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LNA Design and Implementation for Passive Millimeter Wave Imaging System in Ka Band

***Abstract**. There are several methods of creating a Passive Millimeter Wave Imaging System (PMMWIS). One of these methods is to use tripod, 2-axis positioner, control unit, the parabolic reflector antenna (PRA) and the radiometric receiver located at the focal point of the PRA. The radiometric receiver, which is the most important part of the system can be divided into parts such as low noise amplifier (LNA), detector, mixer and video amplifier (VA). In this study; LNA will be explained. PMMWIS is an imaging method that emerged as a result of the weakening of the radiation in other systems due to atmospheric effects. In case of working in certain frequency windows (35 GHz, 96 GHz, 220 GHz, …); the radiation will not be affected by weather events and can be measured. In this study, an LNA has been created for a radiometric receiver that can be operated at Ka-band. Hittite brand HMC1040LP3CE chip from Analog Devices Company, which can theoretically give 23 dB gain in Ka-band has been preferred. The discrete elements and the chip in the circuit are very precisely placed on the board with special solder mixtures using electronic magnifiers, and 2.92 mm connectors are included in the input and output (IO) of the RF line of the circuit. In the last case; the LNA circuit, which was prepared for measurement, was fed with the power supply. It was measured with the help of vector network analyzer (VNA). At last, the LNA working in the Ka-band produced for PMMWIS with a gain value of 19.32 dB at 26.2 GHz center frequency was obtained.*

***Streszczenie**. Istnieje kilka metod tworzenia pasywnego systemu obrazowania fal milimetrowych (PMMWIS). Jedną z tych metod jest zastosowanie statywu, pozycjonera 2-osiowego, jednostki sterującej, parabolicznej anteny reflektorowej (PRA) oraz odbiornika radiometrycznego umieszczonego w ognisku PRA. Odbiornik radiometryczny, który jest najważniejszą częścią systemu, można podzielić na takie części jak wzmacniacz niskoszumowy (LNA), detektor, mikser oraz wzmacniacz wideo (VA). W tym badaniu; LNA zostanie wyjaśnione. PMMWIS to metoda obrazowania, która pojawiła się w wyniku osłabienia promieniowania w innych systemach na skutek efektów atmosferycznych. W przypadku pracy w określonych oknach częstotliwości (35 GHz, 96 GHz, 220 GHz, …); na promieniowanie nie będą miały wpływu zdarzenia pogodowe i można je zmierzyć. W tym badaniu stworzono LNA dla odbiornika radiometrycznego, który może pracować w paśmie Ka. Preferowany jest układ HMC1040LP3CE marki Hittite firmy Analog Devices, który teoretycznie może dać 23 dB wzmocnienia w paśmie Ka. Elementy dyskretne i układ scalony w obwodzie są bardzo precyzyjnie rozmieszczone na płytce za pomocą specjalnych mieszanek lutowniczych za pomocą lup elektronicznych, a złącza 2,92 mm znajdują się na wejściu i wyjściu (IO) linii RF układu. W ostatnim przypadku; do obwodu LNA przygotowanego do pomiaru zasilono zasilacz. Została zmierzona za pomocą wektorowego analizatora sieci (VNA). W końcu uzyskano LNA pracujące w paśmie Ka wyprodukowane dla PMMWIS o wartości wzmocnienia 19,32 dB przy częstotliwości środkowej 26,2 GHz.. (**Projekt i wdrożenie LNA dla pasywnego systemu obrazowania fal milimetrowych w paśmie Ka**)*

Keywords: amplifier, Ka band, radiometric receiver, passive imaging system.
Słowa kluczowe: pasmo milimetrowe Ka, pasywny system obrazowania

Introduction

In an active RF circuit, it is very important to use LNAs to increase the gain and reduce the noise figure (NF) [1-4]. Making impedance matching circuits to the IO of the LNA circuit is essential for providing performance parameters such as S parameters, 1 dB suppression point, drawn current, and NF [2, 5, 6]. Impedance matching in LNA circuits is usually done with 50 ohms. While connecting the next circuit after the LNA, it should be noted whether the harmony is disrupted. In addition, LNAs that consume less energy are more preferred. LNA circuits formed with common source transistors are highly used because they have more stability and cause less capacitance effects between the IO ports [7]. Linearity and stability features can be gained or lost to the LNA by adding circuits to ensure impedance matching [8]. As in all active circuit designs, the final circuit should be designed by paying attention to the coupling effects caused by inductances in LNA circuits [9].

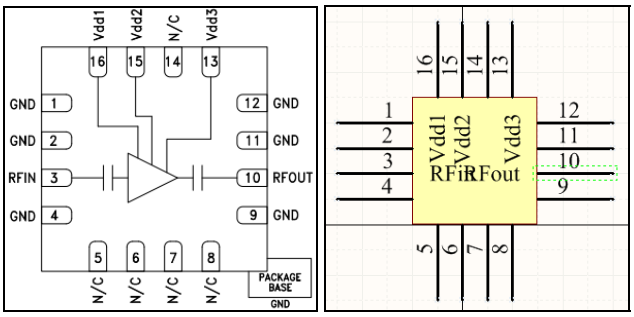
Various soldering techniques such as wire-bonding can be used in LNA circuits where the dimensions can be in order of millimeters [5, 10].

There are plenty of LNA circuits; working with 0.9 V and drawing 2 mA current [5], operating at 1.9 GHz with 3 V supply and consuming 5.2 mW power, having 15 dB gain [11], driving 20 µA current, 15 dB gain with less than 4.5 dB NF [12], etc. Points to be considered while performing these designs are low noise level, high voltage gain, high linearity, good IO impedance matching circuit, and stability [6, 7, 13].

After the LNA circuit is designed, the necessary connectors are connected to the IO ports according to the type of circuits to which the LNA will be connected. The antenna type to be connected to the LNA can be Vivaldi fed [14], antipodal Vivaldi [15] or horn antenna [16]; different methods can be followed for each. These connection methods should be researched [17-19] and the one with less loss should be preferred. In this study; Hittite Analog Devices Company's HMC1040LP3CE LNA chip [20] is used and 2.92 mm connectors are integrated at the IO of the circuit in order to be compatible with the Ka-band. In conclusion; 19.32 dB gain is obtained at 26.2 GHz [2]. Although the gain value is as desired, the operating frequency is shifted a little from the 35 GHz. It is understood that the plate used as the bottom is extremely flexible and the connectors could not fit into their places completely. Nevertheless, the desired LNA design and implementation has been achieved.

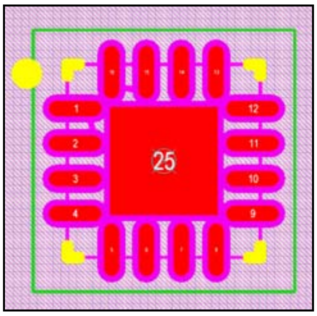
Materials and Method

The design of the LNA circuit, which is the first step in creating a radiometric receiver, has begun. To implement this LNA, it is decided to use the HMC1040LP3CE chip shown in Fig. 1. a. The reason for using this chip; it can work in Ka-Band, its gain is high (20 dB), and its connection structure is SMD type. The operating range of the chip is given in the datasheet between 24 and 43.5 GHz [20].



a. b.

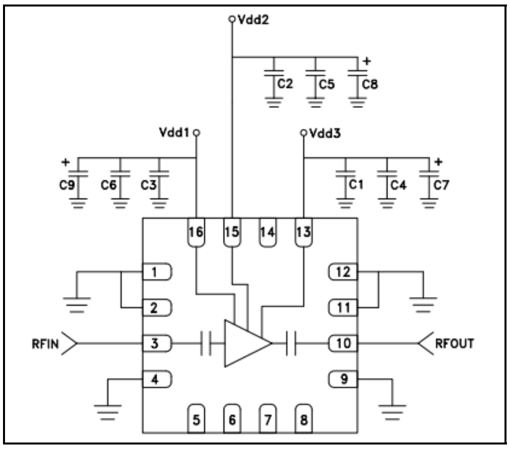
program and the schematic and PCB are transferred into this project as .schlib and .pcblib files. When creating a library in Altium, the schematic and PCB drawing are made as in Fig. 1. b and c respectively. After the additions to the program, the actual full circuit schematic and PCB drawing can be started. In Fig. 2, the schematics in the datasheet (a) and created on the program (b) can be seen.



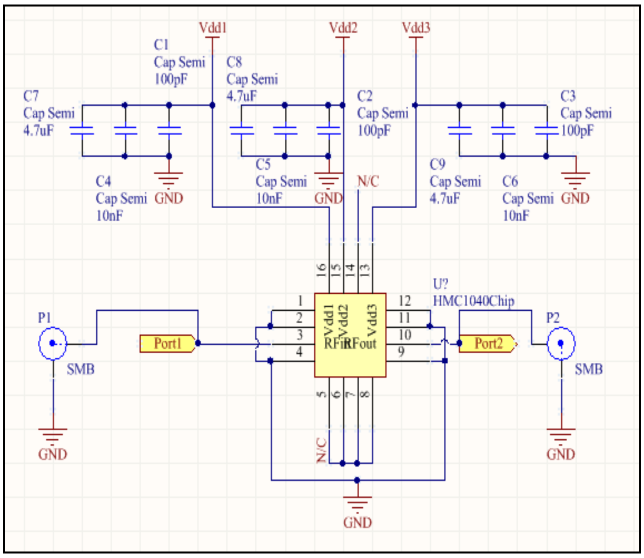
c.

Fig. 1. HMC1040LP3CE chip a. internal schematic diagram b. Altium schematic c. Altium PCB.

Although Vdd voltage inputs can withstand up to 4 V, the operating voltages should be taken as equal and 2.5 V. Pin-3 is RFIN and pin-10 is RFOUT. Pins called N/C are used to better adhere to the substrate named Roger-4350 or Arlon-25fr. Other pins are called ground. The chip, which takes up 16 mm2 in total, will be placed on the base as the top layer. The detailed information can be found in the datasheet of the chip [20].



a.

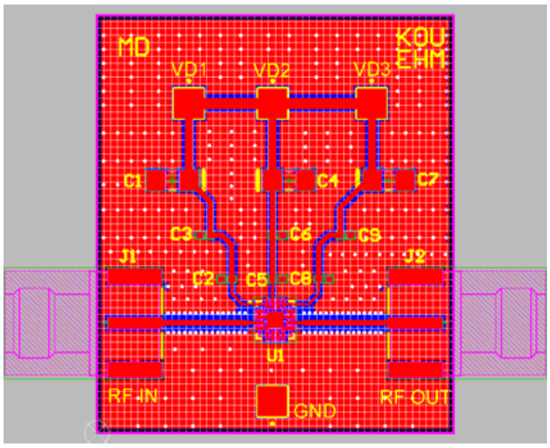


b.

Fig. 2. a. Datasheet schematic b. Created schematic on the program

The schematic drawings are made using the Altium Program. Since the chip is not included in the program, a chip library has been added to the Altium Library section first. For this process, the 'Integrated Library' project is created in the

The PCB design of the full LNA circuit is in Figure 3. While designing this circuit, line thicknesses are taken into consideration. The paths are thinned out on the way to the pins of the chip, and the paths are enlarged on the way to the 2.92 mm connectors. The rest of the lines have been determined with the least loss, according to the datasheet and the TXLine Program, taking care to ensure that the impedance value is 50 ohm. Capacitors with a value of 100 pF provide load balancing of the chip and must be deployed very close to the chip. Tantalum capacitors, on the other hand, must be close to the power source. By the way, names of the capacitors in PCB are different.



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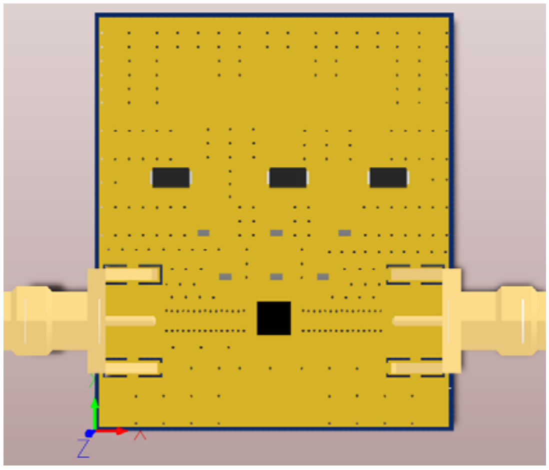
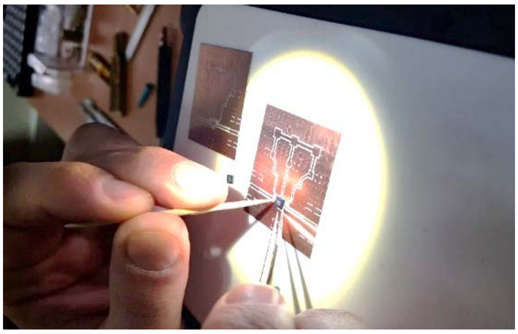


b.

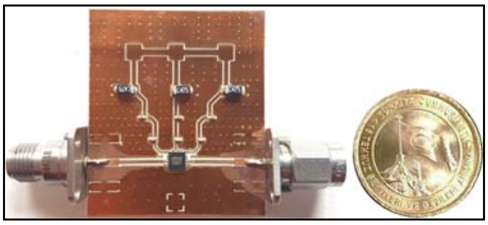
Fig. 3. a. The PCB design b. 3D PCB design of the full LNA circuit on the program

PCB is printed on Rogers-4350 board. In Fig. 4. a, the chip is integrated into the board. Since the materials are very delicate and small, it is necessary to place them very carefully. Capacitor placements are made using an angle electronic magnifier. Soldering processes are made with significant chemical materials and baking.
€)

In Figure 4. b, the connector on the left is female and the connector on the right is male. The purpose of designing it in this way during production is that the mail ended antenna will enter from the left side. The right side will be connected to the detector whose input will be designed with a female. Card dimensions are 3.2 cm wide and 3.7 cm long. The circuit is made ready for measurement by making the supply and ground connections.



a.

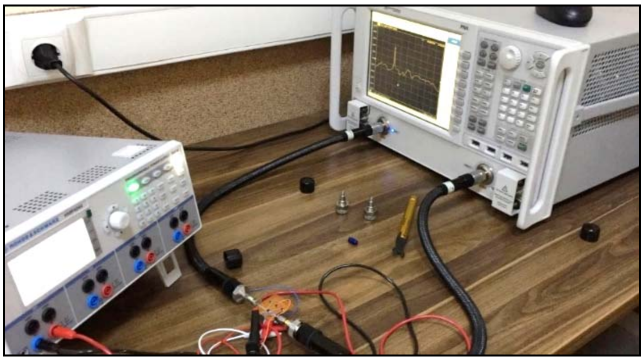


b.

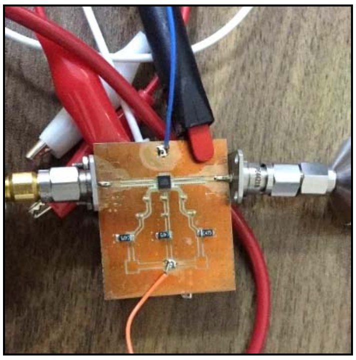
Fig. 4.a. Integrating the chip b. The LNA and 1 ₺ (same size as 1

Results and discussion

To make a VNA connection, a cable supporting the Ka-band is needed. The measurement photos of the LNA circuit with the power supply and VNA connection are given in Fig. 5.



a.



b.

Fig. 5. Measurement photos

The voltage supplied to the circuit and the current drawn by the circuit are obtained in accordance with the datasheet. It is supplied with 2.5 V and current is close to 76.9 mA (typical 70, max. 80 mA). The graph obtained from the VNA screen shows the gain value of S21, one of the S parameters, Fig. 6.

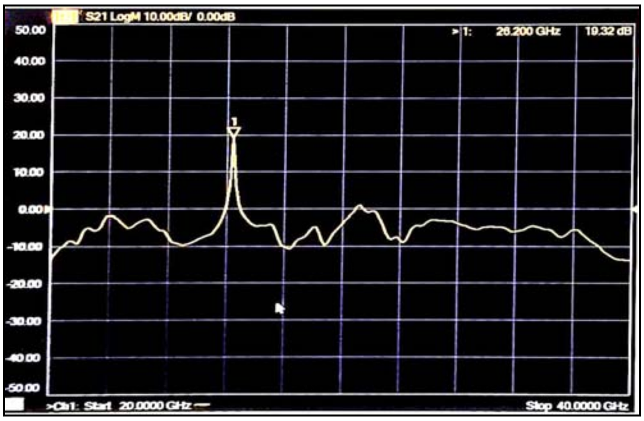


Fig. 6. Gain graph from VNA

The chip gives a wideband gain in the operating frequency range (18 to 45 GHz), ranging from 18 to 28 dB. In the measurement; a gain value of 19.32 dB is achieved only at the sharp frequency of 26.2 GHz. The reasons for this unexpected situation can be discussed as follows: Firstly, because Rogers-4350 substrate ε_r=3,66 is very flexible and thin, especially; 2.92 mm connectors and circuit paths have difficulties in holding onto the card and may remove easily from the card. In order to prevent this situation, the connectors can be connected there by mounting the card on a hard floor first. Therefore; the card will not be bent. Secondly; the variable thickness of the circuit paths may have caused an impedance mismatch. Also; due to the fact that the through calibration in the circuit, suggested in the information page, has not been applied. So, a measurement test of impedance matching could not be made. The absence of this path has led to the inability to test whether the obtained signal could pass over the line. However, a light and small LNA implementation that can be operated in Ka-band with high gain and low energy consumption has been made.

Conclusions

In this article, the LNA design, which is one of the main circuits used in the radiometric receiver is explained together with the schematic and PCB drawing. The production and measurement details of the LNA, which works in the desired band and has sufficient gain, are given and the results are discussed. The article concludes with suggestions for how to achieve better results and future studies. Finally, an LNA with the desired properties is obtained and it can be connected to the other circuits of the radiometric receiver to manufacture a PMMWIS.

In the future, it is considered to remanufacture by placing a hard material under the substrate and to increase the gain by combining multiple LNAs with a cascade connection.

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