Supplemental Information on the Application for Frequency Allocation, CAS-100 ACAS II Processor, TPA-100A

The information below is provided as a supplement to the frequency application. This information should be considered together with the line diagrams on previous pages.

GENERAL

1. ACAS II computes the range of the intruding aircraft by measuring the transmission turn-around time. Altitude rate, bearing, range, and range rate are computed by tracking the reply information.

2. The system has two operating modes: Traffic Advisories (TA) and Traffic/Resolution Advisories (TA/RA). In the TA mode, the system displays the position of proximate aircraft that are or could become collision threats. In TA/RA mode the system also provides resolution advisories (RAs). An RA can be a corrective advisory (which instructs the pilot to deviate from the current flight path) or a preventive advisory (such as, "Don't Climb", when the aircraft is in level flight).

3. In a TCAS-to-TCAS (ACAS II to ACAS II) encounter, each aircraft transmits interrogations to the other via the Mode S data link. These "coordination" interrogations ensure that each aircraft selects complementary RAs. The coordination interrogations are transmitted once per second by each TCAS for the duration of the RA. The line diagram below shows the communications links during a TCAS-to-TCAS coordination.

4. When airborne, the ACAS II system monitors the squitters transmitted by the Mode S transponders. The system transmits periodic interrogations to Mode C and Mode S transponder-equipped aircraft. In response to these interrogations, the transponders respond with signal reporting aircraft altitude. One of the most significant differences between Mode C (also referred to as Air Traffic Control Radar Beacon System (ATCRBS)) transponders and Mode S transponders is that Mode S transponders have unique addresses while Mode C transponders do not. For that reason, Mode C interrogations are “All –Call” broadcast transmissions while Mode S interrogations are directed to individual aircraft. This poses a problem to many potential Mode C aircraft responding all at once with their replies stepping over each other. To handle this (synchronous garble) during surveillance interrogations of Mode C aircraft, ACAS II system utilizes a technique of interrogation sequences referred to as "Whisper-Shout” (WS).

5. A Mode C surveillance WS sequence consists of incremental power steps. Each Mode C pulse train (P1, P2, P3, P4) is transmitted at approximately 1 dB more power than the previous transmission. The object of WS interrogations, as explained below, is to produce a "movable reply area" that looks like a 90 degree arc cutout from a donut shape that goes out further in range for each transmission within a WS sequence.

6. A key element in the mechanism of WS interrogations is the use of transponder Side Lobe Suppression (SLS). Basically, Mode C use of transponders

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will suppress (not reply) if the interrogation waveform has a pulse P2 with equal or greater amplitude than pulse P1 (RTCA/DO-181B, Section 2.2.5).

7. WS interrogations (except the first two lowest power interrogations in each WS sequence) include an additional suppression pulse S1. Pulses S1 to P4 are transmitted in a directional beam while P2 is transmitted omni-directionally. The directional beam has a gain of approximately 3 dB over the omni-directional transmission. The antenna page contains the specific details of the 136 variable transmissions generated by the eight WS sequence of the ACAS II equipment.

8. The first transmission in each sequence is made at 30 dBm (1 Watt). The separation between each transmission within a given WS sequence is 1.5 milliseconds. The spacing from one WS sequence to the other is approximately 100 milliseconds.

9. The result of this WS-SLS technique is that all Mode C equipped aircraft outside of the directional beam are suppressed and do not respond to any of the WS interrogations. This is because those Mode C transponders see the omni-directionally transmitted P2 pulse stronger than P1. Only those aircraft positioned within the directional beam (where P1 is 3 dB stronger than P2) are in a position to respond. Within the directional beam the S1 pulse and the incremental power steps come into play to elicit replies from different aircraft at different ranges. P2 is low in relative amplitude within the directional beam and does not cause suppression. But the S1-P1 pulse combination is spaced to look like a P1-P2 combination and can cause suppression to those transponders that are sensitive enough to detect the lower amplitude S1 pulse. The first two low power transmissions (at 30 and 31 dBm) do not have S1 pulses.

10. Any Mode C aircraft within a two or three mile range should detect and respond. Transponders that are further away in range do not see S1 or P1. As power is gradually increased, the closest target will detect both S1 and P1 and will go into suppression while mid-range aircraft will see P1 but not detect S1 (below the Minimum Triggering Level) so they respond. Far out aircraft still do not see either S1 or P1. Space losses and typical transponder sensitivities are such that, at maximum power of 52 dBm, aircraft located up to 40 miles away will reply to TCAS interrogation.

MODE S SURVEILLANCE INTERROGATIONS

11. Mode S transponder-equipped aircraft transmit squitter interrogations with an average period of one interrogation per second (maximum is 1.2 seconds). These squitters are short-format messages of 56 data bits with the downlink format (DF) field set to 11. The ACAS II system detects the presence of Mode S equipped aircraft by listening (@ 1090 MHz) to the DF11 squitters. Each squitter data field contains the unique Mode S address of the transmitting transponder.

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13. Once per second, the ACAS II system examines a list of received DF-11 squitters to determine if there are new Mode S-equipped aircraft within listening range that should be tracked. For each new Mode S target that is identified via its squitter, a series of short (56 bit) interrogations are conducted to establish its altitude and range. Four interrogation & replies are required to acquire and establish the target with its own surveillance track. The interrogation and replies are all short formats. The data contained in the replies include maximum airspeed and altitude. Range and bearing are determined from time of response and phase directionality of the received signal. The first interrogation in the four transmission-reply track acquisition cycle is conducted at full power (52 dBm). The remaining three interrogations are power-programmed as a function of the aircraft range determined from the first reply. Mode S acquisition interrogations are transmitted out of the antenna that the squitter was received from. Once a Mode S aircraft's track is established, the ACAS II system will go back to that target once per second to maintain surveillance with a power programmed interrogation, unless it meets the 5 second tracking criteria defined in DO-185A. If a target does not reply a second attempt is made at full power.

14. The power-managing algorithm is described in RTCA/DO-185A, Section 2.2.4.6.2.2.4. Basically, targets with ranges greater than 10 nautical miles are interrogated at full power. Other targets are interrogated with reduced power based on the formula:

Power = Maximum Power (in dBw) + 20 Log (Range/10), where Range </= 10

15. The number of Mode S surveillance transmissions is not a constant number as in the case of Mode C "Whisper-Shout" transmissions. Mode S transmissions and the resulting average transmitted power vary as a function of number of Mode S targets and how many re-tries are required to establish a specific target.

17. Since the ACAS II system is limited to tracking a maximum of 30 aircraft (Mode S or Mode C), the worst theoretical case is a scenario in which there are no Mode C aircraft in range and there are 30 Mode S targets all located at ranges exceeding 10 miles requiring maximum power interrogations.

INTERFERENCE LIMITING

18. The ACAS II system will control its interrogation rate or power -- or both -- to minimize interference effects, and it will conform to a set of three specific inequalities defined in the RTCA/DO-185A MOPS. These inequalities ensure that all interference effects resulting from ACAS II interrogations, together with the interrogations from all other ACAS airborne interrogators in the vicinity, are kept to a low level. The limits on interrogation rate and power are functions of the surrounding aircraft density. In the process of checking for compliance with the limits of the inequalities, the ACAS II system counts the number of other ACAS in the vicinity. The "Number of TCAS aircraft" (NTA) is obtained by monitoring Mode S TCAS broadcast interrogations with uplink format 16 (UF16). When the NTA count exceeds 16, Whisper-Shout steps are removed in one step increments to satisfy the inequalities.