7 Practices to Prevent Damaging Power Meters and Sensors

Application Note

Introduction

By their nature, instruments such as power meters and power sensors are used in applications where they are exposed to high RF power measurements. If handled correctly these instruments are very reliable and rugged. However, manufacturers receive a significant number of damaged power sensors every year. Based on an assessment of those repairs, this article highlights practices that will protect and prolong the life span power meters and power sensors.

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Agilent Technologies

Practice 1: Avoid Overpowering

Figure 1 shows the basic method of measuring high-frequency power using a power meter and power sensor. The power sensor converts high-frequency power to a DC or low-frequency signal that the power meter can measure and relate to an RF power level. The meter displays the detected signal as a power value in dBm or watts.

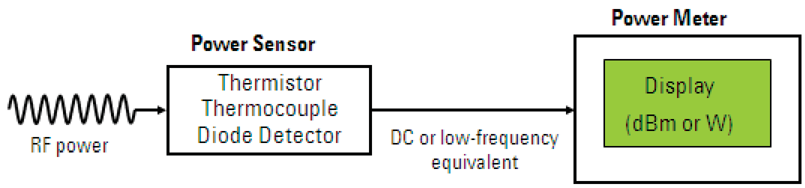

Figure 1. Basic power measurement method using a power meter and sensor

The maximum measurable power for a power sensor can vary from low power, –60 dBm, to high power, +40 dBm. To provide a safety margin, the maximum power rating is slightly higher. Even with the safety margin allowance, over half of the failed sensors received at the Agilent Service Center are caused by over-powering. Inspections typically reveal a destroyed component in the bulkhead thin-film circuit.

The bulkhead is the metal part of the power sensor and is the most expensive module in a power sensor, costing around 80% of the price of a brand new unit of the same model (Figure 2). Inside the bulkhead, there is a plastic bead supporting a fragile, high precision RF input connector center pin, a cartridge with a thin film circuit populated by termination and attenuator resistors, and a sensing element. The function of the bulkhead is to convert the RF input to a low DC voltage which varies in proportion with the input power.

Figure 2. The bulkhead of a power sensor

To prevent overpowering the bulkhead:

- Know the approximate signal level you are measuring
- Make sure the measured power is well within the dynamic range of the power sensor
- Use a RF limiter to attenuate power that exceeds the power sensor's limits

Practice 2: Avoid Overvoltage

The bulkhead of power sensor can be destroyed if the direct current voltage in your signal exceeds the maximum handling voltage of your power sensor. A typical DC-blocked power sensor can handle up to 20 VDC. DC-coupled sensors like the Agilent Technologies U2004A and E9304A models have much lower handling voltages—usually 5 V.

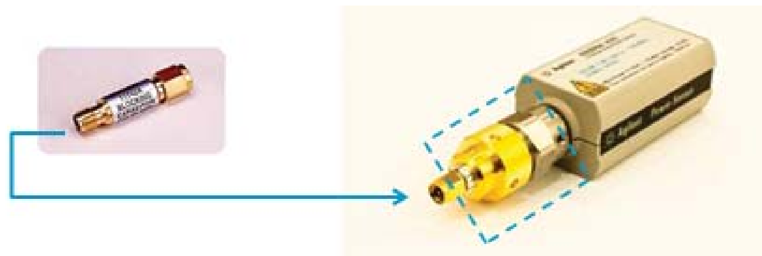

Figure 3. Some power sensors are designed with built-in DC blocked or DC couple

DC-blocked versus DC-coupled

DC-blocked power sensor

A DC-blocked sensor has a capacitor placed serially in front of the sensing element to suppress low frequency signals that may cause damage or affect measurement accuracy. Using a DC-blocked sensor is recommended for accurate power measurements in applications where the DC-bias shares the same path with the RF signal. For a DC-blocked sensor, the lower the frequency, the larger the sensor's capacitance needs to be.

DC-coupled power sensor

DC-coupled power sensors do not use a blocking capacitor. As a result, DC-coupled sensors have better voltage standing wave ratio (VSWR) performance and are able to measure lower frequencies. DC-coupled sensors are good for metrology applications where the sensor can be calibrated by measuring the voltage from the sensor with a voltmeter for a direct comparison.

To prevent overvoltage, select the power sensor best suited for the application based on its capabilities (Table 1).

Table 1. Attribute comparison of DC-blocked and DC-coupled power sensors

DC-blocked power sensor	DC-couple power sensor
A capacitor is placed serially in front of the sensing element	Have slightly better VSWR performance
Prevents DC leakage from entering sensing element	Good for operations at low frequencies to DC
Good for measuring RF signals with DC offset	

Practice 3: Adhere to Warnings and Specifications

Every power sensor has a product label with key specifications and warnings (Figure 4). This label indicates the minimum and maximum power level that the power sensor can measure. This power level span is known as the dynamic range. The label also specifies the minimum and maximum frequency the power sensor can measure, which is specified as the frequency range. If the power sensor measures peak power, the video bandwidth will also be stated. In fine print will be some warnings and reminders. Do not exceed the values provided in the specifications guide or as indicated by the yellow warning labels on the power sensor and meter.

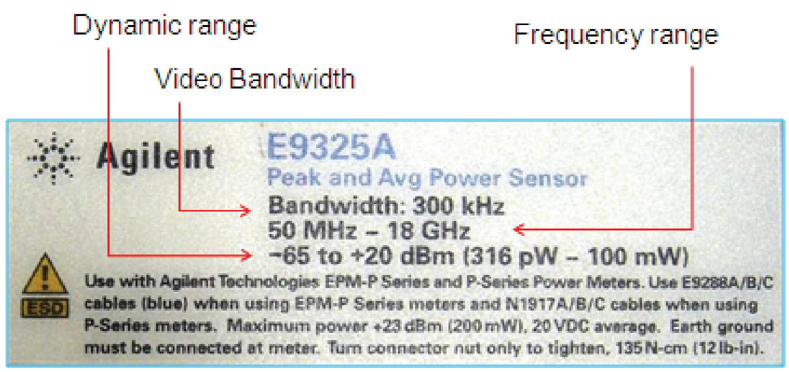

Figure 4. The sensor's product label indicates key specifications and warnings

Practice 3: Adhere to Warnings and Specifications

Select a suitable power sensor

It is always best to start out using a sensor that suits the signal you want to measure. Table 2 shows the compatibility of specific types of power sensors with application-suited power meters.

Table 2. Power sensors and power meter compatibility

			POWER METERS								
			N432A/432A [1]	E4416A/17A EPM-P	N1913A/14A E4418B/9B EPM [2]	E1416A VXI	N1911A/12A N8262A P-Series	8990B	Product Description / Sensor Tech.	Frequency Range	Power Range
POWER SENSORS	N8480 / 8480 Series Thermocouple and Diode sensors	N8482H	—	√	√	—	√	—	High Power Thermocouple Sensor	100 kHz to 6 GHz	–15 dBm (32 µW) to +35 dBm (3 W)
		8481D	—	√	√	√	√	—	Diode Power Sensor	10 MHz to 18 GHz	–70 dBm (100 pW) to –20 dBm (10 µW)
		8485D	—	√	√	√	√	—	Diode Power Sensor	50 MHz to 26.5 GHz	–70 dBm (100 pW) to –20 dBm (10 µW)
		8487D	—	√	√	√	√	—	Diode Power Sensor	50 MHz to 50 GHz	–70 dBm (100 pW) to –20 dBm (10 µW)
	Waveguide sensors	R8486D	—	√	√	√	√	—	Waveguide Power Sensor	26.5 GHz to 40 GHz	–70 dBm (100 pW) to –20 dBm (10 µW)
		Q8486D	—	√	√	√	√	—	Waveguide Power Sensor	33 GHz to 50 GHz	–70 dBm (100 pW) to –20 dBm (10 µW)
		N8486AR	—	√	√	—	√	—	Thermocouple Waveguide Power Sensor	26.5 GHz to 40 GHz	–35 dBm (316 µW) to +20 dBm (100 mW)
		N8486AQ	—	√	√	—	√	—	Thermocouple Waveguide Power Sensor	33 GHz to 50 GHz	–35 dBm (316 µW) to +20 dBm (100 mW)
		V8486A	—	√	√	√	√	—	V-band Power Sensor	50 GHz to 75 GHz	–30 dBm (1 µW) to +20 dBm (100 mW)
		W8486A	—	√	√	√	√	—	Waveguide Power Sensor	75 GHz to 110 GHz	–30 dBm (1 µW) to +20 dBm (100 mW)
	Thermistor mount sensors	478A	√	—	—	—	—	—	Coaxial Thermistor Mount	10 MHz to 10 GHz	–30 dBm (1 µW) to +10 dBm (10 mW)
		8478B	√	—	—	—	—	—	Coaxial Thermistor Mount	10 MHz to 18 GHz	–30 dBm (1 µW) to +10 dBm (10 mW)
	USB sensors	U2000A	—	—	√[3]	—	—	√	Diode Power Sensor	10 MHz to 18 GHz	–60 dBm (1 nW) to +20 dBm (100 mW)
		U2001A	—	—	√[3]	—	—	√	Diode Power Sensor	10 MHz to 6 GHz	–60 dBm (1 nW) to +20 dBm (100 mW)
		U2002A	—	—	√[3]	—	—	√	Diode Power Sensor	50 MHz to 24 GHz	–60 dBm (1 nW) to +20 dBm (100 mW)
		U2004A	—	—	√[3]	—	—	√	Diode Power Sensor	9 kHz to 6 GHz	–60 dBm (1 nW) to +20 dBm (100 mW)
		U2000B	—	—	√[3]	—	—	√	Diode Power Sensor	10 MHz to 18 GHz	–30 dBm (1 µW) to +44 dBm (25 W)
		U2001B	—	—	√[3]	—	—	√	Diode Power Sensor	10 MHz to 6 GHz	–30 dBm (1 µW) to +44 dBm (25 W)
		U2000H	—	—	√[3]	—	—	√	Diode Power Sensor	10 MHz to 18 GHz	–50 dBm (10 nW) to +30 dBm (1 W)
		U2001H	—	—	√[3]	—	—	√	Diode Power Sensor	10 MHz to 6 GHz	–50 dBm (10 nW) to +30 dBm (1 W)
		U2002H	—	—	√[3]	—	—	√	Diode Power Sensor	50 MHz to 24 GHz	–50 dBm (10 nW) to +30 dBm (1 W)
	Discontinued 848x sensors	8481/2/5/7A	—	√	√	√	√	—	Thermocouple Power Sensor	100 kHz to 50 GHz	–30 dBm (1 µW) to +20 dBm (100 mW)
		848xB/H	—	√	√	√	√	—	High Power Thermocouple Sensor	100 kHz to 18 GHz	–10 dBm (100 µW) to +44 dBm (25 W)
		R8486A	—	√	√	√	√	—	Thermocouple Waveguide Power Sensor	26.5 GHz to 40 GHz	–30 dBm (1 µw) to +20 dBm (100 mW)
		Q8486A	—	√	√	√	√	—	Thermocouple Waveguide Power Sensor	33 GHz to 50 GHz	–30 dBm (1 µw) to +20 dBm (100 mW)

1. *The 432A model is superceded by the N432A.*
2. *The E4418B/19B models are superceded by the N1913A/14A.*
3. *Only with N1913A/14A.*

Practice 3: Adhere to Warnings and Specifications

Select a suitable power sensor

After choosing a power sensor, choose a suitable power meter according to your application. The U2000 Series USB power sensor is similar to the EPM Series power meter in that both measure only average power. The USB sensors are light and portable making them well-suited for installation and maintenance purposes. For users needing standard rack-sized equipment there is the EPM Series. The EPM-P is a mid-performance power meter that can measure peak power. It has a 5-MHz VBW which is well suited for GSM, EDGE, and CDMA measurements.

The P-Series is Agilent's high-performance line of meters. With a 30-MHz VBW, these meters are good for LTE, WiMAX™, MIMO, and radar measurements. The N1918A power analysis manager is Windows®-based software which extends the capability of some Agilent meters. The basic version is a free download from Agilent.com.

Table 3. Types of power meter/sensor suit for different applications

Power meter	Product description	Application
U2000x Series USB power sensor	USB base average power	• General purpose average power measurement • Portable for installation and maintenance purposes • Satellite communication test • Self-powered solution (V3500A) for field or lab
V3500A handheld power sensor	Handheld average power	
EPM Series, N1913/14A	Average and pulse power	• General purpose average power measurement • ATE system standard rack size equipment • Aerospace/Defense and military application • Multichannel power measurement up to 4 channels
EPM-P Series, E4416/17A	Peak, average, and pulse analysis, 5-MHz VBW	• Wireless communication (GSM, EDGE, cdma2000®, W-CDMA)
P-Series, N1911/12A	Peak, average, CCDF, pulse analysis, 30-MHz VBW	• Aerospace/Defense radar pulse • Wireless communication and networking (WiMAX, WLAN, MIMO, MCPA) • Research and development, and manufacturing
P-Series modular, N8262A	Peak, average, CCDF, pulse analysis, 30-MHz VBW	• Aerospace/Defense ATE systems • Manufacturing ATE systems
N432A thermistor	CW and average power	• Calibration and metrology lab
N1918A power analysis manager	Extends the capability of USB sensor and P-Series	• Wireless communication and networking • Aerospace/Defense pulse component test • Satellite communication test • Electronic manufacturing

Practice 4: Protect RF Connectors and Adapters

With care and proper use it is possible to minimize performance degradation, which is particularly beneficial when using expensive measurement instrument connectors. A damaged or out-of-specification connector can destroy a good connector attached to it, even on the first connection. Therefore, any damaged connector or adaptor should be disposed of or immediately sent out for repair. A bad connector can result in transmission and reflection losses, which may change when the connection is removed and reconnected, or the connection may be intermittent, resulting in measurement error and repeatability problems.

Making a connection

Figure 5 shows a cross section of a typical male and female connector. Important parts to recognize are the center conductors, the outer conductors (also known as a mating plane), and the nut which tightens onto the female threads to bring the conductors into contact.

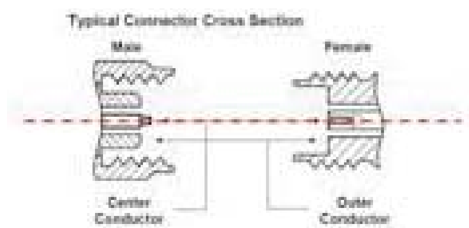

Figure 5. Male and female connector cross section

When making a connection, the center axis of both connectors should be aligned (Figure 6). Pushing the connectors straight together allows the male pin to slide smoothly into the female finger. Electrical contact is made by the internal surfaces of the female center conductor on the external surface of the male pin and physical contact of the mating plane.

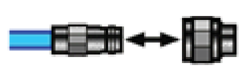

Figure 6. Proper alignment and connection prevents damage

Practice 4: Protect RF Connectors and Adapters

Making a connection *(continued)*

When tightening, rotate only the connector nut. Never ever turn the device or connector body (Figure 7).

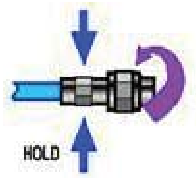

Figure 7. Proper tightening prevents damage

The same rules apply to the power sensor (Figure 8). Rotate the connector nut of the RF input connector; not the device.

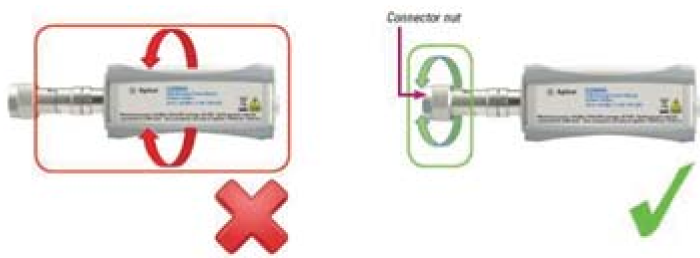

Figure 8. Making connections properly prevents damage to sensors

Practice 4: Protect RF Connectors and Adapters

Separating connection

When breaking a connection, hold the connector body to prevent rocking or bending force on the connectors. If necessary, loosen the connector nut with an open-end wrench (Figure 9). Never use pliers. Complete the disconnection by hand and pull the connectors' straight apart.

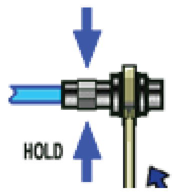

Figure 9. Hold connector body to prevent damage when breaking a connection

Figure 10 shows damaged female fingers on different types of connectors. Such damage is caused by rotation of the male center conductor, or misalignment during connection and disconnection.

Figure 10. Damaged female connector fingers

Practice 4: Protect RF Connectors and Adapters

Use torque

Though many Agilent RF/microwave connectors have been designed for rugged mechanical interfaces, users must be aware that care in applying torque to the connector nut is crucial to long life and full signal performance. Too much torque will result in deformation of the connector parts and probably a mismatch problem. Not enough torque will yield a bad connection with poor VSWR. Table 4 shows the recommended torque for various connector types. Using the correct torque also improves measurement repeatability.

Table 4. Recommended tightening torque by connector type

Connector type	Torque lb-in (N-cm)
Precision 7 mm	12 (135)
Precision 3.5 mm	8 (90)
SMA	5 (56) Use the SMA torque value to connect male SMA connectors to female precision 3.5 mm connectors. Use the 3.5 mm torque value to connect male 3.5 mm connectors to the female SMA (8 lb-in).
Precision 2.4 mm	8 (90)
Precision 1.85 mm	8 (90)
Type-N	Type-N connectors may be connected finger tight if a torque wrench is used. 12 lb-in (135 N-cm) is recommended.

Figure 11 shows an example of a Type-N torque wrench. It is to be held lightly at the end handle when tightening. Stop tightening when breaking-point is reached.

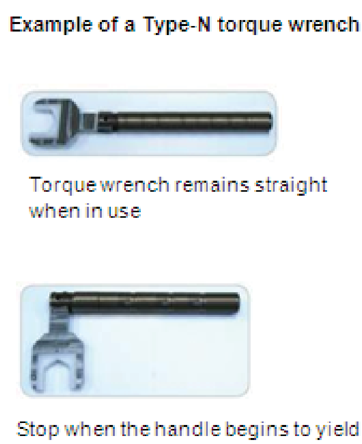

Figure 11. Using a Type N torque wrench prevents over tightening

Practice 4: Protect RF Connectors and Adapters

Use adapters as connector savers

Using an adaptor is one means of protecting the power sensor's RF input connector (Figure 12). The most obvious reason for using an adaptor is if the device under test (DUT) doesn't use the same connector family as the power sensor. Even if the DUT does use the same connector family, using an instrument-grade adaptor can provide protection, preventing damage and costly repairs. Note: Do not use adaptors during metrology calibration as they can compromise high-precision accuracy.

Figure 12. The use of adapters can protect connectors

Visual inspection

It is very important to visually inspect connectors. Because connectors have very precise mechanical tolerances, minor defects, damage, and dirt can significantly degrade repeatability and accuracy. Before making a connection, visually inspect for obvious defects such as badly worn plating, deep scratches, or dents. Gold plated connectors are more susceptible to mechanical damage because the metal is soft.

Damaged threads will usually cause metal flakes to be deposited into other parts of the connector causing severe damage. Discard, or send for repair any connector with an obvious defect. For debris such as loose metal particles or small fibers, use compressed air or nitrogen set to a low velocity of < 400 kPa.

For dirt or stubborn contaminants that cannot be removed with compressed air, use a lint-free swab moistened with isopropyl alcohol. Don't use other solvents as they may attack the plastic dielectric bead that supports the center conductor. Use a radial cleaning motion: not circular. Take care to avoid snagging the cleaning swab on the center conductor fingers.

Practice 4: Protect RF Connectors and Adapters

Use a gauge

The connector gauge is a tool to mechanically inspect RF connectors (Figure 13). It measures pin depth. Because mechanical tolerances for RF connectors can be very precise, even a perfectly clean, unused connector can cause trouble if it is out of mechanical specification (Figure 14). Before using a connector for the first time, record the pin depth to compare with future readings.

Figure 13. Connector gauge measures pin depth

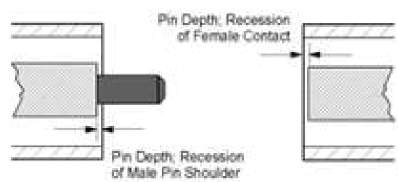

Figure 14. Proper pin depth is necessary for ensuring measurement accuracy

If the shoulder of the male pin protrudes beyond the outer conductor's mating surface, making the connection will generate force against the female contact causing damage to both the male and female parts.

Handling and storage

When not in use, use the manufacturer-supplied protective end caps to protect the connector. Never store connectors, or calibration standards, loose in a box. This storage method is a common cause of connector damage. Do not touch mating plane surfaces. Natural skin oils and microscopic particles are difficult to remove from these surfaces. Do not set connectors contact-end down on a hard surface. The plating and mating plane surfaces can be damaged if the interface comes in contact with any hard surface.

Practice 5: Ensure Proper Grounding

Always use the three-prong AC power cord supplied with the power meter, which ensures that the equipment is properly grounded. The Earth pin connects the exposed metal of the equipment to ground. When the instrument is working properly, there will be no current in the equipment ground. If a malfunction occurs, the equipment ground provides a path for the current to flow. This protects the instrument and the operator.

Check AC power quality and polarity; typically the required AC voltage is 100, 120, or 220 V ±10%, or 240 V +5%/–10%. The typical expected grounding wire resistance is < 1 Ω, and the voltage between the neutral and ground line is < 1 V. Install an uninterruptible power supply (UPS) if necessary.

Practice 6: Take Electro-Static Discharge (ESD) Precautions

Static electricity can build up on our body which can easily damage sensitive internal circuit elements when discharged. Even static discharges too small to be felt can cause permanent damage. The ESD symbol on the labels of power sensors indicates that power sensors are extremely static-sensitive devices (Figure 15). An electrostatic discharge to the center pin of the connector will render the power sensor inoperative.

Figure 15. Labels used on power sensors to indicate their sensitivity to ESD

To prevent damage caused by ESD:

- Always put the connector cap back on an unused power sensor
- Conduct power measurements at a static-free workstation whenever possible
- Perform any cleaning or inspection of the power sensor only at a static-free workstation
- Avoid bringing sources of static electricity within one meter of a static-safe workbench

Practice 6: Take Electro-Static Discharge (ESD) Precautions

ESD protection setup

Figure 16 shows a typical ESD protection setup using a grounded mat and a wrist strap.

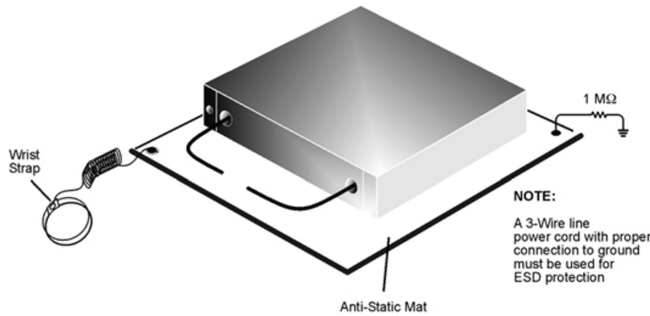

Figure 16. Typical configuration for ESD protection

The table top is covered by a dissipative mat connected to ground through a 1-MΩ resistor. A conductive surface needs to be avoided because the low electrical resistance could result in a transient-like discharge of static electricity. A rapid discharge is far more damaging to the electronic device than a gradually-paced discharge through a static dissipative material. The dissipative mat allows any charge placed on the surface to flow around the mat so that all parts of the mat share the same charge. When the mat is grounded, these charges recombine at a slower rate until the mat is static-free. The 1-MΩ resistor is required in order to limit the fault current to 0.5 mA at the highest voltage that may be encountered.

Grounded workers with a high-resistance wrist strap. The wrist strap slowly dissipates high resistance current, preventing a current rush to the ground that could cause serious injury. This strap is commonly made of elastic nylon fabric with conductive fibers on the inside surface.

The use of anti-static footwear on a grounded floor further enhances the protective capabilities of a static-safe environment. The worker should also wear an anti-static smock.

Practice 7: Check for Temperature and Humidity

All power meters and sensors must be properly stored. Performance of equipment may be impaired by exposure to extremes of humidity, temperature, dust, and other conditions. Power sensors and meters should be kept in a clean and dry environment. Ensure there is ventilation in the equipment rack. Inspect and clean cooling vents and fans on a regular basis.

Refer to the data sheet for the recommended operating and storage environmental conditions. The optimal operating temperature is 23 °C ±5 °C. Always keep the instrument at an ambient temperature of < 30 °C. If the device is used outside of this range, errors can be produced in measurements. The internal electronics of the measuring instrument may be destroyed at extreme temperatures.

Relative humidity is a ratio of how much water vapor is in the air over the maximum possible amount of water vapor at a given temperature and pressure. Often overlooked, relative humidity is a significant environmental factor in ESD. Dry air can cause substantial static charge to build up as it flows.

Conclusion

The understanding and use of the practices outlined in this paper are highly recommended in order to extend the power meter and power sensor instrumentation service life and reduce downtime and maintenance costs. Protecting the instruments in good condition to ensure accurate power measurement in the applications reduces the minimal test time and maximizes the overall throughput.

Related Agilent Literature

Publication title	Pub number
Choosing the Right Power Meter and Sensor Product Note	5968-7150E
4 Steps for Making Better Power Measurements Application Note 64-4D	5965-8167E
Coaxial Systems: Principles of Microwave Connector Care Application Note 326	5954-1566
Fundamentals of RF and Microwave Power Measurements (Part 1) Application Note 1449-1	5988-9213EN
Fundamentals of RF and Microwave Power Measurements (Part 2) Application Note 1449-2	5988-9214EN
Fundamentals of RF and Microwave Power Measurements (Part 3) Application Note 1449-3	5988-9215EN
Fundamentals of RF and Microwave Measurements (Part 4) Application Note 1449-4	5988-9216EN
Agilent Power Meters and Sensors Selection Guide	5989-7837EN
Understanding DC-coupled and DC-blocked Power Sensors and How Your Choice of Sensor Would Impact Measurement Accuracy Application Note	5990-6745EN

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