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Comparative Study of ILS and MLS Systems and Proposed MLS Prototype on Runway 27 of Bangalore International Airport

M.Tech. Scholar Niyonsaba Jeremie Professor Samuel Vivek
Department of Aerospace Engineering,
IIAEM, Jain University, Karnataka , India

***Abstract* -This paper discusses how the instrument landing system (ILS) and microwave landing system (MLS) operate, their subsystems and how to convert Bangalore's international airport ILS system into MLS system. The need of MLS system over ILS system is also covered in this paper.**

***Keywords*-ILS system, MLS system, Instrument landing chart interpretation, MLS system prototype.**

I. INTRODUCTION

ILS system is defined as standard international civil aviation organization (ICAO) precision radiolanding aid(Precision means the aid that provides both lateral and vertical guidance for the aircraft runway approach) under normal and adverse weather conditions like reduced visibility due to rain, fog or snow and low ceilings and It operates in very high frequency band range(VHF) of 108.10-111.95 MHz and the first decimal must be odd number[3], ILS facility is very accurate and dependable mean, in case the pilot is navigating to the runway, in Instrument Flight Rules(IFR) conditions [4].

ILS consists of Localizer, Glide path, markers, distance measuring equipment (DME), the approach lighting system and Runway visual range. But ILS has some shortcomings such as: only 40 channels are available worldwide, azimuth and glideslope are fixed and narrow and this causes landing delays as the aircrafts have to be sequenced and separated, it is difficult to install ILS facility in hilly areas, so it requires large flat expansive cleared land, no procedures for slow moving aircrafts, helicopters and STOL (short take-off and landing) aircrafts [5], so this gives green light to MLS (microwave landing system).

Microwave landing system is defined as precision approach and landing, that operates in super high frequency (SHF) range 5031 to 5090.7 MHz and it uses the principle of Time Division Multiplexing technique(TDM), it transmits data on one of 200 channels and it is normally located about 1000 feet(300 m)beyond the stop end of the runway .It provides following advantages, big number of channels, increased azimuth and elevation coverage which allows the helicopters and STOL aircrafts in their approaches, and so on. The main components of MLS system are: Ground Measuring Equipment (DME) which provides slant range from fixed point to the aircraft, ground protractor components. Though MLS system has many advantages over ILS system, it did not gain spread at many airports mainly due to the following reasons: its installation cost is very high and satellite based landing systems (GPS based) are likely to take over [6].In this work, MLS system will be designed in effort to replace the current ILS system at Bengaluru international airport.

II. OVERVIEW OF ILS SYSTEM

1. Purpose and Function of ILS

ILS system employs combination of radio devices and high intensity lighting to provide lateral, vertical guidance and landing on the runway. While flying on the ILS, the pilot adopts the precision approach after crossing the Decision Height (DH) (the height at which pilot has to make decision of continuing to approach or go around, normally known as missed approach).The pilot is informed on the aircraft's position with respect to the desired approach trajectory, in case of any deviations, the pilot performs adjustments immediately. In lateral guidance, the aircraft is checked whether is aligned with central line of the runway, while in vertical guidance, the aircraft is checked whether it is approaching the touchdown zone [1].

2. ILS Architecture And Components

ILS system has two main components which are ground based equipment and airborne receiving equipment. [1]

3. ILS Ground Based Equipment

Ground based equipment consists of cluster of radio transmitters for localizer, glide path, marker beacons, in some cases Distance Measuring Equipment (DME) is

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sanctioned when markers are not available or it is not possible to install them. In addition to that, it gives assist in localizer interception and holding procedures, by using either Very high frequency Omni range(VOR) or low powered non directional beacons(NDB) normally referred as locator [1,3]. The figure below, show the architecture of ILS system.

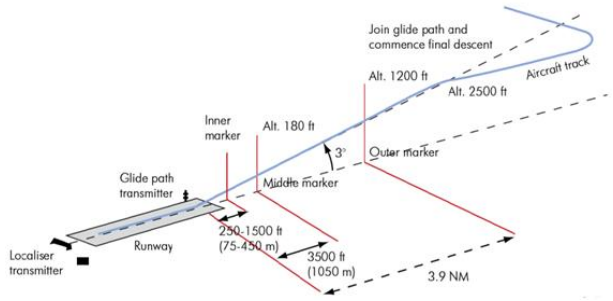

Fig.1. ILS system and ranging, source [3].

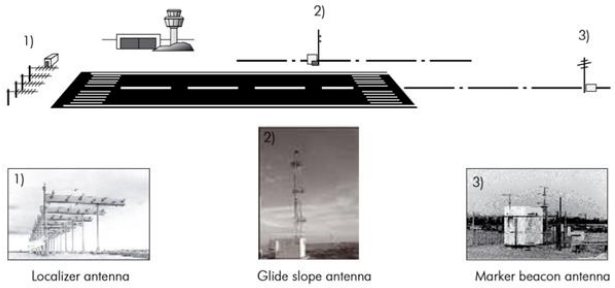

Fig.2. ILS main components and their relative locations, source [3].

4. Localizer

This is cluster of dipole antennas and reflectors, placed 300 m in line of the runway central line, from the upwind end of the runway, which transmit in frequency range of 108.10 to 111.95 MHz of VHF. This aerial is normally 20 m wide and 3m high. It produces the beam with two different modulated lobes, for the approaching aircraft point of view, the beam on left hand side is modulated by 90Hz and it is called "YELLOW SECTOR", while the beam on right hand side is modulated by 150Hz and it is called "BLUE SECTOR".

The receiver on left hand side will detect more of 90Hz modulated tune than 150Hz modulated tune ,this difference is called Difference in Depth of Modulation(DDM) and this will cause the vertical needle on the indicator to show that the right correction is needed, the same principle is used by the receiver on the right hand side. When the DDM is zero, that line shows the central line of the runway, and no deflection is needed [3].

The DDM varies linearly on the either side of the central line, at least up to 3°.Localizer must give signals up to 25NM, with coverage of 10° on either side of central line, It must also give signals up to 17NM, with coverage between 10° and 35° either side of the central line. Finally it must give signals up to 10NM with coverage of 35° on either side of the central line.[1,3] There is 20% overlapping of 90 Hz tuned beam and 150 Hz tuned beam, and this shows that the aircraft is well oriented with respect to the central lines of the runway.
The figures below show the localizer patterns and coverage.

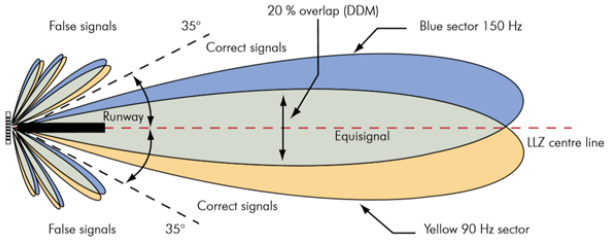

Fig.3. localizer modulation pattern, source [3].

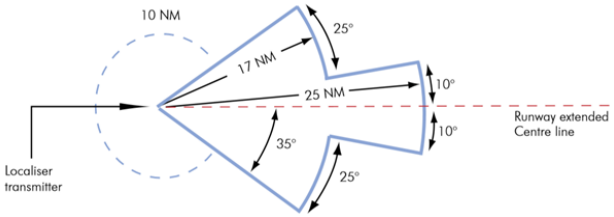

Fig.4.localizer coverage and range, source [3].

5. Glide Path

This is bunch of radiating elements which are placed 300 m upwind, from the threshold of runway, which is considered as the optimal touch down point at which the extension of glide slope intercept the runway and 120 m from the central line [3].They operate in the Ultra high frequency range(UHF) on 40 spot frequencies between 329.15 to 335 MHz [1].Like in the localizer case, the upper lobe of glide path is modulated by 90Hz, while the lower beam is modulated by 150Hz,the receivers in the aircraft receive the tuned signals and indicate whether the aircraft is above or below the glide slope which is normally 3° or varies between 2° to 4° or specified otherwise.

When the DDM is zero, this indicated that the aircraft is aligned with glide slope line [3]. The glide path transmitters must give signals up to 10NM, with coverage of 8°,on either side of the glide slope line, the letter R shows where the downward extended glide path intercept the runway central line [1]. The figures below show the glide path beam and coverage respectively.

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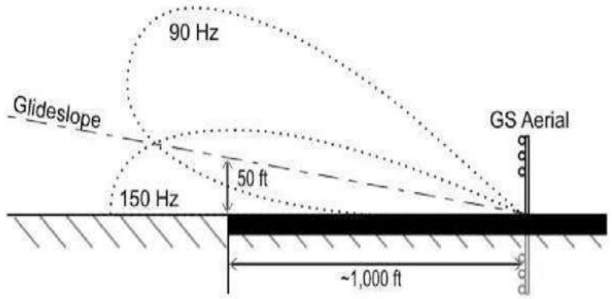

Fig.5. glide path beam, source [1].

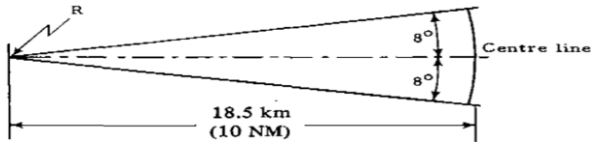

Fig.6.glide path coverage, source [1].

6. Marker Beacons

Those are non-directional beacons (NDBs), which show how far the aircraft is, from the runway, there are three marker beacons which are outer marker, which is located 7 km from the runway and operates at 400 Hz frequency, middle marker which is located 1Km away from the runway and operates at the frequency of 1300Hz and inner marker which is located approximately 60m from runway and operates at 3000 Hz. They inform the pilot on how far the aircraft is, from the runway, by giving color coding, blue shows that aircraft is 7km away, amber shows that the aircraft is 1 km away and white shows that is 60 m away. The figure below shows the location, colors and operational frequencies of those markers.

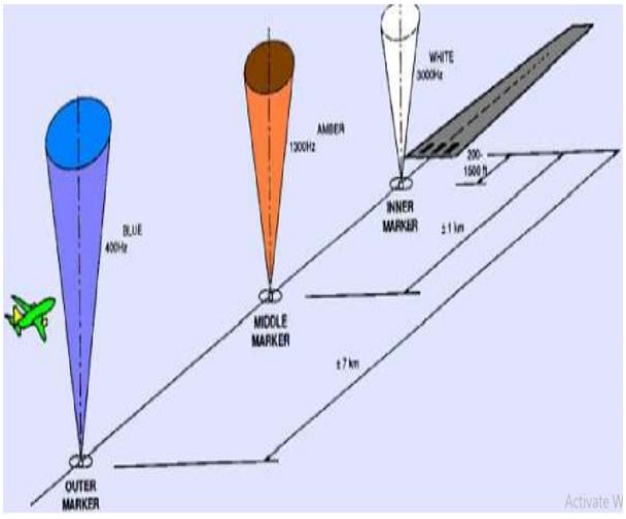

Fig.7. markers positions, frequencies and colors, source [1].

7. ILS Airborne Receiving Equipment

ILS airborne equipment consists of ILS receivers for localizer, glide path and markers signals and displays for Presenting the Information.

8. Localizer Signal Receiver

This equipment receives the signal from localizer transmitter and displays the aircraft's position against azimuth axis and this information is used by the pilot to guide the aircraft into the path axis.
The figure below shows localizer display

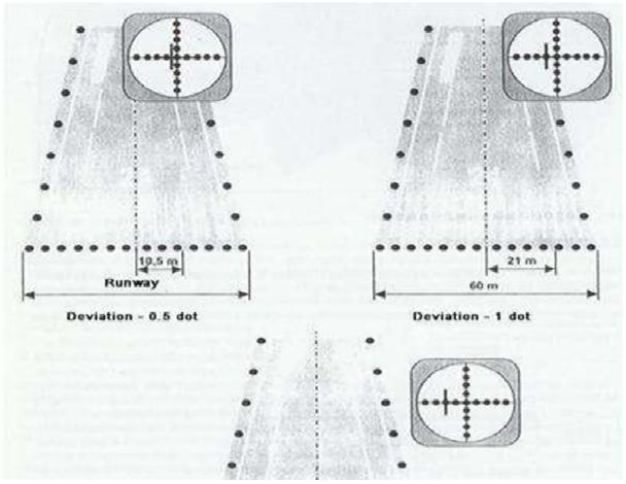

Fig.8. deviation on localizer indicator, source [1].

9. Glide Path Signal Receive

It operates on the same principle as localizer signal receiver; it receives the signals from glide path transmitter array and display the aircraft position with respect to the glide slope line. Outside the outer marker, the deviation of one dot ,means deviation of 500 ft. above middle marker(MM) till the touchdown zone, the deviation of one dot means 45 m deviation in vertical direction from the glide slope line [1] The figure below shows the glide path receiver.

Fig.9. glide slope receiver, source [1].

10. ILS Categories

There three categories, CAT I,CAT II and CAT III ,where the CAT III is the most accurate and also have other three

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subcategories. They are categorized according to decision height and runway visual range. The table below gives summary on ILS categories.

Table I: categories of ILS system

Category	Decision height	Runway visual range
CAT I	200 ft. or above	1800 ft.
CAT II	Less than 200 ft. but more than 100 ft.	1000 ft.
CAT IIIa	Less than 100 ft. but more than 50 ft.	600 ft.
CATIIIb	Less than 50 ft.	150 ft.
CAT IIIc	No limitations	None

.

11.ILS Disadvantages

The ILS system has the following operational disadvantages:

1. Only 40 channels are available worldwide
2. The azimuth and glide slope beams are fixed and narrow and this causes the landing delays
3. It does not provide procedures for slow moving aircraft, helicopters and STOL aircraft
4. It is practically challenging to install ILS system in hilly areas, so large flat cleared surfaces are required
5. Taxying, low flying aircrafts and building have to be kept away from the transmission sites, in order to avoid the bending of localizer and glide path beams

III. OVERVIEW OF MLS SYSTEM

Currently India has taken a major initiative on developing the infrastructures such as express highways, power projects and industrial structures etc., to meet the requirements of globalization, in the construction of buildings and other structures concrete plays the rightful role and a large quantum of concrete is being utilized. This paper presents the feasibility of the usage of Quarry Rock Dust as hundred percent substitutes for Conventional Concrete. Tests were conducted on cubes and beams to study the compressive, flexural strengths of concrete made of Quarry Rock Dust for three different proportions and five different methods. Durability Studies were done for concrete with Quarry Rock Dust and compared with the Conventional Concrete. Microwave landing system (MLS) is an advanced system put in place, in order to give solutions to drawbacks existing in ILS system. MLS system operates in SHF (super high frequency) band of 5031 to 5090 MHz [5] with spacing of 300KHz [6],this gives 200 possible channels worldwide and it can be sited in hilly areas where bending of beams is no longer a problem, as the scanning beams can be interrupted, and therefore avoid the reflections.

1. Need For MLS System

MLS system is required to solve the difficulties faced by ILS system discussed in previous chapter, by providing the following distinctive advantages.

1. Provide a large number of channels, 200 channels.
2. Provide great azimuth coverage of ±40° and variable glide slope between 0.9° to 20° and great range of 20 NM to 30 NM
3. Give back course transmissions, with ±20° coverage, up to 15° elevation, range of 10NM and height of 10000ft.
4. Increased runway utilization and allow STOL aircrafts and helicopters to use it.
5. Compatibility with conventional localizer, glide path instruments, auto pilot systems and area navigation equipment.
6. It gives positive automatic landing indications and on off flags for localizer and glide path needles.

1. Operational Principle of TRSB-MLS

Time Reference Scanning Beam (TRSB)-MLS is the system developed by USA which is adopted by ICAO. It works on the principle of converting the receiver (in aircraft) angular position into time difference of two received pulses which are, the azimuth scan pulses and elevation scan pulses. Azimuth scan employs a fan beam broad in vertical plane and narrow in horizontal plane, while elevation scan uses fan beam broad in horizontal plane and narrow in vertical plane, to scan in up and down motion. So, each beam scans its corresponding sector (azimuth or elevation), at constant sweep rate and enough dwell time.

With the knowledge of scanning rate and the pause time, the elevation angle can be found using the following formula θ= ((t_0-t)*V)/2 [6]; where, To value of t in microseconds at θ=0(4800 microseconds for AZ (azimuth) and 3350 microseconds for EL (elevation))T actual time between received to and fro pulses, in microseconds V Angular speed of scanning beam (0.02 degrees per microsecond) Angular position of the aircraft in degrees

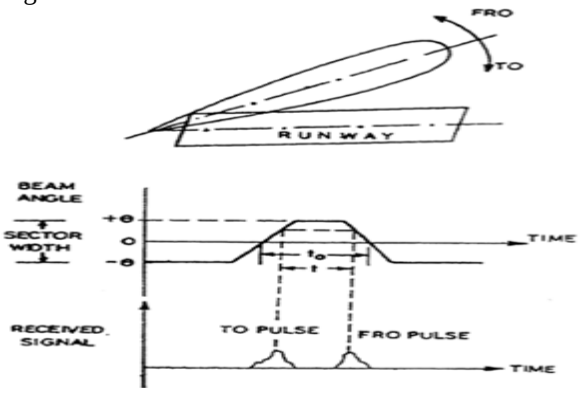

Fig.10. elevation angle measurement, source [6].

2. MLS Signal Format

MLS signal format operates in TDM (time division multiplexing) mode to accommodate 200 channels spaced by 200 KHz in frequency range of 5031 to 5090.7 MHz carrier signal. A full frame occupies 592 ms. and each subsequence has three elevation slots, three flare slots and one azimuth slot. The figure below shows the frame format of MLS signal

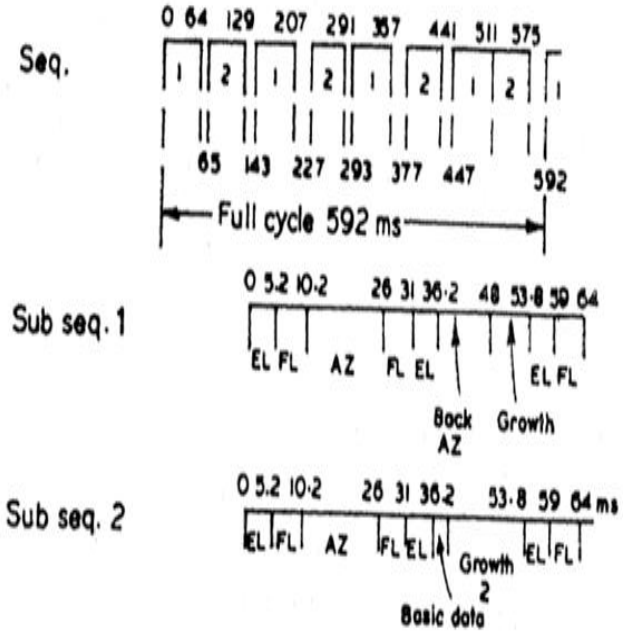

Fig.11. MLS signal format, source [6].

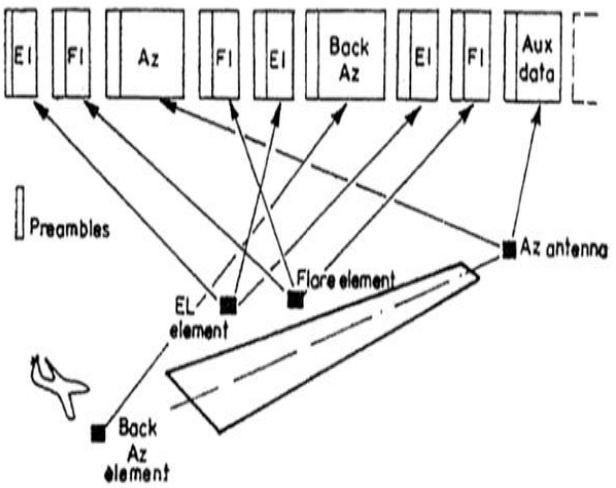

Fig.12.MLS signal format showing correspondence to with different elements (adapted from ICAO source).

4. MLS Components

The MLS components are shown in the figure below,

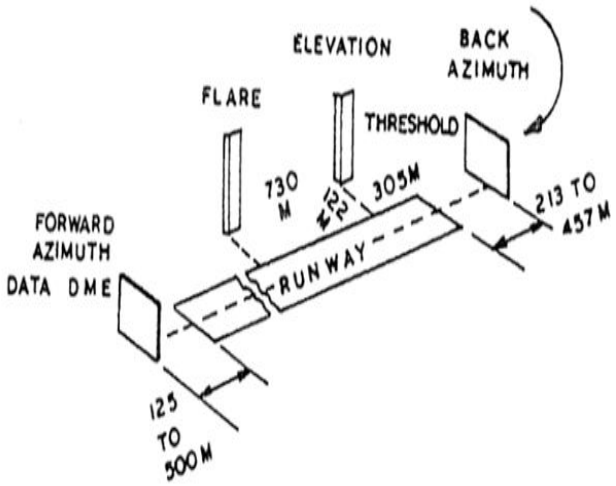

Fig.13.MLS composition, source[6].

1. Approach Azimuth Equipment

Azimuth equipment is installed at the extension of the central line of the runway at the distance of 125 to 500 m, the scanning beam gives azimuth position and auxiliary information, such as station identification, system condition, runway condition and weather information can also be transmitted. The simplified block diagram of the azimuth equipment is shown below.

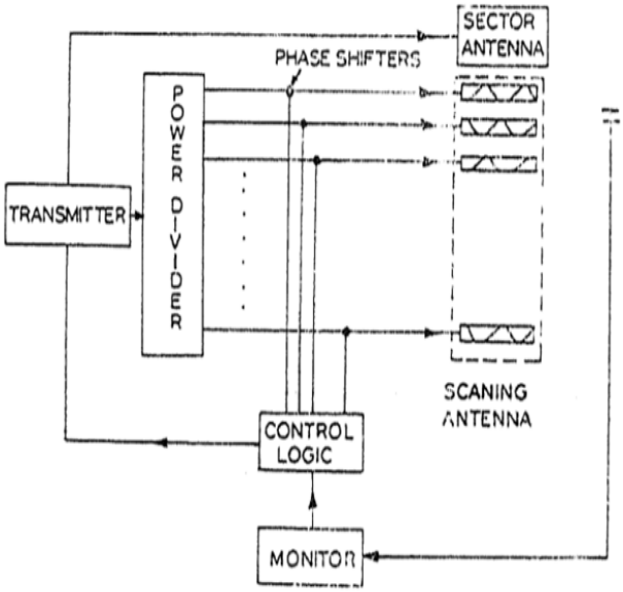

Fig.14. simplified block diagram of azimuth equipment, source [6].

It consists of transmitter, electronically scanning linear phased array, control unit and monitoring system. By appropriate switching shifters it is possible to create a scanning beam at constant sweep rates, the shifters are made of PIN diodes which covers 360° in sixteen steps of 22.5° each. The following antennas are used in approach azimuth equipment: [10]

1. 2° beam width, with ±40° proportional lateral guidance

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2. 1° beam width, with ±40° proportional lateral guidance
3. 1° beam width, with at least ±10° proportional lateral guidance, with low side lobes
4. 1° beam width, with ±60° proportional lateral guidance
5. 3° beam width, with ±40° proportional lateral guidance

The figure below shows the approach azimuth antenna fro and to scanning beams.

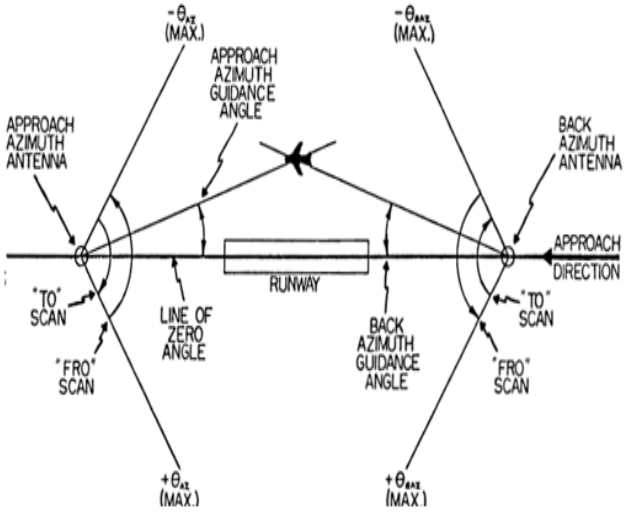

Fig.15. fro and to scanning beams of azimuth antenna, source [10].

The figure below summaries all the components found in AZ /DME station and their relative positions.

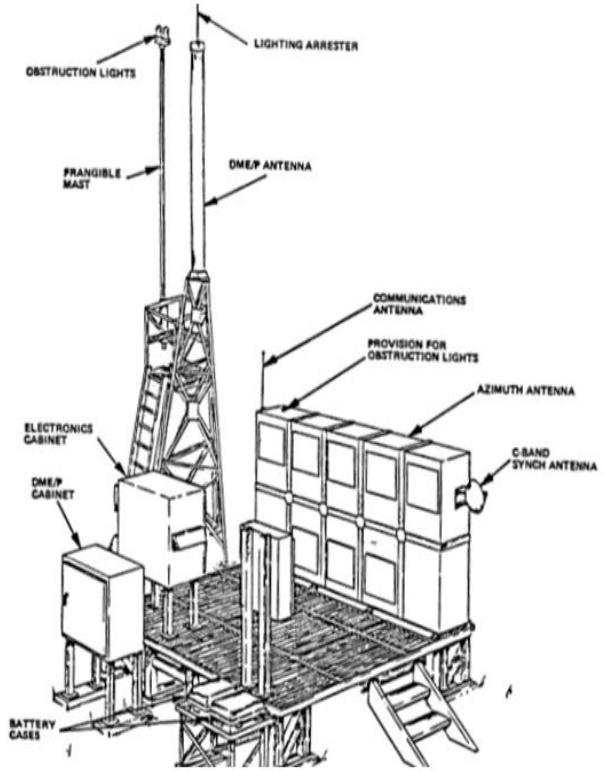

Fig.16. AZ/DME station, source [10].

2. Elevation Equipment

Those are the linear vertical array dipole antennas, placed about 305 m from the beginning of the runway, offset 122m either side of central line. The sector antenna transmits out-of-coverage indication (OCI) to avoid erroneous indication due to the side lobes.

This equipment uses the following type of antennas [10]:

1. 1.5° beamwidth,+0.9° to+15° vertical proportional guidance
2. 1° beamwidth,+0.9° to+15° vertical proportional guidance

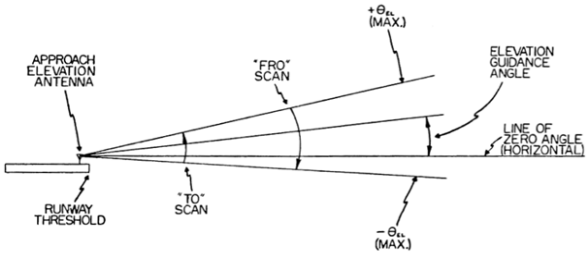

Fig.16. fro and to scans of elevation antenna, source [10].

3. Back Azimuth Equipment

This is the equipment which transmits the azimuth information to aircraft that has missed approach. It is located 213 to 457 m from the beginning of the runway towards the approach side. This equipment has the same components as that of approach azimuth equipment and use the same type of antennas.

4. Flare Equipment

This is the equipment placed at 730 to 915 m from the elevation station, which helps the aircraft glide path sink rate of1.8 _ 4.9 m/s ,to0.6_0.9 m/s descent rate at touch down. The flare needs the elevator deflections to increase the angle of attack, which will create the upward acceleration, and consequently, reduce the sink rate.

Note: This equipment is not intended to be implemented in future. [From literature survey]

5. Precision Distance Measuring Equipment

This equipment operates in L –band frequency(1-2 GHz radio spectrum).DME transponders transmit on 962 to 1213 MHz range and receive at 1025-1150 MHz, the band is split into 126 channels for interrogation and 126 channels for replies. It is co-located with azimuth station.

This station has the following components: [10]

1. DME/P transponder
2. DME/P executive monitor
3. Equipment maintenance monitor
4. Power station
5. Cables, waveguides, connectors and fittings

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6. MLS Flight Deck Control Panel

The deck must be selectable mode, in order to be able to receive signals from ILS, MLS and GPS transmitters.

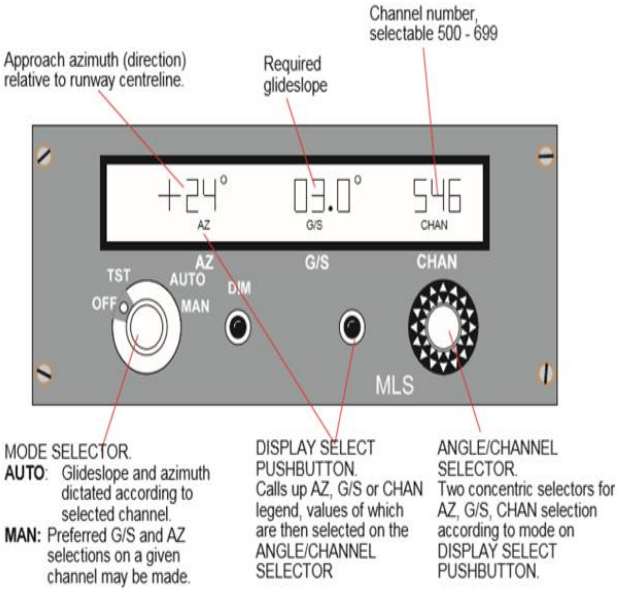

Fig.17. MLS flight deck control panel, source [5].

7. MLS Coverage

The coverage must provide 3D azimuth elevation and range, anywhere in the approach. The figure below explains various aspects of coverage.

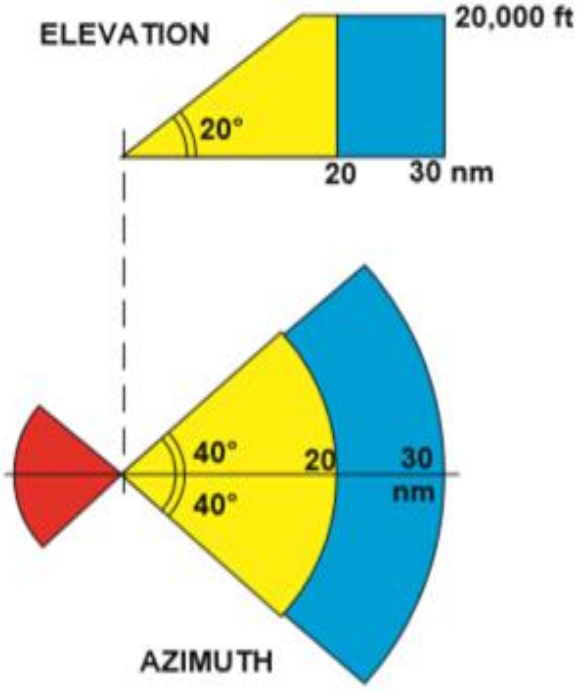

Fig.18. MLS coverage, source [5].

8. MLS Prototype

The figure below shows the placement of various MLS components on runway.

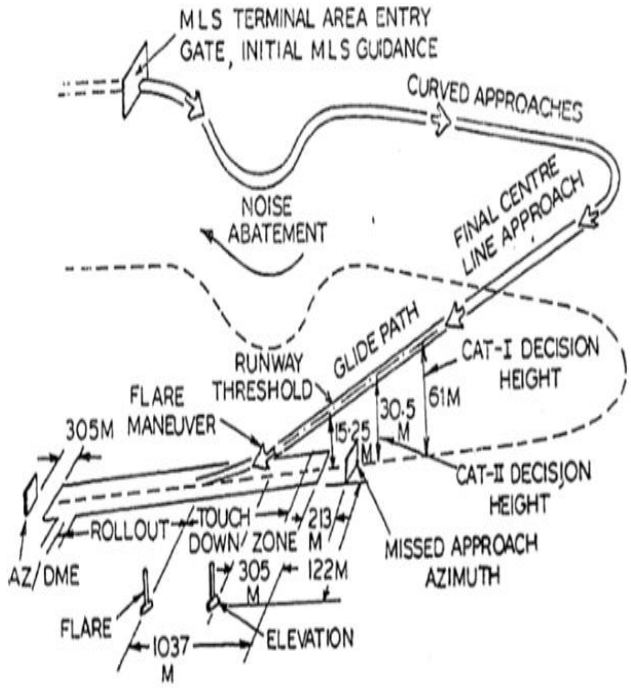

Fig.19. MLS prototype, source [6].

9. MLS Salient Features and Characteristics

The most important features of MLS system are summarized in the table below.

Table II: Salient features of MLS system.

Parameters	Values
Frequency	5031-5090.7 MHz 200 channels spaced 300 kHz apart
Information rate i. Azimuth ii. elevation	 13Hz for wide coverage($\pm 40°$) 39Hz for narrow coverage($\pm 10°$)
Information coding i. Angular information ii. Preamble and data	 Pulse space coding with time reference scanning beam Bi-phase coding in DPSK
Polarization	Vertical
Coverage i. Azimuth ii. Elevation	 $\pm 40°$ $0.9\ to\ 15°$
Distance	20 NM
Guidance accuracy at runway threshold i. PFE ii. CMN	Azimuth Elevation $\pm 6m \pm 0.6m$ $\pm 3.2\ m$ $0.3m$

Note:
1. PFE: Path Following Error
2. CMN: Control Motion Noise

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3. DPSK: Differential Phase Shift Keying

10. MLS Configurations

MLS system has three different configurations, depending on community requirements or ICAO landing requirements for specified categories. The table below shows those configurations and their descriptions. [9].

Table III: MLS configurations.

Configurations	Descriptions
Basic	Approach azimuth, approach elevation and DME/P are mandatory.
Expended	Approach azimuths, Approach elevation, DME/P, Missed approach and flare system are mandatory to meet ICAO CAT III landing requirements.
Small community system	Approach azimuth, approach elevation, with either DME ranging or ICAO marker beacons, it meets ICAO CAT I landing requirements.

III. RUNWAY 27 INSTRUMENT LANDING CHART INTERPRATATION OF BANGALORE AIRPORT

The runway 27 instrument landing chart of Bengaluru international airport is interpreted with reference to Aeronautical chart user's guide, published by Federal Aviation Administration (FAA) [8]. The runway 27(RWY 27) at Bengaluru international airport is an ILS CAT I, that has bearing of 272°, Threshold coordinates of 13°12'24.63" N, 77°43'22.67"E, Threshold elevation of 2917ft. RWY 27 has dimensions of 4000*45 m and lighting system length of 900 m and green color .[7]

1. Briefing Section

The picture below shows a briefing section of approach chart of RWY 27, and the following information is depicted from it.

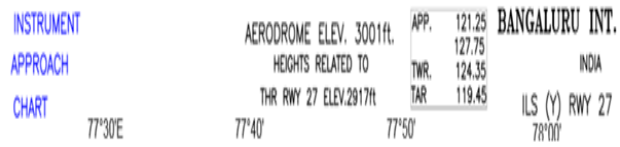

Fig.20. Briefing section of ILS RWY 27 approach chart, source [7].

1. Airport name: BANGALURU INT
2. Airport elevation: 3001ft.
3. Threshold elevation: 2917ft.
4. Bengaluru approach radar :121.25 MHz ,127.75MHz
5. Bengaluru tower:124.35 MHz
6. Runway approach name : ILS(Y) RWY 27

2. Plane view

The plane view is shown below and the following information is extracted from it.

Table IV: Navigational aids at RWY 27

Nav Aids	Identification	Frequency/MHz
Localizer(LOC 27/DME-N)	IDEV	108.3 CH 20X(1044MHz for interrogation and 981 MHz replies, with 12microseconds pulse codes for interrogation and replies) [11]
Glide path(GP 27)		334.1 [11]
Very high Omni range(VOR/DME-N)	BIA	116.8 CH 115X(1139MHz for interrogation and 1202 MHz replies, with 12microseconds pulse codes for interrogation and replies) [11]

Whenever glide path (GP) is in operation;

1. Final Approach Fix(FAF): 8.1D(IDEV) (8.1 miles DME slant range)
2. Altitude at FAF: 5500ft.
3. Descent gradient(glide slope): 3°
4. Missed approach point(MAPt):1D(IDEV)(1 mile DME slant range)

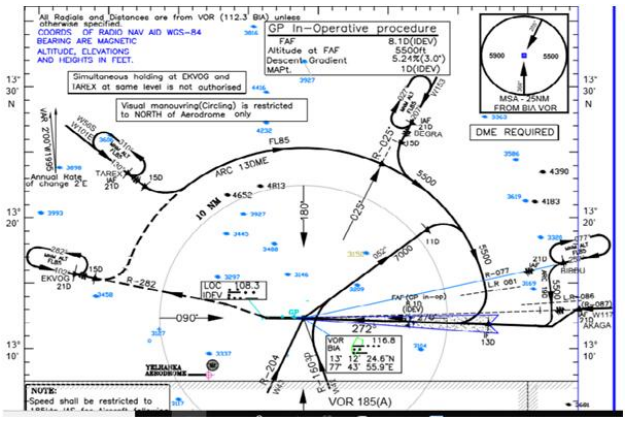

Fig.21. plane view of ILS RWY27, source[7].

3. Minimum Safe Altitude (MSA)

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From BIA VOR, in radius of 25NM, the minimum safe altitude is 5900ft, and 5500 ft. as shown in figure below.

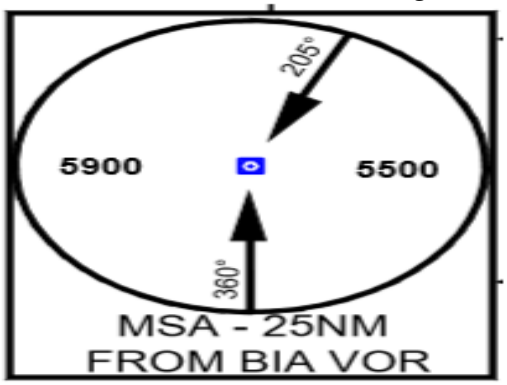

Fig.22. minimum safe altitude, source[7].

4. Profile View and Landing Minimums

The profile view shows that the glide slope angle is 3 degrees and 272 degrees bearing. And it explains the missed approach procedure. While the landing minimums section shows minimums heights, visibility, ground speeds, descent rates, for various aircraft categories and approach types.

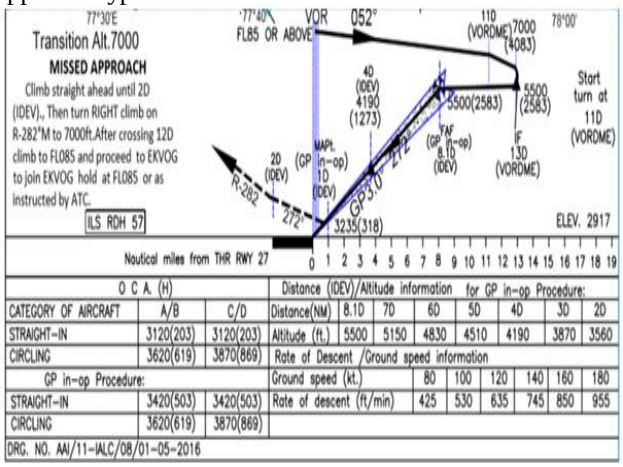

Fig.23. Profile view and landing minimums section of RWY27, source [7].

IV. PROPOSED MLS SYSTEM FOR RUNWAY 27

The MLS system proposed to replace ILS system on RWY 27,has the following main equipments spaced as shown in below figure, the spacing is based on MLS composition spacing discussed in chapter 2.The proposed MLS system meets the ICAO CAT III landing requirements.

1. Salient Features of Proposed MLS System

These are the main characteristics of proposed MLS:

1. Complies with ICAO CAT III landing requirements.
2. Expanded configuration.
3. Note: The flare system is not proposed as it is not intended to be implemented in future.

2. Sitting And Location

The distances between various stations and runway, are considered with respect to obstacle clearance requirements and sitting requirements discussed in [10]

3. Approach Azimuth Site

AZ antenna is located at 1300 ft. (396.24 m) from end point of runway, with 16ft (4.8768 m) height.
DME/P antenna is collocated with AZ antenna, with 22 ft. (6.7056 m) height including lighting rod.

4. Elevation Site

It is offset 122 m front centerline, on right of runway (the obstacle clearance and active taxi way has to be checked by engineer, before deciding the offset distance) EL antenna is chosen to be placed at 305 m from the beginning of runway. 3° planar guide path is considered Asymptotic threshold height of 50 ft. (15.24m) Phase Centre height of 7ft. (2.134 m)

5. Back Azimuth Site

Back AZ antenna is located 213m after the beginning point of the runway, with 16ft.(4.8768m) height.
The figure below shows the prototype of proposed system.

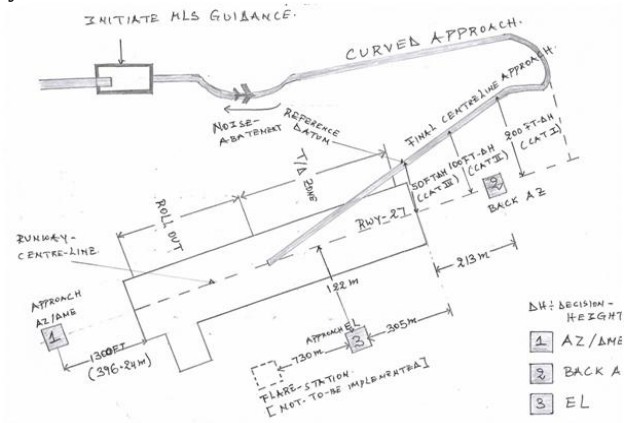

Fig.24. proposed MLS system block diagram, source original hand drawn image.

6. Approach Azimuth And DME/P And Back Azimuthstation Specifications

The proposed MLS system on RWY 27 has the following components in approach azimuth and DME/P station, and back azimuth equipment antennas are chosen according to the configuration table below.
Table V: configuration types of azimuth and elevation antennas for our design, type III is chosen

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TYPES	Azimuth guidance		Elevation guidance	
	Beam width	Scan angle	Beam width	Scan angle
Type I	2°	±40°	1.5°	$0.9°to\ 15°$
Type II	2°	±40°	1.0°	$0.9°to\ 15°$
Type III	1°	±40°	1.5°	$0.9°to\ 15°$
Type IV	1°	±40°	1.0°	$0.9°to\ 15°$
Type V	1°	±10°	1.0°	$0.9°to\ 15°$
Type VI	1°	±60°	1.0°	$0.9°to\ 15°$
Type VII	3°	±40°	2.0°	$0.9°to\ 15°$

Table VI: Approach azimuth and DME/P station specifications.

Components	Specifications
Approach azimuth antenna	1° beam width, with ±40° proportional lateral guidance
Elevation antenna	1.5° beamwidth,$+0.9°to+15°$ vertical proportional guidance
Back Azimuth antenna	1° beam width, with ±40° proportional lateral guidance
DME/P antenna	CH 126X (1050MHz for interrogation and 1213 MHz replies, with 12microseconds pulse codes for interrogation and replies) Note: If this DME station has to be coupled with VOR station.it will have 117.90 MHz

V. FUTURE SCOPE

Though MLS system has a number of advantages over ILS system, it has not obtained the wide spread due to the new landing system GLS or GBAS(ground based augmentation system) landing systemwhich makes use of Global Navigation satellite system (GNSS and GPS),for its operation, but the standard GPS does not provide the required accuracy for precision approaches, so the ground based augmentation system (GBAS) ,is built at airport ,to give differentially corrected GNSS corrections data to equipped aircrafts and let them fly the precision approaches with higher flexibility. ICAO requirements for GLS CAT I are contained in ICAO Annex 10 Volume 1; corresponding procedures for CAT II/III are under development. GLS system is established over 100 airports worldwide, like Blemen, Malaga, Frankfurt, and Zurich and so on. So it is worthy to explore more about this astonishing landing system, which has eclipsed the rise of MLS system and does not require much training for pilots to fly it as it uses the same procedure as that of ILS system [12]. The picture below shows the basic architecture of GLS system.

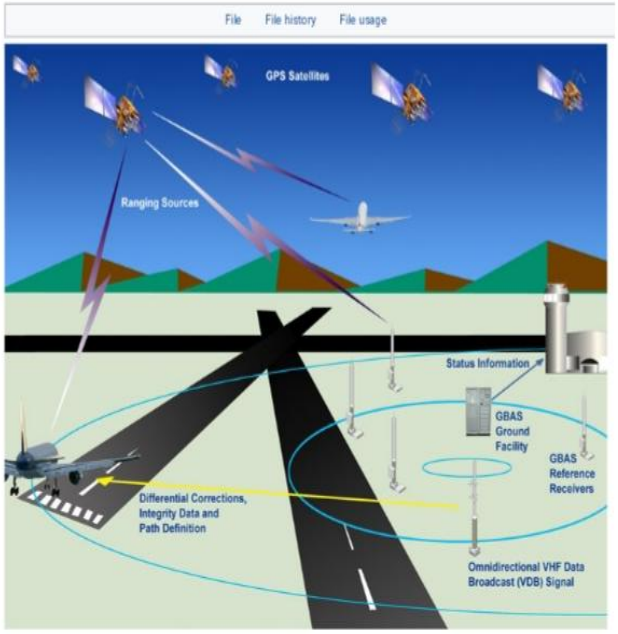

Fig.25. GLS architecture, source [13].

VI. CONCLUSION

The comparative study of ILS system and MLS system has shown that MLS system has many advantages over ILS system such as allowing STOL aircrafts for their approach procedures, having 200 channels and many more. The study of MLS system lead to the proposed MLS prototype on RWY27 of Bangalore international airport, but its feasibility has to be ascertained by experienced engineers after visiting the site, to check obstacle clearance requirements and check the coexistence with current ILS system.

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