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Ki Magnetic field strength measurements

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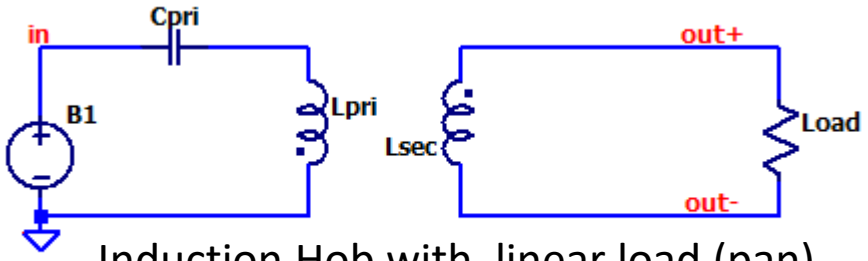
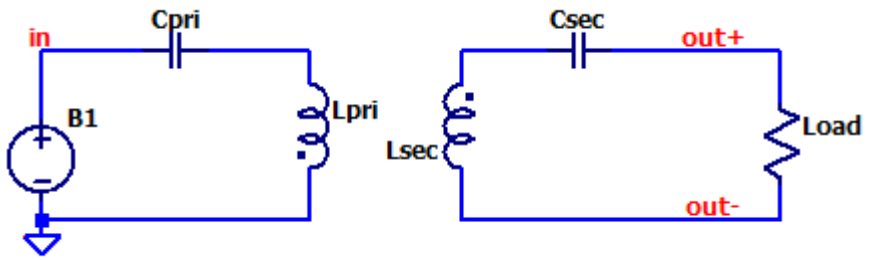
Harmonics investigation with Spice simulations

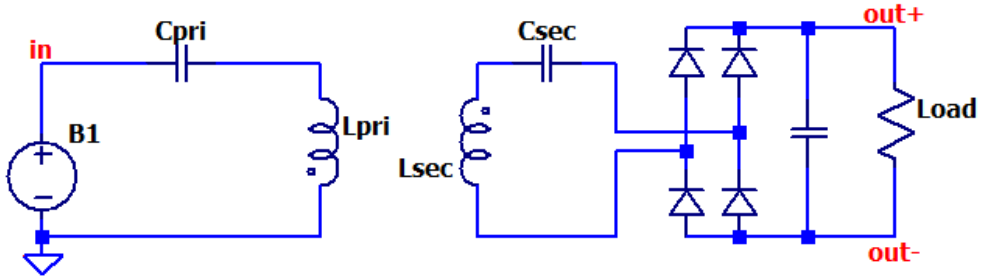
Spice simulation model



Induction Hob with linear load (pan)



Ki transmitter with linear Ki receiver



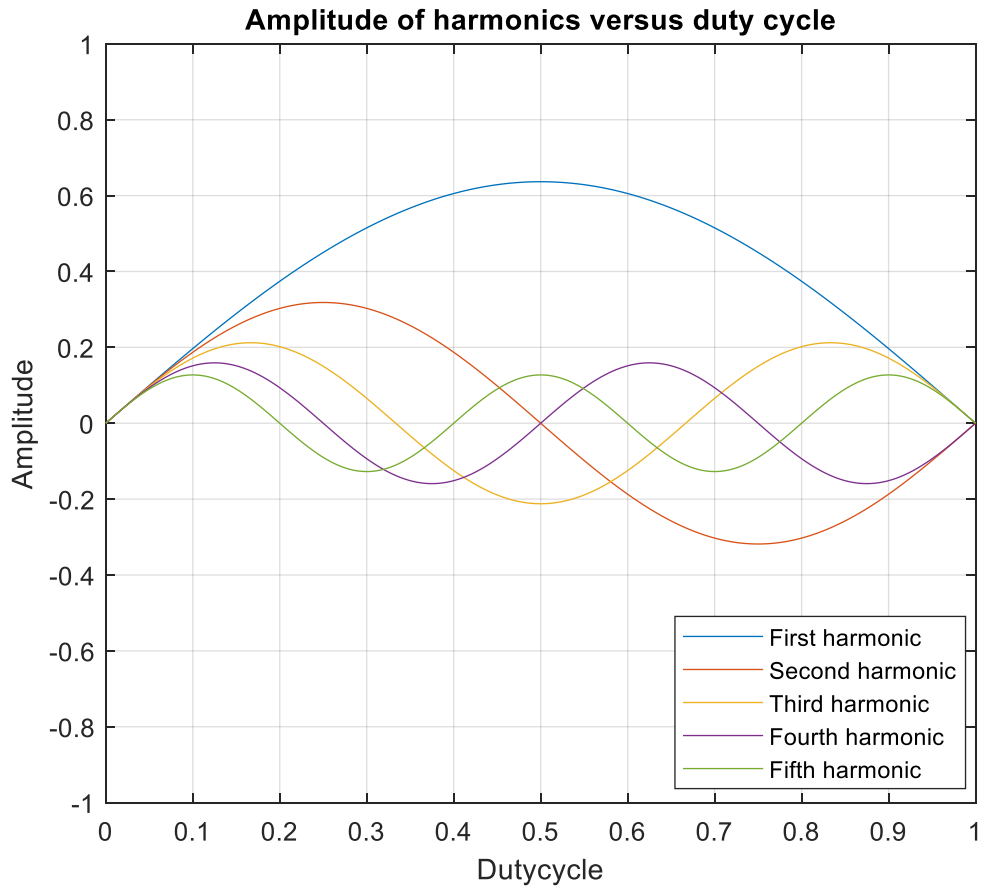
Ki transmitter with non linear Ki receiver

Simulated components:

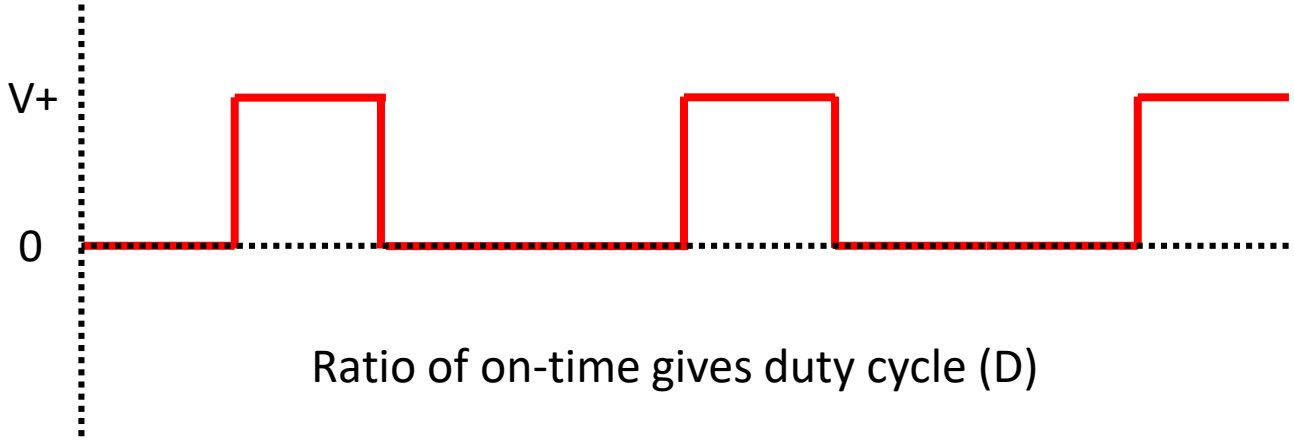
- Voltage source
  - Often a half-bridge
  - Has a 100Hz amplitude modulation and has the zero crossing gap
- Resonant circuit
  - Contains the power coils and the resonant capacitors
  - Coupling factor based on FEMM simulations for hob and hidden case and black dot #3
- Load
  - With only a resistor the system behaves linear
  - With a rectifier and capacitor the system behaves non-linear

Harmonics generation and attenuation

Harmonics caused by duty cycle control of a half bridge inverter

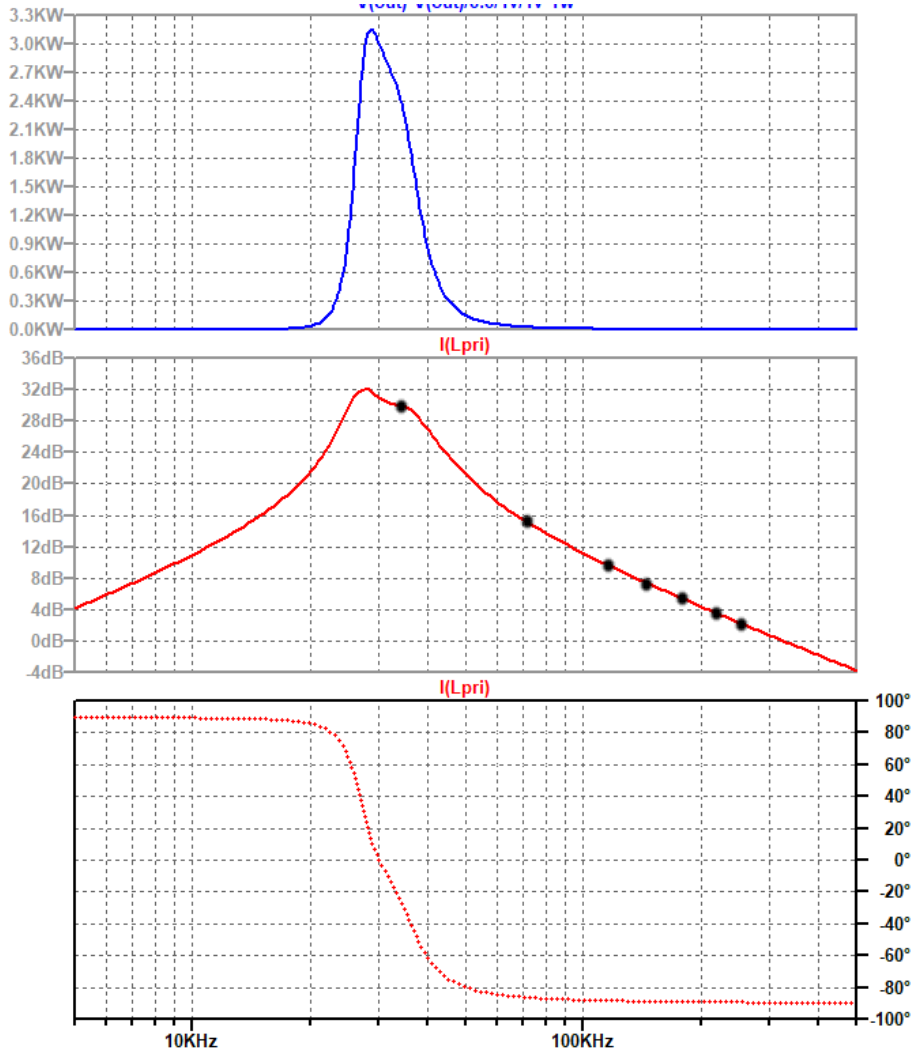


Amplitude of the harmonics versus the duty cycle of the PWM signal



Harmonics generation and attenuation

Attenuation of the harmonics by the resonant system in the hidden case



Blue graph shows received power vs operating frequency

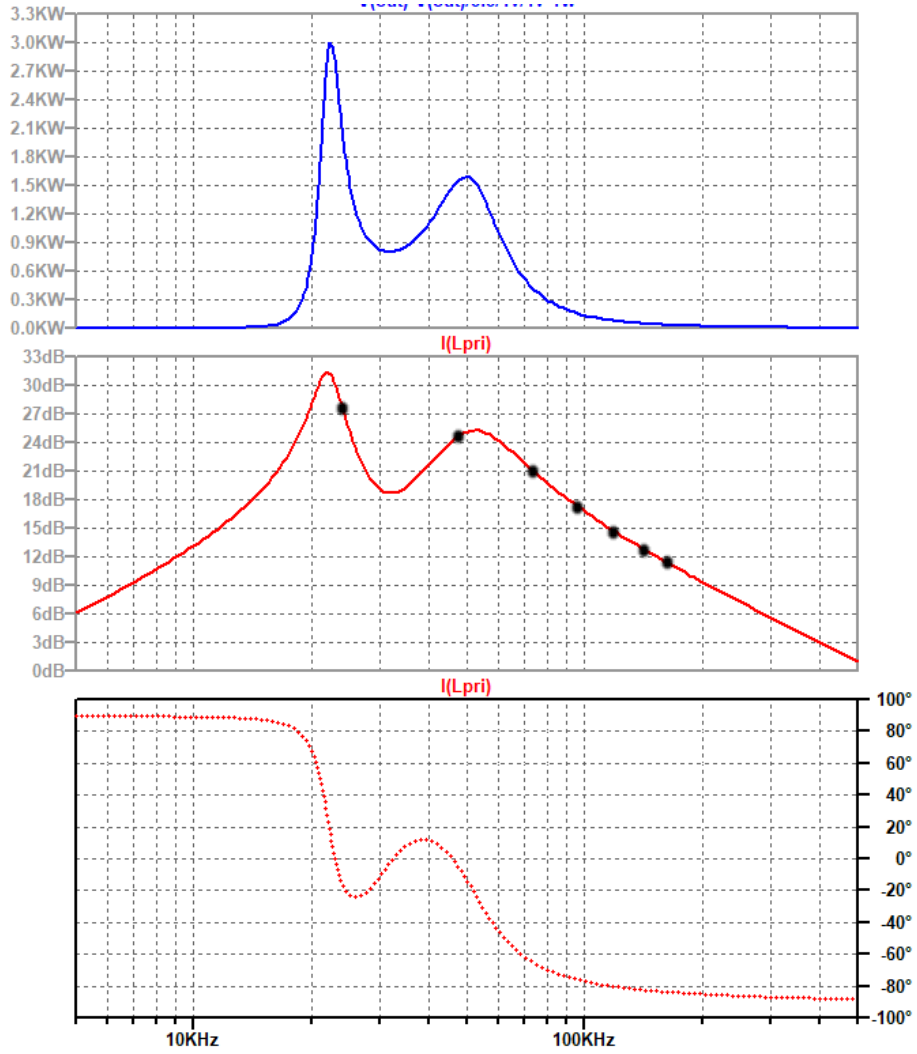
- To reach the desired power the system has to operate at the right side of the resonance peak

The red graph shows input impedance of the resonating network

Harmonic #	Frequency (kHz)	Amplitude (dB)
1	36	29,4
2	72	15,0
3	108	10,3
4	144	7,4
5	180	5,3
6	216	3,7
7	252	2,3

Harmonics generation and attenuation

Attenuation of the harmonics by the resonant system in the hob case



Blue graph shows received power vs operating frequency

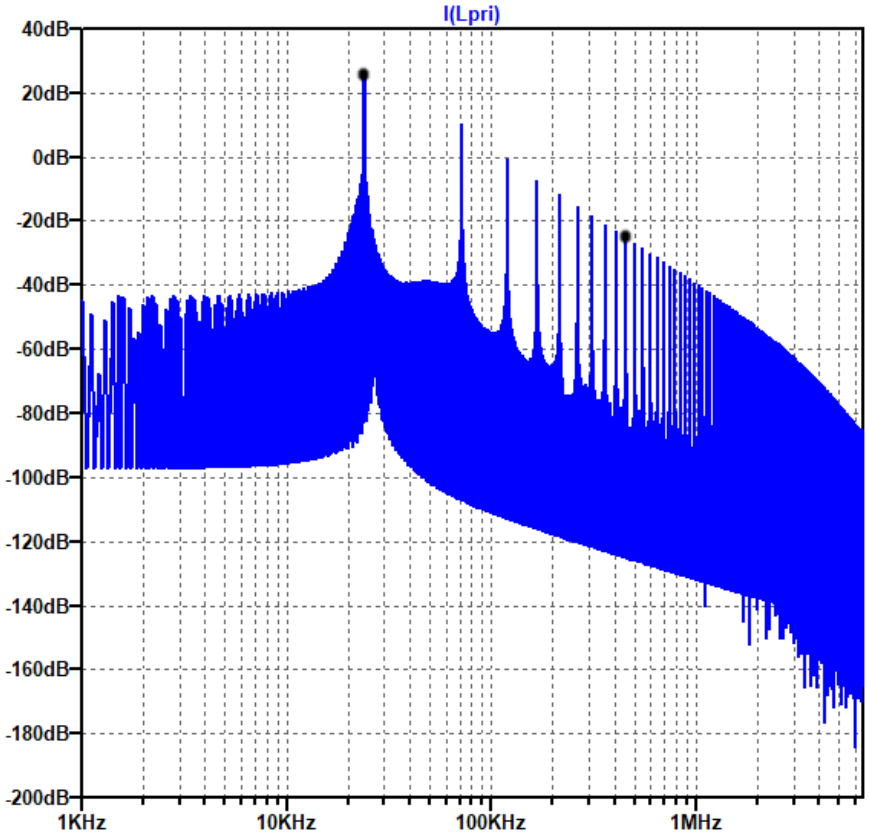
- To reach the desired power the system has to operate at the left resonance peak

The red graph shows input impedance of the resonating network

Harmonic #	Frequency (kHz)	Amplitude (dB)
1	24	27,8
2	48	24,8
3	72	21,3
4	96	17,2
5	120	14,6
6	144	12,5
7	168	11,0

Working on the left resonant peak greatly reduces attenuation of higher harmonics relative to the hidden case

Typical frequency content of the primary current



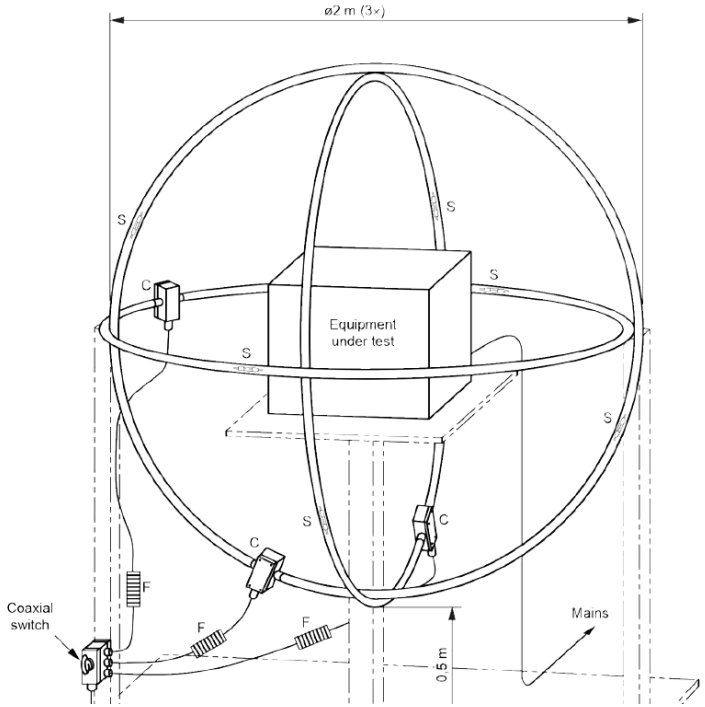
FFT of the primary current with a squarewave

- Squarewave frequency is 24kHz

CISPR14-1 measurement method

Measurements performed with Van Veen loop (LLAS)

- Horizontal and vertical field components picked up separately
  - Both components have different limits, as can be seen in the table
- Measurements performed on multiple devices with the hidden transmitter
  - Blender
  - Airfryer
  - Waterkettle (Black dot 3, worst case)
  - Juicer



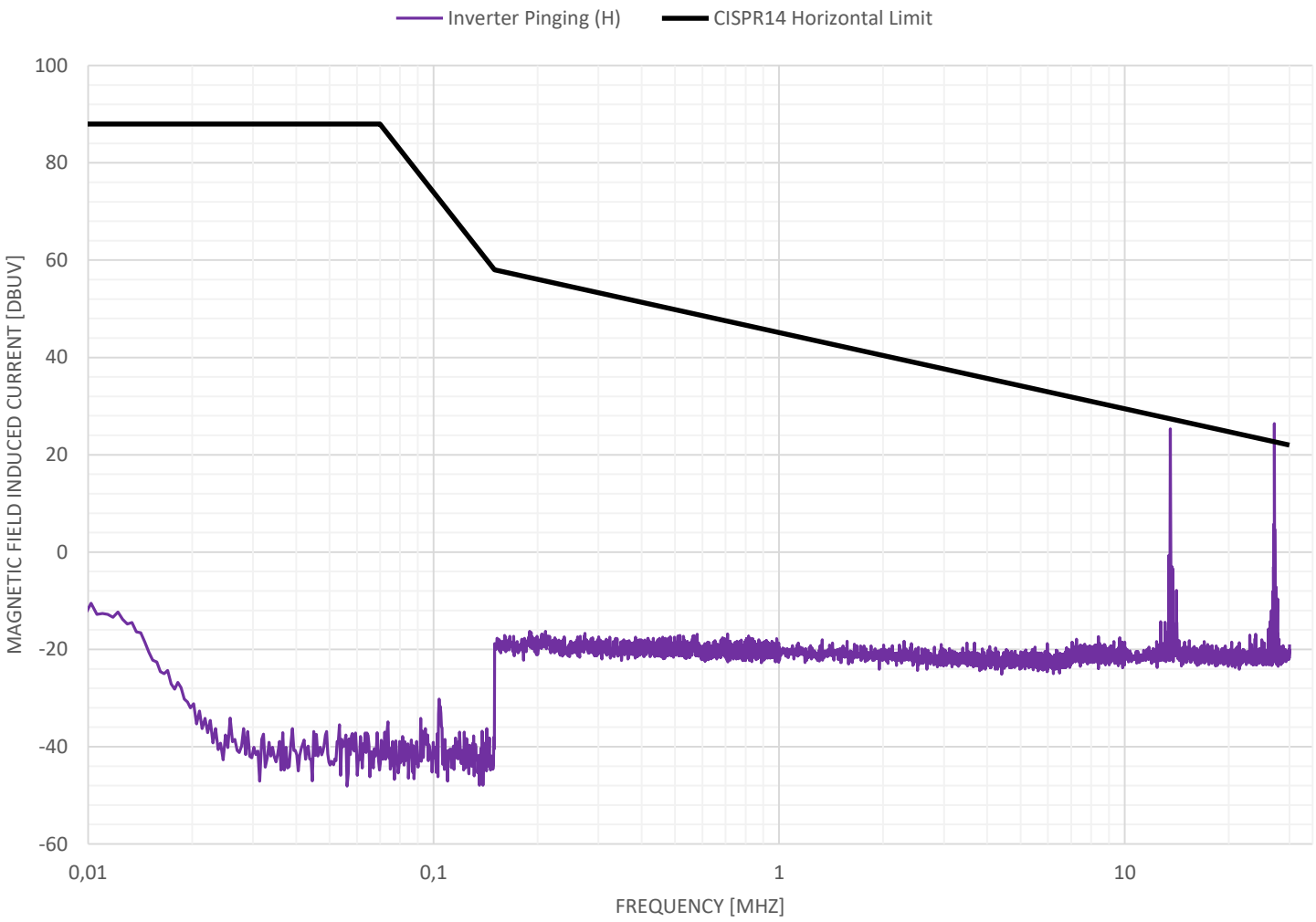
Frequency range MHz	Horizontal component [a,b] Quasi-peak dBµA	Vertical component [a,c] Quasi-peak dBµA
0,009 to 0,070	88	106
0,070 to 0,150	Decreasing linearly with logarithm of frequency from 88 to 58	106 to 76
0,150 to 30	Decreasing linearly with logarithm of frequency from 58 to 22	76 to 40

a The measurement is performed using the 2 m loop antenna system (LAS) as described in 7.2 of CISPR 16-2-3:2010.

b Current induced by the horizontal component of the magnetic field.

c Current induced by the vertical component of the magnetic field.

Horizontal measurement: Idle phase



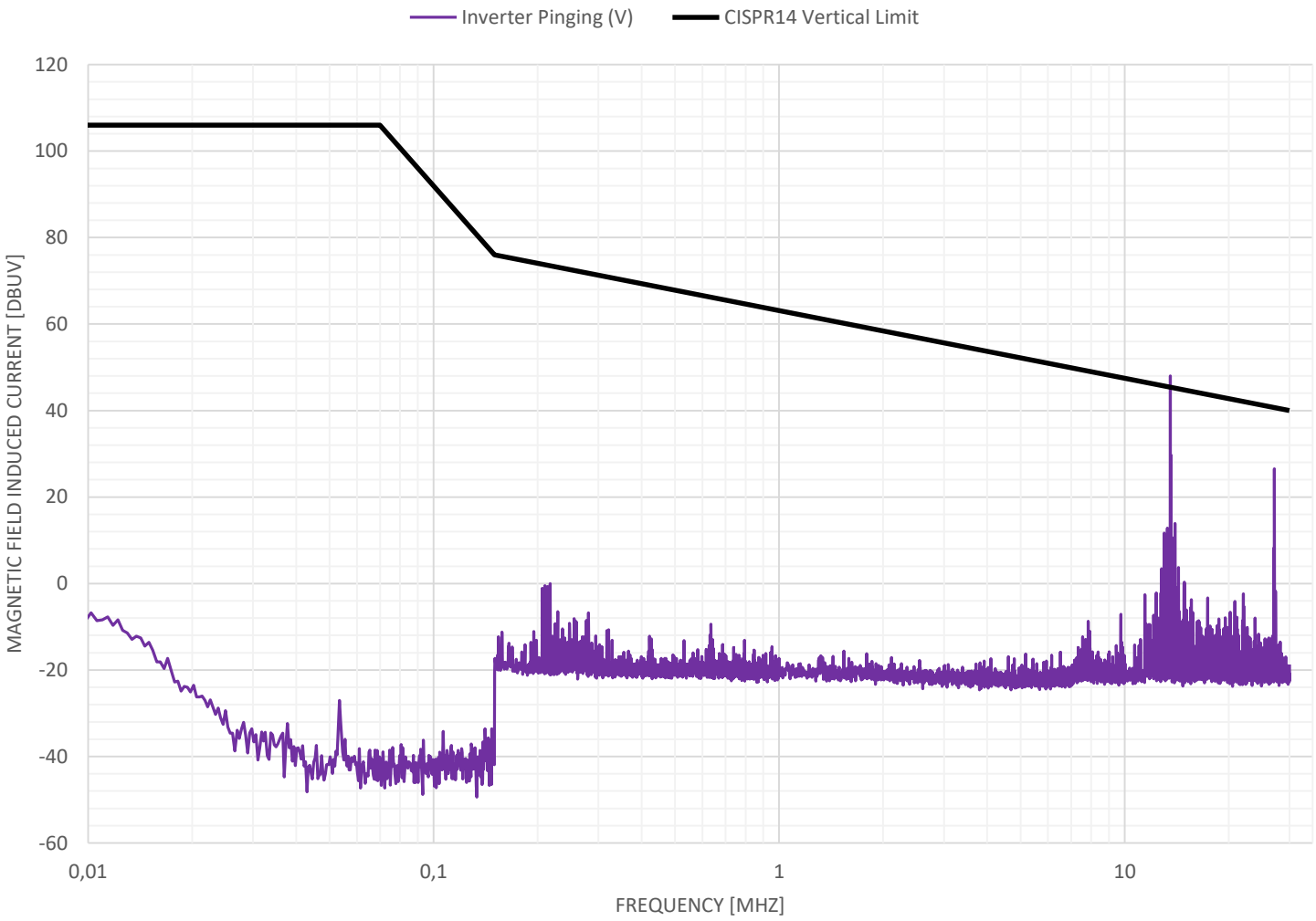
In the idle phase the inverter is pinging with NFC, looking for a appliance

No appliance is present and the power inverter is off

Measurement well below the limit except for the 13,56 and 27,12MHz

- These should be measured according the RED (ETSI EN 300-330)
- The amplitude is well below the RED limits

Vertical measurement: Idle phase



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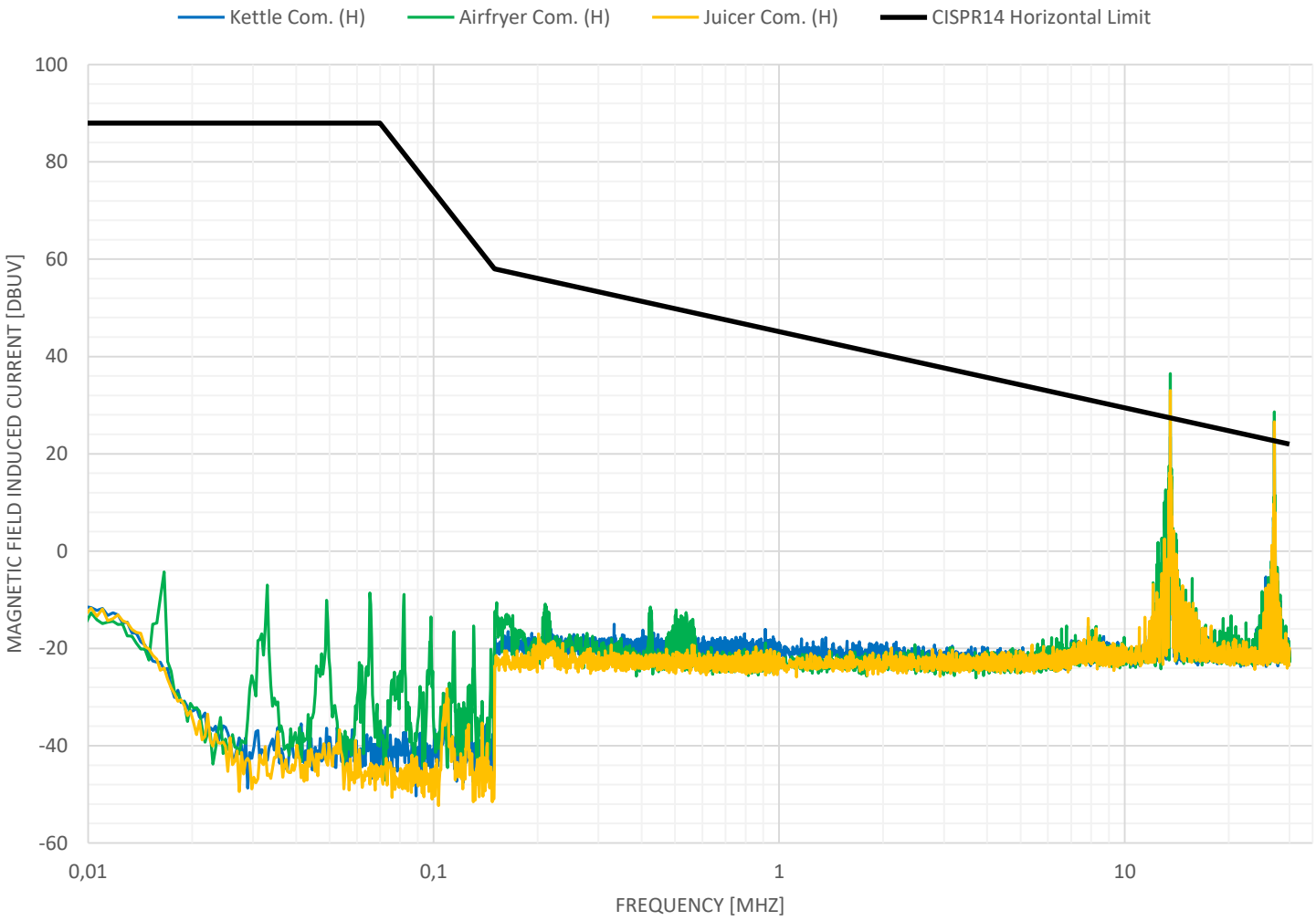
Horizontal measurement: Connected phase



In the connected phase an appliance is placed on the transmitter

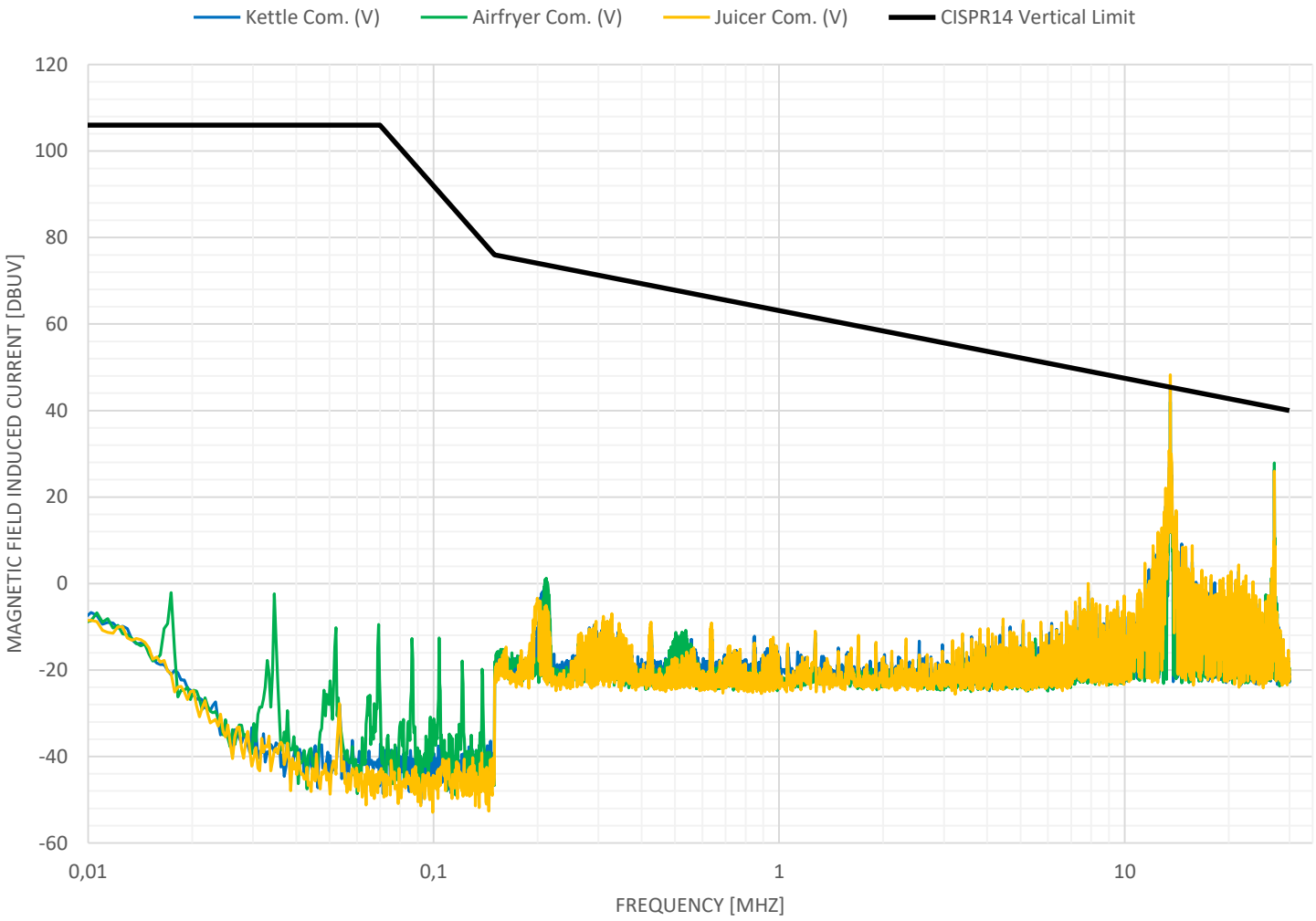
The appliance is harvesting and communicating by the NFC signal

The power inverter is off

Measurement well below the limit

- **NFC is still below the RED limit**

Vertical measurement: Connected phase



In the connected phase an appliance is placed on the transmitter

The appliance is harvesting and communicating by the NFC signal

The power inverter is off

Measurement well below the limit

- **NFC is still below the RED limit**

Horizontal measurement: Power phase

In the power phase the appliance is harvesting and communicating by the NFC signal, and the power inverter is on

Measurement below the limit

- **NFC is still below the RED limit**

Vertical measurement: Power Phase

In the power phase the appliance is harvesting and communicating by the NFC signal, and the power inverter is on

Measurement below the limit

- **NFC is still below the RED limit**

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