A Proposed Model of Aircraft Direction Finding And Integrated Architecture of Theta-Theta-DRDF

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***Abstract*— The aim of this research is to assess feasibility of technology demonstration in developing digital resolution direction finding integrating with theta-theta position fixing method. The proposal is to build an integrated architecture which will simultaneously provide both position and direction of an aircraft in even most adverse situations. Theta-theta is one of the methods of positioning an aircraft in flight. Without the help of 'range' information this method uses only the angles generated from two different VOR transmitters to aircraft; it is possible to find the exact location of the aircraft whereas in proposed digital radio direction finding (DRDF), it is possible to find out aircrafts' direction with respect to runway by simulating the codes containing 'bearing' information generated from VOR transmitters. This integrated architecture will reduce the complexity and cost associated with aviation industry.**

Keywords—Position fixing; direction finding, theta-theta, DRDF, integrated architecture

I. INTRODUCTION

Aircraft navigation is the process of controlling and monitoring the movement of an aircraft. All navigational techniques involve locating the navigator's position compared to known locations or patterns. Position fixing and direction finding are the two important issues in navigating an aircraft from one place to another. For monitoring purpose it is a must to specify the position and direction of aircraft in every stages of flight. Although the term direction finding refers to determining which way to travel but this also involves estimating the direction from which information is coming and the exact location of the aircraft at that point of time. There are different techniques involved in position fixing like rho-rho, rho-theta, theta-theta methods etc. and direction finding like radio direction finding, automatic direction finding, digital resolution direction finding etc. Each specific systems performs specific jobs either position fixing or direction finding. An integrated system of position fixing and direction finding which would provide both the two information at a time would be a cost effective and efficient way of aircraft navigation.

II. POSITION FIXING AND DIRECTION FINDING

A. Position Fixing with theta-theta principle

The earliest method of electronic navigation was by direction finding, the determination of direction of arrival of electromagnetic waves at the receiving station. Being the oldest form of electronic navigation, this method is still in wide use both on ships and aircrafts. Position fixing is the branch of navigation concerned with the use of a variety of electronic methods to determine the position of an aircraft on the surface of the earth. This might be expressed as bearing and range from a known landmark or as angles of latitude and longitude relative to a map datum. Different navigation equipment provides different information. Based on those position can be fixed. Distance Measuring Equipment (DME) provides range (rho) information whereas VHF Omnidirectional Directional Range (VOR) provides bearing (theta). From these range (rho) and bearing (theta) position can be fixed in rho-rho, theta-theta and theta-theta method. Among this theta-theta method is the concern of the research where two VOR stations provide two bearing information from respective transmitters to find a locked position of aircraft in flight conditions. In theta-theta method, two VOR stations are required. One station will provide bearing information θ_1, which gives the decision that aircraft must be any position on the line in the direction of θ_1. Similarly another VOR station will provide θ_2 which gives the decision that aircraft must be any position on the line in the direction of θ_2. If only θ_1 is known in figure-1 then the aircraft can be anywhere on the line AB.

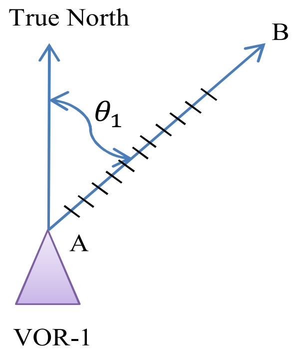

Fig-1: Position of aircraft with one VOR-1 Txr

If only θ_2 is known shown in figure-2, the same thing happens like in figure-1; aircraft can be anywhere in the line CD.

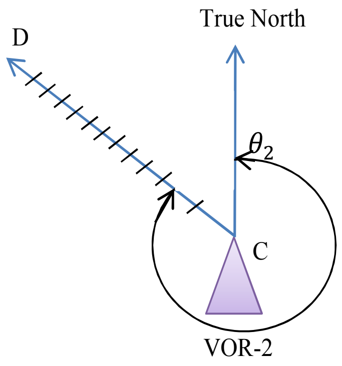

Fig-2: Position of aircraft with VOR-2

When both θ_1 and θ_2 angles are known, then these lines AB and CD intersect at a point and pilot can easily get a fix, shown in figure-3.

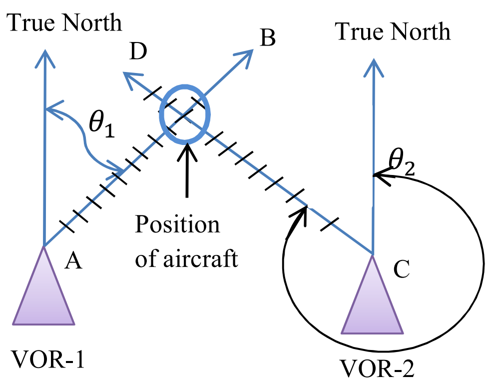

Fig-3: Aircraft fixed position with two VOR

Using the bearing data generated from the VOR transmitters, a system called Digital Resolution Direction Finding (DRDF) can be developed which would use the "bearing" information generated from "theta-theta" method and provide the information of distance and direction of aircraft from runway center line to pilot and Air Traffic Controller (ATC) as well [2-4].

B. Proposed Digital Direction Finding Model

DRDF provides the controller with information on bearings of aircraft in the following forms:

a. Digital pulses are used to give a digital read-out and a vector display.

b. Direct Current (DC) voltage is proportional to the angle of the bearing. This is simulated and displayed on the operator's console.

c. Digital pulses are combined with information from other installations to provide an exact aircraft position on a large scale map that is situated at one of the UK's two main control centers. This is simulated on the model as well.

d. The DRDF is proposed primarily for aircraft in distress, and it helps air traffic controllers pinpoint an aircraft accurately. The 'distressed' aircraft will transmit a code which is detected by a DRDF station and used to determine a directional bearing of the aircraft. This information is passed to a main control center, which uses similar information from other installations to triangulate the aircraft's position (theta-theta method) [1 & 4-7].

The job is to design a system that can show the radial and bearing data of an aircraft with reference to ground based infrared transmitter. The concept of the areal navigation is different to imagine and comprehend. The navigation data of radio and bearing which is in polar co-ordinate system is difficult to comprehend. The electronic circuit designed to replicate the same is named as Digital Resolution Direction Finder. It works on the principle of ADF to show the direction of runway. The circuit consists of three displays indicating relative bearing, compass heading as shown in figure-4. Relative bearing and radial indication are shown by LEDs whereas for heading magnetic compass is used.

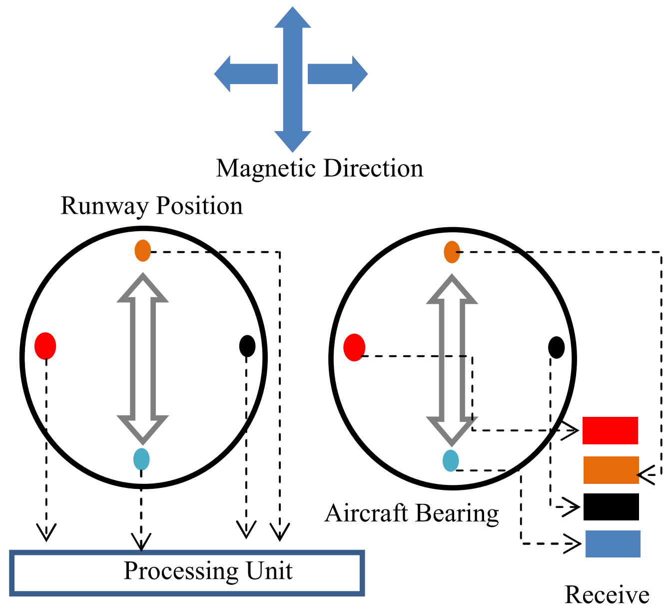

Fig-4: DRDF display (4 directional 90º apart)

It will show the relative bearing of the aircraft with respect to runway. User will easily come to know at which direction of aircraft the runway is located. There will be eight receivers faced at eight directions (each 45º apart) of the aircraft. Signal received through one receiver will let the LED glow at that end in display.

Eight unique codes will be transmitted by eight unidirectional ground based transmitter. Particular code modulated signal will be received. Code will be detected by detector IC and corresponding LED will glow on the radial display. It will show the angular position around the transmitter taking magnetic north as reference of measurement moving in clockwise direction. Magnetic compass will show the heading of the aircraft.

C. Working Principle of proposed DRDF Model

DRDF system consists of eight unidirectional ground based transmitters and eight unidirectional airborne receivers. Each of the eight infrared transmitters has a unique code sequence and having radial sector of 45º each. As the code in each sector is unique, the receiver will interpret the code and respective LED corresponding to unique code will glow on the radial display. Each unidirectional receiver is connected with a signal detector circuit. When signal is received, detector circuit will glow the corresponding LED on the relative bearing display. The signal coverage area for eight transmitters each of covering 45^0 is 360^0 as a whole. This is been illustrated as follows in figure-5.

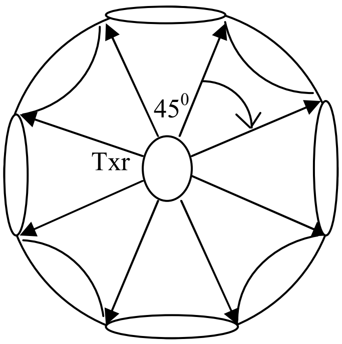

Fig-5: Signal coverage Sector

The block diagram of proposed model is as follows in figure-6.

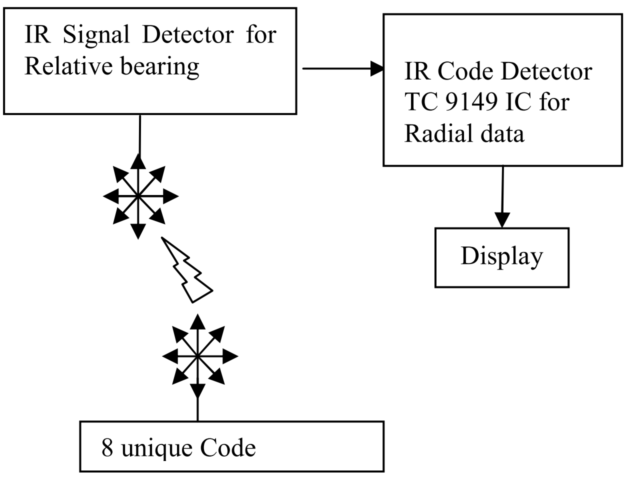

Fig-6: Block diagram of proposed DRDF Model

Ground based transmitter will transmit 8 different codes at 8 unique direction (45º Apart), where each direction is covered by a narrow beam width of 45 degree. Signal received by one of the eight directional airborne receivers will indicate a particular display panel at relative bearing indicator. Simple principle of Infrared signal detection circuit is applied here. Ground transmitter will transmit particular code for unique direction. The code starts from the direction of magnetic north and starting from 000. Respective codes relative to angular direction are shown in table-1.

TABLE-1: PARTICULAR CODES FOR DIFFERENT ANGLES

Code	Angular Direction in degrees
000	Magnetic North(0/360)
001	45
010	90
011	135
100	180
101	225
110	270
111	315

For the Radial indicator, the modulated signal will be demodulated by receiver and for particular code received the receiver will show the radial information on display. For different situations, the display will perform simultaneously. As example, two situations are taken into account.

Situation 1: In case-1, aircraft bearing is 225º and relative bearing is same as aircraft heading is 0º to Magnetic North. The radial is 45º of the ground station. Over the display in aircraft, magnetic compass shows magnetic heading which is 0º. Relative bearing display is indicating 225º from the display. Radial data display indicates 45º by powering up respective display panel and the LED on the indicator scale. As here magnetic heading is 0º so relative bearing and bearing of aircraft are the same.

Situation 2: In case-2, aircraft bearing is 0º and relative bearing is same as aircraft heading is 45º to magnetic north. The radial is 225º of the ground station. Over the display in aircraft, magnetic compass shows magnetic heading as 45º. Relative bearing display indicates 0º by indicating the LED on the display. Radial data display indicates 225º using the similar principle.

III. THETA-THETA-DRDF INTEGRATED ARCHITECTURE

The proposed integrated architecture works on using the data provided by VOR station in any specific runway. The bearing information which is received from VOR transmitter is used by DRDF processor to calculate and send required information to pilot and ATC. The integrated architecture is shown in figure-7.

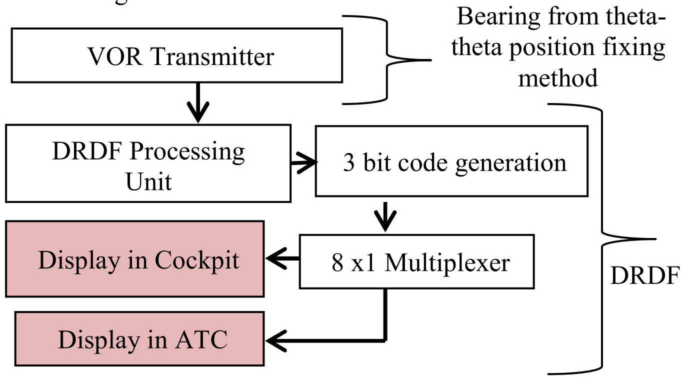

Fig-7: Theta-Theta-DRDF integrated Block Diagram

The combined architecture performs both position fixing and direction finding principles where using the angular position of aircraft a central processing unit of DRDF generates 8 different codes each of 3 bit. This 3 bit code is then sent to a multiplexer who selects which receiver is supposed to receive the code. When both transmitter and receiver codes match, then the specific signal is sent to 2 different locations, one in cockpit from where pilot could visualize the actual position and direction of runway and another to ATC which is situated near the runway. From this two, ATC informs and alerts pilot about its position co-ordinates.

This combined architecture can be a standby system for guiding and piloting the aircraft in adverse conditions when visual navigation is not possible. In such a situation theta-theta-DRDF system would provide an easy understanding about direction and position of nearby airport. This is an advantageous system in different aspects as well. As DRDF can be used for finding bearing of an aircraft, it is also used for making a course for the aircraft to reach to the destination. Approach controller uses this equipment to direct an aircraft to a point above the airfield and from there he controls the aircraft's CDTC (Control Descent through Cloud) to a position with height from where the pilot can land visually.

IV. Conclusion

The needs for reliable standby navigation techniques are always being felt. So, the proposed DRDF system and integrated architecture with theta-theta position fixing method might be a good approach in obtaining redundancy and safety in electronic navigation. The work has been done in theoretical calculations only and proposed model is yet to be demonstrated which is under research right at this moment. More analysis and practical workout is needed to achieve desired output. Further study on Digital Direction Finding and synchronization between transmitter and receivers are to be done. The design and projection of the avionics aid is not only for the purpose of modification, rather this can be considered as a very effective teaching aid for avionics studies as hands-on teaching aid is a big impediment in aviation engineering in any developing country.

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