Tuning Broadband Microwave Amplifiers

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Abstract

Tuning procedures of a wideband solid-state amplifier for the PEP-II longitudinal feedback system G.Alaniz, A. Young

The PEP-II/DAΦNE/ALS longitudinal feedback systems are complex wide bandwidth systems requiring analog, digital and microwave circuits. The solid-state amplifier is one of the components in the microwave circuit that is required to suppress the coupled bunch instabilities that exist in the PEP-II accelerator. The suppression is achieved by using an antenna as a kicker structure that provides an electric field in order to increase or decrease the energy of particles passing through the structure. The amplifier is made up of sixteen 30 to 35W microstrip GaAs FET modules that are combined to obtain 500W over a bandwidth of 850MHz to 1850MHz. The amplifier malfunctioned causing a reduction in the functionality and power output of the individual GaAs FET modules. The amplifier must be repaired. After repair, the amplifier must be tuned to optimize the gain while maintaining proper power output. The amplifier is tuned using microstrip circuit techniques. A variety of microstrip methods are used to obtain the proper line impedance. The result is a working amplifier that operates efficiently.

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Introduction

A 500W amplifier unit is used in the PEP-II longitudinal feedback control system. The amplifier is comprised of two sets of eight, 30W amplifier modules. A preamp is used to provide the correct power level to the two halves, which is distributed by a two-way splitter and is further split with an eight-way divider that feeds power to each 30W module. The power is then recombined using the same scheme of an eight-way combiner followed by a two-way combiner to provide the 500W output. The 30W module has two gain stages of GaAs FET amplifiers with a bandwidth of 850-1850 MHz. The input stage consists of two 5W GaAs FET transistors that provide power to the output stage. The output stage is two pairs of 10W GaAs FET transistors, thus the module has 20dB of gain. A tuning procedure is needed to repair the 30W modules. Gain and phase plot tests will be used on both the 500W and 30W modules to qualify the performance of the amplifiers. The gain and the phase of a functional unit should be relatively constant over the prescribed bandwidth, varying by less than 1/2 dB and 5° respectively. The gain of the 30W module should be 20dB, and the gain of the 500W amplifier should be 57 dB. Power measurements will be done to verify that the proper output of 30W and 500W are correct. Deviations from these specifications are an indication of a malfunction and require further investigation. Further tests require a check of the gate voltage and the drain current of all GaAs FET transistors in the 30W modules. The gate voltage should be approximately -2V when the module is powered at 11V and -1.5V when the module is powered at 5V. Drain current should be 1.0A on the two input stage transistors, and 2.0A on the four output stage transistors. The entire procedure will allow for on-site repair and tuning, reducing the need for sending the modules to the manufacturer. Repairing the

modules on-site will save time and money; it will allow the longitudinal feedback control system to minimize the effects of the loss of gain from not having the amplifier online.

General Calibrations

It is easy to find a cable with 0.6dBm of loss, but the difference in power between 56.9dBm and 57.5dBm is significant. Because of this fact, special care was taken in order to obtain the most accurate measurements. Several calibration procedures were used to minimize apparent losses in cables and inconsistencies in readings. A signal generator must be calibrated every time the frequency or a cable is changed, and a network analyzer must be calibrated every time the frequency range, cable or power output is changed.

Figure 1 illustrates the calibration setup used when measuring the power delivered to the amplifier input. The power output of the signal generator had to be offset to account for the losses in the cable. An example calibration is as follows: an HP 83731B Synthesized Signal Generator was set to 1071MHz frequency and connected to the Agilent E4419B EPM Series Power Meter through the cable being calibrated. The power level on the signal generator was set to 0dBm. The power output of the signal generator was raised by integer values to make sure the offset was linear. The difference in the set power and the meter reading was the magnitude of the offset used on the signal generator. This procedure allowed us to know the power being delivered to the amplifier under test.

A similar calibration procedure was used to compensate for the coupler and cable connected to the output of the amplifier, see figure 2 for a setup diagram. To get an accurate calibration, it was important to offset the signal generator before calibrating for

the output losses of the amplifier. The difference in the set power of the signal generator and the power meter reading was the value used to offset the power meter display.

The HP Network Analyzer 8753D was calibrated, using standard calibration methods. The gain measurement of the Merrimac CBN 30M coupler being used had a non-zero slope over the frequency spectrum, significantly affecting the S-parameter readings of the amplifiers tested. To account for this, the S-parameters of the coupler were saved in the Network Analyzer's memory and all amplifier S-parameter readings were divided by the couplers S-parameters, effectively removing the effects of the coupler.

500W Amplifier Testing Procedure

The first procedure was the DC/AC analysis. This procedure was used to verify that all expected DC and AC voltage and current measurements were correct. During DC/AC analysis procedure, the amplifier was separated into two halves and each half was tested individually using the same basic procedure. The AC and DC power supply voltages were easily verified using the Fluke 87 III True RMS Multimeter. The DC voltage measured between ground and the DC terminal bus located in the amplifier case gave the correct measurement of 11VDC. The AC voltages were read from ground to each of the AC lines. Both voltages were verified to be 120VAC. A Power Designs triple output DC power supply, Model TP340 was used to provide a TTL high to the interlock input of the amplifier. The interlock is a safety mechanism that shuts off the amplifier when the input is a TTL low. The signal will drop to a TTL low when the thermal switch on any module in the amplifier heats up to a temperature greater than 65-75° C. To verify that the interlock signal was functioning correctly, the amplifier was

turned on and then the triple power supply was turned off. When the power supply was turned off, an indicator LED turned on, indicating that the safety mechanism had been activated. Next the current drawn by each 30W module was measured using a Current Gun Plus: Model CG-100D. A working module should draw at least 9.0A.

The second procedure was the power test. This procedure was used to test the power saturation level of the amplifier. The power test was performed on each half of the amplifier separately, then the two halves were combined and the amplifier was retested. For an RF source, an HP 8648C Signal Generator was used and an Agilent E4419B EPM Series Power Meter was used to read power outputs. The test setup used followed the block diagram shown in figure 3. Note that the outputs and inputs not being directly tested were always terminated with a terminating load; this prevents reflections that could potentially damage the unit. The amplifier was tested at four frequencies, 952 MHz, 1071MHz, 1200MHz, and 1500 MHz. The input power levels started at -10dBm and ranged up till the 1dB compression point. The results to this test can be seen on table 1.

The third procedure was the small signal gain and phase test. This procedure was used to verify the consistency of the phase and gain over a frequency interval of 850MHz to 1850MHz. An HP Network Analyzer 8753D was used to measure the gain and phase of the amplifier. This procedure was performed on the two halves of the amplifier put together, not on each individual half. The test setup followed the block diagram in figure 4. The input power from the Network Analyzer was 0dBm . The measured gain and phase should both be relatively flat.

30W Amplifier Testing Procedure

The three procedures used to test the 30W amplifier modules are similar in concept but different in method to the 500W amplifier test procedures. The first procedure was the DC analysis, the second was the small signal gain and phase test, and the third was the saturation power test.

The DC analysis test procedure was used to check the functionality of each of the six GaAs FET transistors used in the 30W modules. An HP 6652A System DC Power Supply was used to power the module. The Fluke Multimeter was used to check the gate voltage and the voltage across the biasing resistor. Any transistors that had a gate voltage of 0 or that was drawing less than 95% of the expected current, which is .950A for the input stage and 1.9A on the output stage, was replaced. After the transistors were replaced, this procedure was repeated.

The gain-phase test used the HP Network Analyzer to measure the gain and the phase of the each amplifier module. The test setup followed the block diagram in figure 3.

The saturation power test required the use of the Mini-Circuits Amplifier ZHL-42-SMA. This amplifier was used to saturate the amplifier modules since there was no power supply available that could provide more than 20dBm of power. Before using the preamp to power the amplifier, a list of preamp outputs compared to inputs was made. The amplifier output power was measured using the Power Meter and was driven by the HP Signal Generator up to 20dBm. After 20dBm and up to 30 dBm, the Signal Generator powered the preamp that powered the amplifier. The test setup followed the block diagram in figure 3.b.

Tuning Procedure

Tuning was performed to stabilize the gain and improve the maximum power output of the 30W amplifier modules. The tuning process involved manipulating the microstrip in order to add and remove inductive and capacitive elements to obtain matching impedances. There were specific areas of the microstrip that were particularly sensitive to the tuning process. The area around the input Sage Wireline on the first gain stage and the output Sage Wireline on the second gain stage were the areas where tuning was most productive in terms of achieving a better $|S_{11}|$ input match^[4]. To change the inductance and capacitance in the microstrip, strips of copper were added and removed from the existing microstrip structure. Different areas of the transmission line had different characteristics based on the microstrip structure. A T-junction in the microstrip gives a lumped circuit element with the inductance being directly proportional to the width of the microstrip line^[2]. Tuning at a T-junction involved cutting some copper of the edges of the microstrip to reduce the inductive elements. An air bridge is used to bridge the signal to the GaAs FET transistors, which couples energy between the signal paths^[3]. A symmetrical microstrip step gives a lump circuit element with the capacitance being directly proportional to the length of the wider line. This allows capacitance to be increased by adding length to the symmetrical steps in the microstrip^[2]. Figure 18 and 19 show the location of the tuning areas on the amplifier. This test used the HP Network Analyzer to observe the tuning effects on the forward and the reflected gain of the amplifier. The objective of tuning was to have a gain spectrum around 20dB that varied less than 1dB, and a return loss that was less than -20dB.

Results

Figures 4.a and 4.b show the gain and the phase plot for the 500W amplifier tested. Figures 5.a-12.a and 5.b-12.b show the gain and phase plot for the eight 30W modules tested. Figure 13 shows the gain plot for the coupler that was used. Figures 14.a and 14.b are an example of what the gain and phase plots looked like before the coupler effects were taken into account and figures 15 shows a gain plot taken on and uncalibrated Network Analyzer. These figures were obtained using the HP Network Analyzer.

Table 1 shows the power measurements taken from the 500W amplifier tested. Table 2.a and 2.b show the voltages and current measured from 30W amplifier modules before and after the faulty transistors were changed. Tables 3.a-3.d show the power readings of the 30W amplifiers tested for the four frequencies tested at. Tables 4.a-4.d show the average power of the 30W amplifiers for the four frequencies tested Figure 16 and 17 show the average power spectrum of the 30W amplifiers for input powers of 10 and 28dBm respectively.

Discussion and Conclusion

Comparing tables 2.a and 2.b shows how replacing the faulty transistors improved the performance of the amplifier. Before taking the coupler effects into account, all the gain and phase plots were similar to figure 15. Figures 5 through 12 show the gain and phase of all the amplifiers after accounting for the coupler effects. Figures 5 through 12 also show that all the amplifier operate at above 20dB of gain at the frequency range of 850-1850MHz, and the phase varies anywhere from 5-10 degrees before roll-off occurs at the end of the bandwidth. The values in figures 16 and 17 were calculated by averaging

the output power of the eight modules tested at the specified input power and the plotting the results over the frequency. Figure 17 shows the saturated power spectrum and figure 16 shows a non-saturated power spectrum. The flatness in both of these figures shows the broadband capabilities of the amplifier modules.

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References

- [1] P. Moore, D. Fitzpatrick, Milmega Ltd., Private communications.
- [2] T.C. Edwards, *Foundations for Microstrip Circuit Design*, New York, NY: John Wiley & Sons Ltd., 1981.
- [3] B. Wadell, "Transmission Line Components and Discontinuities," chap. 5 in *Transmission Line Design Handbook*, Norwood, MA: Artech House, Inc., 1991.
- [4] C.G. Montgomery et al, "General Microwave Circuit Theorem," chap. 5 in *Principles of Microwave Circuits*, London, United Kingdom: Peter Peregrinus Ltd., 1987.

Frequency (Hz)	Power In (dBm)	Power Out (dBm)		
		Bottom half	Top half	Combined
952	-10	41.8	41.6	44.6
	-6	46.06	45.8	48.9
	-3	49.24	49	52
	-2	50.28	0	53.1
	-1	51.27	51	54
	0	52.18	51.9	54.7
	1	52.91	52.7	55.3
	2	53.26	53	55.6
	3	53.4	53.2	55.8
	4	53.4	53.3	55.8
1071	-10	43.16	43.2	45.5
	-6	47.4	47.4	49.7
	-3	50.5	50.5	52.9
	-2	51.48	51.5	53.9
	-1	52.4	52.4	54.8
	0	53.2	53.2	55.6
	1	53.8	53.7	56.2
	2	54.2	54	56.6
	3	54.5	54.2	56.9
	4	54.5	54.2	56.9
1200	-10	43.1	43.2	45.7
	-6	47.3	47.4	49.8
	-3	50.5	50.6	53
	-2	51.5	51.6	54
	-1	52.4	52.4	54.9
	0	53.2	53.2	55.7
	1	53.7	53.7	56.3
	2	54	54.1	56.6
	3	54.2	54.2	56.8
	4	54.2	54.2	56.8
1500	-10	44.8	44.8	46.4
	-6	49	49	50.7
	-3	52.2	52.2	53.8
	-2	53.1	53.2	54.8
	-1	54	54	55.8
	0	54.7	54.6	56.7
	1	55	55	57.3
	2	55.2	55.2	57.6
	3	55.2	55.3	57.8
	4	55.2	55.3	57.8

Table 1: Power measurements for 500W amplifier

Module #	Serial #	Gate Voltage at 5V in (V)						Current through .220ohm or .110ohm (A)					
		Input Stage		Output Stage				Input Stage		Output Stage			
		t1	t2	t1	t2	t3	t4	t1	t2	t1	t2	t3	t4
1	961541	-1.63	-1.63	0	-1.63	0	-1.63	0.959	0.964	0	1.945	0	2.127
2	960342	-1.53	-1.53	0	-1.53	-1.53	-1.53	1.005	1	0	2	1.991	2.027
3	960345	-1.54	-1.54	0	-1.54	-1.53	-1.54	1.018	1.036	0	2.091	2.018	2.073
4	961538	-1.63	-1.64	-1.64	-1.63	-1.64	-1.63	0.945	0.941	1.9	1.836	1.791	1.9
5	961519	-1.56	-1.56	0	-1.56	-1.56	-1.56	0.955	0.95	0	1.982	2	1.882
6	961539	-1.55	-1.55	-1.55	-1.55	-1.55	0	0.955	0.955	1.818	1.864	1.836	0
7	961540	-1.58	-1.58	-1.58	-1.58	0	-1.58	0.982	0.959	1.955	1.982	0	1.991
8	961542	-1.56	-1.56	0	-1.56	-1.56	-1.56	0.991	0.977	0	1.927	1.918	1.964

Table 2.a: Initial DC measurements

Module #	Serial #	Gate Voltage at 5V in (V)						Current through .220ohm or .110ohm (A)					
		Input Stage		Output Stage				Input Stage		Output Stage			
		t1	t2	t1	t2	t3	t4	t1	t2	t1	t2	t3	t4
1	961541	-1.61	-1.61	-1.61	-1.42	-1.61	-1.61	0.927	0.936	1.855	1.891	1.9	2.073
2	960342	-1.64	-1.64	-1.64	-1.64	-1.64	-1.63	0.977	0.968	2.082	1.936	1.936	1.973
3	960345	-1.62	-1.62	-1.62	-1.62	-1.61	-1.62	1	1.014	2.055	2.009	1.945	2.045
4	961538	-1.63	-1.64	-1.63	-1.63	-1.64	-1.63	0.955	0.955	1.982	1.927	1.855	1.955
5	961519	-1.64	-1.64	-1.64	-1.64	-1.64	-1.64	0.95	95.45	1.927	1.909	1.973	1.918
6	961539	-1.64	-1.63	-1.63	-1.63	-1.63	-1.63	0.991	1	1.927	1.927	1.836	1.909
7	961540	-1.65	-1.65	-1.65	-1.65	-1.5	-1.64	0.959	0.936	1.909	1.936	2.018	1.909
8	961542	-1.64	-1.63	-1.63	-1.63	-1.63	-1.63	0.973	0.964	1.991	1.882	1.873	1.918

Table 2.b: DC measurements after faulty transistors were replaced

952MHz								
Power In (dBm)	Power Out (dBm)							
	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6	Module 7	Module 8
10	30.7	30.7	31	31.4	31.2	31.2	31.2	30.9
11	31.7	31.7	32	32.5	32.2	32.2	32.2	31.9
12	32.7	32.7	33	33.5	33.3	33.2	33.2	32.9
13	33.7	33.7	34	34.5	34.3	34.2	34.2	33.9
14	34.7	34.7	35	35.5	35.3	35.3	35.2	34.9
15	35.7	35.8	36.1	36.6	36.3	36.3	36.2	35.9
16	36.7	36.8	37.1	37.6	37.4	37.3	37.3	36.9
17	37.7	37.8	38.2	38.7	38.4	38.4	38.3	38
18	38.7	38.9	39.2	39.7	39.5	39.4	39.3	39
19	39.8	39.9	40.3	40.7	40.5	40.5	40.4	40
20	40.8	40.9	41.4	41.7	41.6	41.6	41.4	41
21	42.1	42.1	42.7	42.6	42.9	42.6	42.5	42
22	43.1	43.1	43.7	43.6	43.9	43.6	43.4	43
23	44.2	44	44.5	44.5	44.7	44.5	44.3	43.9
24	45.3	44.8	45.2	45.2	45.4	45.2	45	44.7
25	45.9	45.3	45.7	45.7	45.8	45.7	45.5	45.3
26	46.2	45.7	45.9	46	45.9	45.9	45.8	45.6
27	46.3	45.8	46	46	45.9	46.1	45.9	45.8
28	46.3	45.9	46.1	46	46.1	46.1	46	45.9
29	46.3	45.9	46	46	46.2	46.2	46	45.9
30	46.3	45.9	45.9	46.1	46	46.1	46	45.9

Table 3.a: 30W amplifier power measurements at 952MHz

1071MHz								
Power In (dBm)	Power Out (dBm)							
	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6	Module 7	Module 8
10	30.9	30.9	31.3	31.8	31.3	31.8	31.3	30.8
11	31.9	31.9	32.3	32.8	32.3	32.8	32.3	31.8
12	32.9	32.9	33.3	33.8	33.3	33.8	33.3	32.8
13	33.9	33.9	34.3	34.8	34.3	34.8	34.3	33.8
14	34.9	34.9	35.3	35.8	35.3	35.8	35.3	34.8
15	35.9	35.9	36.3	36.8	36.3	36.8	36.3	35.8
16	36.9	36.9	37.3	37.9	37.4	37.8	37.3	36.8
17	37.9	37.9	38.4	38.9	38.4	38.9	38.3	37.8
18	39	38.9	39.4	39.9	39.4	40	39.4	38.8
19	40	40	40.5	41	40.5	41	40.4	39.8
20	41	41	41.5	42.1	41.6	42.1	41.4	40.8
21.1	42.3	42.2	42.7	43.6	42.9	43.3	42.8	42.1
22.4	43.4	43.4	43.8	44.5	44	44.5	43.9	43.3
23.5	44.7	44.4	44.8	45.5	45.1	45.4	44.9	44.3
24.7	45.5	45.2	45.5	46.2	45.9	46	45.6	45.2
25.8	46.1	45.7	46	46.6	46.3	46.3	46	45.7
26.9	46	45.9	46.2	46.6	46.4	46.4	46.3	46.1
28	46	45.8	46.3	46.6	46.5	46.3	46.4	46.3
29	46	45.8	46.5	46.6	46.6	46.2	46.5	46.4
30	46.3	46	46.5	46.6	46.7	46.1	46.5	46.4

Table 3.b: 30W amplifier power measurements at 1071MHz

1200MHz								
Power In (dBm)	Power Out (dBm)							
	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6	Module 7	Module 8
10	30.8	31	31.2	31.7	31.2	31.5	31.5	30.7
11	31.8	32	32.2	32.7	32.2	32.5	32.5	31.7
12	32.8	33	33.2	33.7	33.2	33.5	33.5	32.7
13	33.8	34	34.2	34.7	34.2	34.5	34.5	33.7
14	34.8	35	35.2	35.7	35.3	35.6	35.5	34.7
15	35.8	36	36.2	36.7	36.3	36.6	36.5	35.7
16	36.8	37.1	37.2	37.8	37.3	37.6	37.5	36.7
17	37.9	38.1	38.3	38.8	38.3	38.7	38.5	37.7
18	38.9	39.1	39.3	39.8	39.4	39.7	39.5	38.7
19	39.9	40.1	40.3	40	40.4	40.8	40.6	39.7
20	41	41.1	41.4	42	41.5	41.9	41.6	40.7
21	42.4	41.8	42.3	43.3	42.8	43.2	42.6	41.9
22	44.4	42.8	43.2	44.2	43.8	44.1	43.6	42.9
23	45.2	43.7	44	45	44.6	44.9	44.4	43.8
24	45.8	44.5	44.7	45.7	45.4	45.6	45.1	44.6
25	46.1	45.2	45.2	46.3	45.9	46	45.7	45.2
26	46.2	45.6	45.5	46.6	46.2	46.4	45.9	45.6
27	46.2	45.7	45.6	46.6	46.3	46.4	46	45.9
28	46.2	45.8	45.7	46.6	46.3	46.4	46	45.9
29	46.2	45.7	45.6	46.5	46.3	46.4	46	46
30	46.2	45.6	45.6	46.5	46.3	46.6	46	46

Table 3.c: 30W amplifier power measurements at 1200MHz

1500MHz								
Power In (dBm)	Power Out (dBm)							
	Module 1	Module 2	Module 3	Module 4	Module 5	Module 6	Module 7	Module 8
10	31	31.4	31.4	31.9	31.7	32.3	31	31.7
11	32	32.4	32.4	32.9	32.7	33.3	32	32.7
12	33	33.4	33.4	33.9	33.7	34.4	33	33.7
13	34	34.4	34.4	34.9	34.7	35.4	34	34.7
14	35	35.4	35.4	35.9	35.7	36.4	35	35.7
15	36	36.4	36.4	37	36.7	37.4	36	36.7
16	37.1	37.4	37.5	38	37.8	38.5	37	37.7
17	38.1	38.4	38.5	39	38.8	39.5	38	38.8
18	--	--	--	--	--	--	--	--
19	--	--	--	--	--	--	--	--
20	--	--	--	--	--	--	--	--
21	41.9	42.9	42.2	42.7	42.5	43.5	41.8	42.6
22	43	43.4	43.1	43.8	43.6	44.4	42.8	43.5
23	44	44.3	44	44.7	44.5	45.1	43.8	44.4
24	44.9	45	44.7	45.5	45.3	45.8	44.6	45.1
25	45.7	45.7	45.4	46.3	46	46.5	45.4	45.9
26	46.2	46.1	46	46.9	46.4	46.9	46	46.3
27	46.5	46.9	46.3	47.1	46.6	47	46.3	46.5
28	46.6	46.5	46.4	47.2	46.7	47	46.5	46.6
29	46.7	46.5	46.5	47.3	46.8	47	46.7	46.7
30	46.8	46.6	46.5	47.3	46.8	47	46.7	46.7

Table 3.d: 30W amplifier power measurements at 1500MHz

952MHz	
Power In (dBm)	Power Out (dBm)
10	31.0375
11	32.05
12	33.0625
13	34.0625
14	35.075
15	36.1125
16	37.1375
17	38.1875
18	39.2125
19	40.2625
20	41.3
21	42.4375
22	43.425
23	44.325
24	45.1
25	45.6125
26	45.875
27	45.975
28	46.05
29	46.0625
30	46.025

1071MHz	
Power In (dBm)	Power Out (dBm)
10	31.2625
11	32.2625
12	33.2625
13	34.2625
14	35.2625
15	36.2625
16	37.2875
17	38.3125
18	39.35
19	40.4
20	41.4375
21	42.7375
22	43.85
23	44.8875
24	45.6375
25	46.0875
26	46.2375
27	46.275
28	46.325
29	46.3875
30	46.025

1200MHz	
Power In (dBm)	Power Out (dBm)
10	31.2
11	32.2
12	33.2
13	34.2
14	35.225
15	36.225
16	37.25
17	38.2875
18	39.3
19	40.225
20	41.4
21	42.5375
22	43.625
23	44.45
24	45.175
25	45.7
26	46
27	46.0875
28	46.1125
29	46.0875
30	46.1

1500MHz	
Power In (dBm)	Power Out (dBm)
10	31.55
11	32.55
12	33.5625
13	34.5625
14	35.5625
15	36.575
16	37.625
17	38.6375
18	--
19	--
20	--
21	42.5125
22	43.45
23	44.35
24	45.1125
25	45.8625
26	46.35
27	46.65
28	46.6875
29	46.775
30	46.8

Tables 4.a-4.d: Average Power of 30W amplifiers at the four test frequencies

Figure 1:
In this example, the Signal Generator will be offset by 0.6dBm to account for the loss in the cable.

Figure 2:
In this example, the Power Meter display will be offset by 30.8dBm.

Figure3:
This setup is used to test the power output of the 500W amplifier and for the 30W amplifiers for input powers of 20dBm on under.

Figure 4.a: 500W amplifier gain plot

Figure 4.b: 500W amplifier phase plot

Figure 5.a: Module 1 gain plot

Figure 5.b: Module 1 phase plot

Figure 6.a: Module 2 gain plot

Figure 6.b: Module 2 phase plot

Figure 7.a: Module 3 gain plot

Figure 7.b: Module 3 phase plot

Figure 8.a: Module 4 gain plot

Figure 8.b: Module 4 phase plot

Figure 9.a: Module 5 gain plot

Figure 9.b: Module 5 phase plot

Figure 10.a: Module 6 gain plot

Figure 10.b: Module 6 gain plot

Figure 11.a: Module 7 gain plot

Figure 11.a: Module 7 phase plot

Figure 12.a: Module 8 gain plot

Figure 12.b: Module 8 phase plot

Figure 14.a: Gain plot with coupler effects

Figure 14.a: Phase plot with coupler effects

Figure 16: 30W amplifier power spectrum for input of 10dBm

Figure 17: 30W amplifier saturated power spectrum for input of 28dBm

Figure 18: Circled are is the input tuning area

Figure 19: Circled area is the output tuning area