The Design & Simulation of LNA for 2.4-2.5 GHz Using AWR Microwave Office

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Abstract - In this study, a low noise amplifier (LNA) design for 2.4-2.5 GHz application which is one of the most important interests in electronics/microwave engineering is designed. High-frequency microwave transistor ATF-54143 E-pHEMT is used to design low noise amplifier and its datasheet is used to match the input and output ports. A low noise and high gain amplifier is synthesized without any oscillations. In particular, the design of low noise amplifier requires optimization on the performance of the system. Those performance measurements are, working band transducer gain, noise figure, and stability along the whole frequency band. In the first step of the low noise amplifier design; the target space ($\Gamma_{IN} = \Gamma_{opt}$*) of the first phase of this study was determined. The simulation results were obtained with the help of AWR (Microwave Office), tool.

Keywords: LNA, PHEMT, AWR.

1. Introduction

Low noise amplifiers are used extensively in wireless communication networks, where noise is low and gain is very desirable. Designing low-noise amplifiers according to other classical methods presents some difficulties. These difficulties can be summarized as low gain, high noise figure, high turn-around losses and limited bandwidth. For this reason, computer aided programs have been used in the design of low noise amplifiers. In computer simulations, the total gain (GA), noise figure (NF_{min}), stability, input and output reflection loss parameters along a frequency band are used as target features and designed for optimal performance. It is not always possible to achieve the desired result with the desired goals. In order to reach the desired goals;

-Active element selection
-Input Matching Circuit design
-Output Matching Circuit design
-DC Biasing Circuit Design

It needs to be designed in the best possible way.

The phases of the work can be listed as follows:

In the first step, when selecting the active element, the S-parameters are checked in the desired frequency band of the transistor.

The solution is sought to make the transistor stable in this band gap. For the Rollet stability law, for the K and Δ values calculated using the S-parameters of the transistor;

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2|S_{12}S_{21}|} > 1$$
$$\Delta = S_{11}S_{22} - S_{12}S_{21} < 1$$

conditions must be met. When these conditions are satisfied, the transistor is brought to an unconditionally stable state. With this law, it is most desirable to ensure that the Smith chart is completely usable. In the second step, it is necessary to design the input and output matching circuitry, while at the same time maximizing the power transferred to the load ($\Gamma_{IN} = \Gamma_{opt}$*).

In the fourth step, a DC bias circuit is designed. Determination of the V_{DS} and I_{DS} values leading to the operation of the FET in the preferred range.

2. Selection of Transistor and Biasing

2.1 Selection of Transistor

The key element of HEMT is its Hetero-junction PN junction that uses different types of material either side of

it. The most common materials used aluminum gallium arsenide (AlGaAs) and gallium arsenide (GaAs) [1]. GaN has a wide band gap which brings the advantages of higher breakdown voltages and higher operational temperature. Due to the large lattice mismatch between AlN and GaN, a strain in the AlGaN layer is induced, which generates a piezoelectric field [2]. ATF-54143 High-performance transistor manufactured with HEMT technology has been chosen. When we checked the data set of our selected transistor, it was seen that the gain was 2.4 GHz. The transistor we use by entering the S parameters of this transistor into the AWR program is designed as two gates.

2.2 DC Biasing

The designed low noise amplifier is intended to operate properly in a cascaded two-layer structure and for 2.4 GHz to 2.5 GHz Wimax applications. The ATF-54143 active component's S parameters were taken from the data set to determine the stability of the circuit as a 2-port circuit, then the input-output conjugate impedance matches and the interstage matching values for the noise figure and maximum gain parameters were made. DC biasing circuits of the transistors were designed at the last stage.
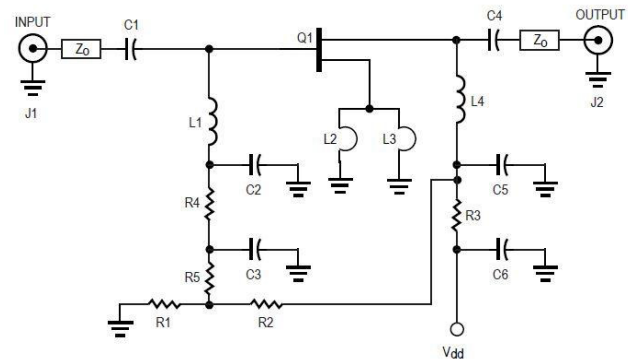

Fig. 1 ATF-54143 DC bias circuit of the transistor.

Table 1 Parameters to be used for DC bias circuit

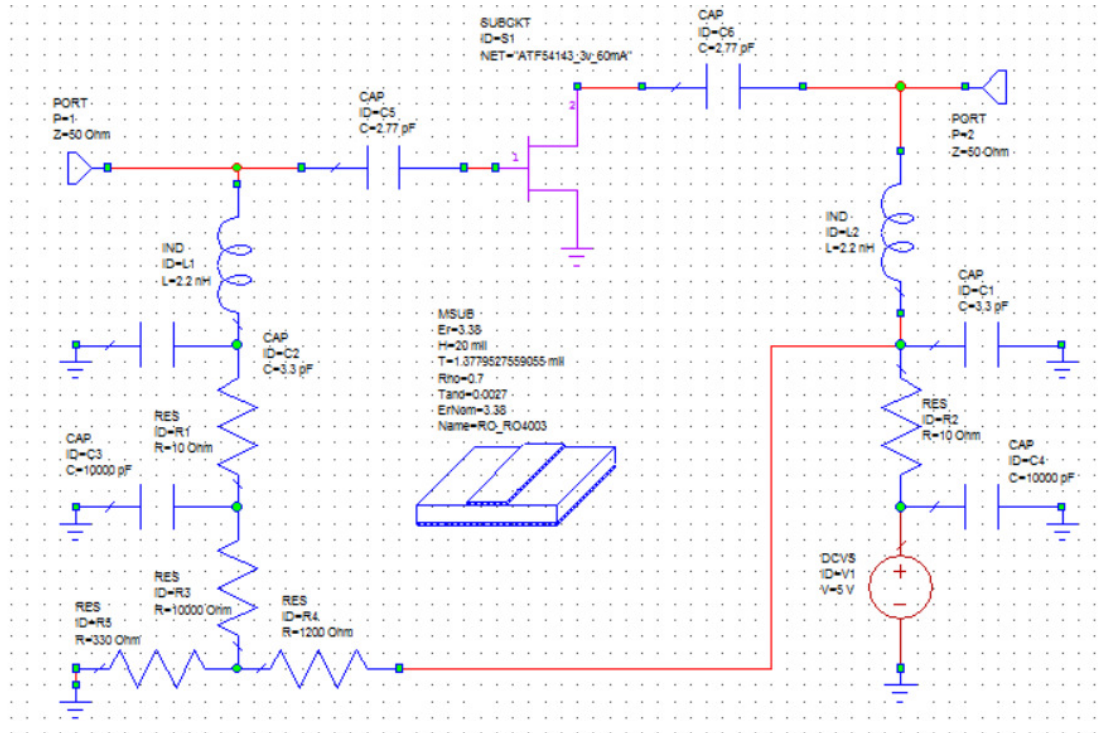| V_{dd}	V_{ds}	I_{ds}	V_{gs}	I_{BB}
5 V	3V	60 mA	0.59 V	2mA

Fig. 2 Single stage amplifier DC biasing circuit

The values of the circuit elements are found using the equations given above. In this case, the values of $R1$, $R2$, $R3$ are found as 290 ohms, 1200 ohms, 32 ohms. Because we use the values we find in the fabrication phase, the actual circuit elements are designed using 330 ohms instead of 290 ohms and 33 ohms instead of 32 ohms. Also the list of circuit elements to be used is given in table 1. The values given are placed in the AWR program and the DC polarity is shown in Fig. 2.

3. Low Noise Amplifier Design

Two ports of 50 Ω have connected either side of transistor and stability of single transistor is checked [7]. As shown in Fig. 1
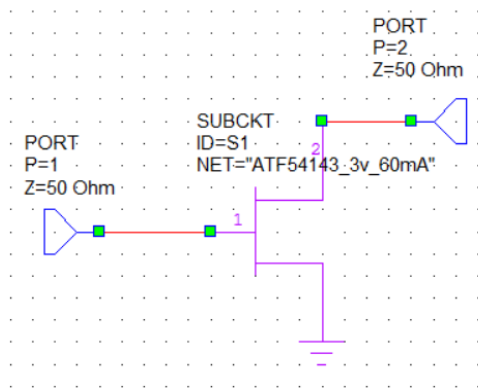

Fig. 3 S-parameter simulation of ATF-54143

The possible extract the S parameters of the amplifier from the data set. The ATF-54143 S parameters depend on the frequency for a given (VDS) voltage and (IDS) current. Fig. 2 shows S-Parameters of ATF-54143 with input return loss is not good as shown in fig. 2. In Fig. 3, it's observed that noise factor is below 0.6 dB but stability is needed to be achieved.
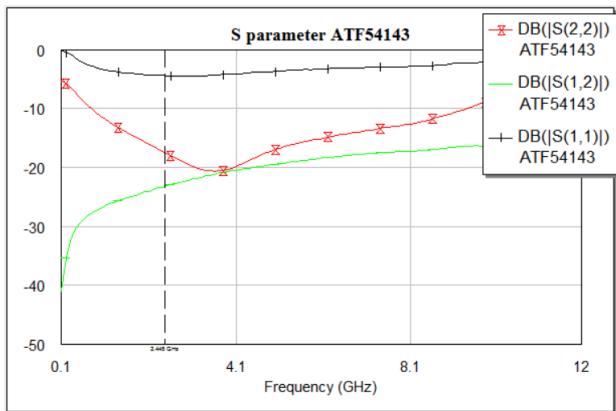

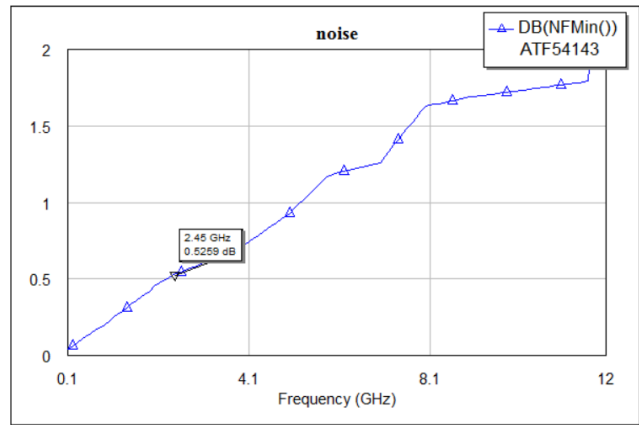Fig. 4 Power gain (S21) and Return Loss (S11) in dB
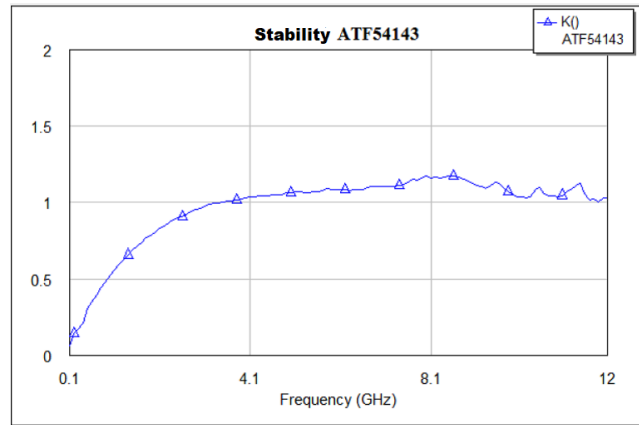

Fig. 5 Noise factor (0.1 - 12 GHz) in dB

Fig. 6 stability factor (K)

For low noise amplifier design, $\Gamma_S = \Gamma_{opt}$ must be first. For a later stage, $\Gamma_S = \Gamma_{opt}{}^*$ must be to be able to draw the greatest power from the input of the amplifier. These two conditions are possible for a certain Γ_L value. Ideally, if $\Gamma_L = \Gamma_{out}{}^*$ can be provided in addition to these conditions, it is obvious that a more perfect design can be achieved [3], [4]. However, since $\Gamma_{IN} = \Gamma_{out}{}^*$ can be achieved for a given Γ_L value, this feedback cannot be achieved without using the regulator. It should be calculated according to whether Γ_L value for Γin = $\Gamma_{out}{}^*$ condition cannot hold the amplifier in a stable state [3] [5]. In other words, if the amplifier is not stable for Γ_L, it is not possible to draw the greatest power from the input [6]. However, the noise, gain and stability circles are drawn and the design is repeated for the highest gain Γ_L with the lowest noise figure.

In order to obtain the maximum gain of the ATF54143 transistor modeled in AWR, the input fixed power circles in the smith chart of the same program are plotted as the first operation. Then, the circle representing the closest point of maximum gain smith chart center Z_{IN} is selected.

The complex matching of this selected point is taken to fit 50 ohms. S_{11} and S_{22} must be less than -10 dB in order to be able to accept the correct operation of the matching circuit.

Table 2: Target frequency characteristics of ATF-54143 transistor

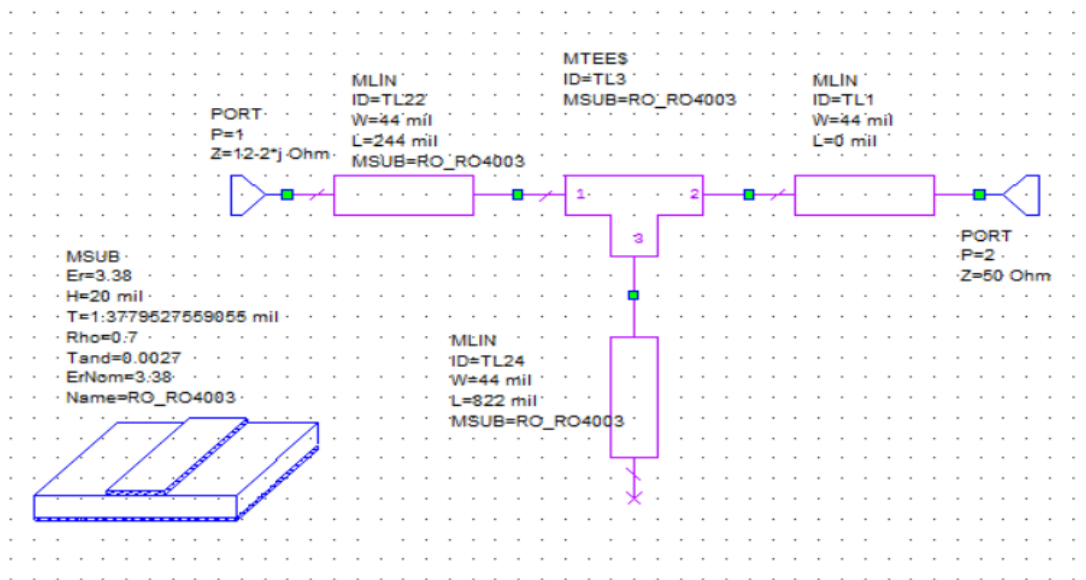| Frequency	Fmin (dB)	Γopt	Γopt (Ang.)	Rn/50	Ga (dB)	Z0 (ohm)
2.4 GHz	0.52	0.26	145.8	0.04	16.65	50
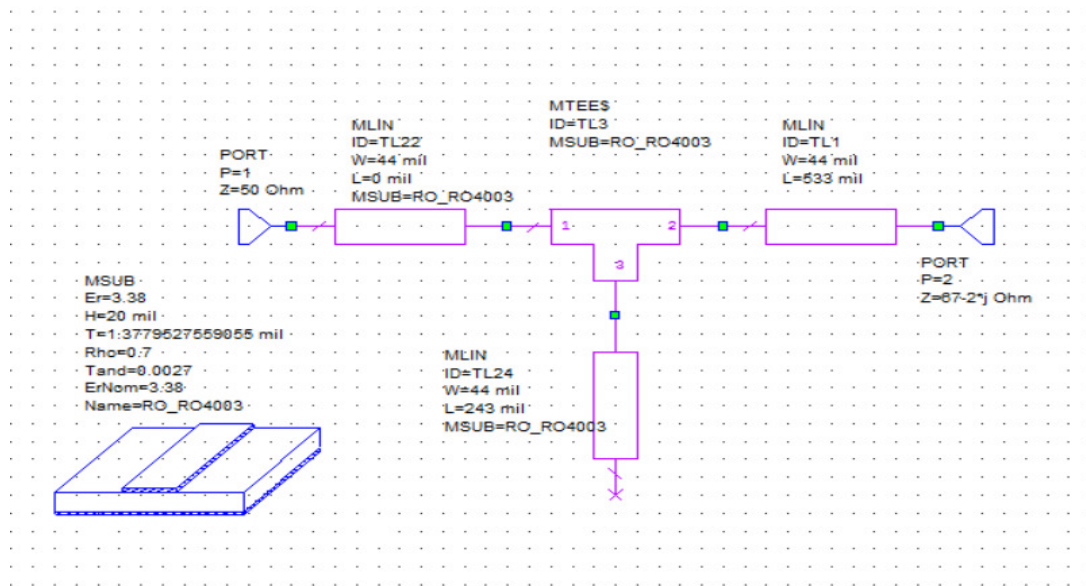
Fig. 7 Input matching circuit.
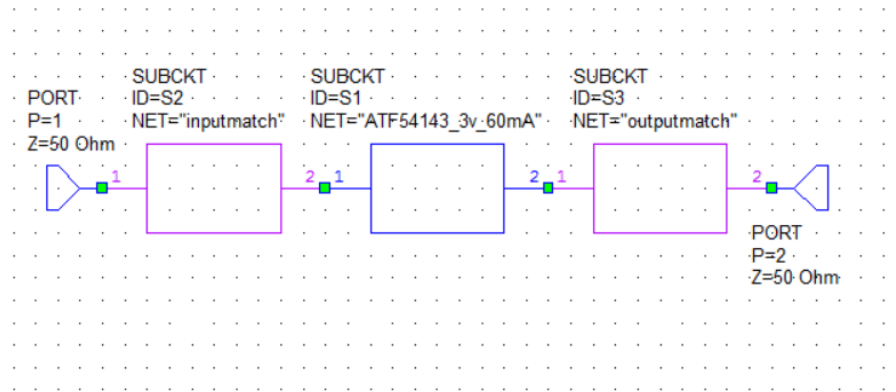

Fig. 8 Output matching circuit

Fig. 9 Input and output matching circuits connected with amplifier circuits.
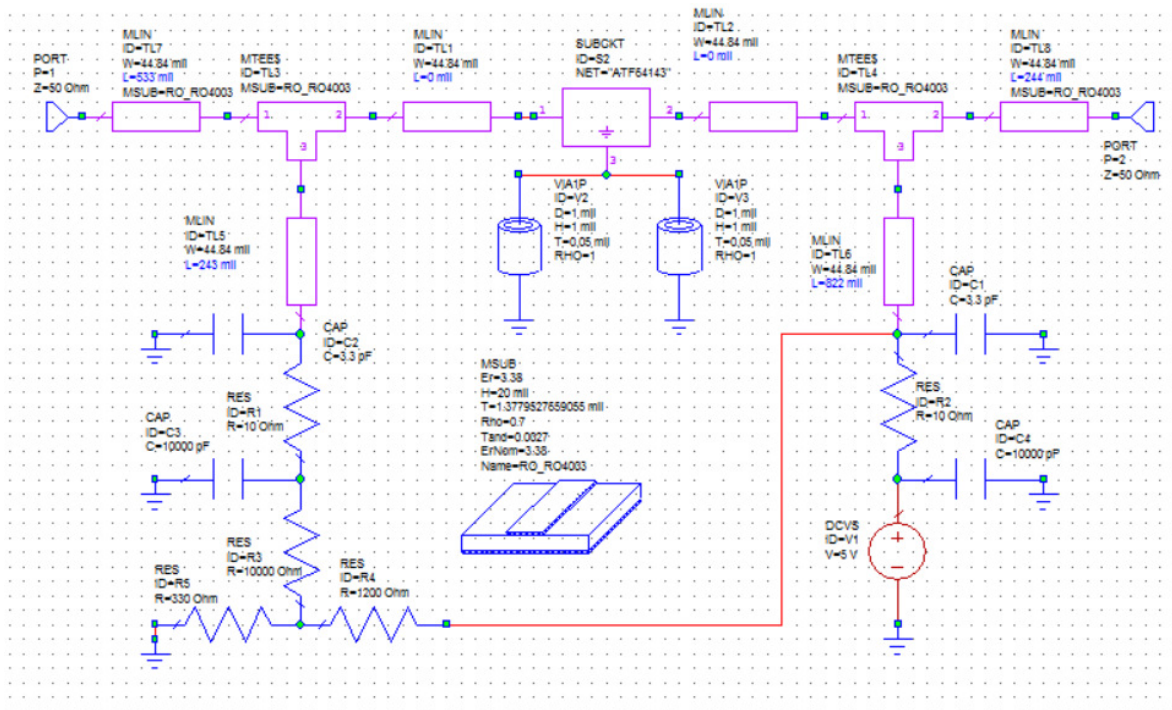

Fig. 10 DC biasing circuits and matching circuits applied low noise amplifier.
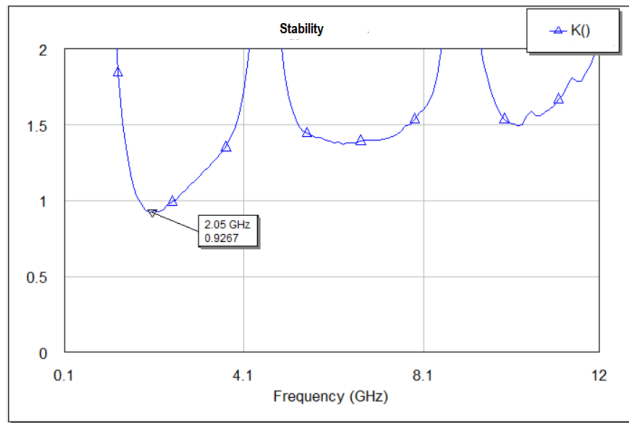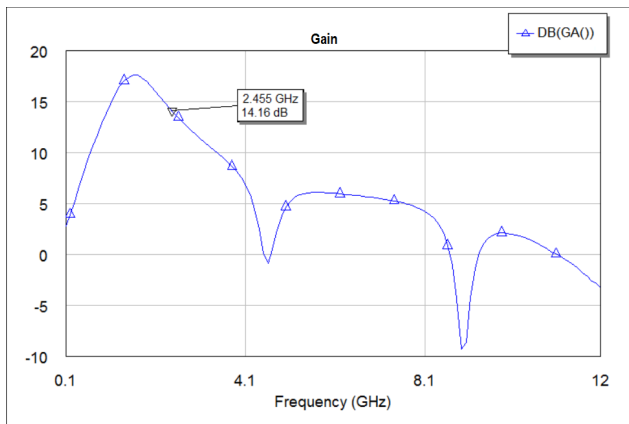
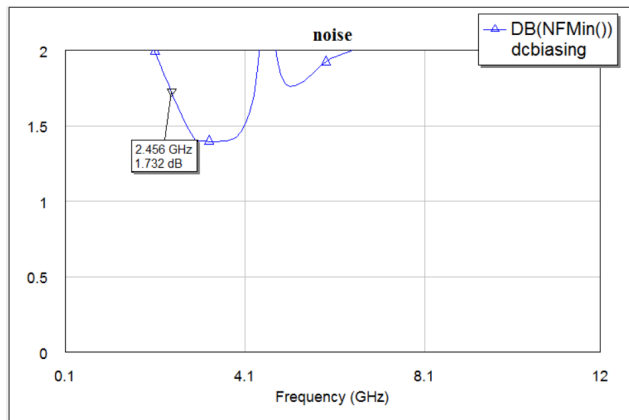Fig. 11 Stability of LNA

Fig. 12 2.45 GHz Gain (S21) of LNA

Fig. 13 2.45 GHz Noise (Fmin) of LNA

Table 3 Performance Summary

Parameter	Goal	Obtained
Frequency	2.45 GHz	2.45 GHz
Power Voltage	5 V	5 V
S21	15 dB	14.16 dB
Noise	1.2 dB	1.7 dB

Conclusions

In this work, the Low Noise Amplifier in the 2.4-2.5 GHz band is designed for WiMAX applications. This designed amplifier takes into consideration the frequency range of 2.4-2.5 GHz. Amplifier designs made on this frequency range; wireless communication devices.

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Osman Selcuk was born in 1991. In 2010, he started his undergraduate studies at the Department of Electrical and Electronics Engineering at Istanbul Haliç University Engineering Faculty and graduated in 2014. In 2014, he started to work both as an academic staff and graduate student at the Department of Electrical and Electronic Engineering of the Faculty of Engineering of Haliç University in Istanbul. He has been still studying Master of Computer Science at Monroe College New York.

Hamid Torpi On March 7, 1967, Germany came to the world of the family of expatriates in the town of Kircheim Unter Teck in Stuttgart. He completed primary school in Private Worker Primary and Primary School, Private Yeşilyurt Primary and Secondary

School and Special Ideal Primary and Primary School respectively. He completed his first two years of secondary school in Fatih college and completed his last year in Yalova High School. He completed his high school education with his diploma in 1984 in Yalova High School. Between 1997-1999, research assistant Dr. He continued to work as a civil servant. In 1997, the same section was assigned to EM fields and Assistant Professor in the Department of Microwave Technology USA. Between 2005 and 2011 he served as Vice President of Department of Electronics and Communication Engineering. Meanwhile UCLA has also been working as a short-term researcher at irvine and Syracuse University NY (USA). He is currently serving as a member of the faculty of EM fields and Microwave Technology.