EXHIBIT NUMBER 1

Signal description

TCAS MODULATION CHARACTERISTICS

The TCAS transmitter output consist of pulse groups whose attributes are defined by RTCA DO-185A. Transmissions fall into two categories – TCAS to ATCRBS transmissions and TCAS to Mode S transmissions.

TCAS to ATCRBS Transmissions

TCAS to ATCRBS transmissions employ the "Mode-C-Only All-Call" format which consists of three pulses P1, P3, and P4. This shall normally be proceeded by an ATCRBS "whisper-shout" suppression pulse designated S1.

The amplitude of P3 shall be within 0.5 dB of the amplitude of P1 and the amplitude of P4 shall be within 0.5 dB of the amplitude of P3. The amplitude of S1 is variable as specified in RTCA DO-185A and typically is 2 or 3 dB less than the amplitude of P1.

All pulses have pulse duration's of 0.8 +/- 0.05 microseconds, rise times between 0.05 and 0.1 microseconds. The rise and decay times are allowed to be less than this provided the side band radiation does not exceed the spectral limits specified in RTCA DO-185A.

The pulse spacings are S1 to P1: 2 +/- 0.1 microseconds, P1 to P3: 21 +/- 0.1 microseconds, and P3 to P4: 2 +/- 0.04 microseconds.

TCAS to Mode S Transmissions

TCAS to Mode S Transmissions consist of a P1 and P2 pulse and either a short or long P6 pulse.

Pulse shapes are given in microseconds as:

Pulse Designator	Pulse Duration	Duration Tolerance	Rise Time Min	Rise Time Max	Decay Time Min	Decay Time Max
P1, P2	0.8	0.05	0.05	0.1	0.05	0.2
P6 (short)	16.25	0.125	0.05	0.1	0.05	0.2
P6 (long)	30.25	0.125	0.05	0.1	0.05	0.2

The short and long P6 pulses have internal modulation consisting of possible 180-degree phase reversals of the carrier at designated times. The first phase reversal is the sync phase reversal and is always present. The presence or absence of subsequent phase reversals indicates a one or zero in the transmitted code respectively. The duration of the phase reversal shall be less than 0.08 microseconds as measured between the 10 degree and 170 degree points of the phase transition. The interval between the 80 percent points of the amplitude transient associated with the phase reversal shall be less than 0.08 microseconds. The tolerance of the 0 and 180 degree phase relationships shall be less than 5 degrees. The 90 degree points of each data phase reversal shall occur at a time N 0.25 +/- 0.02 microseconds after the 90 degree point of the sync phase reversal, where N is greater than or equal to two.

The spacing from P1 to P2 shall be 2 +/- 0.04 microseconds between leading edges. The spacing from the leading edge of P2 to the 90 degree point of the sync phase reversal of P6 shall be 2.75 +/- 0.04 microseconds. The leading edge of P6 shall occur 1.25 +/- 0.04 microseconds before the sync phase reversal.

The radiated amplitudes of P2 and the initial first microsecond of P6 shall be greater than the radiated amplitude of P1 minus 0.25 dB. The maximum envelope amplitude variation between successive phase modulation chips in P6 shall be less than 0.25 dB.

EXHIBIT NUMBER 2

TCAS TRANSMITTER OCCUPIED BANDWIDTH

Pulses emitted by TCAS equipment vary in width and amplitude, and contain angle modulation during the pulse. It is a single channel containing digital information without the use of a modulating subcarrier. The type of information transmitted is for data transmission. Thus, the TCAS emission type as defined in Sect. 2.201 is V1D.

Due to the relatively complex nature of the signals transmitted by the TCAS, there is no one single formula which would predict the necessary bandwidth. The modulation characteristics are outlined in Exhibit 1. The modulation with the fastest temporal characteristics, and thus the greatest effect on frequency domain spectrum, is the binary phase shift keying which occurs during a Mode S transmission.

A search was conducted for a CCIR formula which dealt with binary phase shift key modulation, but none was found. The following was taken from Digital and Analog Communication Systems, Shanmugam, K. Sam, John Wiley, 1979, p. 403. "..the shapes of the psd of the binary PSK signal and the ASK signal are similar. The only difference is that the PSK spectrum does not have an impulse at the carrier frequency. The bandwidth requirements of the PSK signal is the same as that of the ASK signal." Thus, we believe that the formula from the procedures of Report 836 of the International Radio Consultative Committee, Recommendation and Reports of the CCIR, 1982 will accurately predict the necessary bandwidth for a BPSK pulse, as well as for an unmodulated pulse. Since there is no minimum switching time specified in RTCA DO-185A, the formula for a rectangular pulse will be used. Considering the spectrum of a group of pulses to fall within the envelope defined by the spectrum of a single pulse, the formula

$$Bn = 6.36 / t$$

is employed, where Bn is the necessary bandwidth, and t is the pulse width. The narrowest chip permitted by RTCA DO-185A has t = 230 nanoseconds as outlined in Exhibit 1 "TCAS to Mode S Transmissions" section where it discusses the timing between the data phase reversals. The necessary bandwidth then becomes Bn = 27.65 MHz.

Thus the complete emission designation according to Sect. 2.201 and 2.202 is 27M7V1D.

EXHIBIT NUMBER 3
TCAS ANTENNA CHARACTERISTICS

The TCAS directional antenna characteristics are defined by RTCA DO-185A as follows:

Antenna System

The equipment shall transmit interrogations and receive replies from top mounted and bottom mounted antennas.

Note: A TCAS II unit and Mode S transponder may share a single pair of antennas.

Polarization

The antennas shall be vertically polarized.

Transmit Radiation Pattern

The TCAS II equipment shall be capable of providing directional interrogations from top-mounted antennas for surveillance of Mode C targets in densities up to 0.3 aircraft per sq. nmi. An omnidirectional bottom transmit antenna is sufficient for TCAS II since most of the interrogations are transmitted from the top antenna in order to reduce susceptibility to multipath interference from the ground. The use of a bottom directional transmit antenna and the use of directional interrogations for surveillance of Mode S targets and for transmission of TCAS II Broadcast interrogations is optional.

The directional interrogation antenna shall generate an azimuth beam that is sequentially positioned to provide adequate surveillance coverage over 360 degrees azimuth. To ensure adequate coverage, the directional antenna 3 dB beamwidth in azimuth shall not be less than the separation between adjacent azimuth beam positions. Beamwidth control is further provided by the P2 suppression pulse as defined in DO-185A subparagraph 2.2.4.5.4.2.1. Also, the shapes of the antenna azimuth patterns shall be controlled such that a minimum-suppression transponder, defined as one that replies when the received ratio of P1 to P2 exceeds 0 dB shall reply to interrogations from no more than two adjacent directional beams. The requirements of this paragraph shall apply for each elevation angle between +20 degrees and -15 degrees.

The shape of the elevation pattern at the azimuth peak-of-beam of each directional beam should match the shape of the elevation pattern of a matched quarter-wave stub within ± 1 dB over 90% of the region from -15 degrees to +20 degrees in elevation when installed at the center of a 1.2 m (4 ft.) diameter (or larger) circular ground plane that can be either flat or cylindrical.

The gain of an omni-directional transmit pattern (if employed) should not be less than the gain of a matched quarter-wave stub minus one dB over 90% of a coverage volume from 0 to 360 degrees in azimuth and -15 to +20 degrees in elevation when installed at the center of a 1.2 m (4 ft.) diameter (or larger) circular ground plane that can be either flat or cylindrical.

If the antenna gain is not as specified above, the transmitted power shall be adjusted to satisfy the Power requirements specified in DO-185A subparagraphs 2.2.3.1 and 2.2.4.5.4.2.2.

Receive Radiation Pattern

A TCAS II that employs an omni-directional receive pattern shall meet all of the gain requirements specified in DO-185A subparagraph 2.2.4.7.2.1 for an omni-directional transmit pattern.

A TCAS II that employs a directional receive pattern consisting of four simultaneous directional beams shall meet the following pattern requirements when installed at the center of a 1.2 m (4 ft.) diameter (or larger) circular ground plane that can be either flat or cylindrical. The shape of the elevation pattern at the azimuth peak-of-beam of each directional beam shall match the shape of the elevation pattern of a matched quarter wave stub within ± 1 dB over 90% of the region from -15 degrees to +20 degrees in elevation. The gain at the crossover points between adjacent directional beams shall not be less than the adjacent peak-of-beam gain minus 4 dB from -15 degrees to +20 degrees in elevation.

A TCAS II that employs a receive pattern consisting of more than four simultaneous directional beams shall meet the elevation pattern requirement stated above for the four-beam antenna. The gain, relative to peak-of-beam, at the crossover points between adjacent directional beams of this antenna shall match, within 1 dB, the gain required to account for the maximum closing speed that occurs in the direction of the crossover point.

If the antenna gain is not as specified above, the nominal receiver MTL shall be adjusted to account for the antenna gain.

Note: *For example, for a relative peak-of-beam antenna gain of -3 dB, the MTL value associated with a reply received via this beam shall be lowered by 3 dB.*

Use of a Directional Antenna for Mode S Interrogations

Availability of bearing information will allow Mode S interrogations to be made using a directional antenna. If a directional antenna is used for transmission of Mode S interrogations, the transmit radiation pattern shall be as specified in DO-185A subparagraph 2.2.4.7.2.1 with the exception that side-lobe suppression is not used.

Antenna Selection For Squitter Listening

The equipment shall monitor squitters via top and bottom antennas that are capable of simultaneous reception over 360 degrees of azimuth. If reception is switched, the switching times shall be controlled to avoid undesirable synchronism with the squitters transmitted by Mode S diversity transponders.

Note: *This can take the form of simultaneous reception using two receivers and two decoders or switched reception using a single receiver. Mode S transponders alternate the antennas used for squitter transmissions at nominal 1-second intervals. It is acceptable for TCAS II to switch antennas for squitter monitoring after two successive surveillance update periods.*

EXHIBIT NUMBER 3 (cont.)

Antenna Selection For Interrogations and Replies

The equipment shall transmit each Mode C or Mode S interrogation via one or the other of two antennas. Interrogations shall not be transmitted simultaneously via both antennas. Replies shall be received from the same antenna that was used to transmit the interrogation.

EXHIBIT NUMBER 4

(a) This application is intended to cover general TCAS II development activities. TCAS II characteristics are well defined in the RTCA DO-185 MOPS and more recently in an update which has been approved as DO-185A. The update does not contain any modifications to the RF characteristics in the original specification. TCAS II systems certified to DO-185 have been in revenue operation since 1990 onboard aircraft. A general overview of system operation is included below:

The TCAS II system is an airborne traffic alert and collision avoidance system that interrogates ATC transponders in nearby aircraft and uses computer processing to identify and display potential and predicted collision threats. The system consists of:

- TCAS Processor LRU with top and bottom directional 4 element antennas (optionally the bottom antenna may be an omni direction antenna)
- Mode S Transponder LRU with top and bottom omni direction antennas.
- TCAS/Transponder control panel
- Resolution advisory cockpit display(s)
- Traffic cockpit display(s)

This application is being submitted specifically for the TCAS Processor LRU. This LRU consists of a 1030 MHz transmitter, a 1090 MHz receiver, various input/outputs to other aircraft systems, and microprocessors for processing and resolving collision conflicts.

The system protects a volume of airspace around the TCAS II equipped aircraft. The system provides appropriate aural and visual advisories to the flight crew to provide adequate separation when the computer analysis of intruding aircraft transponder replies predicts a penetration of the protected airspace. The system provides two types of advisories. A traffic advisory (TA) indicates the relative position of an intruding aircraft that is approximately 35 seconds from the closest point of approach and may a short time later require a resolution advisory (RA). The TA provides the flight crew the opportunity to visually acquire the intruding aircraft. A resolution advisory will produce a threat resolution in the form of a vertical maneuver that will increase separation when the computer predicts the intruder aircraft is within approximately 25 seconds from the closest point of approach.

The TCAS II system can only generate resolution advisories for intruders equipped with operative Mode S or Mode C transponders, which provide information on the altitude of the intruder. Traffic advisories which display the relative position of the intruder can be generated for aircraft with operative Mode S, Mode C or Mode A transponders. The TCAS II equipment is viewed as a supplement to the pilot who, with the aid of the ATC system, has the primary responsibility for avoiding mid-air collisions. The TCAS II system provides no indication of traffic conflicts with aircraft without operative transponders.

(b) Collins is developing two new model numbers of the TCAS Processor LRU, the TTR-921 and the TTR-4000. During the development, flight testing on the company aircraft and ground testing must be performed. The purpose of this testing is to verify the ability of the equipment to track other aircraft through the interrogation/reply scheme.

EXHIBIT NUMBER 4 (cont.)

(c) This program is intended to develop and certify a next-generation production version of the Collins TCAS II system.

The need for continued experimentation with TCAS equipment will continue on an on-going basis after the TTR-921 and TTR-4000 have received equipment authorizations.