ADS-B for Dummies

1090 MHz Extended Squitter

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Content

- Mode S overview
- Extended Squitter
- Standards
- Reported ADS-B data
- Reception techniques
- Performance and Capacity
- Equipage
- CASCADE activities

Mode A/C SSR (ATCRBS)

- The SSR system is made up of airborne transponders and ground interrogators/ receivers
- **Mode A** replies convey a target id (Code 3/A)
  - 4096 codes allowed
- **Mode C** replies provide the barometric altitude

MODE A/C SECONDARY SURVEILLANCE RADAR
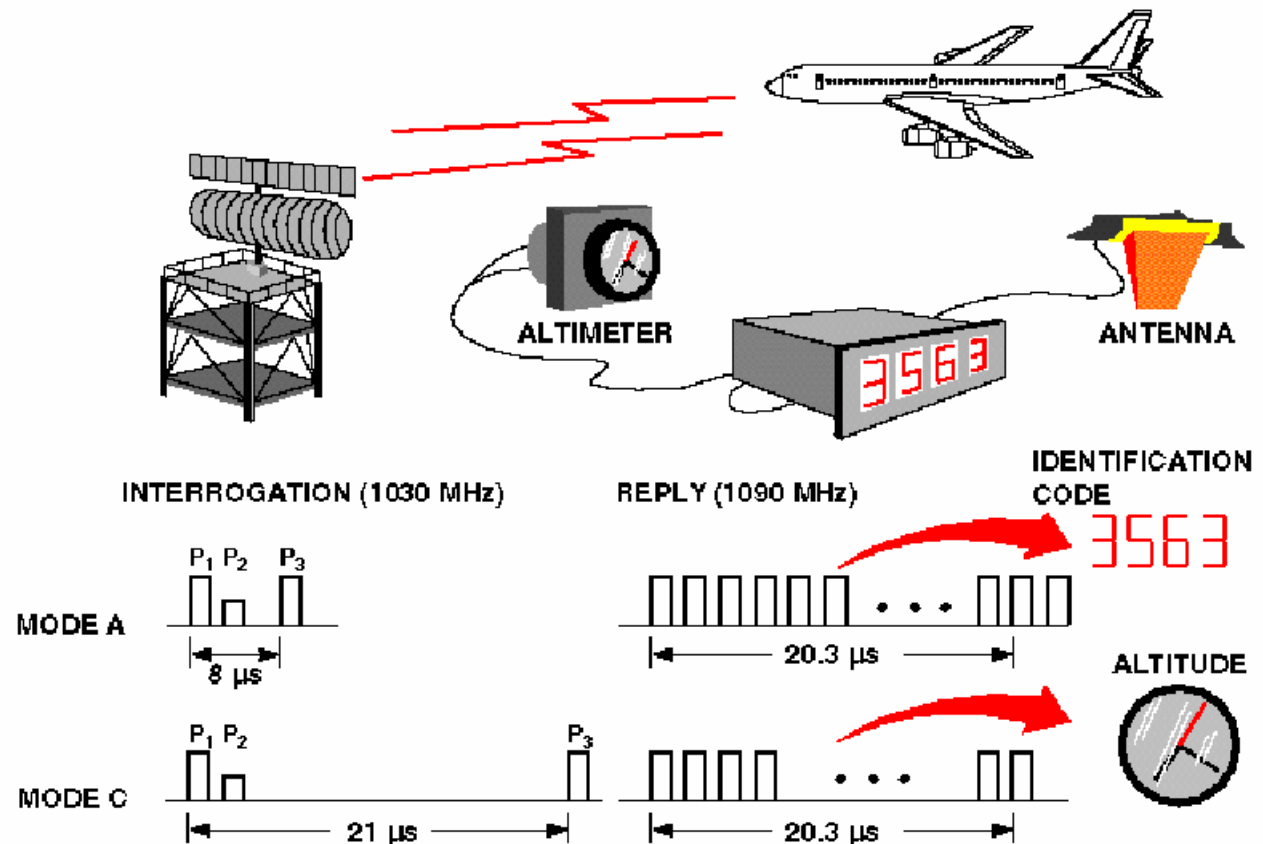
Mode S

- Evolutionary improvement of Mode A/C SSR.
  - globally unique a/c identification (24 bits)
    - overcoming the limitation to 4096 Code A addresses
  - selective interrogation
    - to avoid unwanted replies ("fruit")
  - Interrogator Codes (IC)
    - for unambiguous data exchange with transponders
  - support for the Airborne Collision and Avoidance System (ACAS)
    - acquisition squitter broadcast
  - support for point to point datalink as well as surveillance
  - extension possibilities to
    - ADS-B through the 1090 MHz Extended Squitter (1090ES)
    - multilateration (surface and wide area)
- Backwards compatible with Mode A/C SSR (air/ground)

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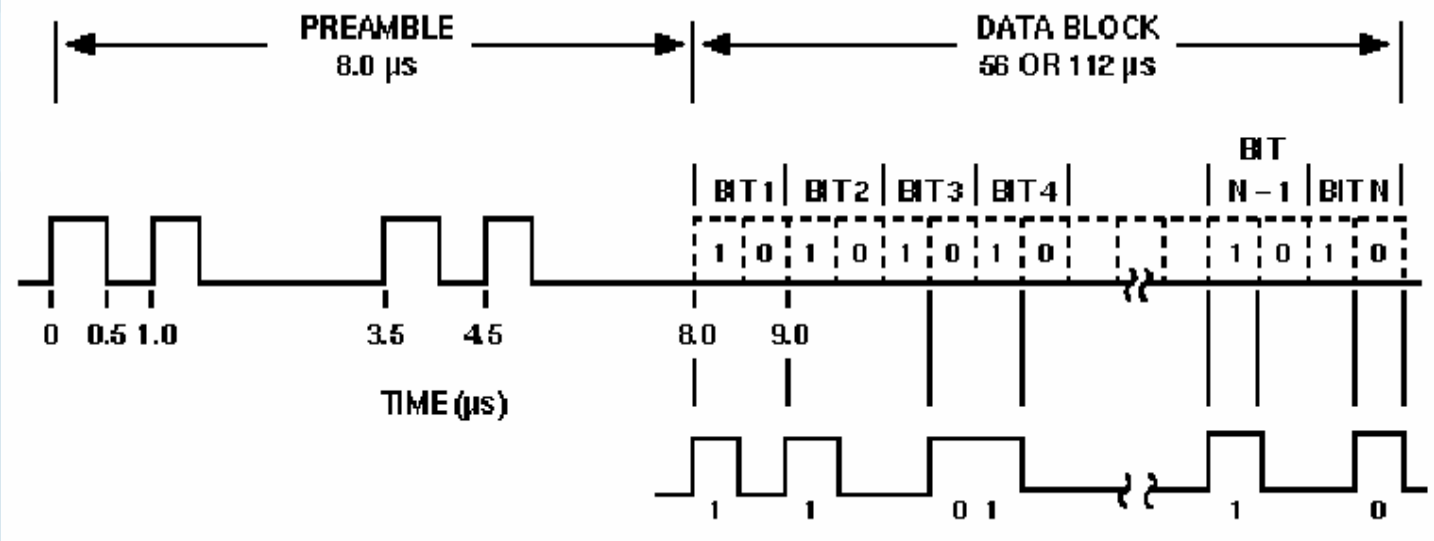EUROCONTROL

Mode S Signals

Mode S Reply
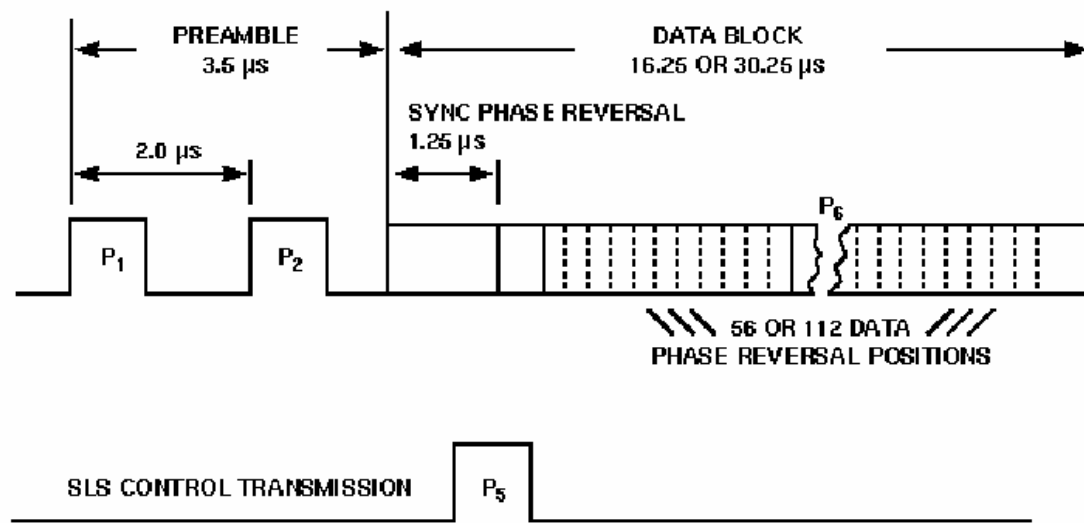
Data rate: 1 Mbps

Modulation: PPM

Pulse Position Modulation: Pulse transmitted in the 1st or 2nd half of the bit period (indicating a 1 or 0, respectively).

Mode S Interrogation

Data rate: 4 Mbps

Modulation: DPSK

Mode S Data Block

SURVEILLANCE INTERROGATION AND REPLY

FORMAT NO. (5 Bits)	SURV. & COMM. CONTROL (27 BITS)	ADDRESS/PARITY (24 BITS)

56 BITS

SURVEILLANCE/COMMUNICATION INTERROGATION AND REPLY - COMM-A AND COMM-B

FORMAT NO. (5 Bits)	SURV. & COMM. CONTROL (27 BITS)	MESSAGE FIELD (56 BITS)	ADDRESS/PARITY (24 BITS)

112 BITS

COMMUNICATION INTERROGATION AND REPLY - EXTENDED LENGTH MESSAGE (ELM)

FORMAT NO. (2 Bits)	COMM. CONTROL (6 BITS)	MESSAGE FIELD (80 BITS)	ADDRESS/PARITY (24 BITS)

112 BITS

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TCAS/ACAS Operation

- Mode S transponders broadcast acquisition squitters for identification
- TCAS interrogates nearby traffic and derives distance and bearing from the replies
- TCAS generates TAs and RAs for display on cockpit HMI
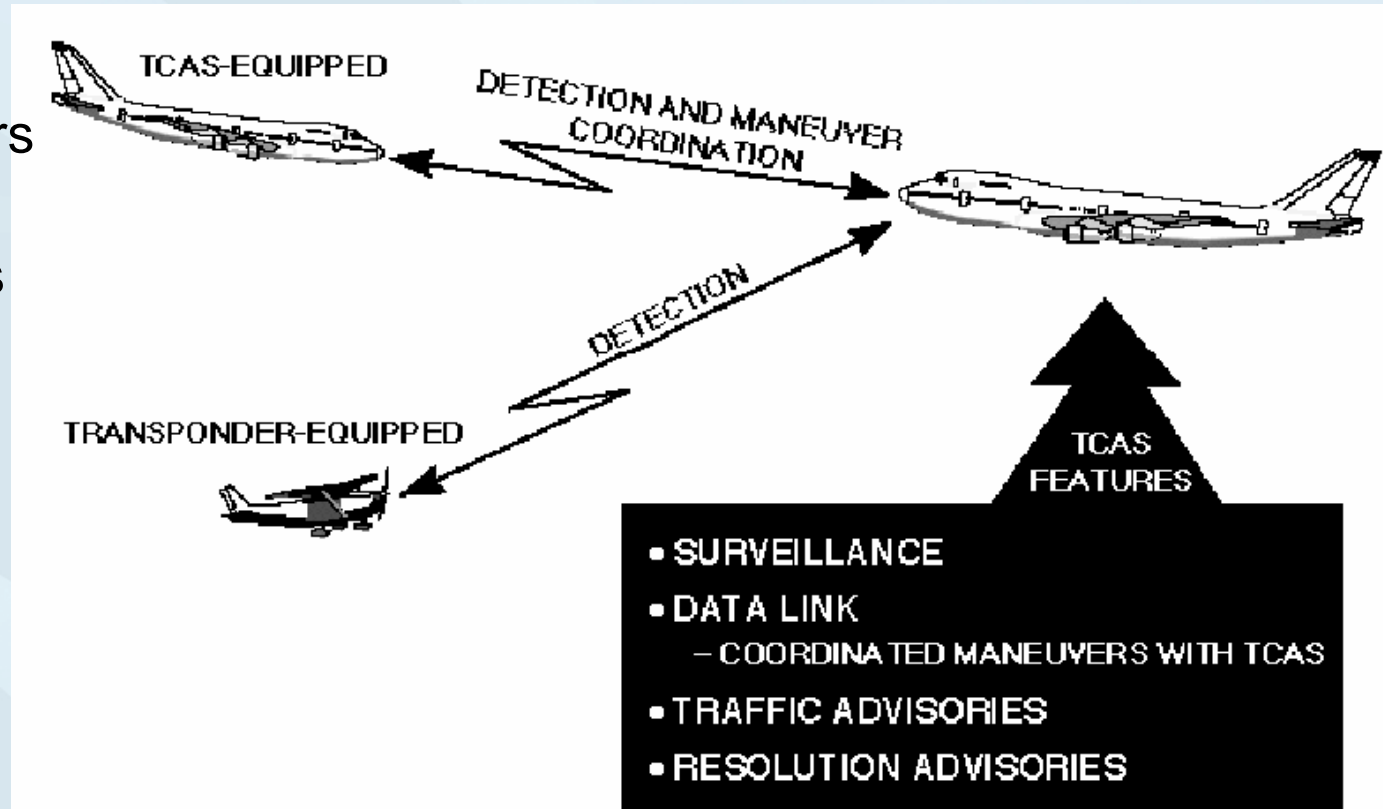
Mode S Acquisition Squitter

- The Mode S transponder outputs an unsolicited transmission once per second to enable ACAS to acquire Mode S equipped aircraft
  - carries only the ICAO 24 bit a/c address, which is a unique aircraft identifier used in Mode S
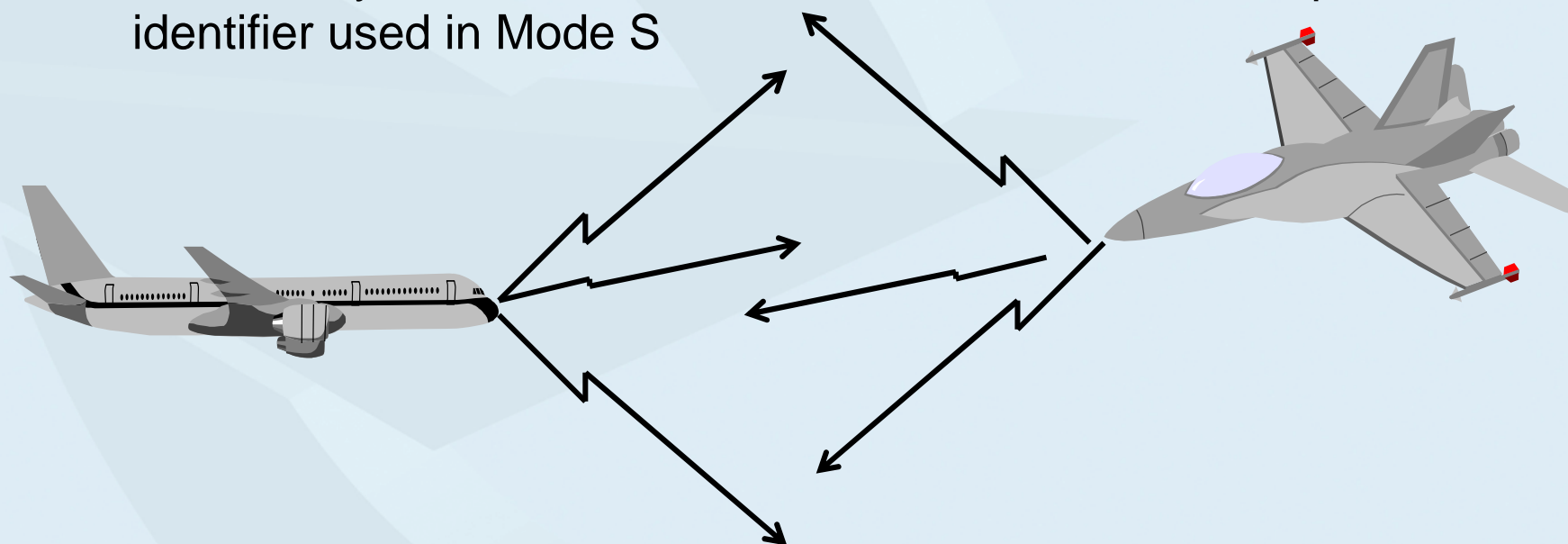
MODE S SHORT SQUITTER (56 BITS)

8 bit CONTROL	24 bit A/C ADDRESS	24 bit PARITY

TRANSMITTED ONCE PER SECOND

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1090 MHz (Mode S) Extended Squitter

1090ES includes a 56 bit data field used to carry ADS-B information

GNSS GNSS GNSS

ADS-B information is derived from the onboard avionics navigation systems

EXTENDED (112 BIT) SQUITTER
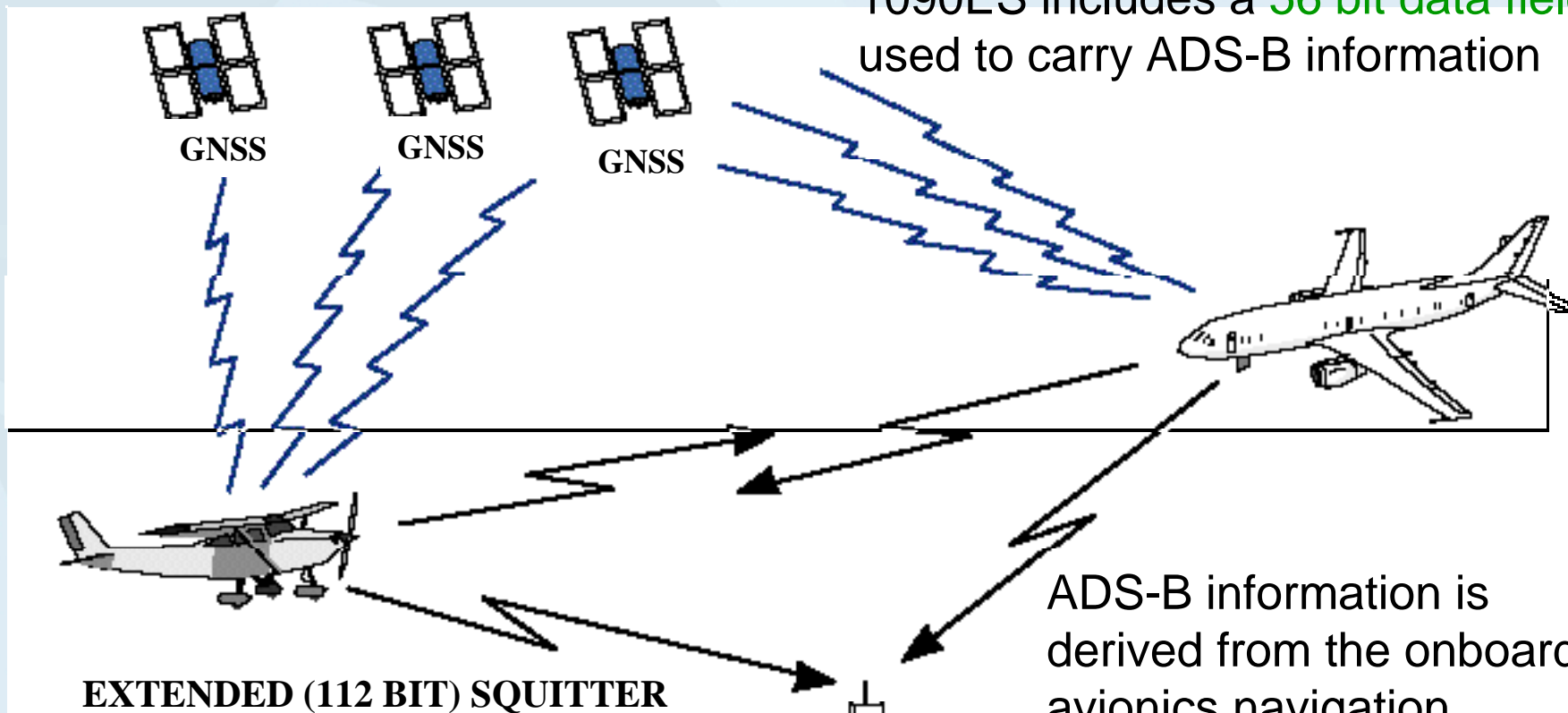
8 bit CONTROL	24 bit A/C ADDRESS	56 bit ADS MESSAGE	24 bit PARITY

EXTENDED SQUITTER GROUND STATION

TO ATC FACILITY

CAS

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Extended Squitter Format

- **Preamble:** Allows synchronisation on reception
- **DF** = Message type
  - **11** Acq squitter
  - **17** ADS-B
  - **18** TIS-B
  - **19** Military
- **CA** = subtype
- **PI** = error detection code
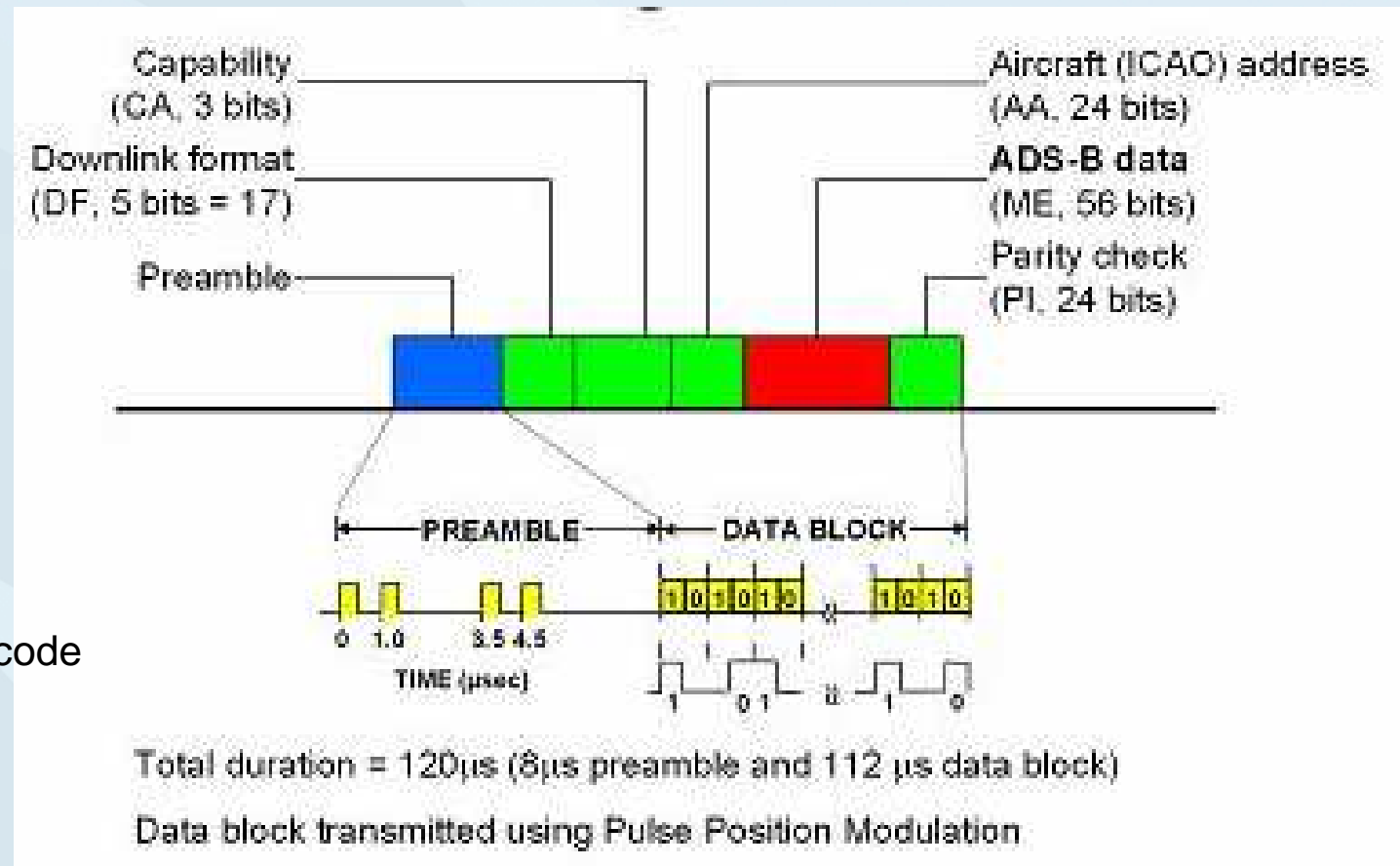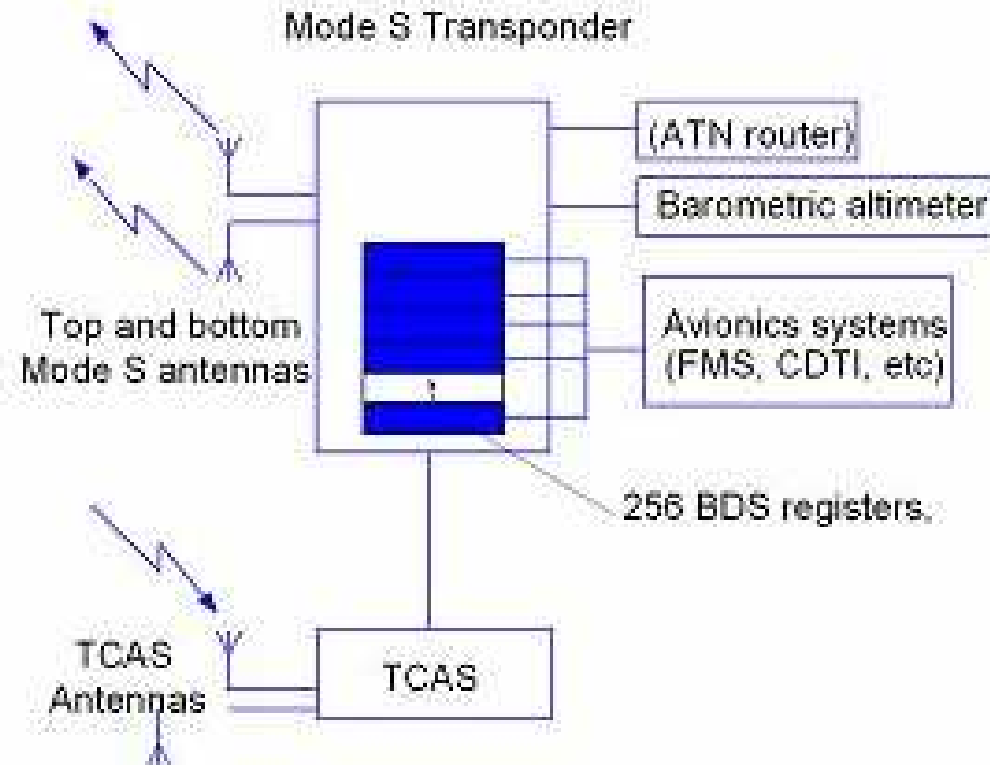
Capability (CA, 3 bits)

Downlink format (DF, 5 bits = 17)

Preamble

Aircraft (ICAO) address (AA, 24 bits)

ADS-B data (ME, 56 bits)

Parity check (PI, 24 bits)

PREAMBLE — DATA BLOCK

0 1.0   3.5 4.5

TIME (µsec)

Total duration = 120µs (8µs preamble and 112 µs data block)

Data block transmitted using Pulse Position Modulation

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Mode S Transponder

- Transponders maintain avionics data in the Binary Data Store (BDS) Registers (56 bit wide).

BDS Registers

- BDS Registers are specified in the ICAO Manual of Mode S Specific Services and the Mode S SARPs
  - BDS registers are also referred to as GICB registers because they can be downlinked via "Ground Initiated Comm B transactions"
- Each register contains the data payload of a particular Mode S reply or extended squitter
- Registers not updated within a fixed period are cleared by the transponder
- Registers are identified by a two digit hex number
  - for example BDS 05h or BDS 0,5 is the position squitter
- Certain BDS registers refer specifically to 1090ES

BDS Registers for 1090ES

- Sixteen registers may feed 1090ES transmissions
  - Commonly used are:
    - BDS 05h Ext. Squitter Airborne Position
    - BDS 06h Ext. Squitter Surface Position
    - BDS 07h Ext. Squitter Status
      - transmitted only in reply to interrogation
    - BDS 08h Ext. Squitter A/C Id & Category
    - BDS 09h Ext. Squitter Airborne Velocity
    - BDS 0Ah Extended Squitter Event Report
    - BDS 61h Ext. Squitter Emergency/Priority Status
      - transmitted once per second during an emergency
    - BDS 62h Target State and Status (DO-260A only)
    - BDS 65h Aircraft Operational Status

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Position Squitter

- **Format:** Ext. squitter type (plus flags)
- **Latitude/Longitude:** Aircraft Position
- **CPR:** Compact Position Reporting
- **Time:** UTC time flag.
- **Single antenna Flag:** Single or dual antennas
- **Movement:** Ground speed
- **Status:** Validity Flag
- **Track:** Direction of movement

Airborne position squitter

Number of bits	Contents
5	Format type code
2	Surveillance status
1	Single antenna flag
12	Altitude
1	Time
1	CPR format
17	CPR encoded latitude
17	CPR encoded longitude
56 bits total	

Surface position squitter

Number of bits	Contents
5	Format type code
7	Movement
1	Status
7	Ground track
1	Time
1	CPR format
17	CPR encoded latitude
17	CPR encoded longitude
56 bits total	

TX rate = 2 /sec

Accuracy ~5.1m

TX rate = 1/sec

Accuracy ~1.2m

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Velocity and Identity Squitters

- **Subtype:** Ground or airspeed flag
- **IFR**:ADS-B Equipage class
- **A/C category**: a/c (small/medium/large) or vehicle or glider or ...

Airborne velocity squitter

Number of bits	Contents
5	Format type code
3	Subtype
1	Intent change flag
1	IFR capability flag
3	Velocity uncertainty
10 + 1	East-West velocity + sign
10 + 1	North-South velocity + sign
9 + 1 + 1	Vertical rate + sign + source
2	Turn indicator
7 + 1	Geometric height diff. from barometric + sign
56 bits total	

Aircraft identification squitter

Number of bits	Contents
5	Format type code
3	Aircraft category
6	Callsign Character 1
6	Callsign Character 2
6	Callsign Character 3
6	Callsign Character 4
6	Callsign Character 5
6	Callsign Character 6
6	Callsign Character 7
6	Callsign Character 8
56 bits total	

TX rate = 2 /sec   TX rate = 0.2 /sec

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1090ES Standards

- ICAO Mode S Ext. Squitter SARPs (Annex 10 Am. 77)
  - defines the DF17, DF18 messages
- Transponder MOPS
  - EUROCAE **ED-73B** and RTCA **DO-181C**
- 1090 ADS-B System MOPS
  - EUROCAE **ED-102** = RTCA **DO-260**
  - RTCA **DO-260A**
- Avionics Form and Fit
  - AEEC Characteristic **ARINC 718A** and EUROCAE **ED-86**
- Safety regulatory standards
  - JAA Technical Service Order **TSO 2C112A** for transponder **ED-73A**
  - FAA **TSO C112** for transponder **DO-181** and **TSO C166** for ADS-B system **DO-260/260A**

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DO-260 versus DO-260A

- **DO 260A** added
  - new message "**Target State and Status**" (CA=29)
    - replaces DO-260 intent squitter [BDS 62h]
  - separate accuracy and integrity indications for position
    - **NIC/NAC/SIL** instead of **NUC**
  - expanded a/c type and ADS-B reporting capabilities
  - broadcast of **Mode A Code**
  - support for **TIS-B** squitter (DF18)
- maintaining backwards compatibility
- and expanding the **enhanced decoding techniques** already defined in DO-260 [as options]

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DO-260/DO-260A Change 1

- Recently RTCA published Change 1 to DO-260/260A
  - clarification of **NUC** calculation from **GPS** error signals
    - enables unambiguous indication of integrity [DO-260]
  - optional broadcast of **Mode A Code** in DO-260 transponders
    - useful for ADS-B report correlation with SSR data
  - clarification of aircraft "**on ground condition**"
    - was ambiguous in both DO-260 and DO-260A
  - removal of "trajectory intent" and "a/c coordination" squitters
    - squitters not used in practice [DO-260]
  - provisions for ADS-B squitter re-broadcast
    - useful for improving ADS-B coverage

- EUROCAE has not adopted Change 1
  - approval of ED-126 may lead to a reconsideration of the need

Target State and Status Squitter

- DO-260A only (BDS 62h)

Number of Bits	Contents
5	Format Type = 29
2	SubType=0
18	Target Altitude and Flags
14	Target Heading/Track
7	NACp, NICb, SIL
5	Reserved
2	ACAS status and RA status
3	A/c emergency/priority status
56	Total

1090ES Performance

- Range and Capacity are the critical 1090ES performance characteristics
- Air-air or air-ground **range** defines the area within which targets will be reported with acceptable **quality**
  - quality refers to accuracy, integrity, update rate …
    - application dependent requirements
- Air-air or air-ground **capacity** refers to the maximum number of targets that can be monitored with adequate quality within the prescribed range
- Range and capacity depend on the 1090 MHz interference ("fruit") and decoder performance
    - replies to SSR/Mode S/ACAS interrogations
    - short and extended squitters broadcasted from ACAS and ADS-B

- 1090 fruit depends on
  - civil and military SSR/Mode S interrogators
    - Fixed ground civil surveillance infrastructure
    - Fixed and tactical military systems
  - aircraft traffic density and ACAS/ADS-B equipage

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1090ES Range and Capacity

- MOPS compliant 1090ES nominal range (with low fruit <4Kmsg/sec) is
  - >90 nmi air to air
  - >150 nmi air to ground
- 1090ES range drops with increasing fruit
  - Air to air range is the most sensitive
    - on the ground, sector antennas can reduce fruit and improve range
  - enhanced decoding techniques can improve resistance to fruit
- The dominant fruit today is Mode A/C replies
  - Core Europe is the area with the highest fruit levels in the world
    - measured in Frankfurt in 2001 at 33K replies/sec
- Fruit is expected to grow almost linearly with traffic growth unless significant de-commissioning of SSR takes place

1090ES decoding techniques

- Squitter reception entails
  - Preamble detection
  - Bit and confidence declaration
  - Error detection and correction
- Current decoding techniques are designed for narrow beam SSR and short range ACAS operations
  - effective only for low interference levels < 4K Mode A/C msg/sec ("fruit")
  - can handle only one overlapping Mode A/C fruit
- Enhanced decoding techniques provide improvements for all 3 reception stages and are designed to handle multiple overlapping Mode A/C fruit
  - can handle >40K Mode A/C fruit
  - **but do not protect better against short and long squitters**
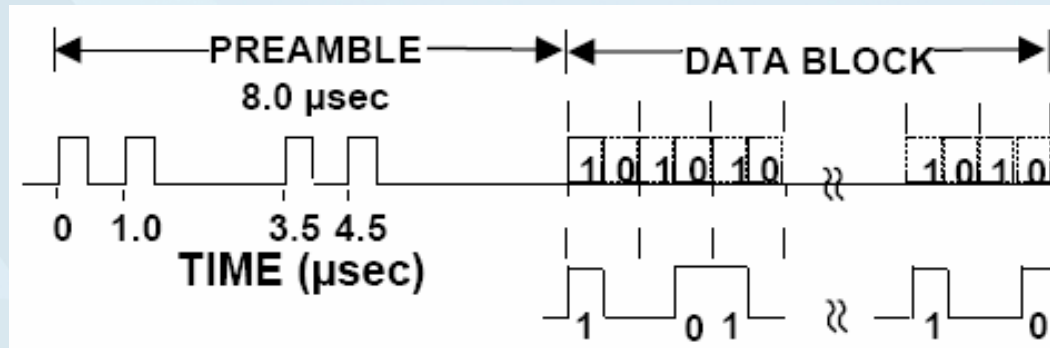
1090ES equipage

- **Current ADS-B 1090ES avionics equipage types:**
  - ADS-B capable Mode S transponder and ACAS
    - products in the market today
  - ADS-B capable Mode S transponder and standalone ADS-B receiver
    - Standalone receivers are just appearing in the market
- **New Airbus/Boeing a/c come wired for ADSB-out**
  - Airbus conforms to DO-260
  - equipment is certified only on non interference basis
  - no provision for ADSB-in
  - suitability of ADS-B data largely depends on type/quality of GPS connection
- **A non transponder 1090ES ADS-B solution would be feasible but is not standardised (yet)**
  - highly desirable for vehicles and non transponder equipped GA
- **1090ES ground stations are available from a number of vendors**
  - Mostly as part of multilateration solutions
  - Standards and certification procedures still in development

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Summary

- 1090ES is an extension of the Mode S technology
  - no new spectrum required
  - recent Mode S transponders can be used for ADSB-out
    - growing number of a/c squittering ADS-B
      - but ADS-B data quality is not certified
  - airborne receiver needed for ADSB-in
- Further standardization work needed
  - ADS-B application requirements must be clarified
  - utility of DO-260A and Change 1 features needs to be validated
  - form/fit and <u>certification</u> standards need to be updated
  - standards for ground stations must be developed
- Risk of eventual 1090 MHz band congestion in Core Europe depending on
  - evolution of air traffic density
  - evolution of civil and military SSR/Mode S infrastructure
  - could be countered with more sophisticated receiver systems

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CASCADE Activities on 1090ES

- ADS-B application requirements development
  - Joint EUROCAE/RTCA development of standards through the Requirements Focus Group (**RFG**)
    - leading to updated certification standards for 1090ES equipage
    - contributing to ICAO standardization
- ADS-B application validation on 1090ES
  - 1090ES equipment specification development
    - airborne and ground ADS-B systems
    - validation tools
  - 1090ES experiments and flight trials
    - Operational and technical feasibility and performance assessments
- Business case development for 1090ES applications
- Support to pre-operational implementations
  - 1090ES airborne equipage monitoring
  - Pioneer airlines scheme
    - Support to aircraft installation certification to **ED-126**
  - Support to deployment for ADS-B 1090ES ground infrastructures