RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS, Revision A

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Proposed Appendix M to the 1090 MHz ADS-B MOPS to define Extended Range Reception Techniques

Background

The attachment to this working paper was prepared as an update to the version last presented at the December 2001, WG3 meeting in London.

Proposal

It is proposed that WG3 accept the updated draft of Appendix M and further develop this material for inclusion into Revision A to the DO-260.

Appendix M

Extended Range Reception Techniques

****** 1/3/2001 Version 4.0 DRAFT ******

M.1 Purpose and Scope

The purpose of this appendix is to provide a description of techniques for extending the air-to-air reception range of 1090 MHz. extended squitter. Three techniques are explored: (1) use of a directional antenna for 1090 MHz extended squitter reception; (2) optimized 1090 MHz ADS-B reception employing a variable bandwidth receiver(s) to provide improved reception sensitivity under low-to-moderate 1090 MHz fruit conditions; and (3) increased receiver sensitivity. These techniques may be applied independently or in combination where maximum air-to-air reception range desired.

M.2 Background

The ADS-B MASPS, DO-242, specifies the required air-to-air reception range for a number of ADS-B applications. The application identified with the longest reception range requirement is the flight path de-confliction application. The reception range requirements associated with this application are asymmetric as a function of target bearing from the receiving aircraft. Specifically:

- 90 nmi. required, 120 nmi. desired in the forward direction
- 45 nmi. toward the port and starboard
- 30 nmi. toward the aft

DO-242 defines the flight path de-confliction application as being applicable to "cooperative separation in oceanic/low density en route airspace." Thus as currently defined by the ADS-B MASPS this application is not required to be supported in moderate to high traffic density en route or terminal airspace. However, some aviation organizations, including Eurocontrol, have identified the potential need for a flight path de-confliction application that could be used by high altitude en route aircraft over-flying airspace with moderate to high traffic densities. Furthermore, it has been suggested by that the desired reception range be extended to 150 nmi. Although RTCA has not accepted changes to the ADS-B MASPS that would impose such enhanced ADS-B reception capabilities as the minimum requirement on ADS-B systems, additional optimizations in the design of airborne extended squitter systems may prove useful in satisfying the requirements associated of future ADS-B applications.

The air-to-air reception range requirement associated with the other ADS-B applications, that are currently defined by DO-242, is 40 nmi., without any target bearing dependency. Thus an ADS-B airborne installation intended to support all of the applications defined by DO-242 must support reception ranges of 90 nmi. forward, 45 nmi. toward the port and starboard, and 40 nmi. to the aft. in low traffic density airspace. For high traffic density airspace the required reception is 40 nmi. from any bearing.

M.3 Current Reception Range

The most capable class of ADS-B receiver specified by these MOPS is for Receiver Class A3E (Extended Capability with Enhanced Reception Techniques). This receiver class is specified to have an MTL of –84 dBm. An A3E class receiver when used in conjunction with omni-directional diversity aircraft antennas is intended to satisfy the requirement of DO-242 for an air-to-air reception range of 90 nmi. This assumes all of the target aircraft of interest at the maximum range are equipped with Transmitter Class A3 having a minimum transmit power (at the antenna port) of 250 watts. The 90 nmi. reception range capability is thus focused on users operating in high altitude airspace where the most capable class of avionics would be applicable.

M.4 Enhanced Reception Range Techniques

The focus of this appendix is on detailing techniques to provide for extended reception range (i.e., beyond 90 nmi.) in the forward direction, especially in low to moderate 1090 MHz. fruit environments. Certain of these techniques apply only to receivers and antennas not shared with TCAS as they employ antennas and receiver characteristics that are optimized specifically for the reception of extended squitters in support of the ADS-B function. The described techniques for enhanced reception range apply primarily to Class A3E receivers (i.e., Class A3 receivers that have also implemented the improved reception techniques specified in section *tbd* of these MOPS). Further, these techniques apply specifically to extending the ADS-B reception range between aircraft operating in high altitude en route or oceanic airspace.

M.4.1 Optimized Receive Antenna Configurations

One technique for supporting an extended squitter reception range is the provision of aircraft antennas with gain patterns that are optimized for the required ADS-B system performance requirements, as summarized in para. M.2 above. The baseline aircraft antenna configuration applicable to Class A3E ADS-B avionics is assumed to employ omni-directional top and bottom diversity antennas and to be consistent with the characteristics described in Appendix C. A more optimum aircraft antenna configuration is possible that is optimized specifically for the reception of extended squitters at the maximum range in the forward direction. Such an optimized aircraft antenna configuration must still support reception at the ranges required by DO-242 in non-forward directions and must also not degrade reception performance in high 1090 MHz fruit environments. A candidate optimized aircraft antenna configuration is described below that satisfies these constraints.

In this optimized configuration the bottom aircraft antenna has antenna pattern characteristics as in the baseline configuration (i.e., omni-directional). However, the baseline configuration's single element omni-directional top aircraft antenna is replaced or supplemented with a multi-element directional antenna providing a nominal +2 to +5 dB of additional gain in the forward direction. The typical configurations of the enhanced top aircraft antenna is summarized below:

- employs one driven quarter wavelength element and one or more passive elements. The elements are tuned to provide peak gain and minimum VSWR at or near 1090 MHz. and providing a nominal +2 to +5 dB gain increase in the horizontal plane in the forward direction (exclusive of any internal amplification), as compared to the baseline omni-directional antenna. The gain to the rear of the aircraft should be no less than –6 dB as compared to the baseline omni-directional antenna.

- includes an internal low noise preamplifier with 12 dB to 15dB of gain and a noise figure at 1090 MHz. consistent with the MTL requirements of the receiver.

A directional top antenna may be used either as the only top mounted antenna for the reception of 1090 MHz. extend squitters or may be used in combination with an omni-directional top antenna and independent receivers. In this latter configuration 3 antennas (i.e., two top and one bottom) would be used in combination with 3 receivers for the reception of 1090 MHz. extended squitters. In any case an omni-directional top antenna will be required for the transmission of 1090 MHz. extended squitters as well as conventional beacon transponder related functions. Thus, a 1090 MHz. directional top antenna will represent an additional antenna on the airframe and not a replacement for an existing beacon antenna. This will perhaps allow for a more optimum mounting location to be selected in support of the goal of providing improved reception performance from the forward direction. This would typically lead to a desired forward mounting location on the airframe's top center-line.

M.4.2 Optimized Receiver Bandwidth

Class A3E receivers not shared with TCAS are specified to have an MTL (at the antenna) of –84 dBm (Table 2-62). The out-of-band rejection for a message frequency difference of ± 5.5 MHz is specified by Table 2-63 to be at least 3 dB above this MTL. These out-of-band rejection characteristics correspond to a receiver design that employs intermediate frequency (IF) filtering with an effective bandwidth of approximately 8 MHz. Modeling of the enhanced decoding techniques, as defined in section *tbd* of these MOPS, have shown that reducing the IF bandwidth to significantly less than 8 MHz (e.g., 4 MHz.) may degrade the enhanced decoder performance in very high 1090 MHz fruit environments. However, such a reduction in the IF bandwidth has also been shown to allow for decreased receiver MTL values resulting in improved reception range when used in low-to-moderate 1090 MHz fruit environments. An optimum 1090 MHz. Extended Squitter airborne architecture would allow for use a narrow bandwidth receiver except in cases there the 1090 MHz. fruit levels are sufficiently high so as to degrade the performance of the decoder. Two approaches to such an architecture are either the use of receivers that can simultaneously support narrow and wide bandwidth reception –or- to enable a receiver to dynamically change the IF bandwidth, thus supporting increased receiver sensitivity, when operating in a high versus low 1090 MHz fruit environment.

The first approach have providing for receivers that can simultaneously support narrow and wide bandwidth reception would in effect result in functional 4 receivers for an aircraft equipped for diversity reception with one top and one bottom antenna. The two receivers connected to the same antenna could perhaps share common hardware at least for the 'front end' functions. While this approach to supporting optimum receiver bandwidth under both low and high 1090 MHz. fruit conditions, it probably requires more hardware components, and thus may be more expensive to implement that the alternative approach described below.

The second technique requires a 1090 MHz receiver design capable of varying the receiver sensitivity and out-of-band rejection characteristics as a function of the 1090 MHz fruit levels. This could be implemented either as a process capable of continuously varying the IF bandwidth over an allowed range or as a simple two step approach (full or reduced IF bandwidth), as assumed below. It cannot be expected that r.f. fruit levels will be directly measured by 1090 MHz ADS-B receivers. Therefore, monitoring of some directly measurable parameter in the received 1090 MHz. signals is the most appropriate approach for inferring the current interference environment. One such approach would be to monitor the percentage of low confidence bits declared by the decoder over a fixed time interval. Specifically using this approach, the out-of-band rejection characteristics could be as listed in Table 2.63 (with an MTL of –84 dBm) for the case where the measured percentage of low confidence bits declared over (*tbd)* seconds is greater than (*tbd)* percent. However for the case where the measured percentage of low confidence bits declared over *tbd* seconds is less than or equal to *tbd* percent, the nominal receiver MTL is decreased by 3 dB (e.g., from –84 dBm to – 87 dBm dB, at the antenna) and the out-of-band rejection characteristics are as defined in Table I-1 below (implying a reduced effective IF bandwidth).

Table M-1 ADS-B Receiver Out-of-Band Rejection for Extended Reception Range Technique

Message Frequency Difference (MHz. from 1090 MHz.)	Triggering Level (dB above the MTL at 1090 MHz.)
± 4*	Greater Than –or- Equal to 3
± 8*	Greater Than –or- Equal to 20
± 12*	Greater Than –or- Equal to 40
± 22*	Greater Than –or- Equal to 60

<<<* Editor's Note: Need to determine/validate correct values>>>>

M.4.3 Improved Receiver Sensitivity

The required MTL for Class A3E receivers is –84 dBm (Table 2-62). Airborne installations may achieve up to a 3 dB improvement from this reception performance level (i.e., MTL= -87 dBm) even for the case where narrow receiver bandwidth, as described above in M.4.2 is not used. Obtaining these performance gains may require use of a low noise preamplifier mounted near or integral with the receiving antenna(s) and the use of low-loss r.f. cables between the antenna and receiver. If such techniques are used in combination with a narrow bandwidth receiver, as described above in M.4.2, then a receiver MTL as low as –90 dBm may be possible. Such a configuration could be used to provide for maximum reception range in a low to moderate 1090 MHz. fruit environment.