Simulation and modeling of aircraft movements passing through VOR

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Abstract. VOR/DME is an air navigation equipment, in flight navigation equipment is needed by the pilot as the direction to fly to the destination airport. The pilot tunes the destination frequency, the HSI on the aircraft will display the bearing, deviation, course data, taking into account these data the pilot will arrive at the destination airport. The research objective is to make aircraft simulation software pass VOR/DME. The software is developed using the prototype method, which is by making a display model first, then comparing the display models that have been made with the existing VOR/DME simulation device. Simulation modeling are developed by placing VOR/DME at the appropriate latitude longitude, map modeling using MapX4.5, the plane is conditioned by selecting at a predetermined point, HSI instrument is modeling using GL Studio, the programming language used is C#. Calculation results obtained are visualized on the HSI instrument kit so that the user can see the flight direction of the aircraft on the map and visualization of the instrument. The calculation results are compared with the Garmin Integrated Flight Deck Trainer. With this software it is expected to be used in flight schools in Indonesia in the pilot learning process.

1. Introduction

Pilot education is very expensive because education is not only introduced in theory but also in the practice of flying using simulators and airplanes. Before flying in an airplane, a prospective pilot will be introduced to the instruments used in flight. These instruments are located on land such as navigation tools (Navigation Aids abbreviated as NavAids), as well as instruments contained in aircraft cockpits such as HSI (Horizontal Situation Indicator).

All aircraft are equipped with aircraft navigation instruments so that the aircraft does not get lost in flight, aircraft navigation instruments receive data from navigation equipment on land. Aviation navigation system consists of a collection of various air navigation equipment that is useful to provide guidance such as direction, distance, speed of an airport, altitude to land, as well as equipment that serves to provide landing guidance (landing) when bad weather all of which aims to flight safety and security.

Before making a flight the pilot is obliged to choose or determine the flight route by making a flight plan that will be traversed by considering weather forecasts (including wind), fuel consumption, and aircraft performance [1]. Flight plan is made by following the existing airways, where these airways connect between waypoints, waypoints in the form of points that have been agreed in the flight in the form of VOR, NDB or intersections (en route and terminal), flight plan data also contains speed and altitude the plane [1].
To conduct flights in accordance with a predetermined flight plan, pilots can use VOR/DME as a reference in the direction of flight. VOR is a medium distance navigation aid, which works using very high radio frequency (VHF), VOR facilities enable aircraft to reach destinations by utilizing VOR stations on land regardless of weather conditions (i.e. using the aid of an instrument or with the help of an autopilot). The pilot can utilize the VOR station closest to the airport during takeoff then choose the next waypoint which can be VOR / DME, likewise if the aircraft will land it can use the VOR / DME closest to the airport, VOR / DME also functions as an Outer Marker that can be used as equipment navigation when the plane landed.

Not all VORs are equipped with DME, VOR works on VHF frequencies from 108 to 117.95 MHz. VOR is an air navigation tool whose function is to provide distance information to the aircraft, the oblique angle between the aircraft and the transmitter from the DME. The working principle of VOR / DME is the pilot doing frequency tune to the destination VOR / DME. Then VOR / DME will provide slant range information between the aircraft and VOR, so that with this information the pilot will reach the destination VOR / DME exactly [2].

A large cost is needed if learning to navigate using an airplane, so for the learning stage it can be done by using a simulation first. Simulations made by placing (modeling) VOR / DME on a place / land modeled with MapX4.5, the position of latitude and longitude VOR / DME in accordance with the location of the land, as well as planes that will pass through the Navaids are determined latitude and longitudinal in this case starting from nearest airport, because in virtual flights pilots can use map-based routes to operate their virtual planes [3]. The learning process is done by setting the heading (the nose plane direction which is calculated based on the North Pole) the aircraft speed as well as the wind speed so that the plane will get to the destination VOR / DME.

2. Methodology

There are several air navigation equipment used in assisting flight directions, in air navigation there are known VOR/DME, NDB, ILS and many more. In this study only made aircraft simulation software at the time of going to and after passing VOR/DME, the results of bearing calculations, course distance were visualized on the HSI instrument model.

The aircraft's HSI instrument visualizes heading, bearings, deviations, and courses in degrees according to the calculation of the signal given to the destination VOR / DME. The pilot uses the VOR station on land during takeoff or to reach the destination airport, after reaching the VOR the pilot tunes the frequency on the next VOR as the flight direction and so on until the aircraft reaches the destination airport.

![Figure 1. Magnetic bearings and relative bearings](image)

The position or position of an aircraft and the location of VOR/DME is expressed by the Geographic Coordinate System (GCS), which is a coordinate system of the surface of the earth that is represented from the surface of the earth to define the position on the surface of the earth.

Every place on the surface of the earth is defined by the values of latitude and longitude. The coordinate unit is degrees. One degree is equal to 60 minutes of arc minute or also equal to 3600 arc
seconds. The distance between the aircraft’s position and VOR/DME can be calculated using the following formulation [3,5],

\[
distance = a \cos(\sin(lat1) * \sin(lat2) + \cos(lat1) * \cos(lat2) * \cos(lon1 - lon2)) \quad (1)
\]

\[
bearing = \text{mod}(\text{atan}^2(\sin(lon1 - lon2) + \cos(lat2), \cos(lat1) * \sin(lat2) - \sin(lat1) * \cos(lat2) * \cos(lon1 - lon2)), 2 * \pi) \quad (2)
\]

With aircraft speed, wind direction, wind speed and aircraft headings, the position of the aircraft at the next time in seconds can be calculated using:

\[
SWC = \left[\frac{WS}{TAS}\right] * \sin(WD - CRS) \quad (3)
\]

\[
lat_{new} = a \sin(\sin(lat1) * \cos(distance)) + \cos(lat1) * \sin(distance) * \cos(bearing) \quad (3)
\]

\[
lon_{new} = \text{mod}(lon1 - a \sin(\sin(bearing) * \sin(distance)) / \cos(lat1)) + (22 / 7), 2(22 / 7) - (22 / 7)
\]

Which:
- \(lat_1\) = latitude 1, aircraft’s latitude
- \(lon_1\) = longitude 1, aircraft’s longitude
- \(lat_2\) = latitude 2, VOR latitude.
- \(lon_2\) = longitude 2, VOR longitude.
- \(bearing\) in radians
- \(distance\) in miles

VOR receiver equipment on an aircraft is used by the pilot to determine the movement of aircraft when going through VOR/DME, VOR/DME data receiving instruments have 3 kinds of functions / indicators [2], which are:

- Determine the azimuth, which is a clockwise angle between the north direction of the VOR station and the line connecting the station with the aircraft.
- Shows the deviation to the pilot, i.e. whether the plane is left, right or right on the correct / selected flight path. So by knowing the position of the aircraft against VOR / DME pilots can position the aircraft in the direction of VOR / DME that will be traversed.
- Indicates whether the direction of the aircraft is heading towards or leaving the destination VOR station.

The HSI instrument as shown in figure 2, there are important components, which are [6]:

- Heading bug that is the compass indicator shows the destination angle of the plane. If activated, the aircraft will fly in the direction of the heading bug.
- Lubber line is a fixed line on the Binnacle compass or radar plan position indicator display pointing towards the front of the aircraft and in accordance with the center line.
- TO-FROM Indicator shows the pilot that the specified bearings will bring the aircraft to or leave the VOR station.
- Aircraft Symbol, aircraft symbol used as a reference, which will provide more information on the use of the instrument.
- Course deviation, used as aircraft navigation to determine how much the deviation of the lateral position of the plane (course) to the destination VOR / DME, if the location of the aircraft to the left of VOR / DME, the needle shifts the position of the plane to the right and vice versa.
Analysis of the VOR/DME air navigation equipment system aims to identify the behavior of the system, in this case the HSI (Horizontal Situation Indicator) equipment, how it works and designs the model. The movement of the aircraft towards and past the VOR/DME must be visible through the map.

The application system that will be developed uses MapX 4 as a map display controller with airport coordinates and VOR/DME coordinates. The aircraft is flown from the nearest airport, heading, course and speed can be arranged [5].

Model aircraft instruments developed using GL Studio Version 4.0.9.0, more complete information can be accessed from the following link https://disti.com/?utm_campaign=product_domain&utm_source=simulation.com&utm_medium=domain&ref=dp2 [8].

The programming language used to develop simulation software is C# Visual Studio 2010. The design of the simulation software starts with making a display design of the software. If the VOR selection aircraft is done by tune the destination VOR frequency, in the software the VOR / DME selection is made by selecting the names VOR1 and VOR 2.

3. Results and discussion
The VOR Simulation software developed was compared with the Garmin Integrated Flight Deck (GIFD) Trainer software, version 14.01 made by Garmin Ltd. Tests carried out at Semarang Ahmad Yani airport, aircraft heading 310°. The GIFD Trainer software is shown in the following figure 4, heading 310° course 114°.

Figure 2. HSI Instrument for VOR [7].

Figure 3. The GIFD trainer software of VOR ANY Course 114.

Figure 4. Simulation results of VOR ANY Course 114.
Comparison of the results of the HSI software developed with the HSI GIFD Trainer, the results of distance calculation against VOR ANY from the GIFD Trainer software are 39.4 NM, while from the VOR Simulator software developed by 41 NM. as shown below,

![Figure 5. The HSI GIFD trainer.](image1)

![Figure 6. HSI software development.](image2)

The test was done by VOR/DME JOG (Yogyakarta) with heading 260° and course 57°, the calculation of the distance to VOR JOG from GIFD Trainer software was 31.6 NM, while from the VOR Simulator software developed by 32 NM.

![Figure 7. The HSI GIFD trainer.](image3)

![Figure 8. HSI software development.](image4)

Tests carried out by aircraft flown from Husein Sastranegara Airport (WICC) VOR 1 using BND and VOR 2 using HLM. The aircraft was simulated flying with 173 knots speed, heading 290 course 289. The simulation results using software developed as in the following picture.
Visualization of HSI is shown in the following image,

![Figure 11. Before VOR HLM.](image1)

![Figure 12. After VOR HLM.](image2)

Figure 11 the distance of the aircraft with HLM is 2 Nm, with bearing 284° course 289° like the green arrow from/to sign still shows to HLM. Figure 12 leaves HLM with bearing 176° course 289°.

4. Conclusions and suggestions

In this research an aircraft simulation and modeling device has been developed through Navai ds VOR/DME. The results of software testing have been compared with the Garmin Integrated Flight Deck (GIFD) Trainer, version 14.01 developed by Garmin Ltd, with the location of the testing airports at Ahmad Yani Semarang, Adi Sumarmo Solo and Husein Sastranegara Bandung airports using VOR/DME ANY, JOG, SLO and BND with the results obtained. corresponding. Thus the system that has been developed can be one of the learning media for those interested in learning and understanding the system / way of flight navigation, especially VOR / DME.

The software needs to be developed further by adding other navigation equipment namely automatic direction finder (ADF) or non-directional beacons (NDB). In determining the direction of flight from the airport to other airports in addition to using VOR / DME also uses ADF.

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