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Pulsed Power
Amplifier Solutions

BONN Elektronik GmbH

Broadband RF Power Amplifiers

Broadband RF Power Amplifiers

BSA Series
Solid State Amplifiers
4 kHz ... 1000 MHz 1 W ... 20 kW

BLWA Series
Solid State Amplifiers
1 ... 1000 (4000) MHz 1 W ... 40 kW

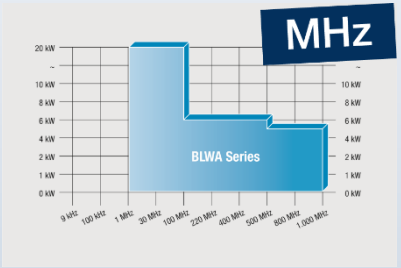
BLMA Series
Solid State Amplifiers
100 MHz ... 50 GHz 0.1 W ... 2 kW

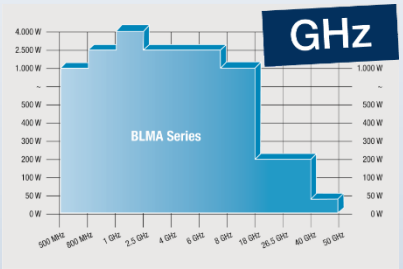
BPA
Pulsed Solid State Amplifiers
150 MHz ... 10 GHz 25 W pk ... 20 kW pk

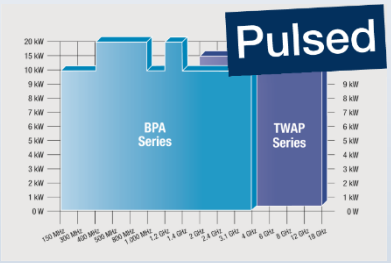
Narrow Band Amplifiers
Solid State Amplifiers
800 ... 2700 MHz 10 W ... 600 W

TWAL Series
TWT Amplifiers
1 GHz ... 50 GHz 20 W ... 1 kW

TWAP Series
Pulsed TWT Amplifiers
1 ... 18 GHz 1.5 ... 50 kW pk



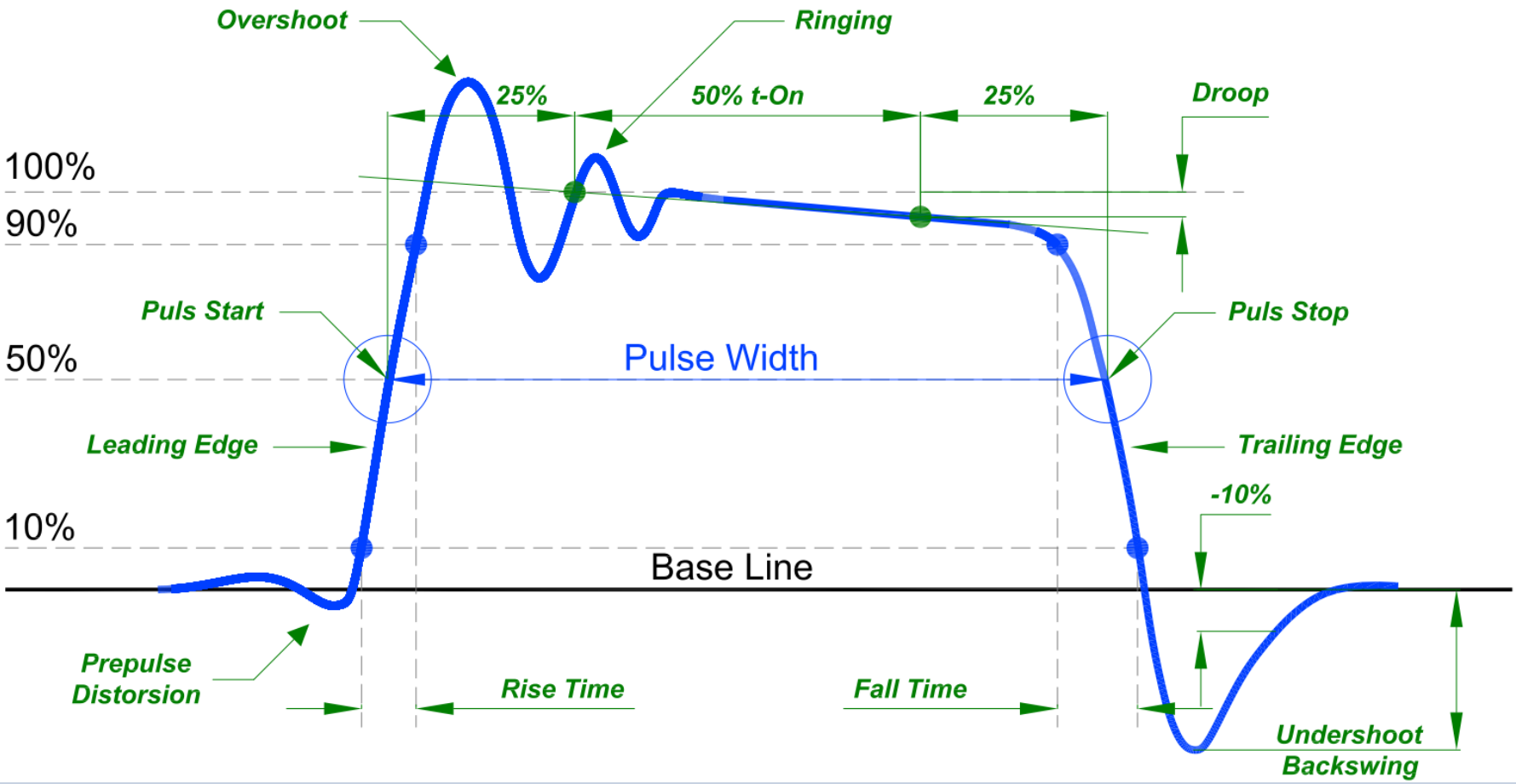




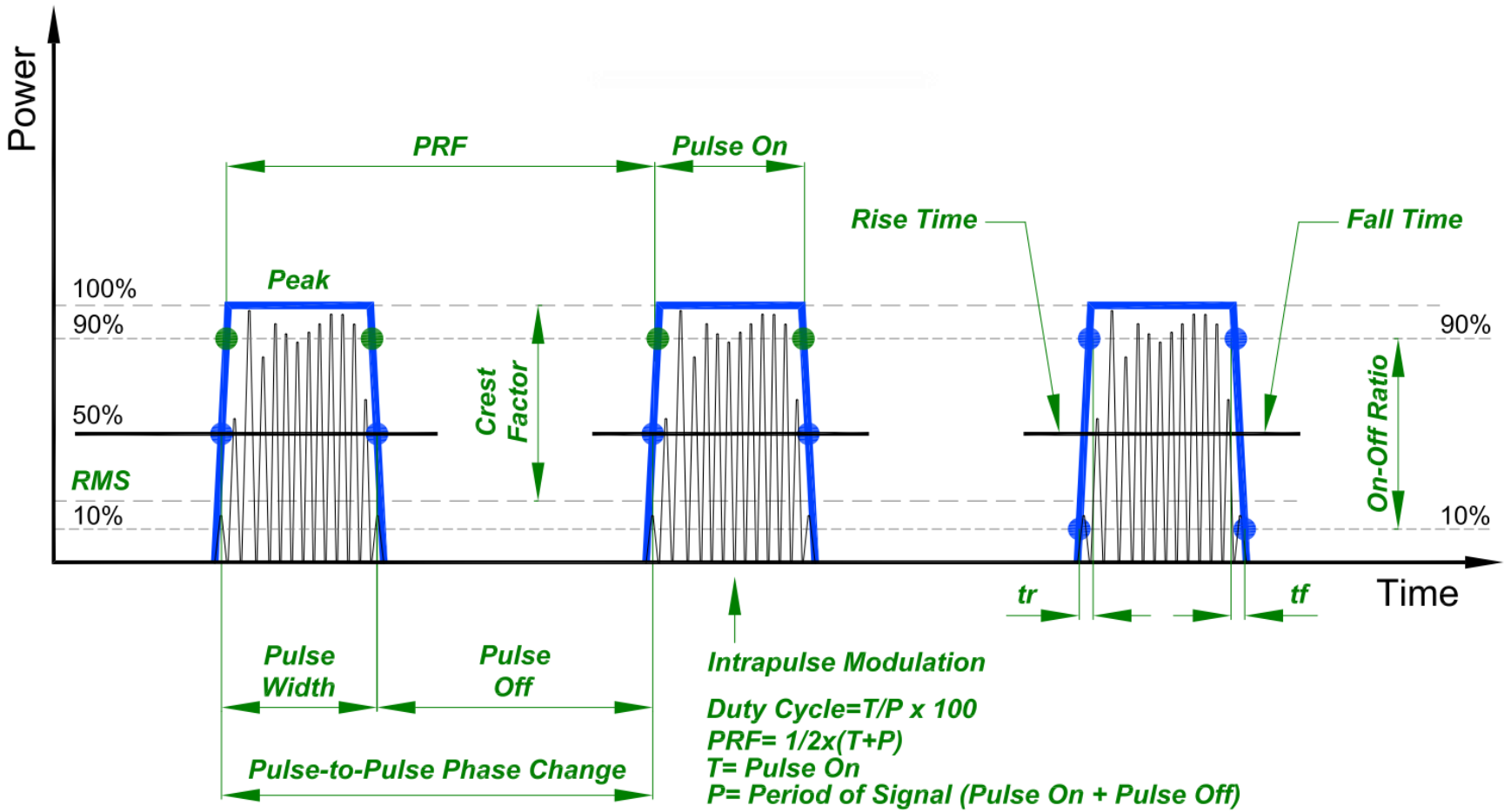
Pulse Power Definitions

- **Comparison of Pulsed versus CW amplifiers**
  - Pulsed signals are primarily defined by
    - rise and fall time
    - pulse width
    - duty cycle (pulse-to-pause ratio)
    - pulse repetition frequency (P-RF)
    - droop (power level drop during pulse width / duration)
  - Every CW amplifier is capable of amplifying pulsed signals
  - Timing of pulsed signals
    It is very important for pulsed signals that the required current is directly available fast in time at the final stage transistors.
  - From our experience we regularly learn about quite difficult combinations of pulse width and pulse repetition frequency. If we know the specific timing in advance we will ensure that they are ideally / perfectly amplified.

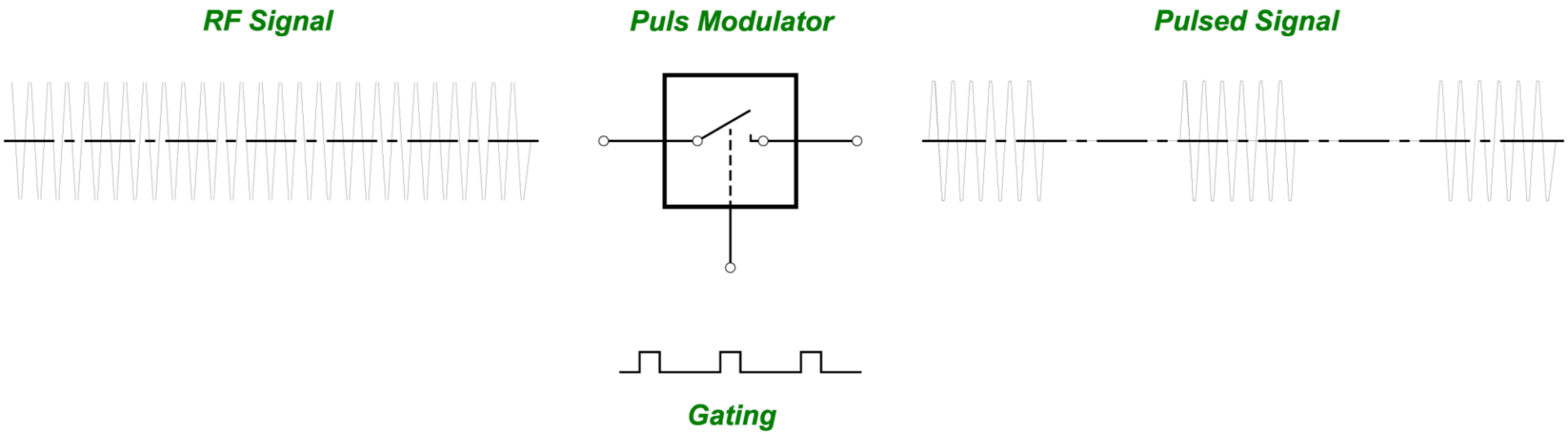
Pulse Elements



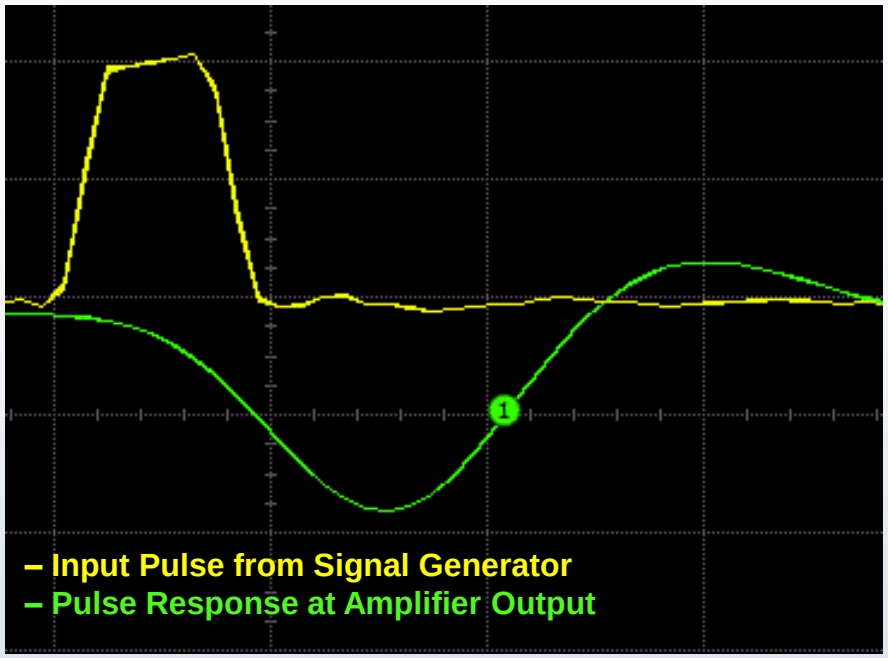
Pulse Timing

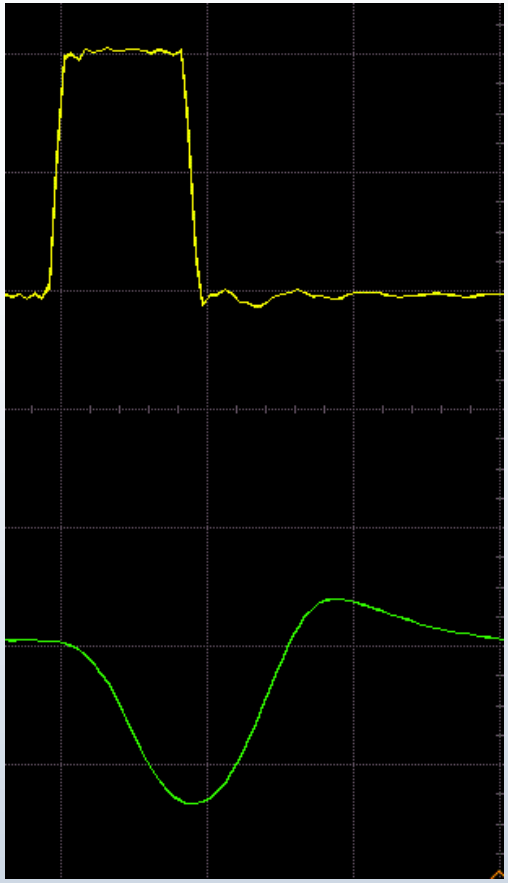


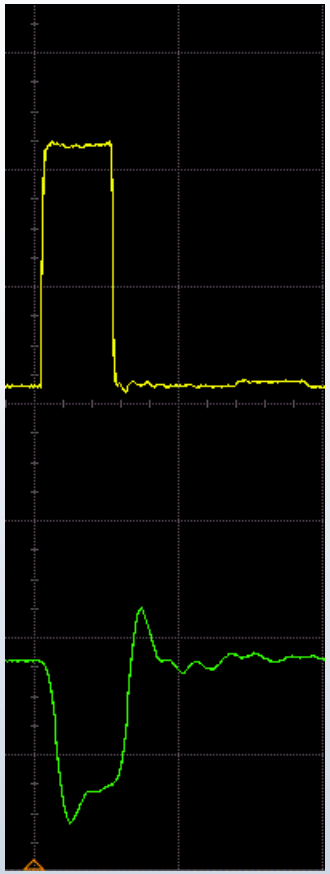
Pulse Modulator



Power Amplifier Pulse Response







BSA 0040-250

800 ps

2 ns

5 ns

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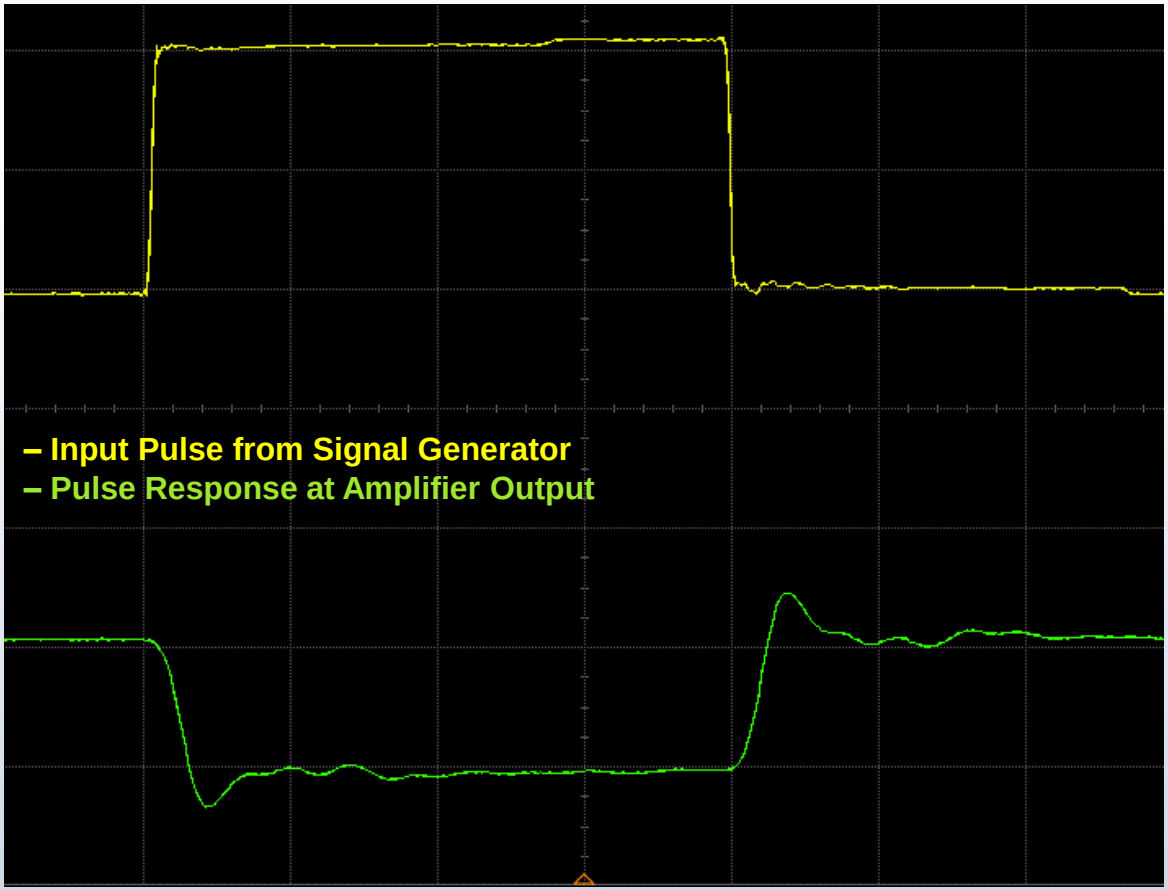
Power Amplifier Pulse Response



BSA 0040-250

20 ns

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Pulsed Power Testing

- **Solid state BPA series pulsed amplifiers up to approximately 10 kW pk**
  - 150 … 4000 MHz
    For wideband ranges no dedicated pulsed transistors are available. Therefore, using CW transistors the optimization for pulsed operation is not that ideal. However, power supplies and cooling can be reduced accordingly. Specifically at higher output levels this still is important.
  - 1 … 10 GHz
    For narrow bands, dedicated pulsed transistors are allowing cost effective designs at significantly higher output power levels compared to CW transistors.
  - Typical duty cycle of pulsed power solid state designs is 10%
  - Typical pulse width is 100 µs
- **Pulsed travelling wave tube amplifiers TWAP series 2 … 18 GHz up to 30 kW pk**
  - Significantly higher output power levels than standard CW tubes
  - Typical duty cycle of travelling wave tube designs is 1 … 6%
  - Standard pulse width is 50 µs; optional for some tubes 100 µs

Popular Pulsed Power Test Standards

- **Automotive Radar Pulse Testing**
  - GM GMW 3097S
    1.2 … 1.4 GHz, 600 V/m at 0.75 m and 1 % Duty
  - Ford EMC-CS-2009.1
    1.2 … 1.4 GHz and 2.7 … 3.1 GHz, 300 or 600 V/m at 1 m and 1% Duty
  - FCA (Fiat Chrysler) CS.0054
    0.8 … 2.7 GHz, 50 V/m at 1 m and 1% Duty
  - VOLVO 515-0003
    1.15 … 1.45 GHz, 600 V/m and 10% Duty
    2.6 … 3.2 GHz, 5.2 … 5.9 GHz and 8.2 … 12.4 GHz, 200 V/m at 1 m and 10% Duty
- **Autonomous Driving**
  - Preliminary
    8.5 … 10.5 GHz, 600 V/m at 1 m and 50% Duty
    15.7 … 17.7 GHz, 600 V/m at 1 m and 50 % Duty
- **Aerospace**
  - RTCA/DO-160
    Section 20.0: Radio Frequency Susceptibility (Radiated and Conducted), Category R
    0.4 … 8 GHz, 150 V/m at 1 m and 4% Duty
- **MIL Testing**
  - MIL 461x, RS103
    2 MHz … 18 GHz, 200 V/m at 1 m and 50% Duty

Example: VW TL 810 00 (2018-03)

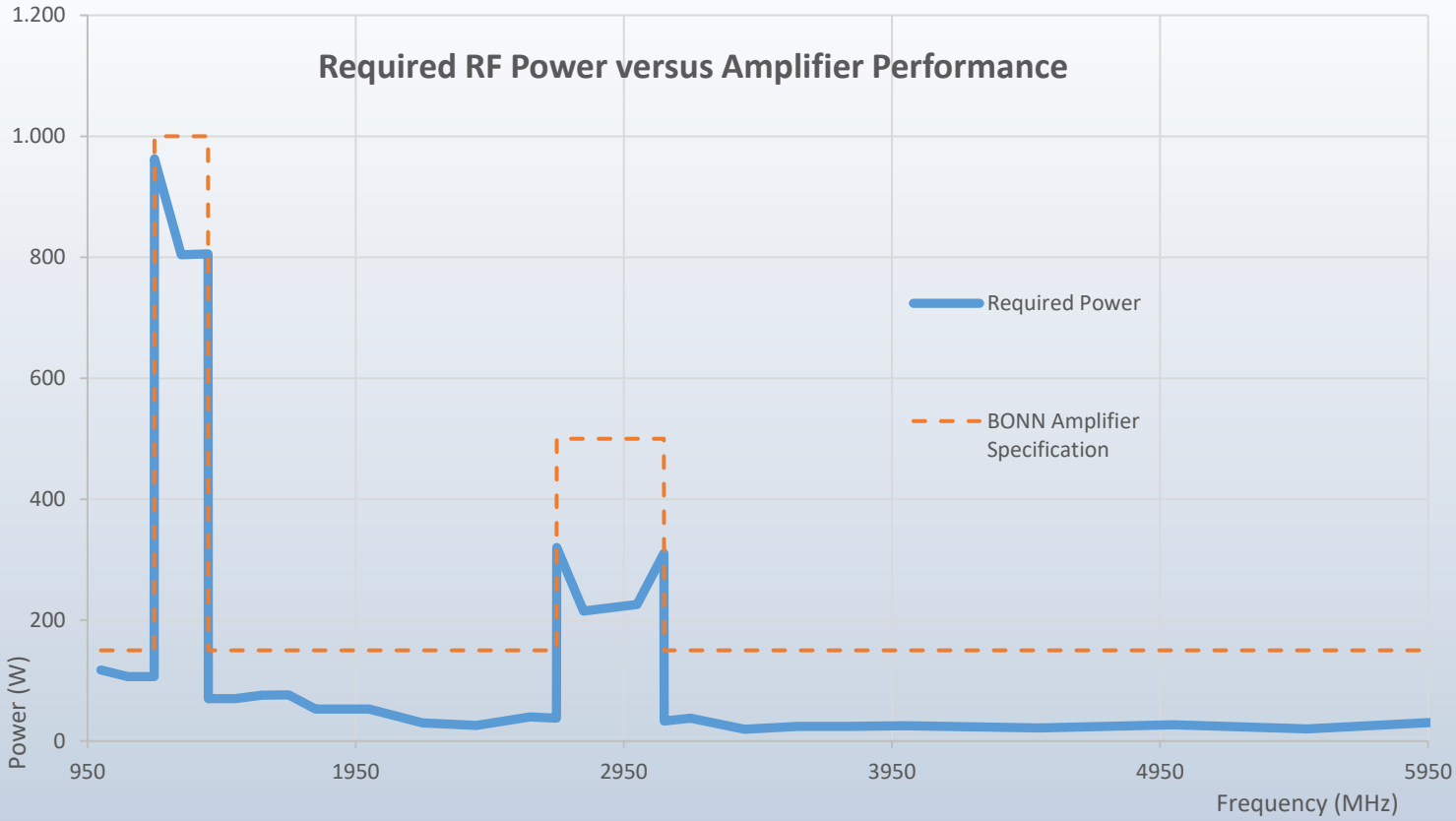
- Requirements

Table 10 – Component testing with the antenna method – requirements

	Frequency range in MHz	Test field strength in V/m	Polarization	Modulation
required	200 to 380	70	vertical and horizontal	CW and AM (1 kHz, 80%)
	380 to 460	140	vertical and horizontal	CW and AM (1 kHz, 80%)
	460 to 806	70	vertical and horizontal	CW and AM (1 kHz, 80%)
	806 to 915	140	vertical and horizontal	CW and phase modulation (PM) (217 Hz, 577 µs)
	915 to 1 200	70	vertical and horizontal	CW
	1 200 to 1 400	140	vertical and horizontal	CW and phase modulation (PM) (300 Hz, 3 µs)
	1 400 to 1 710	70	vertical and horizontal	CW
	1 710 to 1 910	140	vertical and horizontal	CW and phase modulation (PM) (217 Hz, 577 µs)
	1 910 to 2 700	70	vertical and horizontal	CW
	2 700 to 3 400	140	vertical and horizontal	CW and phase modulation (PM) (300 Hz, 3 µs)
Optional	3 400 to 6 000	50	vertical and horizontal	CW and PM (1 600 Hz, 312.5 µs)

Required RF Power 1 … 6 GHz

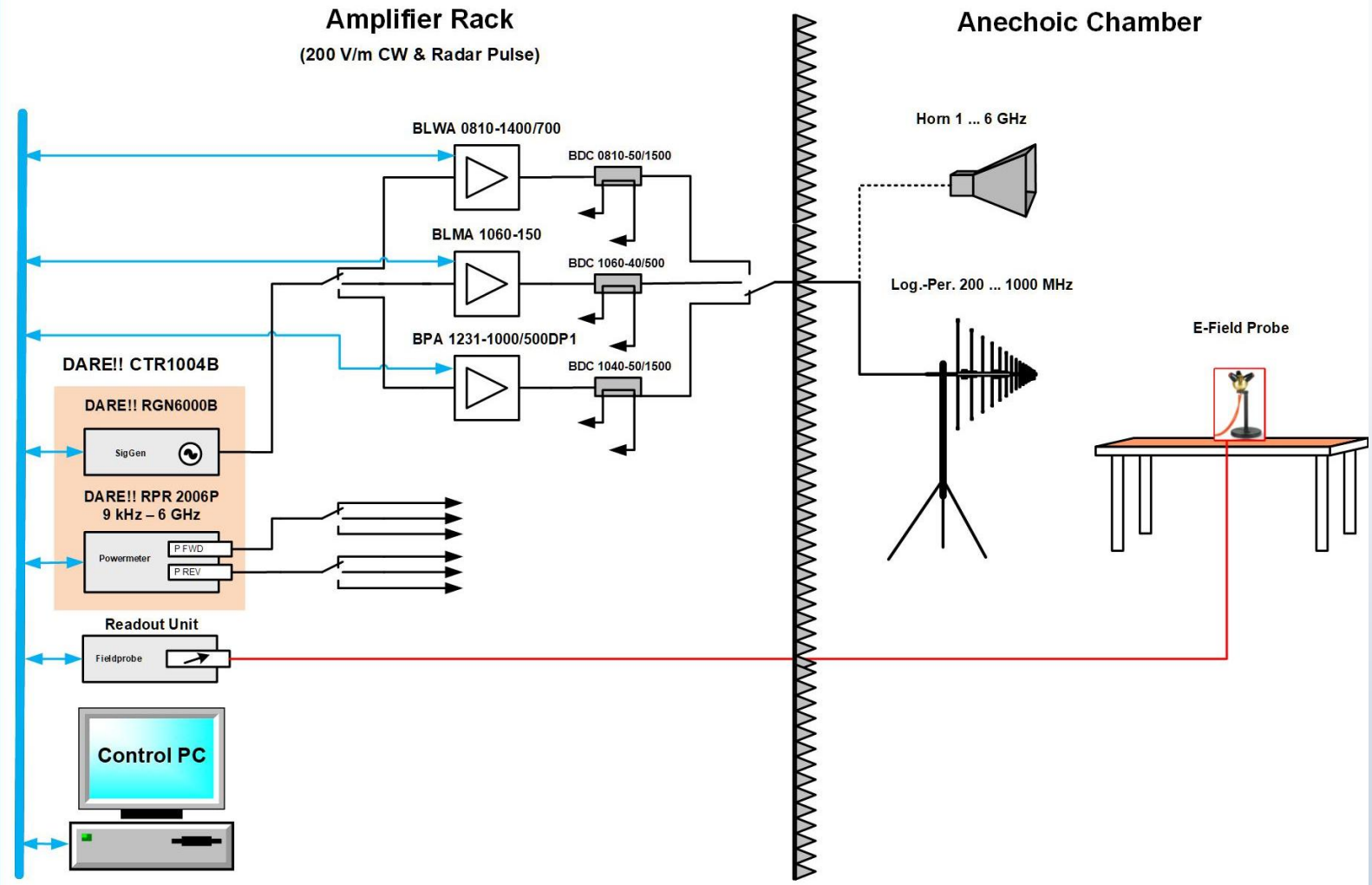
- **Automotive Radar Pulse Testing**
  - 200 V/m CW 1 … 6 GHz
  - 600 V/m Pulse 1.2 … 1.4 GHz and 2.7 … 3.1 GHz



Example: 80 MHz ... 6 GHz

- **Combination of CW and Pulsed Amplifiers**
  - BLWA 0810-1400/700
    CW Amplifier 80 ... 1000 MHz
    80 ... 400 MHz 1400 W CW min. / 1500 W CW typ.
    400 ... 1000 MHz 700 W CW min. / 850 W CW typ.
  - BLMA 1060-150
    CW Amplifier 1 ... 6 GHz
    1 ... 6 GHz 150 W CW min. / 180 W CW typ.
  - BPA 1231-1000/500 DP1
    Pulsed Amplifier 1.2 ... 3.1 GHz
    1.2 ... 1.4 GHz 1000 W pk / 1% Duty Cycle
    2.7 ... 3.1 GHz 500 W pk / 1% Duty Cycle
- **Advantages**
  - Attractive priced
    Complete Turn-Key system solution <300 k€
  - Integrated switching unit avoids inconvenient setup delays
  - Flexible adaption to new requirements
  - Simple expansion of existing installations
  - Mobile solution

System Block Diagram



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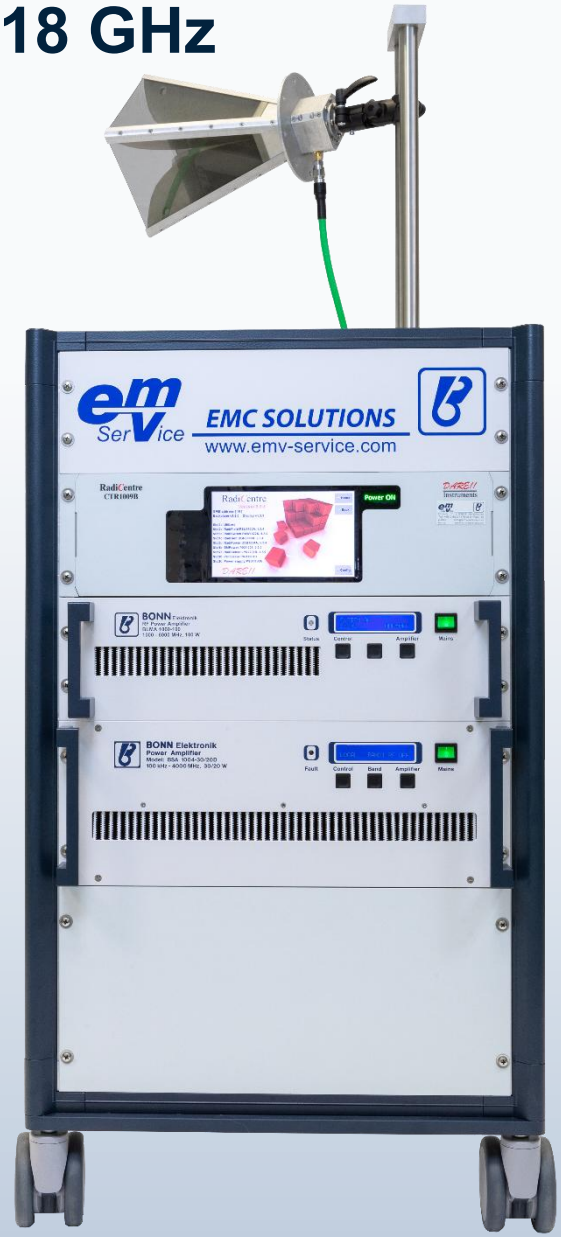
Example: Mobile Solution 6 … 18 GHz

- **Mobile Test Rack**
  To avoid high cable losses.
  The lengths of the RF connection cables between amplifiers and antennas can be significantly shortened with a mobile test rack – which is positioned inside the anechoic chamber directly next to the DUT
- MIL 461G – RS 103 defines e.g. a pulsed signal at 1 kHz pulse repetition frequency (P-RF) and 50% Duty Cycle (alternately termed as 1 kHz square wave modulation).
  This means that no dedicated pulsed amplifiers can be used.
- The advantage when using CW amplifiers is that they can be used to perform related CW tests too.



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Example: MIL 461G – RS 103

- Requirements for different Platforms

TABLE XI. RS103 limits.

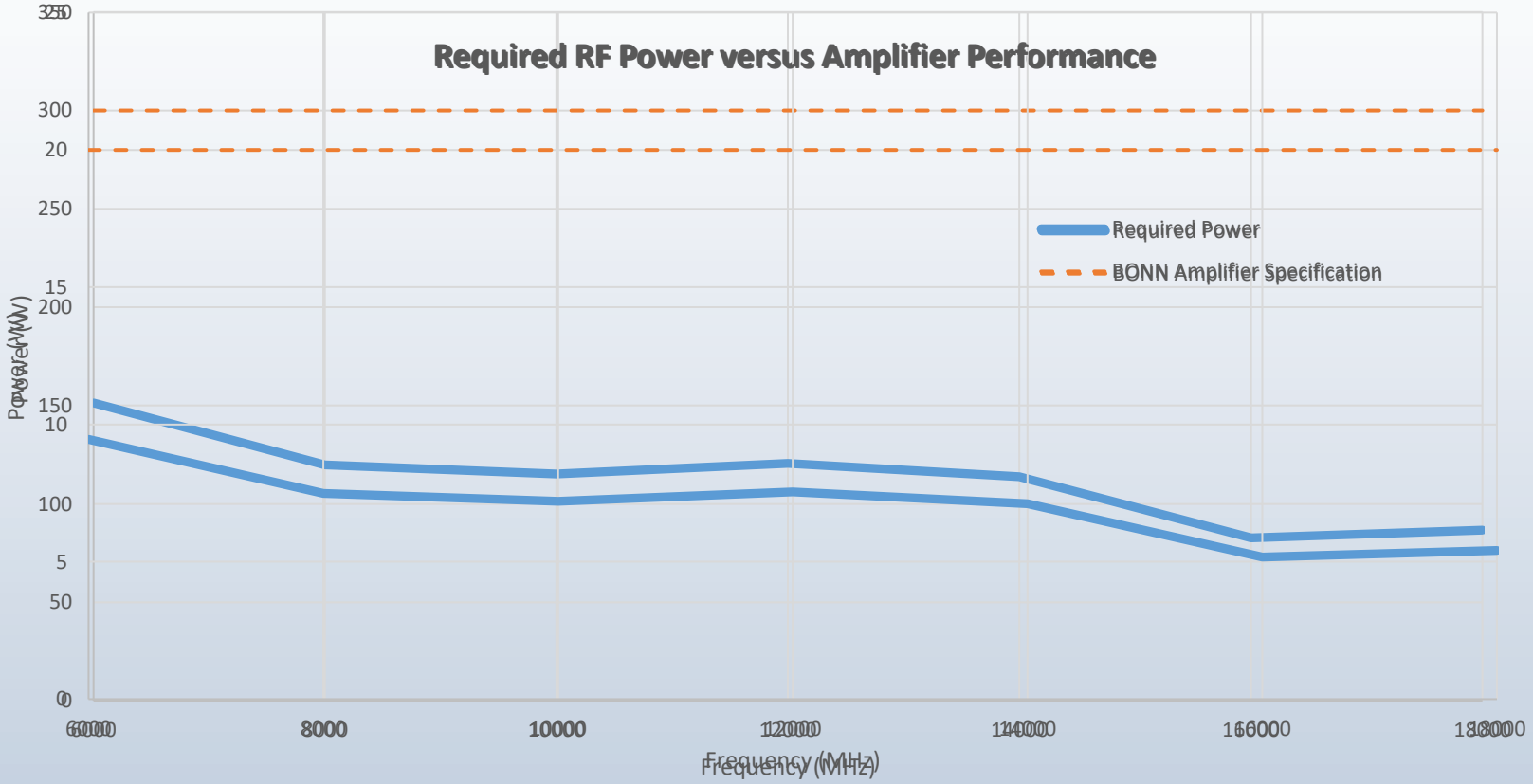
FREQUENCY RANGE / PLATFORM		LIMIT LEVELS (VOLTS/METER)							
		AIRCRFAFT (EXTERNAL OR SAFETY CRITICAL)	AIRCRAFT INTERNAL	ALL SHIPS (ABOVE DECK & EXPOSED BELOW DECK) AND SUBMARINES (EXTERNAL)*	SHIPS (METALLIC) (BELOW DECKS)	SHIPS (NON-METALLIC) (BELOW DECK)**	SUBMARINE (INTERNAL)	GROUND	SPACE
2 MHz to 30 MHz	A	200	200	200	10	50	5	50	20
	N	200	200	200	10	50	5	10	20
	AF	200	20	-	-	-	-	10	20
30 MHz to 1 GHz	A	200	200	200	10	10	10	50	20
	N	200	200	200	10	10	10	10	20
	AF	200	20	-	-	-	-	10	20
1 GHz to 18 GHz	A	200	200	200	10	10	10	50	20
	N	200	200	200	10	10	10	50	20
	AF	200	60	-	-	-	-	50	20
18 GHz to 40 GHZ	A	200	200	200	10	10	10	50	20
	N	200	60	200	10	10	10	50	20
	AF	200	60	-	-	-	-	50	20

KEY: A= Army
N= Navy
AF= Air Force

* For equipment located external to the pressure hull of a submarine but within the superstructure, use SHIPS (METALLIC) (BELOW DECK)
** For equipment located in the hanger deck of Aircraft Carriers

RF Power Requirements 6 … 18 GHz

- **Example MIL 461G – RS 103 Aircraft**
  - Aircraft (external / safety) 200 V/m CW
  - Ground Army 50 V/m CW



Example: MIL 461G – RS 103

- For 50 V/m according to MIL 461G – RS 103 **Ground Army** we e.g. can offer following amplifiers:
  - BLMA 6018-20
    Solid State Power Amplifier
    6 ... 18 GHz 20 W CW min. / 22 W CW typ.
- For 200 V/m according to MIL 461G – RS 103 **Aircraft (external / safety)** we e.g. can offer following amplifiers:
  - TWAL 0618-300
    Travelling Wave Tube Amplifier
    6 ... 18 GHz 300 W CW min. / 320 W CW typ.
  - BLMA 6018-200
    Solid State Power Amplifier
    6 ... 18 GHz 200 W CW min. / 220 W CW typ.
- **Advantages**
  - Attractive priced mobile solution
  - Flexible adaption to new requirements
  - Simple expansion of existing installations

Example: Split-Mount 18 ... 40 GHz

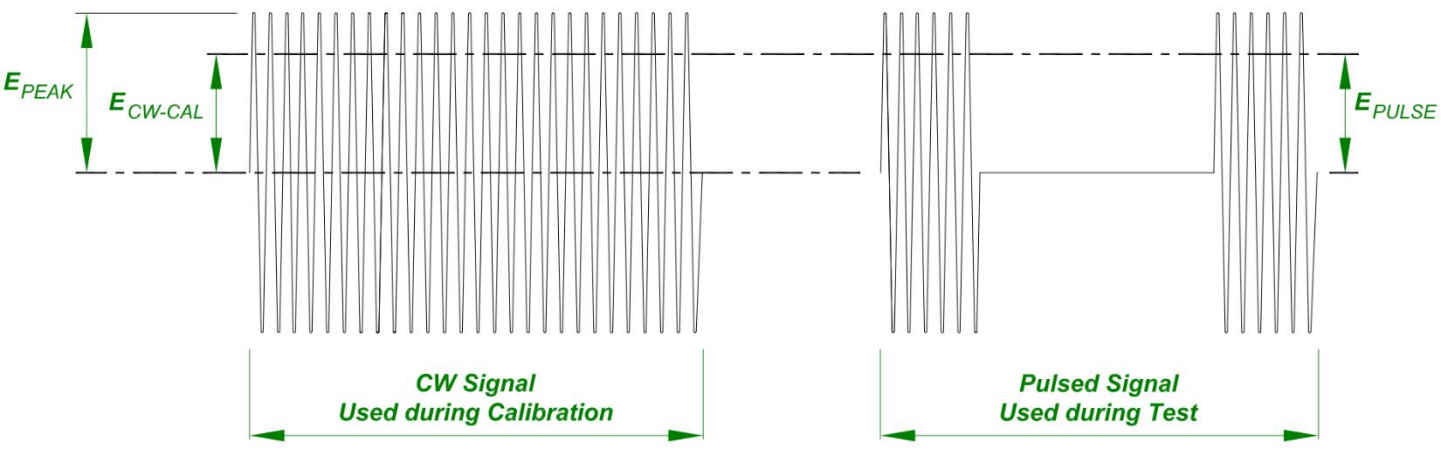
- **High test frequencies (18 … 40 GHz) and exceptional high field strength**

Aerospace	RTCA DO160
MIL Tests	MIL-STD 461, RS103

- **High cable losses at very high frequencies**
  At very high frequencies, the cable loss increases extremely and the use of flexible waveguides is not always ideal
- **Split-Mount configuration**
  Here the power amplifier is split into a RF unit and separate power supply and control unit
  - power supply and control unit are conventionally integrated into 19“ cabinets and are installed into a mobile rack
  - This makes the RF units of the power amplifiers much more compact and lightweight
- **Tripod mounting**
  These compact RF units can be mounted on tripods and the antennas are mounted directly – without any waveguides or cables – to the amplifier output (see example)

Calibration of Pulsed Fields (GMW 3097)

- **CW E-Field Probe Method (Dual Mode)**
  - Peak RMS forward power is the reference parameter for characterization of the field using peak envelope power (PEP) sensors or a spectrum analyser (not recommended by some standards).
  - Characterization at the required field strengths is performed in CW mode.



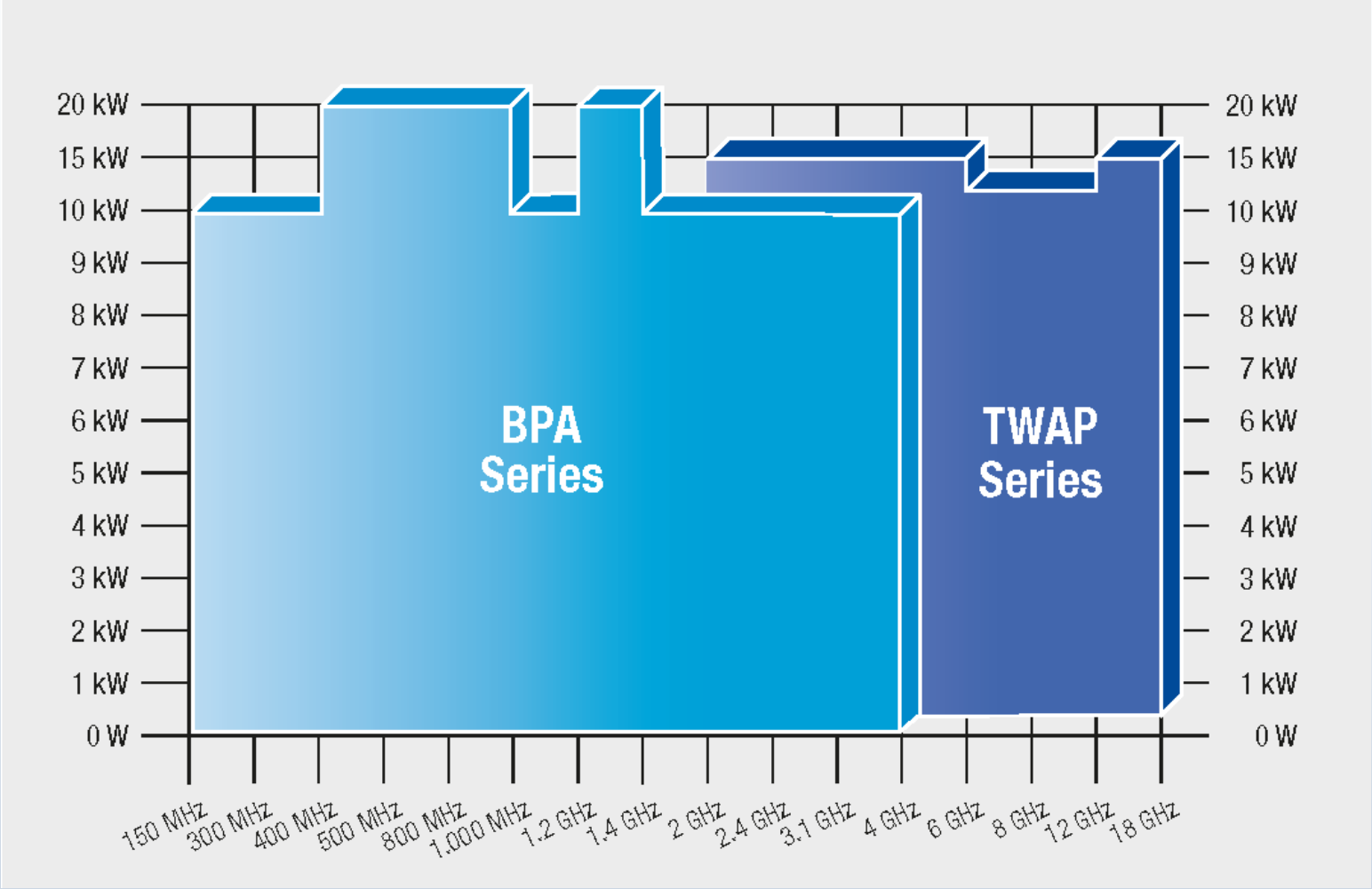
  - If the CW E-Field probe is not capable of measuring the final field levels required, or if a pulsed-only amplifier is used, then it is acceptable to calibrate at a lower CW level using CW power sensors plus CW amplifier and scale up the forward power levels with a PEP sensor accordingly to the corresponding target E-Field during actual testing.

Calibration of Pulsed Fields (GMW 3097)

- **Pulsed E-Field Probe Method**
  - E-Field probes capable of direct measurement of a pulsed field
  - Please note:
    This method is not (yet?) recommended by some standards...
  - Possible solutions
    - Amplifier Research, AR PL7004
      Pulsed E-Field Probe, 0.8 … 3.6 GHz, 80 … 800 V/m
    - EMC Test Design LLC, PI-3P
      Isotropic Pulsed Electric Field Probe, 0.1 … 18 GHz, 70 … 1400 V/m
    - NEC
      Pulsed Power E-Field Test System

- **Antenna Method**
  - This method may be applicable when using either CW or pulsed power amplifiers
  - Peak RMS forward power is used as reference parameter for characterization of the field using peak envelope power (PEP) sensors or a spectrum analyzer (not recommended by some standards)

Pulsed Power Capability



Pulsed Power Capability – BPA

BPA Series

Pulsed Solid State Amplifiers BPA

Model	Frequency Range	PDF
BPA 0305	300 ... 500 MHz	PDF
BPA 0410	400 ... 1000 MHz	PDF
BPA 0520	500 ... 2000 MHz	PDF
BPA 0913	950 ... 1250 MHz	PDF
BPA 1000	995 ... 1003 MHz	PDF
BPA 1011	1 ... 1.1 GHz	PDF
BPA 1020	1 ... 2 GHz	PDF
BPA 1025	1 ... 2.5 GHz	PDF
BPA 1114	1.15 ... 1.45 GHz	PDF
BPA 1214	1.2 ... 1.4 GHz	PDF
BPA 1231	1.2 ... 3.1 GHz	PDF
BPA 2040	2 ... 4 GHz	PDF
BPA 2427	2.4 ... 2.7 GHz	PDF
BPA 2731	2.7 ... 3.1 GHz	PDF
BPA 7510	7.5 ... 10 GHz	PDF

Pulsed Power Capability – TWAP

TWAP Series

Pulsed TWT Amplifiers

TWAP

Model	Frequency Range	PDF
TWAP 0203	2.7 ... 3.3 GHz	PDF
TWAP 0204	2 ... 4 GHz	PDF
TWAP 0208	2 ... 8 GHz	PDF
TWAP 0304	3 ... 4 GHz	PDF
TWAP 0408	4 ... 8 GHz	PDF
TWAP 0810	8.5 ... 10.5 GHz	PDF
TWAP 0811	8.5 ... 11 GHz	PDF
TWAP 0812	8 ... 12 GHz	PDF
TWAP 0818	8 ... 18 GHz	PDF
TWAP 0910	9.2 ... 10 GHz	PDF
TWAP 1218	12.4 ... 18 GHz	PDF

The Power you need for many Applications