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CHAPTER 14 – SECONDAY SURVEILLANCE RADAR (SSR)

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CONTENTS ..... PAGE

CHAPTER 14: SECONDARY SURVEILLANCE RADAR (SSR) 3

THE PURPOSE OF SSR 3
SSR FREQUENCIES 3
TYPICAL SSR OPERATION 3
SYNCHRONIZATION OF SSR TRANSMISSIONS WITH PRIMARY RADAR 4
SSR MODES - THE INTERROGATOR PROCESS 5
SSR MODES - THE REPLY PROCESS 5
MODE A 5
MODE C 6
UNWANTED RESPONSES 7
MODE S 7
SIDE LOBE SUPPRESSION 8
WORKSHEET - SECONDARY SURVEILLANCE RADAR 9

CHAPTER 14: SECONDARY SURVEILLANCE RADAR (SSR)

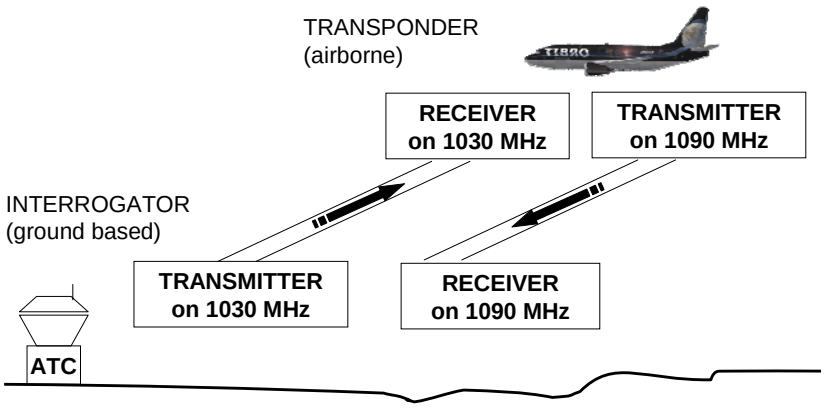
THE PURPOSE OF SSR

It is important that ATC can positively identify every aircraft and this is very difficult using primary radar alone, especially in a crowded situation.

Secondary radar has many advantages (see Chapter 9) but requires the active cooperation of the aircraft to be identified. The equipment carried by the aircraft and used by ATC for this purpose is correctly known as secondary surveillance radar but is often on the aircraft called simply the transponder.

SSR FREQUENCIES

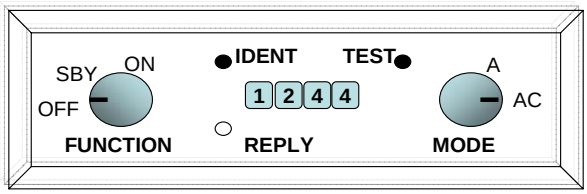
Secondary Surveillance Radar (SSR) which is used world wide operates on only two frequencies, for all modes i.e. Modes A, C and S. The ground-based transmitter which is known as the INTERROGATOR transmits on 1030 MHz. The airborne equipment, consisting of a receiver and a second transmitter, is known as the TRANSPONDER. The transponder, having received the interrogator's transmission on 1030 MHz, replies on 1090 MHz. The receiver on the ground is tuned to accept information on 1090 MHz.



TYPICAL SSR OPERATION

- The pilot selects an identification code.
- The SSR ground transmitter sends a coded interrogation signal on 1030MHz as the primary radar system detects the aircraft. This coded signal is in the form of pairs of pulses and the spacing of the pulses in each pair determines the MODE of the interrogation

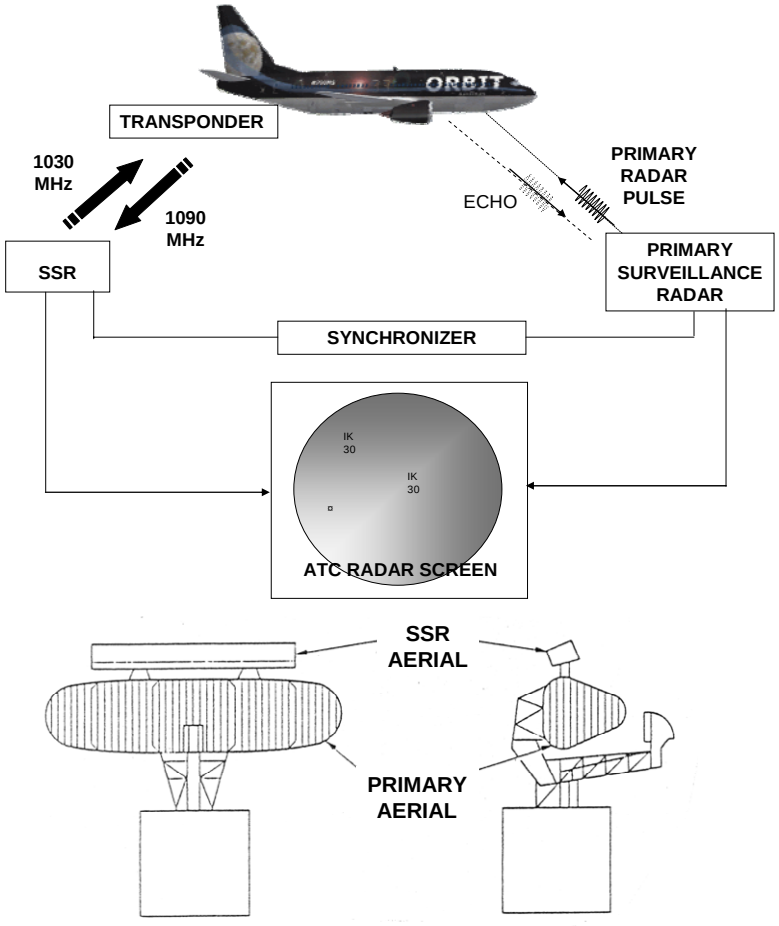
- The interrogation signal is received, detected and decoded by the airborne transponder.
- The airborne transponder encodes and transmits a set of reply signals, depending upon mode and code selected.
- The reply signal is then received, decoded and displayed at the ATC unit.



TYPICAL TRANSPONDER CONTROL PANEL

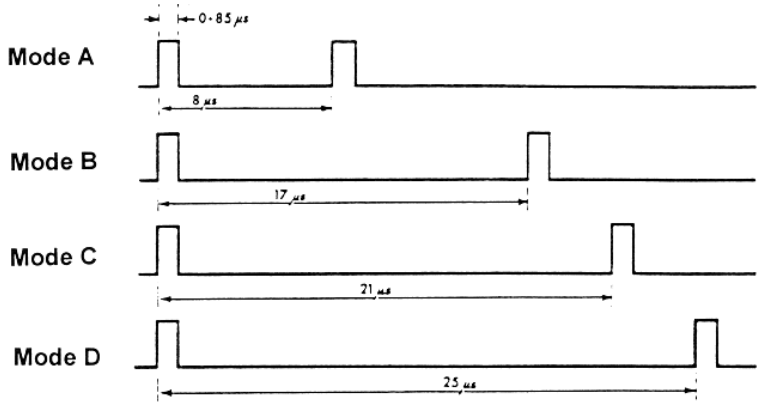
SYNCHRONIZATION OF SSR TRANSMISSIONS WITH PRIMARY RADAR

The interrogator pulses from the ground can be radiated from a directional SSR aerial mounted on the primary radar aerial. The transponder is interrogated every time the radar scans the aircraft.



SSR MODES - THE INTERROGATOR PROCESS

SSR modes are formed by the spacing of the interrogator pulses. The purpose of using pairs of pulses with known spacing is to reduce the chances of transponder operation as a result of receiving spurious (false) signals. There are 4 possible spacings of the interrogator pulses corresponding to Modes A, B, C and D.



Mode A is used for civil and military identification.
Mode B is an additional, optional identification Mode.
Mode C provides automatic pressure altitude information.
Mode D is experimental.

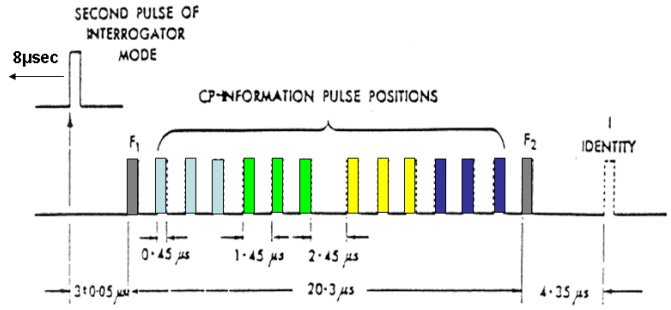
Note: Only Modes A and C are normally used in civil aviation.

The ground interrogator and the airborne transponder must be set to the same mode for the exchange of information to take place. Normally aircraft operate in Mode AC so that both identification and pressure altitude can be interrogated.

SSR MODES - THE REPLY PROCESS

MODE A

The Mode A (Identification) reply comprises 2 framing pulses 20.3 µsec apart between which up to 12 information pulses can be transmitted or suppressed.



Soon after the airborne SSR equipment receives the second of the interrogating pulses it replies with two framing pulses, between which are the information pulses.

The 4-digit code corresponding to the pilot's code setting is formed from the presence or absence of all or any of the 12 information pulses, which are divided for this purpose into 4 groups of 3. In one such group of three, each pulse is given a value, the first being 1, the second 2 and the third 4. By withholding or transmitting these pulses, a single code digit from 0 to 7 can be represented by a 3-pulse group. With 8 possibilities on the first, second, third and fourth groups of 3 pulses, there are 8 X 8 X 8 X 8 or 4096 code combinations that can be set. When selecting a code, the transponder should be in the STANDBY switch position to avoid inadvertently transmitting unwanted codes before reaching the correct setting.
When IDENT is pressed on the control panel (see page 10.1), a further pulse is transmitted after the second framing pulse for about 20 seconds (see diagram above). This so called Special Position Identification (SPI) pulse causes the response on the controller's screen to have a distinctive form so allowing the aircraft that has been instructed to SQUAWK IDENT to be readily identified.
Special codes have been agreed internationally to indicate certain emergency situations:

- A7700-Aircraft emergency/distress
- A7600-Radio(communication) failure
- A7500-Hi-jack (unlawful interference)

Some other special codes are as follows:

- A0000-Transponder malfunction
- A2000-For entering airspace from an area where SSR has not been required
- A7200-Heathrow-Gatwick helicopter lane.
- A7000-Conspicuity code. Outside of airspace requiring the use of transponders, aircraft should use A7000 and Mode C.

MODE C

Mode C interrogation follows Mode A in the same sweep of the radar. Mode C transponder replies are also in the form of up to 12 information pulses, similar to Mode A. However, whereas for Mode A the code for transmissions is selected by the pilot, Mode C codes are determined by the pressure height encoding unit coupled to the pressure altimeter. The information is always based on the datum 1013.2 hPa, regardless of the subscale setting. Mode C data is usually displayed to the controller in flight level terms but it can be related to QNH for aircraft below the transition altitude or to QFE if required. As with Mode A, there are 4096 codes available to encode altitude although not all are used. In practice the codes which are automatically selected provide ATC with height readings at 100ft. intervals to a maximum of 128000 feet. Note that under JAR regulations if, on verification by the controller, there is more than a 300ft discrepancy between the level readout and the reported level, the pilot will normally be instructed to switch off Mode C.

UNWANTED RESPONSES

The aircraft may be in range of a number of ATC units equipped with SSR and so the aircraft's replies may be received as unwanted responses at units other than the unit which was the source of the interrogations. The unwanted responses are not in synchronization with the interrogations and are termed 'fruit' (False Replies Unsynchronised In Time). If aircraft replying to ATC interrogations are too close, their replies may overlap resulting in a meaningless stream of pulses. In this case, the replies are said to be garbled. Both "fruiting" and "garbling" are minimised by circuitry at the ATC unit.

MODE S

The SSR Mode A/C system has problems with fruit and garbling and also difficulties caused by shielding of the aerial, depending on the attitude of the aircraft. It has also become apparent that 4096 Mode A identification codes are not sufficient to accommodate the growth of domestic and international air traffic. To overcome these problems and to allow further development of the SSR system, Mode S (selective addressing) has been introduced.

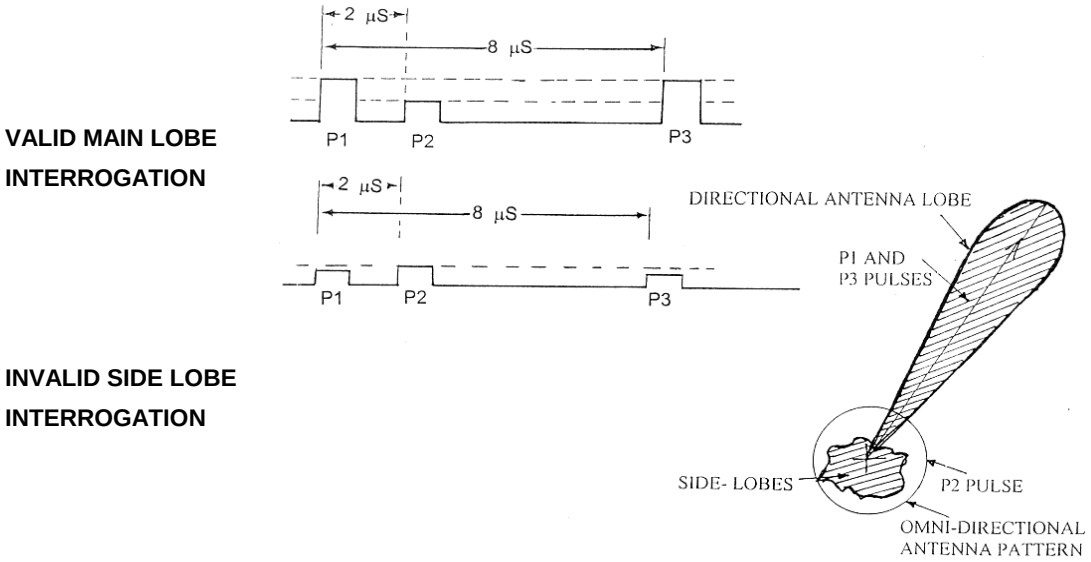
The following are features of Mode-S:-

- Greater data handling capability- more than 5×10^{33} different messages.
- Each aircraft has a unique address, normally incorporated in the avionics during manufacture, which is encoded into both interrogation and reply messages.
- Aircraft interrogations and replies are individually scheduled so problems with over-lapping replies (garbling) are eliminated.
- Single interrogation and reply sequences significantly reduce fruiting.
- Data link capabilities include air-to air information exchange, ground-to-air uplink, air-to-ground downlink and multi-site message procedures.
- Antenna diversity is the term when aerials are mounted on top and bottom of the aircraft to prevent shielding. Automatic selection of aerial occurs depending on interrogation signal strength.
- Mode S data link meets future needs for both communication and surveillance. It is compatible with existing Mode A/C units but also provides for future developments, such as ADS (Automatic Dependent Surveillance). ADS will allow ATC computers to track aircraft from their Mode S Data messages.
- TCAS equipped aircraft can coordinate evasive manoeuvres via their Mode S air-to-air capability. Note: All TCAS II equipped aircraft have Mode S capability. Other aircraft may carry Mode S but not have TCAS.

SIDE LOBE SUPPRESSION

To prevent invalid interrogation of aircraft by the side lobes of the SSR, a side-lobe suppression system is incorporated. The side-lobes are unwanted parts of the main azimuth beam, shown in the following diagram as the directional antenna lobe. The suppression system makes use of an additional pulse (P2), transmitted as an omni-directional signal, with an amplitude at least as large as the maximum amplitude of the side-lobes.

The directional antenna lobe and the unwanted side lobes carry the P1 and P3 pulses, spaced 8 μsec or 21 μsec apart depending on whether they represent Mode A or Mode C interrogations. The P2 pulse is transmitted for the purpose of side-lobe suppression 2 μsec after the first of the two interrogating pulses. The airborne receiver compares the amplitude of the P1 and P3 pulses with the amplitude of the P2 pulse. No reply is made if the amplitude of the P1 and P3 pulses is equal to or less than the amplitude of the P2 pulse as the P1 and P3 pulses may be the result of a side-lobe.



WORKSHEET - SECONDARY SURVEILLANCE RADAR

1. SSR transponder transmissions are on a frequency of _____. Interrogator transmissions are on a frequency of _____.

   (a) 1030 kHz 1090 kHz
   (b) 1090 kHz 1030 kHz
   (c) 1030 MHz 1090 MHz
   (d) 1090 MHz 1030 MHz

2. What is the difference between a Mode A and a Mode C interrogation?

   (a) Each mode has a unique PRF.
   (b) The modes are transmitted by the interrogator on different frequencies.
   (c) The duration of Mode A and Mode C pulses are different
   (d) They have identical formats except for the spacing between the pulses.

3. How many possibilities are there for Mode A replies?

   (a) 7777
   (b) 9999
   (c) 8^4
   (d) 7000

4. The Air Traffic Service Unit measures the range of aircraft by:

   (a) using primary radar principles.
   (b) decoding 1090 MHz reply pulses.
   (c) calculating the elapsed time between the transmission of interrogations and the reception of transponder replies.
   (d) measuring the spacing between pulses in the transponder replies.

5. Mode S transponders have capabilities which include:
   (i) air-to-ground downlink
   (ii) ground-to-air uplink
   (iii) air-to-air information exchange

   (a) All are true
   (b) Only (i) and (ii) are true
   (c) Only (i) is true
   (d) Only (i) and (iii) are true

6. Mode C transponder replies are based on what pressure datum?

(a) 1013.2 hPa
(b) QFE, QNH or 1013.2 hPa, depending on the controller's selection.
(c) 1013.2 hPa above the transition altitude and QNH below the transition level.
(d) the pilot's sub-scale setting.

7. ATC will be aware from the Mode C replies of an aircraft's deviation from its assigned level if that deviation exceeds:

(a) 5 feet
(b) 50 feet
(c) 100 feet
(d) 1000 feet

8. If on verification of Mode C there is a difference of more than _____ feet between the level readout and the reported level, the pilot will be instructed to switch off Mode C or to select Code_____ to indicate a transponder malfunction.

(a) 100 0000
(b) 200 0000
(c) 100 7000
(d) 200 7000

9. To indicate unlawful interference with the planned operation of a flight, a pilot should select:

(a) 7700
(b) 7600
(c) 7500
(d) 7007

10. Transponder replies received by ATS units that are replies to interrogations from other units result in:

(a) squawks
(b) squitters
(c) garbling
(d) fruit

11. Invalid interrogations by the side lobes of the SSR are prevented by a system that compares the _____ of the two framing pulses with that of the additional pulse produced by the omni-directional antenna.

(a) Spacing
(b) Frequency
(c) PRF
(d) Amplitude

12. When required to select the Conspicuity code, pilots should select …….

(a) 2000 and Mode C
(b) 2000 without Mode C
(c) 7000 and Mode C
(d) 7000 without Mode C