Power Meter Menu

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1. Introduction

This document pertains to BPM, PMP and PS power measurement devices (henceforth Power Meters).

- The BPM devices are bidirectional power meters designed for accurate simultaneous measurement of incident and reflected powers in rectangular waveguides in high-power industrial applications.
- The PMP devices are non-directional power meters, or power meter probes, designed for measurement of powers or field strengths in rectangular waveguides in high-power industrial applications.
- The PS devices are standard general-purpose low-power broadband coaxial microwave power meters.

This application note describes the serial RS232 (or RS422) digital interface and the methods of customizing the behavior of the Power Meters through the Power Meter Menu.

For more details, specifications and installation tips, see the respective BPM, PMP or PS datasheets.

2. Serial RS232 Connection

The Power Meters operate in an endless loop, continuously sending results to the RS232 port in the form of ASCII strings (while simultaneously updating the analog outputs). For testing and configuration purposes using a PC, a suitable RS232 COM Port terminal program should be used in the PC.

One option is Tera Term, an open-source free terminal emulator. This program can be downloaded from https://teratermproject.github.io/index-en.html. Examples in this application note will be presented using this terminal emulator. For correct operation, the terminal, including its serial port, should be properly configured.

- The emulator **serial port** should be configured as follows (see example in Fig. 1):
  - Baud Rate: 115200 bits/s (see Note below)
  - Data Bits: 8
  - Parity: NO
  - Stop Bits: 1
  - Flow Control: NO

  Note: The baud rate should be set to 57600 or 38400 bits/s if those baud rates are set on the connected Power Meter device.
- An example of the Tera Term **terminal** configuration is shown in Fig. 2.
  - Proper menu display is ensured by setting New-line > Receive to `LF`.
  - To display complete results of one BPM measurement in a single line (without wrapping), set Terminal size line length to at least 71 characters (it is set to 74 in Fig. 2). For PMP and PS, the line length can be lower.
  - The remaining settings can be left at defaults.

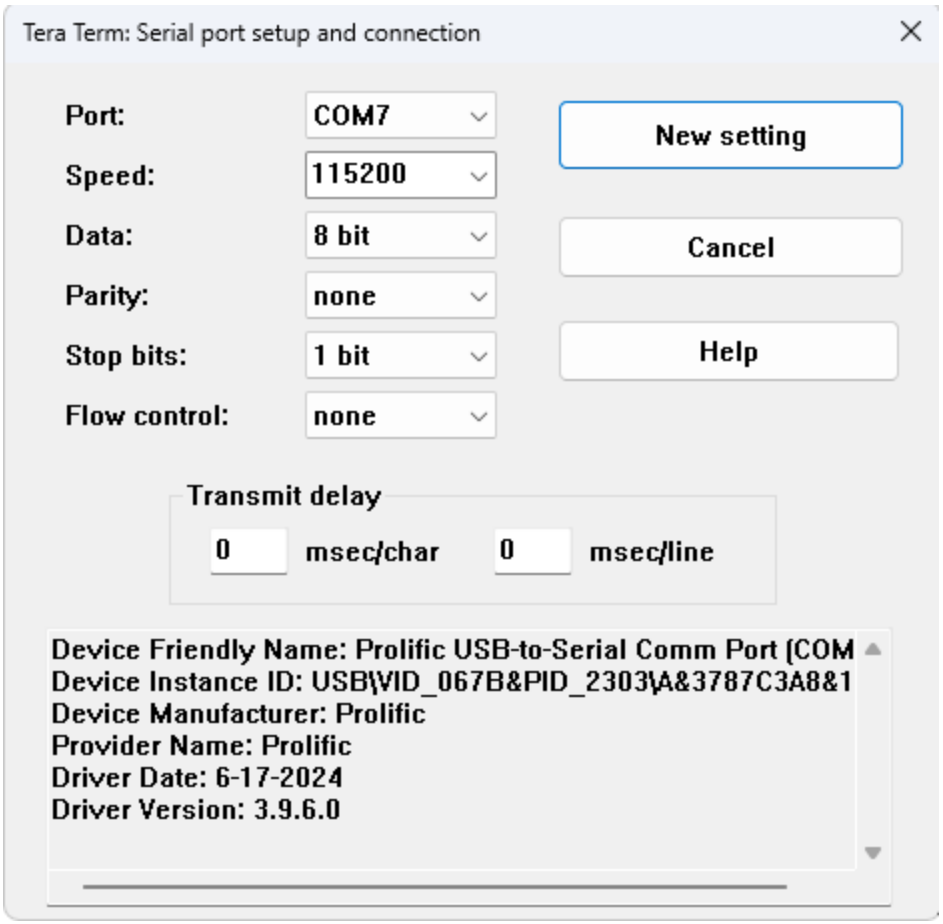

Fig. 1. Configuring the Tera Term serial port.

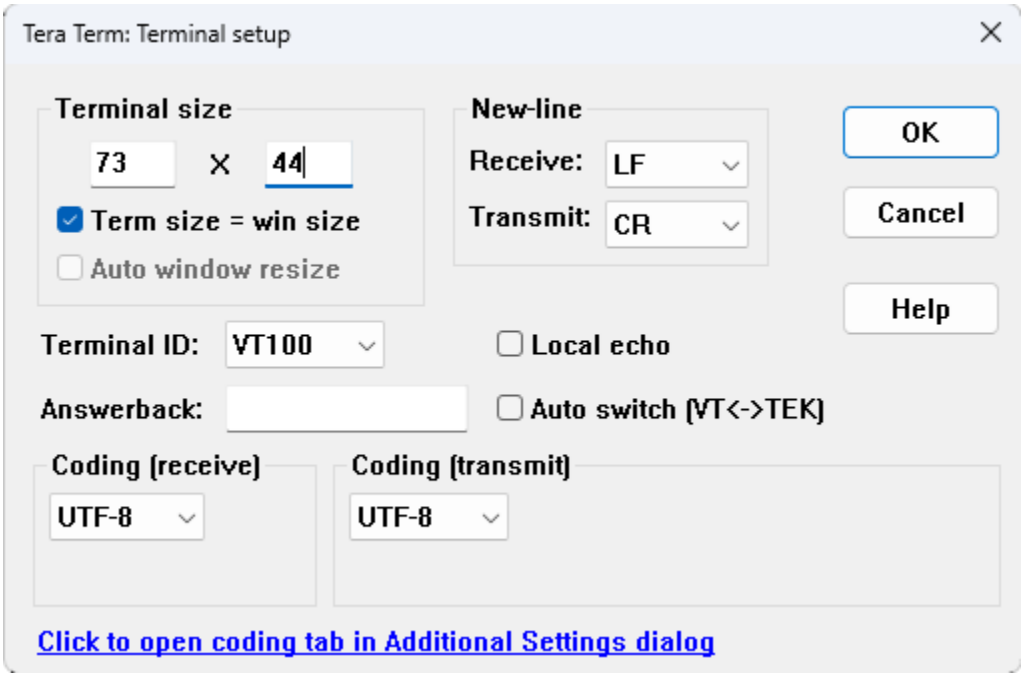

Fig. 2. Configuring the Tera Term terminal.

After setting up the terminal and connecting a Power Meter (see the datasheets for instructions and wiring diagrams), the measured results will display in the terminal. Examples for all three devices are shown in Fig. 3, Fig. 4, and Fig. 5.

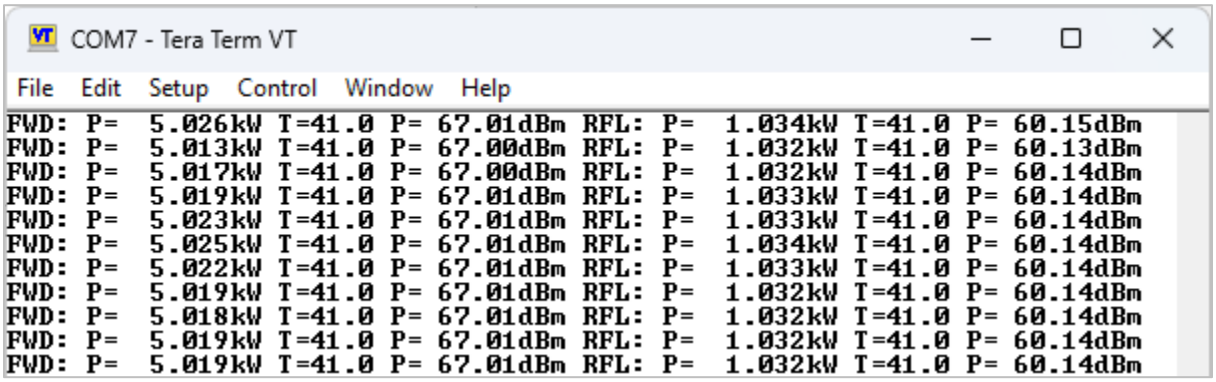

Fig. 3. Display of BPM measured data.

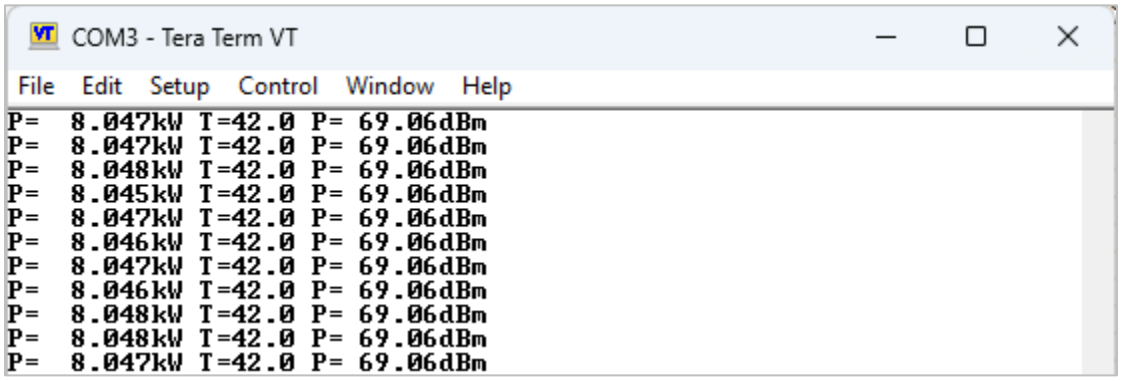

Fig. 4. Display of PMP measured data.

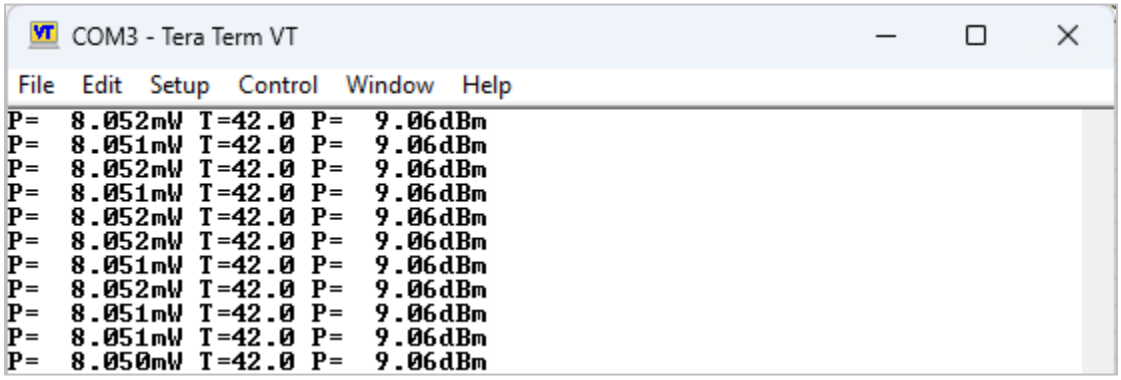

Fig. 5. Display of PS measured data.

Detailed descriptions of the received strings are provided in the respective datasheets. This state is the starting point for invoking the Power Meter Menu.

3. Power Meter Menu

The Power Meter Menu allows the user to:

- Configure the signal sampling.
- Select the type of analog output.
- Set RS232 baud rate.
- Change the orientation of the LCD display (BPM only).
- Scale the analog outputs.
- Introduce a power offset to measured data (e.g., to correct for a waveguide wall thickness differing from the nominal).
- Specify an approximate frequency of the signal to be measured to correct for frequency response of the Power Meter (PS only).
- Enter the approximate frequency of the signal being measured in order to apply frequency-response correction to the Power Meter (PS only).

To use the menu, an RS232 terminal must be installed on your PC. The Power Meter Menu is invoked by transmitting the ASCII character x (ASCII #120 = 0x78) or X (ASCII #88 = 0x58) from the terminal (pressing the lower-case **x** or upper-case **X** key on the PC keyboard). After this command, Power Meter parameters are read from the internal EEPROM. The most important ones, such as SW version, model designation, serial number and currently valid settings are displayed. Examples of User Menus for all three devices are shown in Fig. 6, Fig. 7, and Fig. 8.

The settings can be modified by pressing the corresponding key indicated on the left (for example, pressing **D** enables modification of the sampling period). Please note that the letter case matters.

Some of the settings, although shown and enabled (notably **F** and **E**), do not pertain to all of the devices. Further details are given later in this document.

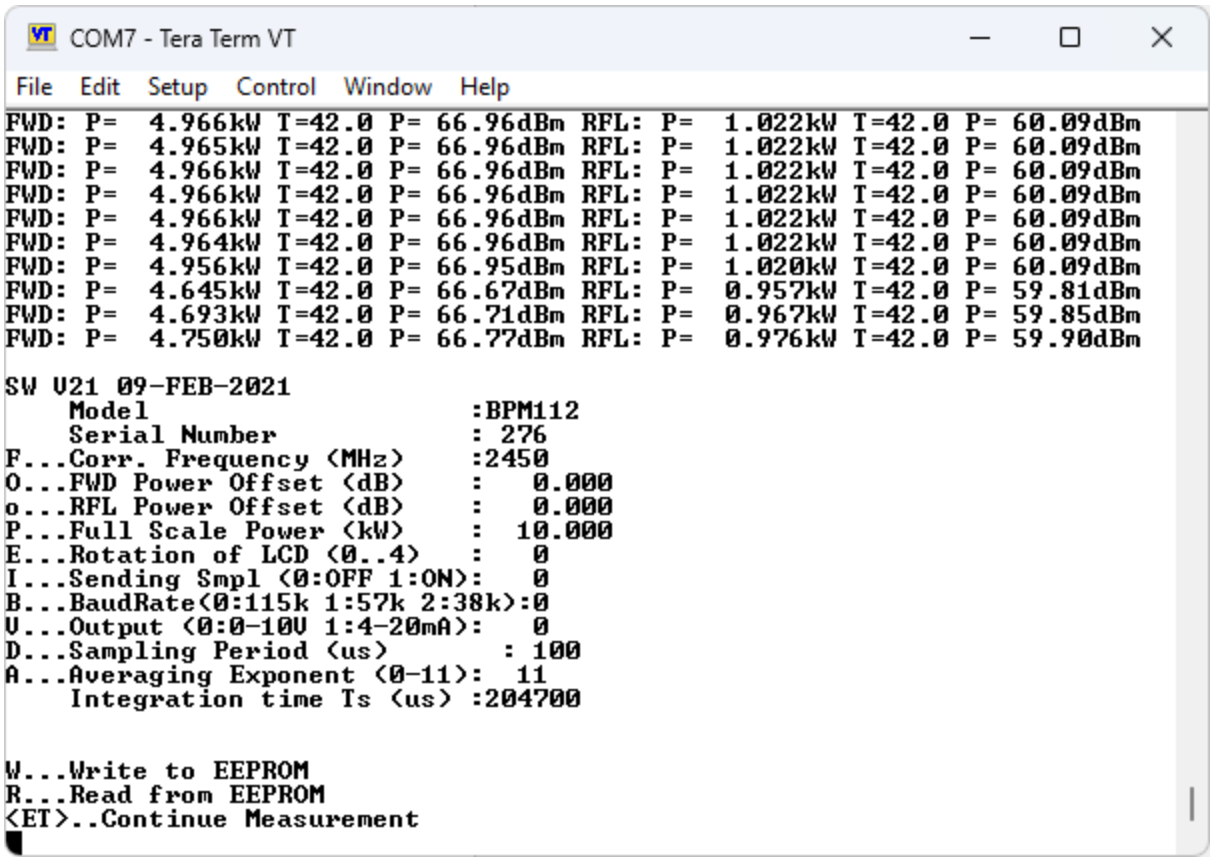

Fig. 6. BPM Power Meter Menu. Setting **F** has no effect. Setting **E** affects only BPM devices with LCD display.

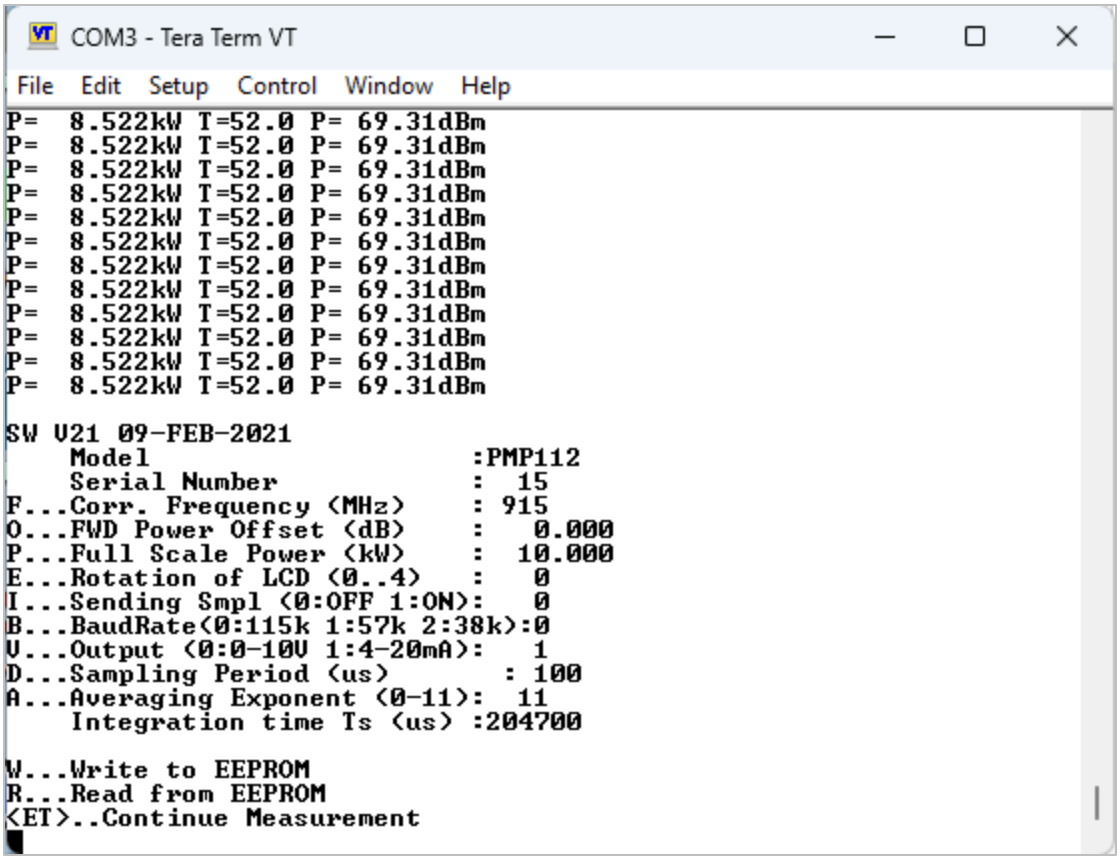

Fig. 7. PMP Power Meter Menu. Settings **F** and **E** have no effect.

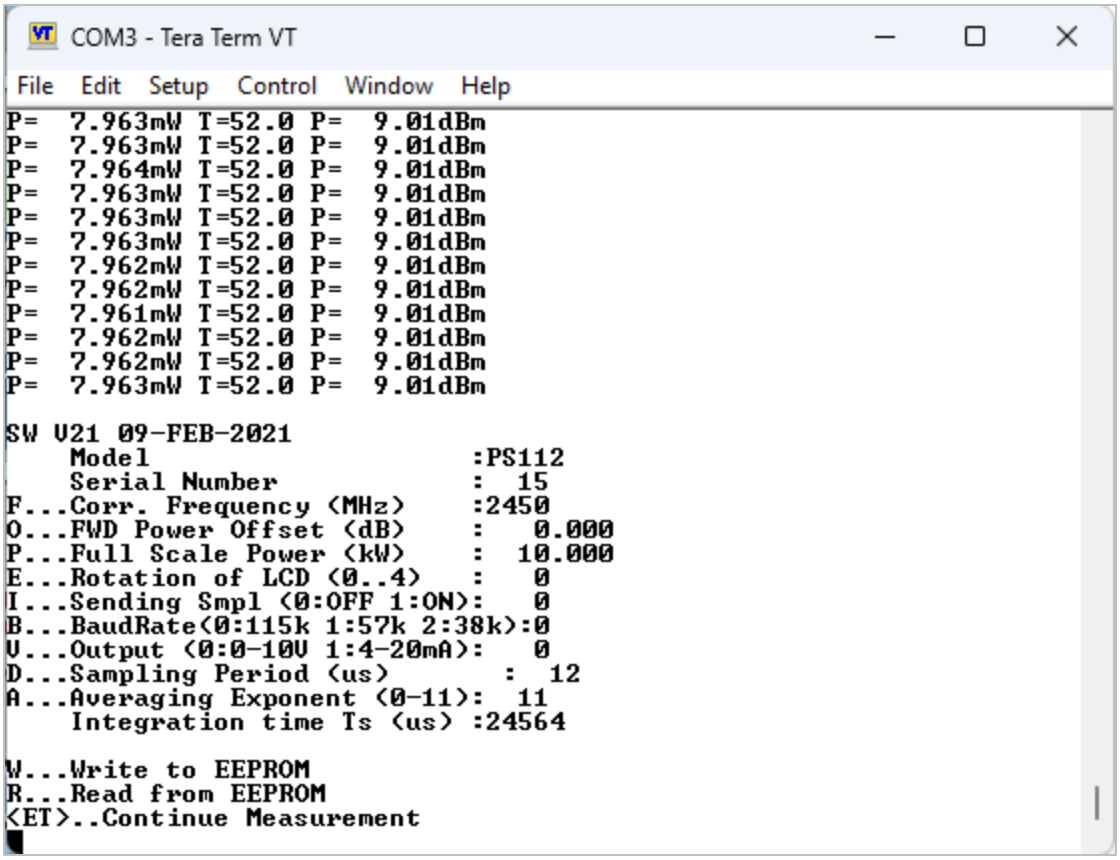

Fig. 8. PS Power Meter Menu. Setting **E** has no effect. Although **P** shows the full-scale power unit as kilowatts, the correct unit is milliwatts.

Notes

- Before any change of the parameters, it is strongly recommended to record all original data.
- The user must act (press a key) within 40 seconds from the previous action, otherwise the internal watchdog resets the device and restarts sending results.

4. Changing Power Meter Parameters

Changing Power Meter parameters generally involves the following steps:

1. Press the key corresponding to the desired parameter (e.g., press `A` to change Averaging Exponent).
2. Following this, a prompt appears to enter the new value. In case of Sample Period and Averaging Exponent, the lower and upper limits are also shown.
3. Type a new value and press `<Enter>`. Following this, the new value is shown in the Menu. If the entered value is outside the allowed range, it will be automatically adjusted to the nearest valid limit. For example, if you enter an Averaging Exponent of 20, the system will set it to 11.
4. Change any other parameter by the same procedure.
5. To make the changes permanent, press the upper-case `W` key to write the new parameters to the device's EEPROM memory. The progress and success are announced by messages (Fig. 9). Note that the command rewrites *all* parameters, not only those you have modified.

6. To verify that the parameters have been successfully changed, you may wish to switch the DC power supply OFF and ON and invoke the Power Meter Menu again.

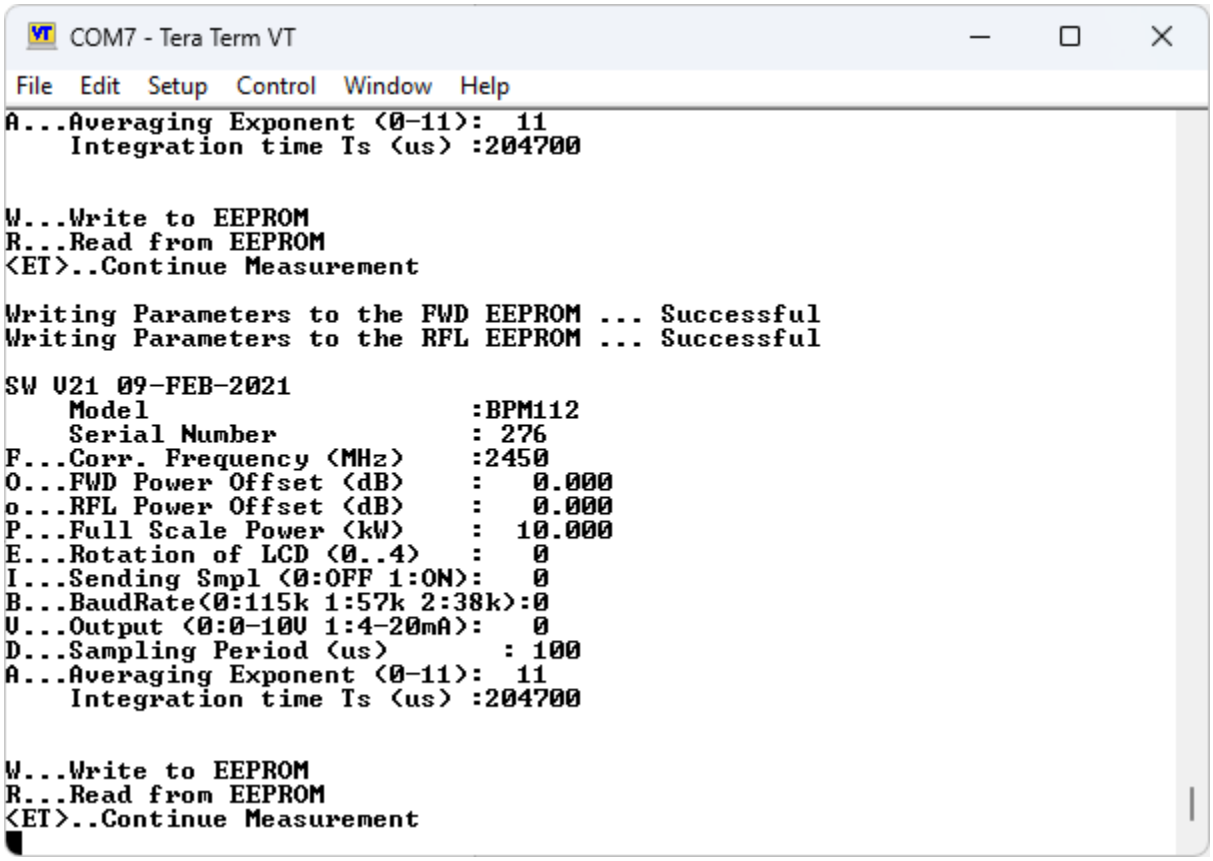

Fig. 9. Writing parameters to a Power Meter non-volatile memory.

4.1 Frequency for Correction

This function specifies the approximate (expected) frequency of the signal to be measured. The purpose is to correct for frequency response of the Power Meter. The function is effective only in PS devices because of their broadband nature.

To set a frequency for correction, press the uppercase F key. Following this, a prompt appears to enter the frequency in MHz. Type the desired value and press <Enter>. The default value is 2450 MHz.

For the narrowband BPM and PMP devices, any entered value will be ignored.

4.2 Power Offset

The user can easily modify the power readings via the Power Offset parameter. The offset is added in dB scale to the measured powers.

To change Power Offset in PMP, PS, or in FWD channel of BPM, press the uppercase O key. The following prompt will appear:

```
Enter FORWARD Power Offset (dB):
```

Now, enter the desired Power Offset in dB units.

To change Power Offset in RFL channel of BPM, press lowercase o key. The following prompt will appear:

```
Enter REFLECTED Power Offset (dB):
```

Now, enter the desired Power Offset in dB units.

See also the example at the end of this document.

4.3 Full-Scale Power Reading

The Full-Scale Power is the measured power that would produce the maximum analog output (10 V or 20 mA, respectively). It does not affect the actual rated peak working power or the resolution of the device; it is serves merely as a zooming factor.

Because the peak working power of a device is fixed by its hardware, it is not wise to change the Full-Scale Power value to an excessively large or small value. For example, if a BPM's peak working power is 10 kW, setting Full-Scale Power value to 100 kW is inadvisable, because the analog output voltage would never exceed 1 V. Conversely, if a BPM's peak working power is 100 kW and the Full-Scale Power will be set to 10 kW, all measured powers above 10 kW would result in the analog output overrange. However, such setting may be meaningful if the actual power never exceeds 10 kW.

To change Full-Scale Power, press `P` key. The prompt appears:

```
Enter Full Scale Power (kW):
```

Now, enter the desired Full-Scale Power value:

- For BPM and PMP in units of kilowatts;
- For PS in units of milliwatts (ignore the fact that both the prompt and the menu show "kW").

4.4 Changing LCD Display Orientation

This function is relevant only for BPM devices equipped with an LCD display. When an LCD is present, the BPM's microcontroller unit (MCU) sends an initialization string through the serial port to the display module during device power-up, configuring it for operation. An example of such an initialization string is shown below:

```
US-TEAM,BPM112,S/N=101,Pmax=10kW,Output 0-10V,LCD=4,SW V16 14-FEB-2018
```

(If the LCD is not present, this string will not be sent.)

To change the orientation of the LCD, press the `E` key. The prompt appears

```
Enter Rotation of LCD (0..4):
```

`0`	`No LCD`	For Power Meter devices without LCD display.
`1`	`Normal Text`	LCD text in the direction of the arrow indicating the incident wave.
`2`	`Rot. Text Down`	LCD text rotated 90° relative to the arrow direction.
`3`	`Rot. Text Up`	LCD text rotated 270° relative to the arrow direction.
`4`	`Rot. Text 180`	a LCD text rotated 180° relative to the arrow direction.

For Power Meter devices without display, it is good practice to leave the rotation constant at zero. This slightly speeds up the system startup, as there is no need to send an initialization string.

4.5 Sending Samples

To switch ON and OFF the sending of all individual samples constituting one measured point, press `I` key. The prompt appears

```
Enter Sending Smpl (0:OFF 1:ON):
```

Enter `0` or `1` to switch the Power Meter to not sending samples (`0`) or to sending samples (`1`). If the parameter is set to 1, all measured samples, separated with `<LF>` (ASCII #10), are transmitted via the

serial port. After transmitting the last sample, the Sampling Period in microseconds and Number of Samples are transmitted.

Below is an example of the transmitted data stream, which includes sending 8 samples after each measurement:

```
FWD: P=2.216kW T=45.0 P=63.46dBm RFL: P=0.264kW T=45.0 P=54.21dBm
2.310
2.264
2.220
2.188
2.168
2.166
2.181
2.215
100
8
```

In the case of BPM, only forward-channel (FWD) samples are transmitted.

4.6 Baud Rate

To change Baud Rate, press the `B` key. The prompt appears

```
Enter Baudrate code (0:115200 1:57600 2:38400):
```

Enter the code for the desired baud rate. Only the values 0, 1, 2 are accepted. This is a list of valid codes with corresponding baud rates:

```
0  This is the default baud rate 115200 bits/s.
1  Baud rate 57600 bits/s.
2  Baud rate 38400 bits/s.
```

The new value must then be written to the EEPROM by entering the `W` key. The new baud rate will be used after the device reboot.

4.7 Analog Output

To switch Analog Output type, press the `V` key. The prompt appears

```
Enter Analog Output code (0:0-10V  1:4-20mA):
```

Valid codes are:

```
0  Voltage output 0 – 10V
1  Current output 4 – 20 mA
```

Note that there are separate outputs pins for the voltage and the current outputs (see the connection diagrams in the respective Power Meter datasheets).

4.8 Setting Sampling Parameters

The sampling of the measured power waveforms is controlled by two input parameters:

- Sampling Period (i.e., the time interval between two consecutive samples)
- Averaging Exponent

These parameters also determine the sampling time (integration time), as explained in the Power Meter datasheets, section Sampling. The maximum sampling time of Power Meters is 5 s. To not exceed it, the upper bounds of Sample Period and Averaging Exponents are automatically limited when entering the parameters.

To change the Sampling Period, press the D key. The prompt appears, such as

```
Enter Sampling Period 12.. 2441  (us):
```

Enter the desired Sampling Period in units of µs. Only integer values are allowed. The minimum value is always 12 µs. The upper bound in this example (2441 µs) has been automatically computed for the current Averaging Exponent.

To change Averaging Exponent, press the A key. The prompt appears

```
Enter Power Averaging Exponent (0-11):
```

Now, enter the desired Averaging Exponent. Only integer values are allowed.

The User Menu also displays the sampling time (integration time) resulting from the current Sampling Period and Averaging Exponent. Here is an example of the pertinent part of the menu:

```
D...Sampling Period (us)       : 100
A...Averaging Exponent (0-11):    11
    Integration time Ts (us) :204700
```

In this case, the integration time has been computed as 100 µs × (2^{11} – 1) = 204700 µs = 204.7 ms.

4.9 Example

Tasks

a) Suppose that a BPM214 incident power reading for the waveguide terminated by a waterload is P_r = 50 kW although you know by calorimetry measurements that the actual incident power is P_a = 40 kW. You know that the source of this discrepancy lies in the waveguide wall thickness. While the BPM has been calibrated for the standard wall thickness h_c = 0.125 inch = 3.175 mm, your actual wall thickness is h = 3 mm. The variation of BPM coupling factor C with wall thickness is approximately $\Delta C/\Delta h$ = -6 dB/mm (the thicker the wall the lower the reading). You want to set the BPM offset factors to correct for this difference.

b) Also, there is a 3-blade mode stirrer in your applicator, rotating with the frequency of one revolution per second. Due to this, the incident power oscillates, resulting in fluctuating reading of the BPM. You want to set the measurement integration time to smooth out these fluctuations.

Calculations

a) The BPM power reading is higher than the actual power by 10*log(P_r/P_a) = 10*log(50/40) = 0.969 dB. To correct for this, power offset in both FWD and RFL channels should be set to `-0.969 dB`.

b) Due to the three blades of the mode stirrer, the frequency of the power ripples is three times the stirrer rotation frequency, i.e. f_r = 3 × 1 Hz = 3 Hz. Therefore, the ripple period is $T_r = 1/f_r$ = 1/3 s ≈ 333 ms. To smooth out the reading, the sampling time (integration time) T_s should be set to n × 333 ms where n = 1, 2, … We will set the sampling duration to T_s = 333 ms. To achieve this, we have to modify the number of samples N_s taken for one measured result, and sampling period Δt_s (time spacing between two consecutive samples). The possible numbers of samples are N_s = 2^E, where E = 0, 1, 2, … 11 is the averaging exponent. The three relevant quantities are constrained by the relation

$$(1) \qquad T_s = \Delta t_s \left(N_s - 1\right) = \Delta t_s \left(2^E - 1\right)$$

If we, for instance, choose the number of samples in terms of E, the required sampling interval will be

$$(2) \qquad \Delta t_s = \frac{T_s}{2^E - 1}$$

We have to round Δt_s expressed in µs because only integers can be entered. Due to the quantization of Δt_s, the actual T_s will slightly differ from the desired value. By trying different values of E, we can find the most suitable Δt_s. Values of E below 8 are not recommended because then higher-frequency details of the power waveform may get lost. For our example, the situation for $E > 7$ is illustrated in Tab. 1.

Tab. 1. Actual sampling time T_s for various settings of E. The desired T_s = 333 ms.

E	N_s	Δt_s (µs)	T_s (ms)
8	256	1307	333.29
9	512	652	333.17
10	1024	326	333.50
11	2048	163	333.66

Any of these settings are acceptable. A good choice is E = 11, Δt_s = 163. In this case, the sampling frequency is $f_s = 1/\Delta t_s$ = 6.13 kHz, and therefore also ripples due to the power line frequency and its multiples will be well sampled.

Settings

Proceed as follows. Each step should start within 40 seconds from the previous step.

1. Press the `x` or `X` key on the PC keyboard to invoke the Power Meter Menu.
2. Press the upper-case `O`. The prompt appears: `Enter FORWARD Power Offset (dB):`
3. Type `-0.969` and press `<Enter>`.
4. Press the lower-case `o`. The prompt appears: `Enter REFLECTED Power Offset (dB):`
5. Type `-0.969` and press `<Enter>`.
6. Press the upper-case `A`. The prompt appears: `Enter Averaging Exponent (0-11):`
7. Type `11` and press `<Enter>`.
8. Press the upper-case `D`. The prompt appears: `Enter Sampling Period (us) (12..2441):`
9. Type `163` and press `<Enter>`.
10. Check all values by inspection of the Power Meter Menu.
11. Press the upper-case `W` to write the settings to BPM non-volatile memory. Watch for the success message. In case of failure, press `W` again.
12. Press `<Enter>` to exit the Power Meter Menu.
13. Final check: Switch OFF the DC power supply to BPM, wait about 5 seconds, and then switch the power supply ON again. Invoke the Power Meter Menu by `x` or `X` key and check the settings. Then press `<Enter>` to exit the Power Meter Menu.

5. Exiting Power Meter Menu

To exit Power Meter Menu, press the `<Enter>` key.