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Computer-Based Drift Radar System Design for Ionspheric Irregularities Measurements and Analysis

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Abstract: A computer based drift radar system has been designed for real time ionspheric irregularities measurements where closely spaced receiver technique has been utilized. A computerized interface with the system a long with real time software has been developed to keep tracking of the measured data for further analysis. The system has been implemented at locations and produced a reliable analysis.

Key words: Radar systems, ionspheric irregularities, real time systems, drift velocity, E and F region

INTRODUCTION

Radio communication especially at low frequency and high frequency ranges depends intimately on the characteristics of the ionosphere. The constituents of the upper atmosphere (i.e. ionosphere) are subject to influence of hydrodynamic and electrodynamics forces, diffusion and temperature effects. The effect of these forces is to cause the concentration of the charged particles to move to in horizontal as well as vertical motion; this motion is called "drift of irregularities"[1]. One of the most widely employed methods to measure the drift of the ionspheric irregularities, is the closely spaced receiver technique (D1).this technique records the amplitude of the reflected signal simultaneously at three closely spaced points on the ground .The radio waves are transmitted vertically upwards from a pulse transmitter. When these waves travel through these irregularities, phase modulation takes place and the returned waves form a diffraction pattern too. This gives rise to amplitude variation on ground with respect to time. The time delays between similar fades at different receivers give the magnitude of the drift velocity of the ground diffraction pattern. Comparison of the closely spaced receiver technique (D1) with rocket techniques, meteor radar technique, back scatter radar and incoherent radar techniques has indicated that this technique gives a reliable estimate of average wind velocity in ionspheric D,E and F regions[2,3].

In order to carry out an accurate measurement of the ionosphere parameters of the E-region and F-region like drift velocity and direction of velocity. A low-cost drift radar system has been designed[4]. In this paper, a computer interface circuit is designed and software is developed to acquire the signals transmitted by the radar and received back by the system. However, software for signal computation, analysis and graphs plotting is developed.

Drift radar system design: The design process consists of two parts; the first part was a hardware design that included the design of the drift radar system, along with an interface circuit design with a computer system. The second part is the software design which includes the development of software to acquire and analyze the data.

System hardware design: The drift radar system circuit design process is based on closely spaced receiver technique, where a pulsed radio signal is transmitted vertically upwards in this method. However, the transmitted pulse will be reflected back by the ionosphere irregularities and then picked up by the receiver. Then, the measured data will be acquired and processed by the computer for further analysis by the software. Hence, the drift radar system circuit consists of four basic parts as shown in Fig. 1.

* The pulsed transmitter unit
* The receiver unit
* Antenna
* Computer interface circuit

The pulsed transmitter design: In order to avoid the overlapping between the transmitted pulse and the received echo, the pulse duration was chosen to be sufficiently short (i.e. less than 0.6 msec). The following parameters have been considered in the design process:

Peak power output	5 k.w.
Pulse width	100-600micro sec

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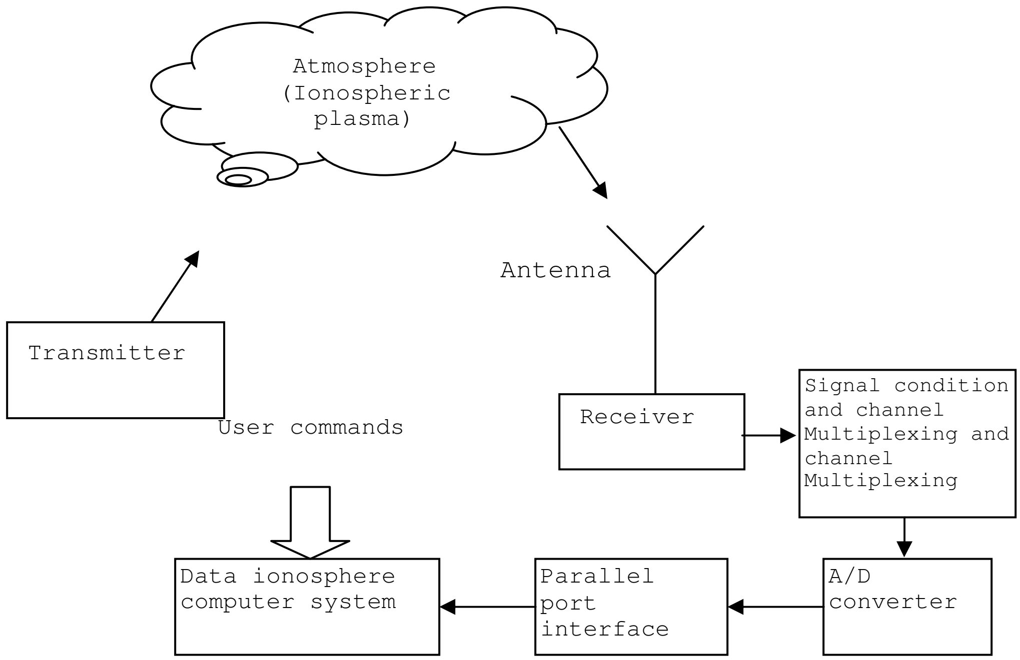


Fig. 1: Block diagram of computer-based drift radar system

Pulse repetition frequency	50 Hz and 100 Hz
Operating frequency	(2.4 MHz – 2.7 MHz for E-region and 5.4-5.8MHz For F-region)
Output impedance	600 ohms balanced

The transmitter unit consists of the following individual parts:

* Pulse generator
* Modulating pulse generator
* Modulator
* Master oscillator
* Power amplifier
* Power supply circuit

The receiver unit design: The main functions of the receiving system are

* To record the signal strength of the echoes reflected back from the ionosphere Region under observations.
* To record the time lags of the similar fades corresponding to the echoes received simultaneously at three closely spaced receiving antennae.
* The signal strength of the echo is required for measurement of the drift velocity and direction utilizing the correlation method. Measurement of time lags of the similar fades, recorded corresponding to the received echoes at the receiving antennae, will enable the measurement of the drift velocity and the direction of movement of the irregularities under study. The receiver consists of the following parts:

* Pulse generator
* Delay pulse generator
* Electric switch
* Band pass Filter and Pre-Amplifier
* Narrow –band receiver

The antenna system: The antenna system used for the hybrid drift system consists of two half wave dipole antennae for transmission and three folded antennae used for reception.

Design of transmission antenna system: The pulsed RF energy was required to be transmitted vertically upwards with maximum power to get a strong reflected echo from the ionosphere and the ionosphere irregularities.

A horizontally polarized half wave dipole antenna fits these requirements extremely well. The horizontally polarized antenna has an electric field lying in a place horizontal to the electric earth’s surface.

The radiation pattern consists of two elliptical loops in the meridian plane on either side of the radiator. The radiation resistance of the half wave dipole antenna is 72 ohms, which can be matched easily. The gain of the half wave dipole antenna is 2.15 dB. The directive gain is 1.64 over the isotropic antenna .The two transmitting antennae were designed to resonate at 2.5 MHz and 5.5 MHz respectively.

The receiving antenna system: The closely spaced receiver technique records the amplitude of the reflected system at three closely spaced receiving antennae on the ground.

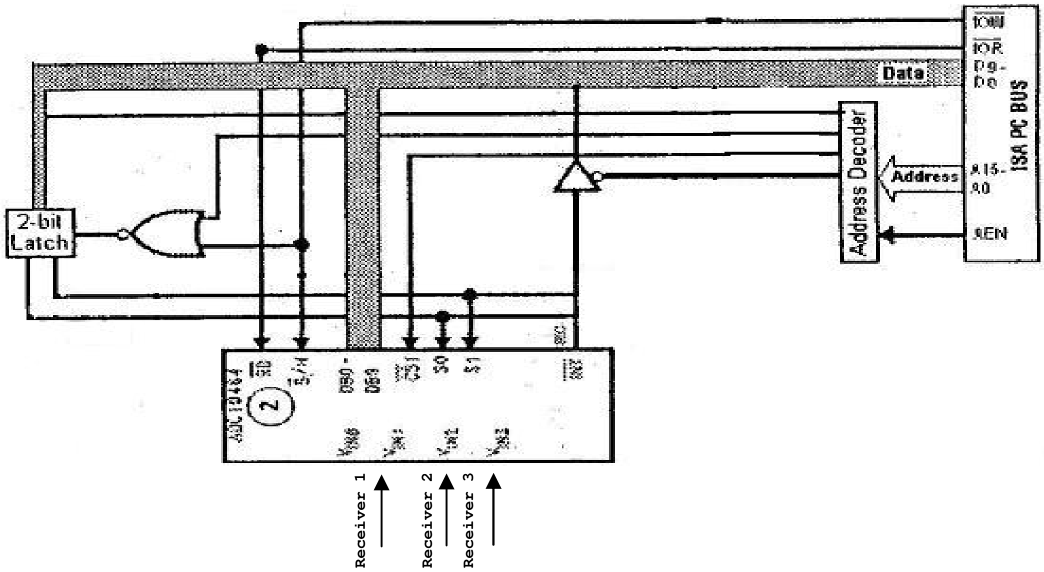
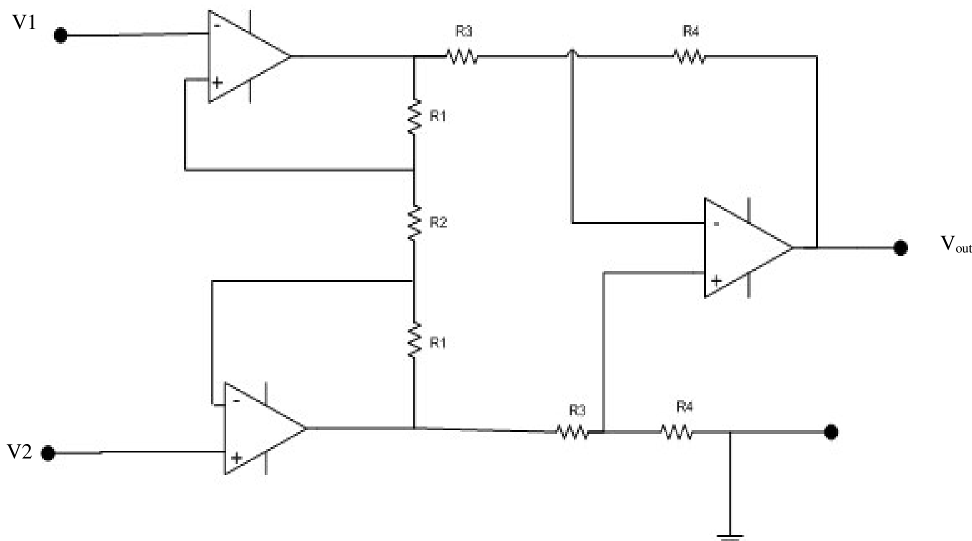


Fig. 2: Block diagram of the drift radar system interface circuit with computer system



R1=120k, R2=33K, R3=R4 = 10 K

Fig. 3: Pre amplification circuit diagram

Three folded dipole antennae were used for receiving simultaneously the reflected signal echoes from the ionosphere layer under study. The three receiving antennae were mounted at three vertices of a right angle. The antenna positioned at the right angle is the reference antenna. The other two antennae are one towards the north and one to the west of the reference antenna. These two antennae were positioned at a distance of 119 meters each from the reference antenna.

Computer interface design for drift radar system: This section describes the analogue and digital interface circuit design, which measures the radio wave signals, reflected from ionosphere atmosphere and provides it to the personal computer in a digital form. The interface circuitry consists of three units: analogue signal conditioning, channel multiplexing, analogue to digital conversion and PC interfacing unit. Figure 2 shows a general block diagram of the radio wave signals received by receiver antennae.

Analogue signal conditioning: This unit brings the receiver antennae signal level up to make it useful for processing and conversion. Further, a desired radio wave signal will often be accompanied by other signals, or by external noise such as alternating voltage picked up from power supply, or during signal amplification. Such noise must be either minimized or removed from the frequency band of the acquired radio wave signal. Each module consists of an instrumentation amplifier, notch and low pass filters and a second amplifier for full-scale adjustment. The latter amplifier is used to adjust the voltage level of the filtered radio wave signal to a level, which meets the input specifications of the used A/D converter. Correct conversion results are obtained for input voltages between 50mV and 5.05 V.

Pre- amplification: Because of its very high input impedance and low output impedance, the instrumentation amplifier is often used to amplify low-level signals. This type of amplifier is commonly a closed loop type and has high common mode rejection ratio. Figure 3 shows a circuit diagram of the instrumentation amplifier used in the present work. The current in the first stage has to be the same everywhere in this voltage divider. The common mode gain circuit is determined by the voltage gain of the second stage, is only 1 and while the difference gains (Ad) is:

Ad = 1 + 2R2 / R1 (1)

The output voltage (Vout) is determined from Vout = V2 -V1 (2)

Analogue multiplexing: The use of a multiplexer in data acquisition systems allows different sources of information to be sent along a common line and therefore reduces the number of A/D converts and connections required in a particular application. An 8 channel CMOS multiplexer is used in the present work for the purpose of signal multiplexing. The selection of input channels is achieved by digital codes provided by computer software via the interfacing circuit as illustrated in Fig. 2. The error caused by the voltage drop on the multiplexer switches is minimized by using a fairly high input impedance operational amplifier at the multiplexer output. The desired full-scale level of this amplifier is designed to be adjustable between 5 and 10 volts, as this range is accepted by most A/D converters.

Filtering: Filtering is used in most data acquisition systems for two purposes[5]; the first is to limit the bandwidth of processed signal to less than half sampling frequency in order to eliminate frequency folding. The second reason is to reduce either the human-made or electrically generated noise (e.g. 50-Hz) in the system. When the bandwidth of the measured signal exceeds the mains interference frequency, it is important to use a filter which has low-pass characteristics and provides high attenuation at the mains interference frequency[6]. In the present work, this task has been achieved by using two cascaded filters, a notch filter followed by a fourth-order low-pass filter. Among the commonly used low-pass filter types, the Butterworth response is found suitable. Circuit diagrams of the used notch and low-pass filters are shown in Fig. 4 and 5, respectively.

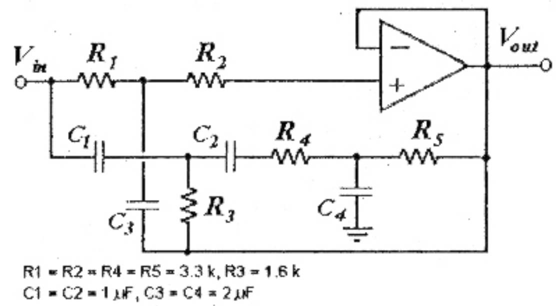


Fig. 4: Notch filter design

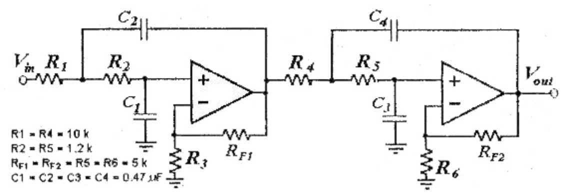


Fig. 5: Low-pass filter design

Channel multiplexing and analogue to digital conversion: The use of a multiplexer in data acquisition systems allows different sources of information to be sent along a common line and therefore reduces the number of A/D converters and connections required in a particular application. A 10-bit A/D converter (ADC 10464) with built-in 4-input multiplexer and sample/hold features is used to convert is used to convert the analogue data provided from the signal conditioning module to digital data. This A/D converter offers sub-microsecond conversion times (600 ns typical) and eases of interface to microprocessors. It has been designed to appear as a latched-input port without the need for external interface logic. In order to ensure fast data acquisition from the three receiver antennae of the signal conditioning, one A/D converter is used as shown in Fig. 2.

PC interface: The basic function of the computer system interface is organizing the process of data transfer from A/D converters to the computer system. Among several scheduling techniques of parallel data transfer[7], the interrupt based data transfer is found the most suitable technique for the present real-time data acquisition task. As illustrated in Fig. 2, The I/O interface circuit consists of an address decoder, a 2-bit latch and a 1-bit input port. The decoder provides a unique chip-select pulse to each of the I/O ports when the corresponding address appears on the address bus. The I/O port assignments of the computer system interface are summarized in Table 1. The conversion starts of the A/D converter is simultaneously activated (via S/H pin) through the IOW control signal. In order to ensure the readiness of digital data from the entire A/D converter, the end of conversion (EOC) status (on the INT pin) is combined by OR-gate preceded the 1-bit buffer, as illustrated in Fig. 2.

Table 1: Ports assignment of the computer system interface

I/O port	Address (H)	Function
2-bit latch	400	Output, channel selector
A/D converter	401	Input, A/D conversions
1-bit buffer	402	Input, end of conversion

System software: The system software was developed using Java. However, the entire structure of system software can be divided into three parts:
A main program
An interrupt service routine
A program for drift radar system signal analysis.

Main program: The main program is developed for user interface and system initialization. The user interface consists of a set of menus, windows and user editor for drift radar system monitoring and data processing. The other part of main program task is developed to initialize the sampling timer and acquisition period, I/O ports, interrupt vectors, stacks and memory buffers and pointers.

Interrupt service routine: The interrupt service routine (ISR) organizes the process of data acquisition from the three antennae receivers and storing the acquired data in data files on the PC memory. Each file corresponds to one of the input receivers. The frequency of the interrupt signal represents the sampling frequency of the acquired radar system signal, is made programmable between 200 Hz and 1KH. The desired sampling frequency (in the specified range is simply achieved by using the variable PC timer. The use of different sampling frequencies avoids alliasing, in accordance with recommendation to use a sampling frequency of 5-10 times the bandwidth of the acquired signal[8].

When interrupt occurs, the program execution is transferred from the main program to the ISR. A sequence of events occur during the execution of the interrupt service routine like start of conversion, read and save samples from A/D, etc.

System signal analysis program: This part of software is developed for radar signal analysis and performing calculations for drift velocity and finding out the drift direction. However, this program will carry out the required graphs like polar weekly graphs of percentage occurrences and histograms for drift velocity. Also, a complete analysis report for radar signal can be obtained at the end.

Drift Radar system Implementation: The developed drift radar system has been tested at Amman – Jordan that lies at (32 deg North, 37.3 deg. East) to study the behavior of irregularities but it has been shown that this area is not in the proximity of the magnetic equator. However, another study is carried out at Muscat, Oman, so the system has been tested at this region (22 deg. North, 57.3 deg. East). The data has been recorded for drift velocity and directions for average weekly for the period April 2004, to Sept. 2004 for E and F regions. The data was acquired by the system and then stored in files. The system analyzed the acquired data and the result of the analysis along with the graph of the velocity occurrence and histogram of drift velocity for E-region and F-region is shown at Fig. 6 and Fig. 7, respectively.

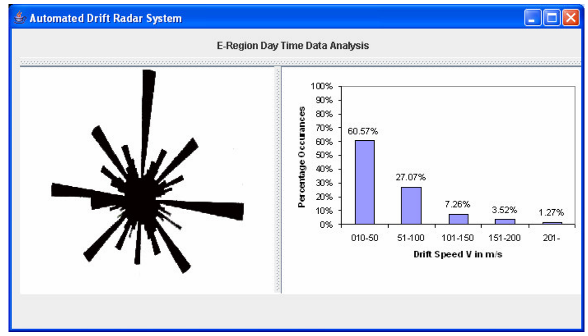


Fig. 6: E-region Day time data analysis for the period April-2004-Sept. 2004

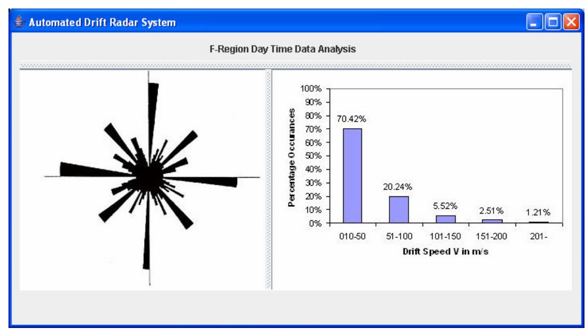


Fig. 7: F-region day time data analysis for the period April 2004-Sept. 2004

The system analysis report can be summarized as follows: The drift radar system has shown that the amplitude and direction of the drift velocity is obtained from the polar graphs and the velocity distribution against percentage of occurrence can be derived from the analysis of histograms.

The analysis of the data has revealed that there is effect for the solar zenith angle on the drift velocities and directions. It can be mentioned that there is gradual increase in the percentage of irregularities having low velocities as compared with the decrease for others and at higher velocities as the Zenith angle of the sun gradually moves up above the equator.

It is also noticed that high velocity drift components decrease continuously as the solar Zenith angle and apparently linked with the total solar flux that changes from winter to summer.

The higher velocity drift has shown a significant dependence on the Zenith angle that remained constant throughout the measurement.

The histograms revealed that the distribution of velocities is such that the low velocity component is the highest while for higher velocities there is no significant spread.

CONCLUSION

The system developed based on closely spaced receiver technique. The system could successfully give complete information about the behavior, nature of origin and the life cycle of ionspheric irregularities for the E and F region over the area under study. This information is useful for setting up a radar system. However, the system has shown a high performance and reliable. It also has shown that it was developed with low cost.

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