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EEE412 Lab #2

"I completed this homework assignment independently."

Question #1

In this question, S-parameters of the transistor are saved as a touchstone file format for 7V and 10V, inside the band 90MHz to 110MHz. Then, S_{21} is plotted on the network analyzer. The chosen frequency is 100MHz. A power sweep is done between -50dBm to -10dBm. Using the markers, 1dB compression point is found with voltage varying from 5V to 12V with 1V steps. Below, measurement photos can be seen for each voltage value (Fig. 1-8).

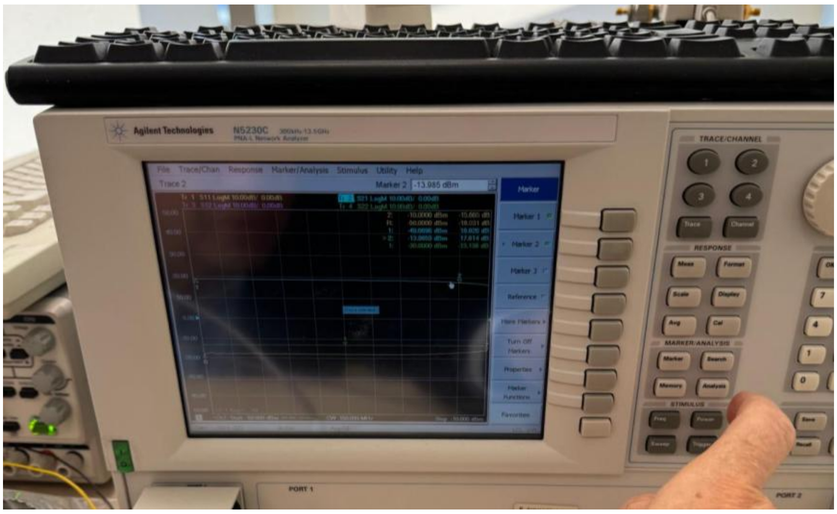

Fig. 1: S_{21} plot for input voltage = 5V

Fig. 2: S_{21} plot for input voltage = 6V

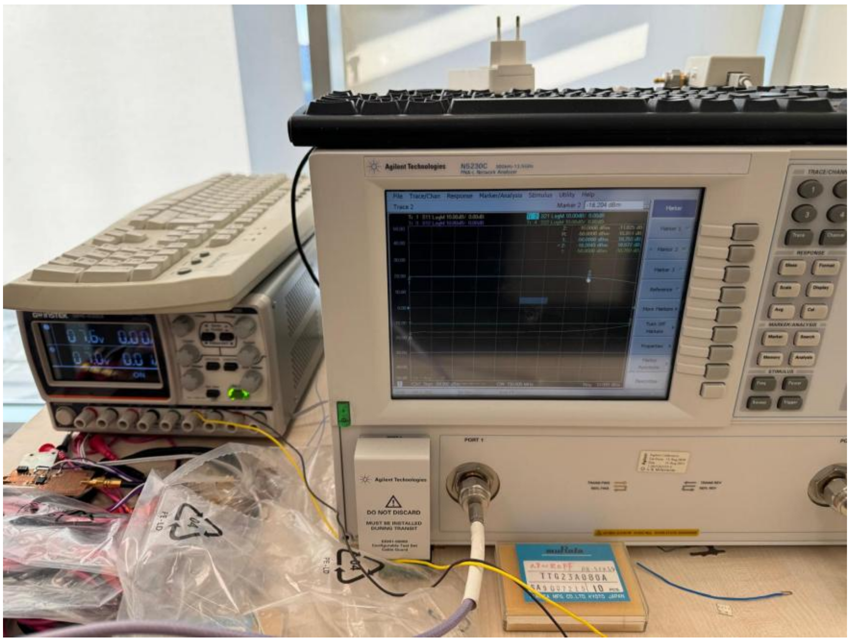

Fig. 3: S_{21} plot for input voltage = 7V

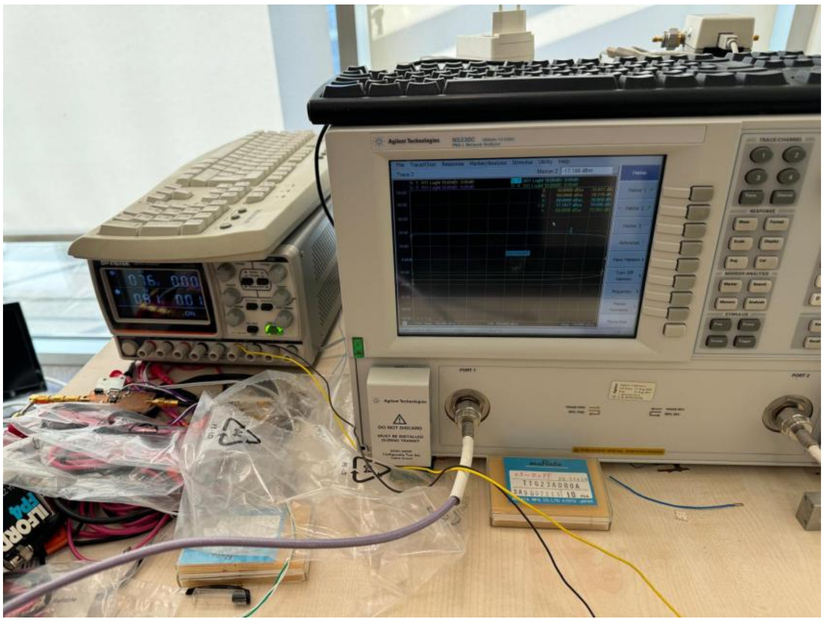

Fig. 4: S_{21} plot for input voltage = 8V

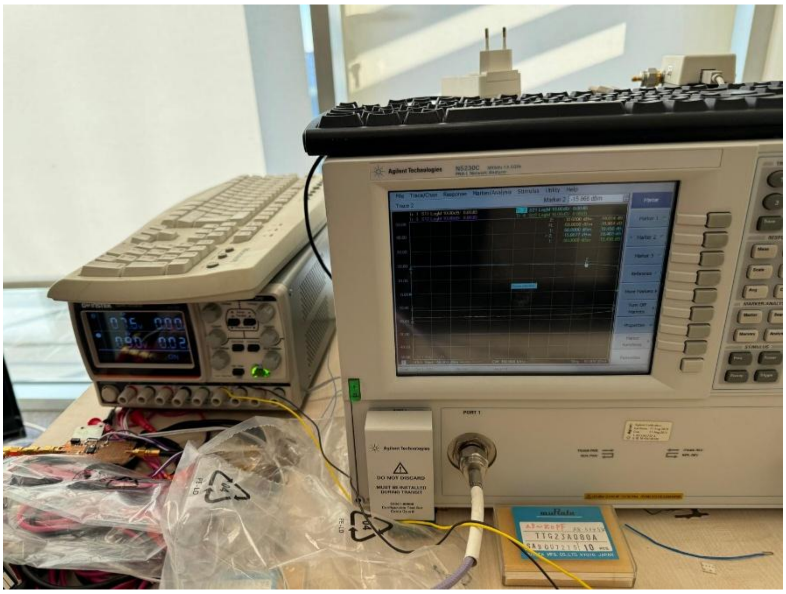

Fig. 5: S_{21} plot for input voltage = 9V

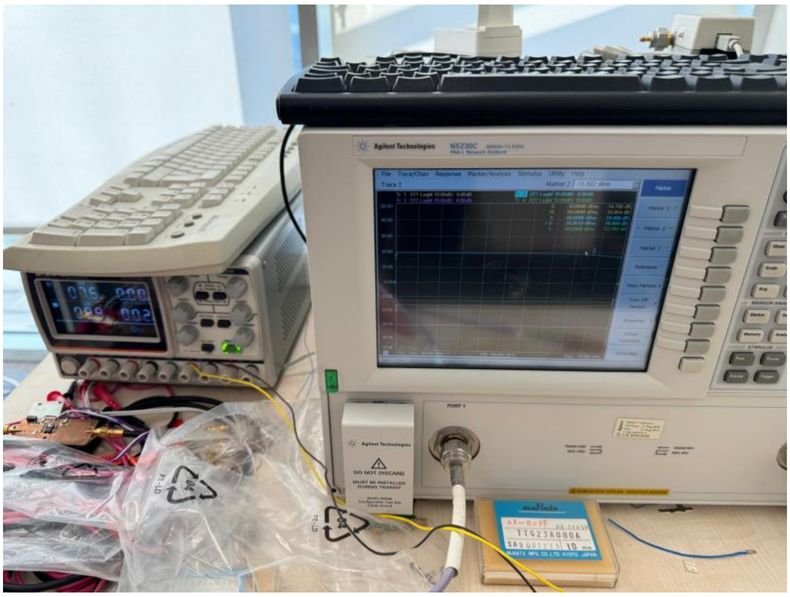

Fig. 6: S21 plot for input voltage = 10V

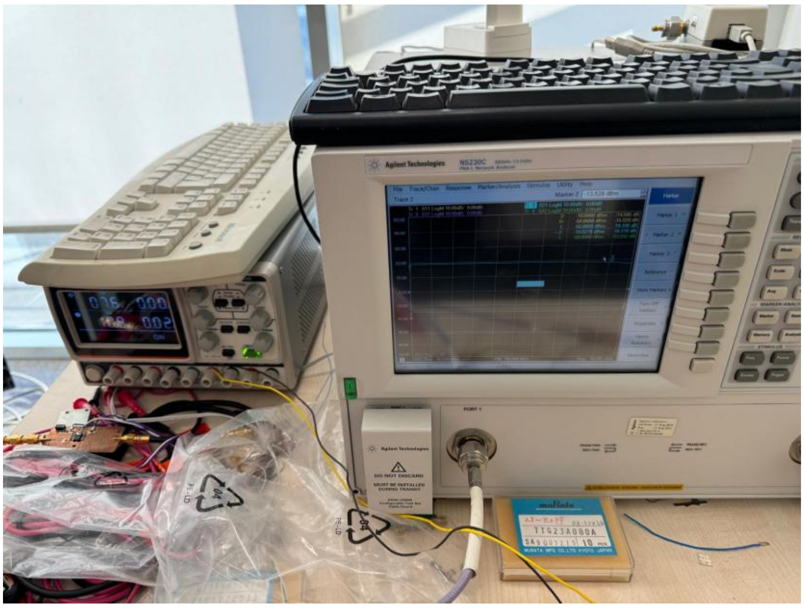

Fig. 7: S21 plot for input voltage = 11V

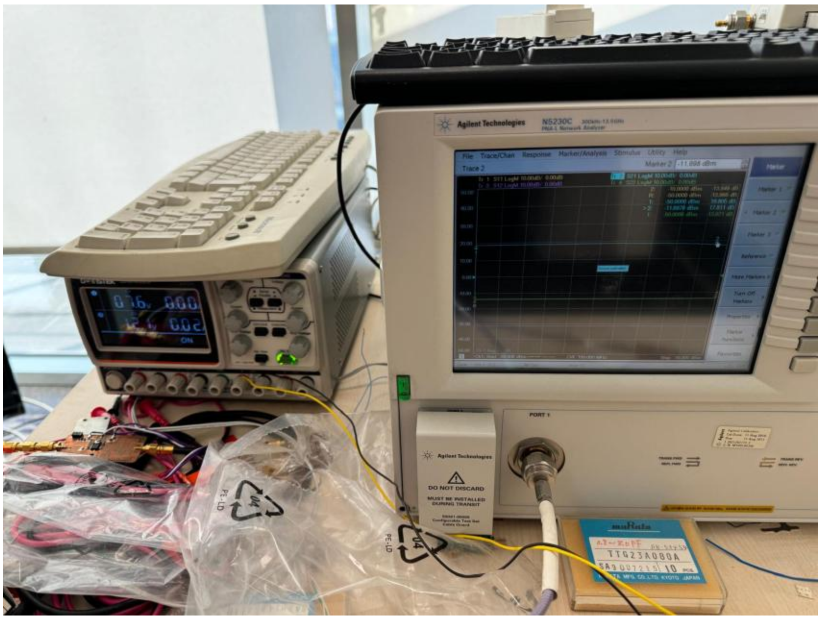

Fig. 8: S21 plot for input voltage = 12V

In all of the figures above, the first marker is set at -50dBm, and the second marker is put at where the gain is 1dB lower. Using the gain information measured, output 1dB gain compression points are calculated. In the table below, $P_{out,1dB}$ value for each case is given.

$$P_{out,1dB} = P_{in,1dB} + Compressed\ Gain$$

Table 1: Measured output 1dB compression points for different voltage levels

Supply Voltage	$P_{in,1dB}$ (dBm)	Compressed Gain (dB)	$P_{out,1dB}$ (dBm)
5V	-22.3916	18.221	-4.1706
6V	-20.8476	18.118	-2.7287
7V	-18.2043	18.672	0.4677
8V	-17.1877	18.099	0.9113
9V	-15.9677	18.463	2.4953
10V	-15.0019	18.484	3.4821
11V	-13.5728	18.179	4.6512
12V	-11.6978	17.811	6.1132

Fig. 9 shows the simulation plot with markers indicating the output 1dB compression points for each voltage level.

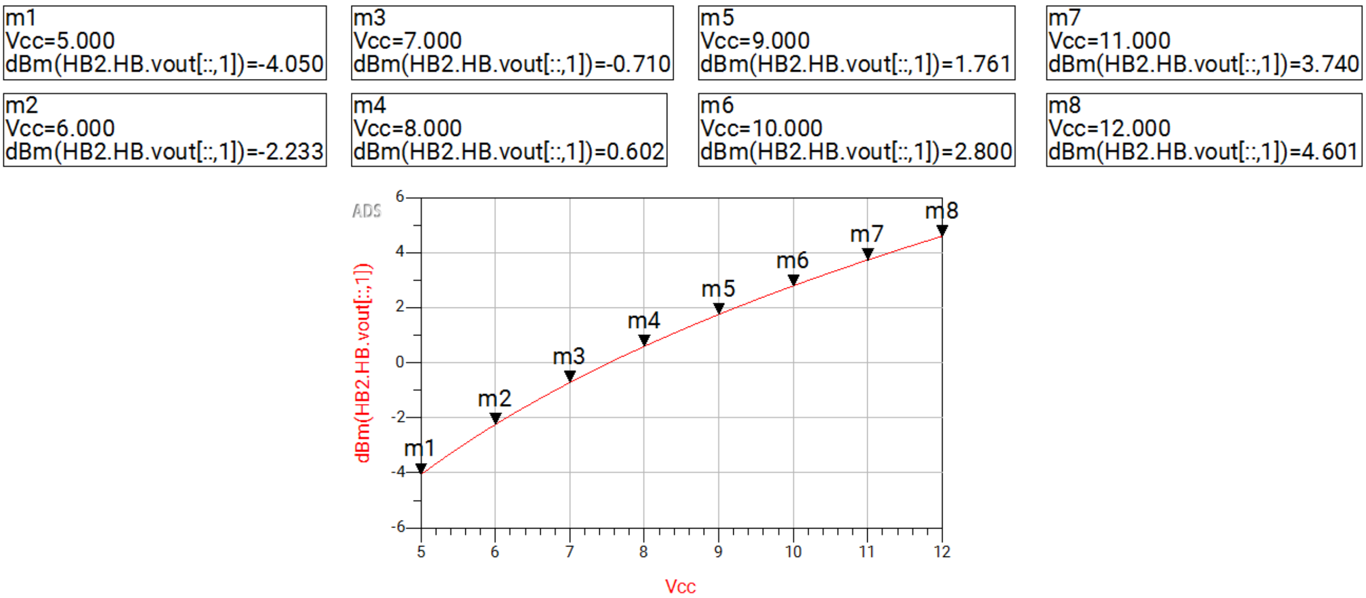

Fig. 9: Simulation results for $P_{out,1dB}$

The experimental values are also plotted, which can be seen on Fig. 10.

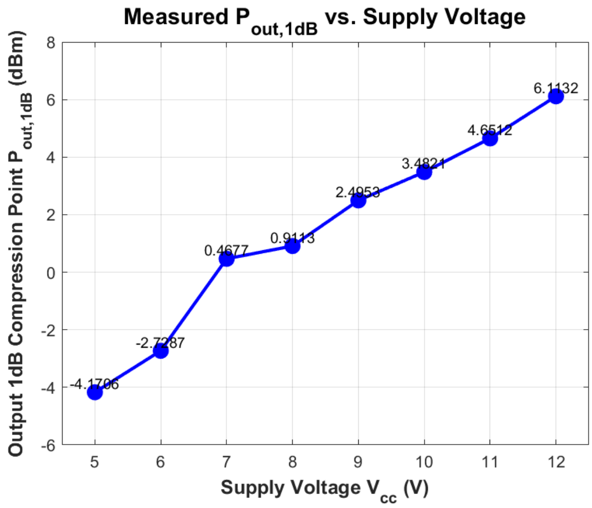

Fig. 10: Experimental results for $P_{out,1dB}$

A comparison table is created to compare the simulation results with experimental results.

Table 2: Comparison Table of Output 1dB Compression Points

Supply Voltage	**Experimental $P_{out,1dB}$ (dBm)**	**Simulation $P_{out,1dB}$ (dBm)**	**Difference (dB)**
5V	-4.1706	-4.050	0.1206
6V	-2.7287	-2.233	0.4957
7V	0.4677	-0.710	1.1777
8V	0.9113	0.602	0.3093
9V	2.4953	1.761	0.7343
10V	3.4821	2.800	0.6821
11V	4.6512	3.740	0.9112
12V	6.1132	4.601	1.5122

Looking at the table above, the maximum difference between the experimental and simulated results is calculated as 1.5122dB, at 12V. Overall, the output 1dB compression points are gradually increasing, which is expected. The results are similar with a slight error included. Therefore, the experimental results are satisfactory.

Question #2

For this question, supply voltage is set to 6V, as chosen in the preliminary part. Frequency is also chosen as 100MHz in the preliminary work. For part a, the amplitude is set to -37dBm because there is 3dB loss. So both generators' amplitude is set to -37dBm. The first generator's frequency is set to 100MHz and second generator's frequency is set to 101MHZ. The magnitudes of the third order products are measured.

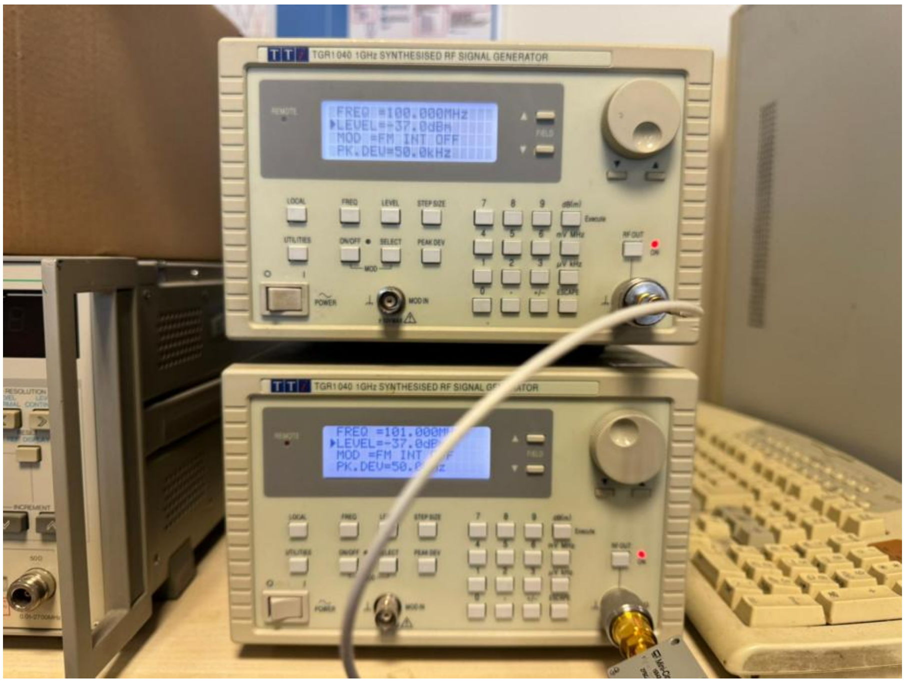

Fig. 11: Generator setup for part a

Because the input signals are at 100MHz and 101MHz, $2f_1$-f_2 third order product will be located at 99MHz, and $2f_2$-f_1 third order product will be located at 102MHz. Fig. 12 shows the first fundamental component of the input signal.

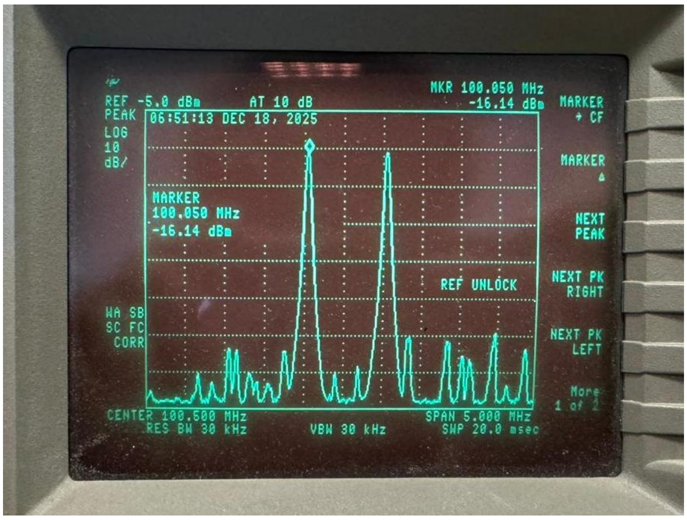

Fig. 12: Magnitude of the signal at 100MHz (f_1), -16.14dBm

$2f_1$-f_2 third order product measurement is given below.

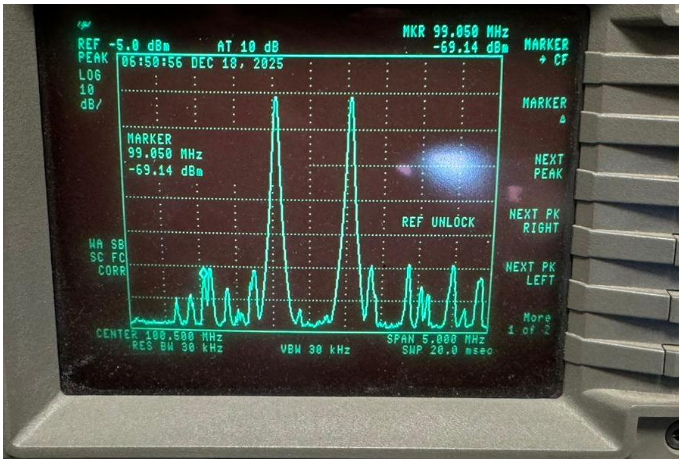

Fig. 13: $2f_1$-f_2 third order product magnitude = -69.14 and frequency = 99MHz

To calculate the OIP3, the following equation will be used.

$$OIP3 = P_{out} + \frac{\Delta P}{2}$$

$$P_{out}\ is\ the\ fundamental\ components\ magnitude\ (f_1\ or\ f_2)$$

$$\Delta P\ is\ the\ difference\ between\ fundamental\ component\ and\ third\ order\ component$$

So at -40dBm, for $2f_1$-f_2, the OIP3 calculation is as follows:

$$OIP3_{-40dBm} = -16.14 + \frac{-16.14 - (-69.14)}{2} = 10.36dBm$$

Fig. 14 shows the second fundamental component, f_2, which is located at 101MHz.

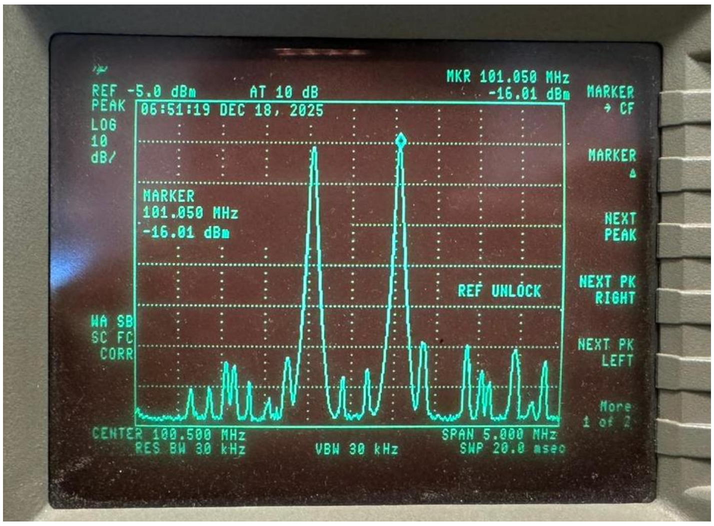

Fig. 14: Magnitude of the signal at 101MHz (f_2), -16.01dBm

At -40dBm input level, for $2f_2$-f_1, the OIP3 calculation is as follows:

$$OIP3_{-40dBm} = -16.01 + \frac{-16.01 - (-72.34)}{2} = 12.155dBm$$

In part b, same procedures will be done for -30dBm and -20dBm. Below figure shows the generator setup for -30dBm.

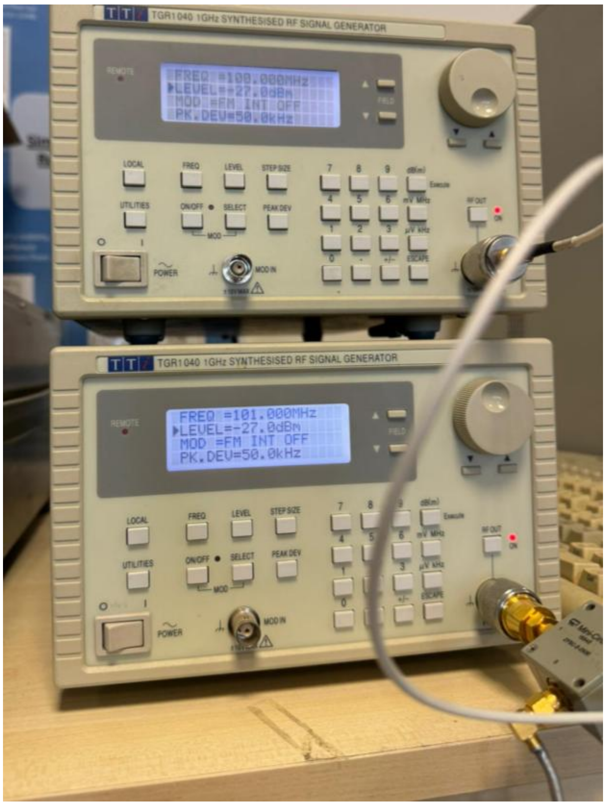

Fig. 15: -30dBm generator setup

Fig. 16 shows the fundamental component, f_1, magnitude for -30dBm.

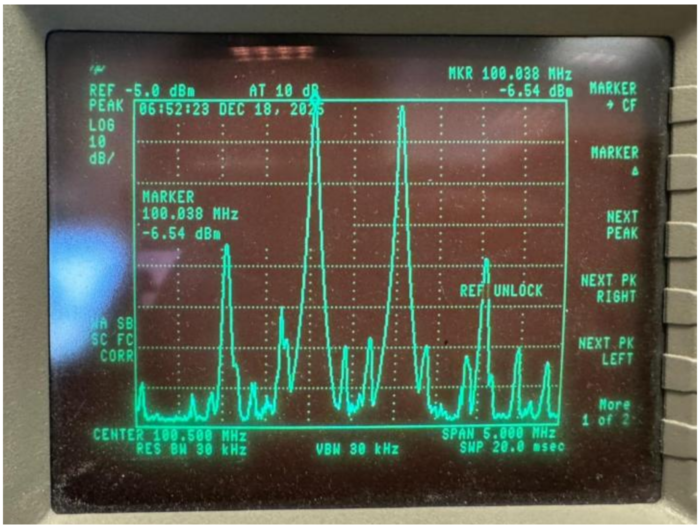

Fig. 16: Magnitude of the signal at 100MHz (f_1), -6.54dBm

Fig. 17 shows the third order component, $2f_1$-f_2, which is located at 99MHz.

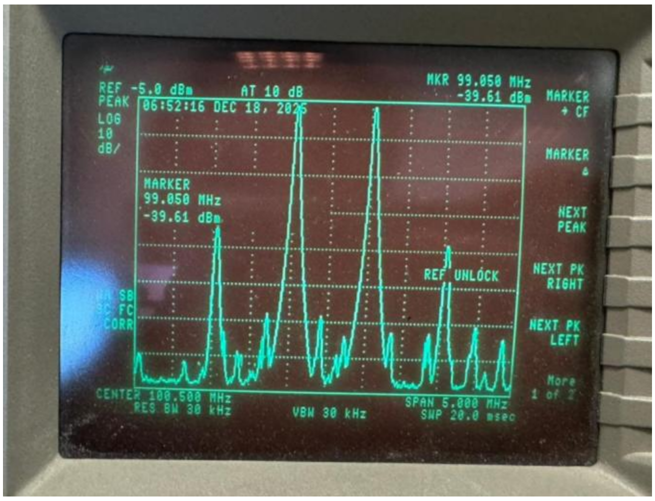

Fig. 17: $2f_1$-f_2 third order product magnitude = -39.61 and frequency = 99MHz

To calculate the OIP3 for $2f_1$-f_2, above equation used.

$$OIP3_{-30dBm} = -6.54 + \frac{-6.54 - (-39.61)}{2} = 9.995dBm$$

Below figure shows the measurement for second fundamental (f_2), which is located at 101MHz.

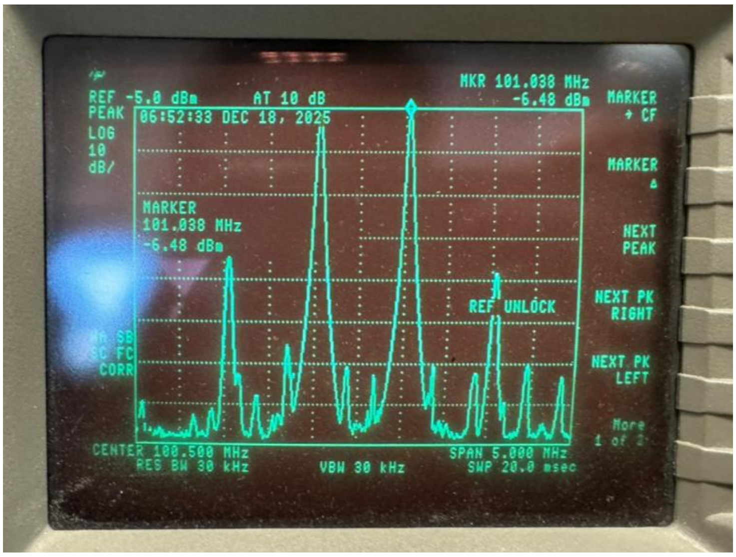

Fig. 18: Magnitude of the signal at 101MHz (f_2), -6.48dBm

Fig. 19 shows the third order product ($2f_2$-f_1), the measurement of its magnitude and frequency.

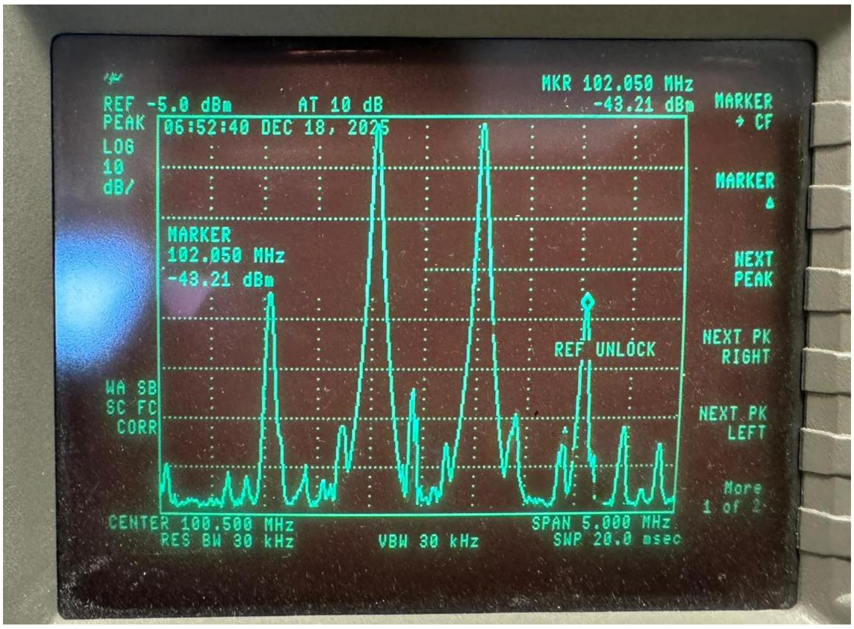

Fig. 19: $2f_2$-f_1 third order product magnitude = -43.21 and frequency = 102MHz

The OIP3 for $2f_2$-f_1 is given below.

$$OIP3_{-30dBm} = -6.48 + \frac{-6.48 - (-43.21)}{2} = 11.885dBm$$

Lastly, for -20dBm, Fig. 20 shows the fundamental component f_1 for -20dBm.

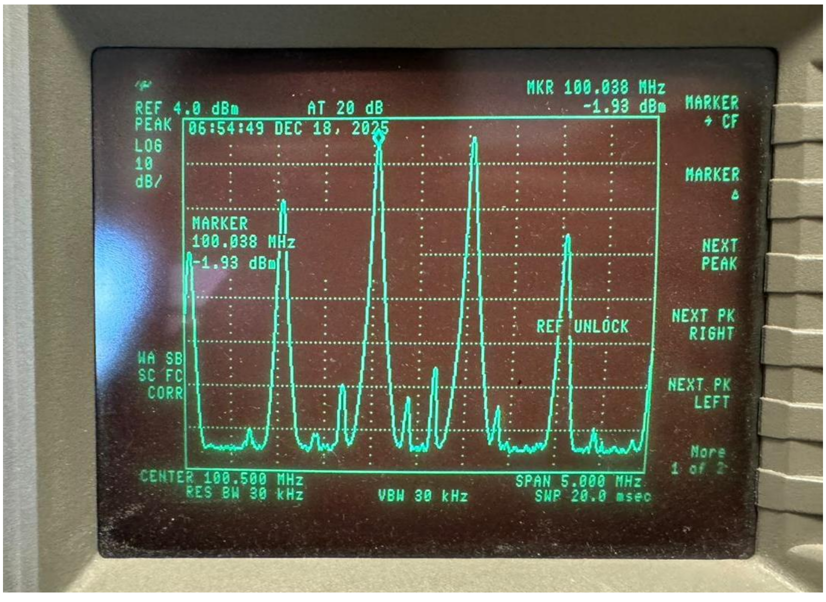

Fig. 20: Magnitude of the signal at 100MHz (f_1), -1.93dBm

Fig. 21 shows the third order component, $2f_1$-f_2, which is located at 99MHz.

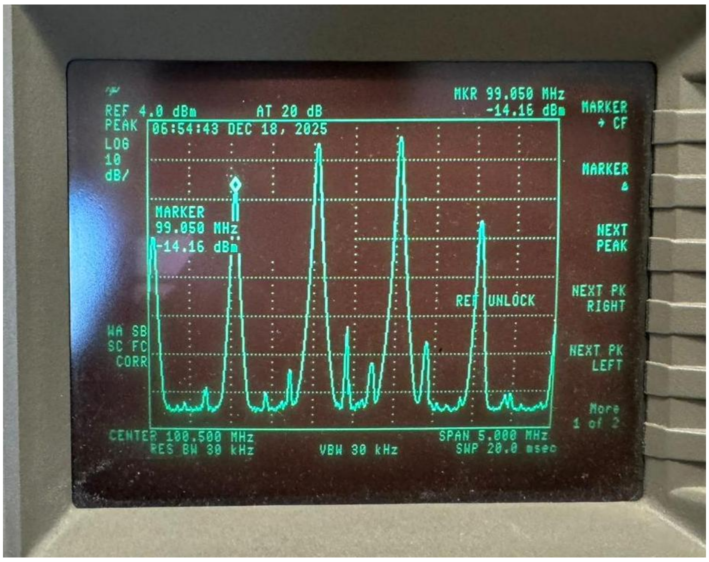

Fig. 21: $2f_1$-f_2 third order product magnitude = -14.16 and frequency = 99MHz

To calculate the OIP3 for $2f_1$-f_2, above equation used.

$$OIP3_{-20dBm} = -1.93 + \frac{-1.93 - (-14.16)}{2} = 4.185dBm$$

Fig. 22 shows the measurement for second fundamental, f_2, which is located at 101MHz.

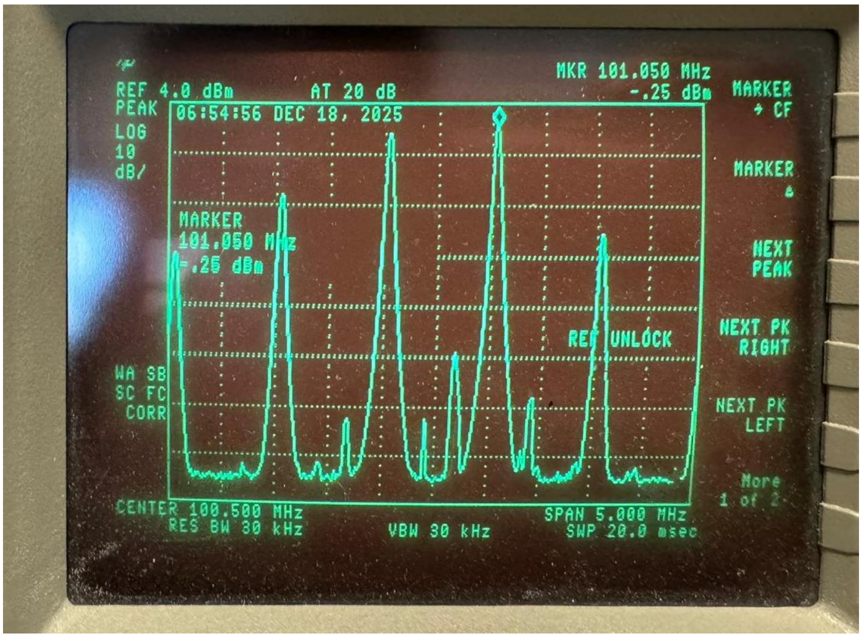

Fig. 22: Magnitude of the signal at 101MHz (f_2), -0.25dBm

Fig. 23 shows the third order component, $2f_2$-f_1, which is located at 102MHz.

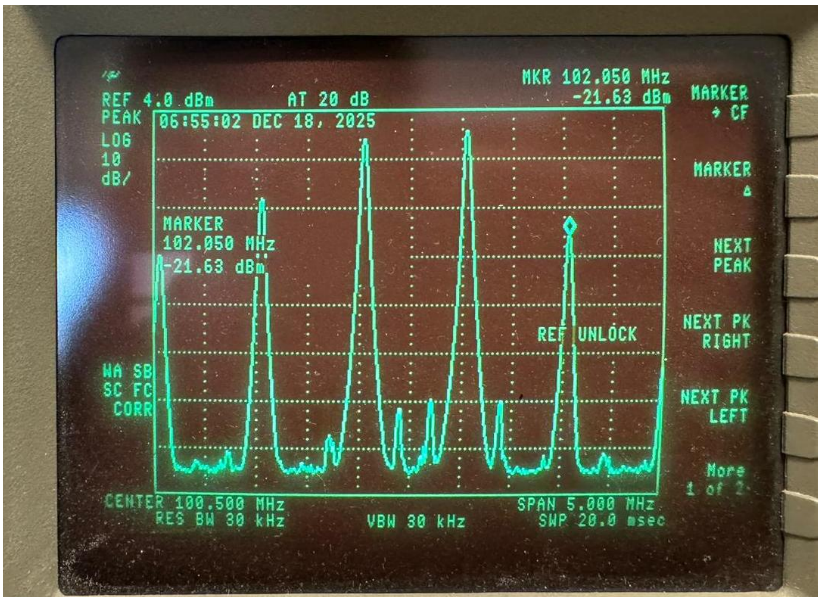

Fig. 23: $2f_2$-f_1 third order product magnitude = -21.63 and frequency = 102MHz

To calculate the OIP3 for $2f_2$-f_1, above equation used.

$$OIP3_{-20dBm} = -0.25 + \frac{-0.25 - (-21.63)}{2} = 10.44dBm$$

Fig. 24 indicates the same measured values for the simulated circuit.

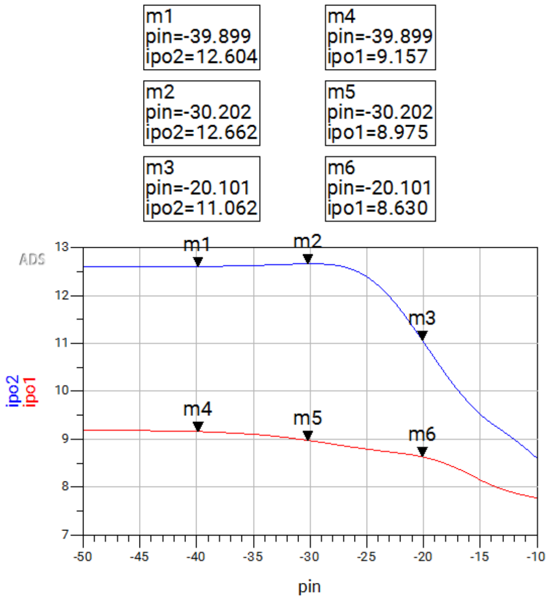

Fig. 24: Measured OIP3 values for the simulation results

Fig. 25 shows the plot for the experimental results.

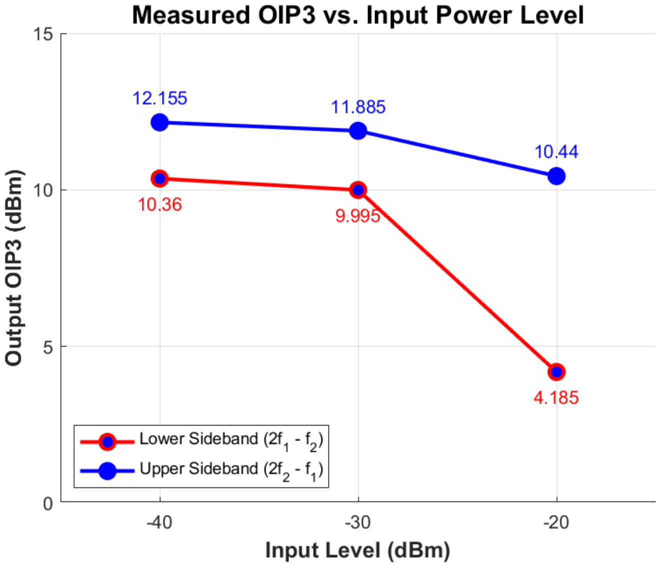

Fig. 25: Measured OIP3 values for the experimental results

Table 3 shows the OIP3 values for both experimental and simulation results, and indicates the difference between the measured values.

Table 3: Experimental and Simulation OIP3 values

	Experimental OPI3		**Simulated OIP3**	
Input Level	**$2f_1$-f_2**	**$2f_2$-f_1**	**$2f_1$-f_2**	**$2f_2$-f_1**
-40dBm	10.36	12.155	9.157	12.604
-30dBm	9.995	11.885	8.975	12.662
-20dBm	4.185	10.44	8.630	11.062

To compare the final result, Table 4 is created.

Table 4: Comparison of OIP3 values

Input Level	Sideband	Exp. OIP3 (dBm)	Sim. OIP3 (dBm)	Difference (dB)
-40 dBm	**$2f_1$-f_2**	10.36	9.157	**1.203**
	$2f_2$-f_1	12.155	12.604	**0.449**
-30 dBm	**$2f_1$-f_2**	9.995	8.975	**1.020**
	$2f_2$-f_1	11.885	12.662	**0.777**
-20 dBm	**$2f_1$-f_2**	4.185	8.630	**4.445**
	$2f_2$-f_1	10.44	11.062	**0.622**

As illustrated in Table 4, only for sideband $2f_1$-f_2, at -20dBm input level, there is a difference of 4.445dB. But other than that value, values are quiet close in experimental and simulated results. This shows that my results are compatible.