EMC output filter recommendations for MA120XX(P)

Audio amplifiers

About this document

Scope and purpose

This document provides EMC output filter recommendations that are tailored to the Merus Audio's MA12040, MA12040P, MA12070 and MA12070P audio amplifiers. The recommendations are a guideline to pass EMC tests for various applications. They are not covering every situation as every product or application is different. The potential to choose and combine components is vast, and the final solution will constitute a tradeoff between size, price, filter characteristics and performance.

This application note describes different applications with different speaker cable length. It includes schematics of the filters and a discussion of the filter components (section 2). Finally it contains Radiated emission measurement results obtained at a certified EMC lab (Section 3).

For further support and assistance for your specific product or application please contact your local Merus Audio Sales and Applications Engineering team.

Intended audience

Audio amplifier design engineers

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1 Filter types

The output filter can be divided into two types: *ferrite filters* and *LC filters*. The ferrite filter is generally smaller and lower cost than the traditional LC-filter. The advantage of the LC-filter is higher attenuation of the out-of-band noise, which makes it suitable for all kinds of amplifiers and speaker cable lengths. The ferrite filter has less attenuation which is not suitable for every class-D amplifier or speaker cable length.

The Merus Audio patented multilevel modulation makes it possible to pass radiated emission test with a ferrite filter only, for speaker cable lengths up to 60 cm. The MA120xx(P) amplifiers additionally feature a power management scheme that dynamically adjusts switching frequency and modulation scheme. This enables the amplifier to optimize power losses and EMI across the output power range. In general, a ferrite filter is sufficient in *active speaker* applications where the speaker cable length is known and relatively short.

The size of the two filter types (one for each BTL output) is illustrated on figure 1. The LC filter is marked with red squares and the ferrite filter with yellow squares. The footprint of a 2 x BTL output with LC filter will take up approximately 300 mm^2 of space, while the ferrite filter will take up only 34.0 mm^2 of space.

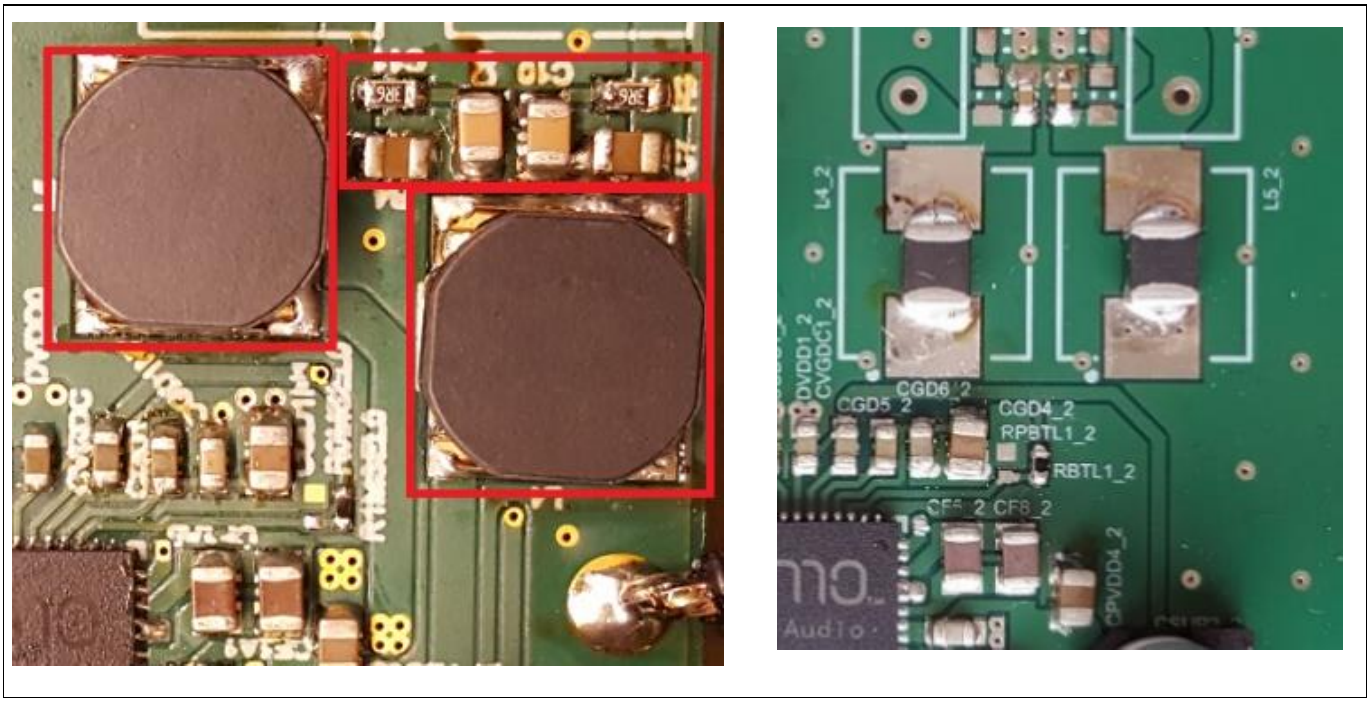

Figure 1 LC-filter (red) for one BTL output, and Ferrite filter (yellow) for one BTL output.

1.1 Ferrite filter

A typical schematic for a ferrite output filter is shown on Figure 2. Each output node has a series ferrite with a capacitor connected to ground. The ferrite is the most critical part and must be chosen carefully.

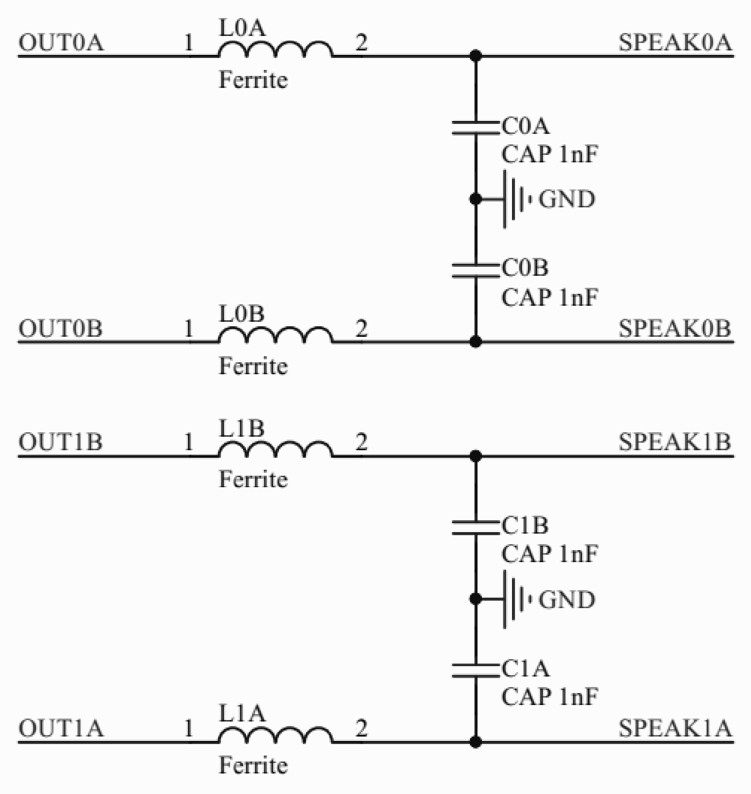

Figure 2 Typical ferrite filter for 2xBTL output for MA120xx(P) amplifiers

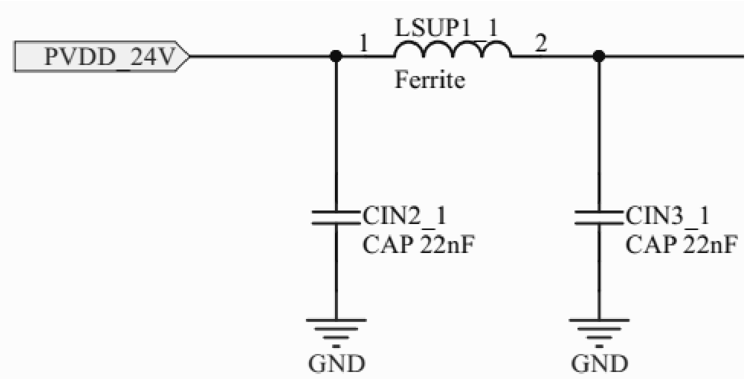

Figure 3 Input voltage Supply ferrite filter

For high-performance and high-power applications Merus Audio recommend the ferrite BLE32PN300SN1L. This enables THD+N levels down to 0.003% with the MA12070. The radiated emission test is passed with a margin better than 5dB over the whole frequency range of 30Mhz to 1Ghz with speaker cables up to 40cm (see section 3). It is also possible to pass radiated emission with 60cm cables, though with less margin than with 40cm cables.

The impedance of the ferrite is rated to 30Ω @ 100Mhz with a DC resistance of maximum 1.6mΩ which gives excellent current handling and low power losses. The high audio performance comes at the expense of higher cost compared to other ferrite beads. The ferrite output filter should be used in combination with an input supply ferrite filter, see Figure 3. This is especially important when longer cables are used between the power supply and the amplifier, as a portion of the radiated signal can pass through this path.

Other ferrite beads may be used. It is important that the bead can handle the required power and current. Beads with a higher impedance gives a better suppression of the harmonics, but that usually come at the expense of higher DC resistance, increased distortion and power losses.

The output capacitor should be 1nF, 50V C0G/NP0 type for the best audio performance. This comes in a 0402 casing and is inexpensive. Increasing the capacitor will lower the cutoff frequency, however values above 1.5nF can lead to increased idle current consumption and output noise. Increasing the output capacitor further can also lead to instability.

1.2 LC filter

For speaker cables longer than 60 cm Merus Audio recommends using an LC filter. A schematic for an LC output filter is shown on Figure 4. Each output node is connected to a series inductor and a capacitor to ground. A damping filter is added to ensure the stability of the amplifier. This also ensures low idle current consumption.

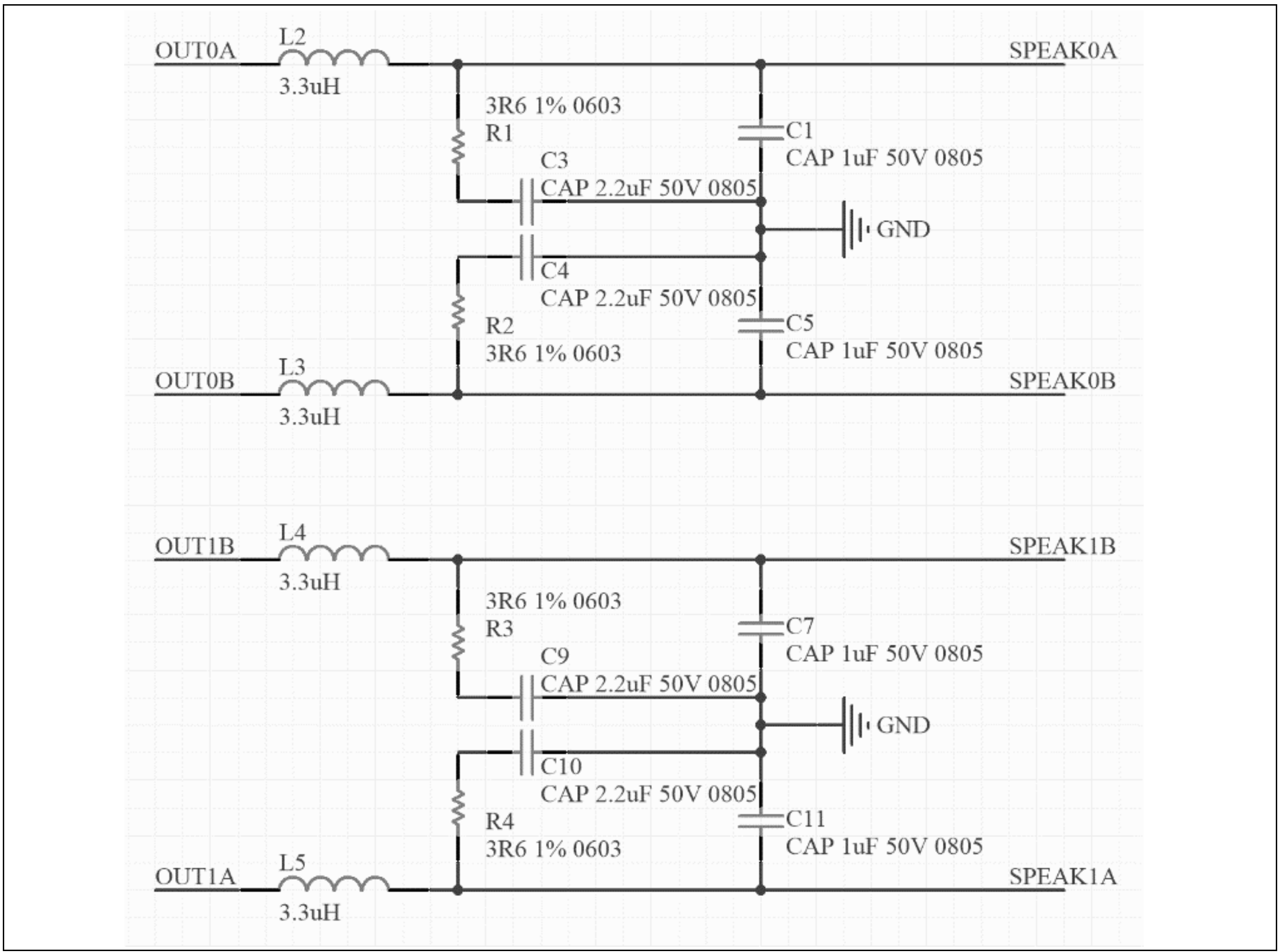

Figure 4 **Example of LC output filter with damping filter for 2xBTL output**

The inductor is the most critical component and must be chosen carefully. Merus audio recommends an inductor of 3.3µH in combination with the components shown in figure 4. Increasing the inductance can lead to higher cost, larger components, increased core loss and lower THD performance. The filter must have a cutoff frequency that is above the audible frequency band but below the effective switching frequency of the amplifier. A cut off frequency between 150-200kHz is adequate.

The schematic in Figure 4 shows the nominal capacitor values with ceramic capacitors. The capacity of ceramics de-rates to roughly 50%, depending on the dielectrics and DC bias voltage. This means that the actual cut off frequency of the filter in Figure 4 is about 172Khz (simulated). For better audio quality use PET film capacitors at roughly half the capacity as shown in Figure 4 (1uF for the damping capacitor and 0.47uF for the filter capacitor).

A good all-round inductor is 1267AY-3R3N=P3 from Murata. It offers a good balance between price, size and performance. The THD performance with the MA12070 amplifier is down to 0.016%, the inductor size is 8x8x4mm (LxWxH) and the price is $0.18 (@5K units) at different retailers. The maximum DC resistance is only 15.6mΩ, and the power loss is low even with a 4Ω speaker. The trade of with 1267AY-3R3N=P3 inductor is a small increase in core loss when current starts to flow through the inductor. For more information contact your Merus Audio support team.

1.3 Filter comparison and recommendation

It is important to notice that every filter must be optimized specifically for the product or application. Every product is different, and Merus Audio do not guarantee that the recommended filters will make products pass EMC tests. The recommendations are a guideline and a starting point for a product designer. It will make it easier to choose a filter that suits the requirements and the product. Good EMC practices and PCB layout are still valid and important.

Table 1 gives an overview of the recommended output filters. All output filters have been tested with the PVDD input filter shown in Figure 3.

The THD+N performance is measured with APx525 and an AUX-0025 measurement filter. The test conditions are 1kHz sine wave, 4Ω load, brickwall filter 20Hz-20kHz. Output power is approximately 10W.

For a THD+N vs. Measured output power sweep see figure 5. The sweep is measured with the Murata ferrite (BLE32PN300SN1L) and the Murata LC-filter.

The pricing estimates in the table are based on typical 10K unit volumes from various component sourcing websites. Note that prices are generally highly volume dependent, which will enable significantly lower filter component prices at high volumes. The estimates in the table should however help provide the basis for a good relative comparison.

The speaker cable length is a dominant factor when it comes to Radiated Emission as the cable will function as an antenna. Although the MA120xx(P) amplifiers can pass the EMI test with speaker cables up to 60cm it is best to twist the cables and keep them as short as possible. Using an LC filter is generally the best option for applications with speaker cables longer than 60 cm.

The idle power consumption without filter at 24V PVDD is 292.38mW. The recommended ferrite filters add less than 3% to the idle power consumption. Lowering the PVDD voltage to 18V will reduce the idle power consumption to approximately 250mW.

Table 1 Filter comparison

Filter type	**Ferrite**	**Ferrite**	**LC**	**Ferrite**
Critical component	Fair-Rite: 2512065007Y6	Laird: HI1612X560R-10	Murata: 1267AY-3R3N=P3	Murata: BLE32PN300SN1L
THD+N 1kHz, 20 Hz -20 kHz	> 0.10%	> 0.020%	> 0.016%	> 0.003%
Size (2xBTL output)	22.5mm2	54.5mm2	300mm2	34mm2
Price total filter in USD	0.102	0.464	0.780	0.864
Component count	4 x (ferrite + 1nF cap)	4 x (ferrite + 1nF cap)	4 x (inductor + 1uF cap) & 4 x (3.6Ω resistor + 2.2µF cap)	4 x (ferrite + 1nF cap)
Cable length	Up to 60 cm	Up to 60 cm	Tested in EMC lab with 5 m speaker cable	Up to 60 cm (tested in EMC lab)
Idle Power consumption: PMP0, PVDD=24V, 4ohm	301.0 mW	301.0 mW	289.4mW	301.0 mW

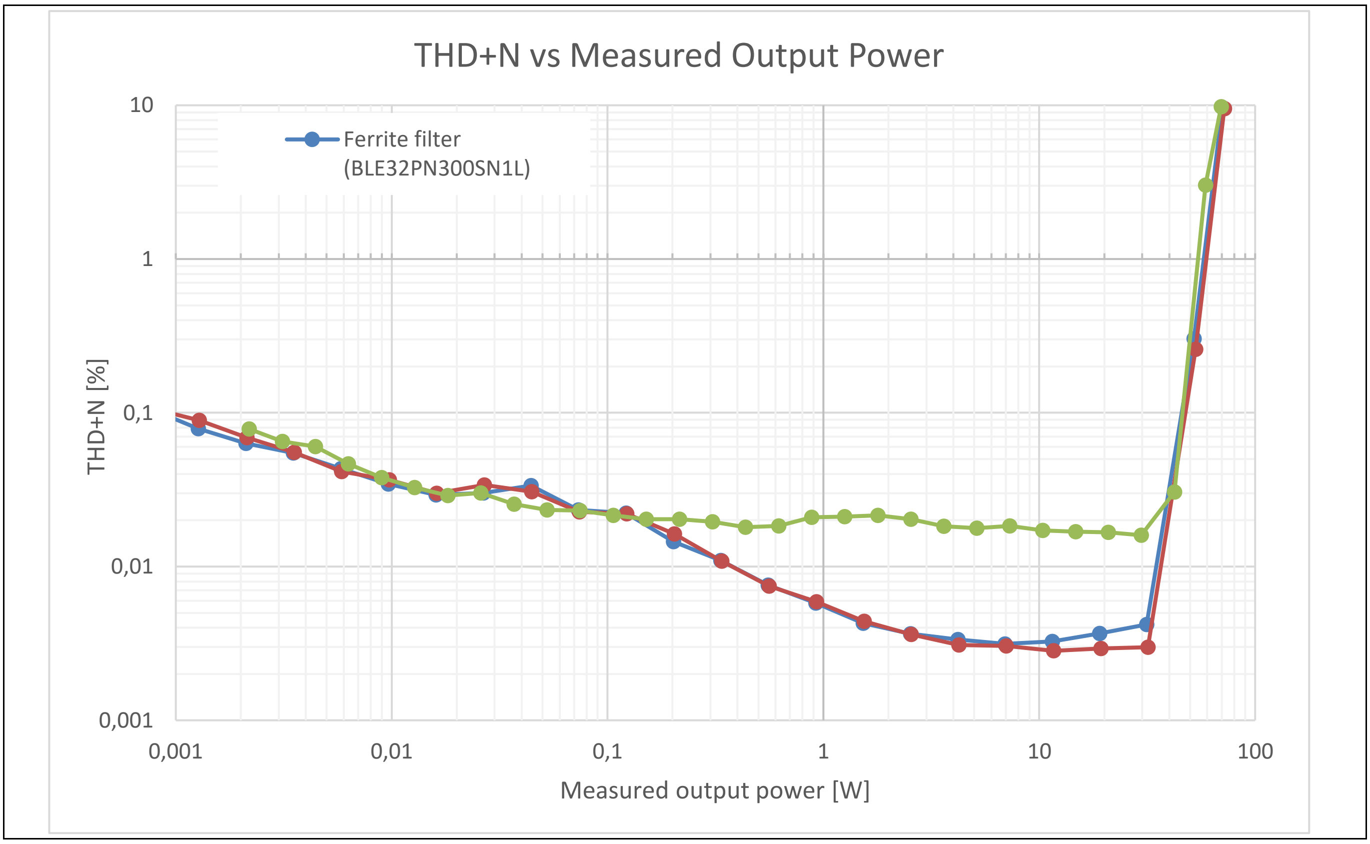

Figure 5 THD+N vs measured output power, 1kHz test tone, PMP2

1.4 Common Mode Filter

Mains powered products must comply with the conducted emissions requirements stated in the EMC standard EN55032. In cases where there isn't enough filtering in the power supply, it is also possible to place a common mode filter in either the PCB or in the cable of the power supply to reduce conducted emission. As every power supply and PCB are different Merus Audio can only provide a guideline for the common mode filter. Every product must be tested and verified in a certified EMC lab. The filter consist of a common mode choke and a capacitor (see below). The starting point for a common mode choke is in the range 2x40µH to 2x100µH + a capacitor in the range of 100nF to 220nF. Left side of the filter is connected to the power supply, right side is connected to the amplifier.

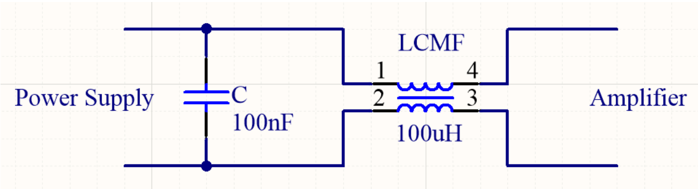

Figure 6 Common mode filter

2 Measurement results

This section shows the measurement results from tests performed on a reference board that demonstrates high audio quality, efficiency and performance.

Measurements include:

- Radiated emission test with Ferrite filter (BLE32PN300SN1L + 1nF capacitor) in BTL configuration, 40cm Speaker cable and Visaton FR 10 WP speaker.
- Radiated emission test with LC filter (1267AY-3R3N=P3 inductor + 1 µF capacitor) + damping filter (3.6Ω resistor + 2.2µF capacitor) in BTL configuration, 5M Speaker cable and Visaton FR 10 WP speaker.

2.1 EMI measurements

2.1.1 Measurement conditions

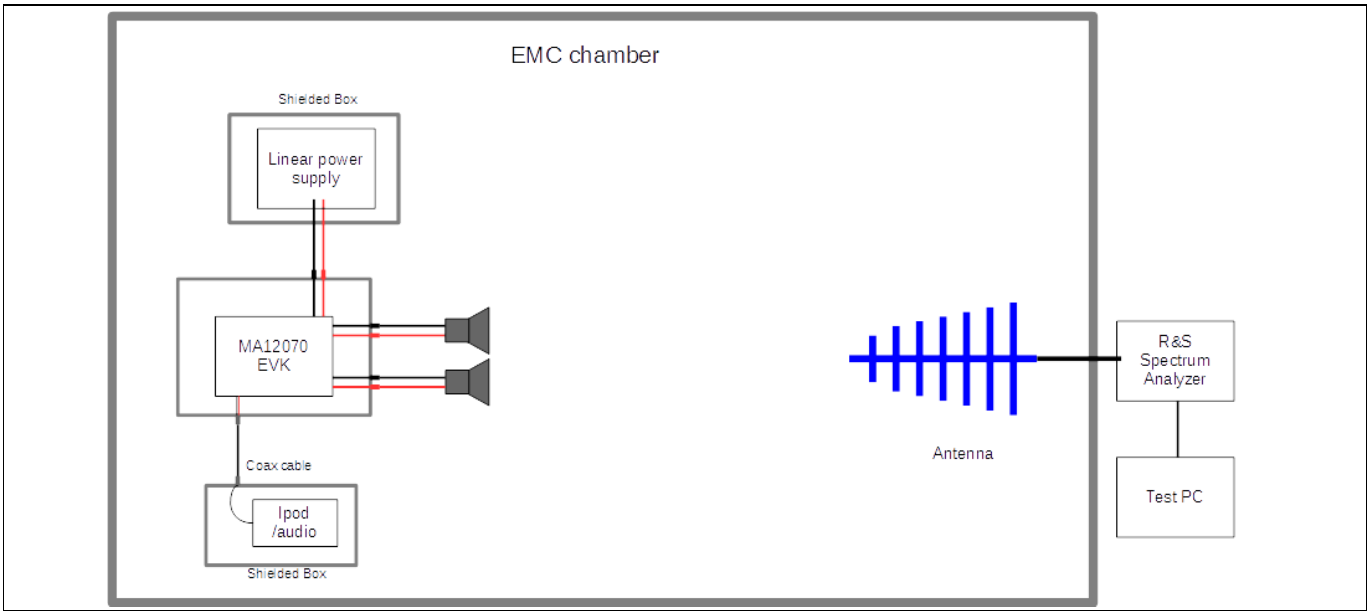

Figure 7 EMI measurement setup

The figure shows the setup for testing. Measurement results were obtained under the following conditions:

- Linear power supply: 18V-24V
- Pink noise test signal output power at 20dB gain = 3W average output power per channel
- Speaker cable length: 40cm
- Amplifier load: 4ohm speaker (Visaton FR 10 WP)
- EMI filter: Murata ferrite BLE32PN300SN1L + 1nF capacitor
- Pi filter on PVDD – Wurth ferrite 74279221100 + 2 x 22nF capacitor
- LC filter (3.3µH + 1 µF cap) + damping filter (3.6Ω resistor + 2.2µF cap).

2.1.2 Measurement results

EMI-radiated results were collected for the EVK with ferrite filter using 8 scenarios:

- Board was positioned towards the antenna and the antenna was vertical (Figure 7)
- Board was turned 90° clockwise and the antenna was Vertical (Figure 8)
- Board was positioned towards the antenna and the antenna was Horizontal (Figure 9)

Board was turned 90° clockwise and the antenna was Horizontal (Figure 10)

EMI-radiated results were collected for the EVK with LC-filter (24V PVDD and 5m speaker cable) using 4 scenarios:

- Board was positioned towards the antenna and the antenna was vertical (Figure 11)
- Board was positioned towards the antenna and the antenna was Horizontal (Figure 12)
- Board was turned 90° clockwise and the antenna was Vertical (Figure 13)
- Board was turned 90° clockwise and the antenna was Horizontal (Figure 14)

2.2 Ferrite filter measurements

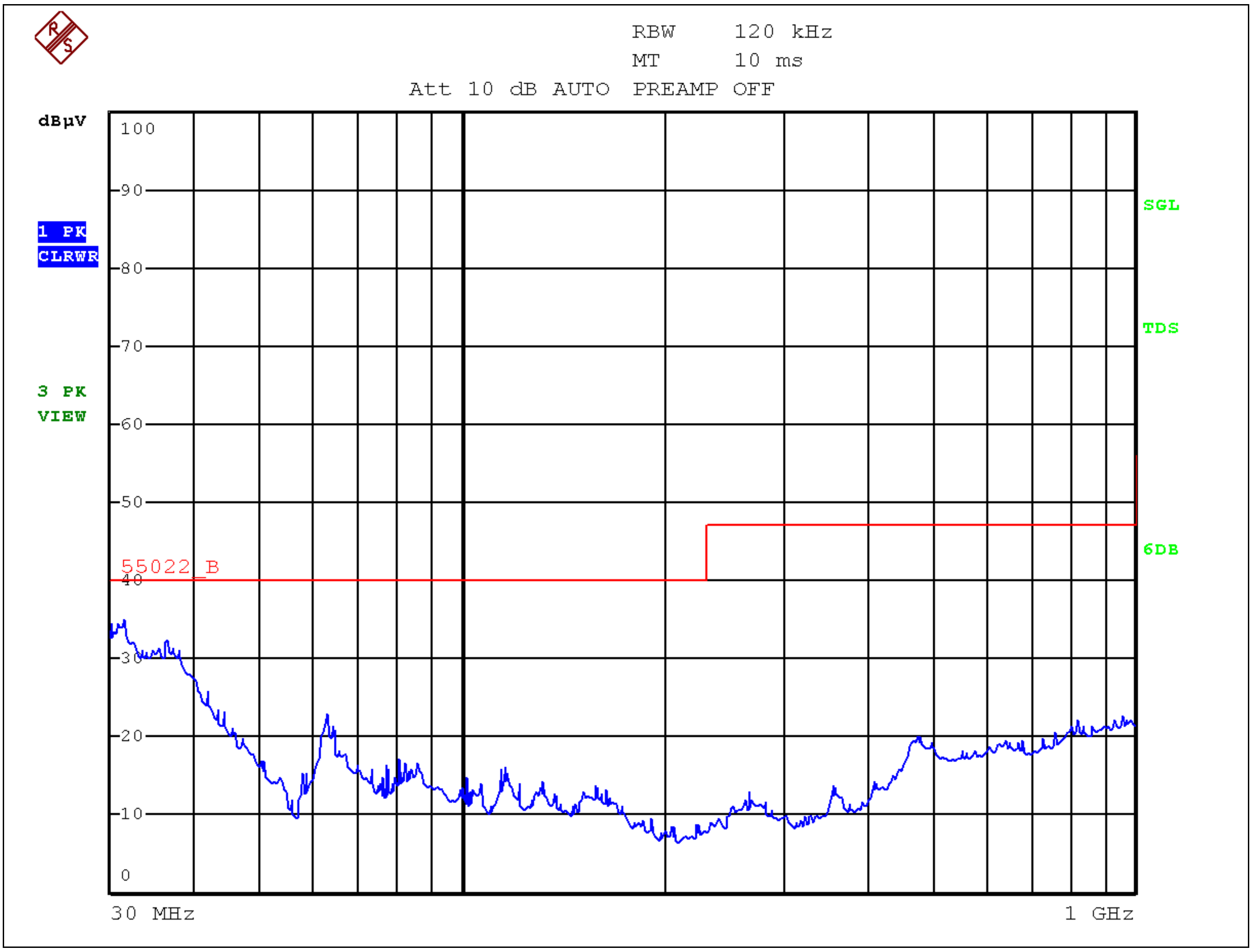

Figure 8 EMI-radiated results for EVK with ferrite filter. Board positioned towards antenna Antenna position is vertical.

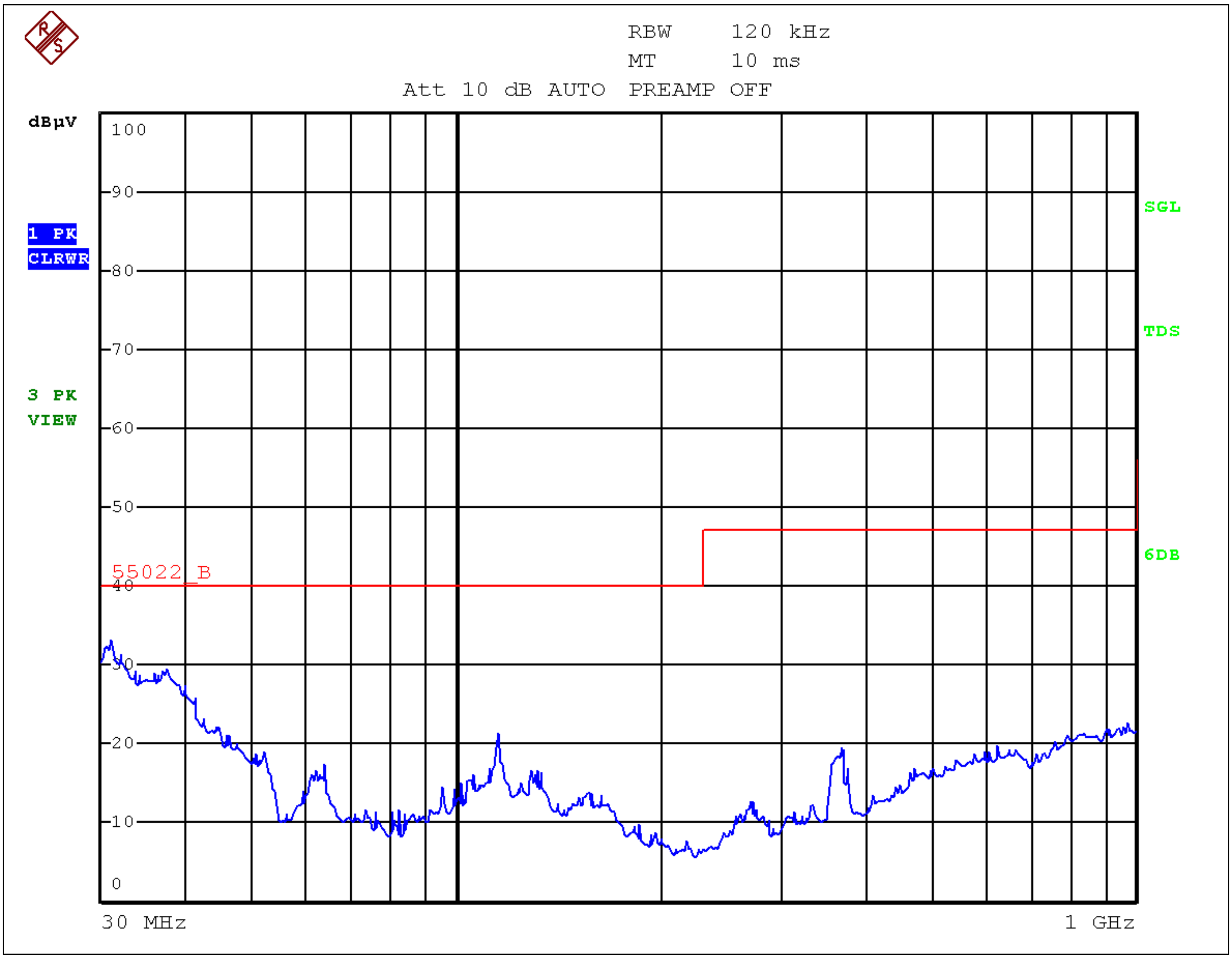

Figure 9 **EMI-radiated results for EVK with ferrite filter. Board turned CW 90°. Antenna position is vertical.**

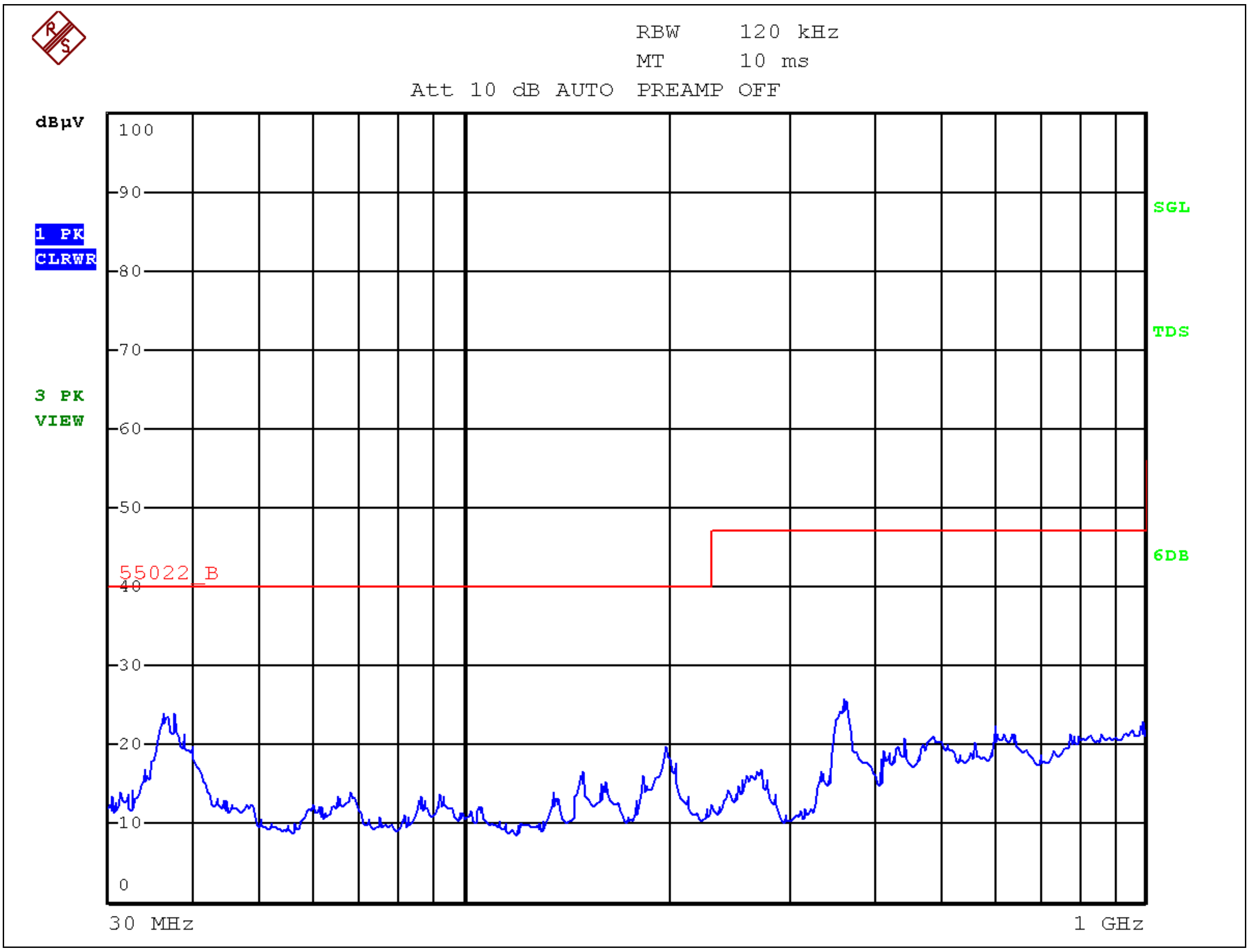

Figure 10 **EMI-radiated results for EVK with ferrite filter. Board positioned towards antenna. Antenna position is horizontal**

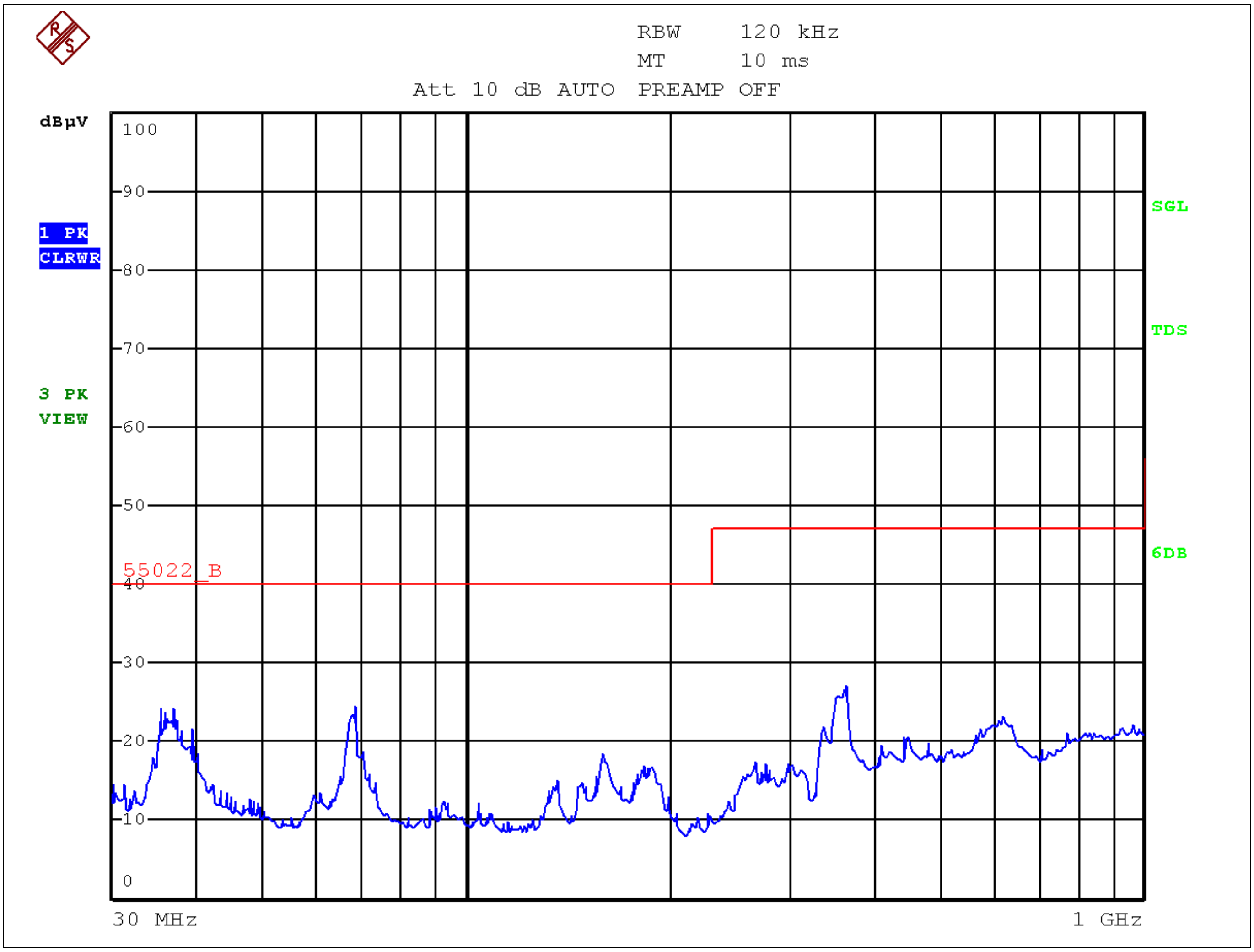

Figure 11 **EMI-radiated results for EVK with ferrite filter. Board turned CW 90°. Antenna position is Horizontal.**

2.3 LC filter measurements

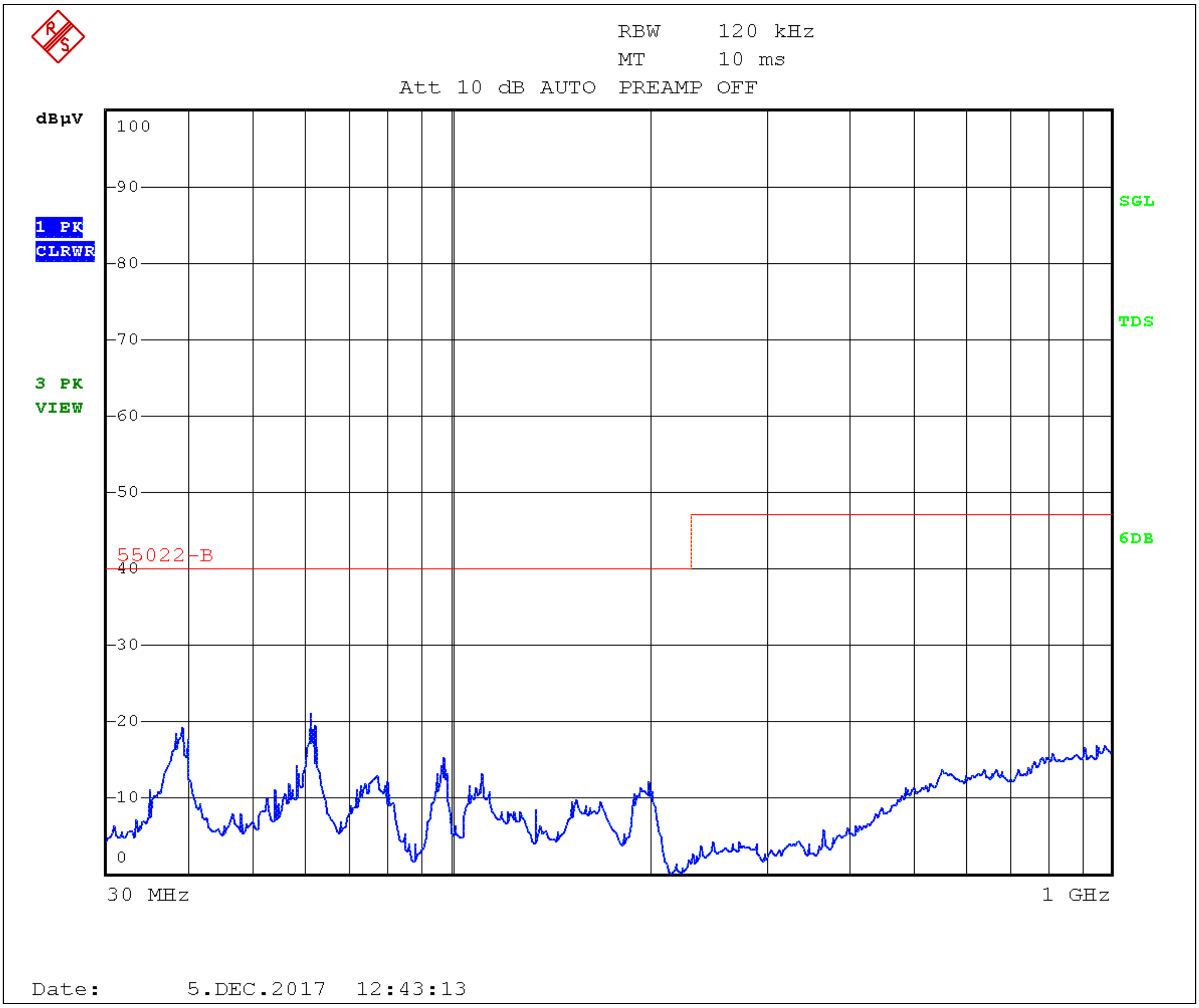

Figure 12 **EMI radiated results for EVK with LC filter. Board positioned towards antenna. Antenna position is vertical.**

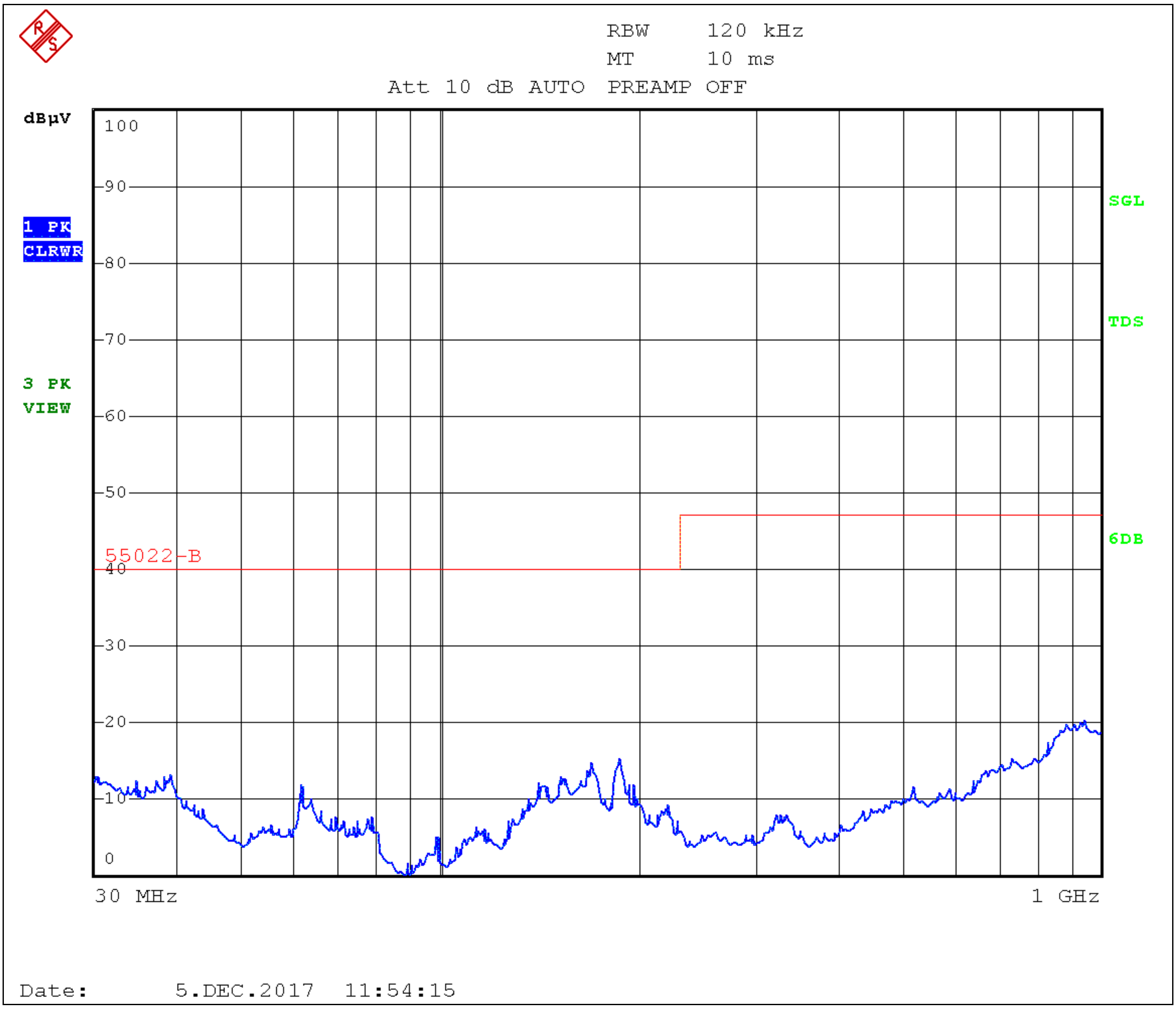

Figure 13 **EMI radiated results for EVK with LC filter. Board Positioned towards antenna. Antenna position is Horizontal**

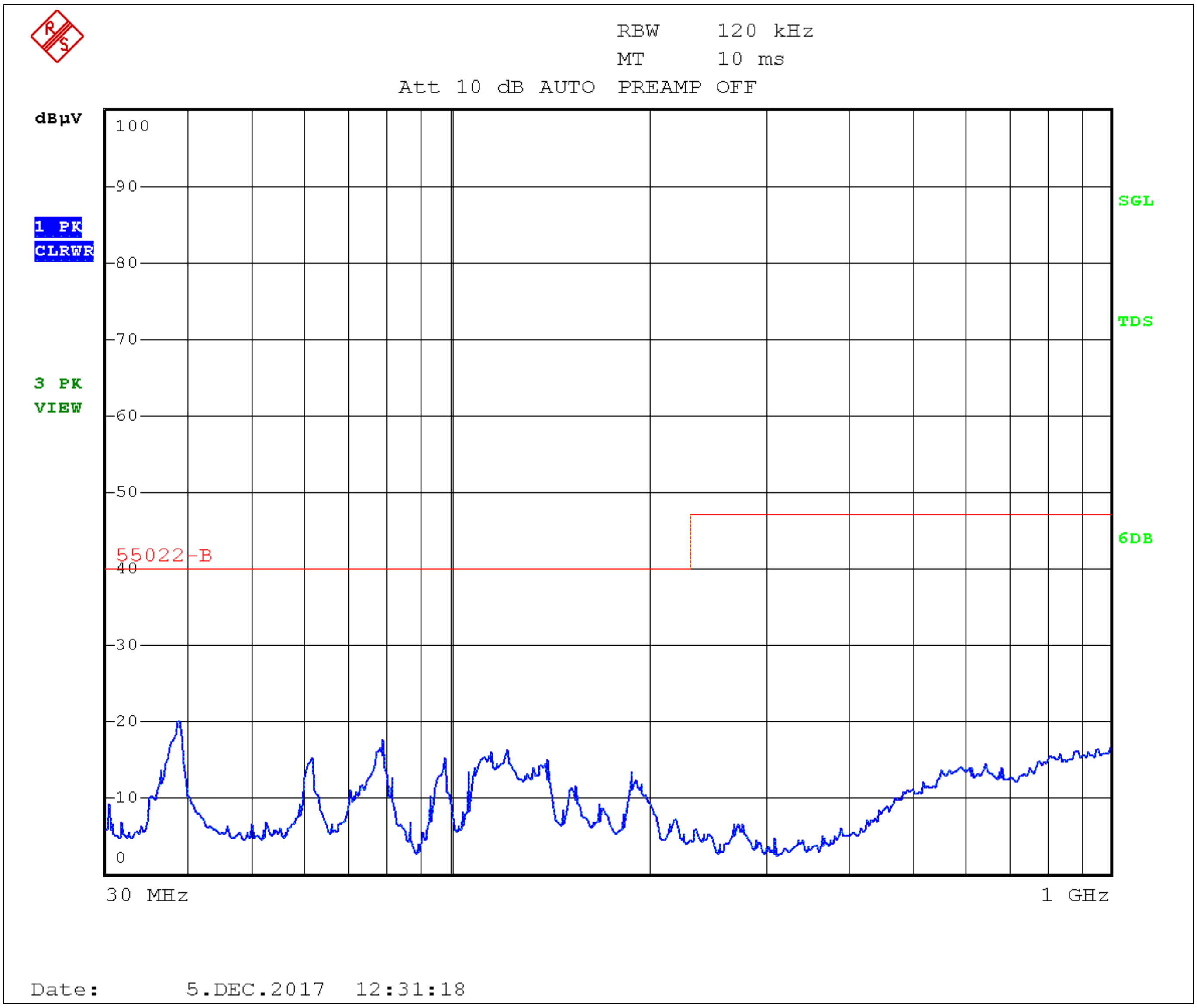

Figure 14 EMI radiated results for EVK with LC filter. Board turned 90° clockwise. Antenna position is vertical.

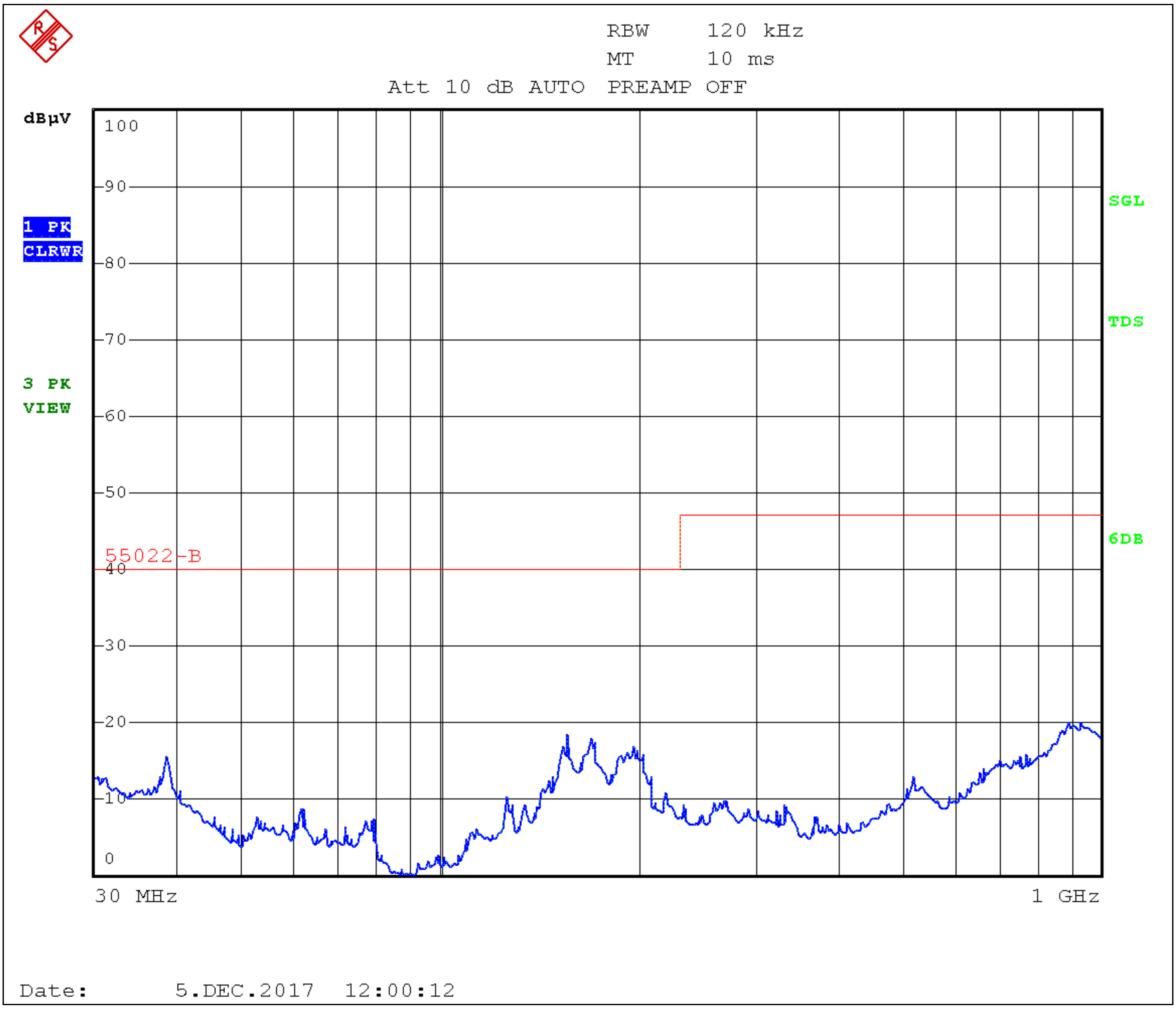

Figure 15 **EMI radiated results for EVK with LC filter. Board turned CW 90°. Antenna position is Horizontal.**

2.4 Use case - Conducted measurement results without and with filter

The following conducted measurements where performed by a customer without and with a common mode filter (2x40µH choke + 100nF cap).

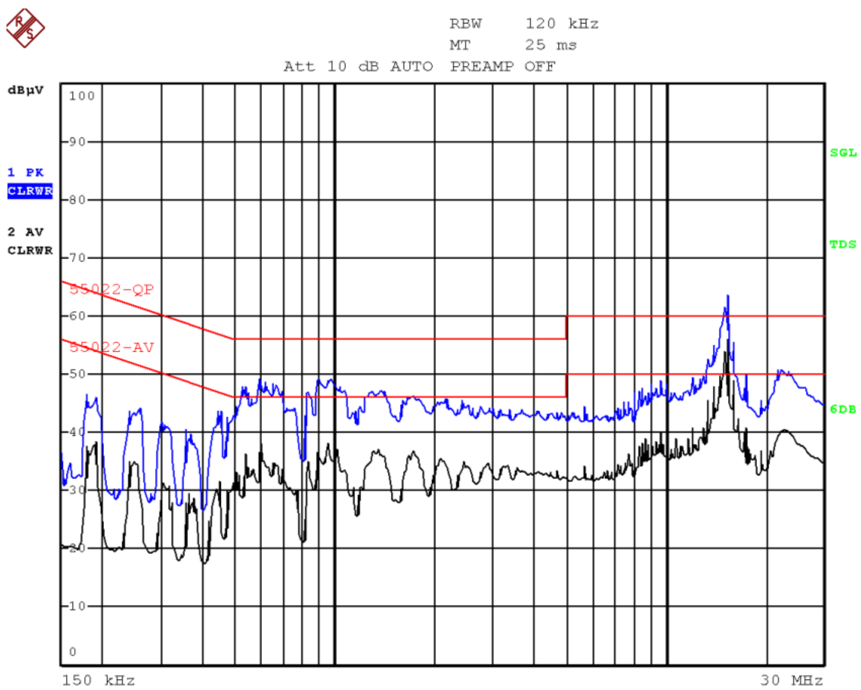

Figure 16 Conducted emission without CM filter

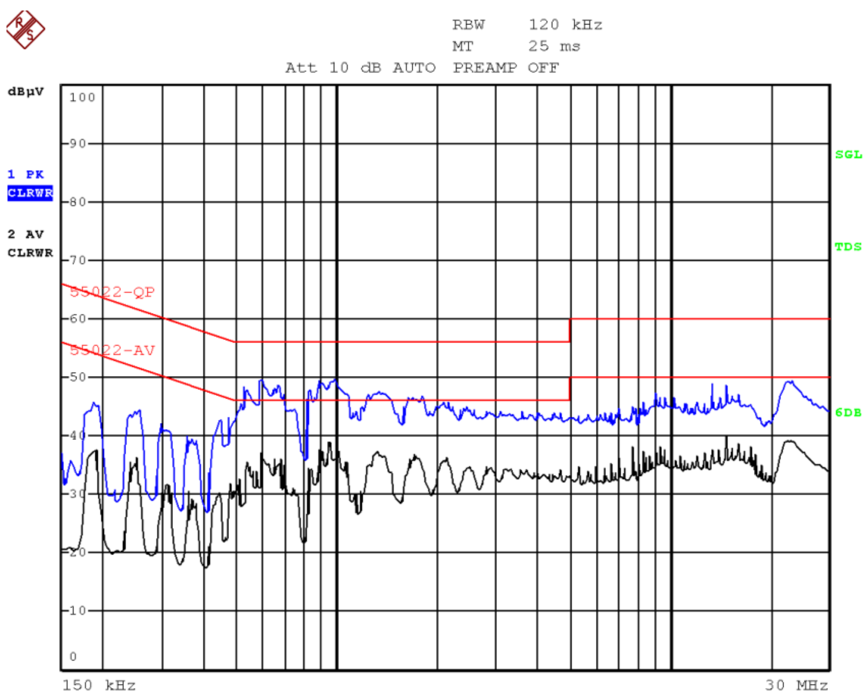

Figure 17 Conducted emission with CM filter

Revision history

Document version	Date of release	Description of changes
1.0	July 2018	Initial release in Infineon format
1.1	September 2018	Update with CM filter

Trademarks

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