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Merits Of Balanced Amplifier

A balanced amplifier has been widely used in low noise and power amplifications in the microwave frequency spectrum because of the low noise, good input and output return losses, and better stability comparing to a single ended amplifier. **Table 1** summarizes the merits and disadvantages of the balanced amplifier comparing to the single-ended amplifier.

Tab. 1 The merits and disadvantages of a balanced amplifier comparing to a single-ended amplifier.

Item	**Singled-Ended Amplifier**	**Balanced Amplifier**
Input/Output Return Losses	Fair or poor	Excellent
Optimum Noise Figure Source Matching With Better Input Return Loss	Difficult	Very easy and excellent
Performance Stability In Temperature	Poor and depend on the selected components	Excellent
Unconditional Stable	Difficult	Easier
Performance Stability With Component Variation	Poor	Excellent
Ip3	--	6 dB better
P1db	--	3 dB better
Total Power Consumption	3 dB less	--
Reliability	--	2 time higher
Cost	2 time less	
Integration	Excellent	Difficult
Size	Small	Larger

1. Introduction Of A Balanced Amplifier

Figure 1 shows a balanced amplifier structure. Two similar (identical is preferred) singled-ended amplifiers are in parallel connected in each branch as shown 102a and 102b. The input signal 105 is fed through a 90º hybrid power divider 100 and equally divided and injected into the inputs of the two singled-end amplifiers. The amplified signal at the output of each amplifier then is combined by a 90º hybrid power combiner 103 as the output signal 106.

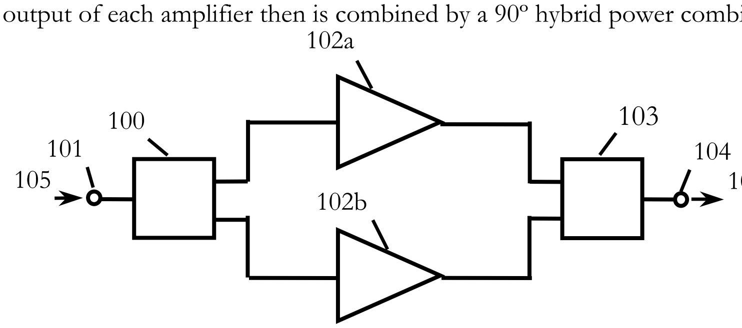

FIG. 1 A balanced amplifier structure

2. Merits Of A Balanced Amplifier

As an example, a single-ended amplifier and balanced amplifier at 3.2 ~3.8 GHz band using NE334S01 GaAs FET transistor are demonstrated. The single-ended amplifier is used in each branch of the balanced amplifier.

a) Input Return Loss And Noise figure

Figure 2 shows the schematic of the singled-ended low noise amplifier. The PCB material is RO4003, h=20 Mils, ½ oz copper.

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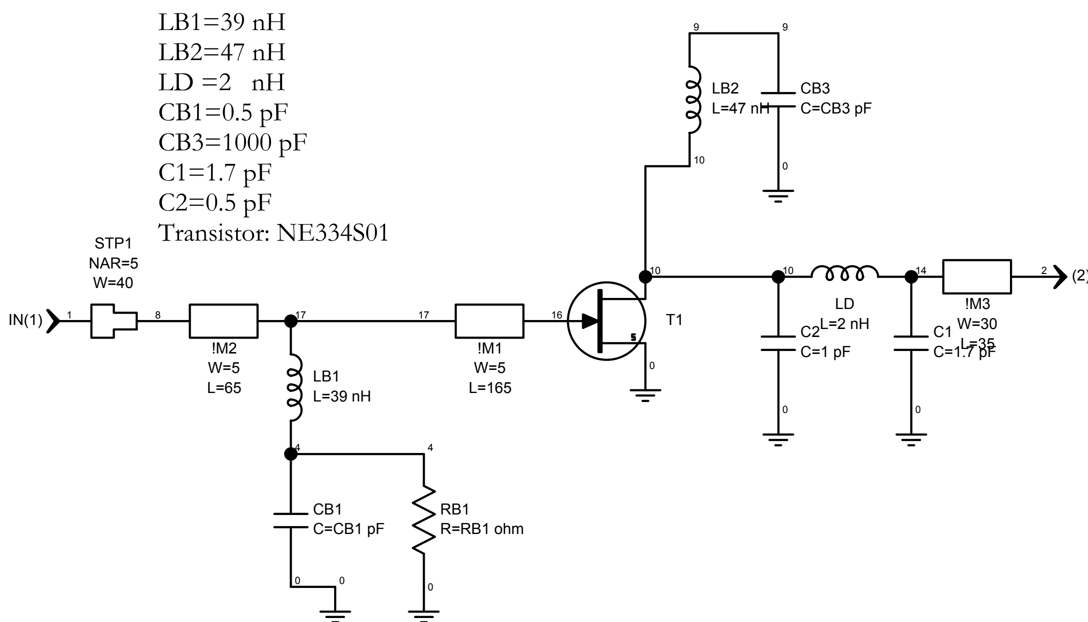

FIG. 2 The schematic of the singled-ended low noise amplifier using NE334S01 FET.

Figure 3 shows the optimum noise impedance of the NE334S01. As is shown, the optimum noise source impedance at 3.4 GHz is located at spot A that is far away from the center of the Smith chart, 50-Ohm matching point. In other words, the input return loss will be very poor if the lowest noise figure is desired. Almost 0.5 dB noise figure increase if the amplifier is designed to have good input return loss, as it can be observed from the equal noise circle NCI in Figure 3. Each NCI circle represents 0.25 dB noise figure increment. NE334S01 has the optimum noise figure of 0.35 dB at frequency 3.4 GHz.

Figure 4 shows the simulated performance of the single-ended amplifier. The input return loss is below 2 dB in order to have 0.35 dB noise figure.

Figure 5 shows balanced amplifier performance consisting two single-ended amplifiers. The total noise figure is 0.42 dB with the input return loss greater than 17 dB. The output return loss is greatly improved as well.

b) Stability k

The balanced amplifier has better stability since each branch amplifier is terminated with the fix load, close to either 50 Ohm or 75 ohm. The actual loads at the input and output of the amplifier will not change the loards to the branch amplifiers too much. Instaed, the single-ended amplifier is loaded with actual loads. The amplifier may be unstable in some frequency range, especially if a load is a bandpass filter. A bandpass filter behaves as 50-Ohm load only in the passband. All the stop bands are either close to open circuit or short circuit to the amplifier. The open or short circuit can cause single ended amplifier unstable potentially.

Figure 6 demonstrate the stability factor k of the balanced amplifier. The amplifier is unconditional stable since k is great than 1 across full frequency spectrum from 50 MHz to 10 GHz. Instead, **Figure 7** shows the stability factor k of the single-ended amplifier. The amplifier is conditional stable since k is less than 1 between 1 GHz and 4.3 GHz. In other words, the single-ended amplifier may oscillate with the frequency in the range of 1 GHz to 4.3 GHz if certain load is applied.

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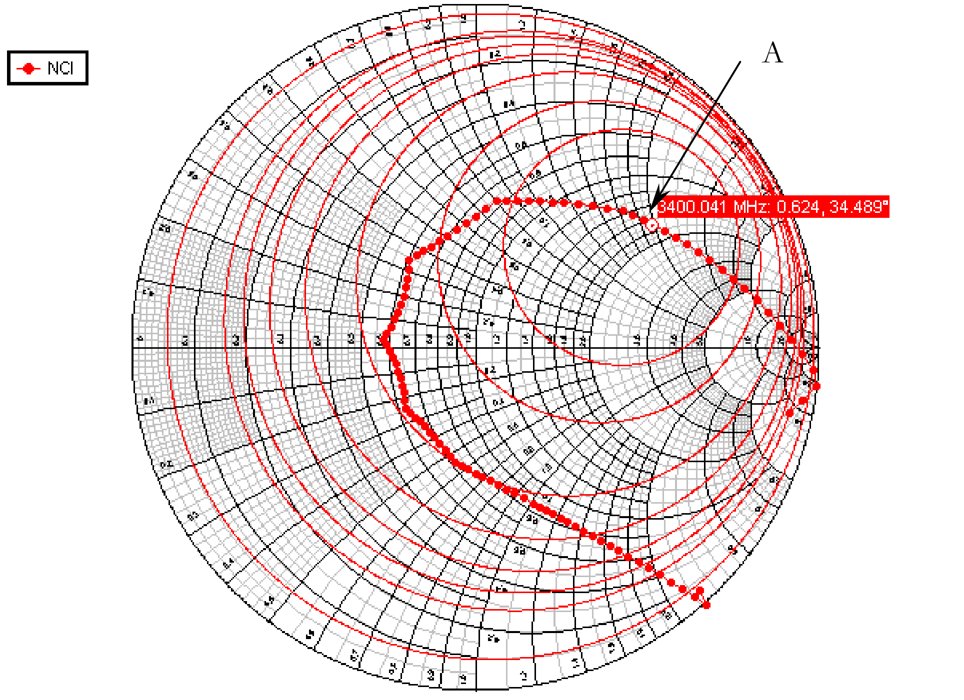

FIG. 3 The optimum noise impedance of the NE334S01 FET.

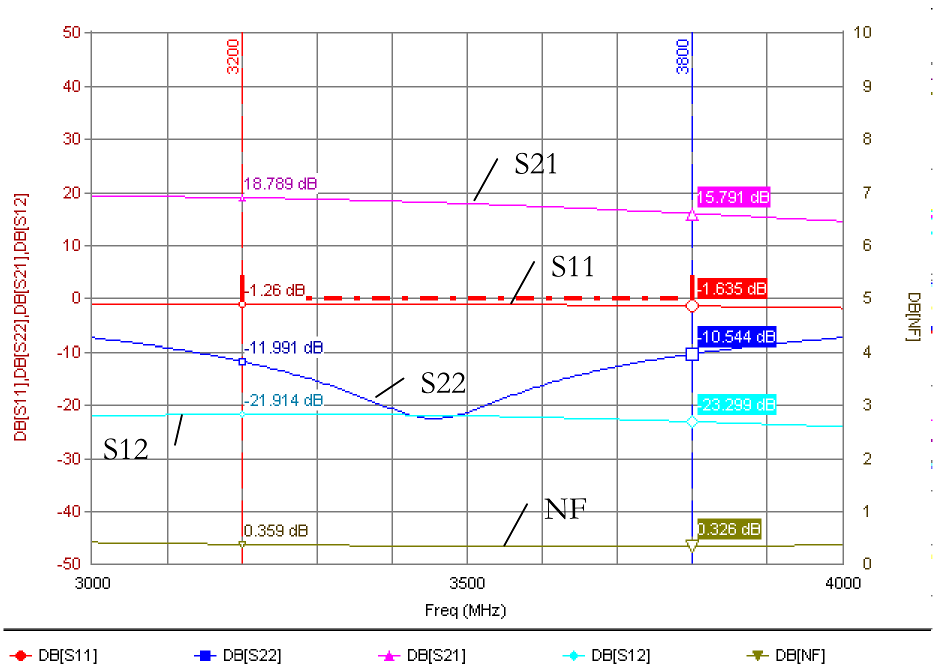

FIG. 4 The simulated performance of the single-ended amplifier using NE334S01 FET.

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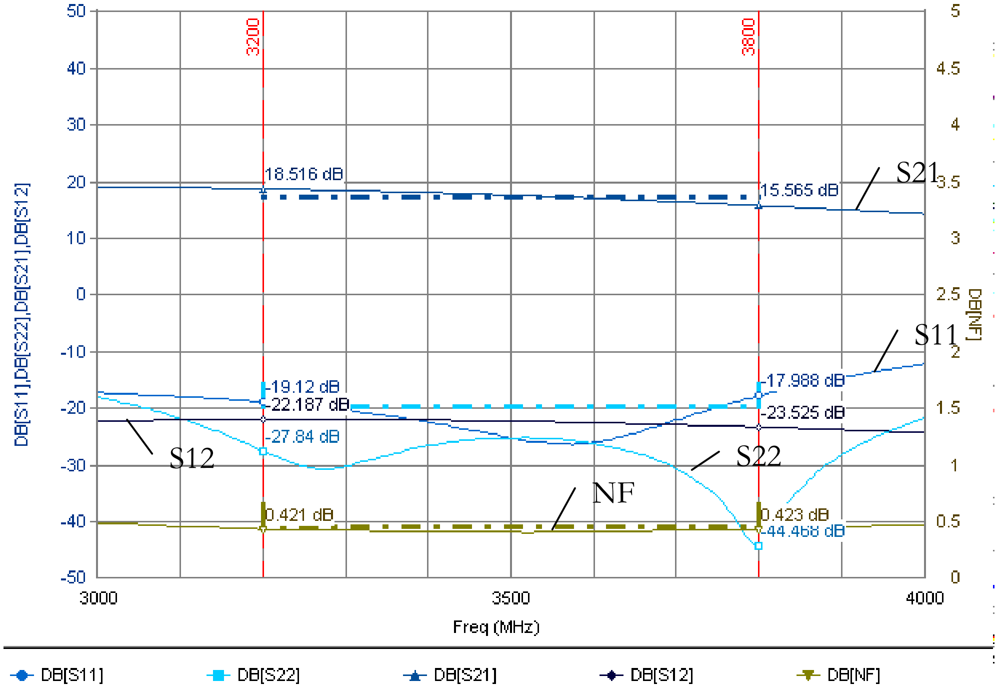

FIG. 5 The balanced amplifier performance consisting two single-ended amplifiers using NE33S01 FETs.

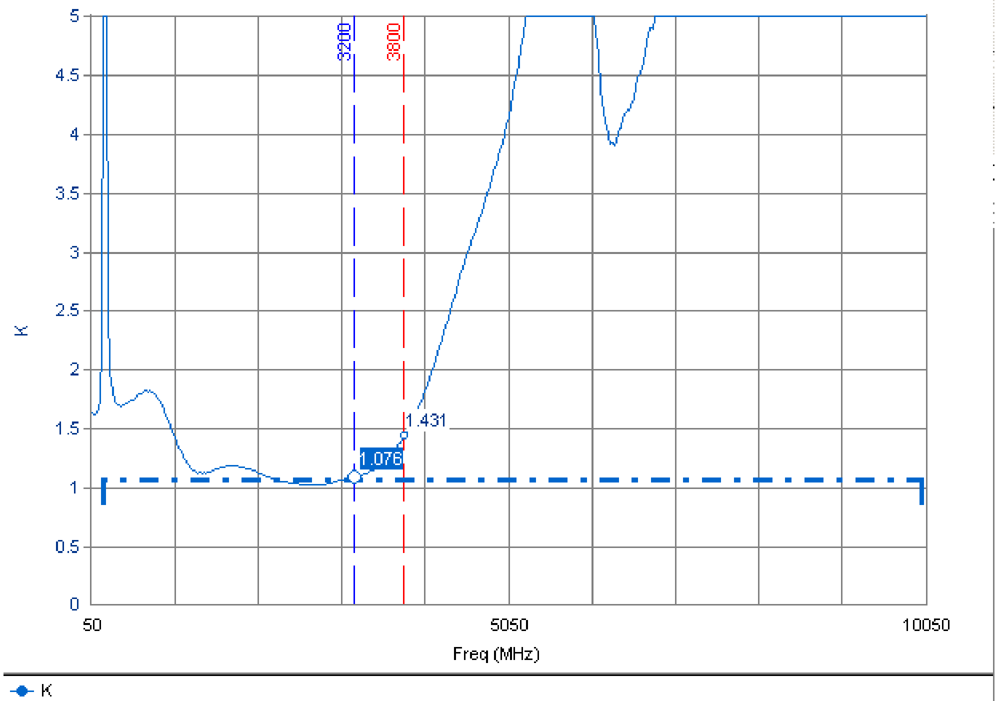

FIG. 6 The stability k of the balanced amplifier using NE334S01 FET.

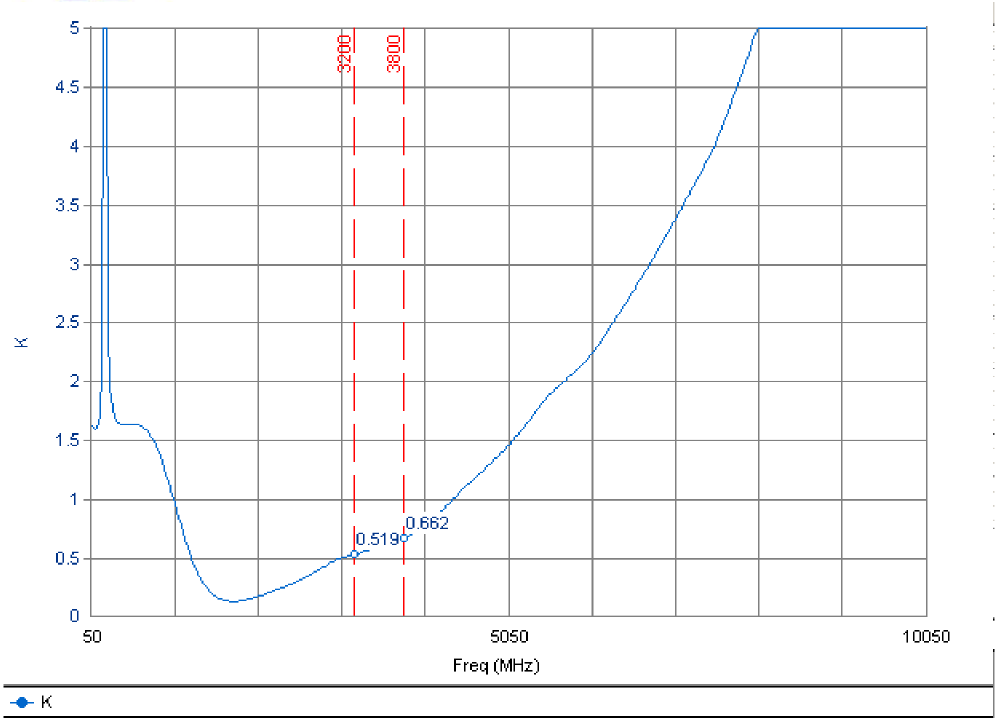

FIG. 7 The stability factor k of the single-ended amplifier using NE334S01 FET.

c) Performance Variation With Components And Temperature

All the components including FETs and PCB are subject to vary randomly. Besides, every component performance changes with the change of the temperature.

Figure 8 shows the Monte Carlo analysis of the balanced amplifier. The gain S21, return losses S11 and S22, isolation S12, and noise figure NF do not change too much when the component values change in the commercial practice and temperature. The reason for the little changed performance is due to each branch amplifier changes the performance at the same time. The varied performance is canceled out by the balanced arrangement due to the 90º divider and combiner. **Figure 9** shows the Monte Carlo analysis of single-ended amplifier under the same component variation conditions. The output return loss, especially, change significantly. The pass band shifts significantly as well.

d) Other Comparisons

Besides the merits over the single-ended amplifier as mentioned above, balanced amplifier offers high reliability and redundancy function. One branch amplifier failure offers reduced performance operation of the amplifier. Both gain and noise figure will only degrade 3 dB instead of complete out of service.

The balanced amplifier does have the following disadvantages: a) difficult integration because of double the component counts and power divider and combiners; b) more expensive because of more components. However, due to higher performance and more subject to the environmental and production conditions, the balanced amplifier is best for high-end amplification such as in the infrastructure applications.

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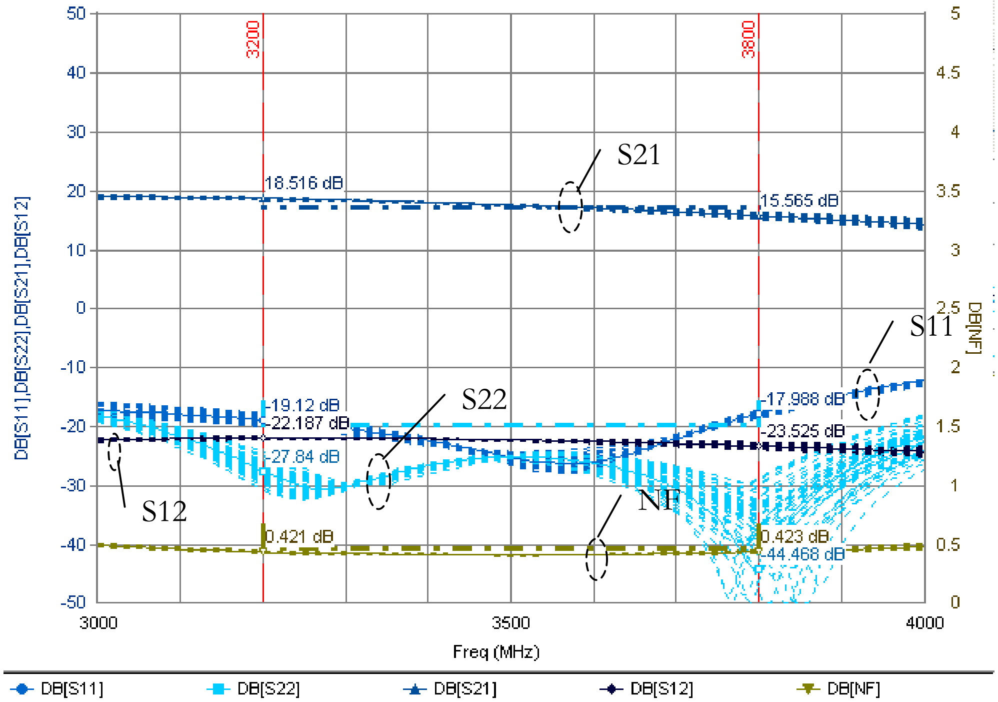

FIG. 8 The Monte Carlo analysis of the balanced amplifier using NE334S01 FET.

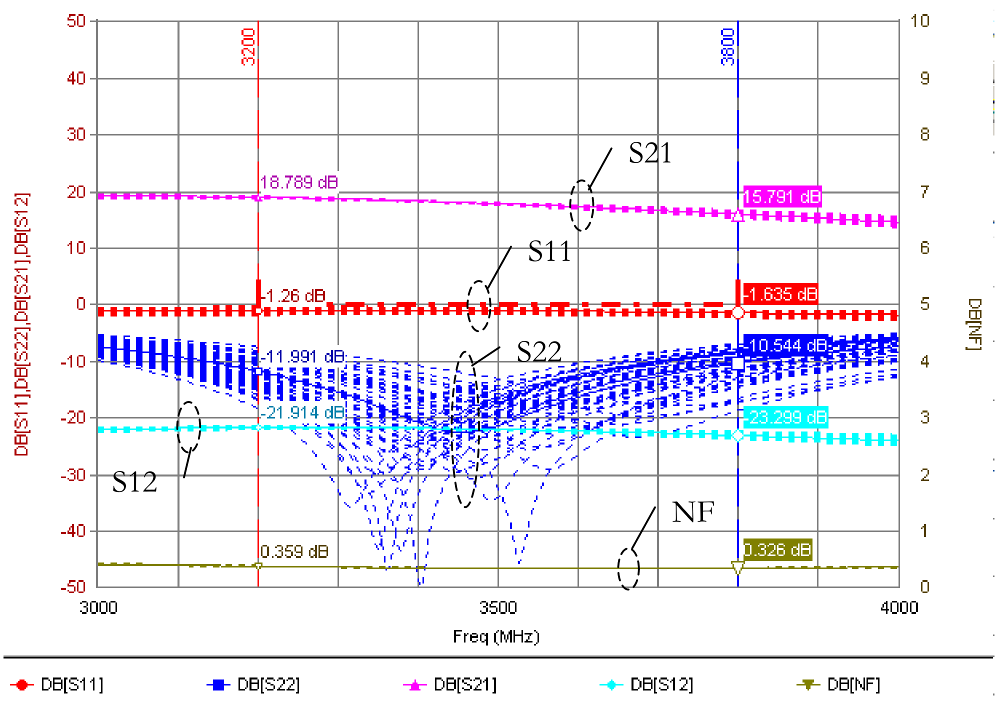

FIG. 9 The Monte Carlo analysis of the single-ended amplifier using NE334S01 FET.