All About MODE S TRANSPONDERS

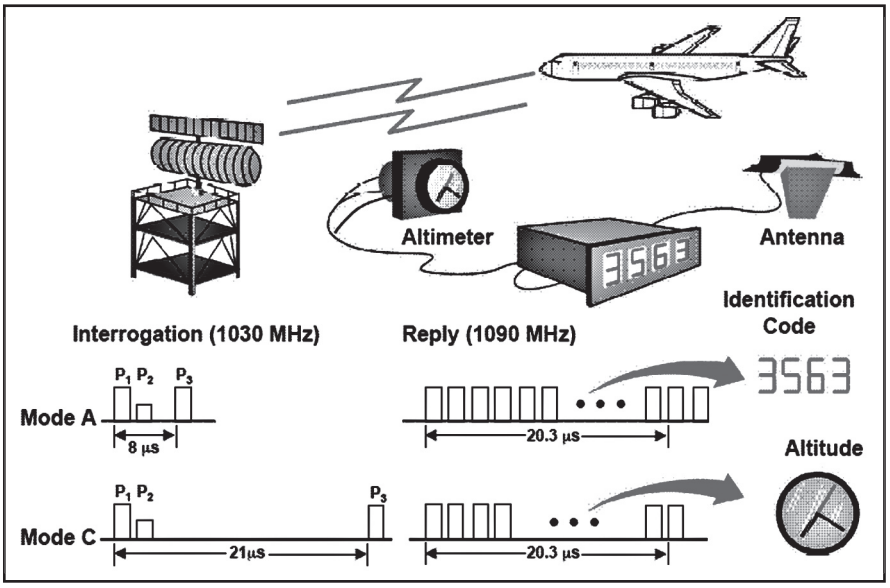
BY TONY BAILEY

With all of the new hype the past few months concerning Elementary Surveillance and Mode S enhancements, it would seem appropriate to discuss the technical characteristics and purpose behind the new functionality and how avionics technicians can appropriately correct problems.

Of course, knowing the purpose of transponders and what affects enhancements have to the functionality are extremely important, especially since this is one system you can count on to continually evolve. The recent mandates for this system are just the tip of the iceberg as the real capabilities and functions have not even been tapped yet. Believe it or not, transponders in aircraft make up the smallest segment of their functionality.

According to market forecasts, the Radio Frequency Identification (RFID) industry is expected to have double digit growth over the next few years and be a multi-billion dollar industry by 2008. New uses for the military and commercial applications are literally staggering. Everything from animal tracking to ski passes are utilizing transponder technology to communicate tracking information between sources. Wal-Mart has issued mandates to their suppliers to incorporate a version of the technology in all of their products. What does this mean for aviation? Well, the technology is definitely getting refined and enhanced.

So what does a transponder do? Technically a transponder is a combined radio transmitter and receiver which operates automatically relaying data between aircraft and Air Traffic Control (ATC) on the ground. The signals sent provide a unique "identity" for each aircraft, essential in crowded airspace to avoid mid-air collisions. Transponders were originally developed for military aircraft in WWII for identification friend or foe (IFF) application but evolved into the commercial arena. Most air traffic control centers rely on the range and altitude information returned by commercial aircraft rather than raw radar data.



Air Traffic Control Radio Beacon System (ATCRBS)

All interrogations are made on 1030 MHz, all replies on 1090 MHz. There are four ways of interrogating, called Modes. When interrogated in Mode A an aircraft is asked for its identity, when interrogated in Mode C it is asked for altitude. Modes B and D are not used. The civil Mode A coincides with the military Mode 3. That is why Mode A is often called Mode 3/A. The replies are called Codes. The Mode A Code is set in the cockpit in four digits, the Mode C Code automatically transmits the altitude, with 1013.2 hPa as the reference pressure, just like in Flight Levels. Coupling a dedicated Mode A Code to a flight plan allows the ATC controller to see the Aircraft Identification (ID) of a particular aircraft directly on his screen. Mode C does the same with the addition of altitude. To-

Bendix/King KT 73 Transponder

gether with the heading, derived from the tracking algorithm, the information available to the radar controller on his screen has enormously improved.

However, because of the increasing commercial traffic there is a lack of Mode A codes. Additionally, the 1090 MHz reply frequency is becoming saturated, with two typical subsequent problems: garbling, which means that the reply pulse trains from more than one aircraft upon one interrogation may overlap, sometimes causing confusion, and erroneous replies received on the ground from transponders that were interrogated by other interrogators on the ground.

The Mode Select Beacon System, commonly referred to as "Mode S," was developed by Lincoln Labs in 1975 as a way to monitor aircraft to support an evolutionary addition to the Air Traffic Control Radar Beacon System (ATCRBS) for automation in dense traffic areas and to solve the Mode A/C short comings. In 1986 a mid-air collision between an Aero Mexico DC-9 passenger aircraft and a single engine Piper over Cerritos, Calif. which killed 82 people placed more emphasis on the technology. The crash was blamed on inadequate automatic conflict alert systems and surveillance equipment resulting in congress passing into law the Airport and Airway Safety and Capacity Expansion Act in 1987.

This new law required that all air carriers (part 121 operators) operating within the United States with more than 30 seats must be equipped with TCAS (Traffic Collision Avoidance System) II by 1993. Air carriers with 10 to 30 seats only had to have TCAS I. Mode S performs all the functions of Mode A and C transponders, and has datalink capability. Mode S transponders are an integral component of all TCAS II installations and replace the Mode A and C transponder for TCAS II equipped aircraft. A Mode S transponder may be installed to replace a Mode A or C transponder without necessitating the installation of TCAS. However, Mode S is required with TCAS in order to facilitate ID, flight status (on ground/in flight) and altitude. Different Classes of transponders that identify the capability levels have been developed over time. However, to meet the EUROCONTROL requirements for Elementary (Basic) Surveillance, a Level 2 transponder is necessary as a minimum capable of supporting both Interrogator Identifier (II) and Surveillance Identifier (SI) codes in accordance with International Civil Aviation Organization (ICAO) requirements.

One new feature of the Mode S Transponder is that each aircraft is assigned a unique address code, which is broadcast in unsolicited "SQUITTER" transmissions occurring approximately every second. ATC or another Mode S equipped aircraft can use this address for interrogation or communication purposes. Flight ID capability is one of the functions required by Elementary Surveillance.

Enhanced Surveillance is the new cat on the block which allows for an extension to the Squitter Code up to 24 bits containing the International Civil Aviation Organization (ICAO) required aircraft address and aircraft reporting information.

The aircraft parameters required for Enhanced Surveillance are as follows:

Magnetic Heading
Speed
Roll Angle
Track Angle Rate
Vertical Rate
True Track Angle
Ground Speed
Selected Flight Level/Altitude
FMS Selected Altitude
Baro Correction Value
Inertial Vertical Velocity

The standards for Mode S specific services are described in ICAO Annex 10 Mode S System. The minimum operational performance standards are described in RTCA DO-181C ATCRBS/Mode S MOPS. A detailed technical definition of all the parameters required for Elementary and Enhanced Surveillance is given in the ICAO Manual on Mode S Specific Services, Doc 9688. These definitions are further refined in EUROCONTROL document SUR.ET2. ST03.2000-ID-04, DAP Technical Characteristics for Mode S Enhanced Surveillance. The transponder design and interface requirements are documented in the ARINC Characteristic 718A.

There are numerous Mode S Transponders in service and troubleshooting begins with identification. There are currently nine manufacturers of aircraft Mode S Transponder systems: ACSS, AlliedSignal, Bendix/King, Filser, Garmin, Honeywell, Narco, Rockwell Collins and Thompson-CSF.

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MODE S MODELS BY MANUFACTURER AND THEIR CAPABILITIES:

ACSS

Model	TC Basis
XS-950	JTSO-2C112(a)

Part Number	Class	Extended Squitter	SI code
7517800-10001	043 121 E11	No	No
7517800-10002	043 121 E11	No	No
7517800-55001	043 121 E11	No	No
7517800-55002	043 121 E11	No	No
7517800-10004	043 121 F11	Yes	Yes
7517800-10005	043 121 F11	Yes	Yes
7517800-55004	043 121 F11	Yes	Yes
7517800-55005	043 121 F11	Yes	Yes

Model	TC Basis
RCZ-852	ETSO-2C112a

Part Number	Class	Extended Squitter	SI code
7510700-951	3A2 121 011	Yes	Yes

AlliedSignal (Honeywell)

Model	TC Basis
TRA67A	TSO-C112

Part Number	Class	Extended Squitter	SI code
066-01127-0001	2A1 101 011	No	No
066-01127-1101	2A1 121 011	No	No
066-01127-1301	2A1 121 011	No	No
066-01127-1401	2A1 121 011	Yes	Yes
066-01127-1402	2A1 121 011	Yes	Yes
066-01127-1501	2A1 121 011	Yes	Yes
066-01127-1502	2A1 121 011	Yes	Yes
066-01127-1601	2A1 121 011	Yes	Yes
066-01127-1602	2A1 121 011	Yes	Yes

Bendix/King (Honeywell)

Model	TC Basis
MST-67A	TSO-C112

Part Number	Class	Extended Squitter	SI code
066-01143-0101	2A1 101 011	No	No
066-01143-0201	2A1 101 010	No	No
066-01143-0301	2A1 101 011	No	No
066-01143-0601	2A1 101 011	No	No
066-01143-1101	3A2 121 011	No	No
066-01143-1201	3A2 121 010	No	No
066-01143-1301	3A2 121 011	No	No
066-01143-1602	3A2 121 011	No	No
066-01143-2001	3A2 121 010	No	Yes
066-01143-2101	3A2 121 010	No	Yes

Filser

Model	TC Basis
TRT-600	LBA NTS-23

Part Number	Class	Extended Squitter	SI code
600ATC-()-()	Level 2s 1)	No	Yes

Model	TC Basis
TRT-800	ETSO-2C112a

Part Number	Class	Extended Squitter	SI code
800ATC-()-()	Level 2es	Yes	Yes

Garmin

Model	TC Basis
GTX 330/	JTSO-2C112a
GTX 330D	JTSO-2C112a

Part Number	Class	Extended Squitter	SI code
011-00455-00	2A1 121 010	No	Yes
011-00455-10	2A1 121 011	No	Yes
011-00455-20	2A1 121 010	No	Yes
011-00455-30	2A1 121 011	No	Yes
011-00455-40	1A0 101 011	No	Yes
011-00455-50	1A0 101 011	No	Yes

Honeywell

Model	TC Basis
Mode S	TSO-C112

Part Number	Class	Extended Squitter	SI code
4061400-905	1A0 121 011	No	No

Model	TC Basis
KT73	JTSO-2C112a

Part Number	Class	Extended Squitter	SI code
066-01164-0101	2A1 121 010	Yes	Yes

Rockwell Collins

Model	TC Basis
TDR-94	TSO-C112

Part Number	Class	Extended Squitter	SI code
622-9352-001	2A1 121 010	No	No
622-9352-002	2A1 121 010	No	No
622-9352-003	2A1 121 010	No	No
622-9352-004	3A2 121 010	Yes	No
622-9352-005	3A2 121 010	Yes	No
622-9352-007	3A2 121 010	Yes	Yes

Model	TC Basis
TDR-94D	TSO-C112

Part Number	Class	Extended Squitter	SI code
622-9210-001	2A1 121 011	No	No
622-9210-002	2A1 121 011	No	No
622-9210-003	2A1 121 011	No	No
622-9210-004	3A2 121 011	Yes	No
622-9210-005	3A2 121 011	Yes	No
622-9210-007	3A2 121 011	Yes	Yes

Model	TC Basis
TPR-720	TSO-C112

Part Number	Class	Extended Squitter	SI code
622-7878-001	3A2 121 011	No	No
622-7878-020	3A2 121 011	No	No
622-7878-120	3A2 121 011	No	No
622-7878-200	2A2 121 011	No	No
622-7878-201	2A2 121 011	No	No
622-7878-301	2A2 121 011	No	No

Rockwell Collins (continued)

Model	TC Basis
TPR-900	TSO-C112

Part Number	Class	Extended Squitter	SI code
822-0336-001	3A2 121 011	No	No
822-0336-020	3A2 121 011	No	No

Model	TC Basis
TPR-901	JTSO-2C112

Part Number	Class	Extended Squitter	SI code
822-1338-001	3A2 121 011	No	Yes
822-1338-002	3A2 121 011	No	Yes
822-1338-020	3A2 121 011	No	Yes
822-1338-()	3A2 121 011	No	Yes

Thompson-CSF

Type	TC Basis
TSR 718 S	TSO-C112

Part Number	Class	Extended Squitter	SI code
9599-614-04502	4	No	No

Once you have identified the unit, it is important to get the correct, most current manual (we always do, right?) because the checkouts are constantly changing. Transponders must be checked and certified for operation every two years as a minimum commonly referred to as the "413" check. Federal Aviation Regulation US FAR § 91.413 states:

ATC transponder tests and inspections.

(a) No persons may use an ATC transponder that is specified in 91.215(a), 121.345(c), or Sec. 135.143(c) of this chapter unless, within the preceding 24 calendar months, the ATC transponder has been tested and inspected and found to comply with appendix F of part 43 of this chapter; and

(b) Following any installation or maintenance on an ATC transponder where data correspondence error could be introduced, the integrated system has been tested, inspected, and found to comply with paragraph (c), appendix E, of part 43 of this chapter.

(c) The tests and inspections specified in this section must be conducted by—

(1) A certificated repair station properly equipped to perform those functions and holding—

(i) A radio rating, Class III;

(ii) A limited radio rating appropriate to the make and model transponder to be tested;

(iii) A limited rating appropriate to the test to be performed;

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[(iv) deleted]

(2) A holder of a continuous airworthiness maintenance program as provided in part 121 or Sec. 135.411(a)(2) of this chapter; or

(3) The manufacturer of the aircraft on which the transponder to be tested is installed, if the transponder was installed by that manufacturer.

While most avionics technicians have been performing 91.411 and 91.413 checks for most of their careers, Enhanced Mode S requires updated test equipment and procedures. The IFR ATC-601 is the most common test set used in conjunction with a pitot/static test set for testing transponder systems. However, any test set can be utilized providing it can test the following transponder responses:

Mode A response
Mode C response with altitude if available
Mode S all-call response
Mode S lockout
Transmitter frequency
Transponder power output
Receiver frequency discrimination
Receiver sensitivity
Receiver interrogation pulse spacing discrimination (all modes)
Individual pulse-width discrimination (all modes)
SLS (Side Lobe Suppression)
Transponder response to invalid address interrogations
SPR on/off
Mode S, UF0 (uplink format 0)
Mode S, UF4
Mode S, UF5
Mode S, UF11
Mode S, UF16
Mode S, UF20
Mode S, UF21
Diversity isolation
Transponder squitter
Airplane identification code

It is very important to test the transponder system in the right steps with the right equipment. In the future, Automatic Dependent Surveillance-Broadcast (ADS-B) and Traffic Information Service–Broadcast (TIS-B) are enhancements currently under development that will add complement to radar for en-route, terminal area and airport surface surveillance, destination weather, Pilot Reports, add support for certain airborne separation maneuvers, facilitate the broadcasting of flight information (e.g. gate, stand, and number of passengers) and the ability to utilize arrival management programs for airport terminals among hundreds of other combinations of data. These additions will require properly trained technicians with all of the right tools in order to maintain the strict tolerances and "stacked" data.

That, in a nut shell is Mode S. Tomorrow's transponders promise to be the backbone of aircraft monitoring and surveillance. It is even possible that transponders are pilots in the making.

Welcome to the future! ❑

Terms and Definitions

ATC	Air Traffic Control
ATCRBS	Air Traffic Control Radar Beacon System
MODE S	Mode Select Beacon System
EAS	Electronic Article Surveillance
TCAS	Traffic Collision Avoidance System
ICAO	International Civil Aviation Organization
ID	Aircraft Identification
II	Interrogator Identifier
SI	Surveillance Identifier
IFF	Identification Friend or Foe
SLS	Side Lobe Suppression
ADS-B	Automatic Dependent Surveillance-Broadcast
TIS-B	Traffic Information Service–Broadcast