A method of time synchronization between the different ground receiver stations of the Coherent Radio Beacon Experiment using GPS

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Abstract

The Coherent Radio Beacon Experiment is a national program for the study of low latitude ionosphere with participation from various national institutes and universities across the country. The program involves the simultaneous reception of beacon transmissions from Low Earth Orbiting beacon satellites at the ground receiving stations, setup at different locations of the country. Time synchronization is thus essential for the data to be valid for the generation of tomograms. An innovative method of time synchronisation using GPS is used here instead of extracting the time code from the orbiting satellites. The paper presents in detail the GUI program developed in-house for GPS synchronised data acquisition.

Introduction

The Coherent Radio Beacon Experiment (CRABEX) is a national project envisaged and being implemented by Space Physics Laboratory, Vikram Sarabhai Space Centre, Trivandrum for the study of ionospheric irregularities by the technique of ionospheric tomography. The project basically involves reception of VHF and UHF signals from radio beacons on board Low Earth Orbiting (LEO) beacon satellites. The beacons on board LEOs transmit two coherent frequencies, 150 MHz and 400MHz, used for navigational purposes earlier, are now used for ionospheric studies. These signals are received in the ground by a coherent beacon receiver which measures the relative phase between the two received signals.

The coherent beacon receiver receives the transmitted 150 and 400 MHz, and the 400 MHz is taken as the reference channel and 150 MHz as the data channel. The receiver then detecyts the instantaneous relative phase difference between the 150 MHz and 400 MHz by phase locking the signals. The phase difference measured is output as I and Q channels, which constitute two data channels. In addition, the receiver also measures the instantaneous amplitude of unlocked 150 and 400 MHz, which form another pair of data channels, thus providing a total of four data output channels. These four signals available as the receiver outputs are to be simultaneously sampled and recorded onto PC. The data thus recorded gives the Total Electron Content (TEC) along the ray path from the satellite to the ground receiver. This parameter TEC is indicative of the Earth's ionospheric variations. The TEC variations represent the changes in the ionospheric electron content between the satellite and ground receiver due to ionospheric irregularities.

For the application of tomographic techniques for the study of ionosphere, multiple receiver stations located along the plane of satellite orbit, are used to receive observe the same satellite pass and record the data. The TEC calculated from the different stations for the common pass time can be used for ionospheric tomography. This requires time synchronization between the various stations. As the satellite is orbiting at an altitude of 900 to 1000 km at a speed of approximately 7 kilometres per second, a difference of 1 second between the stations will give an error of the order of kilometres when tomographic reconstruction is done. Hence this requires a method, which can provide time synchronization of the order of milliseconds.

For time synchronisation, one of the methods, and the most commonly used one in earlier days, was by decoding the time code transmitted by the tracked satellite. This calls for a decoding circuitry in the receiver and is rather complex. The second method, which is opted here, is by the decoding of the time signals using GPS. For this, each station is provided with a GPS module along with the beacon receiver. The compact, easily programmable GPS module is programmed to transmit the required NMEA sentence to the PC, which will be decoded by the software for data acquisition, written in LabView, an object oriented programming language.

System Details

The data acquisition system for the CRABEX receiver consists of an 8 channel simultaneous sampling card, Model SC-2040, am E-series multi channel PCI card Model PCI-6035E and a GPS receiver module Model GPS 25LVS. The block diagram of the system is shown in figure 1.

The SC-2040 has eight differential inputs, out of which four are used for the present system. This is then connected to the PCI-6035 E card in PC using a 68-pin SCSI cable. While configuring the PCI card, this SC-2040 is also enabled as its accessory. This ensures the data acquisition software also sends the required Hold pulses to the card for sampling, at the specified sampling rate.
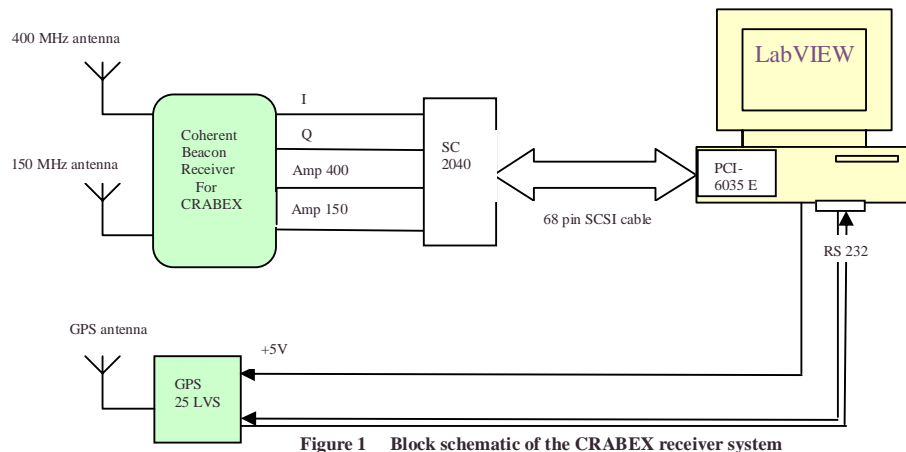
Figure 1   Block schematic of the CRABEX receiver system

The GPS output is connected to the serial port using an RS-232 cable. The power for the GPS is +5V, and is taken from inside the PC. The GPS receiver sends a variety of NMEA sentences indicative of the various parameters received. This NMEA sentence is first programmed to suit our requirement. In this project, the GPS receiver chosen is the low cost, light weight module GPS 25 LVS of M/s. Garmin, USA. This GPS is programmed to transmit at 4800 bauds per second, and the NMEA sentence "*GPRMC*". This sentence gives all the parameters of date, time, latitude and longitude of the station.

There is also a 1 pulse per second output available for the GPS, which is accurate up to microseconds. The command GPRMC starts on the falling edge of this pulse, and lasts for a duration of 100 msec maximum, and repeats every second. The software for GPS acquisition is written such that this command is read from the rising edge of the Start pulse. This ensures that the time accuracy is better than 100 msec between two independent systems. It means that if the program is started after the first rising edge of Start pulse, it will be missing the first NMEA sentence. But it waits till it gets the starting edge of the next pulse and acquires the next NMEA sentence. By this method, the uncertainty in time is less than 100 milliseconds.

Description of the software

The software for data acquisition is written in LabVIEW. It has the following features

- The acquisition is started using software trigger, by giving a start command.
- The file name for storing the acquired data is taken as the name of the satellite, which is entered by the operator. The date and time taken from PC are also appended to the file name and saved as a text file. The filename typically looks like "**xxx mm-dd-yy- hr.min.sec.txt**".
- There are four lines of header which are then saved onto the file.
  - The first one is the scan rate. This is normally fixed at 100 Hz, as the variation of differential phase (also termed as Differential Doppler) is always less than 10 Hz.
  - The second line gives the parameters from GPS. This is taken by reading the NMEA sentence from the GPS, and by properly arranging the obtained data.
  - The next line gives the date and time as taken from the PC. This helps to indicate the exact time difference between the local time and translated GPS time.
  - The last header is the station name. As there are multiple receiving stations involved, this is required for generation of tomogram. The elevation of the satellite pass, which is also entered by the user, is also written in the same header.
- Four channels of data are acquired for the entire duration of the pass.
- The software key stops the acquisition, after the pass is over. The NMEA sentence is again acquired. The date, time, latitude and longitude parameters from GPS are written as footer and the data file is closed.

The front panel of the software is shown in figure 2. It may be noted that the GPS stays invisible to the user, and the program is easy to operate. The block diagram of the software is shown in figure 3. A typical data file acquired in one receiver station, Hyderabad, is also shown below, with filename and headers and footer. The four columns of data are I and Q channels of differential phase, amplitude of 400 MHz and amplitude of 150 MHz.
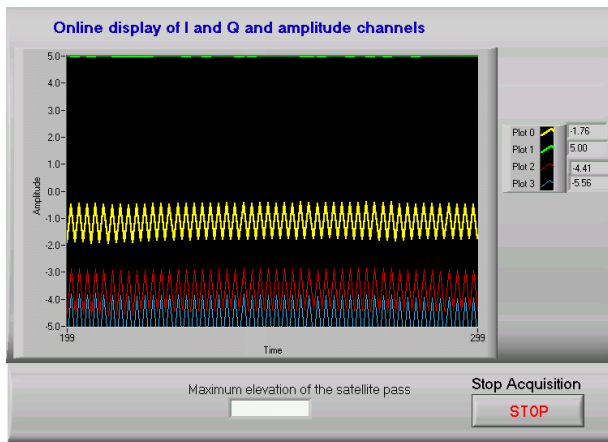
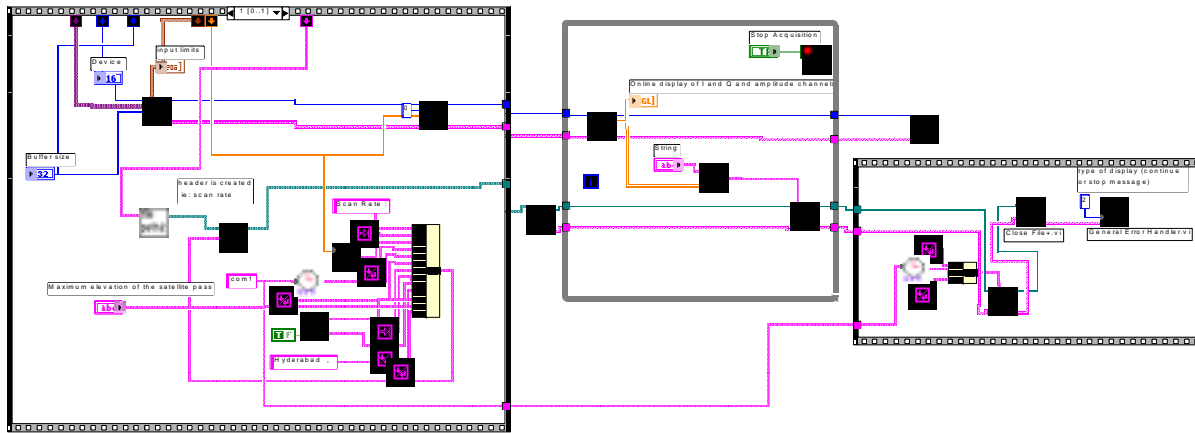**Figure 2   Front panel of the data acquisition software**

Figure 3   Block diagram of the data acquisition software

A typical data file structure:

File name: **oscar31-10-2-04 3-11-57PM.txt**

```
Scan Rate:        100
02-10-2004,       09 h 42 m 13 s UT,        17-01N,        078-11E
10/2/04  3:11:57 PM
Trivandrum, 59º
 2.12    0.41    0.26    0.56
 2.15    0.79    0.29    0.61
 2.15    0.89    0.22    0.62
 2.16    0.78    0.08    0.65
…………………………………………..…
-0.42    1.96    0.35    0.64
 1.20    2.30    0.32    0.66
02-10-2004,       09 h 52 m 03 s UT,        17-01N,        078-11E
```

Conclusions

The use of the data acquisition cards from M/s. National Instruments and LabVIEW software has made the realisation of the data acquisition and time synchronisation easier and faster. The receiver and data acquisition has been successfully installed at five stations in the country, and simultaneous data useful for generation of tomograms, are being acquired.

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