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MODE S SENSOR ALL CALL INVESTIGATION

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INTRODUCTION

The Federal Aviation Administration (FAA) in conjunction with the airline industry is presently conducting operational evaluation of the newly implemented Traffic Alert and Collision Avoidance System (TCAS). The Data Link Test Analysis System (DATAS), developed at the FAA Technical Center, was modified to provide a TCAS monitor function in addition to its existing functions. DATAS, as a TCAS monitor, operated independently of the TCAS systems to collect TCAS data (such as Resolution Advisory (RA) as well as illegal addresses) from the ground. It was further modified to monitor the 1090 megahertz (MHz) radio frequency (RF) signals which are used by Mode Select (Mode S) and Air Traffic Control Radar Beacon System (ATCRBS), as well as TCAS, to characterize the environment so that an assessment can be made of the impact on those systems.

During the debugging phase of this development, it was noticed that occasionally a large number of DF11 (Mode S Downlink Format 11) replies were seen from a particular aircraft. This format is used by the Mode S system to acquire aircraft as they enter the airspace serviced by the Mode S sensor. The Mode S sensor interrogates with a UF11 (Uplink Format) to which aircraft reply with a DF11. After this acquisition phase, aircraft are tracked using DF4 or DF5 which give altitude and identity information to the Mode S sensor. Aircraft are normally "locked out" to DF11 interrogations when tracked by the Mode S sensor. DF11 replies are also used by TCAS as "squitters" to notify other TCAS equipped aircraft of their presence. These replies are unsolicited and occur once each second so that approaching TCAS equipped aircraft can acquire other TCAS aircraft and track them when in proximity. Thus, after the Mode S acquisition process (which requires several DF11's), there should be only a single DF11 from each aircraft per second. When large numbers of DF11's were seen from a single aircraft (up to 35 per second), concerns were raised about the amount of interference this would cause to existing systems if several aircraft were to simultaneously go into this mode.

After discussion with Mode S personnel, it was decided to conduct a test to determine the reason. The environment at the FAA Technical Center is somewhat unique in that a large percentage of the air traffic is contributed by "overflights" (aircraft not enroute to/from Atlantic City). The surveillance antenna systems have a blind spot at high elevation angles called the "zenith cone" where signal strengths are diminished to a point where they cannot be used. The speculation is the fact that "overflight" aircraft are entering the "zenith cone" of the Mode S system and the sensor is not tracking them and they then reply to every "all call" interrogation they see. The modification will be a change in the definition of the "zenith cone" from 34 to 88 degrees. The 88 degree number was used to merely prove that this was the problem. The actual number used should match the actual "zenith cone" of the particular system.

DATA COLLECTION/DISCUSSION

Data was collected on September 21, 1993 with and without the modification installed. The DATAS was positioned on the ramp at the FAA Technical Center and operated in the Environmental Analysis Mode using the combined 1030/1090 MHz mode. It was configured to "listen" on the 1090 MHz frequency for a period of 25 seconds and then switch to an active transmit mode on 1030 MHz for a period of 5 seconds in order to obtain a track on the aircraft. The replies to the Mode S sensor were separated from the TCAS replies. The format of the DF11 replies is the same as that of the "squitters" but the All Call reply to the Mode S sensor contains the identity of the sensor in the reply. This information was used to separate the squitters from replies to the Mode S sensor All Call interrogations (the sensor operated with II = 15). The data is discussed below using specific instances to describe the problem.

Data was collected for three different intervals, one without the modification, a second with the modification and another at the end without the modification. Each interval was approximately a half hour. The table below summarizes the overall reply data for the three conditions.

Condition	# Aircraft	#DF4	#DF11	%DF4	%DF11
No Mod	18	812	253	76	24
With Mod	37	1125	91	92	7
No Mod	25	1381	783	36	63

The second test period with "No Mod" is somewhat misleading. It contains a large number of All Call replies (DF11's) because the sensor is still completing the acquisition phase after restarting when the modification was removed. It is assumed that the normal number would approach that of the test period prior to the mod (24 percent DF11's). In order to get the real information, we would need to conduct the tests for significantly longer periods of time.

SPECIFIC EXAMPLES

Figure 1 shows the data from A34726. It looks like this aircraft was dropped twice by the Mode S sensor during the coverage. The altitude was almost a constant at 14,800 feet. The aircraft was responding to All Calls from the sensor from approximately 10:58:26 to 11:00:01. As indicated on figure 2, the aircraft was above a 35 degree elevation angle during this time.

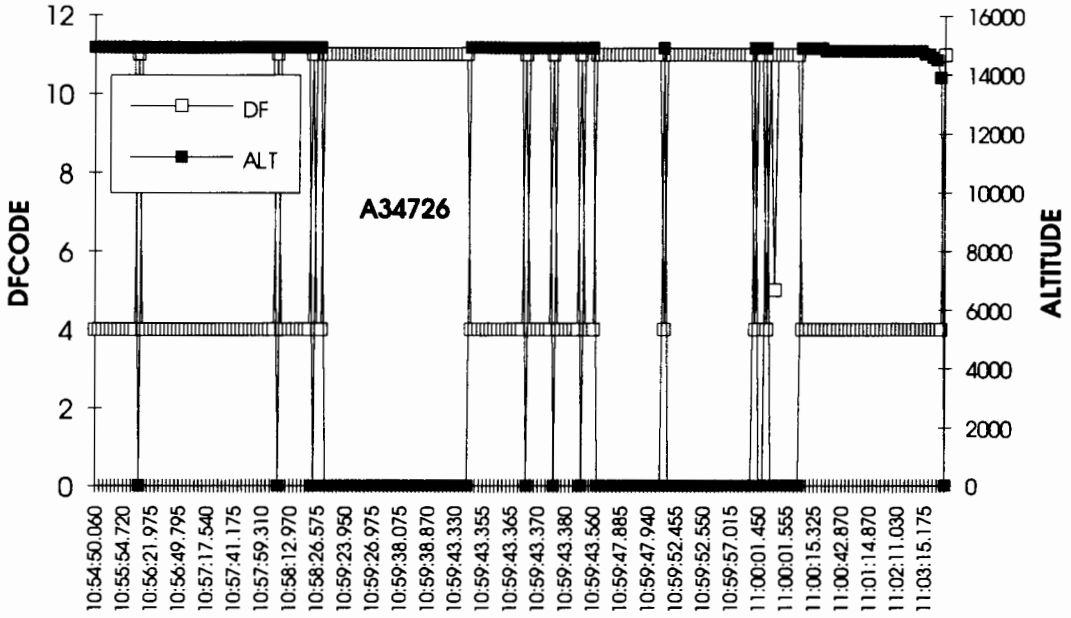

FIGURE 1. DATAS Data - A34726

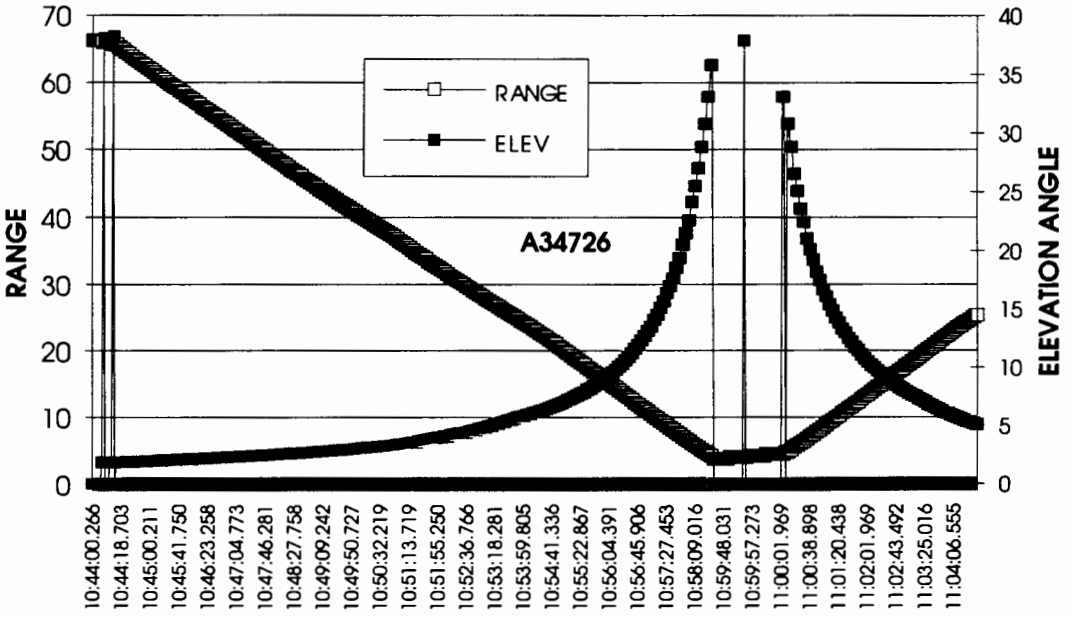

FIGURE 2. Mode S Sensor Data - A34726

Figure 3 shows that A422B4 responded to All Calls from the Mode S sensor from approximately 09:14:07 to 09:14:39 which corresponds to the time it was above the 35 degree elevation as indicated on figure 4.

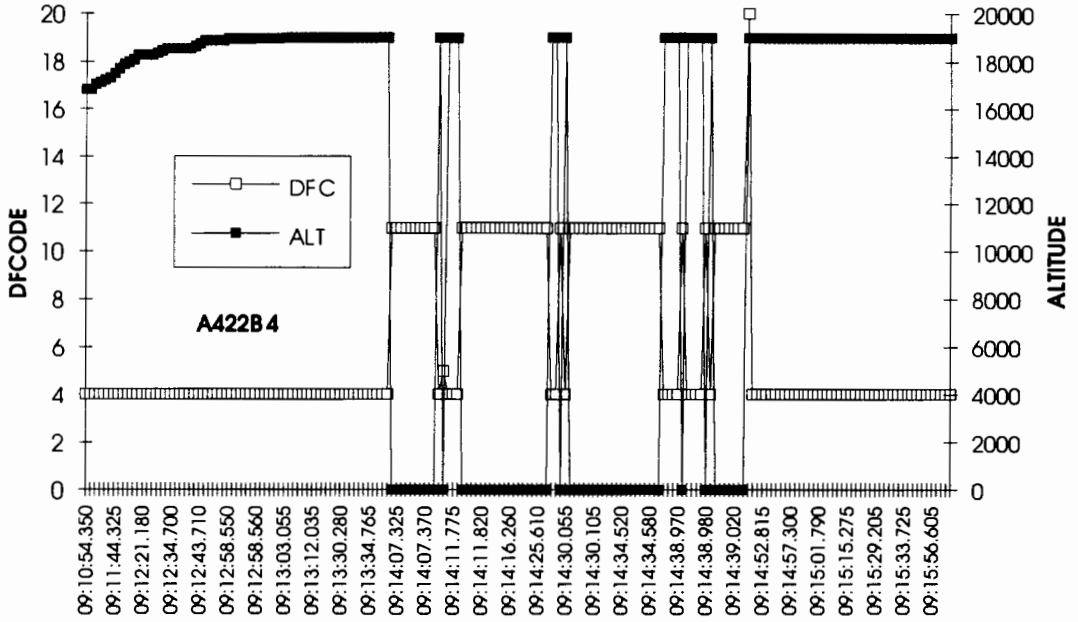

FIGURE 3. DATAS Data - A422B4

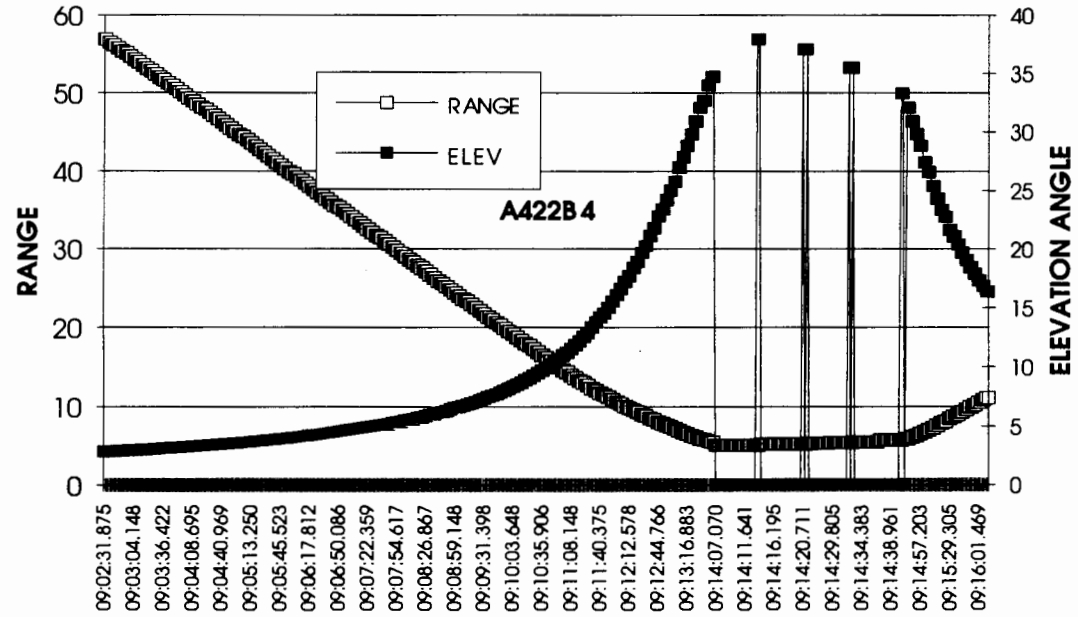

FIGURE 4. Mode S Sensor Data - A422B4

The Mode S data for AD0DD8 is shown on figure 6 below. The aircraft was above the zenith cone from 10:46:13 to 10:47:06. As indicated on figure 5, the plot of the DATAS data, this exactly matches the time when the All Call (DF11) replies were seen.

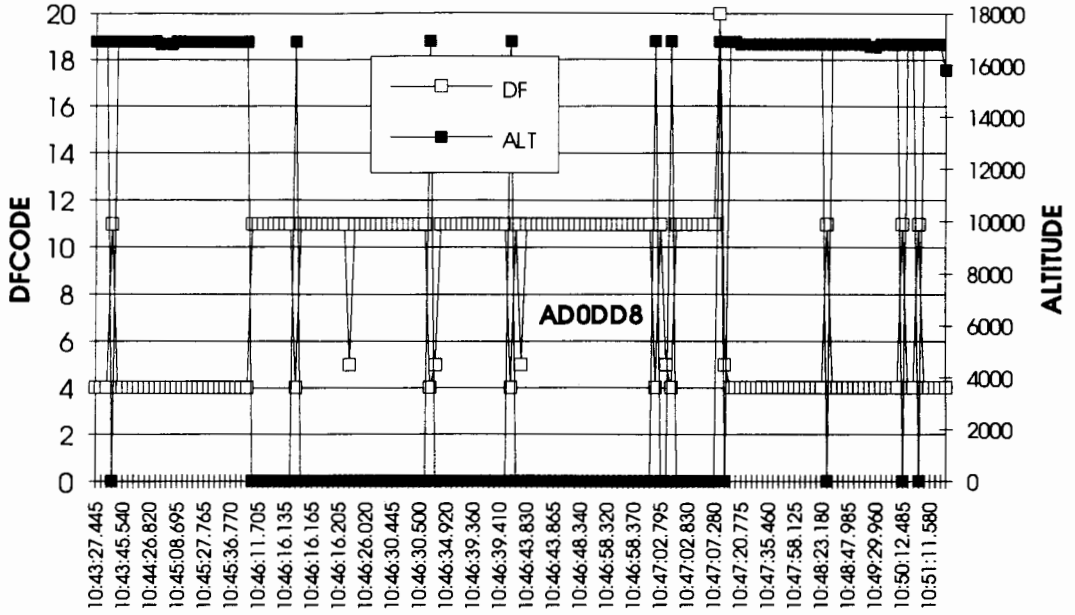

FIGURE 5. DATAS Data - AD0DD8

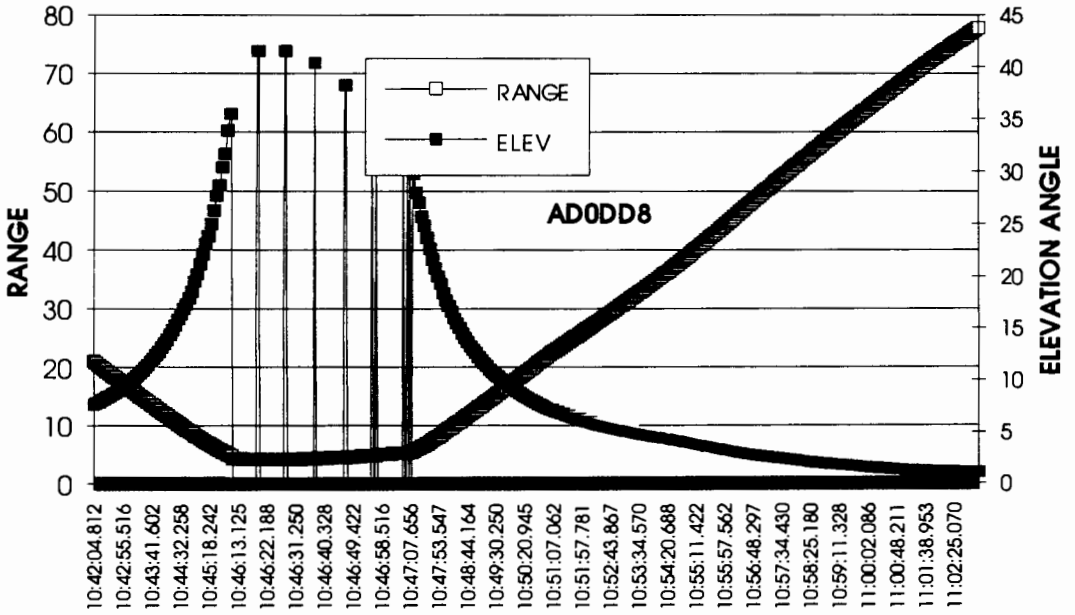

FIGURE 6. Mode S Sensor Data - AD0DD8

Unfortunately, there were no clear cut cases of aircraft which went above the "zenith cone" during the period of time when the modification was installed. A typical flight profile is given below in figures 7 and 8. There is little doubt, however, that the modification will alleviate the problem if it continues to track aircraft at a higher elevation angle (i.e., 88 degrees as in the modification).

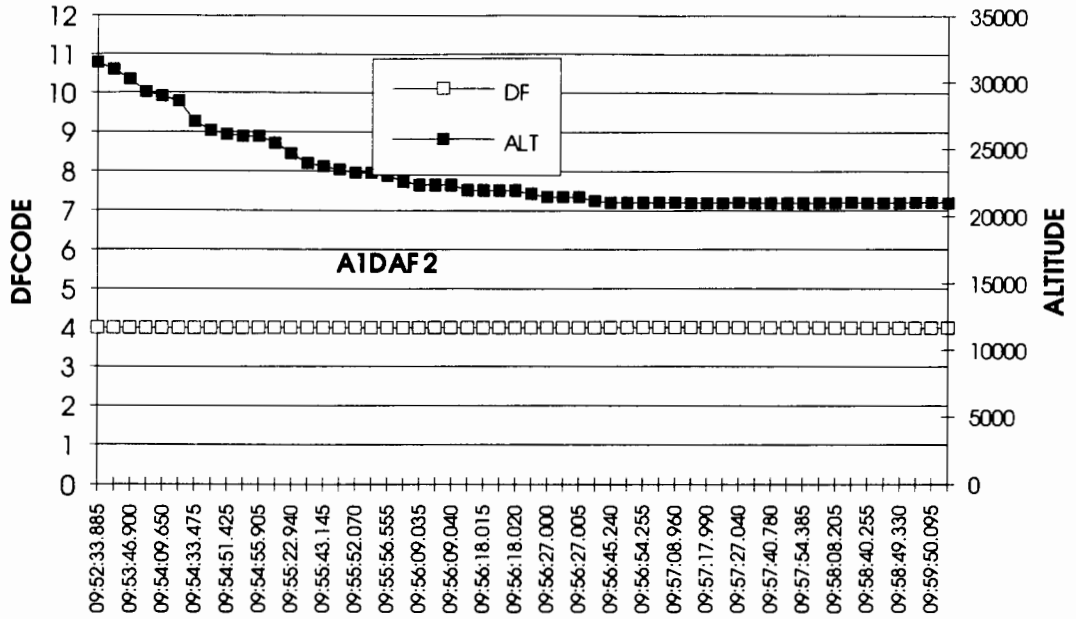

FIGURE 7. DATAS Data - A1DAF2

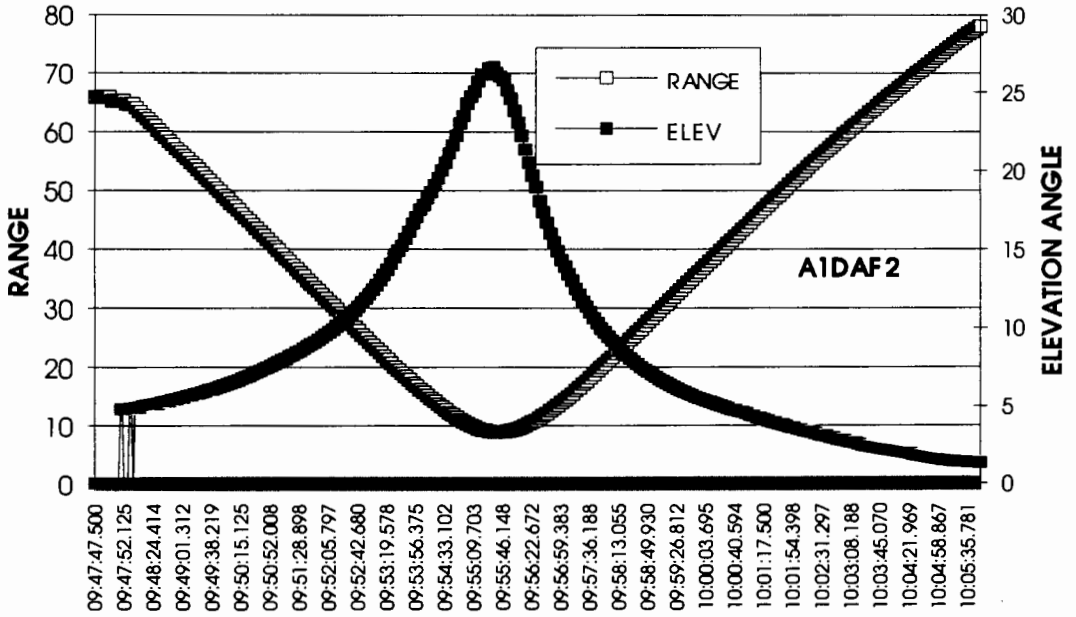

FIGURE 8. Mode S Sensor Data - A1DAF2