Lab 3 - Part I: Measurements on CREE CGH40010F Evaluation board PA

Varun Mannam

***Abstract*—We performed the linear and non-linear measurements on the Cree CGH40010F transistor which is operating at 3.5 GHz. The linear measurements are the small signal gain vs frequency, which is observed using S-parameters of the transistor. The non-linear measurements are the large-signal gain analysis, which includes the AM-AM characteristics (Pin vs Pout) and IM3 vs frequency. These measurement results are matched closely with the given CREE CGH40010F data sheet.**

I. Introduction

In-order to characterize the power-amplifier (PA), we need to measure few parameters of the amplifiers. Those are linear and non-linear measurements. In our lab, professor gave us a CREE CGH40010F PA evaluation board which is operating at 3.5 GHz. This board has RF ports for input and output.

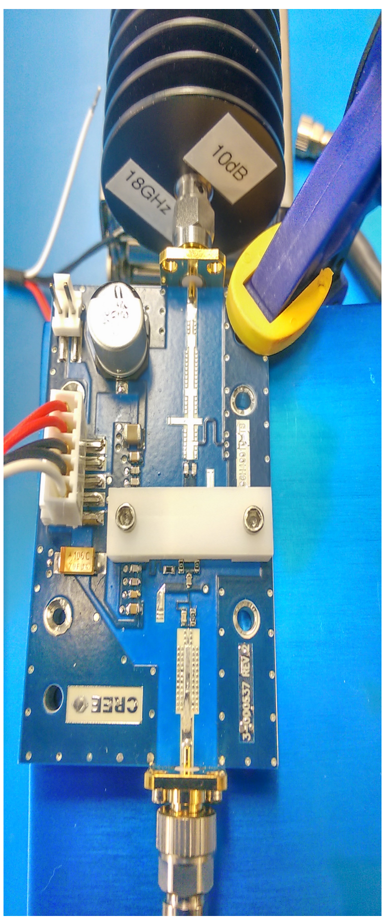

Fig. 1. CG40010F Power Amplifier Evaluation board

From the data sheet of the Cree CGH40010F, the power amplifier is operating at 3.5GHz needs dc power supplies of the 28volts for drain and gate voltage varies from -4volts to -1volts. The red lines in the figure1 represents the drain dc power supplies, white one is gate dc power supply and black wires are the neutral lines.

This evaluation board has matching network. The breakdown voltage is 110volts. Since by using the bias point we are not sure of operating at which class, since class A has peak voltage of $2 * Vds$, where as class E has $3.56 * Vds$, so it is safe to operate the drain at 28volts. The drain maximum current is limited by 200 mAmp. The gate maximum current is limited by 10 mAmp for safe operation. The maximum current is limited by 1.5 Amp from the data sheet.

The linear measurements are the small-signal gain vs frequency. This are measured using the S-parameters of the amplifier. In that measurement of s-pram's the $S21(dB)$ shows the forward gain vs frequency of the transistor. We have to check the $S12(dB)$ to know how-much reverse path gain is attained at the designed band of interest.

The non-linear measurements are like Pin vs Pout with 1-dB compression point and third order inter-modulations. These measurements are performed using 2-tone test which we did in our previous labs.

The power rating of the PA is 13 Watts. We used a couple of attenuators in our circuit to protect the PA and test equipment. From the figure1 we can see an attenuators of 10 dB with high power rating. The spectrum analyzer handles maximum power of 1watts. Here we added one more 10dB attenuators with lower power rating. Accounting the cables in all measurements is important.

We used the CREE PA and measured the RF performance.The performance metrics are compared with the data-sheet values and explained if any discrepancy exists.

II. Small signal gain

It is crucial to measure the S-parameters of the PA, which provides significant in-sight about the forward gain, reverse gain and reflections at input and output ports.

A. Calibration

Before measuring the S-parameters, it is better to calibrate the cables and know the cables loss and prepare the table for each frequency what are the cable loss.

Before inserting the PA in the design, perform the port1 and port2 calibration step. This is done by connecting

3-different loads like Open, Short and matched load (50 Ohms). The Keysight vector network analyzer (PXA) has the option to verify the calibration of each port with these options.

For port1 do the following steps

1) Connect the Open circuit load to port-1, do the calibration in PXA box.
2) Connect the Short circuit load to port-1, do the calibration in PXA box.
3) Connect the matched load (50 Ohms) load to port-1, do the calibration in PXA box.

Repeat the same for port-2 as well.

B. Measurement setup

Now insert the PA in between port-1 and port-2. We provided the dc power supply of 28volts to drain and -2.5volts to gate so that the drain current reaches the 200 mAmp. The PA designed to operates at 3.5GHz, select the frequency range of 10MHz to 10GHz. With proper dc power supplies at this stage the $S21(dB)$ is 14.5dB @ 3.5GHz.

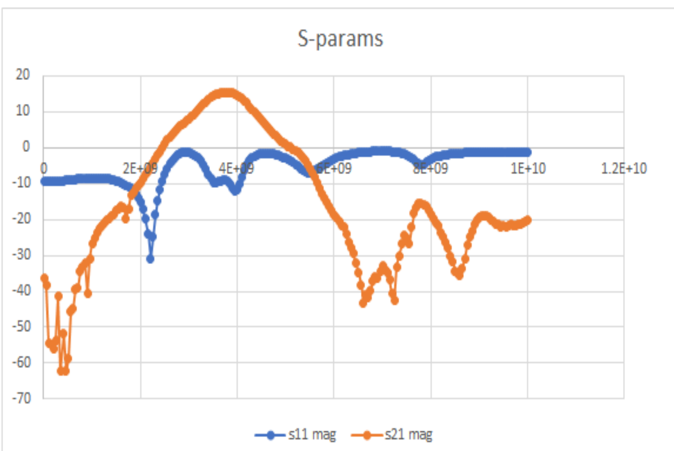

Fig. 2. S-parameters of the Power Amplifier (S11 and S21)

We can save this calibration table to a file in PXA. These are the S-parameters for backward gain and output return loss.

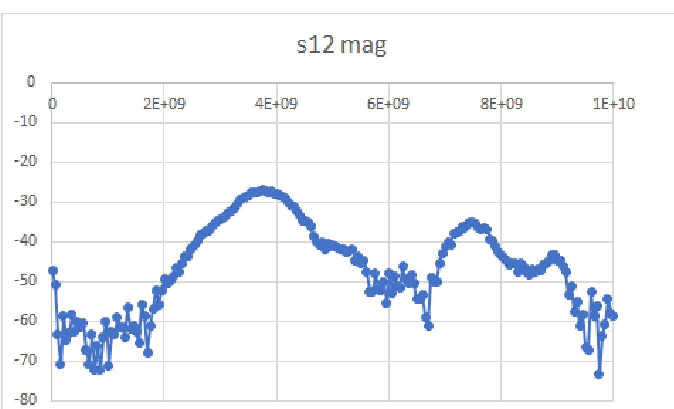

Fig. 3. S12 (dB) of the Power Amplifier

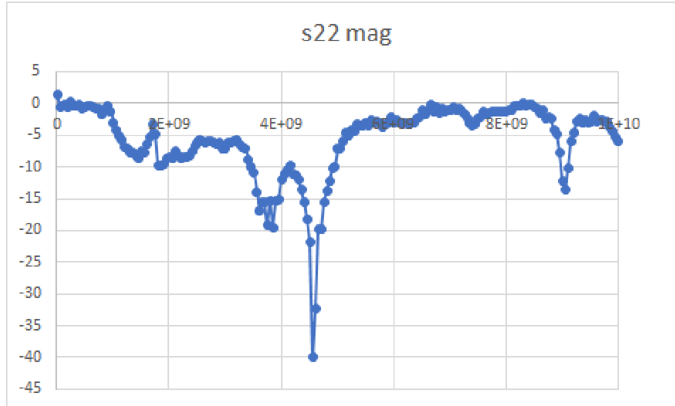

Fig. 4. S22 (dB) of the Power Amplifier

C. Linear Gain

The gate voltage is increased in steps of 0.1v, and observed the $S21(dB)$ values using network analyzer (PXA), clearly we can see as the Vgs increases, drain current increases and $S21(dB)$ which is linear gain is increased slowly.
Professor showed this step of increase $S21(dB)$ at the desired frequency till drain current reaches its maximum value of 200 mAmp. To see the linear gain at each frequency point with drain max current, we can look at the above $S21(dB)$ graph.

III. Non-linear measurements

In this section we perform the non-linear measurements of CGH40010F power amplifier using one-tone and two-tone tests. In this section, we discuss mainly about the Pin-Pout curve and third order inter-modulation values.

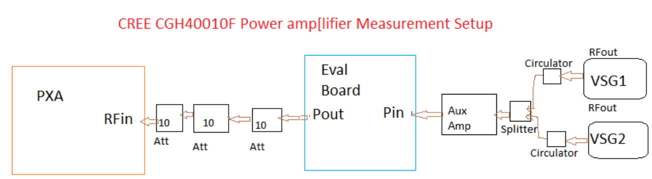

Fig. 5. Measurement Setup for Evaluation board PA

A. Requirements

In-order to use the PA in the full range, we need an auxiliary amplifier to boost the input signal before fed to PA input. We used a microwave buffer amplifier (part number:87415A) which operates at frequencies range of 2-8 GHz.

B. Losses measured in each stage

From the figure5, we measured the total loss with and without amplifier and auxiliary amplifier. We got the loss due to each component. The Coupler and splitter gave the loss of 3.8dB, the each cable has loss of 1.1dB. With PA and aux amp loss is 8.3 dB. Without PA, but with aux amp gain is 22.3 dB.

Without aux amplifier, the loss is 36-37 dB. The gain of the PA is 14dB and gain of auxiliary amplifier is 30dB. (Note: At this stage reference offset is set to 20dB and its compensated in calculations).

C. Pin-Pout curve

We used a single tone (1-tone) input at various power levels and measured the Pout using the VSA. Initially we increased power in steps of 10 dBm, but later power is increased in steps of 1 dBm and 0.1 dBm. The following shows the Pin vs Pout graph (without losses compensation).

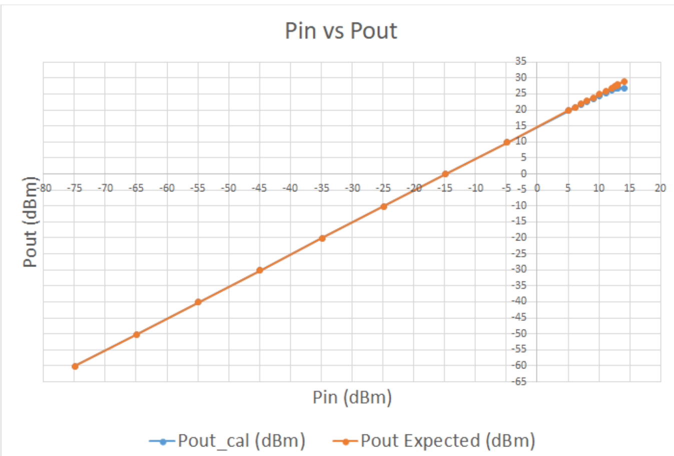

Fig. 6. Pin-Pout characteristics

Clearly from the curve at 13 dBm input power, there is 1-dB compression point which results Pout is 27.8 dBm. So the gain of the Power amplifier is 15dB. From the Auxiliary amplifier data spec it looks like close to 30dB gain @3.5GHz.

D. IM3 vs Frequency

We used a two tone (2-tone) inputs at same power levels and measured the Pout at inter-mods using the PXA. Initially we increased the input power in steps of 10 dBm, but later input power is increased in steps of 1 dBm.

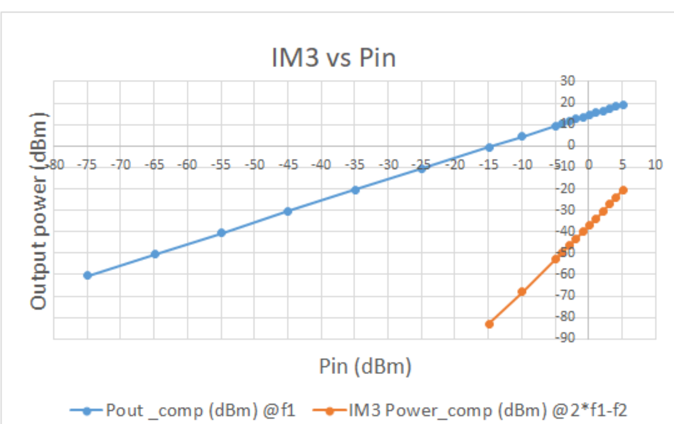

Fig. 7. Third-order inter-modulations vs Pin

To find the IM3 point, the Pout at f1 and IM3 at 2f2-f1 power levels should meet. So we interpolated this data for more number of power levels.

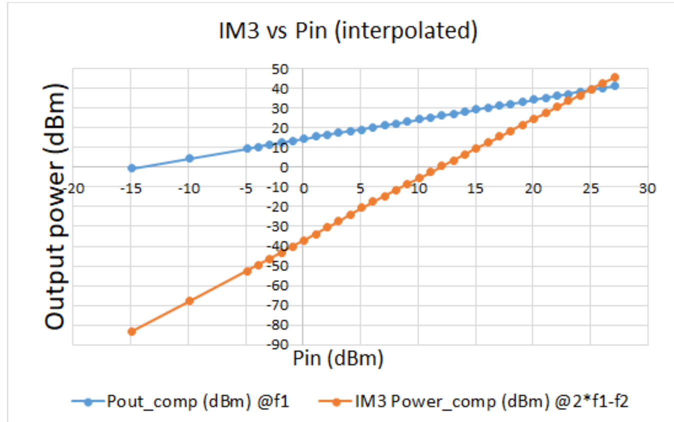

Fig. 8. Third-order inter-modulations vs Pin

We observed the OP1dB and IM3 power are intersecting with

Pin (dBm)	IM3 Power (dBm)
-4.9	-52.67
-3.9	-49.54
-2.9	-46.45
-1.9	-43.33

TABLE I
IM3 POWER VS PIN

30 steps which results 25.1 dBm as IIP3 value and 39.5 dBm as OIP3 values.

IP1dB (dBm)	OP1dB (dBm)	IIP3 (dBm)	OIP3 (dBm)
13	28	25.1	39.5

TABLE II
MEASURED VALUES

IV. CONCLUSION

We did the power amplifier linear and non-linear measurements. We understood how to setup the dc-values for PA and how to measure the S-parameters using PXA. We verified the measured values are closely matching with the data sheet values. This gave us confidence to measure our designed PA in the coming labs. Coming to small signal analysis, we took the $S21(dB)$ values and mapped to the linear gain. For non-linear measurements, we used one-tone and two-tone tests, same as with our previous labs. The compression point and IM3 points are measured and verified using data sheets.

V. ADDITIONAL RESOURCES

1) http://literature.cdn.keysight.com/litweb/pdf/5091-1358E.pdf

REFERENCES