ABSTRACT
This paper validates the idea that no matter the notch width, a conventional NPR test produces optimistic in-band distortion measurements, when compared with an hypothetical continuous spectrum excitation test [1], [2]. It also proposes a set-up able to perform these corrected measurements, which became the unique way of co-channel distortion evaluation of systems with memory or driven into saturation.

I. INTRODUCTION
Noise Power Ratio, NPR, evaluation is progressively replacing the ancient two-tone IMD tests, since it provides a convenient way for in-band distortion observation. However, in two recently published papers [1], [2], the authors have theoretically presented the counterintuitive idea that no matter the NPR notch width, it will produce a non negligible impact on in-band distortion. Indeed, they predicted that the usual NPR figure of merit gives a misjudgment of up to 7dB on those distortion components. This means that a corrected in-band distortion evaluation would impose an increase in output power back-off of a power amplifier, PA, by near 3dB, for similar Co-Channel Power Ratio, CCPR, specifications. A new laboratory measurement set-up for CCPR evaluation is, thus, entirely justified, not only because it could experimentally validate the referred theoretical prediction, as it would provide an adequate alternative for the conventional NPR measurement.

By presenting such a laboratory measurement set-up, the present paper aims exactly at these two purposes: it provides the required experimental validation for the referred theoretical conclusions, and shows a viable solution for corrected NPR measurements.

II. CORRECTED CCPR EXPERIMENTAL SET-UP
As was proved in [1], [2], conventional NPR measurements do not allow total in-band IMD power measurement. This is because the notch eliminates many of the possible mixing products that otherwise would fall exactly onto that frequency position. However, the evident solution of filling in the notch can not also be accepted as it would obviate in-band distortion observation. The reason for this is that the linear response of the device under test, DUT, would mask the much smaller output distortion components. So, it seems that the whole fundamental components are required at the input to generate all possible nonlinear mixing products, but are undesirable at the output where they behave as a dominant perturbation to the sought IMD signals.

To solve that dilemma we suggest the excitation of the DUT with the full input spectrum, but then cancel out the linear components at the device’s output. And that can be easily done with the feedforward cancellation loop shown in Fig. 1. This arrangement has, at least, two advantages for supporting it. The first one is that it is sufficiently simple to be built with components that are trivial in any microwave laboratory. And the second is that it has already been fully tested in all feedforward PA linearizers [3].

The set-up of Fig. 1 is composed of a variable noise input spectrum generator, VNG, a calibrated controlled attenuator, ATT, a microwave spectrum analyzer for visualization, and the feedforward cancellation loop.

Our VNG provides configurable noise channels of 300KHz. They are created by low-pass filtering the output of a low frequency noise generator
(300KHz elliptic filter), followed by up-conversion with a double-balanced mixer and a microwave CW generator. This base-band low-pass filtered noise channel can be up-converted directly to generate the required continuous spectrum of a CCPR test, or it can be first high-pass filtered by a narrow bandwidth elliptic filter of 10KHz, to create the usual notch of a NPR test (gap of 20KHz bandwidth). Some care was put on the driving level applied to the mixer, in order to prevent undesirable distortion in this nonlinear device. The DUT driving level is provided by the high IP3 amplifier, HPA. (In fact, the IMD generated in both this HPA and the mixer should be maintained at a reasonable low level, but need not be completely eliminated since it will be cancelled afterwards by the feedforward loop). To guarantee that no LO signal appears on the notch, LO-to-RF mixer isolation was improved by canceling out this LO spurious signal with another bridge network.

Fig. 1 – Proposed experimental set-up for corrected co-channel distortion evaluation.
The variable attenuator, ATT, is intended for input power level control. And finally, the cancellation loop is composed of two branches: one for the DUT (a PA), which also includes a variable attenuator, and one for providing the auxiliary signal path. The latter one is composed of a phase shifter and stretchable-line for fine and coarse phase adjustment, respectively.

The implemented loop was built for a PA with 2GHz central frequency, and was capable of more than 55dB cancellation within the tested 300KHz channel bandwidths. That allowed easy CCPR measurements as high as 45dBc.

The measurement process is based on the fact that, provided the input level is sufficiently small, any mildly nonlinear DUT behaves linearly. Since low level distortion is dominated by 3rd order products, signal-to-distortion ratio will increase 2dB for each dB of input power reduction. This, in turn, leads to the conclusion that by continuously reducing input power, we will end up in a point where distortion power is negligible, when compared to the fundamental output. Let us refer this input power level as $P_{in0}$.

Now, assuming all feedforward loop passive components behave linearly no matter the operating power, a loop adjustment at $P_{in0}$ imposes cancellation of any DUT’s output linear component, regardless of drive level. Therefore, any signal observed on the spectrum analyzer caused by a decrease on ATT value must be some form of DUT distortion.

Obviously, in the case of an imperfect linear components’ cancellation, the residual fundamental signal consists of distortion measurement perturbation. Fortunately, due to the 3rd order nature of the signals to be measured, and the 1st order of the linear components, the distortion to perturbation ratio increases 2dB per dB of ATT’s attenuation reduction.

### III. CCPR AND NPR EXPERIMENTAL RESULTS

Fig. 2 shows measurement results of a conventional NPR test obtained with the above presented set-up. The trace of lowest power corresponds to the residual signal after loop compensation. The one of highest power is the DUT’s output, obtained after a 10dB increase on its input power. It is the response that should be expected from any conventional NPR set-up. The trace of intermediate level is the DUT’s output, after cancellation. It is, therefore, the wanted distortion. Note the difference of about 10dB between the distortion level inside the channels and within the notch.

![Fig. 2 – Conventional NPR test results as measured with the proposed set-up.](image)

The results of a corrected in-band distortion measurement are shown in Fig. 3.

![Fig. 3 – Corrected CCPR test results as measured with the proposed set-up.](image)
The highest level trace is again the DUT’s output at a drive level 10dB above Pin0, while the one near the noise floor is the residual signal, at Pin0, after loop compensation. The distortion reveals itself when the linear components are cancelled. This is the true co-channel and adjacent distortion that would be obtained if the power amplifier were operated under such a continuous spectrum excitation. The inexistence of the valley on the in-band distortion previously observed in Fig. 2, is the proof of the misleading in-band evaluation predicted by [1], [2] on conventional NPR tests.

A closer look onto Fig. 2 and Fig. 3 reveals that the differences in distortion level observed in the bandwidth center are about 10dB. Also, the differences between these results present on the channel edges are nearly 15dB. These are direct consequences of the corrections of 5.6dB and 7dB theoretically predicted in [1], [2] for the center and the extremes of the operative bandwidth, respectively. In house harmonic-balance simulations have shown that the differences between those measured and predicted figures are due to the fact that the experimental input channel spectrum used is not perfectly rectangular as was theoretically assumed. Nevertheless, these results clearly validate the theoretical statement that NPR measurements underestimate co-channel intermodulation, and that a new distortion measurement setup like the one now proposed is needed.

IV. CONCLUSIONS

As a final conclusion, it should be pointed out that this setup indeed validates the theoretical predictions derived in [1] and [2], and represents an alternative way in circumventing the misleading conventional NPR tests co-channel distortion evaluation. But, because the referred theoretical framework assumed a nonlinear system represented as a perfect memoryless third order nonlinearity (in fact, a 3rd degree power series), this measurement setup is also unique in providing co-channel distortion evaluation where these assumptions fail: systems with memory or driven into saturation.

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