MICROWAVE LANDING SYSTEM

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ABSTRACT

The National Microwave Landing System (MLS) program is a joint DOT/DOD/NASA effort to implement a common civil/military precision landing system to replace the current Instrument Landing System (ILS).

The MLS will be capable of providing precision landing guidance down to Category III minimum while allowing for complex approach paths in both the horizontal and vertical planes. The system is based on the Time Reference Scanning Beam (TRSB) technique which was selected by the International Civil Aviation Organization (ICAO) in April 1978 as the new international landing system standard. MLS is less susceptible to interference from the surrounding area and provides a greater signal coverage area than ILS.

INTRODUCTION

ILS has been in use since the 1940's, but has limitations that make it unusable in some airport environments. The localizer beam is a wide beam (6–10 degrees) that is subject to interference from nearby structures. The glideslope beam requires reflection from the airport surface to form the guidance signal. This requires that at least a 1500 ft. area in front of the antenna is flat and free from obstacles. Due to these problems, ILS cannot be installed in sites with irregular terrain, greatly limiting the usefulness of some airports. (1:312) ILS is also limited to site location due to the size of the antennas. Another problem that ILS is experiencing is the availability of frequencies. ILS has 40 channels allotted, but this is not enough channels for highly populated areas with many airports. The last problem is the ability of ILS to handle the large air traffic loads of the future.

These concerns prompted the Radio Technical Commission for Aeronautics (RTCA) to meet in 1967 and form a Special Committee, SC-117, to develop an operational requirement for a new landing system. The results of the RTCA SC-117 led to the preparation of a five year development plan and a proposal of two formats for the new MLS standard; the "scanning beam" MLS and the "doppler" MLS. The FAA was the lead Government Agency and with the support of DOD and NASA, led to a feasibility study of the two systems. In December 1974, the results of this study led to the Time Referenced Scanning Beam (TRSB) being chosen as the United States recommendation to the International Civil Aviation Organization (ICAO). (1:318)

ICAO had decided at the Seventh Air Navigation Conference in 1972 to proceed with MLS. After evaluating five proposals from various countries, ICAO selected the TRSB in April 1978 as the new international standard for landing systems. (1:318) ICAO has prepared a specification called Standards and Recommended Practices (SARPS) which will assure a standard guidance signal among the 172 member nations. According to the MLS SARPS, ICAO Annex 10, Vol. 1, ILS has a projection date of 1995, at which time MLS will become the only ICAO recognized landing system.

ICAO compatible MLS calls for a single accuracy standard to be implemented worldwide. This standard guarantees, in most cases, that the quality of the MLS signal will be the quality necessary for CAT III ILS and autoland capability. This insures the pilot that he can expect the same guidance performance at each runway.

MLS CONFIGURATION

The Basic MLS configuration consists of an approach azimuth signal, approach elevation signal, a set of basic data words, and a Precision DME (DME/P) signal capable of being transmitted over a 200 channel range. This basic configuration can be expanded to include a back azimuth signal and a set of auxiliary data words.

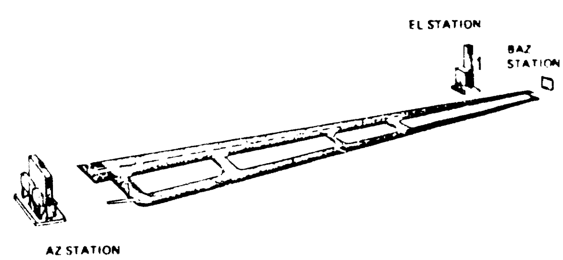

Figure 1. MLS Site Configuration

The MLS site configuration is as shown in Figure 1. The approach azimuth (AZ) antenna is located at the stop end of the runway, as is the ILS localizer, and scans a beam up to ± 60 degrees in azimuth to either side of the runway centerline (Figure 2). Most sites in the U.S. will scan ± 40 degrees. The elevation (EL) antenna is located approximately 1,000 ft. from the runway threshold at the Glide Path Intercept Point (GPIP), as is the ILS glideslope antenna. The EL antenna has a scan coverage of 0.9 degrees to 30 degrees (Figure 3), but most sites will scan to 20 degrees in elevation. The DME/P transponder has a 360 degree coverage up to 22

Based on a paper presented at NAECON 85.

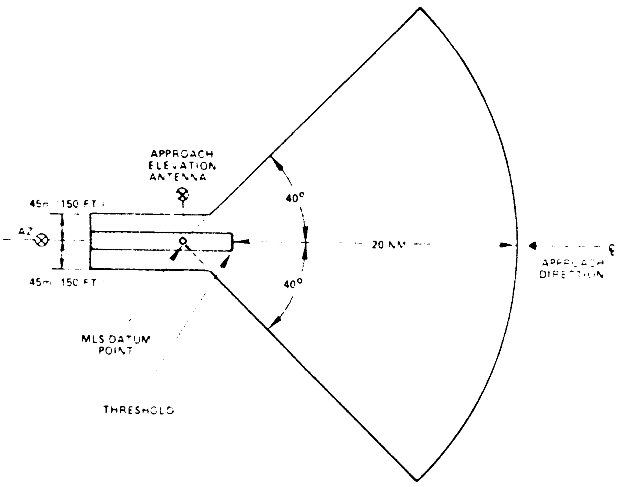

Figure 2. Azimuth Antenna Coverage

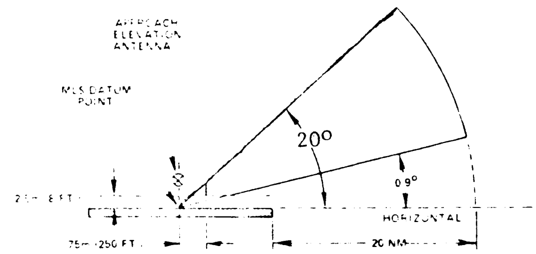

Figure 3. Elevation Antenna Coverage

nm and is usually collocated with the AZ antenna. By using these three signals, AZ, EL, and DME/P, the three dimensional position of the aircraft, in relationship to the runway, can be determined. Adding a back azimuth (BAZ) antenna to the approach end of the runway, (Figure 4), provides guidance to the aircraft for take-off and missed approaches. (1:321–325)

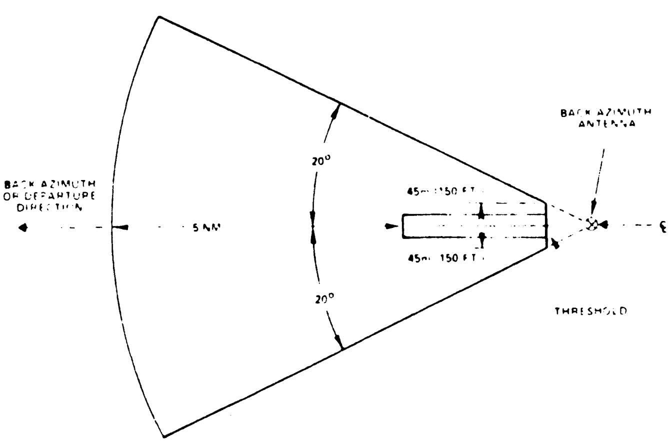

Figure 4. BAZ Antenna Coverage

The Basic Data function provides information which is directly used by the MLS receiver to process the angle functions and provide landing guidance. This consists of six data words transmitted from the AZ antenna. According to the latest revision of the MLS SARPS, ICAO Annex 10, Volume 1, these six data words provide information on coverage area, signal status, beamwidths, runway heading, and station I.D. (2:2A-16–2A-22) The SARPS also provides for three sets of auxiliary (AUX) data words. Presently, four words identify the site geometry of the AZ, EL, BAZ and DME antennas. The rest of the data words are not yet defined, but will most likely provide information necessary for MLS Area Navigation (RNAV) calculations.

All of the MLS signals (AZ, EL, BAZ, Basic and AUX data) are transmitted over the same frequency in a multiplexed fashion as shown in Figure 5. Each signal has a digital preamble preceding it to identify the signal. DME/P is transmitted and received over one of the 200 channels that is paired with the MLS channels.

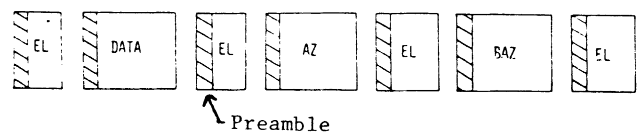

Figure 5. Time Multiplexing of Signals

POSITION DETERMINATION

MLS position is determined by timing the passes of the scanning beam; thus Time Referenced Scanning Beam. Using the AZ signal as an example, it begins its scan at the +40 degree radial of the AZ coverage area. This beam scans at a constant rate through the runway centerline (0 degrees) to the −40 degree radial (Figure 6). This scan is called the "TO"

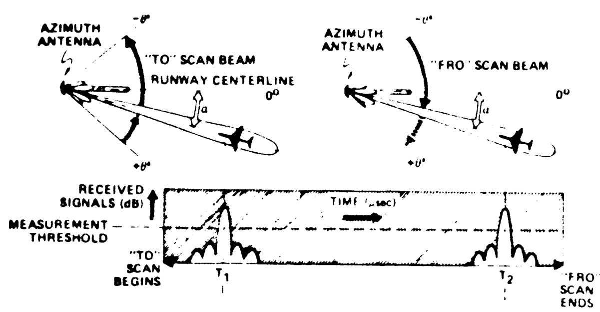

Figure 6. Angle Measurement

scan. After a predetermined pause, the beam scans back from the −40 degree radial to the +40 degree radial. This is called the "FRO" scan. The aircraft's MLS receiver starts a timer when it detects the TO scan and stops the timer when it detects the FRO scan (Figure 6). By using the linear relationship shown in Figure 7, the receiver can calculate the azimuth

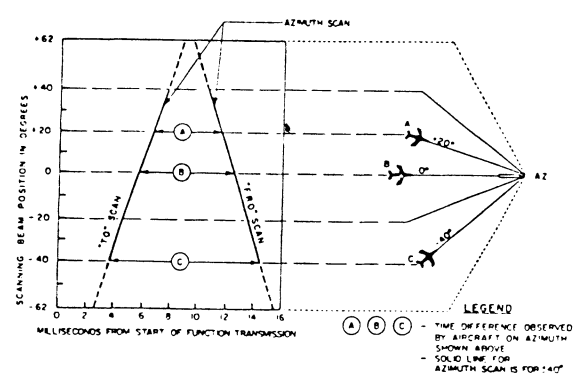

Figure 7. Angle Measurement

angle on which the aircraft is located (1:329). The same process occurs with the EL scan, starting at 0.9 degrees elevation, scanning to 20 degrees elevation, and returning back to 0.9 degrees. These two signals can determine the two dimensional location of the aircraft.

The third signal required to determine the three dimensional position of the aircraft is Precision DME (DME/P). ICAO desired a signal format that was compatible with the standard DME (DME/N) associated with TACAN and VOR, but could still distinguish itself as a precision interrogation. (The accuracy of DME/N is only 0.17 nm which does not meet the accuracy requirements for precision approaches and landings.) The proposed format was two-pulse/two-mode. (3:2) This format uses the same pulse-pair format that is used in DME/N, but also provides a second mode in which DME/P interrogations can occur. The first mode of the DME/P signal is the initial approach (IA). IA interrogations occur frm 22 nm to 8 nm (figure 8). These interrogations are fully interoperable with DME/N and provide accuracies similar to DME/N. At 8 nm, the DME/P interrogator begins to transition to the final approach (FA) mode. This transition is complete by 7 nm and

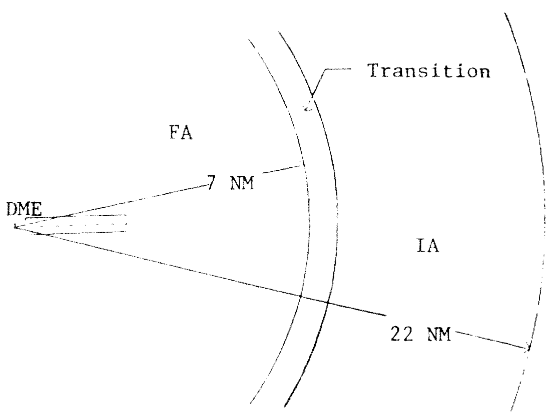

Figure 8. DME/P Coverage

the FA mode is used through landing. The transition for the FA mode is signaled by changing the spacing between the DME pulse-pair interrogation. The DME/P ground transponder recognizes this new spacing and begins to process the signal as a FA interrogation. The increased accuracy in the FA mode is derived by pulse shape modification, lowering the pulse detection threshold, and increasing the rate of interrogation. (For more information on this subject, refer to Reference Three.) Two accuracy standards are provided in DME/P. Standard 1 provides 100 ft. accuracy which is adequate for conventional take-off and landing (CTOL) operations. Standard 2 accuracy is 40 ft. which is needed for STOL operations and CAT III and autoland capability. With this third signal, the position of the aircraft can be accurately determined.

MLS OPERATIONS

The operational advantages of MLS are numerous. It provides a distinct advantage over ILS by providing command guidance in a much greater coverage volume. Because of this increased guidance coverage, the pilot has much more flexibility in his approaches to landing, missed approaches, and take-offs. Presently, many approaches can only be flown to non-precision decision heights due to the complexity of the approach and the lack of positive guidance. Complex approaches are required when conducting noise abatement and obstacle clearance maneuvers and flying in restricted airspace. Several examples of this problem are the River Approach into

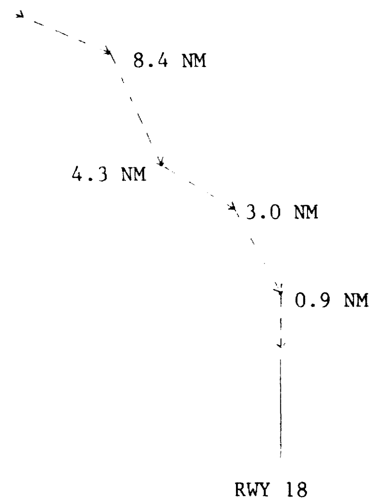

Figure 9. River Approach

Runway 18 at Washington National Airport (Figure 9), the Canarsie Approach into Runway 13 at JFK Airport in New York City (Figure 10) and the Quiet Bridge Approach into

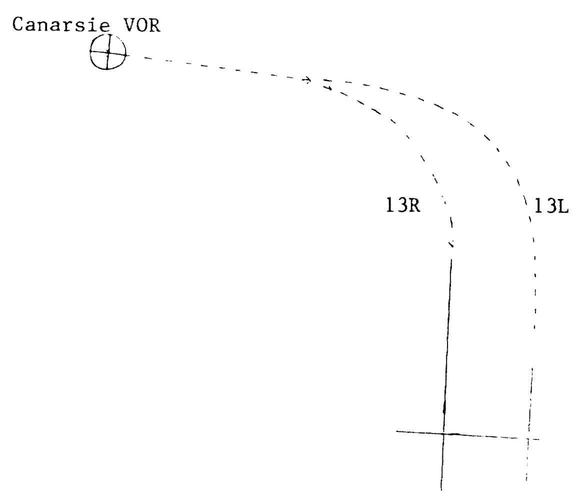

Figure 10. Canarsie Approach

Runway 28 at San Francisco International Airport (Figure 11). These three approaches cannot be flown to precision decision heights. Therefore when weather minimums become low at these airports, these approaches are shut down, either closing the airport or causing a large back-up in air traffic. Neither of these situations are desirable to the airlines or the airports. Since MLS can provide guidance throughout these approaches, they can be flown as precision approaches to at least CAT 1 minimums.

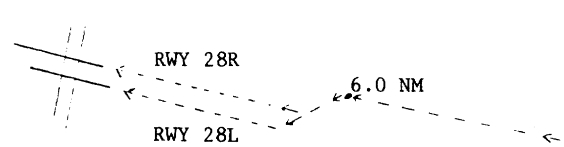

Figure 11. Quiet Bridge Approach

MLS is also advantageous to the Air Traffic Controllers. Once an aircraft is in the terminal and MLS coverage area, the pilot will fly a prescribed approach to landing. The controller will no longer need to provide continuous radar vectors to the pilot for interception of the ILS localizer beam or aircraft separation. This will greatly reduce his workload.

It is anticipated, that with the greater capability of MLS, aircraft separation can be reduced, simultaneous instrument approaches can be flown into parallel runways, and complex approaches can be flown to precision heights. These added capabilities will increase the rate at which aircraft can be recovered and deployed and decrease time in the traffic pattern.

MLS also provides advantages for special operations such as STOL and decelerated approaches. For STOL and tactical applications, a high glideslope angle is desired, but present systems do not have the vertical range necessary to provide instrument guidance for these approaches. Helicopters doing steep approaches need range-rate information for decelerated approaches. Range-rate can be derived from the DME/P range at Standard 2 accuracies.

AVIONICS

Present MLS avionics configurations cannot provide the capability required to fully implement MLS operations. Some kind of navigation computer (MLS RNAV) is needed to fly curved/segmented approaches. This computer must provide the accuracy necessary to fly in the terminal area and conduct approaches to landing. Present RNAV computers used in the enroute structure do not provide the accuracy necessary for terminal procedures. The Radio Technical Commission for Aeronautics (RTCA) has formed a special Committee, SC-151, to define the Minimum Operational Performance Standard (MOPS) for MLS RNAV equipment. This equipment will be required to accept MLS waypoints and provide positive guidance in the terminal area.

Another area that will require further research is in the display of MLS information to the pilot. Previous studies have shown that present electromechanical displays are not adequate to provide information to the pilot for flying curved/segmented approaches. The greatest concerns in this area are with situational awareness (i.e., where the runway is relative to the aircraft) and turn anticipation. Minor modifications have been done to present instruments to supply this information. But as the dynamics of the approaches increase, further cues and transition anticipations are required for the pilot to accurately follow a prescribed course. This problem can hopefully be eliminated by taking advantage of the flexibility provided by an Electronic Flight Instrumentation System (EFIS). Programming the CRTs to display MLS information in new formats should provide the pilot with the guidance commands necessary for high dynamic approaches.The Air Force will be conducting research with different display formats to meet this need.

There has been very little operational implementation of MLS to this date. Therefore the avionics requirements for flying MLS complex approaches have not been totally defined. The FAA and USAF will be involved in operational tests of MLS over the next couple of years to more fully define MLS capabilities and avionics.

REFERENCES

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3. Kelly, R.J. and Jensin, G., "DME/P—The New International Standard." IEEE 1982 Position Location and Navigation Symposium (PLANS 82), Atlantic City, NJ, December 1982.

The following list of equivalents is suggested to help those who have trouble remembering SI prefixes:

10^{18} minations	= 1 examination	10^{-1} mates	= 1 decimate
10^{15} coats	= 1 petacoat	10^{-2} mentals	= 1 centimental
10^{12} bulls	= 1 terabull	10^{-3} cents	= 1 millicent
10^{9} lows	= 1 gigalow	10^{-6} scopes	= 1 microscope
10^{6} phones	= 1 megaphone	10^{-9} nannettes	= 1 nanonannette
2×10^{3} mockingbirds	= 2 kilomockingbird	10^{-12} boos	= 1 picoboo
10^{2} withits	= 1 hectowithit	10^{-15} fatales	= 1 femtofatale
10 cards	= 1 decacard	10^{-18} boys	= 1 attoboy

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