MMIC LNA
Performance Optimisation
Using
Post-production Noise Characterisation

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Presentation Overview

- MMIC vs MIC
- Specific Application : Cryogenic MMIC LNA
- Trade off approach
- Noise Parameters Characterisation activity
  - Measurement method
  - Bench setup
  - Bench characterisation
  - Measurement and data collection
  - Data processing
- Conclusion

MMIC vs MIC

PRO	CONS
Lower cost	Not THE BEST
Higher repeatability	Passive and active elements are limited by foundry library
Compact	Not Adjustable or just a little
Faster and easy to assembly	It requires for design a very precise models
	Substrate not the best for noise

There is another option ?

Specific Application Cryogenic MMIC LNA

Usually cryomodels are not available from commercial foundry

Design the best for room temperature

This is the very best also at cryo temperatures?

Often we approach pioneer technologies

Models are not so consolidated as we'd like

Emerging Receiver architecture has multiple channel

We need several similar devices

We'd like to "save" as much kelvin as possble

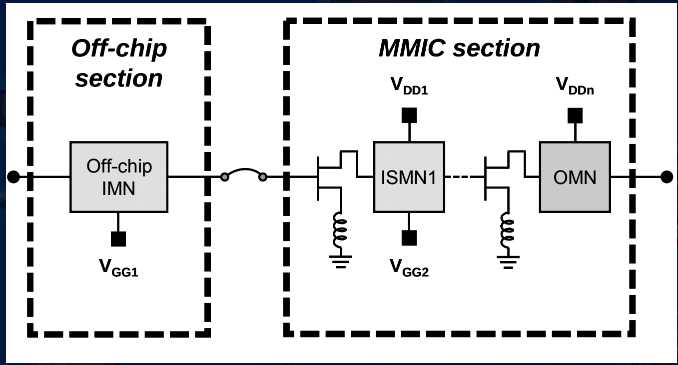
Reduce losses

Optimize the design

Simplify the packaging

Trade off approach :

External Input Matching network
Tunable
Low loss substrate (Fused Silica,PTFE)



A little bit more flexibility
We can re-optimize the Off-chip IMN using the "real" Noise parameters

We need the real $F_{min,MMIC}$, Rn_{MMIC}, mag and phase $\Gamma_{opt,MMIC}$

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Noise Parameters Characterisation activity

Method
Setup
Characterisation

↓

Measurement
and
data collection

↓

Data Processing

We used an InP 0.1um NGC MMIC LNA without Input matching Network

In order to get $F_{min,MMIC}$, Rn_{MMIC}, $\Gamma_{opt,MMIC}$ we have to map the DUT Output Noise Power under various Input Load conditions

Noise Parameters Characterisation activity

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- In order to sintetize different Load conditions we need a Tuner
- Tuner introduce accuracy and uncertainty issue

- Cold source Noise measurement method doesn't imply the connection of the tuner between noise source and the receiver
- We can forget about the Tuner losses
- We have to characterise every single element in the receiver chain

Noise Parameters Characterisation activity

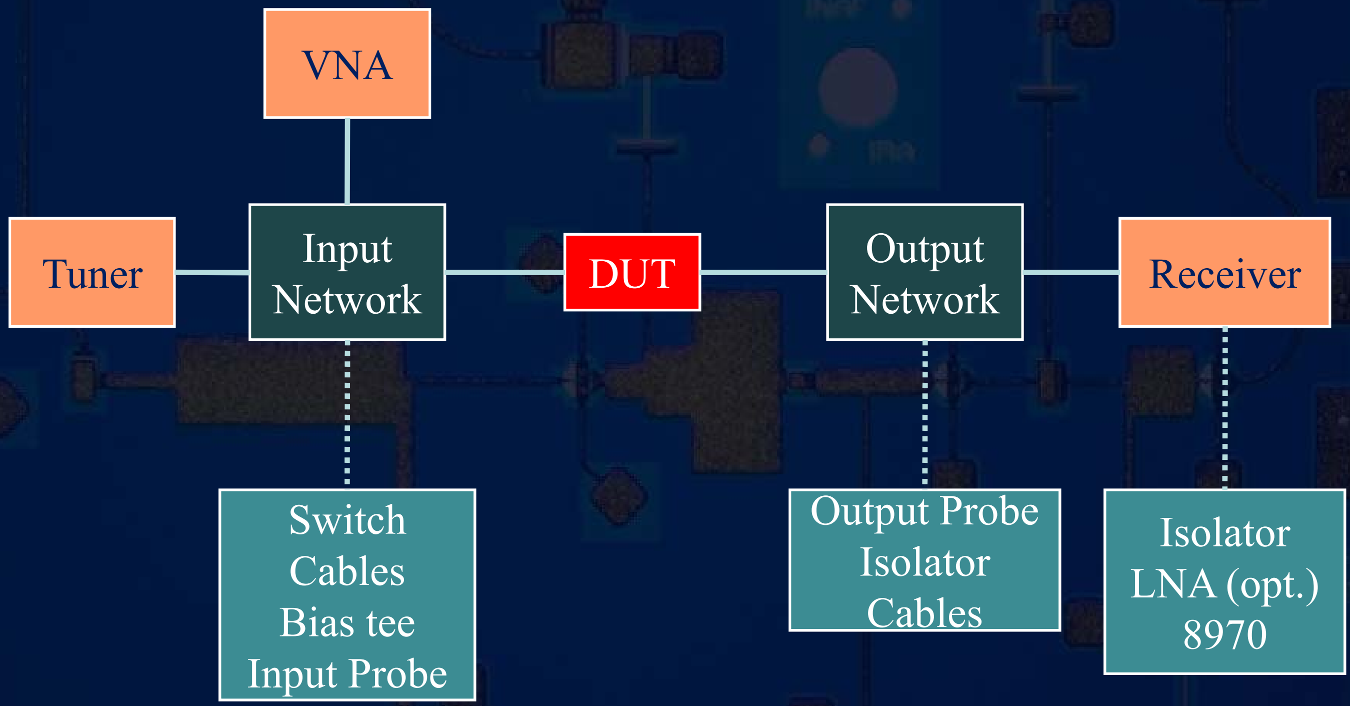
Method

Setup

Characterisation

Measurement and data collection

Data Processing



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Noise Parameters Characterisation activity

Components characterization : Necessary to calculate G_{av}

Method
Setup
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Data Processing

[S] parameters of

- Switch
- cables
- bias tee
- Isolators
- DUT

Probes contribution has been removed using adapter removal algorithm

Uncertainty	Accuracy
δInstrument δStandardcal	Warm up time Connector tight and clean Cable position probing

Noise Parameters Characterisation activity

Receiver Calibration : We get G_p, NF_{REC}

Method
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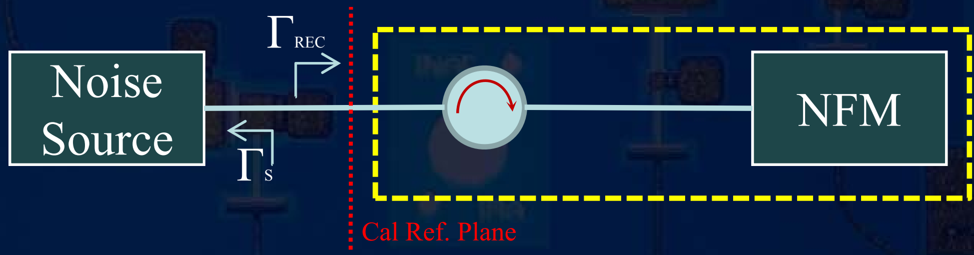

$$Meas = 10 \cdot \log_{10}\left(\frac{P_{meas}}{kBT_0}\right)$$

$$P_{meas} = kB(T_{rec} + T_S) \cdot \frac{1}{MM} \cdot G_p$$

$$MM = \frac{P_{av}}{P_{in}} = \frac{\left|1 - \Gamma_S \Gamma_{rec}\right|^2}{\left(1 - \left|\Gamma_S\right|^2\right) \cdot \left(1 - \left|\Gamma_{rec}\right|^2\right)} \rightarrow MM_{cal} = \frac{P_{av}}{P_{in}} = \frac{1}{\left(1 - \left|\Gamma_{rec}\right|^2\right)}$$

Noise Parameters Characterisation activity

Receiver Calibration : We get G_p, NF_{REC}

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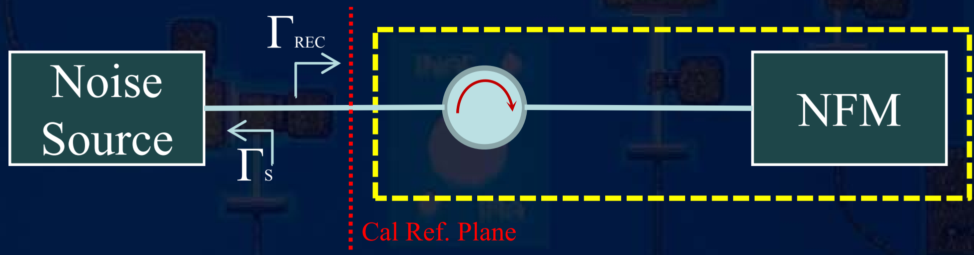

$$T_H = T_0 \cdot 10^{ENR/10} + T_0$$

$$G_p = \frac{P_{hot} - P_{cold}}{(T_H - T_C)} \cdot MM_{cal}$$

$$T_{rec} = P_{hot} \cdot \frac{MM_{cal}}{kBG_p} - T_H$$

$$F_{rec} = 1 + \frac{T_{rec}}{T_0}$$

Noise Parameters Characterisation activity

Receiver Calibration : We get G_p, NF_{REC}

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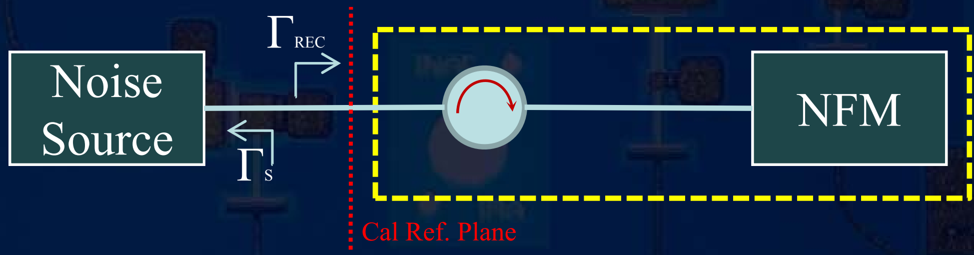

$$per \quad T_C \neq T_0 \Rightarrow \Delta T = T_C - T_0$$

$$F_{rec}(\Gamma_{NS}) = F_{iso}(\Gamma_{NS}) + \frac{F_{NFM}(\Gamma_{iso}) - 1}{G_{av,iso}(\Gamma_{NS})} =$$

$$= 1 + \frac{T_C}{T_0} \cdot \left(\frac{1}{G_{av,iso}(\Gamma_{NS})} - 1 \right) + \frac{F_{NFM}(\Gamma_{iso}) - 1}{G_{av,iso}(\Gamma_{NS})} =$$

$$= \frac{\Delta T}{T_0} \cdot \frac{1 - G_{av,iso}(\Gamma_{NS})}{G_{av,iso}(\Gamma_{NS})} + \frac{F_{NFM}(s_{22iso})}{G_{av,iso}(\Gamma_{NS})}$$

Noise Parameters Characterisation activity

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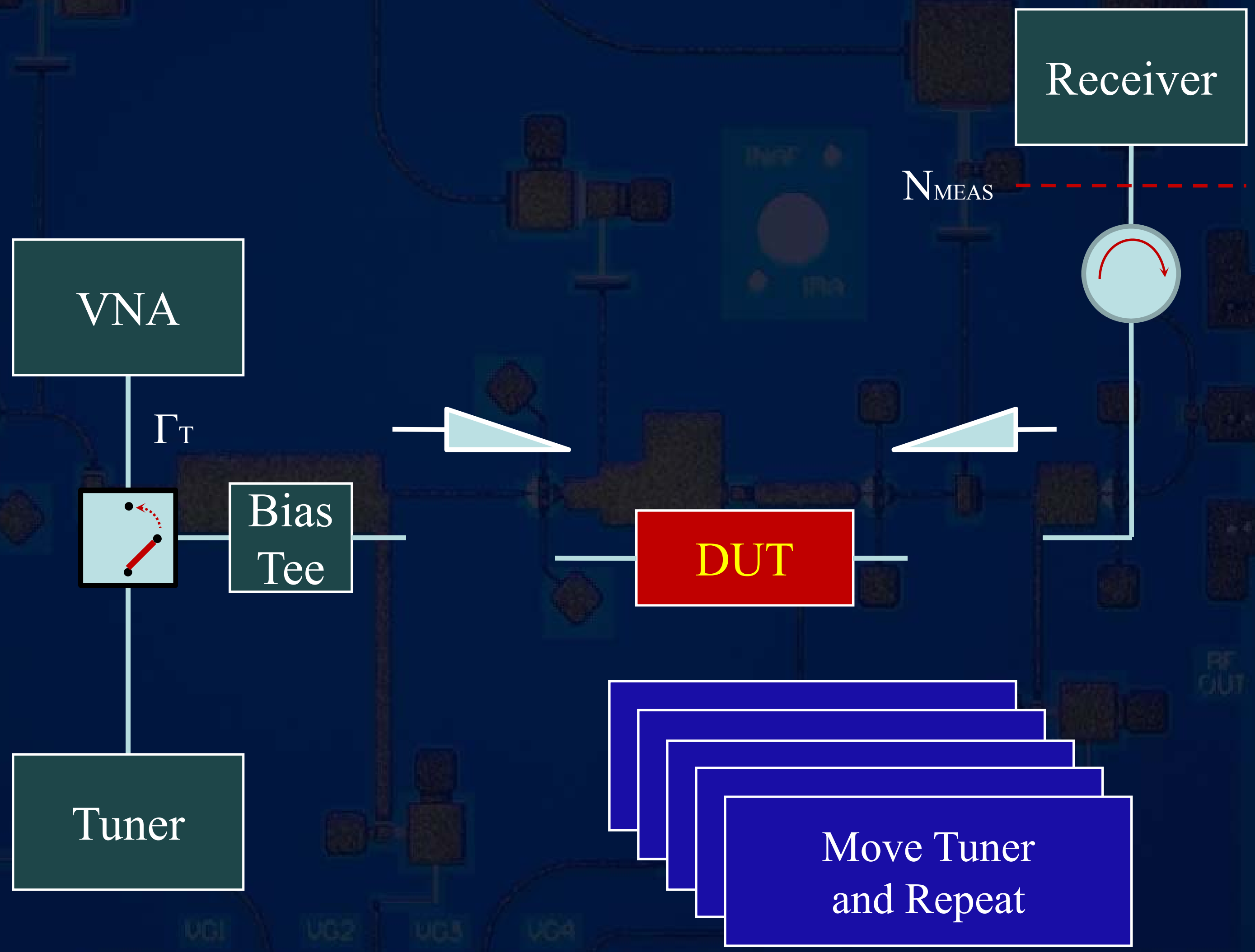
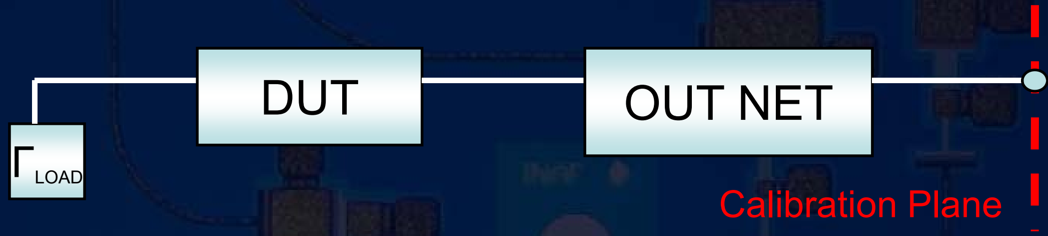


Noise Parameters Characterisation activity



Method
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Data Processing

$$F_{DUT} = 1 + \frac{T_{DUT}}{T_0}$$

$$T_{meas,av} = T_{rec,misura} + \left(T_{DUT} + T_C\right)\cdot G_{av,DUT}\cdot G_{av,RETEOUT} + T_C\cdot\left(\frac{1}{G_{av,RETEOUT}} - 1\right)\cdot G_{av,RETEOUT}$$

$$T_{DUT} = \frac{T_{meas,av} - T_C\cdot\left(\frac{1}{G_{av,RETEOUT}} - 1\right)\cdot G_{av,RETEOUT} - T_{rec,misura}}{G_{av,DUT}\cdot G_{av,RETEOUT}} - T_C$$

$$T_{meas,av} = \frac{T_0\cdot 10^{(Meas/10)}}{G_p}\cdot MM_{meas}$$

$$T_{rec,misura} = T_0\cdot\left(F_{rec}\left(\Gamma_S\right) - 1\right)$$

$$F_{rec}\left(\Gamma_S\right) = \frac{\Delta T}{T_0}\cdot\frac{1 - G_{av,iso}\left(\Gamma_S\right)}{G_{av,iso}\left(\Gamma_S\right)} + \frac{F_{NFM}\left(s_{22iso}\right)}{G_{av,iso}\left(\Gamma_S\right)}$$

Noise Parameters Characterisation activity

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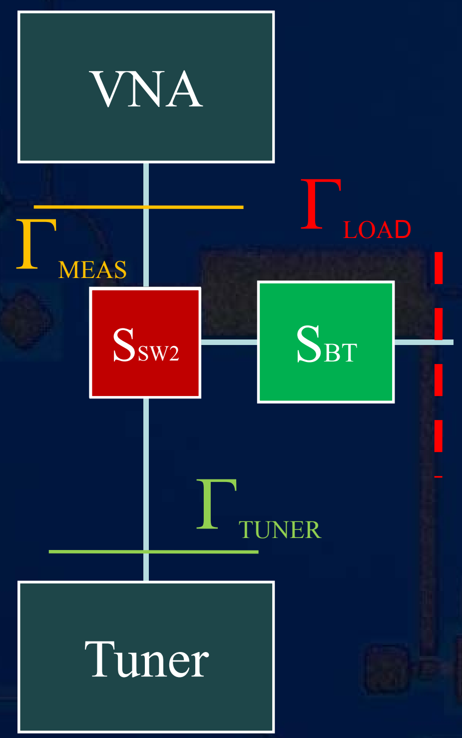
$$\Gamma_{MEAS} = S_{11}^{SW1} + \frac{S_{12}^{SW1} \cdot S_{21}^{SW1} \cdot \Gamma_{TUNER}}{\left(1 - S_{22}^{SW1} \cdot \Gamma_{TUNER}\right)} \Rightarrow \Gamma_{TUNER}$$



$$\left[S^{SW2}\right] \Rightarrow \left[T^{SW2}\right]$$

$$\left[S^{BT}\right] \Rightarrow \left[T^{BT}\right]$$

$$\left[T^{OUT}\right] \Rightarrow \left[T^{SW2}\right] \cdot \left[T^{BT}\right] \Rightarrow \left[S^{OUT}\right]$$

$$\Gamma_{LOAD} = S_{11}^{OUT} + \frac{S_{12}^{OUT} \cdot S_{21}^{OUT} \cdot \Gamma_{TUNER}}{\left(1 - S_{22}^{OUT} \cdot \Gamma_{TUNER}\right)}$$

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$$F(G,B) = F_{\min} + \frac{R_n}{G}\cdot\left[\left(G - G_{opt}\right)^2 + \left(B - B_{opt}\right)^2\right]$$

$$Y = G + jB$$

$$\begin{cases} F_{\min} = A + \sqrt{4\cdot B\cdot C - D^2} \\ R_n = B \\ G_{opt} = \dfrac{\sqrt{4\cdot B\cdot C - D^2}}{2\cdot B} \\ B_{opt} = -\dfrac{D}{2\cdot B} \end{cases}$$

$$d_i = F_{meas,i}(G_i, B_i) - \left\{F_{\min} + \frac{R_n}{G_i}\cdot\left[\left(G_i - G_{opt}\right)^2 + \left(B_i - B_{opt}\right)^2\right]\right\} \quad ; \quad d_i \neq 0$$

$$dm_i = \frac{1}{F_{meas,i}(G_i, B_i)}\cdot\left\{F_{meas,i}(G_i, B_i) - \left\{F_{\min} + \frac{R_n}{G_i}\cdot\left[\left(G_i - G_{opt}\right)^2 + \left(B_i - B_{opt}\right)^2\right]\right\}\right\}$$

$$\sum_{i=1}^{N} dm_i = \varepsilon$$

Noise Parameters Characterisation activity

Results @6.5 GHz : Simulated & Measured

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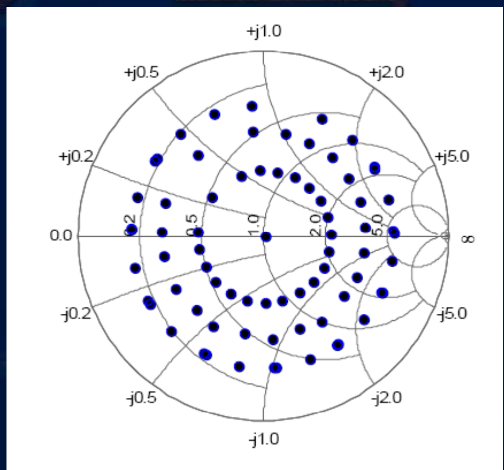
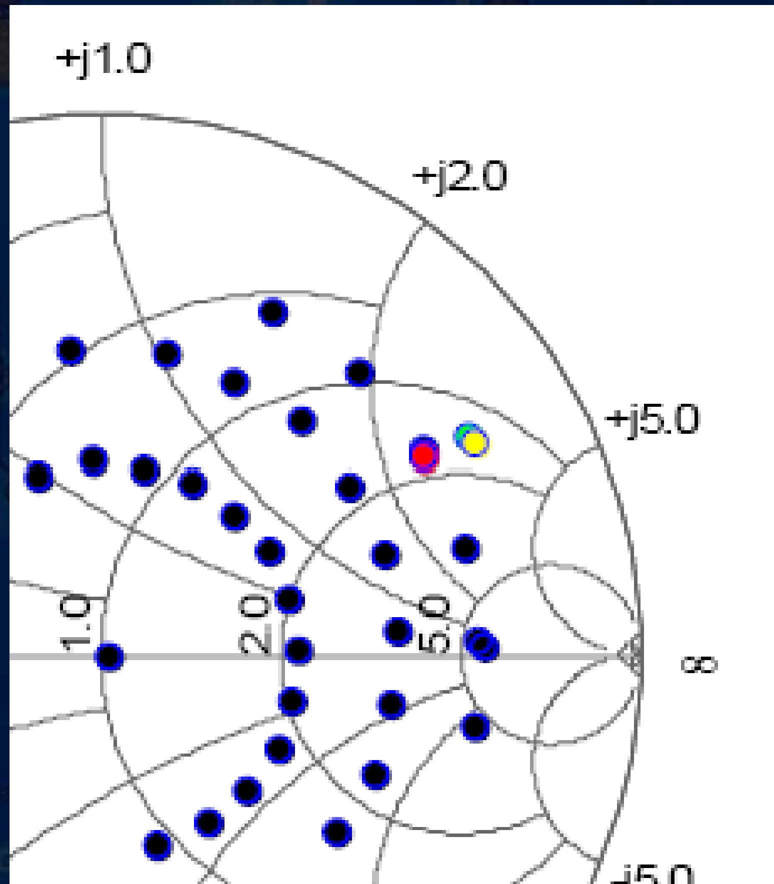
$$
\begin{cases}
\dfrac{\partial \varepsilon}{\partial A} = 0 \\
\dfrac{\partial \varepsilon}{\partial B} = 0 \\
\dfrac{\partial \varepsilon}{\partial C} = 0 \\
\dfrac{\partial \varepsilon}{\partial D} = 0
\end{cases}
$$





Conclusion

- A measurement setup to optimize LNA Performances has been presented
- Accuracy and uncertainty sources had been evaluated
- Good results has been obtained at some frequencies
- Work is still in progress in order to reduce uncertainty and improve the accuracy over an extended frequency range

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Thanks
For your attention

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