Design of a Wide Band RF Amplifier using Scattering Parameters

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ABSTRACT
This paper presents a new concept of a wide band RF amplifier using scattering parameters that is often used in the radio frequency communication system. This amplifier operates from 80MHz to 1.1GHz frequency and it is based on BFG65 NPN transistor that has a high transition frequency of 7.5GHz [1]. The simulation results show good performances. The power gain S_{21} is varied between 10 and 14.34 dB. For the input reflection coefficient S_{11} is changed between -29.3 and -17.61 dB. Regarding the output reflection coefficient S_{22} is varied between -19.78 and -10.36 dB. For the reverse transmission S_{12} is changed between -23.23 and -24.65 dB. Regarding the noise figure NF is varied between 3.6 and 3.9 dB. For the 1 dB compression point is changed between -13.94 and -8.24 dBm.

Keywords
Wide band RF amplifier, Input matching, Output matching, RF communication system.

1. INTRODUCTION
In the input of the radio frequency reception chain, the RF signal is mitigated because its power decreases during emission stage. For this reason, The RF amplifier is very significant. In addition, without this part the receipt information can not be recognized. On the other hand, the power gain of this amplifier must be sufficient to predict the useful information.

The narrow band and the wide band microwaves amplifiers are very used in the communication and detection systems (spatial telecommunication, radio communication, radar detection, control system, …) [2]. The matching networks of these amplifiers are designed by means of localized elements (inductances and capacitors) or to basis of distributed elements (transmission lines) or a combination of the two [3], [4], [5], [6]. The use of the matching networks by means of the localized elements or distributed elements depend on the operation frequency. Indeed, for the frequencies lower than 6GHz the localized elements are mainly used, and for the more high frequencies the distributed elements are extensively used, this for the economic and technological constraints [5].

In this paper, we present a novel design of a wide band RF amplifier using the transistor BFG65 that of type BJT (Bipolar Junction Transistor). Also, it is a UHF/microwave transistor. This amplifier uses two RC matching networks to match the input and output at 50 Ohm.

In what follows, we present the design of a wide band RF amplifier using scattering parameters, where we study the RF amplifier in the DC mode and then we simulate the amplifier using ADS (Advanced Design System) simulator. Also, we show the performances of the RF wide band amplifier. Finally, we conclude.

2. DESIGN OF A WIDE BAND RF AMPLIFIER USING SCATTERING PARAMETERS
Mainly, designing an RF amplifier, the input and output matching network are considered to achieve the required stability, small signal gain, and bandwidth [7]. The basic idea of high frequency amplifier design is to match the input and the output of a transistor at high frequencies using S-parameters at a particular DC-bias point with source impedance Z_0 and load impedance also Z_0. The input and output matching networks are fundamental to reduce the undesirable reflection of signal and to improve effectiveness of the transmission from source to load [8], [9]. Figure 1 shows the basic block schematic of RF amplifier including input/output matching networks.

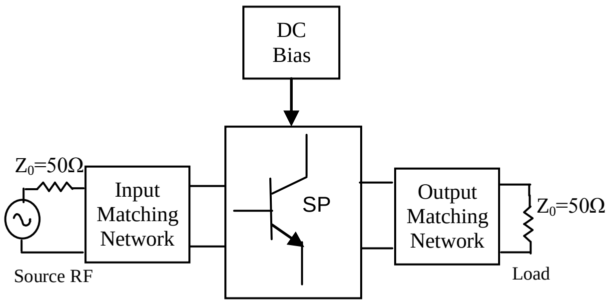

Fig 1: Basic RF Amplifier schematic

In this paper, we propose a wide band RF amplifier using the idea noticed above (figure1). The circuit of this amplifier is shown in figure 2.

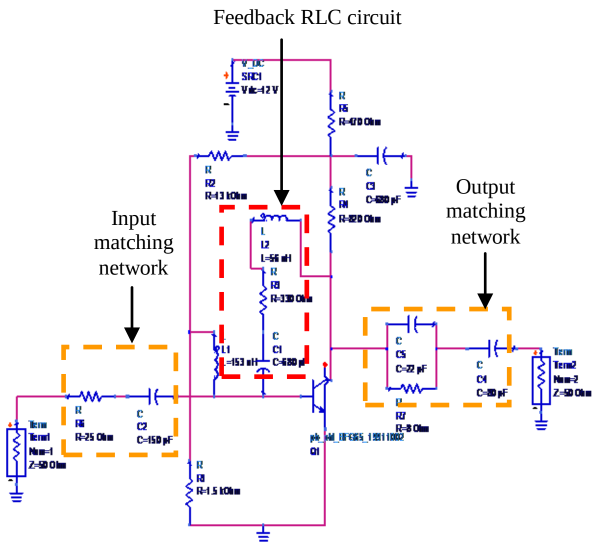

Fig 2: Wide band RF Amplifier Circuit

The proposed amplifier presents a feedback RLC circuit between the collector and the base of the transistor BFG65. This circuit is used to ensure the stability of the amplifier in the low frequencies of operating frequency band. Also, the amplifier shows two RC networks of input and output matching.

2.1 RF Amplifier Study in DC-Mode

To study the functioning of BFG65 transistor in DC mode, we raised the characteristics network I_C=f(V_{CE}, I_B) by means of the ADS simulator. Figure 3 shows this network.

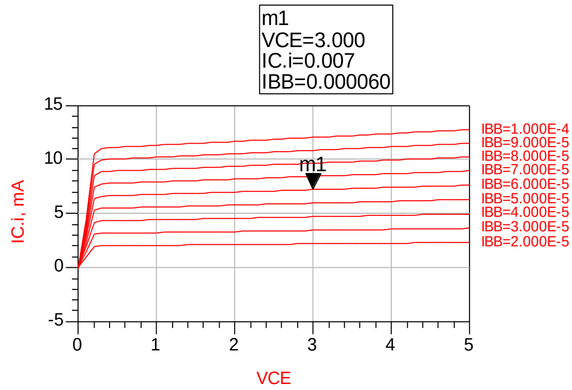

Fig 3: Characteristics network IC=f(VCE, IB) of the transistor BFG65

To polarize the transistor in the linear zone of its characteristic, we adopted the DC equivalent schematic of RF amplifier that is shown in the figure 4. We determine the resistances of polarization R_1, R_2, R_4 and R_5 allowing to get the polarization point; I_C = 7 mA, V_{CE} = 3 V and I_B = 60 µA from a bias source V_{dc} of 12 V.

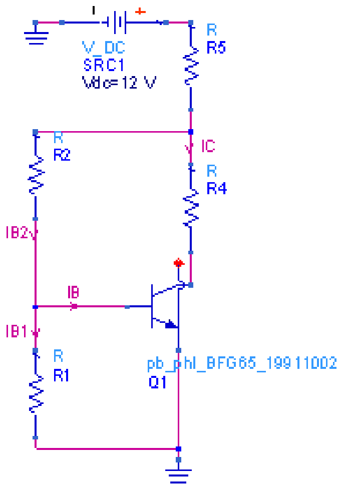

Fig 4: DC Equivalent schematic of RF Amplifier

In order to find the values of the polarization resistances, we must have four equations; two equations are determined from Kirchhoff's loop rule, and the two others from the two following conditions: I_{B1} = 9 IB and we want a voltage fall to boundary-marks of R_5 equals to 3.5V.
From the figure 4, the resistance R_1 can be expressed as:

$$R_1 = \frac{V_{BE}}{I_{B1}} \tag{1}$$

Where the voltage V_{BE} is given by the transistor Characteristic V_{BE} =f(V_{CE}, I_B) associated to V_{CE} = 3 V and I_B = 60 µA. This characteristic is presented in figure 5.

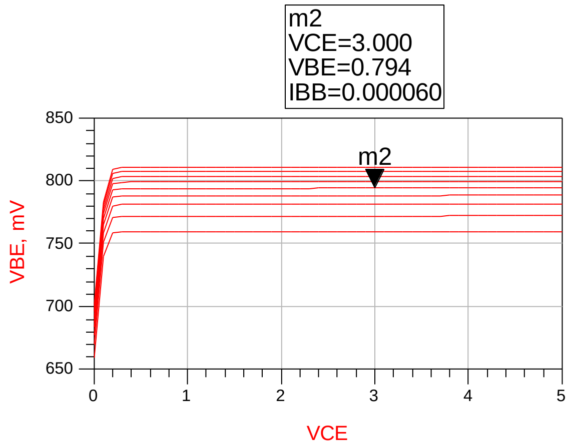

Fig 5: Characteristics network V_{BE} =f(V_{CE}, I_B) of the transistor BFG65

The value of the resistance R_5 is given by the equation (2):

$$R_5 = \frac{3.5}{I_C + 10 I_B} \tag{2}$$

The resistance R_4 is calculated using the equation (3):

$$R_4 = \frac{V_{CC} - V_{CE} - 3.5}{I_C} \tag{3}$$

The value of resistance R_2 is given by equation (4):

$$R_2 = \frac{V_{CE} - V_{BE} + R_4 I_C}{I_{B2}} \tag{4}$$

The normalised polarization resistances are illustrated in the table 1.

Table 1. Values of normalized polarization resistances

Bias resistances	Values
R1 (KOhm)	1.5
R2 (KOhm)	13
R4 (KOhm)	820
R5 (Ohm)	470

2.2 Simulation and Results

The necessary and sufficient conditions for unconditional stability of a transistor are given by the equations (5) and (6) [10]:

$$K = \frac{1 - |S_{11}|^2 - |S_{22}|^2 + |\Delta|^2}{2.|S_{12}.S_{21}|} > 1 \tag{5}$$

$$B_1 = 1 + |S_{11}|^2 - |S_{22}|^2 - |\Delta|^2 > 0 \tag{6}$$

Where:

$$\Delta = S_{22}S_{11} - S_{12}S_{21} \quad (7)$$

In order to satisfy the unconditional stability and guarantee an input/output matching at 50Ohm of RF amplifier, the elements of feedback circuit and input/output matching networks are determined by the command “TUNE” of ADS simulator. Figure 6 shows the curves of the stability factor K and the stability measure B_1 versus frequency.

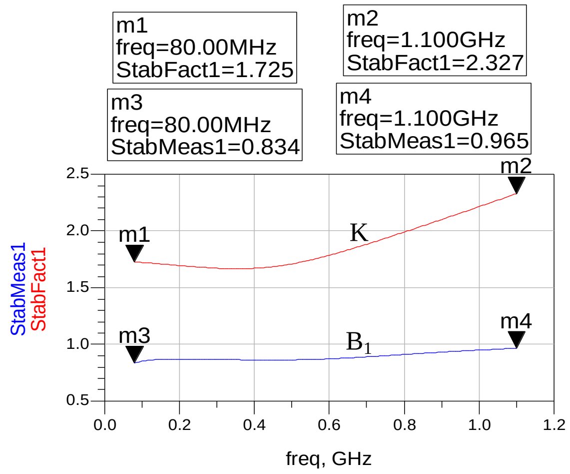

Fig 6: Curves of the stability factor and the stability measure B_1 versus frequency

From figure 6, it can be seen that K >1 and B_1>0 over operating band [80MHz – 1.1GHz]. Thus, the conditions for unconditional stability are confirmed on the operating frequency band. Then, one does not risk to have oscillations.
We simulated the scattering parameters S_{ij} to demonstrate the good operating of the RF amplifier in the frequency range [80MHz – 1.1GHz]. Figure 7 presents the variation of the power gain S_{21} between 80MHz and 1.1GHz. It can be seen that this gain varies between 10dB and 14.34dB. Therefore, these values show a good amplification of the RF amplifier over a wide band.

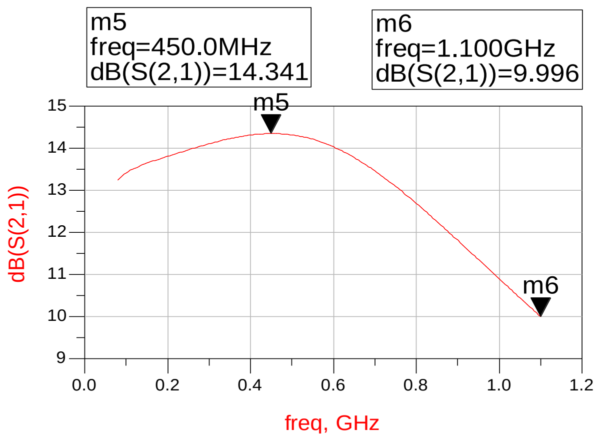

Fig 7: Curve of the power gain S_{21}versus frequency

Figure 8 shows the variation curve of the input reflection coefficient S_{11} in the frequency band [80MHz - 1.1GHz]. We notice that the parameter S_{11}changes between -29.3dB and -17.61dB in this band. Therefore, these values show a good input matching of the RF amplifier over a wide band and the reflection of signal from the amplifier input to the source is feeble.

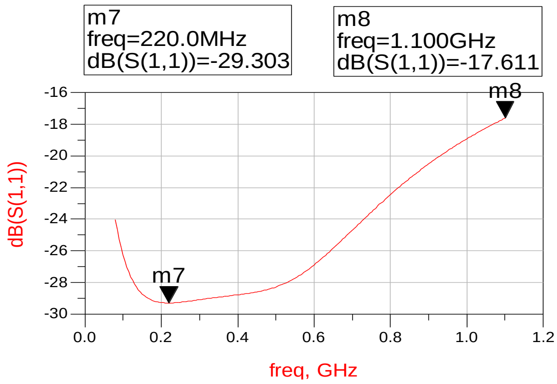

Fig 8: Curve of the input reflection coefficient S11 versus frequency

The good output matching can be established by simulating the output reflection coefficient S_{22}. Figure 9 presents the curve of this parameter. It can be seen that the output matching is good since S_{22} varies between -19.78dB and -10.36dB. Then, the reflection of signal from the amplifier output to the load is relatively weak.
Figure 10 shows the curve of the reverse transmission S_{12}. We remark that this parameter varies between -23.23dB and -24.65dB. These values are weak. Hence, the return of the power from load to source is negligible.

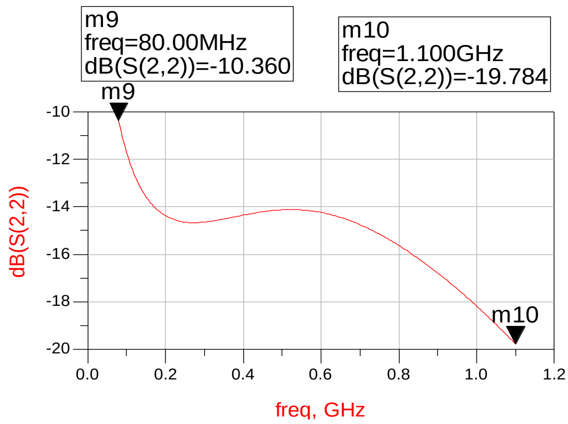

Fig 9: Curve of the output reflection coefficient S22 versus frequency

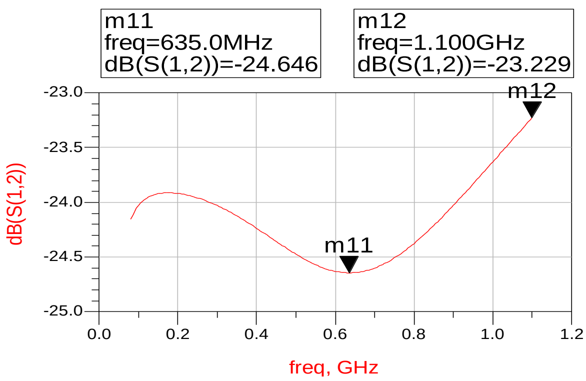

Fig 10: Curve of the reverse transmission S12 versus frequency

Figure 11 presents the variation curve of the noise figure NF versus frequency between 80MHz and 1.1GHz. It can be seen that NF changes between 3.6dB and 3.9dB. Then, the noise figure is low.

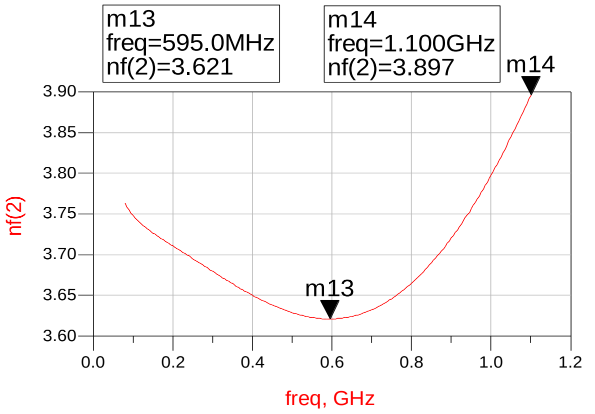

Fig 11: Curve of the noise figure NF versus frequency

Figure 12 shows the variation curve of the 1dB compression point PC1 versus frequency between 80MHz and 1.1GHz. It can be seen that PC1 changes between -13.94dBm and -8.24dBm. Thus, the linearity of the RF amplifier in the operating band is good.

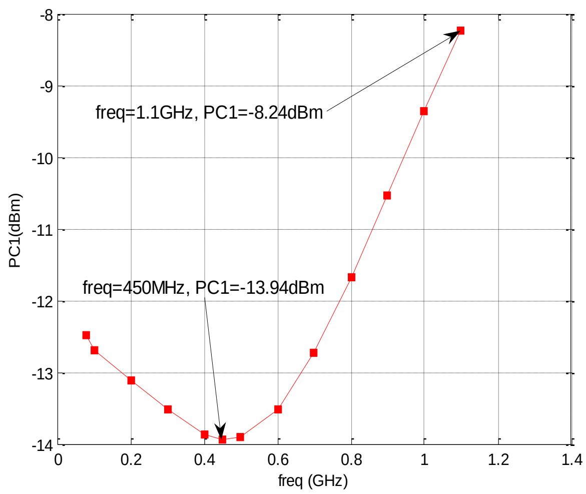

Fig 12: Curve of the 1dB compression point PC1 versus frequency

3. CONCLUSION

In this paper, we designed a wide band RF amplifier using scattering parameters. We confirmed that this amplifier is stable and have good power gain S_{21} with input and output matching at 50Ohm over a wide band. The noise figure, the reverse transmission and the linearity are also good. The simulation results show a variation of the power gain S_{21} between 10dB and 14.34dB. The input reflection coefficient S_{11} changes between -29.3dB and -17.61dB. The output reflection coefficient S_{22} varies between -19.78dB and -10.36dB. The reverse transmission S_{12} changes between -23.23dB and -24.65dB. The noise figure NF varies between 3.6dB and 3.9dB and the 1dB compression point changes between -13.94dBm and -8.24dBm.

4. REFERENCES

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