MOVING TARGET DETECTOR (MTD)

DIGITAL SIGNAL PROCESSOR

Y563 FINAL PROJECT

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1.0 INTRODUCTION

The utilization of primary radar data in the Federal Aviation Administration (FAA) automated air traffic control system, until the mid-1970's, had been impeded by the inability of existing signal processors to reliably detect aircraft in regions of strong ground and precipitation clutter, particularly when the aircraft was moving tangentially to the radar. For four years, under FAA sponsorship, M.I.T. Lincoln Laboratory developed new techniques which significantly enhanced automated aircraft detection in all forms of clutter. These techniques were embodied in a digital signal processor called the Moving Target Detector (MTD). This processor was integrated in the Automated Radar Terminal System, Model III (ARTS-III) system at the National Aviation Facilities Experimental Center, Atlantic City, New Jersey (NAFEC), now known as the Federal Aviation Administration Technical Center (FAATC), and underwent careful testing in the summer of 1975.

An ideal primary radar sensor for a terminal (60 mile) radar control system allows automatic radar-only acquisition and tracking of all aircraft in the system's field of view. Such a sensor should provide consistent, reliable detection of small low-flying aircraft and should do this in all expected clutter conditions. Departures from this idea occur when the radar sensor has inadequate subclutter visibility or produces excessive false tracks. Therefore, the tests of the MTD were designed to measure the radar signal processor's ability to resolve

aircraft from clutter backgrounds while providing adequate sensitivity in detected small low-flying aircraft at longer ranges.

This term paper will attempt to provide a background and description of the Moving Target Detector processor, then an explanation of the test results. Finally, this paper will give the status of radar systems currently using the MTD processor, and recent developments in the possible use of the MTD processor in other radar systems.

2.0 BACKGROUND

In order for any solution to the problem of providing high probability of detection with low false alarm rate in an automated aircraft surveillance system to be truly useful, several types of clutter have to be addressed. For example, both ground clutter and precipitation may be present. In addition, the false alarms which are sent to the tracker must be spatially and temporally uncorrelated, or even a relatively small number of false alarms will give rise to an excessive false track rate.

Hence, these several radar problems were the forces that drove the design of the MTD. These problems were classified according to the types of returns. They were: 1) fixed ground clutter, 2) second-time-around ground clutter, 3) precipitation clutter, 4) angels and 5) surface vehicles. The philosophy behind the design of the MTD was to incorporate features which attack all of these radar problems simultaneously.

1. Fixed Ground Clutter

By far, the largest undesired radar reflections come from fixed objects on the ground. Ground clutter usually extends out to about 20 nmi. In hilly or mountainous areas, it may extend out to the maximum radar range (~60 nmi). Prior to the MTD, ground clutter was reduced by three mechanisms: MTI filtering, antenna tilt, and by mounting the antenna close to the ground to take advantage of the shielding effect of nearby objects. MTI filtering is accomplished by using two cascaded delay line cancellers with and without limiting. The purpose of the limiting is to normalize the video output so that clutter residue from the MTI filter is reduced to the average noise level. Unfortunately, this limiting action spreads the clutter spectrum so that considerably poorer subclutter visibility (SCV) is achieved than if the normalization had been done by some other mechanism not involving nonlinearities.

It is also common practice to achieve greater signal-to-clutter advantage by tilting the antenna upward by 2 to 5 degrees depending on the local clutter situation. If tilted, there is a 17 dB advantage (maximum range divided by zero elevation range to the fourth power) in input signal to clutter for an aircraft flying in the peak of the antenna pattern, for a 1 m^2 target at 15 nmi. This advantage is degraded as the aircraft gets out of the peak patterns so that detection gets spotty due to competition with ground clutter for small aircraft below about 1.5 degrees or above 9 degrees. The angles change depending on the antenna and ground intensity.

Another undesirable feature is the very wide notch around the blind speeds. The effects of higher order speeds are usually reduced by using a staggered pulse repetition frequency (PRF). However, the notch around zero means that targets will be lost for a considerable distance on the scope when the aircraft flies tangentially to the radar. The 3-pulse canceller with limiting is worse in this respect than the 2-pulse canceller with limiting.

A further limitation in performance is the presence of buildings or hills which limit the minimum elevation visible to the radar. Increasing the height of the antenna to overcome this limitation causes an undesirable increase in ground clutter level which could be overcome by improvement in SCV.

To give complete flexibility in siting, and tilting the antenna while still rejecting ground clutter, an approximate 20 dB improvement in performance over that of existing airport surveillance radars (ASRs) was needed. This required linear processing of clutter and target signals.

In order to assess quantitatively what could be considered a "good" MTI processor for improving the performance of ASR radars against fixed ground clutter, calculations were made of the performance of the so called "optimum processor". Given the initial conditions, the optimum processor has, by definition, the highest improvement in the target-to-interference ratio of any processor. By knowing the performance of such a processor, one can judge how closely any other processor approaches the theoretical limit.

Therefore, to deal with fixed ground clutter, the processor would have two parts: a clutter filter followed by a target filter. The filter used to reduce clutter multiplies the signal vector by the antenna weighting and by the inverse of the interference covariance matrix. The target filter used to enhance the target is a discrete Fourier transform (DFT). The near-optimum processor could consist of a digital filter which approximates as closely as possible the frequency response of the clutter filter followed by a DFT for the target filter. This combination gives an improvement factor within a few decibels of the optimum processor and is much less complex than implementation of the optimum processor.

2. Second-Time-Around Clutter

Second-time-around clutter is caused by radar returns from ground clutter which are illuminated by the next-to-last radar pulse which was transmitted. This radar clutter is beyond the unambiguous range of the radar. Present ASR systems use pulse trains with staggered interpulse periods so as to avoid blind speeds. This causes the second-time-around clutter return to fall in different range cells on succeeding returns so that there is no hope of filtering it out. To effectively filter out second-time-around clutter, a fully coherent (pulse-to-pulse) transmitter and a constant PRF must be used. The PRF need not be constant forever, but only over an interval sufficient to collect a group of pulses for processing.

3. Precipitation Clutter

Backscatter from precipitation has been studied extensively. Heavy rainfall is considered to have, for example, mean volume reflectivity at 15 mm/hr of 10^{-12} m^{-1} at a frequency of 200 MHz. The reflectivity/frequency log-log slope is 2/log(3) m^{-1}/MHz. The radar should be designed to reject at least this level and as much higher a level as possible. The rain clutter spectrum is spread around some mean value determined by the wind velocity. The spectral spread observed by the radar is fixed by wind shear conditions. The standard deviation of the rain velocity spectrum typically reaches values of 25 knots at 30 nmi and increases with range. This spread is due chiefly to wind shear. The center velocity of the storm may be anywhere from -60 to +60 knots depending on wind conditions relative to the pointing direction of the antenna. Because the mean velocity of the storm is not centered at zero radial velocity for most antenna azimuths, the storm return will leak through the MTI filter for many azimuth angles of the antenna.

Circular polarization is normally used to reduce rain clutter by about 15 dB, while reducing the aircraft signal level to a much lesser extent. The use of MTI helps to reduce rain clutter except when the antenna is looking toward or away from the wind direction. In these directions, the rain clutter spectrum is such that all of the rain clutter signals may pass through the MTI filters.

Previous attempts to build a digitizer which works well in rain have failed due to a lack of recognition of the correlation properties of the clutter. Rain clutter signals are partially correlated from pulse to pulse so that noncoherent integration in the azimuth direction produces random signals whose variance is much greater than if the rain signals were noise-like uncorrelated. This greater variance requires a large increase in the detection threshold over that set for noise and a consequent loss in detectability of aircraft targets. If the threshold is not reset, a high false alarm rate in rain results.

Since the detected rain clutter residue is partially correlated from azimuth to azimuth, the statistical spread of the noncoherently added returns is much greater than from receiver noise which is uncorrelated. The correlation of the clutter can be measured adaptively and the threshold raised accordingly, but most of the signal-to-noise improvement due to incoherent integration is forfeited. Therefore, noncoherent integration in the presence of correlated clutter such as rain can only be done if the time between samples being noncoherently integrated is much greater than the correlation time of the correlated clutter.

A good approach is to use the filter bank produced by the near-optimum ground clutter filter. It is only necessary to set the threshold on each filter adaptively. A so-called "mean-level" thresholding algorithm is employed. Since storms are rarely less than about a mile in extent, the moving clutter is averaged over a half mile on either side of the cell being examined for a target.

Further, a multiple PRF system, rather than a staggered PRF system is used so that high speed aircraft typically fall in different filters in the filter bank on successive PRFs. Only for aircraft whose true radial velocity coincides with that of the rain will there be serious degradation in detection performance.

Precipitation clutter often appears in the zero radial velocity doppler filter. Sometimes, relatively large zero velocity returns are received from a weather front which is moving quite rapidly through the radar's coverage. When this happens, changes in the zero velocity signal, for particular range azimuth cells, can occur faster than the ground clutter map can react. In this situation, large numbers of zero velocity threshold crossings can occur in areas which are spatially correlated from scan to scan. This would then give rise to false tracks if nothing were done about it. This problem can be solved by adding instructions in the post-MTD software which prevents the tracker from initiating tracks on target reports whose radial velocity is zero.

4. Angel Clutter

Angel clutter refers to all returns that cannot be explained as being ground or precipitation clutter or targets. It is believed that nearly all, if not all, angels are caused by bird flocks. Returns from single birds at S-band range in size from 10^{-4} to 10^{-2} m^2. The radar return is principally from the body with very little from the wings. Typically, there may be anywhere from one to several hundred birds in a resolution cell. Birds have been seen as high as 12,000 feet altitude, but usually fly less than 7,000 feet. Birds fly between 15 and 45 knots true air speed. Taking into account winds, radial velocities over the range +/- 80 knots or so may be observed.

A fairly effective radar improvement used against bird clutter is a carefully tailored sensitivity time control (STC). The STC varies the radar gain with range and is adjusted so that the minimum detectable target is a specific value, for example $1m^2$. This calls for an R^{-4} law. Even with an R^4 STC applied, during the migratory season, flocks of birds have caused many short false tracks in ASRs.

The R^4 STC is most effective when the antenna provides uniform gain over the elevation coverage. However, ASR radar antennas generally have cosecant-squared elevation patterns. Under this condition, STC applied to reduce bird return has the undesired effect of reducing the short range coverage against high altitude airplanes. The MTD processor provides target amplitudes as well as range, azimuth, and doppler of the target. The target amplitude output can be used to set a secondary (post-MTD) threshold for each doppler channel. Schemes using such thresholds were developed at the FAA Technical Center.

These have proven to be quite effective at filtering out bird returns while operating with no observable degradation in detection sensitivity of high altitude aircraft.

5. Surface Vehicles

The cross-section of ground vehicles is in the same range as aircraft, that is, from 1 to 100 m^2. Radial velocities can range over +/- 60 knots. However, some reduction in ground vehicle returns is achieved by tilting the radar upwards. One solution is to censor areas on the scope known to contain visible roads carrying cars with radial velocities outside the notch at zero velocity. For example, the ARTS-III system starts these detections in track, and by measuring the velocity of the target, while in tentative track, applies a speed threshold of about 50 knots before declaring it a firm track. This technique has proven to be reasonably effective and results in, at worst, a few false tracks from surface vehicles.

In summary, a radar which is used for air traffic control and uses a scanning beam antenna should have: 1) a fully coherent transmitter, 2) a linear, large dynamic range receiver, 3) a signal processor containing a near-optimum ground clutter filter bank, 4) a fine-grained ground clutter map to set ground clutter thresholds, and 5) mean-level thresholding on weather. It would employ multiple PRFs for elimination of blind speeds and would output target range, azimuth, doppler velocity, and amplitude for use in higher level thresholding and other software for filtering clutter and interference. These are the signal processing adaptive thresholding techniques which are employed in the MTD processor.

3.0 DESCRIPTION OF MTD PROCESSOR

The MTD processor is implemented as a hard-wired, pipeline digital signal processor. It processes the full 360 degrees coverage of an ASR radar out to a nominal range of about 60 nmi. The azimuth coverage of the radar is broken into 480 Coherent Processing Intervals (CPIs), each about one-half of an antenna beamwidth (3/4 degree) in extent. The range cell size is 1/16 nmi. During one CPI, ten pulses are transmitted at a constant PRF. These are processed by the MTD into eight doppler cells. Thus, there about 2,900,000 range-azimuth-doppler cells in the MTD's coverage (Figure 1).

A block diagram of the processor is shown in Figure 2. The I and Q (In-phase and Quadrature) signals are sampled at 2.6 MHz rate by 10-bit A/D converters. The I and Q channels are then added coherently, two at a time, to produce 11-bit I and Q channel words at a 1.3 MHz rate. Samples of both the I and Q channels for each of 760 range gates (60 miles of range) from each of 10 consecutive radar pulses are stored in 8192-word memory. These 7600 words of memory are then processed sequentially (ten samples for each range cell) by a 3-pulse MTI canceller. The I and Q channels are each processed by separate hardware in the 3-pulse canceller section of the processor. Note that the ten samples of 11-bit I and Q channel samples are transformed by the 3-pulse canceller to eight 13-bit words. The output of the 3-pulse canceller for both the I and Q channels (real and imaginary parts of the signal) is fed into an 8-point Discrete Fourier Transform (DFT).

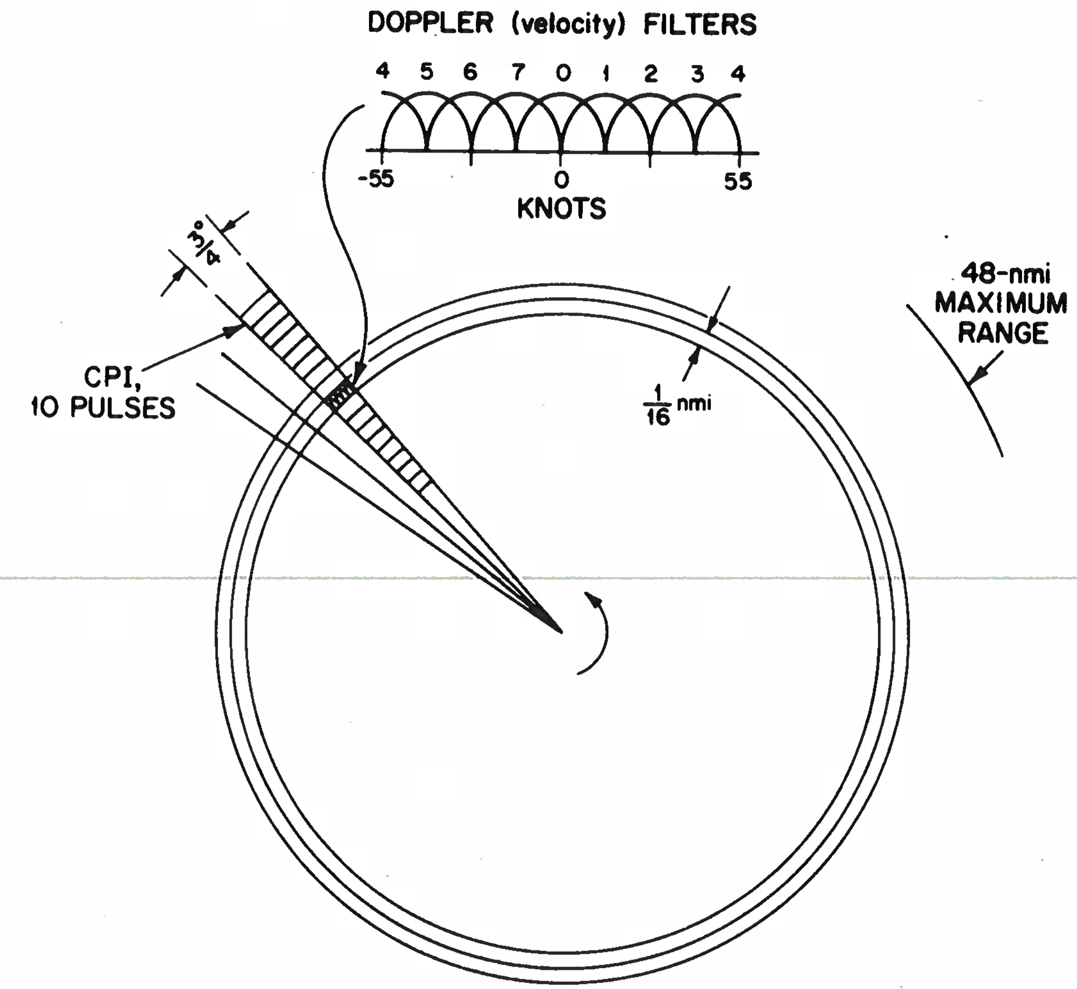

FIGURE 1

MTD Resolution

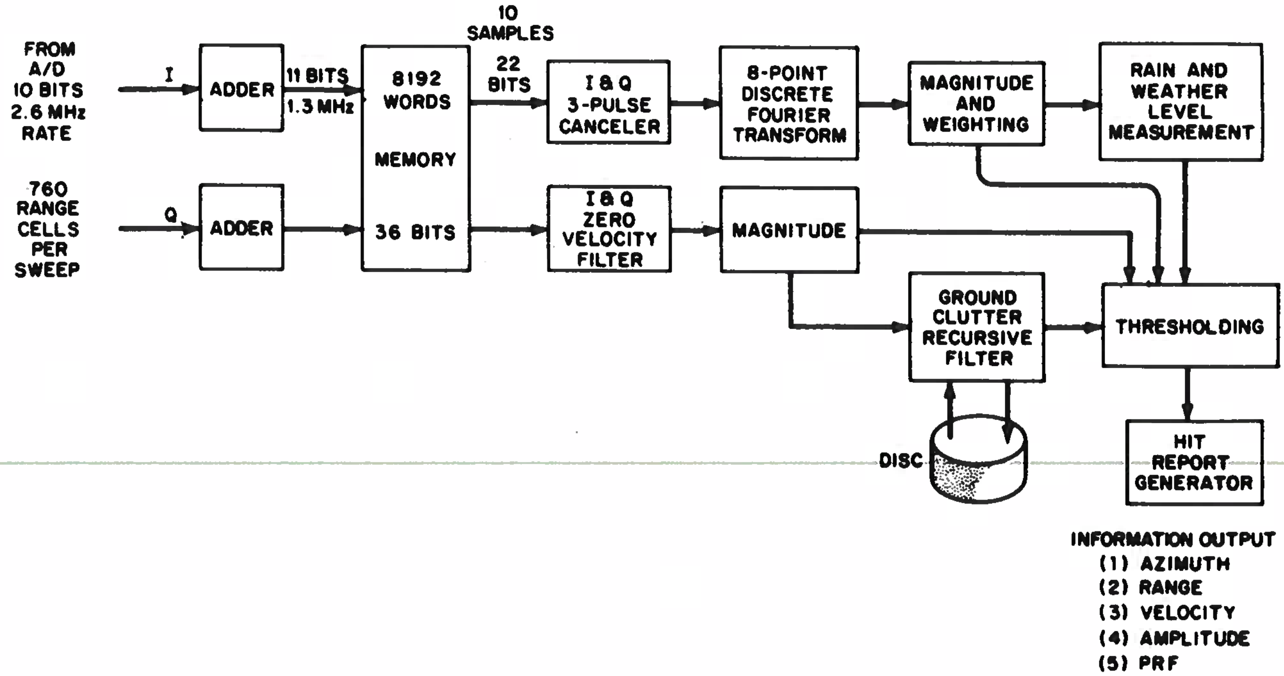

FIGURE 2

MTD Processor Block Diagram

The DFT produces a complex frequency coefficient for each of eight doppler cells.

The 8-point Fast Fourier Transform algorithm requires four real multiplications of $1/\sqrt{2}$. They are performed in a fixed-wired multiplier which approximates $1/\sqrt{2}$ as $1/2 + 1/8 + 1/16 + 1/64 + 1/256$ and requires only four adders. The remainder of the MTD is configured so that all multiplications are by integral powers of 2 and can be computed by simply shifting the binary data.

Weighting of the I and Q channel signals to reduce the side lobe level is done after the DFT. Subtracting 1/4 of the output of the two doppler filters adjacent to the one of interest is equivalent to a cosine on a pedestal weighting in the time domain.

Since the 3-pulse canceller has poor low doppler frequency response, a zero velocity filter (ZVF) is employed to see low radial velocity targets. This low-pass filter is implemented by coherently adding the first five samples of each of the I and Q channels, respectively, taking their magnitude, and adding to this the magnitude of the sum of the last five samples. This gives a broader frequency response than simply adding coherently all ten samples and then taking the magnitude. The magnitudes of the signals which come out of the 3-pulse canceller-DFT-weighting chain are then taken.

After magnitudes are taken, adaptive thresholds are set and threshold crossings (detections) are noted and output. The adaptive thresholds are set depending on the clutter phenomena which are present. The doppler domain is divided into three domains: doppler cell 0, doppler cells 2 through 6, and doppler cells 1 and 7.

In doppler cell 0, the clutter is generally due to ground backscatter. The average ground backscatter cross section varies from range-azimuth cell to range-azimuth cell. The average backscatter signal level for each cell is measured and stored on a disc memory (see Figure 2). To build up an accurate map, careful registration of the clutter map with the true pointing direction of the antenna is essential. This is achieved by breaking up each revolution of the antenna, marked by 4096 Azimuth Change Pulses (ACPs), into 240 units containing 17 or 18 ACPs each. Each unit contains two CPIs. The disc is accessed every two units (34 to 36 ACPs, approximately 44 msecs), during which time four CPI's worth of ground clutter data is read onto and off of the disc. The disc has a maximum access time of 18 msecs. Two 3000-word MOS buffers are used to store the data for use in the processor. A recursive filter is used to update on a scan-to-scan basis the average signal level stored on the disc. This disc holds 480 x 768 = 368,640 clutter words, one for each range-azimuth (CPI) cell in the coverage. The words are stored in 10-bit floating point format to preserve the large dynamic range of the clutter signal.

On each scan, 1/8 of the stored clutter level is subtracted from the stored level. One-eighth of the signal level output from the ZVF is added to the value remaining after subtraction. This new level is then stored on the disc for thresholding in the next scan. The threshold for the zero doppler cell is a fixed value between 4 and 7 1/2 times the level stored on the disc. This fixed value may be altered by changing a plug.

In the doppler cells 2 through 6, the clutter is due chiefly to rain. For each doppler and range cell, the average signal level is measured by averaging the received signal over 14 range cells centered on the range cell of interest. This average is multiplied by a constant 'a' to form the threshold for that range-azimuth-doppler cell for that scan. Since only coherent integration has been performed, the 14 outputs are statistically independent Rayleigh distributed numbers regardless of whether from noise or rain clutter so that the false alarm rate associated with multiplying constant 'a' does not change as weather comes into the area. Figure 3 shows the false alarm rate as a function of threshold setting when averaging over various numbers of statistically independent samples. Note that for 14 samples and a probability of false alarm of 10^{-6}, the threshold is only about 2 dB above that derived assuming perfect knowledge ($N = \infty$) of the rain or noise conditions. The use of this type of mean-level threshold assumes that the rain level is constant over 14 cells (~1 nmi) of interest. The experience with rain to date indicates an

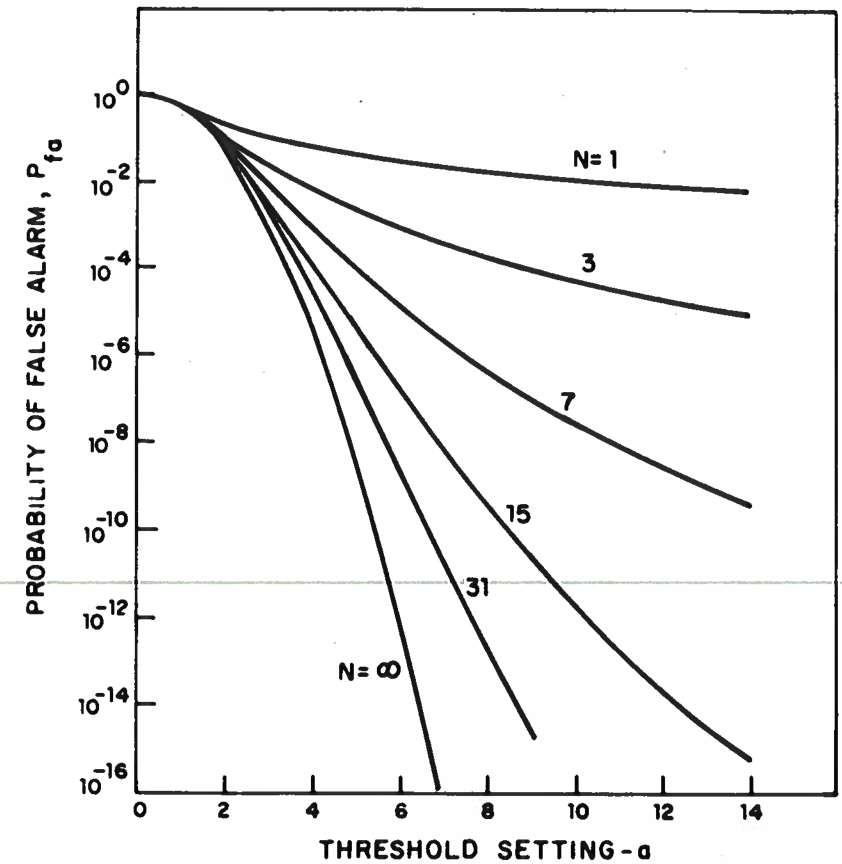

FIGURE 3

False Alarm Rate as a Function of Threshold Setting

inconsequential increase in the false alarm rate when rain enters the region of interest.

In the actual implementation of the MTD, the PRF is changed by about 20 percent between groups of 10 pulses so that a higher velocity target will be aliased into a different filter on each PRF (Figure 4). Therefore, it is highly probable that all targets will be free of weather clutter on at least one of the two PRFs, except for those whose true radial velocity is within about 25 knots to that of the rain.

Doppler cells 1 and 7 can contain clutter due to rain or spillover from the ground backscatter in cell 0. The threshold set in these cells is the greater of two thresholds: a) the threshold set as in doppler cells 2 through 6, or b) a fixed binary fraction - $(1/2)^n$, n = integer - of the threshold set in cell 0, n is set by changing a plug.

Finally, note that if any I or Q channel sample is noted to have all of the bits on (i.e., be in saturation), any target detections for that range cell are deleted.

An interference eliminator circuit has been hard-wired in the MTD to eliminate non-synchronous pulsed interference. The magnitude of each of the 10 pulses in each CPI is taken by adding the absolute values of I and Q. This algorithm, though primitive, is accurate to within 3 dB.

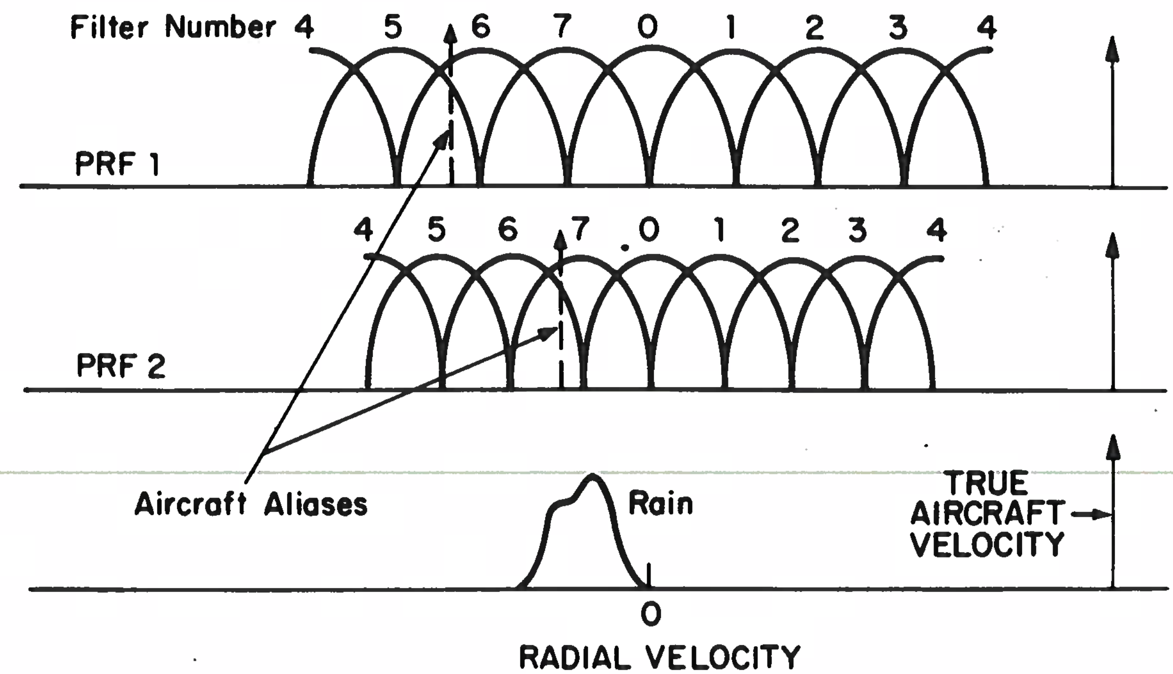

FIGURE 4

Detection In Rain Using Two PRFs

The average is multiplied by five and stored. The 10 magnitudes are also stored until the average has been computed. They are then compared sequentially with five times the average. If any one exceeds this number, then any threshold crossings that might have occurred in that range gate during that CPI interval are inhibited.

The output message of circuitry of the MTD contains double buffering for up to 38 detections per CPI. Double buffering is required because the MTD and the Input/Output Processor (IOP) are asynchronous devices. At the start of each CPI, a PRF/azimuth (PAZ) word is entered into the first buffer. When a threshold crossing takes place, a velocity/range/strength (VRS) word for that detection is entered in the first buffer. At the end of each CPI, the PAZ word and any VRS words for that CPI are transferred from the first to the second buffer. During the next CPI, the contents of the second buffer are transferred to the IOP. A NOVA minicomputer is also connected to this output and receives the data in parallel with the IOP.

A single aircraft target will typically result in threshold crossings in many range, azimuth, and doppler cells. These multiple threshold crossings must be associated as belonging to the same target. This process is known as report correlation. Also, a more accurate measurement of the target range, azimuth, and doppler may be obtained by averaging amplitudes over the multiple threshold crossings. This is called report interpolation. These two functions are performed by the

ARTS-III software at the FAATC. In addition, the target doppler returns received at the two different PRFs are used to calculate the aircraft's unambiguous radial velocity. If the threshold crossings are from only one PRF, than an ambiguous velocity flag is set.

Range and azimuth adjacency are the sole criteria used to correlate target reports. Doppler adjacency was not used as a criterion because it was found that amplitude modulation of the target cross section can give rise to split target reports.

For each range-azimuth cell (CPI), doppler report consolidation is performed. The doppler filter number with the largest strength response is noted. Since different doppler filters have different gains, the amplitude of each threshold crossing is divided by a specific normalization factor. After range and azimuth adjacency are used to consolidate in range and azimuth, target interpolation is performed. The range of the target is reported as the range cell of the largest response. The azimuth of the target report is calculated by taking the first moment of target intensity averaged over azimuth. The doppler interpolation is performed by taking the ratio of the strengths of the doppler filter with the largest strength, and the adjacent doppler filter with the second largest strength. This ratio forms an estimate of the target's radial velocity. It is made with a precision of 1/64 of the PRF. This interpolation is done using a look-up table. If there are no threshold crossings from a doppler filter adjacent to the doppler filter with the largest strength, then doppler interpolation is bypassed and the doppler is assumed to be the center frequency of the filter with the largest strength. Doppler interpolation is done separately for each PRF. The interpolation doppler numbers at each of the PRFs are then used to calculate the unambiguous radial velocity of the target.

The MTD hardware, itself, comprises of standard TTL circuits except for the MOS buffer to the disc memory. The construction utilizes wire-wrap boards to hold the integrated circuits. Besides the input core memory and the clutter map disc memory, the MTD consists of approximately 1000 integrated circuits. The MTD includes all of the digital timing for the radar and generates a 31 MHz, 1.0 microsecond pulse which is up-converted in the transmitter to S-band to become the transmitted pulse.

4.0 TEST RESULTS

Upon completion of the design of the MTD radar processor system, an evaluation was made to determine its capability to provide radar data which was suitable for utilization by the ARTS-III system. The major objective of testing was to compare the target detection in clutter performance of the MTD system with that of the best terminal radar processor system, which at the time was the Radar Video Digitizer, Model 4 (RVD-4). The comparative tests were conducted using test signals and flight test aircraft. The test signals were used to determine: 1) false alarm rates, 2) probability of detection, 3) accuracy, 4) velocity response, and 5) subclutter visibility capabilities. Flight testing was performed to determine: 1) system sensitivity, 2) tangential target detection in clutter, 3) subclutter visibility, 4) subweather visibility, and 5) target resolution capabilities.

The two radar systems for data acquisition that were compared were the ASR-7/RVD-4 and the FPS-18/MTD systems. The MTD/RVD-4 experimental test set is shown in Figure 5. The FPS-18 is an S-band coherent radar. The two radar systems were located at the FAA Technical Center and were operated independently by means of a waveguide diplexer. The normal, log normal, and moving target indicator (MTI) video outputs of the ASR-7 were available to the RVD-4, while low-level IF information from the FPS-18 was sent to the MTD receiver/ processor. A functional schematic diagram of the MTD system is shown in Figure 6.

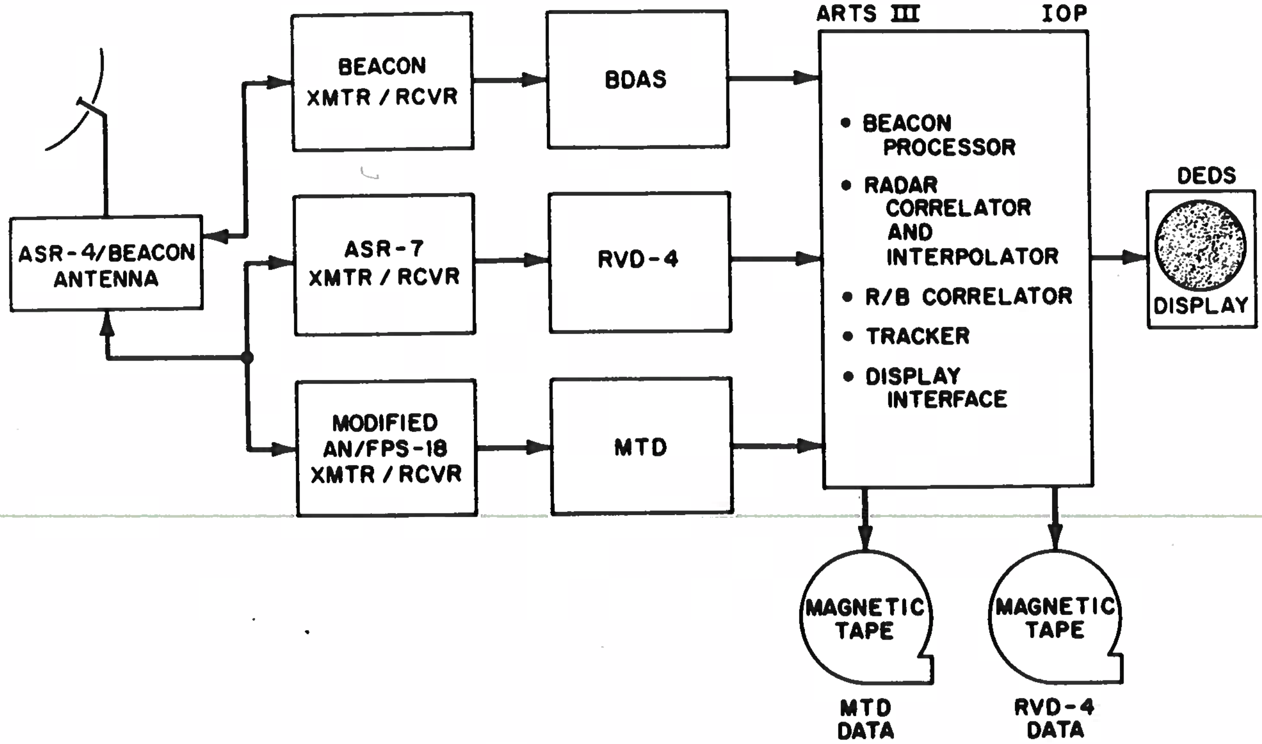

FIGURE 5

MTD/RVD-4 Experimental Test Set-Up

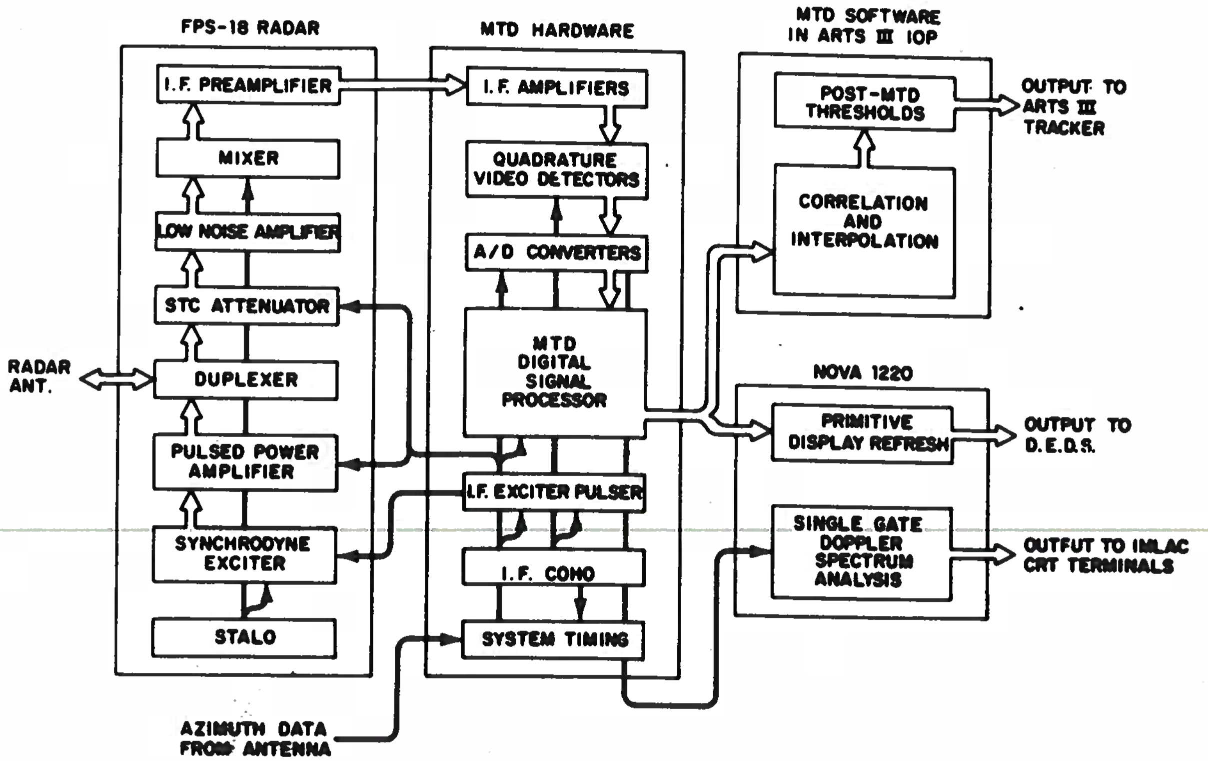

FIGURE 6

MTD System Functional Schematic

The general test results (See References 3 and 4) indicated that while both radar systems exhibited adequate detection and false-alarm performance in the clear, the detection and false alarm performance of the MTD was far superior to that of the RVD-4 in rain and ground clutter. The MTD processed radar reports were significantly more accurate than RVD-4 radar reports, and the MTD did not suffer from track dropout while tracking tangentially flying aircraft, as did the RVD-4. The MTD provided a 20 dB improvement in subclutter visibility over the ASR-7/RVD-4 system. The MTD zero velocity filter provided superclutter visibility and interclutter visibility for low-velocity targets. The MTD system, also, provided superclutter visibility for tangential targets during controlled aircraft flight tests. In tangential segments (within 30 knots radial velocity of the tangential point), the MTD and ASR-7/RVD-4 systems provided P_d's of 96 and 33 percent, respectively. Controlled aircraft subclutter visibility flight tests produced P_d's of 95 and 38 percent, respectively. Controlled aircraft subweather visibility flight tests produced the following P_d's:

ASR-7/RVD-4	Radar Reports	41 percent
FPS-18/MTD	Radar Reports	96 percent
ASR-7/RVD-4	Tracking Outputs	35 percent
FPS-18/MTD	Tracking Outputs	96 percent

Finally, the average minimum target resolution distances for two flight test aircraft for the ASR-7/RVD-4 and FPS-18/MTD systems were 0.44 and 0.25 nmi, respectively.

5.0 CONCLUSION

The conclusion that was arrived at based on the test results was that the FPS-18/MTD system is superior to the ASR-7/RVD-4 system. The MTD processor also provides data suitable (low false alarm rate and high probability of detection, P_d) for automated systems. Finally, the combination of MTD and ARTS-III processing effectively eliminates clutter (weather, ground, and angel) and nonsynchronous interference experienced in the FAA Technical Center environment.

Currently, most terminal airports are equipped with either an ASR-4, ASR-7, ASR-8, or ASR-9 radar system. Except for the ASR-4 system, which uses tubes, the others use solid-state devices. The ASR-4 and ASR-7 radars use a magnetron transmitter oscillator, while the ASR-8 and ASR-9 radars use a klystron transmitter oscillator. The klystron oscillator maintains coherency pulse to pulse and tends to be more stable, features which are very beneficial for MTD processing. Except for the ASR-9 radar, which uses MTD processing, the other radars use MTI filtering.

The ASR-9 radar is built by Westinghouse Electric Corporation (my former employer) in Baltimore, Maryland, and thus far, about twenty of the contractual one hundred ASR-9/MTD systems have been installed and FAA commissioned, and are fully operational. The first few sites to be commissioned were: Huntsville, AL, Stuart Field (West Point), NY, FAA Aeronautical Center (Oklahoma City), OK, Orlando (because of the weather environment), FL, and Brownsville, TX. Also, high volume traffic commercial airports such as Chicago's O'Hara International Airport and Los Angeles' International Airport have received ASR-9/MTD systems. The remaining ASR-9/MTD systems to be installed in the future will replace some ASR-7/MTI and ASR-8/MTI radar systems. In turn, these ASR-7 and ASR-8 radar systems will replace (called leapfrogging) the few remaining ASR-4/MTI (low volume traffic) radar systems.

Finally, this past February, I attended a meeting at the FAA Technical Center (where I am currently employed) to discuss the upgrading of the ASR-7 and ASR-8 radar systems to become "ASR-9 like" systems. Ideally, the ASR-7 and ASR-8 systems would be retrofitted with MTD, levels of weather, and wind shear capability. In attendance from Lincoln Labs, M.I.T., Massachusetts, was Dr. Melvin Stone, a prominent radar expert. Some of the dialogue included that since the ASR-8 already has a klystron oscillator, then retrofitting should not be a major problem. However, since the ASR-7 has a magnetron oscillator, retrofitting may present a problem. Other very important issues were discussed. Overall, I found the meeting extremely informative and very interesting.

REFERENCES

1. Description and Performance Evaluation of the Moving Target Detector, by L. Cartledge and R. M. O'Donnell, Project Report ATC-69, Lincoln Laboratory, M.I.T., March 8, 1977.

2. Comparison of the Performance of the Moving Target Detector and the Radar Video Digitizer, by R. M. O'Donnell and L. Cartledge, Project Report ATC-70, Lincoln Laboratory, M.I.T., April 26, 1977.

3. Test and Evaluation of the Moving Target Detector (MTD) Radar, by R. S. Bassford, W. G. Goodchild, and A. De La Marche, Federal Aviation Administration, Report No. FAA-RD-77/118, October, 1977.

4. Preliminary Evaluation of the Use of MTD Range Rate Data In NAS Tracking, by R. Lefferts, National Aviation Facilities Experimental Center, Report No. NA-79-17-LR, April, 1979.