International Journal of Signal Processing, Image Processing and Pattern Recognition
Vol.9, No.4 (2016), pp.47-60
http://dx.doi.org/10.14257/ijsip.2016.9.4.05

Design and Fabrication of Multi-Band GNSS RF Front-End Receiver

Almas Kaveh

Electronic Engineer BS graduated from Khaje Nasir Aldin Toosi University-Tehran Iran and Master Degree of Global Navigation Satellite System graduated from Beihang University-Beijing China.
Email: almas.kaveh@yahoo.com

Abstract

Wireless network communicating area constantly up developing. Consequently require this sort of a regular equipment with an increase of trustworthiness for numerous uses. To complete these types of requirements the advanced receivers, RF front-end is essential portion. As a result efficient design and style of RF Front-End is required to be a more suitable alternative, not just straightforward but as well as trustworthy and also advanced receiver which might be utilize in most GNSS system. the basic purpose of the paper are definitely to construct a Multi-Band RF Front-end to any of Universal Navigating Satellite System (GPS, Galileo, BeiDou, Glonass) receiver which supplies civic signals to numerous frequencies, comparable to that accessible today for exclusively authority application lastly executed and then examined the front-end receiver. A number of receiver IC have already been viewed, lastly the MAX2769B chip device is preferred as a result of its actual specific features, price and also functionality. Multi-Band GNSS RF Front-end which is designed, executed as well as tested out.

Keywords*: We would like to encourage you to list your keywords in this section*

1. Introduction

One of the most significant utilizations of employing satellites, is Universal Positioning System. Worldwide Navigating Satellite System Composed feasible universal positioning allows any kind of consumers accurate positioning available anywhere.

Universal Navigating Satellite System (GNSS), is the regular common expression for satellite navigating systems which providing 3-dimentional (3D) positioning all over the world. GNSS receivers compute the position of the user with regards to latitude, longitude, velocity, direction, and also time. For computation utilize, a mathematical procedure referred as trilateration. In recent times, the one perfectly operational and also functioning system is the American Worldwide Positioning System (GPS navigation). The European Union system, recognized as Galileo, is forecasted to be built and then be functioning in 2019 as well as Beidou-2 (Compass) is going to be universal functional in 2020. Additionally the Russian system, Glonass is under construction.

GNSS Receivers, process the signals that is generally passed down by the satellites. The receivers are the utilizer interface to each of the Universal Navigating Satellite System (GNSS). And though a common GNSS receiver delivers the information and facts, it is able to be utilized by a variety of functions. A majority of the functions is dependent upon the navigating solution of receiver that could be computed Positioning, Speed as well as Time (PVT). GNSS receivers identify the consumer situation, speed, and also accurate time (PVT) by handling the signals transferred by the satellites. By reason that the satellites are continually relocating in the sky, and the receiver should attain and track the signals repeatedly from the satellites in sight, because measuring an sustained method, like preferred in most of applications. Every navigating method which can be

ISSN: 2005-4254 IJSIP

supplied by a GNSS receiver, is dependent on the measurement of its length from a number of satellites, by utilizing removing the time of propagation of the arriving signals, traveling along space by velocity of light, based on the regional clocks of satellite and receiver. The time change (dt) is changed into a range, the pseudo range, therefore by multiplying the time difference with the speed of light in the vacuum (c), the length is ,$R = c \times dt$.

2. Schematic Design

First the RF Front-end receiver designed and fabricated, then test and measurement is required. The evaluation board has some blocks such as LNA which possible to test and validate, however some other blocks impossible to test because they have not any output pin such as mixer and filter. Initially, this chapter deals the test and characterization of some blocks (LNA, IF-output,...) and finally deals the test and measurement of the complete RF Front-end receiver. There are some different setup for some test used for different blocks and described each of them. Furthermore, the printed circuit board (PCB) and external components that is required for test, are also presented.

Initially schematic circuit design of RF Front-end receiver has been explained. The schematic circuit are designed based on MAX2769B chip, which components are require for the blocks depending on input and output signals and clocks. The secondary, printed circuit board (PCB), is presented.

The schematic circuit of the evaluation board are designed and provided as shown in Figure1. It includes several blocks such as, MAX2769B chip, single-ended line receiver block, buffer/driver block, power supply block, oscillator and some external components. The additional support circuitry enables testing of the device performance. The MAX2769B chip is a future-generation GNSS receiver, which covers GPS, Galileo, GLONASS, and Compass (BeiDou) navigating satellite systems on a particular small microchip. It is planned, low-power usage, process technology of SiGe BiCMOS, and has the largest functionality and also integration in a low-cost, smaller size packaging. The absolute RF Front-end receiver, comprises of a dual-input Low Noise Amplifier (LNA), Mixer, Image Rejection filter, Voltage Controlled Oscillator (VCO), Programmable Gain Amplifier (PGA), crystal oscillator, fractional-N frequency synthesizer, and a multibit ADC. The MAX2769B completely do not need for external intermediate filter (IF filters) because it has monolithic filters on-chip and only needs a small number of outer elements to produce a thorough low-priced and also smaller size GPS RF receiver. The overall cascaded noise figure (NF) of this RF Front-end receiver is definitely low 1.4dB. The MAX2769B chip is regarded as the adaptable front-end receiver on the market. The fractional-N frequency synthesizer, cause programming of the IF frequency with an accuracy of ±30Hz at a crystal frequency of $f_{XTAL} = 32MHz$ while working with any reference frequencies which are accessible in the host system. The schematic circuit of evaluation board is shown in Figure 1.

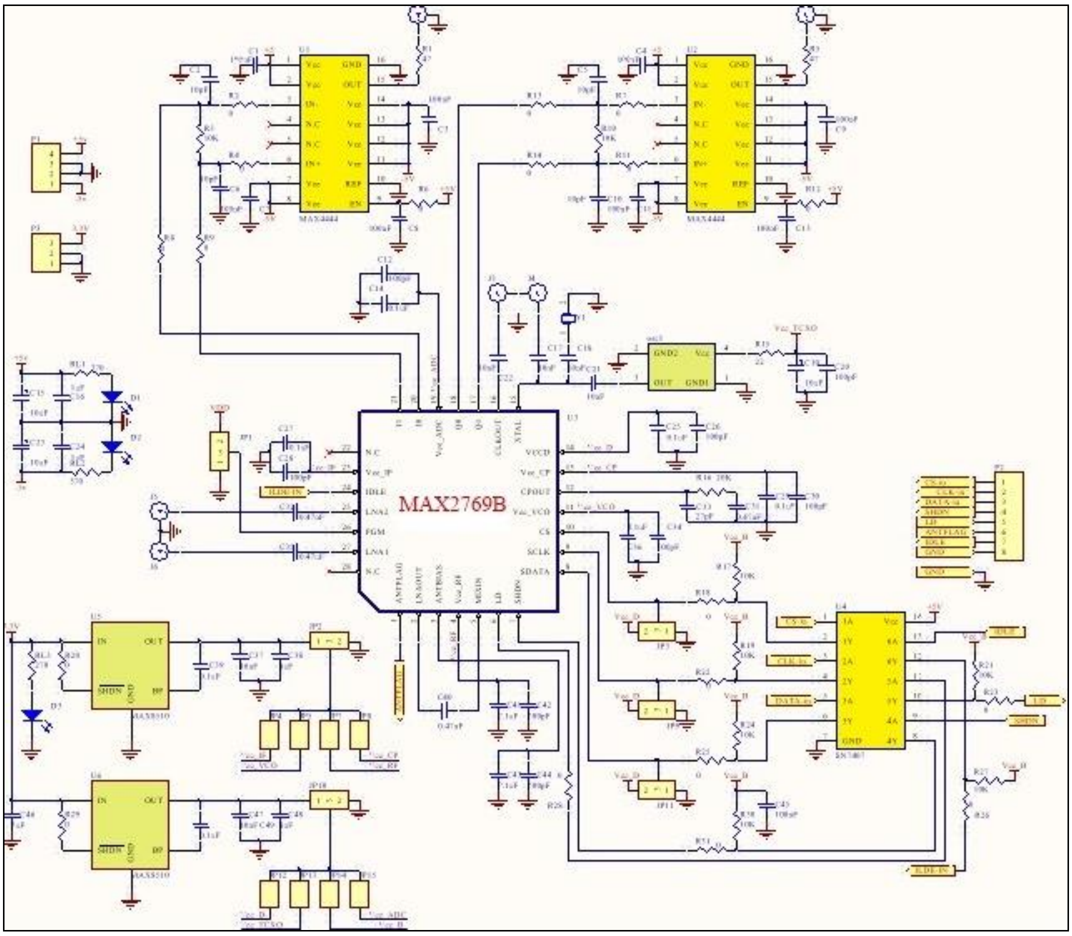

Figure 1. Schematic Circuit of Evaluation Board

3. Requirement Components

Table 1 provides a list of components that is required to make the RF front-end receiver with MAX2769B. These components are several integrated circuits (IC's), resistors, capacitors, connectors and crystal oscillator. The footprint of capacitors and resistors are SMD-0402.

Table 1. Component List of RF Front-end Receiver

Element List of Receiver					
Comment	Description	Designator	Accuracy	Footprint	Quantity
0	Resistor	R2, R4, R6, R7, R8, R9, R11, R12, R13, R14,	5%	SMD-0402	10
0	Resistor	R18, R20, R22, R23, R25, R26, R27, R28, R29, R	5%	SMD-0402	10
0.1uF	Capacitor	C14, C25, C27, C29, C36, C39, C41, C43, C49	10%	SMD-0402	9
100nF	Capacitor	C1, C3, C4, C7, C8, C9, C11, C13, C45	10%	SMD-0402	9
100pF	Capacitor	C12, C20, C26, C28, C30, C34, C42, C44	5%	SMD-0402	8
2pin	Connector	JP4, JP5, JP7, JP8, JP12, JP13, JP14, JP15		HDR1X2	8
370	Resistor	RL1,RL2	5%	SMD-0402	2
270	Resistor	RL3	5%	SMD-0402	1
10k	Resistor	R3, R10, R17, R19, R21, R24, R30	1%	SMD-0402	7
10nF	Capacitor	C17, C18, C21, C22, C37, C47	10%	SMD-0402	6
3-pin	Connector	JP1, JP2, JP3, JP9, JP10, JP11		HDR1X3	6
1uF	Capacitor	C16, C24, C38, C46, C48	10%	SMD-0402	5
0.47nF	Capacitor	C31, C32, C35, C40	10%	SMD-0402	4
10pF	Capacitor	C2, C5, C6, C10	5%	SMD-0402	4
SMA-con	SMB Straight Con	J1, J2, J3, J4,J5,J6		SMA	4
10uF	Polarized Capacito	C15, C19, C23	10%	capc-SMD	3
47	Resistor	R1, R5	1%	SMD-0402	2
LED	LED-Diode	D1,D2,D3		D-153-0004	3
MAX4444ESE	Line Receiver	U1, U2		16-Narrow S	2
MAX8510ESK29	IC-Regulator	U5, U6		SC70-5	2
20k	Resistor	R16	5%	SMD-0402	1
22	Resistor	R15	1%	SMD-0402	1
27pF	Capacitor	C33	5%	SMD-0402	1
3-pin miniator	Header, 3-Pin	P3		HDR1X3	1
4-pin miniator	Header, 4-Pin	P1		HDR1X4	1
8-pin miniator	Header, 8-Pin	P2		HDR1X8	1
IT3205B	Crystal TCXO	osc1-16.368MHz			1
MAX2769B	GPS Receiver	U3		28 Pin QFN T	1
SN74LV07A	Driver	U4		14-Narrow S	1

4. Printed-Circuit Board (PCB)

A good Printed-Circuit Board (PCB) is an essential part of an RF circuit design. The electronic PCB board can be used as a guide for laying out using the MAX2769B chip. In designing PCB board, the traces that carry RF signals must be as short as possible to minimize loss of radiation and insertion. Moreover, impedance matching control, must be used on all RF signal traces and lines. For proper operation, the exposed paddle must be soldered evenly to the ground plane of PCB board. On the other hand, using the abundant vias bottom the exposed paddle and between RF traces, cause to minimize undesired coupling radio frequency.

To decreasing as much as coupling between different sections of the integrated circuit(IC), each VCC pin, must have a bypass capacitor with low impedance to the closest ground at the interest frequency. The ground vias must not be shared among multiple connections to the PCB ground plane. Figure 2, 3 and 4 show the printed-board circuit.

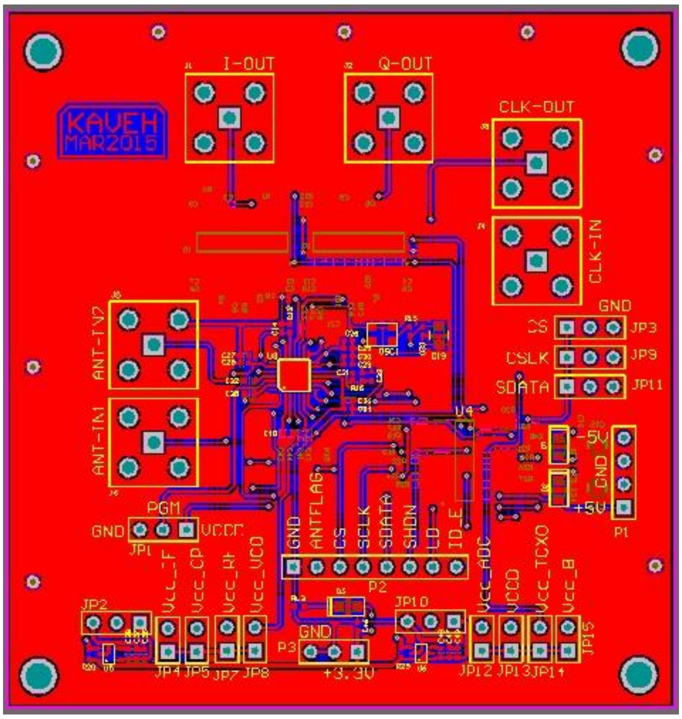

Figure 2. Printed Board Circuit

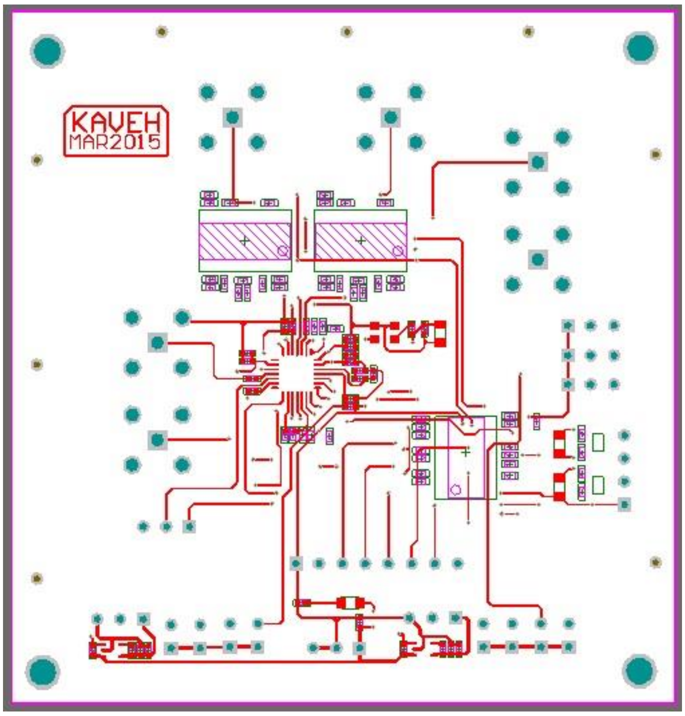

Figure 3. Printed Board Circuit (Top Layer)

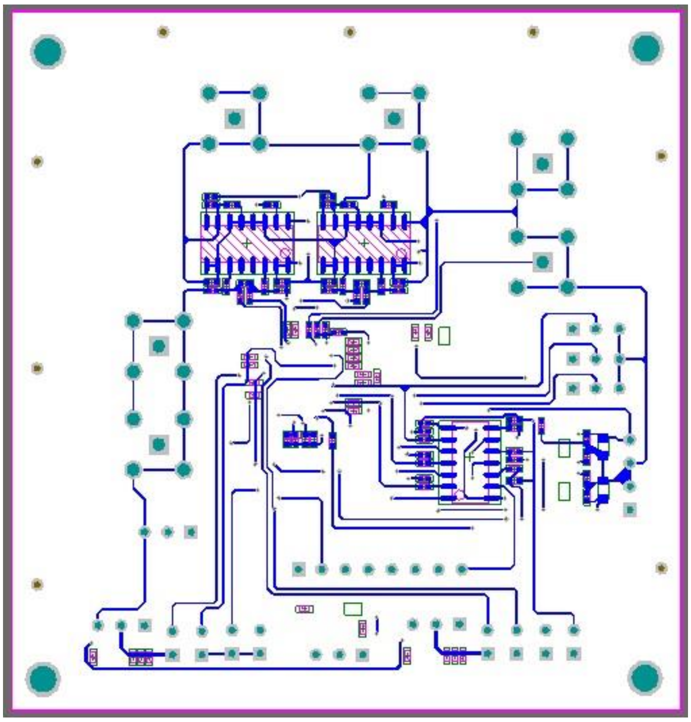

Figure 4. Printed Board Circuit (Bottom Layer)

5. Fabrication

The RF Front-end receiver are designed and fabricated. The IC MAX2769B with a QFNT 28 package, is installed on a PCB board that consists all the demanded outer elements. These elements consist of the decoupling capacitors, SAW filtration, bypass capacitors, crystal oscillator, matching network, and a number of connectors. In addition, line receiver block and buffer-driver block are employed in the receiver. The PCB board includes two on-board MAX8510 chip as linear regulators for powering up the MAX2769B chip to a regulated supply voltage of +2.85V.

There is a 3 pin connector prior the regulators that provides the power voltage of 3.3v. the voltage after regulator divide into eight path of powering signal that are called: V_{cc_IF}, V_{ccRF}, V_{CC_VCO}, V_{cc_CP}, V_{CCD}, V_{cc_ADC}, V_{cc_TCXO}, V_{cc_B}. A four pin connector is used to powering MAX4444ESE and SN74LV07ADR by $\pm 5v$.

Another eight pin connector that is relate to serial interface; SDATA, SCLK, CS and several other pins such as IDLE, LD, SHDN, ANTFLAG and GND. Six SMA connectors are used for signal input and output and clock input and output. Two of them are ANT-IN1 and ANT-IN2 for antennas inputs, another two of them are I-OUT and Q-OUT for I and Q channel outputs and the other two are CLK-IN and CLK-OUT for clock input and output.

There are three 3 pin are employed for serial interface (SDATA, SCLK, CS), which can be change manually. By means of these 3pins, the SDATA, SCLK and CS can be connect to low level (GND) or high level (V_{cc_B}). In the Figure 5 the top layer and bottom layer of the fabricated RF Front-end receiver are shown respectively.

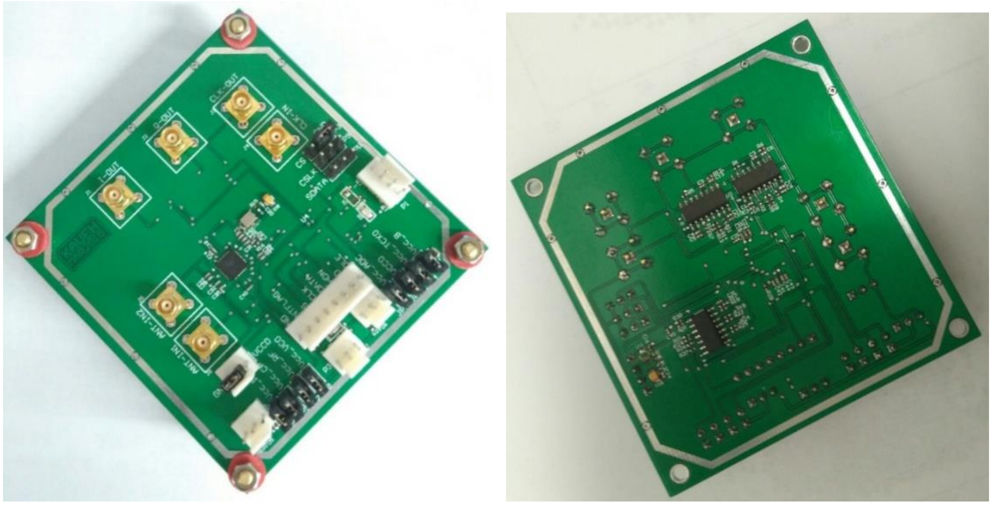

Figure 5. Fabricated Board of Front-end Receiver (Top and Bottom Layer)

6. Test and Measurement

First, the RF Front-end have been designed and fabricated, then the fabricated electronic board have been tested and validated. This section initially explain the test and characterization of the blocks such as LNA and finally describe the test and measurement of the complete RF front-end receiver. The setup test for blocks may be different that is used and described for test the blocks.

6.1. Individual Test of Receiver Blocks

The basic elements of the receiver feature can be recognized as the LNA, mixer, phased-lock loop (PLL) , Intermediate Frequency (IF) Amplifier , and analog-to-digital converter (ADC). The LNA1, LNA2, IF-output, Maximum and Minimum Gain, Noise Figure, Digital output observation, Output clock and so on have been tested and measured, with the setup test as shown in Figure 6. Some tests are possible because their inputs and outputs pins are accessible, but some other tests for that reason is impossible. In the Figure 6, the power supply block provide +3v and ± 5v for the Front-end receiver. The signal generator (Agilent Technologies-E8267C, 250KHz-20GHz), provides input signal frequency and the spectrum analyzer (9KHz-3GHz), is employed as output display. Also the digital phosphor oscillator (500MHz), is used as IF digital output monitor. By using the RF output of LNA’s the spectrum analyzer is setting to $L_1 = 1.57542GHz$ center frequency with 4MHz BW. When used as IF frequency, it is setting to 4.092MHz.

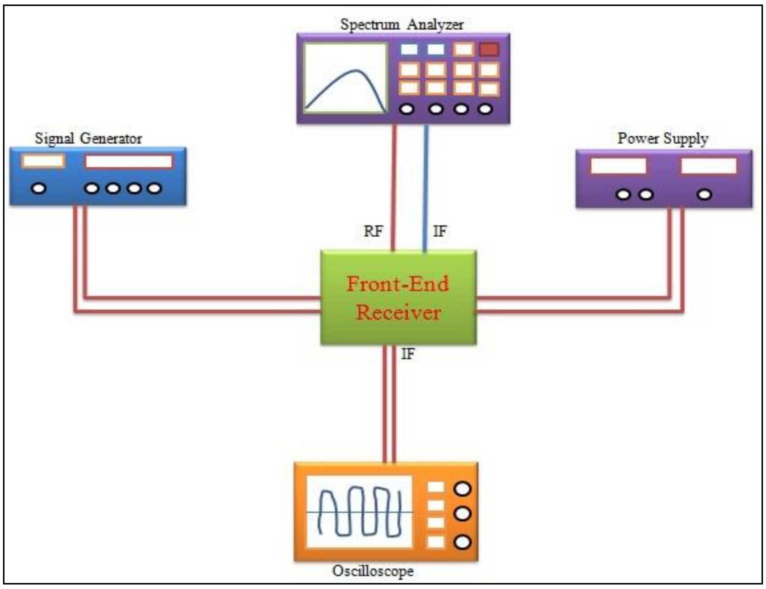

Figure 6. Test Setup for RF Front-End Receiver

LNA Test and Measurement: The input signal is provided by the signal generator as:

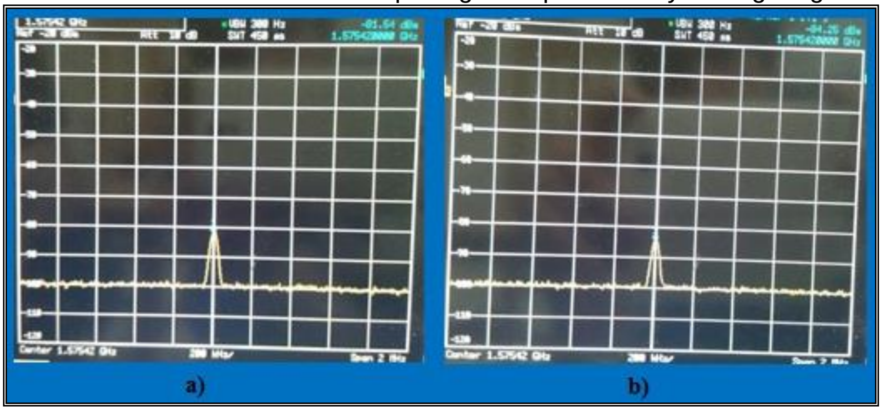

Figure 7. Frequency Response; a) LNA1 Output b) LNA2 Output

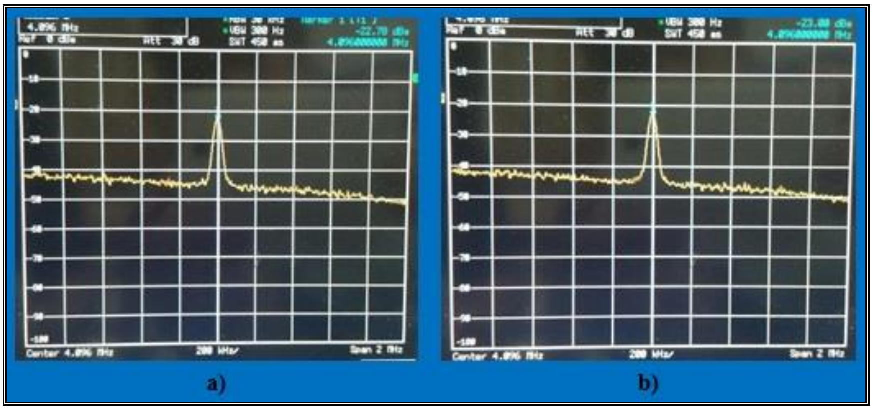

Figure 8. Frequency Response of the IF Output; a) Antenna 1 Input b) Antenna 2 Input

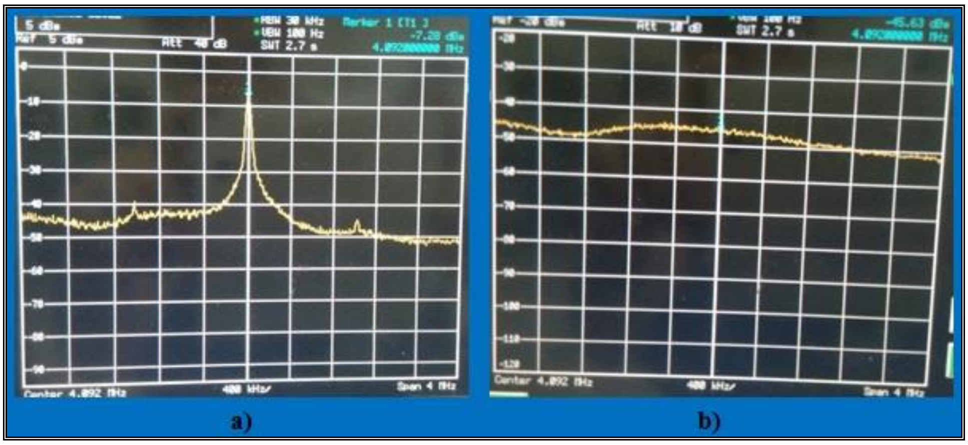

Figure 9. Gain of the RF Front-end; a) Maximum Gain b) Minimum Gain

1- **Noise Figure**: For measuring Noise Figure a method is used that is called Gain method. This method involve more measurements as well as calculations, but very certainly, therefore it is more convenient and more accurate:

In this method, Noise is depends two effects, the interference that comes to the input of a RF system, the random fluctuation of carriers in the RF system (LNA, mixer, filter, *etc*). so as mentioned before in chapter IV, the following equation:

$$NF = \mathrm{P_{ntot}} - (-174\,\mathrm{dBm/Hz} + 10\log_{10}(\mathrm{BW}) + \mathrm{Gain})$$

Where, P_{ntot} is the measured total output noise power. The noise density in 290°K of ambient noise is $-174\ dBm/Hz$. BW is the frequency bandwidth of the interest range in the system. In this test, the spectrum analyzer resolution bandwidth (RBW) is reduced to such as 300Hz.

The scale of everything in the equation is in log. By simplifying the formula, the output noise power density (in dBm/Hz) can be measured directly, thus the equation becomes:

$$\mathrm{NF} = \mathrm{P_{ntot}} + 149\,\mathrm{dBm/Hz} - \mathrm{Gain}$$

In this process, to compute the noise Figure NF, the gain of device is required to be identified. After that the input of the device is completed with the conventional impedance (50Ω for most RF functions). Then the output noise power densityP_{ntot}, is measured with a spectrum The setup for NF measurement is shown in Figure10.

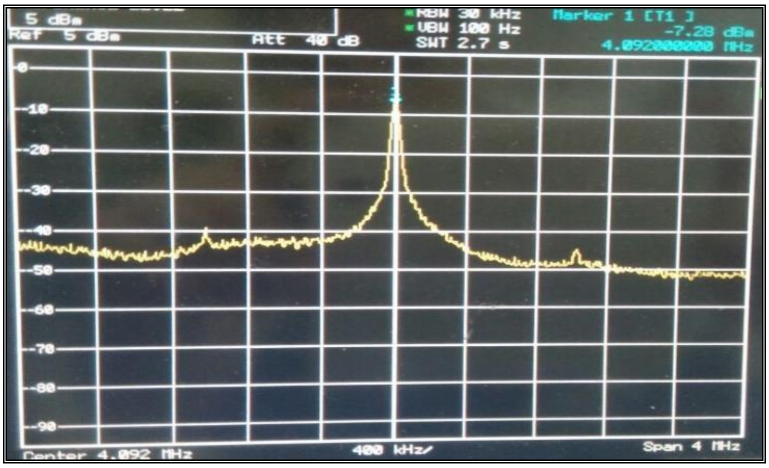

Figure 10. Frequency Response with Maximum Gain

For this test, with an input of -110dBm and with 115dB gain for the system, the receiver will not be in compression. Therefore the input S/N would be:

$$-110dB-(-149dB)=39dB$$

The output signal would be:

$$-110dB+115dB=5dB$$

and the background noise level is $-32dB$. So the S/R must be:

$$5dB-(-32dB)=37dB.$$

Therefore the noise Figure NF of the system would be the degradation in the S/N ratio, or $NF_{LNA1}=39dB-37dB=2dB$.

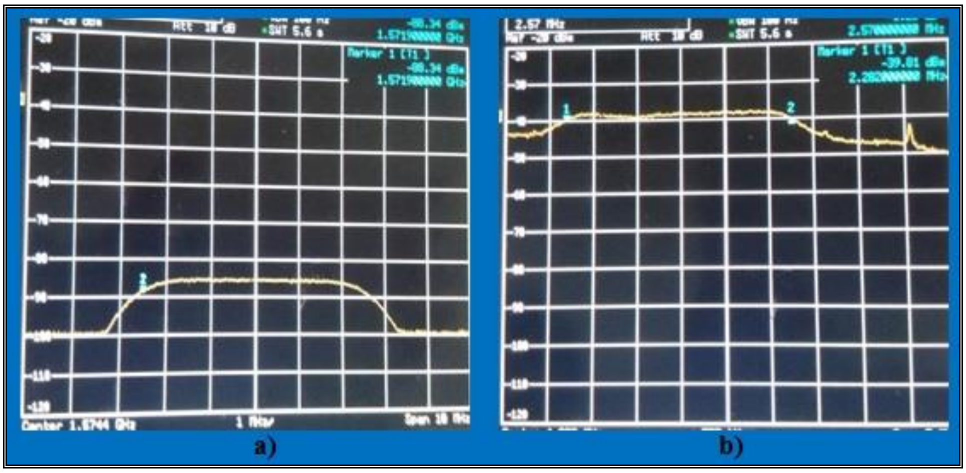

Figure 11. IF BW Test a) LNA1 Input b) IF Output (BW=2.5MHz)

2- **Comparison of IF-Output with Two Input:** For comparison of IF-outputs, the input signal of signal generator is set to -$90dBm$ with frequency of $L_1=1.57542\ MHz$.

By setting RBW(Resolution Band Width) to 30Hz, VBW(Video Band Width) to 300KHz and SWT=450ms, observe and record the results as Figure 12 (a,c). Then by setting RBW(Resolution Band Width) to 100Hz, VBW(Video Band Width) to 300KHz and SWT=130ms, again observe and record the results as Figure 12 (b,d). In the figure the a) and b) are outputs with LNA1 input and c) and d) are outputs with LNA2 inputs.

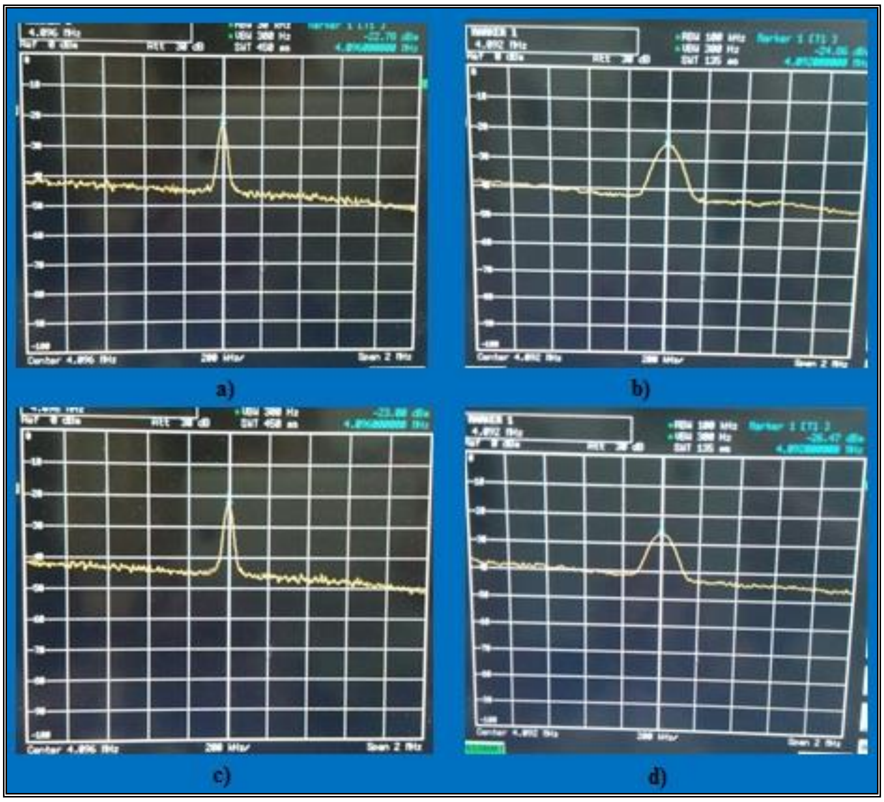

Figure 12. IF Output Frequency Response with Antenna 1 and Antenna 2 Inputs

In the Figure 12, a) input antenna1 with RBW=30Hz, VBW=300KHz, SWT=450ms b) input antenna1 with RBW=100Hz, VBW=300KHz, SWT=130ms c) input antenna2 with BW=30Hz, VBW=300KHz, SWT=450ms d) input antenna2 with RBW=100Hz, VBW=300KHz, SWT=130ms.

6.2. GNSS Receiver Test

The complete GNSS receiver includes one antenna, a RF front-end, an interface board (IF sampler) as shown in Figure 13. A PC or notebook employed for receiver software and displays the position of user, visible satellites number, Doppler shift, troposphere error and some other characteristics. The antenna receives signal from the satellites and then the RF front-end block converts the signal to a low frequency as IF frequency, after that this signal enters to the interface board which is using for data processing.

The position of user is defined by latitude=39.97900, longitude=116.34422, height=113.06831 as determined and observed with receiver software.

Figure 13. Result of GPS Positioning with Display the Visible Satellites

7. Conclusion

The basic and also significant target of this paper is to display and describe how to feature, build, and then evaluation an especially built-in, low-noise, low-power, as well as low-priced RF front-end, by being focused on the building an RF Front-end with MAX2769B as a universal Navigating Satellite System of GPS, Compass, Galileo and also Glonass.

The possibilities of interoperability of four satellite have been analyzed and reviewed as well as has been verified that a receiver can deal with the four regulations at the same time. After that, RF front-end necessities relating to gain, noise figure, bandwidth, image rejection as well as interferences have often been fixed to be well-matched to four GNSS platform.

Even though simulations together with exploring deliver precise predictions of the RF front-end functionality, however to the mass manufacturing, as well as a check affirmation level is essential. To test, evaluation as well as verify the feature, the RF front-end receiver should be built entirely.

Additionally, from all of the current architectures for an RF front-end, the intermediate frequency (IF) have been chosen and its capability for any of GNSS RF front-end has also been established. This uncomplicated architecture is not difficult to make use of, and also its essential drawback could in fact be defeated by utilizing a reliable frequency system, that is, image signal rejection may be accomplished. Besides, this architecture is matched for the three offered buildings that provide the utilization of the front-end for functions, based on power usage as well as the antenna that provides the consumer a large degree of flexibility.

Almost any portion of the front-end have been explored and specified, as well as the architecture feature, has been correctly executed. This has additionally been magnified in the trial outcomes. The functionality of each block of the RF front-end of the feature example like LNA low noise amplifier, radio frequency amplifier, intermediate amplifier, analog to digital conversion, frequency synthesizer, voltage controlled oscillator, pulse swallow divider, and also pierce oscillator comprehensively investigated and then mentioned .

Manufacturing of the printed circuit board (PCB) for IC definition, in addition to the variety of desired outer elements are extremely crucial. A perfect printed-circuit board (PCB) is a significant part of an RF circuit design and style. The electronic PCB board can be utilized as an aid for constructing up applying the MAX2769B micro-chip. In creating PCB board, the traces that move RF signals should be as shorter as feasible to decrease loss in emission and also insertion. Additionally, impedance matching control must be applied on all of the RF signal traces as well as lines. For appropriate operating, the uncovered paddle should be soldered correctly to the ground level of PCB board. On the other side, utilizing the numerous vias bottom the uncovered paddle and within RF traces, cause to diminish unwanted coupler radio frequency.

Ultimately, the soldering, planning and also manufacturing of RF front-end, have already been performed, doing the test as well as affirmation of the over-all prototype feasible. Next, the creation of the GPS/Compass/Galileo/Glonass front-end have been successfully finished. Each phase of the creation, from standards investigation to characterization, have been mentioned within this thesis. Then the finalized made receiver have actually been tested. At first, the test and also characterization of a few blocks are done and then the evaluation of the overall front-end receiver. The results of each test or measurement are documented as shapes.

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Author

Almas Kaveh, Electronic Engineer BS graduated from Khaje Nasir Aldin Toosi University-Tehran Iran and Master Degree of Global Navigation Satellite System graduated from Beihang University-Beijing China.

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