Vulcan RFID™ Power Mapper

The Vulcan RFID™ Power Mapper is a worldwide battery-free RFID Field-Mapper and Power-Meter, designed specifically for **RAIN Gen 2 UHF tagging systems**. This product is ideally suited for system installation, research, and teaching**.**

Features:

- No battery – it harvests the RF power
- Range SET adjustment 0 to 14 meters (45+ Feet)
- Wide frequency range, all world regions
- Works with all Gen2 UHF RFID Readers
- Modulation output for oscilloscope use
- DC Level output for data logging or voltmeter
- 0dBm measurement reference, factory CAL

What it can do:

- Shows nulls and dead spots in the RF signal
- Accurately maps the RFID field for reliable installations
- Detects which antennas are transmitting
- Test's polarization of antennas; linear, circular, and cross-polarized
- Excellent installation, research, and teaching tool
- Ideal for beam angle measurements and antenna direction setup
- Notify-time and other transmit interruptions can be detected
- Oscilloscope output to view the modulation or for data logging the signal strength
- Fault finding, it can detect cable faults and bad connections
- It can be mounted permanently in the RF field to monitor, or data log the RF power
- dB scale for comparison power measurements (user-adjustable)
- 0dBm calibration switch for power measurements
- Removable antenna with grip cover, so other antennas can be tested

Specifications:

- Frequency range 860MHz to 955 MHz: Europe, USA, and the Far East
- Tested with dipole, linear, circular, and cross-polarized antennas
- Tested for use to EN302-208, 866 MHz EU readers
- Tested for use with 915MHz US FCC approved RFID readers
- Tested for use with 922.5MHz China readers
- CE, Fcc marked and compliant with all known radio standards
- The Power-Mapper contains no lead or other banned substances, RoHs compliant
- The Power-Mapper does not transmit or radiate any RF signals
- Height 107mm, Width 71mm, Depth 41mm
- 0dBm reference +-1dB accuracy; can be user recalibrated
- SMA (female) Input 50 Ohms, max power +12dBm
- Input VSWR, typically 1 to 1.13 at 889MHz; +-1 dB over the frequency range

Basic Instructions (Mapping Mode)

Switch to Map mode and hold the Power-Mapper between your finger and thumb, avoiding the antenna. Then, move the meter slowly around the area you want to test. Note, moving the Power-Mapper up and down vertically will show the signal nulls at any given location. If you are using tags horizontally, then hold the meter horizontally and do the same as above.

In a good open-field location, almost no significant nulls will be detected; however, in an indoor environment, nulls of almost zero can often be seen. A reading of less than 4% on the scale means a stationary tag may not be detected at that location.

If the meter is too sensitive for your measurements, then the range can be reduced in two ways. The first quick method is to move the top switch over to the 0dBm mode, this will give a significant reduction in the range allowing measurements and comparisons to be made much closer to the transmit antenna.

If the range is still an issue the meter can be adjusted using the SET preset on the back. This adjustment works in both Map and 0dBm modes. Turn the SET control fully clockwise to regain calibration.

General Best Practice

The best mapping method is to walk away from the antenna, not towards. Constructive interference will cause some reading areas at a longer range than the first dead zone. This is even more pronounced when tags are placed horizontally.

The area further than the full range is referred to as the ‘spotty null’ region. Often tags can be read in this region; but only if the tags are moving through the field or on a turntable. This is the reason handheld readers work so well; you are moving the spotty nulls and constructive peaks over the tags. Note, do not assume there will be a null behind a metal post or panel. UHF signals re-radiate from edges creating new signals and polarizations; this meter will give you some surprises.

Height is beneficial in RFID installations, mainly due to the reduction in ground bounce which in turn reduces null regions. This applies to both tag height and antenna height. Try to prevent antennas from pointing directly at each other, even when one is off. Avoid antennas pointing directly at the ground; if any signals are reflected back to the antenna, large-signal nulls will be created.

These problems arise because we are dealing with coherent waves which add and cancel at spot locations. Theoretically, they can cancel to zero at one point and then at another point, further from the antenna, they can add to give twice the expected power. It is recommended that all installations which are dormant for any length of time have the RF output switched off. Most readers have I/O ports just for this purpose. PIR detectors or simple door switches can be used to reactivate the RF signal when needed.

Currently, the USA has 50 channels around 916MHz dedicated to Gen2 RFID. In Europe, and the UK etc. four channels are used at 865.7 MHz, 866.3 MHz, 866.9 MHz and 867.5 MHz. The lowest frequency is in Europe 865.7 MHz. The highest frequencies are in Japan with 952 MHz to 954 MHz.

Remember that your body will reflect and absorb radio energy; setting the meter on a non-conductive stand and moving away, or well behind the meter, is preferred. The meter is omnidirectional so you can turn it towards you to view the dial.

That's it! You can now complete accurate and reliable RFID installations, do valuable research and use the meter as a teaching tool. You're no longer working blind.

Expert user instructions:

Key to Fig2

1. Map/0dBm switch (long or short-range)

2. Removable 889MHz antenna, matched to the 50 Ohm, female SMA type meter input.

3. Signal ground for external equipment

4. Factory calibrated to 0dBm. Expert use only. Do not adjust unless you are re-calibrating to a known reference signal.

5. User range control, turn back to fully clockwise for true 0dBm measurements

6. DC or Modulation output, for external equipment. (Selected by the fast/slow switch)

7. Fast/slow switch for detector speed.

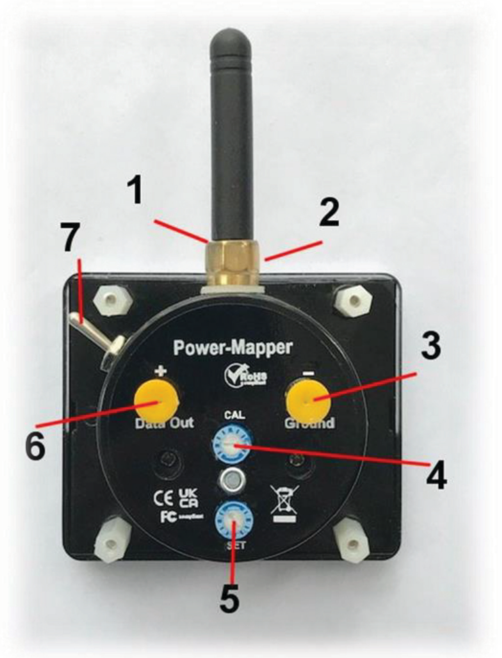


Fig2

1) Reader antenna analysis:

Switch to 0dBm mode, then take a reading close to the antenna; use the SET adjustment or turn the reader power down to get closer if needed; 1 to 3 meters for most systems. Rotate the Power-Mapper 90 Degrees from vertical to see the power in the horizontal polarization plane.

For example, a vertical linear antenna will give a very low reading in this horizontal plane and a high reading when vertical. A horizontal linear antenna will give the opposite, a very low signal in the vertical plane and a high signal when the meters antenna is horizontal. As you would expect a circularly polarized antenna will show a strong signal in both orientations. If a reduced signal is seen at 45 degrees it's likely the antenna is cross-polarized.

Circularly polarized antennas have become very popular in RFID; however, they do have drawbacks. First, is the power efficiency, which is half of that of a linear antenna (with the same gain) and secondly, the signal is affected more by reflections from the ground.

To test circular polarized antennas for the most common dead zone region, use the meter horizontally at about 3 to 5 meters range; the dead zone can then be found by moving the meter up and down vertically. Try other distances to map the depth of the dead zone. This dead zone is caused by the signal bouncing off the ground, reversing phase and cancelling with the direct signal at the tag. This is known as destructive interference and is one of the main reasons for unreliable RFID installations before power mapping was introduced. Now that low-cost paper tags are available for wine bottles etc. vertically polarized antennas have become popular again; with reading ranges of 14+ meters, (45 feet) or more.

If you point the Power-Mappers antenna or a tag, directly at any antenna the reading will be very low; this is called ‘end on reading’. 3D tags are specially designed to avoid this problem.

2) Reader attenuators:

Some readers have built-in attenuators. With the meter reading 0dB, switching the reader's attenuator to -3dB, you will see a similar change on the meter. Tip: the meters output terminals give more accuracy than the meter scale (see the graph below).

3) Antenna beamwidth measurements:

First, check the environment for multipath nulls; an open outdoor area gives more consistent results for the antenna measurements. However, you may want to know the beam width at various heights in your RFID installation environment so that antenna and tag positions can be optimized. Note: high gain antennas usually have narrow beamwidths.

Method: Switch all other antennas off and find a position in front of the antenna under test. This should be about half the range of the antenna. Set the meter to read about 0dBm using the SET adjustment. Move to one side keeping a constant distance from the antenna. When the meter drops to read -3dB mark this location. Then, maintain the same distance from the antenna, move to the other side and mark this location. The angle between the antenna and the two locations is the antennas beamwidth. Note: -3dB is half the transmitted power.

4) Antenna polar plot:

This measurement requires a working area with very little multipath unless you are measuring the polar plot in the area of installation to find the best compromise tag locations. One quick method is to set up as above in the beam angle measurement. Then, as well as marking the two locations at either side mark over 10 locations around the antenna beam where the meter is reading approximately -3dB. This will give you a good reference polar plot in the area where tags will be located. Doing this measurement at various heights will create a 3D field strength plot of the installation area. Switch the meter to slow for best results.

5) Antenna comparisons:

Set the meter to 0dBm mode and the SET adjustment fully clockwise. Then, position the meter at a location when it is reading -3dBm. Replace the antenna with the antenna you want to test and compare the results. For example, if the meter reads 0dBm with the new antenna it is transmitting twice the power of the original antenna. Beware! This means that the new antenna has a much narrower beam which may reduce the number of tags read. Note: it is good practice to turn off the RF power when connecting or disconnecting antennas.

6) The Power Mapper 0dBm and Effective Radiated Power:

The reason that this is estimated power is that accurate measurement can only be made by a test house using an RF anechoic chamber. These chambers eliminate the multipath signals and hence constructive and destructive nulls are almost eliminated. The power mapper allows you to measure the power in your installation environment, which could be quite different from the antenna’s specification due to metal in the flooring, metal posts etc.

Switch to 0dBm mode and adjust the SET adjustment fully clockwise; the meter has now been set to its factory calibrated input; the full scale 0dB is now at a 1mW power level. This corresponds to 0dBm at the meter input connector.

In this configuration, with the supplied antenna, a 2W ERP (EU) or a 4W EiRP (US) transmission will give full scale at a range of approximately 1.5Meters. (5 feet). For a circularly polarized antenna, this may reduce to 1.125 Meters, unless the reader has increased power to compensate for the -3dB loss or the antenna has +3dB extra gain. Note: EiRP = ERP+2.15dB and so tag read ranges are similar in Europe and in the USA etc. Note, 1.5 Meters is the actual reading in an open environment. Inside a building, ground bounce can extend this to 2 meters (6' 7").

7) Fixing the meter in a set location:

As the meter harvests the power from the transmitted signal, it can be installed permanently at the installation site. It will show clearly the changes in the power level, instantly indicate faults and also display changes in the field strength when people are within the reading area. The hex standoffs on the back of the meter can be unscrewed and so lengthened (a screw kit is supplied with the meter for various attachments).

8) Viewing the modulation:

An oscilloscope can be connected across the data out terminals to show the modulation on the signal. For this, the fast/slow switch, at the side of the meter, must be in the 'fast' position. The signal on the oscilloscope is the modulation sent from the Reader to the tag; seeing the reflected signal from the tag is almost impossible unless the TX-RX pulse can be obtained from the reader. Tip: to see the modulation, switch your oscilloscope to AC input.

9) Data Logging the output from the meter:

When the fast/slow switch is in the slow position, the internal detector is switched to 'slow' peak detection of the signal. This is ideal for feeding instruments such as voltmeters, data logging devices, plotters etc. The power-mapper creates a DC voltage representing the signal strength. Note: Bluetooth multimeters can data log the voltage to your smart device. AN9002 is one example.

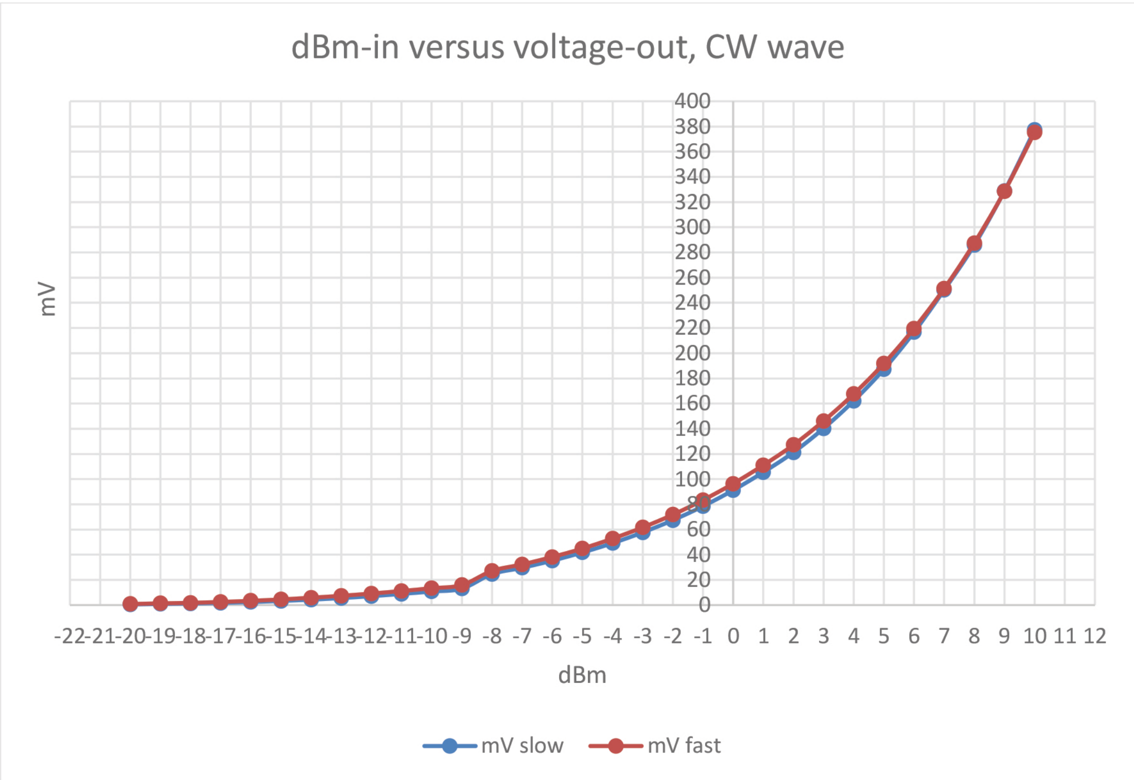


Table 1: Typical output voltage versus input power in dBm, carrier wave input.

It is useful to know that a -3dB reduction in radiated power is half the power transmitted, this will give an approximately 25% reduction in range due to the square law of power with distance effect The Mapping mode is approximately 8dB more sensitive than the calibrated 0dBm mode.

Expert RF engineer section: Advanced.

10) Direct antenna measurement:

The meter's antenna can be removed by hand and replaced by other Gen 2 compatible antennas for evaluation and comparison. The graph above, of voltage out against dBm, can be used for more accurate tests over a wider power range than using the needle scale. Use a good high impedance voltmeter for the best accuracy.

11) Power Meter Mode:

This power-mapper has been factory calibrated so that 0dBm, at the 50 Ohm input, will be at full scale; this is with the SET adjustment fully clockwise. The dB scale will then read absolute dBm. The calibration is made at 889MHz (between the two main RFID bands). At this frequency, the input VSWR is typically 1.03 to 1. With no cable loss, the needle will be within 1 dB of 0dBm (0dBm = 1mW of power).

There is a CAL preset at the back of the meter for recalibration or calibration to other references. Note: if you are comparing a power meter with a spectrum analyzer you need to set the resolution bandwidth 'RBW' of the spectrum analyzer very wide so that the power in the sidebands is included.

The maximum input level to the meter should not exceed +12dBm. The SET adjustment can be used to temporarily offset the calibration to read higher power levels than 0dBm on the meter's scale. The output voltage can also be used for higher power readings when attenuators are not available.

12) Reader Power output, conducted measurement:

Note, a test house is required to acquire radio approvals; however, this meter is good for preparing for submission and understanding the reader power in your installation area.

Please do not connect this power meter directly to your reader, this could cause damage to the meter if the power is above 15dBm.

Preparing the reader: Turn off the other reader ports (antennas), switch to one transmit channel only, switch the number of cycles to about 5. Switch the internal attenuator to 0dB. Most fixed readers can output over 33dBm and so you will need attenuation of about 30dB to 36dB between the reader and the meter; variable attenuators are very useful for this task.

Results: If the reader output is 33dBm for example, with a 36dB attenuator the meter will read about -3dB (-3dBm). However, with a 30dB attenuator, the meter will be off the scale! A voltmeter at the output will read about 145mV; using the above chart this is +3dB. And so, in both cases, we have estimated the power to be 33dBm.

13) Power Measurement Pitfalls:

One quick check to see if you are going to get a good answer is to go back to using the meter with its antenna connected and see if the meter changes when the reader is reading a tag. If you see the meter change then check that the reader is performing about 5 read cycles to ensure steady RF power. Alternatively, you may be able to switch the reader to CW mode, all the power is then in a narrow band.

14) Radiated power calculations:

Note: the maximum power in the USA is 4W EiRP and in Europe, the maximum is 2W ERP note EiRP - 2.15dB = ERP. In the USA, an isotropic antenna reference is used; in Europe, a dipole reference is used; the difference is 2.15dB.

A new band has been released in Europe at 916 MHz; some channels can be used at 4W ERP. This is twice the power in the lower band and so this increase of 3dB will give 25% extra range.

15) Radiated Power example, for the USA:

Let's say we have measured 30 dBm at the output of the reader. We did this using a 33dB attenuator in the signal path.

This was simple as we had a 33 dB attenuator and the meter read 3dB down. 33 - 3 = 30 dBm. However, we want to know if our system could be compliant with the regulations. To do this we need to know the gain of the linear antenna. Looking on the back of the antenna, it could say (for example) 6dBi.

As we are in the USA this is a radiated power of 30 dBm + 6 dBi so we have 36 dBm from the antenna; now, we want this in Watts. Using an online calculator, the result is 3.98 Watts. If you like to calculate, then P in Watts, is (10^(36/10))/1000) = 3.98 W EiRP (alternatively, use the chart at the back of these instructions).

What we have now is Effective isotropic Radiated Power. This is just inside the legal limit of 4W EiRP for the USA so we should be ok. Note, we can't use a 7dBi antenna on this system as we would be transmitting 5W EiRP, which is not compliant with regulations.

Note. For a circular-polarized antenna, we can add 3dB extra power as the power has been split into two separate polarizations.

16) Radiated Power example, for Europe and the UK:

We must now calculate ERP and not EiRP and so the calculation is slightly different. For example, let's say we have measured 29dBm at the output of the reader. We did this using a 33dB attenuator in the signal path.

To get the result was simple as we had a 33dB attenuator and the meter read -4dB down. 33 - 4 = 29dBm of power from the reader. However, we want to know if our system could be compliant with the regulations and so we need the result in Watts.

To do this we need to know the gain of the linear antenna. Looking on the back of the antenna, it could say (for example) 6dBi.

In Europe our radiated power is 29dBm + 6 dBi – 2.15dB; this -2.15 will take into account that the antenna is specified in dBi, (not dBd), so now we will get our answer in ERP. We have 32.85 dBm from the antenna; we now want this in Watts. Using an online calculator, the result is 1.93 dBm. If you like to calculate for yourself, then P in Watts, is (10^(32.85/10))/1000) = 1.93W ERP(alternatively, use the chart at the back of these instructions).

We can see that we may be just within the limit of 2W ERP. Note: we cannot use a 7dBi antenna on this system as we would be transmitting 2.4W ERP, which is not compliant with regulations in the lower band; however, it is compliant in the upper band.

Note. For a circularly polarized antenna, we can add 3dB extra power as the power has been split into two separate polarizations.

We hope you find the results from using this meter useful, interesting and educational.

17) Other information

The white plastic hex standoffs at the back of the meter can be extended for better stability vertical/horizontal; or, for permanent fixing to other equipment.

The front center screw sets the meter zero. (two turns to cover max and min settings).

18) Small print:

Safety Regulations state that you should not work within 25cm 9.5” of a 4W EiRP transmission for long periods.

Disclaimer. We will take no responsibility for errors in these instructions. We reserve the right to make changes and additions when required.

Conforms to all radio standards for RFID, EN and FCC included.
The Power-Mapper can be returned for disposal, it is RoHs compliant and EN60950 safety-compliant.

USEFUL NOTES:

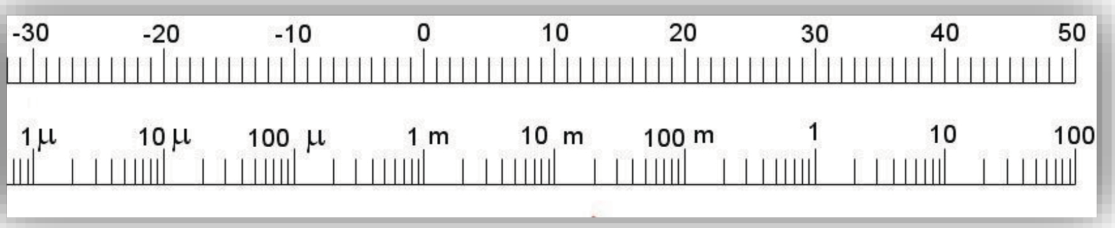
Why is power measurement important?

Answer: Some people may think that because you can only see tags at 15 meters, this is where the transmission ends. The transmission actually travels more than 3km (1.86 miles) and so, it is easily detected by radio amateurs and authorities. If you are using a reader in the wrong world region, it can be detected by mobile-phone base stations and the military! Heavy fines are imposed.

Conversion Chart

A vertical line converts dBm to W or W to dBm in a 50 Ohm system.

dBm



Watts

Note: if the signal transmitted is reduced by -3 dB, using an internal or external attenuator then the transmitted power is halved. However, this power reduction only reduces the range by 25% (square law effect).

Conversely, if you want to double the range, you need to use four times the power, this is +6dB.

EiRP = ERP + 2.15 dB**.** Note, EiRP compares an antenna to a point source and ERP compares an antenna to a dipole. Dipoles have a gain of 2.15 dB in the USA; dipoles have a gain of 1 in the EU and UK etc.
EiRP = 1.64 x ERP
dB = 10 LOG_{10} (P1/P2), compares any two power levels.
dBm = 10 LOG_{10} (P/1mW), compares power with 1mW (0 dBm) reference
P in Watts = $(10\text{^}(^{dBm}/10))/1000$

Regulations, max power:
2W ERP max in the lower band in Europe and UK. See EN 302-208 for the formula.
4W ERP max in the upper band in Europe. 4W ERP = 6.56W EiRP for comparison with the USA
4W EiRP max in the USA = 2.44W ERP for comparison with Europe lower band.

Note: the Gen2 standard does not transmit your Bar Code/ePc data or any other data useful to competitors from the antenna.

Note: contrary to spell checkers and many documents: Volts, Amps, Hertz, Ohm, Bells, etc. are names of amazing people and so should have a capital letter; for example, MHz, dBm, mV, Ohm etc.