PHILIPS

www.philips.com

System Characterization part 2

Jan Draak, Aleksei Agafonov, Pascal Lebens
Philips
11-12-2019

innovation you

System characterization

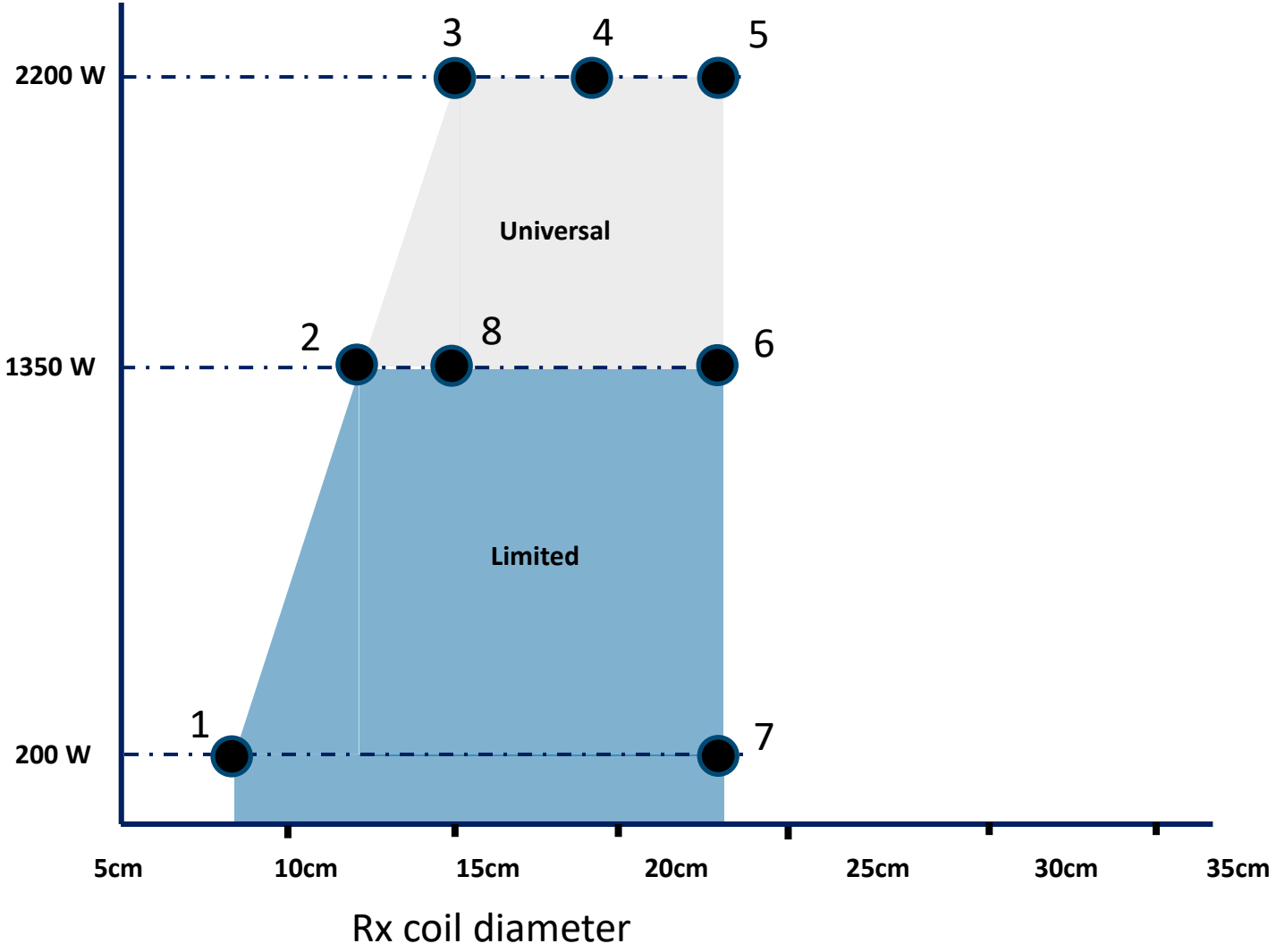
The hidden and hob case

In the Ki Cordless Kitchen ecosystem there are two different use cases

- Hob case
  - The appliance is placed on an induction hob
  - The coil-to-coil distance is around 1cm
- Hidden case
  - The appliance is placed on a table or a countertop
  - The coil-to-coil distance can be up to 4cm

In both cases the same appliances can be used, but the coupling factor differs greatly

Black dots: test receivers for transmitters



The black dots have widely varying parameters:

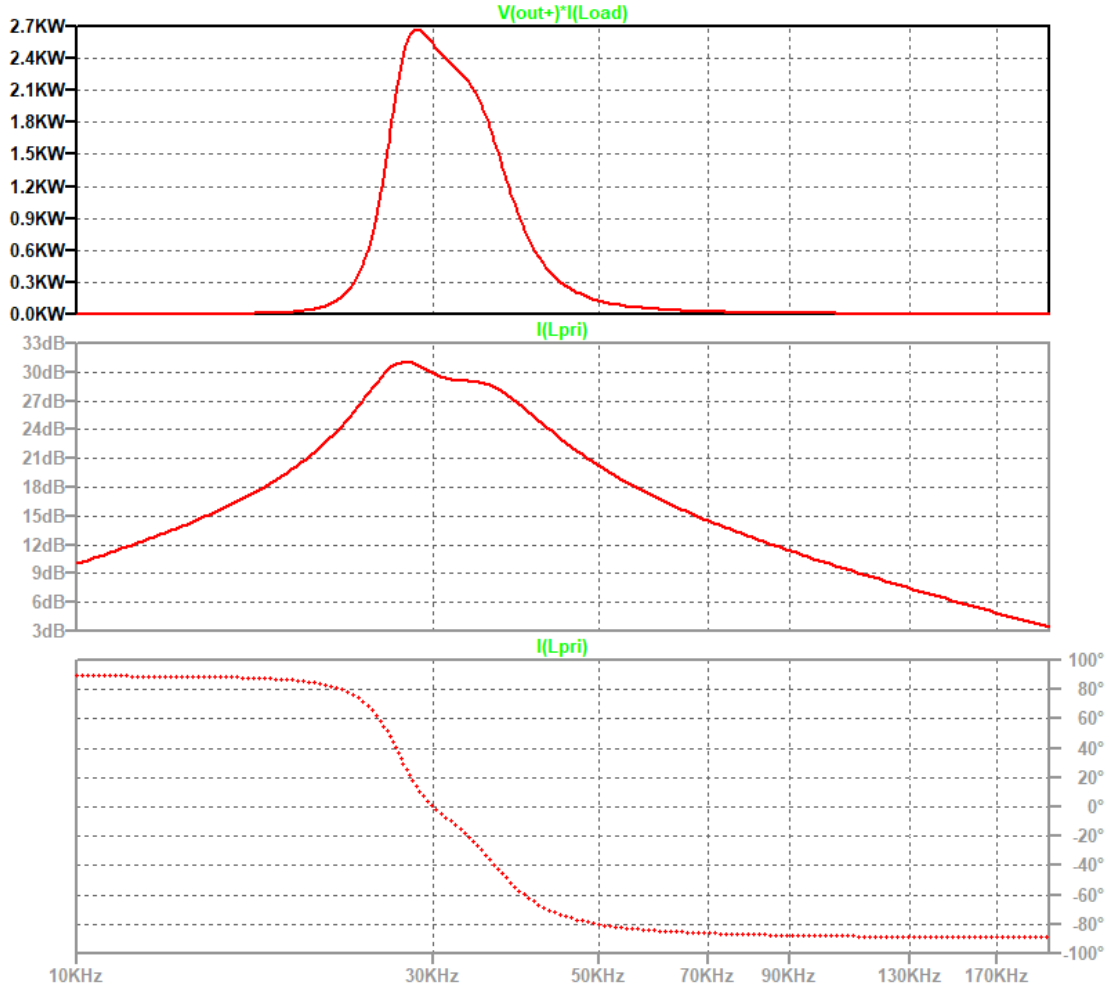
- Induction value
- Diameters
- Power level
- PRx coil standoff height

The black dots span up the appliance design space. Appliances can be created in the complete range.

Black dots: test receivers for transmitters

Receiver side													
System Design Parameters						**Hob case** (Lp = 56u)				**Hidden case** (Lp = 60u)			
fs = 30.0 KHz / Qs = 50						fp = 26.8 kHz / Qp = 30 / D = 180mm				fp = 30.0 kHz / Qp = 33 / D = 210mm			
				Uload = 115V	**Uload = 230V**								
Black dot #	**Q_{PRx} @30kHz**	**Power [W]**	**Dcoil [cm]**	**Ls nom [uH]**	**Ls nom [uH]**	**K**	**f_op [kHz]**	**I_p [A rms]**	**η [%]**	**K**	**f_op [kHz]**	**I_p [A rms]**	**η [%]**
1	1,11	200	8.0	**390**	**1560**	0,36	**39,3**	**10,4**	83,9%	0,16	**36,5**	**22,7**	52,3%
2	2,16	1350	12.0	**112,5**	**450**	0,60	**26,8**	**16,6**	90,3%	0,26	**32,0**	**28,9**	79,6%
3	2,20	2200	15.0	**70,0**	**280**	0,70	**23,6**	**26,5**	87,5%	0,34	**31,9**	**28,1**	85,7%
4	1,72	2200	18.0	**55,0**	**220**	0,75	**23,5**	**25,0**	88,9%	0,39	**33,0**	**26,9**	87,2%
5	1,49	2200	23.5	**47,5**	**190**	0,71	**24,3**	**24,8**	89,4%	0,45	**31,2**	**25,3**	88,5%
6	1,06	1350	23.5	**55,0**	**220**	0,71	**30,3**	**15,6**	92,7%	0,45	**36,3**	**21,5**	87,0%
7	0,63	200	23.5	**220**	**880**	0,71	**49,0**	**5,70**	94,1%	0,45	**50,0**	**8,6**	86,8%
8	1,35	1350	15,0	**70,0**	**280**	0,71	**25,2**	**15,2**	90,3%	0,34	**31,2**	**17,3**	81,7%

Transfer Functions: Hidden case



In the hidden case the coupling factor is low

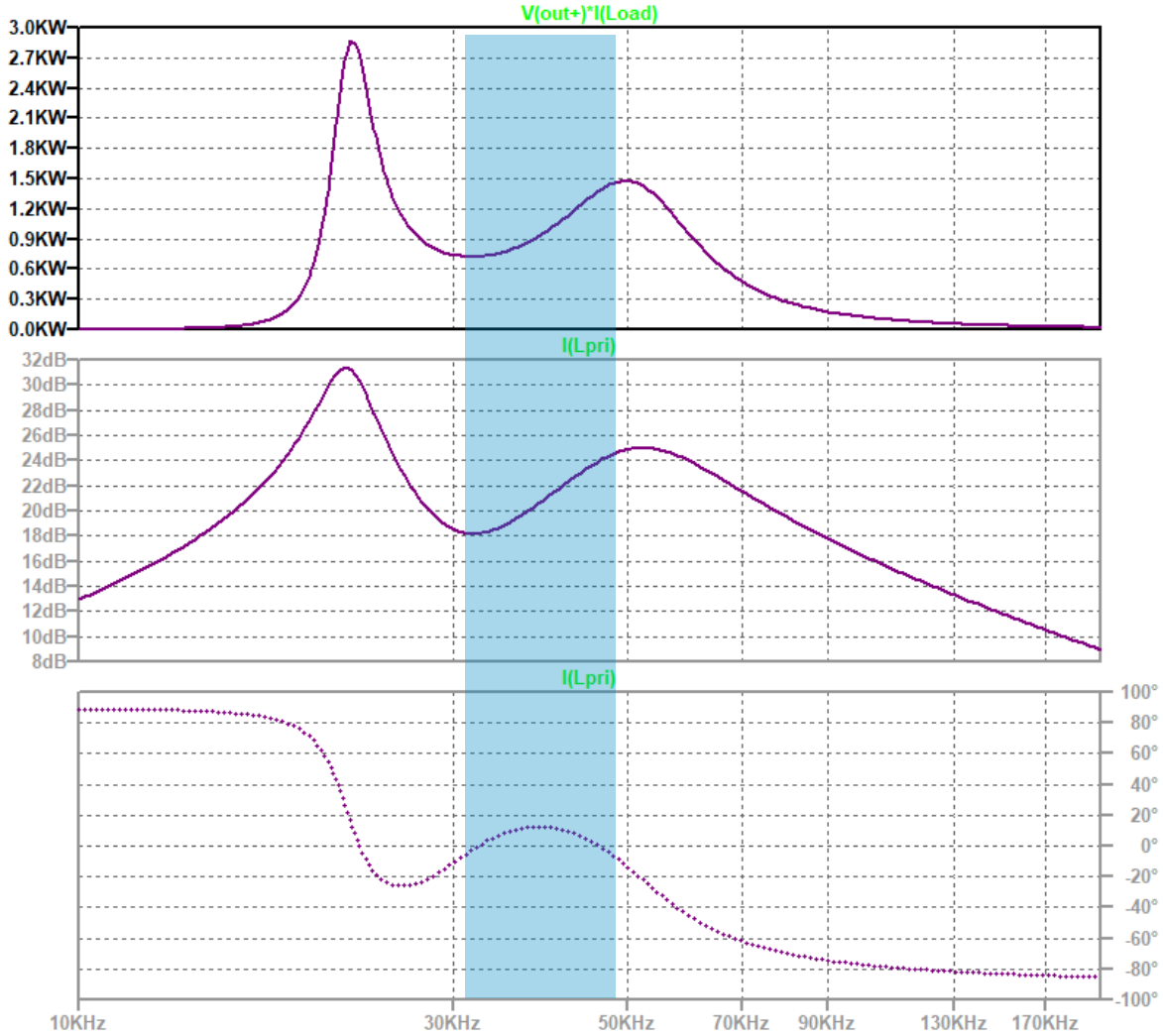
- K=[0.16;0.45]
- Only a single resonance peak is present
- Valid for every black dot

Depicted is the worst case:

- Maximum power
- Maximum coupling

- **Zero-voltage switching is always possible on the right side of the resonance peak.**

Transfer Functions: Hob case



In the hob case the coupling factor is increased

- K=[0.36;0.75]
- Single and double peaks can be present
- Dot 2, 3, 4 and 5 have a clear second resonance peak

Depicted is the worst case

- maximum power
- maximum coupling

The presence of a second peak and positive phase lag depends on coupling factor and PRx Q-factor

Area where soft switching is not possible and the power is high

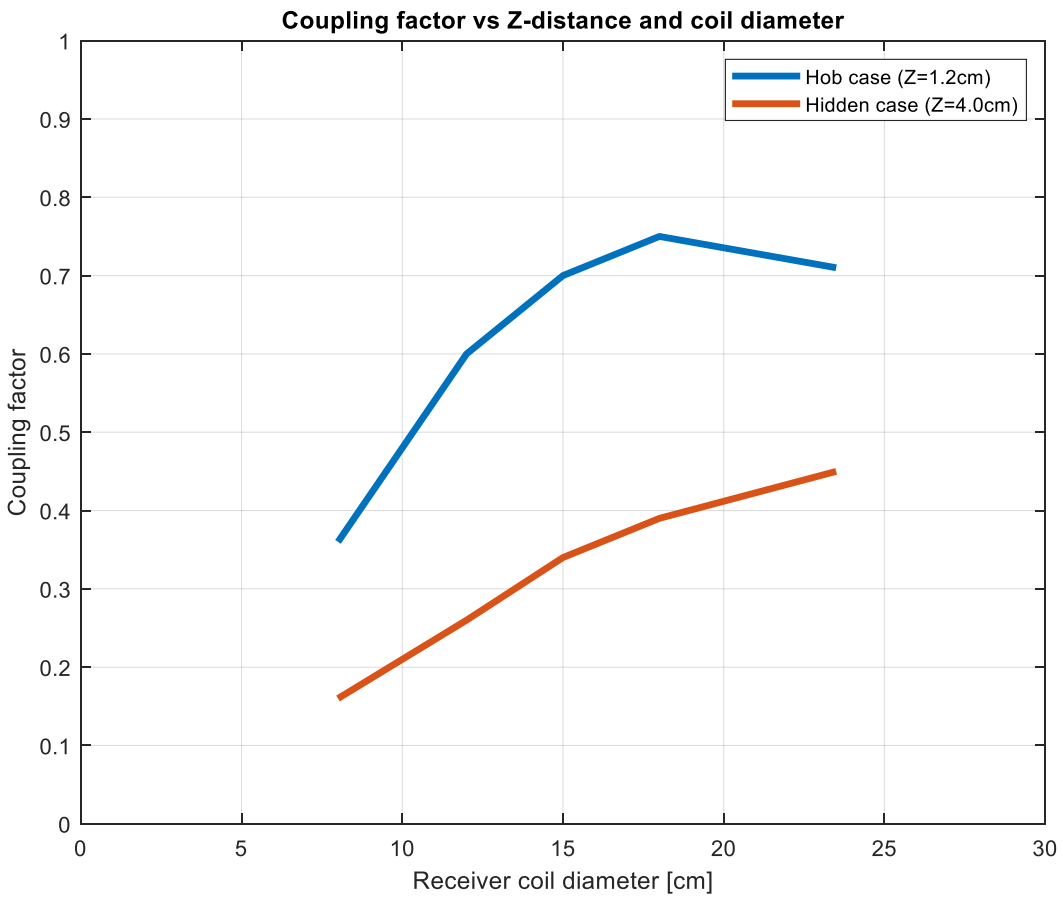
PRx Parameters:

- To estimate second peak presence in the system, two parameters are required:

- **K-factor**
  - Based on Z-distance, coil diameter and alignment
  - Worst case should be used (high K)
  - Can then be extracted by calculation, or with calibration data

- **Q-factor (of starting operating point)**
  - Inductance
  - Resonance frequency
  - Power levels
  - Load voltage

$$Q_{PRx} = \frac{2 * \pi * f_{res} * L_{sec}}{R_{load}}$$



Solution

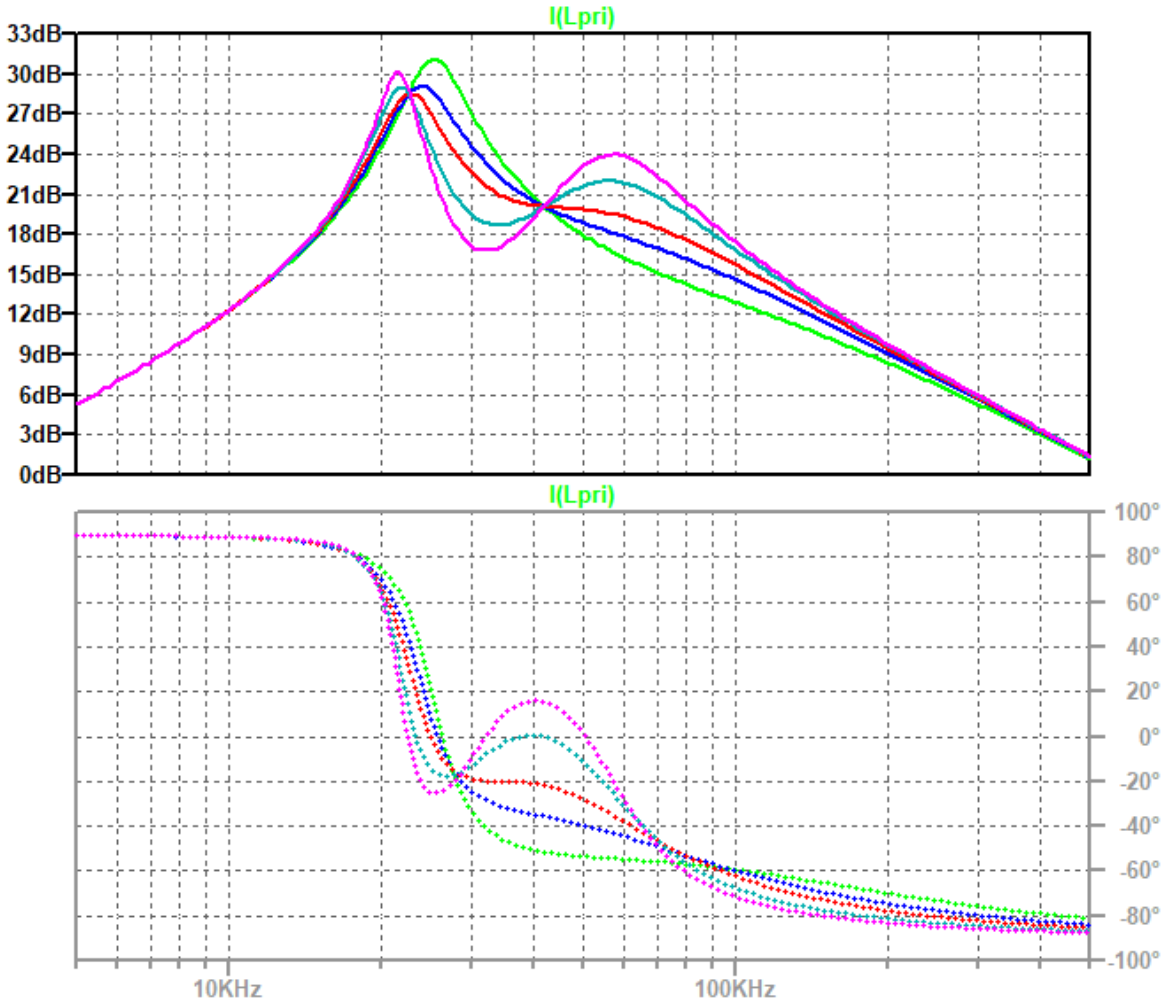
- **PRx parameters to be implemented to kitchen-specific part of NDEF message:**
  - Receiver inductance
  - Load voltage
  - Receiver circuit resonance frequency
  - Coil diameter
  - Coil stand-off height
  - List of power levels
- **PTx has to estimate a initial operating point**
  - Coupling factor calibration/simulation data
- **After reaching operating point fast power level control function can be used**

Proposal for addition to NDEF message

	b_7	b_6	b_5	b_4	b_3	b_2	b_1	b_0
B_m	Receiver inductance, uH							
B_{m+1}								
B_{m+2}	Load Voltage, Vrms							
B_{m+3}	Receiver circuit resonance frequency, kHz							
B_{m+4}	Coil diameter, mm							
B_{m+5}	Coil stand-off height, mm							
B_{m+6}	Number of power levels							
B_{m+7}	Power level 1, W							
B_{m+8}								
...								
B_{n-1}	Power level K, W							
B_n								

PHILIPS

PRx Q-factor vs second peak presence



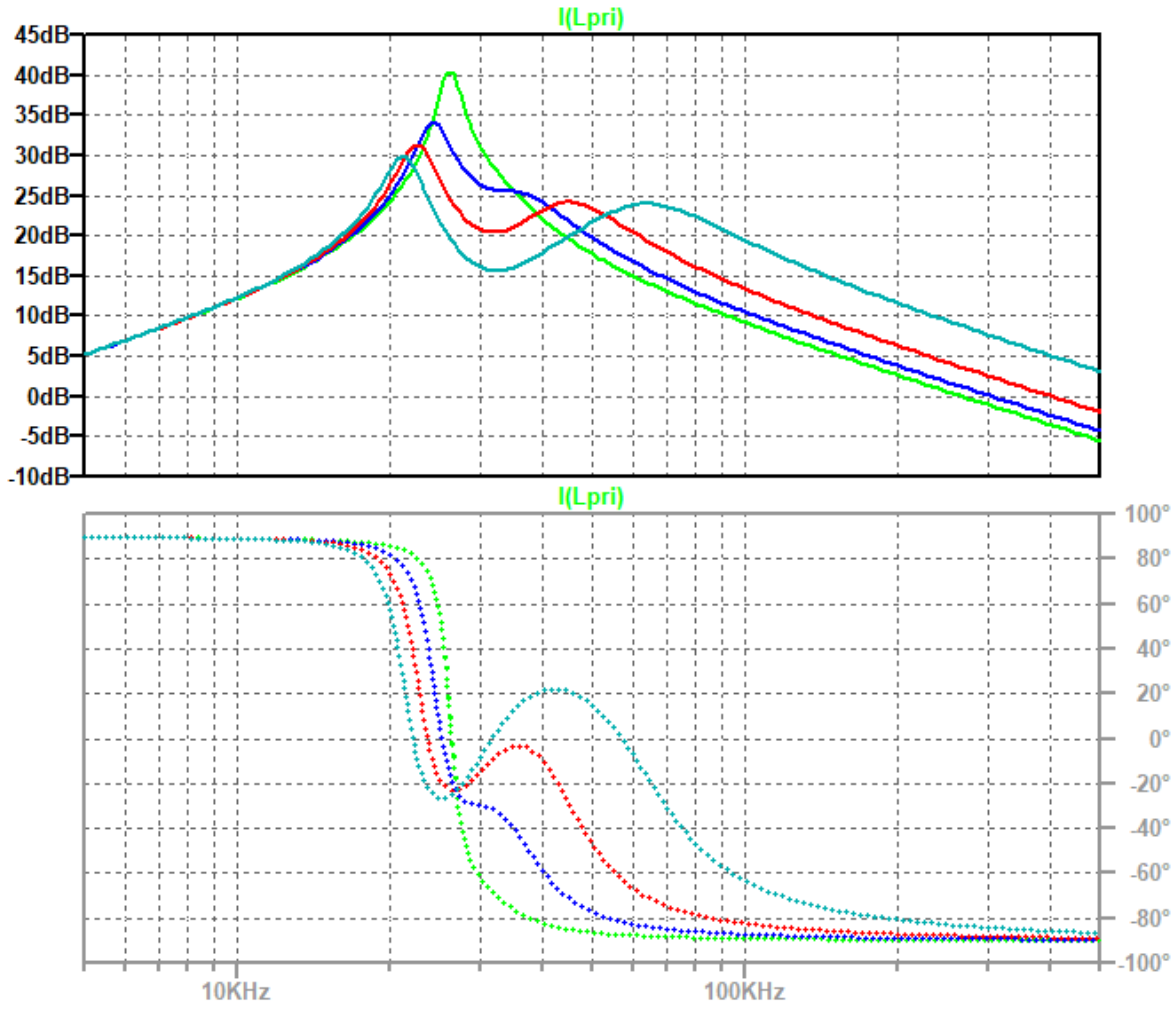
Coupling factor is 0,75

- Worst case

- Green Q=0,50
- Blue Q=0,75
- Red Q=1,00
- Cyan Q=1,50
- Magenta Q=2,00

If the secondary Q-factor is above 1, a second peak could appear

Coupling factor vs second peak presence



Q factor is 2

- Worst case black dot is 2,2

- Green K=0,20
- Blue K=0,40
- Red K=0,60
- Cyan K=0,80

The lower the k-factor, the more a second peak is suppressed