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RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS, Revision A

Meeting #13

Draft 6 of the Proposed DO-260A Appendix M on Extended Range Reception Techniques

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SUMMARY
Several drafts of a new Appendix M to DO-260A were presented at previous WG3 meetings. The most recent was 1090-WP-10-11 from meeting #10 in March 2002. The attached updated draft of Appendix M is presented for approval by WG3.

Reference: WP10-11, Proposed Appendix M draft version 5, March 26, 2002

Attachment: Proposed Appendix M draft version 6

1. Introduction

Several drafts of a new Appendix M to DO-260A were presented at previous WG3 meetings. The most recent was WP10-11 from meeting #10 in March 2002. The attached updated draft of Appendix M is presented for approval by WG3. This new draft includes some editorial corrections and new material on the use of higher sampling rates for the extended squitter decoders and a statement on transmitter power for Class A3 avionics.

2. Proposal

It is proposed that WG3 review and accept the attached draft Appendix M as being sufficiently mature for incorporation into the draft of DO-260A.

ATTACHMENT

Appendix M

Draft Version 6
12 August 2002

Extended Range Reception Techniques

M.1 Purpose and Scope

The purpose of this appendix is to provide a description of techniques for extending the effective air-to-air reception range of 1090 MHz. ADS-B systems. Two reception techniques are explored: (1) use of a directional antenna with an integral low noise preamplifier for 1090 MHz extended squitter reception; (2) optimized 1090 MHz ADS-B reception employing a reduced bandwidth receiver to provide improved reception sensitivity under low-to-moderate 1090 MHz fruit conditions. Also the transmission power for Class A3 airborne installations is discussed.

M.2 Background

The ADS-B MASPS, DO-242A, specifies the required air-to-air reception range for a number of ADS-B applications. The one application identified by DO-242A with the longest reception range requirement is the Long Range Conflict Management application. When the requirements of all applications defined by DO-242A are considered, the required reception range varies as a function of target bearing from the receiving aircraft. Specifically as defined in DO-242A, Note 3 to Table 3-4(a), the required air-to-air reception range that would be applicable to Class A3 ADS-B systems is:

- 90 NM required (120 NM desired) in the forward direction
- 64 NM required (85 NM desired) +/- 45 degrees of forward direction
- 45 NM required toward the port and starboard directions
- 40 NM required (42 NM desired) toward the aft

DO-242A defines the Long Range Conflict Management (i.e., 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 explicitly required to be supported in moderate to high traffic density en route or terminal airspace. Currently the most demanding applications applicable to high density, high interference airspace are associated with separation assurance and sequencing. DO-242A only requires air-to-air reception ranges of 40 NM to support such applications. However, DO-242A includes similar notes under Tables 2-8 and 3-4(a) stating that "…the operational concept and constraints associated with using ADS-B for separation assurance and sequencing have not been fully validated. It is possible that longer ranges may be necessary. Also, the minimum range required may apply even in high interference environments, such as over-flight of high traffic density terminal areas." The latter statement in this note applies by reference to the Long Range Conflict Management application.

Additional optimizations in the design of airborne 1090 MHz ADS-B systems may prove useful in satisfying the air-to-air reception range requirements associated of future ADS-B applications.

M.3 Current Reception Range

The most capable class of ADS-B receiver specified by these MOPS is for Class A3. 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-242A 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 transmit power (at the antenna) of 125 watts to 500 watts (see M.5 below). 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 Class A3 requirements included in these MOPS that are associated with a 90 NM reception range were predicated on a low density airspace with low levels of RF interference.

M.4 Techniques for Extended Reception Range

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 or used for by Mode S transponders for transmissions. This is a consequence of employing antennas and receiver characteristics that are optimized specifically for the reception of 1090 MHz extended squitters in support of the ADS-B function. The described techniques for enhanced reception range apply primarily to Class A3 receivers. Further, these techniques apply specifically to extending the ADS-B reception range between aircraft operating in high altitude en route or oceanic airspace. Some of the described techniques are expected to also prove useful in supporting increased air-to-air reception range while over-flying high density, high interference operational environments.

The approach described 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 Optimized 1090 MHz Antenna

The proposed 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 baseline diversity 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 that is applicable to Class A3 ADS-B airborne systems is assumed to employ omni-directional top and bottom diversity antennas and are assumed 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 1090 MHz extended squitters at the maximum range in the forward direction. Such an optimized aircraft antenna configuration employing 3 antennas must still support reception at the ranges required by DO-242A in non-forward directions and must, at least, not degrade reception performance in the highest 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 gain pattern characteristics as in a baseline 1090 MHz ADS-B configuration (i.e., omni-directional). However, for extended reception range these standard diversity antennas are supplemented with a top-mounted multi-element directional antenna providing a nominal +2 to +5 dB of additional gain in the forward direction, as compared to an omni-directional antenna. A typical configuration for 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 at or just above the horizon 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 overall MTL requirements of the receiving system.

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 directional 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.4.2 Optimized Receiver Characteristics

M.4.2.1 Optimized Receiver Bandwidth

Class A3 receivers that are 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 $\pm$ 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 slightly degrade the enhanced decoder performance in very high 1090 MHz Mode A/C fruit environments. However, such a reduction in the IF bandwidth will 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 narrower bandwidth receiver connected to a dedicated top-mounted directional antenna, as described in section M.4.1 above.

The use of a dedicated ADS-B receiver with reduced bandwidth provides the opportunity for improving the sensitivity of the receiver. The MTL for Class A3 receivers, conformant to these MOPS, is –84 dBm or lower (Table 2-62). Airborne installations may achieve up to a 3 dB improvement from this reception performance level (i.e., MTL less than or equal to -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 M.4.1 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.

M.4.2.2 Optimized Receiver Extended Squitter Decoding

Class A3 receivers are required by these MOPS to incorporate enhanced reception techniques. The associated test procedures of these MOPS are consistent with an 8 MHz sampling rate of the received video waveform (i.e., 8 samples per bit). Higher sampling rates are known to provide improved probability of correct decoding when using the baseline multi-sample enhanced decoding techniques defined in Appendix I in a high Mode A/C fruit environment. Therefore, a sampling rate of 10 MHz or higher is recommended for use as a means of extending the reception range of 1090 MHz ADS-B in high Mode A/C fruit environments. Applying a decoder with a higher sampling rate is expected to help offset the degradation to decoding performance that would result from use of a reduced bandwidth receiver as described in M.4.2.1 above.

M.5 Transmission Power

Currently all 1090 MHz ADS-B airborne systems, other than Class A0, are required by these MOPS to have a transmit power within the range of 21 dBW (125 watts) to 27 dBW (500 watts), as measured at the antenna port. As noted in §2.2.2.1.1.4 of these MOPS: "Future version of these MOPS may require that Class A3 1090 MHz ADS-B systems have a transmission capability with a minimum RF peak power of 23 dBW (200 Watts) measured at the antenna terminals." As the ADS-B MASPS mature, further refinements to the air-to-air range requirements are expected. Also as the ASA MASPS are completed new requirements may emerge that require either improvements in received update rates or increased reception ranges. A 1090 MHz ADS-B airborne installation satisfying only the minimum transmit power requirement of 21 dBW, as currently required by these MOPS, is expected to be compatible with the 90 NM reception range requirement, as applicable to Class A3 systems, only under near ideal conditions (with a nominal antenna gain patterns and in a RF non-interference environment). A 2dB increase in the minimum transmit power from 21 dBW to 23 dBW for Class A3 airborne systems is expected to offer a meaningful improvement in the actual air-to-air reception range supported between Class A3 users, especially under non-ideal conditions.