Aircraft Systems – Radio Systems

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- Communications
  - HF
  - VHF
  - SATCOM
- Radar
  - Radio Altimeter
  - Weather
- Collision Avoidance
  - ATC Transponder
  - TCAS

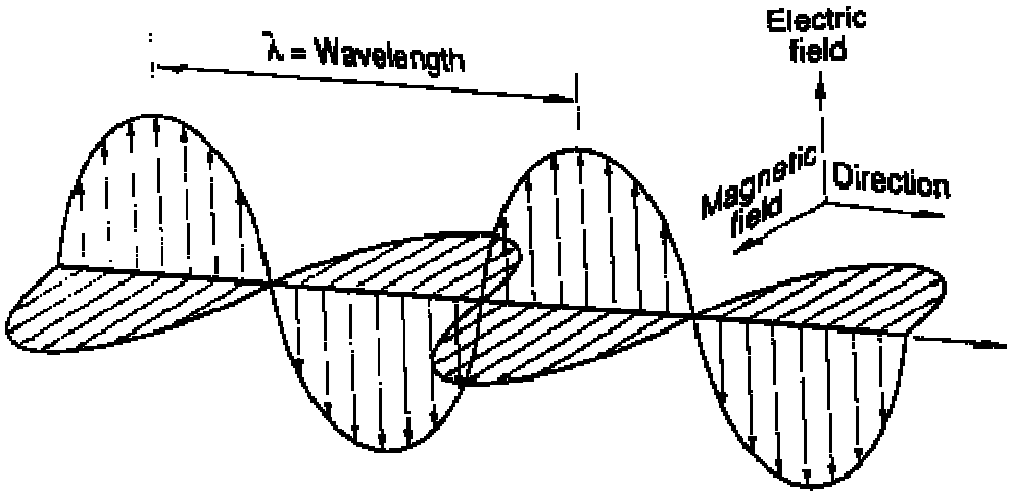
Communications

- Radio Frequency (RF) systems are used to provide communications between the aircraft and the ground or between two aircraft.
- *RF is also used for navigation systems*.....

- Early systems were developed to provide voice communications
- More recent systems were developed to provide a data link with operational and safety information as well as provide services for the passengers.
- New improvements being made all the time in response to issues (e.g. MH370)

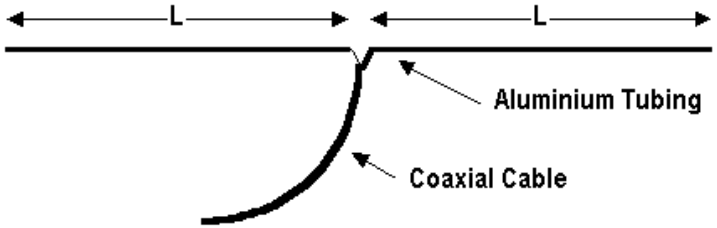
Radio Waves

- Electro-magnetic radiation – travelling waves of orthogonal electric and magnetic fields



Radio Transducers

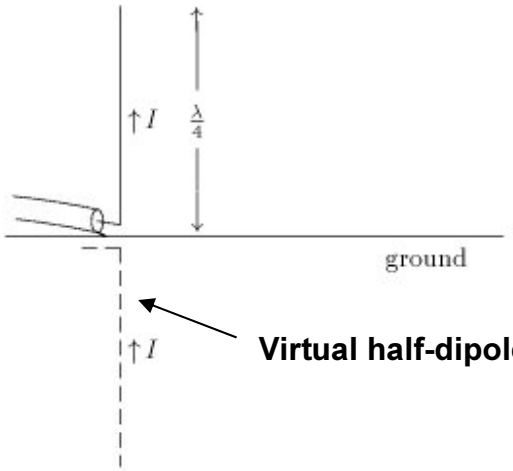
- The transducer between the electrical conduction (i.e. in the wires and cables of our avionic systems) and the broadcast EM radiation domains is an ‘antenna’ or ‘aerial’.
- Antennas work by having an electrical length of similar dimensions to the wavelength of the EM wave in air.



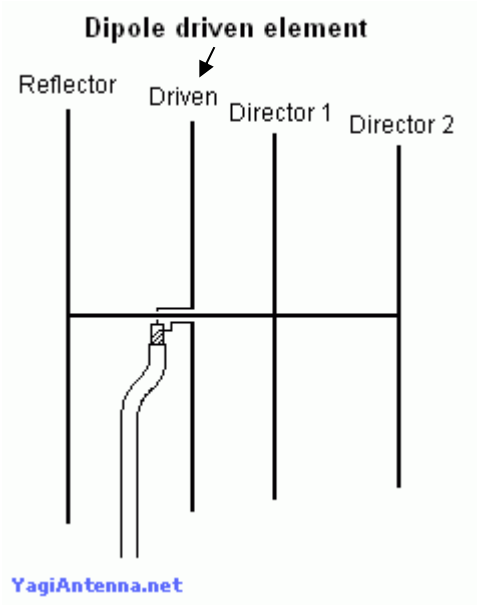
Half Wave Dipole

$L = \lambda/4$

More antennas



- Monopole antenna (e.g. on a car) use 'ground' to form a reflected dipole. The physical antenna is λ/4.



- Multi element antenna like a TV antenna have passive reflecting elements around a dipole to create directional response..

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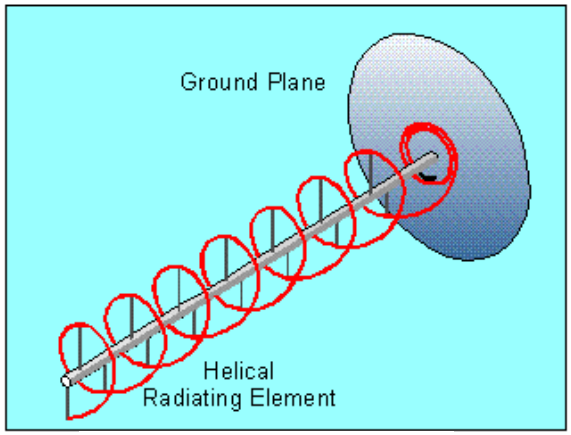
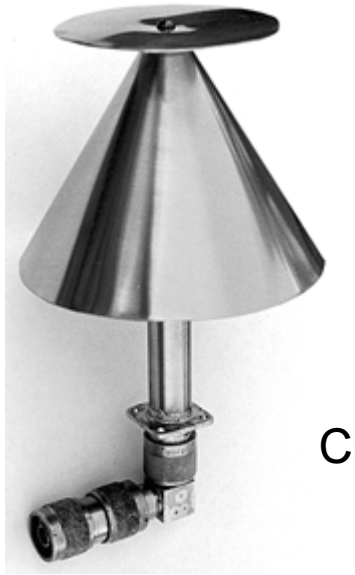
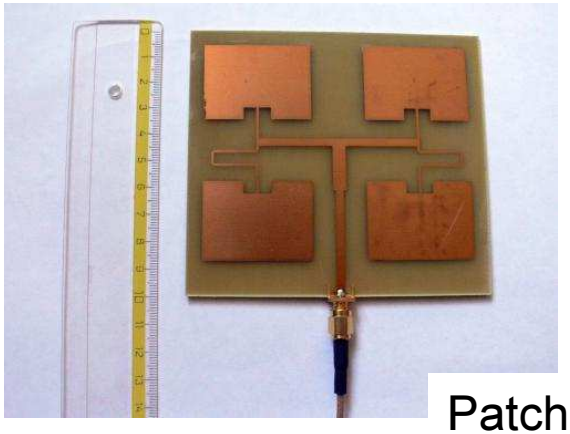
Even more….



Helical Antenna



Cone Antenna



Patch Antenna

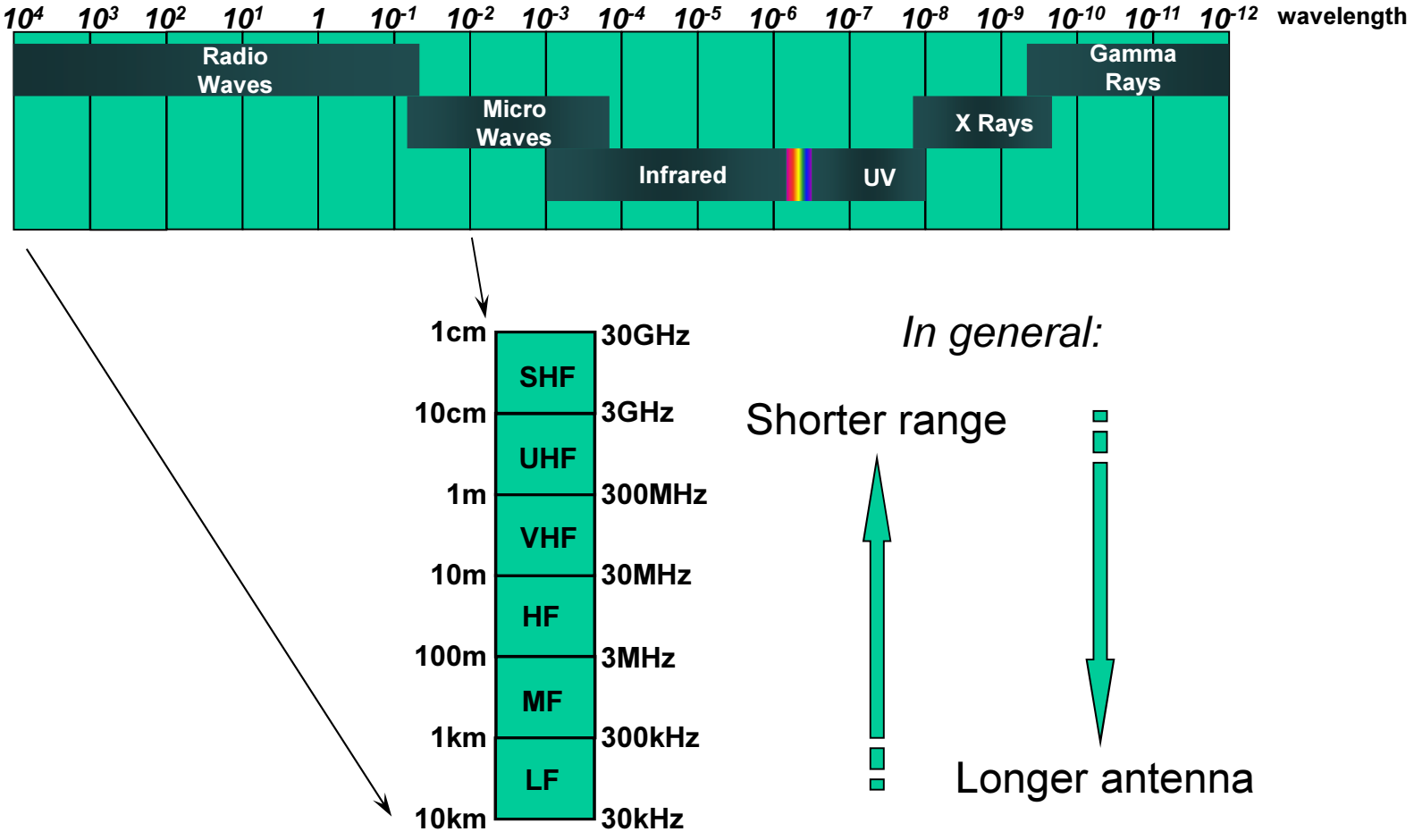
Aircraft-mounted folded monopole

Radio propagation

- Differing frequencies of EM radiation propagate in differing ways.
- Long wavelengths tend travel further and bend around obstructions.
- Shorter wavelengths tend to be ‘line of sight’.
- Some frequencies can bounce off layers in the atmosphere.

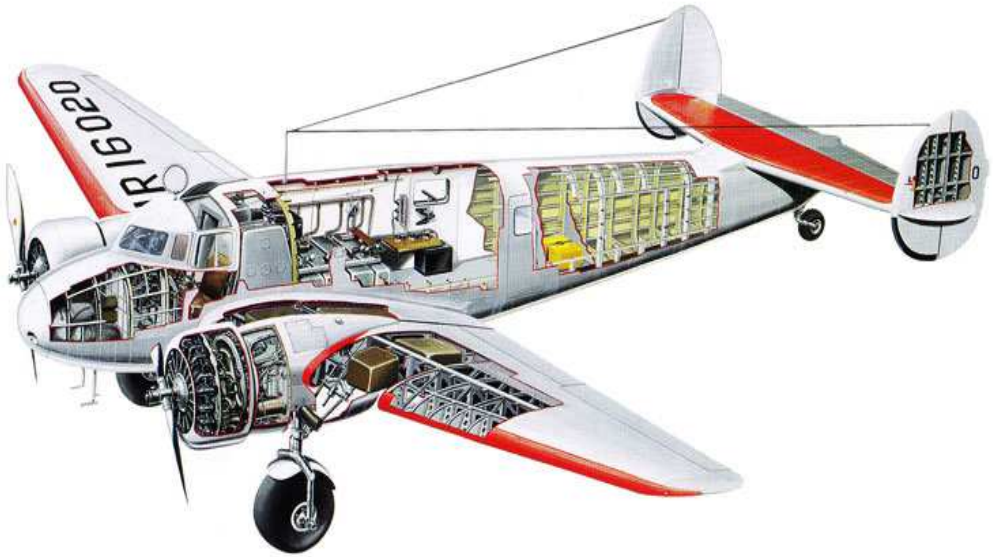
- The wavefront of a transmitted signal spreads out over time – RF transmission distances are often long so the received power is usually many, many orders of magnitude below that transmitted.
  - e.g. a sensitive receiver may pick up signals ~ 1x 10^{-10} mW

RF Spectrum



HF communications

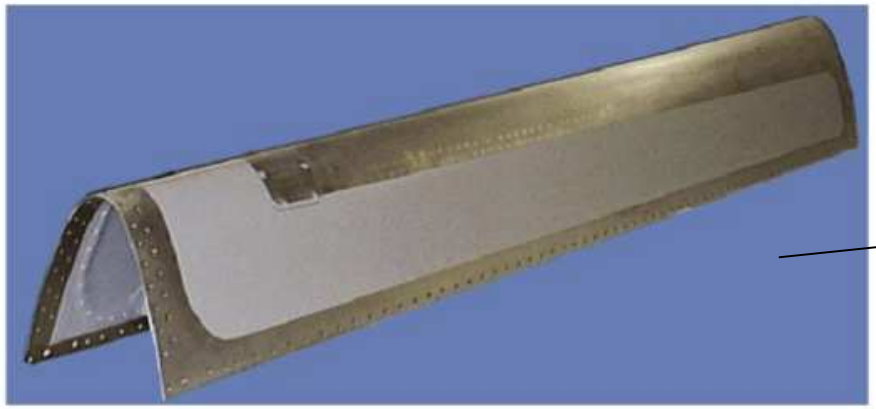
- The first aircraft used the HF part of the spectrum. This provided long range associated with the long wavelength radio waves (over the horizon as they are reflected by the atmosphere)
- Still used for long range (~2000km) civil data and comms links
- Only system with coverage of the north pole



•But HF has drawbacks
•Susceptible to interference and fading as it is affected by atmospheric conditions
•Low information rates (1800bps max)
•Long antenna required

HF Antenna

HF S98-5000



DESCRIPTION

S98-5000: HF Shunt Antenna

The HF Shunt antenna is incorporated in the leading edge of the vertical fin and provides optimum performance for HF data link and HF voice operations. This antenna is approved for installation on all models of the Boeing 757-200. The antenna installation meets all the airworthiness requirements of Part 25 of the Federal Aviation Regulations and is covered under Supplemental Type Certificate Number ST01997AT.

The same type of antenna can be incorporated on other aircraft models such as the Boeing 737 and 747.

SPECIFICATIONS

ELECTRICAL

Frequency	2-30 MHz
VSWR	1.3:1
Impedance	50 ohms
Power Handling	400 Watts
Lightning Protection	D.C. Grounded

MECHANICAL

Material	Aluminum, Epoxy Glass
Finish	Polished Aluminum
Connector	Feedline

ENVIRONMENTAL

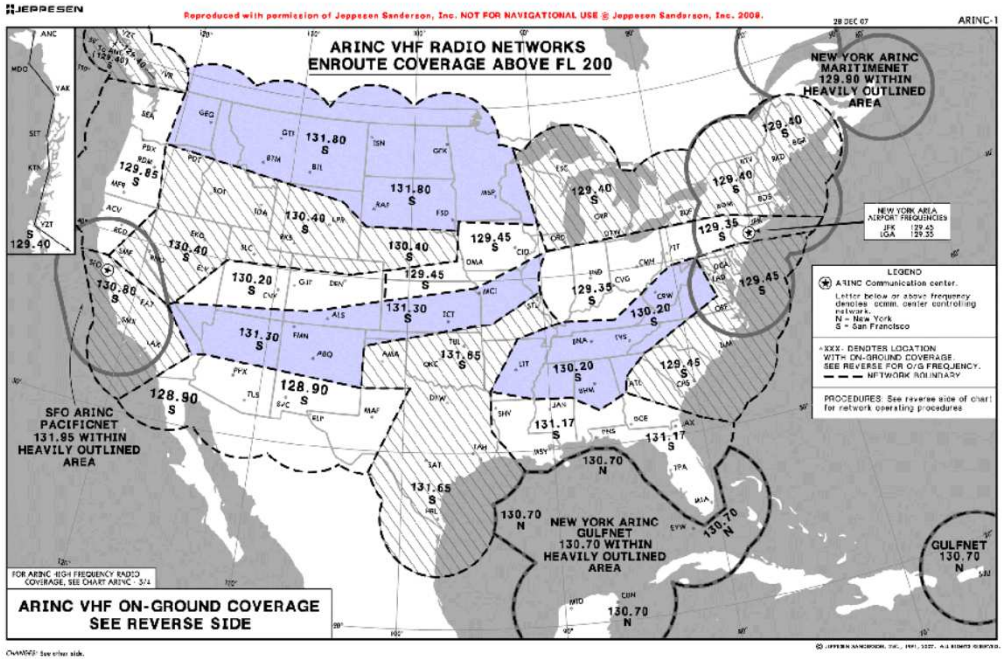
Temperature	-40°F to +185°F
Vibration	10 G's
Altitude	55,000 ft

Photo: Eduard Marmet

The long wire antennas found on older aircraft have been replace by ones embedded in the structure

VHF - communications

- VHF is the most commonly used radio communications link for data and voice on aircraft.
- The shorter range (~200km) of VHF means that it is generally used for domestic communications.



ARINC (US standards for Aircraft systems) VHF US domestic coverage map

ARINC = Aeronautical Radio INC.

VHF Antenna

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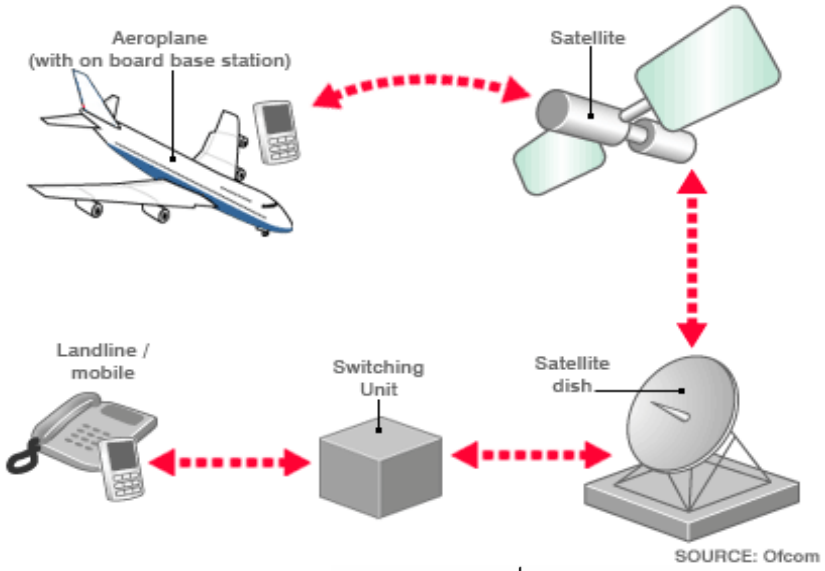
SATCOM – satellite communications

- Satellite communications provide the highest data rates and widest coverage.
  - Used for voice, data and passenger services
- Aerospace operators use the IMMARSAT constellation of geo-stationary satellites or iridium low earth orbit.



SATCOM can be used for advanced services, such as to provide mobile phone service in addition to operational data for the flight

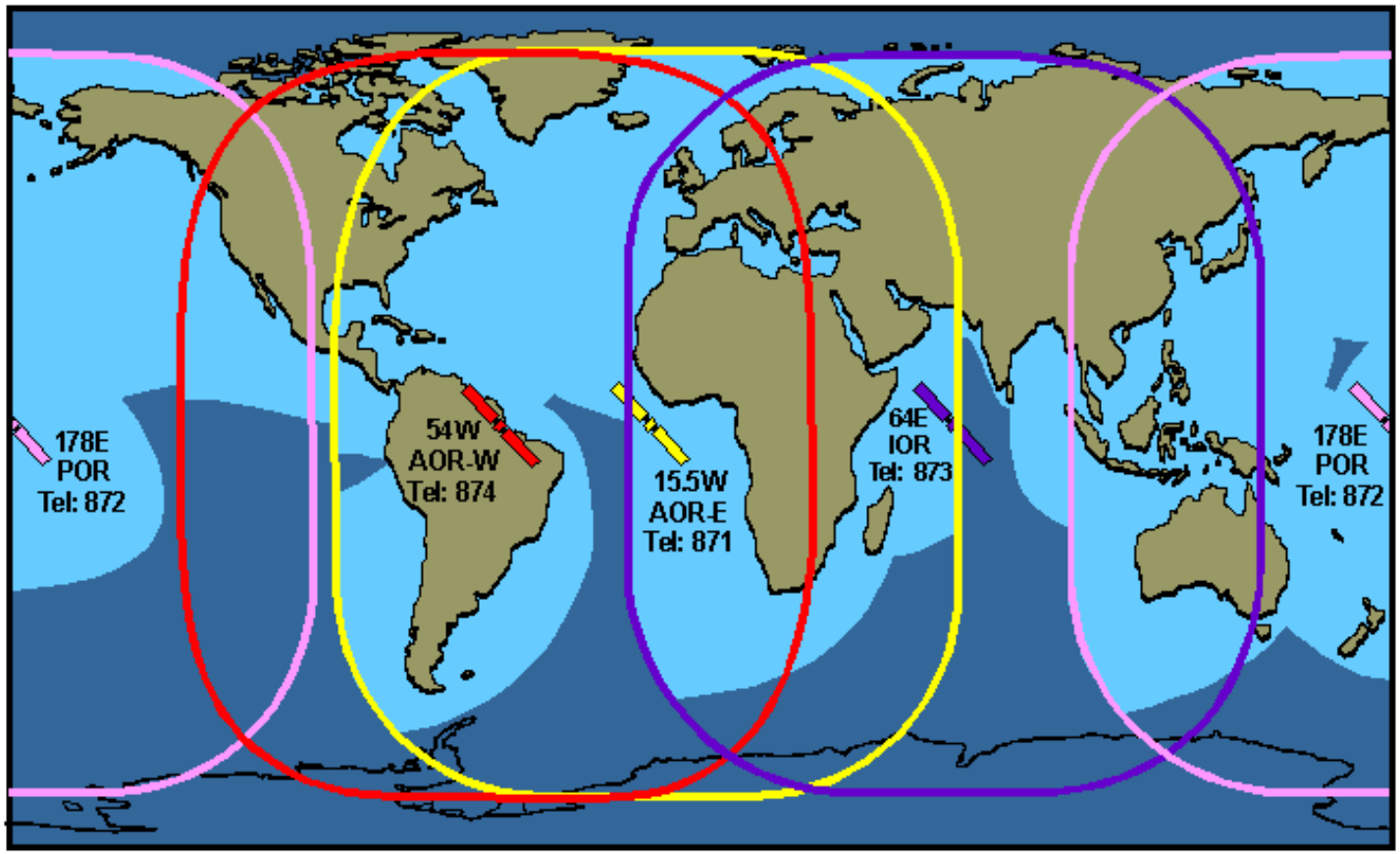
SATCOM antenna

High gain antenna – fixed wing, pod mounted

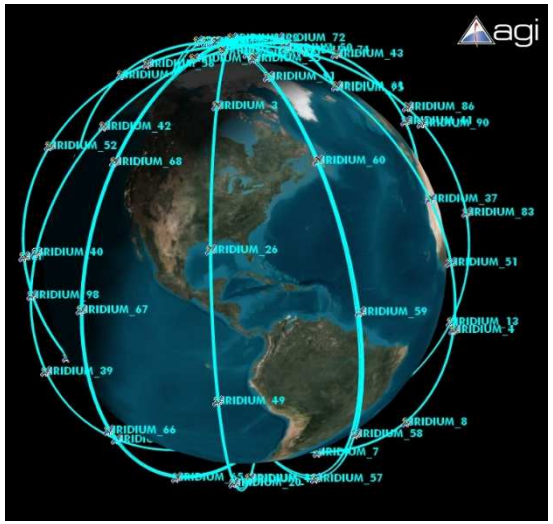
Electronically steered, low gain

High gain antenna – Rotary wing

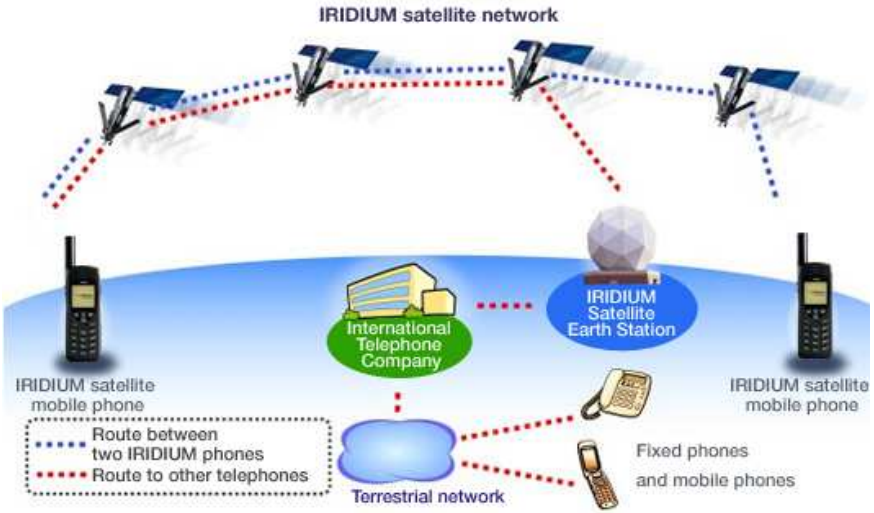
IMMARSAT coverage



Iridium



Agi.com



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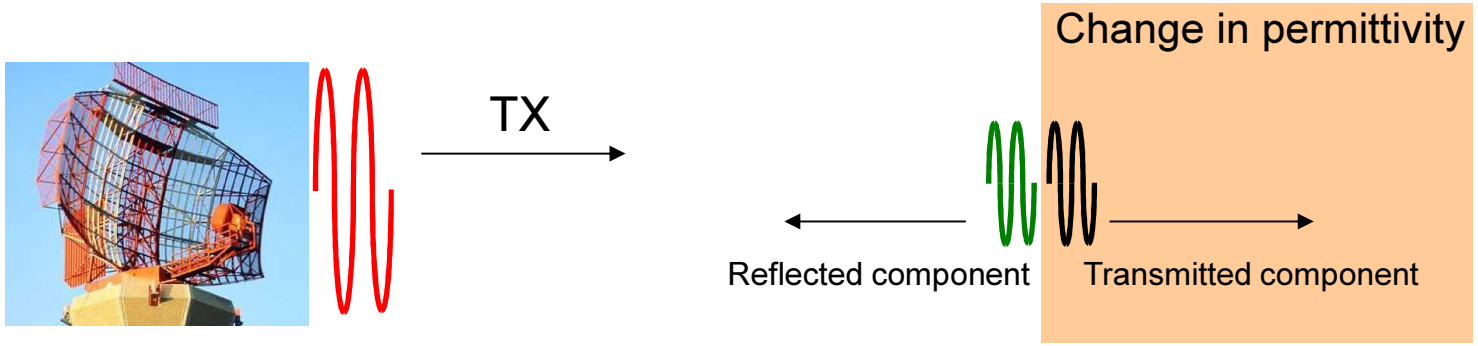
- The iridium network use low earth orbit satellites to provide complete coverage of the globe.
- The service is commonly used with ‘satphones’ but there are products for aviation, particularly business jets to provide onboard ‘wifi’, but the speeds are very low – its 1990’s technology. New products are being released.
- All satcoms are expensive, hence are premium services

Radar

Radar

- Originally RAdio Detection And Range – now a ‘proper’ word
- Radar systems transmit RF energy and listen for a reflection.
- By directing the transmission, and from the characteristics of the received reflection, relative position, motion and size of an object can be determined.
- Obvious use for military in defensive/offensive roles.
- Also used in civil aircraft for weather detection and as a means of measuring altitude .

How it works



- Where there is a change in permittivity in the transmission medium, some EM energy is reflected back.
- Metallic surfaces are particularly good at reflecting.
- The timing of the return pulse can determine range.
- The signal is attenuated as its wave front expands – results in received power proportional to $1/R^4$. Radars transmit high powers and receive low powers.

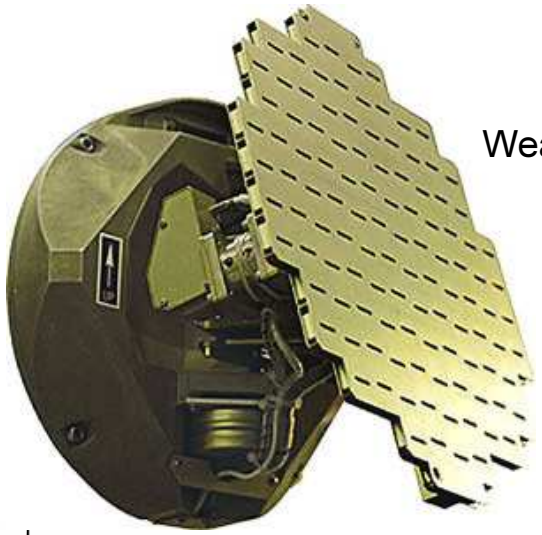
Weather radar

- Weather radar lives under the ‘radome’ – the nose of the aircraft. The radome is always made of a non-conductive material so that it is transparent to RF radar pulses.
- The radar scans the forward flight path for potentially unsettled weather conditions.
- Water droplets, hail, and snow produce a radar reflection. Modern systems can tell a great deal about the conditions and structure of storms.
- The system indicates to the pilot the best course to minimise turbulence or damage to the aircraft .

Weather radar

Civil and Military radomes

Weather radar display



Weather radar antenna

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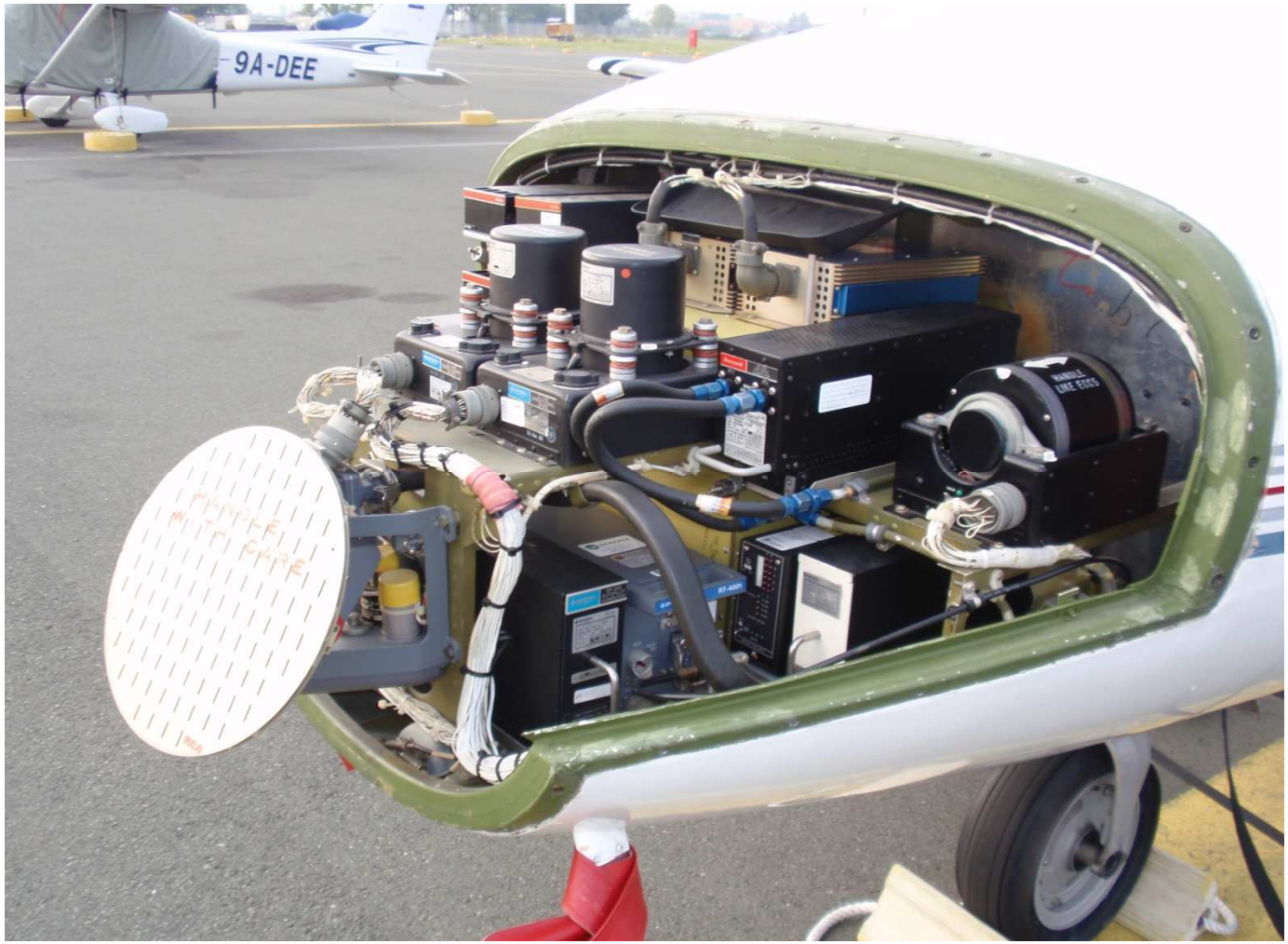
Military Radome

Cessna business jet



Radio altimeter

- If a radar is pointed down, it can measure the height of an aircraft above the ground.
  - Note a ‘radio altimeter’ measures height not altitude (which is height relative to sea level)

- Radio altimeters are most useful at lower altitudes (<600m) and are commonly used as a landing aid and also as a sensor for GPWS (Ground Proximity Warning Systems).

- CFIT (Controlled Flight Into Terrain) can still occur even with the GPWS. Military planes that fly close to the ground to avoid enemy radar use a forward looking system.

Collision Avoidance

ATC (Air Traffic Control) Transponder

- The ATC transponder is required to be fitted to almost all aircraft (including hot air balloons in some areas).
- It is a radio device that can identify the aircraft – it originated as a device to identify friendly aircraft during conflict, and still has this role (IFF - Identify Friend Foe) amongst others.
- It is often described a 'radar' but in reality it is a RX/TX system that transmits specific data when requested to do so by a received interrogating signal.
- In its basic form it transmits an code to identify the aircraft when requested by air traffic control.

TCAS – Traffic alert & Collision Avoidance System

- The TCAS system is an extension of the ATC transponder.
- All aircraft (properly equipped) send out interrogation pulses and listen for replies. Each aircraft thus builds up a picture of other aircraft in the vicinity.
- By doing this many times a second the TCAS system can work out if any of the aircraft nearby are likely to either collide or come to close to each other.

TCAS – Traffic alert & Collision Avoidance System

- TCAS I
  - System implemented around 1991.
  - Provides ‘TA’ (Traffic Advisory) to the pilot.
  - Pilot decides on mitigating action.
- TCAS II
  - Current system used by majority of civil aircraft.
  - System provides ‘TA’ and ‘RA’ (Resolution Advisory).
  - RA instructs pilot what action to take.

- After high profile accidents TCAS now takes precedence over air traffic control. Only GPWS and stall warnings have high authority.

TCAS – Traffic alert & Collision Avoidance System

- TA
  - TA displayed when the point of least separation is between 20 and 48 seconds
  - Audio warning of 'Traffic, Traffic' announced
  - TA will proceed RA by around 15 seconds, the crew should attempt to gain visual contact with the aircraft in conflict
- RA
  - RA displayed when the point of least separation is between 15 and 35 seconds
  - Typical audio warnings are
    - 'Climb, Climb'
    - 'Descend, Descend'
    - 'Reduce climb, Reduce climb'
  - Finally 'Clear of conflict'

Instruments

Older stand alone ATC instrument – typical of aircraft ~30 years ago (although many still fly)

Modern integrated radio control unit – with ATC, comms, ADF etc

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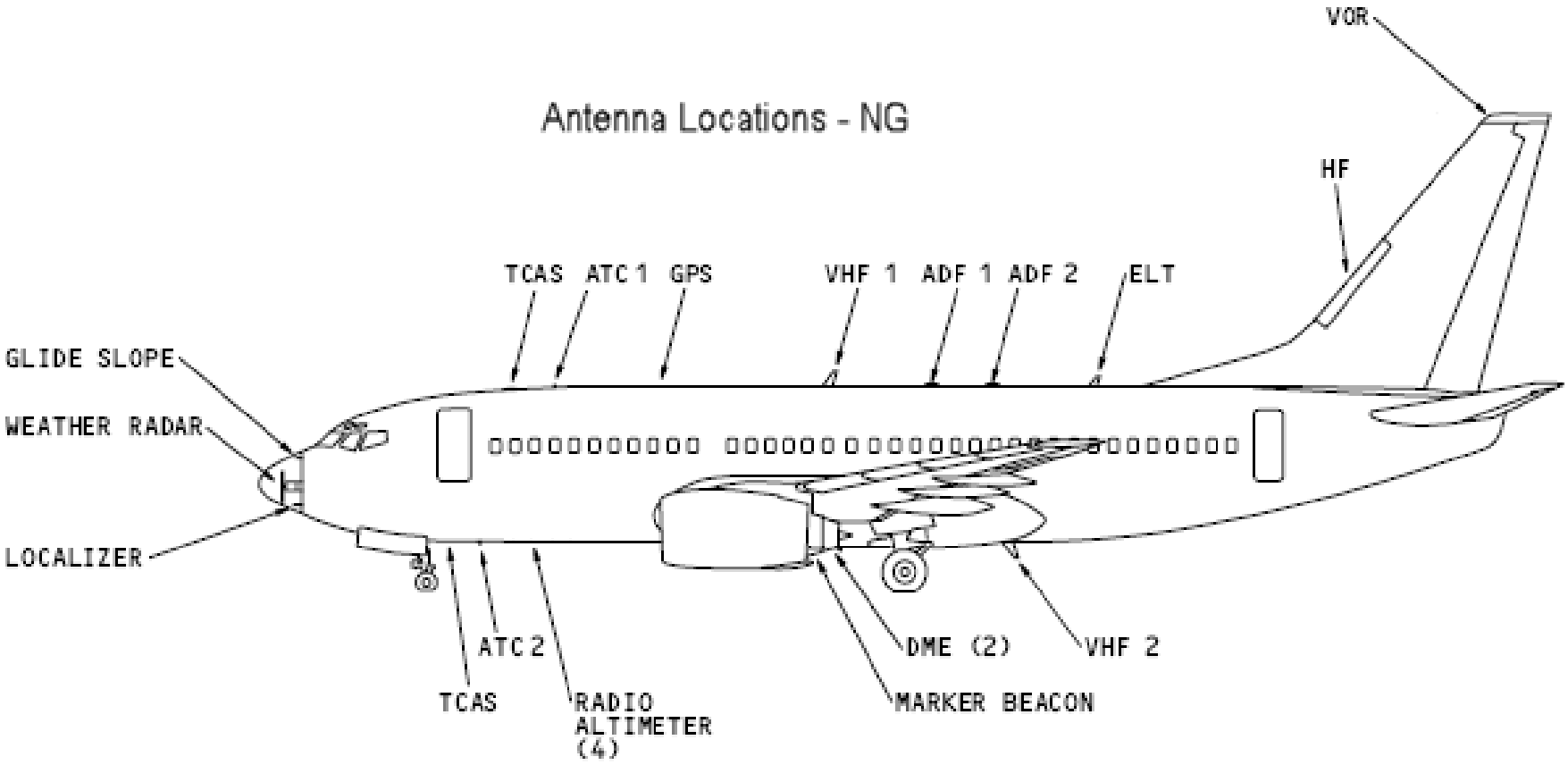
Antenna on a civil airliner



RF Spectrum – Aircraft