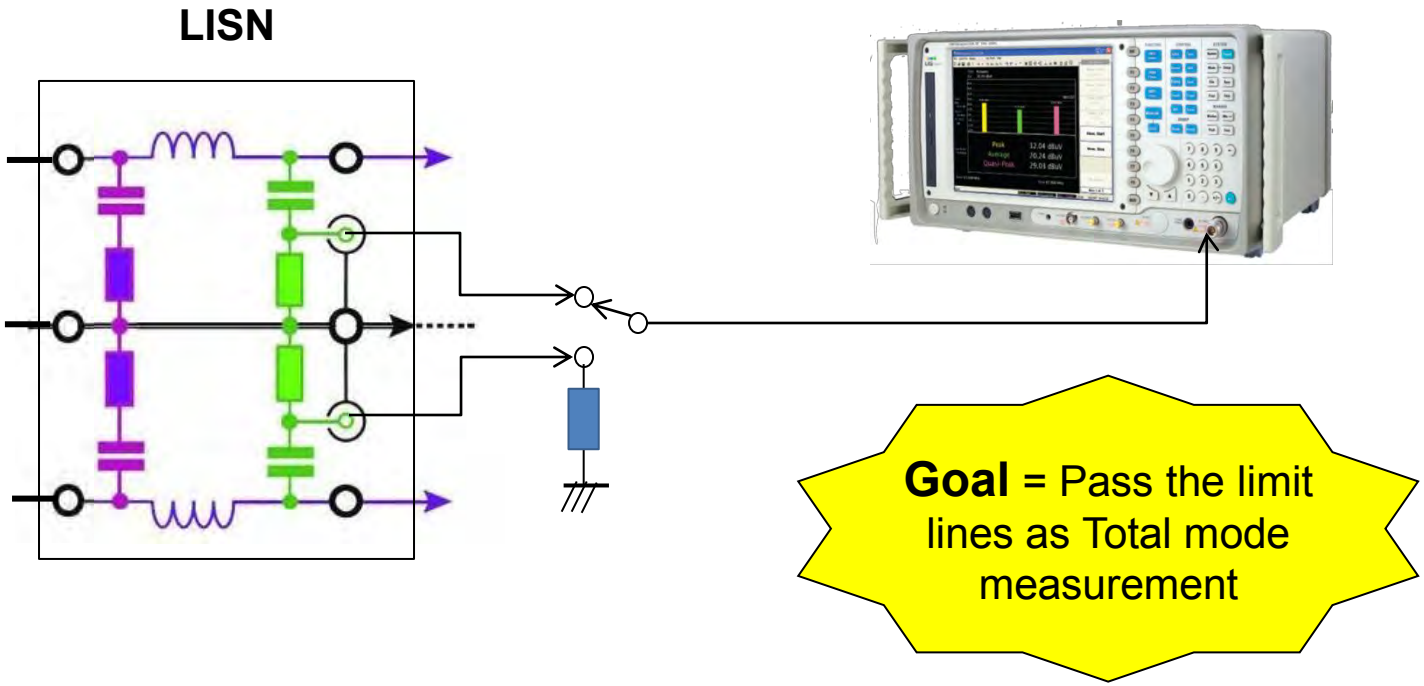
With EMI Analyzer

Verification of Optimal EMI Filter Design

Table

1. EMI Measurement

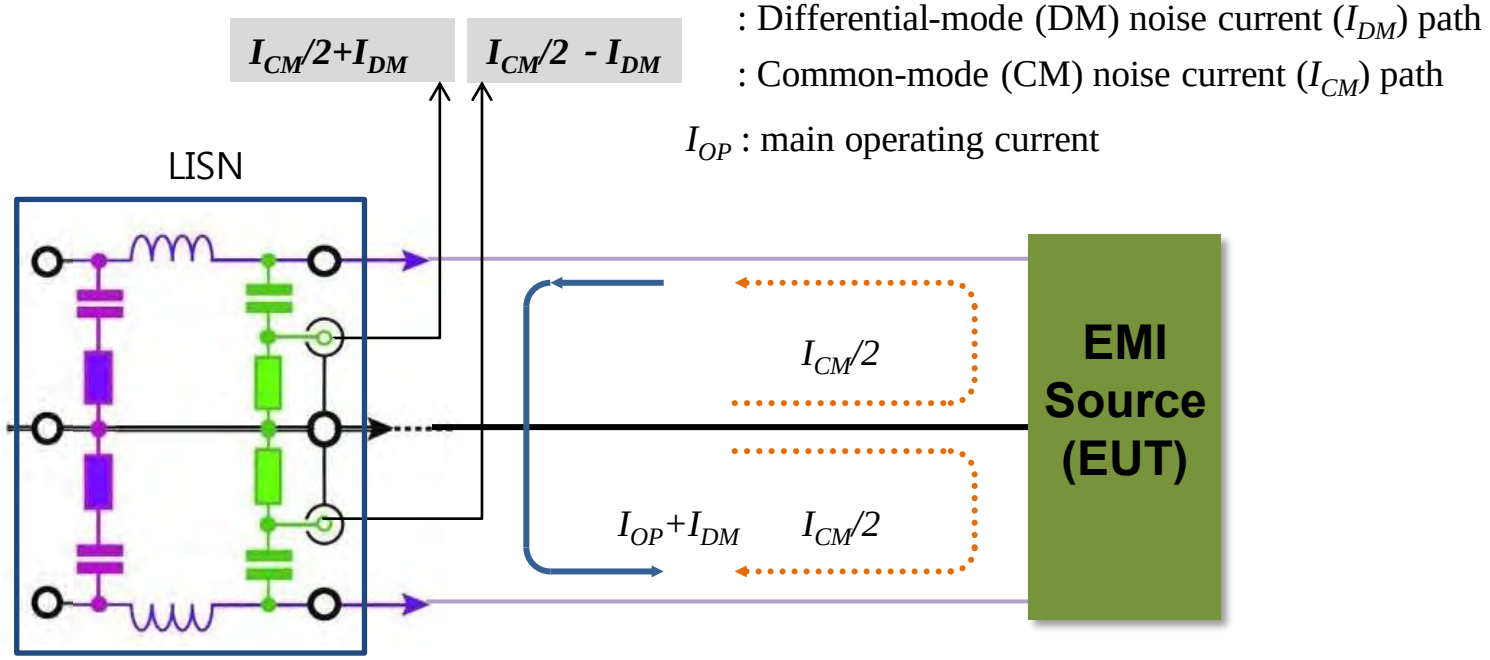
1) Total Mode Noise Measurement



- **Measured results of Each Line should be passed the requirements/specification.**
- **Measure Voltage at 1kΩ point. (Line and GND)**
- **Impedance of LISN = 50Ω (Link the not-measured output to 50Ω)**

1. EMI Measurement

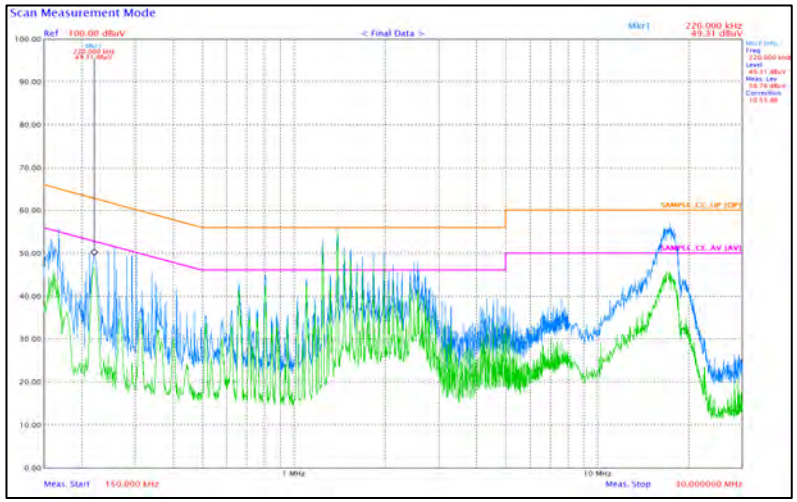
1) Total Mode Noise Measurement



- **The measured results is the mixture of CM &DM Noises**
- **The measured results shown on the instruments is only the higher level between CM & DM noises**

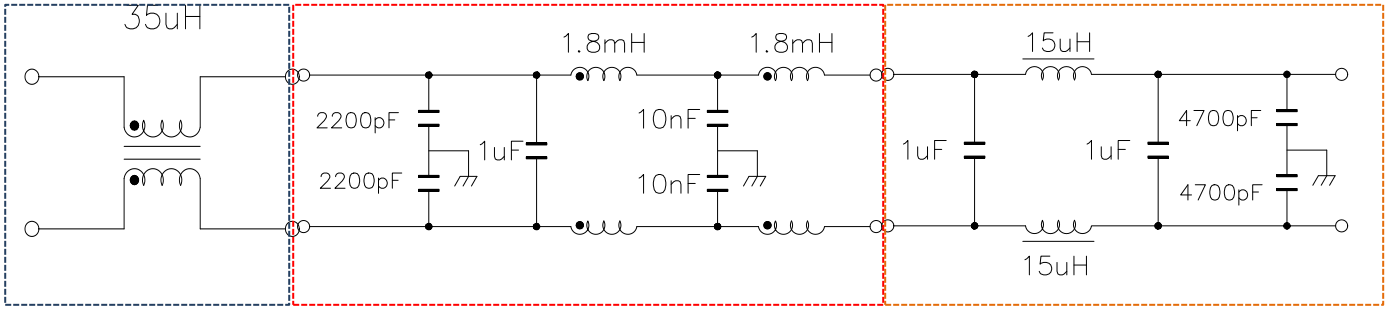
1. EMI Measurement

1) Total Mode Noise Measurement



- Takes a long time
- Cost up
- Larger filter sizes

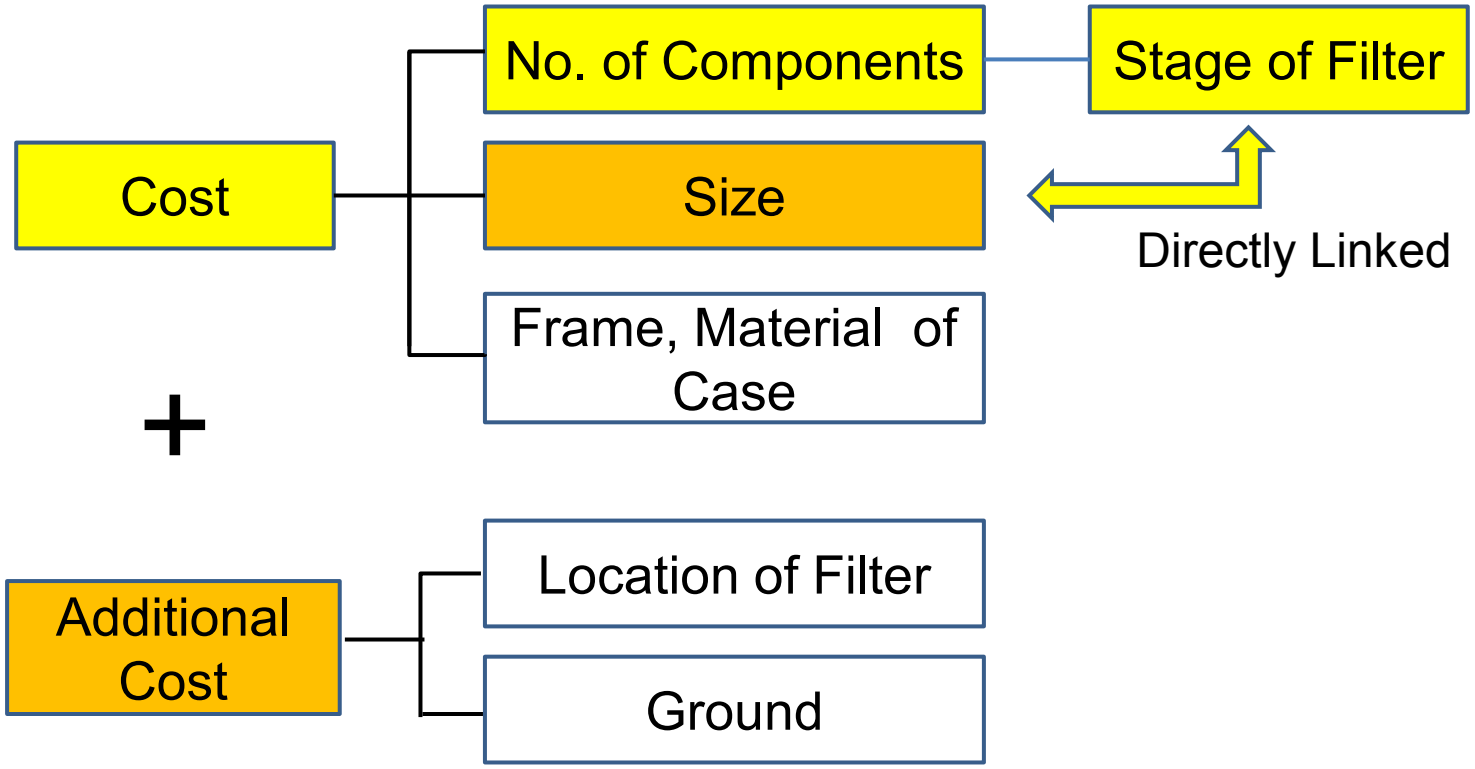
Interpretation difficulties for circuit



Multi-stage filter circuit

2. Optimal filter design

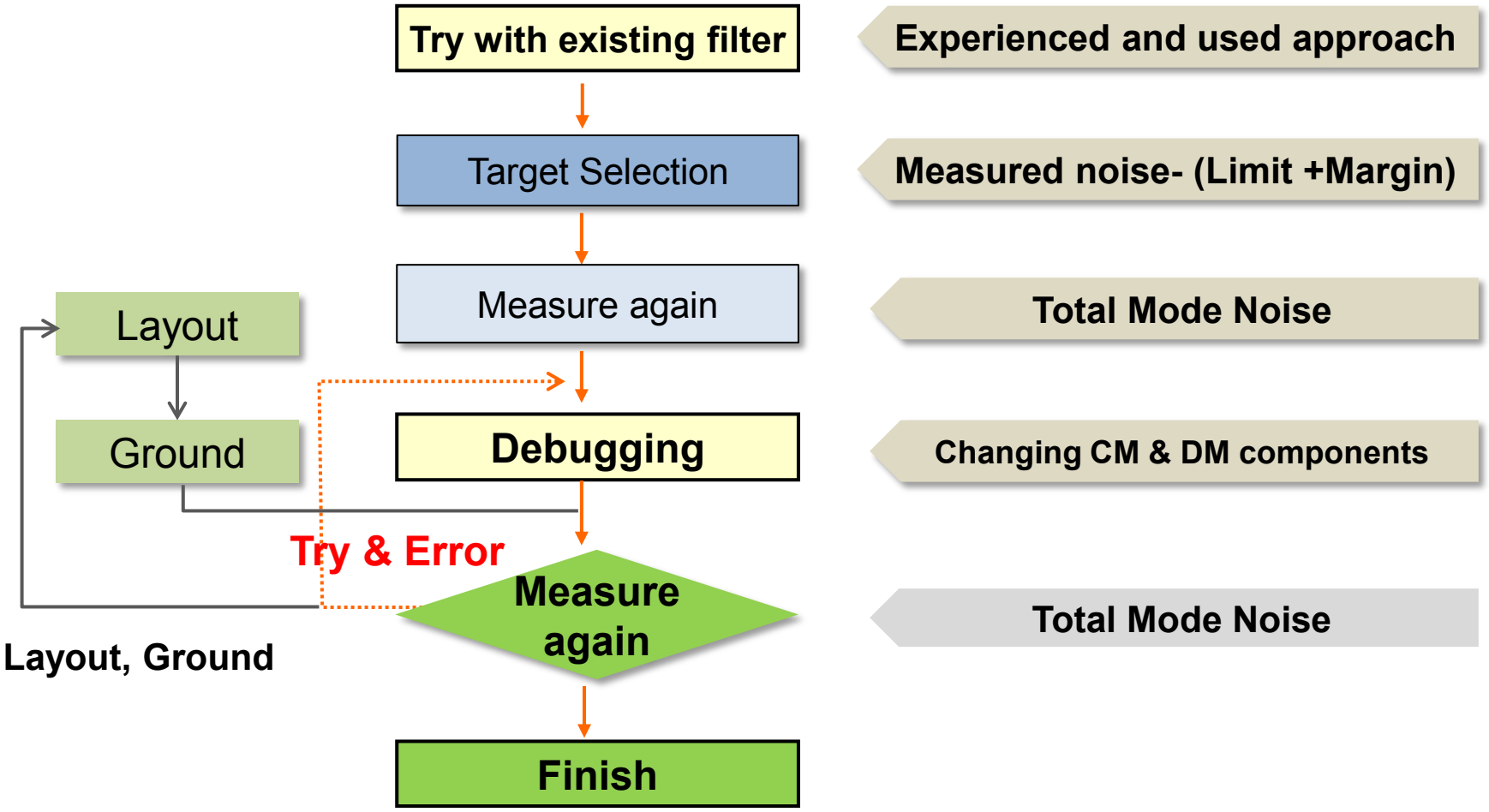
1) Must-Be consideration in Optimal Filter Design



2. Optimal filter design

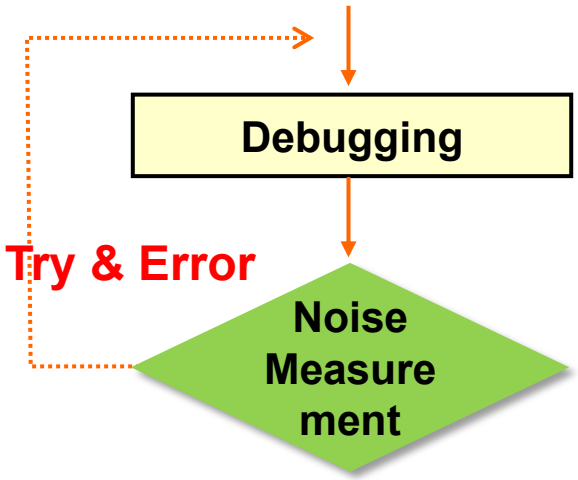
2) Current Method in Filter Design

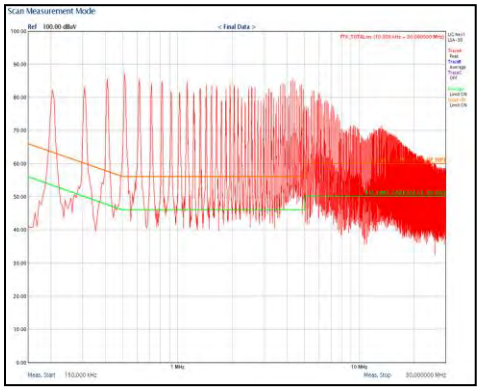
Measure only Total Mode Noise



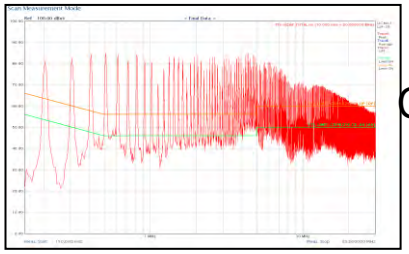
2. Optimal filter design

Why Debugging is repeated ??

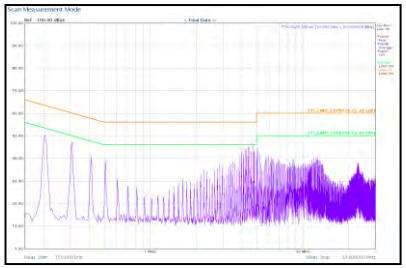




Total Mode

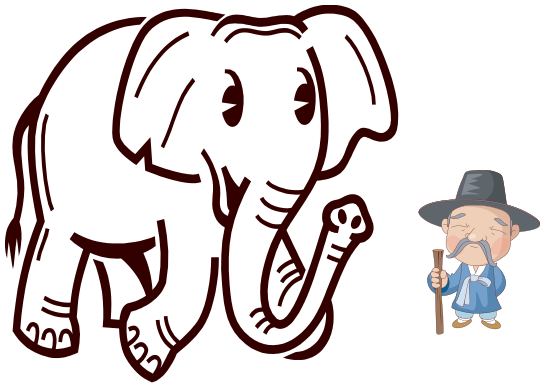


CM Mode



DM Mode

CM, DM Noise Solution =



2. Optimal filter design

3. Filter Design with EMI Analyzer

EMI Analyzer EA-300

Impedance Module

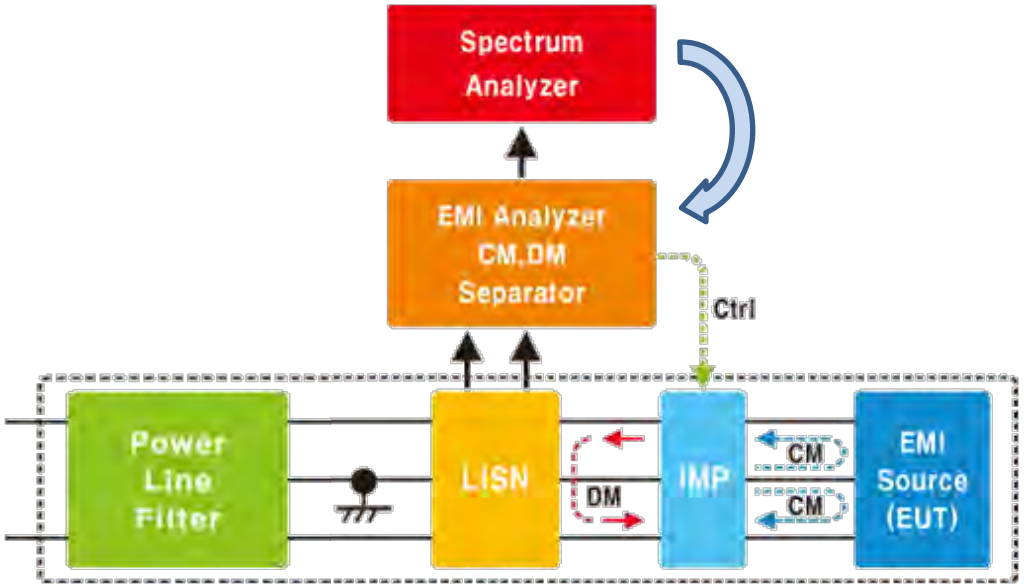
System

2. Optimal filter design

3) Filter Design with EMI Analyzer

EMI Analyzer
(EA-300)

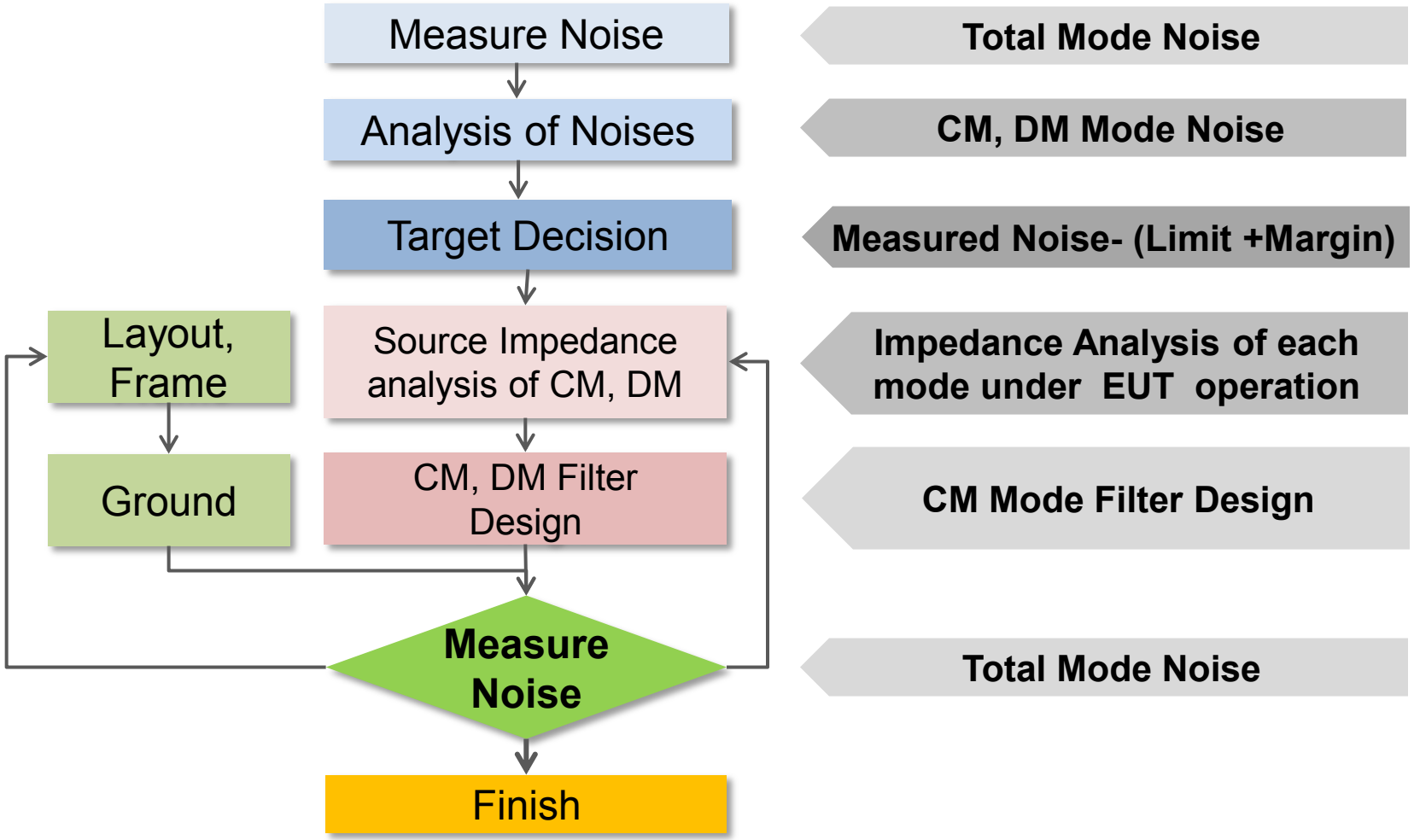
1. Measure Total Mode Noise
2. CM, DM Noise Analysis
3. Source Impedance Analysis
4. Analysis of each components
5. EMI Filter Design (Basic)



EMI Measurement and Analysis

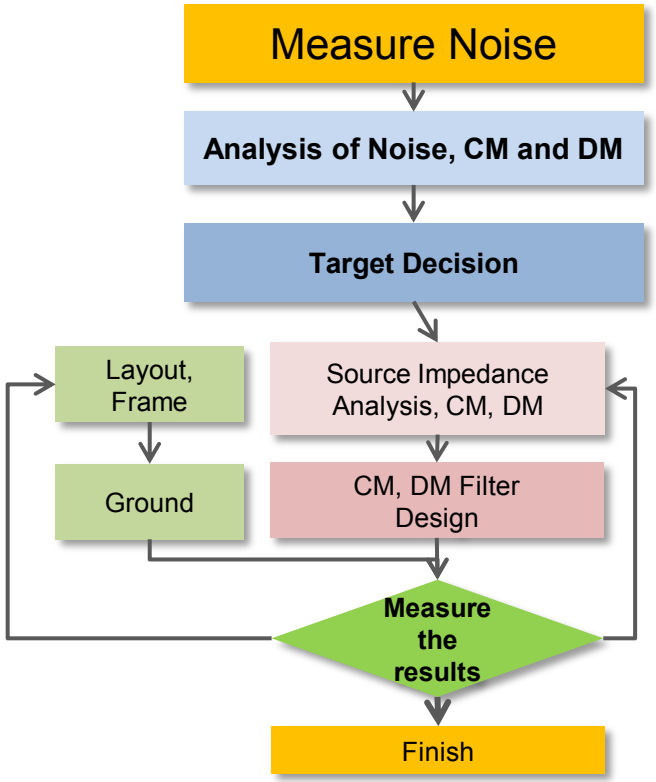
2. Optimal filter design

4) EMCIS Filter Design Process

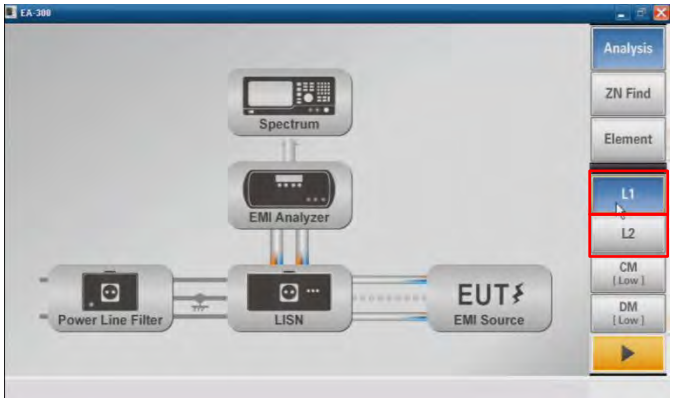


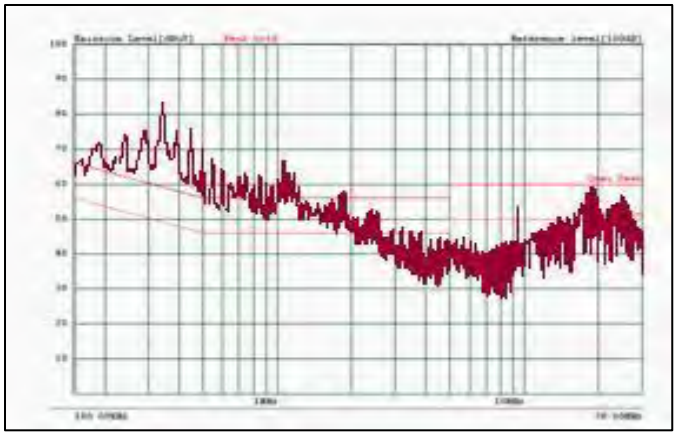
2. Optimal filter design

4) EMCIS Filter Design Process



Total Mode Noise measurement

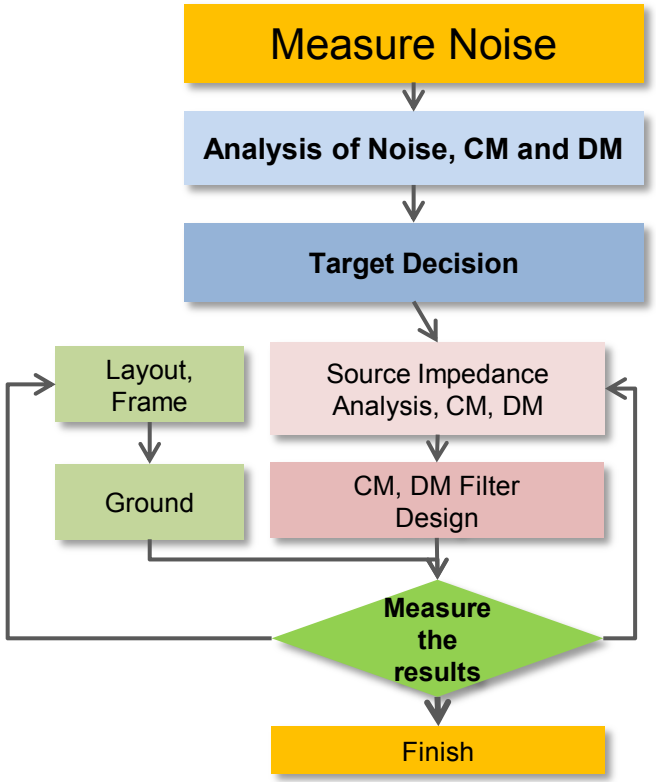




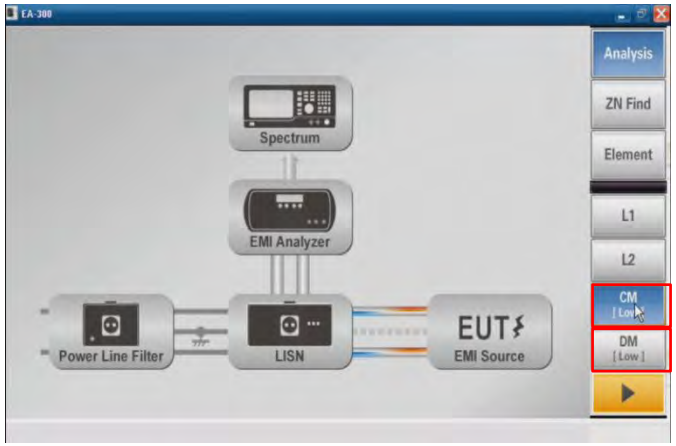
L1 or L2 Noise (Total Noise)

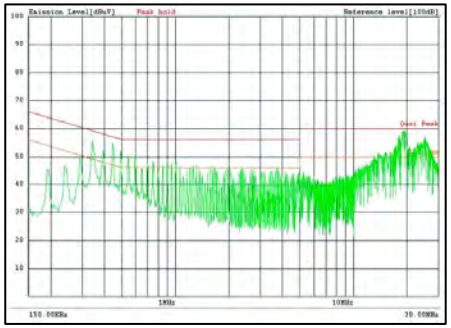
2. Optimal filter design

4) EMCIS Filter Design Process

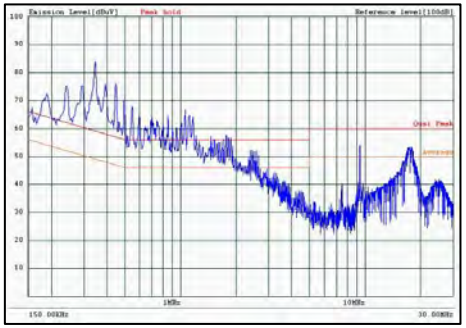


CM, DM Mode Analysis





CM Mode Noise

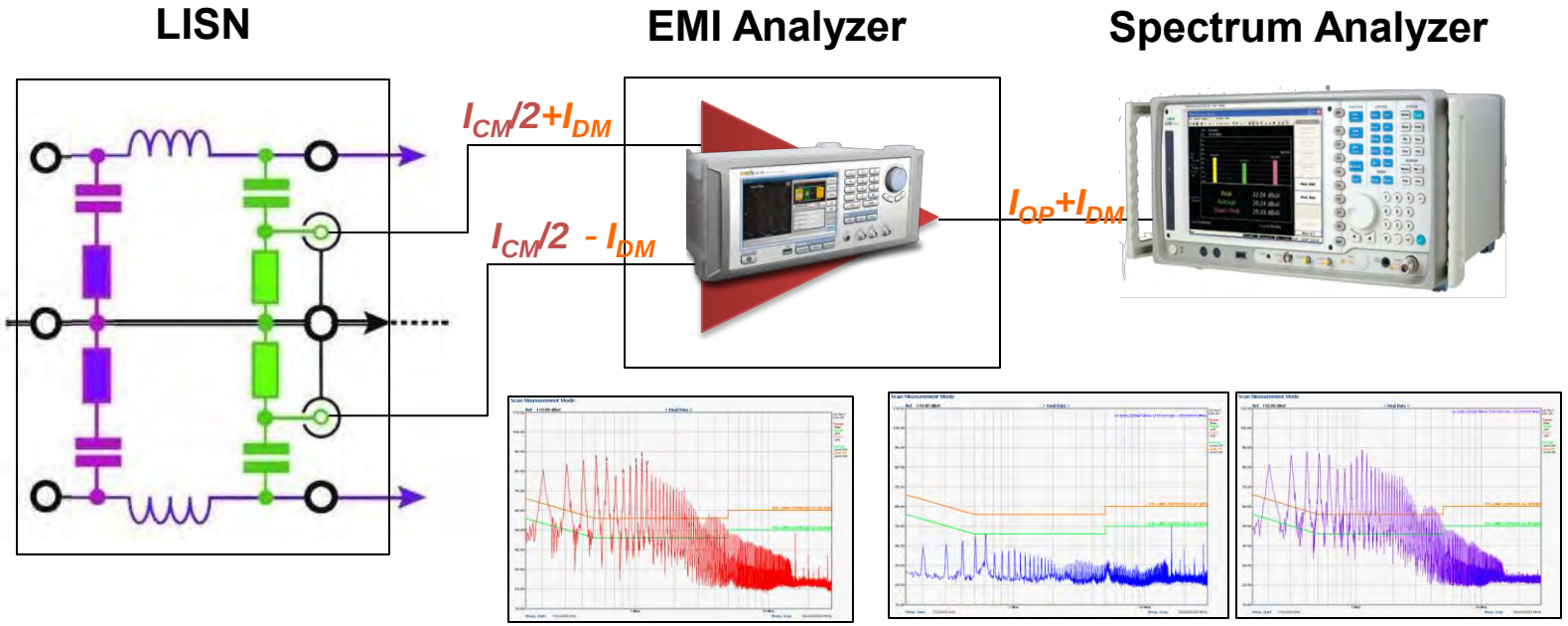


DM Mode Noise

2. Optimal filter design

4) EMCIS Filter Design Process

CM, DM Mode Noise Measurement



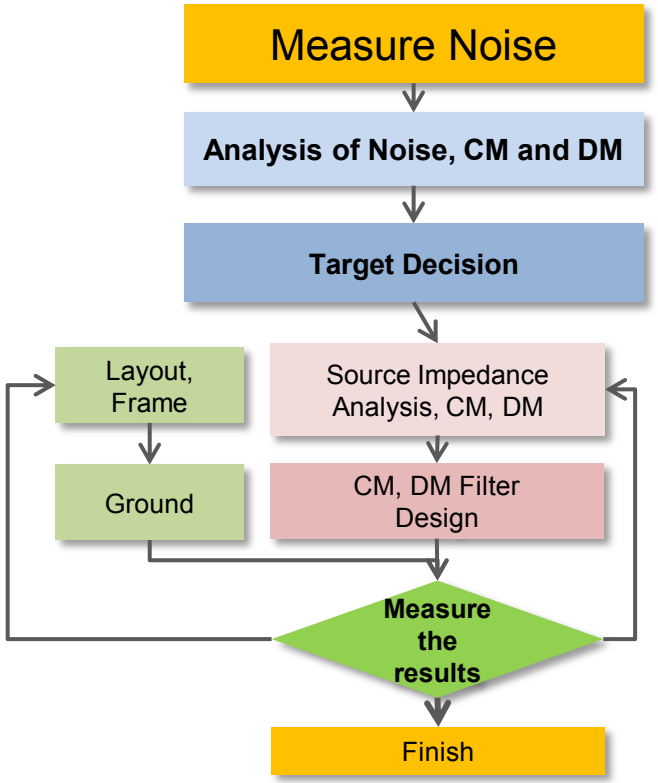
Through 2ports of LISN, Pick up Noise (Total Noise)

EMI Analyzer separates and analyzes them

Common Mode (CM) and Difference Mode (DM) respectively

2. Optimal filter design

4) EMCIS Filter Design Process

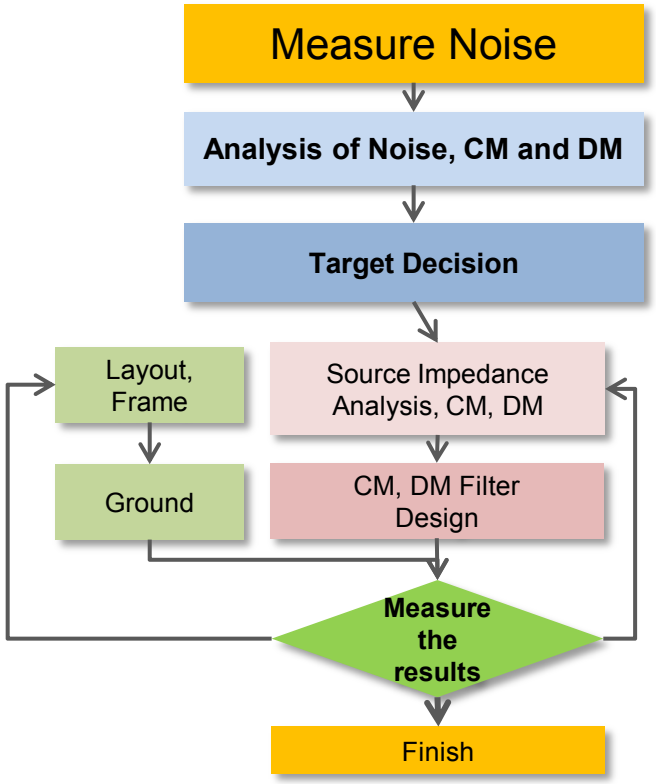


200kHz	Total	CM Mode	DM Mode
Noise Level	90dBuV	81dBuV	86dBuV
LIMIT	53dBuV	53dBuV	53dBuV
Margin	3dBuV	3dBuV	3dBuV
Insertion loss	40dBuV	31dBuV	36dBuV

Target - Solution

2. Optimal filter design

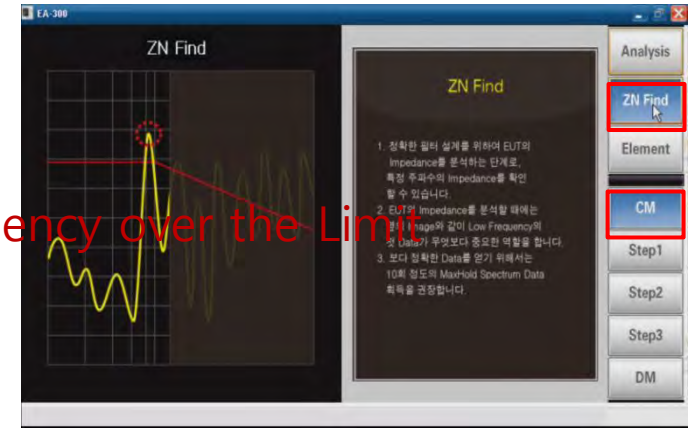
4) EMCIS Filter Design Process



Source Impedance Analysis

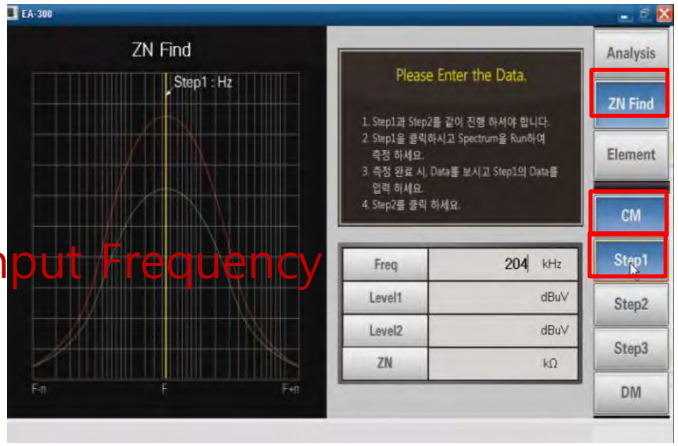
CM Mode

1) Select CM Mode



1st frequency over the Limit

2) Set up Frequency

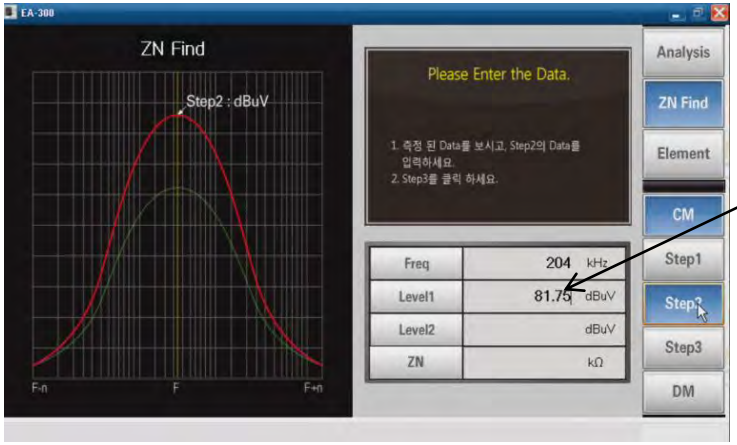


Input Frequency

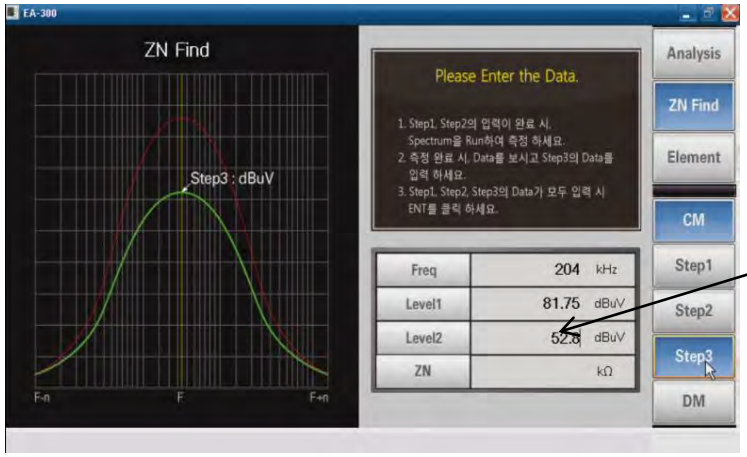
2. Optimal filter design

4) EMI Filter Design Process

3) Input Noise Level

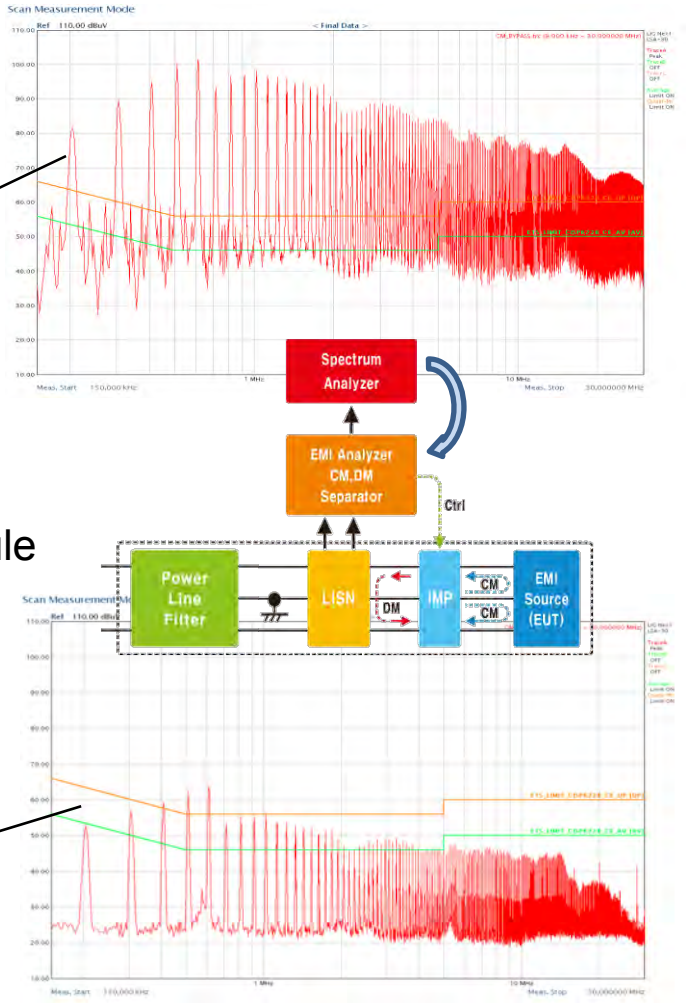


4) Auto changing/tracing the Level by IMP Module



Source Impedance Analysis

CM Mode

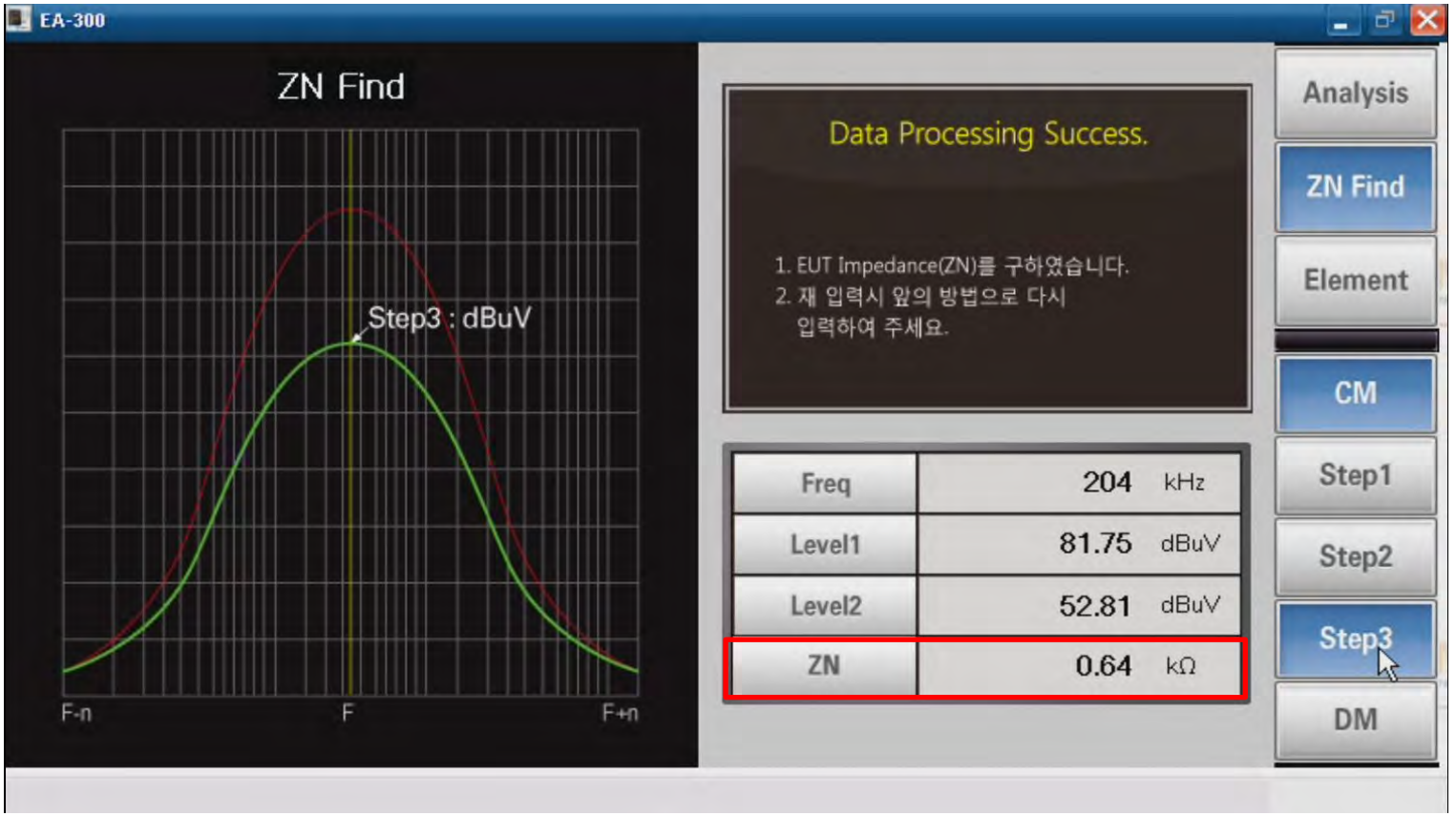


2. Optimal filter design

4) EMCIS Filter Design Process

Source Impedance Analysis

CM Mode



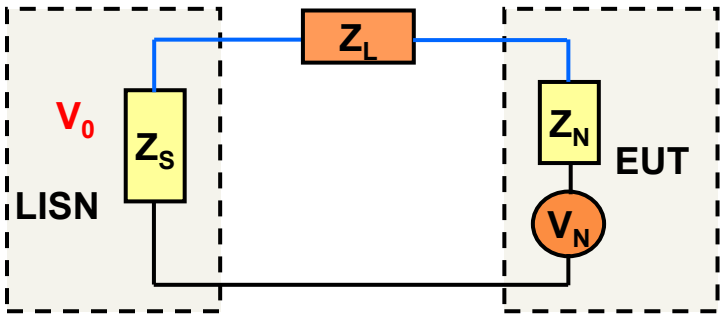
DM Mode Impedance is same as CM case

2. Optimal filter design

4) EMCIS Filter Design Process

Source Impedance Analysis

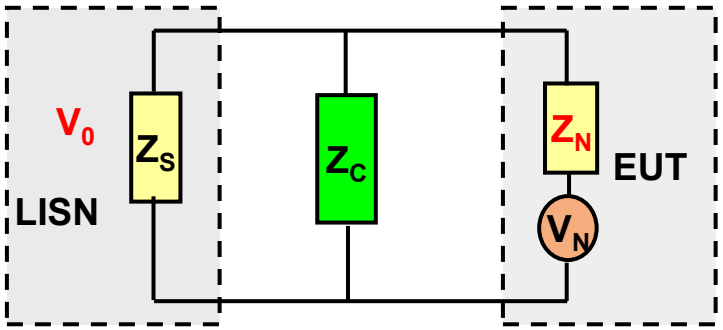
CM Mode



$$V_O = \frac{Z_S}{Z_S + Z_N + Z_L} \cdot V_N$$

$$IL = 20\log\left|\frac{v_N}{v_O}\right| = 20\log\frac{\sqrt{(\omega L)^2 + (Z_N + Z_S)^2}}{Z_S}$$

DM Mode



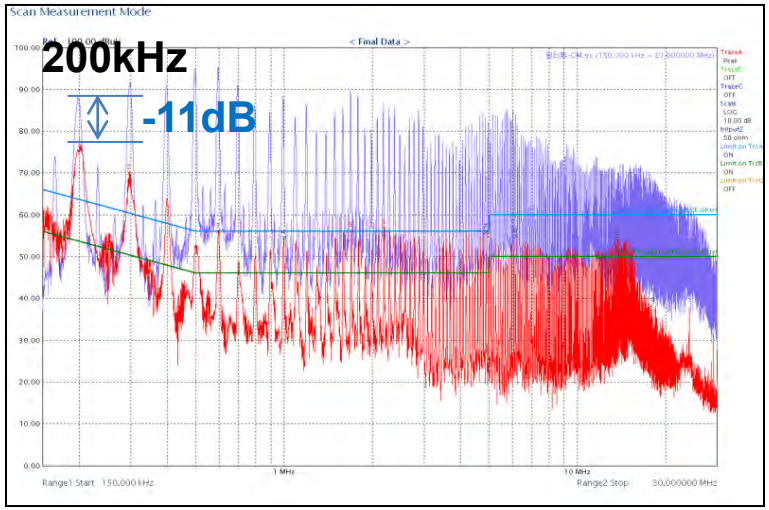
$$v_O = \frac{Z_S Z_C}{Z_N Z_S + (Z_S + Z_N) Z_C} \cdot v_N$$

$$IL = 20\log\left|\frac{v_N}{v_O}\right| = 20\log\left|\frac{sCZ_S Z_N + Z_N + Z_S}{Z_S}\right|$$

$$= 20\log\frac{\sqrt{(\omega C Z_S Z_N)^2 + (Z_N + Z_S)^2}}{Z_S}$$

2. Optimal filter design

4) EMCIS Filter Design Process



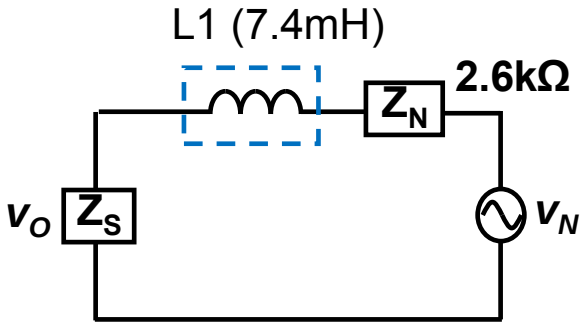
88dBuV -> 77dBuV = -11dB

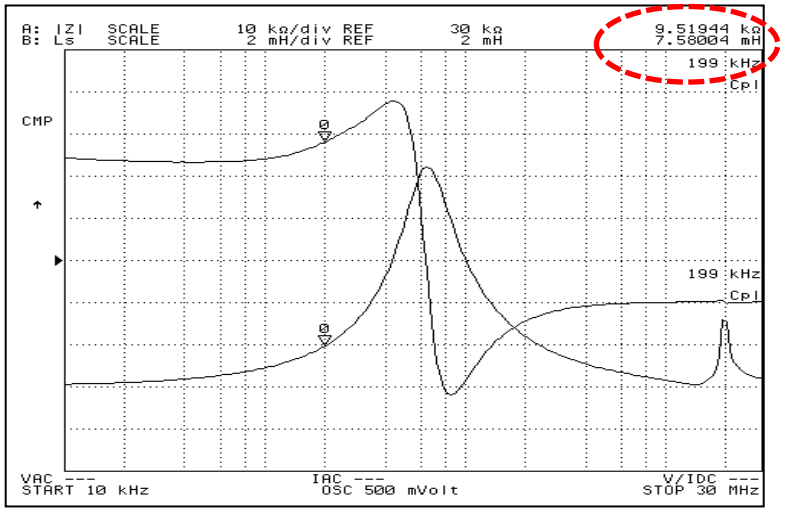
$$IL = 20\log \frac{Zn}{CM_{Z\text{-}200kHz}}$$

$$IL = 20\log \frac{2.6k\Omega}{9.5k\Omega} = -11.3dB$$

CM Mode

Source Impedance Analysis



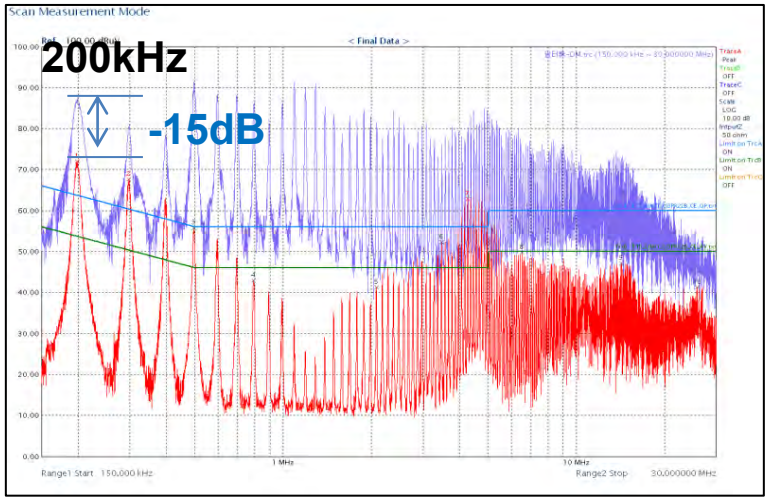


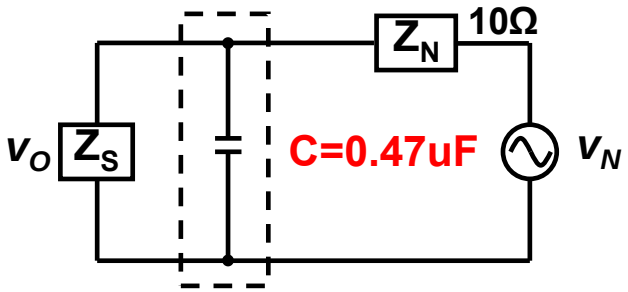
2. Optimal filter design

4) EMCIS Filter Design Process

DM Mode

Source Impedance Analysis

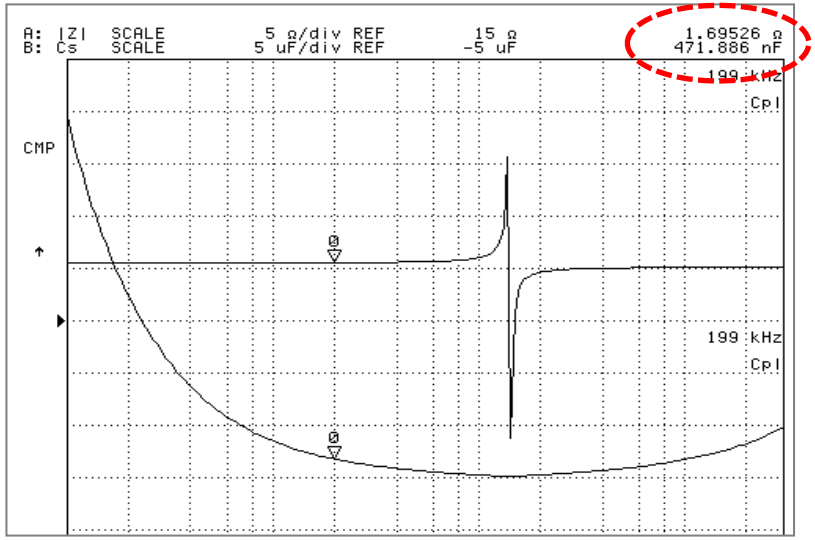




87dBuV ->72dBuV = -15dB

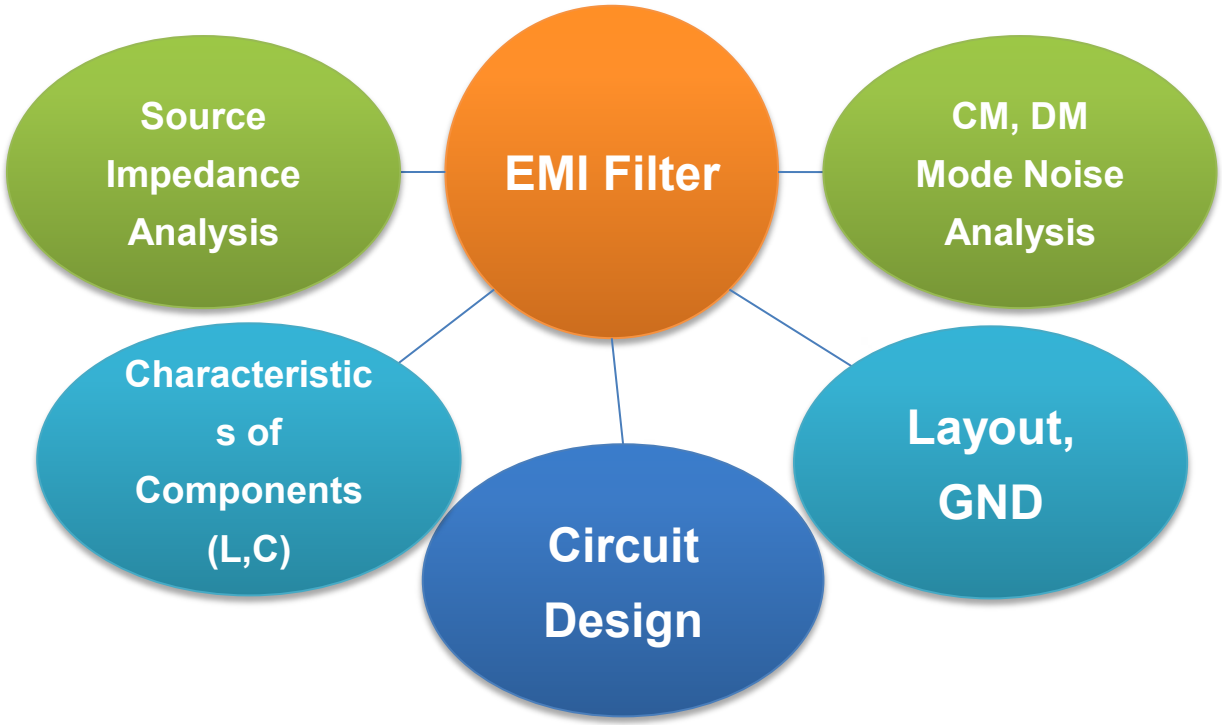
$$IL = 20\log \frac{XC_{Z\text{-}200kHz}}{Zn}$$

$$IL = 20\log \frac{1.7\Omega}{10\Omega} = -15.4\ dB$$



2. Optimal filter design

5) Filter Design



Optimal Design (Cost down)

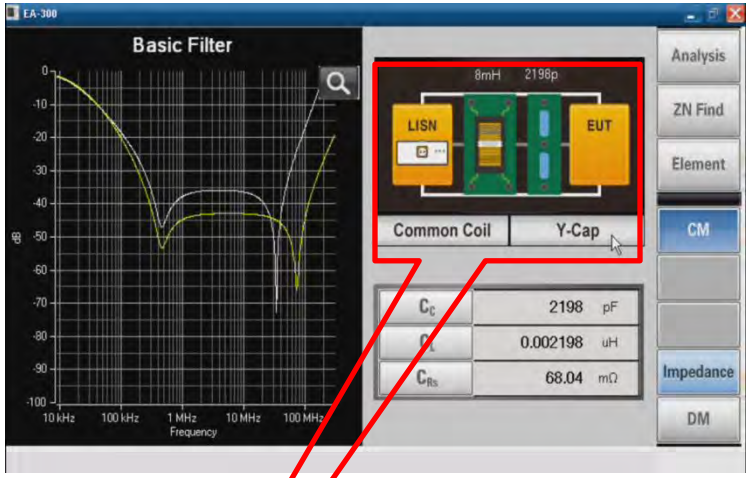
Fast Solution (Competitiveness)

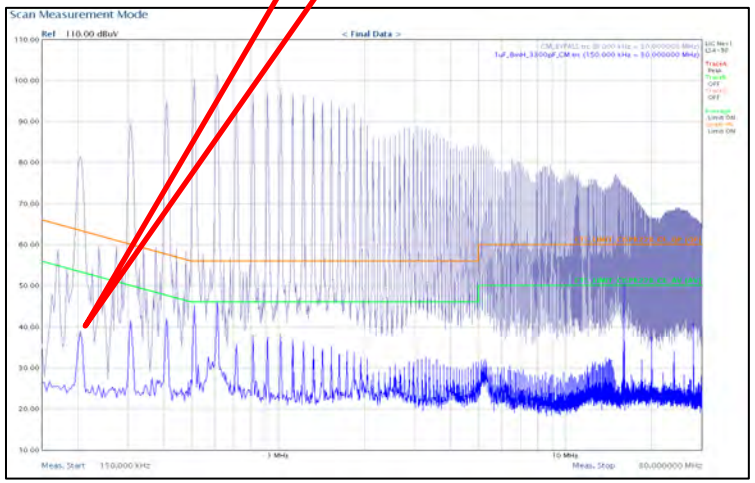
Optimized Layout and Structure (Cost, Competitiveness)

2. Optimal filter design

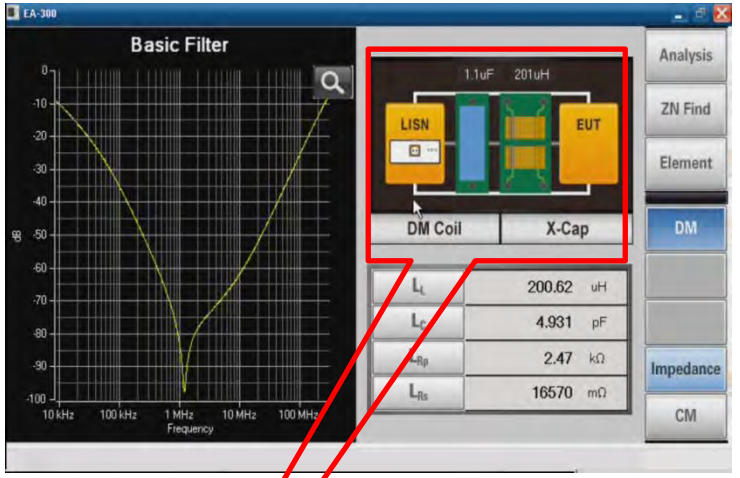
5) EMI Filter Design (Basic)

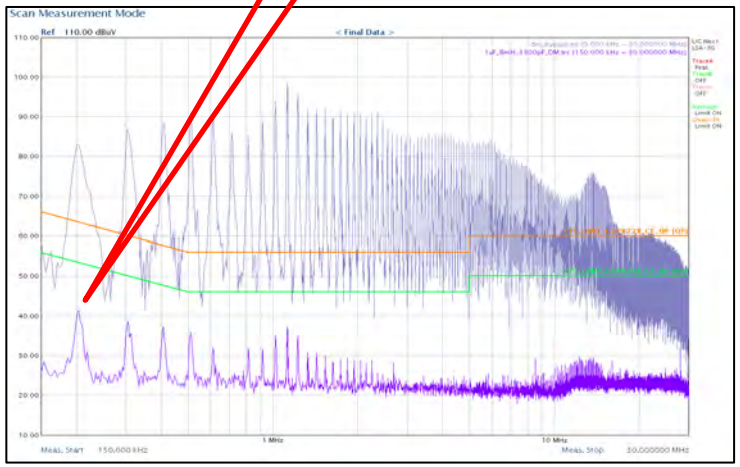
(CM Mode)





(DM Mode)

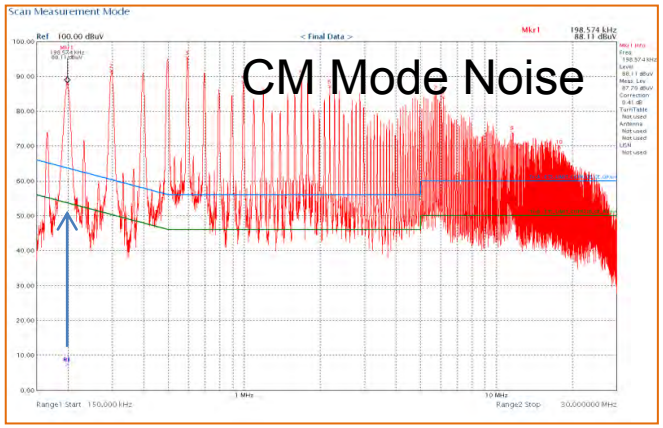


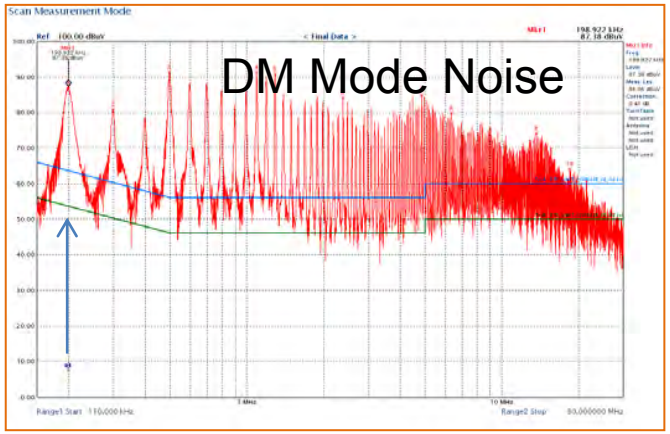


3. Verification of EMI Filter Design

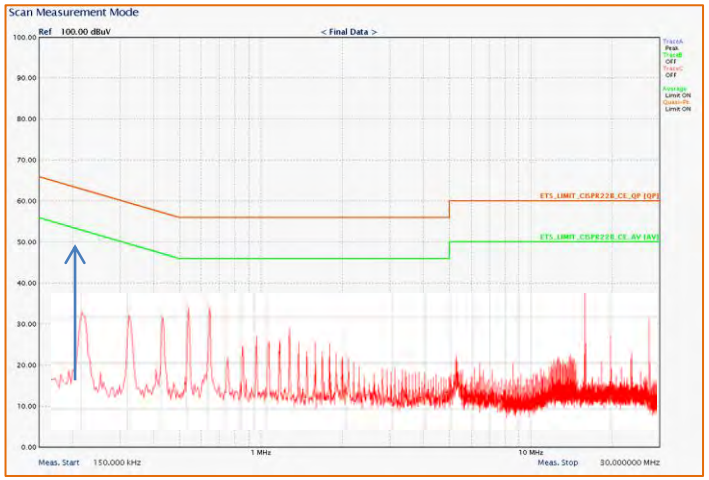
1) Verifying by Noise characteristics

- Check the proper margin (from the limit line) at each mode, CM,DM, and Total Mode with EMI Analyzer
- Recommended/acceptable about 3dB margin at Low frequency range



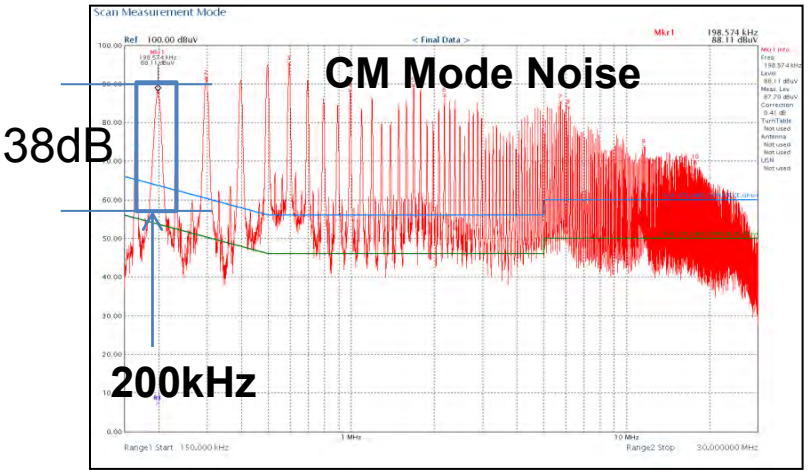


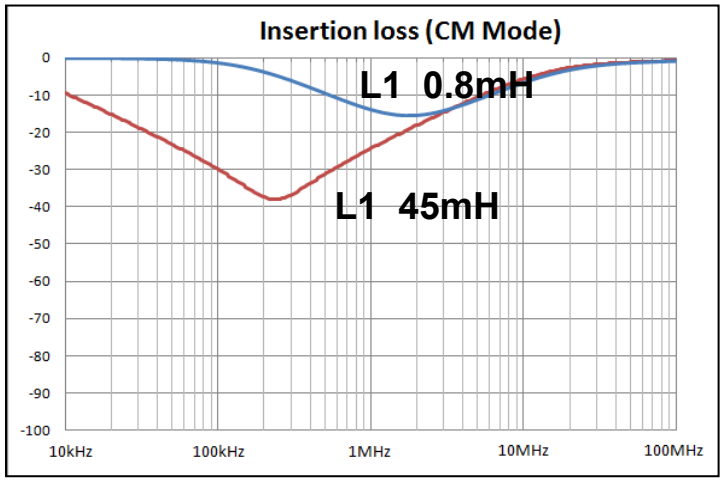
Total Mode Noise



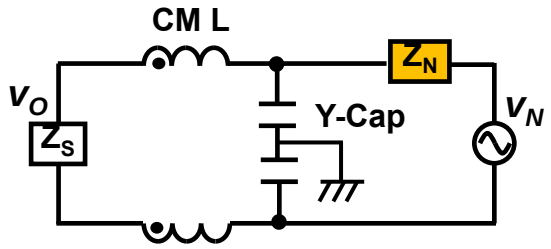
3. Verification of EMI Filter Design

2) Theatrical Verification of Filter Design

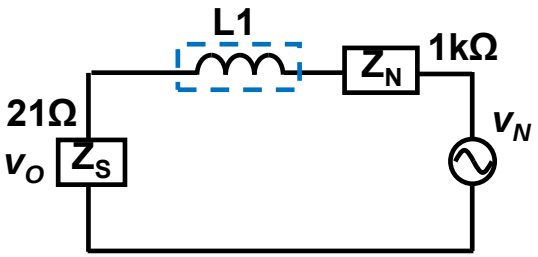




CM Mode Filter



Check the capacity of CML & Y-Capacitor is reasonable ??



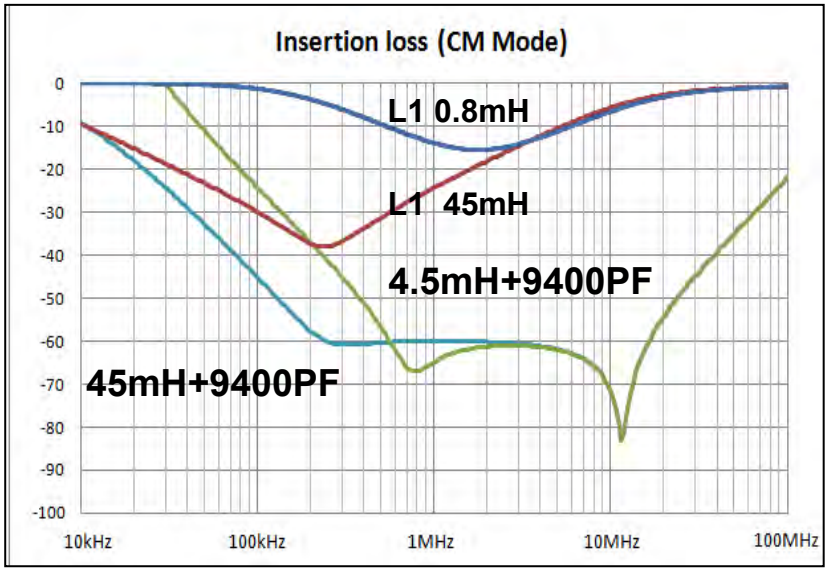
$$\text{Ref L} = \frac{Z_N}{2\pi F} = 0.8\text{mH (-3dB)}$$

$$20\log \frac{0.8\text{mH}}{45\text{mH}} = -35\text{dB} = -38\text{dB}$$

3. Verification of EMI Filter Design

2) Theatrical Verification of Filter Design

CM Mode Filter



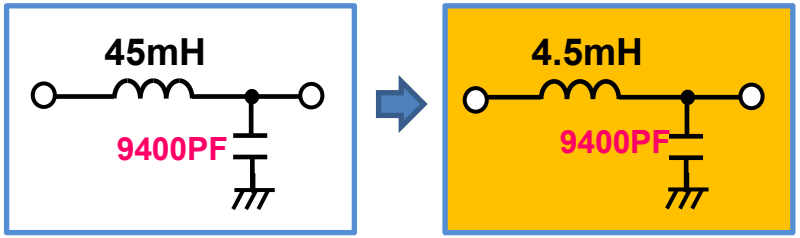
$$20\log \frac{C_S}{Y_C}$$ **1/10 of YC resonance**

$$20\log \frac{10PF}{9400PF} = -59.5dB$$

45mH+9400PF =-58dB (200kHz)

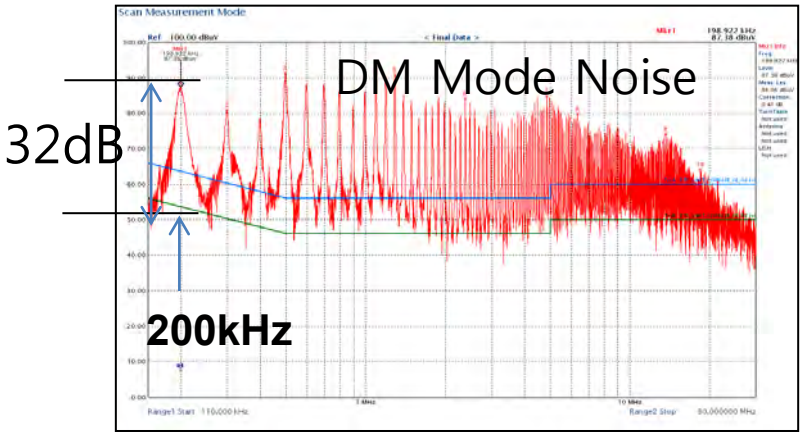
20dB Margin

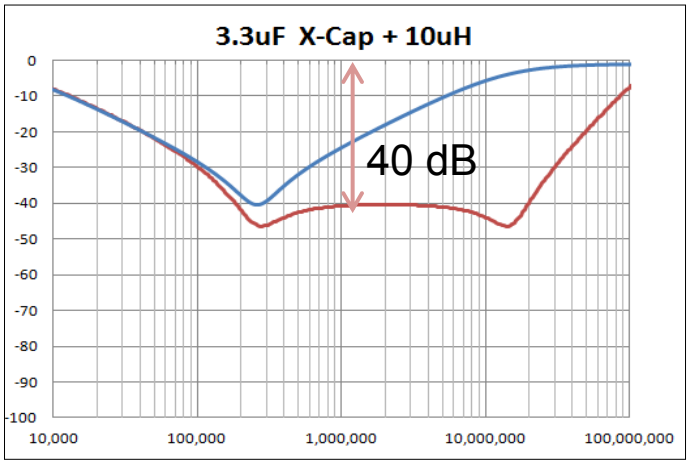
$$\mathbf{20\log \frac{45mH}{4.5mH} = +20dB}$$



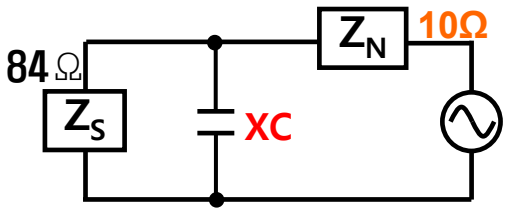
3. Verification of EMI Filter Design

2) Theatrical Verification of Filter Design



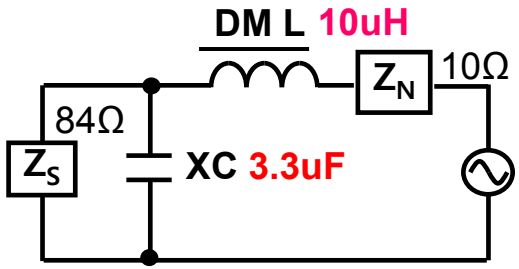


DM Mode Filter



$$\text{Ref } X_C = \frac{1}{2\pi F Z_N} = 0.08uF$$

$$20\log \frac{0.08uF}{3.3uF} = -32dB = -35dB$$

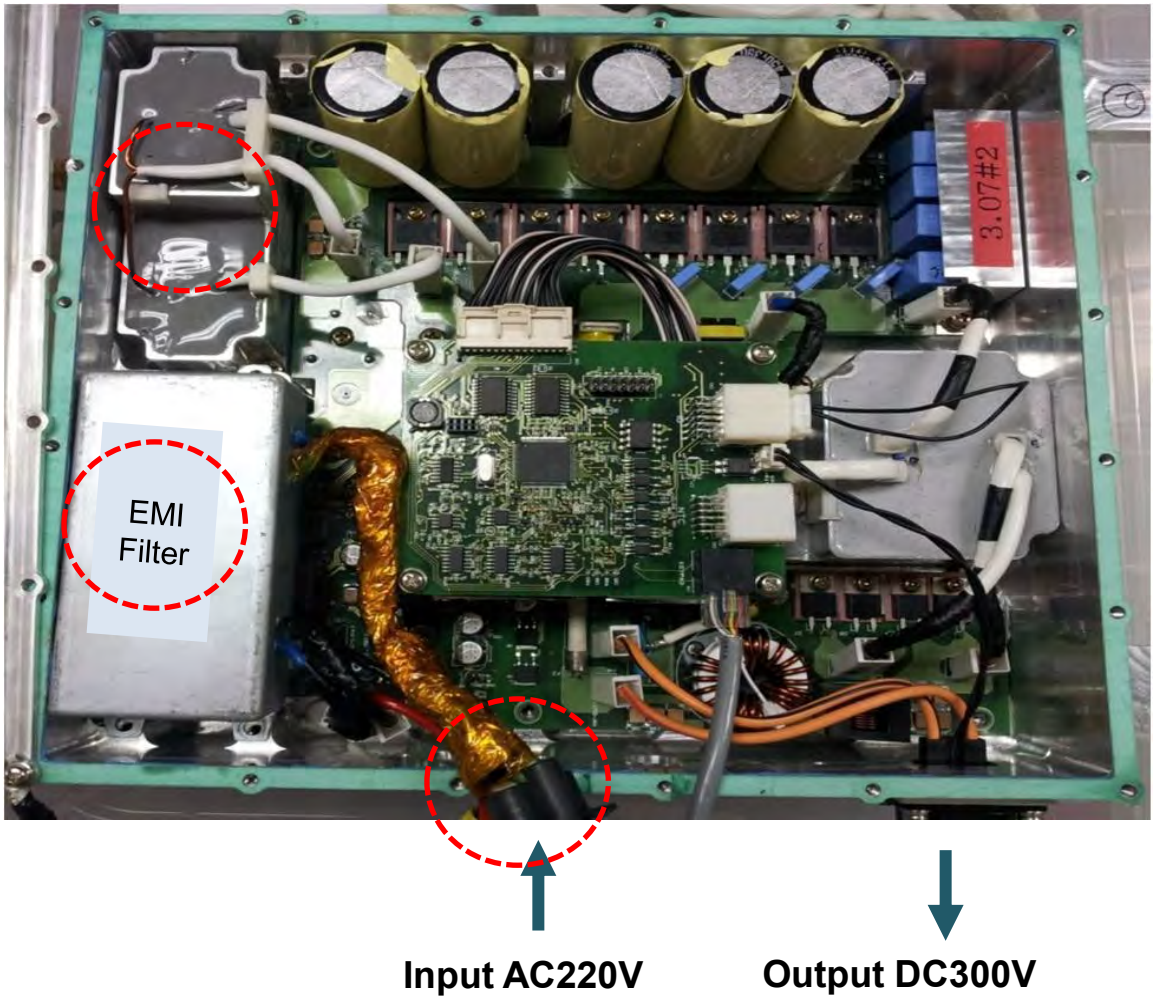


$$20\log \frac{XC_L}{DM_L}$$ **1/10 of DML resonance frequency**

$$20\log \frac{100nH}{10uH} = -40\ dB$$

4. Case Study of EMI Filter Design

1) Battery charger on Hybrid Vehicle

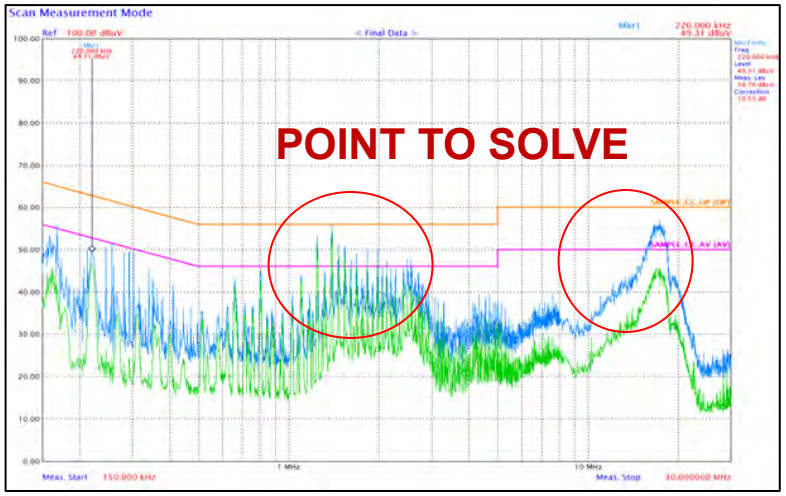


4. Case Study of EMI Filter Design

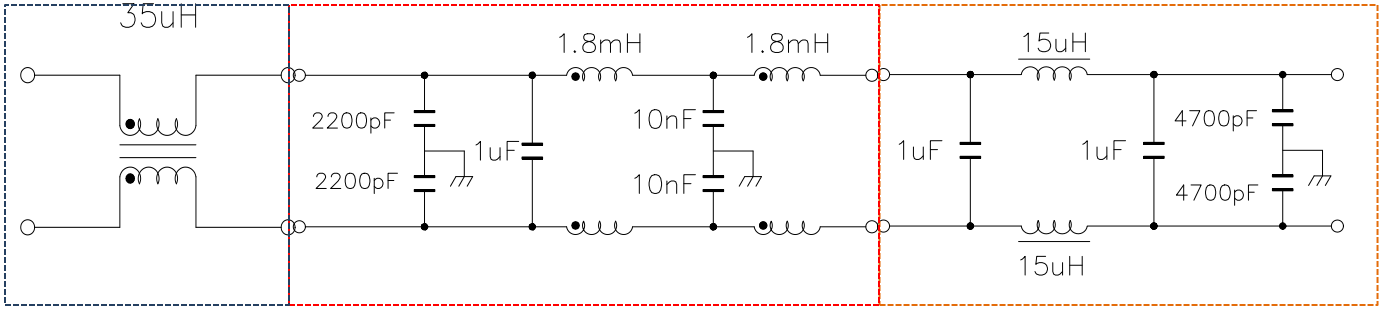
2) Customer Design - current

Battery charger on Hybrid Vehicle

Total Noise



Even spending 3months, not solved



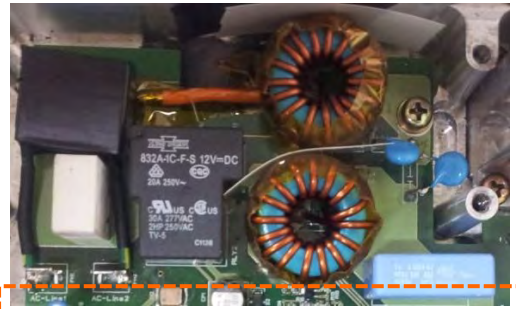
Designed/Applied Filter

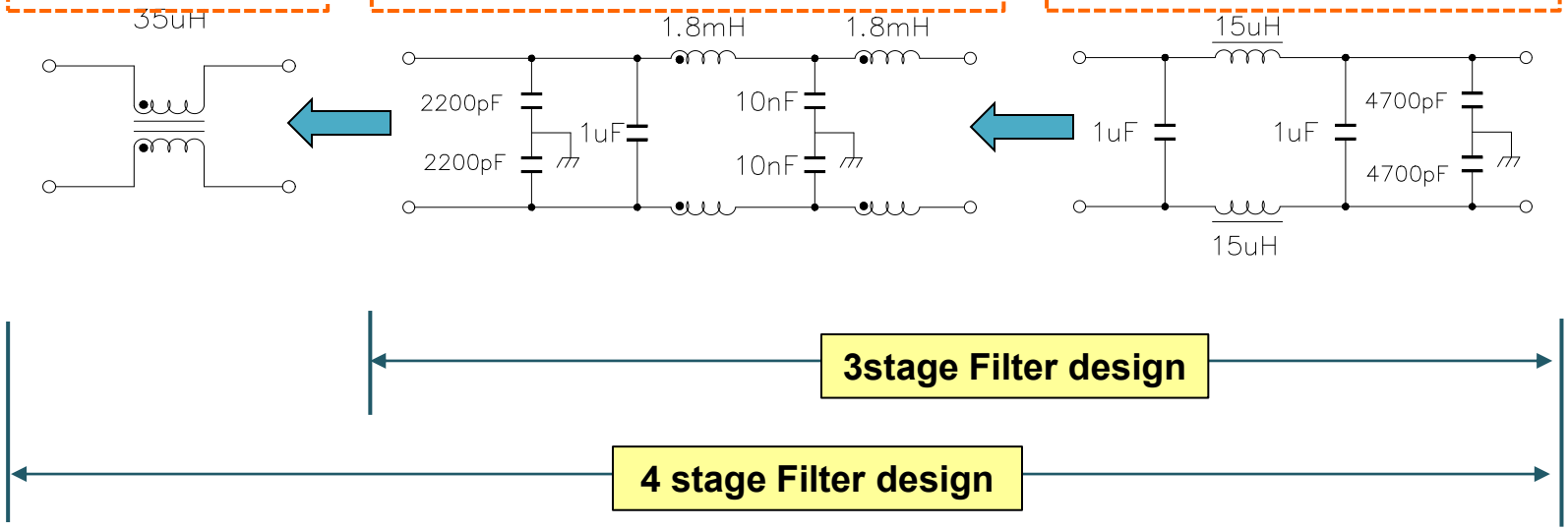
4. Case Study of EMI Filter Design

2) Customer design - current

Battery charger on Hybrid Vehicle

2 Ferrite cores feed on cable -2 turns (35uH)

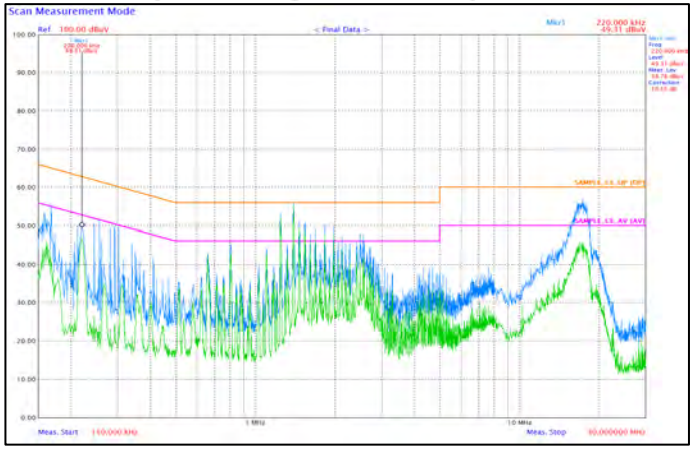




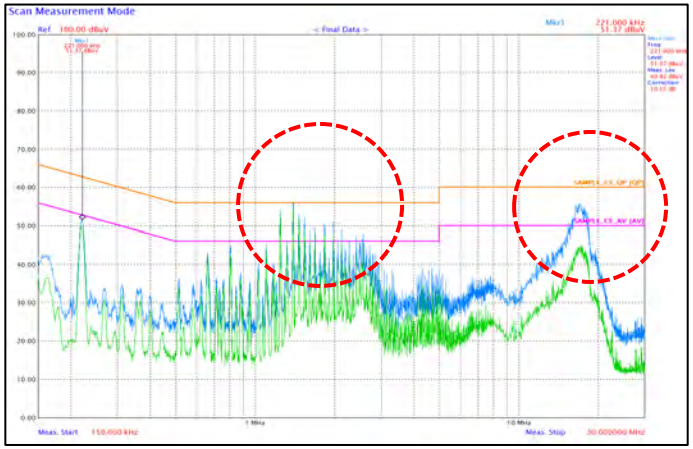
4. Case Study of EMI Filter Design

3) Noise Analysis – EMCIS

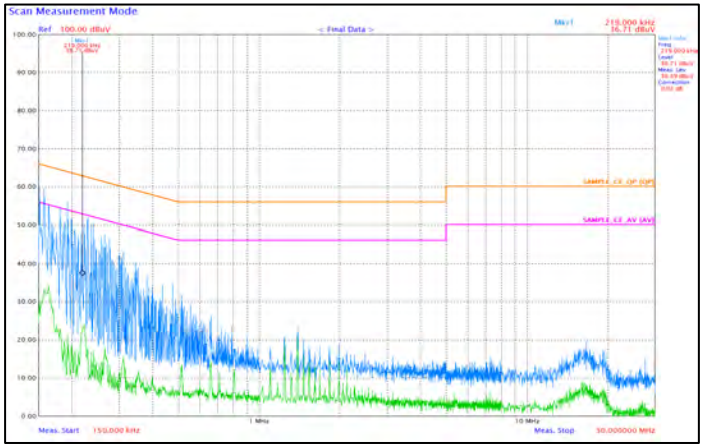
Battery charger on Hybrid Vehicle



Common Mode



Differential Mode



Result : the Noise in target is determined as Common Mode Noise

4. Case Study of EMI Filter Design

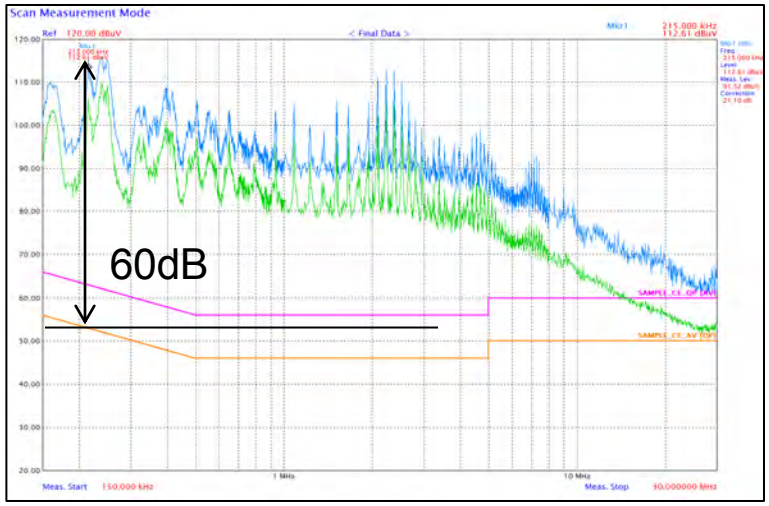
Battery charger on Hybrid Vehicle

4. Case Study of EMI Filter Design

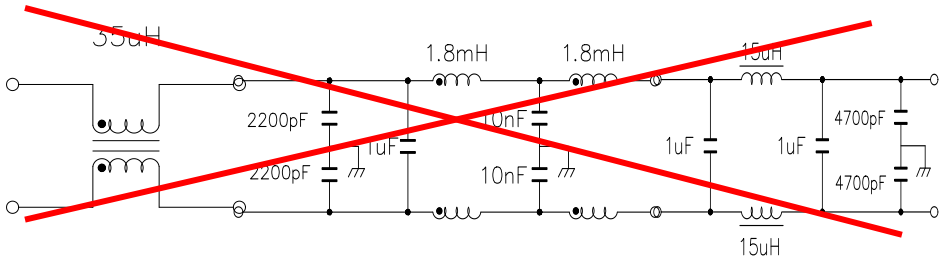
4) Measure the noises

Battery charger on Hybrid Vehicle

Total Noise



(Meausre without any filter)



Measure the current noise to decide the target and the Filter design

Target

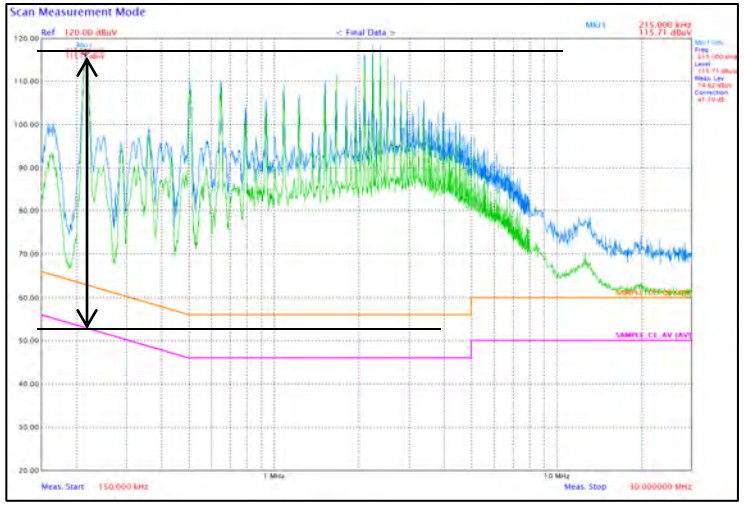
215kHz 112.7dBuv->53dBuV = Min 60dB deduction

4. Case Study of EMI Filter Design

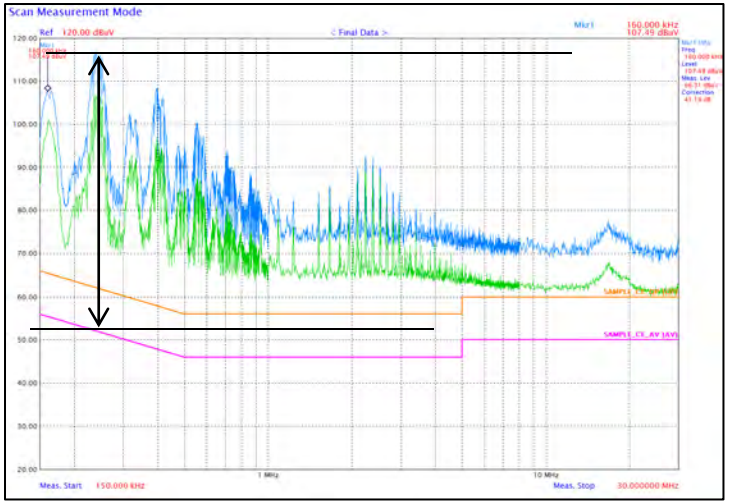
5) Analyze the Noise characteristics

Battery charger on Hybrid Vehicle

Common Mode



Differential Mode



Measure each mode, CM & DM respectively for Filter Design

Target

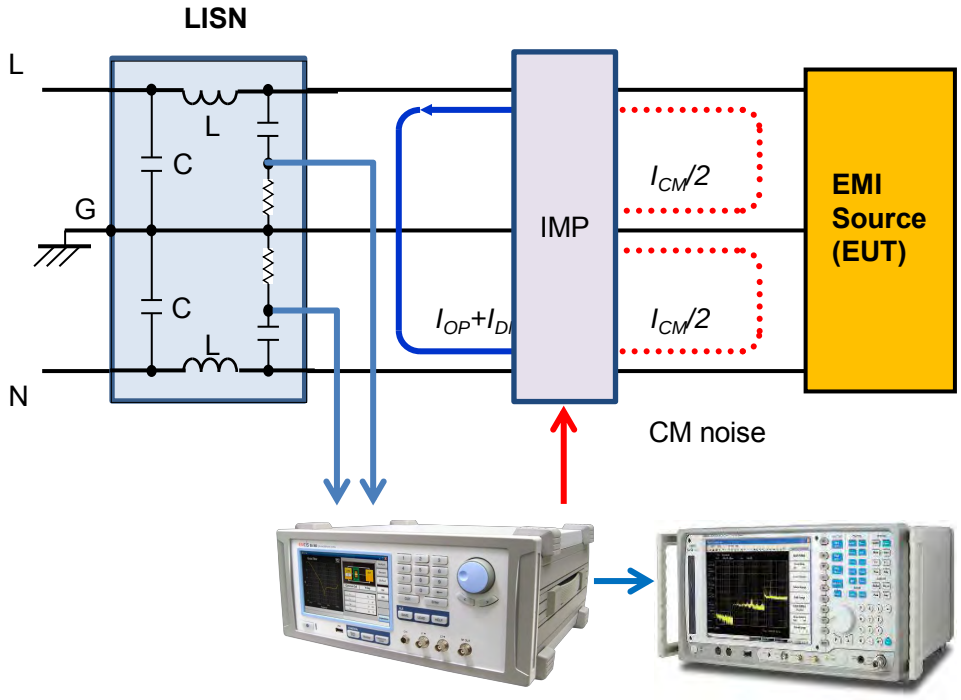
CM Mode : 215kHz 123.7dBuV -53dBuV =70dB

DM Mode : 240kHz 116.7dBuV -53dBuV =70dB

4. Case Study of EMI Filter Design

6) Source Impedance Analysis

Battery charger on Hybrid Vehicle



CM Mode	
Frequency	216kHz
By Pass	123dBuV
Impedance Module Control	116dBuV
Level Difference	7dB
Source Impedance	7 kΩ

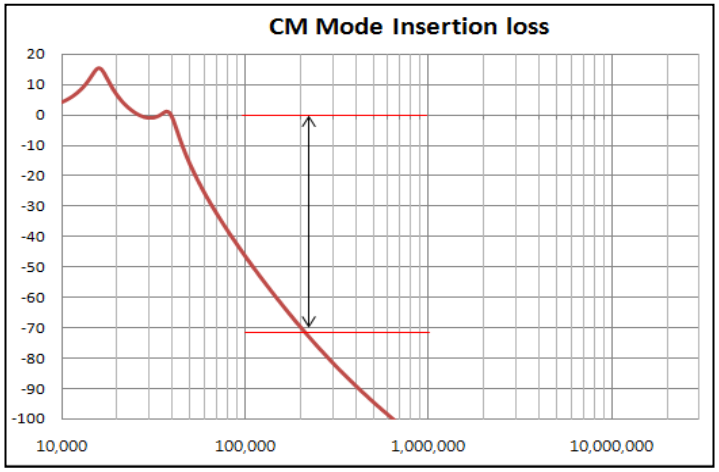
DM Mode	
Freq	240kHz
By Pass	116.7dBuV
Impedance Module Control	95.2dBuV
Level Difference	21.5dB
Source Impedance	16.8Ω

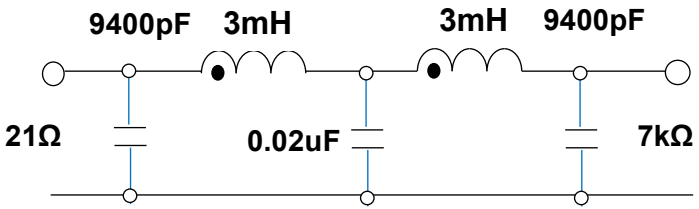
4. Case Study of EMI Filter Design

Battery charger on Hybrid Vehicle

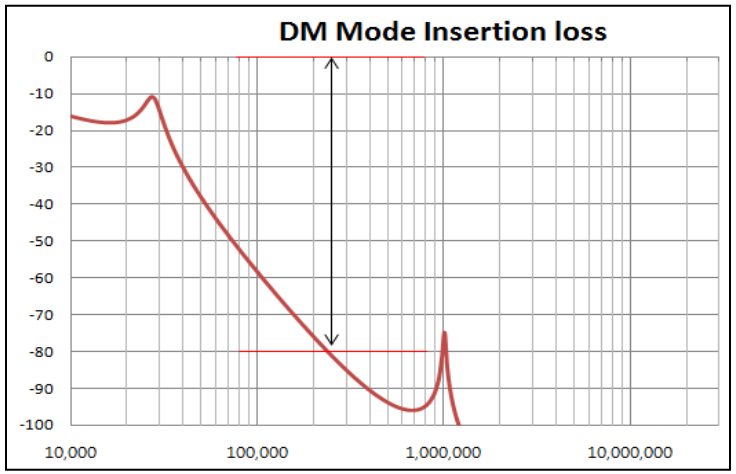
7) Filter Design

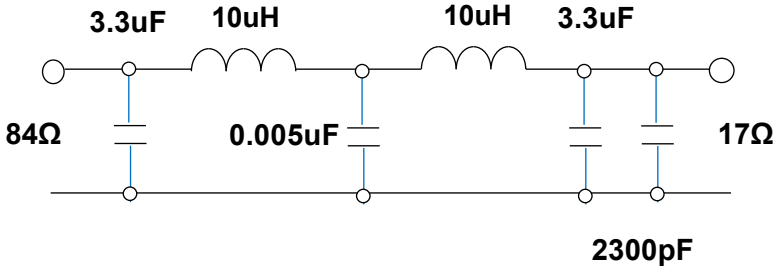
CM Mode





DM Mode



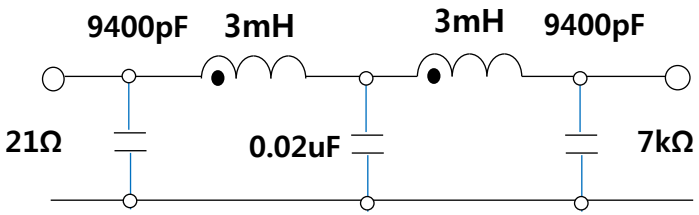


4. Case Study of EMI Filter Design

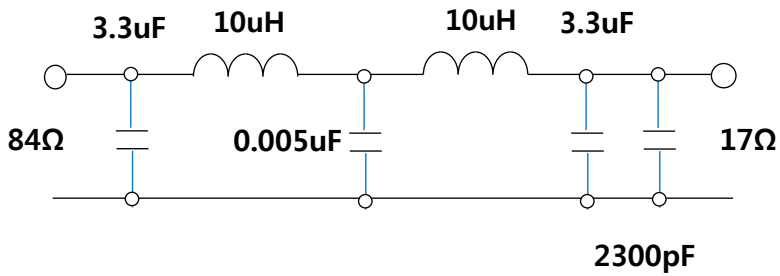
7) Filter Design

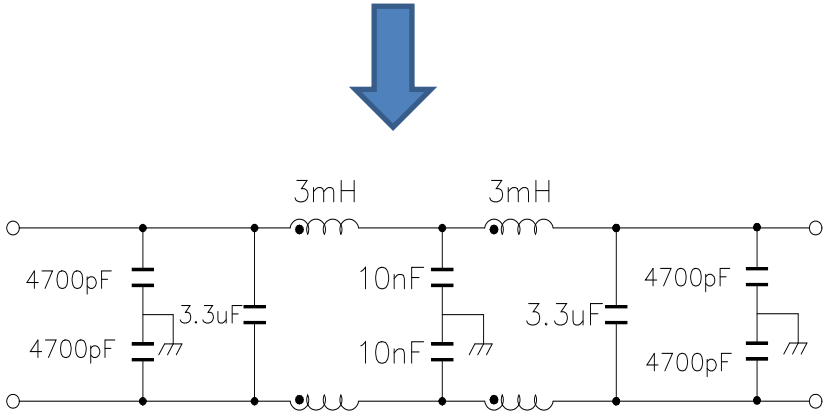
Battery charger on Hybrid Vehicle

CM Mode



DM Mode

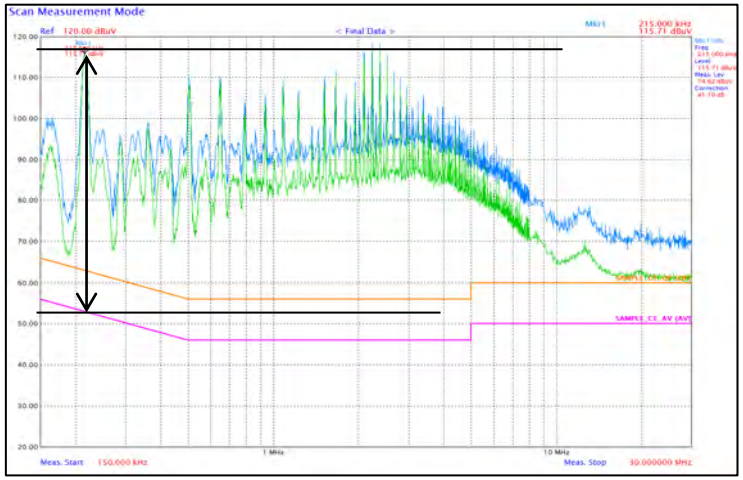


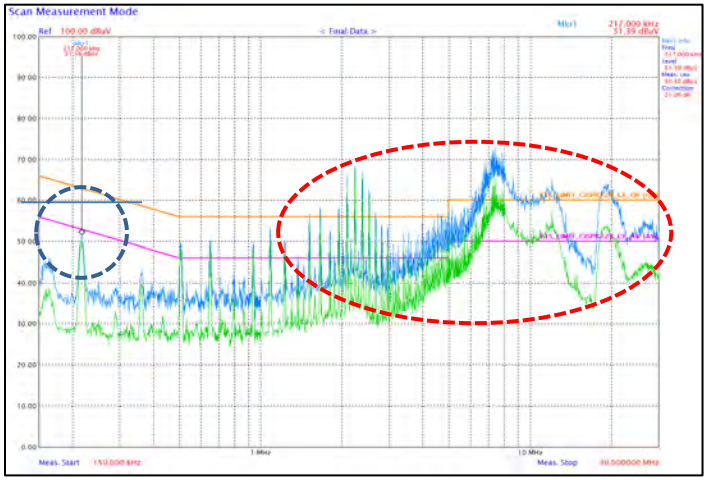


4. Case Study of EMI Filter Design

Battery charger on Hybrid Vehicle

8) Measure applying EMCIS design filter





The noise is over the limit line beyond 1MHz frequency

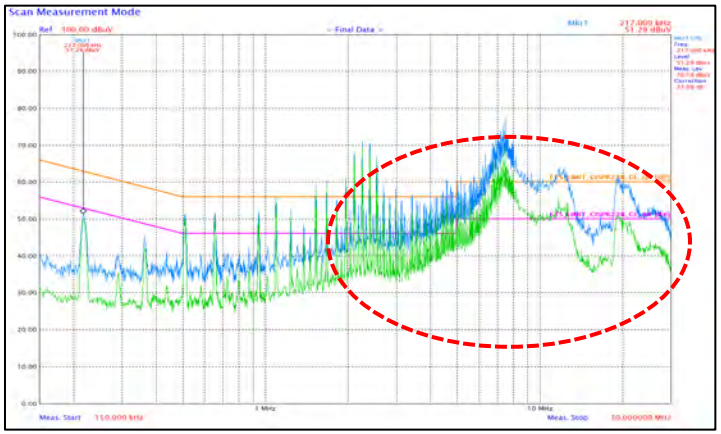
EMI Filter Design = Very Good !!!

This is the Point why EMI solution is impossible for last 3months!!

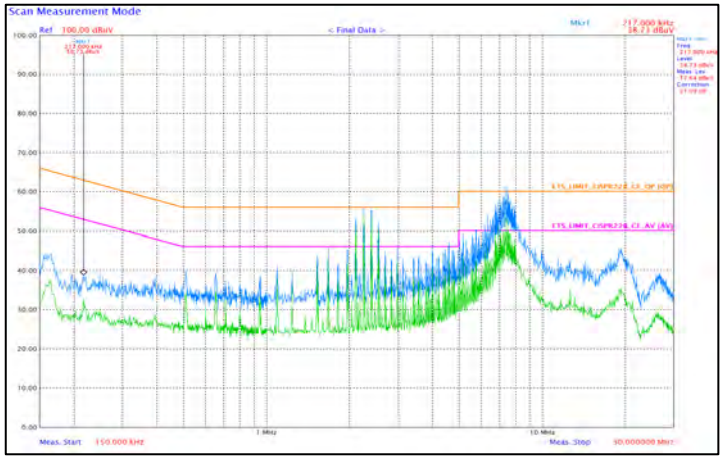
4. Case Study of EMI Filter Design

9) Analysis of the Pointed range

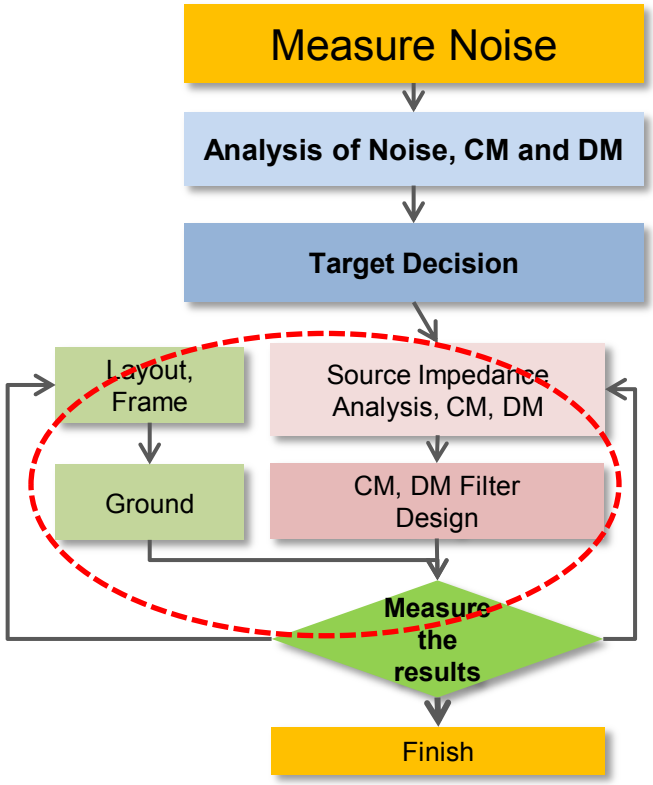
Common Mode



Differential Mode



Battery charger on Hybrid Vehicle



Results – the Cause

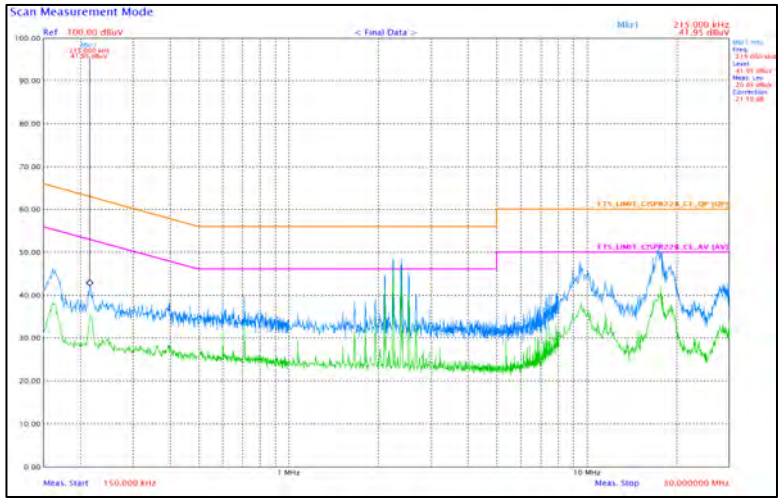
1. **the problem is by Common Mode Noise**
2. **Ground**

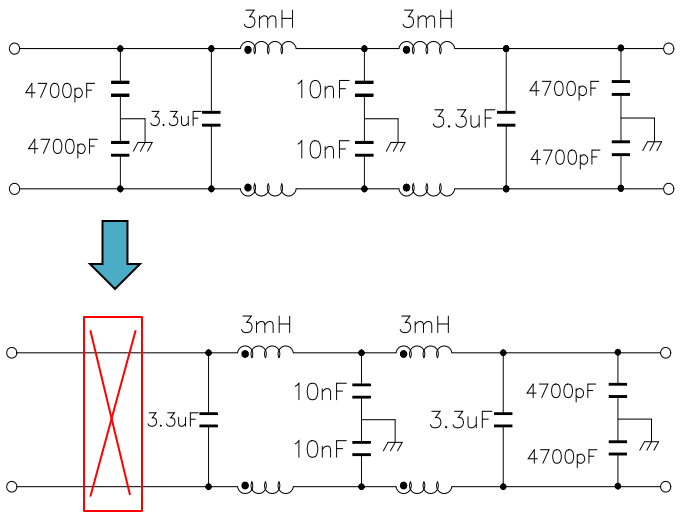
4. Case Study of EMI Filter Design

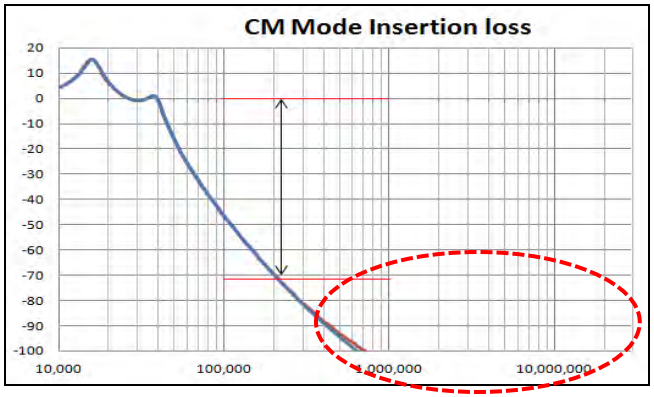
10) Circuit modification

Battery charger on Hybrid Vehicle

Total Noise : L1, L2







* Delete 472Y-CAP

* The purpose of Y-Cap in input portion

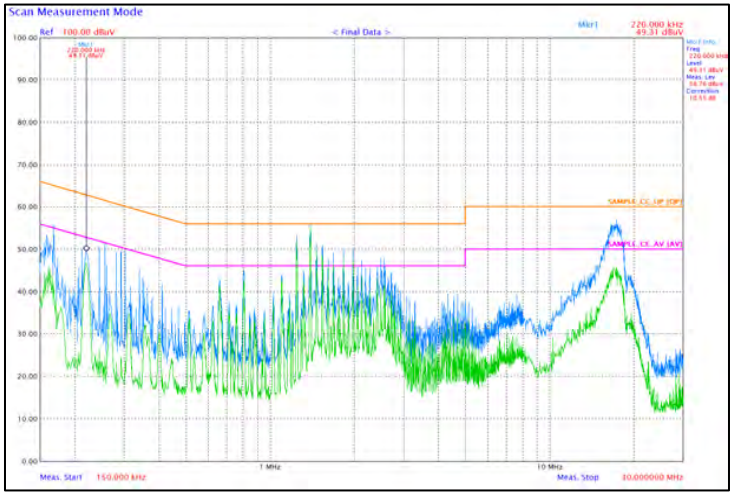
: Coupling noise elimination caused by layout

4. Case Study of EMI Filter Design

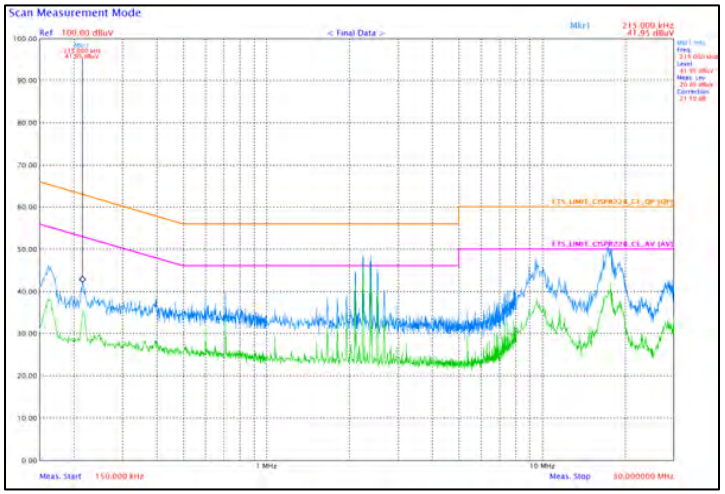
11) Conclusion

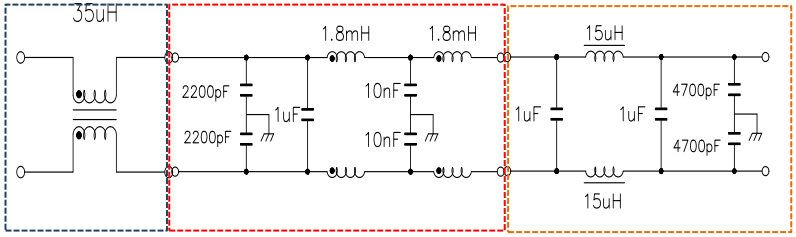
Battery charger on Hybrid Vehicle

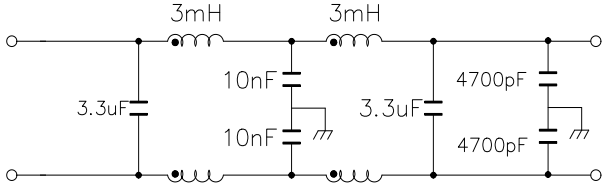
Before



After



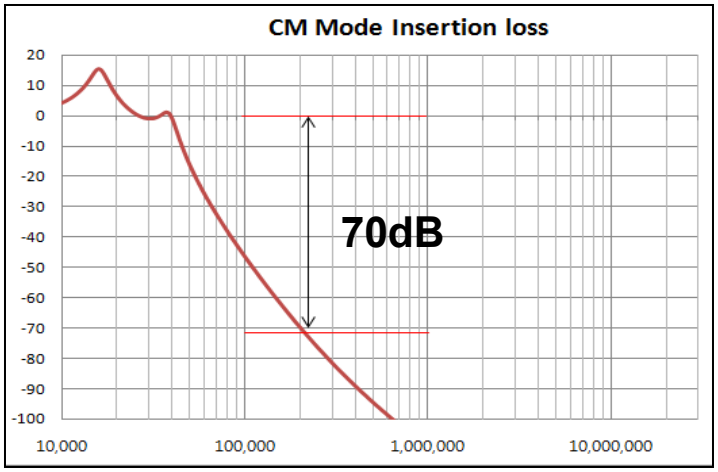


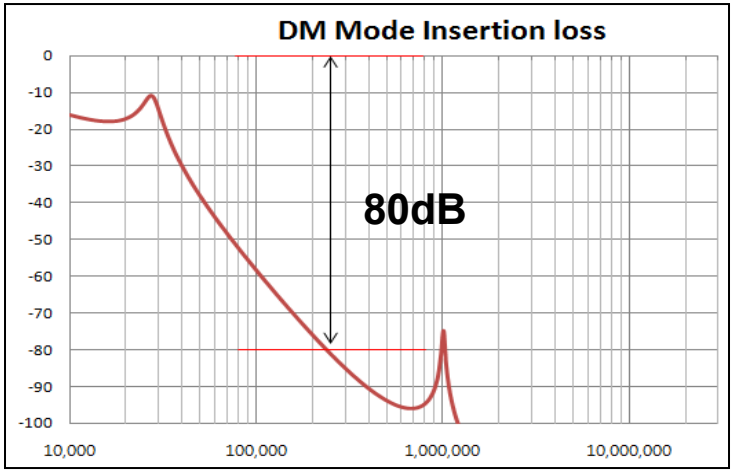


4. Case Study of EMI Filter Design

11) Conclusion

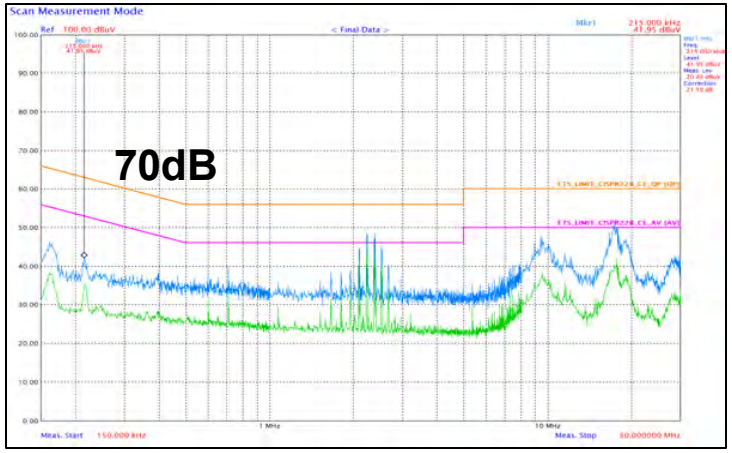
Battery charger on Hybrid Vehicle





Target

215kHz 112.7dBuv->53dBuV
59.7dB ≒ 60dB이상



Result

215kHz 112.7dBuv->43dBuV
69.7dB ≒ 70dB

Thank you