Research, Design, Fabrication Receiver of Ground station for Vietnamese Satellite at S band with digitalizing I/Q channel at Intermediate frequency

1st Thi Ha Bui
R&D satellite department
Vietnam National Space Center
Ha Noi, Viet Nam
btha@vnsc.org.vn

2nd Chinh Doan Tran
Faculty of Electronics & Telecomminiction
Vietnam National University, Ha Noi
Ha Noi, Viet Nam
chinhdoan310@gmail.com

2nd Tien Dat Nguyen
School of Emectronics and Telecommunications
Hanoi Univeristy of Science and Technology
Ha Noi, Viet Nam
ntiendat3497@gmail.com

2nd Gia Duong Bach
Faculty of Electronics & Telecommunication
Vietnam National University, Ha Noi
Ha Noi, Viet Nam
duongbg@vnu.edu.vn

***Abstract*—This paper deal with design, fabrication receiver with digitalizing I/Q channel at intermediate frequency. Intermediate frequency module was standardized by applying this design. This module will be applied for first Vietnamese satellite, such as: MicroDragon satellite and NanoDragon satellite. They operate at S band and X band. But authors foucuse on S band. Obtain result: digitalizing I/Q channel at intermediate frequency with low cost, small size, easy manufacture, flexible integrate, and satisfy Nanosatellite's requirement. Vietnam have satellite. Standardizing technology for designing and manufacturing ground station is necessary. This standardizing help to manufacture the series of ground station for communicating with Vietnamese satellite.**

Keywords—Receiver, Ground station, Nanosatellite, S band, LNA, LO, I/Q channel…

I. INTRODUCTION

In recent years, there has been a growth of interests in space missions among various organizations for education, research, commercial, and military purposes. One of key to success to a mission is to have ground station system; without ground station, the satellite is not able to send data to user and user can not control satellite. Ground station hepl people understand how satellite system work, and verify technology. So, the building a ground station is necessary.

Vietnam is developing, has a coastline of 3,260 km that crosses 13 degrees in latitude, from 8°23'N to 21°39'N and 42% of the country's land are is forests. The country is also affected by tropical depressions, tropical storm and typhoons. Its economy has been largely on agriculture. So, the applications of satellite are imprortant elements that affect Vietnemese' life.

Aeronautics in Vietnam is newborn. In January 2019, MicroDragon (MDG) satellite was launched in orbit by Japan Aerospace Exploration Agency (JAXA). MDG is first Vietnamese satellite, it made by Vietnamese and Japanese . The main mission of MDG satellite is ocean color remote sensing to acquire maritime information of Vietnamese coatal seas. From 2018 to currently, Vietnam National Space Center started working NanoDragon (NDG) satellite project. Mission of NDG are Vietnamese Ocean – observation, tracking ship.

Vietname have satellite, but have not enough ground station respond to communication with satellite. Almost of datas and informations of Vietnamese satellite were send to foreign ground sation. Then these informations were send to Vietnam by report. This is inconvenint. It is become a problem.

This paper try to solve this problem. Authors designed, fabricated receiver with digitalizing I/Q channel at intermediate frequency, which will be applied for ground station of Vietnamese satellite (such as: MicroDragon satellite and NanoDragon satellite). This research contribute to help Vietnamese own ground station with low budget, reducing its dependency on other nations even in an emergency situation like nature disaster.

In MDG case, it is about 50-kg microsatellite class, assess coastal waver quality of Vietnams to support aquaculture and locate living aqua creatures by observing ocean color. S -band communication (4 kbps command uplink, up to 64 kbps telemetry downlink) is used for satellite operations; X-band communication (up to 10Mbps downlink) is used for mission data downlink.

This paper researched, designed, simulated, fabricated receiver operates at S band with digitalizing I/Q channel at intermediate frequency. Focused on 2 GHz to 2.5 GHz suitable for requirement of Vietnamese's satellite.

A mission of MDG satellite was shown in the Fig. 1.

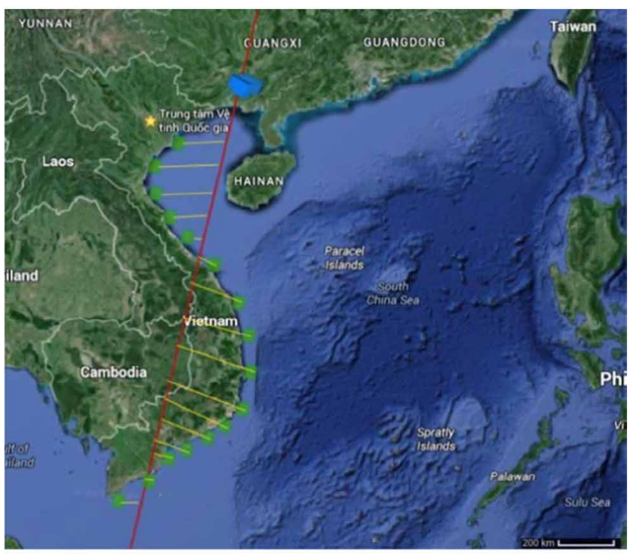

Fig. 1 A mission of Vietnamese satellite [10]

II. DESIGN, FABRICATION RECEIVER WITH DIGITALIZING I/Q CHANNEL AT INTERMEDIA FREQUENCY

Intermediate frequency module of receiver was designed in this research. This design is different from traditional receiver. It can digitize immediately two I/Q channels of intermediate frequency. This design has some advantages, such as: reducing time delay, reducing loss signal, reducing noise.

Firstly, this module will be applied for Nanosatellite at S band. Then this module will be developed and applied for X band. This developed module will be reached to next research.

Receiver was standardized have block diagram as Fig. 2 below.

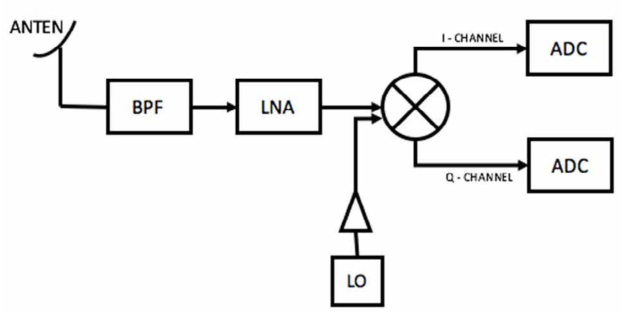

Fig. 2 Receiver of ground station

Signal was received by antenna. Then it was transferred to LNA, I/Q detector and ADC.

A. *Analog to digital converter (ADC)*

ADC of receiver can be performed by some products. Such as: ADRV 9364 – 9361; … This product can convert directly analog to digital after receiving signal from antenna. But its price is high. Designer want to design ground station with low budget, small size and suitable for Vietnamese satellite. So, analog digital converter was used in paper is AD9655.

Specification of AD9655: It is a dual, 16 bit, 125 MSPS analog – to – digital converter. Low power: 150 mW/channel.

AD9655 was chosen by designer, because it enough to satisfy requirement of ground station (can handling directly from 60 MHz) and have low – cost, low power (consumes less than 2 mW), small size (5mm x 5 mm).

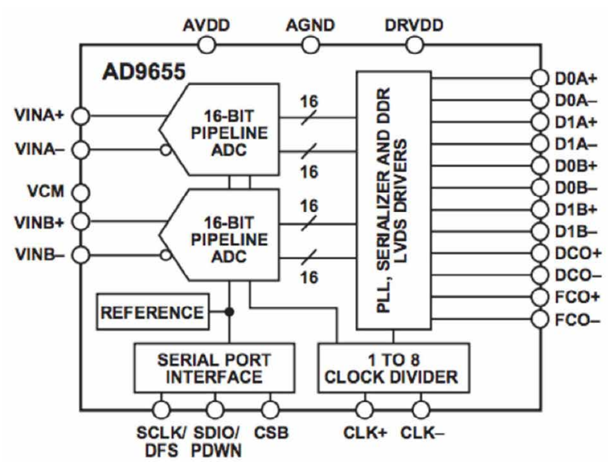

Fig. 3 Function block diagram [9]

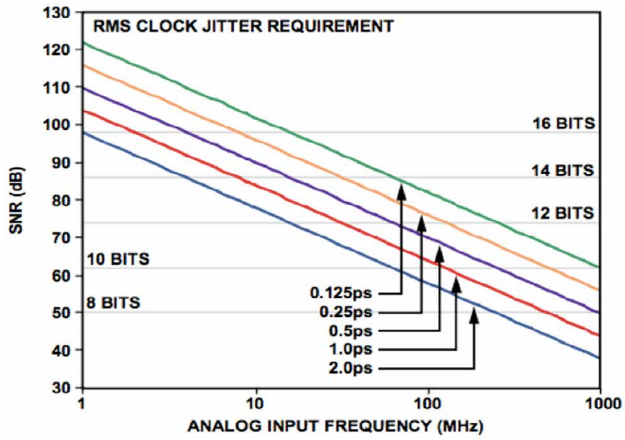

Fig. 4 SNR with analog input and Jitter [9]

The Fig. 4 shows the relationship between signal to noise ratio (SNR), analog input and Jitter.

As block diagram of receiver at Fig. *2* and function block diagram at Fig. 3, channel I and channel Q were connected to channel A B of ADC analog inputs. This matching is very convenient.

This paper focuses on digitize I channel and Q channel at intermediate frequency on receiver of ground station. So, selection of AD9655 device is accordant with both purpose of research and requirement of ground station.

B. *Low noise amplifier (LNA)*

Low noise amplifier (LNA) is an important part of designing a high quality rig for receiving weak signal. This amplifier is put as close as possible to the antenna, so that cable loss is minimized. This LNA use RF transistor SPF-3043 of Stanford Micro-devices. SPF-3043 is a high performance 0.25 μm pHEMT Gallium Arsenide FET. This product has low cost and spend low current.

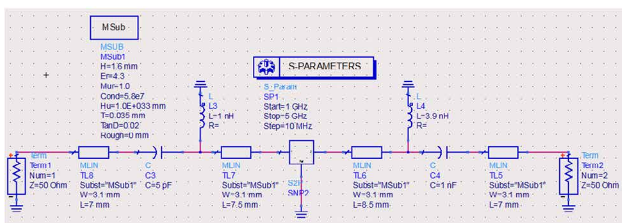

Fig. 5 Schematic of LNA

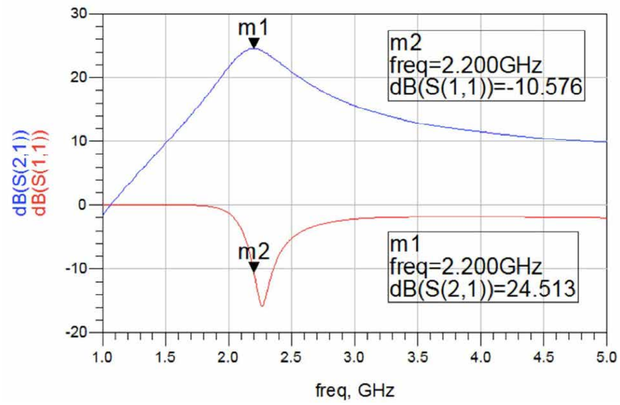

Fig. 6 S-parameter of simulation result of LNA

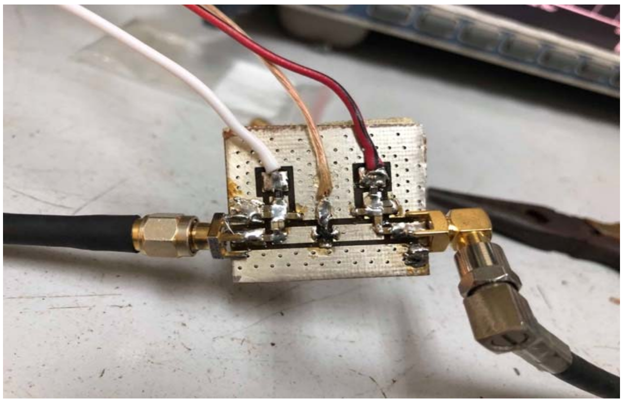

Fig. 7 Fabricated LNA

By using ADS software with permeability Mur = 1, conductor thickness T = 0.035, dielectric constant Er = 4.3. Schematic of LNA was designed as Fig. 5.

Simulation result of LNA was show in Fig. 6. The figure below illustrated S_{21} parameter and S_{11} parameter. This LNA operate well in large range frequency from 1.1 GHZ until 5 GHz. At 2.2 GHz, Obtain gain is 24.513 dB, reflection coefficient S_{11} is -10.576 dB.

Fabricated LNA with FR4 substrate was show in Fig. 7.

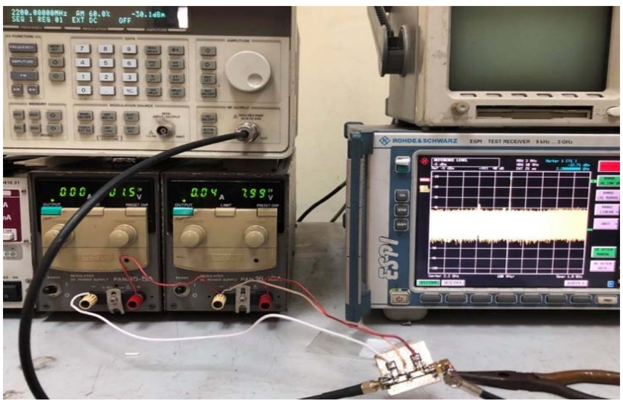

Fig. 8 Measurement LNA

Measurement and measurement result of LNA was shown in the Fig. 8.

Result of measurement LNA is more than 20 dB. This LNA obtain high gain (more than 20 dB with LNA circuit and more than 24.5 dB with simulation of schematic), have small size.

C. I/Q channel detector

In the paper, author used LT5575 of Linear Technology for I/Q modulator. LT5575 is an 800 MHz to 2.7 GHz direct conversion quadrature demodulator optimized for high linecurity receiver application. It is suitable for communications receivers where an RF signal is directly converted into I and Q channel at intermediate frequency. The LT5575 incorporates balanced I and Q mixer, LO buffer amplifiers, a precision, high frequency quadrature phase shifter.

Output of I/Q modulator is I – channel and Q – channel. These outputs can connect directly to ADC (AD9655).

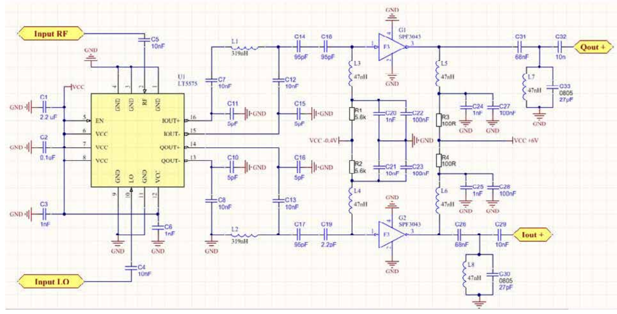

Fig. 9 Schematic of I/Q detector

Schematic of I/Q detector was show in the Fig. 9. In schematic show two inputs (RF input and LO input) and two outputs (I – channel and Q – channel).

Inside I/Q detector, authors simulated two main sections. There are input/output matching and selective amplifier. These sections were designed in ADS as shown in the Fig. 10 and Fig. 11.

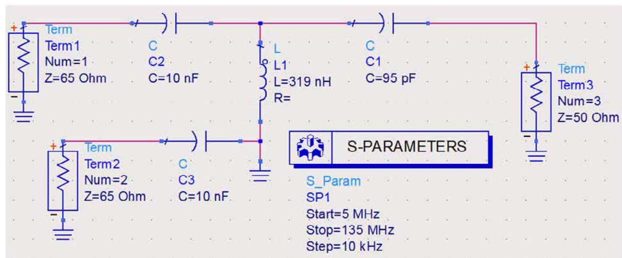

Fig. 10 Input/output Matching

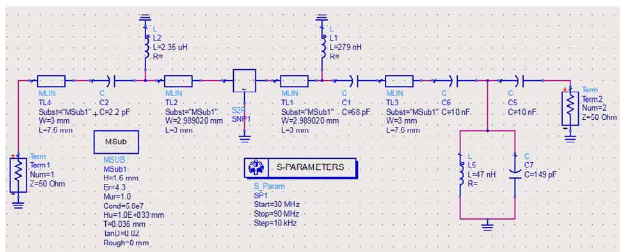

Fig. 11 Selective amplifier of I/Q detector

Simulation result of input/ output matching and simulation result of selective amplifier were shown in the Fig. 12 and the Fig. 13.

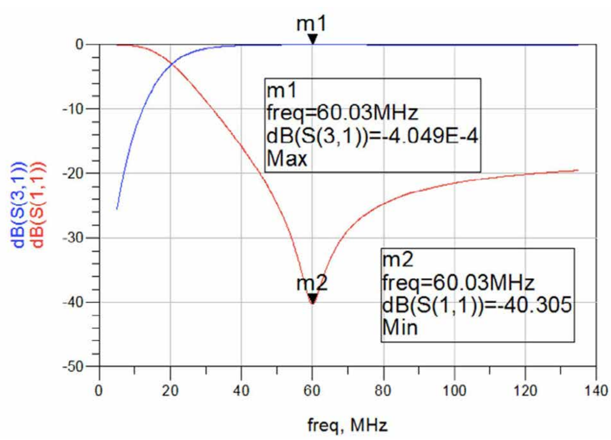

Fig. 12 Simulation result of input/ output matching

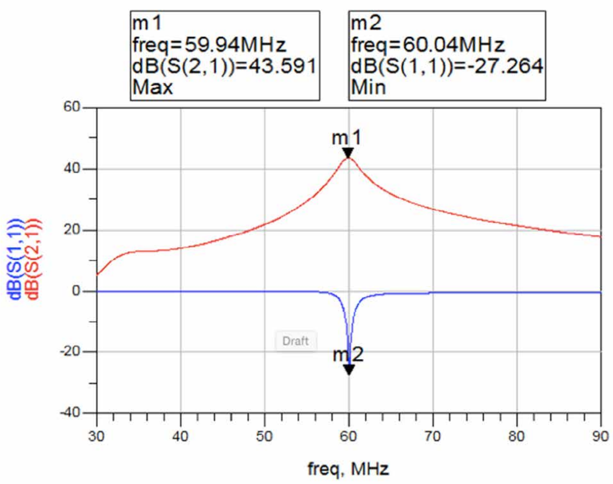

Fig. 13 S-parameter of selective amplifier simulation

See in the Fig. 13, S_{21} of selective amplifier of I/Q detector is over 43.5 dB.

This I/Q detector was shown in the Fig. 14.

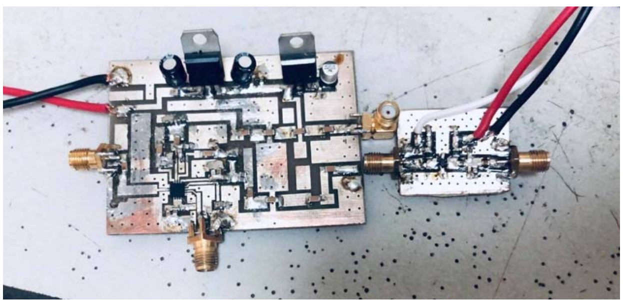

Fig. 14 The fabricated I/Q detector

Measurement results were shown in Fig. 15 and Fig. 16.

See in the I/Q detector's measurement results, microwave frequency was changed to become intermediate frequency 60 MHz have two channels (I channel and Q channel).

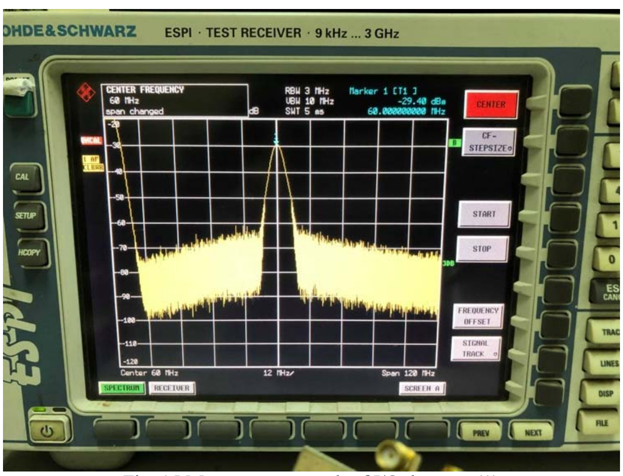

Fig. 15 Measurement result of I/Q detector (1)

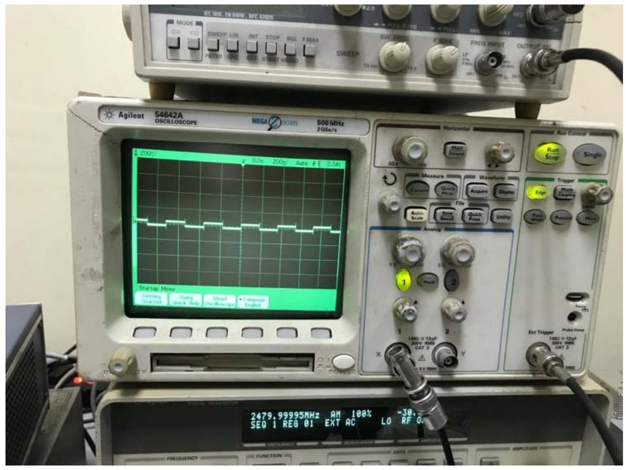

Fig. 16 Measurement result of I/Q detector (2)

D. Local oscillator (LO)

In this paper, author used PM2503 for LO circuit. PM2503 is a GaAs. It requires 3.0 Voltage to 5.0 Voltage supply and 40 mA supply current. Output power is 14 dBm from 2 GHz to 3 GHz. Inside this RF IC is fundamental oscillator, integrated matching network, buffer amplifier.

The features of this RF IC is suitable for local oscillator. PM2503 RF IC becomes the perfect choice.

LO was designed in Fig. 18. Output of LO was connected to 50 Ohm microstripline. Output frequency be changed when voltage supply to circuit changed. Output frequency was calculated by:

$$f = \frac{1}{2\pi\sqrt{L_1 D_1}} \quad (1)$$

The tuning curves of PM2503 was show in the Fig. 17. When tuning voltage supply for PM2503 circuit, output frequency also change.

Schematic of LO was shown in the Fig. 18. The LO design used capacitor and inductor.

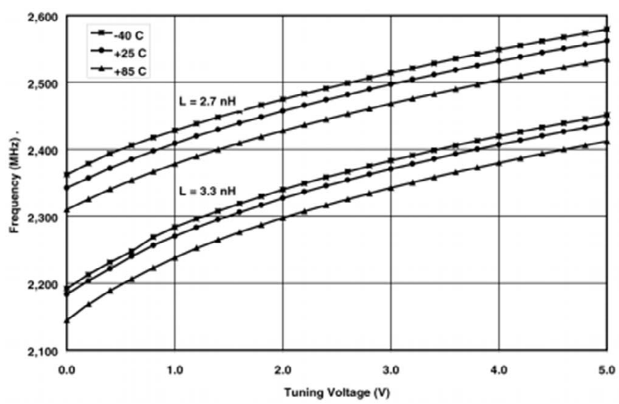

Fig. 17 Tuning curves

2019 International Conference on Advanced Technologies for Communications (ATC)

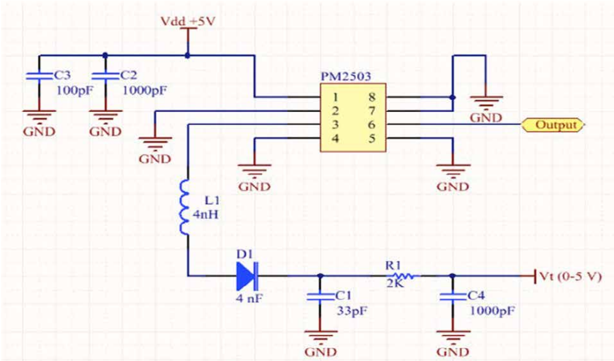

Fig. 18 Schematic of LO

Board design LO was fabricated on FR – 4 PCB material. It was shown in Fig. 19.

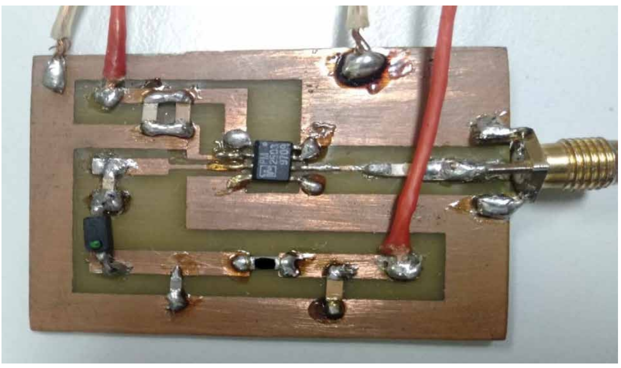

Fig. 19 Board design of LO

Relationship between voltage supply input and frequency output was shown in Fig. 20.

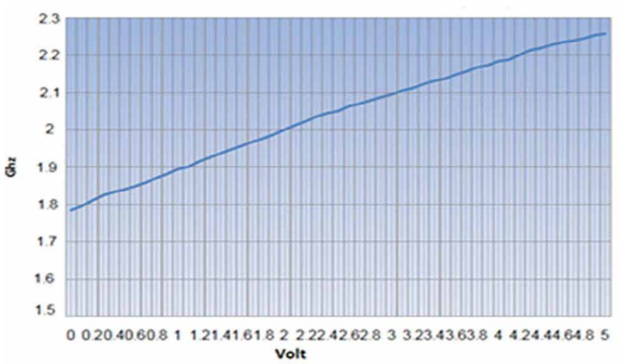

Fig. 20 Output frequency depend on voltage supply input

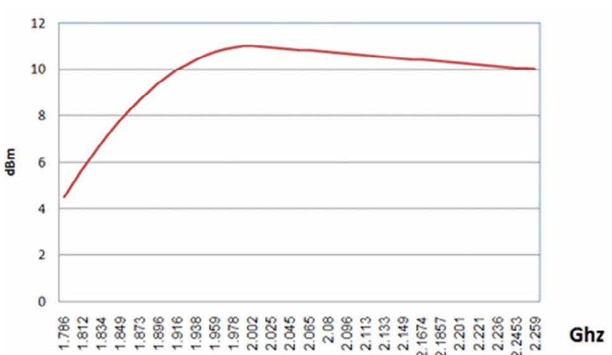

Fig. 21 Output power of LO

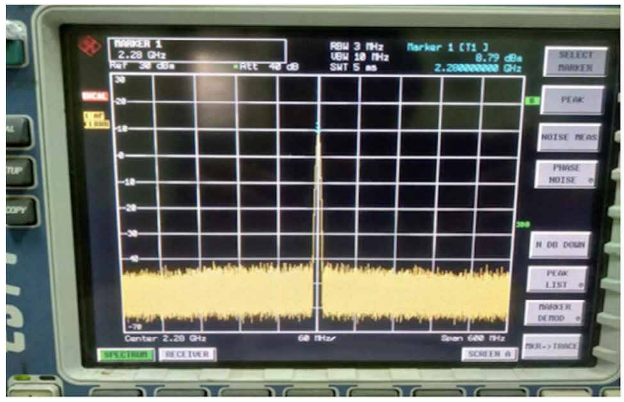

Fig. 22 output signal of LO at 2.2 GHz

See in the Fig. 21, output power is over than 10 dBm from 1.986 GHz to 2.259 GHz. This result can guarantee input requirement of AD9655.

The above result proves that this LO design respond to requirement of receiver of ground station and satellite at S band.

III. Conclusion

In the paper, receiver of ground station at S band was designed and fabricated with digitalizing I/Q channel at intermediate frequency. With this design, intermediate frequency module of receiver become more flexible. The module can be applied not only for Nanosatellite at S band but also be applied for Nanosatellite at X band when changing some parameters value, solving budget and design time issue. The module was standardized by digitalizing two channels (I/Q channel) combine reasonable low noise amplifier local oscillator. Low noise amplifier obtained over 24.5 dB gain, low NF. The local oscillator was stable operation from 2 GHz to 3 GHz with output power is 14 dBm.

These parameters satisfy requirement of ground station's Nanosatellite. By applying this module for receiver, ground station can be built with low cost, small size, enough function and high effective. Specifically, this design is easy to compatible with digital signal processing technology at intermediate frequency.

References

[1] David M.Pozar, "Microwave Engineering", 4th ed,, John Wiley & Sons.

[2] Peter Fortescue, Graham Swinerd and John Stark, "Spacecraft systems engineering", 4th ed, A John Wiley & Sons, 2011.

[3] James R.Wertz, David F.Everett and Jeffery J.Puschell, "Space Mission Engineering: The New SMAD", Space Technology Library, 2011.

[4] The Anh Nguyen Dinh, Minh Ngo Duc and Duong Bach Gia, "Design of an S-Band Vessel Monitoring System Using Satellites", International Journal of Applied Engineering Research, Volume 13, Number 8 (2018) pp.6063-6068, 2018.

[5] Bui Thi Ha, Bach Gia Duong, "Research, Design and Fabrication Microwave Modules of Receiver for Nanosatellte at S Band", IEICE technical Report SANE 2018-67 (2018-11), unpublished.

[6] Nguyen Dinh The Anh, Le Xuan Huy, Vu Anh Tuan and Bach Gia Duong, "Research, Design and Monitoring Systems", The 2016 International Conference on Advanced Technologies for Communication (ATC16), pp.524-529, October 2016.

[7] T.V.Hoi and B.G.Duong, "Study and Design of wide band low noise amplifier operating at C band", VNU journal of Mathematics – Physics, Vol.29, pp. 16-24, 2013.

[8] Jeaine M.Hunter and David E.Horton, "Design and Construction of a VHF Ground Station at San State University", Int.1.Engng Ed. Vol.10.No.5, pp.459-465, 1994.

[9] AD9655 datasheet, Anlog Devices, 2015.

[10] Takashi HIRAMATSU[1], Seiko SHIRASAKA[1] and Sinichi NAKASUKA, "MicroDragon: a Vietnamese Ocean-observation Microsatellite Based on Hodoyoshi Architecture", 7th Nano-Satellite Symposium and the 4th UNISEC-Global Meeting, NSS-07-0103.

[11] PM2503 datasheet, Pacific Monolithics.