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™ **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 Infineon sales and engineering team.

Intended audience

This application note is intended for 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 that it has 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 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.

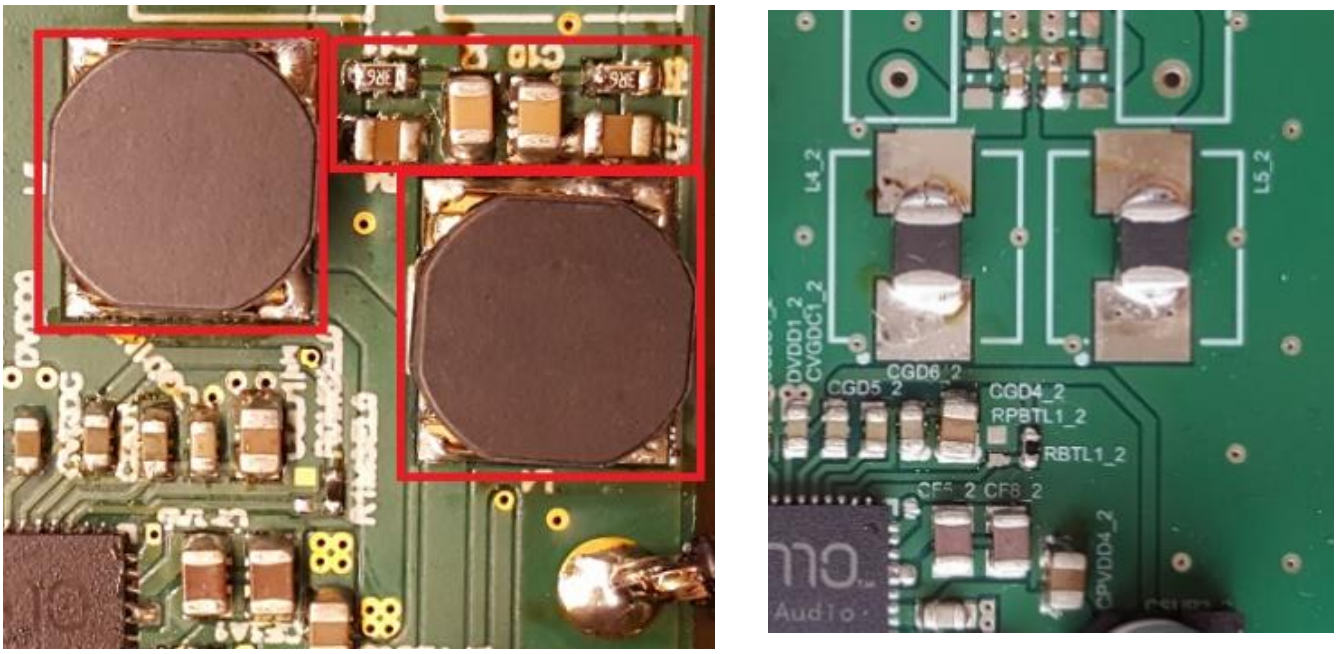

Figure 1 LC-filter (red) for one BTL output, and Ferrite filter (yellow) for one BTL output.

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.

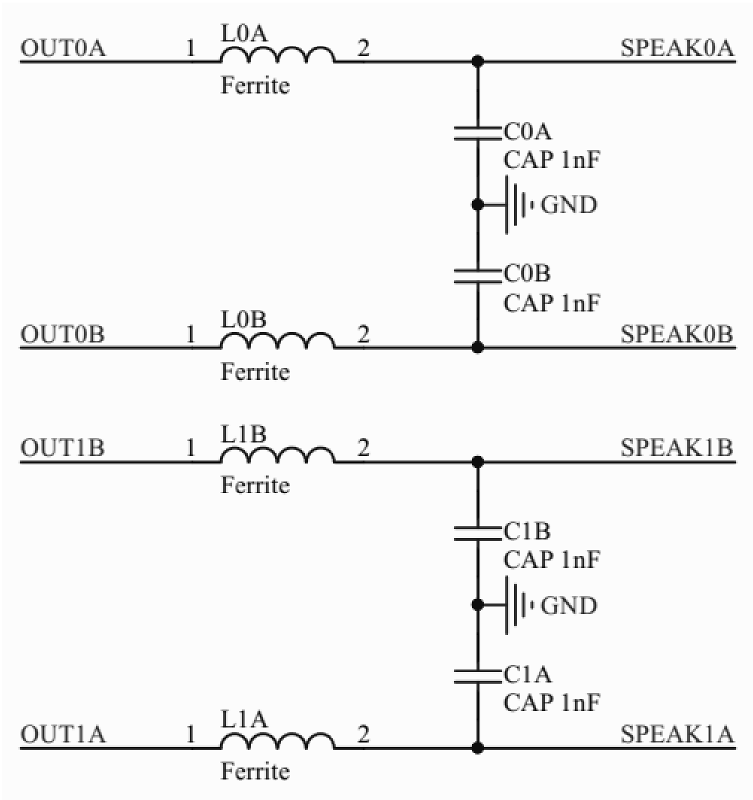

Figure 2 Typical ferrite filter for 2xBTL output for MA120xx(P) amplifiers

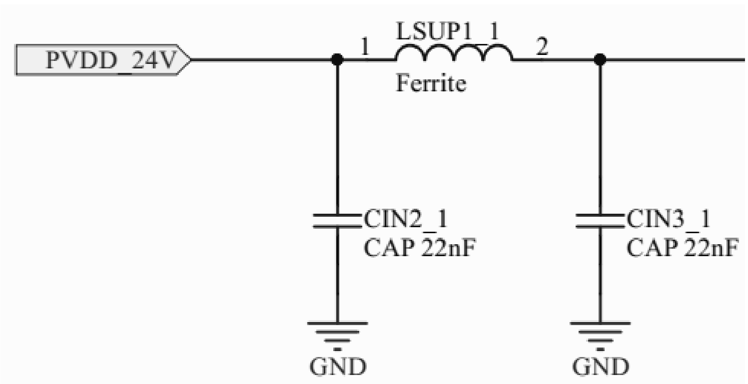

Figure 3 Input voltage Supply ferrite filter

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

The impedance of the ferrite is rated to 30 Ω at 100 MHz with a DC resistance of maximum 1.6 mΩ 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, 50 V 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 1.5 nF 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 it is recommended to use an LC filter. The schematics for the typicall recommended LC output filters are shown in **Figure 4** and **Figure 5** respectively. 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. When maximum emissions suppression is necessary in the end product design while using long speaker cables (> 60 cm), configuration 1 is the typical recommendation. This is especially valid when using more than 2 amplifiers in a multichannel design too. Configuration 2 is more suitable for single or dual amplifier designs but still when long speaker cable lengths are needed.

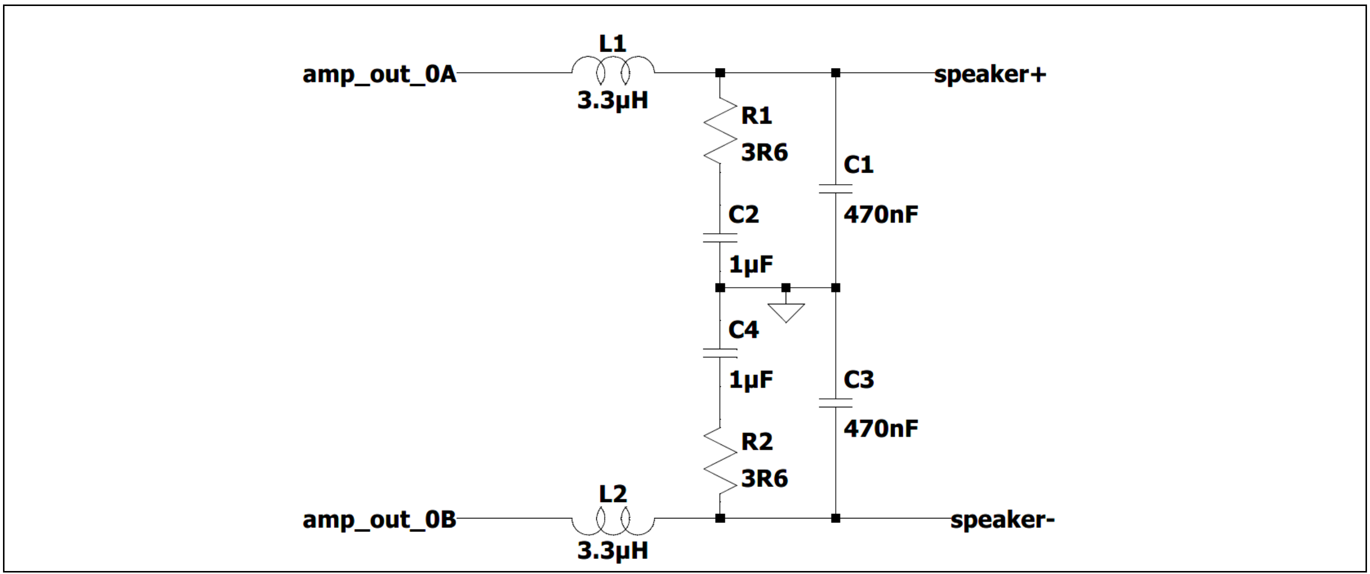

Figure 4 LC output filter configuration 1 with damping filter for 1xBTL output

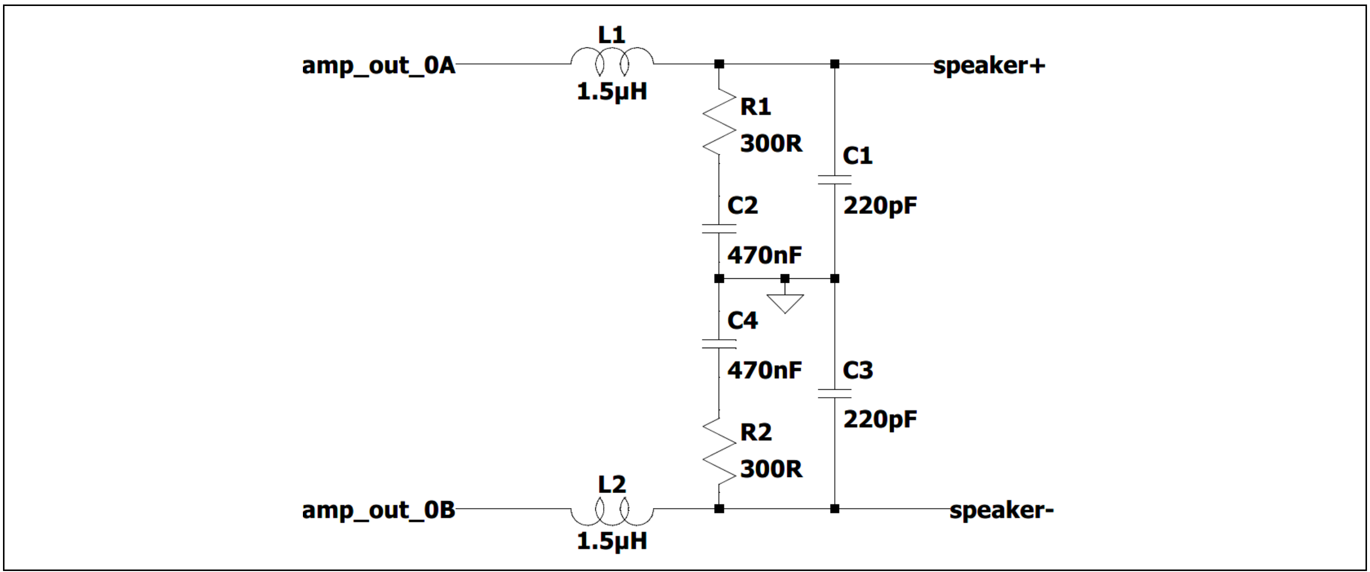

Figure 5 LC output filter configuration 2 with damping filter for 1xBTL output

The inductor is the most critical component and must be chosen carefully. An inductor of 1.5 µH or 3.3 µH (depending on the sleected configuration) in combination with the components shown above is recommended. 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 150-200 kHz is adequate.

For example, the schematic in **Figure 4** shows the nominal capacitor values with ceramic capacitors. The capacity of ceramics de-rates to roughly 50 percent, depending on the dielectrics and DC bias voltage. This means that the actual cut off frequency of the filter in **Figure 4** is about 172 kHz (simulated). For better audio quality use PET film capacitors.

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 percent, the inductor size is 8x8x4 mm (LxWxH) and the price is $0.18 (at 5K units) at different retailers. The maximum DC resistance is only 15.6 mΩ, and the power loss is low even with a 4 Ω speaker. The trade of with 1267AY-3R3N=P3 inductor is a small increase in core loss when current starts to flow through the inductor.

Amplifier stability is another issue that needs to be handled carefully when designing the LC filter. This is one of the trade-offs when using small inductors while having a low cut-off frequency close to the audible band limit (20 KHz). Even though low value inductors are cost, size and efficiency effective, configuration 1 can show some stability issues in very specific conditions depending on the loudspeaker charateristics and PVDD level. Therefore, when using high PVDD levels > 20 V, configuration 3 shown below is recommended. By increasing the inductance from 3.3 uH to 6.8 uH lower ripple current is generated which is one of the most important parameters in the amplifier control system and hence increased stability is obtained.

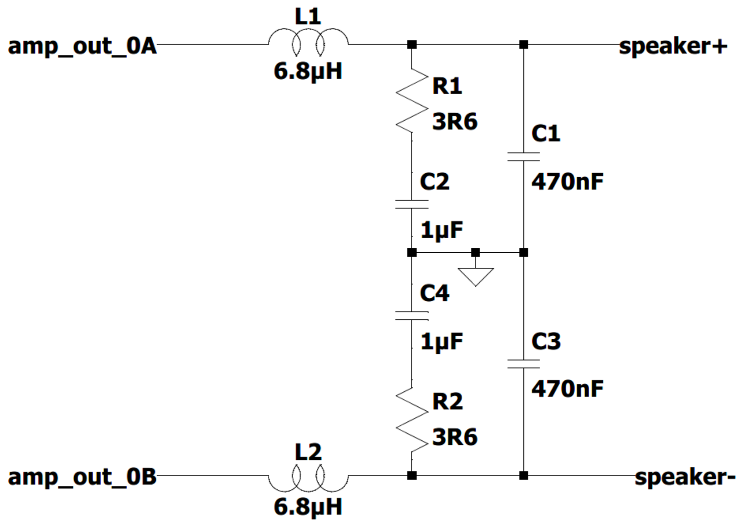

Figure 6 **LC output filter configuration 3 with damping filter for 1xBTL output**

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 it is not guaranteed 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 Figures 2 to 6.

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 7**. 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 24 V PVDD is 292.38 mW. The recommended ferrite filters add less than 3 percent to the idle power consumption. Lowering the PVDD voltage to 18 V will reduce the idle power consumption to approximately 250 mW.

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=24 V, 4 ohm	301.0 mW	301.0 mW	289.4mW	301.0 mW

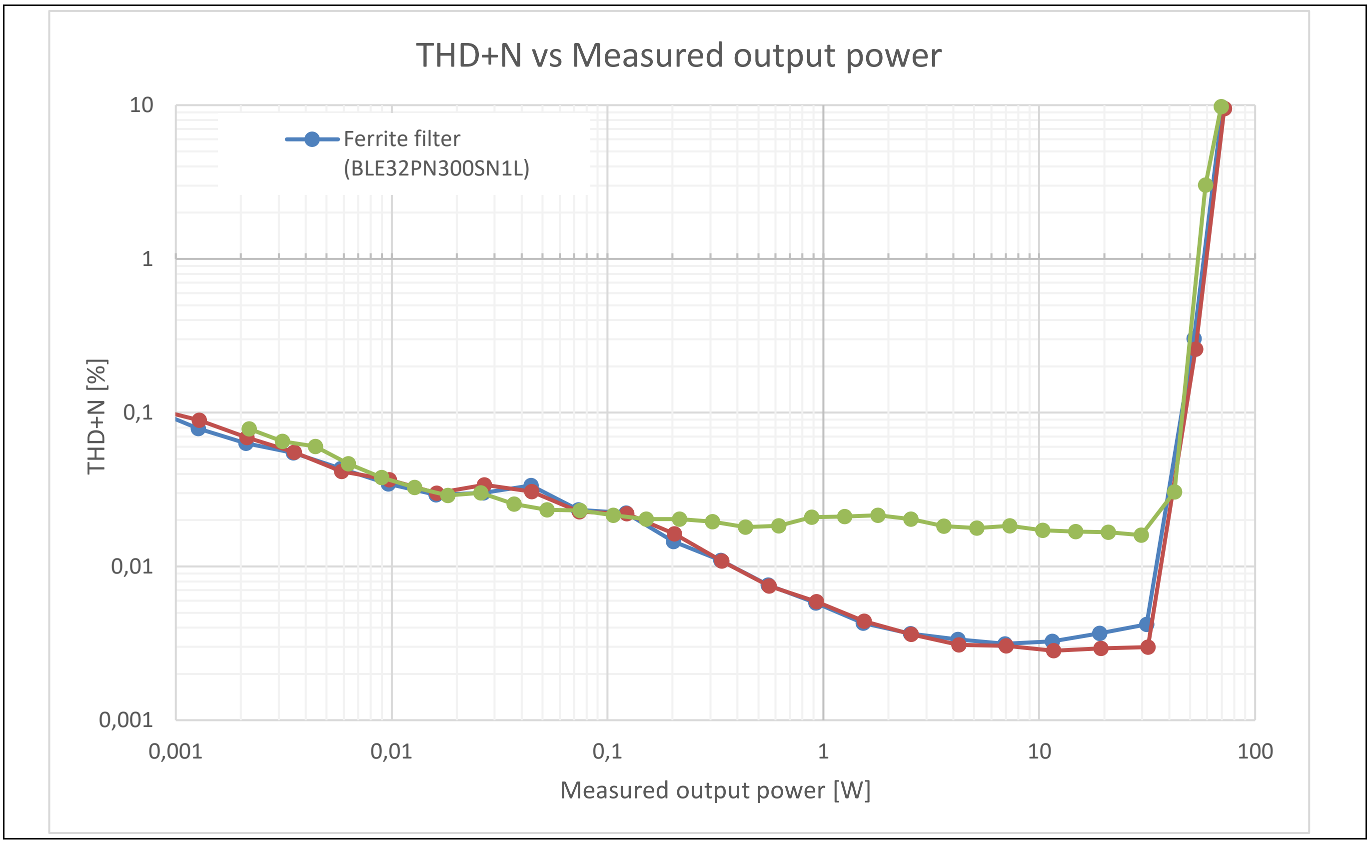

Figure 7 THD+N vs measured output power, 1kHz test tone, PMP2

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™ 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 2x40 µH to 2x100 µH + a capacitor in the range of 100 nF to 220 nF. Left side of the filter is connected to the power supply, right side is connected to the amplifier.

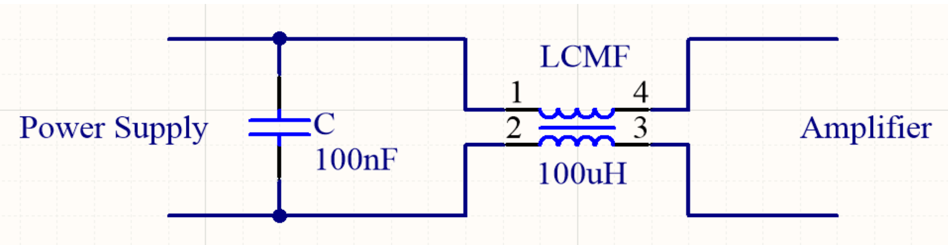

Figure 8 Common mode filter

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, 40 cm speaker cable and Visaton FR 10 WP speaker.
- Radiated emission test with LC filter configuration 1 (1267AY-3R3N=P3 inductor + 1 µF capacitor) + damping filter (3.6 Ω resistor + 2.2 µF capacitor) in BTL configuration, 5M speaker cable and Visaton FR 10 WP speaker.
- Radiated emission test with LC filter configuration 1 (1267AY-1R5N=P3 inductor + 220 pF capacitor) + damping filter (300 Ω resistor + 0.4 7µF capacitor) in BTL configuration, 5M speaker cable and Visaton FR 10 WP speaker.

2.1 EMI measurements

2.1.1 Measurement conditions and setup

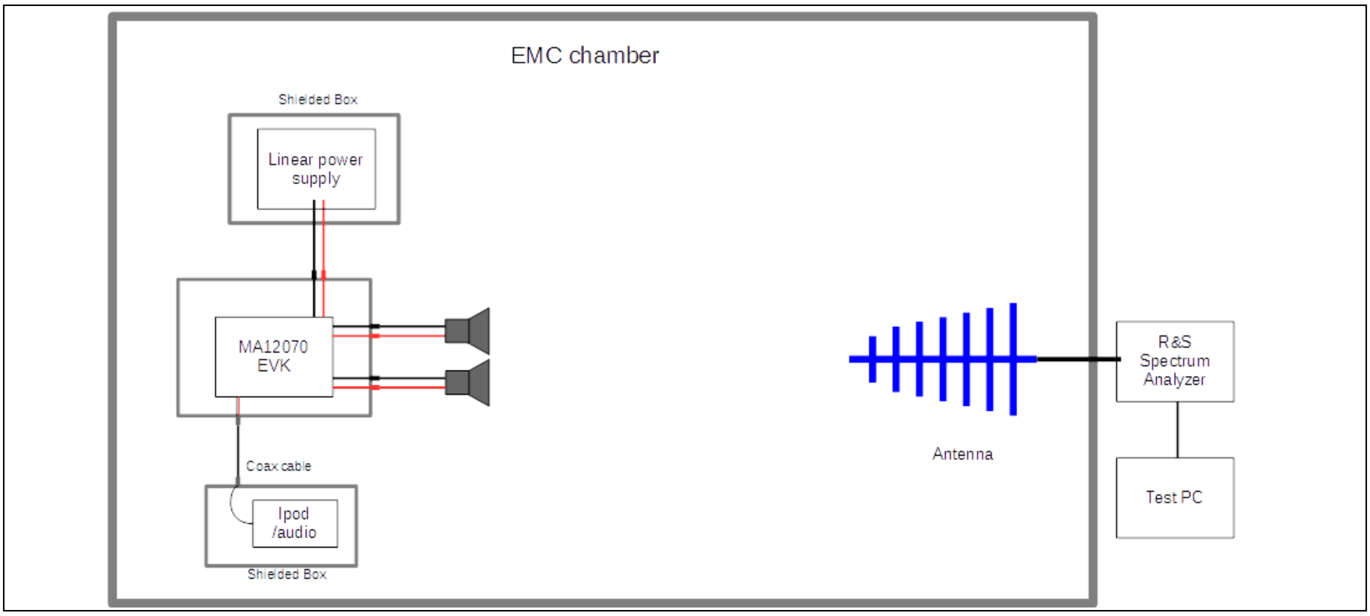

Figure 9 EMI measurement setup

Figure 9 shows the setup for testing. Measurement results were obtained under the following conditions:

- Linear power supply: 24 V
- Pink noise test signal output power at 20 dB gain = 3 W average output power per channel
- Speaker cable length: 40 cm
- Amplifier load: 4 ohm speaker (Visaton FR 10 WP)
- Pi filter on PVDD – Wurth ferrite 74279221100 + 2 x 22nF capacitor

2.2 Measurement results

EMI-radiated results were collected for the EVK with ferrite filter (24V PVDD and 40 cm speaker cable) using 4 scenarios:

- Board was positioned towards the antenna and the antenna was vertical
- Board was turned 90° clockwise and the antenna was vertical
- Board was positioned towards the antenna and the antenna was horizontal
- Board was turned 90° clockwise and the antenna was horizontal

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

- Board was positioned towards the antenna and the antenna was vertical
- Board was positioned towards the antenna and the antenna was horizontal
- Board was turned 90° clockwise and the antenna was vertical
- Board was turned 90° clockwise and the antenna was horizontal

2.2.1 Ferrite filter measurements

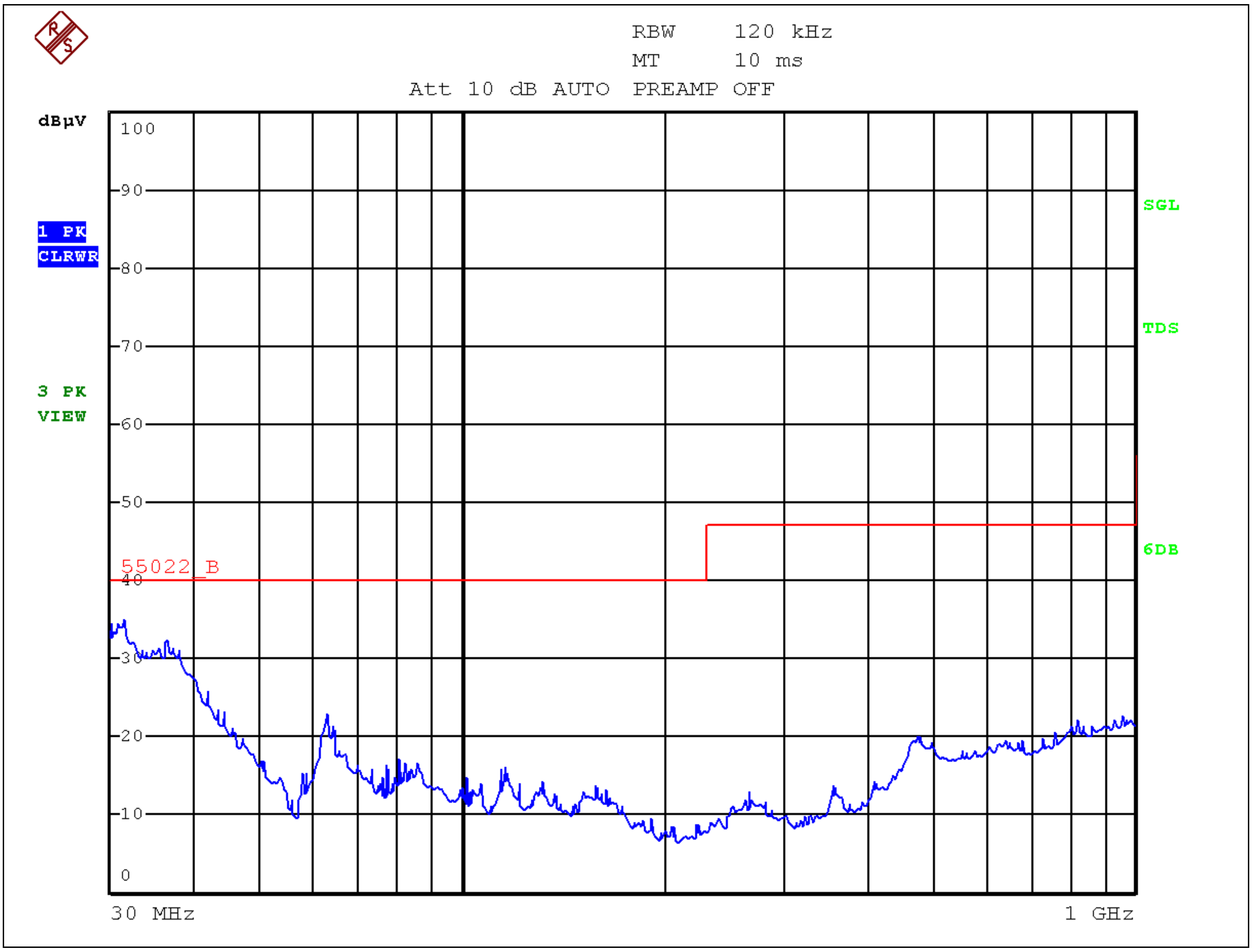

Figure 10 **EMI-radiated results for EVK with ferrite filter. Board positioned towards antenna. Antenna position is vertical.**

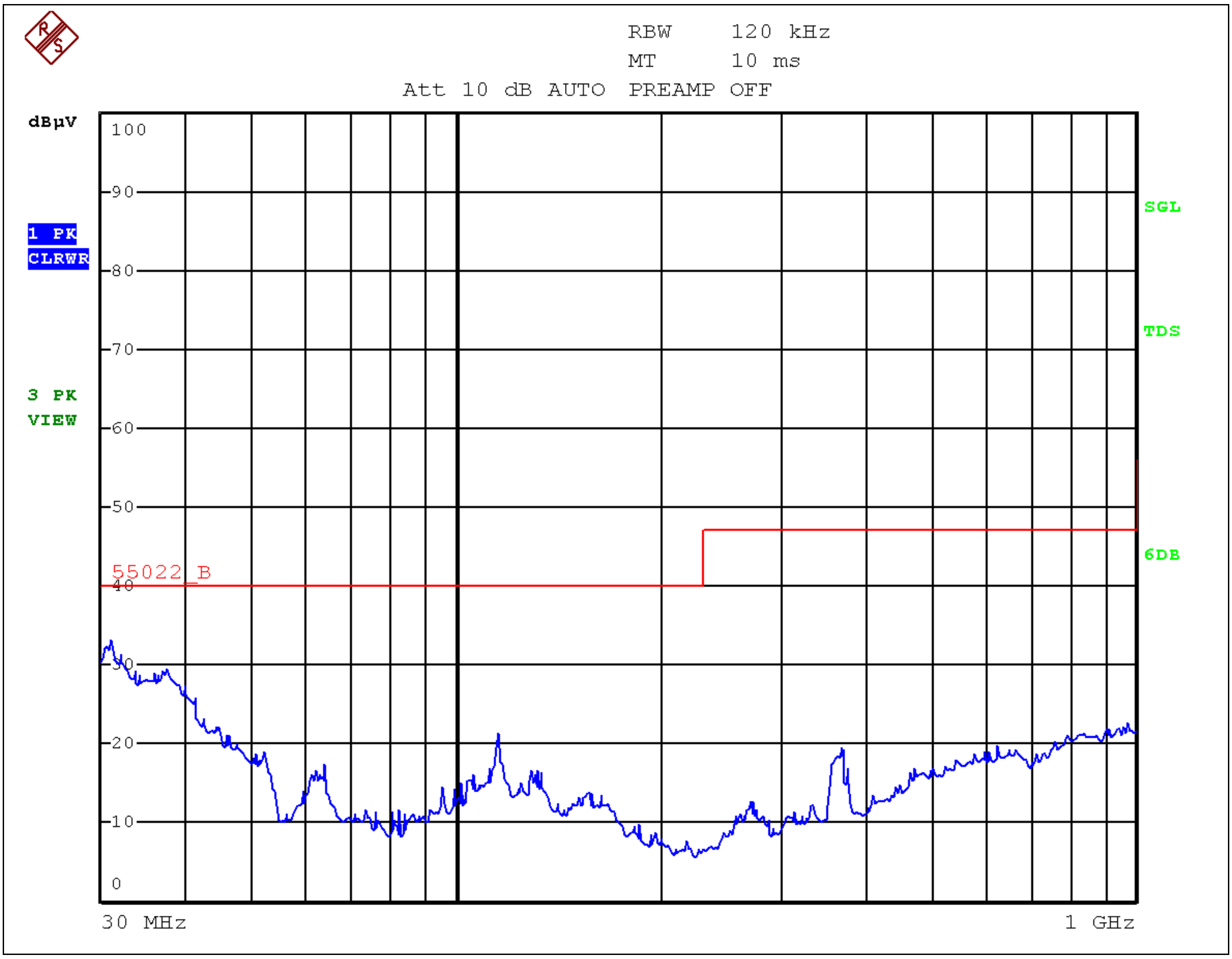

Figure 11 **EMI-radiated results for EVK with ferrite filter. Board turned CW 90°. Antenna position is vertical.**

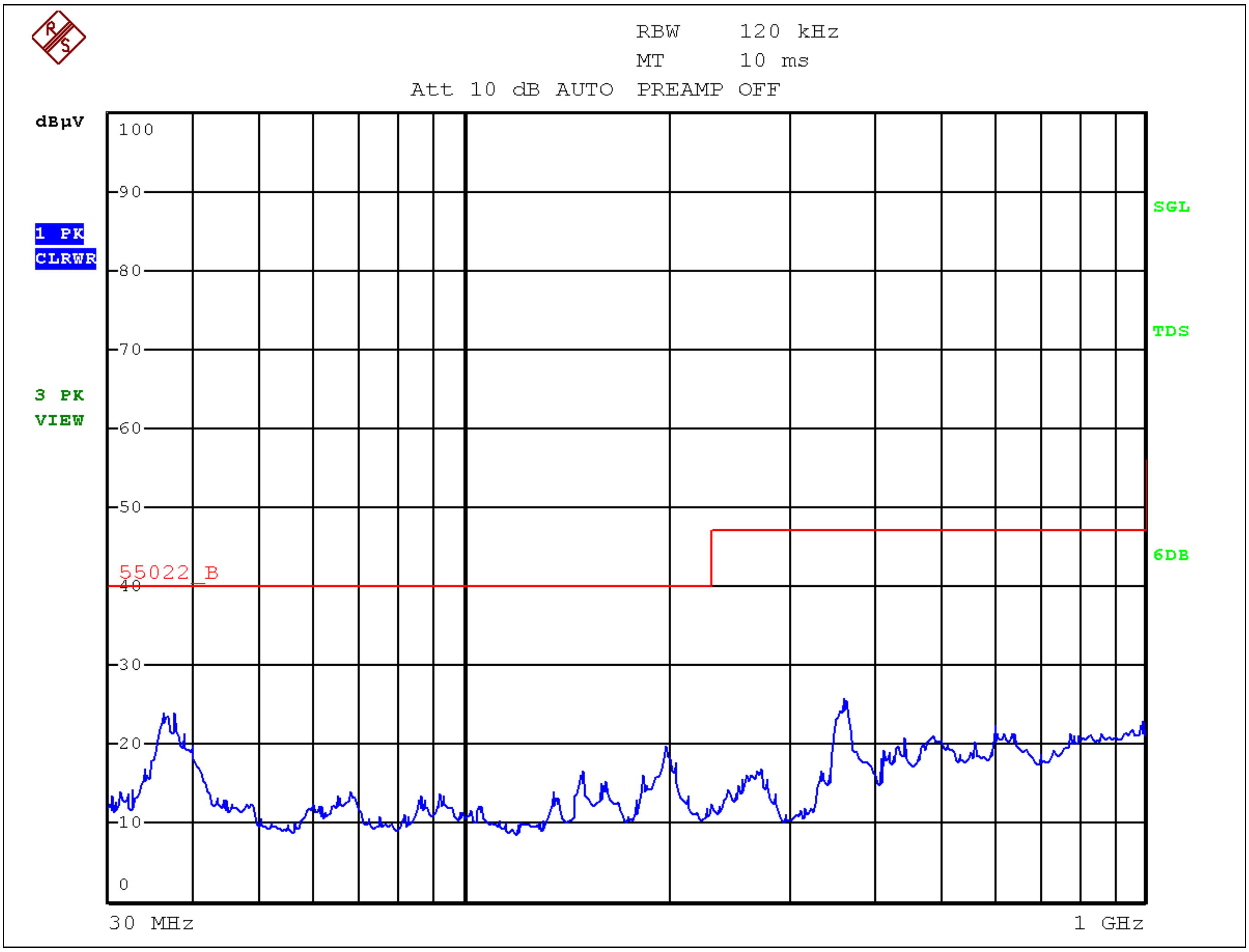

Figure 12 **EMI-radiated results for EVK with ferrite filter. Board positioned towards antenna. Antenna position is horizontal**

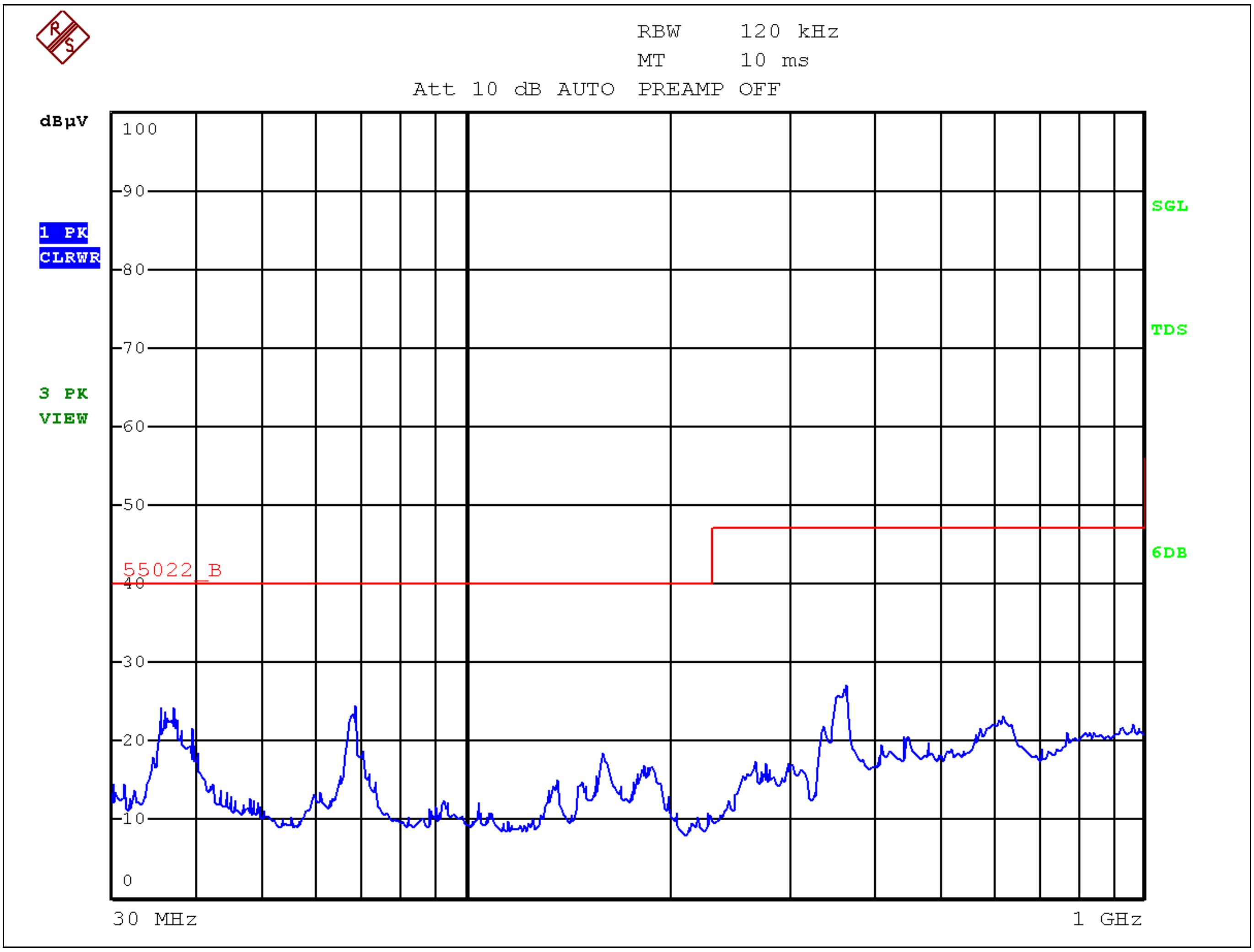

Figure 13 **EMI-radiated results for EVK with ferrite filter. Board turned CW 90°. Antenna position is horizontal.**

2.2.2 LC filter configuration 1 measurements

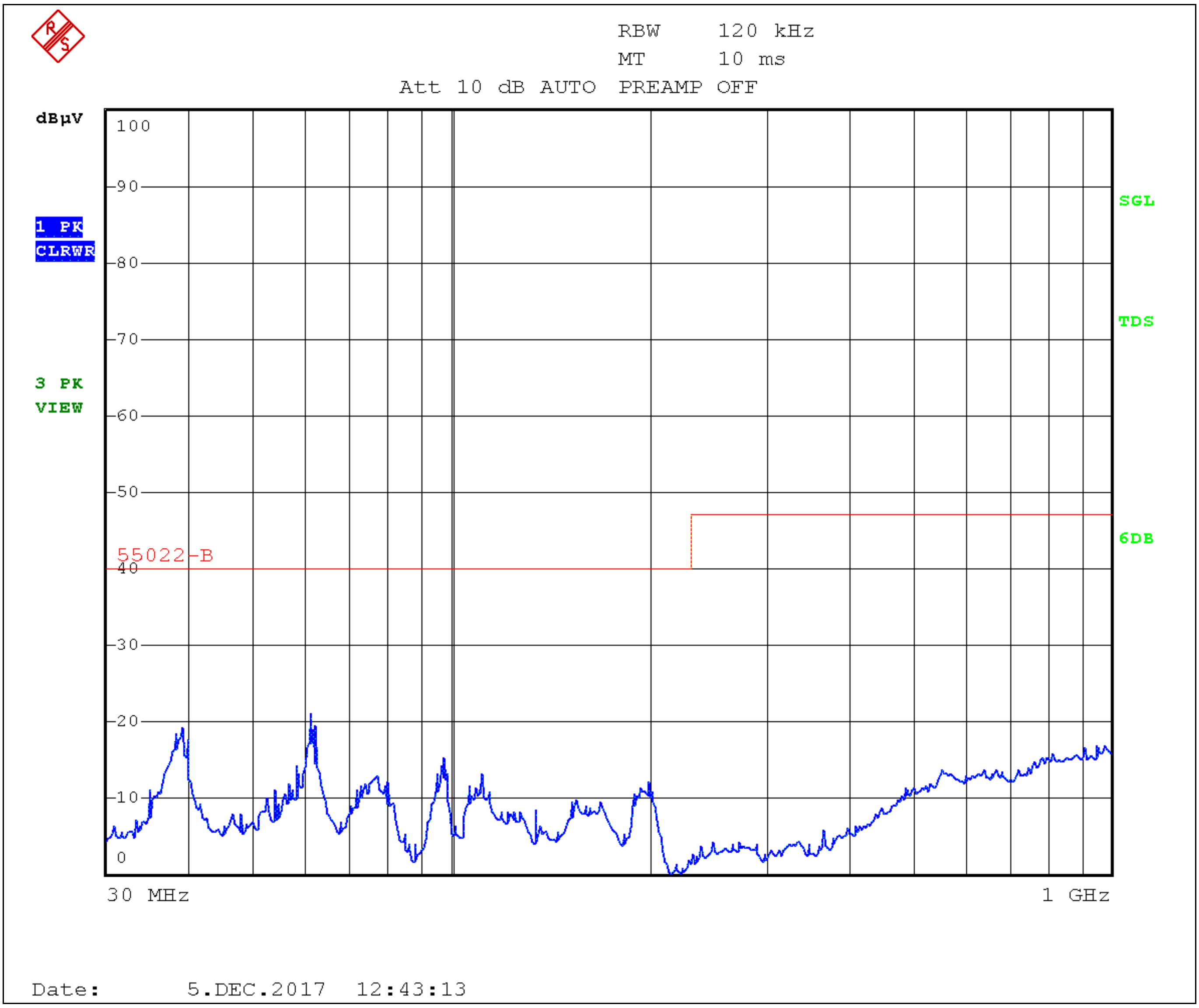

Figure 14 **EMI radiated results for EVK with LC filter. Board positioned towards antenna. Antenna position is vertical.**

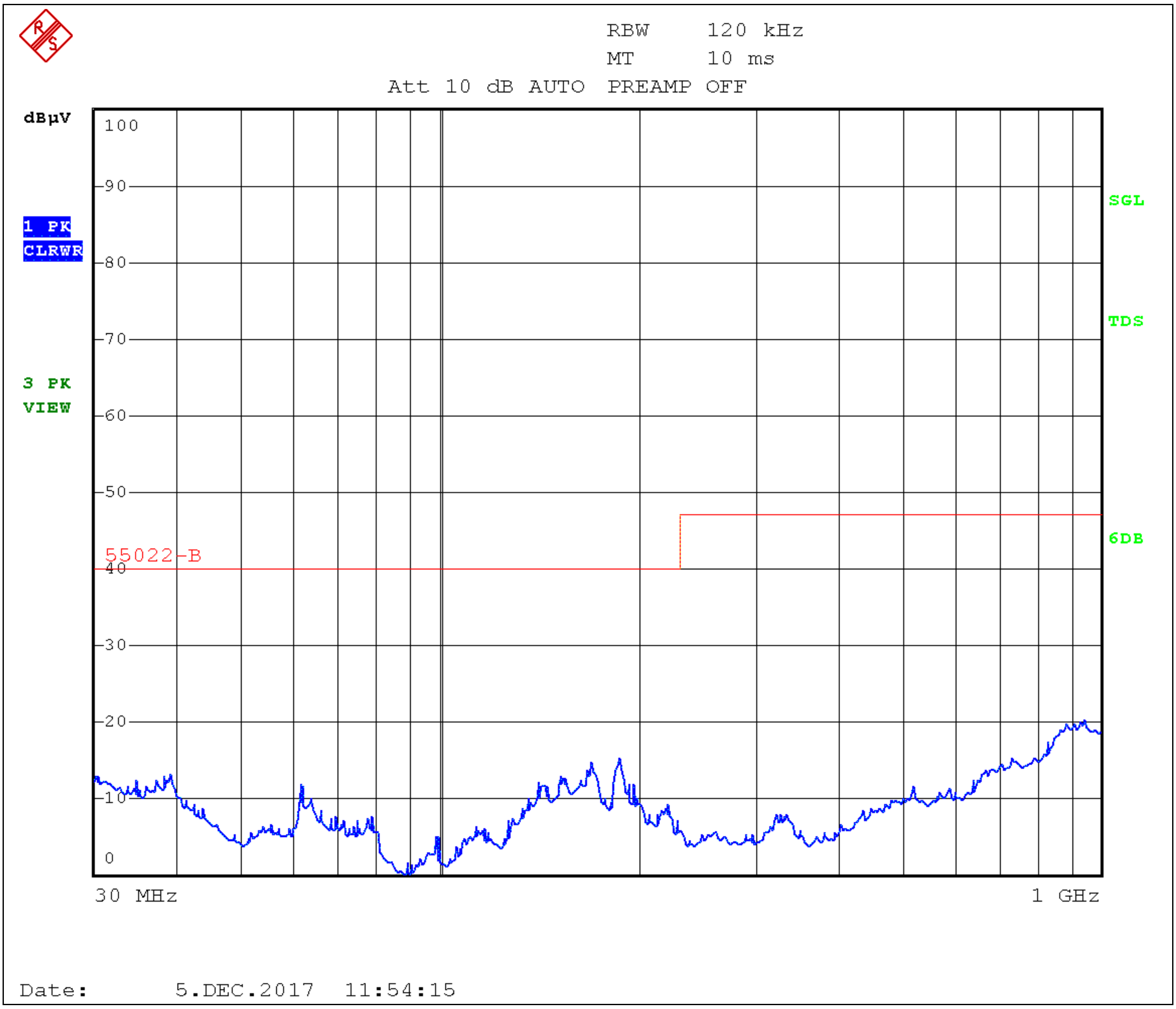

Figure 15 **EMI radiated results for EVK with LC filter. Board Positioned towards antenna. Antenna position is horizontal.**

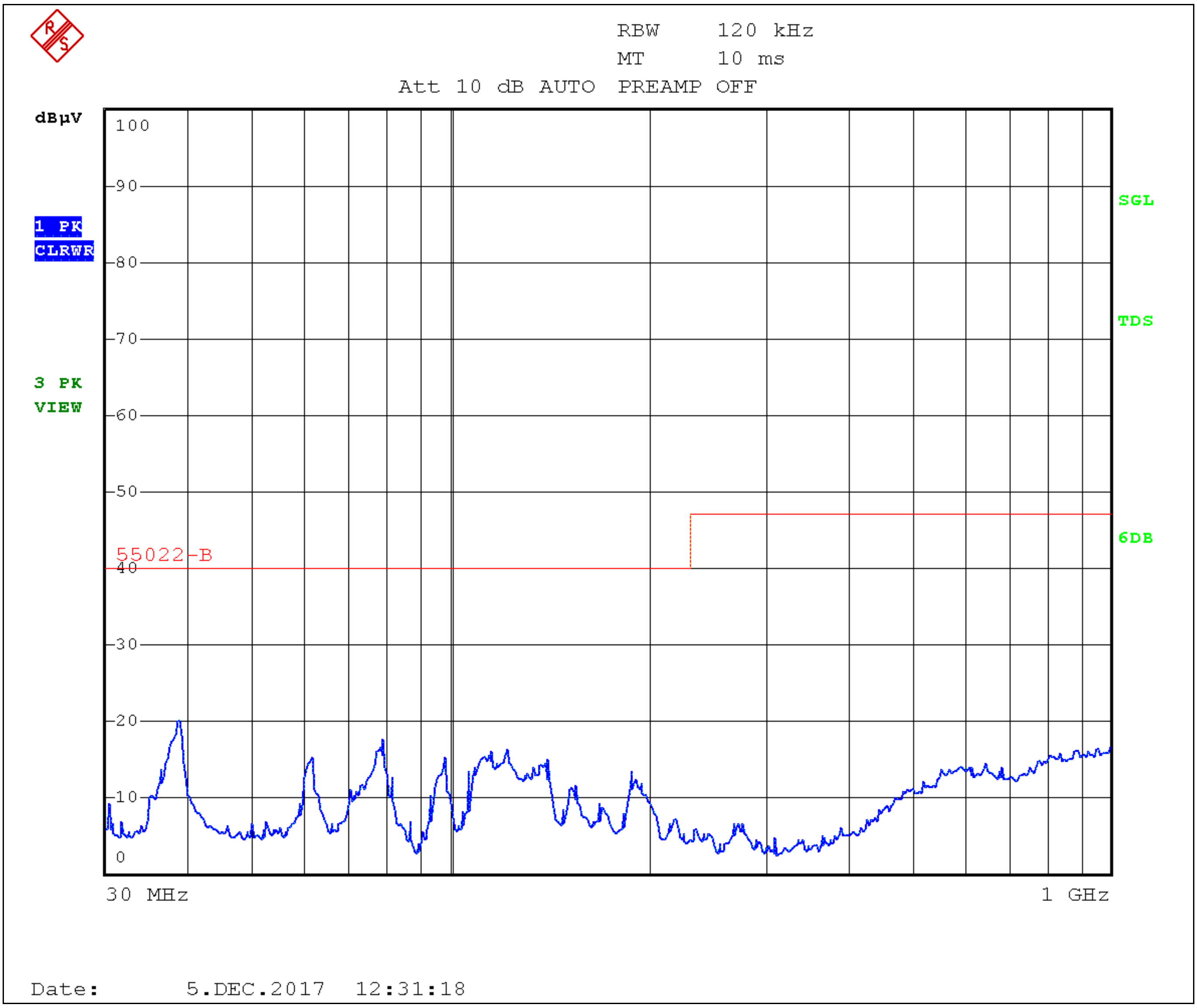

Figure 16 **EMI radiated results for EVK with LC filter. Board turned 90° clockwise. Antenna position is vertical.**

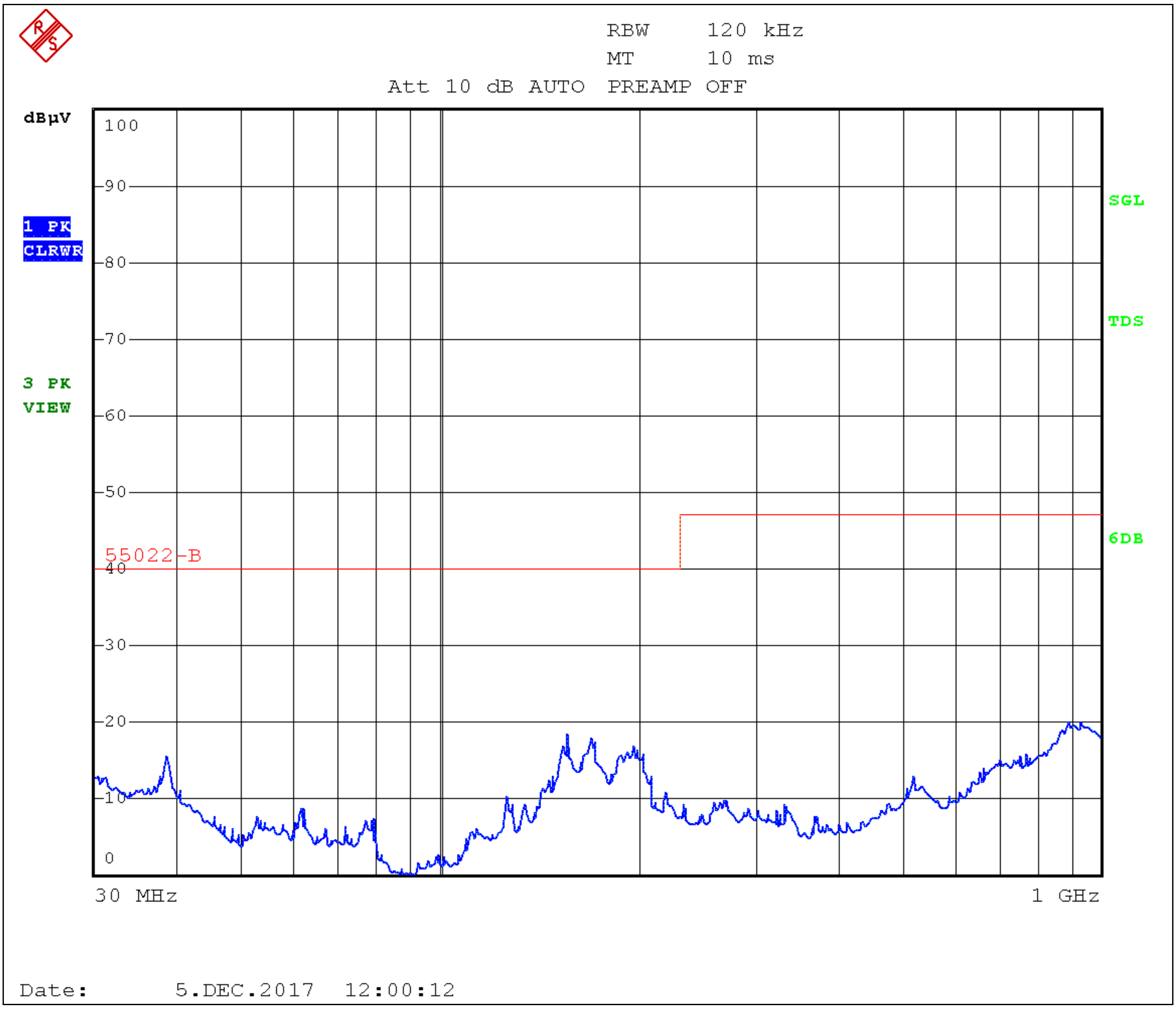

Figure 17 **EMI radiated results for EVK with LC filter. Board turned CW 90°. Antenna position is horizontal.**

2.2.3 LC filter configuration 2 measurements

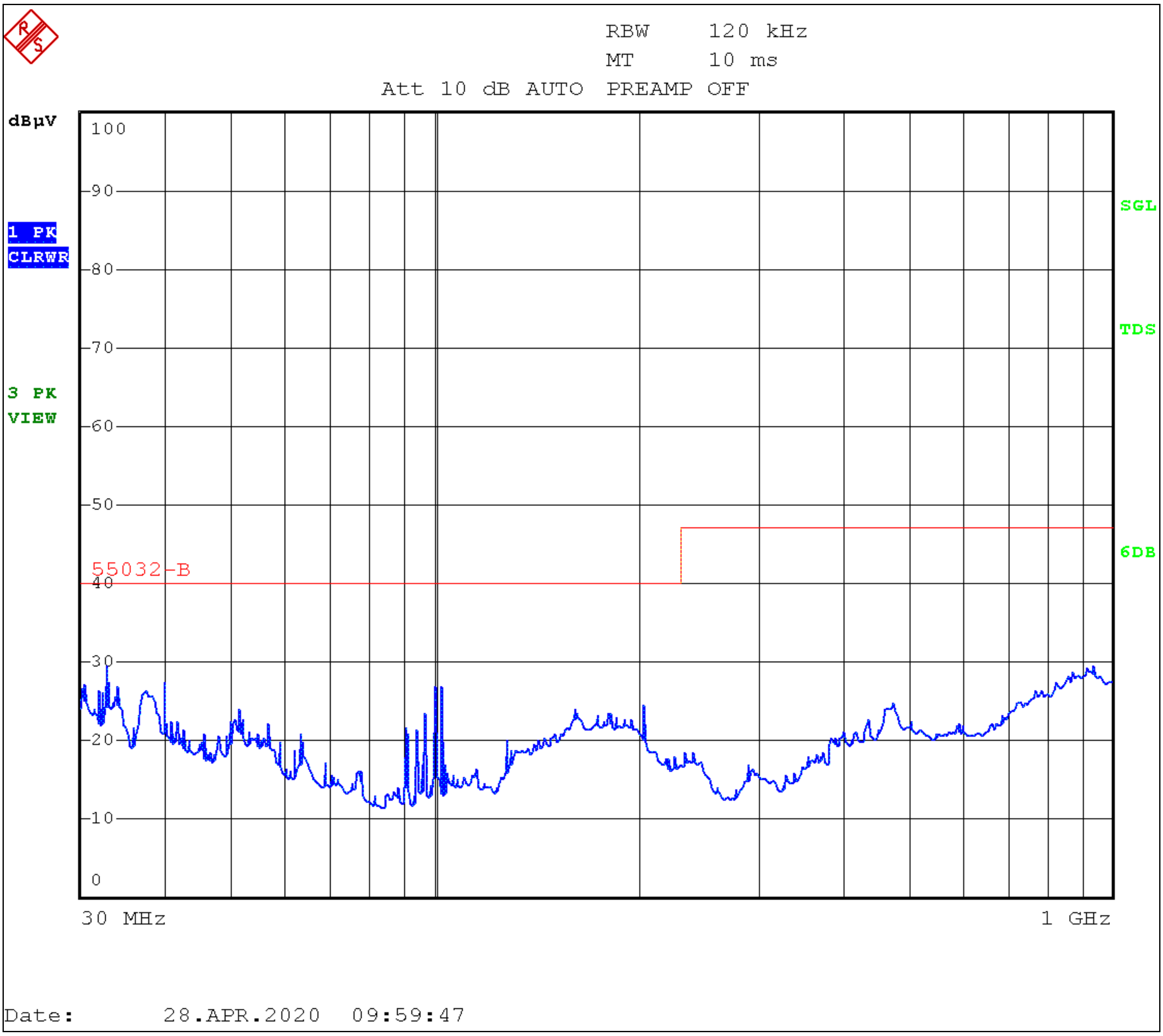

Figure 18 **EMI radiated results for EVK with LC filter configuration 2. Board positioned towards the antenna. Antenna's position is vertical.**

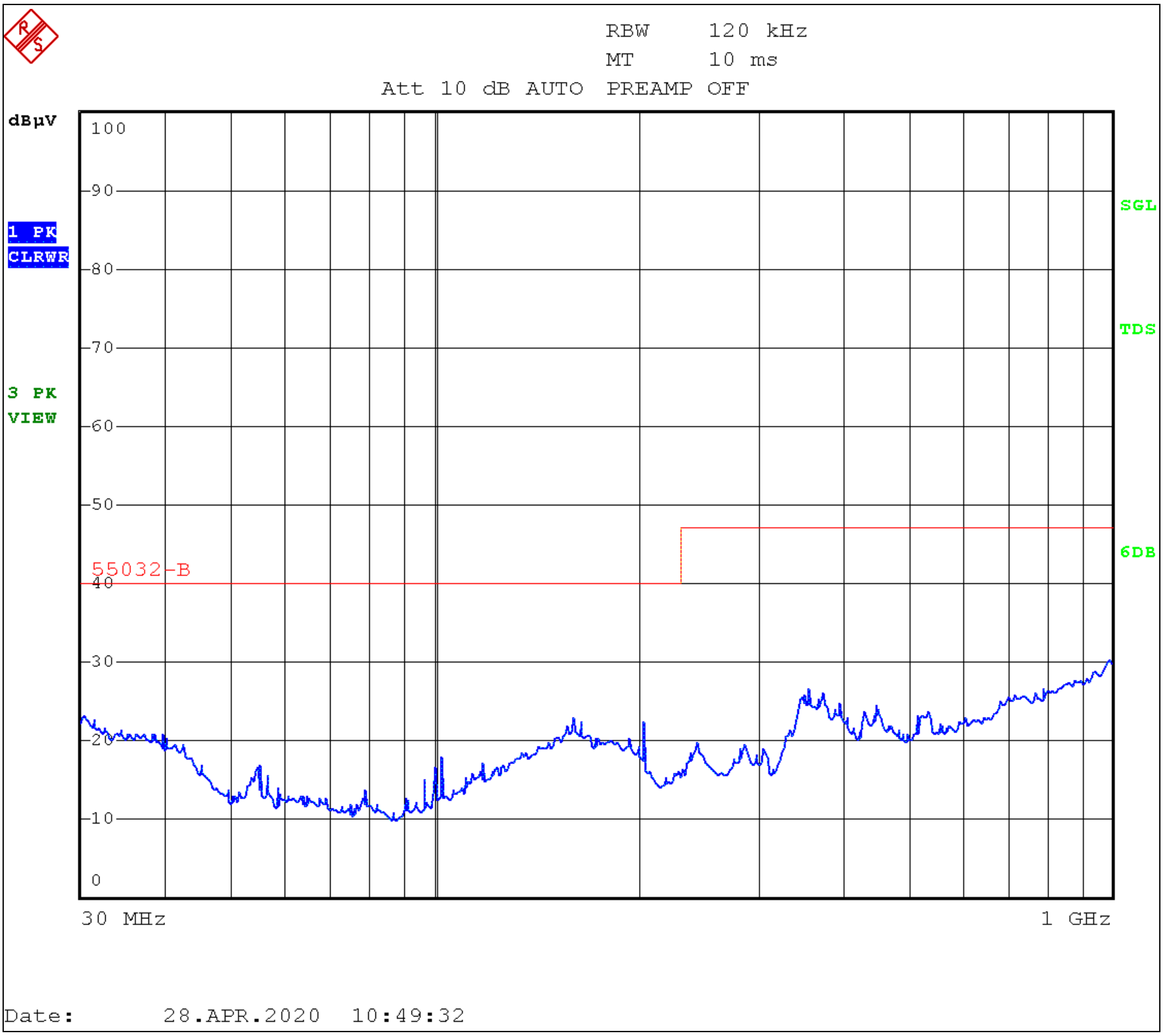

Figure 19 EMI radiated results for EVK with LC filter configuration 2. Board positioned towards the antenna. Antenna's position is horizontal

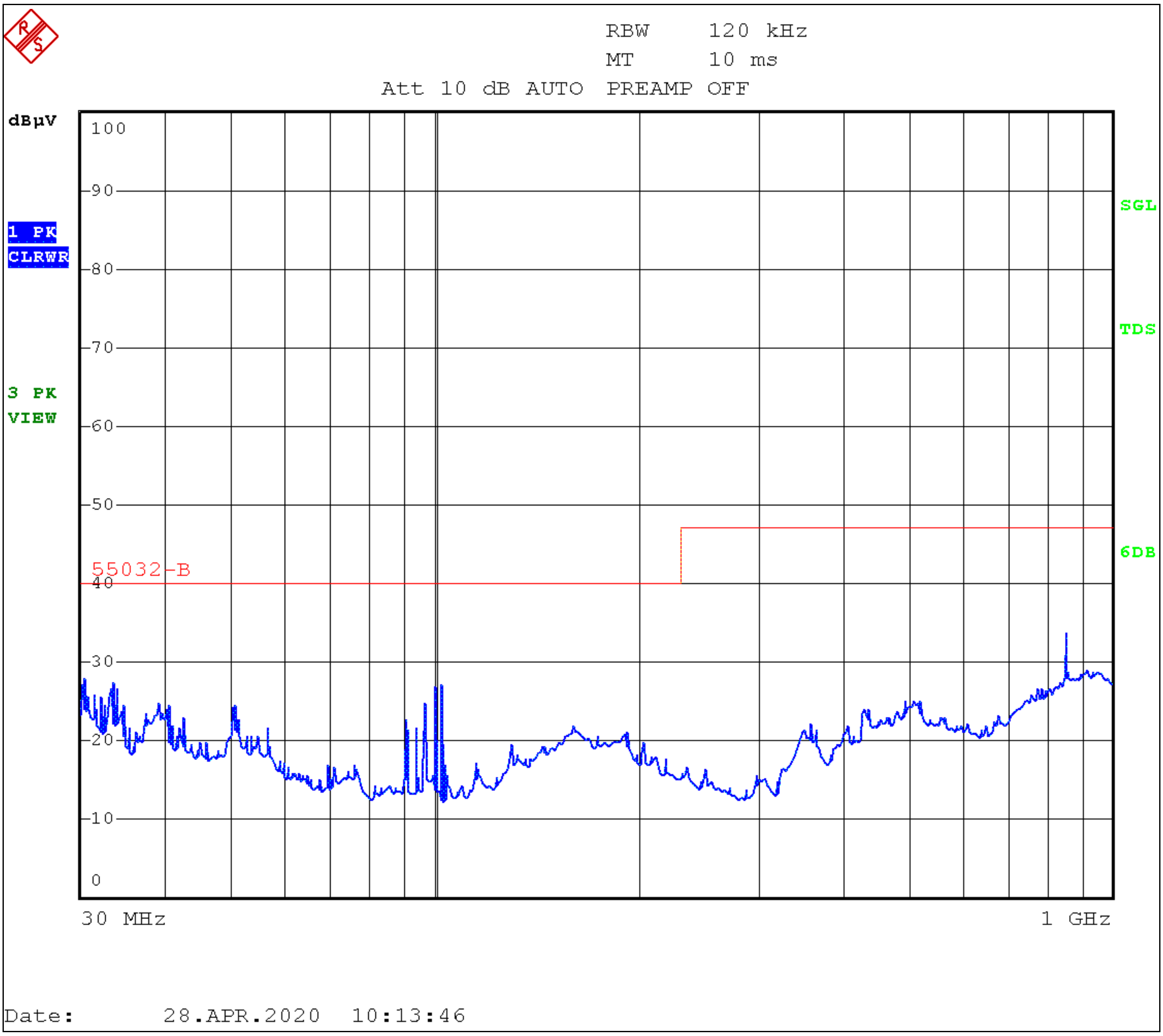

Figure 20 **EMI radiated results for EVK with LC filter configuration 2. Board turned 90° clockwise. Antenna's position is vertical.**

Measurement results

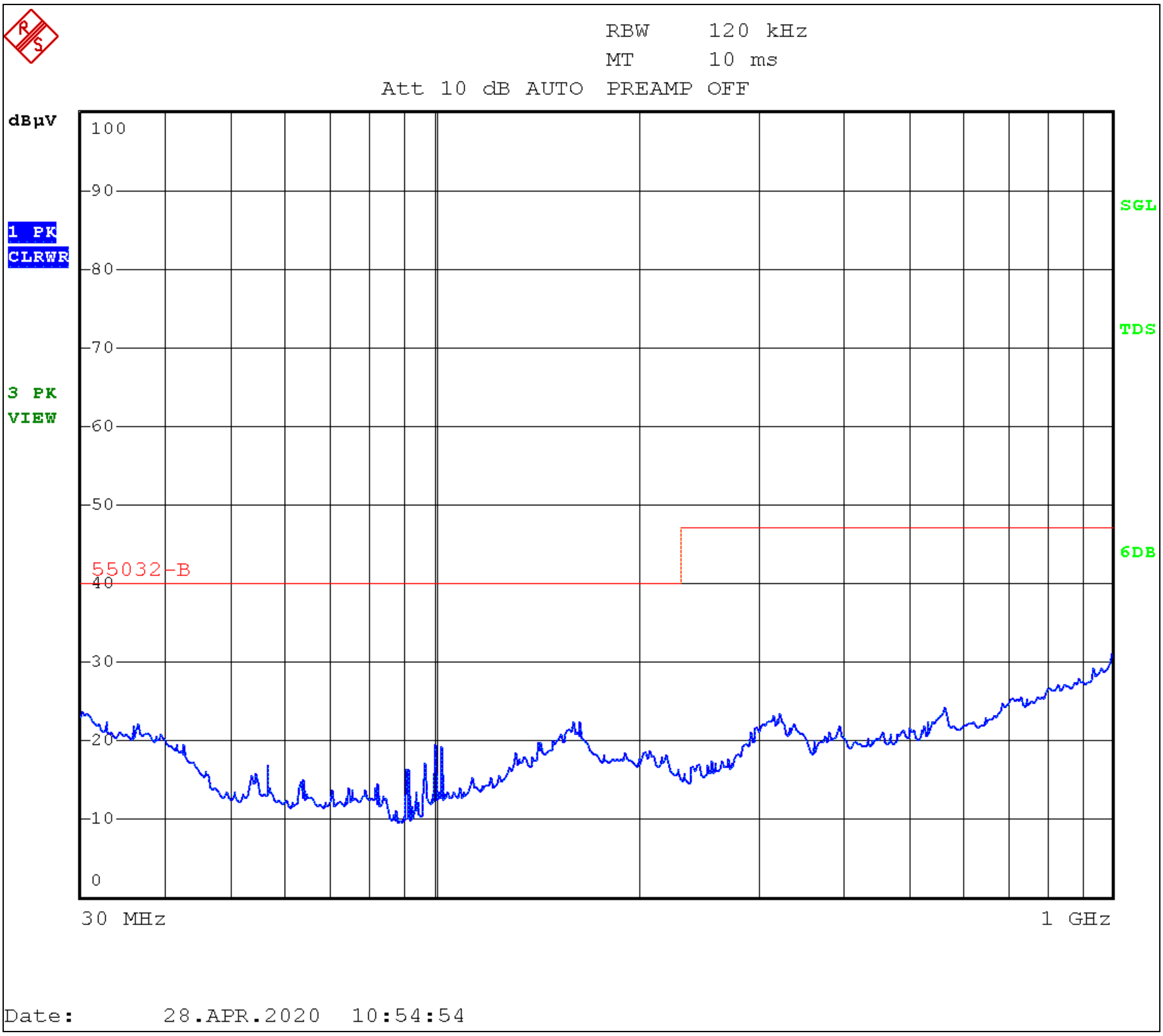

Figure 21 **EMI radiated results for EVK with LC filter configuration 2. Board turned CW 90°. Antenna's position is horizontal.**

2.2.4 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).

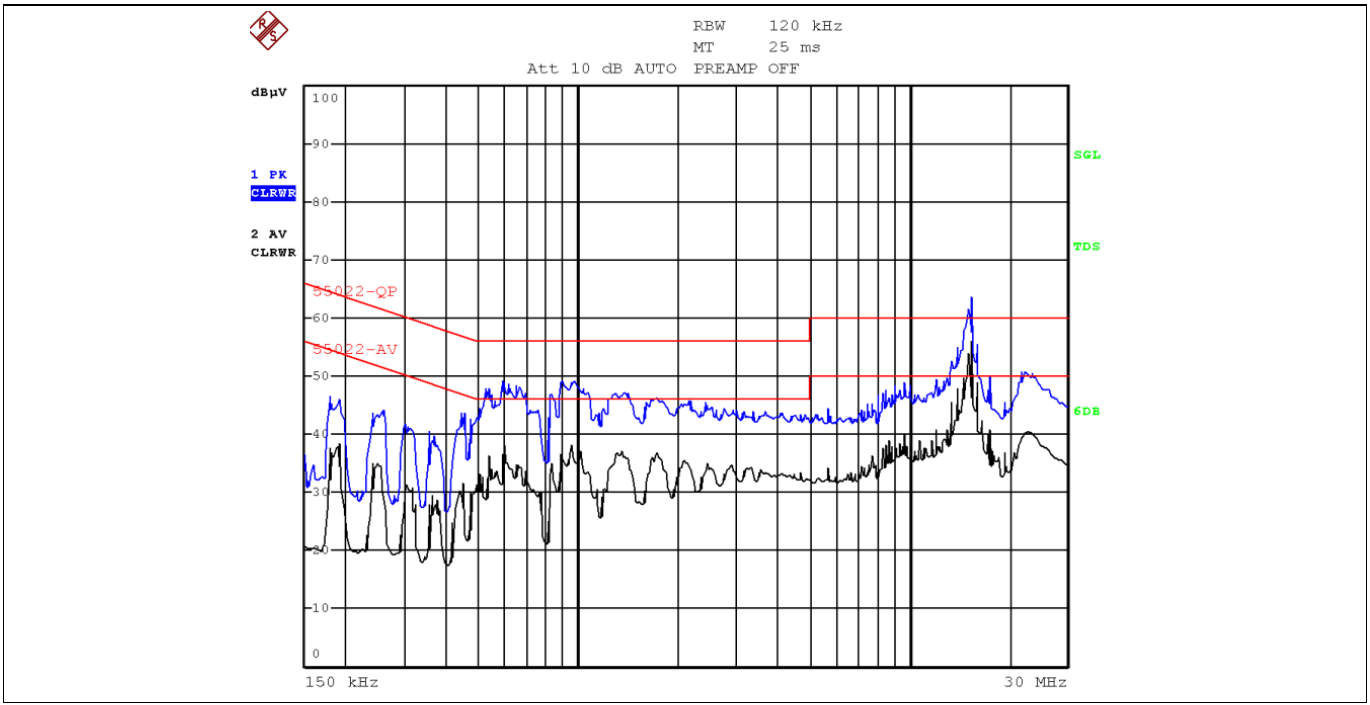

Figure 22 Conducted emission without CM filter

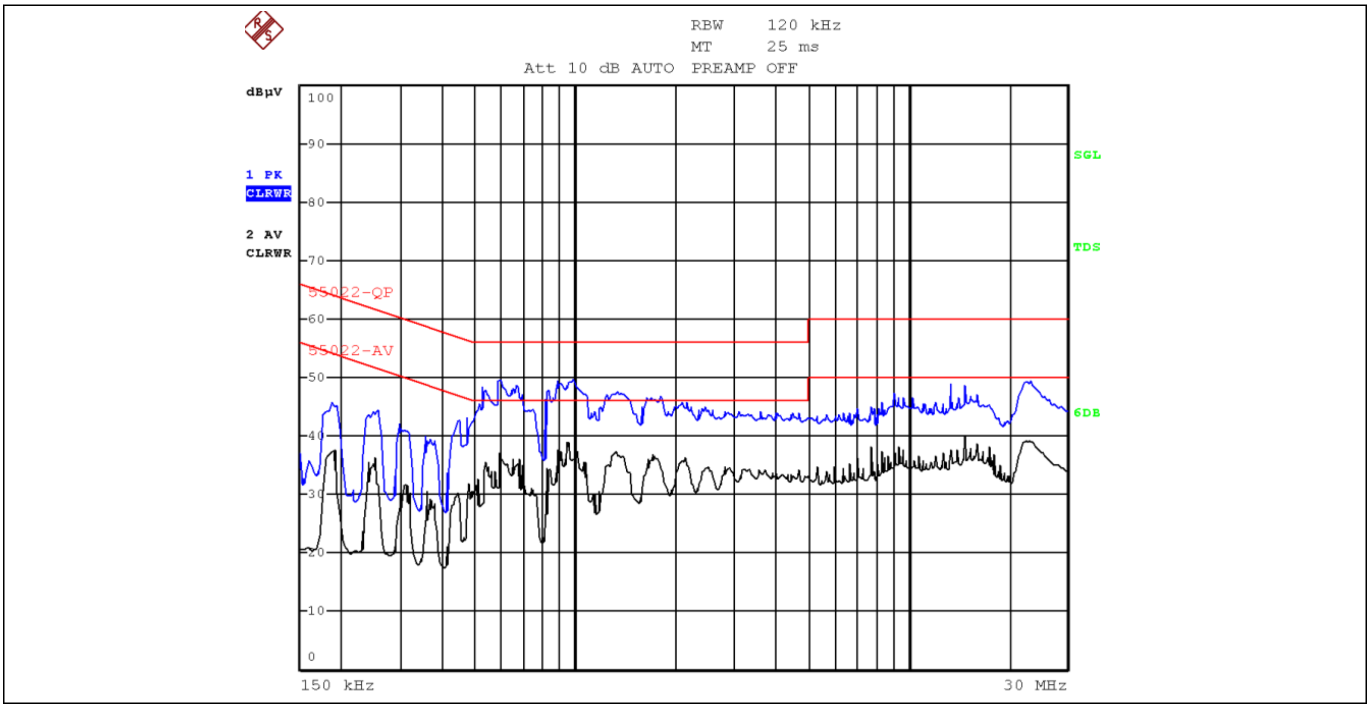

Figure 23 Conducted emission with CM filter

Revision history

Document version	Date of release	Description of changes
V 1.0	19 July 2018	Initial release in Infineon format.
V 1.1	September 2018	Update with CM filter.
V 1.2	26 May 2021	Update with LC configurations 2 and 3.

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