CAD AND PERFORMANCE OF THE ULTRAWIDE - BAND GaAs FET AMPLIFIERS

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Abstract-In this paper the effect of feedback elements on noise figure is discussed.The numerical analysis shows clearly the contribution of each sensitive element to noise figure and to other performance. A circuit analysis method concerned with tree- structured circuits is proposed. This method allows it possible to analyse such microwave two -port circuit which contains feedback networks (serial,parallel) and T branches more quickly and efficiently.As an example,three experimental amplifier modules have been developed that cover the frequency band 1.4-11.7 GHz,2-10 GHz and 1.5-6.25 GHz.

I. INTRODUCTION

In designing an ultrawide-band GaAs FET amplifier,the following performance must be considered concurrently , gain ,gain flatness,input VSWR,output VSWR and noise figure.Referred to (1),feedback technique can broaden bandwidth and decrease VSWR, while noise performance going bad because of the introduction of the feedback resistor. So it is quite important to consider the effects of feedback network on noise figure.

II. EQUIVALENT NOISE PARAMETERS OF TWO CORRELATED NOISY TWO-PORT NETWORKS

The noise figure F by four parameters R_{nv}, R_{ni}, $Y_{cor}=G_{cor}+jB_{cor}$ can be expressed as follows:

$$F=1+\frac{1}{R_{ni}G_s}+\frac{R_{nv}}{G_s}\left[|Y_s|^2+2\mathrm{Re}(Y_sY_{cor}^*)\right]$$

Where Y_s is the source admittance, Y_{cor} is the correlation admittance , $R_{nv}=v_n^2/4kt\Delta f$ and $R_{ni}=4kt\Delta f/i_n^2$ .The equivalent noise parameters of two correlated noisy two -port networks are as follows:

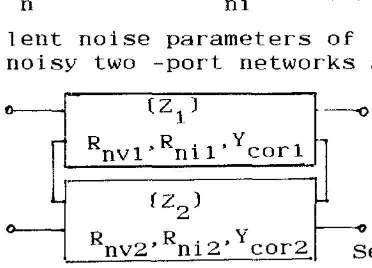

Fig.1. Series connection

$$R_{nv}=R_{nv1}[1+2\mathrm{Re}(A_1Y_{cor1})]+|A_1|^2/R_{ni1}$$
$$+R_{nv2}[1+2\mathrm{Re}(A_2Y_{cor2})]+|A_2|^2/R_{ni2}$$

$$1/R_{ni}=|B_1|^2/R_{ni1}+|B_2|^2/R_{ni2}$$

$$Y_{cor}R_{nv}=B_1Y_{cor1}R_{nv1}+B_2Y_{cor2}R_{nv2}$$
$$+A_1^*B_1/R_{ni1}+A_2^*B_2/R_{ni2}$$

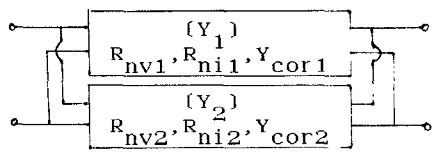

Fig.2. Parallel connection

$$R_{nv}=|D_1|^2R_{nv1}+|D_2|^2R_{nv2}$$

$$\frac{1}{R_{ni}}=\frac{1}{R_{ni1}}+\frac{1}{R_{ni2}}+R_{nv1}[|C_1|^2+2\mathrm{Re}(C_1^*Y_{cor1})]$$
$$+R_{nv2}[|C_2|^2+2\mathrm{Re}(C_2^*Y_{cor2})]$$

$$Y_{cor}R_{nv}=(C_1+Y_{cor1})D_1^*R_{nv1}$$
$$+(C_2+Y_{cor2})D_2^*R_{nv2}$$

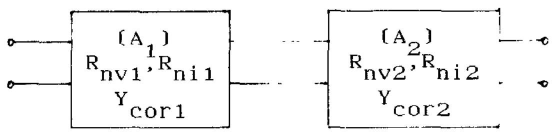

Fig.3. Cascade connection

$$R_{nv}=R_{nv1}+[|A_{111}|^2+2\mathrm{Re}(A_{111}A_{121}^*Y_{cor2}^*)]R_{nv2}$$
$$+|A_{121}|^2/R_{ni2}$$

$$1/R_{ni}=1/R_{ni1}+|A_{221}|^2/R_{ni2}+[|A_{211}|^2$$
$$+2\mathrm{Re}(A_{211}A_{221}^*Y_{cor2}^*)]R_{nv2}$$

$$Y_{cor}R_{nv}=Y_{cor1}R_{nv1}+[A_{111}^*A_{211}+A_{111}^*A_{221}Y_{cor2}$$
$$+A_{121}^*A_{211}Y_{cor2}^*]R_{nv2}+A_{121}^*A_{221}/R_{ni2}$$

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where $A_1=(Z_{112}Z_{211}-Z_{111}Z_{212})/(Z_{211}+Z_{212})$

$A_2=-A_1$

$B_1=Z_{211}/(Z_{211}+Z_{212})$

$B_2=Z_{212}/(Z_{212}+Z_{211})$

$C_1=(Y_{112}Y_{211}-Y_{111}Y_{212})/(Y_{211}+Y_{212})$

$C_2=-C_1$

$D_1=Y_{211}/(Y_{211}+Y_{212})$

$D_2=Y_{212}/(Y_{211}+Y_{212})$

III. TREE ANALYSIS METHOD

In this paper four variables are assumed to describe the circuit completely, they are element type variable (Type), correlation variable (Topol), processing sequence variable (Pointer) and tree (or subtree) variable (Tree).

The meanings are described in following:

Type(i): type of a certain element. See Table 1.

Tree(i): i is tree (subtree) number, it's value is the first element of the tree.

Pointer(i): i is the element number, Pointer (i) is the next element of the tree.
- =0 , this subtree ends.
- =-1, this tree ends.
- =-2, T branch subtree ends.

Topol(i): correlation of two elements
- =0, the first element
- =1, fore-cascading
- =2, cascading
- =3, parallel
- =4, serial
- =5, that single-port network connects with two-port network in T branch
- =6, that single-port network connects with single-port network in T branch.

As an example, the single stage feedback amplifier circuit is shown in Fig.4. The relevant topology tree according to this method can be obtained in Fig.5.

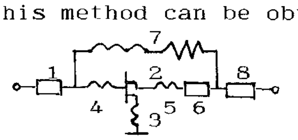

Fig.4.

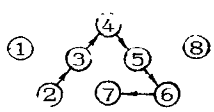

Fig.5.

The four variables are as follows:

Element No.	1	2	3	4	5	6	7	8
Type	1	4	8	7	7	1	9	1
Topol	0	0	4	1	2	2	3	0
Pointer	-1	3	4	5	6	7	-1	-1

Tree No.	1	2	3
Tree	1	2	8

IV. NUMERICAL ANALYSIS

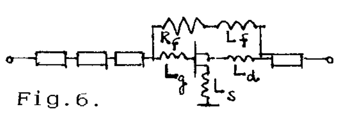

Fig.6.

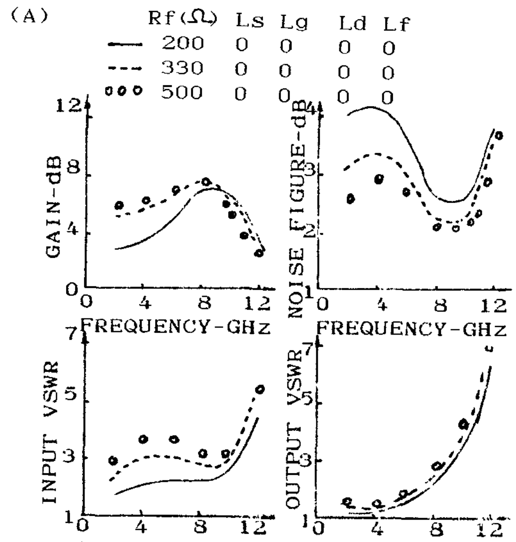

Fig.7

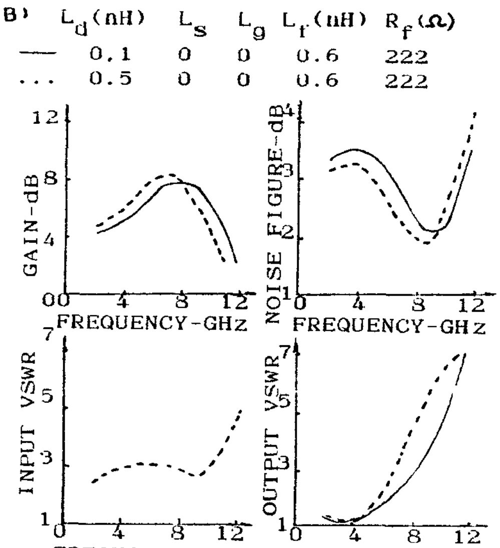

Fig.8

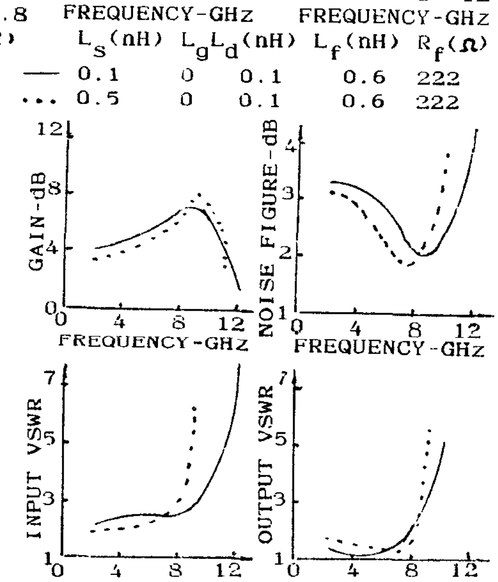

Fig.9

(D)

	L_g(nh)	L_s	L_d(nh)	L_f(nh)	R_f(Ω)
——	0.1	0	0.1	0.6	222
- - -	0.5	0	0.1	0.6	222

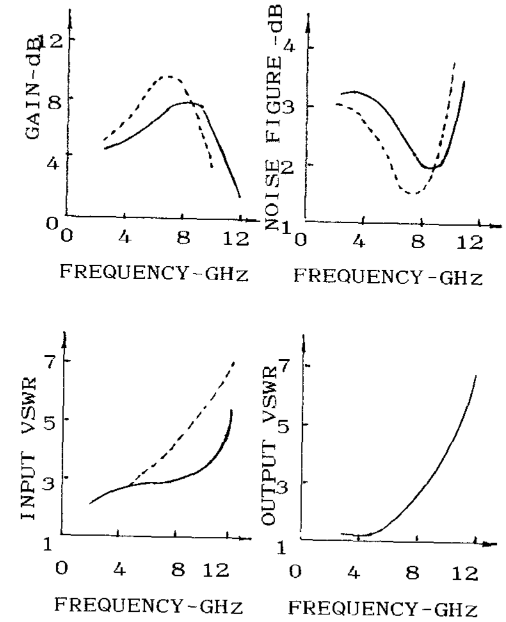

Fig.10. Power gain,noise figure,input VSWR and output VSWR versus FREQUENCY

(E)

	L_f(nh)	L_s	L_g	L_d	R_f(Ω)
- - -	0	0	0	0	222
∘∘∘	0.6	0	0	0	222
. . .	1.3	0	0	0	222

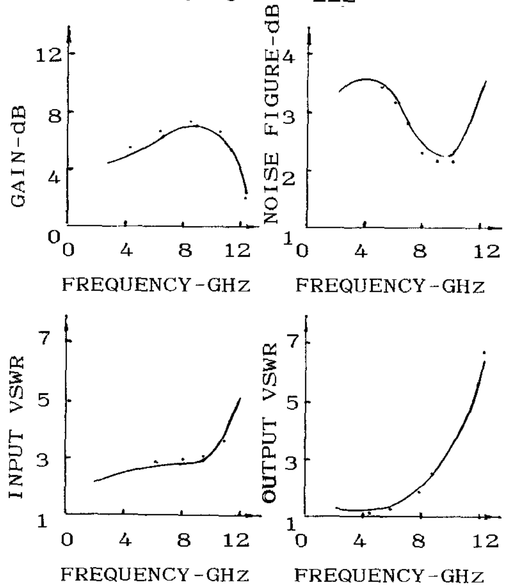

Fig.11. Power gain,noise,figure,input VSWR and output VSWR versus frequency

V. MICROWAVE PERFORMANCE

Experimental results

By the program based on optimization and this method, three ultrawide-band amplifiers have been developed. The experimental results are shown in Fig.12.,Fig.13. and Fig.14 .

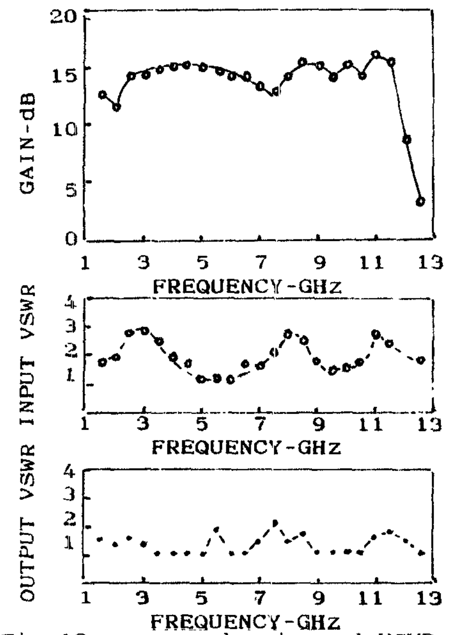

Fig.12 measured gain and VSWR versus frequency

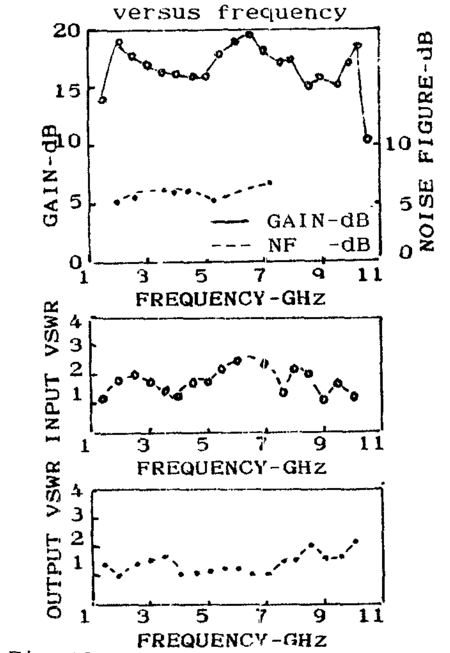

Fig.13 Measured gain,VSWR and noise figure versus frequency

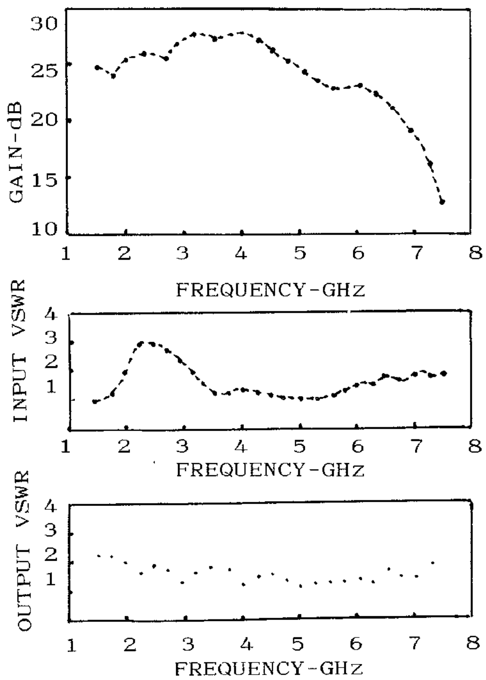

Fig.14. Measured gain and VSWR versus frequency

The HP-8410 C network analyzer and the HP 8350 B sweep generater have been used for measurements of gain, input VSWR, output VSWR of the feedback GaAs FET amplifiers.

VI. CONCLUSION

In manyapplications such as in microwave ultrawide-band communication or sweep-frequency measurement or electronic surveillance systems that require ultrawide-band amplifiers.

The noise performance of ultrawide-band GaAs FET amplifier is discussed in detail theoretically and experimentally. A set of curves including the effects of sensitive elements such as lead inductances on noise figure is given, therefore it is possible to design the ultrawide-band amplifiers more precisely and efficiently.

VII. REFERENCES

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(3) K.B.Niclas, W.T.Wilser. R.B.Gold and W.R. Hitchens, "The Matched Feed-back Amplifier: Ultrawide-Band Microwave Amplification with GaAs MESFET's," IEEE. Vol. MTT-28, Apr. 1980.

Table 1
[A] and noise parameters of several basic unit

Type	Circuit Unit	[A] Matrix		Noise Parameters
1	R, Z Ø	$ch\varnothing$	$Rch\varnothing+Zsh\varnothing$	$R_n=R.\|A_{11}\|^2$
		$\frac{sh\varnothing}{Z}$	$ch\varnothing+\frac{R}{Z}sh\varnothing$	$G_n=R.\|A_{21}\|^2$ $Y_{cor}=A_{21}/A_{11}$
2	R, Z Ø	1	0	$R_n=0$
		$\frac{1}{R+Zth\varnothing}$	1	$G_n=Re(A_{21})$ $Y_{cor}=0$
3	R, Z Ø	1	0	$R_n=0$
		$\frac{1}{R+Zcth\varnothing}$	1	$G_n=Re(A_{21})$ $Y_{cor}=0$
4	[S]	*		
5	Z Ø, R	1	0	$R_n=0$
		$\frac{Z+Rth\varnothing}{Z(R+Zth\varnothing)}$	1	$G_n=Re(A_{21})$ $Y_{cor}=0$
6	Z Ø, R	$Y_{in}=\frac{1}{Z}.\frac{Rth\varnothing+Z}{R+Zth\varnothing}$		
7	C, L, G	1	$\frac{1}{G+j(wC-\frac{1}{wL})}$	$R_n=Re(A_{12})$ $G_n=0$
		0	1	$Y_{cor}=0$
8	G, l, C	1	0	$R_n=0$
		$G+j(wC-\frac{1}{wL})$	1	$G_n=Re(A_{21}0$ $Y_{cor}=0$
9	L, C, G	1	$jwL+\frac{1}{G+jwc}$	$R_n=Re(A_{12})$ $G_n=0$
		0	1	$Y_{cor}=0$
10	L, G, C	1	0	$R_n=0$
		$\frac{1}{jwL+\frac{1}{G+jwC}}$	1	$G_n=Re(A_{21})$ $Y_{cor}=0$
11	L_2, L_1, R	1	jwL_1	$R_n=0$
		$\frac{1}{jwL_2+R}$	$\frac{jwL_1}{jwL_2+R}+1$	$G_n=Re(A_{21})$ $Y_{cor}=0$
12	L_1, L_2, R	$\frac{jwL_1}{jwL_2+R}+1$	jwL_1	$R_n=\|A_{12}\|^2Re(A_{21})$ $G_n=Re(A_{21})$
		$\frac{1}{jwL_2+R}$	1	$Y_{cor}=\|A_{12}\|Re(A_{21})$

$$* \; A_{11}=(1+S_{11}-S_{22}-\Delta S)\sqrt{Z_{01}/Z_{02}}/(2S_{21})$$
$$A_{12}=(1+S_{11}+S_{22}+\Delta S)\sqrt{Z_{01}Z_{02}}/(2S_{21})$$
$$A_{21}=(1-S_{11}-S_{22}+\Delta S)/(2S_{21}\sqrt{Z_{01}Z_{02}})$$
$$A_{22}=(1-S_{11}+S_{22}-\Delta S)\sqrt{Z_{02}/Z_{01}}/(2S_{21})$$
$$\Delta S=S_{11}S_{22}-S_{12}S_{21}$$