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Design of ionosphere sensor for total electron content measurement

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Design of ionosphere sensor for total electron content measurement

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Abstract. National Institute of Aeronautics Space (LAPAN) develops satellites for many applications, such as for remote sensing, with camera and sensors for atmospheric parameter measurement. Distribution of electron density in altitude 60 to 1000 km, is very important for many applications, such as for radio communication and as early warning indicator. Many papers indicate the correlation of electron density variation to earthquake event and also mountain eruption. For covering wider area on ionosphere region of earth are needed a sensor based on satellite to collect the ionospheric data. Nanosatellite in constellation give more data in space and time. Although nanosatellite limited in of size and power, some nanosatellites already implemented and launched for scientific mission. In this research, we conduct a simulation and then fabrication steps, to validate the consistency of simulation one and the measurement. The antenna for beacon transmitter, and for telemetry has been fabricated and have a good result with antenna gain more than 4 dB. This paper discusses the design of ionospheric sensor that is proposed for ionospheric TEC measurement and its progress.

1. Introduction

The ionosphere region which is the boundary between atmosphere of the earth and space have electron and photon. Many instruments have already launched to monitor that region. The big size satellites for ionosphere research has discussed in papers [1, 2]. But, the big size satellites have limitation to get more data in space and also relatively expensive for construction and launching. Nanosatellite in constellation will gives more data in space and time. Although nanosatellite have limited resources of size and power, some nanosatellite already implemented and launched for scientific mission [3-6]. Design and re-configurable communication system for nanosatellite presented in paper [7]. Dual-band beacon transmitter for total electron content (TEC) in ionosphere discussed in papers [8, 9]. National Institute of Aeronautics Space (LAPAN) develops many satellites, is intended for deriving the earth gravity, distribution of neutron in the atmosphere, electron density and for others in altitude 60 to 600 km in vertical profile and others. For covering wider area on ionosphere region of earth are needed the satellites to collect ionospheric data. This paper discusses the design of ionospheric sensor onboard nanosatellite for ionospheric TEC measurement. The antenna for beacon transmitter and for telemetry use micro strip antenna with circular polarization. This polarization is more stable in amplitude of signal in receiver system. In the future research is to fabricate, to combine and to test the all blocks that consisting of beacon antenna, telemetry antenna, signal oscillator and power amplifier with a space standard.

2. Principle of Total Electron Content (TEC) Measurement

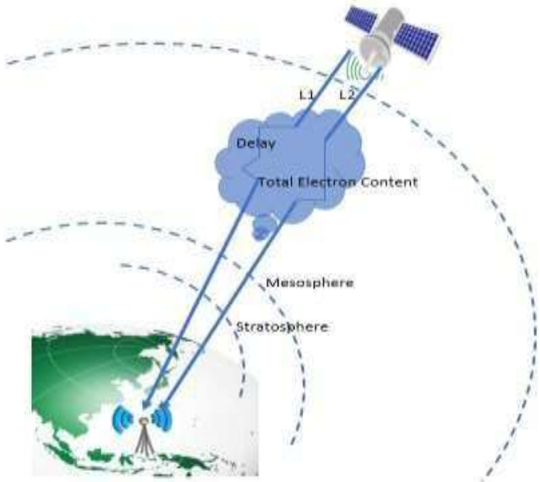

Figure 1. Principle of TEC measurement

Principle of TEC measurement is showed on figure 1. The satellite transmits two unmodulated signals to ground of earth with the same phase and different frequencies, $_1$ = 1.5 GHz and f_2 = 2.2 GHz passed the ionosphere. The radio wave signal will be affected and bended by the electron density on ionosphere layer. The signals having frequency L1 and the frequency L2 undergo a difference effect caused by electron in ionosphere. Phase differences between $_1$ and $_2$ is calculated to determine electron density in ionosphere as explained on equation [1-3, 9].

$$u = \cos\{2\pi \quad (\frac{}{c_p} -)\} = \cos\{2\pi \quad (\frac{}{c} -)\} \tag{1}$$

$$= \frac{2\pi}{c} - \frac{\pi A}{c} \int dx + \tag{2}$$

$$\text{TEC} = \int \tag{3}$$

where U is amplitude, f is frequency, is phase velocity, c = 2.998 × 10^8 m^2 s^{-1} is the speed of light, x is position, and t is time. is electron density, is phase of signal and is error value.

3. Design of Nanosatellite and Ionospeheric Sensor

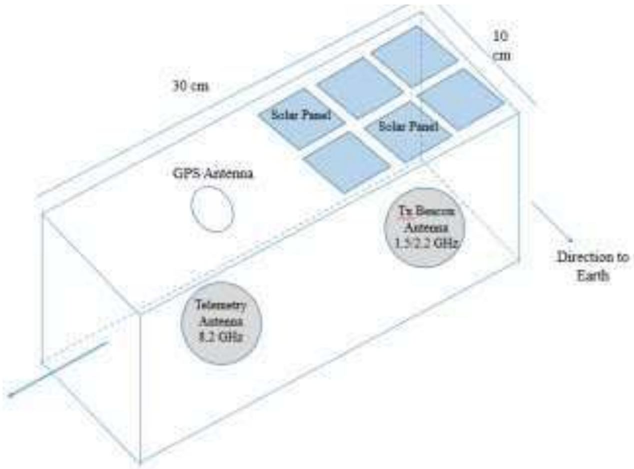

Figure 2. Design of nanosatellite for ionospheric mission

Figure 2 depict a design of nanosatellite for ionospheric mission consist of a beacon transmitter, a telemetry transmitter, a GPS system and solar panels. A beacon transmitter uses a Tx beacon antenna in frequency of 1.5 GHz and 2.2 GHz. For telemetry data uses a telemetry antenna in frequency of 8.2 GHz.

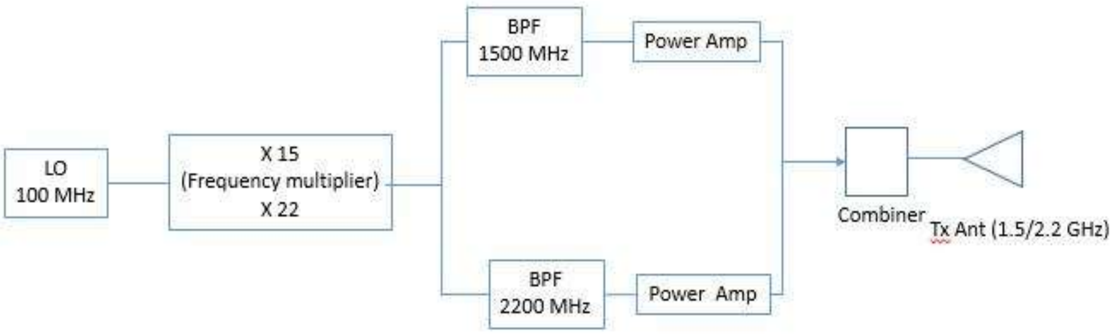

Figure 3. Simplified diagram block of beacon Tx for nanosatellite

Figure 3 depicts a simplified diagram block of beacon Tx for nanosatellite. A local oscillator (LO) generates a sinusoidal signal, then inputted to the frequency multiplier input of 15 and 22 times for getting of 1500 MHz and 2200 MHz. The output of signal multiplier inputted to band pass filters (BPF) of 1500 MHz and 2200 MHz for getting purely signals. The output signal of BPF inputted to power amplifiers to get higher power as input for transmitter antenna. Before signal transmitted by antenna, the signal of 1500 MHz and 2200 is mixed for one antenna with dual band frequencies.

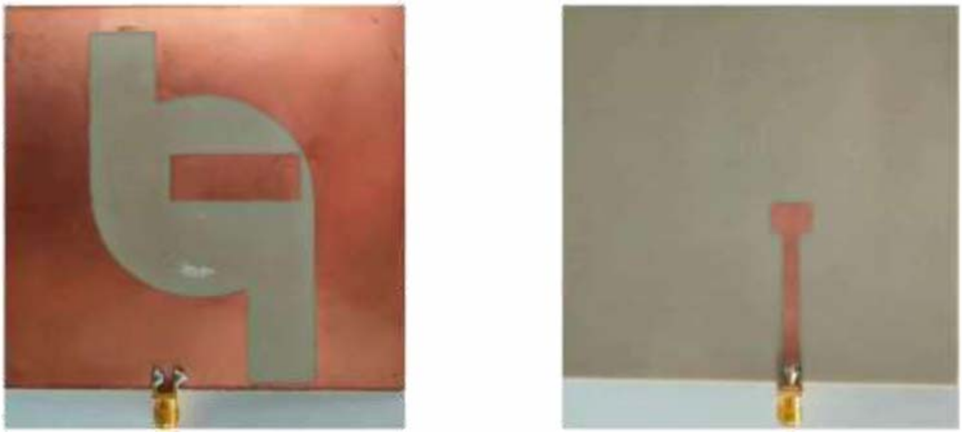

Figure 4. Fabricated antenna for beacon signal transmitter [10]

Figure 4 depicts the fabricated antenna, with a SMA-type connector, as explained on [10] as a basic design. The antenna for beacon signal transmitter must considers the weight, size, antenna gain and its polarization. A dual-frequencies antenna, for beacon signal transmitter to ground receiver of 1.5 GHz and 2.2 GHz, having size of 100 x100 mm is described on table 1. The proposed antenna give a very simple design compared to previous design [1] that using a crossed dipole antenna and have a good antenna gain more than 4 dB.

Table 1. The specification of fabricated antenna for beacon signal transmitter:

No	Parameters	Remarks
1.	Frequency (GHz)	1.5 and 2.2
2.	Polarization	Circularly Polarized
3.	Size (mm)	< 100 x 100
4.	Weight (g)	< 40
5.	Input resistance (ohm)	50

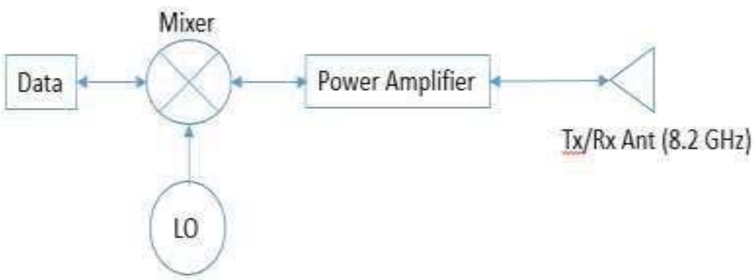

Figure 5 Simplified diagram block of telemetry system for nanosatellite

Diagram block for tele command and telemetry system consist of a local oscillator (LO), a mixer and a power amplifier as depicted on figure 5. The antenna for telemetry must considers the weight, size, antenna gain and its polarization. The center frequency of antenna, for data telemetry to ground receiver is 8.2 – 8.4 GHz, the antenna gain is up to 6 dB, the size of antenna is 38 x 38 mm as described on table 2. Figure 6 depicts the fabricated antenna, as explained on [11] as a basic design with a SMA-type connector.

Figure 6. Fabricated antenna for data communication [11]

Table 2. The specification of fabricated antenna:

No	Parameter	
1.	Frequency (GHz)	8.2–8.3
2.	Gain (dB)	up to 6
3.	Polarization	Circularly-polarized
4.	Size (mm)	< 40 x 40
5.	Weight (g)	< 40

4. Conclusion
A simplified design of nanosatellite and its progress for ionospheric mission is presented. The nanosatellite size is a total size of 300 mm x 100 mm x 100 mm. The antenna for beacon transmitter having dual-band frequency of 1.5 and 2.2 GHz have size of < 100 mm x 100 mm. Frequency for TTC communication of 8.2-8.3 GHz with frequency center of 8.25 GHz and gain > 5 dB, size of < 40 mm x 40 mm. The antenna for beacon transmitter and tele command (TTC) and telemetry has already fabricated and have good results.

Acknowledgment
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