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STATISTICAL ANALYSIS OF MICROWAVE BALANCED AMPLIFIERS

G. V. Petrov
Department of Electronics
Moscow Engineering Physics Institute
Kashirskoe shosse 31, 115409, Moscow, USSR

Abstract

Statistical analysis of microwave balanced amplifiers using Monte Carlo method is presented. Yield of balanced amplifiers using tuning of matching networks is defined.

Introduction

Microwave balanced amplifiers are widely used in various receivers and measurement systems, because they have some advantages in comparison with single - ended amplifiers [1, 2]. As a rule a balanced amplifier shown in Fig. 1 consists of two single-ended amplifiers connected by two 3 dB directional couplers.

Different matching networks can be used in single-ended amplifiers. In our case simple matching networks are used (Fig. 1). They have the following sizes: w_i, l_i ($i=1 \div 4$).

The main parameters of microwave balanced amplifiers are gain G, noise figure F_n, input VSWR ρ_1 and output VSWR ρ_2.

Computers are widely used for calculation of the output characteristics of amplifiers. However calculation gives possibility to define the characteristics of an ideal balanced amplifier only which is very difficult to realize. The main reason of this situation is the variation of parameters of active and passive elements of an amplifier. This variation decreases the yield of amplifiers.

In this paper statistical analysis for the preliminary definition of amplifier output characteristics using Monte Carlo method is proposed. The increase of the yield of balanced amplifiers with tuning of the amplifier matching networks is also considered.

Variation of output characteristics

The scattering matrix (S - parameters) and noise parameters (τ - parameters) were used for the calculation of G, F_n, ρ_1 and ρ_2 [3]. S - parameters and τ - parameters of a bipolar transistor are shown in Tables 1 and 2 (U_{CE} = 7 V, I_C = 5 mA). Using these parameters a balanced amplifier was calculated and G, F_n, ρ_1 and ρ_2 were defined. Received geometrical sizes of microstrip lines of the matching networks are shown in Table 3. Geometrical sizes, S and τ - parameters are initial parameters for statistical analysis of a balanced amplifier. The generator of random numbers is used for modeling the distribution of the initial parameters. It is important to notice that statistical analysis is carried out using large quantity of random situations. In our case this quantity was changed from 500 to 1000.

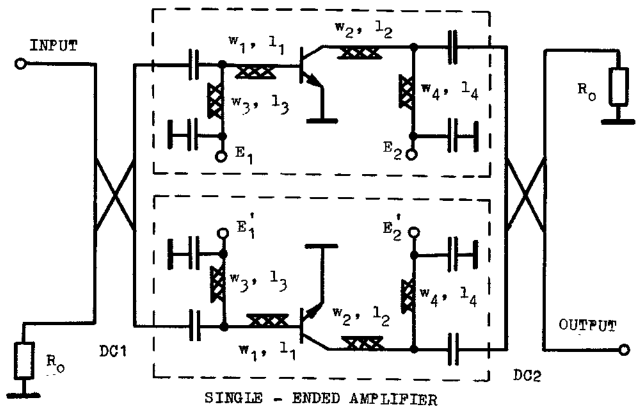

Fig. 1. Schematic diagram of a microwave balanced amplifier.

Statistical analysis gives the possibility to prognosticate the balanced amplifier output characteristics for the case of variation of:

1. geometrical sizes of microstrip lines;
2. S - parameters;
3. τ - parameters;
4. geometrical sizes of microstrip lines, S - and τ - parameters.

The values of gain G, input VSWR ρ_1 and output VSWR ρ_2 as functions of frequency are plotted in Fig. 2. In Fig. 2a it is shown the influence of variation of geometrical sizes of microstrip lines, in Fig. 2b - the influence of variation of S - parameters, in Fig. 2c - the joint influence of variations of geometrical sizes and S - parameters. Solid curves denote the balanced amplifier parameters calculated using values of Tables 1 and 2. Other curves denote the variation of G, ρ_1 and ρ_2.

Noise figure F_n as a function of frequency is plotted in Fig. 3. The influence of variation of τ - parameters is shown in Fig. 3a, that of S - parameters in Fig. 3b, and the joint influence of variation of S - and τ - parameters - in Fig. 3c. Solid curves denote the balanced amplifier noise figures calculated using values of Tables 1 and 2. Dashed curves denote the variation of F_n.

It is seen from Fig. 2 and 3 that amplifier parameters depend more strongly on the variation of S - parameters.

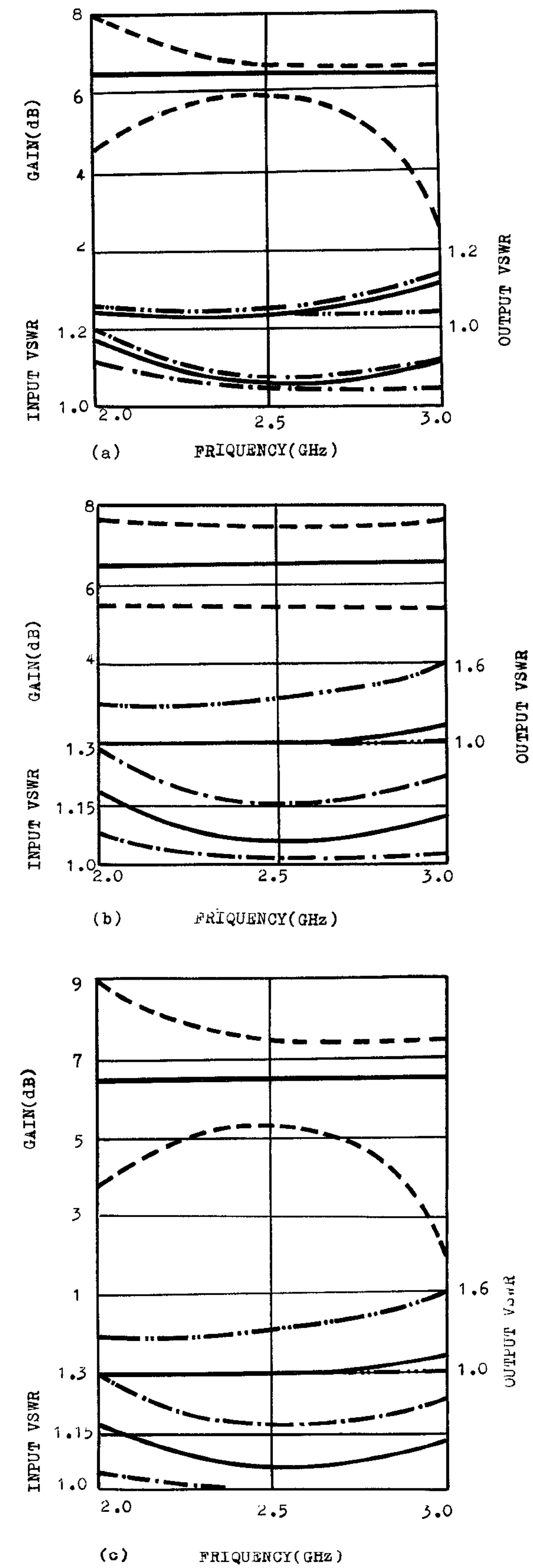

Fig. 2. Frequency responses of balanced amplifier gain, VSWR ρ_1 and ρ_2.

Table 1

S - parameters of bipolar transistor

F(GHz)	$\|S_{11}\|$	φ_{11}, rad	$\|S_{12}\|$	φ_{12}, rad	$\|S_{21}\|$	φ_{21}, rad	$\|S_{22}\|$	φ_{22}, rad
2.0	0.321	2.25	0.099	0.138	2.52	0.276	0.463	-1.69
2.5	0.241	2.01	0.099	-0.24	1.88	-0.29	0.534	-1.88
3.0	0.157	1.16	0.101	-0.47	1.63	-0.57	0.591	-2.08

Table 2

τ - parameters of bipolar transistor

F(GHz)	τ_{11}	τ_{22}	$\|\tau_{12}\|$	$\varphi_{\tau 12}$, rad
2.0	0.199	6.06	0.901	4.22
2.5	0.310	4.64	1.12	4.56
3.0	0.8	5.44	1.92	0.31

Table 3

Geometrical sizes of microstrip lines in centimetres

$\frac{w_1}{l_1}$	$\frac{w_2}{l_2}$	$\frac{w_3}{l_3}$	$\frac{w_4}{l_4}$
$\frac{0.039}{1.777}$	$\frac{0.0201}{0.3551}$	$\frac{0.4381}{0.9851}$	$\frac{0.1157}{1.537}$

Yield of balanced amplifiers

As a rule the balanced amplifiers output characteristics differ from the desired ones, because of the variation of parameters of active and passive elements of an amplifier. Therefore it is very important to define the yield of amplifiers. If it is small we should use the tuning of the amplifier. For the definition of yield of an amplifier the following balanced amplifier parameters were chosen: declination from average value of gain $\pm$ 0.5 dB, $\rho_1 \leq 2$, $\rho_2 \leq 2$. The tuning of an amplifier was produced by changing the values l_3 and l_4: $l_3 = 0.7 \div 1.2$ cm, $l_4 = 1.2 \div 1.8$ cm.

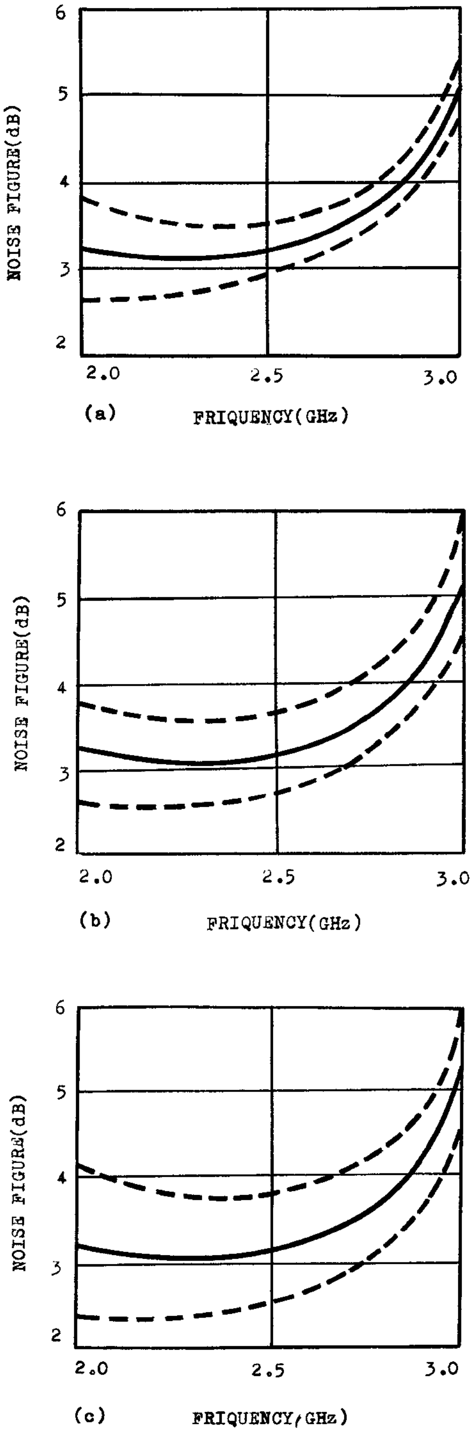

Fig. 3. Frequency responses of balanced amplifier noise figures.

The yield of balanced amplifiers was defined for the case of variation of

1. geometrical sizes of microstrip lines of matching networks;
2. S - parameters;
3. geometrical sizes and S - parameters;
4. geometrical sizes and S - parameters using tuning of amplifiers.

Results of calculation are shown in Table 4. It is seen from Table 4 that the tuning allows to increase the yield of amplifiers more than 3.5 times.

Table 4

The yield of balanced amplifiers

$w \pm \Delta w$ $l \pm \Delta l$	$s \pm \Delta s$	$w \pm \Delta w$ $l \pm \Delta l$ $s \pm \Delta s$	$l \pm \Delta l$ $s \pm \Delta s$ (tuning)
25.6	39.8	14.2	47

Conclusion

Statistical analysis gives the possibility to calculate the variation of balanced amplifier output characteristics and to define beforehand the yield of amplifiers by tuning the amplifier matching networks.

References

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