PART I

A NOVEL EXPERIMENTAL MULTICARRIER MEASUREMENT METHOD FOR MICROWAVE POWER AMPLIFIERS

T. REVEYRAND[*], D. BARATAUD[*], J.M. NEBUS[*],
A. MALLET[**], L. LAPIERRE[**], J. SOMBRIN[**]

[*] IRCOM - Faculté des sciences - UMR CNRS n° 6615

123, Avenue Albert Thomas - 87060 LIMOGES Cédex
Phone : (033) 555-457517 - Fax : (033) 555-457666
e-mail : tibo@ircom.unilim.fr
www : http: //ircom.unilim.fr

[**] Centre National d'Etudes Spatiales

18, avenue Edouard Belin - 31401 TOULOUSE Cedex 4
Phone : (033) 561-273131 - Fax: (033) 561-273179
e-mail : alain.mallet@cnes.fr
www : http: //www.cnes.fr

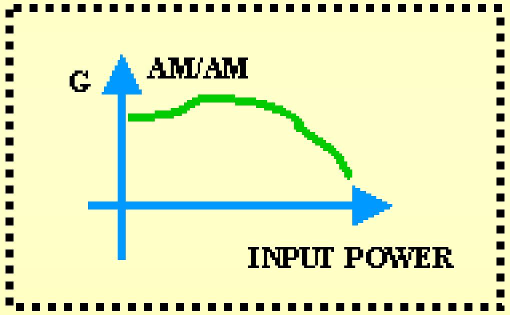
OUTLINE

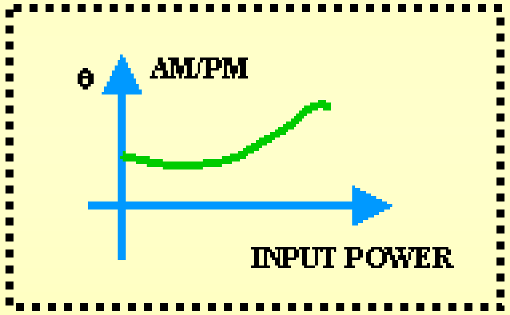
- Basic considerations
- NPR approach using a digital synthesis of a bandlimited gaussian noise
- The proposed experimental set-up
- Measurement results
- Conclusion

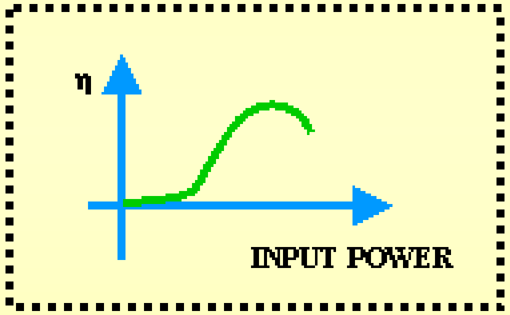
BASIC CONSIDERATIONS (I)

Linearity versus efficiency characterization of power amplifiers

<u>Classical approach</u> **: (CW center frequency AM/AM and AM/PM measurements)**







$$\tilde{x}(t) = A(t)e^{j\varphi(t)}$$

NL Device

$$\tilde{y}(t) = G(A(t))e^{j(\varphi(t)+\theta(A(t)))}$$

$$\tilde{y}(t) = \sum_k G(A(t_k))e^{j(\varphi(t_k)+\theta(A(t_k)))}$$

$$\eta = \frac{\sum \eta(A(t_k))}{\sum k}$$

MEMORYLESS APPROACH

Neither high frequency memory effects (standing in RF matching circuits)

Nor low frequency memory effects (standing in bias circuits)

ARE TAKEN INTO ACCOUNT

For HF dispersive effects :

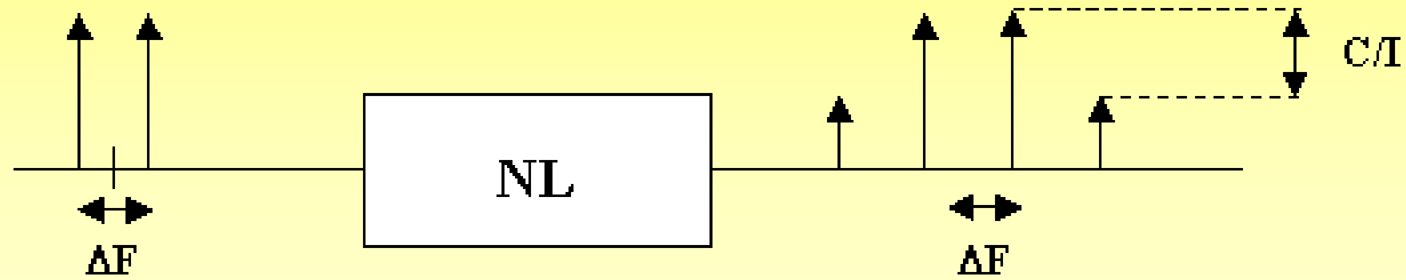
There is a modeling improvement which consists in cascading.
The small signal transfert function of the amplifier with the center frequency
AM/AM AM/PM large signal characteristics.

For low frequency dynamic behavior :

Two tone or multitone measurements are required.

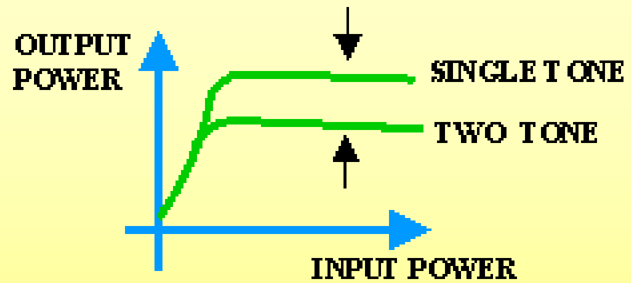
BASIC CONSIDERATIONS (II)

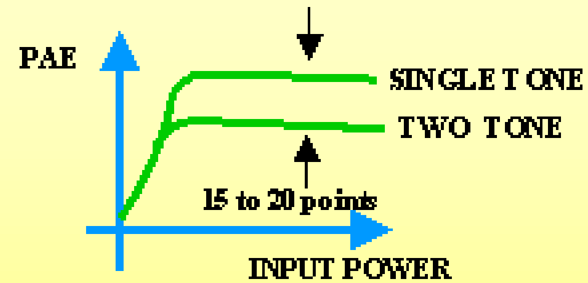
Two tone characterization (Third order intermodulation criterion)



Peak to average power ratio of this test signal = 3 dB

Typical relationship observed between single tone and two tone measurements





ADDITIONAL REMARKS

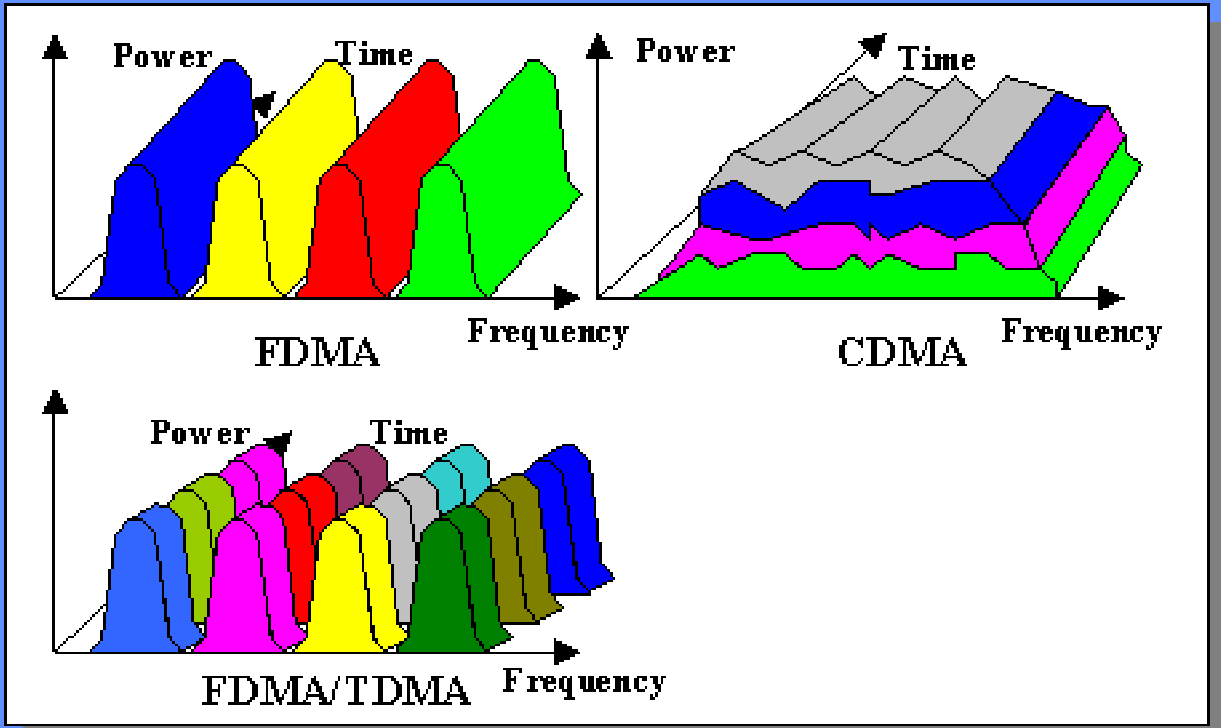
C/I is a function of carrier frequency spacing (non linear memory effects)

What is the correlation between C/I and the BER degradation of a digital communication link ?

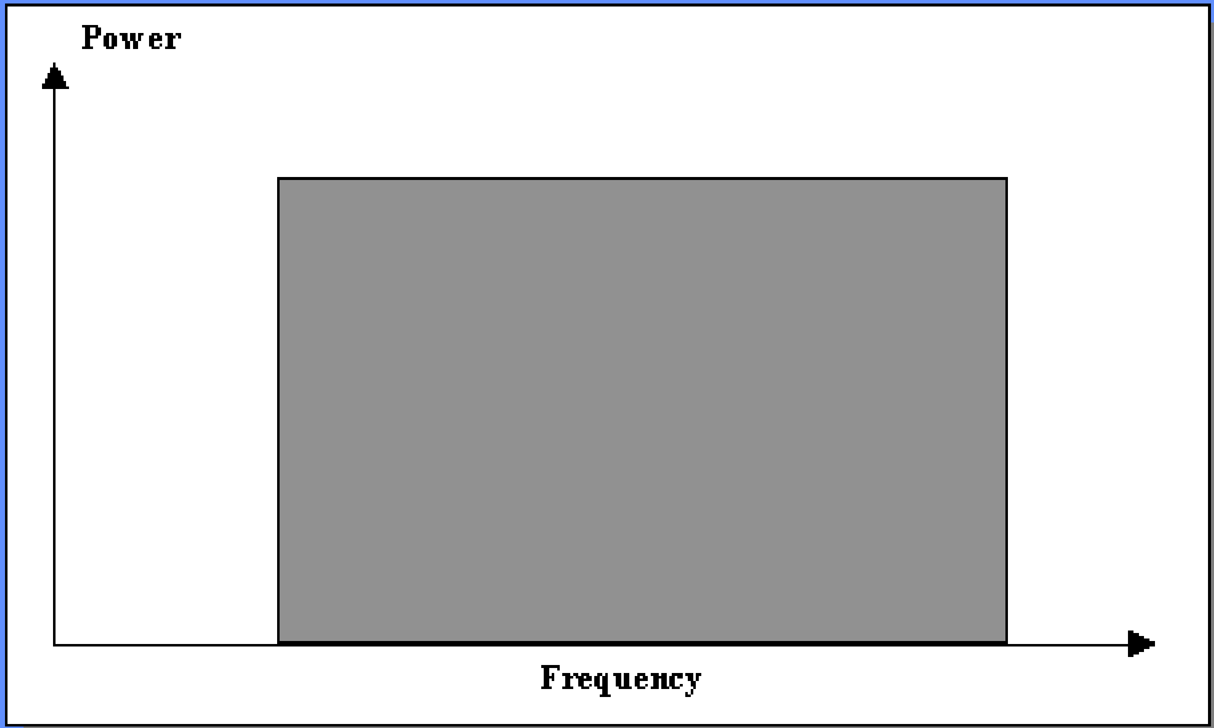
IN THE CASE OF THE USE OF A FEW CARRIERS ⇒ SAME DIFFICULTY + (PHASE RELATIONSHIPS BETWEEN CARRIERS)

A TENTATIVE OF A GENERALIZED APPROACH
THE BANDLIMITED WHITE GAUSSIAN NOISE

Typical signals encountered in communication systems



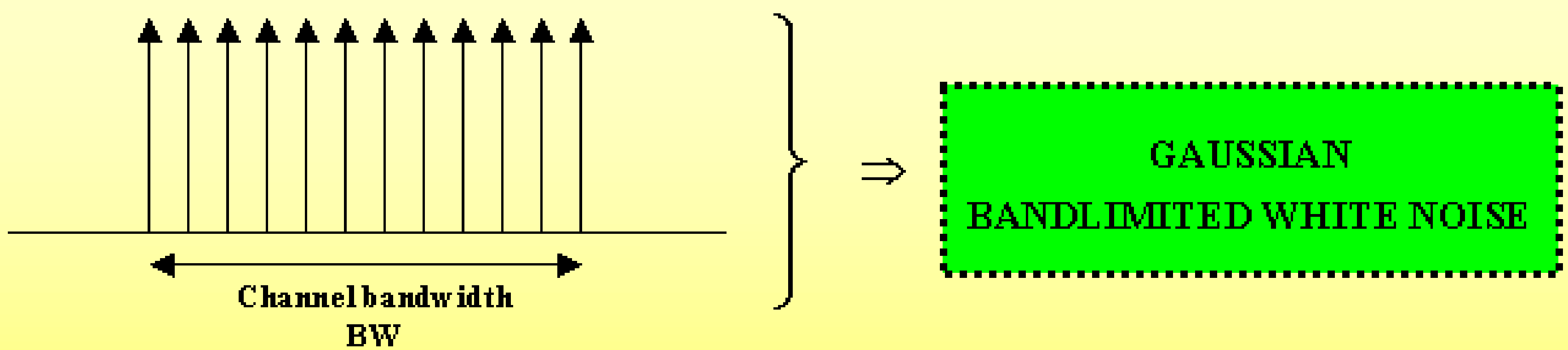
May be approximated by a bandlimited white gaussian noise



BANDLIMITED WHITE GAUSSIAN NOISE
A POSSIBLE PRATICAL REALIZATION

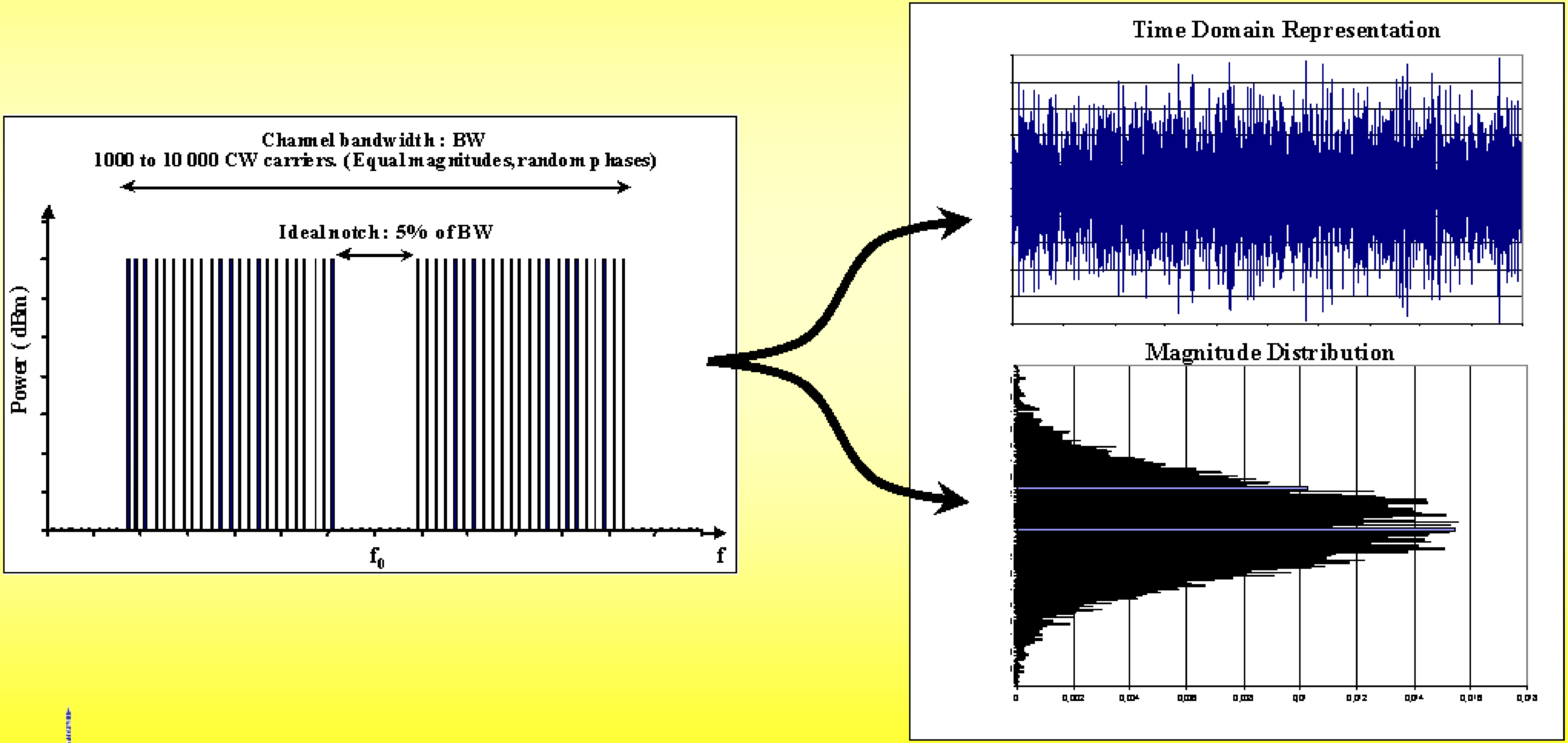
According to the central limit theorem

Synthesis of a great number of CW carriers with equal magnitude and a random phase draw

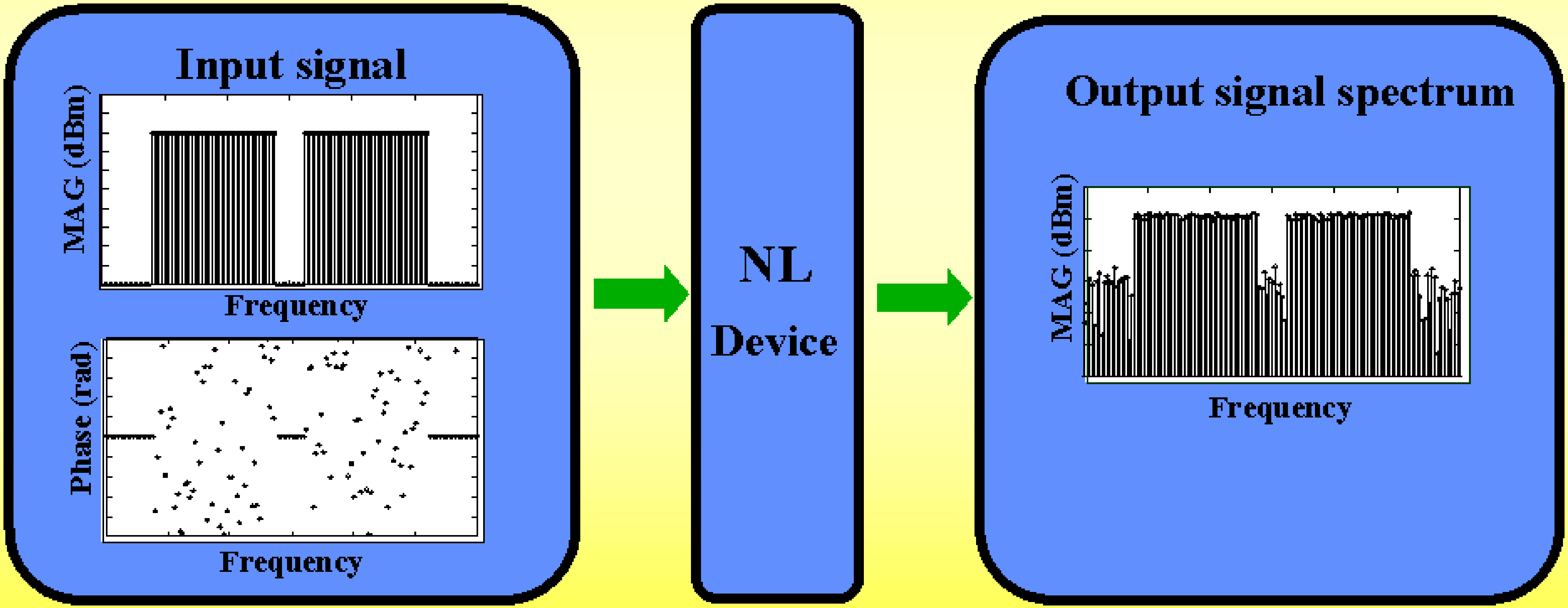


BASE BAND SIGNAL SYNTHESIS USING A COMPUTER CONTROLLED ARBITRARY WAVEFORM GENERATOR (AWG)

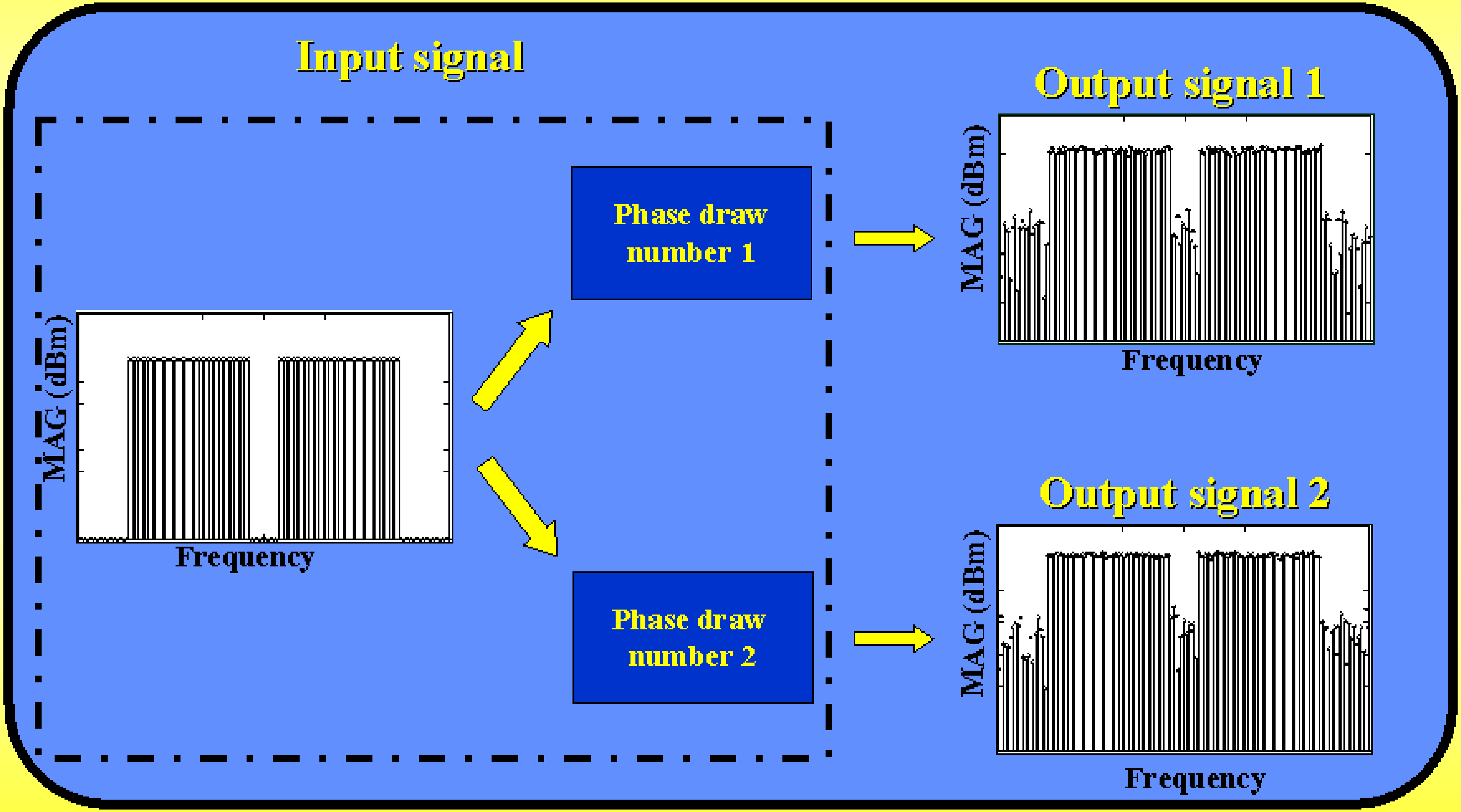
NOISE TEST SIGNAL CONDITIONING FOR LINEARITY CHARACTERIZATION OF POWER AMPLIFIERS



OUTPUT SIGNAL SPECTRUM OF A POWER AMPLIFIER

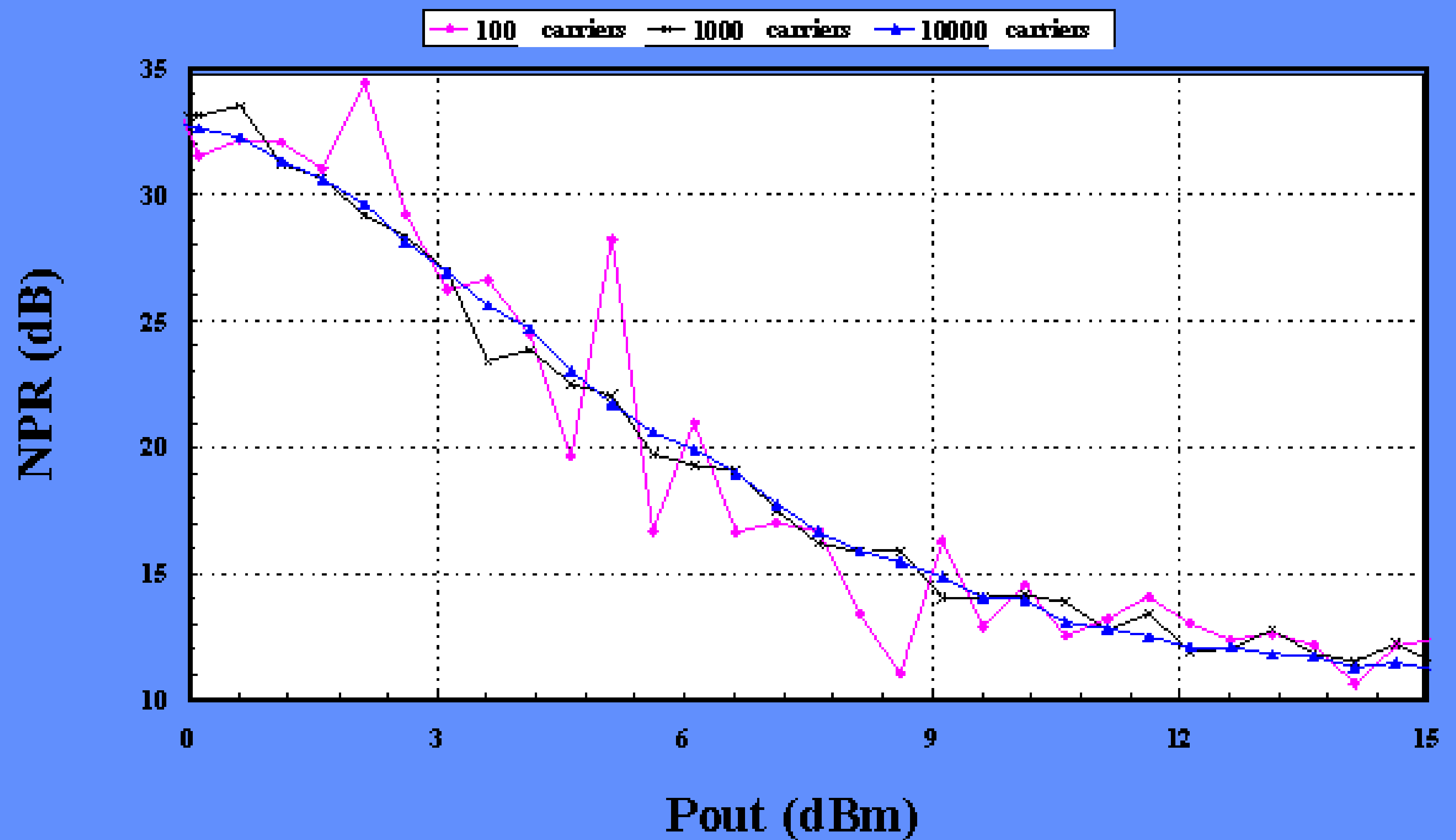


- Limited number of carriers (few hundred) - Influence of the phase draw



➢Example of NPR versus output power

- Different phase draws at different input powers
- Notch = 10% of the channel bandwidth
- Three cases : 100, 1000, 10 000 carriers



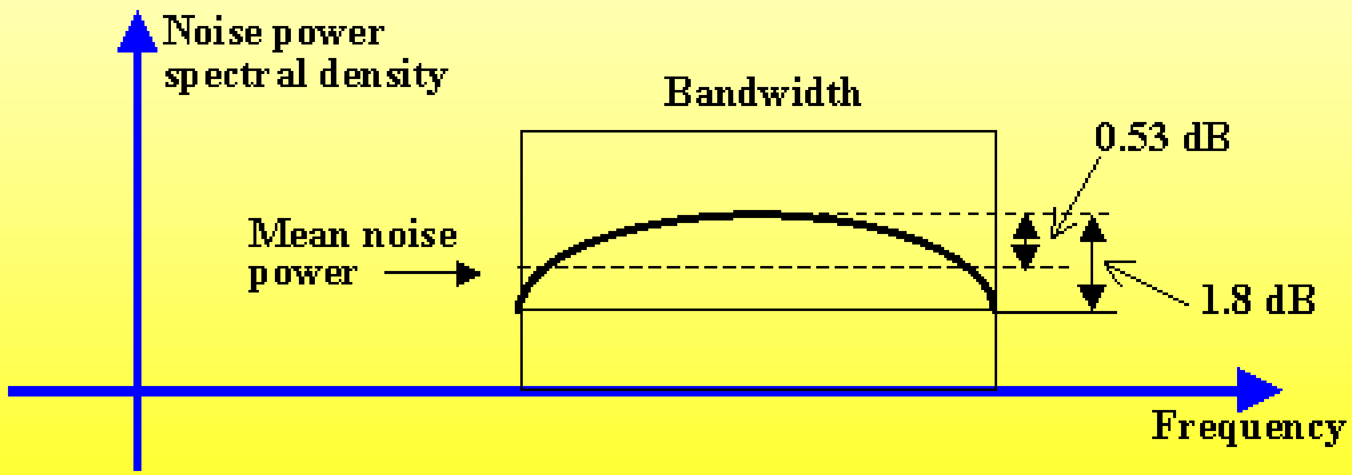
SUMMARY

1 To reach an accuracy in the order of 0.5 dB for NPR simulations or measurements

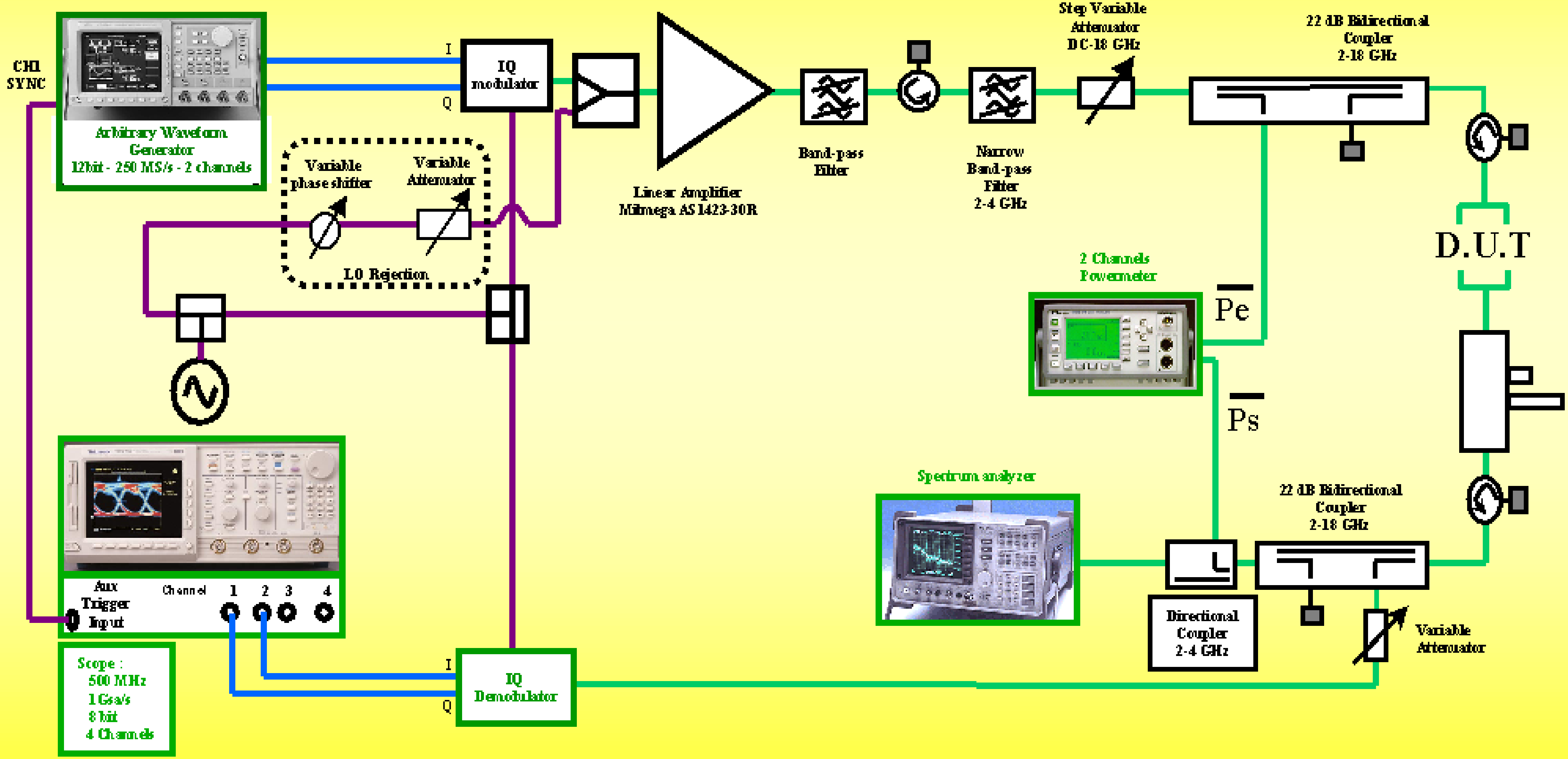
400 (samples (or carriers)) within the notch are required

For example :
- 400 carriers
- 5 % notch → 20 carriers
- Averaging between 20 different phase draws

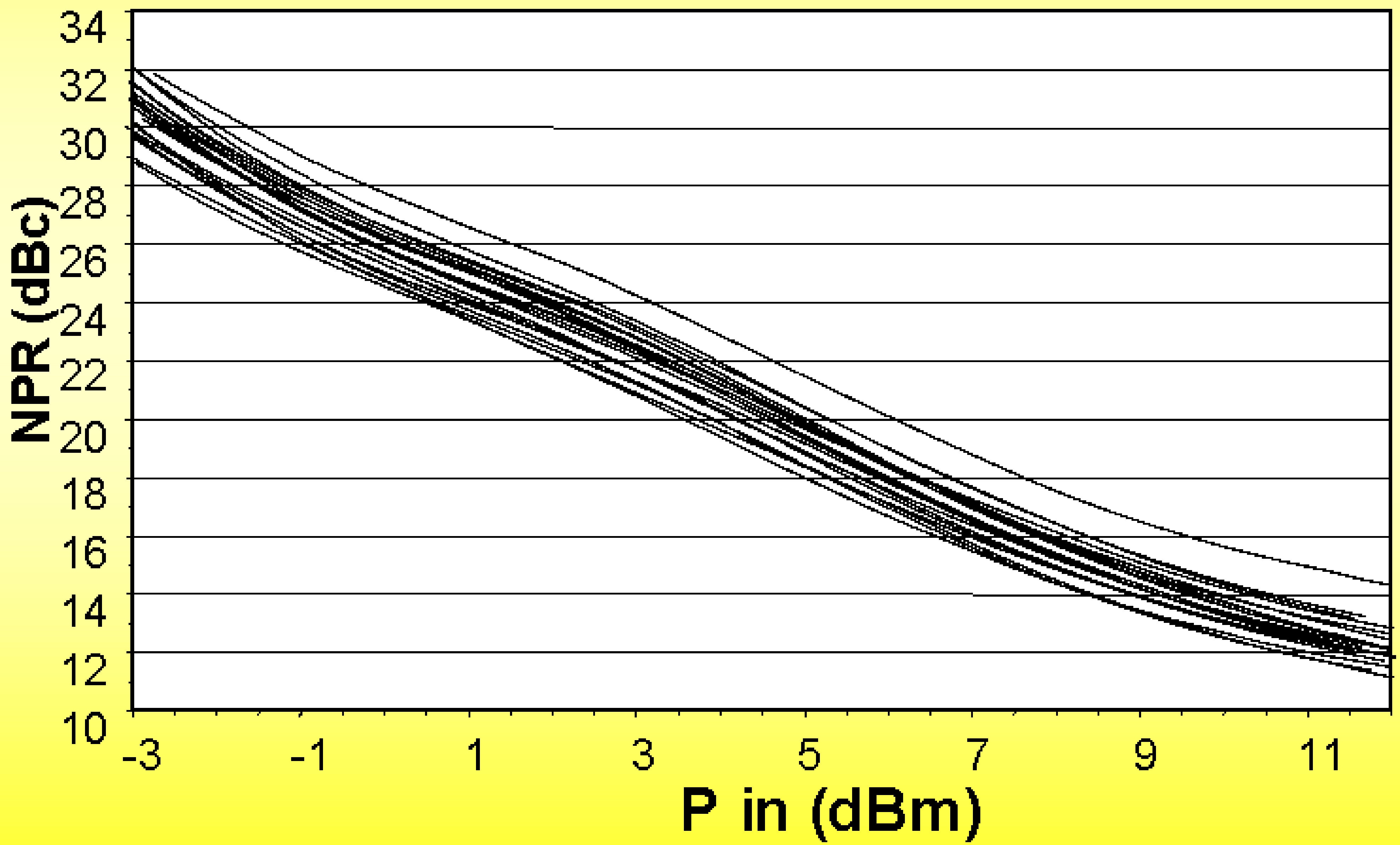
2 Typical shape of the intermodulation noise distribution



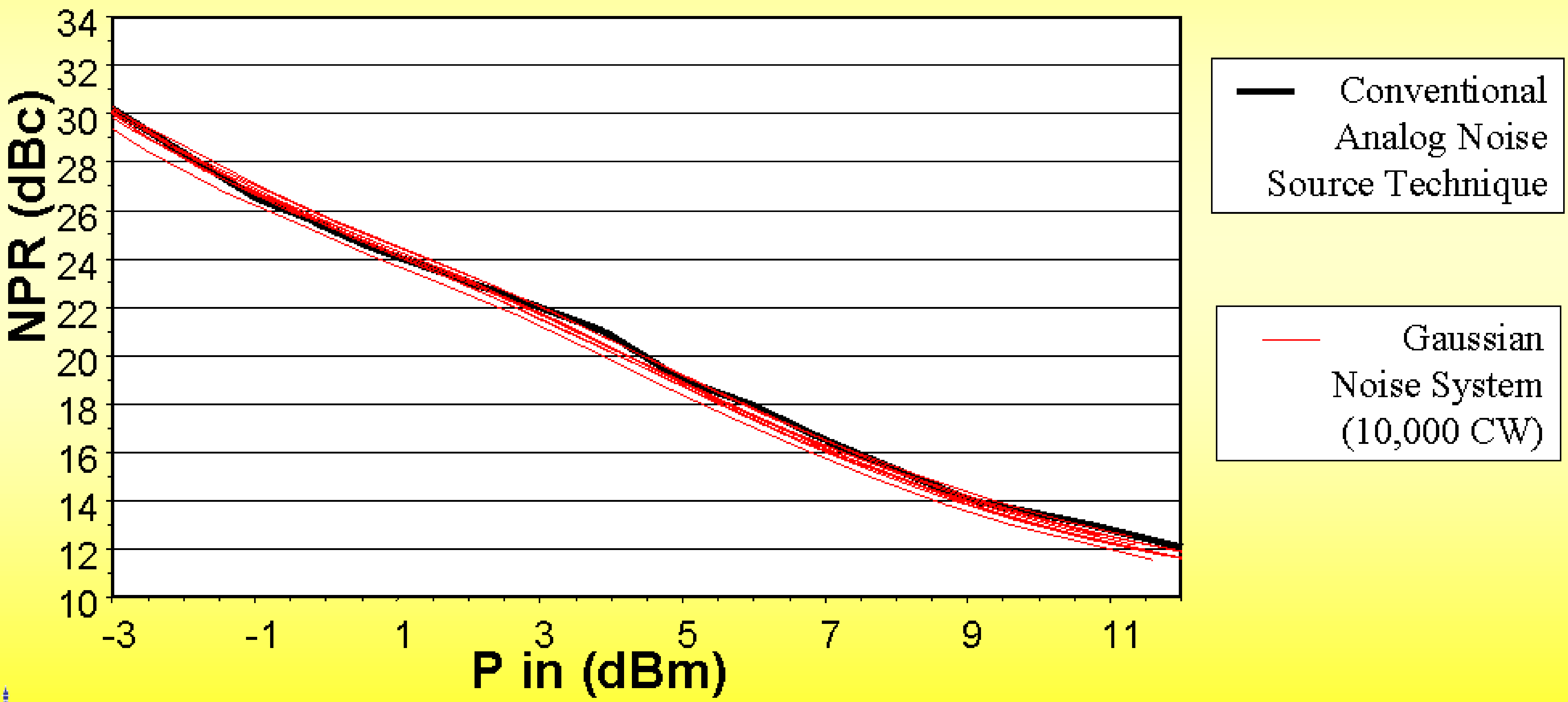
NPR MEASUREMENT SETUP



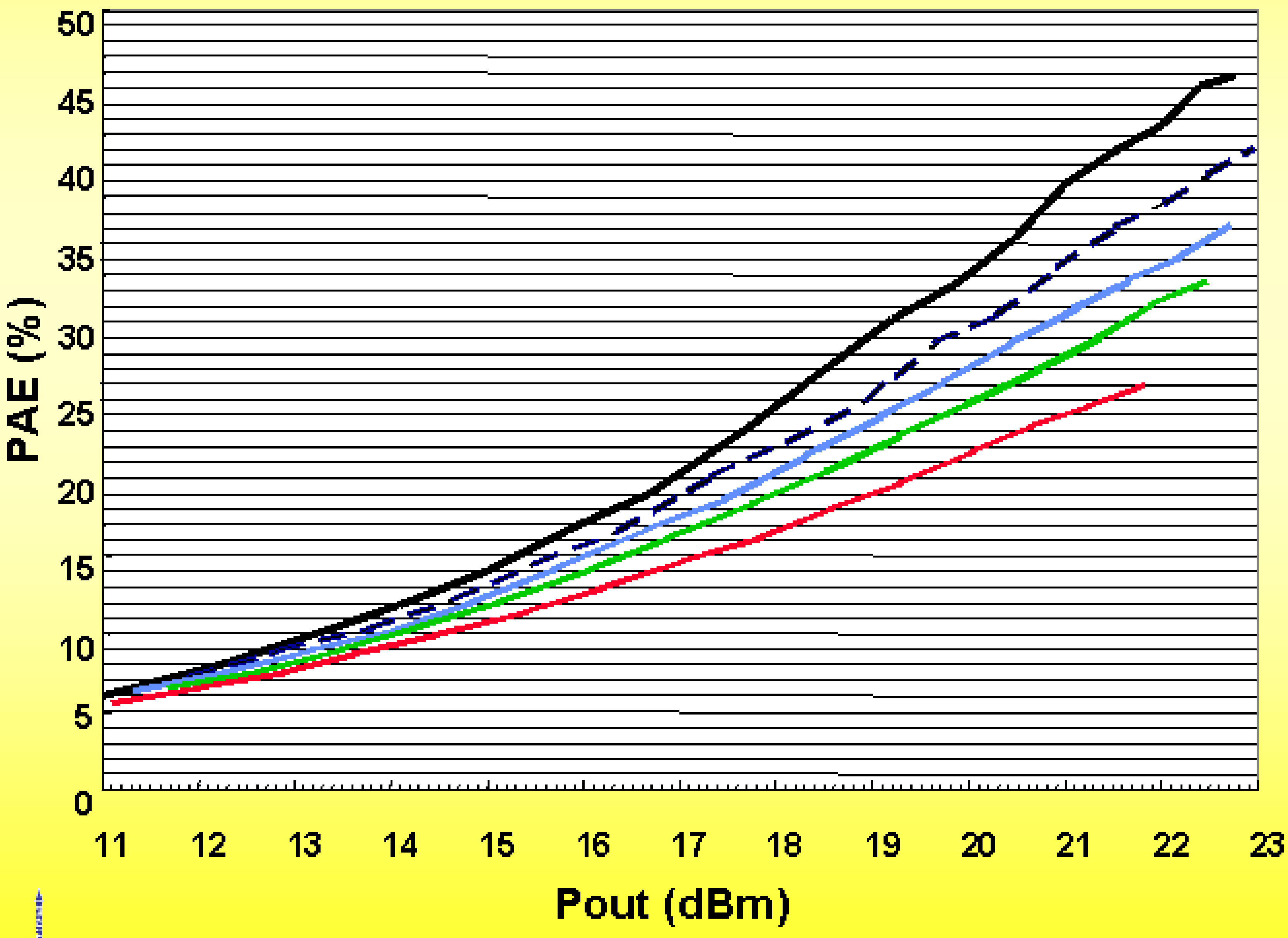
MEASUREMENTS WITH A 1000 TONES
CHANNEL BANDWIDTH 20 MHZ - NOTCH = 5 % - F_0 = 2 GHZ
HP 87415A AMPLIFIER

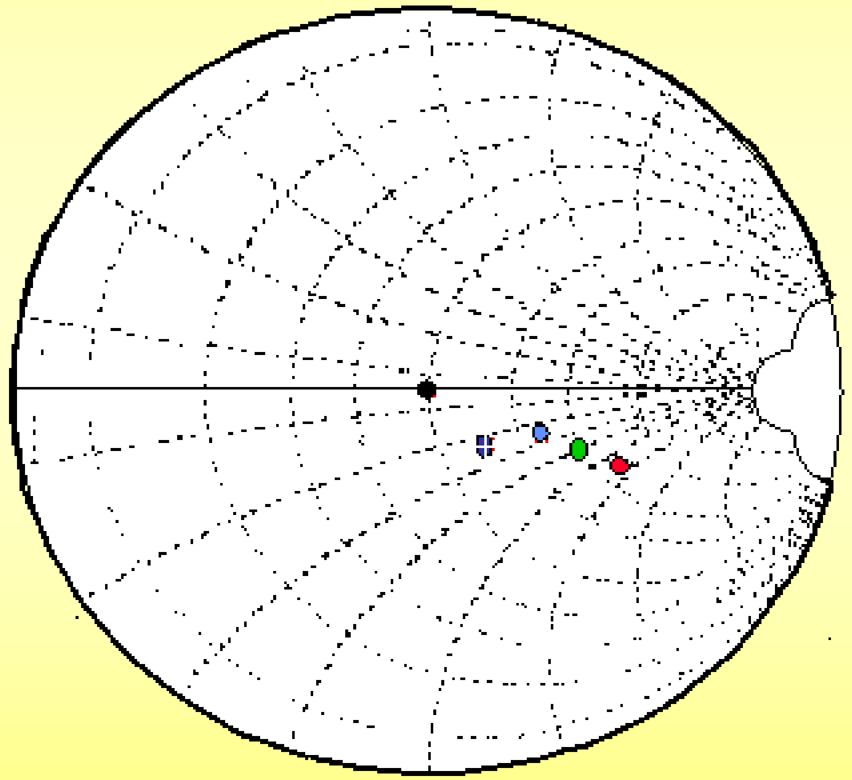


MEASUREMENTS WITH AN ANALOG NOISE SOURCE AND 10 000 TONES - F_0 = 2 GHZ HP 87415A AMPLIFIER

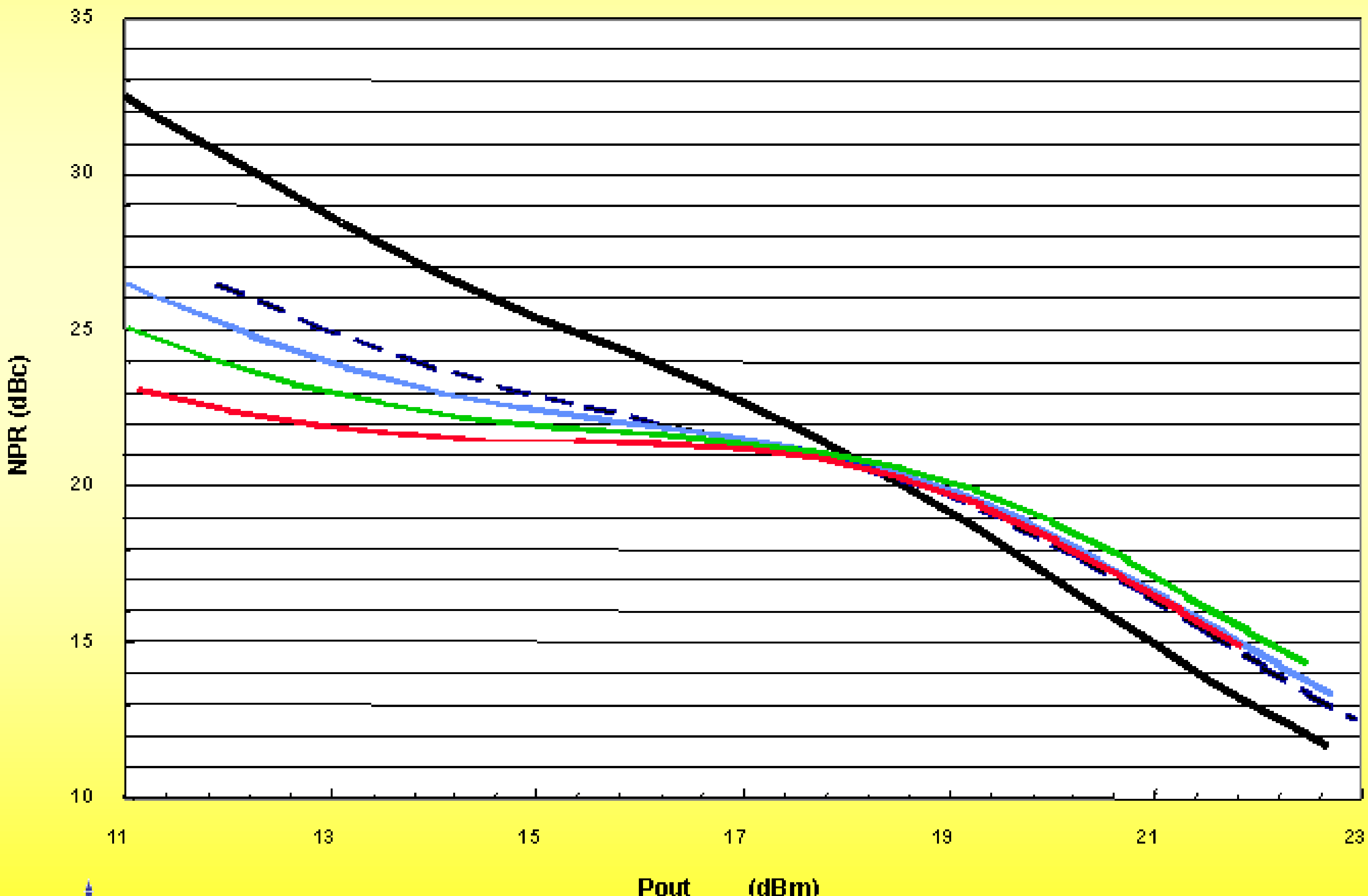


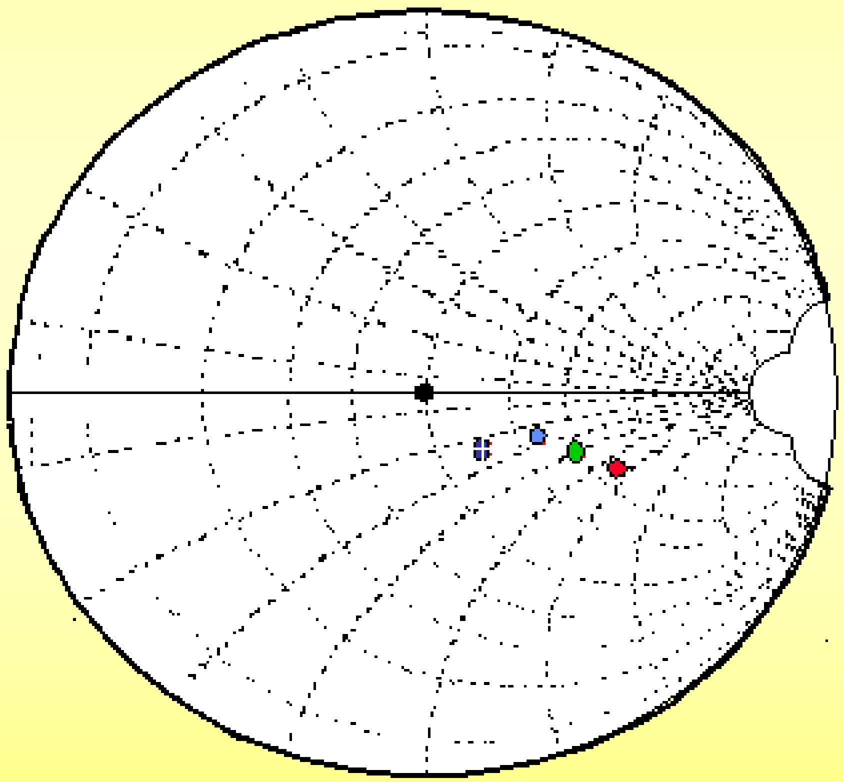
MEASUREMENT OF A SINGLE CELL
1 200 μM TI HFET POWER AMPLIFIER AT 2.18 GHZ
POWER ADDED EFFICIENCY VERSUS OUTPUT POWER



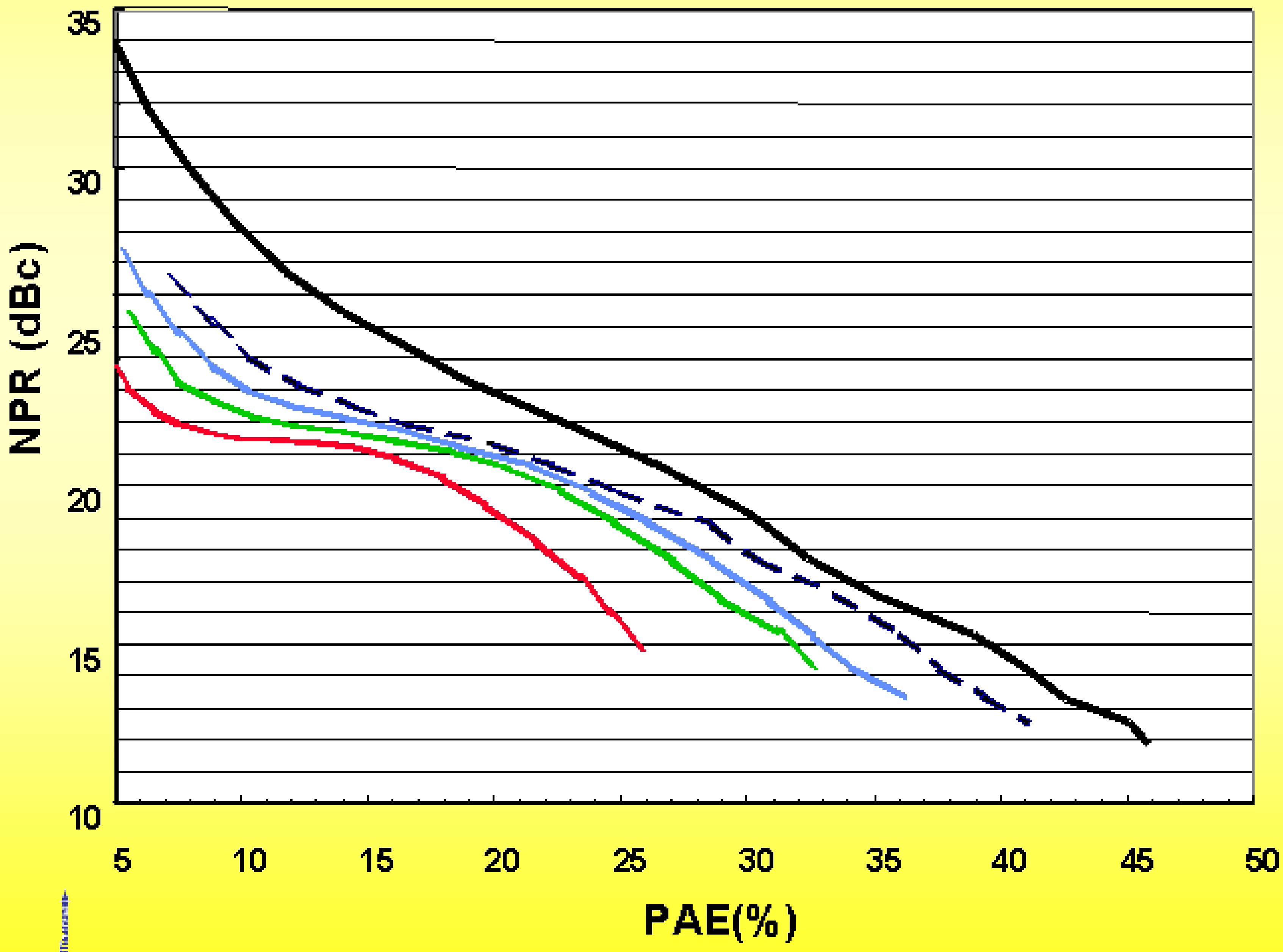


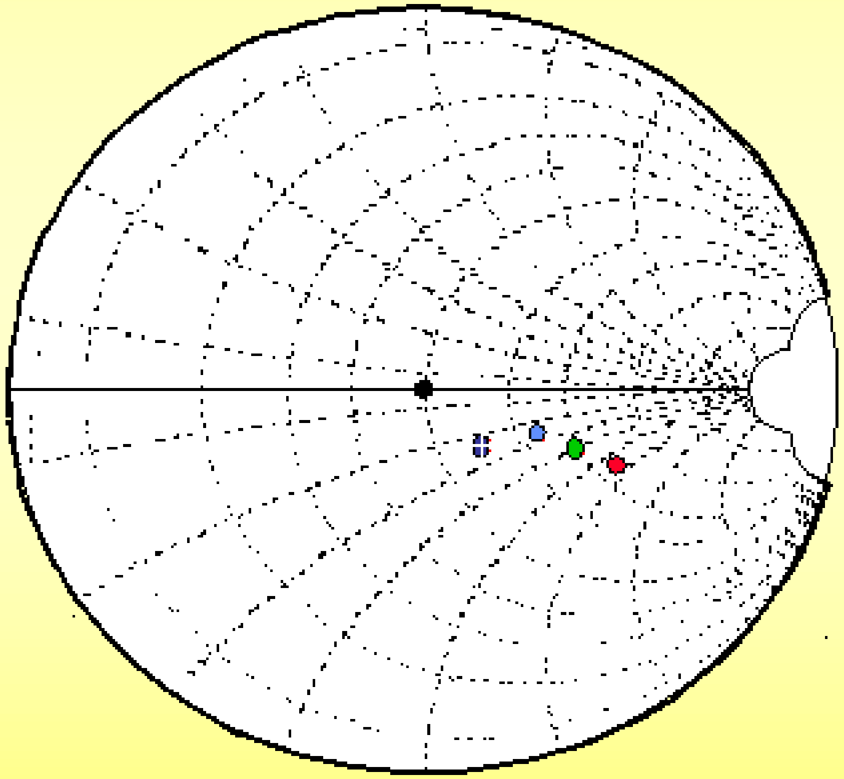
MEASUREMENT OF A SINGLE CELL 1 200 μM TI HFET POWER AMPLIFIER AT 2.18 GHZ NOISE POWER RATIO VERSUS OUTPUT POWER





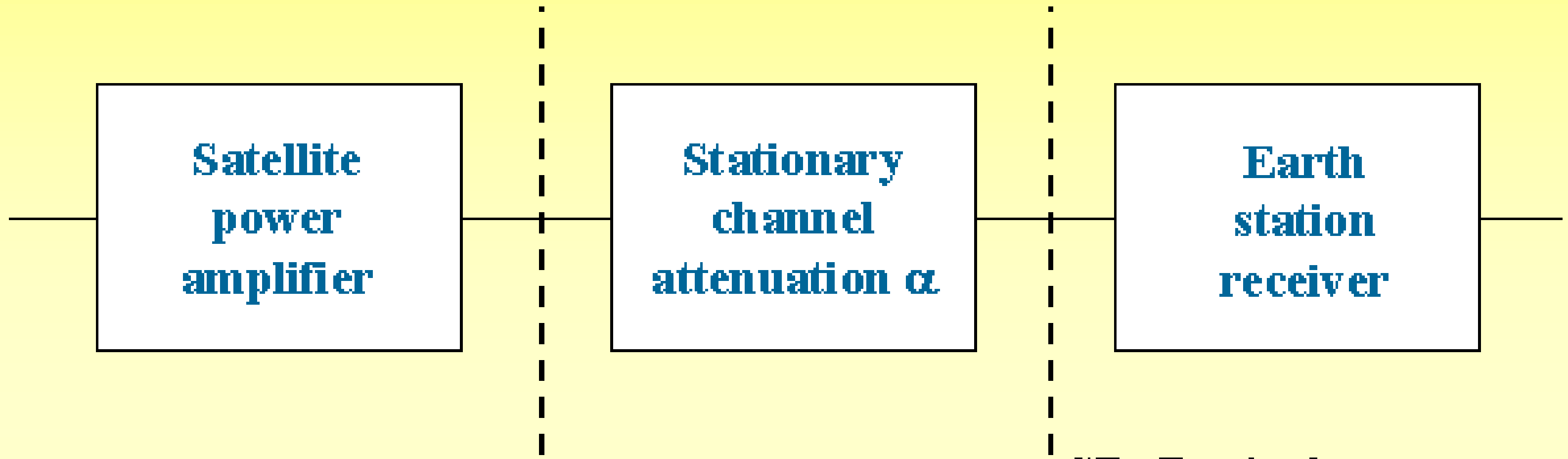
MEASUREMENT OF A SINGLE CELL
1 200 µM TI HFET POWER AMPLIFIER AT 2.18 GHZ
NOISE POWER RATIO VERSUS POWER ADDED EFFICIENCY





The NPR/PAE information in a system level analysis

Example of a satellite downlink :



C : Output power
I : Intermodulation noise

$N = \dfrac{N_R}{\alpha}$ equivalent thermal noise

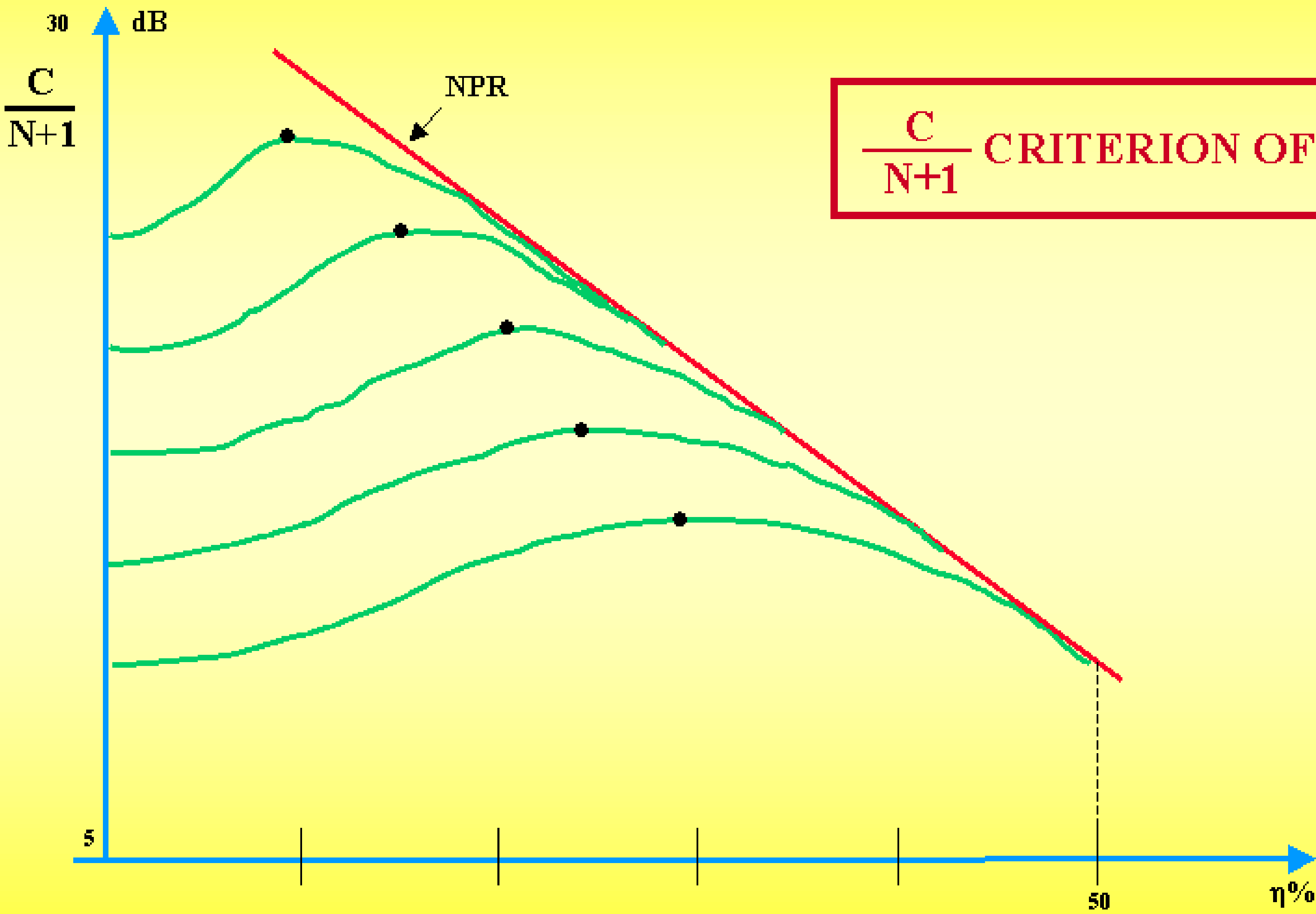
CR : Received power
NR : Thermal noisse

Equivalent signal to noise ratio : $\dfrac{S}{N} = \dfrac{C}{N+1}$

$$\left(\frac{S}{N}\right)^{-1} = \left(\frac{S}{N}\right)^{-1} + \left(\frac{S}{I}\right)^{-1}$$

← N.P.R.

$\frac{C}{N+1}$ CRITERION OF POWER AMPLIFIERS



CONCLUSION

The presented measurement system propose :

- An interesting NPR characterization technique SIMILAR TO THE ONE USED IN envelope transient simulation techniques or multitone HB analysis

- A more general evolutive tool for the characterization of power amplifiers in terms of dynamic input - output envelopes.