Establisment of Ionospheric TEC and Scintillation Measurement System Using Radio Beacon Satellite Receiver at Pontianak Indonesia

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ABSTRACT
Characteristics of the ionosphere which is usually represented by Total Electron Content (TEC) is useful for communications, satellite navigation and also aerospace vehicles. The ionopheric scintillation often cause effects on communications with satellite, and also affects on GPS perfomances. A new developed measurement system called radio beacon satellite receiver to measure the ionospheric TEC and scintillation has been implemented in Pontianak (0.003°S, 109.366°E) as a part of ionospheric observation network in equatorial Indonesia. The open source toolkit for software defined radio, namely GNU Radio and an open source hardware, called Universal Software Radio Peripheral (USRP) have been used to develop receiver system in order to conduct digital signal processing and to receive satellite radio beacon satellite signal of 150 and 400 MHz. GRBR installation at Pontianak was successful and has been operated since March 2011. TEC and scintillation data were received and collected, and the results showed a good agreement or much better compare to an analog beacon receiver operated in the similar place. In this paper, the description of the system, the experiment and application first results of the observation at Pontianak Observatory, including data comparison with an analog beacon receiver is reported.

Keywords: radio beacon receiver, GNU radio, USRP, TEC and scintillation

1 INTRODUCTION

The ionosphere is a part of the upper atmosphere which ionized by solar radiation, and plays an important role for electromagnetic wave propagation such as HF radio and GPS signal. The ionosphere affect radio propagation to distant places on earth, and need to be observed continuously because the ionosphere reflect, refract, diffract and scatter the radio waves. Information about the characteristics of the ionosphere, which usually represented by the characteristics of the TEC (Total Electron Content), are useful for telecommunication, GNSS positioning, and the aerospace vehicles. TEC is the number of electrons in vertical columns (cylindrical), corresponding to a square meter along the signal path in the layer of the ionosphere.

Scintillation events that occur in the ionosphere often result in disruption of communications with the satellite. Scintillation at L-band is also influence GPS performance that works at frequency GHz (L-band), especially in equatorial regions. As a result, satellite-based navigation systems, aviation, determining the location and time which very much depend on the GPS are also affected [1].

A new developed measurement system namely GNU Radio Beacon Receiver (GRBR) is a digital receiver based on open source devices which is consist of an open source toolkit for software defined radio, called GNU Radio is used to perform digital signal processing, and an open source hardware, namely Universal Software Radio Peripheral (USRP) is used to receive radio beacon satellite signals of 150 and 400 MHz [2]. The system has been implemented in Pontianak (0.003°S, 109.366°E), as a part of ionosphere observation network in equatorial of Indonesia. It will be the compliment for the facilities installed for the ionosphere observations operated in Indonesia such as MF radar, Ionosonde, GPS receivers, ITS-30, TEC-meter, Magnetometer, Win

Radio, VLF receivers, etc., which will be very useful to study low latitude ionosphere over Indonesia.

2 SYSTEM DESCRIPTION

Figure 1 shows the block diagram of the radio beacon receiver system, where PC Linux and USRP are the main components. The Quadrifilar Helicoidal Antenna (QFH) antenna receive signals of 150 and 400 MHz. Amplified by pre-amplifier and filtered by band-pass filter (BPF).

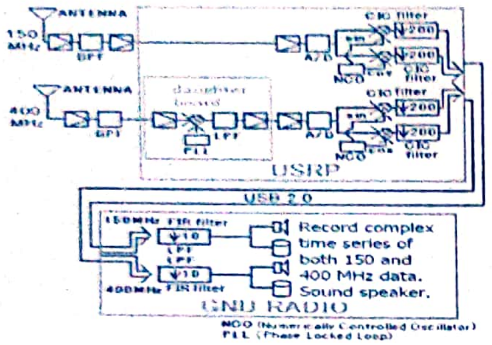

Figure 1. Block diagram of the radio beacon satellite receiver.

Signal of 150 MHz is amplified by Low Noise Amplifier (LNA) before enter the USRP. In the USRP, the signals are sampled by Analog to Digital Converter (ADC), and signal processing is performed on FPGA. Digitized signals for both 150 and 400 MHz are multiplied with SIN and COS signals generated by numerical controlled oscillator (NCO), and converted to complex signal. Then signals are filtered by cascaded integrator comb (CIC) filter before transferred to LINUX PC. Sample rate are finally reduced to 32 kHz by GNU-radio program before processing. Both complex signals are stored in separated baseband Inphase (I) and Quadrature (Q) files.

Figure 2 shows the block diagram of software-defined radio using USRP and GNU radio to describe how the Software-Defined Radio (SDR) developed by using GNU Radio, USRP, and daughterboards are implemented in this system. On USRP, function of ADC/DAC and FPGA (Field-Programmable Gate Array) are available, while daughterboard combined to the USRP to have a RF function translates receiving signals [3]. The technique is implemented to the receiver system with freeware hardware and software, and available at GNU Radio. (http://gnuradio.org/trac) and Ettus Research (http://www.ettus.com). [2],[4].

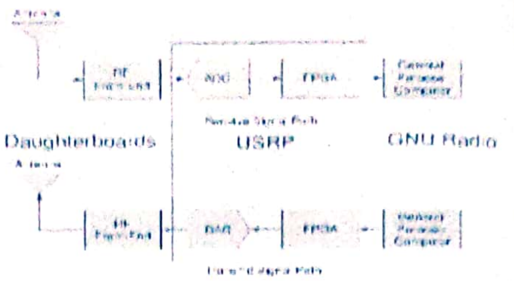

Figure 2. Block diagram of software-defined radio using USRP and GNU radio

The structure of the GRBR software as shown in Figure 3 consists of the main program i.e. *GRBRhousekeeping.py* that runs multiple supporting programs, while *GRBRmon.py* is a program to monitor the status on GRBR while running. By this program system setting, satellite name and schedule, on going process, will be displayed [2],[4]. The main program is GRBRhousekeeping.py which control all process in system, consist of three sub program. First, the *GRBRautorun.py*, which utilized to capture signals from the processing that has been done in the USRP to GNU Radio. By this program bandwidth of the signals are limited by the Finite Impulse-Response (FIR) filter and convert 10 times, so the sample rate become 32 KHz. Then signal is processed to separate it from the information signal. Each frequencies are stored in a separate file.

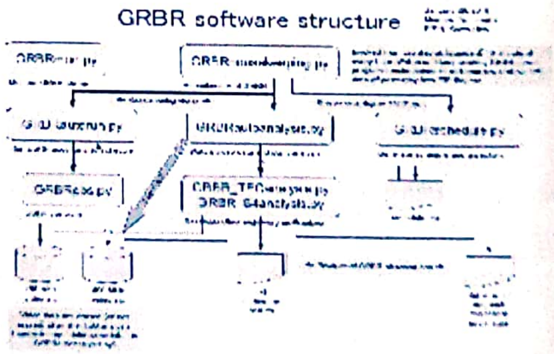

Figure 3. Software structure of GNU-radio Beacon Receiver

Secondly is *GRBRautoanalysis.py*. The signal that has been stored in raw data file is processed to calculate ionospheric TEC and scintillation by using two programs, *GRBR_TECanalysis.py* and *GRBR_S4analysis.py*. The third is a supporting important program, *GRBRschedule.py*, which prepare the schedule and trajectory of the satellite received by the GRBR based on the cosmic.tle data.

3 GNU-RADIO BEACON RECEIVER (GRBR) AT PONTIANAK

The GNU-radio Beacon Receiver (GRBR) has been installed and operated since March, 2011 at Pontianak LAPAN Observatory, West Kalimantan (0.003°S, 109.366°E).

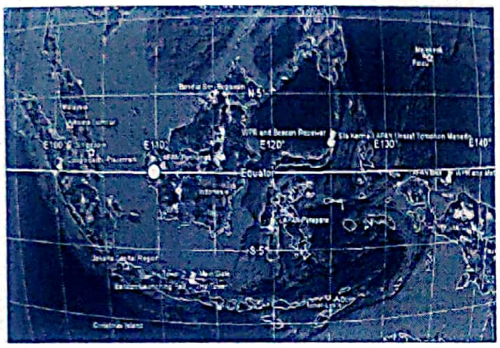

Figure 4. LAPAN Observatory at Pontianak West Kalimantan, right on the equator

GRBR consist of outdoor and indoor devices Quadrifilar Helicoidal (QFH) and GPS receiver are placed outside of the control room [5]. The receiving 150 and 400 MHz antenna are equipped with pre-amplifier with compact water resistant casing. GPS receiver is used to get position of the LAPAN Pontianak observatory and to accurate time data for synchronies with the satellites pass timing.

The indoor devices contain of a low-pass filter (LPF) set for both 150 and 400 MHz frequency, a low noise amplifier (LNA) for 150 MHz signal, the USRP and PC system and software. All modules supplied by electricity power back up with UPS and generator, so the system will be able to operate 24 hours a day. System is then connected to a network for data transfer and monitoring remotely. GRBR data is accessible near real time by VPN to LAPAN Bandung Data Center (http://foss.dirgantara-lapan.or.id)

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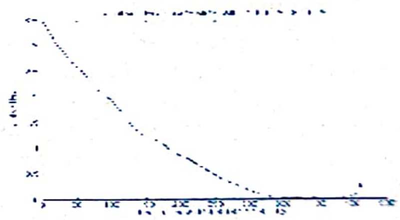
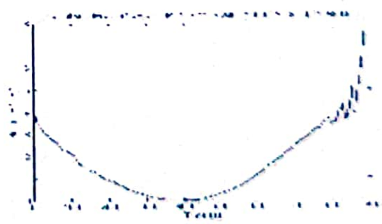
4 OBSERVATION RESULTS

Figures 5 shows satellite pass over Pontianak station on 19 March 2011, i.e. COSMOS and RADCAL pass in polar orbit, and CNOFS passes in equatorial orbit. COSMOS2414 satellite passed on 19 March 2011 from 00:25:39 until 00:42:20 UT, which is morning in local time (UT+7). The satellite appeared from the south horizon at the azimuth 184°, reached the maximum elevation 86° at 00:34 UT, and set at the azimuth 2°, moved to the north and lost reception at 00:42:20 UT. Duration of the receiving signals was around 17 minutes (1002 seconds). RADCAL satellite passed on 19 March 2011 04:07:23 until 04:21:58 UT, which is noon time in local time (UT+7). The satellite appeared from the south horizon at the azimuth 165°, reached the maximum elevation 55°, and set at the azimuth 5°, moved to the north and lost reception at 04:21:58 UT. Duration of the receiving signals was around 14 minutes (870 seconds). CNOFS satellite pass was on 19 March 2011 from 08:42:16 until 09:00:24 UT, which is afternoon in local time (UT+7). The satellite appeared from the west horizon at the azimuth 300°, reached the maximum elevation 40°, and set at the azimuth 100°, moved to the east and lost reception at 09:00:24 UT. Duration of the receiving signals was around 14 minutes (865 seconds). Data obtained in every satellite pass are also shown. The data contain of Relative Power, Frequency Doppler Shift, TEC and S4 Index derived from COSMOS, RADCAL and CNOFS respectively.



(a)



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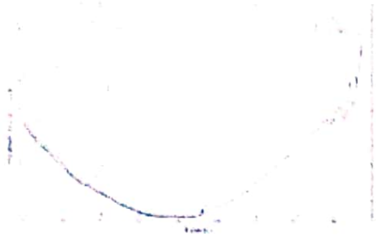

(c)

Figure 6. Comparison of data by digital receiver GRBR and analog receiver

The relative TEC data obtained by receiving beacon satellite signals from COSMOS satellite passed on 18 March 2011, 21:22:58 UT (04:22:58 LT) are shown in Figure 6. Data received by both analog receiver (6a) and digital receiver GRBR (6b), operated simultaneously in Pontianak Observatory. Both data are plotted on similar scale to compare the value (6c). Different on receiving time may due to different on synchronization of satellite TLE data. GRBR data was updated every day automatically, while the analog receiver was not updated daily. The GRBR data has high resolution data compare to analog receiver, and both data showed a good agreement on relative TEC value.

5 CONCLUSION

GRBR for ionospheric TEC and scintillation measurement in Pontianak Indonesia has been established successfully. The GRBR is a part of the equatorial network provides TEC and scintillation data at Bandung Data Center in a near real time.

Compare to a beacon analog receiver were installed at the same location, data showed good agreement on relative TEC value. GRBR data has high resolution data compare to analog receiver.

6 ACKNOWLEDGMENT

Authors would like to thank LAPAN and Professor Dr. Mamoru Yamamoto for supporting us to study GRBR. Thanks also to Rizal, Mario, Hendro and Yana for discussion and helping us.

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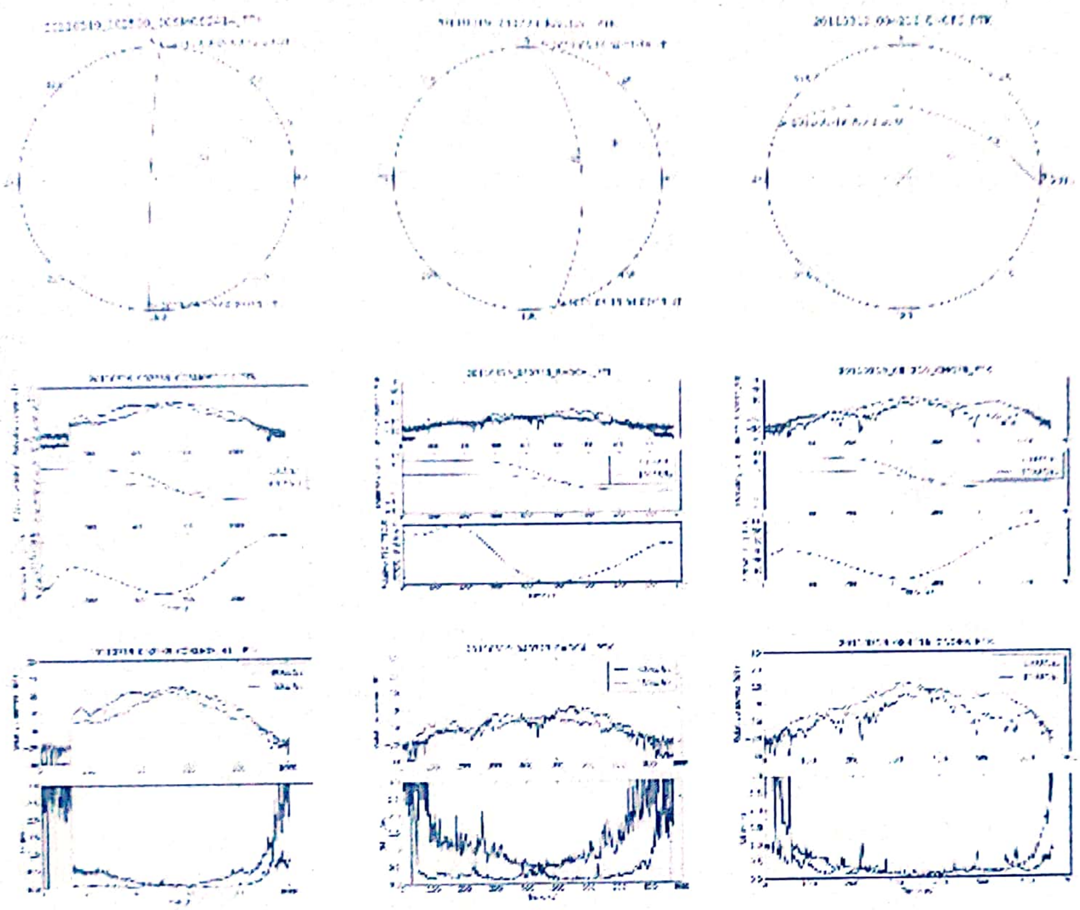

Figure 5. LEO satellite trajectory data at Pontianak Space Observatory and data obtained on every satellite pass, received on 19 March 2011