

WaveMon RF-60 E+H

Calibration procedure



Document	Version	Date
WaveMon RF-60 E+H. Calibration Procedure	1.0	15/11/2021

CONTENT

1	General.....	2
2	Calibration setup and fields calculation	3
2.1	Calibration Setup.....	3
2.1.1	Net power calculation	4
2.2	Electric and magnetic field calculation.....	5
2.3	Preliminary checks	6
2.4	Probe positioning	6
3	WaveMon Calibration	8
3.1	Field generation	8
3.2	Field Reading	8
3.3	Expected measurement	9
3.3.1	Electric Field	9
3.3.2	Magnetic Field.....	9
4	Setup Validation procedure	10

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Document	Version	Date
WaveMon RF-60 E+H. Calibration Procedure	1.0	15/11/2021

1 GENERAL

This procedure describes how to calibrate the WaveMon RF-60 Personal Monitor.

The chosen method is the calibration using calculated field strengths as described by the IEEE Std 1309-2013: *IEEE Standard for Calibration of Electromagnetic Field Sensors and Probes (Excluding Antennas) from 9 kHz to 40 GHz*. The unit under calibration is placed in a reference field that is calculated based on the geometry of the field generator (TEM cell in this case) and its measured input parameters.

CONFIDENTIAL

Document	Version	Date
WaveMon RF-60 E+H. Calibration Procedure	1.0	15/11/2021

2 CALIBRATION SETUP AND FIELDS CALCULATION

For the calculated field strength method, it is recommended using the net power delivered to the TEM Cell. Setup and calculations are described in this chapter.

2.1 CALIBRATION SETUP

The recommended setup is shown below:

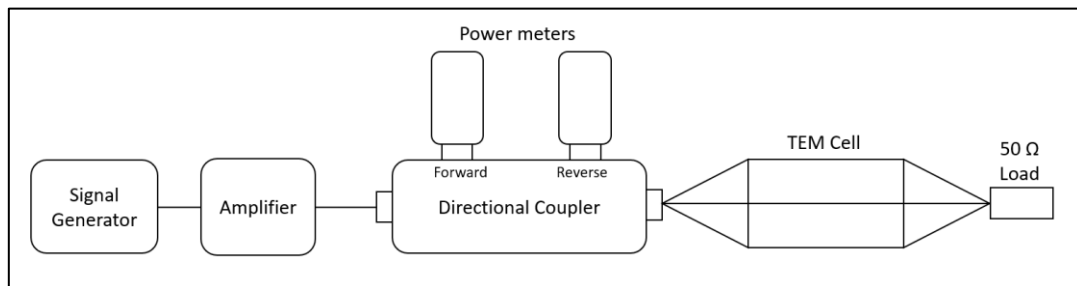


Figure 1. Net power method setup

Laboratory equipment requirements:

- Signal Generator:
 - o Frequency range must include the range [1 – 500] MHz
 - o Maximum output level > +5 dBm
- Amplifier
 - o Frequency range must include 100 MHz
 - o Gain > 40 dB
 - o Output Power at 1dB compression > 40 dBm
- Directional Coupler
 - o Frequency range must include: 100 MHz
 - o Coupling factor (CF) \approx 40 dB
 - o Maximum power CW > Amplifier power at 1dB compression
 - o Directivity > 20 dB
 - o Insertion losses < 0.5 dB
- Power meters
 - o Frequency range must include 100 MHz
 - o Power measuring range:
 - Pmin < -55 dBm
 - Pmax > + 10 dBm
 - o Pmax (dB) > Pmax amplifier (dB) – Coupling Factor Directional Coupler (dB)
- 50 Ω Load
 - o Maximum power (Watt) > Amplifier power (Watt)
 - o Maximum VSWR: 1.1:1

Document	Version	Date
WaveMon RF-60 E+H. Calibration Procedure	1.0	15/11/2021

Reference devices that need calibration:

- Power meters
- Directional coupler
- TEM Cell: Distance from septum to the plate

2.1.1 Net power calculation

The net power delivered to a transmitting device can be measured with a 4-port dual-directional coupler. A typical setup is shown below:

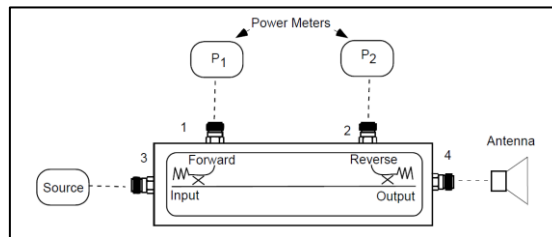


Figure 2. Directional coupler ports

The forward and reverse coupling coefficients under conditions of matched-load terminations at the ports are defined by the following power ratios. These coefficients are provided by the directional coupler manufacturer or by the calibration laboratory.

$$C_{fwd} = \frac{P_4}{P_1} \quad C_{rev} = \frac{P_2}{P_1}$$

The net power delivered to the transmitting device is then

$$P_{net} = C_{fwd} P_1 - C_{rev} P_2$$

where P_1 and P_2 are the power meter readings (linear units).

Document	Version	Date
WaveMon RF-60 E+H. Calibration Procedure	1.0	15/11/2021

2.2 ELECTRIC AND MAGNETIC FIELD CALCULATION

Rectangular TEM cells are designed to have a characteristic impedance of 50 Ω.

The fields at the test point (the geometrical center between the septum and the bottom or top plates) can be calculated from Equation 1 and 2.

$$E = \frac{V}{b} = \frac{\sqrt{P_{\text{net}} Z_0}}{b} \quad (\text{eq. 1})$$

$$H = \frac{E}{377} \quad (\text{eq. 2})$$

Where:

- V is the voltage at the input or output port of the cell
- Z₀ is the real part of the characteristic impedance of the cell
- b is the distance from the upper plate to the center plate
- P_{net} see A.2.2 for determination of this parameter

These field values apply only at the test point for a well-matched TEM cell, and significant variation will be seen closer to or farther from the septum. Equation 1 gives the field at the midpoint between the top or bottom plate and the septum. Field probe calibrations shall be limited to use of this center position.

Document	Version	Date
WaveMon RF-60 E+H. Calibration Procedure	1.0	15/11/2021

2.3 PRELIMINARY CHECKS

Before starting the calibration, the following checks need to be performed:

- Verification of temperature and humidity values in the calibration environment. Ensure that these magnitudes are between 20 and 26°C and between 20 and 70% RH of humidity.
- Switching on all equipment for warm-up 15 minutes before the start of calibrations.
- Verification of all RF connections (connectors well tightened by hand).
- Check that the ambient electric field in the calibration area is under 0.2 V/m.

2.4 PROBE POSITIONING

The WaveMon must be placed perpendicular to the E-Field vector and with a 45° to the H-field vector.

Three positions are used to perform the calibration. The first position is described below. For the position 2 and 3 the WaveMon must be rotated +120° and -120° from the first position.

The electric and magnetic field sensors will be calibrated using the same positions.

Position 1	Position 2	Position 3
<p>TOP VIEW</p>	+120° rotation regarding position 1.	-120° rotation regarding position 1.

Figure 3. E-Field & H-Field positioning

Document	Version	Date
WaveMon RF-60 E+H. Calibration Procedure	1.0	15/11/2021

The sensors zone must be in the midpoint between the top or bottom plate.

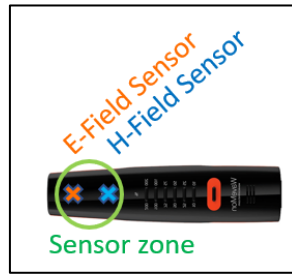


Figure 4. Sensor Zone

CONFIDENTIAL

Document	Version	Date
WaveMon RF-60 E+H. Calibration Procedure	1.0	15/11/2021

3 WAVEMON CALIBRATION

3.1 FIELD GENERATION

A linearly polarized electromagnetic field, approximating a plane wave, must be generated at the WaveMon position.

The recommended levels to calibrate are 100% and 50% of the limit.

FCC Standard at 100 MHz		
Power density percentage	Electric Field	Magnetic Field
100 %	61.4 V/m	0.1629 A/m
50 %	43.42 V/m	0.1152 A/m

Bellow there is an example of how to calculate the P_{net} to obtain the desired electric field.

E = 61.4 V/m

b = 0.147 m

Z = 50 Ω

$$P_{net} = \frac{(E \cdot b)^2}{Z} = 1.63 \text{ W}$$

Once the P_{net} is calculated, the signal generator power must be set to obtain this P_{net}.

3.2 FIELD READING

A software is provided to read the measurement data from the WaveMon's optical interface.

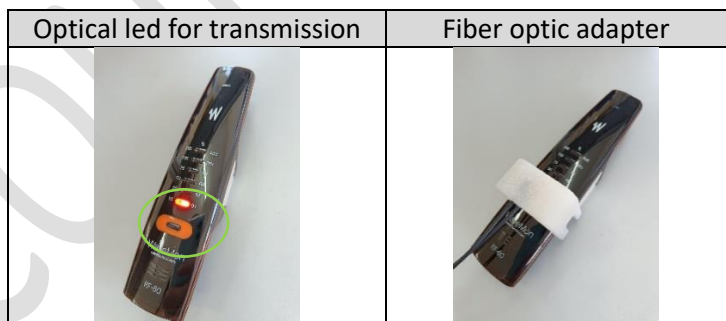


Figure 5. Optical communication

Data frames received by the optical interface:

```

//***** Electric Field *****//
//***** Magnetic Field *****//
//***** Total *****//
X-axis (N)      Y-axis (N)      Z-axis (N)      Total (N)      X-axis (N)      Y-axis (N)      Z-axis (N)      Total (N)
Ref_wv_473_380646; @AP19/RMS-wvEa:23.123322  FvEa:4.374778  WvEy:67.537354  FvEz:11.472652  WvEz:12.283788  FvEz:12.148642  FvEz:18.216872; 1/FP17/RMS-wvMz:71.399963  FmZ:32.918991  WvMz:18.111214  WvMz:9.903566  FvMz:4.460332  FvMz:45.487808;
Ref_wv_473_380646; @AP19/RMS-wvEa:23.262271  FvEa:4.380866  WvEy:67.786348  FvEz:11.738959  WvEz:12.137651  FvEz:12.242262  FvEz:18.213171; 1/FP17/RMS-wvMz:71.406858  FmZ:32.732476  WvMz:18.141218  WvMz:9.871406  FvMz:4.458624  FvMz:45.504621;
Ref_wv_473_380646; @AP19/RMS-wvEa:21.159911  FvEa:4.381939  WvEy:67.578613  FvEz:11.478793  WvEz:12.160939  FvEz:12.144466  FvEz:18.207386; 1/FP17/RMS-wvMz:70.841492  FmZ:32.458085  WvMz:18.051202  WvMz:9.951638  FvMz:4.487188  FvMz:45.204449;
Ref_wv_473_348689; @AP19/RMS-wvEa:22.288227  FvEa:4.342314  WvEy:67.380758  FvEz:11.828125  WvEz:12.204953  FvEz:12.183286  FvEz:18.187856; 1/FP17/RMS-wvMz:71.405858  FmZ:32.752476  WvMz:18.194304  WvMz:9.823781  FvMz:4.426819  FvMz:45.130809;
Ref_wv_473_426421; @AP19/RMS-wvEa:22.379156  FvEa:4.346508  WvEy:67.426871  FvEz:11.456894  WvEz:12.238190  FvEz:12.188891  FvEz:18.164446; 1/FP17/RMS-wvMz:71.826885  FmZ:32.735544  WvMz:18.574288  WvMz:9.853241  FvMz:4.442338  FvMz:45.161678;
Ref_wv_473_380646; @AP19/RMS-wvEa:22.921988  FvEa:4.375336  WvEy:66.903589  FvEz:11.486274  WvEz:12.184482  FvEz:12.088821  FvEz:18.027441; 1/FP17/RMS-wvMz:70.211968  FmZ:32.487711  WvMz:18.722261  WvMz:9.880356  FvMz:4.370461  FvMz:44.886818;
Ref_wv_473_380646; @AP19/RMS-wvEa:22.775965  FvEa:4.387106  WvEy:66.799776  FvEz:11.564443  WvEz:12.179747  FvEz:12.072940  FvEz:17.952264; 1/FP17/RMS-wvMz:70.760995  FmZ:32.312861  WvMz:18.728836  WvMz:9.868733  FvMz:4.368832  FvMz:44.892357;
Ref_wv_473_380646; @AP19/RMS-wvEa:22.961887  FvEa:4.312071  WvEy:66.792518  FvEz:11.563815  WvEz:12.179747  FvEz:12.072940  FvEz:17.952264; 1/FP17/RMS-wvMz:69.760995  FmZ:32.149213  WvMz:18.857991  WvMz:9.861615  FvMz:4.318055  FvMz:44.820481;
Ref_wv_473_472139; @AP19/RMS-wvEa:22.713135  FvEa:4.284155  WvEy:66.688223  FvEz:11.564450  WvEz:12.179747  FvEz:12.072940  FvEz:17.952264; 1/FP17/RMS-wvMz:69.871875  FmZ:32.184666  WvMz:18.848611  WvMz:9.842837  FvMz:4.325885  FvMz:44.836844;
Ref_wv_473_426421; @AP19/RMS-wvEa:22.784437  FvEa:4.292888  WvEy:66.820864  FvEz:11.567824  WvEz:12.187616  FvEz:12.087568  FvEz:17.948103; 1/FP17/RMS-wvMz:70.182134  FmZ:32.385286  WvMz:18.472991  WvMz:9.878951  FvMz:4.371888  FvMz:44.268817;
Ref_wv_473_348689; @AP19/RMS-wvEa:22.628125  FvEa:4.278156  WvEy:66.724611  FvEz:11.564451  WvEz:12.179747  FvEz:12.072940  FvEz:17.952264; 1/FP17/RMS-wvMz:69.848121  FmZ:32.232658  WvMz:18.631346  WvMz:9.850855  FvMz:4.312411  FvMz:44.832975;
Ref_wv_473_380646; @AP19/RMS-wvEa:22.434326  FvEa:4.259081  WvEy:66.257925  FvEz:11.488763  WvEz:12.157113  FvEz:12.103135  FvEz:17.784879; 1/FP17/RMS-wvMz:69.781599  FmZ:32.118336  WvMz:18.423546  WvMz:9.874188  FvMz:4.332465  FvMz:44.825884;
Ref_wv_473_380646; @AP19/RMS-wvEa:22.778264  FvEa:4.278156  WvEy:66.724611  FvEz:11.564451  WvEz:12.179747  FvEz:12.072940  FvEz:17.952264; 1/FP17/RMS-wvMz:69.848121  FmZ:32.232658  WvMz:18.631346  WvMz:9.850855  FvMz:4.312411  FvMz:44.832975;
Ref_wv_473_380646; @AP19/RMS-wvEa:16.071190  FvEa:4.280399  WvEy:66.488746  FvEz:11.449111  WvEz:12.168483  FvEz:12.128876  FvEz:18.243588; 1/FP17/RMS-wvMz:49.284878  FmZ:22.644653  WvMz:19.925440  WvMz:9.161139  FvMz:4.371504  FvMz:44.841431;
Ref_wv_473_426421; @AP19/RMS-wvEa:16.621926  FvEa:4.272818  WvEy:67.190519  FvEz:11.925182  WvEz:12.184610  FvEz:12.052824  FvEz:18.430234; 1/FP17/RMS-wvMz:12.859378  FmZ:18.586238  WvMz:11.571814  WvMz:9.189895  FvMz:4.853881  FvMz:45.168852;
Ref_wv_473_426421; @AP19/RMS-wvEa:16.428375  FvEa:4.071549  WvEy:67.789224  FvEz:11.808232  WvEz:12.161542  FvEz:12.184933  FvEz:19.079741; 1/FP17/RMS-wvMz:12.841875  FmZ:19.932211  WvMz:9.788881  FvMz:4.195249  WvMz:9.688283  FvMz:4.801388  FvMz:45.174888;
Ref_wv_473_380646; @AP19/RMS-wvEa:16.183261  FvEa:4.024193  WvEy:68.479686  FvEz:11.118377  WvEz:12.179160  FvEz:12.053864  FvEz:18.482463; 1/FP17/RMS-wvMz:12.174321  FmZ:18.121291  WvMz:9.853197  FvMz:4.212897  WvMz:9.648521  FvMz:4.913893  FvMz:45.173781;
Ref_wv_473_380646; @AP19/RMS-wvEa:16.089670  FvEa:4.087561  WvEy:68.895813  FvEz:11.158695  WvEz:12.113255  FvEz:12.039880  FvEz:18.480794; 1/FP17/RMS-wvMz:12.642188  FmZ:18.252778  WvMz:9.815998  FvMz:4.179267  WvMz:9.643794  FvMz:4.889988  FvMz:45.173523;
Ref_wv_473_348689; @AP19/RMS-wvEa:16.348870  FvEa:4.028861  WvEy:68.471188  FvEz:11.351981  WvEz:12.183257  FvEz:12.033193  FvEz:18.134216; 1/FP17/RMS-wvMz:14.384963  FmZ:11.493844  WvMz:9.488228  FvMz:4.180547  WvMz:9.639323  FvMz:4.910968  FvMz:45.184882;
Ref_wv_473_380646; @AP19/RMS-wvEa:16.348870  WvEy:68.247795  FvEz:11.384447  WvEz:12.174791  FvEz:12.031676  FvEz:18.135728; 1/FP17/RMS-wvMz:14.548975  FmZ:11.165897  WvMz:9.781222  FvMz:4.121459  WvMz:9.651718  FvMz:4.926872  FvMz:45.181248;

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Document	Version	Date
WaveMon RF-60 E+H. Calibration Procedure	1.0	15/11/2021

Sample of data frame in text format:

```
Ref_mV:473.380646; 0/WP19/RMS->mVEx:23.123322 FEx:4.374778 mVEy:67.537354 FEy:11.672652 mVEz:12.281708 FEz:2.168642 FET:18.216072;
1/WP17/RMS->mVHx:71.399963 FHx:32.910591 mVHy:18.971863 FHy:8.111214 mVHz:9.903564 FHz:4.465232 FHT:45.487038;
```

3.3 EXPECTED MEASUREMENT

The frequency response of the WaveMon determines the measurement deviation at each frequency. At 100 MHz there is an adjusted deviation that optimizes the frequency response in the full range.

Acceptance criteria: the measured deviation should be less than ± 1.5 dB from the expected reading (%). The resultant percentage of power density is calculated below:

3.3.1 Electric Field

Frequency (MHz)	RF-60 Response (dB)	Generated Field (%)	Generated Field (V/m)	Expected reading (%)	Min (%)	Max (%)
100	-0,5	100	61,40	89,1	63,1	125,9
100	-0,5	50	43,42	44,6	31,5	62,9

3.3.2 Magnetic Field

Frequency (MHz)	RF-60 Response (dB)	Generated Field (%)	Generated Field (A/m)	Expected reading (%)	Min (%)	Max (%)
100	+1,1	100	0,1629	128,8	91,2	182,0
100	+1,1	50	0,1152	64,4	45,6	91,0

Document	Version	Date
WaveMon RF-60 E+H. Calibration Procedure	1.0	15/11/2021

4 SETUP VALIDATION PROCEDURE

A double check of the generated field is recommended every time a new set of calibrations is performed (on a daily basis).

A reference WaveMon RF-60 unit can be used (always the same unit). The purpose of this test is to ensure that there is no drift or damage in any of the reference devices: power meters, attenuator, coupler, etc.

The reference WaveMon should be placed in the calibration area and the measurement registered. It should be checked that it does not deviate more than ± 0.5 dB from the average of the last 5 measurements.

The following table shows an example of this validation:

			CONDICIÓN \pm dB
			0,5
DAY	% Power density Measurement	Average last 5 calibrations (%)	Deviation (dB) $10 \cdot \log(\text{current meas} / \text{average})$
1	143,985916		
2	143,416611	144,0	-0,02
3	139,988495	143,7	-0,11
4	139,878	142,5	-0,08
5	140,51	141,8	-0,04
6	140,87	141,6	-0,02
7	139,578	140,9	-0,04
8	142,5489	140,2	0,07
9	141,5994	140,7	0,03
10	143,549	141,0	0,08
11	140,59	141,6	-0,03
12	139,577	141,6	-0,06
13	140,87	141,6	-0,02
14	143,778	141,2	0,08
15	125	141,7	-0,54