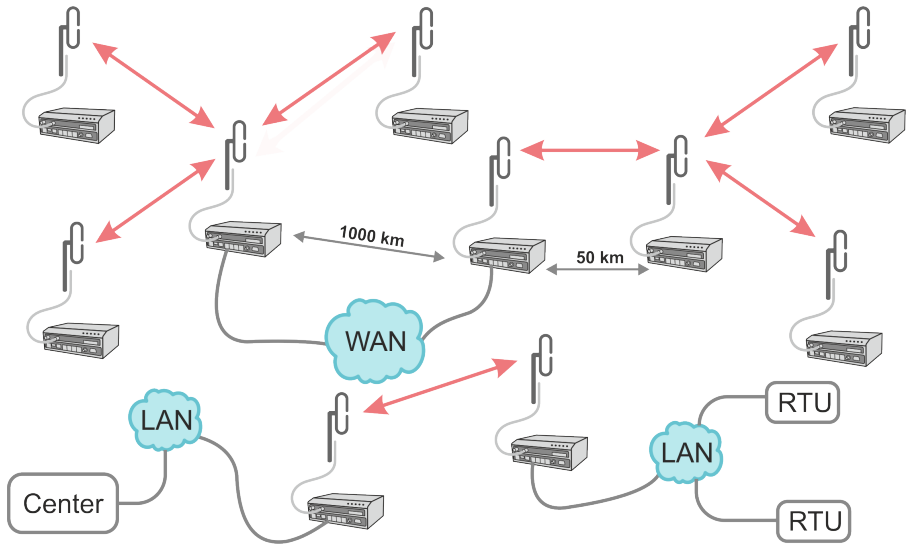
RACOM
RADIO DATA NETWORKS

Application notes



RipEX2 - PEP versus RMS RF power

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1. PEP versus RMS RF power

With an introduction and wider utilization of multi-mode operation using high-state QAM modulation constellations such as 16QAM, 64QAM and 256QAM it is necessary to understand the difference between **peak-envelope power (PEP)** and **root-mean squared (RMS)** power level and their relation.

It is all related to the **modulation envelope** that can be either:

- constant for **constant modulation envelope** formats such as 2CPFSK and 4CPFSK
  - In this case, the relation is simple:
  - **PEP[dBm]=RMS[dBm]**

Or

- Non-constant for **non-constant modulation envelope** formats such as DPSK, QPSK and all QAM.
  - In this case, the relation depends on selected modulation format
  - **PEP[dBm]=RMS[dBm]+PAPR[dB]**
  - ...where PAPR is the peak-to-average power ratio in dB.

See Figure 1 for better understanding of what the modulation envelope is.

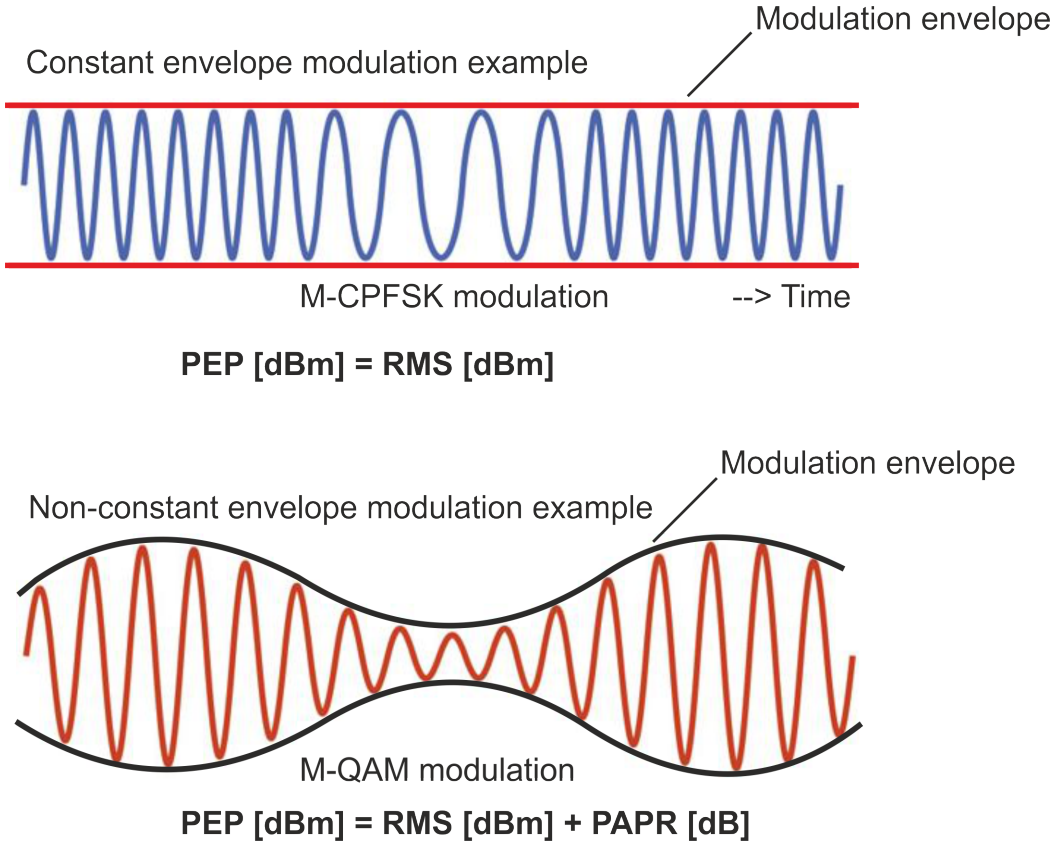

Fig. 1.1: The graphical example of the constant and non-constant envelope modulation

Typically, the high power amplifier is capable to deliver a specific peak power, e.g. 40 dBm. Depending on the modulation format however the RMS power level will be lower, because the instantaneous power level is dropping over modulation symbol. For constant PEP power value, the higher the modulation order the lower the RMS power level, because, statistically the signal stays more often at lower amplitudes.
In Table 1 there is an example of the **maximum** RF power level setting in the form of 40 dBm PEP and corresponding RMS values for all modulation format supported by the RipEX2 device.

Tab. 1.1: Maximal power for individual modulations

RipEX2 Maximum RF Power levels PEP, RMS and PAPR values			
Modulation	**PEP Peak Envelope Power [dBm]**	**RMS Average Power [dBm]**	**PAPR Peak to Average Power Ratio [dB]**
2CPFSK	40	40	0
4CPFSK	40	40	0
DPSK	40	37	3
π/4-DQPSK	40	37	3
D8PSK	40	36	4
16DEQAM	40	35	5
64QAM	40	34	6
256QAM	40	33	7

Please note that:

1. The RF output power (PEP values) can be set with a step of 1 dB in the range between 40 dBm down to 20 dBm.

2. The RMS values for different PEP values can be calculated using the PAPR values from Table 1

   e.g. for 64QAM:

   - *PEP of 30 dBm relates to 24 dBm RMS taking 6 dB PAPR value for 64QAM into account*

3. Both values either PEP or RMS describes the RF power level and can be defined in log values typically dBm or in linear values **Watts** or **miliWatts.**

4. PEP, RMS and PAPR values **do not** depend on selected bandwidth e.g. 12.5 kHz, 100 kHz etc.

5. The RMS value is useful in link budget calculation, because the sensitivity levels are given in RMS notation.

   - *SystemGain = RMS [dBm] - SensitivityLevel [dBm]*

   - *e.g. pi/4-DQPSK:*
     SystemGain = 37 dBm - (-117 dBm) = 154 dB

1.1. Why do we complicate the power setting by PEP values?

- Simply said, it is the PEP value which describes the capability of the RF high power amplifier. With wider use of QAM modulation the range of RMS power setting is significant (PAPR up to 7 dB).
- In situations where the single RipEX2 device uses different modulation formats (as is the case for instance for the base-station in BDP protocol) with various PAPR levels, the PEP value is just one value to be set (and calibrated for precision), instead of multiple RMS values that depends on modulation format, packet length or even packet data (packet preambles typically have different RMS power levels than the rest of the packet).
- If ACM (automatic coding and modulation) feature is used, it is again a single value to be set, calibrated and controlled for all modulation formats.
- The PEP values of RF output power are important and have to be known in many situations for regulatory or hygienical purposes.
- Various manufacturers state either PEP or RMS values, but it is usually very important to know which values are compared. PEP values are higher, so even if it was possible to work with RMS values, the PEP values should be known for fair comparison.