

# Modulated Wideband Power Amplifier

## 1 Introduction

Tekbox provides a complete solution for affordable pre-compliance conducted immunity testing: Coupling Decoupling Networks along with suitable calibration adapters and 150 Ohm transitions; BCI probes, suitable modulated wideband power amplifiers and EMCview PRO software. A third-party spectrum analyzer with tracking generator serves as signal source.

The TBMDA-CDN25 modulated amplifier provides the necessary power, bandwidth and modulation for conducted immunity testing using CDNs and BCI probes in the frequency range from 100 kHz to 250 MHz. It is designed to be driven by signal generators or by tracking generators of spectrum analyzers. With a 1 dB compression point of up to 25 W in the frequency range 100 kHz to 250 MHz it can generate test levels class 1, class 2, class 3 and class X according to ISO / EN 61000-4-6. A built in AM / PM - modulator enables use of tracking generators as signal source. The TBMDA-CDN25 has sufficient gain to achieve maximum output power with 0 dBm provided by a spectrum analyzer tracking generator.

Besides 1 kHz, 80% AM, the TBMDA-CDN25 provides built in modulation capability to generate 1 kHz, 50% duty cycle PM signals. In PM mode, the TBMDA-CDN25 can also generate a 217 Hz Signal with 12.5% duty cycle in order to simulate mobile phone TDMA noise.



Picture 1 – TBMDA-CDN25 modulated wideband driver amplifier, front view



Picture 2 – TBMDA-CDN25 modulated wideband driver amplifier, rear view

# Modulated Wideband Power Amplifier

## **Application:**

General-purpose wideband RF power amplifier

Wideband RF power amplifier for conducted immunity testing driving CDNs or BCI-probes

Wideband RF power amplifier for radiated immunity testing, driving near field probes

Wideband RF power amplifier for radiated immunity testing, driving TEM Cells

## **Features:**

CW amplifier (modulation off)

1 kHz, 80% AM modulation

1 kHz, 50% duty cycle pulse modulation

217 Hz, 12.5% duty cycle pulse modulation

## **Dimensions:**

32 cm x 28 cm x 13 cm, 5.7 kg

## 2 Electrical Specifications

### **Technical Data:**

Input / Output: 50 Ohm, N female

Supply Voltage range: 110 V...240 V

Supply power consumption: 108 W @ 220V

Operating temperature range: -20°C to 50°C

Frequency range: 100 kHz – 250 MHz

Small signal gain: 47 dB typ.

Gain flatness 100 kHz – 250 MHz / Pin = -3 dBm: 3.5 dB typ.

Saturated output power @ 100 kHz / Pin = 0 dBm: 44.1 dBm (25.7 W) typ.

Saturated output power @ 150 kHz / Pin = 0 dBm: 44.6 dBm (28.8 W) typ.

Saturated output power @ 500 kHz / Pin = 0 dBm: 45.1 dBm (32.4 W) typ.

Saturated output power @ 1 MHz / Pin = 0 dBm: 45.3 dBm (33.9 W) typ.

Saturated output power @ 10 MHz / Pin = 0 dBm: 45.3 dBm (33.9 W) typ.

Saturated output power @ 50 MHz / Pin = 0 dBm: 45.6 dBm (36.3 W) typ.

Saturated output power @ 80 MHz / Pin = 0 dBm: 46.6 dBm (45.7 W) typ.

Saturated output power @ 100 MHz / Pin = 0 dBm: 46.5 dBm (44.7 W) typ.

Saturated output power @ 150 MHz / Pin = 0 dBm: 44.5 dBm (28.2 W) typ.

Saturated output power @ 200 MHz / Pin = 0 dBm: 43.8 dBm (24 W) typ.

Saturated output power @ 230 MHz / Pin = 0 dBm: 44.9 dBm (30.9 W) typ.

Saturated output power @ 250 MHz / Pin = 0 dBm: 44.8 dBm (30.2 W) typ.

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1dB output compression point @ 100 kHz: +43.7 dBm typ. (Pin: -5 dBm)

1dB output compression point @ 150 kHz: +44.1 dBm typ. (Pin: -4 dBm)

1dB output compression point @ 500 kHz: +44.6 dBm typ. (Pin: -3 dBm)

1dB output compression point @ 1 MHz: +45 dBm typ. (Pin: -3 dBm)

1dB output compression point @ 10 MHz: +45 dBm typ. (Pin: -2 dBm)

1dB output compression point @ 50 MHz: +45.6 dBm typ. (Pin: 1 dBm)

1dB output compression point @ 80 MHz: +46.5 dBm typ. (Pin: 1 dBm)

1dB output compression point @ 100 MHz: +46.5 dBm typ. (Pin: 0 dBm)

1dB output compression point @ 150 MHz: +42.9 dBm typ. (Pin: -4 dBm)

1dB output compression point @ 200 MHz: +42.2 dBm typ. (Pin: -4 dBm)

1dB output compression point @ 230 MHz: +44.1 dBm typ. (Pin: -3 dBm)

1dB output compression point @ 250 MHz: +43 dBm typ. (Pin: -4 dBm)

2<sup>nd</sup> harmonic, 100 MHz, Pout=46dBm: < - 12 dBc typ.

2<sup>nd</sup> harmonic, 100 MHz, Pout=40dBm: < - 15 dBc typ.

3<sup>rd</sup> harmonic, 100 MHz, Pout=46dBm: < - 22 dBc typ.

3<sup>rd</sup> harmonic, 100 MHz, Pout=40dBm: < - 22 dBc typ.

Total harmonic distortion:

17.7% @100MHz, Pout=37dBm typ.

19.6% @100 MHz, Pout=40 dBm typ.

22.1% @100 MHz, Pout=43 dBm typ.

26.9% @100 MHz, Pout=46 dBm typ.

Third order output intercept point: +51 dBm, @100 MHz,  $\Delta f = 2\text{MHz}$ , typ.

Internal modulation frequency AM: 1 kHz  $\pm 20\%$

Internal modulation frequencies PM: 1 kHz  $\pm 20\%$ , 217 Hz  $\pm 20\%$

Duty cycle, PM: 50%  $\pm 10\%$  @ 1 kHz; 12.5%  $\pm 20\%$  @ 217 Hz

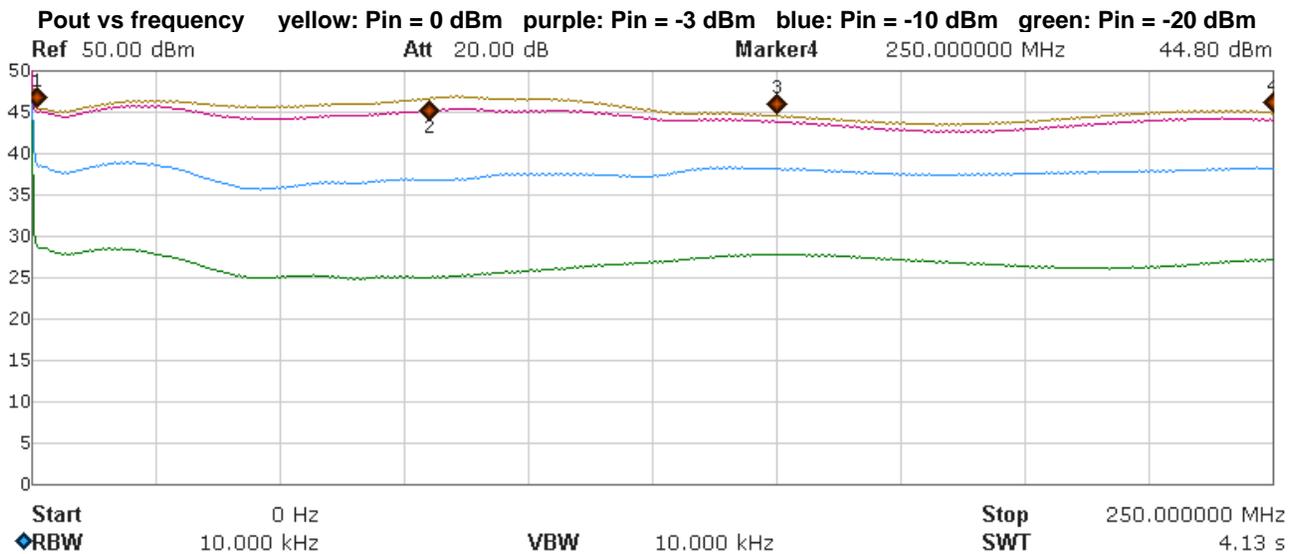
### Maximum ratings:

Maximum input power: +3 dBm

The output of the TBMDA-CDN25 is quite tolerant to output mismatch, however open or shorted load is not recommended, as it potentially can cause damage to the output transistor. When driving near field probes, current probes or any load of unknown impedance, it is highly recommended to insert a  $\geq 3\text{dB}$  attenuator at the output of the amplifier in order to protect the output stage.

## Modulated Wideband Power Amplifier

### Gain flatness:



### Marker Table

Marker	Trace	Readout	X Axis	Ampt
Marker1	A	Frequency	1.000000 MHz	45.29 dBm
Marker2	A	Frequency	80.000000 MHz	46.56 dBm
Marker3	A	Frequency	150.000000 MHz	44.45 dBm
Marker4	A	Frequency	250.000000 MHz	44.80 dBm

### Small Signal Performance (@ Pin = -10 dBm):

Frequency [MHz]	0.1	0.15	0.5	1	10	50	80	100	150	200	230	250
Output power [dBm]	39.44	39.19	38.66	38.46	38.00	35.79	36.75	37.44	38.05	37.49	37.84	38.07
Gain [dB]	49.44	49.19	48.66	48.46	48.00	45.79	46.75	47.44	48.05	47.49	47.84	48.07

Table 1 – TBMDA-CDN25 small signal gain, typ.

### 1 dB compression point:

Frequency [MHz]	0.1	0.15	0.5	1	10	50	80	100	150	200	230	250
Output power [dBm]	43.36	44.06	44.57	44.98	45.04	45.62	46.54	46.46	42.86	42.23	44.01	43.02
Pin [dBm]	-5	-4	-3	-3	-2	1	1	0	-4	-4	-3	-4

Table 2 – TBMDA-CDN25, 1 dB compression point versus frequency, typ.

### Saturation (@ Pin = 0 dBm):

Frequency [MHz]	0.1	0.15	0.5	1	10	50	80	100	150	200	230	250
Output power [dBm]	44.12	44.62	45.07	45.29	45.34	45.56	46.56	46.46	44.45	43.76	44.93	44.80
Gain [dB]	44.12	44.62	45.07	45.29	45.34	45.56	46.56	46.46	44.45	43.76	44.93	44.80

Table 3 – TBMDA-CDN25, Saturation versus frequency, typ.

# Modulated Wideband Power Amplifier

## Modulation:

Zero span, 10 ms sweep time, peak detector

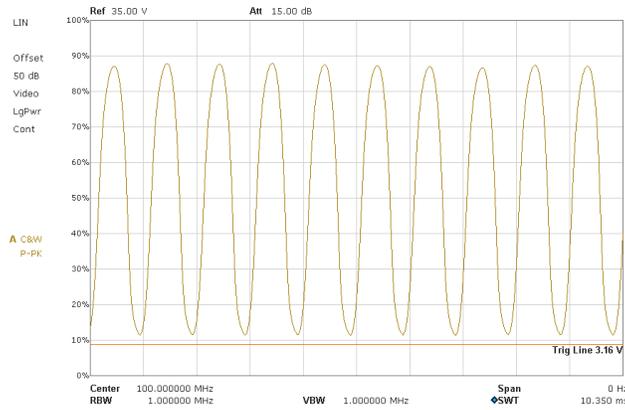


Figure 1 – 1 kHz, 80 % AM, envelope, 100 MHz, Pout = 44 dBm peak;

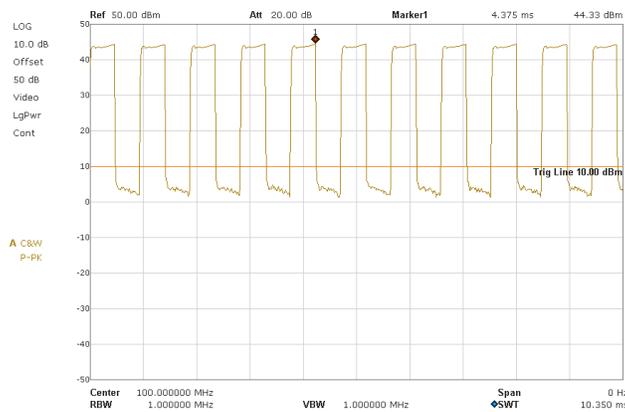


Figure 2 – 1 kHz, 50 % PM envelope, 100 MHz, Pout = 44 dBm peak

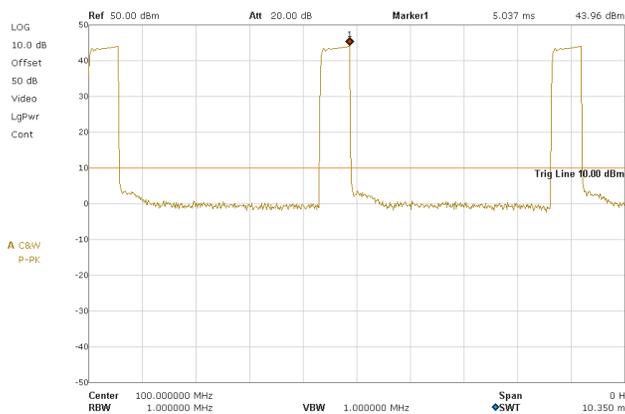


Figure 3 – 217 Hz, 12.5 % PM envelope, 100 MHz, Pout = 44 dBm peak

## Modulated Wideband Power Amplifier

### 3 Applications - radiated immunity

#### Immunity testing using a TEM cell

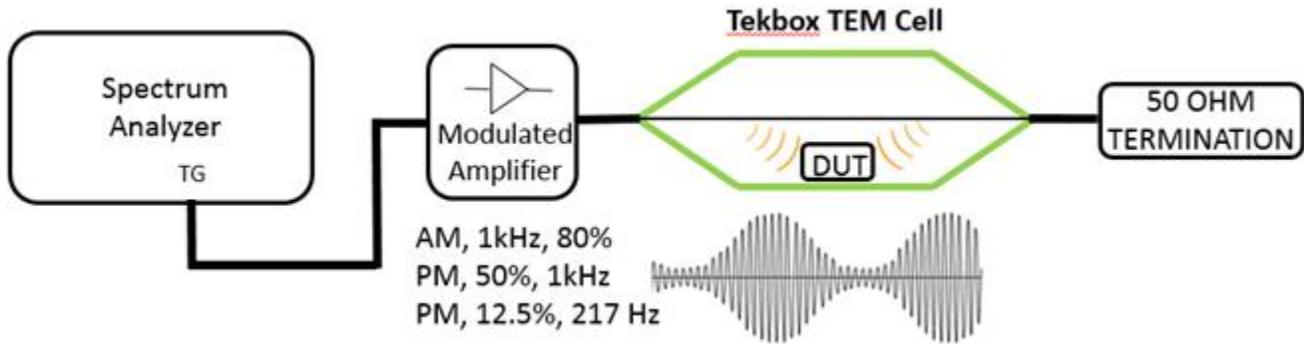


Figure 4 – immunity testing set up

#### Immunity testing using near field probes

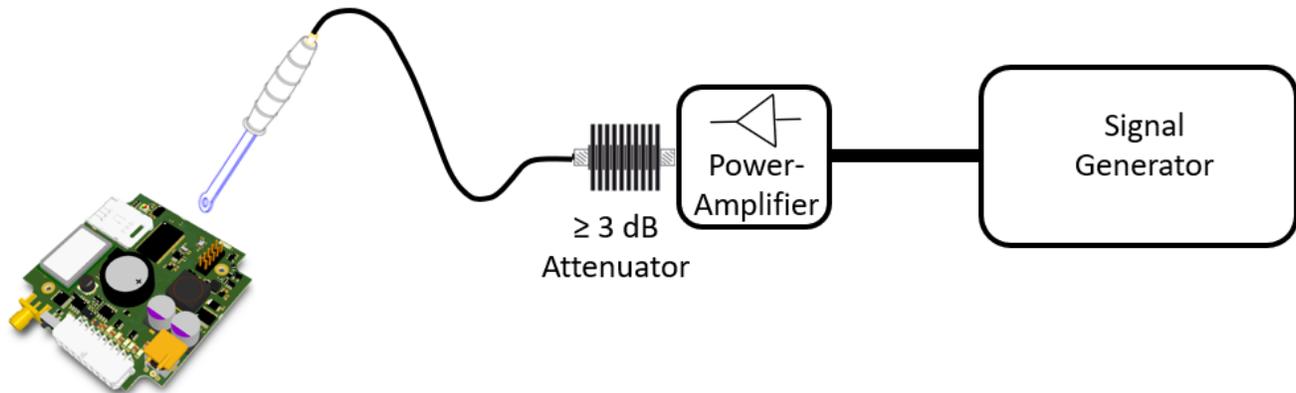


Figure 5 – immunity testing set up to locate susceptible areas on PCBAs

Radiated immunity EMC pre-compliance is typically a 2-step procedure. First, a TEM cell is used to investigate for immunity issues of the DUT. In case of any failure, near-field probes will be used to locate the sensitive circuitry on the PCBA.

## Modulated Wideband Power Amplifier

### TEM Cell field strength

A typical pre-compliance set up for immunity testing is typically not equipped with an E-field probe to measure the real field strength inside the TEM cell. However, the field strength can be calculated with sufficient accuracy for EMC pre-compliance set-ups.

The E-field (V/m) between septum and lower (upper) wall of a TEM cell is  $E = V/d$  where V is the RMS voltage of the applied signal and d is the distance between septum and lower (upper) wall. This is based on the simplified assumption that the E field would be perfectly homogenous/evenly distributed. A more practical formula is  $E = V*Cor/d$  where Cor is a correction factor for the average field strength over the volume of the DUT derived from the analysis of the field distribution over the cross section of the cell.

Assuming the DUT is placed in the center of the cell and in the middle between bottom wall and septum, we can use the simplified formula with sufficient accuracy.

$$TBTC0: d = 2.8 \text{ cm} \rightarrow E_{[V/m]} = (\sqrt{P*50\Omega}) * 35.7$$

$$TBTC1: d = 5 \text{ cm} \rightarrow E_{[V/m]} = (\sqrt{P*50\Omega}) * 20$$

$$TBTC2: d = 10 \text{ cm} \rightarrow E_{[V/m]} = (\sqrt{P*50\Omega}) * 10$$

$$TBTC3: d = 15 \text{ cm} \rightarrow E_{[V/m]} = (\sqrt{P*50\Omega}) * 6.66$$

The power P in the formulas above has to be entered in [Watt]

$$P_{[W]} = 0.001 * (10^{(P_{[dBm]}/10)})$$

Frequency [MHz]	Input power [dBm]	Output power [dBm]	Field strength TBTC0 [V/m]	Field strength TBTC1 [V/m]	Field strength TBTC2 [V/m]	Field strength TBTC3 [V/m]
0.1	-3	43.86	1245	697	349	232
0.15	-3	44.32	1313	735	368	245
0.5	-3	44.57	1351	757	378	252
1	-3	44.98	1416	793	397	264
10	-3	44.76	1381	774	387	258
50	-3	44.13	1284	719	360	240
80	-3	45.07	1431	802	401	267
100	-3	45.01	1421	796	398	265
150	-3	43.77	1232	690	345	230
200	-3	42.86	1110	622	311	207
230	-3	44.01	1267	710	355	236
250	-3	43.92	1254	702	351	234

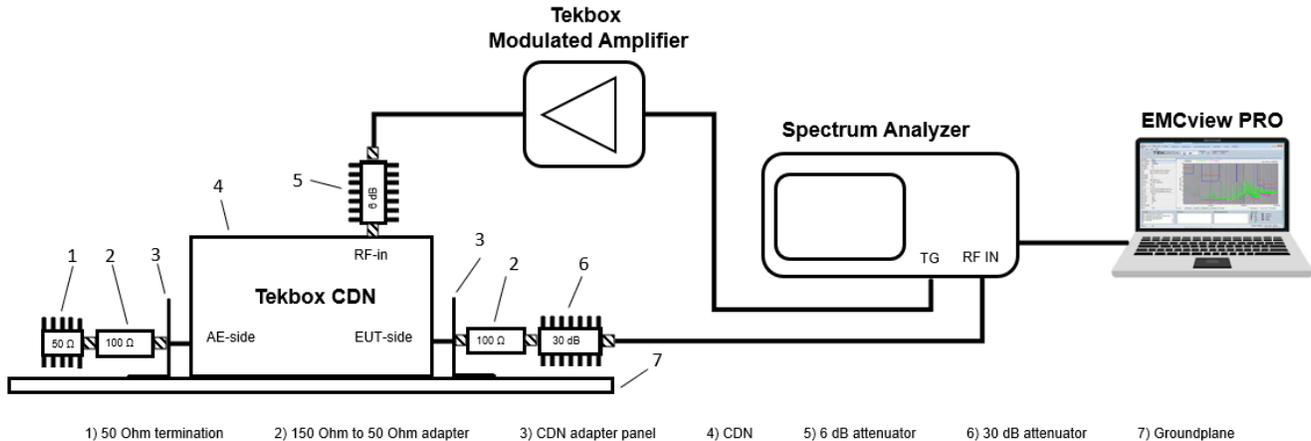
Table 4 – calculated field strength for the TBMDA-CDN25 driving Tekbox TEM cells

The above output power is the RMS output power in case of a CW signal. Note that in case of 80% AM modulation, the RMS power of the modulated signal will be 5.1 dB lower than the RMS power of the CW signal.

## Modulated Wideband Power Amplifier

### 4 Applications - conducted immunity, using CDNs

#### EN 61000-4-6 calibration set up using EMCview PRO



- Test Level 1:        1V RMS, 1 kHz / 80% AM modulated
- Test Level 2:        3V RMS, 1 kHz / 80% AM modulated
- Test Level 3:        10V RMS, 1 kHz / 80% AM modulated
- Test Level X:        special (unspecified)

The specified test levels are open circuit voltages at the EUT port of the CDN.

The voltages measured during calibration must be multiplied by 3 to allow for the 50 Ohm to 150 Ohm conversion and again by 2 to reach the open circuit voltage.

Hence, the measured voltage at the output of the 150 Ohm to 50 Ohm adapter is 1/6<sup>th</sup> the voltage of the desired stress level. In logarithmic figures, the measured voltage is 15.5 dB lower than the open circuit voltage.

Example: Test level 3

$U_0 = 10V$  RMS open circuit voltage at the EUT port of the CDN =  $10V/6 = 1.667V$  RMS at the output of the 100 Ohm to 50 Ohm adapter.

The required power at the output of the modulated amplifier is:

$U_0/6$  [dBm] + CDN insertion loss + 6 dB (Attenuator) + 5.1 dB (80% AM RMS)

Assuming 10 dB insertion loss for the CDN, the required RF power is:

$17.4 \text{ dBm} + 10 \text{ dB} + 6 \text{ dB} + 5.1 \text{ dB} = 38.5 \text{ dBm} = 7.08 \text{ Watt}$

During calibration, EMCview Pro will make a stepped sweep, for each frequency adjusting the tracking generator level in order to achieve  $17.4 \text{ dBm} + 5.1 \text{ dB} - 30 \text{ dB} = -7.5 \text{ dBm}$  at the spectrum analyzer input. The tracking generator level table will then be used to set levels during the actual immunity test.

## Modulated Wideband Power Amplifier

The typical insertion loss of a CDN with attached 150 Ohm to 50 Ohm adapter is 10 dB.

Adding the 6 dB attenuator and 5.1 dB for the AM RMS conversion results in a quasi-insertion loss of 10 dB + 6 dB + 5.1 dB = 21.1 dB.

For open circuit voltages of 1V, 3V and 10V, the corresponding power at the output of the 150 Ohm to 50 Ohm adapter is -2.6 dBm, 7 dBm, 17.4 dBm RMS CW. Add 5.1 dB to cover the RMS power of 80% AM modulation.

Consequently, the required power at the input of the 6 dB attenuator for class 1/2/3 is 18.5 dBm / 28.1 dBm / 38.5 dBm.

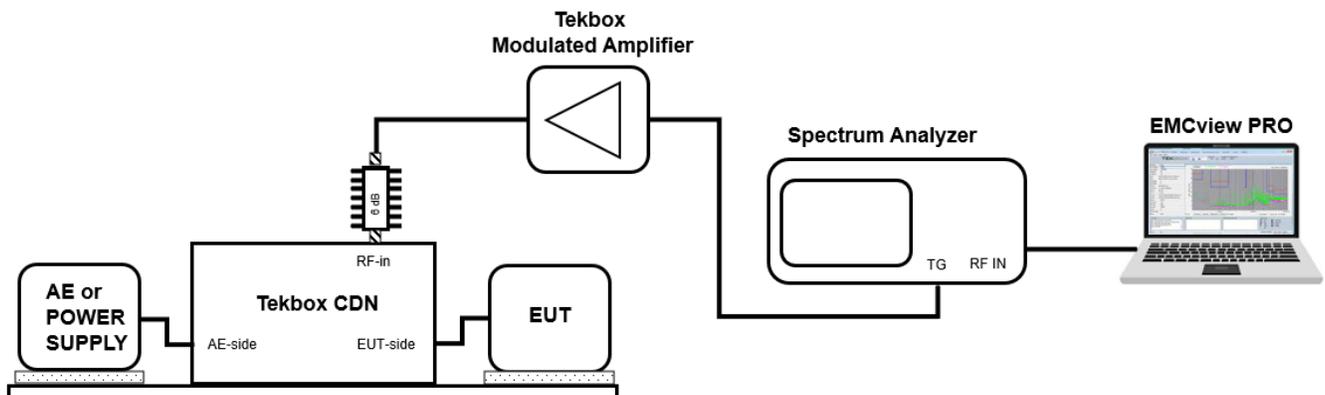
The table below reflects the insertion loss versus frequency of a real CDN in order to set the required input power for the TBMDA-CDN25.

Frequency [MHz]	TBMDA-CDN25 output power to achieve stress level 1 [dBm]	Corresponding TBMDA-CDN25 input power [dBm]	TBMDA-CDN25 output power to achieve stress level 2 [dBm]	Corresponding TBMDA-CDN25 input power [dBm]	TBMDA-CDN25 output power to achieve stress level 3 [dBm]	Corresponding TBMDA-CDN25 input power [dBm]
0.15	17.2	-32 dBm	27.2	-22 dBm	37.2	-12 dBm
0.5	16.7	-32 dBm	26.7	-22 dBm	36.7	-12 dBm
1	17.5	-31 dBm	27.5	-21 dBm	37.5	-11 dBm
10	18	-30 dBm	28	-20 dBm	38	-10 dBm
100	18.9	-27 dBm	28.9	-17 dBm	38.4	-9 dBm
230	19.8	-27 dBm	29.8	-17 dBm	39.8	-9 dBm

Table 4 - measured input power settings for the TBMDA-CDN25 in order to achieve stress level 1, 2 and 3

EMCview PRO has the capability to automatically adjust the tracking generator level in order to achieve the desired stress level voltage. The output is a calibration table, which is loaded and applied during the immunity test.

### EN 61000-4-6 immunity test set up using EMCview PRO

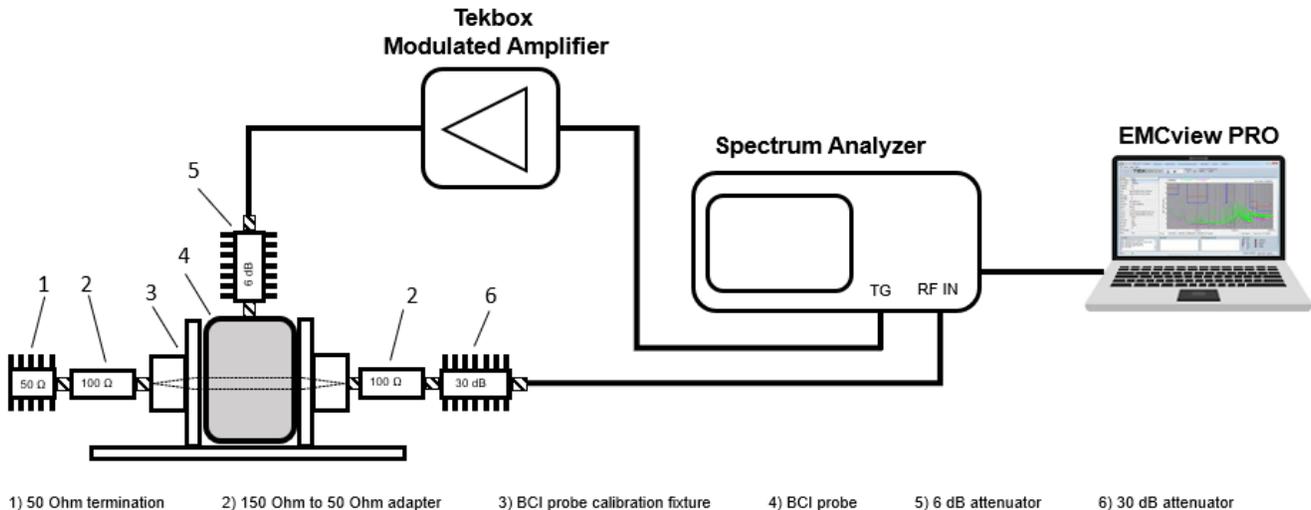


## Modulated Wideband Power Amplifier

### 5 Applications - conducted immunity, using BCI probes

EN 61000-4-6 specifies stress levels in terms of voltage and calibrates the immunity set up using a 300 Ohm loop. Other standards specify stress levels in terms of injected current.

#### EN 61000-4-6 300 Ohm loop BCI calibration set up using EMCview PRO



- Test Level 1:        1V RMS, 1 kHz / 80% AM modulated
- Test Level 2:        3V RMS, 1 kHz / 80% AM modulated
- Test Level 3:        10V RMS, 1 kHz / 80% AM modulated
- Test Level X:        special (unspecified)

The specified test levels are open circuit voltages at the output of the calibration fixture.

The voltages measured during calibration must be multiplied by 3 to allow for the 50 Ohm to 150 Ohm conversion and again by 2 to reach the open circuit voltage.

Hence, the measured voltage at the output of the 150 Ohm to 50 Ohm adapter is 1/6<sup>th</sup> the voltage of the desired stress level. In logarithmic figures, the measured voltage is 15.5 dB lower than the open circuit voltage.

Example: Test level 3  $U_0 = 10V$  RMS open circuit voltage at the output of the calibration fixture =  $10V/6 = 1.667V$  RMS at the output of the 100 Ohm to 50 Ohm adapter.

The required power at the output of the modulated amplifier is:

$$U_0/6 \text{ [dBm]} + \text{BCI probe insertion loss} + 6 \text{ dB (Attenuator)} + 5.1 \text{ dB (80\% AM RMS)}$$

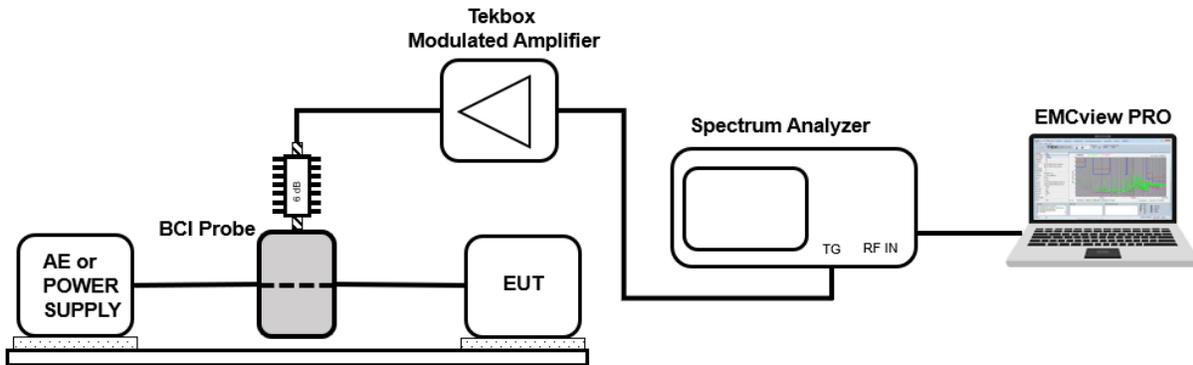
Assuming 16 dB insertion loss for the BCI probe in a 300 Ohm loop, the required RF power is:

$$17.4 \text{ dBm} + 16 \text{ dB} + 6 \text{ dB} + 5.1 \text{ dB} = 44.5 \text{ dBm} = 28.2 \text{ Watt}$$

During calibration, EMCview Pro will make a stepped sweep, for each frequency adjusting the tracking generator level in order to achieve 17.4 dBm -30 dB = -12.6 dBm at the spectrum analyzer input. The tracking generator level table will then be used to set levels during the actual immunity test.

## Modulated Wideband Power Amplifier

### EN 61000-4-6 immunity test set up using a BCI probe and EMCview PRO



## 6 PC Software for immunity testing

Tekbox provides two software versions for EMC pre-compliance measurements

EMCview provides a feature to control the tracking generator output frequency and level and carry out sweeps with constant tracking generator level.

EMCview PRO provides a more sophisticated feature, which is able to carry out calibration sweeps for CDN and BCI based set ups. The resulting calibration file is used to set the tracking generator level during the immunity test sweep.

Tekbox EMCview currently supports Rigol, Siglent, Owon, R&S FPC and FPH series spectrum analyzers.

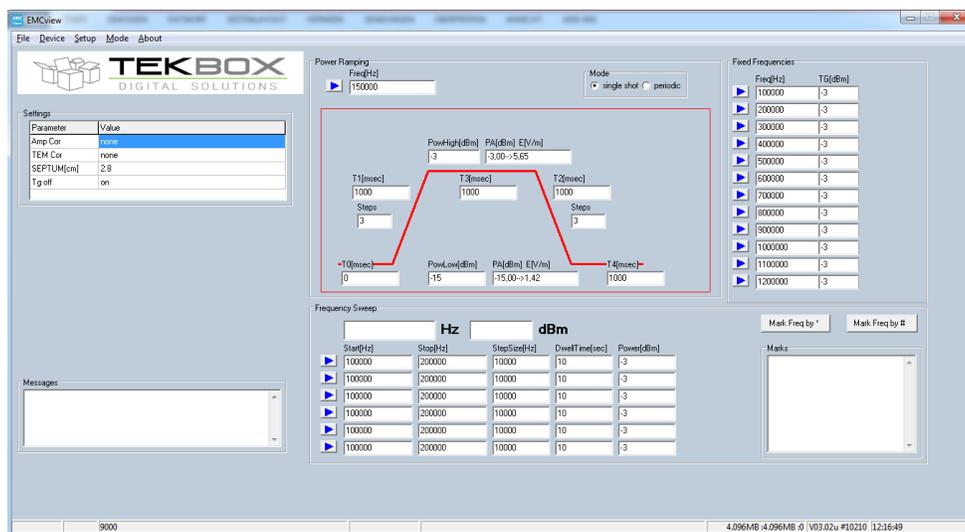
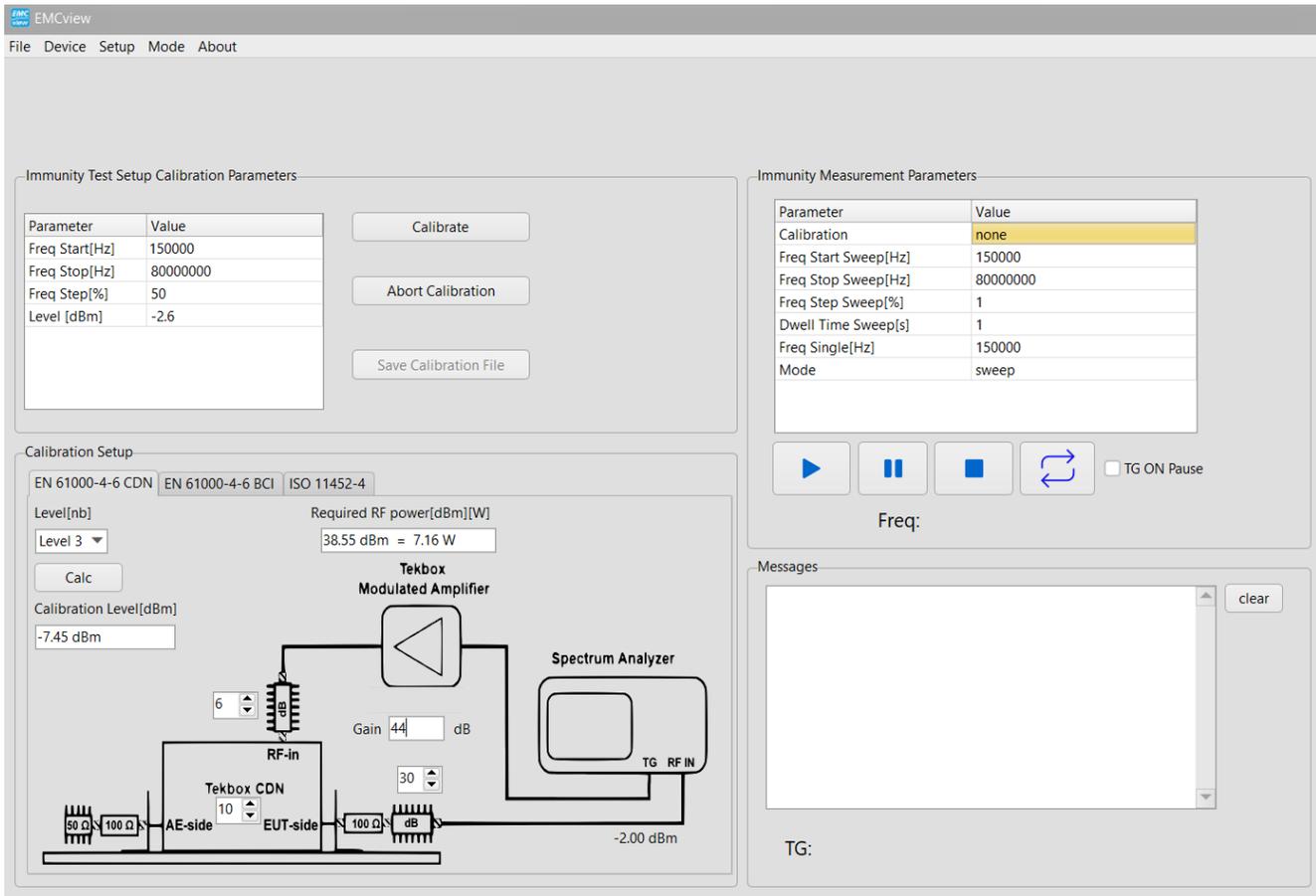


Figure 11 – screenshot of the tracking generator control feature of EMCview / EMCview Pro

## Modulated Wideband Power Amplifier



The screenshot displays the EMCview Pro software interface for configuring an immunity test. It is divided into several sections:

- Immunity Test Setup Calibration Parameters:** A table with columns for Parameter and Value.
 

Parameter	Value
Freq Start[Hz]	150000
Freq Stop[Hz]	80000000
Freq Step[%]	50
Level [dBm]	-2.6

 Below the table are buttons for 'Calibrate', 'Abort Calibration', and 'Save Calibration File'.
- Immunity Measurement Parameters:** A table with columns for Parameter and Value.
 

Parameter	Value
Calibration	none
Freq Start Sweep[Hz]	150000
Freq Stop Sweep[Hz]	80000000
Freq Step Sweep[%]	1
Dwell Time Sweep[s]	1
Freq Single[Hz]	150000
Mode	sweep

 Below the table are control buttons: a play button, a pause button, a stop button, a refresh button, and a 'TG ON Pause' checkbox.
- Calibration Setup:** Includes standard compliance options (EN 61000-4-6 CDN, EN 61000-4-6 BCI, ISO 11452-4), a 'Level[nb]' dropdown set to 'Level 3', and a 'Calc' button. It shows 'Required RF power[dBm][W]' as '38.55 dBm = 7.16 W'. The 'Calibration Level[dBm]' is set to '-7.45 dBm'.
- Block Diagram:** Shows the physical test setup. A 'Tekbox Modulated Amplifier' is connected to a 'Spectrum Analyzer'. The amplifier's output is connected to the 'RF IN' of the spectrum analyzer through a '30 dB' attenuator. The amplifier's gain is set to '44 dB'. The spectrum analyzer's 'TG' (Test Generator) output is connected to the 'RF IN' of the amplifier through a '100 Ω' attenuator. The 'TG' output level is set to '-2.00 dBm'. A 'Tekbox CDN' is connected to the amplifier's 'RF-in' port, with 'AE-side' and 'EUT-side' connections. The CDN has a '50 Ω' and '100 Ω' port.
- Messages:** A text area for displaying test messages, with a 'clear' button.

Figure 12 – screenshot of the immunity test feature of EMCview Pro

### WARNING:

Never connect the output of the TBMDA-CDN25 directly to the input of a spectrum analyzer. Check the maximum input ratings of the spectrum analyzer and protect it with an appropriate attenuator.

Open or shorted load is not recommended, potentially can cause damage of the RF output stage. Use a  $\geq 3$  dB attenuator at the amplifier output, when driving loads with poor SWR.

### Example:

Rigol DSA815 – maximum input power rating: +20dBm

## Modulated Wideband Power Amplifier

### 7 Ordering Information

Part Number	Description
TBMDA-CDN25-EU	modulated power amplifier, 2 pcs 75cm N-male to N-male cables, 1 pc 6 dB attenuator, 1 pc 30dB / 50W attenuator with N-connectors, C13 Schuko power cord
TBMDA-CDN25-US	modulated power amplifier, 2 pcs 75cm N-male to N-male cables, 1 pc 6 dB attenuator, 1 pc 30dB / 50W attenuator with N-connectors, C13 US power cord
TBMDA-CDN25-UK	modulated power amplifier, 2 pcs 75cm N-male to N-male cables, 1 pc 6 dB attenuator, 1 pc 30dB / 50W attenuator with N-connectors, C13 English power cord
TBMDA-CDN25-AU	modulated power amplifier, 2 pcs 75cm N-male to N-male cables, 1 pc 6 dB attenuator, 1 pc 30dB / 50W attenuator with N-connectors, C13 Australian power cord

Table 5 – Ordering Information

### 8 History

Version	Date	Author	Changes
V1.0	13.12.2022	Mayerhofer	Creation of the document

Table 6 – History

www.tekbox.com

**TekBox Digital Solutions Vietnam Pte. Ltd.**

Factory 4, F5, Lot I-3B-1, Saigon Hi-Tech Park, Tan Phu Ward, District 9, Ho Chi Minh City, Vietnam