Underground Pipelines Wireless Sensor LNA Circuit Design and Simulation Based On ADS

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***Abstract*—LNA (Low-noise amplifier) is RF front-end major device for receiving the signal, which is used to amplify the signal close to noise. Stability, gain, input and output VSWR and noise are the most important factors to be considered in the LNA actual design. In this paper, we use the ADS software for the low noise amplifier S-parameter simulation. LNA design requires a good stability in the operating frequency band i.e. the stability factor is greater than 1, the gain is approximately 20dB, the input VSWR less than 1.5, the output VSWR less than 2; In the practical design of underground pipelines wireless sensor, the result of simulation is stable and reliable.**

Keywords-LNA;ADS; S-parameter; VSWR ;gain; noise

I. INTRODUCTION

With the development of the smart pipe, the terminal equipment and sensor devices are showing explosive growth trend. Each sensor is a source of information, collected environmental data and send it in a certain frequency, for example 433MHz. Low-noise amplifier is major device for receiving the signal in RF front-end circuit, which is used to amplify the signal close to noise. Stability, gain, input and output VSWR and noise are the most important factors to be considered in the LNA actual design. Due to the presence of the amplifier input output port reflection, under certain conditions, an amplifier no longer amplify the signal and generates the oscillation, so the stability simulation test is necessary for the amplifier design. Since the role of the amplifier is to amplify the signal, the amplifier gain must meet the design requirements. Input and output VSWR is a function of the reflection coefficient, which to a certain extent reflects the situation in the port matching of amplifier design, and the quality of its properties to a certain extent will have an impact on the stability of the low noise amplifier [1]. Due to the low noise amplifier operating at low signal state, so S-parameter simulation has practical significance for the actual circuit design of the low noise amplifier. But LNA noise figure can not be S-parameter simulation, this article does not validate noise figure. Since LNA noise figure can not be verified by S-parameter simulation, this paper does not validate noise figure.

II. LAN PARAMETERS SIMULATION

HMC616LP3 is used in this design, which works in 175MHz-660MHz. HMC616LP3 is the product of Hittite, which uses 3V-5V low-voltage power supply and it's I_{dd} can be set by R_{bias}. The size of the R_{bias} also has an impact on the stability of LNA. In order to ensure the stability of the LNA in operating frequency, the value of R_{bias} should not be less than 1K. Within the operating frequency, HMC616LP3 has maximum gain up to 24dB and noise figure 0.5dB. The stability, gain, input and output VSWR and input and output impedance data of the HMC616LP3 can be get through S-parameter simulation. HMC616LP3's S-parameter files can be downloaded in Hittite official website. The low noise amplifier HMC616LP3 ADS S-parameter simulation schematic is shown in Figure I [2].

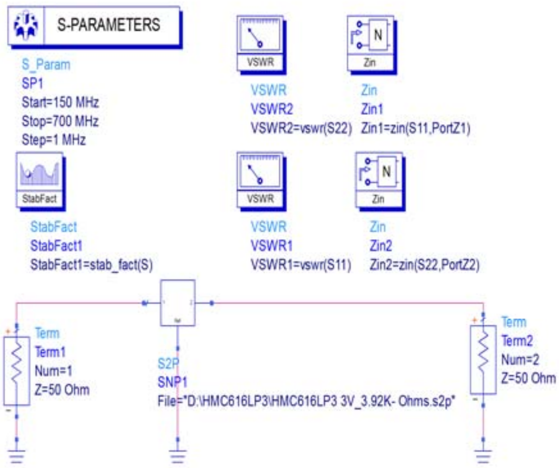

FIGURE I. HMC616LP3 ADS S-PARAMETER SIMULATION SCHEMATIC

Figure I show the HMC616LP3 S-parameter simulation schematic under 3V power supply, R_{bias} is R3.92k conditions. As shown in Figure I, frequency range of the S-parameter simulation is 100MHz-1GHz, and the simulation step is 1MHz; The stability factor, input and output VSWR, input and output impedance parameters can be calculated by the S-parameter simulation. The low noise amplifier HMC616LP3 ADS S-parameter simulation results is shown in Figure II.

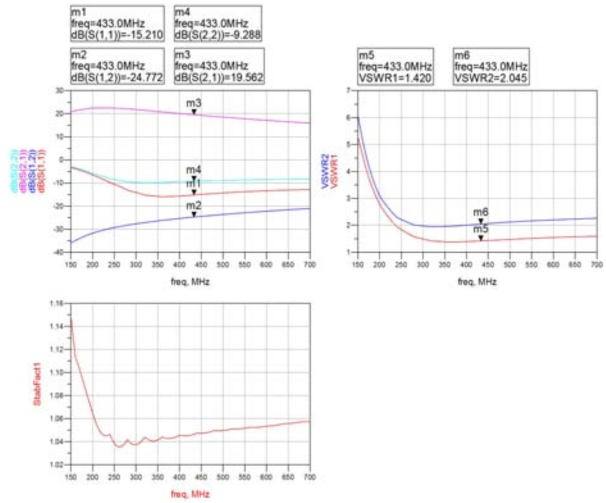

FIGURE II. THE RESULT OF HMC616LP3 S-PARAMETER SIMULATION

Shown in Figure II, the parameter S (2,1) of HMC616LP3 in the 433MHz is 19.562dB, basically meet the design requirements of about 20dB. LNA input VSWR is 1.420 (less than 1.5), reached the design requirements of the input VSWR. LNA output VSWR is 2.045 (more than 2.0), did not meet the design requirements of the output VSWR. As shown in Stabilizing factor graph, in the 433MHz working frequency the stability factor is greater than 1, indicating that LNA is stable.

III. OPTIMIZATION DESIGN OF LNA CICUIT

Since the amplifier output VSWR at the operating frequency of 433MHz does not meet the design requirements, it is necessary to adjust the output VSWR .The output VSWR can be adjusted by adjusting the input and output impedance[3]. Figure III show the input and output impedance values of HMC616LP3 at different frequencies.

freq	Zin1
150.0 MHz	32.868 - j73.677
160.0 MHz	32.741 - j66.446
170.0 MHz	34.084 - j60.411
180.0 MHz	35.257 - j54.790
190.0 MHz	36.312 - j49.524
200.0 MHz	37.291 - j44.561
210.0 MHz	39.037 - j41.239
220.0 MHz	40.656 - j37.862
230.0 MHz	42.149 - j34.433
240.0 MHz	43.514 - j30.957
250.0 MHz	45.296 - j29.134
260.0 MHz	46.927 - j27.124
270.0 MHz	48.381 - j24.943
280.0 MHz	49.633 - j22.610
290.0 MHz	51.132 - j21.593
300.0 MHz	52.501 - j20.421
310.0 MHz	53.717 - j19.111
320.0 MHz	54.758 - j17.683
330.0 MHz	55.887 - j17.148
340.0 MHz	56.969 - j16.523
350.0 MHz	57.996 - j15.812
360.0 MHz	58.957 - j15.019
370.0 MHz	59.813 - j14.804
380.0 MHz	60.676 - j14.539
390.0 MHz	61.542 - j14.221
400.0 MHz	62.410 - j13.848
410.0 MHz	63.060 - j13.834
420.0 MHz	63.725 - j13.796
430.0 MHz	64.404 - j13.734
440.0 MHz	65.096 - j13.645
450.0 MHz	65.571 - j13.746
460.0 MHz	66.056 - j13.839
470.0 MHz	66.549 - j13.923

freq	Zin2
150.0 MHz	46.945 - j100.016
160.0 MHz	47.396 - j90.256
170.0 MHz	50.413 - j83.172
180.0 MHz	52.834 - j76.206
190.0 MHz	54.715 - j69.400
200.0 MHz	56.113 - j62.782
210.0 MHz	58.992 - j59.030
220.0 MHz	61.463 - j54.973
230.0 MHz	63.480 - j50.679
240.0 MHz	65.014 - j46.221
250.0 MHz	67.278 - j44.079
260.0 MHz	69.316 - j41.716
270.0 MHz	71.094 - j39.163
280.0 MHz	72.588 - j36.456
290.0 MHz	74.260 - j35.292
300.0 MHz	75.868 - j34.012
310.0 MHz	77.402 - j32.621
320.0 MHz	78.850 - j31.123
330.0 MHz	80.117 - j30.580
340.0 MHz	81.387 - j29.978
350.0 MHz	82.658 - j29.316
360.0 MHz	83.926 - j28.592
370.0 MHz	84.875 - j28.447
380.0 MHz	85.839 - j28.278
390.0 MHz	86.817 - j28.084
400.0 MHz	87.810 - j27.863
410.0 MHz	88.503 - j27.979
420.0 MHz	89.206 - j28.090
430.0 MHz	89.920 - j28.193
440.0 MHz	90.644 - j28.291
450.0 MHz	91.086 - j28.572
460.0 MHz	91.531 - j28.856
470.0 MHz	91.979 - j29.141

FIGURE III. INPUT AND OUTPUT IMPEDANCE VALUES OF HMC616LP3 AT DIFFERENT FREQUENCIES

As shown in Figure III, the input impedance of the LNA is 64.404-j*13.734 and the output impendence of the LNA is 89.920-j*28.193 at the frequency of 430MHz. Matching network can be designed by ADS Smith Chart tool as shown in FIGURE IV[4].

FIGURE IV. ADS SMITH CHART TOOL

ADS simulation schematic after optimization of the input impedance is shown in Figure V.

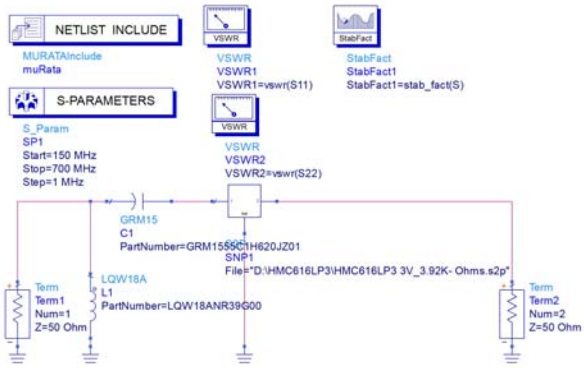

FIGURE V. OPTIMIZED ADS SIMULATION SCHEMATIC

The module of inductance and capacitance used in the simulation is provided by Murata, which has the same characteristics as the actual components.

The inductance and capacitance module used in the simulation is provided by Murata, they have the same characteristics as the actual components. So the simulation results using this model are more instructive. The simulation results after optimizing input impedance is shown in figure VI.

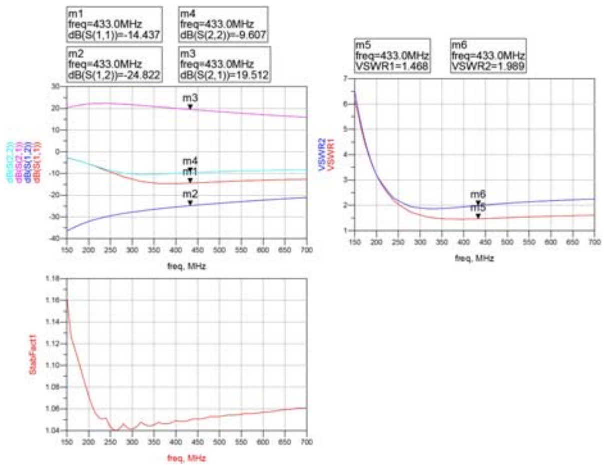

FIGURE VI. THE SIMULATION RESULTS AFTER OPTIMIZING INPUT IMPEDANCE

As shown in figure VI, at the frequency of 430MHz the value of output VSWR has changed into 1.898. After optimizing input impedance the output VSWR has met the requirement of design. At the same time, the stability factor has been improved. If the input impedance is adjusted and then yet not meet the design requirements, then the adjustment of output impedance is needed[5]. It can be optimized by ADS using 'Optim' control tool and the 'Goal' target control tool. Then it is just need to replace the simulating value with the value closest to the actual component to optimize Components, and confirm the final simulation results.

IV. Circuit Design of LNA

As shown above, after series of simulation and optimization, using the Murata GRM series 52pF capacitor and LWQ series 390nH inductance the actual impedance matching circuit is shown in Figure VII.

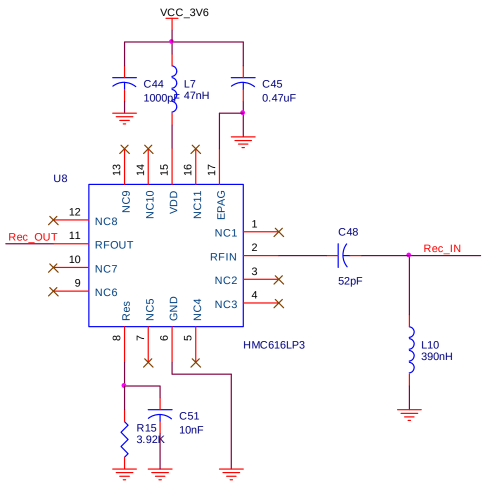

FIGURE VII. ACTUAL IMPEDANCE MATCHING CIRCUIT

V. Conclusion

This article describes the S parameter simulation in RF circuit design and the performance of circuit designed by this method is stable and reliable in the practical application of wireless sensors in underground pipelines, the actual results met the design requirements.

References

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