

System And Method For Simultaneous Use Of Transponders With Overlapping Identification Modes On An Aircraft

Field of the Invention

- 5 The invention is related to system and method for simultaneous use of transponders with overlapping identification modes on an aircraft.

Background

- 10 A military aircraft, for example, may usually be equipped with a secondary surveillance transponder for military and civilian identification of the aircraft when interrogated by secondary surveillance radar (SSR) of an air traffic controller (ATC) or another aircraft. The secondary surveillance transponder in the aircraft operates at respective identification modes of one or more communication modes, which can be for military use, civilian use, or both.

- 15 A large military aircraft, for example, may also be equipped with a second transponder providing traffic alert and collision avoidance function when interrogated by secondary surveillance radar (SSR) of a traffic alert and collision avoidance system (TCAS). The second transponder in the aircraft also operates at respective identification modes of one or more communication modes, which can be for military use, civilian use, or both.

- The first and second transponders may have overlapping identification modes in one or more communication modes. Therefore, when both the transponders are operated simultaneously, a phenomenon called synchronous garbling happens. Synchronous garbling occurs when a reply from one transponder interferes with another reply from another transponder responding to an interrogation on the same mode. Synchronous garbling can give the false analysis of two aircrafts being located at the same distance, within the interrogator's 3° beam width.

- 30 To avoid synchronous garbling, in a first option, the aircraft may be operated with only one transponder in 'ON' position. In a second option, the two transponders may be replaced with an integrated transponder providing the functions of military and civilian identification and traffic alert/collision avoidance.

- 35 In the first option, when the first transponder (for military and civilian identification) is turned 'ON', and the second transponder (for civilian identification and traffic

alert/collision avoidance) is turned 'OFF', the aircraft loses the capacity to provide traffic alert and collision avoidance warning to another aircraft and this put the aircraft in danger of potential air collision. In case the first transponder (for military and civilian identification) is turned 'OFF', and the second transponder (for traffic alert/collision avoidance) is turned 'ON', the aircraft loses the capacity to be identified as a friend or foe to military ATC interrogations, which can then result in fratricide.

In the second option, the cost for retrofitting an integrated transponder, providing the functions of military & civilian identification and traffic alert/collision avoidance, may be very high. In addition, the cost for spares support (e.g. trays, wires, connectors etc) for the integrated transponder, providing the functions of identification and traffic alert/collision avoidance, can be significant. Furthermore, system Integration and kit proofing of the integrated transponder can be challenging.

Accordingly, there is a need for a system and method for simultaneous use of transponders with overlapping identification modes on an aircraft, which seeks to address one or more of the above problems.

Summary of the Invention

According to a first aspect of the present invention, there is provided a system for simultaneous use of transponders with overlapping identification modes on an aircraft, the system comprising: a first transponder operating in respective identification modes corresponding to one or more communication modes; a second transponder operating in respective identification modes corresponding to one or more communication modes, wherein the first and second transponders have one or more overlapping identification modes; and a switching means coupled to the first and second transponders such that in each switched state, only one of the transponders operates in said one or more overlapping identification modes.

In each switched state, at least one of the transponders may operate in a non-overlapping identification modes.

In a first switched state, one of the transponders may be powered OFF, while the other transponder may operate in all of its identification modes.

In a second switched state, the transponder which was powered OFF may be powered ON and operates in all of identification modes, while the other transponder may operate only in non-overlapping identification modes.

- 5- The first transponder may provide identification information of the aircraft when interrogated by secondary surveillance radar (SSR) of an air traffic controller (ATC) or from another aircraft.

- 10 The first transponder may comprises an air traffic control radar beacon system (ATCRBS) identification of friend or foe (IFF) Mark X (A) system [AIMS MARK X(A) IFF]. The first transponder may comprise an AN/APX-101 IFF transponder.

- 15 The first transponder may operate in identification modes corresponding to civilian modes, mode 3/A and mode C and military modes, mode 1 and mode 2.

- The second transponder may provide traffic alert and collision avoidance functions when interrogated by secondary surveillance radar (SSR) of a traffic alert and collision avoidance system (TCAS).

- 20 The second transponder may be a mode S transponder. The second transponder may operate in identification modes corresponding to civilian modes, mode 3/A, mode C, and mode S.

- 25 The switching means may comprise one or more set of contacts for selectively coupling one of the transponders to a power supply.

- The switching means may comprise one or more set of contacts for selectively connecting respective mode enable ports of one of the transponders to respective mode enable signals from a control panel.

- 30 The switching means may comprise a relay switch, an electronic switch or a mechanical switch.

- 35 According to a second aspect, there is provided a method for simultaneous use of transponders with overlapping identification modes on an aircraft, the method comprising the step of: operating a first transponder in respective identification modes

corresponding to one or more communication modes; operating a second transponder in respective identification modes corresponding to one or more communication modes, wherein the first and second transponders have one or more overlapping identification modes; and switching between the first and second transponders such that in each
5 switched state, only one of the transponders operates in said one or more overlapping identification modes.

Brief Description of the Drawings

The present invention is further described by way of non-limiting embodiments,
10 with reference to the accompanying drawings, in which:

Figures 1a and b are schematic diagrams to illustrate a system for simultaneous use of transponders with overlapping identification modes in accordance with an embodiment of the present invention based on switches for deconflicting the overlapping identification modes;

15 Figure 2 is a schematic diagram to illustrate a system for simultaneous use of transponders with overlapping identification modes in accordance with one implementation of the embodiment of the present invention based on relays when the overlapping identification modes are deconflicted.

Detailed Description of Preferred Embodiments

20 Transponders used in the embodiments of the present invention use one or more of the following modes:

Mode 1 is for military use only. In this mode, the first digit of the reply code is a number
25 from 0 to 7. The second digit is a number from 0 to 3. The remaining two digits are normally 0. Emergency replies in Mode 1, called 4X or four train emergencies, include the normal reply plus 3 sets of framing pulses.

Mode 2 is also for military use only. Each of the reply codes in mode 2 and mode 3/A is
30 a number from 0 to 7. Emergency replies in Mode 2, called 4X or four train emergencies, include the normal reply plus 3 sets of framing pulses.

Mode 3/A is applicable for military or civilian use. Emergency replies in military mode 3/A consist of a combination of 4X and 7700 codes, while emergency replies in civilian
35 mode use the 7700 code only. A reply in 7600 code in both military and civilian use, indicates a failure in radio communication, while a reply in 7777 code is assigned to

interceptors on active air defense missions. Any transponder sending replies to mode 3/A with codes of 7500, 7600, 7700, or 7777 will trigger an alarm at a nearby air traffic controller (ATC) tower. The ATC's nationwide computer network tracks all assigned mode 3/A codes. The Department of Defense is assigned four Mode 3/A code blocks
5 (50XX, 54XX, 61XX, 64XX) for use within the countries' air space.

MODE 4 is applicable for military use only and allows for secure identification of friendly aircraft and surface vessels. Identification of friend or foe (IFF) automatically generates a reply code according to a preset crypto key list. Mode 4 interrogations use encoded,
10 multi-pulse trains with 4 (sync) pulses and an ISLS (Interrogation SideLobe Suppression) pulse, followed by up to 32 information pulses. When the transponder receives and processes a valid mode 4 interrogation, it sends out a time-coded, three-pulse reply. The interrogator converts the valid mode 4 reply back to one pulse. The reply is then time decoded before it is presented on the indicator. There are no
15 emergency replies for mode 4.

MODE C is used for civilian and military use to indicate the altitude of the aircraft, which is taken automatically from the aircraft's barometric altimeter. Mode C interrogations are the same as those for SIF (Selective Identification Feature) modes. Replies are binary
20 codes contained between bracket pulses, which are similar to those for SIF modes. The reply, derived from an encoder linked to the aircraft altimeter, may represent any altitude from -1,000 feet to +126,700 feet in 100-foot increments. Commercial aviation use a Traffic Alert and Collision Avoidance System (TCAS), which uses a low-power mode C interrogator-processor. Using mode C altitude reports, mode C interrogator-processor
25 computes the closest point of approach (CPA) to other aircraft and displays the information as an overlay on the weather radar indicator. General aviation aircrafts that fly below 12,500 feet reply to mode C with empty brackets (i.e. code 0000). There are no emergency replies for mode C.

30 In MODE S or Mode Select operation, a transponder replies to interrogation by Air Traffic Controller (ATC) Secondary Surveillance Radar (SSR) using a distinctive aircraft address (unique 12 Bit address) such that only a particular aircraft will respond. Mode S is also used in conjunction with Traffic Alert and Collision Avoidance System (TCAS) II to provide information on proximity of air traffic, warning of air traffic on potential collision
35 path, and suggested maneuver recommendation to pilot in command. Mode S is also

used for automatic surveillance of air traffic ADS (Automatic Dependent Surveillance) either in Contract (ADS-C) or Broadcast (ADS-B) mode.

Typically, when the transponder receives a valid mode S discrete interrogation, it will return a reply 128 μ s pulse after reception. The reply is transmitted on 1090 MHz and uses a 56-bit or 112-bit pulse position modulation (PPM) transmission. Each mode S interrogation will have a 24-bit address unique to the aircraft as well as a 24-bit parity check for validation. In basic mode S surveillance, the information is limited to altitude reporting, aircraft identification and basic airframe information.

The Secondary Surveillance Radar (SSR) is the main component of the interrogation and reply. The interrogation happens about 50 Hz pulsed radio frequency (PRF). The reply will happen at the same PRF. Once the SSR has received the reply it will decode the mode (A, C or S) and demodulate the information within each mode.

One or more of the above modes can be selected by manipulating a control panel indicated in Figures 1a, 1b and 2. The controls and indications on control panels 130 are described in the following table (TABLE I).

TABLE I
Control Panel 130 Control/Indication Function Description

CONTROL OR INDICATOR	Function
MASTER Switch	Turns transponder set on and off, selects receiver sensitivity, and selects emergency operation: OFF - Removes power from transponder set and transponder computer. STBY- Enables transponder receiver and computer; disables transponder transmitter. LOW- Places transponder set in operation at reduced receiver sensitivity. NORM- Places transponder set in operation at normal receiver sensitivity. EMER- Causes automatic transmission of emergency reply signals to Mode 1, 2, or 3/A interrogations only, regardless of mode switch settings (not affected by Mode C or 4 interrogations).
M-1 Switch	ON position selects Mode 1 operation of transponder set; TEST position selects Mode 1 test operation; OUT position turns off Mode 1

	operation.
M-2 Switch	ON position selects Mode 2 operation of transponder set; TEST position selects Mode 2 test operation; OUT position turns off Mode 2 operation.
M-3/A Switch	ON position selects Mode 3/A operation of transponder set; TEST position selects Mode 3/a test operation; OUT position turns off Mode 3/A operation.
M-C Switch	ON position selects Mode C operation of transponder set; TEST position selects Mode C test operation; OUT position turns off Mode C operation.
MODE 1 Reply-code Selector Switches	Select and indicate Mode 1 two-digit reply code number.
MODE 3/A Reply-code Selector Switches	Select and indicate Mode 3/A four-digit reply code number.
IDENT-OUT-MIC Switch	IDENT position selects identifier pulse; MIC position permits selection of identifier pulse when microphone keying switch is closed; OUT position turns off identifier pulse circuit.
RAD TEST-OUT-MON Switch	Selects test signals: RAD TEST position permits transponder set to be interrogated by selected Mode signals from an AN/APM-123(V)() or similar equipment; MON position turns on the monitoring circuits of Transponder Test Set TS-1843()/APX; OUT position disables test circuits.
TEST Light	Lamp lights when transponder set responds properly to Mode 1, 2, 3/A, or C test signal.
MODE 4 CODE Switch	Selects type of Mode 4 operation: HOLD- When held in position, overrides zeroizing function and enables transponder computer to retain Mode 4 code settings when AC power is removed. When released, returns to A position. A- Enables transponder system to respond to Code A interrogations. B- Enables transponder system to respond to Code B interrogations. ZERO- Cancels (zeroizes) Mode 4 code settings from transponder computer provided other operational requirements are met.
MODE 4 ON-OUT Switch	ON- Enables transponder system to reply to Mode 4 interrogations. OUT- Disables Mode 4 operation.
MODE 4 AUDIO-OUT-LIGHT Switch	Selects Mode 4 monitoring method: AUDIO - Enables aural monitoring (short burst 300 to 400 cycle buzz) of Mode 4 interrogations (valid or invalid) and REPLY light monitoring of Mode 4 replies. LIGHT- Enables only REPLY light monitoring of Mode 4 replies. OUT- Disables aural and REPLY light monitoring.
MODE 4 REPLY Light	Lights to indicate valid Mode 4 replies when

MODE 4 AUDIO-LIGHT-OUT switch is set to either AUDIO or LIGHT.
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Figure 1a is a schematic diagram to illustrate a system 100 for simultaneous use of civilian and military transponders in accordance with an embodiment of the present invention.

In the embodiment, the system 100 utilises a legacy air traffic control radar beacon system (ATCRBS) identification of friend or foe (IFF) mark X (A) [AIMS MARK X(A) IFF] secondary surveillance transponder 120 equipped on a military aircraft for identification of the aircraft when interrogated by a secondary surveillance radar (SSR) of an air traffic controller (ATC) or by another aircraft. In an embodiment, the system uses a legacy AN/APX-101 (AN/APX - US military equipment designator for Airborne Radar Equipment) IFF transponder, which will be referred herein afterward as IFF transponder 120. The IFF transponder 120 communicates with the ATC via antennae 105, 107.

The secondary surveillance transponder 120 in the aircraft operates in identification modes corresponding to civilian modes, such as mode 3/A and mode C of the air traffic control radar beacon system (ATCRBS). The secondary surveillance transponder 120 in the aircraft also operates in identification modes corresponding to military modes, such as mode 1, mode 2, mode 3/A and mode C of secondary surveillance radar (SSR) of an air traffic controller (ATC) or by another aircraft.

In the embodiment, the system 100 utilises another mode S transponder 110 for providing traffic alert and collision avoidance functions when interrogated by secondary surveillance radar (SSR) of a traffic alert and collision avoidance system (TCAS). The transponder 110 will be referred herein afterward as mode S transponder 110. The mode S transponder 110 communicates with the ATC or other interrogation sources via antennae 101, 103.

The mode S transponder 110 in the aircraft operates in identification modes corresponding to civilian modes, such as mode 3/A, mode C, and mode S of the air traffic control radar beacon system (ATCRBS).

Since the aircraft is equipped with IFF transponder 120 (operating in military modes, such as mode 1, mode 2, and civilian modes, such as mode 3/A, mode C) and mode S

transponder 110 (operating in civilian modes, such as mode 3/A, mode C and mode S), it is important that the military modes (such as mode 1, mode 2, mode 3/A and mode C) and civilian modes (such as, mode 3/A, mode C and mode S) of operation must always be present. This requires both the IFF transponder 120 and mode S transponder 110 to
 5 be always switched 'ON', which, in turn, causes synchronous garbling on the identification mode (e.g. mode 3/A and mode C) replies of IFF transponder 120 and civilian mode (e.g. mode 3/A and mode C) replies of mode S transponder 110.

10 In order to avoid synchronous garbling, a switch matrix 140 is provided to deconflict the overlapping identification modes in the example embodiment. This matrix appropriately connect the mode 3/A enable terminals 113a, 113b, mode C enable terminals 115a, 115b and a 28 V DC power supply line 117, 119 to the transponders 110, 120 and the control panel 130.

15 The respective military mode 1 enable terminal 109 and military mode 2 enable terminal 111 of the IFF transponder 100 are connected directly to the control panel 130, whereby mode 1 and mode 2 replies of the IFF transponder 120 are always available. The civilian mode 3/A enable terminal 113b in the control panel 130 is connected to the corresponding mode 3/A enable terminal 113 a of the IFF transponder 120 by an
 20 electronic switch 125. The civilian mode C enable terminal 115b in the control panel 130 is connected to the corresponding mode 3/A enable terminal 115a of the IFF transponder 120 by an electronic switch 135. The electronic switches 125, 135 are connected in parallel. i.e. the switches toggle between 'ON' and 'OFF' positions together.

25 The 28 V DC power supply terminal 117 from the IFF transponder 120 and the corresponding 28 V DC power supply terminal 119 in the mode S transponder 110 are connected by an electronic switch 145.

30 The system 100 is designed such that when switch matrix 140 is turned 'ON', it causes the electronic switch 145 to turn 'ON', whereby the 28 V DC power supply is connected to the mode S transponder 110, which, in turn, switches 'ON' the mode S transponder 110, whereby the civilian modes, such as mode 3/A, mode C and mode S from the mode S transponder 110 are activated. The 'ON' position of the switch 145 causes the
 35 switches 125 and 135 to switch 'OFF', whereby the civilian mode 3/A enable lines 113a, b and civilian mode C enable lines 115a, 115b between the control panel 130 and the

IFF transponder 120 are disconnected. Therefore, as long as the switch matrix 140 is in 'ON' position, the civilian modes, such as mode 3/A, mode C and mode S are only available from the mode S transponder 110, in addition to the military modes, mode 1 and mode 2 from the IFF transponder 120. In essence, the embodiment maintains the 'ON' state of both transponders (110 and 120) during operation (with full complements of traffic alert & collision avoidance, Mode S, 1, 2, 3/A and C functions) but avoids the synchronous garbling problem by disabling the overlapping mode 3/A and C via switches 125 and 135.

If for some reason the mode S transponder 110 fails during operation causing the loss of traffic alert and collision avoidance and identification mode S, 3/A, C functions; putting the electronic switch 145 in the switch matrix 140 to 'OFF' turns off the 28 V DC power supply to the mode S Transponder 120 also put the switches 125 and 135 to 'ON' thus enabling all the identification modes of the IFF transponder 120. Under this situation the IFF transponder provides identification modes in the military mode 1, 2 and civilian modes of 3/A & C.

Furthermore, Figure 1b also illustrates an operation of the system 100 when the mode S transponder fails during operation for whatever reason. The system 100 is designed such that when the switch matrix 140 is turned 'OFF', the electronic switch 145 is turned 'OFF', whereby the 28 V DC power supply is not connected to the mode S transponder 110, which, in turn, switches 'OFF' the mode S transponder 110. The 'OFF' position of the switch 145 causes the switches 125 and 135 to switch 'ON', whereby the civilian mode 3/A enable lines 113a, b and civilian mode C enable lines 115a, 115b of the control panel 130 and the IFF transponder 120 are connected respectively via the switches 125 and 135. Therefore, as long as the switch matrix 140 is in 'OFF' position, the civilian modes, mode 3/A and mode C are only available from the IFF transponder 120, in addition to the military modes, mode 1 and mode 2 as the switches 125 and 135 are in 'ON' positions.

In essence, the switching state of the embodiment referred to in Fig. 1a maintains the 'ON' state of both transponders (110 and 120) during operation (with full complements of traffic alert & collision avoidance, Mode S, 1, 2, 3/A and C functions) but avoids the synchronous garbling problem through disabling of the overlapping mode 3/A and C via switches 125 and 135; while the switching state of the embodiment referred to in Fig. 1b

ensures the military and civilian identification modes of 1, 2, 3/A and C remains available in the case of a failed mode S transponder 110.

5 It can be appreciated that the switch matrix 140, including the switches 125, 135, 145, can be physically implemented using separate or integral switches of various types.

Figure 2 is a schematic diagram to illustrate the system 100 for simultaneous use of transponders with overlapping identification modes, using a relay switch matrix 150 in an example implementation.

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The terminals of the switches 126, 136 respectively connect the mode 3/A and mode C enable signals from the control panel 130 to the IFF transponder 120, while the switch 146 connects a DC voltage from the IFF transponder 120 to the mode S transponder 110. A trigger 160 (e.g. a knob or a button) of the relay switch matrix 150 is used to toggle between an ON and OFF position.

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In an ON position, as indicated in Figure 2, the switches 126, 136 are switched to OFF positions, while the switch 146 is switched ON, whereby a DC voltage from the IFF transponder 120 is connected to the mode S transponder 110, which activates the mode S transponder 110 thus causing the mode S transponder to operate in respective identification modes of mode S, mode 3/A and mode C, while the IFF transponder 120 only operates in respective identification modes of mode 1 and mode 2.

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In an OFF position (not shown), the switches 126, 136 are switched to ON positions, while the switch 146 is switched OFF, whereby the mode S transponder 110 is switched OFF and the IFF transponder operates in respective identification modes of mode 1, mode 2, mode 3A and mode C.

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The switch 146 can be located anywhere in the flight deck but within an ergonomic reach of a seated operator.

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The switch matrix 140 (electronics form or solid state types) and 150 (relay) are representative of switching mechanism that can be used in the embodiment. Other switching mechanism like mechanical switches, such as toggle switches or pushbutton switches or a combination of the switching mechanisms mentioned herein are also possible.

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Since both the IFF transponder 120 and mode S transponder 110 can be operated simultaneously to respond to civilian and military mode interrogations, embodiments of the present invention can assist in preventing synchronous garbling.

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Embodiments of the present invention can assist in integrating the capabilities both mode S transponder 110 and IFF transponder 120 to cover the entire military secondary surveillance system. Therefore the legacy military IFF transponder 120 can be retained to supplement the mode S transponder 110 on military mode 1, mode 2, while mode S
10 transponder 110 continues to operate on mode 3/A, mode C and mode S. This results in cost saving as compared to retrofitting the two transponders 110, 130 with an integrated transponder. The cost can be significantly lower for a fleet of aircrafts.

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Embodiments of the present invention help in reducing cost for procuring spares for new transponders, which can be significant for a fleet of aircrafts. Time and risk involved to retrofit an integrated transponder can also be saved. Costs for installing kits to retrofit new integrated transponder (e.g. tray, new connectors, wirings) can be reduced.

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The invention is not limited the above embodiments. However, those skilled in the art will recognize that the invention can be practised, with modification, in the light of the information contained herein without departing from the scope of the invention.

Claims

1. A system for simultaneous use of transponders with overlapping identification modes on an aircraft, the system comprising:

5 a first transponder operating in respective identification modes corresponding to one or more communication modes;

a second transponder operating in respective identification modes corresponding to one or more communication modes, wherein the first and second transponders have one or more overlapping identification modes; and

10 a switching means coupled to the first and second transponders such that in each switched state, only one of the transponders operates in said one or more overlapping identification modes.

2. The system as claimed in claim 1, wherein in each switched state, at least one of
15 the transponders operates in a non-overlapping identification modes.

3. The system as claimed in claim 1 or 2, wherein in a first switched state, one of the transponders is powered OFF, while the other transponder operates in all of its identification modes.
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4. The system as claimed in claim 3, wherein in a second switched state, the transponder which was powered OFF is powered ON and operates in all of identification modes, while the other transponder operates only in non-overlapping identification modes.
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5. The system as claimed in any one of the preceding claims, wherein the first transponder provide identification information of the aircraft when interrogated by secondary surveillance radar (SSR) of an air traffic controller (ATC) or from another aircraft.
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6. The system as claimed in claim 5, wherein the first transponder comprises an Air traffic control radar beacon system (ATCRBS) identification of friend or for (IFF) Mark X (A) system [AIMS MARK X(A) IFF].

35 7. The system as claimed in claim 6, wherein the first transponder comprises an AN/APX-101 IFF transponder.

8. The system as claimed in claim 7, wherein the first transponder operates in identification modes corresponding to civilian modes, mode 3/A and mode C and military modes, mode 1 and mode 2.

9. The system as claimed in any one of the preceding claims, wherein the second transponder provides traffic alert and collision avoidance functions when interrogated by secondary surveillance radar (SSR) of a traffic alert and collision avoidance system (TCAS)

10. The system as claimed in claim 9, wherein the second transponder is a mode S transponder.

11. The system as claimed in claim 10, wherein the second transponder operates in identification modes corresponding to civilian modes, mode 3/A, mode C, and mode S.

12. The system as claimed any one of the preceding claims, wherein the switching means comprises one or more set of contacts for selectively coupling one of the transponders to a power supply.

13. The system as claimed in any one of the preceding claims, wherein the switching means comprises one or more set of contacts for selectively connecting respective mode enable ports of one of the transponders to respective mode enable signals from a control panel.

14. The system as claimed in any one of the preceding claims, wherein the switching means comprises a relay switch, an electronic switch or a mechanical switch.

15. A method for simultaneous use of transponders with overlapping identification modes on an aircraft, the method comprising the step of:

operating a first transponder in respective identification modes corresponding to one or more communication modes;

operating a second transponder in respective identification modes corresponding to one or more communication modes, wherein the first and second transponders have one or more overlapping identification modes; and

switching between the first and second transponders such that in each switched state, only one of the transponders operates in said one or more overlapping identification modes.