Communication and surveillance systems

Modulation

- On-Off modulation (morse code) → pulses
- Amplitude modulation (AM) → continuous wave (CW)
- Frequency modulation (FM) → continuous wave (CW)

Types of waves

Ground wave (<3MHZ)

- Follow the curvature of the earth
- Allows the introduction of long-range radio navigation systems (LORAN)
- Needs very large antenna(half wavelength), difficult to construct
- Ground wave propagation velocity not entirely constant → limits accuracy of position fixes at large range
- Always arrive first (before sky wave)

Sky wave (<30 MHZ)

- Reflection on the ionosphere
- Occurs only at some minimum distance for a given frequency and degree of ionization.
- Skip distance → Inside no return to earth at the particular operating frequency

Line-of-sight waves (>30 MHZ)

- Radio waves follow a straight line
- Range depends on
    - the height of the transmitter
    - the height of the receiver
    - curvature of the earth

CNS: Communication

Definition

Means of exchanging information between aircraft, ground stations and satellites

Types

- Radio- Transceivers
    - VHF: limited to LOS operations
    - HF: 'over the horizon' communications → vulnerable to atmospheric disturbance
- AFTN (Aeronautical Fixed Telecommunications Network) → Between Air Traffic Services
- ACARS (Aircraft Communications Addressing and Reporting System)

CNS: Surveillance

Definition

Determination of the position and velocity of a moving vehicle → done outside the vehicle

RADAR

Two types on board

- Primary Surveillance Radar (PR)
  Pulses of radio frequency energy are transmitted and the signals scattered back by the surface of an aircraft are received → yields distance and heading of the aircraft relative to the radar
- Secondary Surveillance Radar (SSR)
  Signal transmitted by this radar initiates the transmission of a reply signal from the transponder of an aircraft. Allows air-to-ground digital communication.

SSR

The transponder reply consists of twelve data pulses uniformly spaced between two framing pulses

・SSR Mode A : interrogation interval P1 and P3 equals 8µs
Transponder replies with Aircraft Identification Code (ACID), defined by ATC and set by the pilot on the transponder cockpit interface
12 'bits' : 212 possibilities ⟶ 4096 ACID codes
・SSR Mode C : interrogation interval P1 and P3 equals 21µs
Transponder replies the aircraft pressure altitude in steps of 100 ft (QNE), i.e. aircraft flight level (FL).

Primary radar together with SSR Mode A/C provides controller information about the aircraft position relative to the radar beacon(heading, distance, altitude) and an aircraft identification.

LOB SUPPRESSION

- Every antenna has a main lob and several side-lobes→ impossible to know the difference between main lob far away and side lob close by
- Therefore P2 is sent with an additional Omni-directional antenna with a magnitude larger than any of the antenna's side lobes
- Transponder only replies to the main lobes i.e. when P1 and P3 are 9 dB larger than P2

Other problems with SSR

Over-interrogation

The aircraft transponder is interrogated by more than one SSR and gets saturated → replies are no longer valid.

Fruiting

A particular SSR considers the answers of an aircraft transponder to another SSR as answers to its own interrogation → solved by introducing characteristic 'jitter' in SSR frequency (in a similar way as DME).

Garbling

Two aircraft are at the same time and at approx. the same distance in the beam of an SSR, and they both reply to the same interrogation. The replies will be merged and no valid answer can be determined.

SSR mode S

SSR Mode S permits discrete addressing of aircraft: a unique 24-bit Mode S address is assigned to each aircraft so that aircraft can be unambiguously identified and addressed worldwide: $224 \approx 17$ million.