TPM Calibration Methods

Bird Systems/Applications Engineering

Introduction

The Transmitter Power Monitor (TPM), designed for transmitter manufacturers and specialty applications, is a very versatile and useful tool for any power measurement situation. Although the unit is an inexpensive solution for true average power measurement, its greatest benefit is that the TPM can be calibrated in the field, at the exact frequency and power level at which the system will be operated. This gives individual field service representatives with an appropriate RF power measurement reference instrument the ability to recalibrate a unit without having to remove it from the transmitter.

The TPM has an output of 0 to 4.1 volts, with linear correspondence to power. Each unit also comes with calibration data (Figure 1) that can be used to specially configure the unit. The calibration data includes a full frequency sweep of the coupling between the main line and each of the test ports (Figure 2). In addition, there is also a high power test run at either 100.1 MHz or 600 MHz, depending on the frequency range of the unit (VHF or UHF). This test is conducted at multiple power levels and the DC voltage output (V_T) at those power levels. Based on that data, there are three methods to configuring the unit; Indirect, Direct, and Independent.

Figure 1: Example TPM Calibration Report

Model: xxxx
S/N: xxxx
Date: xxxx

Frequency Response

Frequency	Forward TP Coupling	Reflected TP Coupling	Non-Directional Coupling
473	-60.57	-60.04	-40.50
485	-60.57	-60.04	-40.50
497	-60.57	-60.04	-40.50
509	-60.57	-60.04	-40.50
521	-60.57	-60.04	-40.50
533	-60.57	-60.04	-40.50
545	-60.57	-60.04	-40.50
557	-60.57	-60.04	-40.50
569	-60.57	-60.04	-40.50
581	-60.57	-60.04	-40.50
593	-60.57	-60.04	-40.50
600	-60.57	-60.04	-40.50

High Power Testing – 600 MHz

Forward RF Power (W)	Forward Voltage Output
5000	3.958 V
500	0.425 V

Reflected RF Power (W)	Reflected Voltage Output
500	4.011 V
50	0.432 V

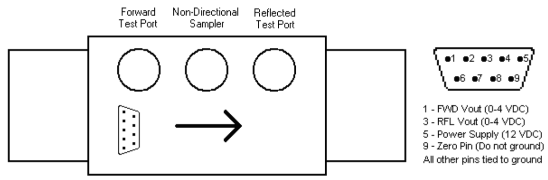
This note will guide you through each of the calibration procedures.

Every calibration procedure will finish by providing a table of voltages that correspond to power levels at the calibration frequency (V_O). It will be up to the user to use those voltages to generate an equation or fill in a look up table on whatever they choose to use as an output.

Variables

- **f_T** Test Frequency – Frequency of calibration at the factory (100.1 or 600 MHz)
- **f_O** Calibration Frequency - Frequency the unit is being calibrated to.
- **R_t** Test Coupling – Coupling value (forward or reflected) at the test frequency
- **R** Calibration Coupling – Coupling value (forward or reflected) at the calibration frequency.
- **C_O** Coupling Variation – Difference between the Calibration Coupling and the Test Coupling
- **k_O** Coupling Constant – The ratio between the calibration and the test coupling values
- **V** Test Voltage – Voltage output of the TPM with a given power lever at the test frequency
- **V_O** Calibration Voltage – Voltage output of the TPM with a given power level at the calibration frequency

Figure 2: TPM Diagram



Indirect Calibration

The Indirect method is the simplest method for calibrating the TPM. This method requires no additional equipment. The TPM can undergo indirect calibration without even being implemented into the system. It simply relies on the calibration data and the desired calibration frequency to calculate the output of the unit at the user's frequency.

1. Find the forward coupling factor for both the test frequency (100.1 MHz or 600 MHz) and the desired calibration frequency from the calibration data provided (Figure 1).

2. Calculate the difference between the calibration frequency coupling and the test frequency coupling to get the coupling variation of the calibration frequency in dB (C_O).

   $$C_O = r_O - r_T$$

3. Calculate the coupling constant for the calibration frequency (k_O) by using the following equation.

   $$k_O = 10^{(C_O/10)}$$

4. Convert the high power test voltages to match the calibration frequency.

   $$V_O = k_O V_T$$

5. Repeat steps 1-4 using the reflected coupling factors

6. Use the V_O values to set the external metering.

The following example of indirect calibration is performed using the sample calibration data provided in Figure 1.

Example:

The TPM in question is to be calibrated to a TV system operating at 473 MHz. We will use the indirect method to come to the correct calibration voltages for 473 MHz

1. *Find the forward coupling factor for the test frequency and the desired calibration frequency.*

Test frequency

600 MHz Calibration Frequency: 473 MHz

Forward Coupling: -60.49 dB

Forward Coupling: -60.57 dB

2. *Calculate the difference between the calibration frequency coupling and the test frequency coupling to get the coupling variation.*

$C_O = r_O - r_T$
$C_O = -60.57 - (-60.49) = -0.08$ dB

3. *Calculate the coupling constant.*

$k_O = 10\text{^}(C_O/10)$
$k_O = 10\text{^}(-0.08/10) = 0.98175$

4. *Convert the high power test voltages to match the calibration frequency*

$V_O = k_O V_T$
$V_{O\,500W} = (0.98175)*(0.425\text{ V}) = 0.417$ V @ 500 W Fwd.
$V_{O\,5000W} = (0.98175)*(3.958\text{ V}) = 3.886$ V @ 5000 W Fwd.

5. *Repeat for the reflected port of the TPM.*

Test frequency
600 MHz Calibration Frequency: 473 MHz

Reflected Coupling: -59.94 dB

Reflected Coupling: -60.04 dB

$C_O = r_O - r_T$
$C_O = -60.04 - (-59.94) = -0.10$ dB

$k_O = 10\text{^}(C_O/10)$
$k_O = 10\text{^}(-0.10/10) = 0.97724$

$V_O = k_O V_T$
$V_{O\,50W} = (0.97724)*(0.432\text{ V}) = 0.422$ V @ 50 W Ref.
$V_{O\,500W} = (0.97724)*(4.011\text{ V}) = 3.920$ V @ 500 W Ref.

Finally, you have the voltages you would use to generate a curve or look up table for this particular unit.

Forward Power	Voltage	Reflected Power	Voltage
500 W	0.417 V	50 W	0.422 V
5000 W	3.886 V	500 W	3.920 V

Direct Calibration

The direct method is a more empirical way to calibrate the TPM. In order to calibrate the TPM Directly, you will need a high power transmitter, ideally the same one the TPM will be monitoring in operation. You will also need a reference power meter to measure the output of the test port on the TPM as well as a dummy load to absorb the power.

The process will use the coupling factor between the main line and the test port for the frequency of calibration to establish the power input into the TPM. By using several different power levels, an equation or lookup table can be generated for the voltage output of the TPM as a function of power level at the frequency of calibration.

1. Connect the TPM between the transmitter and a dummy load so that the arrow is facing the transmitter. This will allow you to calibrate the reflected port of the TPM. Make sure that the dummy load has the appropriate specifications in order to handle the power output of the transmitter for this test. (Figure 3)

2. Connect the reference meter to the reflected test port. Make sure all the RF ports, including both test ports, are terminated with a 50 ohm dummy load of some sort.

3. Enter the reflected coupling factor for the frequency of calibration into the reference, in order to get an accurate representation of power in the line

4. Turn the transmitter's RF power on. Remember that the maximum power for the reflected channel is 10% of the forward channel. Do not overpower the reflected port.

5. Record the power level from the reference power meter and the DC voltage output of the TPM

6. Repeat step 5 at different power levels appropriate for your transmitter metering requirements.

7. Turn off the transmitter power and reverse the TPM in the transmission line (Figure 4)

8. Repeat steps 2-6 using the forward port and its corresponding coupling factor.

Figure 3: Reflected Calibration Setup

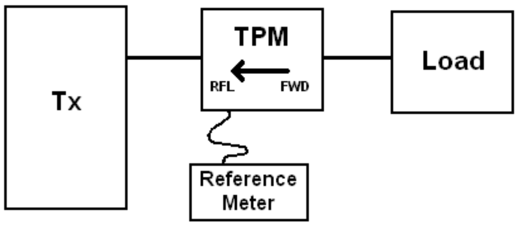
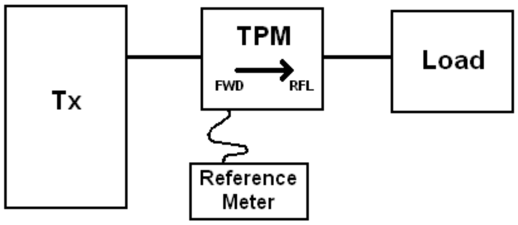


Figure 4: Forward Calibration Setup



Independent Calibration

The independent method will recalibrate the TPM completely. This procedure will void the calibration and accuracy specifications for the unit. The accuracy will be based on the accuracy of the reference power meter used for this procedure. In addition to the equipment needed for the direct calibration, you will need a small, flathead screwdriver to adjust the potentiometers on the TPM.

This process will completely recalibrate the unit to give you the output voltage of your choice (between 0 and 4 V) for your calibration frequency and power levels.
You will set the transmitter's RF output to a power level you desire, using the reference meter on the test port and the test port calibration data. Then, using the screwdriver, you will turn the potentiometers until you have the voltage output you desire. Extra data points are taken at different power levels to confirm the linearity and generate a lookup table to drive the rest of the power levels.

The benefit of this calibration method is that the customer can set the output voltage they want to drive their external meter. With the other calibration methods, the customer simply uses TPM output voltages as set at the factory. Using this method, you can make multiple TPMs all read approximately the same output voltage at full scale, even if the full-scale power of each individual TPM is different, as calibrated at the factory.

1. Connect the TPM between the transmitter and a dummy load, with the arrow pointing towards the transmitter. Make sure that the dummy load has the appropriate specifications in order to handle the power output of the transmitter for this test. (Figure 3).

2. Connect the reference power meter to the reflected test port. Make sure all the RF ports are terminated with a 50 ohm dummy load of some sort.

3. Enter the reflected test port coupling factor for the frequency of calibration into the reference, in order to get an accurate representation of power in the line.

4. Remove the covers from the TPM in order to access the forward and reflected adjustment potentiometers.

5. Turn the transmitter's RF power on. For the best accuracy, the output power should be as close to full-scale power for the reflected port on the TPM as possible. Remember that the maximum power for the reflected channel is 10% of the forward channel.

6. Turn the forward power potentiometer until you get the voltage output that you desire. Record the power level from the meter and the DC voltage output of the TPM.

7. Continue to record power level and the DC voltage output of the TPM at different power levels appropriate for your transmitter metering requirements.

8. Turn off the transmitter power and reverse the TPM in the transmission line (Figure 4)

9. Repeat steps 2-7 using the forward port and coupling factor

Conclusion

The Transmitter Power Monitor gives the customer a level of customization never before offered in a power measurement opportunity. The calibration can be performed a number of ways depending on the level of conformity desired by the user. In addition, the simplicity of the design of the TPM makes the unit ideal for integration into other applications, such as transmitters, switches, combiners, etc. This flexibility makes the TPM a worthwhile addition to any high power system.

Table 1:
Equipment Requirements for TPM Calibration

Calibration Method	Indirect	Direct	Independent
Factory Cal Data	x	x	x
High-Power Transmitter*		x	x
Dummy Load*		x	x
Reference Power Meter		x	x
Small Screwdriver			x

*Transmission system should be specified as close to full scale power of the TPM as possible.