Modulated Wideband Driver Amplifier

1 Introduction

The TBMDA1 modulated wideband driver amplifier is designed in order to create an inexpensive signal source for immunity testing of electronic building blocks and products. It is designed to be driven by the tracking generator output of spectrum analyzers. With its gain of 22 dB and 1dB compression point of +22dBm, it can boost the output power of a tracking generator up to 150mW. The TBMDA1 is ideal to drive Tekbox near field probes in order to find the sensitive spot of an electronic circuit or to create electric fields up to 50V/m when driving the Tekbox TEM Cell TBTC1, 25V/m when driving the TBTC2 or 18V/m when driving the TBTC3. Test signals for immunity testing can be CW, AM or PM. Consequently, the TBMDA1 provides built in modulation capability to generate 1kHz AM or PM signals. In PM mode, the TBMDA1 can also generate a 217Hz Signal with 12.5% duty cycle in order to simulate mobile phone TDMA noise.

Picture 1 – TBMDA1 modulated wideband driver amplifier front view

Picture 2 – TBMDA1 modulated wideband driver amplifier rear view

Modulated Wideband Driver Amplifier

Application:

general purpose gain block

signal source for immunity testing, driving near field probes

signal source for 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

2 Electrical Specifications

Technical Data:

Input: 50 Ohm, SMA female

Output: 50 Ohm, SMA female

Nominal supply Voltage: 5V, typ. 235mA, Mini-USB-B connector

Maximum supply voltage: 5.5V

Maximum input power: +9dBm

1dB output compression point @ 40MHz: +21.5dBm

1dB output compression point @ 2 GHz: +22.5dBm

3rd order output intercept point @ 40 MHz: +39dBm

3rd order output intercept point @ 2 GHz: +42dBm

Reverse isolation S12: -45dB

Noise Figure: 3 … 4 dB

Internal modulation frequency AM: 1 kHz ±10%

Internal modulation frequencies PM: 1 kHz ±10%, 217 Hz ±20%

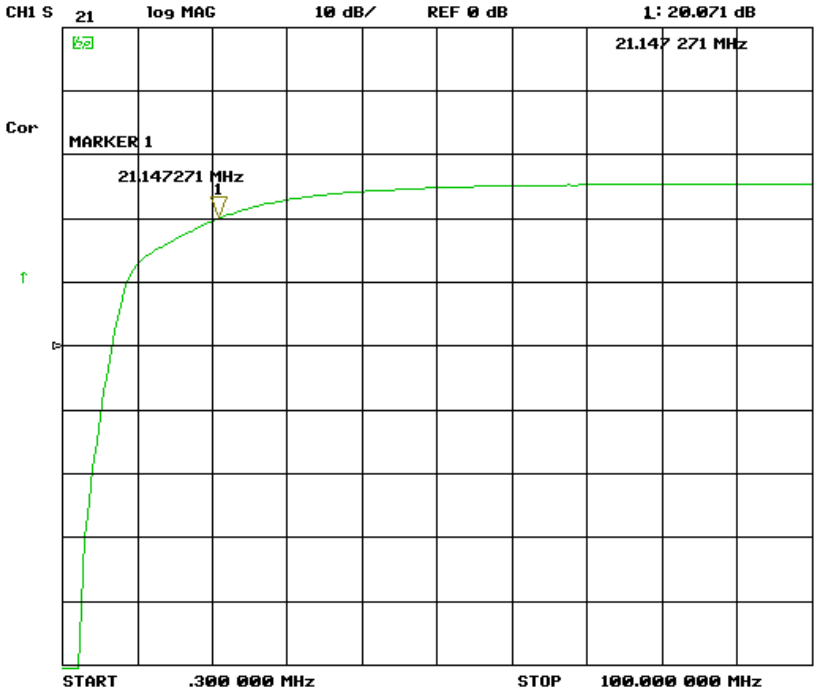
Duty cycle, PM: 50% ±10% @ 1 kHZ; 12.5% ±20% @ 217 Hz

Gain:

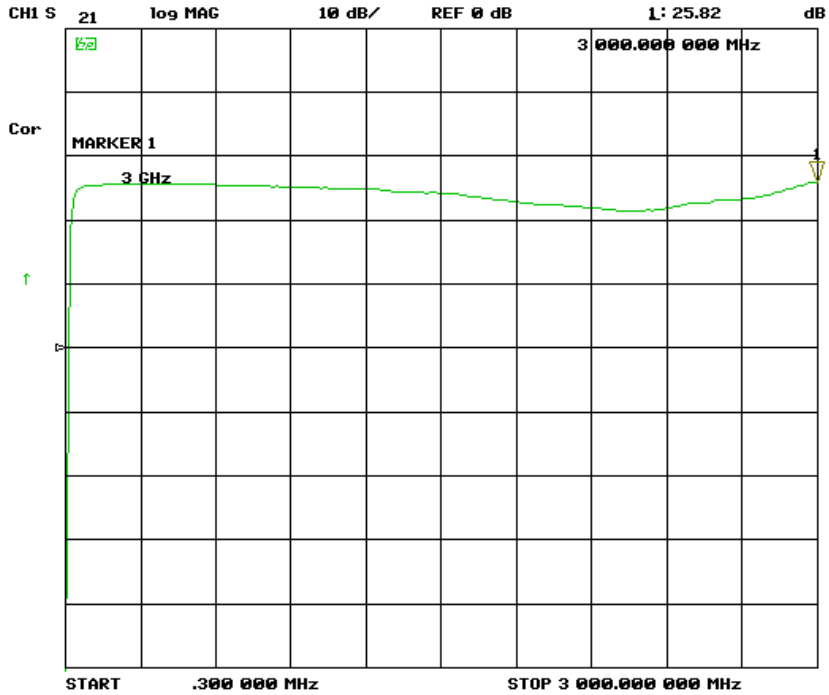
25 MHz	50 MHz	100 MHz	500 MHz	1 GHz	1.5 GHz	2 GHz	2.5 GHz	3 GHz
21.6 dB	24.9 dB	25.5 dB	25.6 dB	24.9 dB	24.1 dB	22.2 dB	22.8 dB	25.8 dB

Table 1 – TBMDA1 gain

Modulated Wideband Driver Amplifier



Picture 3 – TBMDA1, gain, 300 kHz – 100 MHz*, lin.*



Picture 4 – TBMDA1, gain, 300 kHz – 3 GHz, lin.

Modulated Wideband Driver Amplifier

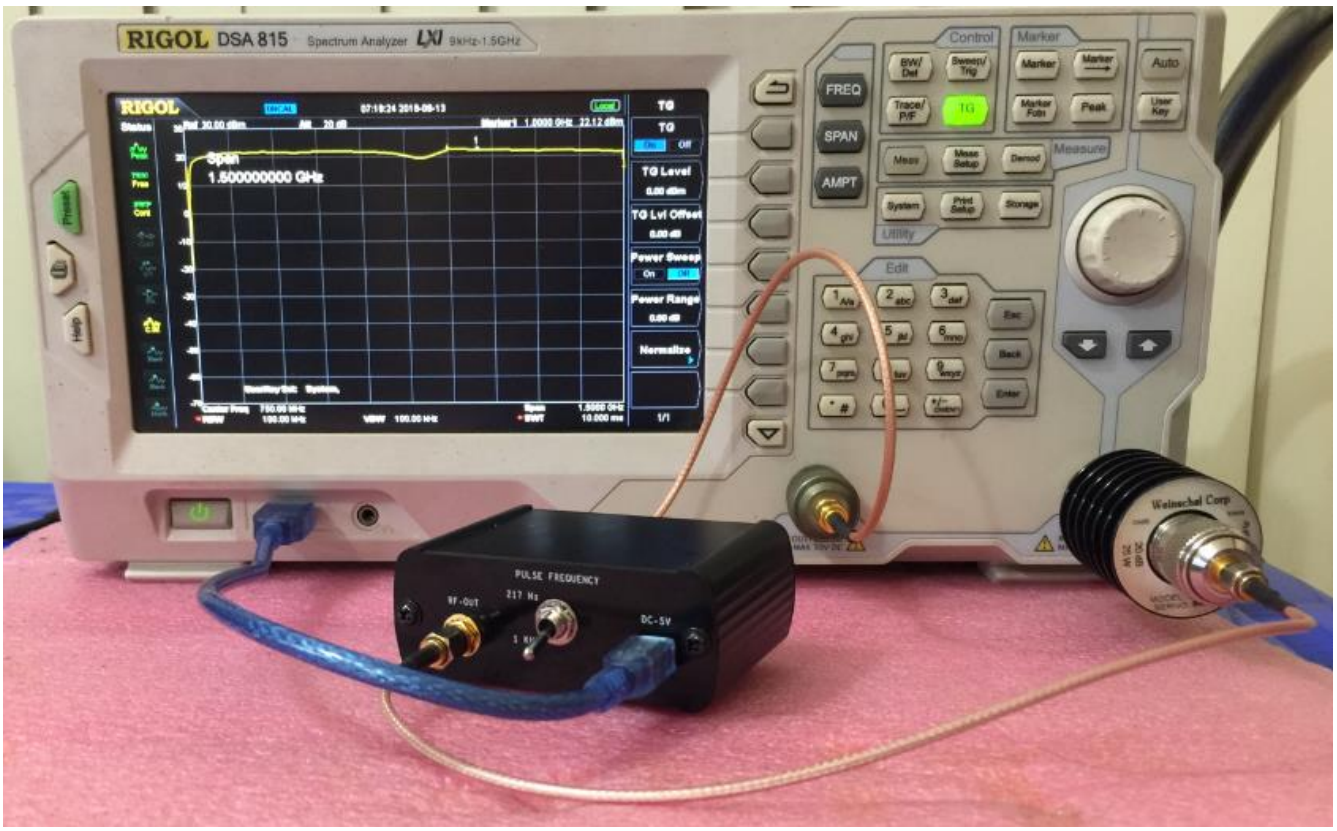
3 Driving the TBMDA1 with a tracking generator

WARNING:

Never connect the output of the TBMDA1 directly to the input of a spectrum analyzer. Check the maximum input ratings of the spectrum analyzer and protect it with an appropriate attenuator.

Example:

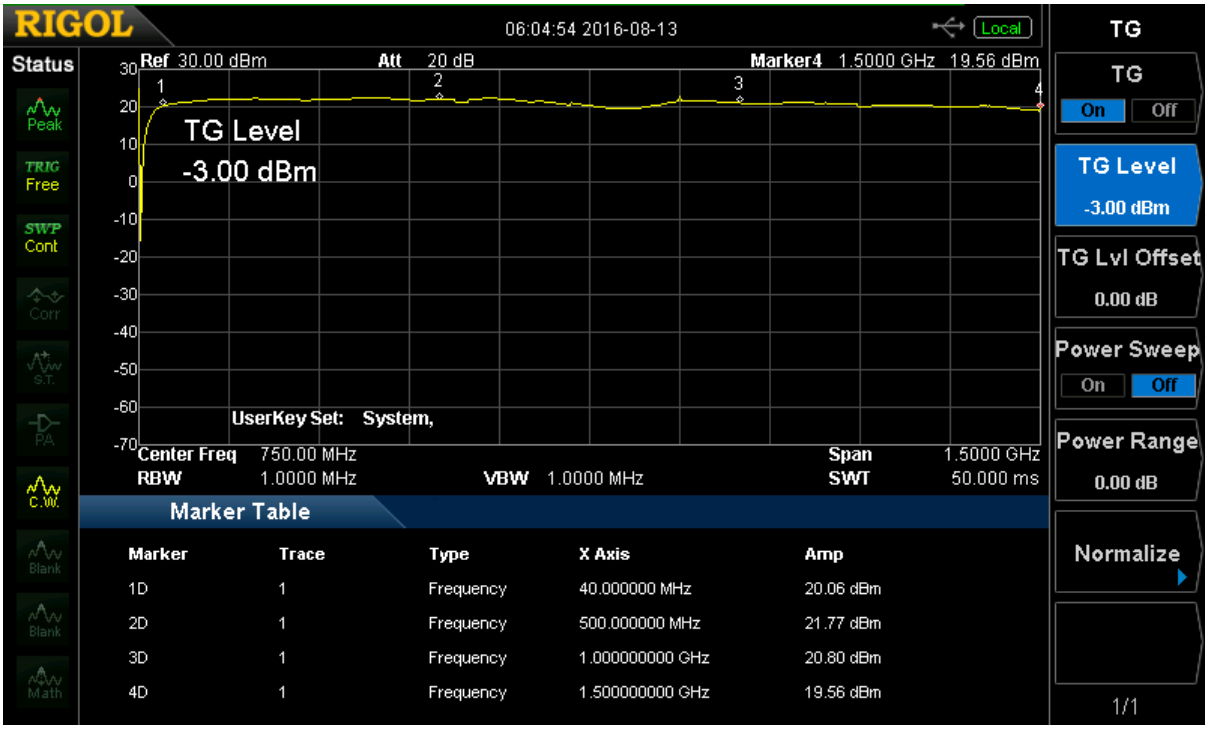
Rigol DSA815 – maximum input power rating: +20dBm



Picture 5 – DSA815 input protected with a 20dB attenuator

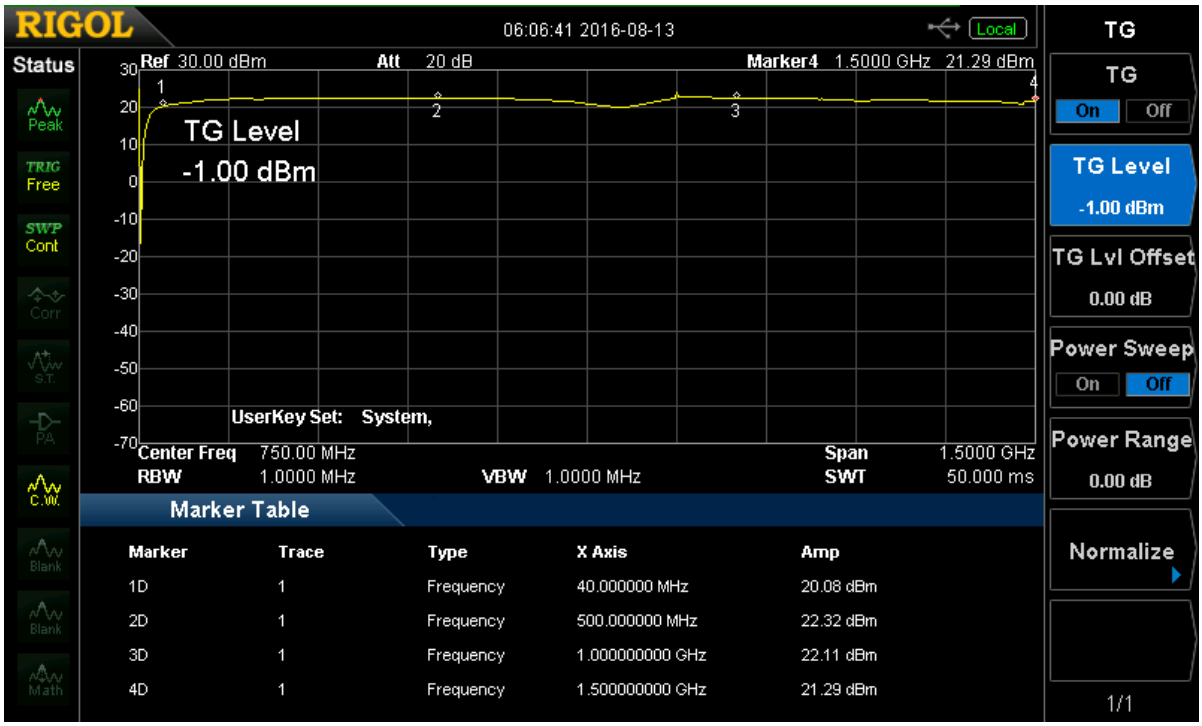
Modulated Wideband Driver Amplifier

Picture 6 – output power of the TBMDA1, CW, driven by the DSA815 tracking generator set to -5dBm

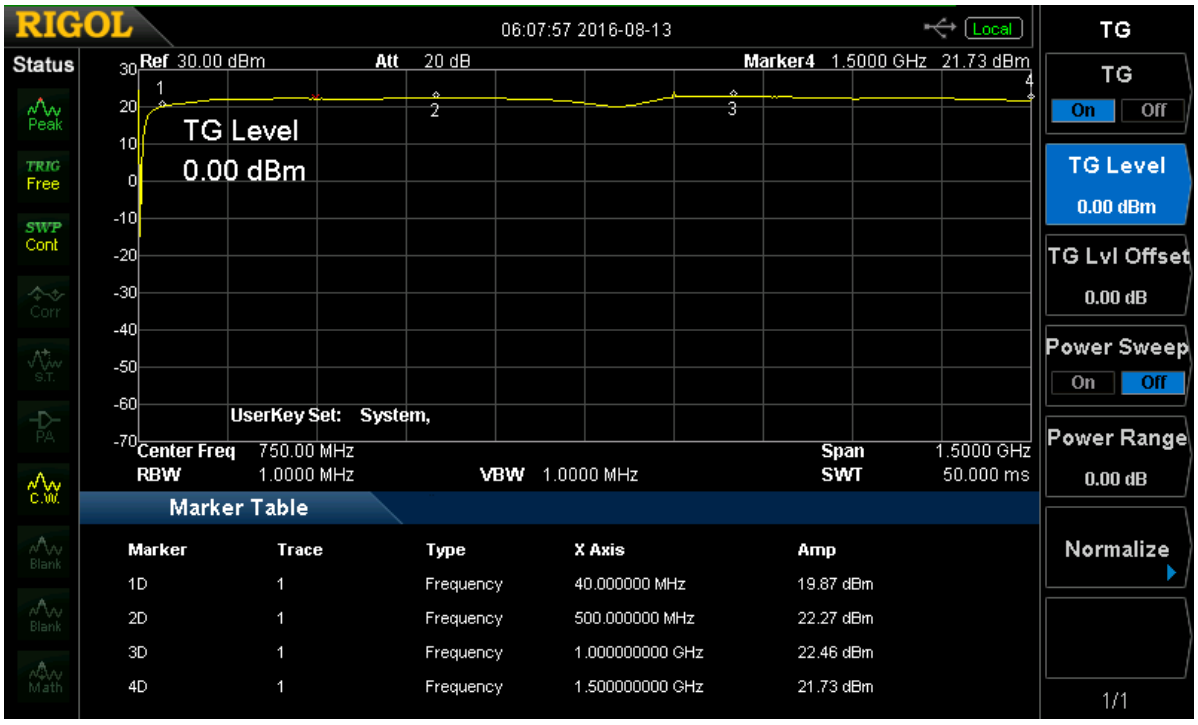


Modulated Wideband Driver Amplifier

Picture 7 – output power of the TBMDA1, CW, driven by the DSA815 tracking generator set to -3dBm

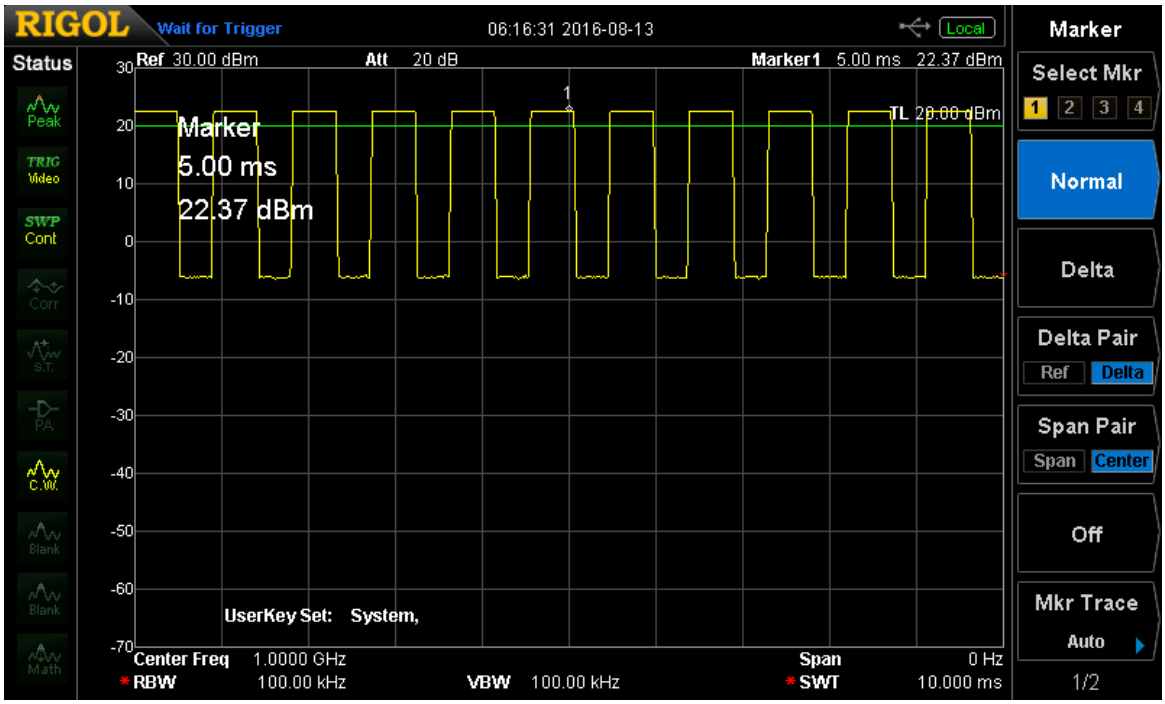


Picture 8 – output power of the TBMDA1, CW, driven by the DSA815 tracking generator set to -1dBm

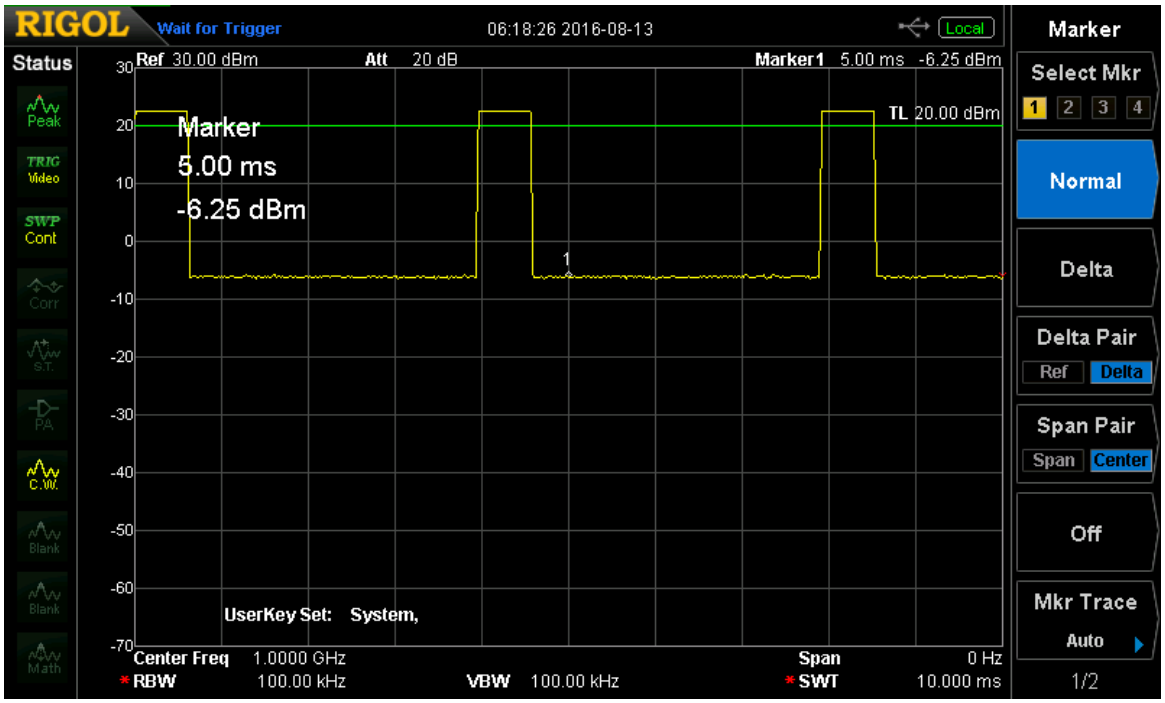


Modulated Wideband Driver Amplifier

Picture 9 – output power of the TBMDA1, CW, driven by the DSA815 tracking generator set to 0dBm

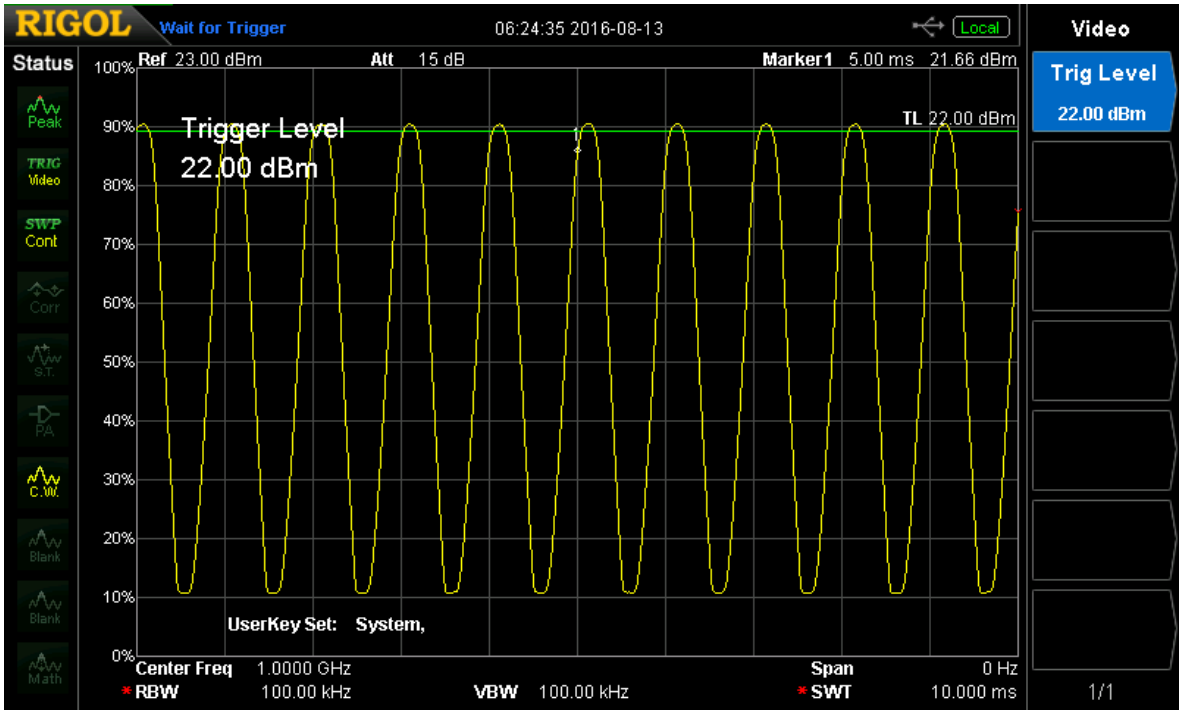


Picture 10 – output power of the TBMDA1, 1 kHz, 50% pulse modulation, driven by the DSA815 tracking generator set to 0dBm, zero span, 1GHz



Modulated Wideband Driver Amplifier

Picture 10 – output power of the TBMDA1, 217 Hz, 12.5% pulse modulation, driven by the DSA815 tracking generator set to 0dBm, zero span, 1GHz

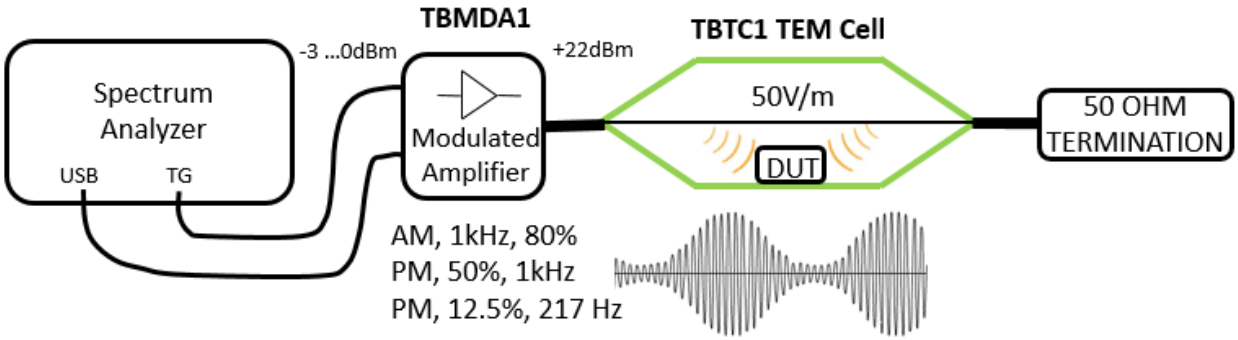


Picture 11 – output power of the TBMDA1, 1 kHz, 80% amplitude modulation, driven by the DSA815 tracking generator set to 0dBm, zero span, 1GHz

4 Applications

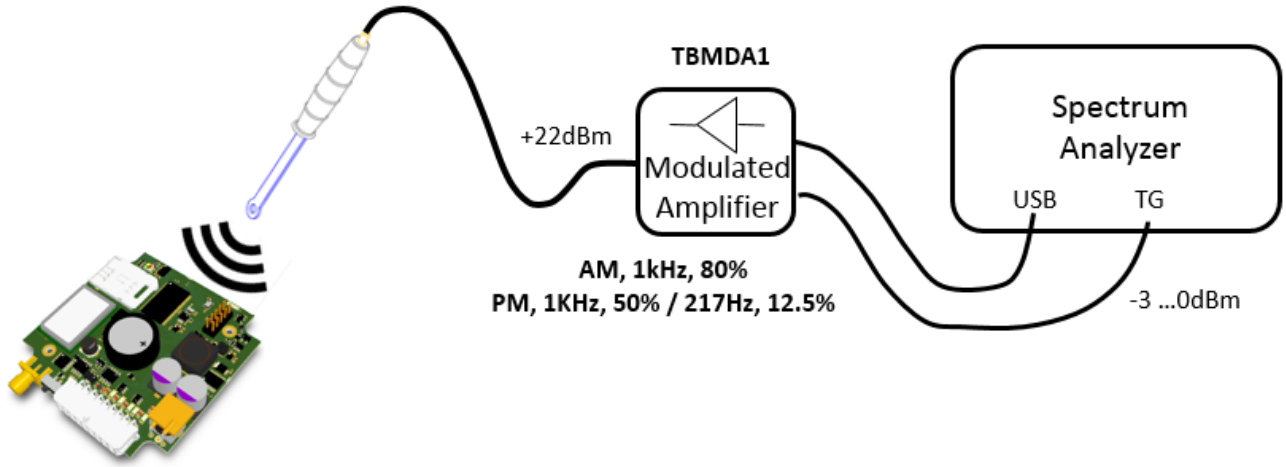
Immunity testing using a TEM cell

Modulated Wideband Driver Amplifier



Modulated Wideband Driver Amplifier

Immunity testing using near field probes



5 Ordering Information

Part Number	Description
TBMDA1	modulated driver amplifier, 1 pc 25cm SMA-male to SMA-male cable, 1 pc 75cm SMA-male to N-male cable. 1 pc SMA-female to N-male coaxial adapter, USB cable, measurement plot

Table 2 – Ordering Information

6 History

Version	Date	Author	Changes
V1.0	13.8.2016	Mayerhofer	Creation of the document
V1.1	16.8.2016	Mayerhofer	Chapter 2 updated
V1.2	10.9.2016	Mayerhofer	Frequency response updated
V1.3	14.11.2016	Mayerhofer	Chapter 5 updated, deliverables

Table 3 – History

Modulated Wideband Driver Amplifier

1 Introduction

The TBMDA2 modulated wideband driver amplifier is designed in order to create an inexpensive signal source for immunity testing of electronic building blocks and products. It is designed to be driven by the tracking generator output of spectrum analyzers. With its 1dB compression point of +27dBm, it can boost the output power of a tracking generator up to 500mW. The TBMDA2 is ideal to drive Tekbox near field probes in order to find the sensitive spot of an electronic circuit or to create electric fields up to 170V/m when driving the Tekbox TEM Cell TBTC0, 100V/m when driving the TBTC1, 50V/m when driving the TBTC2 or 30V/m when driving the TBTC3. Test signals for immunity testing can be CW, AM or PM. Consequently, the TBMDA2 provides built in modulation capability to generate 1 kHz AM or PM signals. In PM mode, the TBMDA2 can also generate a 217 Hz Signal with 12.5% duty cycle in order to simulate mobile phone TDMA noise.

Picture 1 – TBMDA2 modulated wideband driver amplifier, front view

Picture 2 – TBMDA2 modulated wideband driver amplifier, rear view

Modulated Wideband Driver Amplifier

Application:

General-purpose gain block

Signal source for immunity testing, driving near field probes

Signal source for 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

2 Electrical Specifications

Technical Data:

Input / Output: 50 Ohm, SMA female

Nominal supply Voltage: 5V, typ. 700mA, Mini-USB-B connector

Maximum supply voltage: 5.5V

Maximum input power: -8dBm continuous, 0 dBm @ 25°C for 5 minutes max.

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

Frequency range: 10MHz – 1.5 GHz

1dB output compression point @ 10MHz: +24 dBm typ.

1dB output compression point @ 100 MHz: +27 dBm typ.

1dB output compression point @ 1 GHz: +27 dBm typ.

1dB output compression point @ 1.5 GHz: +26.5 dBm typ.

Harmonics: < - 30 dBc typ.

Internal modulation frequency AM: 1 kHz ±10%

Internal modulation frequencies PM: 1 kHz ±10%, 217 Hz ±20%

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

Gain:

10 MHz	25 MHz	100 MHz	200 MHz	300 MHz	400 MHz	500 MHz	600 MHz	700 MHz
44.2 dB	46.3 dB	46.7 dB	46.6 dB	45.3 dB	44.2 dB	43.8 dB	42.9 dB	41.7 dB

800 MHz	900 MHz	1 GHz	1.1 GHz	1.2 GHz	1.3 GHz	1.4 GHz	1.5 GHz	
39.6 dB	40.1 dB	39.3 dB	38.5 dB	37.3 dB	36.8 dB	35.9 dB	34.8 dB	

Table 1 – TBMDA2 gain

Modulated Wideband Driver Amplifier

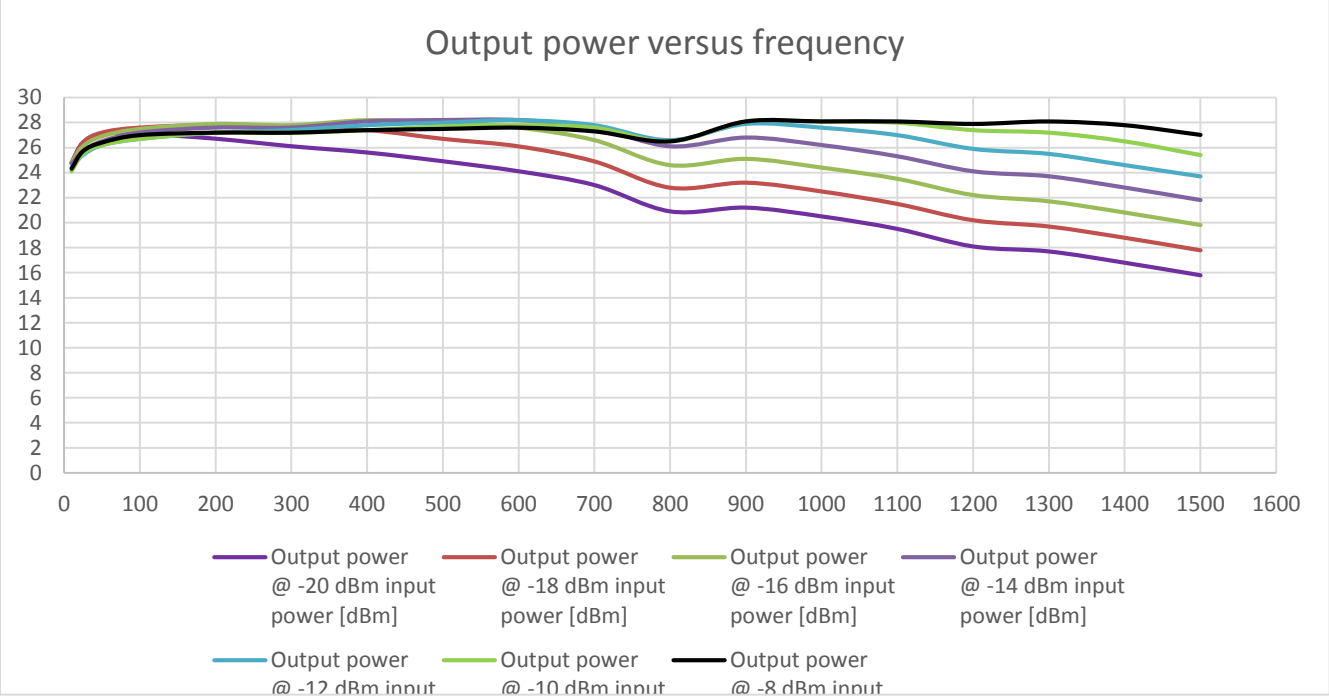


Figure 1 – TBMDA2, output power versus frequency, 10MHz – 1.5GHz

Frequency [MHz]	Output power @ -20 dBm input power [dBm]	Output power @ -18 dBm input power [dBm]	Output power @ -16 dBm input power [dBm]	Output power @ -14 dBm input power [dBm]	Output power @ -12 dBm input power [dBm]	Output power @ -10 dBm input power [dBm]	Output power @ -8 dBm input power [dBm]
10	24.8	24.8	24.8	24.7	24.4	24.1	24.3
25	26.4	26.4	26.1	25.7	25.4	25.5	25.7
50	27.1	27.2	26.9	26.5	26.2	26.2	26.4
100	27.1	27.6	27.5	27.2	26.7	26.7	27
200	26.7	27.8	27.9	27.6	27.2	27.2	27.2
300	26.1	27.5	27.8	27.6	27.4	27.2	27.2
400	25.6	27.4	28.2	28.1	27.8	27.4	27.4
500	24.9	26.7	28	28.2	28	27.7	27.5
600	24.1	26.1	27.6	28.2	28.2	27.8	27.6
700	23	24.9	26.6	27.6	27.8	27.6	27.3
800	20.9	22.8	24.6	26.1	26.6	26.5	26.5
900	21.2	23.2	25.1	26.8	27.9	28.1	28.1
1000	20.5	22.5	24.4	26.2	27.6	28.1	28.1
1100	19.5	21.5	23.5	25.3	27	28	28.1
1200	18.1	20.2	22.2	24.1	25.9	27.4	27.9
1300	17.7	19.7	21.7	23.7	25.5	27.2	28.1
1400	16.8	18.8	20.8	22.8	24.6	26.5	27.8
1500	15.8	17.8	19.8	21.8	23.7	25.4	27.02

Table 2 – TBMDA2 power table

Modulated Wideband Driver Amplifier

Frequency response:

The tables above show a 10dB gain variation across the frequency range 10 MHz to 1.5 GHz. When driving the TBMDA2 with the tracking generator of a spectrum analyzer, the TG level can be set to -8 …-12 dBm to get a flat output power response over the frequency range. This will drive the amplifier into compression for lower frequencies. This is acceptable when using CW or pulse modulation for immunity testing. However, when doing immunity tests with an AM modulated signal, it would clip the AM envelope, as the modulator is in front of the output stage of the TBMDA2.

Hence, when using AM modulation, the input power shall be set to levels where the TBMDA2 is in linear operation.

Linear operation:

You can calculate the drive levels for linear operation using following approximation formula or the table below:

P_{input} [dBm] = 0.008 *frequency [MHz]-20

Frequency [MHz]	Input power [dBm]	Output power [dBm]	gain [dB]
10	-19.92	24.3	44.22
25	-19.8	26.5	46.3
50	-19.6	27.1	46.7
100	-19.2	27.4	46.6
200	-18.4	27.6	46
300	-17.6	27.7	45.3
400	-16.8	27.4	44.2
500	-16	27.8	43.8
600	-15.2	27.7	42.9
700	-14.4	27.3	41.7
800	-13.6	26	39.6
900	-12.8	27.3	40.1
1000	-12	27.3	39.3
1100	-11.2	27.3	38.5
1200	-10.4	26.9	37.3
1300	-9.6	27.2	36.8
1400	-8.8	27.1	35.9
1500	-8	26.8	34.8

Table 3 – input drive levels for linear operation

As tracking generator levels usually can only be adjusted in 1dB steps, apply the closest integer value.

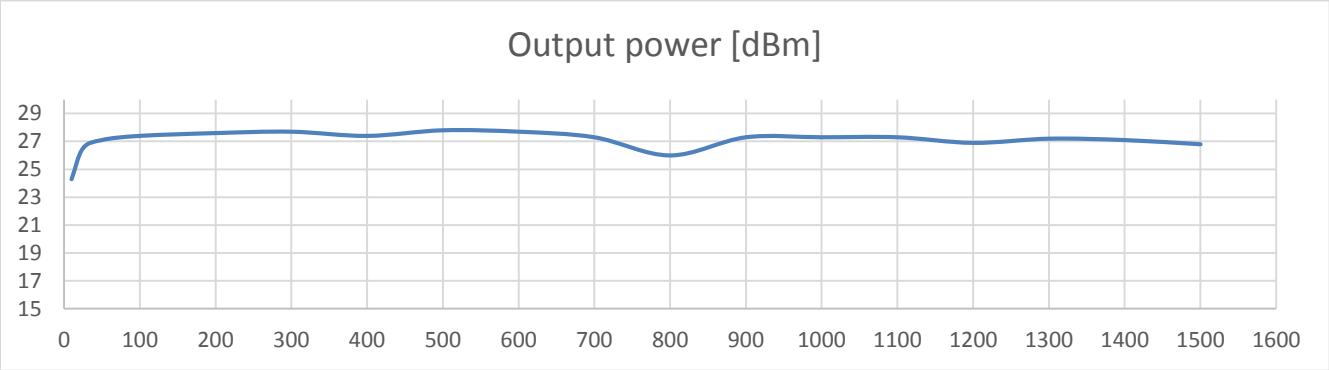


Figure 2 – output power, applying the drive levels given in table3, 10MHz – 1.5GHz

Modulated Wideband Driver Amplifier

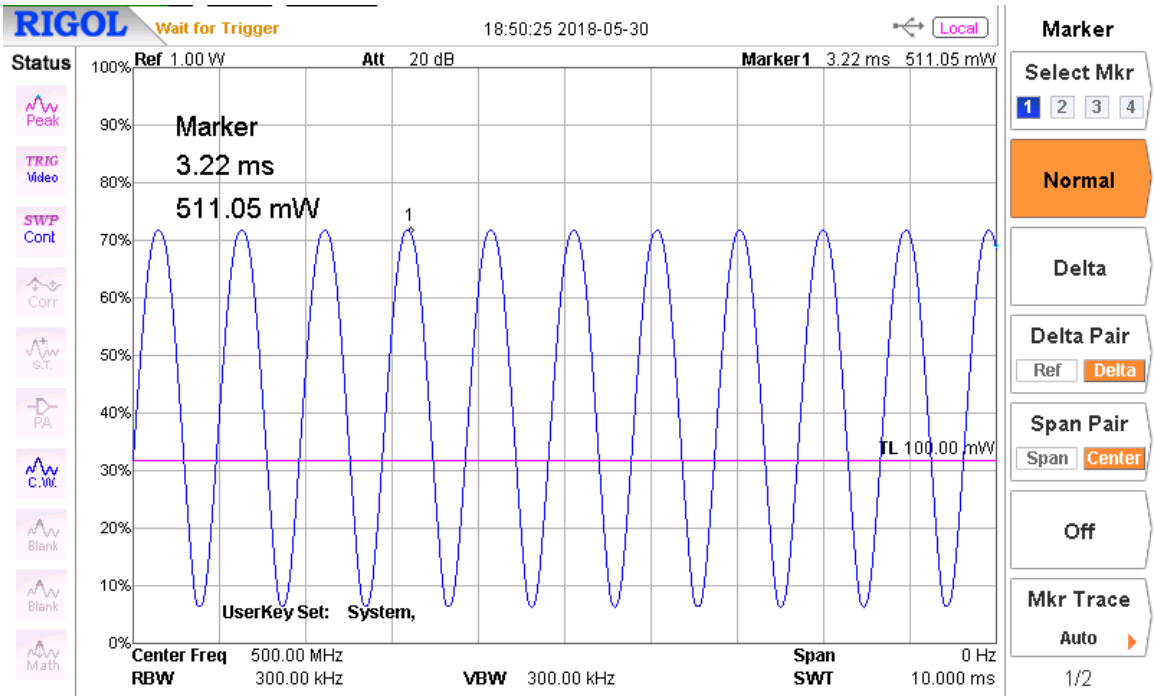


Figure 3 – 1 kHz, 80 % AM envelope, applying the drive levels given in table3, 500 MHz

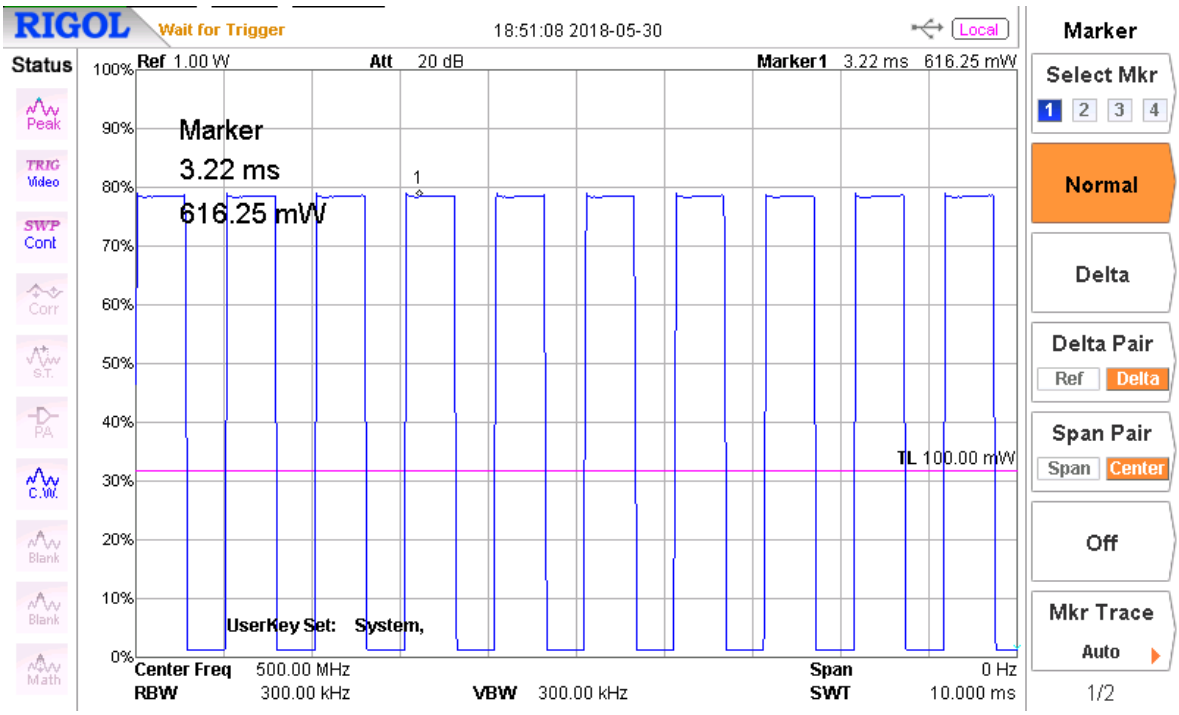


Figure 4 – 1 kHz, 50 % PM envelope, 500 MHz

Modulated Wideband Driver Amplifier

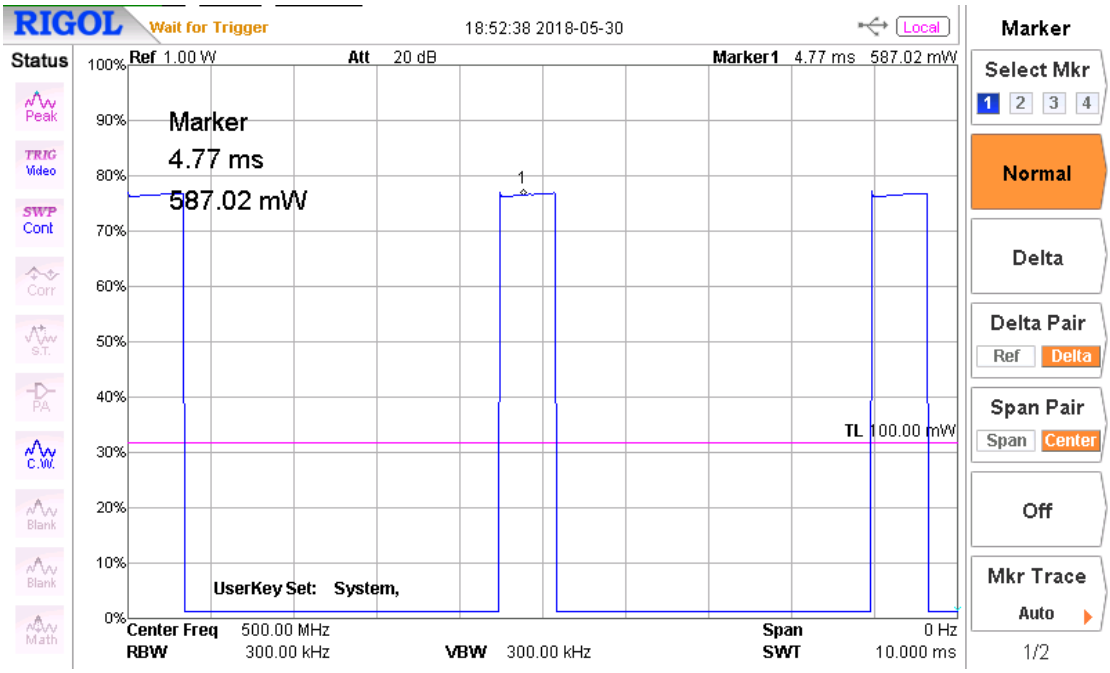


Figure 5 – 217 Hz, 12.5 % PM envelope, 500 MHz

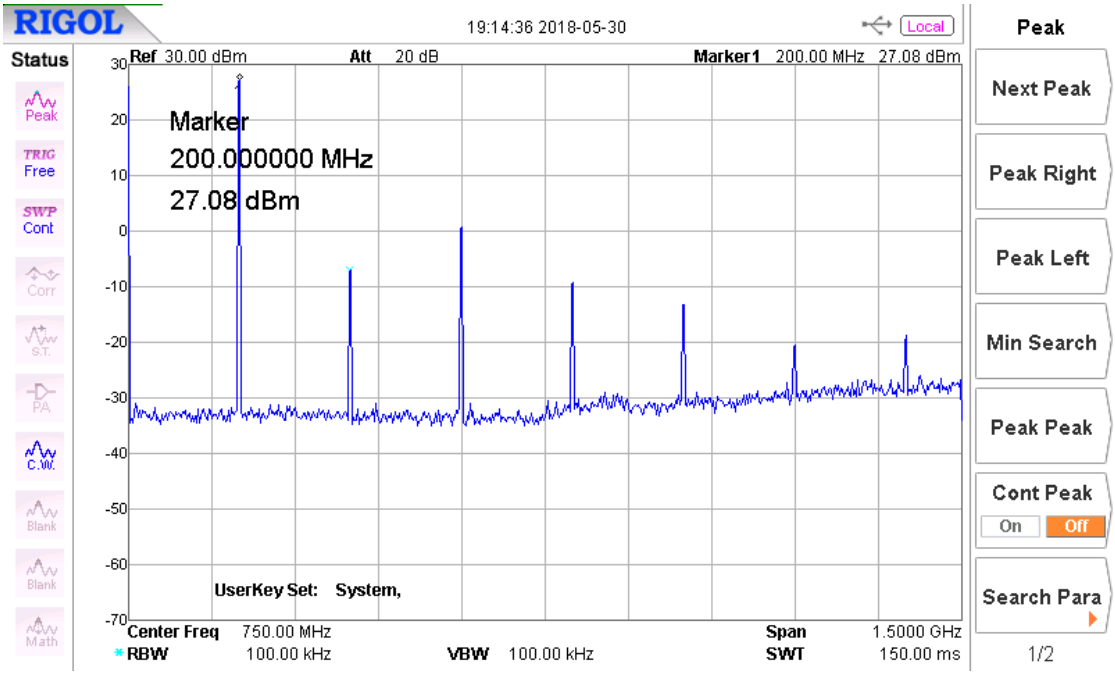


Figure 6 – CW, harmonics, 200 MHz

Modulated Wideband Driver Amplifier

3 Power supply

The current consumption of the TBMDA2 is 700mA and consequently exceeds the current limit of USB 2.0 ports. Supply the TBMDA2 through a USB 3.0 port or a mobile phone charger with an output current capability of 1A or higher.

Connector: Mini-USB-B

4 Applications

Immunity testing using a TEM cell

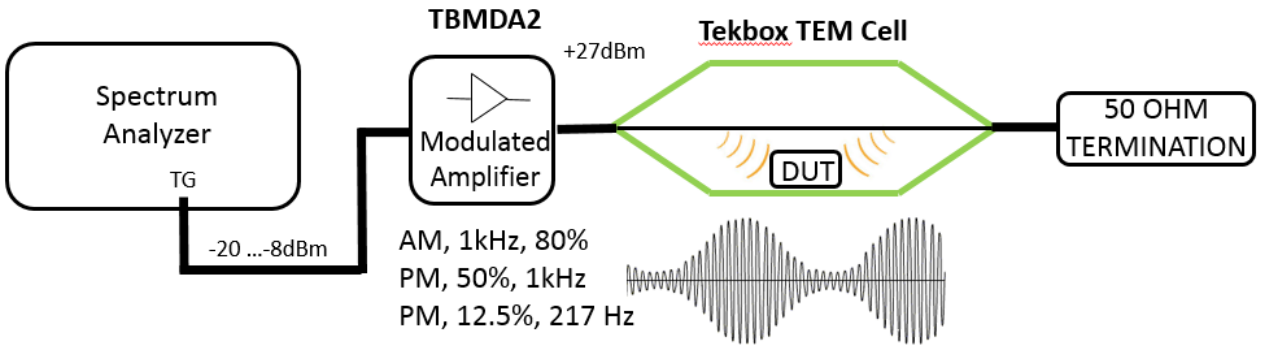


Figure 7 – immunity testing set up

Immunity testing using near field probes

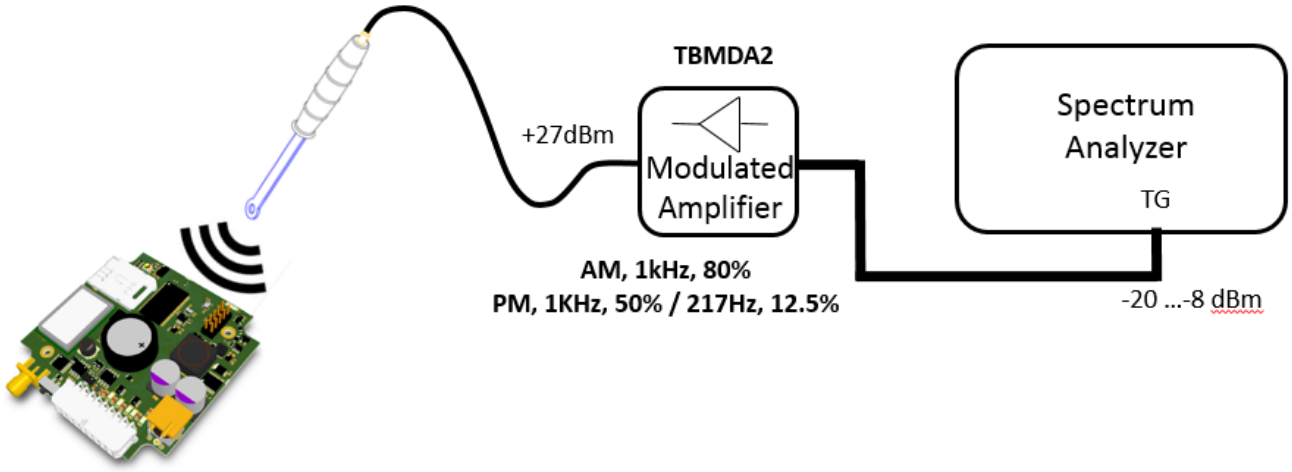


Figure 8 – immunity testing set up

5 TEM Cell field strength

A typical pre compliance set up for immunity testing is typically not sophisticated enough to measure the real field strength inside the TEM cell. However, the field strength can be approximated mathematically.

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 however use the simplified formula with sufficient accuracy.

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

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

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

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

The power P in the formulas above hast 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]
10	-19.92	24.3	131	73	37	24
25	-19.8	26.5	169	95	47	31
50	-19.6	27.1	181	101	51	34
100	-19.2	27.4	187	105	52	35
200	-18.4	27.6	191	107	54	36
300	-17.6	27.7	194	109	54	36
400	-16.8	27.4	187	105	52	35
500	-16	27.8	196	110	55	37
600	-15.2	27.7	194	109	54	36
700	-14.4	27.3	185	104	52	35
800	-13.6	26	159	89	45	n.a
900	-12.8	27.3	185	104	52	n.a
1000	-12	27.3	185	104	52	n.a
1100	-11.2	27.3	185	104	52	n.a
1200	-10.4	26.9	177	99	49	n.a
1300	-9.6	27.2	183	102	51	n.a
1400	-8.8	27.1	181	101	51	n.a
1500	-8	26.8	175	98	49	n.a

Table 4 – calculated field strength for TBMDA2 driving Tekbox TEM cells

6 PC Software for immunity testing

The Tekbox EMCview SW is regularly updated and now supports immunity testing with a feature for automated tracking generator control. This significantly simplifies immunity testing, especially in case of repeated testing during validation of DUT modifications/improvements.

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

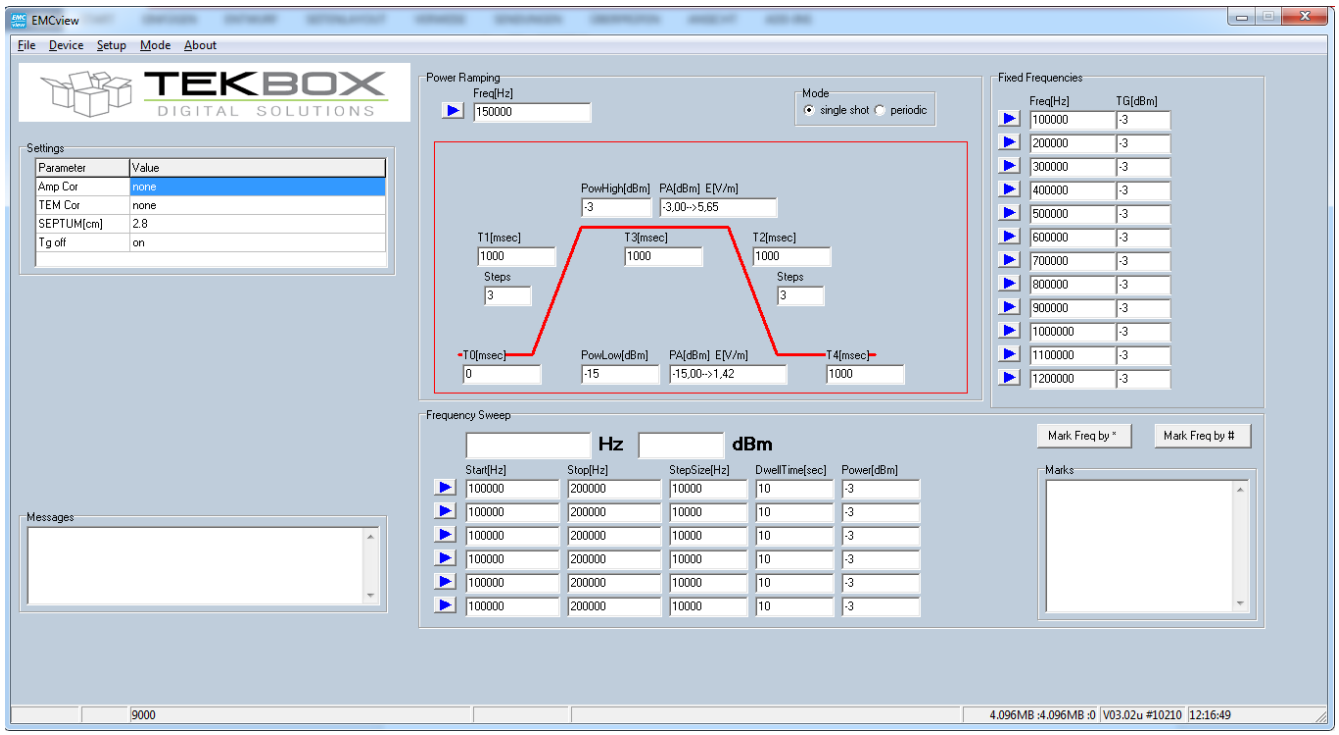


Figure 9 – screenshot of the tracking generator control feature of EMCview

WARNING:

Never connect the output of the TBMDA2 directly to the input of a spectrum analyzer. Check the maximum input ratings of the spectrum analyzer and protect it with an appropriate attenuator.

Example:

Rigol DSA815 – maximum input power rating: +20dBm

Modulated Wideband Driver Amplifier

7 Ordering Information

Part Number	Description
TBMDA2	modulated driver amplifier, 2 pcs 75cm SMA-male to N-male cables, 1 pc 20dB attenuator with N-connectors, USB cable,

Table 5 – Ordering Information

8 History

Version	Date	Author	Changes
V1.0	31.5.2018	Mayerhofer	Creation of the document

Table 6 – History

Modulated Wideband Power Amplifier

1 Introduction

The TBMDA3B, 10MHz – 1 GHz modulated wideband power amplifier is designed to provide a low-cost RF power source for pre-compliance immunity testing of electronic building blocks and products. Driven with an input power of less than 0 dBm, it can deliver a saturated output power of up to 8 W. The TBMDA3 is ideal to drive Tekbox near field probes in order to find the sensitive spot of electronic circuits, or to generate strong electric fields for radiated immunity testing in TEM cells. It can generate up to 700V/m when driving the Tekbox TEM Cell TBTC0, 400V/m when driving the TBTC1, 200V/m when driving the TBTC2, or 130V/m when driving the TBTC3.

A built in AM- modulator enables the use of tracking generators as signal source. The TBMDA3B has sufficient gain to achieve its maximum output power when driven with the tracking generator of a spectrum analyzer. Besides 1 kHz, 80% AM, the TBMDA3B provides built in modulation capability to generate 1 kHz, 50% duty cycle PM signals. In PM mode, the TBMDA3B can also generate a 217 Hz Signal with 12.5% duty cycle in order to simulate mobile phone TDMA noise.

Picture 1 – TBMDA3B modulated wideband driver amplifier, front view

Picture 2 – TBMDA3B modulated wideband driver amplifier, rear view

Modulated Wideband Power Amplifier

Application:

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

2 Electrical Specifications

Technical Data:

Input / Output: 50 Ohm, N female

Supply Voltage range: 110 V…240 V

Supply power consumption: 25 W @ 220V

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

Frequency range: 10 MHz – 1 GHz, usable from 5 MHz to 1.1 GHz

Small signal gain: 42 dB typ.

Gain flatness 10 MHz – 1 GHz / Pin = -15 dBm: 2 dB typ.

Saturated output power @ 5 MHz / Pin = 0 dBm: 39.1 dBm (8.1 W) typ.

Saturated output power @ 10 MHz / Pin = 0 dBm: 39.3 dBm (8.5 W) typ.

Saturated output power @ 50 MHz / Pin = 0 dBm: 39.7 dBm (9.3 W) typ.

Saturated output power @ 75 MHz / Pin = 0 dBm: 39.7 dBm (9.4 W) typ.

Saturated output power @ 100 MHz / Pin = 0 dBm: 39.7 dBm (9.4 W) typ.

Saturated output power @ 250 MHz / Pin = 0 dBm: 40.5 dBm (11.2 W) typ.

Saturated output power @ 500 MHz / Pin = 0 dBm: 40.5 dBm (11.3 W) typ.

Saturated output power @ 750 MHz / Pin = 0 dBm: 39.5 dBm (8.8 W) typ.

Saturated output power @ 1000 MHz / Pin = 0 dBm: 39.8 dBm (9.6 W) typ.

Saturated output power @ 1100 MHz / Pin = 0 dBm: 38.7 dBm (7.3 W) typ.

Modulated Wideband Power Amplifier

1dB output compression point @ 5 MHz: 38.4 dBm typ. (Pin: -2 dBm)

1dB output compression point @ 10 MHz: 38.4 dBm typ. (Pin: -3 dBm)

1dB output compression point @ 50 MHz: 39.4 dBm typ. (Pin: -1 dBm)

1dB output compression point @ 75 MHz: 39.4 dBm typ. (Pin: -1 dBm)

1dB output compression point @ 100 MHz: 39.4 dBm typ. (Pin: -1 dBm)

1dB output compression point @ 250 MHz: 40.2 dBm typ. (Pin: -1 dBm)

1dB output compression point @ 500 MHz: 40.1 dBm typ. (Pin: -1 dBm)

1dB output compression point @ 750 MHz: 38.9 dBm typ. (Pin: -2 dBm)

1dB output compression point @ 1000 MHz: 38.5 dBm typ. (Pin: -3 dBm)

1dB output compression point @ 1100 MHz: 38 dBm typ. (Pin: -2 dBm)

2^{nd} harmonic, 100 MHz, Pout = 39.4 dBm: < - 21.5 dBc typ.

2^{nd} harmonic, 100 MHz, Pout = 34 dBm: < - 15.5 dBc typ.

3^{rd} harmonic, 100 MHz, Pout = 39.4 dBm: < - 13 dBc typ.

3^{rd} harmonic, 100 MHz, Pout = 34 dBm: < - 23 dBc typ.

Total harmonic distortion:

15.3% @100 MHz, Pout = 31 dBm typ.

18.2% @100 MHz, Pout = 34 dBm typ.

20.1% @100 MHz, Pout = 37 dBm typ.

26.8% @100 MHz, Pout = 39.4 dBm typ.

Third order output intercept point: 44 dBm, @100 MHz, Δ f = 2 MHz, typ.

Internal modulation frequency AM: 1 kHz ± 20%

Internal modulation frequencies PM: 1 kHz ± 20%, 217 Hz ± 20%

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

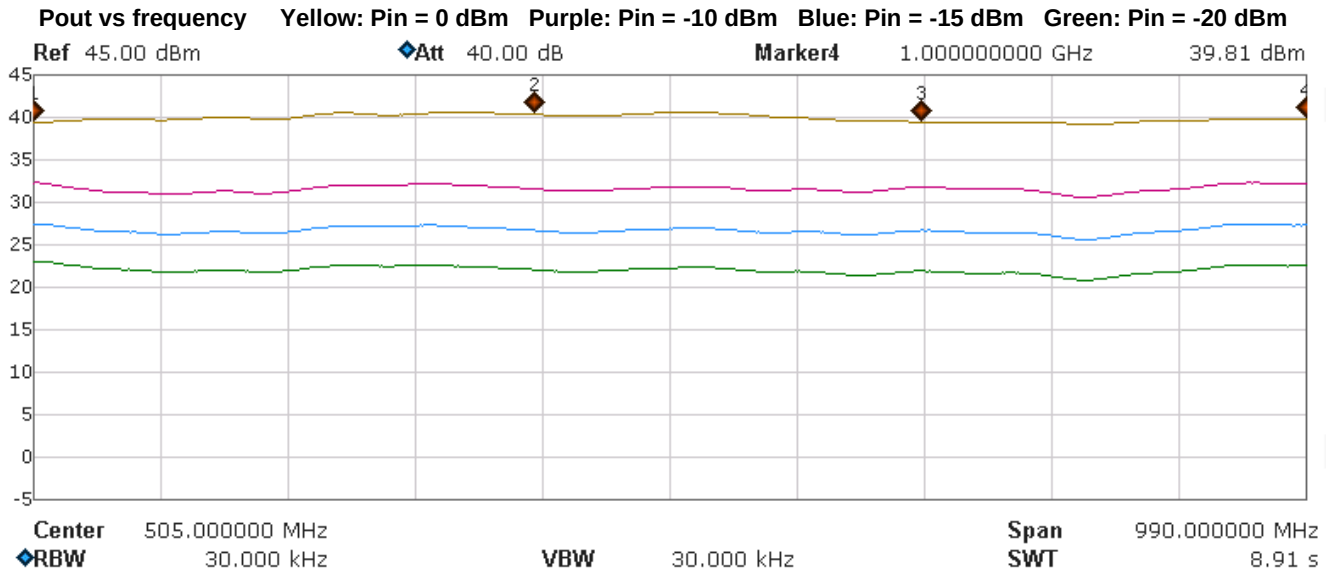
Maximum ratings:

Maximum input power: +0 dBm

The output of the TBMDA3B 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 3dB 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	10.000000 MHz	39.28 dBm
Marker2	A	Frequency	400.000000 MHz	40.30 dBm
Marker3	A	Frequency	700.000000 MHz	39.41 dBm
Marker4	A	Frequency	1.000000000 GHz	39.81 dBm

Small Signal Performance (@ Pin = - 15 dBm):

Frequency [MHz]	5	10	25	50	75	100	250	500	600	750	1000	1050	1100
Output power [dBm]	26.02	27.41	27.27	26.83	26.49	26.35	27.17	26.84	26.52	26.4	27.29	27.12	26.29
Gain [dB]	41.02	42.41	42.27	41.83	41.49	41.35	42.17	41.84	41.52	41.4	42.29	42.12	41.29

Table 1 – TBMDA3B small signal gain, typ.

1 dB compression point:

Frequency [MHz]	5	10	25	50	75	100	250	500	600	750	1000	1050	1100
Output power [dBm]	38.43	38.43	39.45	39.43	39.44	39.37	40.16	40.14	38.97	38.87	38.54	38.9	37.95
Pin [dBm]	-2	-3	-2	-1	-1	-1	-1	-1	-2	-2	-3	-2	-2

Table 2 – TBMDA3B, 1 dB compression point versus frequency, typ.

Saturation (@ Pin = 0 dBm):

Frequency [MHz]	5	10	25	50	75	100	250	500	600	750	1000	1050	1100
Output power [dBm]	39.06	39.28	39.45	39.67	39.74	39.71	40.49	40.52	39.99	39.45	39.81	39.47	38.66
Gain [dB]	39.06	39.28	39.45	39.67	39.74	39.71	40.49	40.52	39.99	39.45	39.81	39.47	38.66

Table 3 – TBMDA3B, Saturation versus frequency, typ.

Modulated Wideband Power Amplifier

Modulation:

Zero span, 10 ms sweep time, peak detector

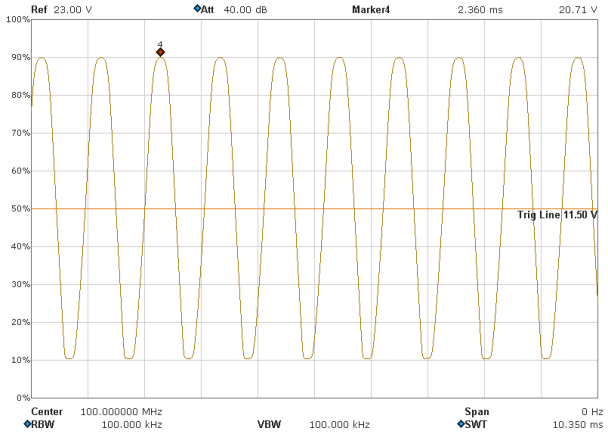


Figure 1 – 1 kHz, 80 % AM, envelope, 100 MHz, Pout = 39.9 dBm peak;

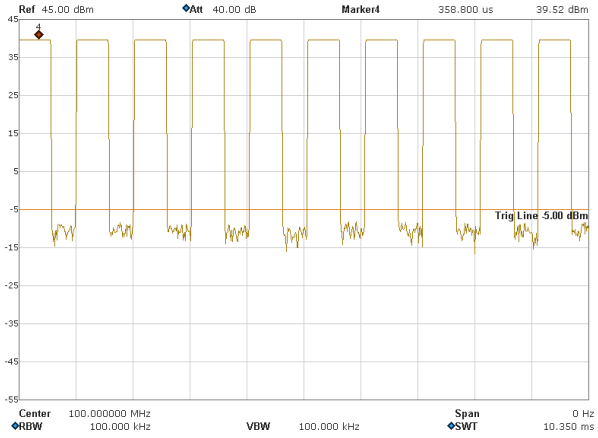


Figure 2 – 1 kHz, 50 % PM envelope, 100 MHz, Pout = 39.9 dBm peak

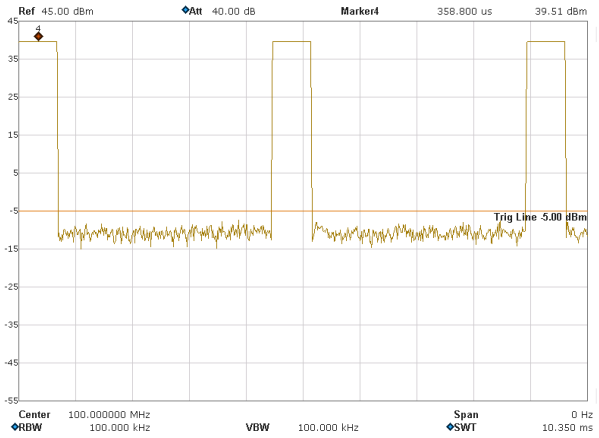


Figure 3 – 217 Hz, 12.5 % PM envelope, 100 MHz, Pout = 39.9 dBm peak

Modulated Wideband Power Amplifier

3 Applications - radiated immunity

Immunity testing using a TEM cell

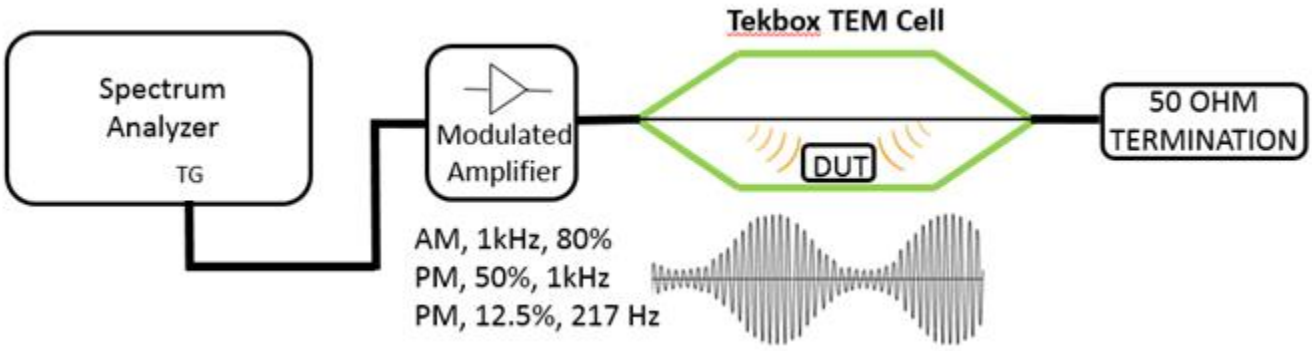


Figure 4 – immunity testing set up

Immunity testing using near field probes

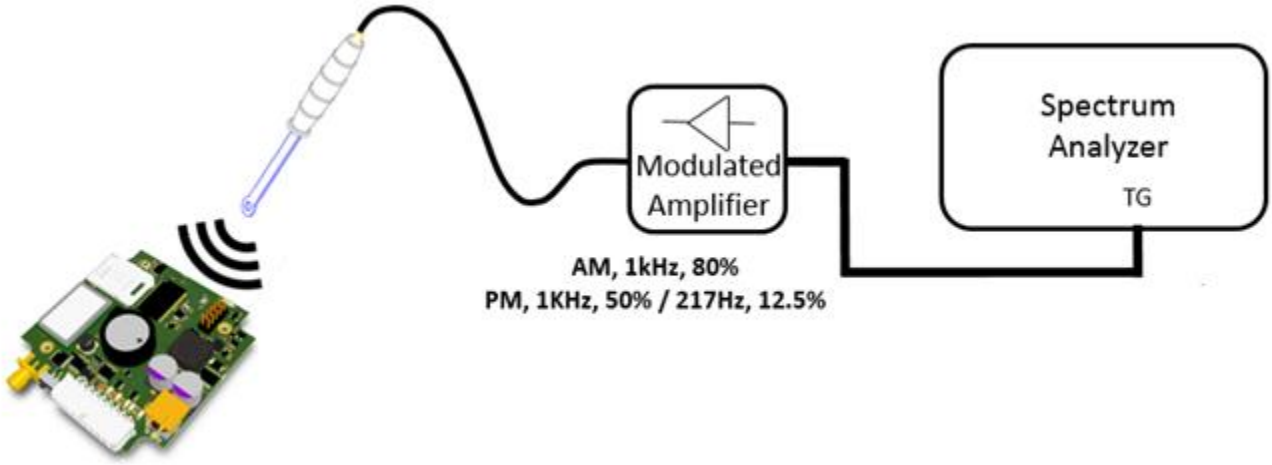


Figure 5 – immunity testing set up to locate susceptible areas on PCBAs

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 cm -> $E_{[V/m]} = (\sqrt{(P*50\Omega)})*35.7$

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

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

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

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

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

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]
5	-3	38	634.1	355.2	177.6	118.3
10	-3	38.7	688.1	385.5	192.7	128.4
25	-3	39	712.3	399	199.5	132.9
50	-3	38.9	704.9	394.9	197.5	131.5
75	-3	38.6	678.7	380.2	190.1	126.6
100	-3	38.4	662.5	371.1	185.6	123.6
250	-3	39.2	725.5	406.5	203.2	135.4
500	-3	39.2	724.7	406	203	135.2
600	-3	38.2	651.1	364.8	182.4	121.5
750	-3	38.3	657.1	368.1	184.1	122.6
1000	-3	38.5	674.8	378	189	-
1050	-3	38.4	664.7	372.4	186.2	-
1100	-3	37.4	591.1	331.1	165.6	-

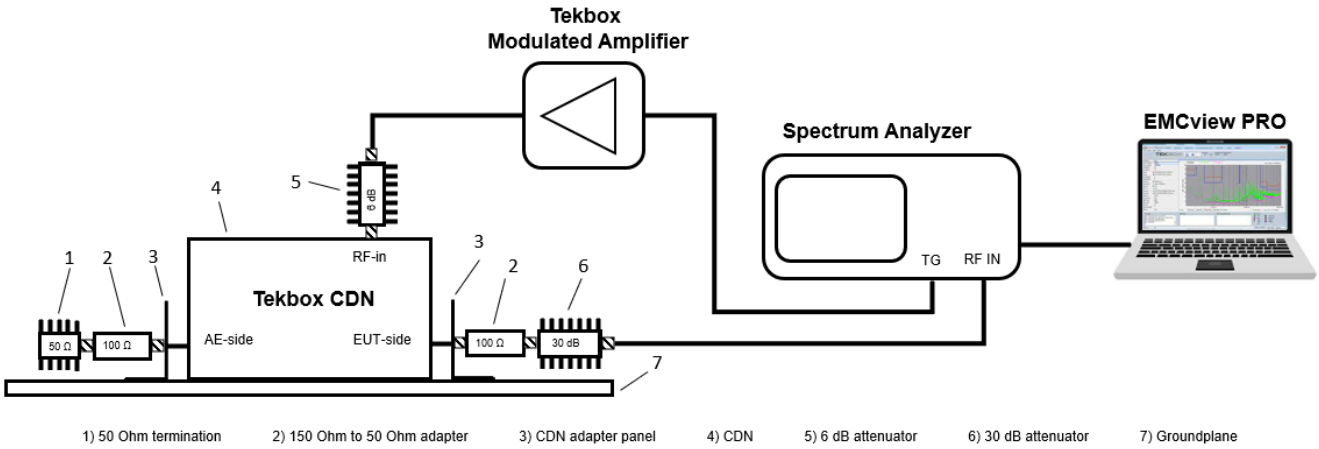
Table 4 – calculated field strength for the TBMDA3B driving Tekbox TEM cells

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 th 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 2

U_0= 3V RMS open circuit voltage at the EUT port of the CDN = 3V/6 = 0.5V 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:

7 dBm + 10 dB + 6 dB + 5.1 dB = 28.1 dBm = 0.65 Watt

During calibration, EMCview Pro will make a stepped sweep, for each frequency adjusting the tracking generator level in order to achieve 7 dBm + 5.1 dB -30 dB = -17.9 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.

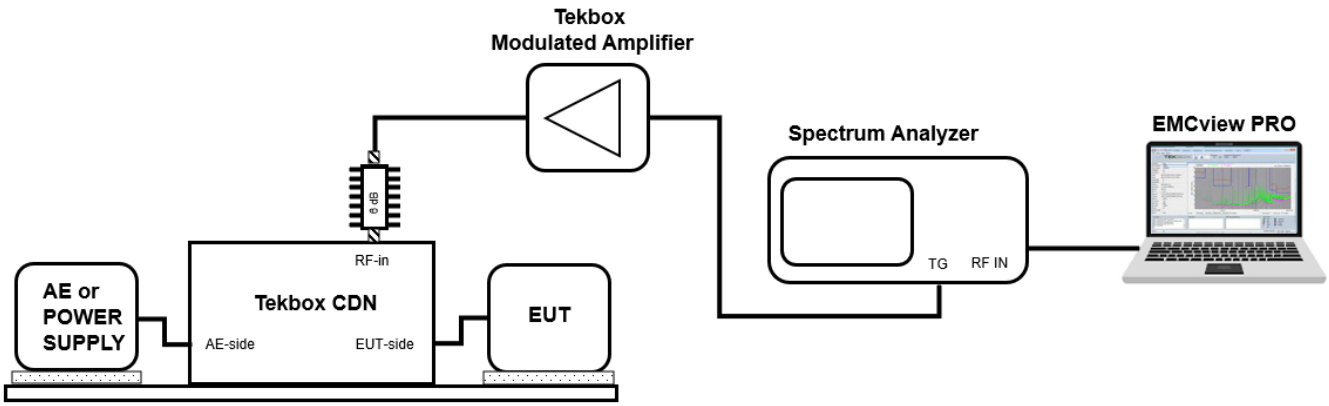
The table below reflects the insertion loss versus frequency of a real CDN in order to set the required input power for the TBMDA3B.

Frequency [MHz]	TBMDA3B output power to achieve stress level 1 [dBm]	Corresponding TBMDA3B input power [dBm]	TBMDA3B output power to achieve stress level 2 [dBm]	Corresponding TBMDA3B input power [dBm]	TBMDA3B output power to achieve stress level 3 [dBm]	Corresponding TBMDA3B input power [dBm]
5	17.3	-24	27.3	-14	37.3	-4
10	16.6	-26	26.6	-16	36.6	-6
50	16.9	-25	26.9	-15	36.9	-5
100	17.8	-24	27.8	-14	37.8	-4
150	18.7	-23	28.7	-13	38.7	-3
230	20	-22	30	-12	40	-1

Table 4 - measured input power settings for the TBMDA3B in order to achieve stress level 1 and 2

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

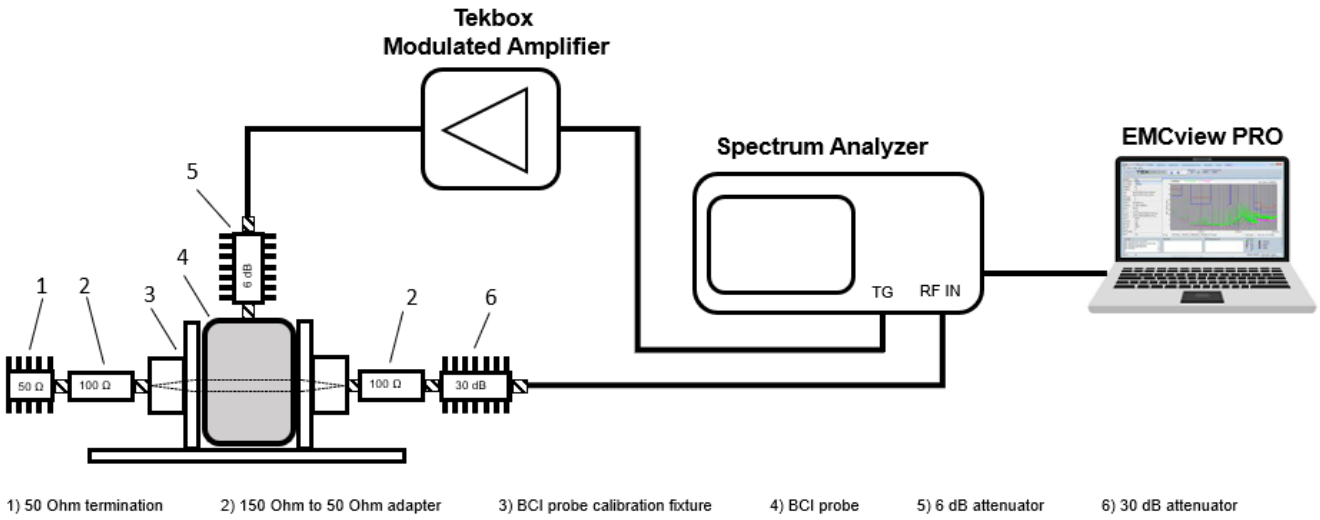


Modulated Wideband Power Amplifier

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



1) 50 Ohm termination 2) 150 Ohm to 50 Ohm adapter 3) BCI probe calibration fixture 4) BCI probe 5) 6 dB attenuator 6) 30 dB attenuator

- 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 1/6th 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 2 U_0= 3V RMS open circuit voltage at the output of the calibration fixture = 3V/6 = 0.5V 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] + BCI probe insertion loss + 6 dB (Attenuator) + 5.1 dB (80% AM RMS)

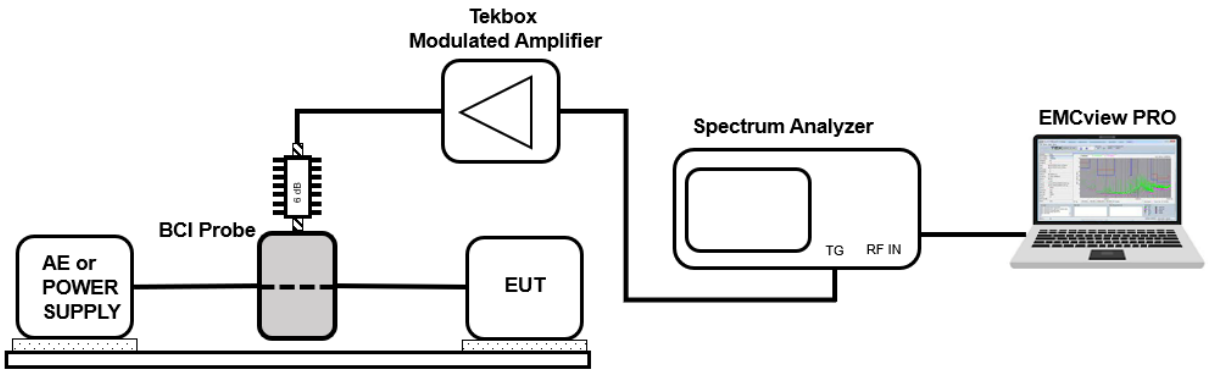
Assuming 16 dB insertion loss for the BCI probe in a 300 Ohm loop, the required RF power is:

7 dBm + 16 dB + 6 dB + 5.1 dB = 34.1 dBm = 2.6 Watt

During calibration, EMCview Pro will make a stepped sweep, for each frequency adjusting the tracking generator level in order to achieve 7 dBm -30 dB = -23 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



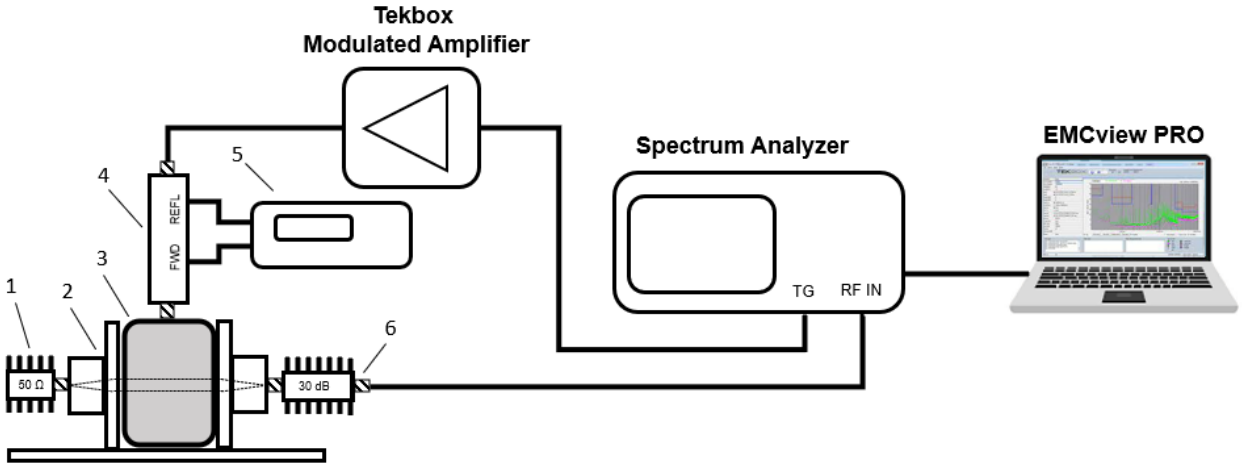
ISO 11452-4 / MIL-STD-461 / DO 160A calibration set up using EMCview PRO

The automotive immunity standard ISO 11452-4 as well as immunity standards for defense and avionic products specify stress levels in terms of induced disturbance current.

Traditional calibration and test methods use current monitoring probes in order to create a control loop, thereby maintaining the required disturbance current. Levelling loops can be fooled by cable resonances. High impedance resonances cause the RF amplifiers output power to raise, in order to achieve the specified disturbance current. Similarly, low impedance resonances may significantly reduce the RF amplifiers output power. This situation is unrealistic of most real-life electromagnetic environments and could create a severe over-test or under-test situation.

In order to get around the over-test / under-test problems associated with the closed loop test method, the standards offer the substitution method (open loop), where the disturbance current is set by measuring current induced into a 100 Ohm loop. Forward and reflected power is measured using a directional coupler while setting the RF power to achieve the required disturbance current levels into the 50 Ohm load. During actual immunity test, the forward power level is set according to the value recorded during calibration.

<u>Substitution calibration method set up for pre-compliance purpose:</u>



1) 50 Ohm termination 2) BCI probe calibration fixture 3) BCI probe 4) directional coupler 5) RF power meter or similar 6) 30 dB attenuator

Example: Test level I – 60 mA

A power of 22.6 dBm is required to achieve a current of 60 mA in a 50 Ohm load.

Assume 8dB insertion loss for a typical BCI probe in a 100 Ohm loop.

Assume 1 dB insertion loss for the directional coupler

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

Test level [dBm] + BCI probe insertion loss + 6 dB (Attenuator) + 5.1 dB (80% AM RMS)

22.6 dBm + 8 dB + 1 dB + 5.1 dB = 36,7 dBm = 4.7 W

Example: Test level IV – 200 mA

A power of 33 dBm is required to achieve a current of 200 mA in a 50 Ohm load.

Assume 8dB insertion loss for a typical BCI probe in a 100 Ohm loop.

Assume 1 dB insertion loss for the directional coupler

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

Test level [dBm] + BCI probe insertion loss + 6 dB (Attenuator) + 5.1 dB (80% AM RMS)

33 dBm + 8 dB + 1 dB + 5.1 dB = 47.1 dBm = 51.3 W

ISO 11452-4 / MIL-STD-461 / DO 160A immunity test set up using EMCview PRO

Refer to the standards for detailed drawings of the corresponding test set ups.

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.

Modulated Wideband Power Amplifier

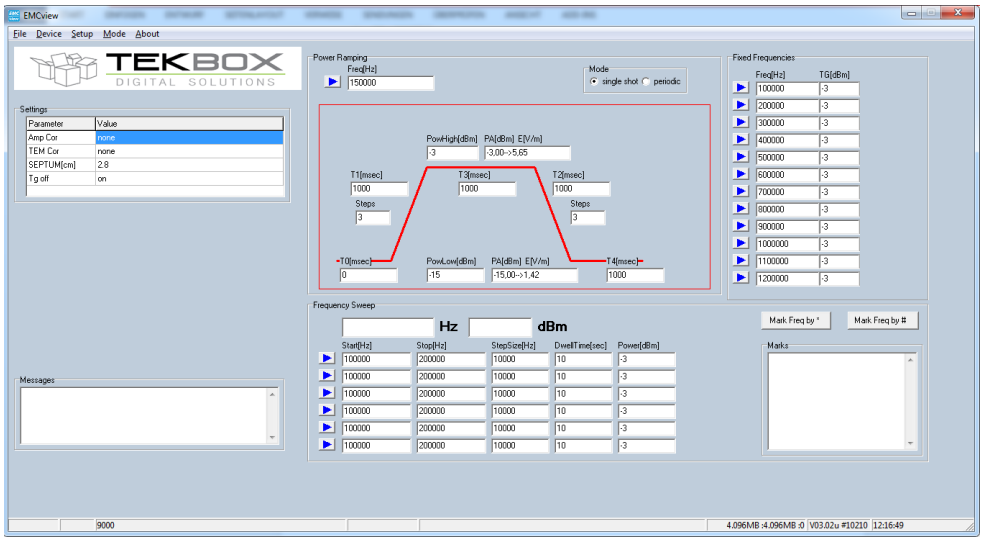


Figure 11 – screenshot of the tracking generator control feature of EMCview / EMCview Pro

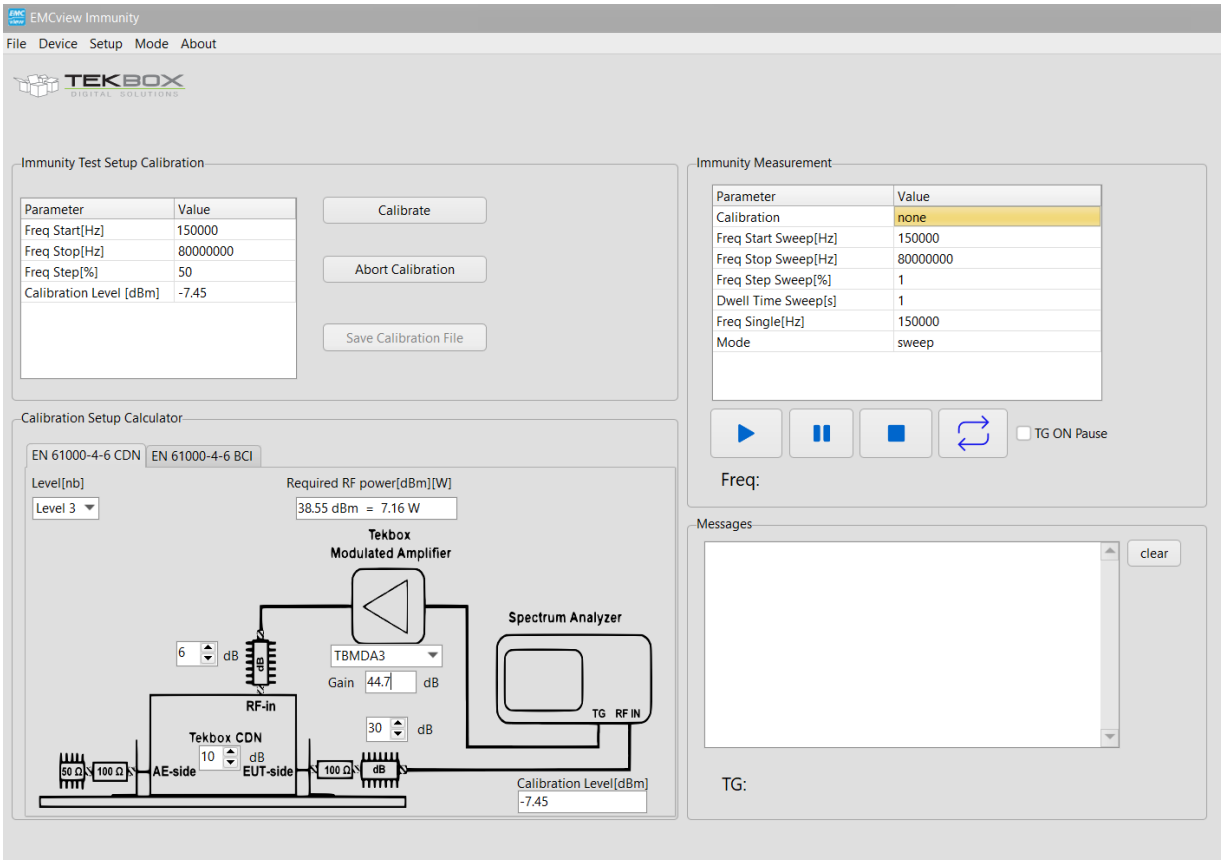


Figure 12 – screenshot of the immunity test feature of EMCview Pro

Modulated Wideband Power Amplifier

WARNING:

Never connect the output of the TBMDA3B 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.

Example:

Rigol DSA815 – maximum input power rating: +20dBm

7 Ordering Information

Part Number	Description
TBMDA3B-EU	modulated power amplifier, 2 pcs 75cm N-male to N-male cables, 1 pc 6 dB attenuator, 1 pc 30dB / 10W attenuator with N-connectors, C13 Schuko power cord
TBMDA3B-US	modulated power amplifier, 2 pcs 75cm N-male to N-male cables, 1 pc 6 dB attenuator, 1 pc 30dB / 10W attenuator with N-connectors, C13 US power cord
TBMDA3B-UK	modulated power amplifier, 2 pcs 75cm N-male to N-male cables, 1 pc 6 dB attenuator, 1 pc 30dB / 10W attenuator with N-connectors, C13 English power cord
TBMDA3B-AU	modulated power amplifier, 2 pcs 75cm N-male to N-male cables, 1 pc 6 dB attenuator, 1 pc 30dB / 10W attenuator with N-connectors, C13 Australian power cord

Table 5 – Ordering Information

8 History

Version	Date	Author	Changes
V1.0	9.2.2023	Mayerhofer	Creation of the document
V1.1	17.2.2023	Mayerhofer	Updated chapter 6
V1.2	27.2.2023	Minh Nguyen	Updated Picture 1
V1.3	27.3.2023	Thinh Nguyen	Updated perfomance

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