

## Measurement of Zenith and Azimuth Angles for the 2D Doppler Skymap Plot: Labview Based Implementation

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### ABSTRACT

An Ionosonde is a special type of Doppler radar, which has used for the examination of the ionosphere. It has used to find out the desired operational frequencies for broadcasts or two-way communications in the high frequency range. Ionosonde system is under development at SAMEER, IIT Bombay Campus. Skymap is a presentation technique for the drift measurement data in which a large number of individual echoes from the ionosphere ("sources") are resolved by their time of arrival and further by their Doppler shift that corresponds to the line-of-sight velocity of the reflecting area of plasma. This Skymap has plotted in 2D by using Zenith and Azimuth angle. Measurement of Zenith and Azimuth angle has implemented by using LabVIEW.

**Keywords** – Azimuth angle, Drift, Ionosonde, Ionosphere, LabVIEW, Skymap, Zenith angle

### I. INTRODUCTION OF IONOSPHERE AND IONOSONDE SYSTEM

High frequency communication has been becoming the important part of day-to-day life. Therefore, for better communication study of ionosphere is necessary. The word 'SONDE' stands for devices that are used for testing physical and meteorological conditions at high altitudes above the earth's surface. In addition, the word 'IONO' stands for the ionosphere. A region extending from about 50 km to 500 km above the earth, most of the molecules of the atmosphere have ionized by radiation from the Sun. This region has called the ionosphere. Most of the ionosphere is electrically neutral, but when solar radiation strikes on the electrons, their chemical constituents have dislodged from atoms and molecules to produce the ionospheric plasma. The presence of these charged particles makes the upper atmosphere an electrical conductor, which possesses electric currents and affects radio waves. Electron density of ionosphere changes due to variations in source of ionization. By scanning the transmitted signal, frequency within a fixed range and calculating the time delay of echo received at receiving antenna. This sounder can provide a profile of electron density vs. height. The refractive index of the ionospheric plasma is dependent on its electron density, by using this refractive index it is easy to provide profile of electron density. According to Appleton equation, the behavior of plasma depends upon earth's magnetic field. This equation indicates that there are two values of refractive index, which are resulting in splitting of the polarized wave into two different components. These components are ordinary wave

and extraordinary wave. They are travel with different wave velocities therefore; they appear as a two distinct echoes. They are also appears as a two different polarizations, therefore they can be easily distinguishable. These properties of ionosphere make it extremely useful for HF communication. This makes study of ionospheric immensely important. Ionosonde has used for the study of ionosphere.

### II. WORKING OF IONOSONDE SYSTEM

An Ionosonde is high frequency radar. It transmits very short pulses of radio waves vertically into the ionosphere. These pulses are reflects back towards the ground, if the radio frequency is not too high. The operation of Ionosonde system is briefly shows in the fig. 1. It is mainly a combination of radio transmitter and receiver capable to transmitting pulses towards the ionosphere above the earth and receiving the same signal pulse returns back at the receiver end. The time delay at different frequencies has calculated while changing the carrier frequency of pulses. The Ionosonde keeps the record of the time delay between transmission and reception of the pulses over a range of different frequencies. Minimum range in which Ionosonde can work is 0.5 MHz to 20 MHz. The Ionosonde records the time delay between transmission and reception of the pulses over a range of different frequencies. Echoes appear first from the lower E region and subsequently, with greater time delay, from the F1 and F2 regions. At night, echoes have returned only from the F region since the E region is not present. These echoes have received with the help of antennas

and then they have processed to get the Doppler Spectrum for each range bin.

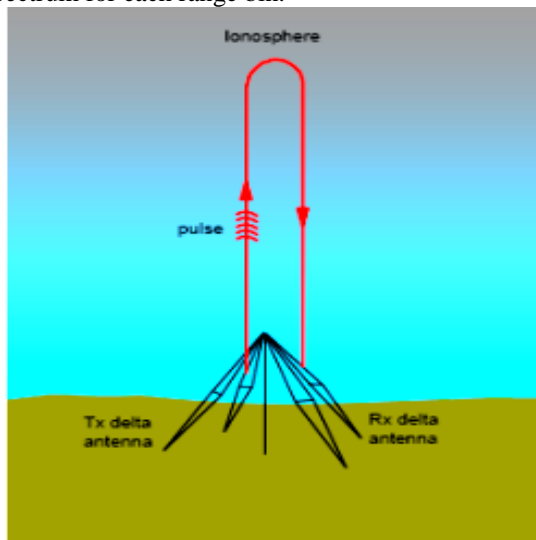


Figure 1

### III. ABOUT A SKYMAP[1]

The Doppler Skymap is a representation method for the d calculated drift data of ionosphere. In which a large number of individual echoes from the ionosphere are resolved by their time of arrival and further by their Doppler shift that corresponds to the line-of-sight velocity of the reflecting area of plasma. Then, for each range/Doppler bin that has now assumed to contain a single ionospheric echo, four channel phases have used for the Interferometry calculation of azimuth and zenith angles of source.

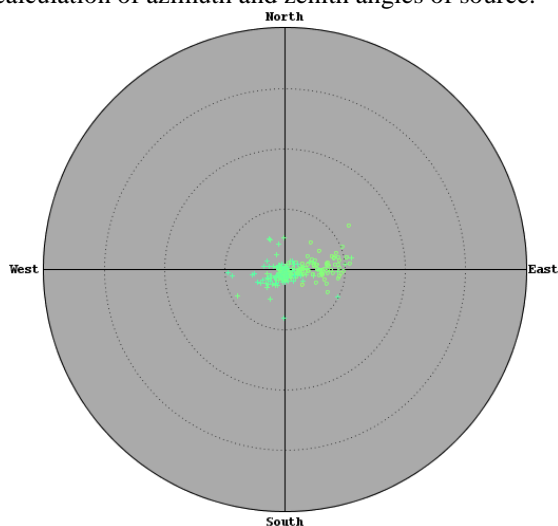


Figure 2

### IV. METHOD FOR CALCULATION OF ZENITH AND AZIMUTH ANGLE[4]

Skymap presents ionospheric echoes in 2D sky coordinate system that maps the echoes ("sources") onto a 2D fundamental Skymap plane

using their azimuth and zenith arrival angles, thus discarding the range information. The Skymap plane presents the zenith angle as radius and azimuth angle as polar angle of the polar coordinate system.

In this calculation principle of Doppler, Interferometry is used. This technique is relying on the frequency and phase analysis of the signal received at the receiver antennas. Receiver system consists of four antennas, which have placed in the geometric barycentre and in vertices of equilateral triangle as shown in the figure. These antennas should be in a plane at an appropriate distance. In order to better discriminate the phase angles it is important to increase the triangle size (more than 50 m), and to eliminate the phase ambiguity, the distances between the antennas from the centre of the triangle must not be greater than the wavelength  $\lambda$  used in the Ionosonde system.

All the phase differences of the single spectral component  $\Delta\phi_{ij}$  are measured (CFFT output),  $\Delta x_{ij}$ ,  $\Delta y_{ij}$  are known quantities of receiver antennas, while the unknown are  $k_x$  and  $k_y$  which is important part of the Zenith and Azimuth calculation equations.

Matrix A formed by change in the X and Y coordinates of four antennas respectively. It has shown in equation 1.

$$[A] = \begin{bmatrix} \sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta X_{ij}^2 & \sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta X_{ji} \times \Delta Y_{ji} \\ \sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta X_{ji} \times \Delta Y_{ji} & \sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta Y_{ji}^2 \end{bmatrix} \dots \dots \dots [1]$$

$\phi$  Matrix formed by change in the phase of four antennas.

$$[\phi] = \begin{bmatrix} \sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta\phi_{ji} \times \Delta X_{ji} \\ \sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta\phi_{ji} \times \Delta Y_{ji} \end{bmatrix} \dots \dots \dots [2]$$

We need to calculate  $K_x$  and  $K_y$  i.e. wave vector is shown in equation 3.

$$k_x = \frac{\sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta Y_{ji}^2 \sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta\phi_{ji} \cdot \Delta X_{ji} - \sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta X_{ji} \cdot \Delta X_{ji} \sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta\phi_{ji} \cdot \Delta Y_{ji}}{|A|}$$

$$k_y = \frac{\sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta X_{ji}^2 \sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta\phi_{ji} \cdot \Delta Y_{ji} - \sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta X_{ji} \cdot \Delta X_{ji} \sum_{j=1}^{N-1} \sum_{i=j+1}^N \Delta\phi_{ji} \cdot \Delta X_{ji}}{|A|}$$

$$[K] = \begin{bmatrix} K_x \\ K_y \end{bmatrix} \dots \dots \dots [3]$$

Taking inverse of A matrix and multiplying it with  $\phi$  matrix, we can get K matrix component  $K_x$  and  $K_y$ .

$$[K] = [A]^{-1} \times [\phi] \dots \dots \dots [4]$$

The last two yield the wanted result including the Azimuth angle  $\phi$  of the Doppler source. In the framework of the antennas, barycentre  $\phi$  has calculated by equation 5.

$$\theta = \tan^{-1} \frac{K_y}{K_x} \dots\dots\dots [5]$$

While the vertical component  $K_z$  has calculated by using equation 6.

$$K_z = \sqrt{K^2 - K_x^2 - K_y^2} \dots\dots\dots [6]$$

With  $k$  defined as  $2\pi/\lambda$ . In theory  $k = 2\pi(f + fD)/c$  but being  $fD \ll f$  one will assume  $k = 2\pi f/c$ . The order of magnitude of the error is  $10^{-4}$  rad/m.

$$\theta = \cos^{-1} \frac{K_z}{K} \quad \text{And,}$$

$$\phi = \tan^{-1} \frac{K_y}{K_x} \dots\dots\dots [7]$$

### V. WHY LABVIEW

LabVIEW is a graphical programming language. Graphical system design is a modern approach to designing, prototyping, and deploying systems. It combines open graphical programming with hardware to simplify development. It gives us the flexibility of a powerful programming language without the complexity of traditional development environments in less development time.

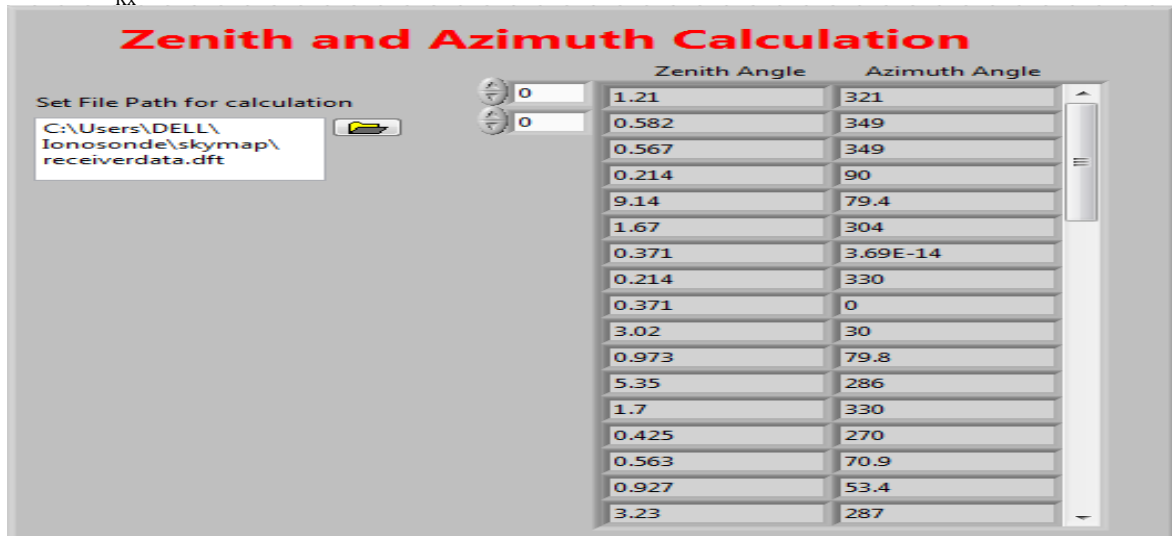


Figure 3 Front Panel of VI

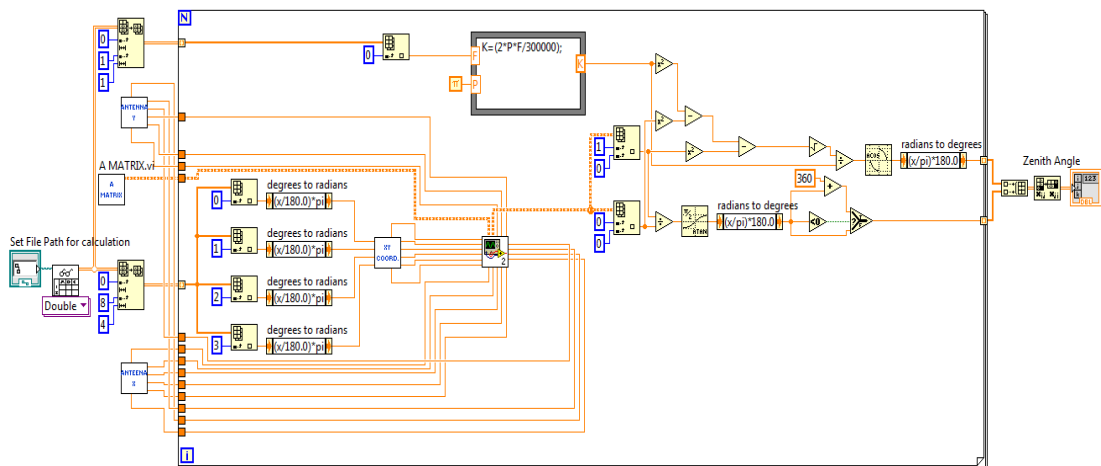


Figure 4 Block Diagram of VI.

### VI. IMPLEMENTAION IN LABVIEW

The skymap plane presents the zenith angle as radius and azimuth angle as polar angle of the polar coordinate system. The calculation of zenith and azimuth angle has implemented using LabVIEW. After receiving of echo signal at Ionosonde receiver, it processed at real time processing software of Ionosonde. Then the required data for analysis of zenith and azimuth angle has generated and it is stored in a file. This file consist of Frequency of the

received signal (MHz), Range from where signal has reflected (This range is above the earth and it is in Km), Doppler shift present in the echo, and Amplitude and Phase of the received signal. This file is an input for this VI. It has extracted in the block diagram by using functions of the LabVIEW, and then formulas given above have applied on it. Front panel and Block diagram of this LabVIEW implementation has shown in the figure respectively.

## VI. RESULT AND DISCUSSION

In order to test the algorithm and LabVIEW based implementation, the raw data has taken from commercially available Ionosonde system (Lowell Digisonde). The Zenith and Azimuth Angles have computed by the developed LabVIEW VI and compared with the data processed by the commercial system software. The results have generated in less time and are matching with commercial system.

The Front panel and Block diagram of this VI have shown Fig 3 and Fig 4 respectively, Front panel shows the controls and indicators for the convenience of the user. User has provided with selectable control for setting the .dft file for the calculation of zenith and azimuth angles. In addition, calculated angles have displayed on front panel using 2D numeric array indicator.

The results obtained from this implementation are matching with the data processed by commercial software accepted worldwide.

The calculated azimuth and zenith angles of the ionospheric targets will be used to compute drift velocity of the ionospheric layer.

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