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**BONN Elektronik GmbH**

# Pulsed Power Amplifier Solutions

# BONN Elektronik GmbH

# Broadband RF Power Amplifiers

# Broadband RF Power Amplifiers

| BSA Series |
|---|
| Solid State Amplifiers |
| 4 kHz ... 1000 MHz<br>1 W ... 20 kW |

| BLWA Series |
|---|
| Solid State Amplifiers |
| 1 ... 1000 (18000) MHz<br>1 W ... 20 kW |

| BLMA Series |
|---|
| Solid State Amplifiers |
| 100 MHz ... 40 GHz<br>0.1 W ... 2 kW |

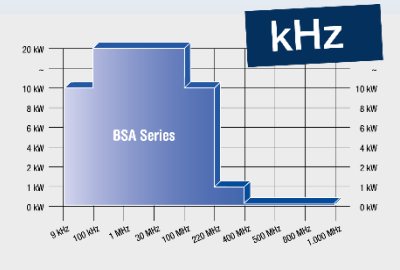
| BPA Series |
|---|
| Pulsed Amplifiers |
| 300 MHz ... 10 GHz<br>25 W pk ... 20 kW pk |

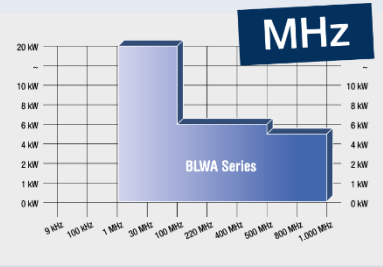
| |
|---|
| |
| |

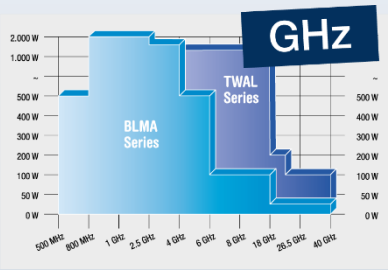
| Cellular Bands |
|---|
| Solid State Amplifiers |
| 800 ... 2700 MHz<br>10 W ... 600 W |

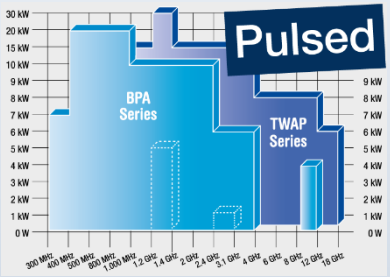
| TWAL Series |
|---|
| TWT Amplifiers |
| 1 GHz ... 50 GHz<br>20 W ... 1 kW |

| TWAP Series |
|---|
| Pulsed TWT Amplifiers |
| 1 ... 18 GHz<br>1.5 ... 30 kW pk |



# EMI Preamplifiers

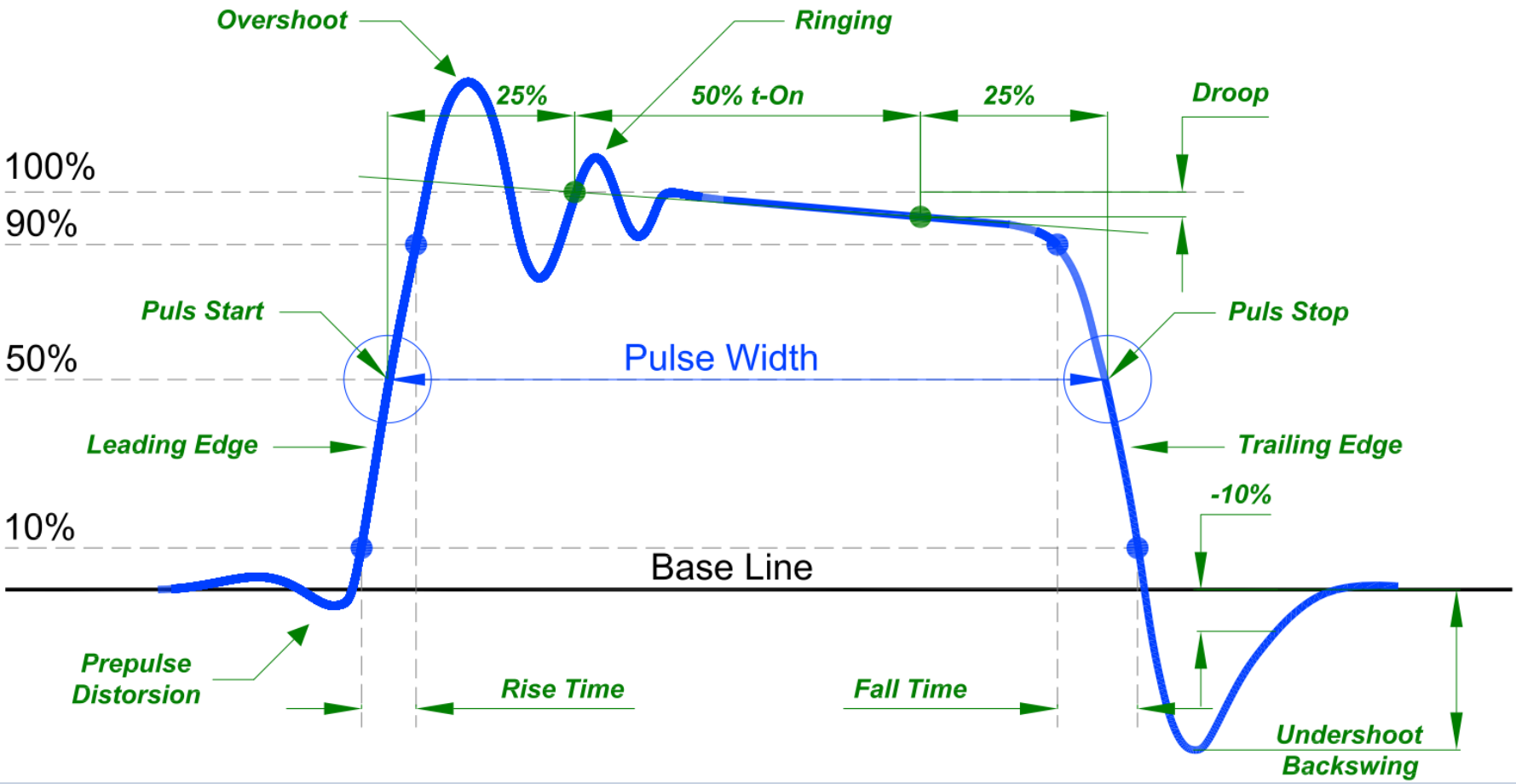
## LNAs with optional Antennas

| Model | Frequency Range |
|---|---|
| BLNA 0110 | 9 kHz ... 1000 MHz |
| BLNA 0125 | 9 kHz ... 2500 MHz |
| BLNA 0160 | 10 ... 6000 MHz |
| BLNA 0118 | 10 MHz ... 18 GHz |
| BLNA 0220 | 20 ... 2000 MHz |
| BLNA 0240 | 20 ... 4000 MHz |
| BLNA 0360 | 30 ... 6000 MHz |
| BLNA 0130 | 100 ... 3000 MHz |
| BLMA 0118 | 1 ... 18 GHz |
| BLMA 0126 | 1 ... 26.5 GHz |
| BLMA 1826 | 18 ... 26.5 GHz |
| BLMA 1840 | 18 ... 40 GHz |
| BLMA 2640 | 26.5 ... 40 GHz |

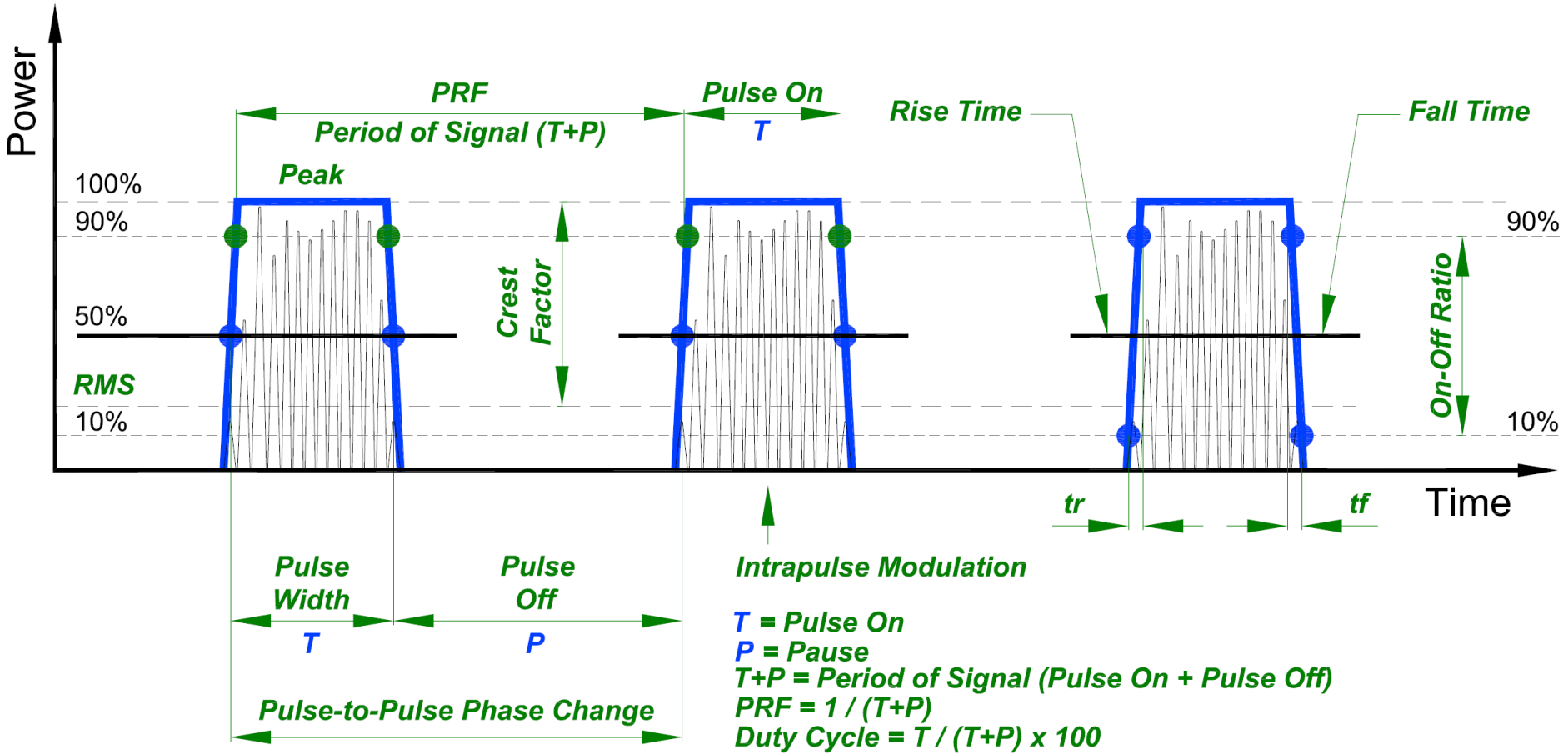
# Pulse Power Definitions

- **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.

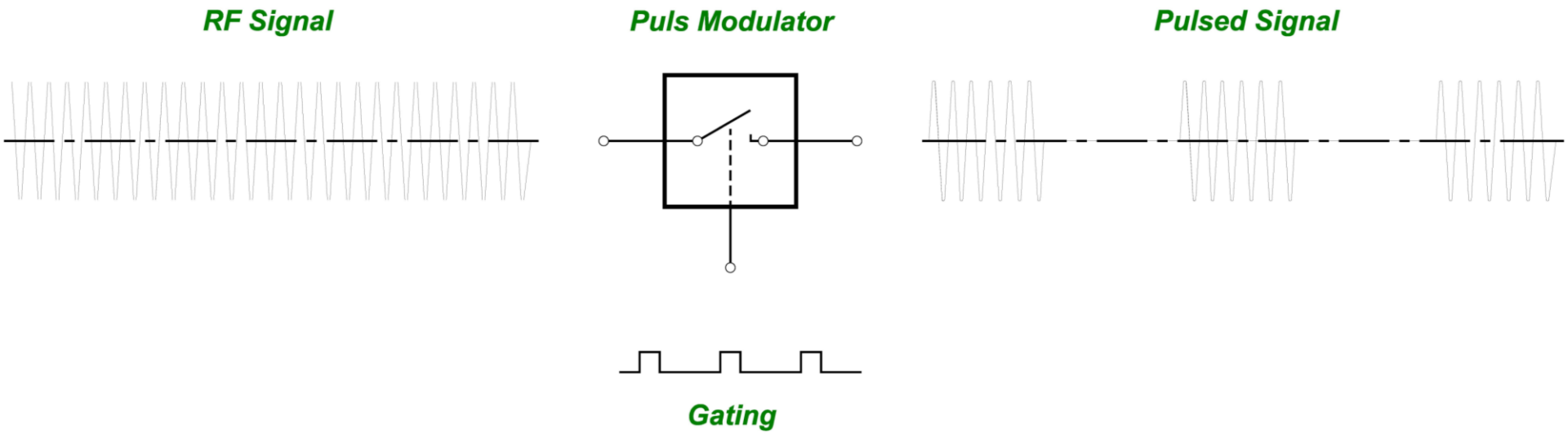
# Pulse Elements



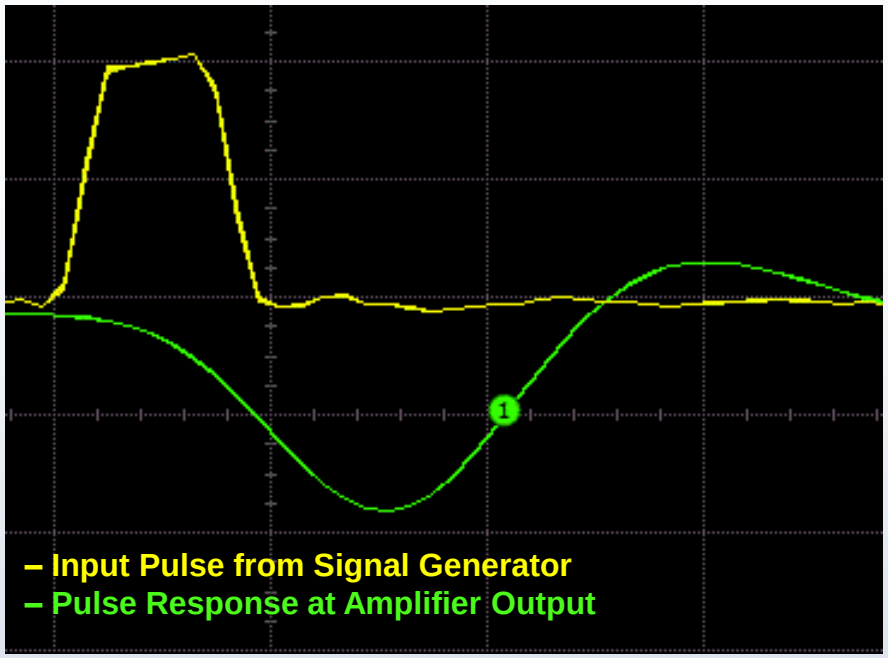
# Pulse Timing

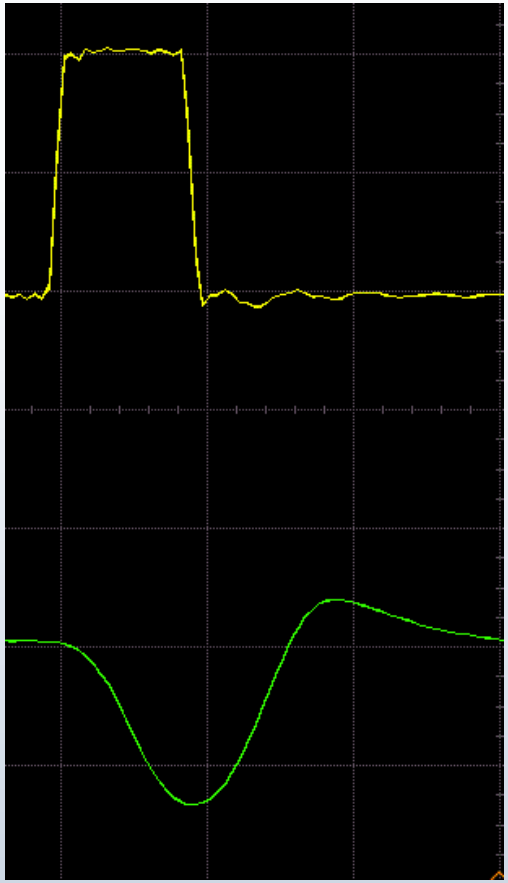


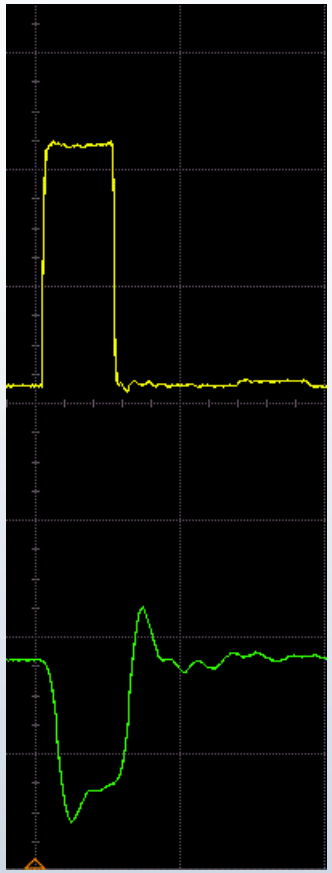
# Pulse Modulator



# Power Amplifier Pulse Response





BSA 0040-250

800 ps

2 ns

5 ns



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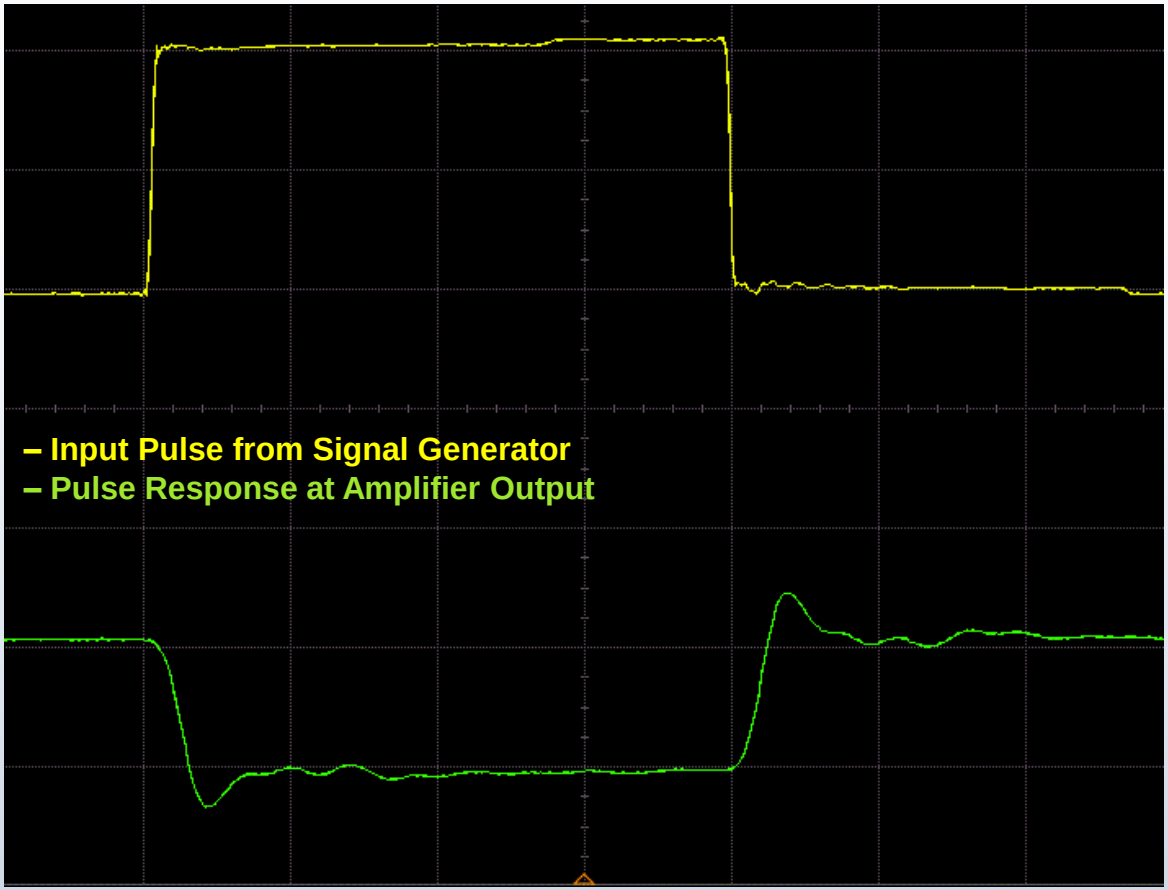
# Power Amplifier Pulse Response




BSA 0040-250

20 ns



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# Pulsed Power Testing

- **Solid state BPA series pulsed amplifiers up to approximately 10 kW pk**
  - 300 … 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 1 … 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)

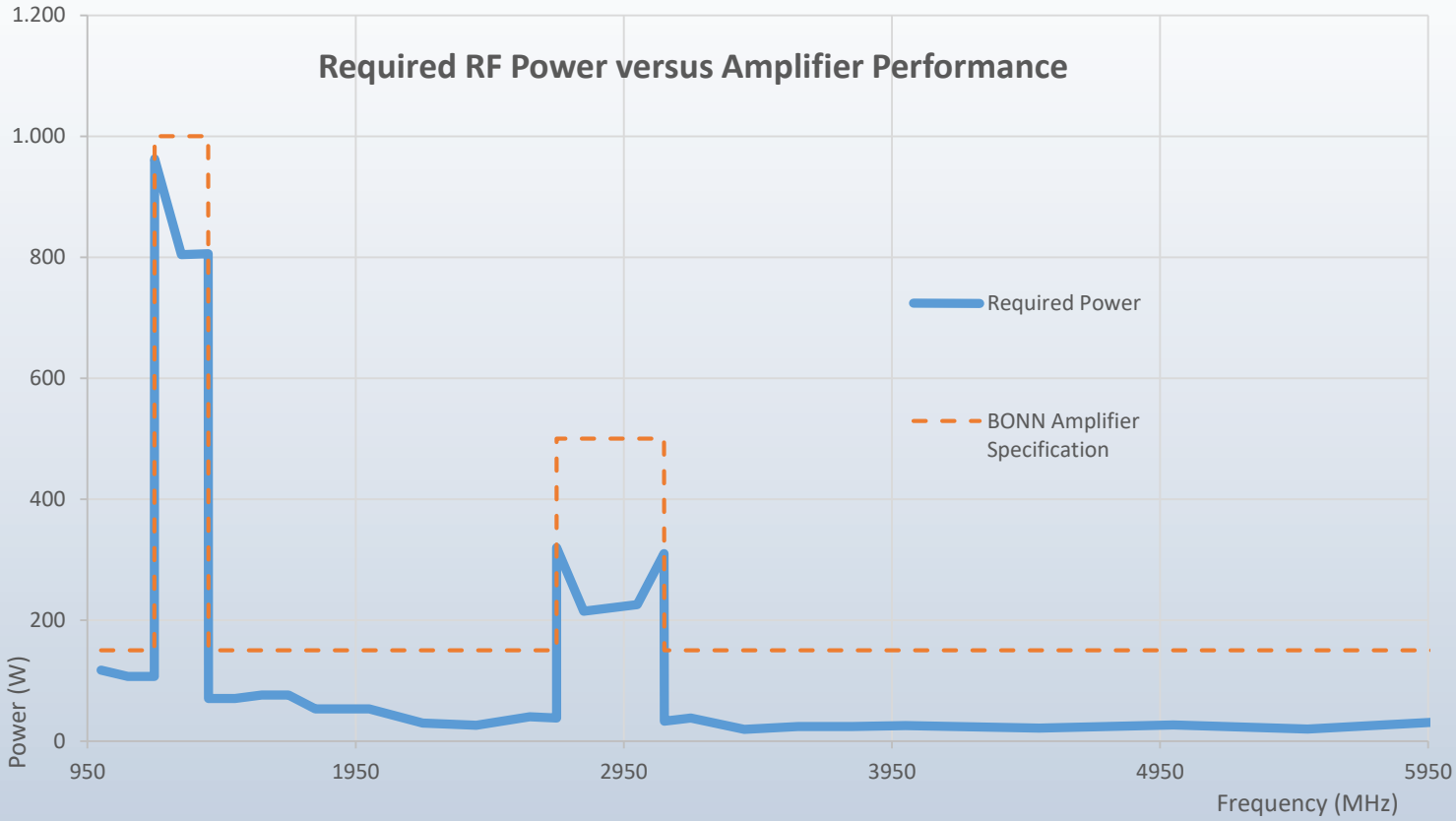
- Requirements

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

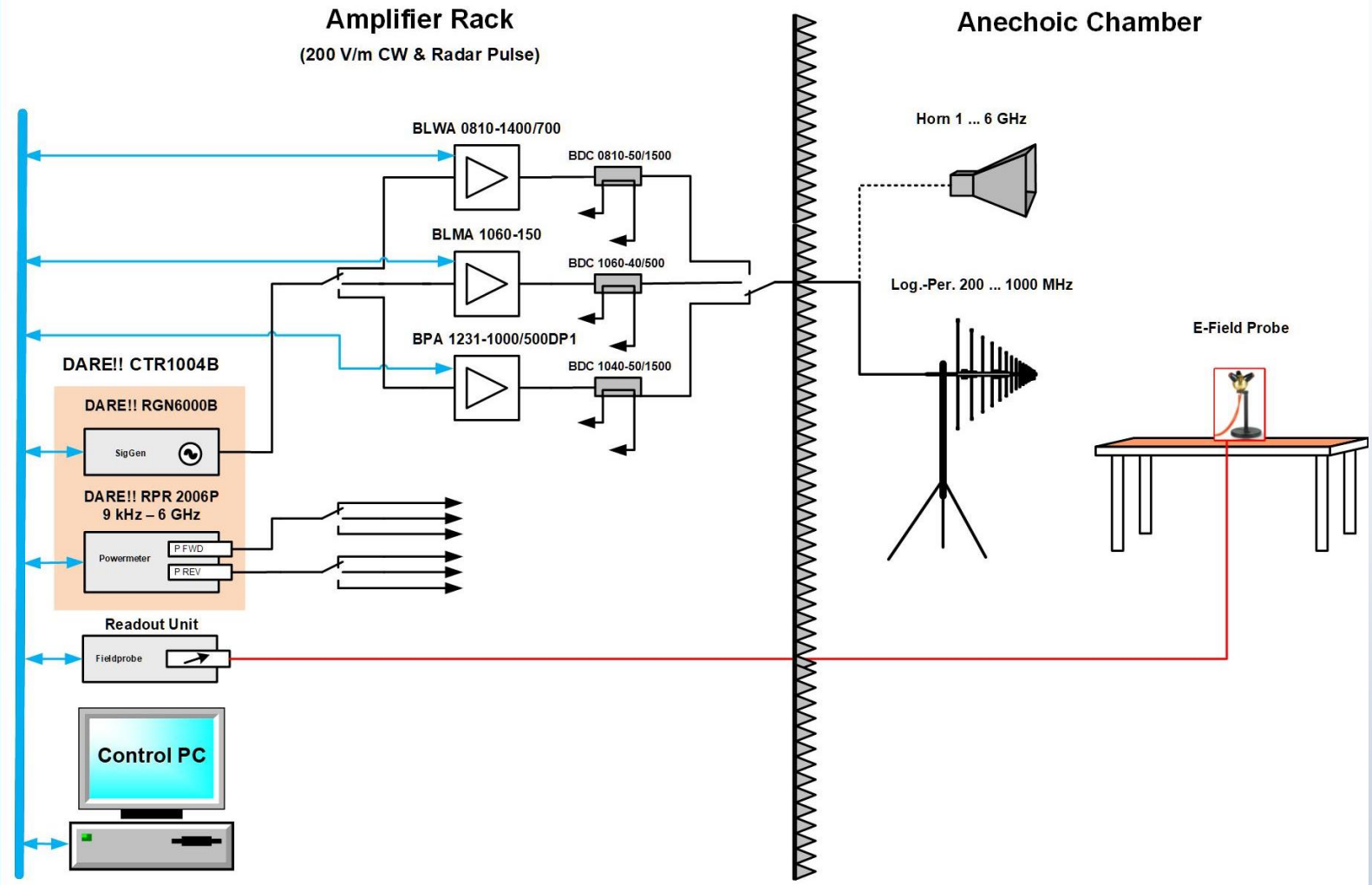
- **Automotive Radar Pulse Testing**
  - 200 V/m CW  1 … 6 GHz
  - 600 V/m Pulse  1.2 … 1.4 GHz and 2.7 … 3.1 GHz



# 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% Tastverhältnis
    2.7 ... 3.1 GHz 500 W pk / 1% Tastverhältnis
- **Advantages**
  - Attractive priced
    Complete Turn-Key system solution <300 k€
  - Integrated switching unit saves inconvenient setup delays
  - Flexible adaption to new requirements
  - Simple expansion of existing installations
  - Mobile solution

# System Block Diagram



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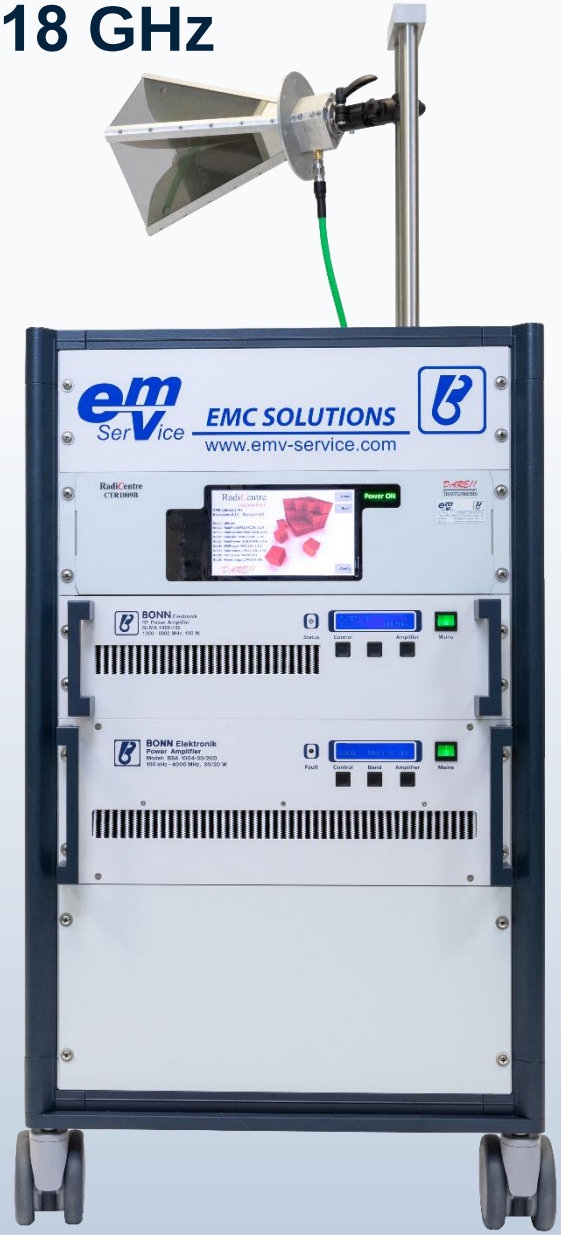
# Example: Mobile Solution 6 … 18 GHz

- **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 puls 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.



# Example: MIL 461G – RS 103

- Requirements for different Platforms

TABLE XI. RS103 limits.

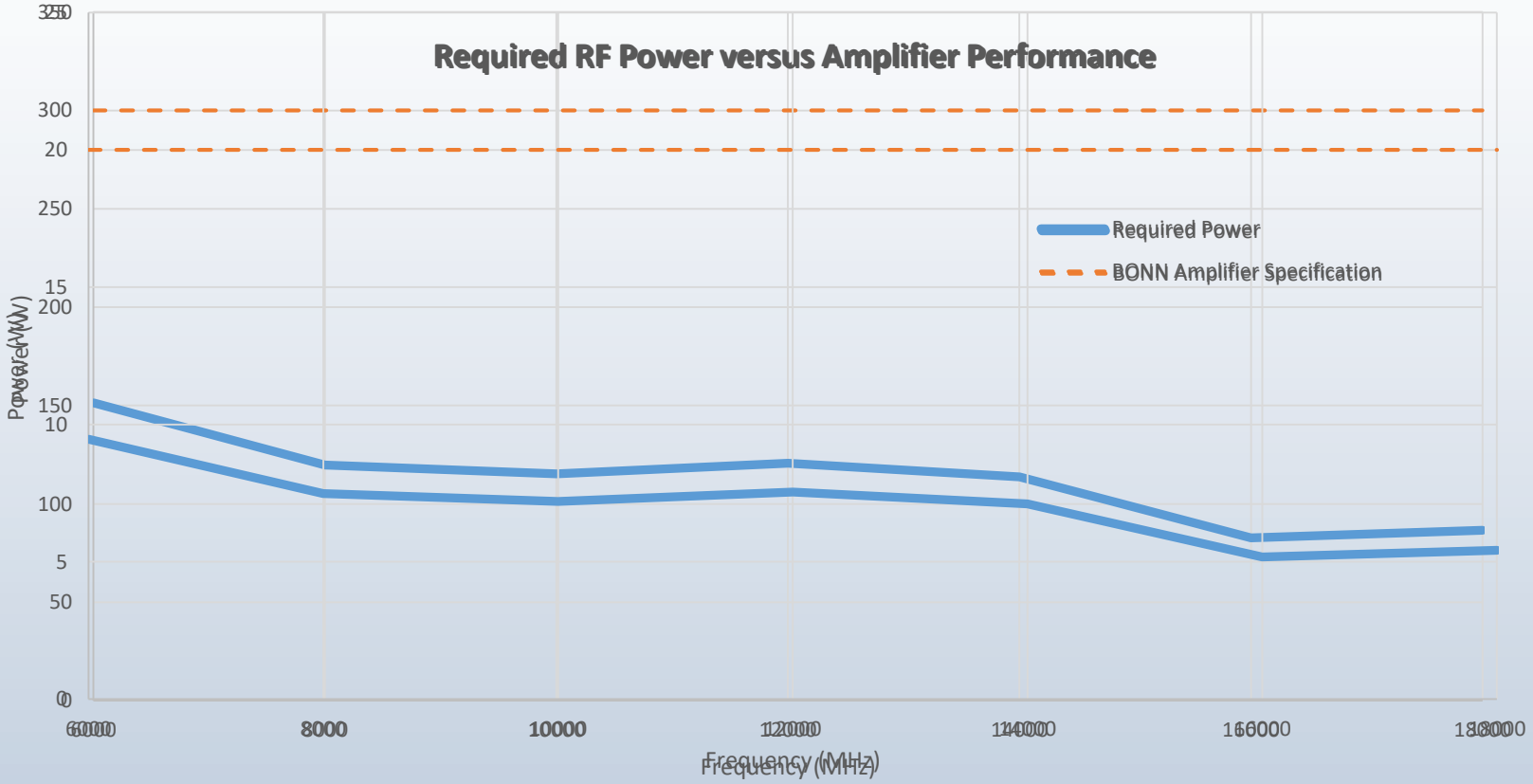
| FREQUENCY RANGE / PLATFORM | | LIMIT LEVELS (VOLTS/METER) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | AIRCRFAFT (EXTERNAL OR SAFETY CRITICAL) | AIRCRAFT INTERNAL | ALL SHIPS (ABOVE DECK & EXPOSED BELOW DECK) AND SUBMARINES (EXTERNAL)* | SHIPS (METALLIC) (BELOW DECKS) | SHIPS (NON-METALLIC) (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



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# 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**

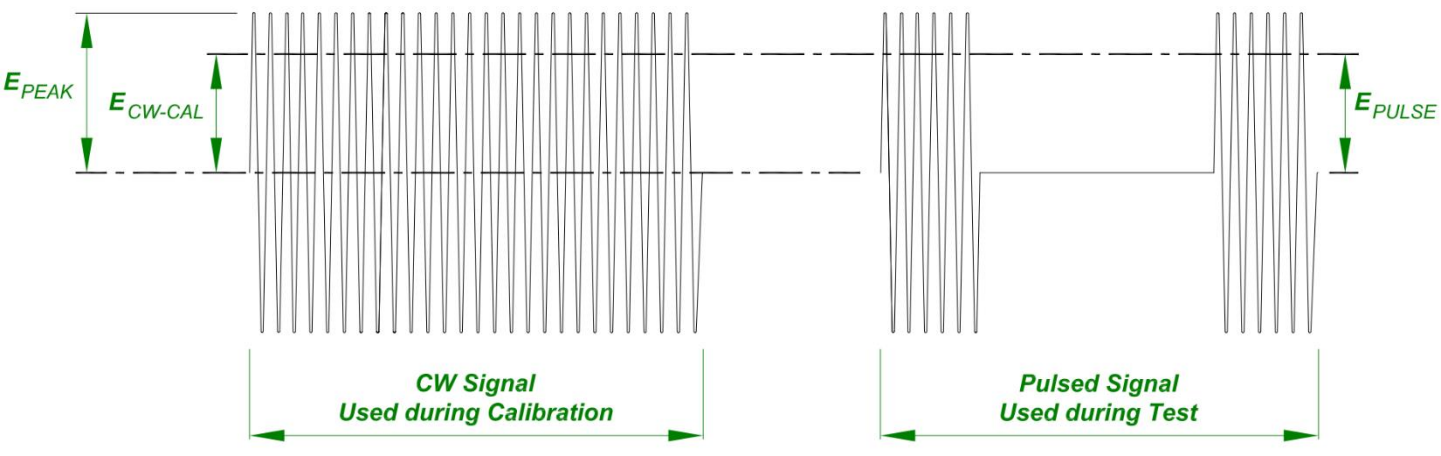
| | |
|---|---|
| Aerospace | RTCA DO160 |
| MIL Tests | MIL-STD 461, RS103 |

- **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)

# Example: Split-Mount 18 ... 40 GHz

# 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.



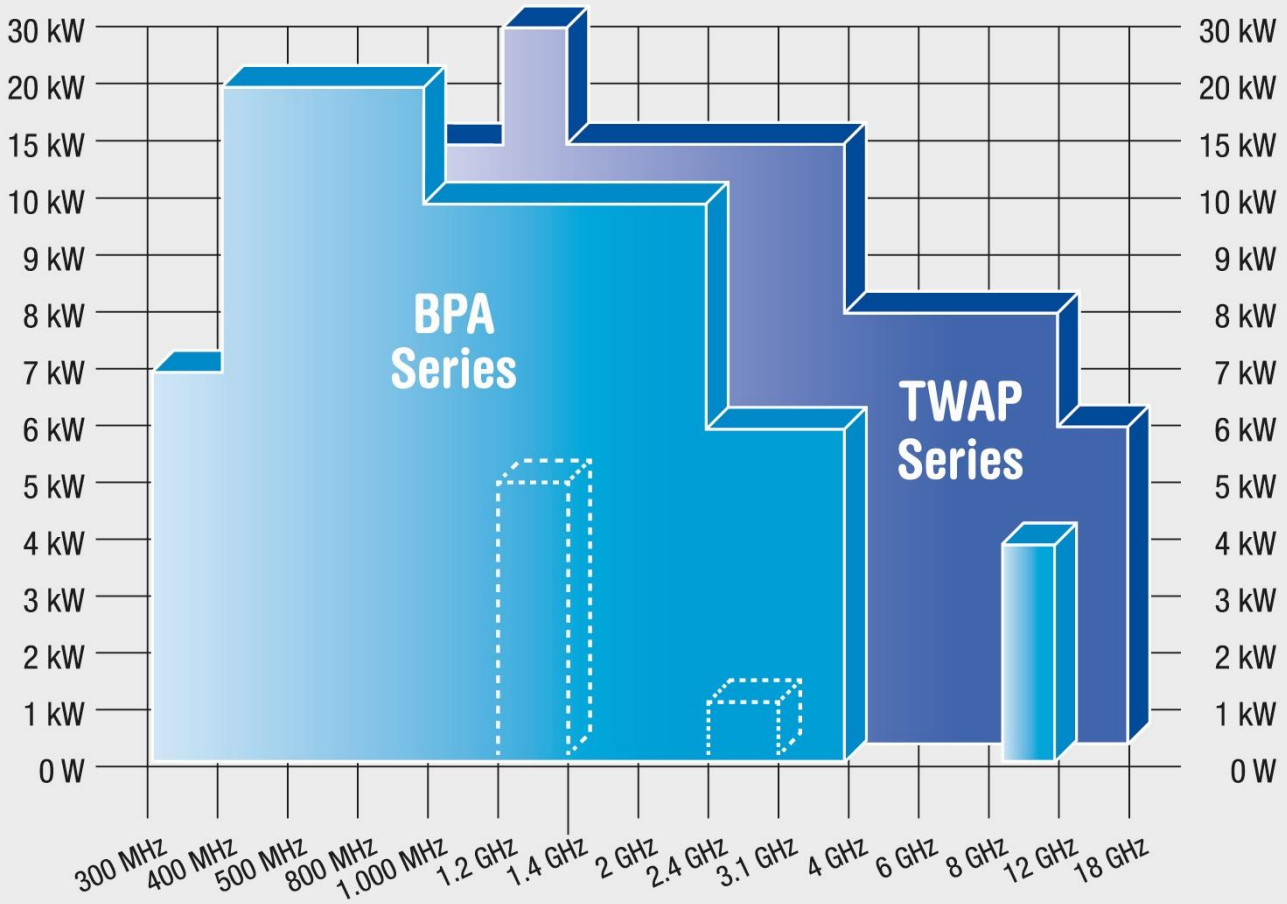

  - If the CW E-Field probe is not capable of measuring the final field levels required, or if a pulsed-only amplifier is used, then it is acceptable to calibrate at a lower CW level using CW power sensors plus CW amplifier and scale up the forward power levels with a PEP sensor accordingly to the corresponding 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 analyser (not recommended by some standards)

# Pulsed Power Capability



# Pulsed Power Capability

BPA / TWAP Series

## Pulsed Solid State Amplifiers — BPA

| Model | Frequency Range | PDF |
|---|---|---|
| BPA 0305 | 300 ... 500 MHz | PDF |
| BPA 0410 | 400 ... 1000 MHz | PDF |
| BPA 0420 | 400 ... 2000 MHz | PDF |
| BPA 0913 | 950 ... 1250 MHz | PDF |
| BPA 1000 | 995 ... 1003 MHz | 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 2427 | 2.4 ... 2.7 GHz | PDF |
| BPA 2731 | 2.7 ... 3.1 GHz | PDF |
| BPA 7510 | 7.5 ... 10 GHz | PDF |

## Pulsed TWT Amplifiers — TWAP

| Model | Frequency Range | PDF |
|---|---|---|
| TWAP 0115 | 1 ... 1.5 GHz | PDF |
| TWAP 0102 | 1 ... 2 GHz | PDF |
| TWAP 0103 | 1 ... 2.5 GHz | PDF |
| TWAP 1113 | 1.1 ... 1.3 GHz | PDF |
| TWAP 1115 | 1.1 ... 1.5 GHz | PDF |
| TWAP 1502 | 1.5 ... 2 GHz | 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 0811 | 8.5 ... 10.5 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