Verification of the Accuracy of an Instrument Landing System's Localizer: A Study of an International Airport in Nigeria

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ABSTRACT

This work investigates the accuracy of an Instrument Landing Systems' (ILS) Localizer in a Nigerian International Airport. It involved a twelve-month measurement of the Difference in Depth of Modulation (DDM) in the ILS localizer transmitter with respect to Angular Displacement, via ground measurements, using R & S "EVS300 Analyzer" and subsequent analysis using Graph-pad prism 5.01. The ILS is a precision approach electronic aid which provides pilots with both vertical and horizontal guidance during landing.

It was observed that during the months of January, February, and May to September, the radiations from the 90Hz and 150Hz sectors vary insignificantly, producing mean DDM (%/m) of: 0.0031, 0.0043, 0.0027, 0.0022, 0.0042, 0.0035, and 0.0045, respectively. However, for March, April, October, November, and December, appreciable values of: 0.043, 0.028, 0.033, 0.035, and 0.032, respectively, were obtained from the radiations. These not only indicate that the amplitudes of the electromagnetic wave from the 150Hz sector were higher than those from the 90Hz sector, but also, the localizer indicator in an in-flight situation would indicate corresponding values of displacement from the course line. Thus, for the aircraft to land on the center line, the pilot would have to yaw to the left of the approaching axis.

Since, the ILS localizer provided adequate signal between $\pm 30^{\circ}$ and has minimum and maximum DDM values of: 0.003 and 0.043, respectively, which are less than the course sector value of 0.155 stipulated in ICAO, Annex 10, volume 1, it could be said to have a high accuracy.

(Keywords: accuracy, ILS localizer, transmitter and receiver, runway centerline, course line, DDM deviation, frequency, equi-signal, in-flight, electromagnetic, and radiation)

INTRODUCTION

Research has shown that 51% of plane crashes occur during final approach and landing (Robert, et al., 2015) as shown in Figure 1. There have been reports of radio signal interference on the signals from some Navigational Aids (Nav-Aids) present in some major airports of the world (FAA, 2014; CNS, 2017) which could lead to false signals, which in turn, reduces the precision of the Nav-Aids. The better the precision of any Nav-Aid, the smaller the deviation of the aircraft from the runway center line, the lower the risk of crash during landing (Mahbuba, et al., 2017). Therefore, it is essential to subject radio navigation aids to routine flight and ground checks to ensure that they have high integrity, accuracy, availability, and continuity.

Pragmatically, the performance of certain ILS parameters can be accurately determined with greater reliability via the ground measurement than flight technique (Mahbuba, et al., 2017; ICAO, 2000). In general, the essence of ground measurement is not only to ensure that the electromagnetic radiation from the ILS meets the standards of annex 10, volume 1, but also, to confirm the correct monitor operations (CNS, 2017). Although each of the listed conditions is important, the accuracy of the ILS Localizer will be investigated in this research via ground measurement.

Figure 1: A Landing Case Crash of Overland Aircraft on Fire at Lagos Airport, Nigeria (*Daily Post*, 2018).

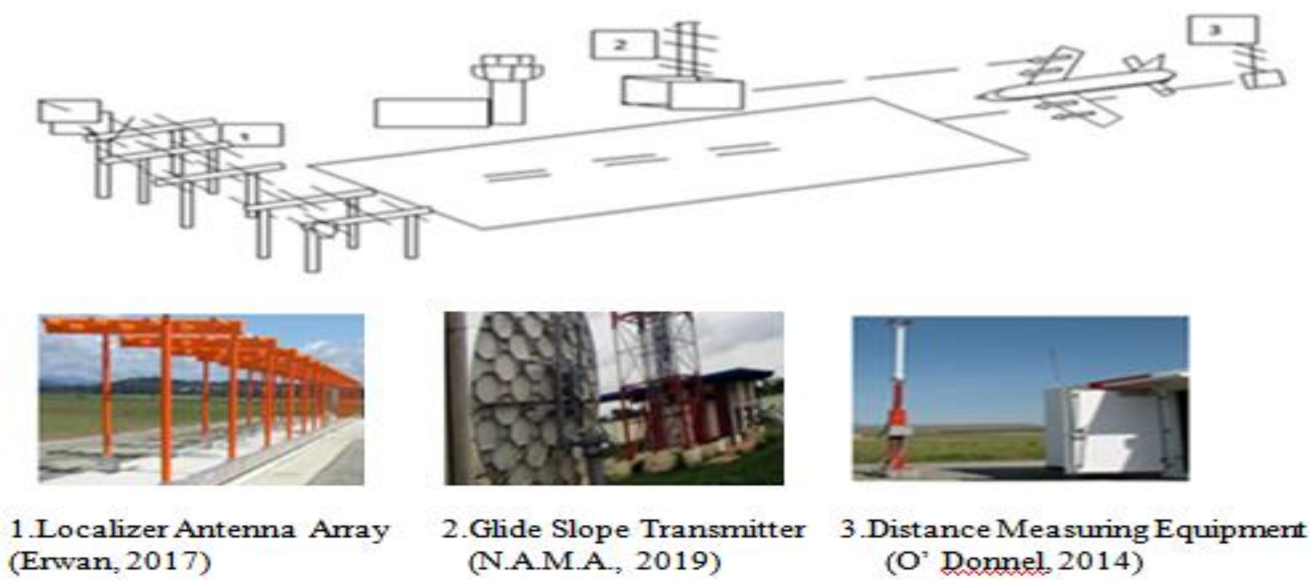

Figure 2: The Instrument Landing System with its Components: Localizer Transmitter, Glide Path Transmitter, and Distance Measuring Equipment.

The ILS is not only a short range, precision runway approach navigation aid which provides vertical and horizontal guidance to a pilot of an aircraft approaching landing (Mahesh, 2012), but it is also a terminal area surveillance in an environment. This instrument finds great application during poor visibility and night landings in civil aviation. In fact, it furnishes the pilot with information of its aircraft's position relative to the ideal landing course via the signals produced by the Localizer and Glide Path Transmitters and Distance Measurement Equipment (DME).

It is interesting to note that, the signals from these transmitters produce the approach angles of Azimuth and Elevation, respectively, while the Marker or DME provides the range from predetermined points along the descent path (namely, outer marker, middle marker and inner marker) to touch down (Muzaffar, 2015). The azimuth and the elevation are observed by means of cross pointers present in two cockpit meter indicators, while the range is observed by means of light system, in conjunction with audio signals received via the pilot's headset. A pointer indicates the direction of approach to align the aircraft to the center line on the runway. However, when the received signal is insufficient for the aircraft, a Flag indication or Warning is raised (FAA, 2014).

Localizer

The Localizer antennas transmit signals of two amplitude modulated carrier frequencies operating between 108MHz and 111.975MHz. The Localizer produces two main lobes of electromagnetic radiation, which overlap along the center of the runway. The lobes on the left and the right sides of the approaching aircraft are modulated by frequencies of 90Hz and 150Hz, respectively (ICAO, 2014).

By convention, the 90Hz modulation is called the YELLOW SECTOR, while the 150Hz modulation is termed the BLUE SECTOR. The line along the runway in which both sectors have equal modulation is termed the Center line (Christopher, 2014). The difference in intensity of the radiations between the two sectors divided by 100 is called the 'Difference in Modulation Depth (DDM)' (ICAO, 2014) which indicates the aircraft's position relative to the approach axis. Thus, center line may be regarded as that position along the runway in which the DDM is zero. The principle operation of the ILS localizer is the production of an equi-signal beam by two overlapping directional radio transmissions: Any difference in strength from the two patterns results in deviation from the equi-beam and the aircraft receiver indicates this as a deviation from the Localizer course on the ILS indicator (Capkova, 2010; Erwan, 2017).

Furthermore, at ground stations, the ILS provides signals that vary linearly in modulation depth from the course line at a rate of 0.145% per meter. At the outer extremity of the course sector, the DDM has a full-scale deflection current of 150μA or 0.155%/m. During final approach to the runway, the localizer utilizes the concept of space modulation to provide horizontal guidance to an aircraft. Prior to rectification and transmission as voltage to the vertical needle of the cross-pointer indicator, Band-pass filters are utilized in the airborne receiver in the separation of the localizer output signal into 90Hz and 150Hz components.

Pilots of aircrafts with multiple Very High Frequency (VHF) navigation system are provided with switching that enables quick connection to any of the receiver with the indicator. The localizer transmits signal up to a range of 46.3km (Kumar, 2016; FAA, 2014; Christopher, 2014). Angular displacement sensitivity is the quotient of the recorded DDM with the corresponding angular displacement from the appropriate reference line (GN, 2017) and this is a measure for the determination of the accuracy of the ILS localizer.

The Glide Path

The Glide Path Transmitter operates in the Ultra High Frequency (UHF) Band between 328 and 335MHz and the electromagnetic radiation form equi-signals that are modulated at 90Hz, above and 150Hz, below the glide path. Glide-path transmitters generate a space modulated signal by the vector addition of two or more signals that vary with the position of the plane.

The difference between the two modulation depths from the ground station generates an error current signal through an airborne receiver which the deflection of a moving coil indicator, called; Horizontal Situation Indicator (HIS) interprets (FAA, 2014). The transmitted power from the two radiations are not equal, the 90Hz radiation is more powerful than the 150Hz. This condition immediately makes apparent any false equi-signal indication to the pilot. ICAO, (2014), specifies that any false glide path shall occur at an angle of at least 15^0 above the horizontal. The glide path transmitter has a signal range of up to 18.5 km, (Erwan, 2017; Titze, 2011, Kumar, 2016).

Distance Measuring Equipment (DME)

The DME is a standard navigation instrument that furnishes the pilot of an in-flight with a slant, line of site range measurement in nautical miles, (NM) from a specific beacon in the airport. It consists of a UHF transponder collocated with the VOR on the ground and a UHF transceiver in the aircraft (GCAPL, 2016). Its operation is based on the transmission of 1kW peak power on a frequency range of 1025-1150MHz. Each pulse is delayed by 12μs or 36μs providing 252 channels of operation.

The frequency of transmission behaves like a local oscillator in which the pulses received by the transponder on the ground is delayed by 50μs and replied with the same power on the provided frequency channel of 252. DME has a range of 185 km and an accuracy of 30m (Richardson, 2012).

METHODOLOGY

Data Collection

In this research, readings were taken at the Runway Localizer Antenna station of the Nigerian International Airport once in a month for a period of 12 months during the wet and dry seasons using the ground measurement technique.
The procedure involves:

- The measurement of difference in the depth of modulation of the Instrument Landing System (ILS) localizer with respect to angular displacement for each month using the R&S evs300 Analyzer.

- The analysis of the data using Graph pad prism 5.01.

The Measurement Site

The International Airport is located in Western, Nigeria, and it is approved by the following bodies: International Air Transport Association (IATA) and ICOA (International Civil Aviation Organization)). It is one of the busiest airports in the country. The Airport consists of an international and a domestic terminal, located about one kilometer apart.

Both terminals share the same runways. The airport has two asphalt-built runways, the: $2.743\text{km} \times 0.045\text{km}$, 18L and $3.900\text{km} \times 0.060\text{km}$, 18R.

Figure 3: An Aircraft Landing on the Centerline of one of the Runways at an International Airport in Nigeria (Abbey, 2014).

Instrumentation

The following measures were taken when using the R&S EVS300 Analyzer shown in Figure 4 for data collection:

- The Measurement instrument's Antenna was made to face the ILS Transmitter Antennas in order to maintain line of site transmission, LOS.

- All obstructions were avoided.

- All readings were stable before proper documentation in the logbook.

- As much as possible, parallax error was avoided when taking the readings from the R&S EV300 Analyzer. Figure 4: presents the picture of of R&S EV R&S EV300 Analyzer.

The Instrument Landing System (ILS) at the airport consists of the following:

I. The Localizers- located at the ends of the respective Runways radiate at frequencies of 108.1 MHz and 110.3MHz respectively. The antennas are sited beyond the stop-end of the runway at a distance of 250m. The transmitter shelter is offset from the center line of the runway so as not to cause obstruction. Figure 5 presents the schematics of the antenna system and the transmitter cabinet of the Localizer, while, table 1 presents the specification of the Localizer present in the airport. The localizer at the airport consists of an array of 12, high gain and directivity dipole antennas which enables the pilot of an in-flight to determine and land on the center-line of the runway.

II. Two Glide Slopes antennas (GS) are located adjacent to the Runways in alignment with the touchdown positions on the runways and Transmit UHF signals at 335MHz and 334.7MHz respectively. The signals provide an upper and lower range of slope to an approaching aircraft up to a distance of 10NM.

III. The Distance Measuring Equipment (DME) which is co-located with the VHF Omni directional Radio Range VOR.

Figure 4: Picture of R&S EVS300 Analyzer (Rohde & Schwarz, 2014).

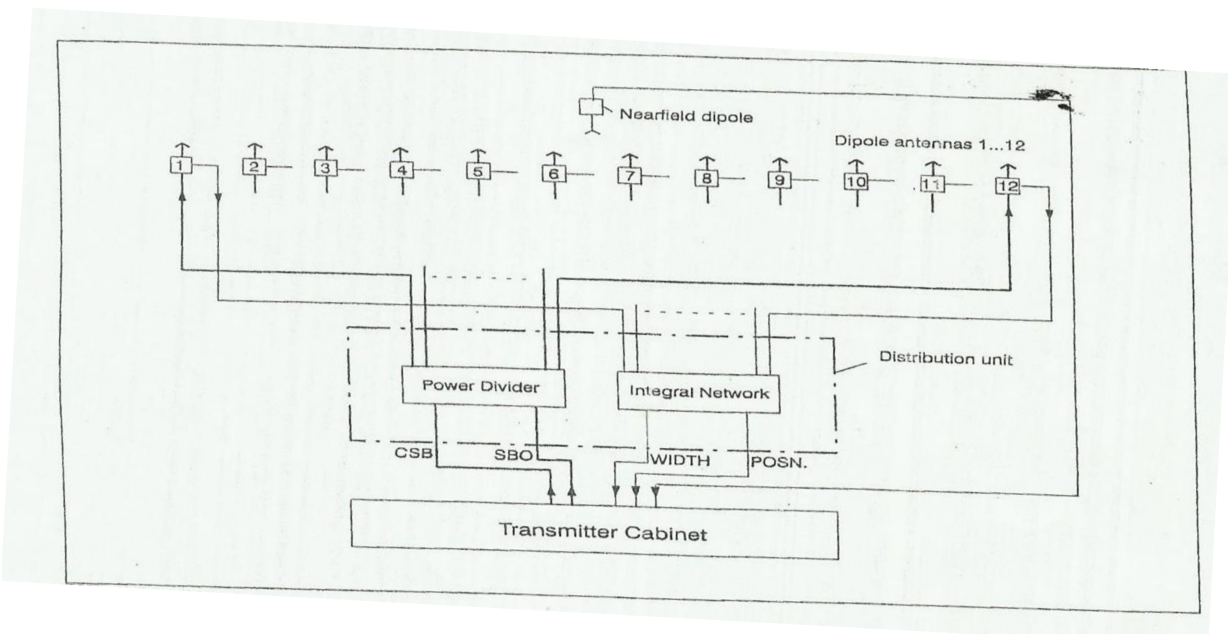

Figure 5: Schematics of the Antenna System and the Transmitter Cabinet of the Localizer (NATM).

Table 1: Specification of the Localizer Present in the Airport.

Frequency of Transmitter 1& 2 18L Runway	110.3MHz
Frequency of Transmitter 1& 2 18R Runway	108.1MHz
Number and Type of Transmitter Antenna	12 –element Log Periodic Dipole array
Transmitter Antenna Height	3.2m
Visibility Minimal	800m
Range	25NM
Modulation Frequency	90 and 150Hz
DDM Stability	$\pm 0.002\ \%$
CSB Power Output	15W

RESULTS

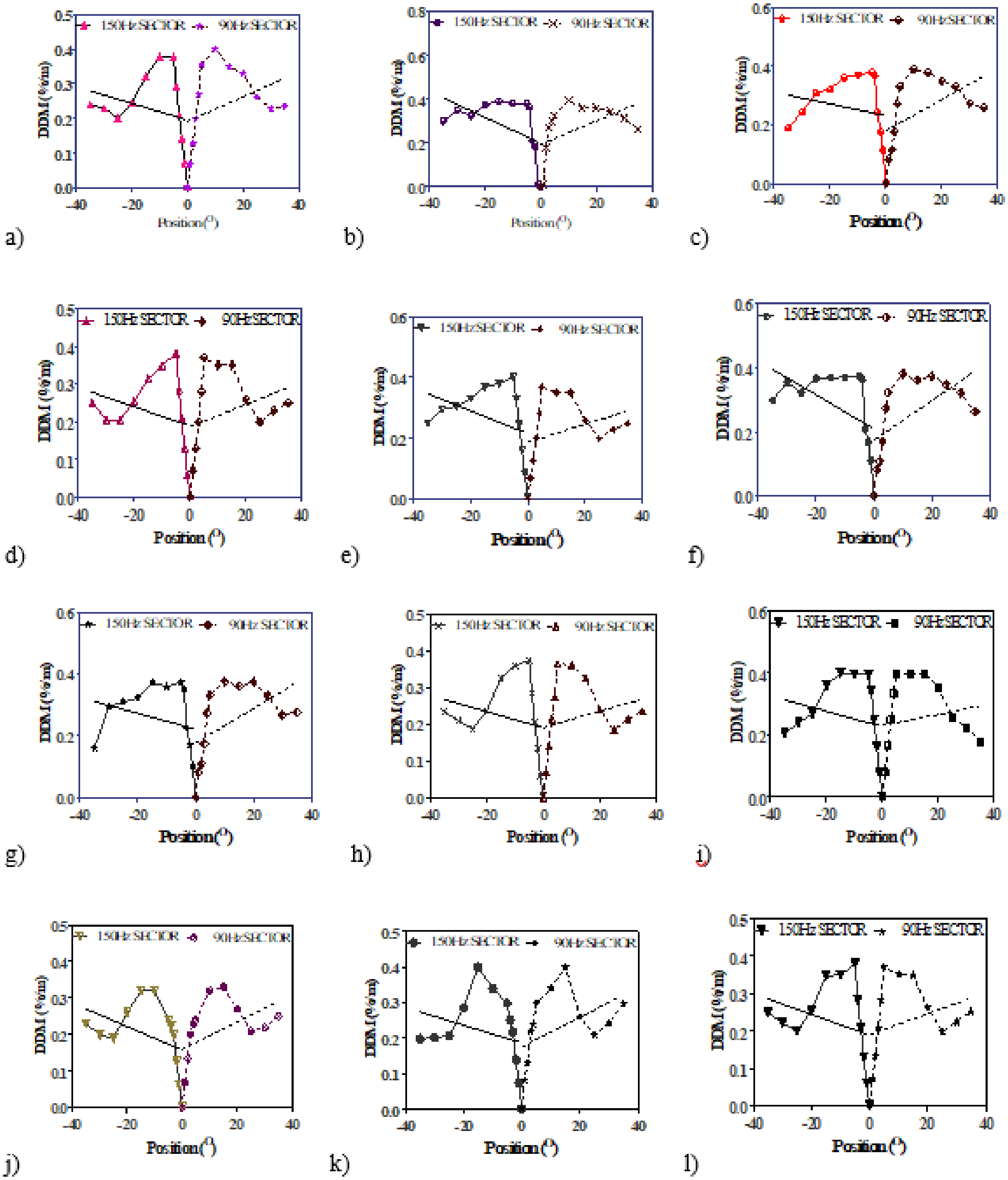

Figure 7: The Variation of DDM with Position for Different Flights in the Months of (a) January, (b) February, (c) March, (d) April, (e) May (f) June (g) July, (h) August, (i) September, (j) October, (k) November, and (l) December at the International Airport in Nigeria.

DISCUSSION

The radio signal transmitted by the localizer's 12-element, log periodic, dipole array, produces a composite electromagnetic field that consist of 90Hz and 150Hz amplitude modulated signals on a frequency band of (108.1 MHz -110.3 MHz). It is important to note that, this signal is horizontally polarized and consists of Electric field, E, and Magnetic field, M, with the direction of the Poynting vector: $(S = E \times H(W/m^2))$ the same as the direction of propagation of the wave.

Prior to transmission, a power amplifier is employed in modulating the two signals in space. An equi-signal beam is produced where the 90Hz signal overlaps the 150Hz signal and at this point the DDM is zero thus, an in-flight would land on the center line. However, a deviation from the position of equi-signal indicates a difference in strength of the modulated signals and an approaching air craft's indicator instrument, indicates this, as a deviation from the center line.

It was observed from Figures 7 (a), (b), (d), (g), (i), (j) and (l) that, the radiation patterns of the electromagnetic wave from the 90Hz and 150Hz sectors of the ILS localizer were symmetrical about the Localizer centerline. Thus, for the indicated periods, the amplitudes of the radiation from the two sectors vary insignificantly, producing DDM Deviation (%/m) of: 0.0031, 0.0043, 0.0027, 0.0022, 0.0042, 0.0035 and 0.0045 respectively. Since these values were less than the tolerance values specified in CNS, 2017, they signify that, there was little or no signal obstruction which could cause any significant interference with the radiated electromagnetic waves from the 90Hz and 150Hz sectors. Furthermore, it could be deduced from the above values, that, the track bar of the in-flights would be slightly deflected from the Localizer center line by those insignificant values and would land on the runway center line with greater precision.

However, observation of Figures 7(c), (e), (f), (h) and (k) revealed that the radiation patterns of the electromagnetic wave from the 90Hz and 150Hz sectors of the ILS localizer were fairly symmetrical about the Localizer centerline. Thus, for the indicated periods, the amplitudes of the radiation from the two sectors vary slightly producing DDM Deviation (%/m) of: 0.043, 0.028, 0.0342, 0.033, 0.035, and 0.032, respectively. These indicate that, for each of those periods, the amplitudes of the radiation of the electromagnetic wave from the 150Hz sector were a bit higher than those from the 90Hz sector by the above values, which signifies that the in-flight position would be in the direction of the 150Hz (the right of the runway centre line).

Since, the values are less than DDM value of 0.155 necessary for the aircraft to be off course as stipulated in SARP, ICAO, Annex 10, Volume 1, in -flights at those periods would still be within the course sector with little deviations from the runway's center line. Thus, the track bar of the approaching aircraft would be deflected a little to the left of the course plan (horizontal). Therefore, in order that the approach aircraft would be on the center line, the pilot would have to perform some course correction by flying to the left of the approaching axis in correspondence to the indicated values for each of those flights. Furthermore, should the correction be ignored the in-flights would land on the centerline of the runway with less precision. The slight DDM variation could be attributed to a little interference with the radiated electromagnetic waves from the antennas of the ILS localizer at those periods.

In general, the observed DDMs were substantially linear from the front course line i.e., ±10° from either side of the point at where the angle was 0°. It was further observed that between ±10° to ±35° the DDMs were less than 0.0775 which indicates that the radiations were within the half course sector which is an indication that the ILS localizer radiates electromagnetic beams with a high accuracy.

CONCLUSION

The ILS localizer has a minimal DDM value of 0.003%/m and maximum value of 0.043%/m and the values are less than the course sector value of 0.155 stipulated in ICAO, Annex 10, volume 1 therefore it could be said to have a high accuracy level.

RECOMMENDATIONS

Since, ILS antennas are prone to electromagnetic interferences from mobile phones, communication masts, buildings, fences, and power-lines, the aforementioned should not be operated or located near any of its antennas. Furthermore, rather than having a simple approach lighting system on the 18L Runway, it is advised that it be furnished with a higher precession approach lighting system as in the 18R Runway, as this would aid better landing with ease during poor visibility or at night.

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