Characterization of Angular Error in Magnetic Head Tracking

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ABSTRACT
The head tracking system in a helmet mounted display (HMD) play a vital role in obtaining its full functionality. It tracks and calculates the current location and coordinates of the pilot's head movements and updates the head movement's location in real time. They provide accurate information to the flight computer about the orientation of the head of the pilot with high degree accuracy and extremely low impact on Helmet mounted display (HMD) weight, size and packaging. The magnetic head tracking are used widely for head tracking. It determines the pilot's head position, relaying this position to the sensor, the sensor's movement to the correct line-of-sight, the sensor's acquisition of the scene, and transmitting and presenting the final imagery on the helmet mounted display. All this takes some finite time. In this paper, discussions have been made about the angular error associated with the magnetic head tracking technique which is mostly used today due to its several advantages. The magnet head tracking has been evaluated and the angular error and the factors associated with this technique have been studied in detail. Since magnetic sensors are very sensitive to environment, their operational limitation was evident in the experimental results when the magnetic receiver located on the helmet was moved away from the magnetic transmitter in the linear as well as the angular distance. Hence, they are not easy to operate. The angular error in magnetic head tracking has been characterized and subsequently the correction algorithm has been implemented using LabVIEW in real time.

Keywords
Helmet mounted display, Magnetic head tracking, Line of sight, Magnetic field, cDAQ.

1. INTRODUCTION
Helmet mounted displays used in modern aircraft application allow pilot to view critical flight and data projected onto the inside of their visor, so they do not have to look down at their cockpit instruments to lock on sensor or weapons to target [1]. Need for a HMD to present flight, weapon, and targeting in the pilot's line of sight (LOS) gets major importance as mission and weapon sensors increase in complexity [2]. The helmet effectively blocks out any input from the outside world, thus creating a very immersive environment for the pilot. The pilot changes his view of the outside world by moving his head thus moving the helmet in the process. For this reason, head tracking system while using head-mounted displays is extremely important [3]. Head tracking is used to update the position of head movements. Speed and accuracy of these updates is even more critical because any lag in the head tracking and image update will be immediately obvious to the pilot. To determine the angular coordinates of pilot's line of sight, it is required to measure the orientation of pilot's head. The problem becomes complex due to the fact while measuring the angular orientation of an object, both translation and rotation causes measurement interactions. Head tracker provide the accurate information to the flight computer about orientation of pilot head with high degree of accuracy and low impact on HMD weight, size, etc.

Head tracking systems are of various types viz. magnetic, optical, mechanical, acoustic and inertial [4]. The magnetic head tracking technique and associated angular error have been studied in detail in the work presented in this paper. Magnetic head tracking use the magnetic sensors for updating the position and orientation of head movements. It uses set of coils in cockpit that produce magnetic field and magnetic sensors are mounted onto helmet which determines the strength of magnetic field. According to change in magnetic field, the sensor output changes which are then analyzed to determine the position and orientation of the head movements.

2. DISCUSSIONS ON MAGNETIC HEAD TRACKING
A narrow-band magnetic field transmitter in a cockpit is a common technology for tracking the pilot's LOS [5]. A common LOS tracker for HMD system is based on transmitting a narrow band magnetic field within the cockpit area and analyzing the signal received at the helmet to calculate the pilot's head orientation in real time domain [6]. Magnetic tracking systems can measure 6-dimensional positions. Accuracy is impaired seriously in magnetic tracking by distortions of the magnetic fields caused by many types of metal which are omnipresent within the cockpit area or at real sites [7]. Magnetic motion trackers have advantages such as less size, low cost, less drift, both wireless and wired model, occlusion-less tracking environment and high sample rate. Issues such as latency and jitter leave magnetic tracker technology disadvantageous as compared to other tracker technologies. While latency is due to tracker hardware devices, the jitter is due to magnetic field distortion caused by the presence of metallic structures present nearby. These issues are very important when employed for virtual environment systems, virtual reality or augmented reality applications [8].

Magnetic tracking is accomplished by creating magnetic field that can be sensed by a set of sensors. Assembly of many stationary orthogonal coils, known as a transmitter, generates low frequency field. Another sensor functions as receiver to sense the relative position with respect to transmitter. The receiver senses the changes in the magnetic field caused by movement. These changes are processed and recorded by an algorithm that determines the position and orientation of the receiver in relation to the transmitter. The position and orientation data is then sent to the computer to update the virtual environment display [9].

Magnetic head tracking has many advantages viz. measurement of position and orientation in 3-dimensional space, no requirement of direct line of sight, low hindrance, good performance close to emitter, easy scalability into finished devices, and earth magnetic field good for 3 degree of freedom. Its disadvantages include latencies due to filtering, electromagnetic interference, decrease in accuracy with distance, and ferromagnetic/metal conductive surface cause field distortion [10].

3. SENSOR CONFIGURATION AND METHODOLOGY

The correction algorithm is depicted in fig. 1.

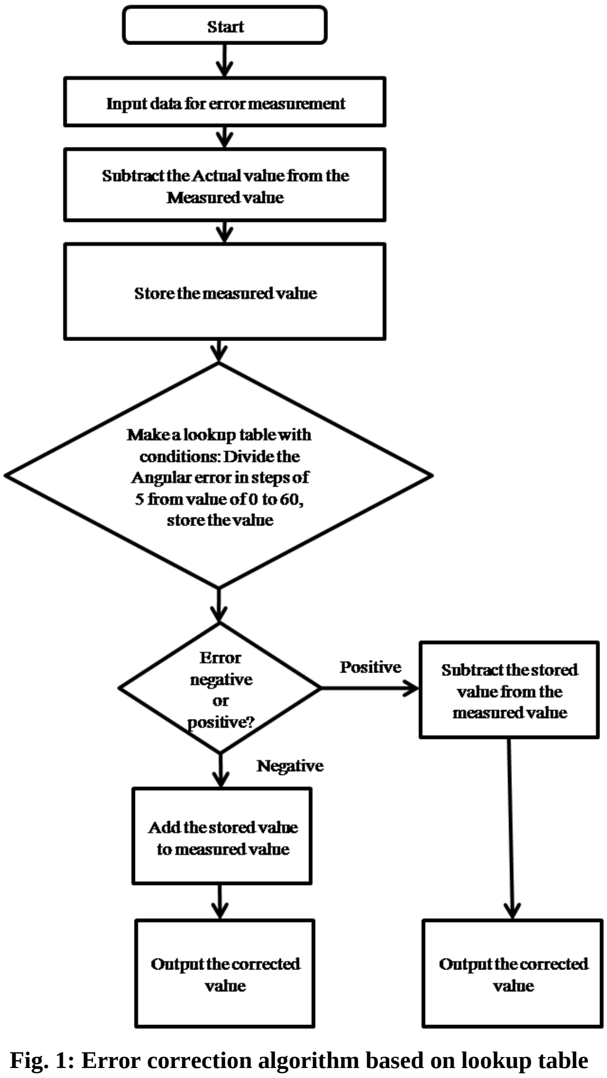

Fig. 1: Error correction algorithm based on lookup table

Choosing the physical medium and sensors for a tracking system decides only a part of its capability. The geometric configuration and the relative location of the source and sensor have a significant effect. Magnetic sensors are different from other sensors in several aspects. They do not measure directly the physical property of interest, but can detect changes or disturbances in magnetic field created or modified. From these measurements, direction, rotation, angle, electrical currents, etc. are estimated. The output signal of these sensors is required to be conditioned to result in translation into the desired parameter. Magnetic sensors are classified based on whether they are measuring the total magnetic field or the vector components of the magnetic field. The techniques utilized to make both types of magnetic sensors embrace many aspects of physics and electronics. Common techniques used for magnetic field sensing include flux gate, search coil, optically pumped, nuclear precession, SQUID, Hall-effect, anisotropic magneto-resistance, giant magneto-resistance, magnetic tunnel junctions, giant magneto-impedance, magneto-piezoelectric composites, magneto-diode, magneto-transistor, fiber-optic, magneto-optic, and microelectro-mechanical systems based magnetic sensors [11].

The device KMA210 has been used as magnetic angle sensor in the experimentation. The devices integrate the magneto resistive (MR) sensor bridges, mixed signal integrated circuit and the required capacitances. The device is pre-programmed, pre-calibrated and allow user defined tuning of angular range, zero angle and clamping voltages. It amplifies two orthogonal differential signals from MR sensor bridges followed by converting them into digital domain. Coordinate rotation digital computer (CORDIC) algorithm is used to calculate the angle. After a digital-to-analog conversion, the analog signal is provided to the output as a linear representation of the angular value. The selected device has many advantages which high precision angular measurement, high temperature range up to 160˚C, magnet-loss, power-loss and broken bond wire detection, low supply voltage detection and over voltage protection [12].

4. EXPERIMENT SETUP

Fig. 2 shows the experimental setup used for measurement of angular distance using magnetic sensor. The experimental setup included [1]Magnetic sensor, [2]NI-CDAQ 9172, [3]Computer Installed LabVIEW, [4]Magnetic Field Generator, [5]Power Supply and [6]Helmet.

The detector was placed on the helmet. The helmet was allowed to rotate from 0 to 180 degree while relative distance between helmet sensor and the transmitter was varied and kept at 250mm, 300mm, 350mm and 400mm. The resultant analog voltage is conditioned by CDAQ card of NI and converted into digital data. The code written in LabVIEW computes the values and estimates the error. The error is then minimized. The fig. 3 shows the block diagram of methodology employed on LabVIEW GUI screen.

Fig. 2: Experiment setup

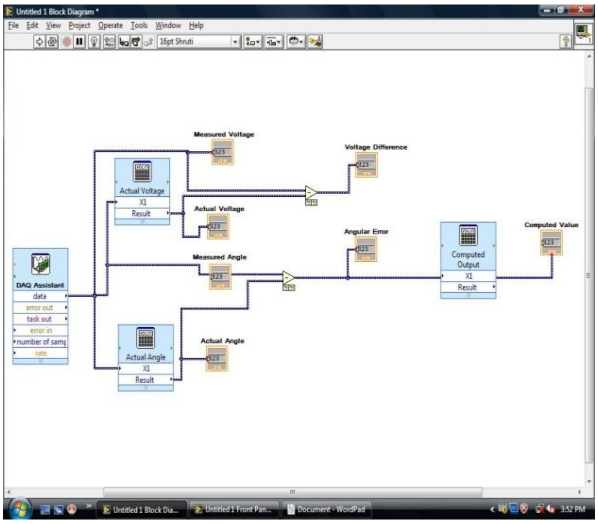

Fig. 3: Block diagram employed for angular error correction in magnetic head tracking using NI LabVIEW platform.

5. RESULTS

This section presents the detailed results. The angular error is due to the electromagnetic interference from radio, metal conductive surface cause field distortion, environment conditions, low magnetic field strength, and other parameters like hardware components used. The resultant angular measurement has been carried out for four different distances and accordingly angular measurement error is estimated. The experiment has been carried by varying distance between the transmitter and the receiver keeping it 250mm, 300mm, 350mm and 400mm.

5.1 Setup 1

a) At distance of 250 mm between the transmitter and receiver, the sensor voltage output is measured for different angular positions of the helmet sensor corresponding to the helmet movement.
b) A graph plotted with the voltage (actual and measured) on y axis and angular field on the x axis is shown in fig. 4.
c) Fig. 5 shows the relationship of Actual angular field vs. the measured angular field.
d) Fig. 6 shows the relationship of the actual angular field with the angular error before and after correction.

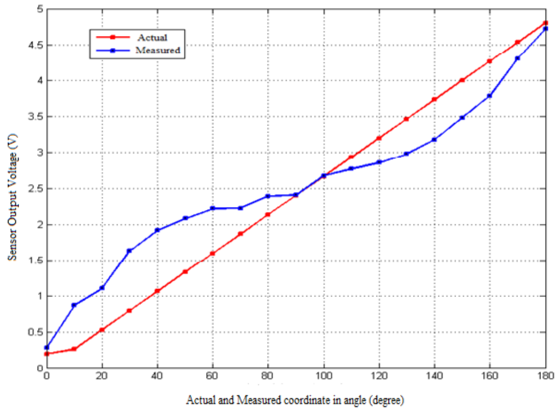

Fig. 4: Variation of the voltage (actual and measured) against the angular field in degrees for magnetic transmitter located at distance of 250mm from the magnetic receiver

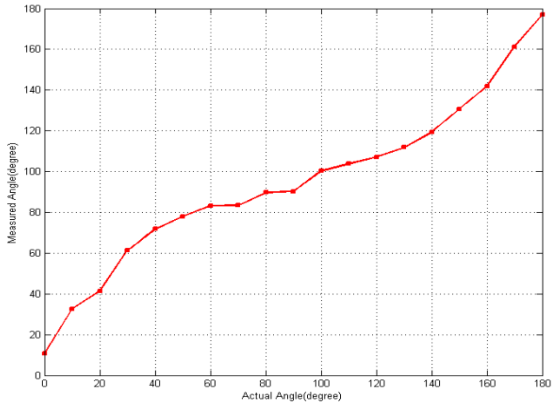

Fig. 5: Variation of the measured angular field against the actual angular field for magnetic transmitter located at distance of 250mm from the magnetic receiver

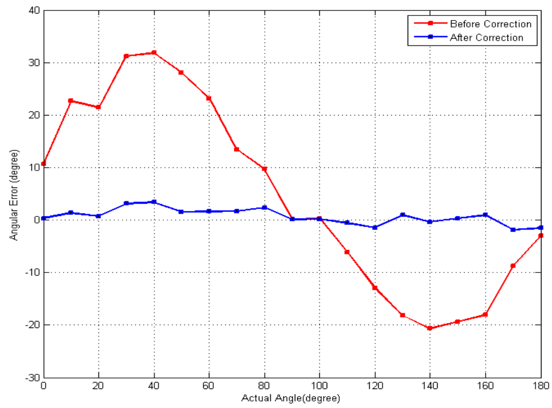

Fig. 6: Relationship of the angular error before and after correction with the Actual field for magnetic transmitter located at distance of 250mm from the magnetic receiver

For distance of 250mm between the magnetic transmitter and the receiver, the pattern of error varied between positive to negative value as the position of the magnetic receiver situated on the helmet crosses the 90 degree position during its movement from 0^0 to 180^0 through 90^0 positions with respect to the position of the magnetic transmitter. The error varies from $+32^0$ to -20^0 through 0^0 before implementing correction factor. After implementing the correction factor, the error varies between $+3^0$ to -2^0 as the magnetic receiver on the helmet moves from 0^0 to 180^0 position through 90^0 with respect to the magnetic transmitter location.

5.2 Setup 2

a) At distance of 300 mm between the transmitter and receiver, the sensor voltage output is measured for different angular positions of the helmet sensor corresponding to the helmet movement.

b) A graph plotted with the voltage (actual and measured) on y axis and angular field on the x axis for this condition (relative distance of 300 mm between the transmitter and receiver) is shown in fig. 7. Fig. 8 shows the relationship of Actual angular field vs. the measured angular field. Fig. 9 shows the relationship of the actual angular field with the angular error before and after correction.

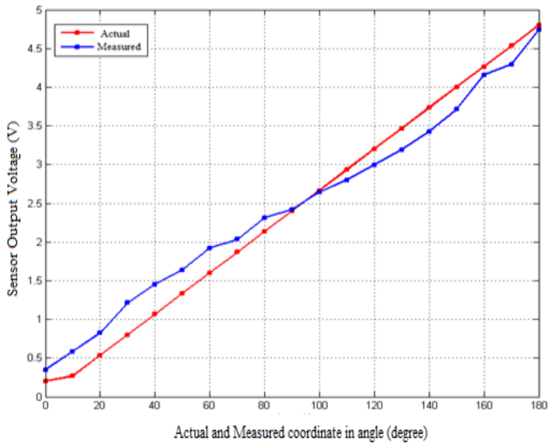

Fig. 7: Variation of the voltage (actual and measured) against the angular field in degrees for magnetic transmitter located at distance of 300mm from the magnetic receiver

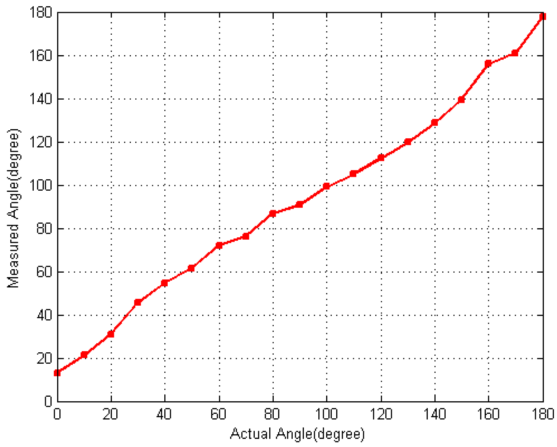

Fig. 8: Variation of the measured angular field against the actual angular field for magnetic transmitter located at distance of 300mm from the magnetic receiver.

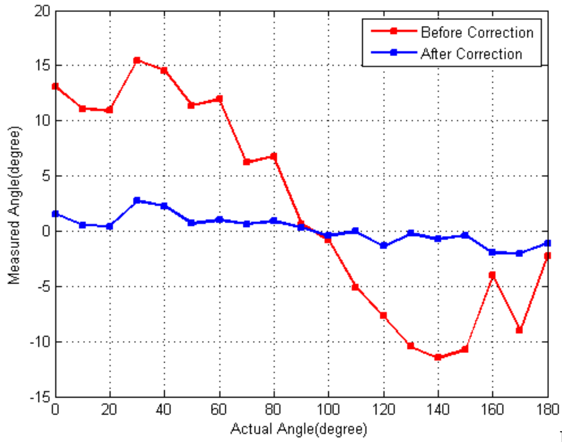

Fig. 9: Relationship of the angular error before and after correction with the Actual field for magnetic transmitter located at distance of 300mm from the magnetic receiver.

For distance of 300mm between the magnetic transmitter and the receiver, the pattern of error varied between positive to negative value as the position of the magnetic receiver situated on the helmet crosses the 90 degree position during its movement from 0^0 to 180^0 through 90^0 positions with respect to the position of the magnetic transmitter. The error varies from $+16^0$ to -13^0 through 0^0 before implementing correction factor. After implementing the correction factor, the error varies between $+2.5^0$ to -2^0 as the magnetic receiver on the helmet moves from 0^0 to 180^0 position through 90^0 with respect to the magnetic transmitter location.

5.3 Setup 3

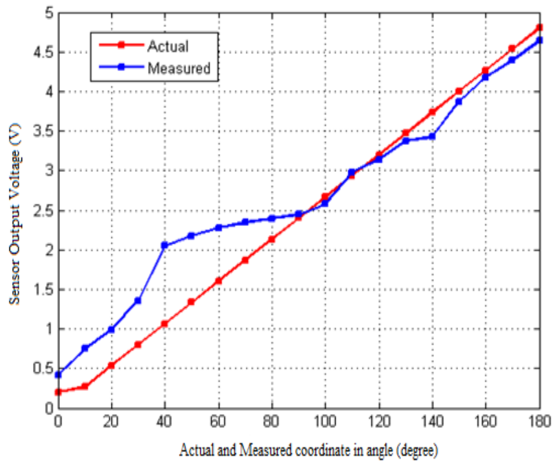

Fig. 10: Variation of the voltage (actual and measured) against the angular field in degrees for magnetic transmitter located at distance of 350mm from the magnetic receiver.

a) At distance of 350 mm between the transmitter and receiver, the sensor voltage output is measured for different angular positions of the helmet sensor corresponding to the helmet movement.

b) A graph plotted with the voltage (actual and measured) on y axis and angular field on the x axis for this condition (relative distance of 350mm between the transmitter and receiver) is shown in fig. 10. Fig. 11 shows the relationship of Actual angular field vs. the measured angular field. Fig. 12 shows the relationship of the actual angular field with the angular error before and after correction.

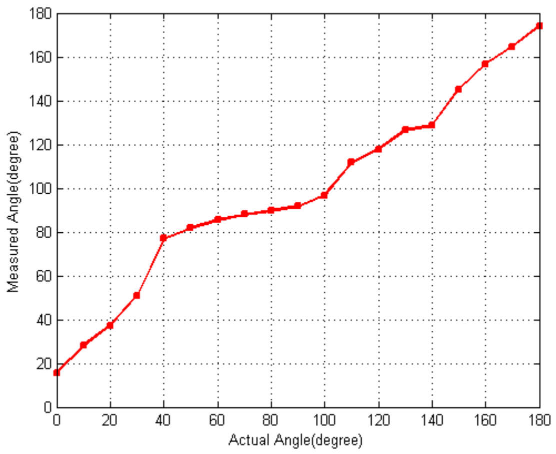

Fig. 11: Variation of the measured angular field against the actual angular field for magnetic transmitter located at distance of 350mm from the magnetic receiver.

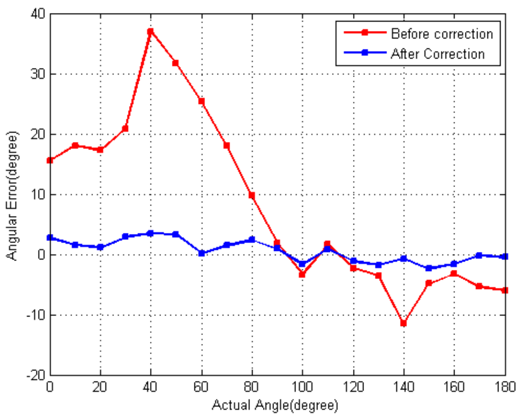

Fig. 12: Relationship of the angular error before and after correction with the Actual field for magnetic transmitter located at distance of 350mm from the magnetic receiver.

For distance of 350mm between the magnetic transmitter and the receiver, the pattern of error varied between positive to negative value as the position of the magnetic receiver situated on the helmet crosses the 90 degree position during its movement from 0^0 to 180^0 through 90^0 positions with respect to the position of the magnetic transmitter. The error varies from +37° to -12° through 0° before implementing correction factor. After implementing the correction factor, the error varies between +3° to -2° as the magnetic receiver on the helmet moves from 0^0 to 180^0 position through 90° with respect to the magnetic transmitter location.

5.4 Setup 4

a) At distance of 400 mm between the transmitter and receiver, the sensor voltage output is measured for different angular positions of the helmet sensor corresponding to the helmet movement.

b) A graph plotted with the voltage (actual and measured) on y axis and angular field on the x axis for this condition (relative distance of 400 mm between the transmitter and receiver) is shown in fig. 13. Fig. 14 shows the relationship of Actual angular field vs. the measured angular field. Fig. 15 shows the relationship of the actual angular field with the angular error before and after correction.

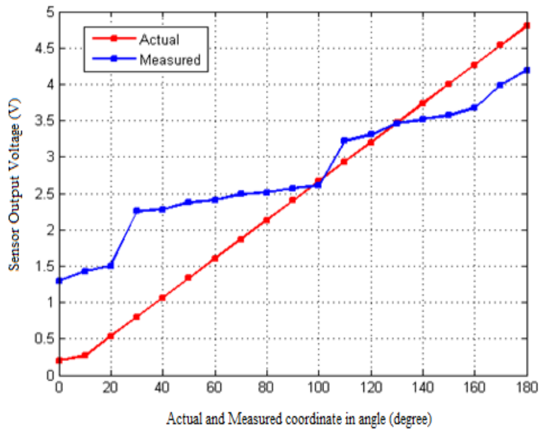

Fig. 13: Variation of the voltage (actual and measured) against the angular field in degrees for magnetic transmitter located at distance of 400mm from the magnetic receiver

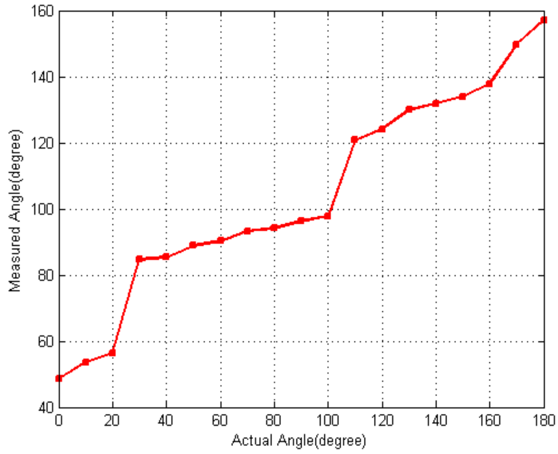

Fig. 14: Variation of the measured angular field against the actual angular field for magnetic transmitter located at distance of 400mm from the magnetic receiver

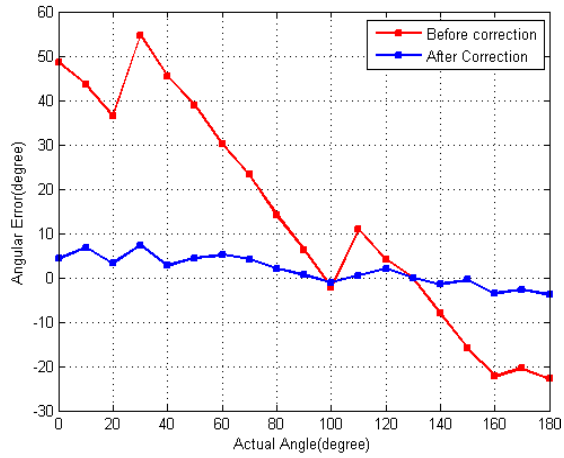

Fig. 15: Relationship of the angular error before and after correction with the Actual field for magnetic transmitter located at distance of 400mm from the magnetic receiver

For distance of 400mm between the magnetic transmitter and the receiver, the pattern of error varied between positive to negative value as the position of the magnetic receiver situated on the helmet crosses the 90 degree position during its movement from 0^0 to 180^0 through 90^0 positions with respect to the position of the magnetic transmitter. The error varies from $+55^0$ to -22^0 through 0^0 before implementing correction factor. After implementing the correction factor, the error varies between $+6^0$ to -4^0 as the magnetic receiver on the helmet moves from 0^0 to 180^0 position through 90^0 with respect to the magnetic transmitter location.

6. CONCLUSION

The head tracking system calculates the current location and coordinates of the pilot's head movements and updates the head movement's location in real time. In this work, the angular error associated with the magnetic head tracking technique has been measured and subsequently calculated for various linear and angular distances between magnetic sensor located on the helmet and the magnetic transmitter. Owing to its sensitivity to environment, the experimental results shows that as the magnetic receiver located on the helmet is physically placed away from the magnetic transmitter in the linear as well as the angular distance, the angular error increases. The angular error in magnetic head tracking has been characterized and subsequently the correction algorithm has been implemented using LabVIEW in real time. Pilot's position and orientation have been calculated with respect to the simulated cockpit magnetic transmitter location. Experimental results show that the head location estimation is more accurate when the distance between the magnetic transmitter and the receiver is less and its angular position is nearly 90^0. For either side of this angular location, the error increases. The implemented algorithm reduces the error considerably thus reporting nearly correct location of the pilot's head position.

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