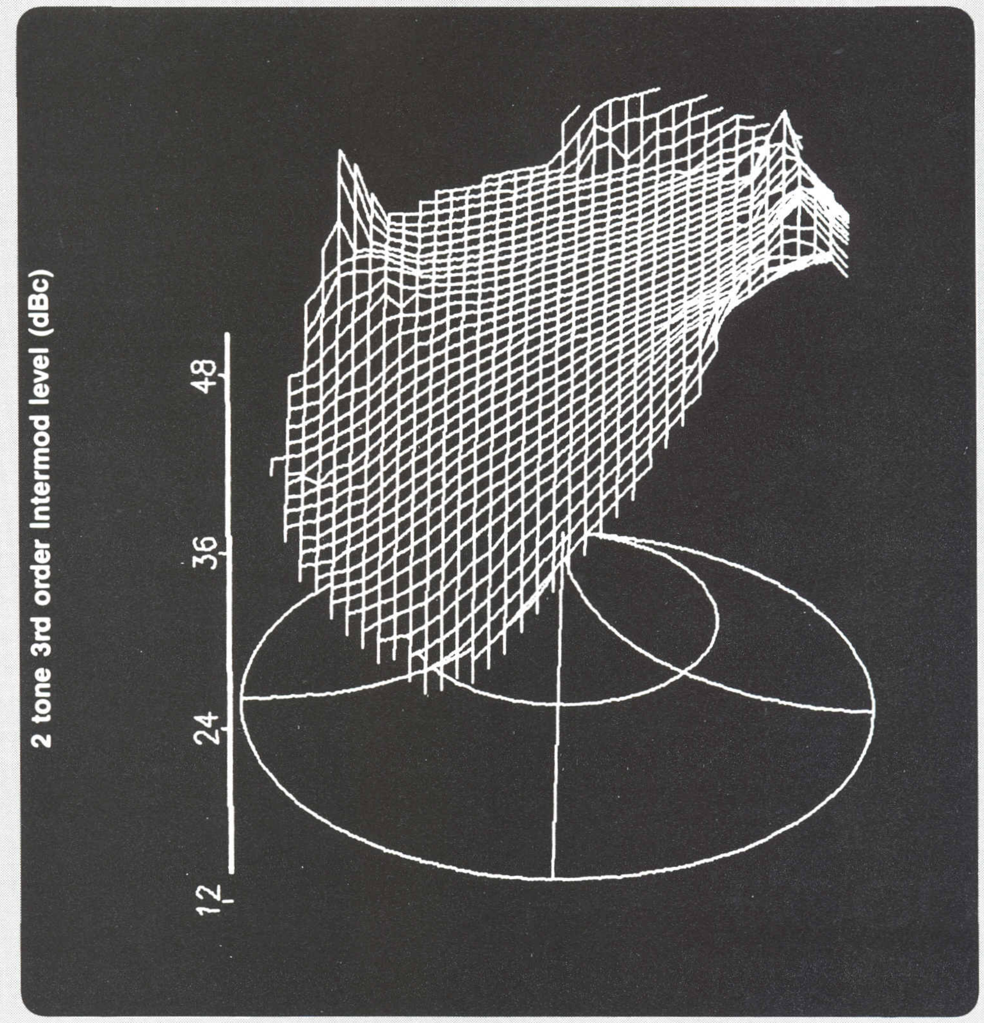
Application Note 1-89

FOCUS
MICROWAVES
INC.

# Two Tone Intermod Measurements Using the Computer Controlled Microwave Tuner




## SUMMARY

Computer controlled Microwave Tuners (CCMT) open new possibilities in the systematic characterization of FETs and other devices used in high linearity microwave applications. This note describes a method for automatic generation of constant 2 tone 3rd order Intermod contours with a dynamic of over 50 dB using computerized tuners (CCMT) of **FOCUS Microwaves** and a standard HP 8569A spectrum analyzer. Combining these contours with jointly measured constant Gain or output Power contours would permit easy design of low distortion amplifiers.

# INTRODUCTION

High linearity solid state amplifiers are needed in all types of multi-channel communication links. The tedious cut-and-try approach for designing such components has been allegated recently with the introduction of various models to simulate the devices' nonlinear behaviour. Though all the models promote better understanding of the nonlinear phenomena they are related to a number of assumptions which make their practical use questionable. It is common understanding in the microwave community that models are used only if there is no practical and accurate measuring technique for the microwave quantity needed. Trying to model nonlinearities down to 40 or 50 dBc which may come from minor nonlinear, mixing or transient phenomena in the FETs is very inacurrate if not impossible.

This note presents a practical method for fast and accurate generation of constant two tone 3rd order intermodulation (IMD) contours associated with constant gain and output power contours. It is based on a Computerized Microwave Tuner measuring system to set the microwave impedance conditions at the input and output ports of the devices, control, read and properly correct associated instruments like power meters and spectrum analyzers.
The measured data files are then converted into 2D contour or 3D surface plots.

# SETUP FOR AUTOMATIC POWER GAIN AND INTERMOD MEASUREMENTS

The setup used (figure 1) allows measurement of Source and Load Pull of output power, gain and 2 tone IMD characteristics. It uses analog or GPIB programmable power meters, two signal sources, a spectrum analyzer and a computerized tuner system (CCMT). The last includes two programmable tuners, one IBM AT system computer with GPIB (IEEE 488) interface and a tuner controller (figure 2). The tuner controller includes besides the stepping motor controller also an analog 12 Bit data acquisition bus.

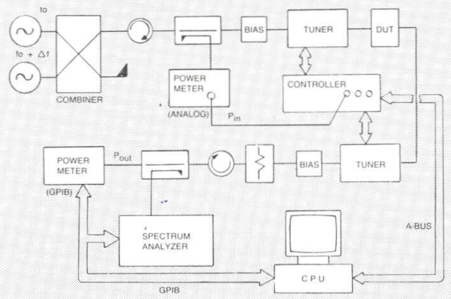



*Fig. 1 - Block diagram of setup used for Power and 3rd order (two tone) intermod characterization of GaAs FETs.*

The input and output tuners were calibrated using an automatic vector network analyzer HP 8510A. They define the source and load impedance conditions at the center frequency with a precision of the order of $\pm 0.005$ reflection factor units. If the frequencies of the injected signals do not differ by more than about 10 MHz the nominal phase error due to difference in the impedances at the two signal frequencies is limited to 1.5°, because the CCMT tuners are inherently wideband devices.

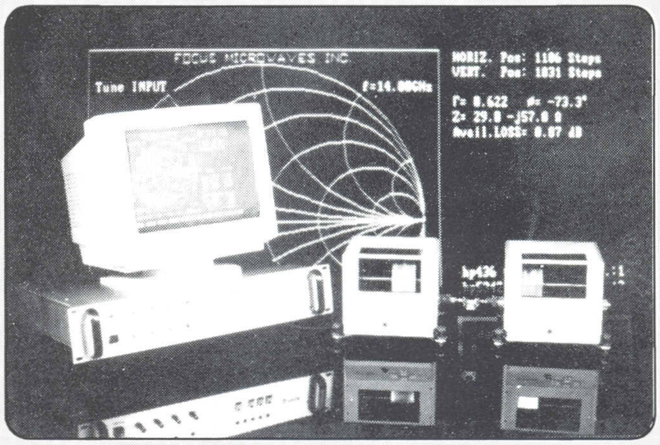


*Fig. 2 - Computer Controlled Microwave Tuner system of FOCUS Microwaves inc.*

When the two signals are injected into the FET the well known image of figure 3 appears on the screen of the spectrum analyzer. The ratio between the two main and the two secondary harmonic pairs is the 2 tone 3rd order intermodulation distortion product.
The CCMT control and application software includes drivers for control and reading the HP 8569 and 8562 spectrum analyzers, the HP 436/7 power meter and a number of other popular GPIB instruments.

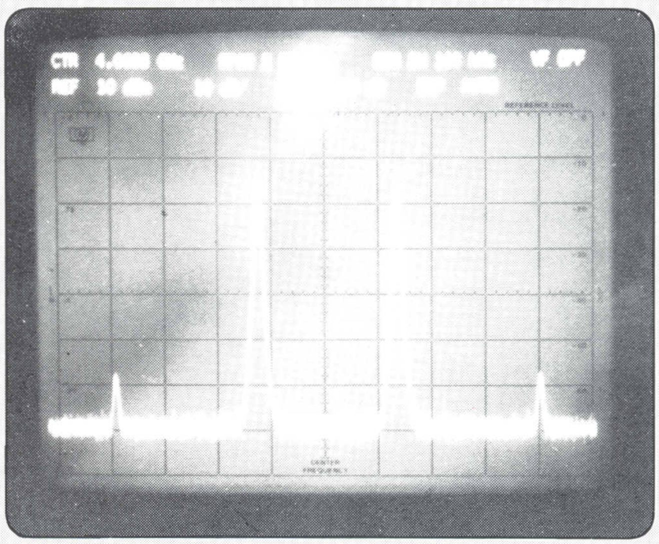


*Fig. 3 - Third order (two tone) IMD shown on HP 8569 spectrum analyzer.*

In the case of the spectrum analyzer however the evaluation of the produced image with up to six arbitrarily appearing harmonic components on the digital screen is quite more complex than a simple numeric reading of other instruments via the IEEE bus.
In particular the case where the secondary intermod products nearly disappear in the noise floor of the analyzer has to be interpreted correctly by the control software.

The CCMT application software includes routines which accomplish this task succesfully under all conditions for a dynamic of more than 60 dB, which is mainly imposed by the characteristics of the spectrum analyzer.

The CCMT has manual or automatic tuning capability to microwave source or load impedances in order to search optimum power gain or intermod conditions.
The results described in this note however have been obtained using the automatic impedance scanning capability of the system.

This consists of automatically tuning to a great number of reflection factor values perfectly equally distributed over the Smith Chart and measuring the Power, Gain or Intermod values at each point, save them as binary data file on disk and process the data after the end of the measurement to iso-contours or 3D surface plots (see cover page).
The number of points the system can measure automatically can be set by the user between a maximum of 360 points and a minimum of under 50 points per measured frequency. Experience shows that at least 90 points should be used in order to get a reasonable amount of information on the contour plots.

Figure 4 shows the typical distribution and density of the 180 measurement points used to generate the contours of figures 6 and 7.

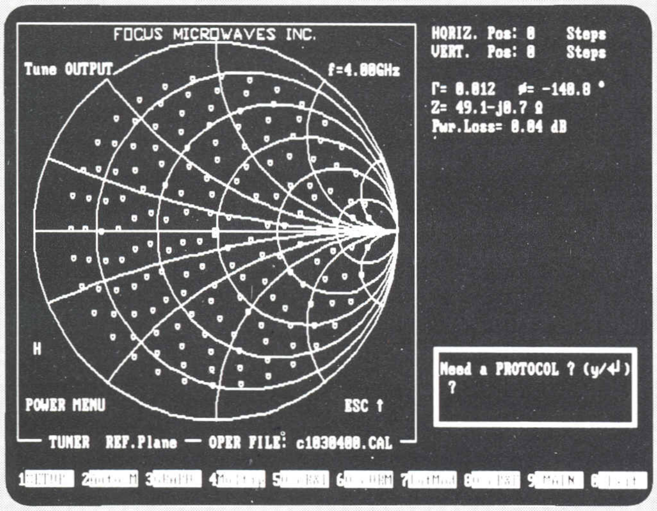



*Fig. 4 - Distribution of impedances for automatic load / source pull measurement.*

# MEASURED RESULTS

The power, gain and two tone IMD load pull of a medium power GaAs FET, NE8002 of NEC, have been measured using the setup of figure 1 at the frequency of 4 GHz. The total power injected into the device by the signal sources was 11 dBm and the maximum device gain was measured to 9.9 dB. The NE 8002 is rated at P−1db = 29 dBm. Under actual conditions the output power of the FET at maximum gain becomes 20.9 dBm.

Figure 5 shows the intercept levels of this device.

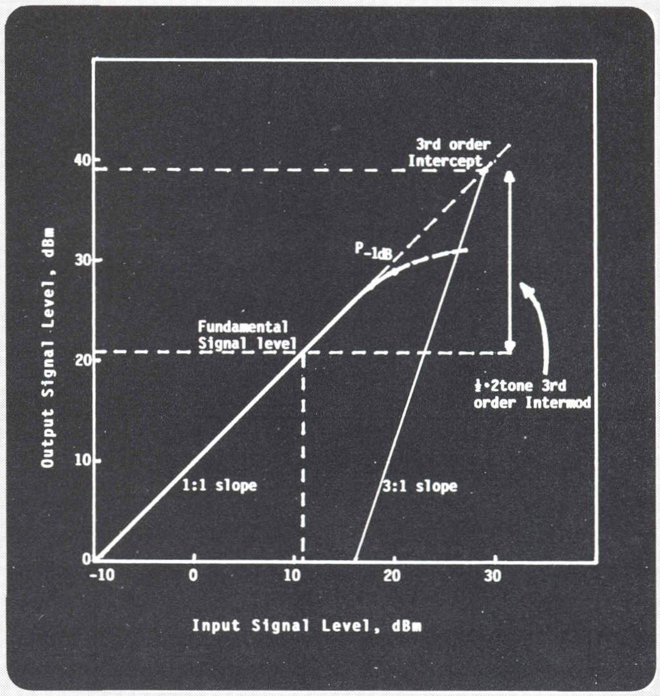



*Fig. 5 - Intercept diagram*

According to the "rule of thumb" for microwave GaAs FET amplifiers

Intercept point

$$= 10\text{ dB} + P-1\text{dB} \quad (1)$$

2 tone 3rd ord IMD

$$= 2 \times \{ \text{Intercept Point} - \text{Pout} \} \quad (2)$$

We obtain in the case of the NE8002 (figure 5):

Intercept point

$$= 10\text{ dB} + 29\text{ dBm} = 39\text{ dBm} \quad (3)$$

2 tone 3rd ord IMD

$$= 2 \times \{ 39\text{ dBm} - 20.9\text{ dBm} \} \approx 36\text{ dBc} \quad (4)$$

Figure 6 shows the constant small signal gain contours of the NE8002 measured over the complex load reflection factor.

Figure 7 shows the constant two tone 3rd order Intermodulation Distortion contours measured under the same conditions.

The intermod level of 36 dBc at point A in figure 7 which corresponds to gain matching (point A in figure 6) signifies that the result of the measurement is well consistent with the rule of thumb, equation (4), at this specific load value.

However figure 7 also shows that linearity can be increased substantially at the price of some loss in power gain.

This can be seen very easily when the plots of figures 6 and 7 are superposed; If the FET is matched at the output for maximum gain (Z-load = 20 Ω + j 6.5 Ω, point A), then it will provide 9.9 dB of linear gain associated with 36 dBc IMD.
If however the device is loaded with Z-load = 15 Ω − j 15 Ω (point B) it will provide 45 dBc IMD (increase of 9 dB) at 8 dB associated gain (loss of only 1.9 dB!). Proper selection of the loading conditions however requests that the design engineer has access to this type of charts.

Typical data of commonly used FETs, as shown in figures 6 and 7 should therefore become available to the designers in order to enable effective designs of low distortion microwave amplifiers.

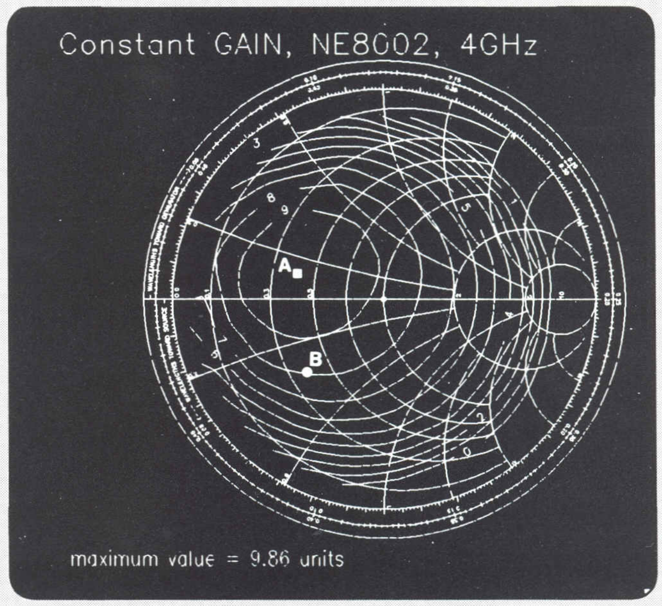



*Fig. 6 - Constant Gain contours of FET NE8002 at 4 GHz (Pin = 11 dBm, input matched for maximum gain)*

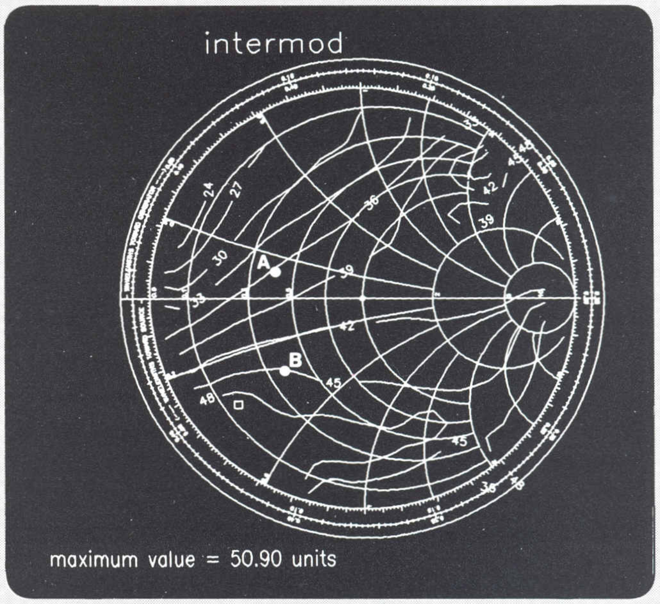



*Fig. 7 - Constant 3rd order (two tone) IMD of NE8002 at 4 GHz (Pin = 11 dBm, input matched for maximum gain)*

## CONCLUSION

A fully automatic setup based on a calibrated programmable microwave tuner has been described. It provides key information data on how to optimize the design of low distortion FET microwave amplifiers especially in respect to a tradeoff between gain and linearity. These data include load and source pull contours for constant gain, output power and two tone 3rd order IMD characteristics.

Measured data have been provided for a NE8002 GaAs FET at 4 GHz.