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DEVELOPMENT OF COHERENT BEACON RECEIVER SYSTEM FOR THE INDIAN CRABEX STATIONS

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Abstract. This paper presents in detail the design and development of a coherent radio beacon receiver system with the associated data acquisition and control software, being used in the Coherent Radio Beacon Experiment (CRABEX)[4] project. The CRABEX is a national project involving the participation of various national institutes and universities and envisaged by Space Physics Laboratory of Vikram Sarabhai Space Centre, Thiruvananthapuram. The project involves setting up a chain of beacon receiving systems across the country for receiving coherent beacon signals from the Low Earth orbiting beacon satellites. The simultaneous data so obtained is primarily used for calculation of Total Electron Content (TEC), which is eventually used for 2-D tomographic imaging of ionosphere over India.

1 INTRODUCTION

It is an established fact that ionospheric tomography is an effective, modern and comparatively inexpensive method for the generation of maps of electron density over a wide region of the ionosphere, in a short time. In satellite radio tomography, a number of groundbased receivers simultaneously obtain the radio signals transmitted from Low Earth Orbiting beacon satellites. These receivers measure the relative phase difference between the incoming coherent signals, and this parameter is proportional to the integral of electron density along the ray path from the satellite to the ground receiver, termed as Total Electron Content (TEC). The ground receiver stations are so chosen as to form a chain along the plane of satellite movement and have some common intersecting data, which can be used for derivation of electron density maps.

In order to find the relative phase difference between the incoming coherent signals, it is required that the ground receiver be of coherent type and provide instantaneous phase difference between the incoming signals, for the entire duration of satellite visibility period. The first step in the ground receiver design starts with understanding the onboard transmitted coherent beacon signals. With a proper link budget calculation, the minimum sensitivity required for the receiver is calculated, along with finalizing the antenna type. As the present operational beacon satellites are mostly of *OSCAR* series, two separate left circularly polarized, offset fed patch antennae, one for VHF and other for UHF, is used.

2 SYSTEM ARCHITECTURE

The receiver system consists of two separate units - the outdoor unit and the indoor unit[2,3]. The outdoor unit forms the front end and down-converts the incoming signal. The phase locking, data acquisition, data storage and processing are done in the indoor unit connected to a PC.

As indicated in the block diagram of the outdoor unit in Figure 1, the received signals from the two antennae is fed to the front end of the receiver, where it is down-converted to two intermediate frequencies using a single local oscillator. This helps maintain the coherency of the down-converted signals. The UHF of 400 MHz is converted to 10.7 MHz and the VHF of 150 MHz is converted to 4.0125 MHz, thus maintaining the 3:8 ratios.

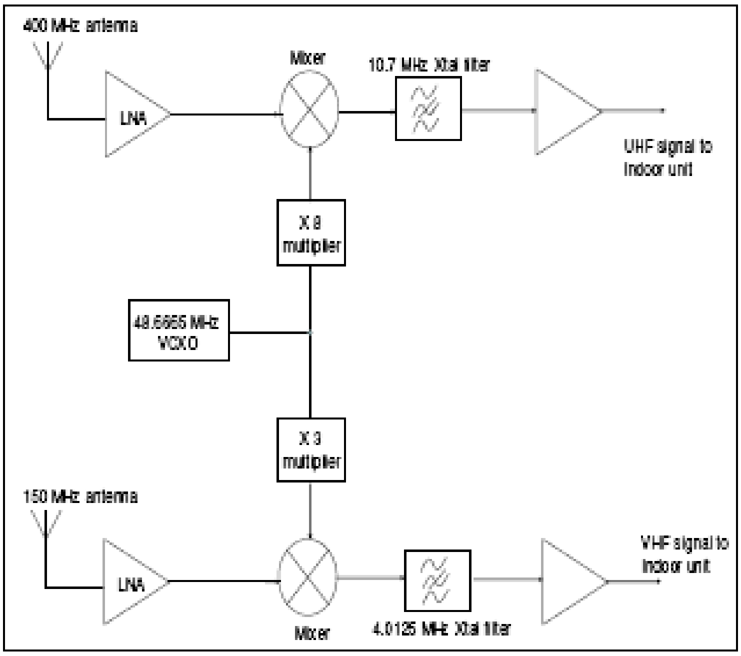

Figure 1: Block diagram of outdoor unit

In the indoor unit as represented in the block diagram of Figure 2, these signals are locked to two separate analogue phase locked loops. As the signal has to be tracked over a dynamic range of $\sim$ 35dB, a wide band logarithmic amplifier is used before both the PLLs. Both these PLLs provide 1.3375 MHz reference and data signals, locked to a stable source.

These form the two inputs to the phase detector module, whose outputs are quadrature signals. These quadrature I and Q signals along with the amplitude channels are fed to a 4-channel simultaneous sampling card. These are then fed to a 16 bit analog-to-digital converter card residing in the PC, wherein each signal is sampled at the rate of 100 Hz.

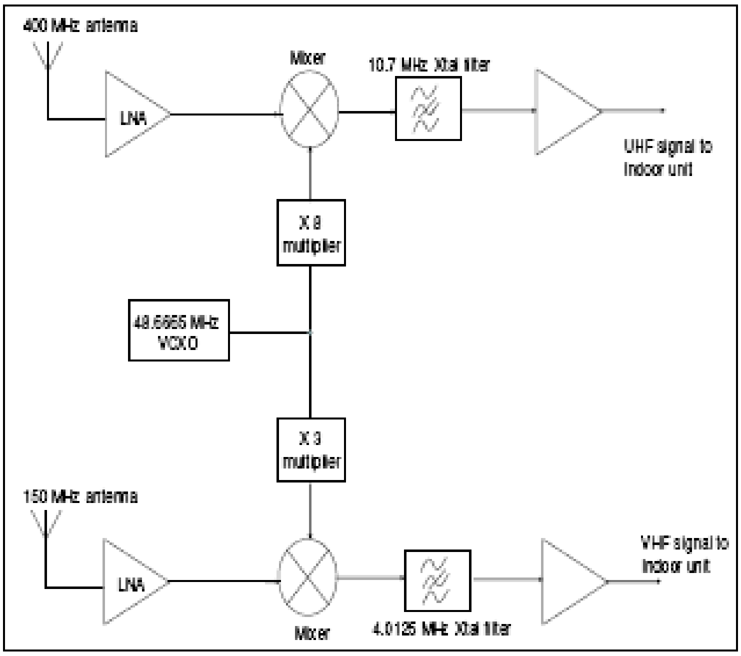

Figure 2: Block diagram of indoor unit

The receiver system also has a microcontroller which does the satellite tracking, by varying the dc voltage given to the front end local oscillator VCXO. The receiver can track satellites in the + 80 ppm, 0 ppm, -80 ppm and -145 ppm offsets in the 150 MHz and 400 MHz band, by appropriately tuning this VCXO.

2.1 Time synchronization

The data from the I and Q channels of the receiver forms the raw data set and is used to compute the instantaneous relative phase between the coherent signals. For the tomographic reconstruction of the ionosphere, it is imperative that this data be obtained from a number of receiver locations simultaneously. This calls for accurate time synchronization between these different receiver stations. For this, a commercially available GPS receiver module is used[1].

The GPS receiver module selected is very compact and is of low cost, with an active patch antenna and a 2m long cable. The in-house developed data acquisition software gets the time, latitude and longitude from the GPS receiver connected to the PC through serial port, prior to recording every set of data from the satellite. The GPS receiver is programmed initially to get the time stamp with an accuracy of better than 100 milliseconds.

3 AUTOMATION OF THE RECEIVER SYSTEM

For unattended operation of the receiver system for all the required satellite passes, the data acquisition has been made automatic according to the satellite pass schedules. A software named *ASTraS, (Automatic Satellite Tracking Software)* has been developed in-house with *LabView*, which automates the data acquisition, by collecting the samples at a prescribed rate, processes the data once the pass is over and archives both the raw and processed data into unique files. The input for this software is the *Two Line Element (TLE)* data of each satellite, which contains the satellite orbital parameters.

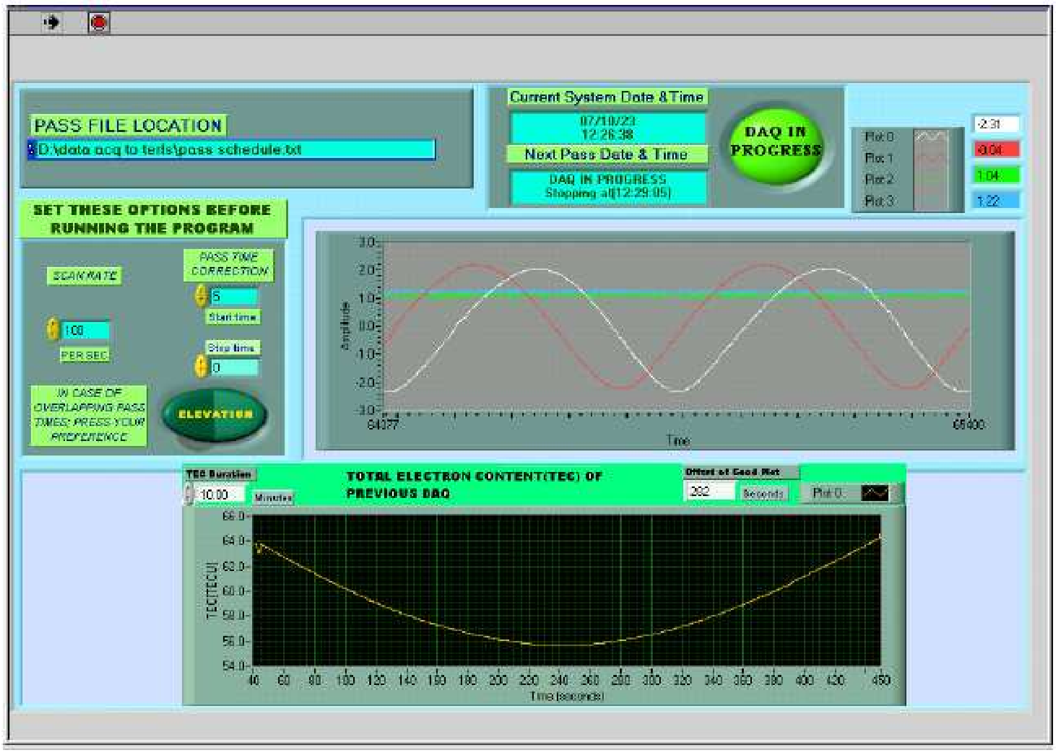

Figure 3: Front panel screenshot of ASTraS

The major features of ASTraS can be summarized as:

- Combining different satellite pass files for a month, into a single one.
- Arranging the above in a chronological order, with the relevant details of each pass, like start time, end time, maximum elevation etc represented in a single line.
- Inclusions of only those passes which have elevation more than, say 30 degrees (User defined elevation).

- Protection against power failure.
- Intelligent enough to switch to the desired pass in the cases of satellite pass overlap, with a user defined option.
- Automatic data acquisition for required duration with GPS time stamping.
- Indication of when the next pass is due.
- Online data plots and TEC plot.
- Easily upgradable to include other/new similar satellites.
- Raw data stored as a text file, with PC date, time and station code as the filename, and the details of the pass, station code and GPS time as the header.
- Processed data with TEC and S4 indices after every pass is also stored as unique files.

4 CONCLUSION

The CRABEX receiver has been installed at six stations across the country from Trivandrum to New Delhi, with a total longitudinal separation of ~ 20 degrees. As mentioned, the stations are along the same meridian to give meaningful data for tomographic reconstruction of the ionosphere. The chain is being operated continuously with data from the various stations being sent to the nodal center at Space Physics Laboratory, Trivandrum. Access of data via the Internet/ftp for authorized users is the immediate step in the future.

REFERENCES

[1] A method of time synchronization between the different ground receiver stations of the Coherent Radio Beacon Experiment using GPS, Sreelatha P et al, presented at URSI, Oct 23 29, 2005, NPL, New Delhi.

[2] CRABEX receiver manual

[3] Communications receivers: Principles and design, Ulrich L.Rohde.

[4] Smitha V Thampi et al, Coherent radio beacon experiment (CRABEX) for tomographic imaging of the equatorial ionosphere in the Indian longitudes - Preliminary results, Advances in Space Research, 2007.