PART I

A NOVEL EXPERIMENTAL MULTICARRIER MEASUREMENT METHOD FOR MICROWAVE POWER AMPLIFIERS

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OUTLINE

- Basic considerations
- NPR approach using a digital synthesis of a bandlimited Gaussian noise
- The proposed experimental set-up
- Measurement results
- Conclusion
Linearity versus efficiency characterization of power amplifiers

Classical approach: (CW center frequency AM/AM and AM/PM measurements)

\[
\begin{align*}
\tilde{x}(t) &= A(t)e^{j\varphi(t)} \\
\tilde{y}(t) &= G(A(t))e^{j(\varphi(t)+\theta(A(t)))}
\end{align*}
\]

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

\[
\eta = \frac{\sum k \eta(A(t_k))}{\sum k}
\]
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.
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

FDMA

FDMA/TDMA

CDMA

May be approximated by a bandlimited white gaussian noise
According to the central limit theorem

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

\[ \Rightarrow \]

GAUSSIAN BANDLIMITED WHITE NOISE

BASE BAND SIGNAL SYNTHESIS USING A COMPUTER CONTROLLED ARBITRARY WAVEFORM GENERATOR (AWG)
NOISE TEST SIGNAL CONDITIONING FOR LINEARITY CHARACTERIZATION OF POWER AMPLIFIERS

Channel bandwidth: BW
1000 to 10000 CW carriers. (Equal magnitudes, random phases)

Ideal notch: 5% of BW

Time Domain Representation

Magnitude Distribution
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
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
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 - $F_0 = 2\ \text{GHz}$

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

**Graph:**
- **Y-axis:** PAE (%)
- **X-axis:** Pout (dBm)
- Multiple curves indicating varying output power levels.
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:

- **Satellite power amplifier**
- **Stationary channel attenuation** $\alpha$
- **Earth station receiver**

C : Output power
I : Intermodulation noise
$N = \frac{NR}{\alpha}$ equivalent thermal noise

**Equivalent signal to noise ratio**:

$$\frac{S}{N} = \frac{C}{N + 1}$$

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

N.P.R.
\[ \frac{C}{N+1} \text{ CRITERION OF POWER AMPLIFIERS} \]
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.