control Center may service all the airports. The airspace boundaries and altitudes assigned to a Terminal Control Center, which vary widely from airport to airport, are based on factors such as traffic flows, neighboring airports and terrain. A large and complex example is the London Terminal Control Centre which controls traffic for five main London airports up to 20,000 feet (6,100 m) and out to 100 nautical miles (190 km).

Terminal controllers are responsible for providing all ATC services within their airspace. Traffic flow is broadly divided into departures, arrivals, and overflights. As aircraft move in and out of the terminal airspace, they are handed off to the next appropriate control facility (a control tower, an en-route control facility, or a bordering terminal or approach control). Terminal control is responsible for ensuring that aircraft are at an appropriate altitude when they are handed off, and that aircraft arrive at a suitable rate for landing.

Not all airports have a radar approach or terminal control available. In this case, the en-route center or a neighboring terminal or approach control may co-ordinate directly with the tower on the airport and vector inbound aircraft to a position from where they can land visually. At some of these airports, the tower may provide a non-radar procedural approach service to arriving aircraft handed over from a radar unit before they are visual to land. Some units also have a dedicated approach unit which can provide the procedural approach service either all the time or for any periods of radar outage for any reason.