# RF Power Measurements in the Field

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## Introduction

There are many valid reasons to make RF power measurements in a field environment. It may be difficult to actually select the top reasons but I feel reasonably comfortable in selecting some important reasons to make a field power measurement.

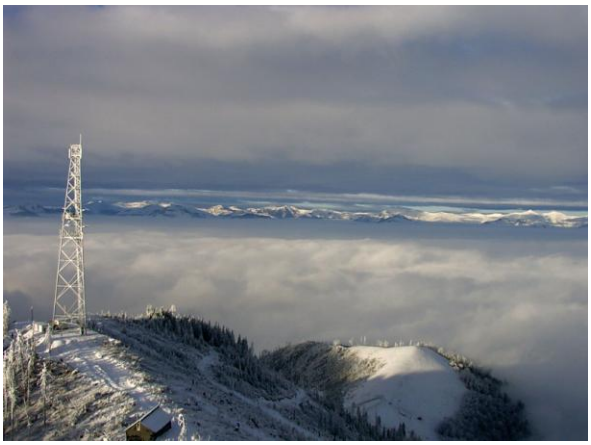
**Validation of Manufacturer**

Any transmitter manufacturer producing a high quality product goes to great extremes and expense to ensure that their product meets the RF power output that it was designed and marketed for. In other words a customer expects a transmitter designed and manufactured to produce a reliable 5kW signal to meet published specifications. Transmitter manufactures use a variety of methods when calibrating RF power in their factory settings, depending on the ratings and purpose of their product. If the transmitter is a vehicle radio capable of producing 50 watts then a relative small test load can be used to terminate the output power and an in-line directional wattmeter can be used to calibrate the power output. Some manufacturers also choose to use a directional coupler, terminating sensor and a display meter to set RF power. A high power transmitter capable of 50kW will, more than likely, be using a water cooled load and to set the power a calorimetric calculation will be used. These are naturally pristine environments where the highest quality standards are met and the use of lab quality instruments is expected and utilized on a daily basis. Many manufactures also adhere to ISO test, manufacturing, and quality standards. That would require all of their test equipment to be calibrated on a specified time cycle and the data is recorded thus ensuring all of their equipment in use meets published quality standards.

Reflecting on what happens when the testing is complete and the factory data has been recorded. The transmitter is disassembled and gently moved to the shipping department where it is safely packaged for transport to practically anywhere in the world. Small transmitters will be safely boxed in protective packaging ready for distribution. Larger transmitters can be moved across the country, or across the world, in trucks, trains, and even shipping containers for transport by ships and planes. Once these arrive to a near final destination they need to be cleared by the local customs. They are again loaded and sent to the final destination. This can involve pickup trucks, helicopters and sometimes horse powered carts depending on the transmitter site location. In extreme cases for mountain top installations there is no way for transmitter site access but access by cable car. The picture depicts a site where access consisted of a two mile walk on a washed out logging road which led to a cable car. The cable had a load restriction of less than 800 pounds. Everything had to be uncrated and disassembled beyond normal to meet the weight restrictions of the cable. On the mountain top the transmitter room was up many flights of winding stairs. This equipment received bumps and joggles on a monumental level.

Finally arriving on site a qualified person, or persons, is in charge of reassembly and system installation. In this case a field power measurement will be essential to verify that the reassembly was correct and to validate the original test data.

The view from the site was spectacular.



**System Installation**

Transmitters just do not work on their own they do need other components to facilitate a working system. Again if it is a vehicle radio then the system has a smaller approach than a complex system. The vehicle radio consists of the DC connection, a section of coax and the antenna. This can take anywhere from an afternoon unless more equipment is involved then a complete day may be required. If the system is a complex transmitter installation then the time frame can range from a week to months before any power measurements can even be considered. Sometimes just installing framework to support the RF system can even take weeks and require architects, building contractors and inspectors to ensure adherence to all local building codes. AC power, surge suppressors, dummy loads, water lines if needed and more system components are involved at this time. All of the equipment has to be interwoven through conduit, air handling ductwork and in a great deal of instances the installation is in the same room with operating transmitters. Great care has to be taken to ensure nothing happens which would shut the operating transmitter off. Frequently standby generators and UPS systems are also part of these installations, so testing under backup source power will also be required. Once all system installation has been accomplished, then a field power measurement is essential. This verifies that the operating parameters are still met based upon original factory test data.

Higher power installations usually have built in power measuring capability. This built in capability usually consists of, independent supplied, precision directional couplers installed in the transmission path which are measured and recorded. The measurement is in the form of a coupling factor based on the frequency of interest. For new installations specifying the precision coupler at the time of the order makes great sense as they can arrive built into the RF system. Another way of having a precision coupler is to install one on an existing line section. This can involve a drill, a hole saw, a saddle coupler and an hour or two of off air time. The manufacturers' installation instructions are straightforward very clear. Some manufacturers also produce flanged or unflanged line sections with directional couplers installed. This eliminates the need to drill into any transmission line. The line sections can just be added to the RF system, they are specified by power handling capability and frequency of operation.

Often high power installations have standby transmitters for backup and can be routed through an RF switch or Patch Panel with "U" links. In this way the main transmitter can be broadcasting on the antenna and the standby transmitter can be routed to a dummy or test load. Rotating the switch steers the standby transmitter to the antenna and then the main transmitter is routed to the load for service, repair or routine testing. The transmission line leading to the RF switch is a great location in this configuration to place an independent directional coupler for power measurement. This allows the main transmitter or the standby transmitter to have power monitored while broadcasting and still use the coupler if the transmitter is steered to the test load.

**FCC Rules and Regulations**

The FCC issues guidelines which specify power output tolerances. Depending on the license of the end user it can specify a window of operation. In other words you must operate at 100% power +/- a certain percentage of power. The FCC even has the power to levy fines if the transmitting system is out of its rated licensed operating power. In most cases it will be less expensive to verify RF power measurements than to take any chance of operating outside the limits of the license. The FCC also requires a verification which necessitates field power measurements to be taken, recorded and reports to be filed stating that all of the guidelines are being met.

**Component Loss**

Regardless of what system components are specified or used each one will have signal loss. A section of RG/58 coax from a vehicle radio routed to the antenna will have cable loss. The dB value is dependent on frequency, cable type and cable length. It is well accepted that all coaxial cable manufactures publish the nominal attenuation in dB/feet or dB/meter and frequency. RG/58 cable will have a different attenuation loss than a RG/6 cable at the same frequency. Consider the following:

50 Watts transmitter power and using 25' of RG/58 cable

| Frequency | Cable loss dB | Power loss in Watts |
|---|---|---|
| 100 MHz | .95dB | 9.83 |
| 400 MHz | 2.1dB | 19.17 |
| 900 MHz | 3.42dB | 27.25 |

50 Watts transmitter power and using 25' of RG/6 cable

| Frequency | Cable loss dB | Power loss in Watts |
|---|---|---|
| 100 MHz | .675dB | 7.25 |
| 400 MHz | 1.475dB | 14.44 |
| 900 MHz | 2.35dB | 20.9 |

This example does not include any connectors or adapters which are notorious for loss.

Next look at high power with a mask filter that has a loss of .3dB:

| Transmitter Power | Filter loss | Power loss in Watts |
|---|---|---|
| 25000 | .3dB | 1720 |
| 50000 | .3dB | 3334 |
| 75000 | .3dB | 5016 |

These are simple examples showing that minor changes even those as simple as coaxial cable length or mask compliance filters have effects on working transmitters in the field. These components added to a real world environment are usually not part of a transmitter test at a factory where the original test data was recorded, and transmitter output power was originally set to display on the transmitter metering. This gives rise to the necessity for field power measurements.

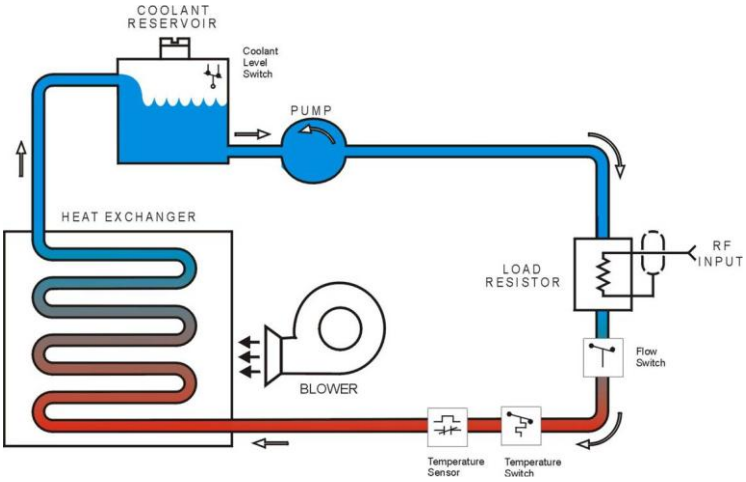
**Equipment Selection for Field Power Measurements**

The equipment selection to make field measurements is almost as extensive as the reasons to make the measurements themselves. The selection naturally is based upon each individual application. It can be as simple as an inline wattmeter. On the other hand it can be as complex as network analyzers and spectrum analyzers used for system characterization and optimization or other equipment to measure complex digital signals now in use everywhere and in almost every country.

For a vehicle installation a thru-line wattmeter and a terminating load is a great choice to test the system. A thru-line wattmeter can also verify that coax and antenna are in good condition and operating to specification. Some trouble shooting can also be accomplished with the meter. Once the correct element for frequency and rated RF power is selected, the wattmeter is placed in the transmission path (in-line) and the forward power out of the transmitter is set. By rotating the element in the wattmeter 180 degrees, the meter then displays reflected power. The last step is to nullify the reflected power to the smallest reading by adjusting the length of the antenna. One of the outstanding features of the wattmeter is that it can be left in the transmission line for continuous monitoring of the forward transmitter output power or reflected power from the antenna.

High power systems have somewhat different setups for power measurements based upon how the system has been designed. For most, if not all, instances the proper way to measure power is to utilize a dummy load, not while broadcasting on the antenna. This ensures the transmitter is terminated in a perfect 50 ohm load. The precision coupler has been previously tested and the coupling factor has been recorded and is usually printed on the transmission line. By using a terminating power sensor and a display meter power can be accurately set. A simple process of entering the offset or coupling factor, into the wattmeter then the power is accurately displayed when the sensor is connected to the coupler. Most wattmeters of this type can display power in watts, or dBm. Terminating power sensors provide true average power, regardless of the modulation. The terminating power sensor and power meters are usually portable and are even helpful for some trouble shooting purposes.

Many liquid cooled systems have built in calorimetric capability. A calorimetric measurement is when RF heats a terminating resistor and water transfers the heat away to a heat exchanger where the liquid is cooled and then transferred to a reservoir tank. A simple calculation of water flow and inlet vs. outlet temperature of the water shows RF power. A block diagram of a calorimetric system is shown.




Measuring RF power and system match characteristics now can be made, and monitored, in any installation, regardless of the signal waveforms. These measurements can be made while continuously broadcasting without the need to terminate the transmitter in a system dummy load. Complex waveforms such as 8-VSB and COFDM used in IBOC, DAB and HDTV systems as well as FM, AM and CW signals are accurately measured to ensure total power is achieved. This sophisticated state of the art equipment can also alert you via email or Ethernet if a user settable alarm has tripped.

**Summary**

Measuring RF power in a field environment can be a simple task which can be accomplished accurately and inexpensively. It can also involve a great deal of care and proper training to ensure equipment is accurately measured. Either way accurate field power measurements will ensure transmitting equipment is operating properly. This will guarantee broadcast coverage is being utilized to its full potential.