Active Low Noise Terminations: Simulation Approach and Verification

$F_b =$

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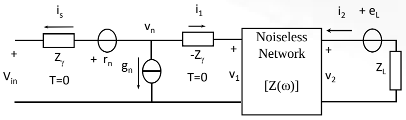
Introduction

- The equivalent noise temperature T_e has a different implication for a 2- or a 1-port network. In the former it is related to the network's noise factor, while in the latter, the equivalent noise temperature is proportional to available noise power from the network. Typically CAD applications are able to compute the first type of equivalent noise temperature but not the second.
- An analytical overview of the noisy behaviour of the circuit is explained representing the two port noisy network through the ABCD representation with two independent noise source (r_n and g_n) , a correlation impedance Z_γ and a noiseless network described in terms of *[Z]* parameters.
- **Two CAD oriented simulation's approaches are presented to allow the circuit performance optimization**
- **The design of a monolithic active low noise termination realized using the OMMIC ED02AH foundry process is presented**
- **The measured performance of the monolithic active termination are reported**

DESIGN FLOW

1. Basic theory



$$V_{in} = r_n + g_n z_{11} + \frac{z_{12}\left(e_L + g_n z_{21}\right)}{Z_L + z_{22}}$$

$$\left|V_{in}\right|^2 = \left|r_n\right|^2 + f\left(\left[Z(\omega)\right]\right)\left|Z_{in} - Z_\gamma\right|^2 \left|g_n\right|^2$$

$$T_e = \frac{P_{av}}{k_B B} = \frac{\left|V_{in}\right|^2}{4\,\mathrm{Re}\left[Zin\right] k_B B}$$

$$T_e = \frac{\left|r_n\right|^2 + f\left(\left[Z(\omega)\right]\right)\left|Z_{in} - Z_\gamma\right|^2 \left|g_n\right|^2}{4\,\mathrm{Re}\left[Z_{in}\right] k_B B}$$

Analytic derivation of the equivalent noise temperature starting from the 4 noise parameters of the 2-port active network

2. Simulation approach-I

$$P_{Z_0} = \frac{\left|e_n\right|^2}{Z_0}$$

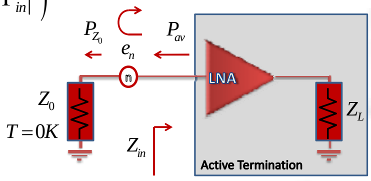
- AC simulation provides e_n that allows to compute P_{Z0} (noise power delivered to Z0)

$$P_{av} = \frac{P_{Z_0}}{1 - \left|\Gamma_{in}\right|^2}$$

- P_{av} is computed knowing the input reflection coefficient

$$T_e = \frac{P_{Z_0}}{k_B B\left(1 - \left|\Gamma_{in}\right|^2\right)}$$

- Equivalent noise temperature is obtained



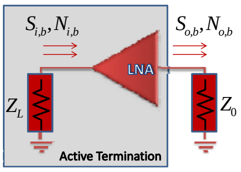
Required DATAs:

- **Input reflection coefficient (function of *Z_L*)**
- **Root mean square of the noise voltage (e_n) @ node n (function of *Z_L*)**

AC simulations considering a noiseless input termination

3. Simulation approach-II

- *[S]* parameters simulation provides F_b and allows to compute G_{av}
- Equivalent noise temperature is obtained



$$F_b = \frac{S_{i,b}/N_{i,b}}{S_{o,b}/N_{o,b}} \rightarrow N_{o,b} = N_{i,b} F_b \frac{S_{o,b}}{S_{i,b}} = N_{i,b} F_b G_{av,b}$$

$$T_e = \frac{N_{o,b}}{k_B B} = k_B T_0 B \frac{F_b G_{av,b}}{k_B B} = T_0 G_{av,b} F_b$$

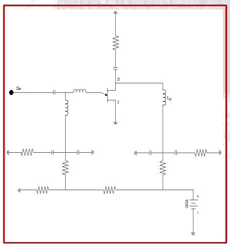
Required DATAs:

- **Reverse available gain (function of *Z_L*)**
- **Reverse noise factor (function of *Z_L*)**

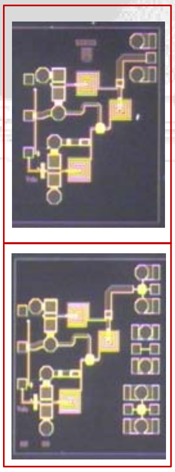
S parameter simulations combined with reverse device noise factor computation

4. Design

Schematic



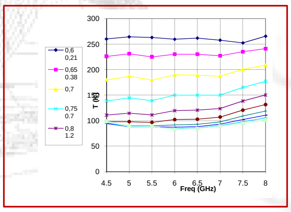
Micro-photo



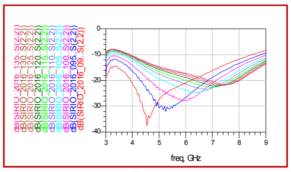
MMIC information:

- **Design bandwidth 4-8Ghz (full C band)**
- **Single bias voltage**
- **OMMIC ED02AH foundry process (GaAs 0.18um)**

5. Measurements



Equivalent Noise Temperature versus frequency and bias condition (V_{dd} (V), I_d (mA))



50 Ohm matching versus frequency and bias condition

Measurements of the full C-band active termination

6. Applications & conclusions

Two possible application scenarios are introduced:

- **In the field of noise model extraction, using the F50 method and the proposed termination, it is possible to obtain an increased accuracy compared to the standard F50 method**
- **In the field of antenna arrays, where the proposed circuit could be used as dummy load in the arrays, allowing to lower the overall equivalent noise temperature of the system without affecting the symmetry of the antenna system**

Conclusions and further developments

- **Further circuit optimization should be directed toward a reduction in the terminating impedance variation (as function of the bias voltage) and toward an higher temperature variation range to allow the usability as a two state noise source.**