OPTIMUM LOADING FOR MICROWAVE LOW NOISE GAAS MESFET

G. Capponi, B. Di Maio, P. Livreri.

Department of Electrical Engineering
University of Palermo, ITALY

ABSTRACT

In this work it is proven that on the load reflection coefficient plane of a microwave low noise GaAs MESFET amplifier a locus of optimum values $\{\Gamma_{LO}\}$ does exist depending only on the transistor noise and scattering parameters and on the operating power gain to be obtained. The existence of this locus is proven in a rigorous way for lossless input equalizer amplifiers. The knowledge of $\{\Gamma_{LO}\}$ allows us to foresee the noise figure, the amplifier input reflection coefficient and any other performance useful in the low noise amplifier design.

Keywords: CAD, Low Noise Amplifiers

1. INTRODUCTION

Best tradeoff among noise figure, transducer gain and input VSWR is a qualified design goal for low - noise amplifiers since the input condition giving rise to the minimum noise figure often results in low value of associated transducer gain and high input VSWR of the amplifier [1].

Given the active device to be employed, a suitable operating power gain value G_{PO} together with the associated circle on the plane of the load reflection coefficient can be a good starting step in seeking for an acceptable compromise trading noise figure for transducer gain and input VSWR.

In fact, this work shows that one of the points of the just mentioned circle gives rise to an "optimum" reflection coefficient Γ_{LO} representing the necessary load condition to obtain from the given device the lowest values of noise figure and input VSWR compatible with the operating power gain G_{PO}.

The knowledge of the optimum load reflection coefficient is demonstrated to be particularly useful when dealing with general low noise amplifier design, since this concept allows extending to the multi - stage case a performance prediction already proposed by the Authors for the single - stage configuration [2]

2. THEORETICAL RECALLS.

With reference to the usual block diagram of a single - stage microwave amplifier (Fig. 1), the Authors have shown [3] that a particular family of curves can be drawn, whose property is to express noise versus VSWR performance of any active device.

Let us recall the relationship linking together the input reflection coefficient magnitude $|\Gamma_{in}|$, the reflection coefficient Γ_S and the reflection

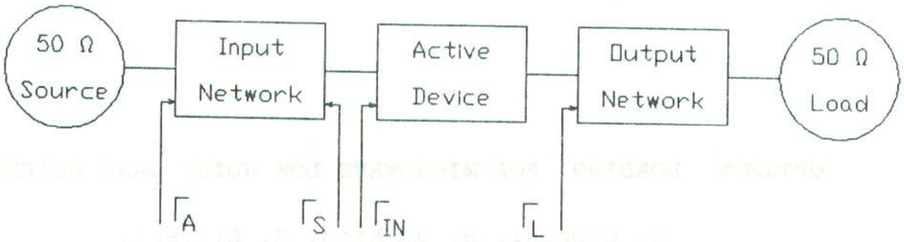

Fig. 1 Block diagram of a single - stage amplifier

coefficient S_{11}', under the mild assumption that the input impedance transformer is lossless [4]:

$$|\Gamma_{in}| = \frac{|S_{11}' - \Gamma_S^*|}{|1 - S_{11}' \Gamma_S|} \tag{1}$$

Where s_{11}' is function of the scattering parameters of the device and the of the load reflection coefficient Γ_L, as follows:

$$S_{11}' = S_{11} + \frac{S_{12} S_{21} \Gamma_L}{1 - S_{22} \Gamma_L} \tag{2}$$

For specified values of $|\Gamma_{in}|$ and of Γ_S, the Eq. 1 defines a circle on the S_{11}' plane. In turn, the conformal transformation represented by Eq.2 maps such circles into other circles on the Γ_L plane.

In what follows, $|\Gamma_{in}|$ will be denoted by W for simplicity.

Let us recall also that, given a constant noise figure circle labeled $F > F_0$ on the Γ_S - plane, having center **C** (in vector notation) and radius R, the following relationships hold:

$$\mathbf{C} = \frac{\mathbf{\Gamma_0}}{1 + K\,(1 - |\Gamma_0|^2)} \tag{3}$$

$$R = \frac{(1 - |\Gamma_0|^2)\,(K^2 + K)^{\frac{1}{2}}}{1 + K\,(1 - |\Gamma_0|^2)} \tag{4}$$

having defined the variable K as a normalized noise figure

$$K = \frac{(F - F_0)}{4 N_0} \qquad (5)$$

For $W = 0$ the Eq. 1 yields: $S_{11}' = \Gamma_S^*$; therefore the circle of the Γ_S-plane whose center and radius are reported in Eq. 3, is transferred on the S_{11}'-plane in a circle Q having center C^* and radius R.

If W increases above 0, the relationship 1 defines a circle on the S_{11}'-plane for each point of the Γ_S noise circle corresponding to K.

It was shown [4] that such circles are enveloped by two other circles, external and internal to circle Q, respectively.

Each one of these circles can be identified by a pair (K, W). Obviously, as W vanishes, the envelope circles tend to coincide with the circle Q.

It can be shown that, starting from one generical circle Qo labeled (Ko,0), for each reflection coefficient $W > 0$ a normalized noise figure $K < Ko$ can be found so that the envelope circle labeled (K, W) will shrink back to coincide with the circle Qo.

As W increases, there is a limit condition; namely that one for which the circle coincidence occurs for $K = 0$ ($F = Fo$). The resulting limit value Wo is

$$Wo^2 = Ko / (1 + Ko) \qquad (6)$$

Without entering intricate calculations, which would be beyond the scope of this work, it can be shown that the relationship linking together W and K in intermediate conditions between the pairs (Ko, 0); (0, Wo), and giving rise to envelopes coinciding with the circle Qo, is:

$$W = \frac{Wo^2 (1 + K) - K}{Wo + (1 - Wo^2)(K^2 + K)^{\frac{1}{2}}} \qquad (7)$$

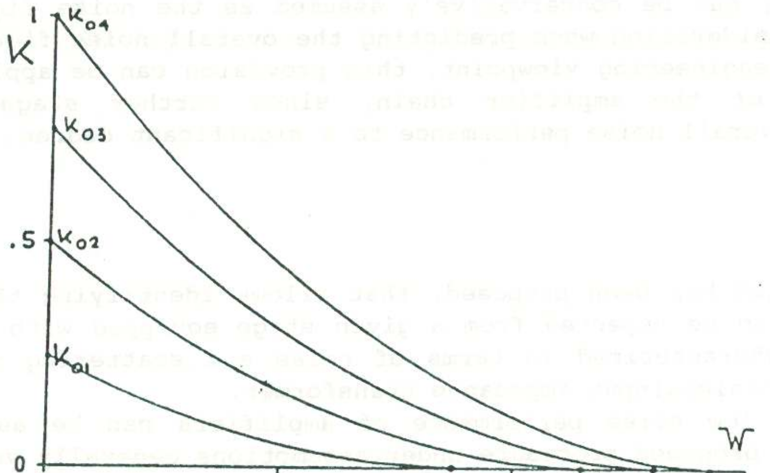

Fig. 2 General curves K versus W

3. DETERMINATION OF THE OPTIMUM LOAD REFLECTION COEFFICIENT.

The relationship 2 transfers the general envelope circle (K, W) in a conformal way into another circle (K, W)' on the plane of the load reflection coefficient Γ_L. Since on the s11' plane the circles (K, W) are internal to one another, so are also the circles (K, W)' on the Γ_L plane. On this plane a set of circle exist giving rise to constant values of operating power gain.

Under the hypothesis that the active device exhibits a power gain value G_{PO} in correspondance to the optimum noise input termination, one of the mentioned circles, corresponding to a power gain value $G_p > G_{PO}$ will result to be externally tangent to the circle (K, W)'.

The reflection coefficient relative to the contact point between the two circles represents the sought optimum $\Gamma o(G_p)$ corresponding to the power gain G_p. In fact any other reflecion coefficient $\Gamma(G_p)$ belonging to the same constant gain circle labeled G_p will belong also to an envelope circle (K1, W1) totally external to the circle (K, W).

The circle (K1, W1) will be tangent, in turn, to a circle corresponding to an operating power gain $G_{P1} > G_p$ in a point relative to a reflection coefficint $\Gamma o(G_{P1})$.

This shows that the reflection coefficient $\Gamma(G_p)$ is not optimal, since the triplet (GP, K1, W1) is not optimal with respect to the triplet (GP1, K1, W1) which the reflecion coefficent $\Gamma o(G_{P1})$ is associated with.

4. THE OPTIMUM REFLECTION COEFFICIENT IN CAD OF LNA.

As anticipated in the introduction, the optimum load reflection coefficient find a noteworthy application in multi - stage amplifier design, since the i - th stage of a low noise amplifier chain can be assumed to contribute a specified value of operating power gain G_p [5].

Therefore the optimum load reflection coefficient of the stage can be calculated by means of the above outlined procedure .

In such a condition, the curve of Fig. 2 yields the minimum values of the noise figures obtainable through a lossless impedance transformer at the input of the stage.

The maximum of these values $F_i(0)$ corresponds to the input matching condition, whereas, in general, the stage will work with a mismatched input.

Therefore $F_i(0)$ can be conservatively assumed as the noise figure F_i of the stage under consideration when predicting the overall noise figure of the amplifier. From an engineering viewpoint, this provision can be applied up to the second stage of the amplifier chain, since further stages do not contribute to the overall noise performance to a significant degree.

5. CONCLUSIONS

A new design aid has been proposed, that allows identifying the maximum noise figure that can be expected from a given stage equipped with an active device completely characterized in terms of noise and scattering parameters and fed through a losslessinput impedance transformer.

Multi - stage low noise performance of amplifiers can be assessed in accordance with the proposed procedure under assumptions generally verified in practice.

6. REFERENCES

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