FAA TECHNICAL CENTER LETTER REPORT

INVESTIGATION OF MTD AZIMUTH BIAS OF TANGENTIAL TARGETS

by

ROBERT OLIVER

January, 1982

U. S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
TECHNICAL CENTER
Atlantic City Airport, N.J. 08405

PURPOSE.

During May of 1981 tests of the azimuth accuracy of the Moving Target Detector (MTD) were conducted at the Federal Aviation Administration (FAA) Technical Center. These tests consisted of flying an aircraft in an orbital pattern around the radar and comparing the position reported by three FAA sensors; the NIKE tracking radar, the Mode S test bed, and the MTD test bed. The results of these tests confirmed suspicions that under some conditions the MTD radar processor was introducing an azimuth bias in the direction of flight into the reported position of the target. The test indicated that an aircraft traveling in an orbital path at 160 knots and 10 nautical miles (nmi) from the radar was experiencing an azimuth bias of about 10 azimuth units (AU) or .22 degrees which caused the Mode S radar-beacon correlator to interpret the radar and beacon replies as two separate targets. This report shows that the bias can be accounted for by the operation of the clutter map and centroiding algorithms used in the MTD.

DISCUSSION

AZIMUTH BIAS ANALYSIS

Because the azimuth bias is dependent on the direction of aircraft travel, the mechanism which causes the problem must contain some scan to scan memory. The only scan to scan memory in the MTD is the clutter map, a very large array of range-azimuth cells, which covers the entire surveillance area, with a resolution of one range gate by one coherent pulse interval (CPI). The value of the clutter map is dependent only on the radar return in each given cell. The clutter map acts as a single pole low pass doppler filter by implementing the following algorithm for each cell of the map: add the magnitude of the output from the zero velocity doppler filter to 7/8 of the previous contents of the clutter map and store this value in the clutter map. The zero velocity threshold of a given range-azimuth cell is determined by multiplying the value of the clutter map in this cell by 5/8. This value is approximately equal to five times the average value of the zero velocity doppler filter or, in other words, about 14 dB above the average clutter level.

If a target has a near zero radial velocity component, it will cause the clutter map to build in the range-azimuth cell it occupies. If the target is moving slowly enough, the zero velocity doppler filter threshold will increase and after a few scans the target will not be detected in the zero velocity doppler filter. This is how the MTD reduces ground clutter detection. If a target is moving in an orbital path, it will have a zero radial velocity component and therefore will build the clutter map in those cells it occupies. These cells will then become desensitized because the threshold has been increased. If the target is moving slowly enough in azimuth, it may occupy cells that were desensitized by it's own return on the previous scan or even several scans before. This causes a loss of target detection in those cells which are near where it has already been, Hence the estimate of the target's position leads the target's true position in the direction of flight. To estimate the magnitude of this effect a clutter map and centroiding simulation program was written. This program simulated sixteen CPI cells at the same range. For each cell, the values for the input target signal strength were computed for values of angular velocity from zero to 2.6 degrees per scan. Those values that exceeded the detection threshold established by the clutter map were used to compute the centroid of the detected target. The input target was assumed to be at zero azimuth so the computed centroid value was equal to the bias. The results of this program agree favorably with those measured by the May 1981 flight tests. Figure 1 shows the azimuth bias expected for a target in an orbital flight path for a number of angular velocities. For very low values of angular velocity the target would not be able to be detected in practice because of thermal noise and so these values are not indicated on the graph. For the flight test conditions of 150 knots, and 10 nmi., the angular velocity is 1.28 degrees per scan. Figure 1 shows the simulated bias to be .4 degrees, somewhat larger than the bias measured during the test flight.

There are several reasons for this difference. Inaccuracies in the model of the MTD processing undoubtedly cause some of the difference but this error is expected to be small. The two principle differences seem to be contributions from the nonzero doppler filters in the centroiding process and effects caused by radial movement of the target.

The first effect reduces the azimuth bias because the nonzero doppler filters are not affected strongly by the clutter map threshold and therefore have no azimuth bias. When nonzero primitive targets are used in centroiding, the bias effect is essentially diluted.

The second effect results because the target is likely to wander from an ideal orbital path. If the target moves slightly, the trailing CPI's of the target will not fall in the same range cells where the clutter map has been greatly increased. This also tends to reduce the bias.

ANALYSIS OF RELATED PROBLEMS.

Two other problems similar to the azimuth bias problem were also determined to exist. The first problem arises when clutter exists in one or more of the cells occupied by the target. One of two things may happen; first, the clutter may be of a high enough level to cause a missed detection in one or more CPI's or the clutter may not inhibit detection but only change the detected amplitude. If the clutter inhibits detection, the error will be of about the same magnitude as the azimuth bias problem discussed above but it will appear to be a random fluxuation in the target azimuth. If the target is detected over ground clutter, the clutter will affect the magnitude computation of the target and thus affect the centroiding by giving this cell more weight in the azimuth computation. The effect of missing a detection is expected to be much more severe than that of estimating the wrong magnitude.

The second problem arises when a target is moving through an area of weather. The weather return will cause some CPI's information from the target to be missed and others to have the wrong magnitude computed. This is similar to the problem of flying over clutter but it is compounded because all of the doppler filters may be affected, not just the zero velocity doppler filter. Again this problem manifests itself as a random azimuth error.

PROPOSED SOLUTIONS

The problems described above are basic system problems and can apparently be solved only by major system changes. None of the solutions presented here will guarantee effectiveness and some could adversely affect performance in some other part of the system. These proposed solutions will be investigated at a later time in accordance with project schedules. The solutions are of three types, changes to the clutter map algorithm, changes to the centroiding algorithm, and the inclusion of new algorithms.

1. Changes to the clutter map algorithm consist mainly of modifications to increase the clutter map time constant or update rate. Both of the options reduce the targets angular velocity necessary to cause significant bias. The time constant is increased by increasing the feedback constant (it is now 7/8). The feedback constant can not simply be increased because it is limited by the quantization of the clutter map storage, hence, the preferable alternative is to increase the update rate. The major drawback of increasing the clutter map time constant is that fast moving weather may not allow the clutter map to build fast enough to reject the leading edge of the weather thus causing a large number of false alarms. If the amount of build up that is allowed per scan is limited, the clutter map would be fast acting for low values of amplitude but would be slow acting for high values of amplitude. This could solve the problem, but only for large amplitude targets. Perhaps the most effective solution would be to cause the clutter map update rate to depend on the weather thresholds generated in the other seven doppler filters. In the presence of fast moving weather, the weather thresholds would almost certainly increase in some of the nonzero doppler filters. This would cause the clutter map to update quickly when necessary but normally it would update more slowly.

2. Changing the centroiding algorithm at best attacks the problem after much of the damage is already done by the clutter map. Changing the centroiding algorithm to detect the peak of the target instead of the mean is one possibility. A problem exists with this technique in that the target would tend to be captured by the peak returns of ground clutter in the vicinity of the target. Another technique which could prove effective is to weight the nonzero filters greater than the zero filter in computing the centroid. A problem that could exist with this technique is that tangential targets are likely to have very little return in the nonzero filters. This could result in an even greater

inaccuracy than that caused by the clutter map problem. Changing the centroiding algorithm is not expected to solve the problem completely but it could be necessary if the clutter map modifications do not prove effective.

3. The last proposed alternative is to add additional algorithms to the system. One of these would implement a tracker which would be used only to correct the bias in tangential targets. Changes in the information sent from the MTD parallel microprogrammable processor (PMP) would be necessary if the algorithms are to arrive at a good estimate. This alternative is expensive in terms of both time and hardware and should be implemented only as a last resort.

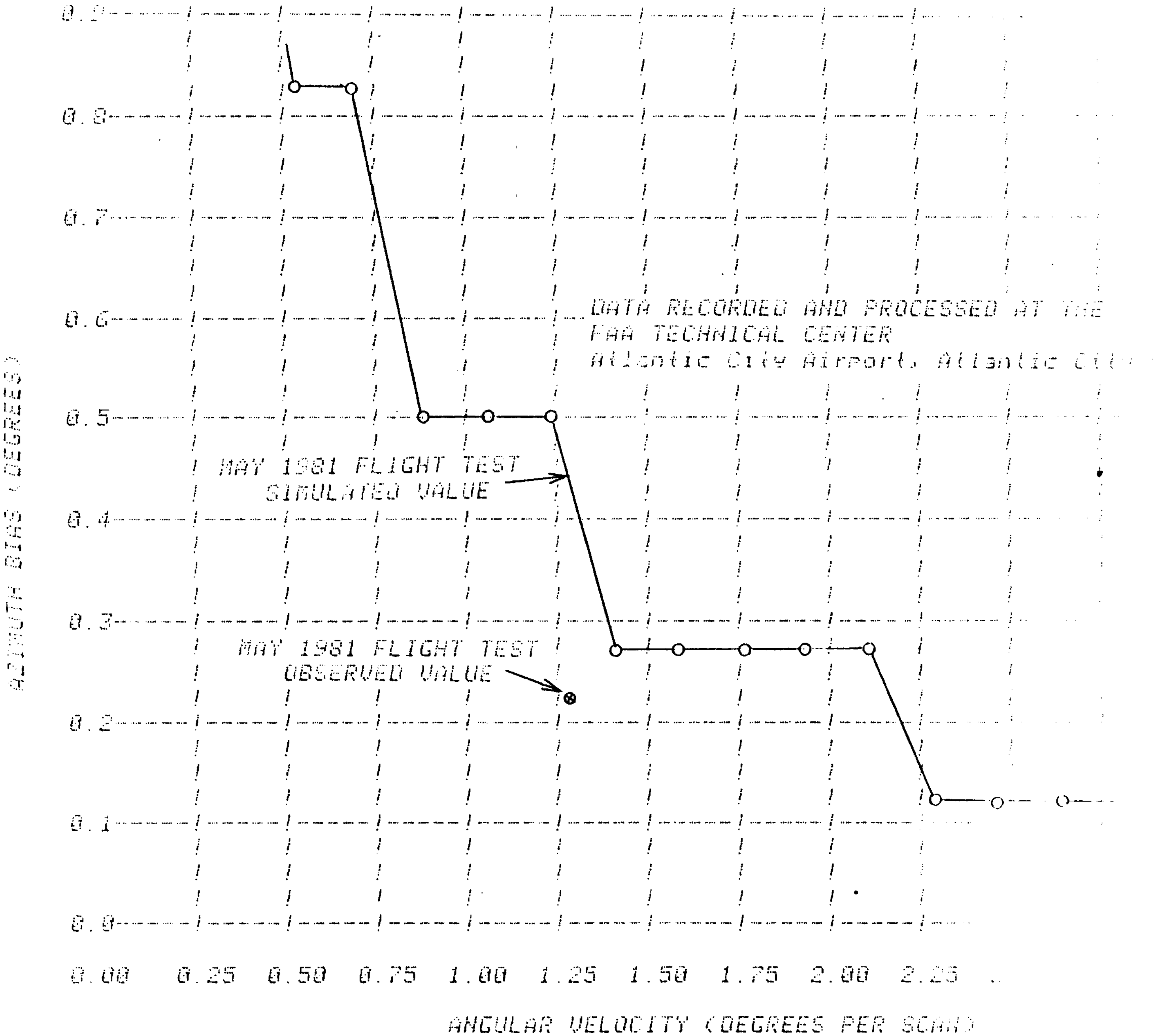

FIGURE 1. AZIMUTH BIAS VS. ANGULAR VELOCITY FOR MTD AZIMUTH BIAS ...