CONSTANT INTERMODULATION LOCI MEASURE FOR POWER DEVICES USING H.P. 8510 NETWORK ANALYZER

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Abstract:

A method of characterization for the IMD behaviour of power FET is presented. Curves with constant IMD and constant gain lie on the Γ_L locus have been obtained in order to select the appropriate load for the FET and to maximize the device linearity.
Examples to correlate the validity of this approach referred to the other one for the designing of amplifier chains are presented too.

Introduction:

The distortion level of a FET output signal is deeply affected by the RF load. Its knowledge is of remarkable importance to the design of power linear amplifiers for digital applications.
It is presented here, a method allowing a distortion characterization of the device by using the HP 8510 network analyzer and other instruments usually available in a laboratory.
The characterization vs. distortion of the device is analogous to the one performed by Sèchi (1).
The main difference between the now adopted test circuit and the ones previously employed for distortion measurements (1), (2) lies in the presence of the HP 8510 network analyzer which is connected to the system by means of a coaxial switch.
This latter permits to read simply and accurately the load seen from the device.

Measurement:

The distortion value can be measured by performing the following operations:
- through a matching network, it sends to the device input two sinusoidal signals having the same power, at frequencies W1 and W2 a few MHz apart from the working frequency.
- By reading on a spectrum analyzer at the output the difference (in dB) between the two sinusoidal signals and the first intermodulation products having the following frequencies: 2W1-W2, 2W2-W1.

The block diagram of the utilized set-up is shown in Fig.1.
The device is housed inside an appropriate fixture permitting its connection to the components making up the test circuit.
By means of a coaxial switch, the fixture output is connected to an output matching network, through which the load reflection coefficient can be adjusted.
Such switch allows to connect the output matching network both to the HP 8510 network analyzer and to the fixture containing the FET.
The two connection sections have a different path, but due to the symmetry of the switch internal channels, the reflection coefficient read by the HP 8510 is equal to the one present at the fixture output. Any slight phase difference between the two channels may be adjusted by using the "PORT EXTENSION" option. Use has been made of the "PORT EXTENSION" option in order to take the fixture measurement back to the device drain section. By means of the "PORT EXTENSION" option the calibration section position (to which the measurement is referred) can be adjusted by one "lo" length.

To determine such length, a shortcircuit has been inserted into the fixture: furthermore the calibration section has been lengthened for taking the read reflection coefficient to 180°.
By connecting the HP 8510 network analyzer to the switch, this section is taken back to the same length value (lo).
Several coaxial line parts provided with two internal slugs, described at point (3), are used as matching networks. These networks are narrow band type and so the two input tones have to differ by a few MHz in order to keep the same Γ_L between the fundamental frequency and the intermodulation one.
Anyway, a slight change in distiortion levels has been observed when varying the two tones separation by 10 MHz max.

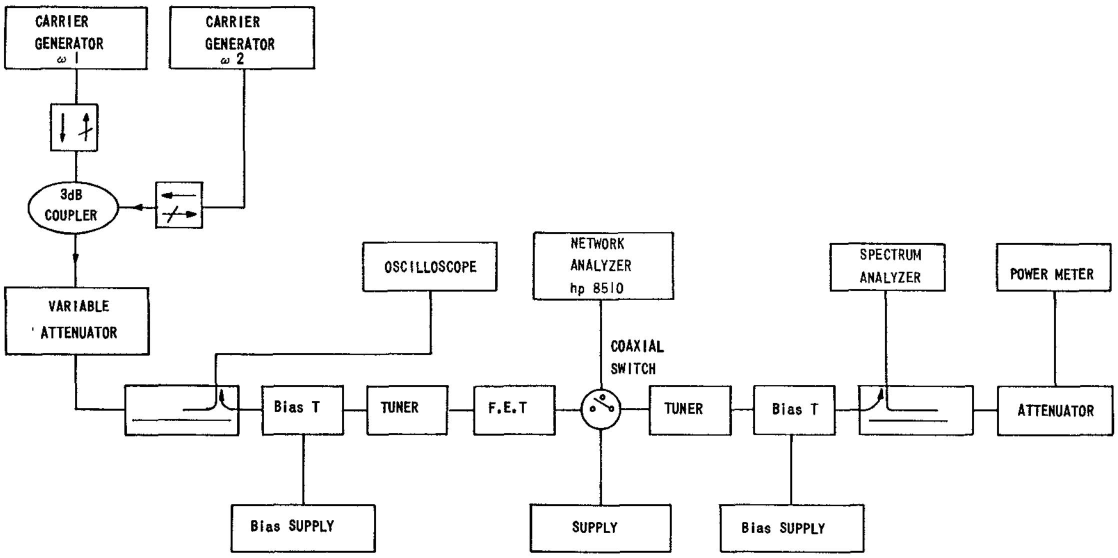

Fig. 1 - TEST SET DIAGRAM

Since in a low distortion power amplifier every stage works in a depth linear region use of S parameters to get the constant power gain circles on the Γ_L locus can be made.

Several gain measurements performed for some Γ_L values have demonstrated an excellent agreement with the gain previewed by the S parameters theory.

Given the high accuracy of the obtained reflection coefficient measurement by means of the HP 8510, the error source is to be found with the reading of the distortion level of the spectrum analyzer comprised within 1 dB.

Results:

Curves with constant IMD and constant gain lying on the Γ_L locus have been obtained in order to simulate the application to amplifying chains.

By making use of the above curves the Γ_L can be obtained thus reducing the IMD to a prefixed gain level.
The utilization of such constant IMD locus is similar to constant noise figure circles for low noise figure amplifiers design (see Fig. 2).

On the basis of measurements performed on the MESFET with Point 1 dB g.c.p. of 1 W in the X band of hermetic ceramic package, it has been observed that the distortion level dependance on the load, increases with the frequency.

On the basis of the measured diagrams at 7.7, 8.0, 8.3 GHz several Γ_L can be chosen, that can optimize not only the maximum gain but also the maximum linearity performance of the device.

For instance, with 7.7 GHz a maximum gain of 6.7 dB with a 48-49 dBc distortion is obtained.
By decreasing to 6 dB the optimum Γ_L with respect to distortion a value of 53-54 dBc is ensured, thus obtaining a distortion level improved by 4-5 dB with a 0.7 dB gain decrease.

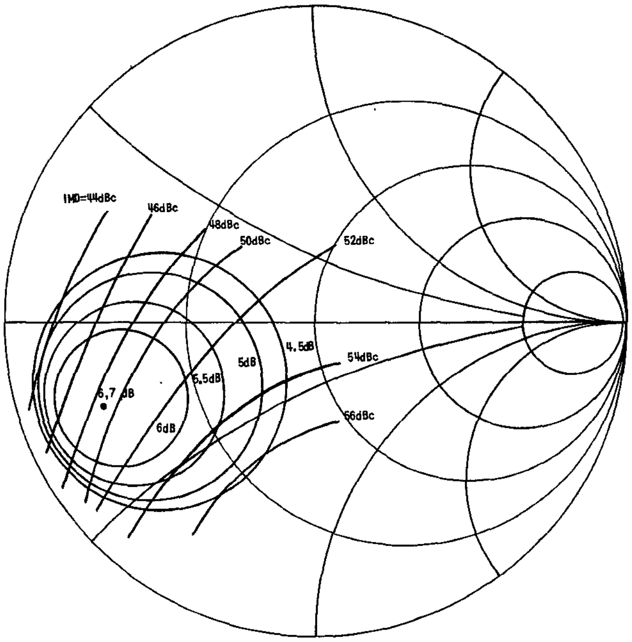

Fig.2a : F = 7.7 GHz Pin=12 dBm

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Fig.2b : F = 8 GHz Pin = 12 dBm

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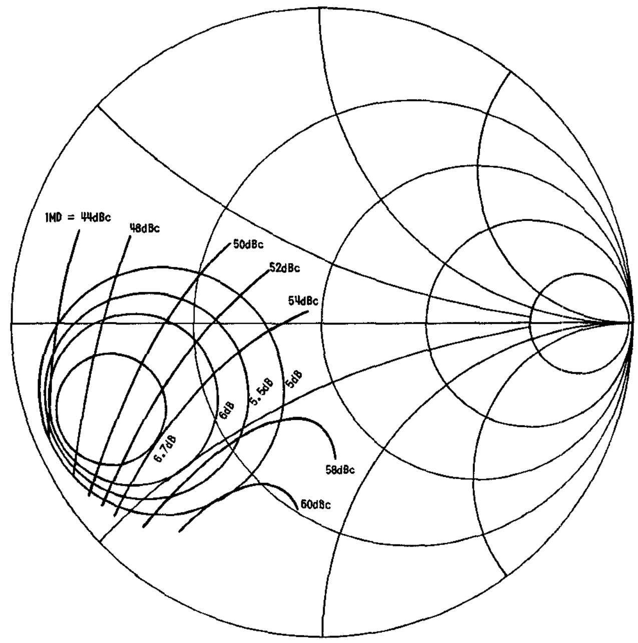

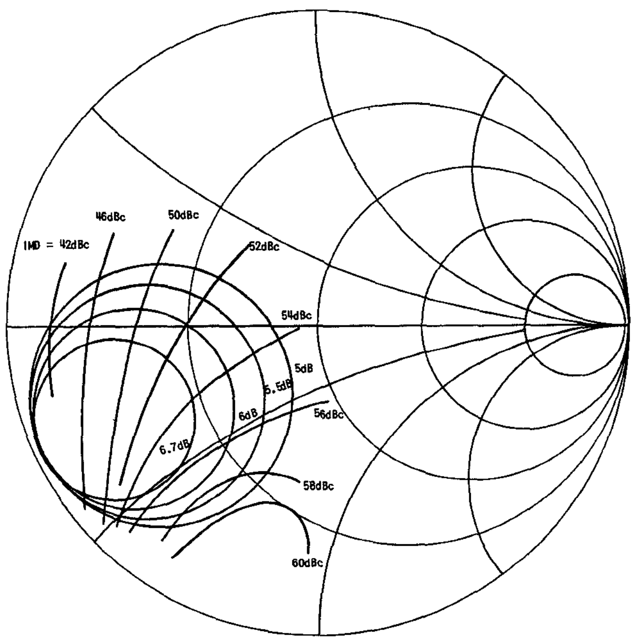

Fig.2c : F = 8.3 GHz Pin = 12 dBm

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Comparison:

Two different amplifiers have been designed; one has been realized with maximum gain and field tuning towards the distortion techniques; while the other is realized by directly utilizing the data obtained by the constant IMD locus. In this way the method efficiency has been demonstrated.
Fig. 3 shows the outputs, read on a spectrum analyzer, of the two designed amplifiers.
Fig. 4 shows the low distortion amplifier scheme together with its matching networks.

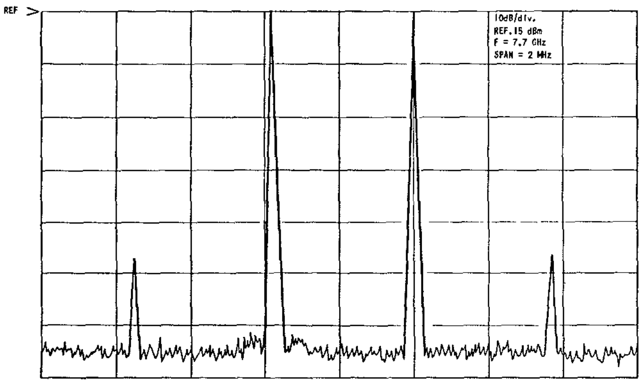

Fig.3a - OUTPUT SIGNALS OF 1 WATT GaAs FET MAXIMUM GAIN AMPLIFIER

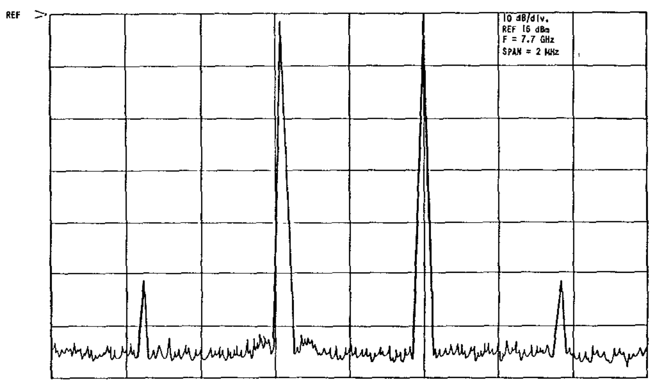

Fig.3b - OUTPUT SIGNALS OF 1 WATT GaAs FET LOW DISTORTION AMPLIFIER

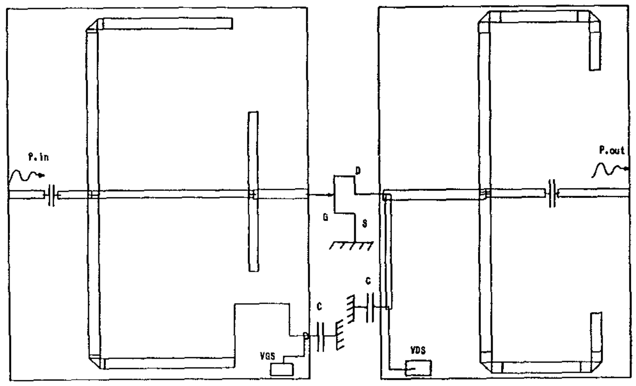

Fig.4 - INPUT AND OUTPUT MATCHING NETWORKS

Conclusions:

In high capacity digital transmissions with critical modulations (16-64-256 QAM) the intermodulation factor acquires a first importance rôle.
It is emphasized the presence of output loading loci with low distortion, not-corresponding to the conjugated matching, able to improve the device linearity, thus keeping the same output power by means of a slight increase of the input power.
Therefore it is of extreme importance to obtain a load characterization vs. distortion, which could be rapidly achieved by means of the adeguate software machines, thus obtaining excellent final results.

References:

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