Indonesian Journal of Electrical Engineering and Computer Science
Vol. 6, No. 3, June 2017, pp. 656 ~ 662
DOI: 10.11591/ijeecs.v6.i3.pp656-662

Design and Performance Analysis of 1.8 GHz Low Noise Amplifier for Wireless Receiver Application

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Abstract

In present stereo audio system is a most popular audio system for different purposes. Now a day's stereo system is commonly used in communication and other purposes. Moreover Normalized Least Mean Square (NLMS) based adaptive filtering is an effective filtering process in case of communication and other applications. However adaptive filtering is an adaptive filter process to cancel out the noise from audio signal successfully. Hence the main objective of this paper is to design a NLMS adaptive filter which cancels out the noise from a noisy wave format stereo audio file. Moreover by varying the order of the adaptive filter (such as 8th, 16th, 32th and 64th), the performance of the NMLS adaptive filtered signal with respect to reference and noisy stereo audio signal are analyzed as well.

Keywords: *low noise amplifier (LNA), pseudomorphic high electron mobility transistor (PHEMT), advanced design system, decibel (dB), reflection coefficients*

1. Introduction

Wireless communication is vastly used communication system in present days. Hence wireless communication system provides low cost and mobility so this is very popular communication system now a day. However the problem is to design a low noise and moderate gain amplifier for receiver end of wireless communication system. Since noise plays a vital role in case of communication system specially wireless devices, so in case of high noise figure in amplification end causes the received signal noisy and it creates more complexities as well. Moreover the gain flatness can make the amplifier more effective to integrate it at the RF receiver end [1-2]. The main concept of this paper is to design a effective low noise amplifier for 1.8 GHz RF wireless receiver system. Hence in theoretical calculation and designing segment, the theoretical calculations will be performed to design the open shunt stub matching network. However the design precise parameters such as reflection coefficients of source and load end, stub length and width, gain and noise figure circle are also calculated by ADS for a PHEMT (ATF-34143) transistor [3]. However the placement of real components as well as the transistor is also done in second segment. Furthermore the biasing voltage, current and biasing resistances are also integrated with the model to make the design more practical. In result and discussion segments the performance evaluation of the designed 1.8 GHz amplifier will be analyzed based on gain flatness, noise figure, harmonic balance, two tone testing and 1dB compression point etc. by ADS simulation of the designed model.

2. Parameter Calculation and LNA Design

The main objective of this paper is to design an effective LNA for 1.8GHz and evaluate the performance. Hence firstly the design parameters are calculated manually by theoretical equations, afterwards the parameters are simulated by ADS to design a perfectly 50 Ω matching LNA for 1.8 GHz. Thus the reflection coefficient in source side (Γ_s) from the intercept point of noise and gain circle has been chosen. Consequently calculate the reflection coefficients in the load side (Γ_L) as well. Then by using smith chart the open shunt stub lengths and widths are calculated theoretically.

Received February 2, 2017; Revised April 29, 2017; Accepted May 13, 2017

Transistor is a main factor of any amplifier designing, so a PHEMT transistor (ATF-34143) has been used here. So from the data sheet of specific PHEMT transistor ATF-34143 the values of S-parameters for biasing point drain source voltage (V_{ds}) is 3V and drain source current (I_{ds}) is 20 mA [4]. Choose this point because Noise figures (F_{min}) is lowest in this point. So the chosen S-parameters along with other parameters such as noise figure and optimum reflection coefficients are given below [4].

S_{11}: 0.78∟-115 S_{21}: 6.843∟98 S_{12}: 0.083∟28 S_{22}: 0.28∟-1

F_{min} = 0.17 dB Γ_{opt} = 0.74∟57 $R_{n/50}$ = 0.10

By using equations (1-6) are used to draw noise and gain circles enclose in smith chart given below to choose the Γ_s from the gain and noise circle intercept point. First check the stability check using equation 1 and 2 [5].

$$K = \frac{1-|S11|^2-|S22|^2+|\Delta|^2}{2|S21*S12|} \quad (1)$$

$$\Delta = S_{11}S_{22} - S_{21}S_{12} \quad (2)$$

$$C_L = \frac{(S22-\Delta S11^*)^*}{|S22|^2-|\Delta|^2} \quad (3)$$

$$R_L = \left|\frac{S21*S21}{|S22|^2-|\Delta|^2}\right| \quad (4)$$

$$C_S = \frac{(S11-\Delta S222^*)^*}{|S11|^2-|\Delta|^2} \quad (5)$$

$$R_S = \left|\frac{S21*S21}{|S11|^2-|\Delta|^2}\right| \quad (6)$$

Here the stability parameters are K=0.385 and |Δ|=0.353. Where K<1 and |Δ| <1, so it is potentially unstable. So now draw the stability circles using equations 3, 4, 5 and 6, however choose a point which is outside of unstable circle. Since point inside the unstable circle region are unstable which converts this amplifier to an oscillator. Hence any point outside the unstable circle has been selected. So the calculated center and radius of the source side and load side unstable circles which are given below accordingly [5-7].

Source side Unstable Circle:
Center, C_s=1.81∟116.62 Radius, R_s=1.174

Load side Unstable Circle:
Center, C_L=11.92∟-62.39 Radius, R_L=12.291

In this case 16 dB Gain and 0.5 dB noise factor are chosen since it is low noise amplifier. As this LNA will be used in receiver end so the noise should be low whether the gain could have reasonable value. So to design the low noise amplifier, the gain and noise circle with appropriate center and radius should be calculated by equation 7, 8, 9, 10 and 11 [5, 6, 8-9].

$$G_A = |S_{21}|^2 g_A \quad (7)$$

$$r_A = \frac{\sqrt{1-2(gA)|S21*S12|K+gA^2|S21*S12|^2}}{|1+gA(|S11|^2-|\Delta|^2)|} \quad (8)$$

$$C_A = \frac{gA(S11^*-S22\Delta^*)}{|1+gA(|S11|^2-|\Delta|^2)|} \quad (9)$$

The formula for Noise circle is given below,

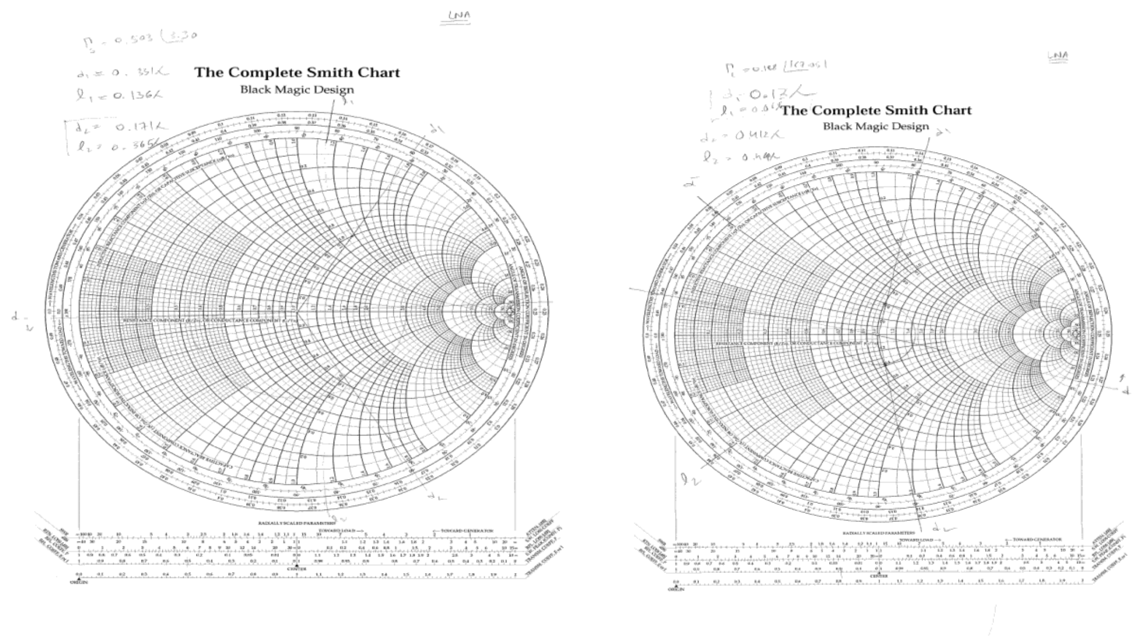
$$C_F = \frac{\Gamma opt}{N+1} \quad R_F = \frac{\sqrt{N(N+1-|\Gamma opt|^2)}}{N+1} \tag{10}$$

$$\text{Where, } N = \frac{|\Gamma s-\Gamma opt|^2}{1-|\Gamma|^2} = \frac{F-Fmin}{4^{Rn}/_{Zo}}|1-\Gamma_{opt}|^2 \tag{11}$$

For gain circle the center, C_A (0.373 ∟116) and radius, R_A (0.444) are calculated. Consequently for noise circle the center C_F (0.5∟57) and radius, R_F (0.12) has been calculated as well. Afterwards by using the smith chart the value of reflection coefficient, (Γs) 0.503 ∟3.30 along with the length and width of the open shunt stub has been calculated for source side, d= 0.171λ and l= 0.365 λ which is showed in Figure 1(a). Subsequently for load side the reflection coefficient (Γ_L) has been calculated by Equation 12 & 13 [5].

$$\Gamma_{out} = S_{22} + \frac{S21*S21*\Gamma s}{1-S11\Gamma s} \tag{12}$$

$$(\Gamma_{out})^* = \Gamma_L \tag{13}$$



(a) (b)

Figure 1. a) Smith chart for theoretical calculation of source side length of width of open shunt stub b) Smith chart for theoretical calculation of load side length of width of open shunt stub

So the calculated reflection coefficient (Γ_L) is 0.188 ∟167.051 [6]. Moreover the length and width of the open shunt stub in case of load side from the smith chart are d= 0.13 λ and l=0.44 λ as well which is showed in Figure 1 (b). For ADS simulation the gain circle and noise figure circle are analyzed by connecting the s2p file of ATF-34143 with termination port of 50 Ω [10-11]. Hence it is a low noise amplifier the minimum noise is the main concern rather than gain. So the interception point of 14 dB gain circle and 0.5 dB noise circle are selected which is showed in Figure 2. Moreover the measured values of normalized impedances and reflection coefficients are illustrates in Figure 2.

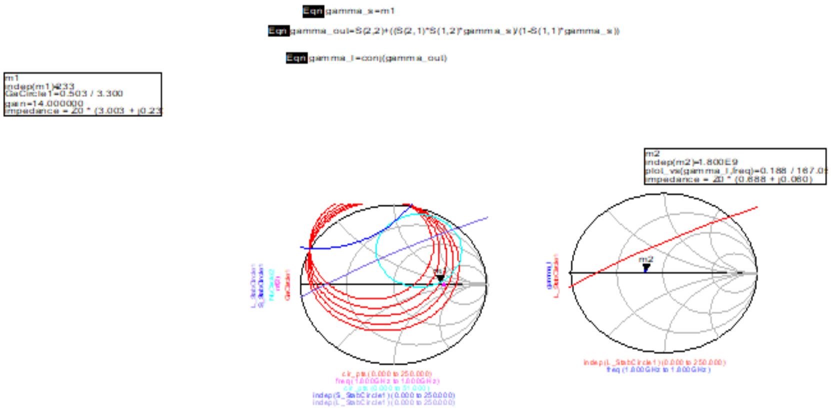


Figure 2. Gain, noise circles, source reflection coefficient (Γs) and Load reflection coefficient ($\Gamma_{L)}$ for 3V and 20 mA

Moreover for LNA designing purpose the reflection coefficients for source and load sides are measure as well from the simulation, which is showed in Figure 2 also. All the design parameters are illustrates in Figure 2 for the gate source voltage of 3 V and the gate source current of 20 mA for the PHEMT transistor, hence this biasing points provides less noise and reasonable gain which is showed in Figure 2 [6]. However to design the LNA, line calculation tool has been used and by exploiting this wavelength (λ=114.852 mm) the open shunt stub matching network for 50 Ω characteristics impedance has been designed in ADS which is showed in Figure 3.

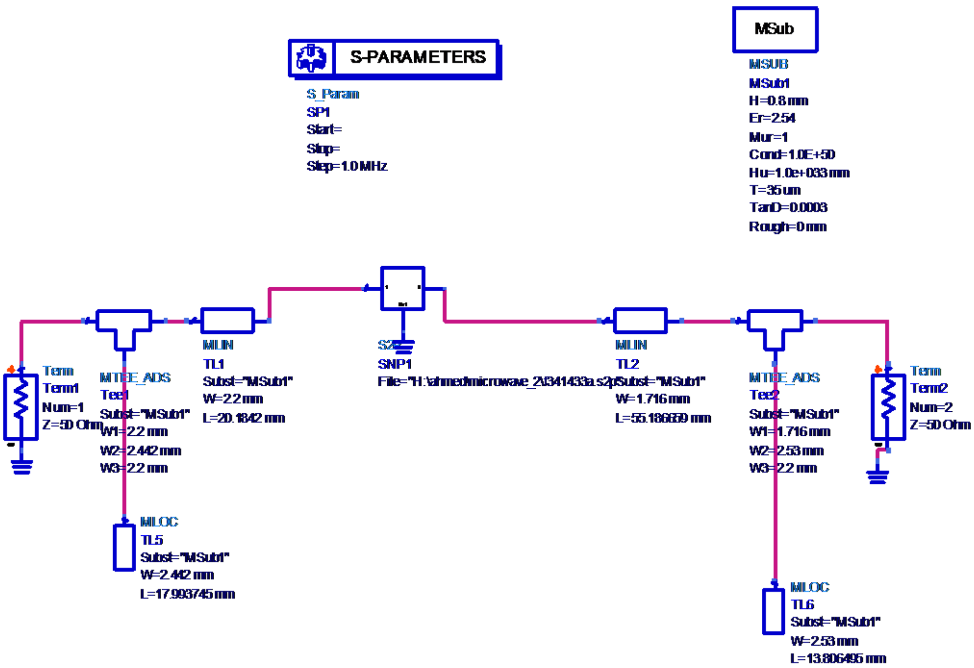


Figure 3. Stub matching network in ADS for 1.8 GHz Low Noise Amplifier

Moreover to give the designed amplifier more realistic view a real PHEMT transistor model (ATF-34143) has been integrated with the model. Moreover to set up the accurate biasing voltage and current the values of passive biasing resistances (R1= 1.45 KΩ, R2= 2.096 KΩ and R3= 86.95 Ω) are calculated by Kirshoff's Voltage Law and Kirshoff's Current Law. Furthermore the values of drain voltage (V_{DD} =+5 V) and source voltage (V_{ss} -5V) are also calculated [12]. Moreover frim the simulation the value of gate source voltage (V_{gs} =-0.66V) have been measured as well. These resistances and biasing voltages are integrated with the model of the transistor and set with the stub matching network to make the simulation more realistic which is showed in Figure 4.

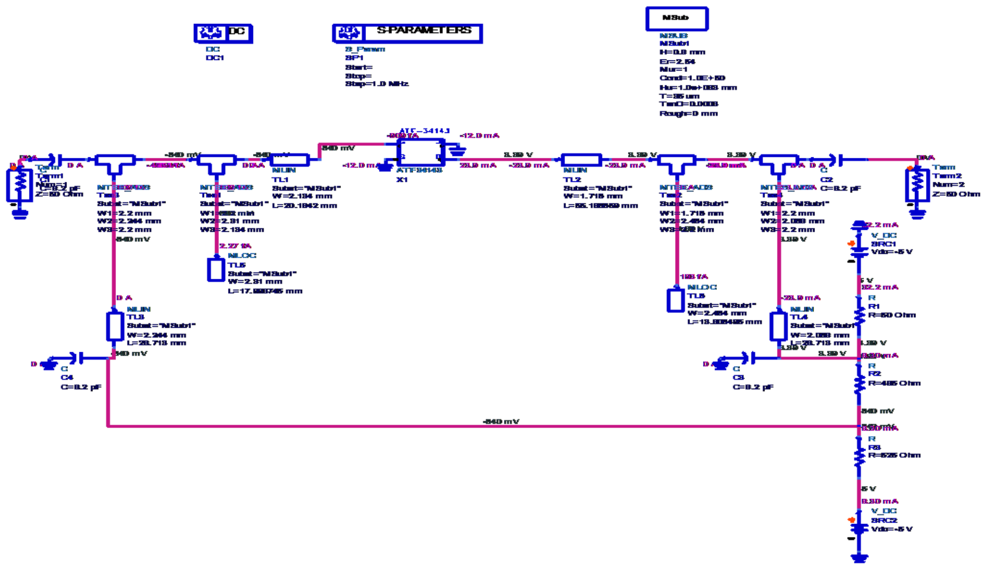


Figure 4. 1.8 GHz low noise amplifier with appropriate biasing and real components

Figure 4 shows the setup of the open stub matching network for result analysis. Here the real components such as the simulation model of ATF- 34143 along with biasing voltage, current and calculated biasing resistances are connected as well for result analysis. To evaluate the performance of the designed amplifier the gain flatness, reflection coefficients, harmonic balance, two tone testing and 1dB compression point will be analyzed in the result Segment (Section 3).

3. Results and Analysis

According to the measurement setup of the designed 1.8 GHz low noise amplifier which is showed in Figure 4 of segment 2, the result analysis and performance evaluation has been analyzed in this section. As the gain flatness and noise figure is the main concern in case of LNA, so Figure 5 shows the result of gain flatness and noise figure of the designed LNA for 1.8 GHz wireless receiver.

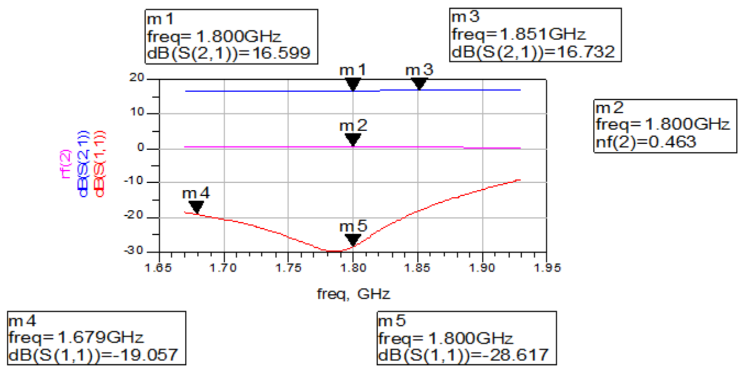
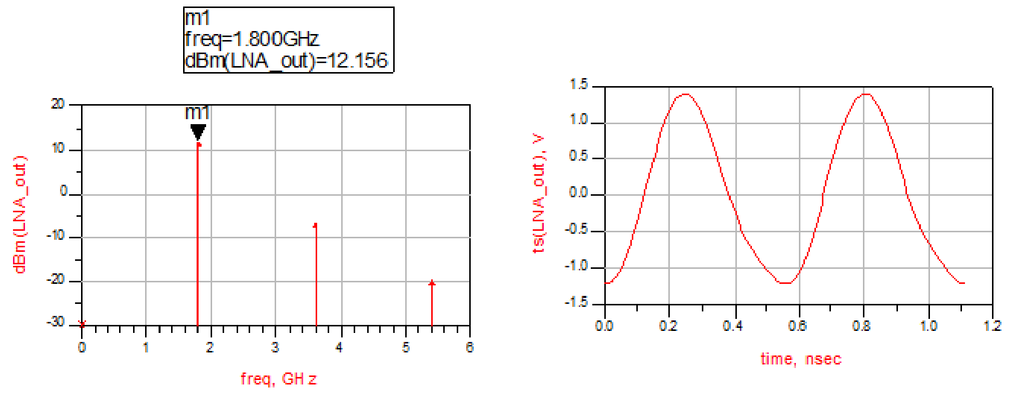
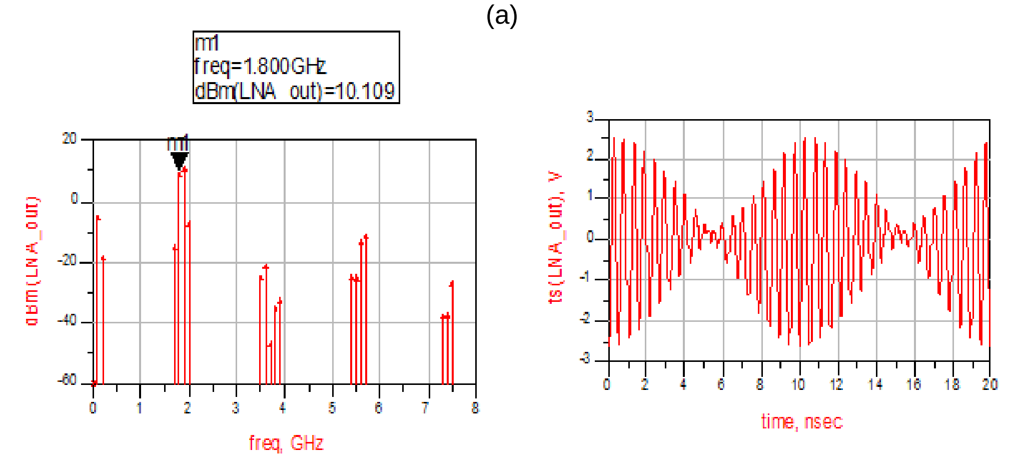


Figure 5. Gain flatness and noise figure of the designed LNA for 1.8 GHz

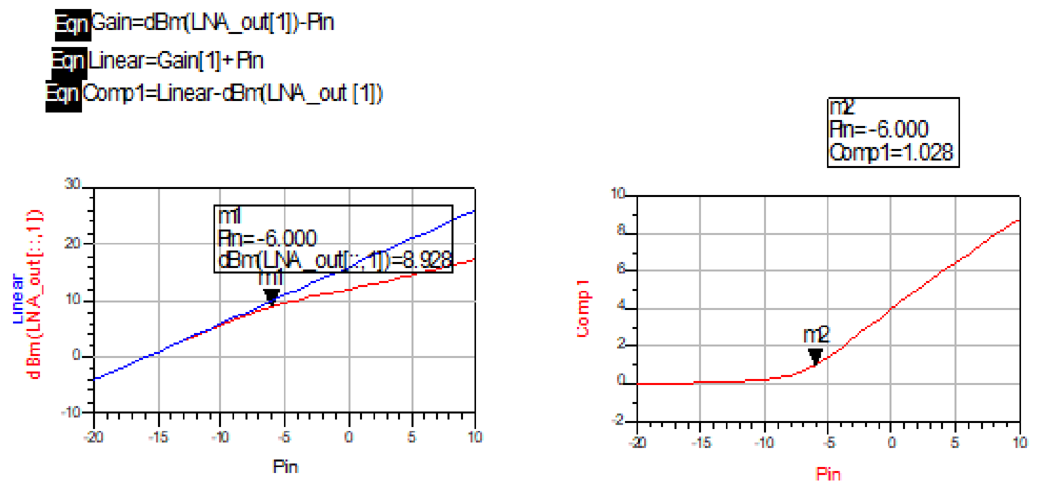
Figure 5 shows that the gain remains flat at around 16 dB from almost 1.68 GHz to 1.94GHz. However the noise figure is 0.463 dB at same frequency band. In addition the return loss is below -20 dB at that frequency range however it is around -29 dB at 1.8 GHz frequency. So afterwards the harmonic balance, two tone testing and 1dB compression points are showed in Figure 6 (a, b and c).



(a)



(b)



(c)

Figure 6. (a) Response of harmonic balance measurements (b) Response of 2 tone test measurements (c) Result for 1 dB compression of the designed 1.8 GHz LNA

Figure 6 (a) shows that the powers of different order harmonics are suppressed around -10 dBm. However the power of main tone is around 12 dBm. Moreover in figure 6 (b) two tonetesting has been successfully done by 1.8 GHz and 1.9 GHz signal which shows that there is not much non linearity of the designed low noise amplifier. In addition figure 6 (c) shows that the 1 dB compression starts for around the input signal power is -6 dBm input and the output power remains constant at 8.928 dB. So the 1.8 GHz low noise amplifier provides satisfactory results and performance at each and every perspective of performance analysis. Moreover the designed amplifier provides satisfactory gain of around 16 dB and noise figure of around 0.5 dB as well to implement this system with wireless communication receiver to enhance the performance

4. Conclusion

The main concern of this paper is to design and result analysis of 1.8 GHz low noise amplifier for wireless receiver application. Hence the open shunt stub matching network has been designed based on stability circle, gain and noise circle as well. Afterwards a PHEMT transistor (ATF-34143) has been integrated with proper biasing voltage and current along with biasing resistances as well. The LNA provides satisfactory gain of 16 dB along with proper gain flatness. Nevertheless the noise figure is around 0.5 dB as well hence noise is the main concern in case of receiving end of any wireless communication system. Moreover the harmonic balance, two tone testing and 1 dB compression point provides acceptable results as well for wireless receiver application for 1.8 GHz frequency.

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