1090-WP-10-11
26 March 2002

RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS, Revision A

Meeting #10

Proposed Appendix M (draft version 5) to the 1090 MHz ADS-B MOPS to define Extended Range Reception Techniques

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Background

The attachment to this working paper was prepared as an update to the version last presented at the January 2002, WG3 meeting in Ft. Lauderdale, Florida. Discussions at that meeting moved the concept for extended range reception to a combination of a directional receive-only antenna connected to a dedicated narrow bandwidth 1090 MHz ADS-B receiver using the enhanced reception techniques. The draft appendix M has now been modified in this direction.

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

****** 3/19/2002 Version 5 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 NM required, 120 NM desired in the forward direction
- 45 NM toward the port and starboard
- 30 NM toward the aft

It is noted that the ballot draft of DO-242A has proposed increased reception ranges toward the port and starboard directions as compared to DO-242. 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, the ballot draft of DO-242A indicates the full 90 NM range may be required for high altitude en route aircraft over-flying terminal airspace with high traffic densities. 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 NM, without any target bearing dependency. For high traffic density terminal airspace the required reception is 40 NM from any bearing.

M.3 Current Reception Range

The most capable class of ADS-B receiver specified by these MOPS is for Receiver Class A3 with Enhanced Reception Techniques. This receiver class is specified to have an MTL of –84 dBm. An A3 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 NM. 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 NM reception range capability is thus focused on users operating in high altitude airspace where the most capable class of avionics would be applicable. Also the A3 requirements associated with a 90 NM reception range were predicated on low density airspace.

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 NM) 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 more used for by Mode S transponders for transmissions 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 A3 receivers that have also implemented the improved reception techniques specified in section 2.2.4.4 and appendix I 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 1090 MHz Antenna and Receiver Combination

This approach would add a dedicated directional receive-only antenna to the top of the airframe in combination with a 1090 MHz receiver optimized for extended squitter reception.

M.4.1.1 Optimized 1090 MHz Antenna

This approach for supporting an extended squitter reception range would include the provision of an additional dedicated aircraft 1090 MHz receive-only antenna (i.e., a third antenna in addition to the standard diversity top and bottom antennas) with a gain pattern that is optimized for the required ADS-B system performance requirements, as summarized in section M.2 above. The baseline aircraft antenna configuration applicable to Class A3 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 where a third antenna is added that is optimized specifically for the reception of extended squitter at the maximum range in the forward direction. Such an optimized aircraft antenna configuration employing a 3 antennas 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 diversity top and bottom aircraft antenna have antenna pattern characteristics as in a baseline 1090 MHz ADS-B configuration (i.e., omni-directional). However, for extended reception range these standard diversity antennas can be supplemented with a top-mounted multi-element directional antenna providing a nominal +2 to +5 dB of additional gain in the forward direction. The typical configurations of the enhanced directional 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.

- 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.

The directional top antenna is to be used in combination with omni-directional top and bottom diversity antennas and each of the three antennas would be connected to independent 1090 MHz receivers. Since the direction top antenna would be dedicated to ADS-B reception, this could 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 mounting location forward on the airframe's top center-line.

M.4.1.2 Optimized Receiver Bandwidth and Sensitivity

Class A3 receivers not shared with TCAS are specified to have an MTL (at the antenna) of –84 dBm (Table 2-62 of these MOPS). The out-of-band rejection for a message frequency difference of ± 5.5 MHz is specified by Table 2-63 of these MOPS 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 Appendix I of these MOPS, have shown that reducing the IF bandwidth to significantly less than 8 MHz (e.g., 4 MHz.) may somewhat degrade the enhanced decoder performance in very high 1090 MHz Mode A/C 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 Mode A/C fruit environments. An optimum 1090 MHz. Extended Squitter airborne architecture would allow for use of a narrow bandwidth receiver connected to a dedicated top-mounted directional antenna, as described in section M.4.1.1 above. The out-of-band rejection for the narrow bandwidth ADS-B receiver should be as shown in Table M-1.

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

The use of a dedicated ADS-B receiver with reduced bandwidth provides the opportunity for improving the sensitivity of the receiver. The required MTL for Class A3 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) as a direct result of the reduction of the receiver bandwidth, as described above. Additional improvements in receiver sensitivity are possible with the use of a low noise preamplifier mounted near or integral with the dedicated receiving antenna as described in section 4.1.1 above. If an antenna mounted low noise preamp is used in combination with a narrow bandwidth receiver, 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.