Radar and Navigation(EC0607)

Unit-3

B.Tech (Electronics and Communication)

Semester-VI

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Navigation and Hyperbolic Systems of Navigation

Introduction

- Navigation may be considered as the art of directing the movement of a vehicle from one place to another. It is an art practiced by all who travel but its development is rooted firmly in the fundamental laws of science
- In today's context it can be formally defined as the determination of a strategy for estimating the position of a vehicle along the flight path, given outputs from specified sensors

A navigation system may provide information in a variety of forms, appropriate to the needs of the aircraft

- Position Information
- Steering Information
- Displays

TYPES OF NAVIGATION

- Dead reckoning
- Position fixing

Dead Reckoning

- Dead reckoning consists of extrapolation of a ’known’ position to some future time. It involves measurement of direction of motion and distance traveled
- The actual computation is performed by taking the last known position and the time at which it was obtained, noting average speed and heading since then and the present time
- The speed is usually resolved to get North and East components and each is multiplied by the time elapsed since the last position to get distance traveled. This can be added to the initial position to get the present position

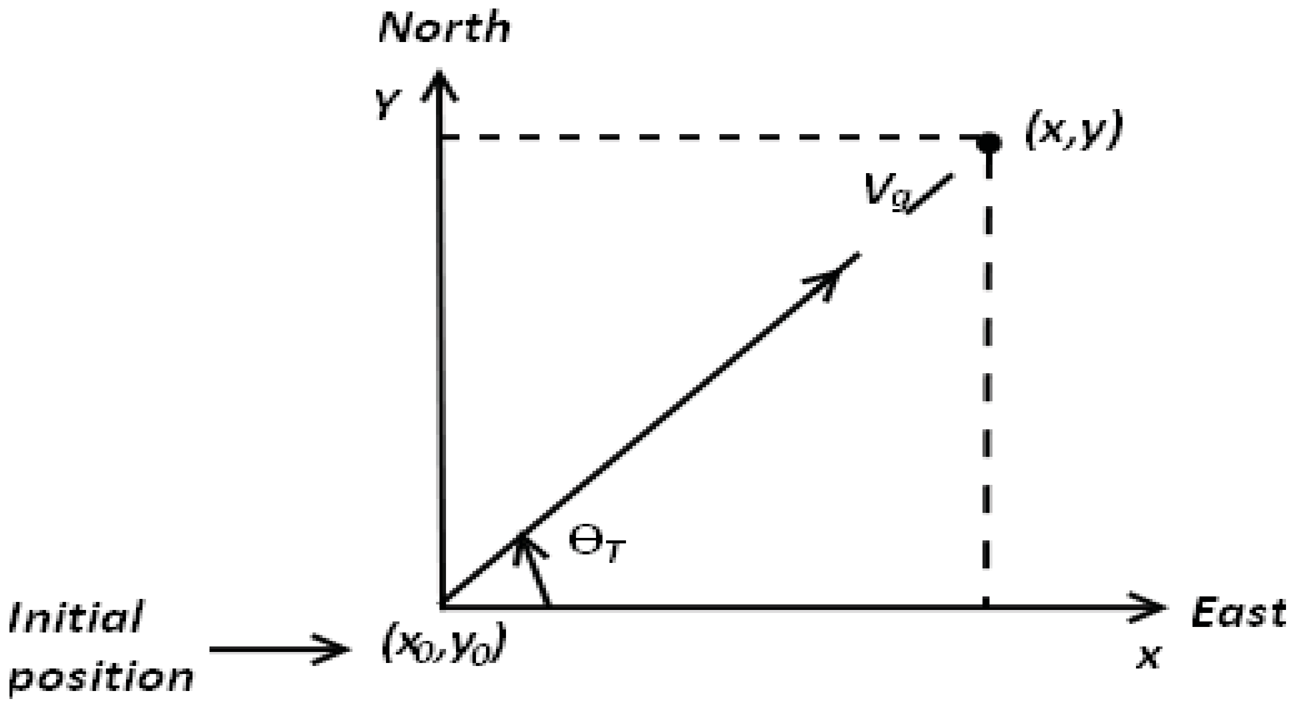
To perform all these functions the Navigation system requires the following instruments:

(1) A speed measuring device

(2) A heading sensor

(3)A timer and

(4) A computer



Dead reckoning computations

Position Fixing

In contrast to dead reckoning, position fixing is the determination of the position of the craft (a fix) without reference to any former position. There are three basic methods of fixing position

(1) Map reading

(2) Celestial navigation

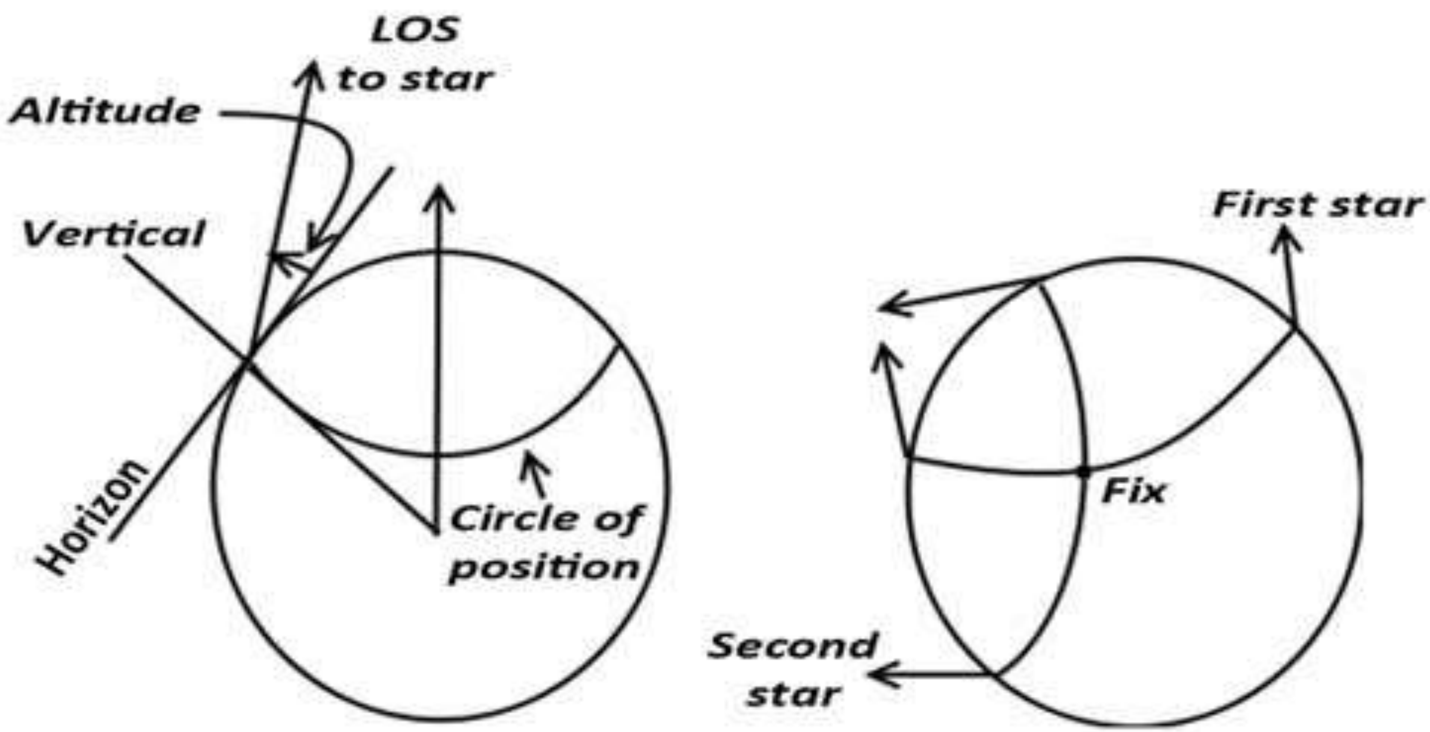
(3) Measuring range and/or bearing to identifiable points

Map reading

Map reading involves matching what can be seen of the outside world with a map and is the traditional method of position fixing on land and is also used by general aviation in clear weather. Modern systems adopting this technique uses a radar to obtain a picture of the ground from the air and a computer matches it with a map stored in the form of a digital land mass database. These system are called terrain referenced navigation aids

Celestial navigation

- Celestial navigation has been used by mariners for centuries. The basis of celestial navigation is that if the altitude of a celestial object (measured in terms of the angle between the line-of-sight and the horizontal) of a celestial object is measured then the observer's position must lie on a specific circle (called the circle of position) on the surface of the earth centered on the point on the earth which is directly below the object
- This is shown in Fig. If the time of observation is noted and the celestial object is a star then this circle can easily be found using astronomical tables and charts



Celestial navigation

- Sightings on two or more such celestial objects will give two or more such circles of position, and their intersection will give the position of the craft.
- Though in the early days some aircraft did use celestial navigation this has been abandoned nowadays in favour of better navigational aids
- However, we shall show that its basic principle (that of intersection of circles of position to determine the exact position) will be used in a more general form in more advanced navigation system

Range and bearing navigational techniques

- Range and bearing navigational techniques are the basis of most modern position fixing systems. They use modern electronic equipment for doing this kind of measurement. Through individual measurements of range and bearing, a line of position a line on which the craft is presumed to be located-is established. In principle, it is somewhat similar to celestial navigation
- The line might be a small circle, great circle, hyperbola or some other curve constituting the intersection of the surface of the earth (or a concentric surface at the altitude of the aircraft) with a plane or a cone or a hyperboloid etc

The common intersection of two or more nonparallel lines of position constitutes the fix. If the lines are determined at different times, then one or more of them must be adjusted for the assumed motion during the interval provide a running fix. Occasionally, an actual position is not needed, a line of position being adequate to ensure safety. This is called homing. The method is not suitable when other aircraft are in the vicinity and a means of avoiding them is not available

Another classification of navigation may be according to the portion of flight involved. Usually, this classification is done as En-route phase and terminal phase

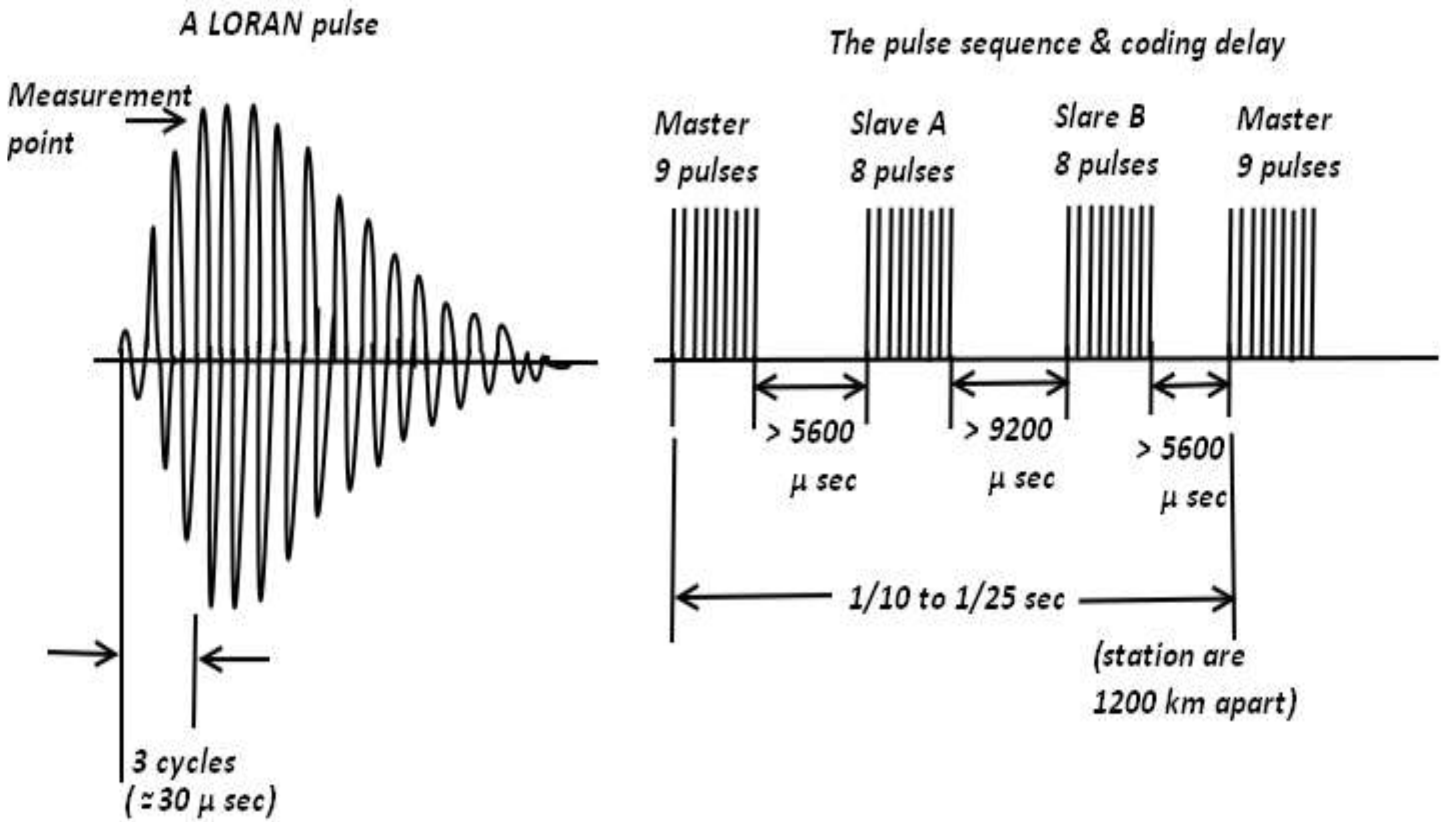
LORAN SYSTEM

- The LORAN (Long-Range-Navigation) is a position fixing aid. It operates on a single frequency of 100 KHz and has a long range (greater than 1200 km). The latest version of this system called LORAN-C is very widespread, having many chains throughout the continental USA, much of Europe and the Middle East
- The European countries, as well as the Russians have confirmed their intention to use and expand LORAN-C (and the Russian equivalent called Chayka)as a primary radio-navigation source. On August 6 1992, six nations in the European Community signed a treaty to expand LORAN-C coverage
- Installations of LORAN-C chains by the governments of India and China indicate the worldwide interest in LORAN

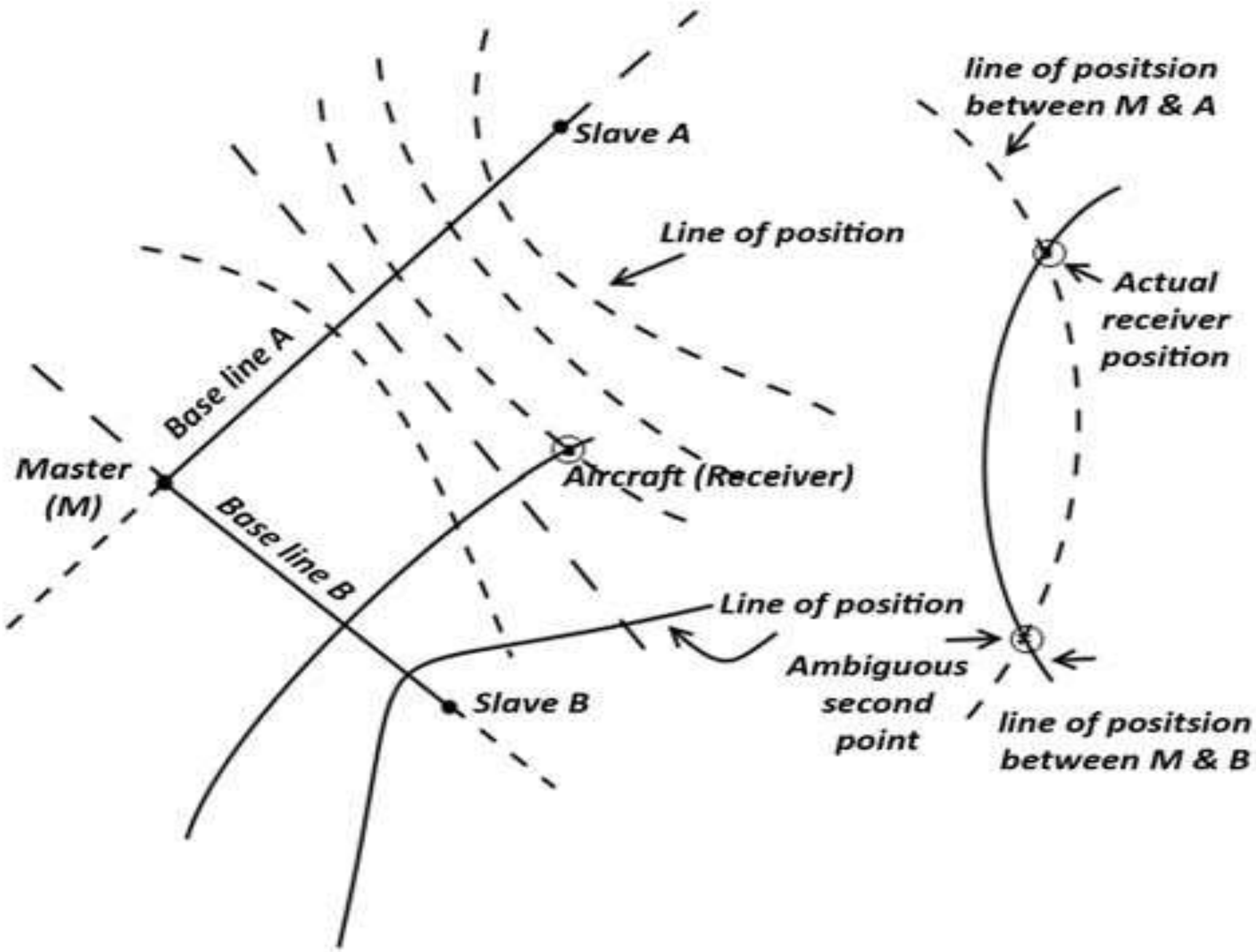
Basic principle of LORAN

- Each LORAN chain consists of a master station and two, three or more slave stations. The aircraft receiver must be tuned to select a chain (of master and slave stations) by manual or by computer selection. Each chain transmits a sequence of pulses. First the master and then after a fixed coding delay, the slaves
- Each slave in a chain has a unique coding delay that allows the aircraft to receive its signal before any other slave transmits

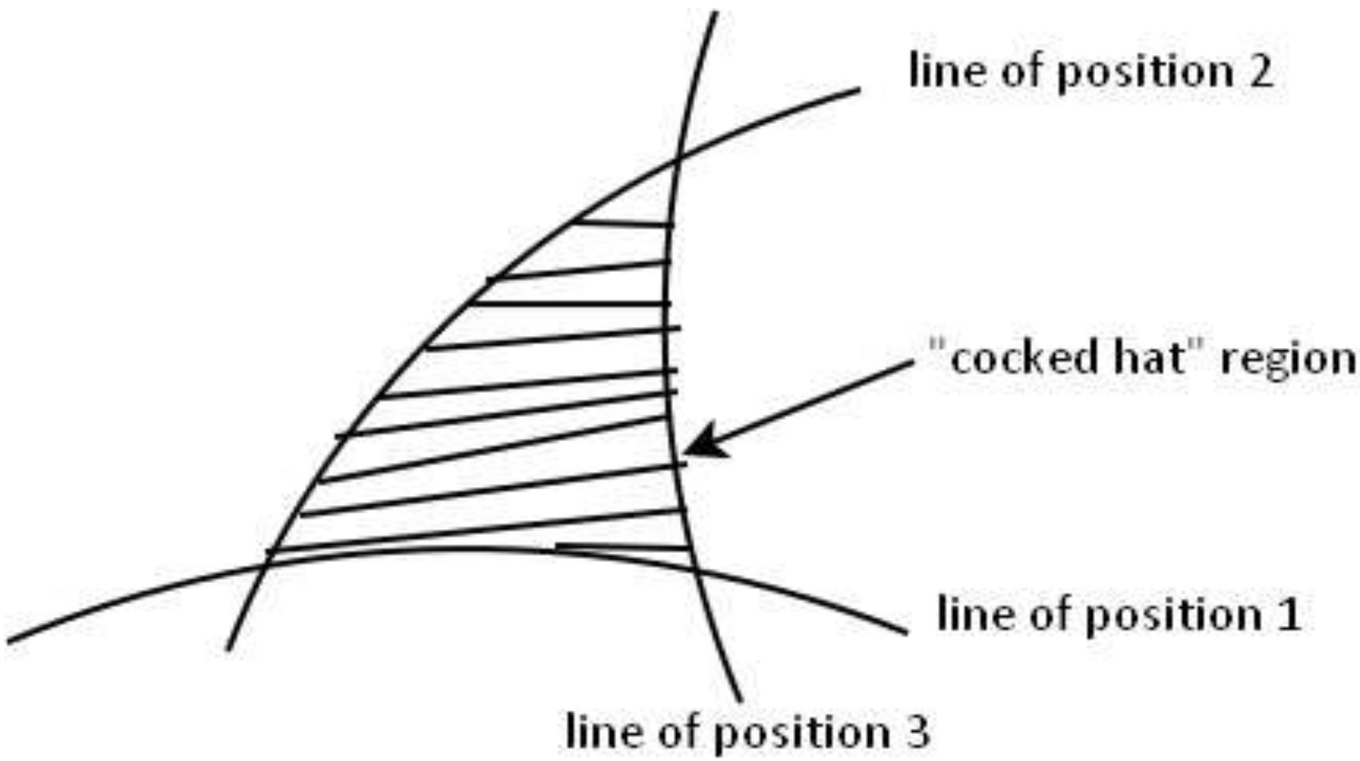
- Usually the master’s signal is received by the slaves and retransmitted after the specified coding delay. The number of pulses (eight or nine) and the coding delay identifies the master and slaves of a given chain. the navigation computer in the aircraft is fed with the position information of the master and slave stations in a chain



The LORAN-C pulses



LORAN lines-of-position

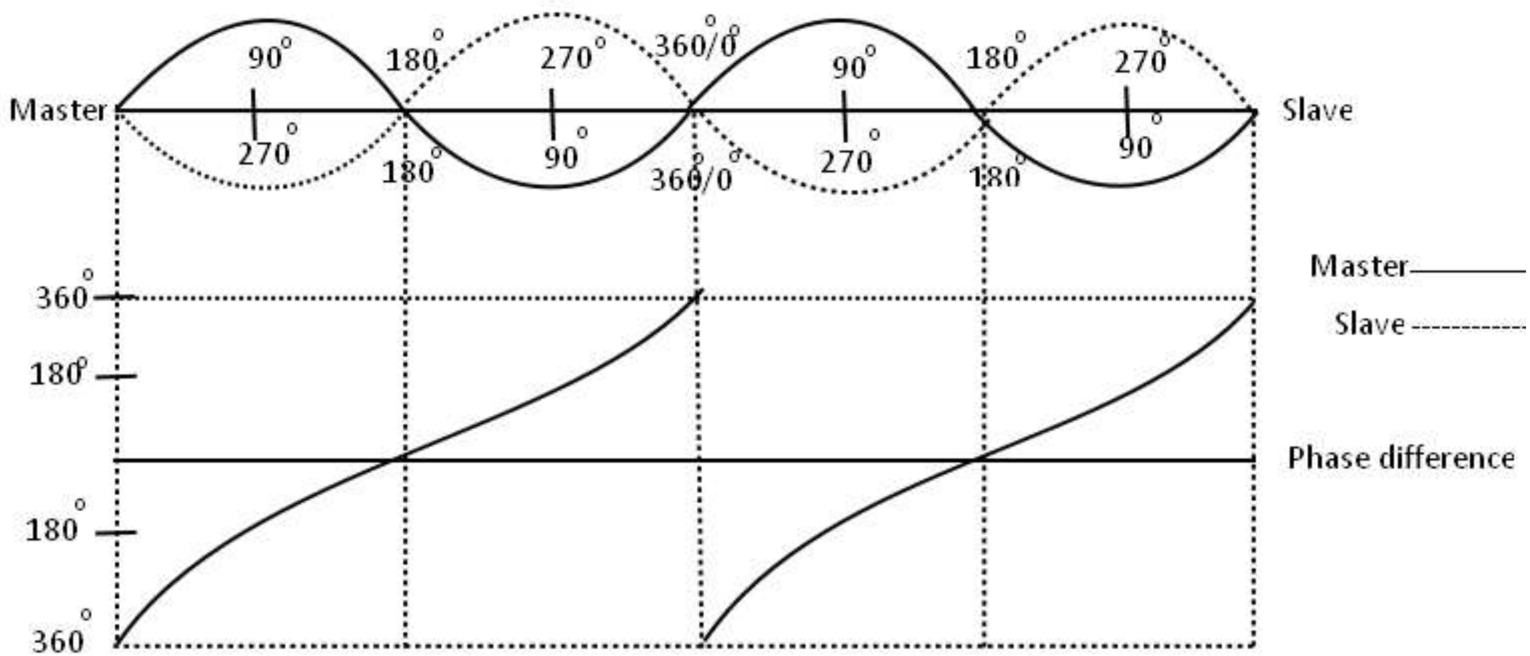


The “cocked hat”

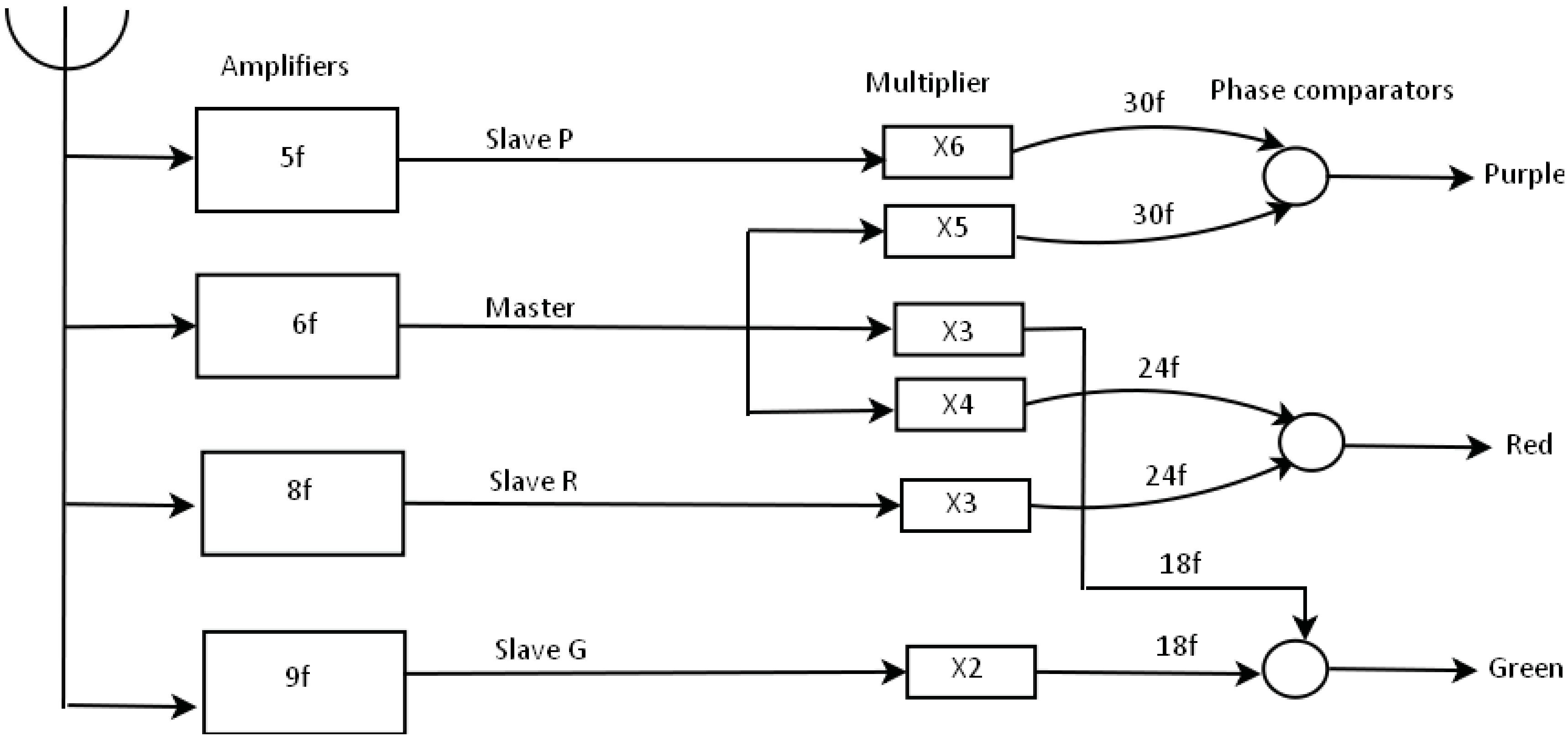
DECCA

- Decca is also a position-fixing hyperbolic navigation system which uses continuous waves and phase measurements to determine hyperbolic lines-of position
- When two stations at a distance from each other transmit synchronized continuous wave signals, a receiver placed somewhere between them can relate its position to the phase difference between the two signals, i.e., there is a change in phase difference as the receiver changes position

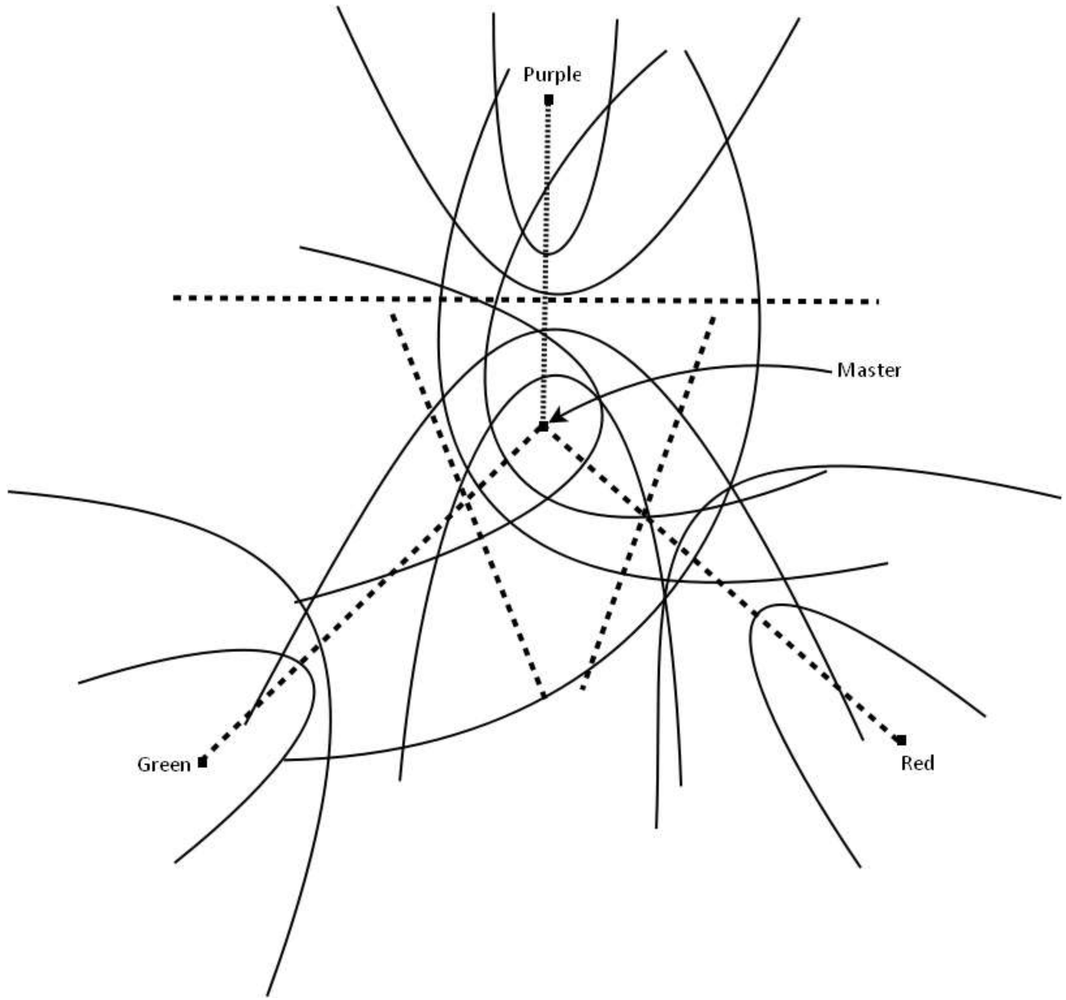
- The transmitted signal frequency is between 70 to 130 KHz with range approximately 200 km. Four stations, a master and three slaves, form a chain
- They transmit at frequencies which are multiples of a base frequency f (which is about 14 KHz)



The phase difference in Decca



The phase comparator in Decca



The iso-phase lines in Decca

OMEGA

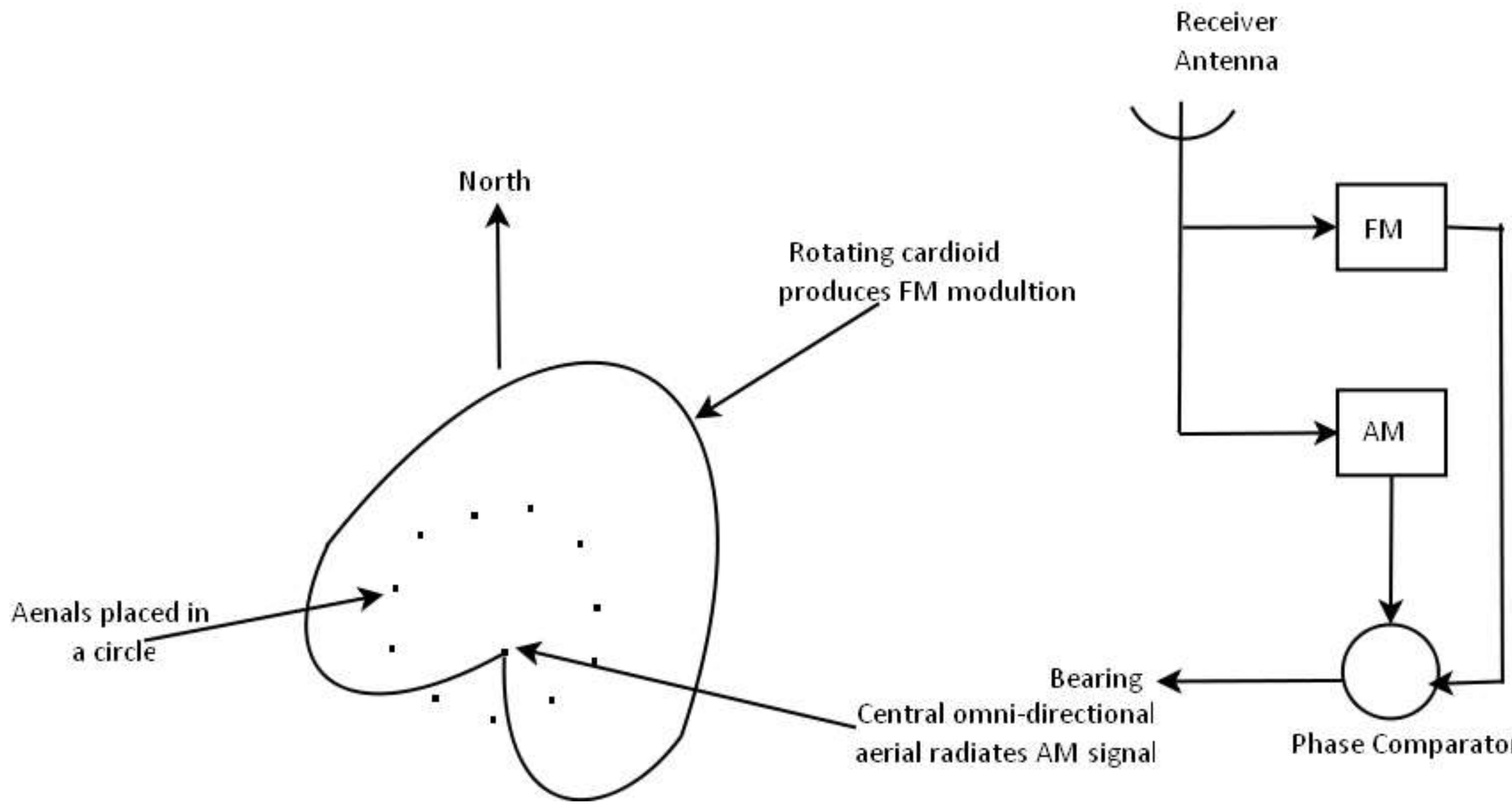
- Omega is a system which works on the same principle as Decca. But its operating frequency is very low (VLF). Essentially ground based transmitters are employed to transmit in four fixed frequencies - 10.20 KHz, 11.05 KHz,11.33 KHz and 13.60 KHz. Using VLF enables full worldwide coverage with only eight transmitters placed at stations in Norway, Liberia, Hawaii, North Dakota, La Reunion Islands, Argentina, Australia and Japan
- To give station identification the stations transmit the various frequencies at set times in a common 10 sec sequence

- To give station identification the stations transmit the various frequencies at set times in a common 10 sec sequence. The low operating frequency of Omega causes quite large inaccuracies in position identification, but it has the advantage that submarine vehicles can receive its signals at appreciable depths underwater
- Though Omega was developed for maritime use, it has been widely adopted as a navigational aid on the transoceanic air routes
- It was also used by the British quite extensively in the Falklands war, even though one of the transmitters was located in Argentina

VERY HIGH FREQUENCY OMNI-DIRECTIONAL RANGE (VOR)

- Range and bearing are the basis for most modern position fixing systems
- The range and bearings to a number of points whose position is known are obtained and used to calculate the position of the observer. Hence, the bearings to any existing radio transmission stations of known location could be used for navigation purposes
- Usually radio transmission is done at low and medium frequencies to get wide coverage but when such signals are used for bearing measurement, ionospheric and atmospheric conditions cause large errors

- In the VOR, a series of aerials, situated in a circle around a central reference aerial at the ground station, transmit a constant amplitude VHF carrier frequency (108 - 118 MHz) which is switched between them to simulate a rotating cardioid (heart-shaped) beam
- At a receiver this gives a frequency (which is usually 30 Hz)
- A reference signal at the rotation frequency amplitude
- modulates a carrier which is transmitted from the omni-directional reference aerial



The VOR system

INERTIAL NAVIGATION SYSTEM

- Inertial navigation , which are essentially dead-reckoning systems, avoid the detection problem by measuring the acceleration of the vehicle using internal sensors and then calculating its velocity by integration. The position of the vehicle can then be computed by a second integration, given the initial position and velocity
- Accelerometers are used for measuring accelerations. Signals from gyroscopes are used to prevent the accelerometers from tilting as the vehicle rotates in space

INTEGRATED NAVIGATION SYSTEMS

- Where several sensors or navigational aids providing separate outputs are available, it is possible to feed all of these outputs into one or more computers, which then provide a single output to the pilot or the autopilot
- One reason for integration is to improve reliability and another is to increase accuracy
- The need for greater accuracy than that attainable by individual navigational aids must be weighed against the added cost and complexity of the integrated system
- Such an integrated navigation system uses both dead-reckoning and position fixing, each assisting the other to give a solution better than either can give alone

Reference

- NPTEL