Integration from the view point of electric components

I deeply appreciate these responsible persons for their support and discussion at GND/EMC session.

If you need technical detail, please go to

http://www-esys.kek.jp/r-and-d/emc/emc-related-references

2015.02.07 MT on behalf
of GND/EMC group

Responsible persons

PXD: F.Arteche
SVD:M.Friedl
CDC:S.Uno
TOP:M.Andrew
ARICH:S.Korpar
ECL:Y.Usov/D.Epifanov
KLM:G.Visser
Timing:M.Nakao
DAQ,E-hut,Safety:R.Itoh
Magnet:M.Kawai

What we should do for electric integration

- **Electric Safety Guideline (incl. procedure)**
  - No fire and no smoke save our budget and our beam time.
- **Grounding/Shielding Guideline**
  - We will integrate detector subsystems into ideal case(faraday cage, grounding network) as much as possible.
    if you need technical detail, please go to http://www-esys.kek.jp/r-and-d/emc/belle-iigrounding.pdf
- **EMC test plan**
  - Life is not ideal. There are boundary conditions(i.e. mechanical, cost, schedule etc.)
    We had better understand emission and susceptibility of each subsystem before integration to avoid predictable electro-magnetic interferences.

Safety

Safety Considerations when connecting your equipments to KEK Power Distrbution Panel

R.Itoh

Electric Facility Officer of IPNS, KEK

- As you know, the safety is the priority number 1 issue in the Belle II construction work.

- The careless use of power can cause fatal accidents.
  * Fire
    -> remember the recent fire accident in J-PARC
  * Electrocute

- To avoid the accidents, we should be careful when connecting new equipments to the power.

- I'm responsible for the safety of electric equipments in Tsukuba hall and supposed to control your connection of new equipments.

- I will discuss the procedure when connecting a new equipment to KEK power distribution panel.

More details in
http://kds.kek.jp/sessionDisplay.py?sessionId=206&confId=17439#20150203

Survey of the existing connections

Inspection

- We need to clarify which equipment is connected to which distribution panel.

- We are planning to have a survey.
  * Query to each detector group
  * Inspection by us

- We will try to complete the survey by next B2GM and to come up with the result.

- Tanaka (S) san is proposing to put “label” to the certified cables.
  -> will do.

Procedure definition

- When connecting your equipments to one of the power distribution panel (all the panels in Tsukuba hall), you need to follow the procedure below:

1. Before connecting the equipments to the distribution panel, inform Itoh of the connection. You need to tell him the location of distribution panel, the voltage (100V or 200V, phase), and the expected consumption current.

2. Itoh inspects the connection and gives a temporary permission if the connection is made properly.
   -> You can turn on your equipments.

3. Itoh asks for the official inspection by the IPNS safety group. After their inspection, the permanent permission is given.

Note: Connection to the existing AC outlet placed around racks is not required to be declared. The above procedure is applied only for the direct connection to the distribution panel.

Preparation of Document in English

✅ : indicates the part has no big issue

	Safety	Shielding	Grounding	emission test plan	susceptibility test plan	Integration test schedule
PXD	✅	Most sub-detector groups are planing to start integration in the next JFY.				JFY2016~
SVD	✅					JFY2016~
CDC	✅					JFY2016~
TOP	✅	they are using existing inspected Belle resources				JFY2015~
ARICH	✅	and it will be checked by safety group.				JFY2016
BECL	✅					started
EECL	✅					JFY2015~
KLM	✅					started
Timing	✅					
DAQ	✅	No problem now.				

Grounding/Shielding

- **We agreed with the grounding/shielding scheme in the last B2GM.**

  if you need technical detail,

  please visit http://www-esys.kek.jp/r-and-d/emc/belle-iigrounding.pdf

- Simplified diagrams for all detector subsystems are made and updated for

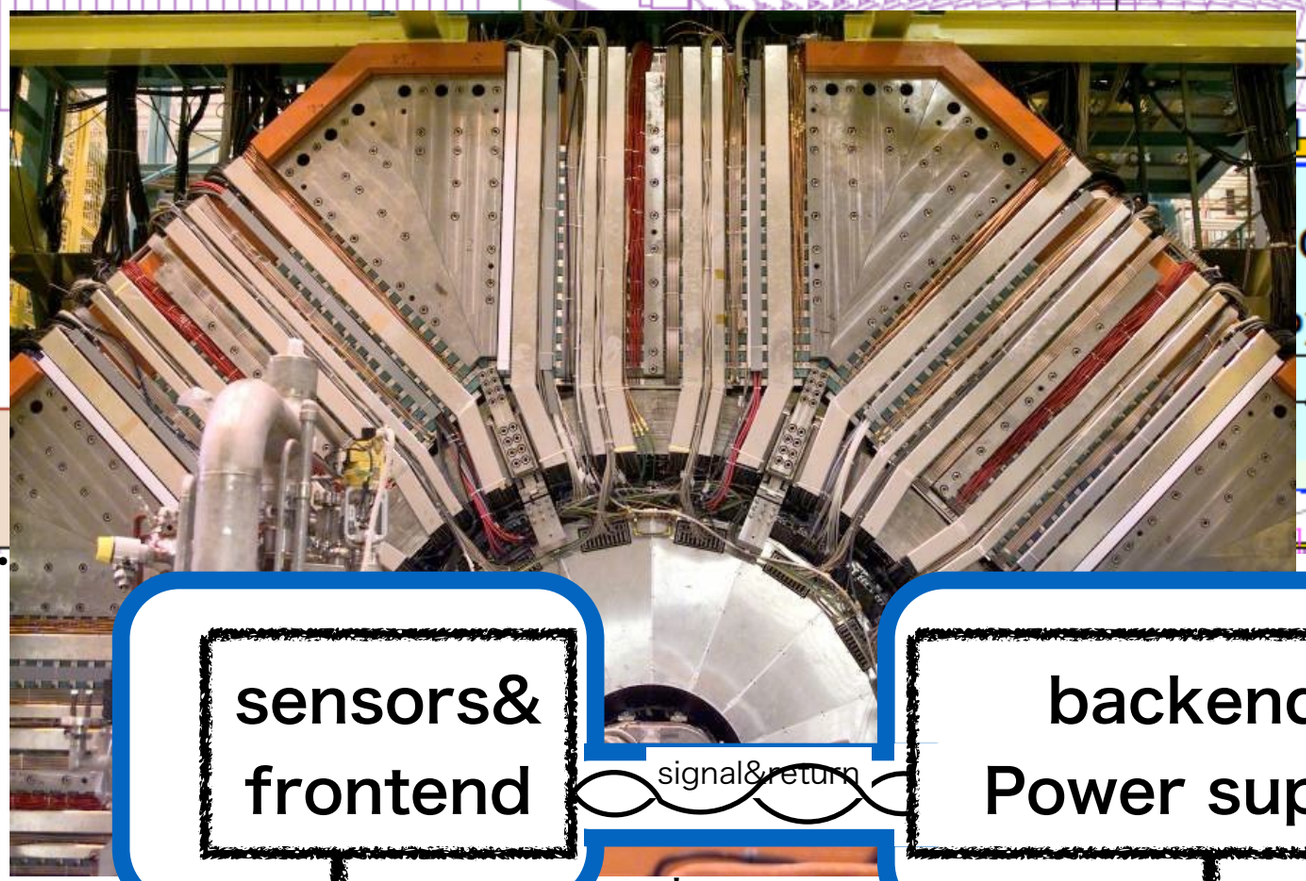
  - making clear remaining issues

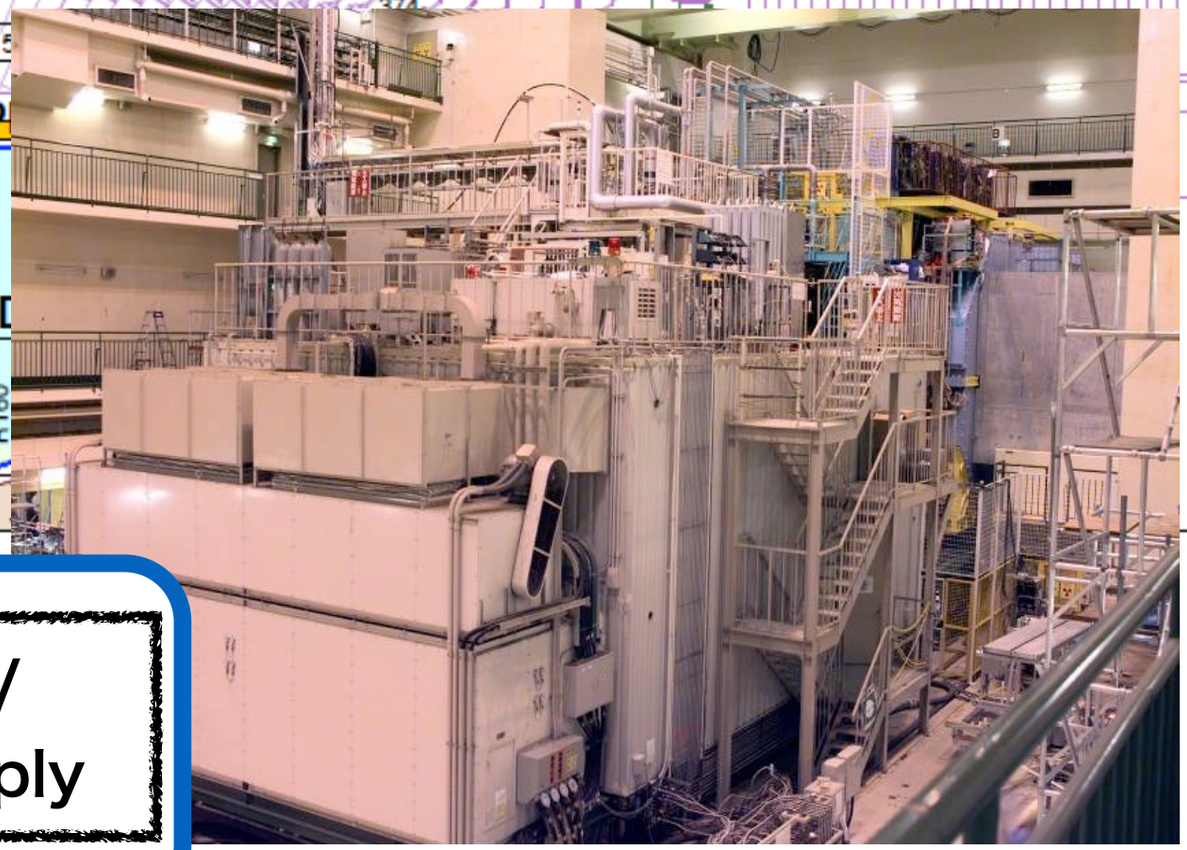
  - support materials during integration.

Belle II

SIDE VIEW

Super conducting coil





sensors& frontend

signal&return

backend/ Power supply

ental antenn

5. Routing of cables(signal/power/ground line) should minimize the area of send/

Vacuum vessel & E-hut -> Earth of B4 Tsukuba exp hall

-> see. Return path

- Solid ld be mad and sub-detector shields

-> se ble shield

6. Ca

-> s gation

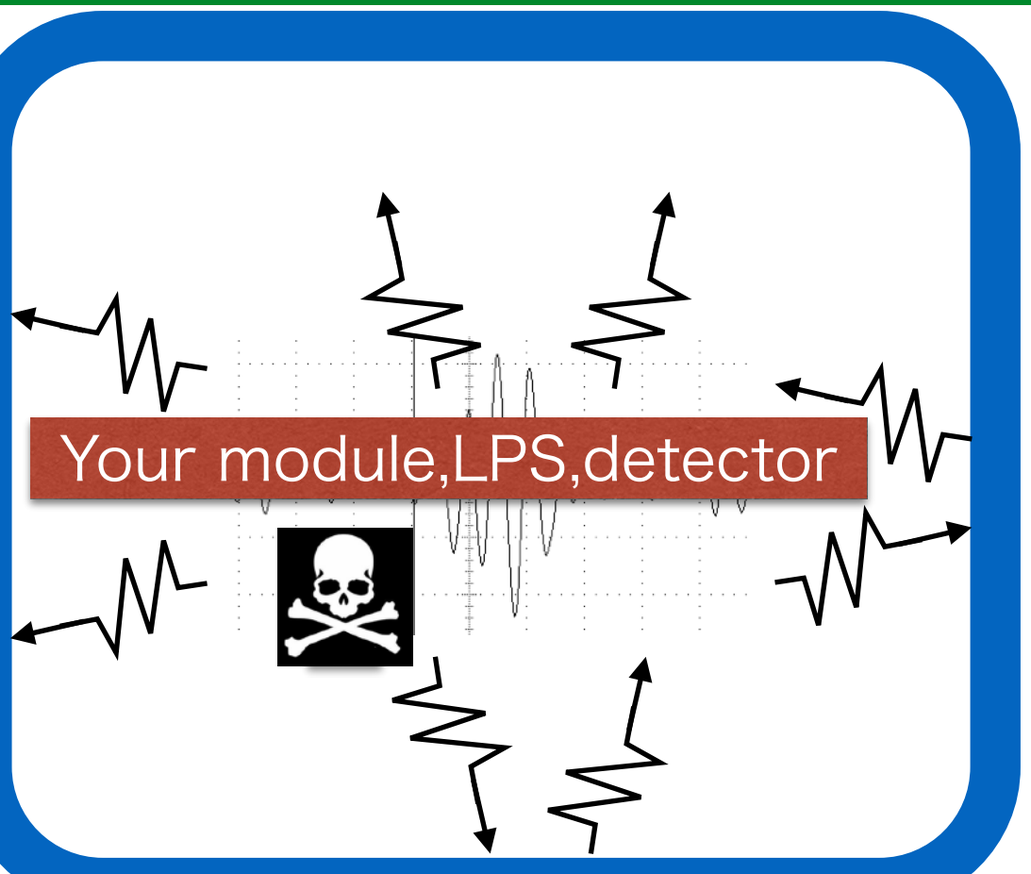
sensors& frontend

signal&return

backend/ Power supply

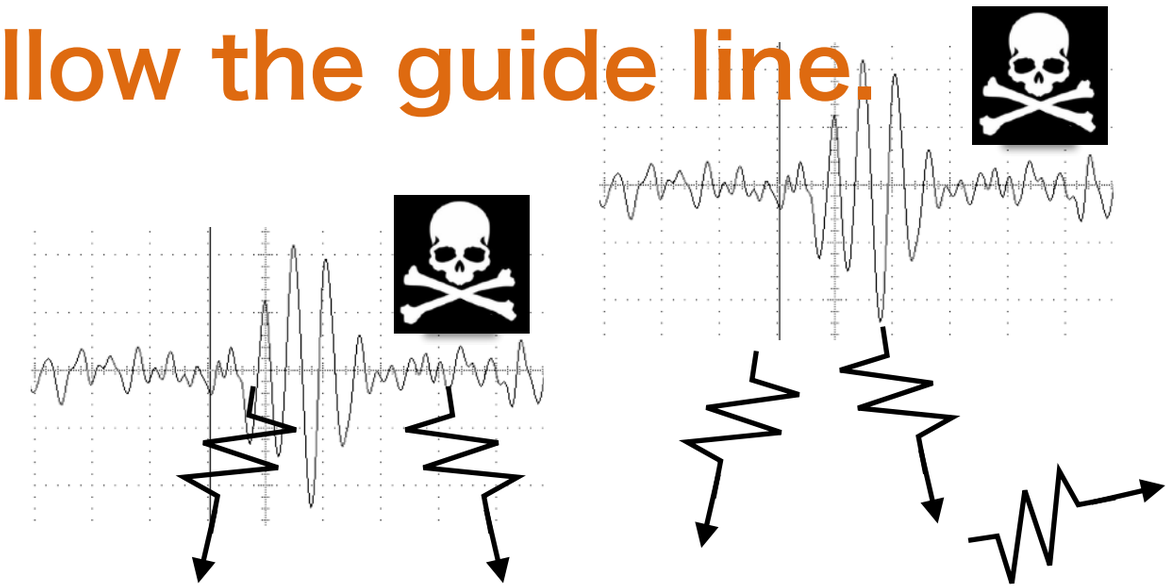
We are trying to integrate system into ideal case as much as possible to follow the guide line.

Your system shall not generate EM disturbance



Emission : suppression/control

&



Your module,LPS,detector

Your system shall not be influenced by EM disturbance from other system

Immunity:strength

Grounding/Shielding

- We agreed with the grounding/shielding scheme in the last B2GM.

  if you need technical detail,

  please visit http://www-esys.kek.jp/r-and-d/emc/belle-iigrounding.pdf

- Simplified diagrams for all detector subsystems are made and updated for

  - making clear remaining minor issues.

  - support materials during integration.

annotation

Sens

Sensor

FE

frontend electronics

BE

backend electronics

LV

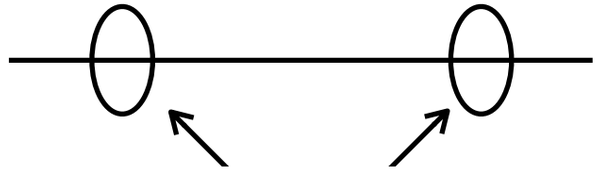
Low Vol. PS.

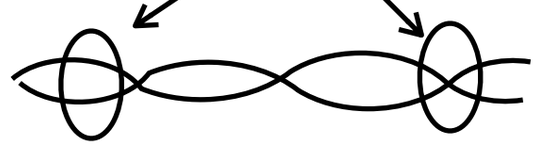
HV

High Vol. PS.

Bonding structure

shield





LV or HV cable

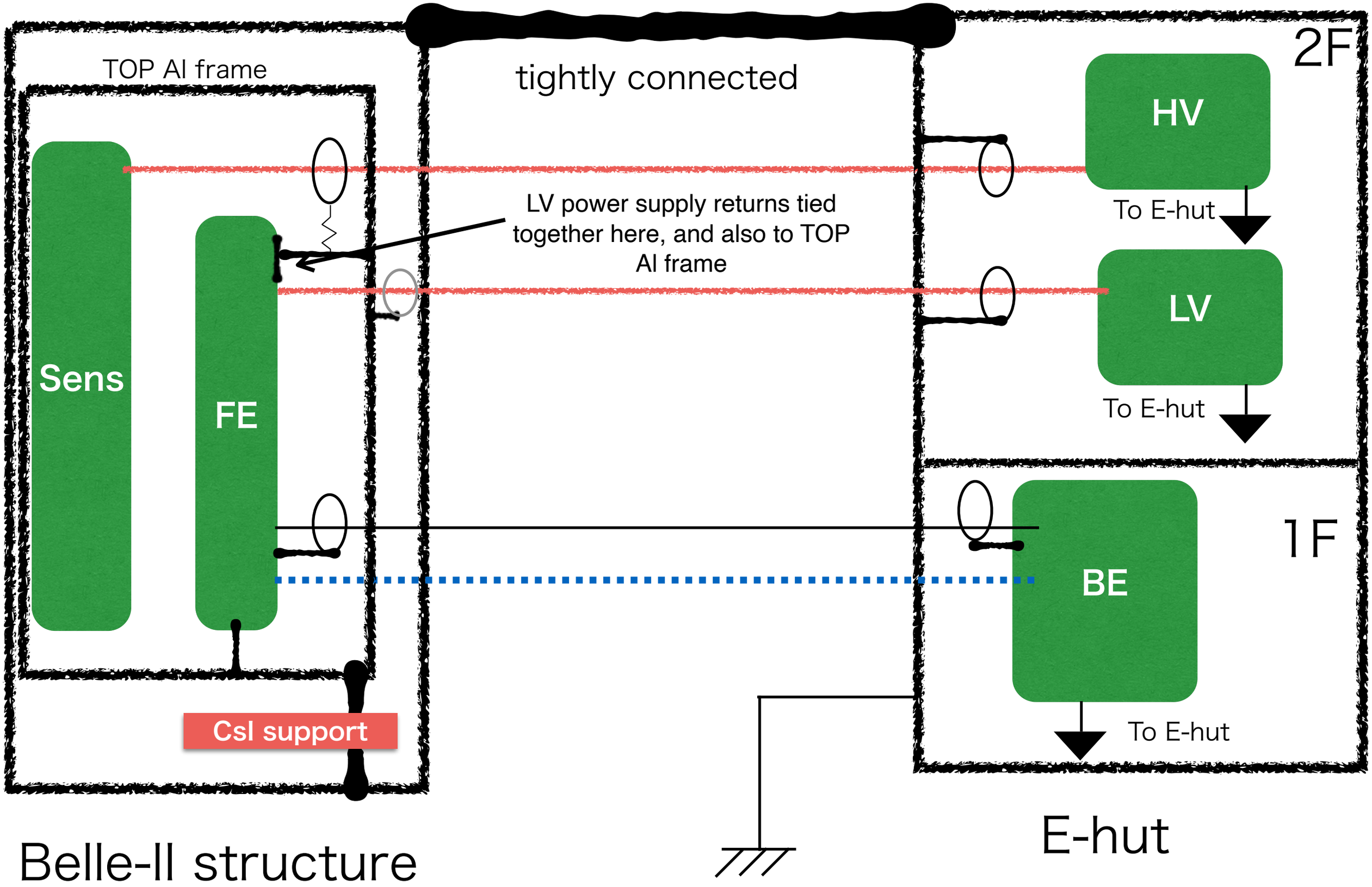
Opt fibre

earth

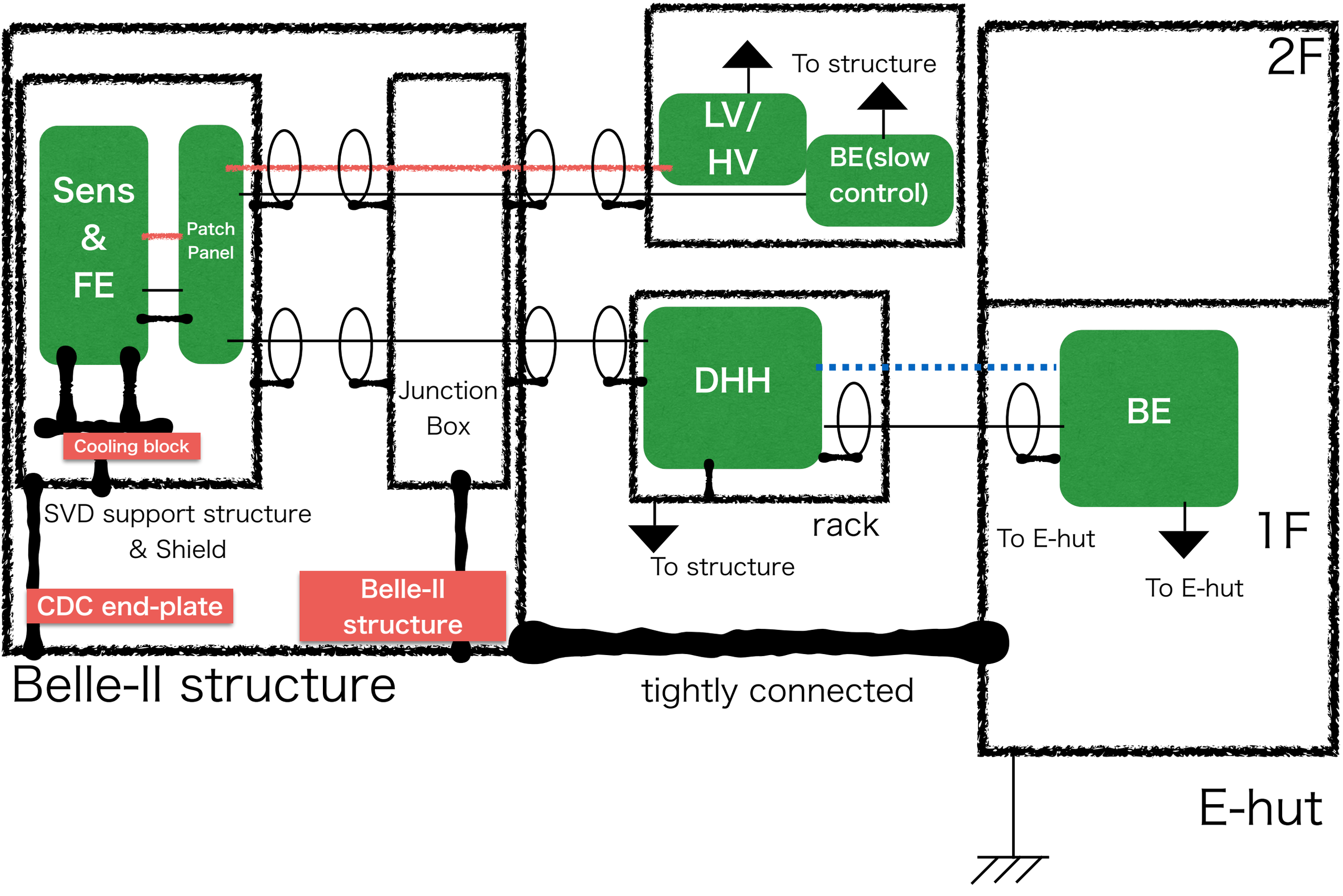
ground

To ……

TOP grounding/shielding scheme@2015



PXD grounding/shielding scheme@2015



✅ : indicates the part has no big issue

	Safety	Shielding	Grounding	emission test plan	susceptibility test plan	Integration test schedule
PXD	✅	✅	✅			2016~
SVD	✅	✅	✅			2016~
CDC	✅	✅	✅			2016~
TOP	✅	✅	✅			fall 2015~
ARICH	✅	✅	✅			2016
BECL	✅	✅	✅			started
EECL	✅	✅	✅			2015~
KLM	✅	✅	✅			started
Timing	✅	✅	✅			
DAQ	✅	✅	✅	No problem now.		

EMC test

-Emission issue & Immunity issue-

Your system shall not generate

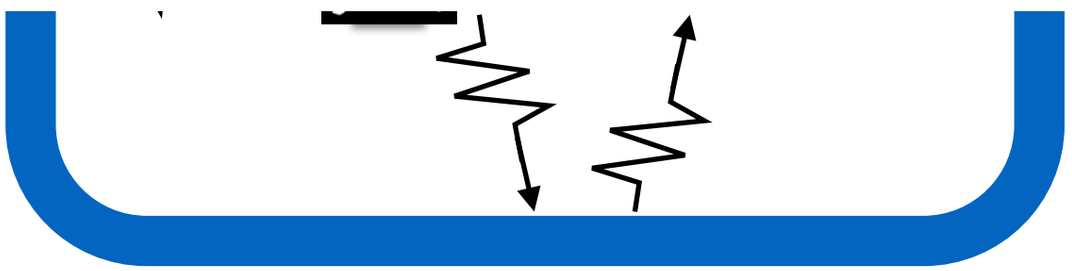
In Belle-II case, yes real life is complex ..

There have been already installed components.

No cable shield due to space constraint.

It is difficult to bond because of mechanical constraint.

etc



Emission : suppression/control

Immunity:strength

EMC test

- Real world is not ideal. Two major violations exit.
  - holes of faraday cage -> not major problem
    - 100MHz<—>3m, 1GHz <—> 30cm
  - interferences of common mode current path on the gnd network -> problem
    - it depends on impedance of materials and the shape.
- At least values for identification of emission sources are required for investigation during installation, when EMI problem happens
  - emission frequency
  - susceptible frequency

✅ : indicates the part has no big issue

	Safety	Shielding	Grounding	emission test plan	susceptibility test plan	Integration test schedule
PXD	✅	✅	✅	✅	✅	2016~
SVD	✅	✅	✅	✅	✅	2016~
CDC	✅	✅	✅	Plan	Plan	2016~
TOP	✅	✅	✅	Plan	Plan	fall 2015~
ARICH	✅	✅	✅	Plan	Plan	2016
BECL	✅	✅	✅	Plan	Plan	started
EECL	✅	✅	✅	Plan	Plan	2015~
KLM	✅	✅	✅	Plan	Plan	started
Timing	✅	✅	✅	?	-	
DAQ	✅	✅	✅	-	-	

Proposal and discussion

Status and Plan

- There are three issues. Safety, Gnd/shield and EMC test.
- Lights of “safety and grounding/shielding” are green.
- We will agree with
  - standard test setup and observables
  - possible solution(measurement) under limited man power, cost and schedule.
- by the next B2GM.

Bonding and Interconnection

Since it is difficult to use star bonding(single point grounding/earthing) for RF shielding in general.(see. ghost/misunderstanding of ground/ shield loop), the meshed common bonding network (MESH-CBN) is using instead of single point grounding in computer housing, telecommunication, aerospace etc.

Figure 2C shows the recommended common bonding scheme for a fixed installation, often called mesh earthing. This achieves a low impedance from 50Hz up to higher frequencies (depending on average mesh size).

Meshing the CBN helps protect equipment against the damaging effects of lightning surges, and surge protection devices (SPDs) function better when they are connected to a low-impedance CBN. For lightning protection (where most of the energy occurs at frequencies below 10kHz), it is generally recommended that no part of a site should have a CBN whose mesh size exceeds 3 or 4 metres, in any dimension.

Belle-II is better than this example. We can use Belle-II structure as CBN, when the bonding in the Belle-II structure is well designed and managed.

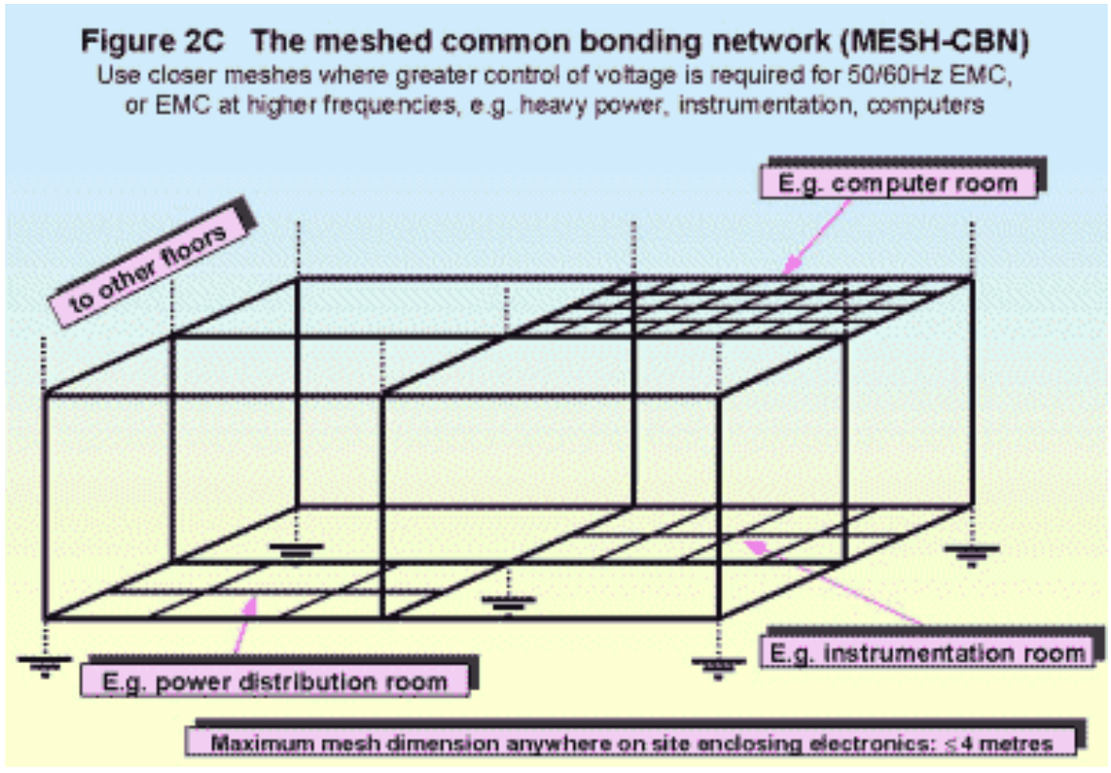


Fig. was copied from ref[1] Part 2.4.2

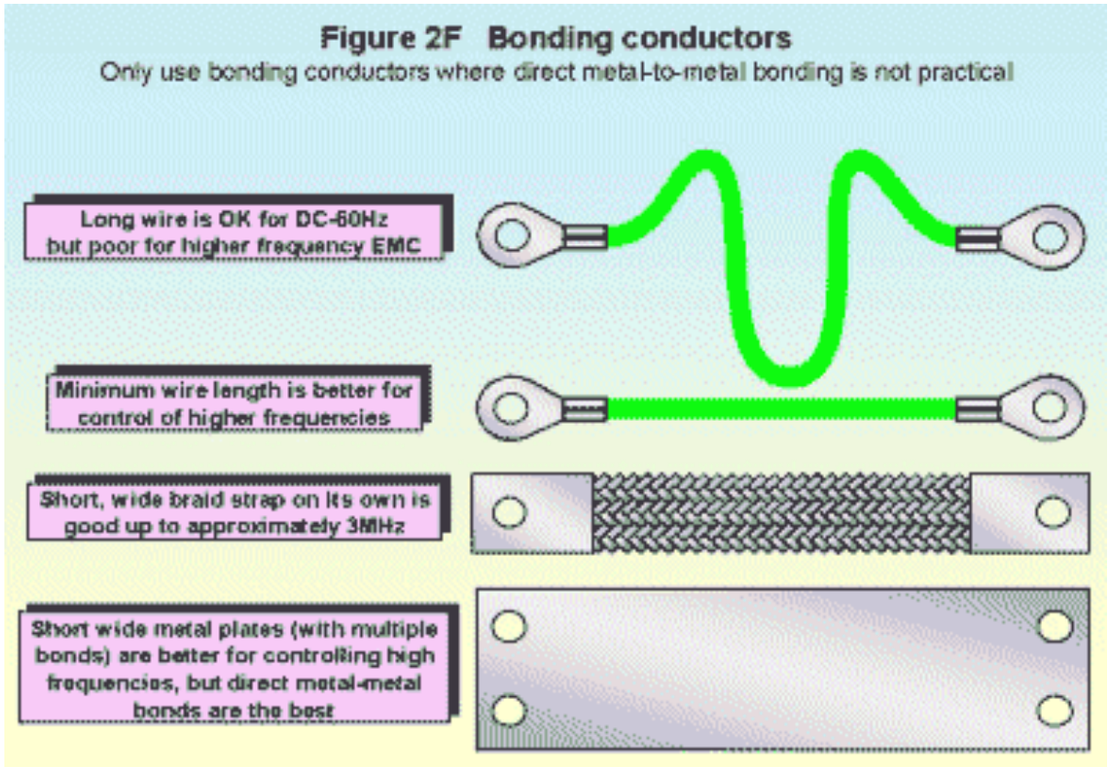


Fig. was copied from ref[1] Part 2.4.2

Return Path

There are always some CM currents and voltages, and we must control them to achieve good EMC. To do this, **we use the conductive chassis or external 'earth/ground' as our CM return path. To reduce emissions and improve immunity, the CM current's send/return loop should have as small an area as possible,** and we achieve this by routing our cables very close to metalwork or bonding conductors along their entire route.

Direct electrical connections are best but not necessarily essential for the CM current return path; capacitors of suitable types and values can be used in series with the CM return path to achieve galvanic isolation at the frequencies used by the electrical power supply whilst allowing the RF CM current to flow in the smallest loop area.

In conclusion: **we design our metal interconnections to control our send/return current paths, to minimize DM to CM conversion and reduce CM currents and voltages**; then we control the CM send/return current paths (wherever we can).

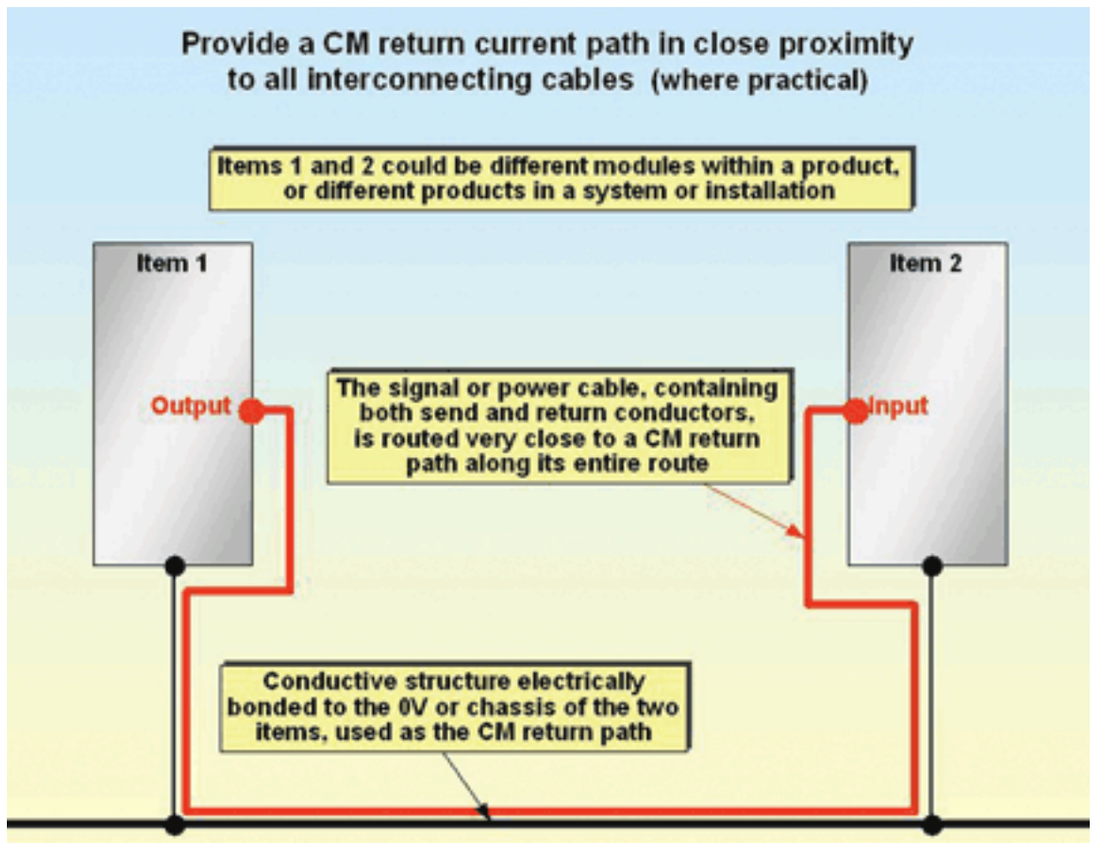


Fig. was copied from ref[2] Part 2.2.3 Figure 2D

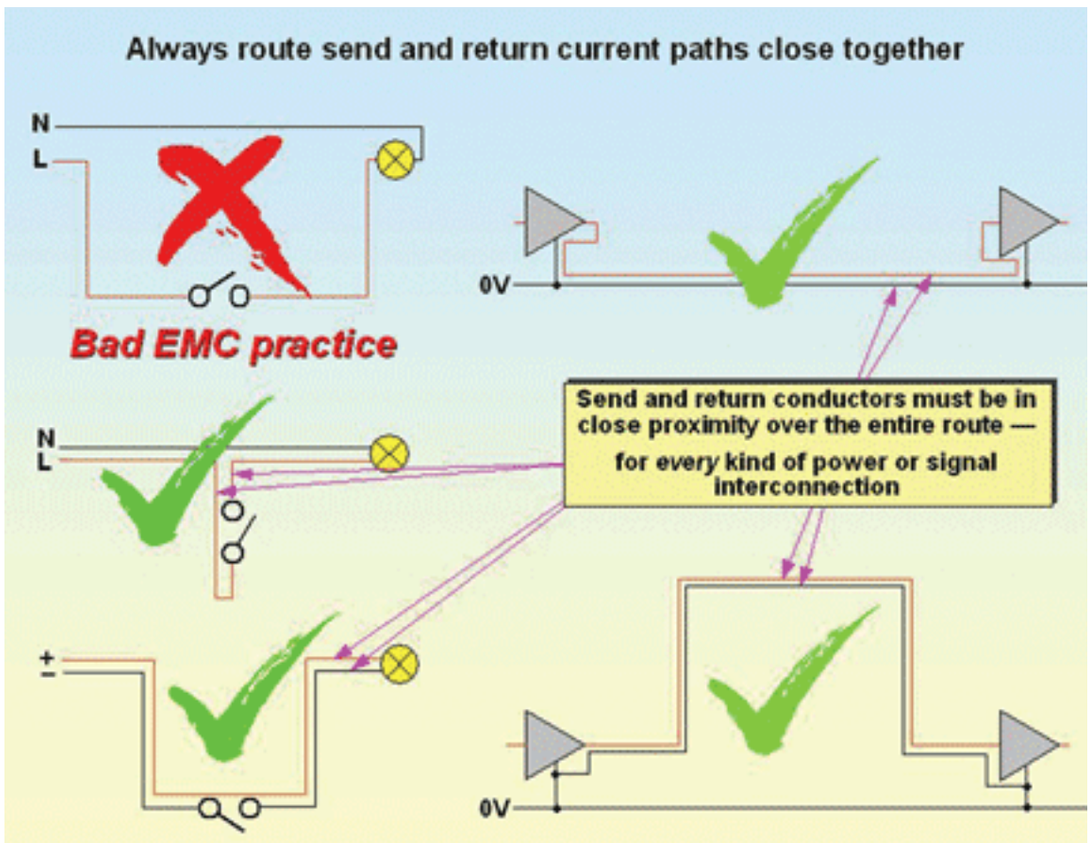
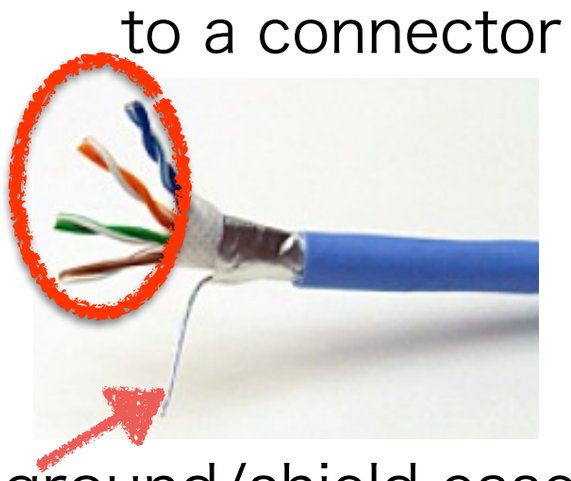


Fig. was copied from ref[2] Part 2.2.3 Figure 2E

Treatment of cable shield

- All shielded cables must have their shields bonded 360° to the enclosure's wall at their point of entry.

- It is always very important to bond cable shields metal to metal and **not to use a pig tail(see. next page)**



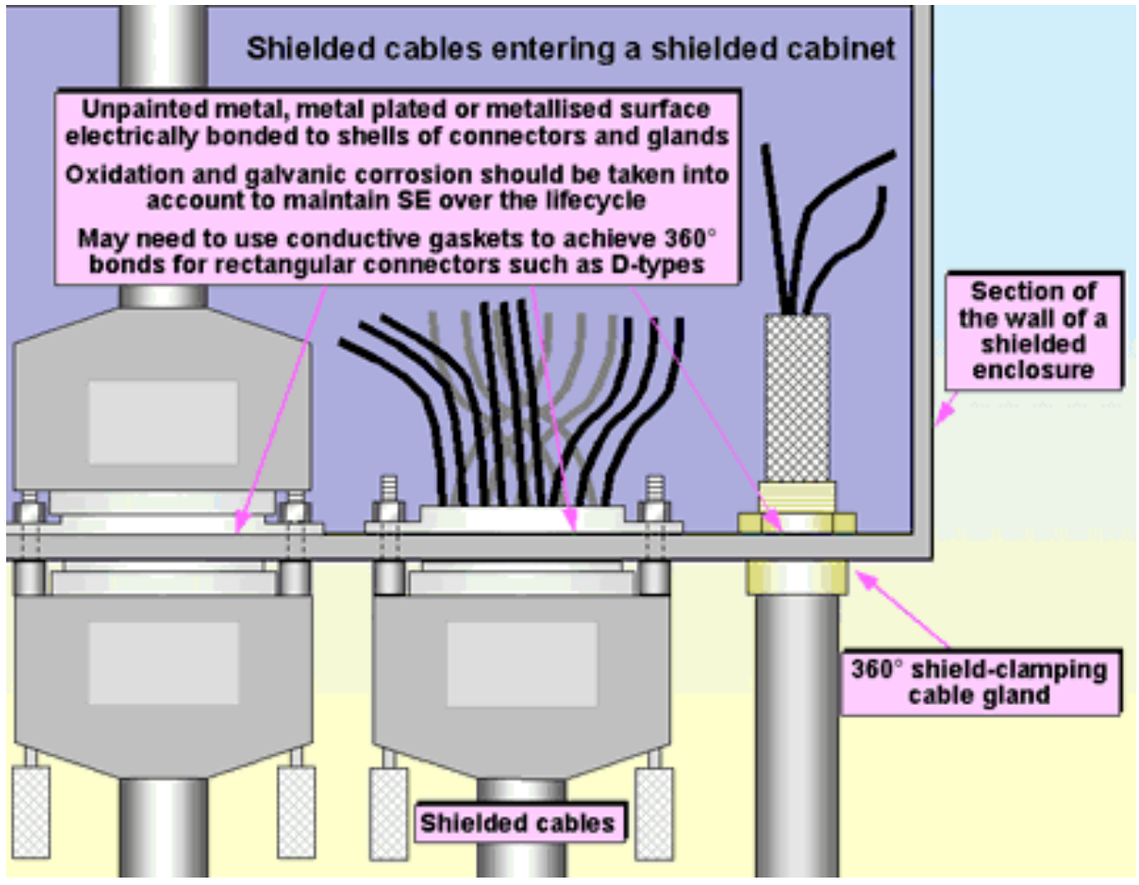


Fig. was copied from ref[2]
Part 2.6.5 Figure 2W

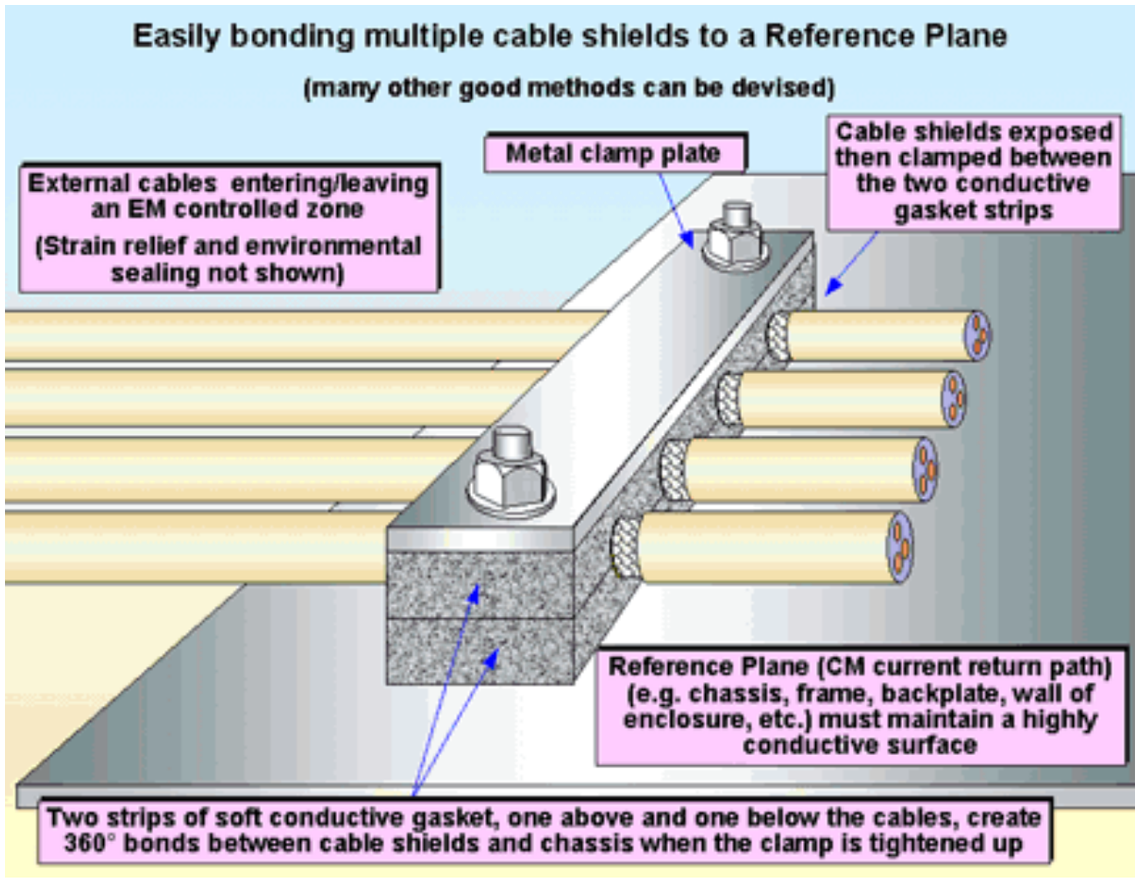


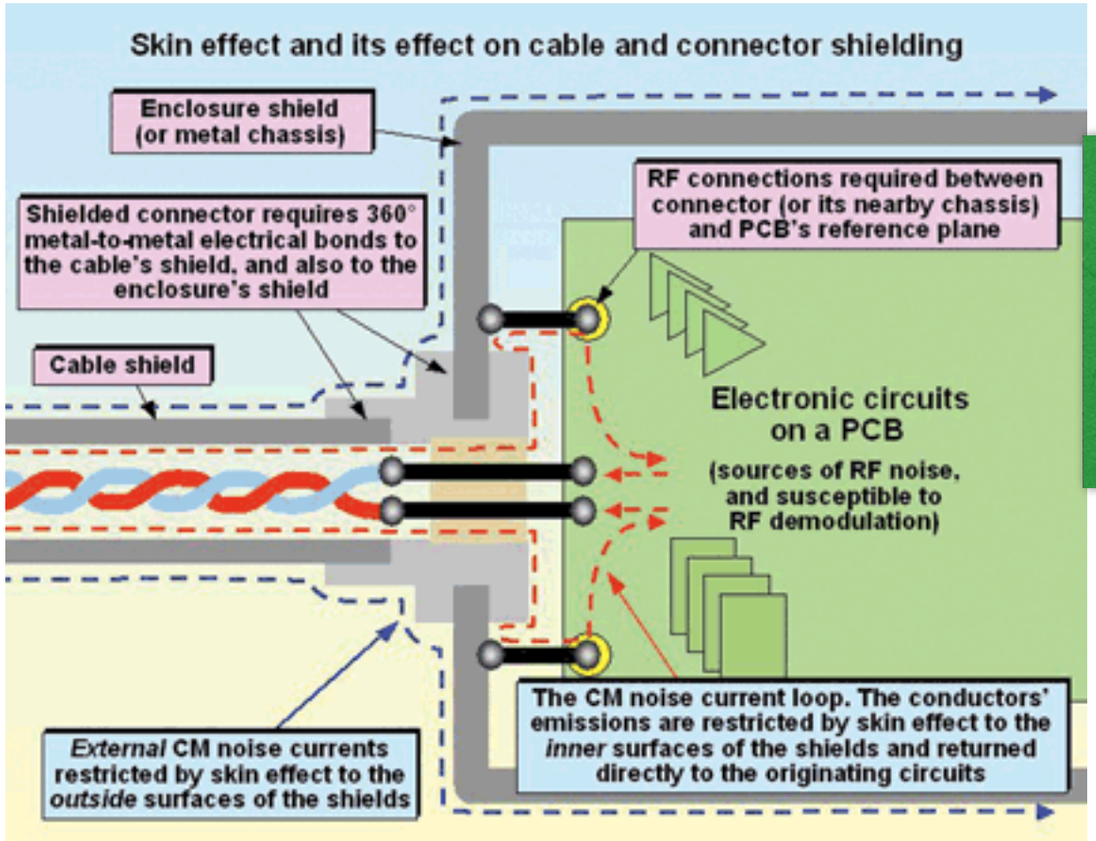
Fig. was copied from ref[2]
Part 2.6.7 Figure 2AB

How shielded interconnections work 1

In ideal case(i.e. metal-to-metal connection between cable's shield and enclosure shield without a hole: 360° shield coverage) *external noise currents restricted by skin effect to the **"outside surface"** of the shield, and the conductor's emissions are restricted by skin effect to the **"inner surface"** of the shield and returned directly to the original circuits.*

"Pigtail and/or incomplete connection between shield of cable and shield of enclosure" ruins the RF shielding performance of the cable, allowing external surface currents to access internal circuits and devices (causing problems for immunity), and allowing internal surface currents to access external surfaces (causing problems for emissions).
Any length of pigtail ruins the shielding performance of cable shields at RF, as Figure 2Y shows using the example of a 25-way subminiature D-type. L Hoeft, "Analysis of Electromagnetic Shielding of Cables and Connectors", 2002 IEEE International Symposium on EMC

- also see http://www.murata.co.jp/products/emc/knowhow/basic/chapter04/index04.html (written in Japanese sorry)



Here Z_T is surface transfer impedance.

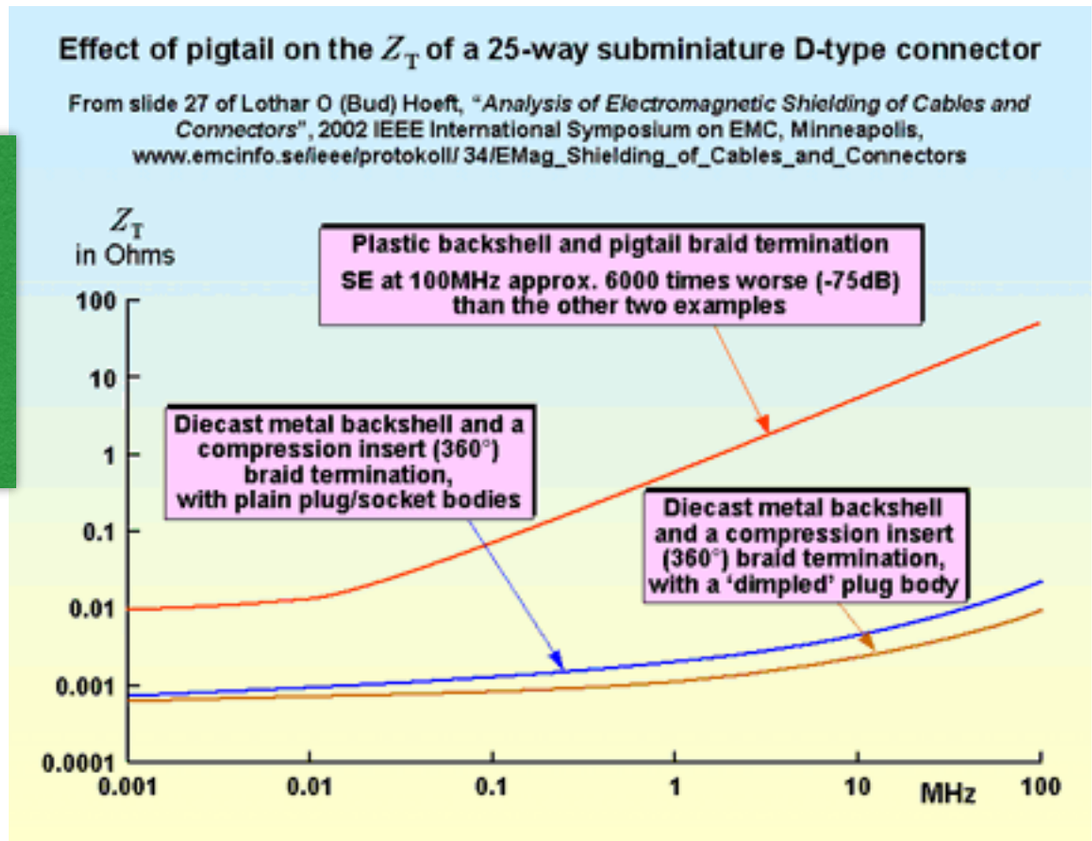


Fig. was copied from ref[2] Part 2.6.2 Figure 2P

Fig. was copied from ref[2] Part 2.6.6 Figure 2Y

Additional reference : L Hoeft et al., "Measured Electromagnetic Shielding Performance of Commonly Used Cables and Connectors", IEEE Trans on Electromagnetic Compatibility, vol.30, No3, 1988, p260

How shielded interconnections work 2

Comparison of Z_T for several structures

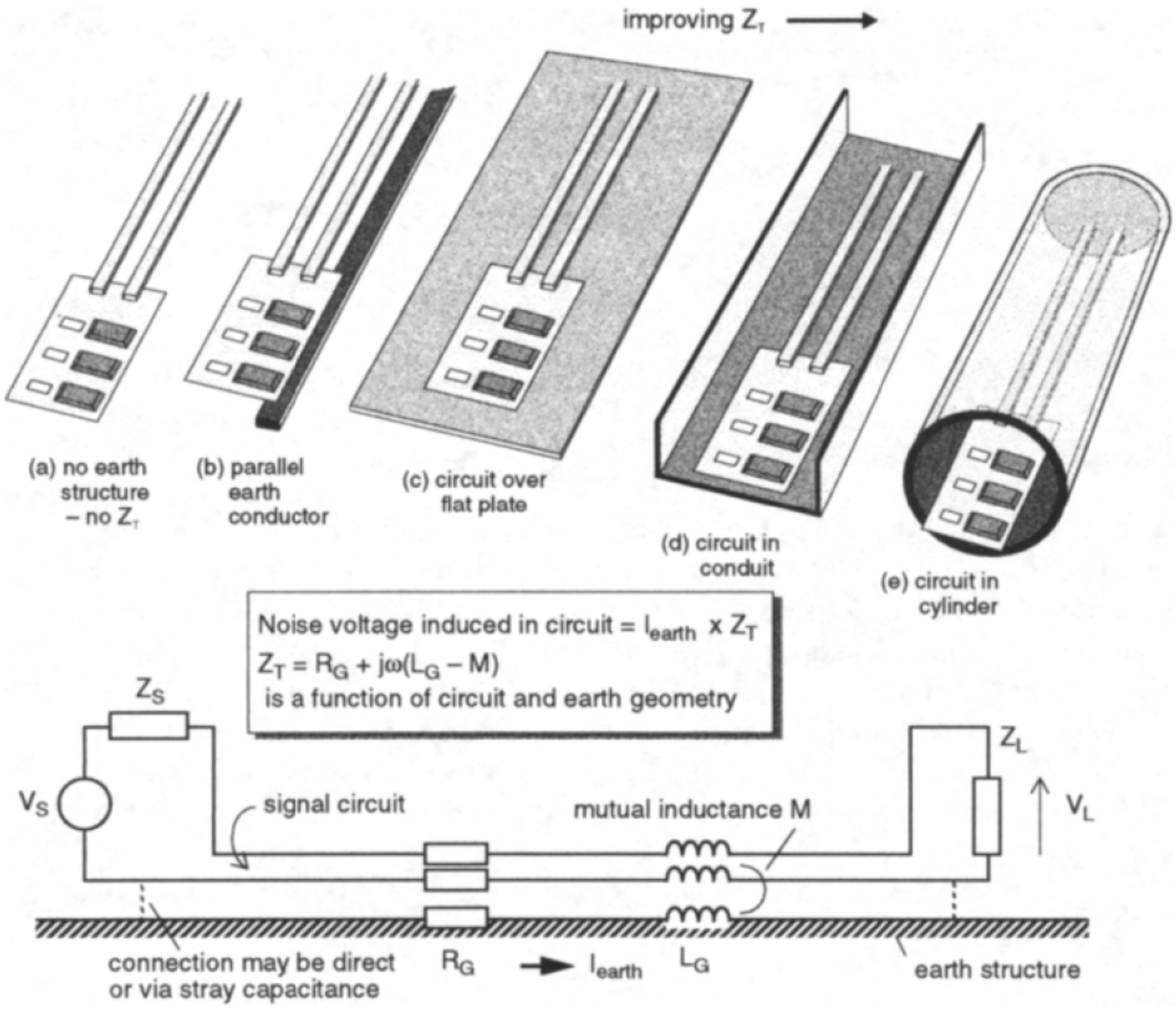


Figure 5.2 The transfer impedance of structures

Fig. was copied from ref[1]

Filter and RF bonding

The correct way to install filters is to ensure that an area of the enclosure's shield wall is free from paint or anodizing, and has a highly conductive surface that will be pressed firmly against the filter's metal body when it is assembled.

Figure 3V shows the sorts of bad effects that even a short length of interconnecting wire can have on a standard single-stage mains filter even when measured with 50Ω/50Ω source and load impedances - its best possible case. If the 10mm wire were replaced with at least one direct metal-to-metal bond, performance at 30MHz and above would improve dramatically.

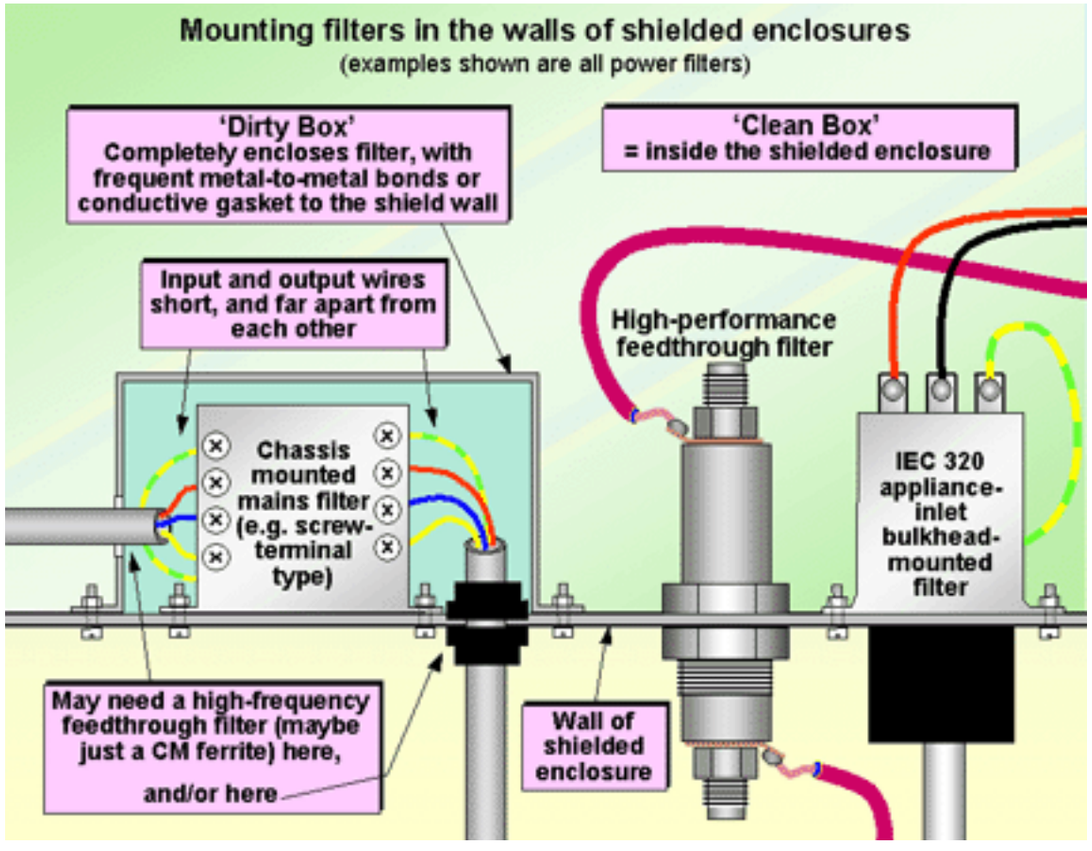
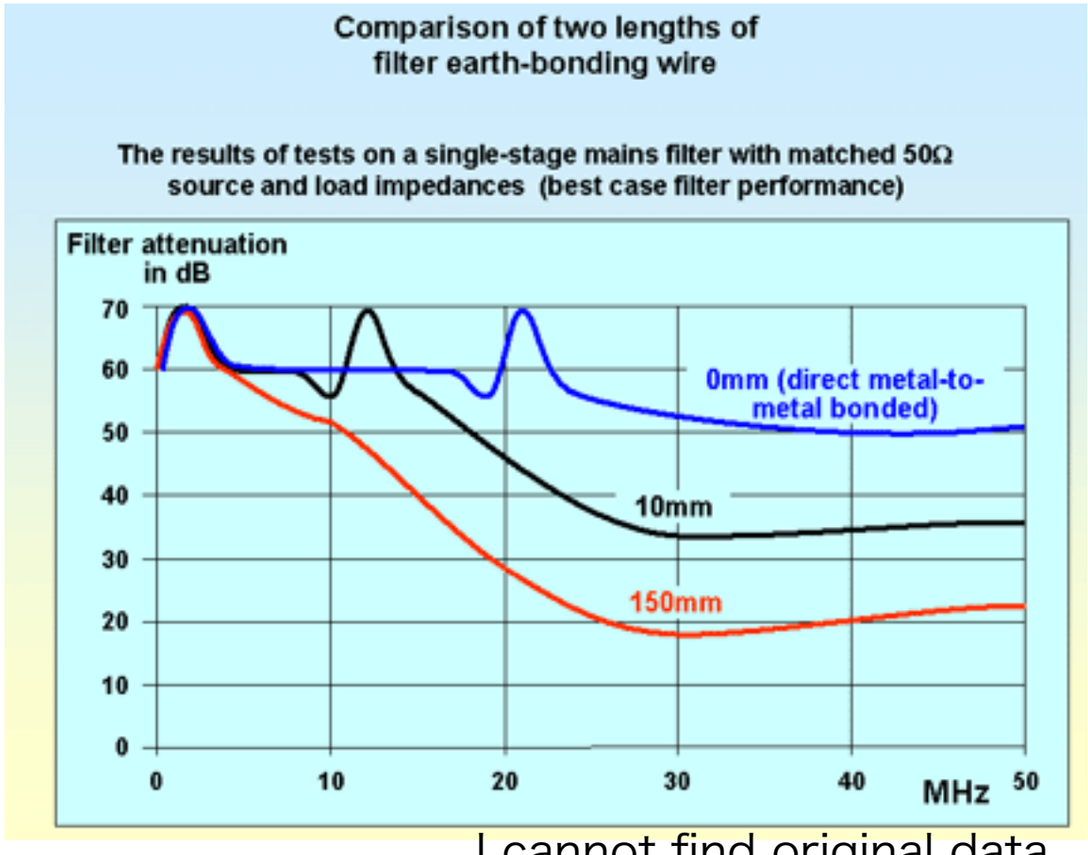


Fig. was copied from ref[2]
Part 3.3.4 Figure 3AA



I cannot find original data

Fig. was copied from ref[2]
Part 3.3.2 Figure 3V

Skin depth and shield material

- Skin depth equation: http://www.rfcafe.com/references/electrical/skin-depth.htm
- and its calculator : http://www.rfcafe.com/references/calculators/skin-depth-calculator.htm
- Other material table at 1MHz, 10MHz, 100MHz are useful.
- http://www.rfcafe.com/references/electrical/cond-high-freq.htm

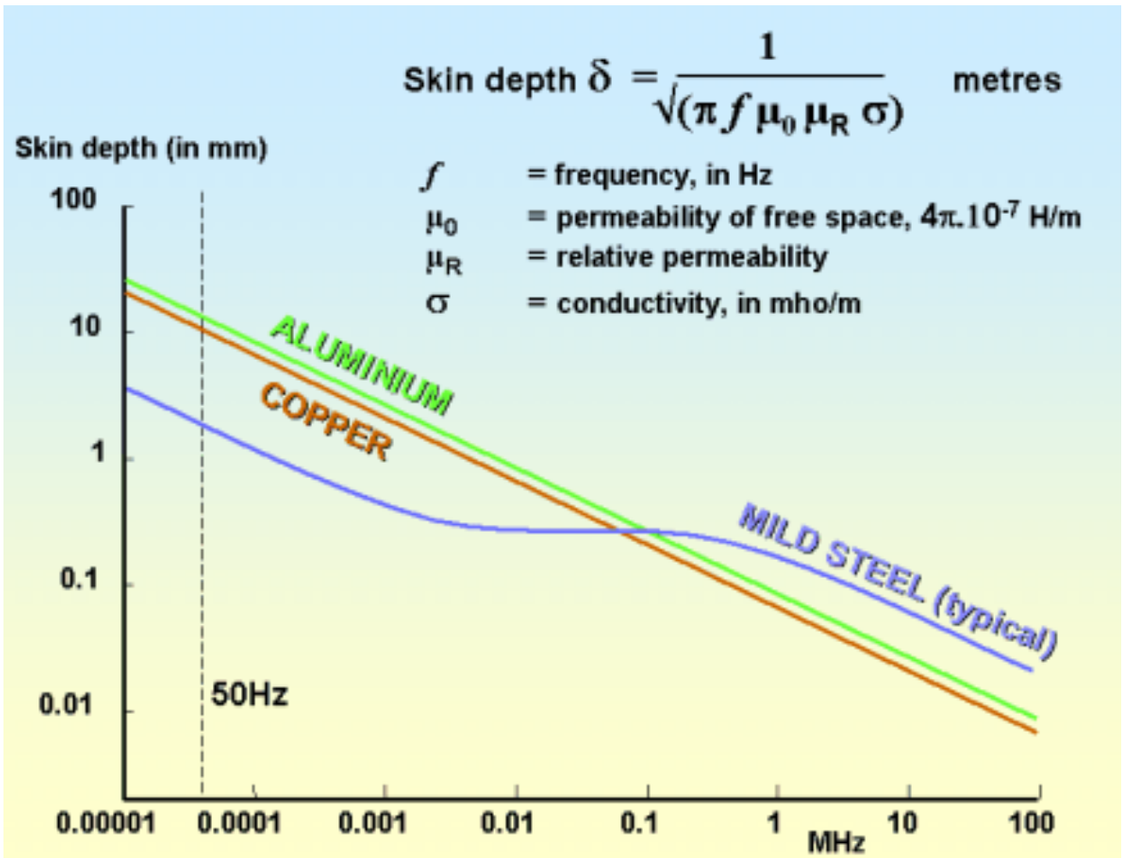


Fig. was copied from ref[2]
Part 4.3.3 Figure 4G

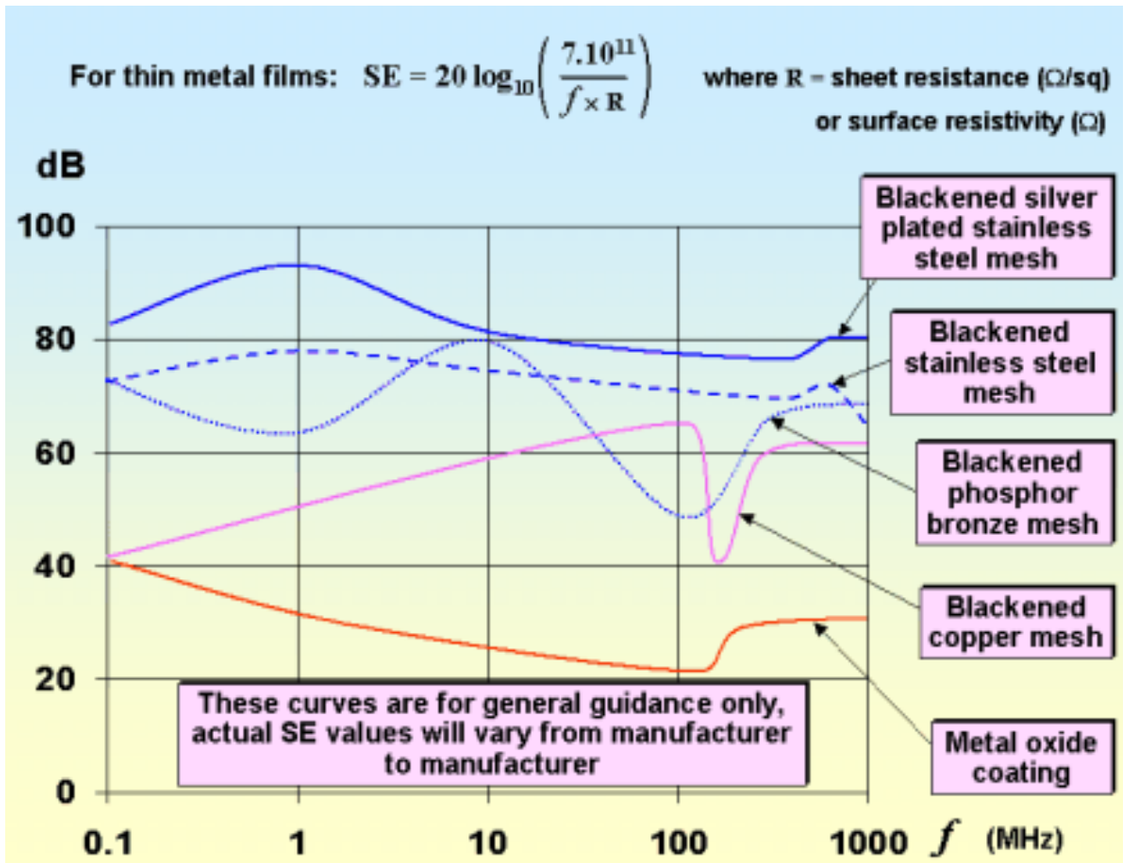


Fig. was copied from ref[2]
Part 4.3.12 Figure 4AG

references

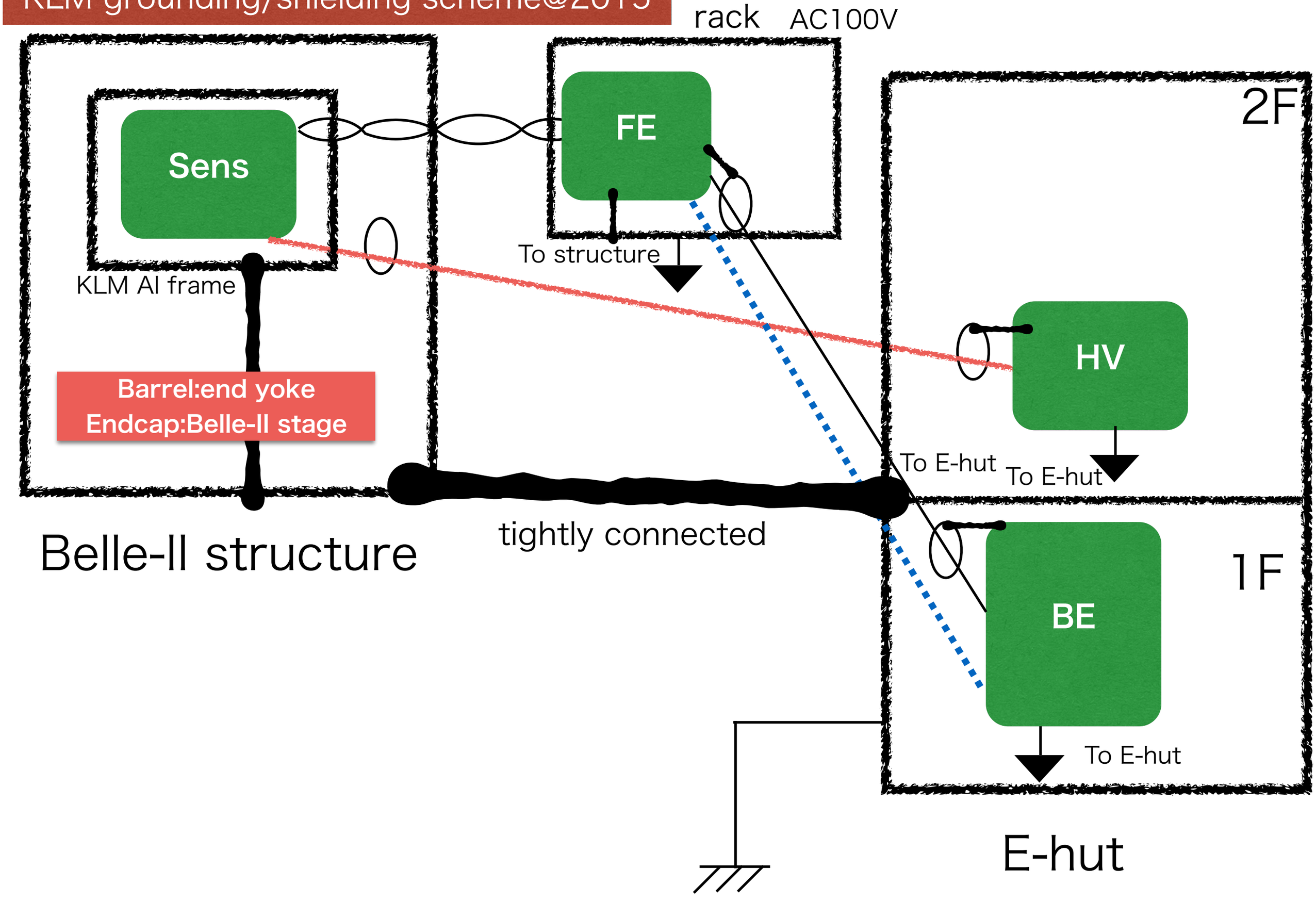
- ref[0] “Grounding & EMC Committee review report”, Aug. 2013, F. Arteche et al.(Review Committee)(see. http://kds.kek.jp/getFile.py/access?contribId=5&resId=0&materialId=0&confId=13577)
  “Belle II:Grounding and Electronics integration Issues”, F. Arteche, B2GM, July 6-9, 2011, Nagoya, Japan. (see. http://www-esys.kek.jp/r-and-d/emc/emc-related-references)
  “EMC:Electronics system integration for HEP experiments” F. Arteche B2GM Nov 15-20, 2011, KEK, Japan. (see. http://www-esys.kek.jp/r-and-d/emc/emc-related-references)
  “EMC issues for cabling and racks layout design”, F. Arteche, B2GM, Mar4-7, 2013, KEK, Japan.
  (see. https://belle2.cc.kek.jp/~twiki/bin/view/Public/WebHome#review)
  “Grounding & EMC : Status and Plans”, F. Arteche, Belle II Focused Review, Sept. 9-10, 2013, KEK, Japan. (see. http://kds.kek.jp/conferenceDisplay.py?confId=13464)
  “EMC: A mapping for the CMS experiment”, F. Arteche 2004, Doctor thesis, University of Oviedo
  (see. http://www-esys.kek.jp/r-and-d/emc/emc-related-references)

- ref[1] “EMC for Systems and Installations”, Tim Williams and Keith Armstrong, ISBN 9780750641678
  Systems EMC procedure check list in “Appendix A” will help some of you.

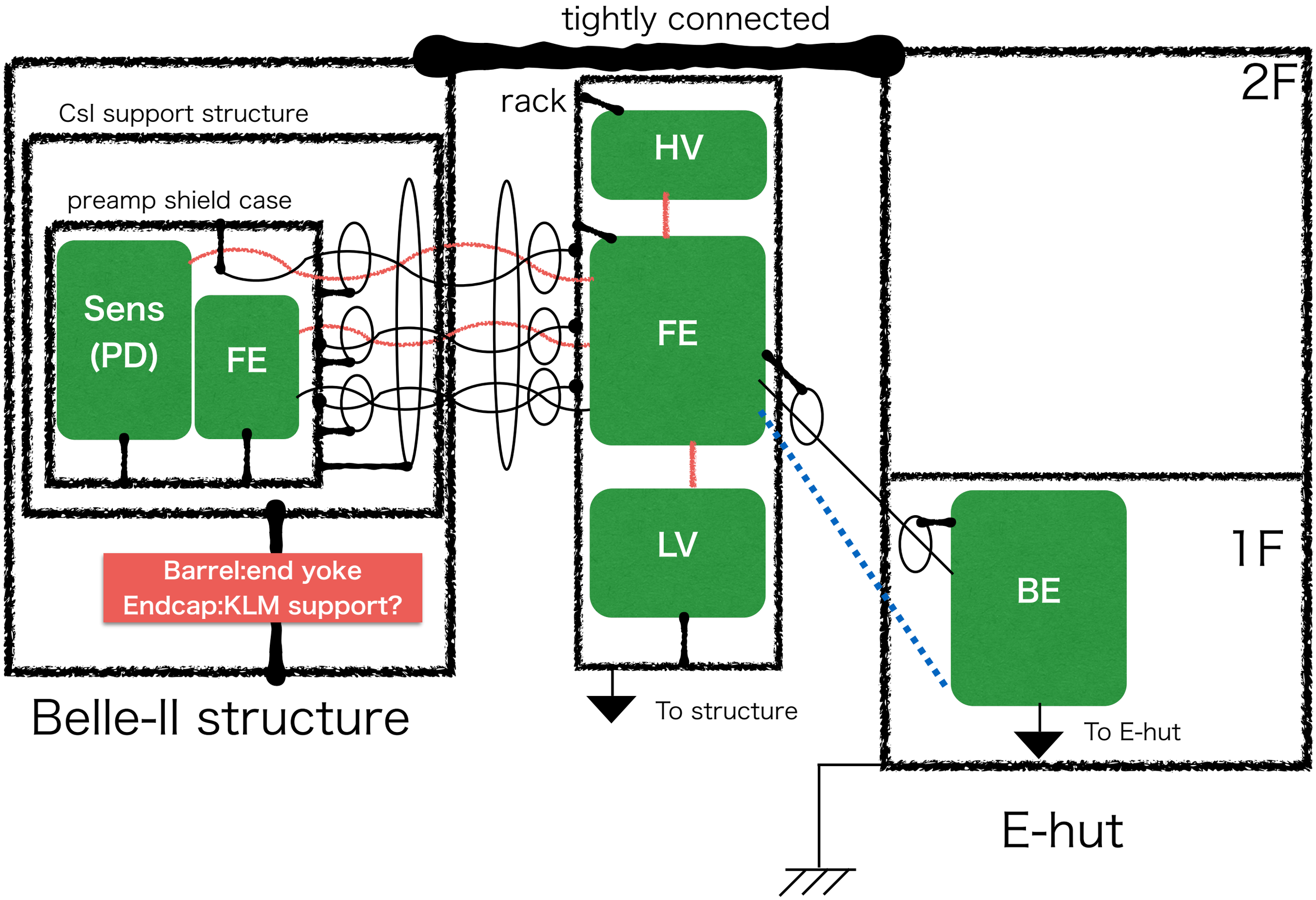
- ref[2] Design techniques for EMC series (Part1~6), Keith Armstrong, EMC journal
  (please visit http://www.compliance-club.com you can download them from free member page.)

- ref[3] Engineering electromagnetic compatibility, V. Prasad Kodali, ISBN 9780780347434
  There are some descriptions and relation among regulations and standards in several countries.

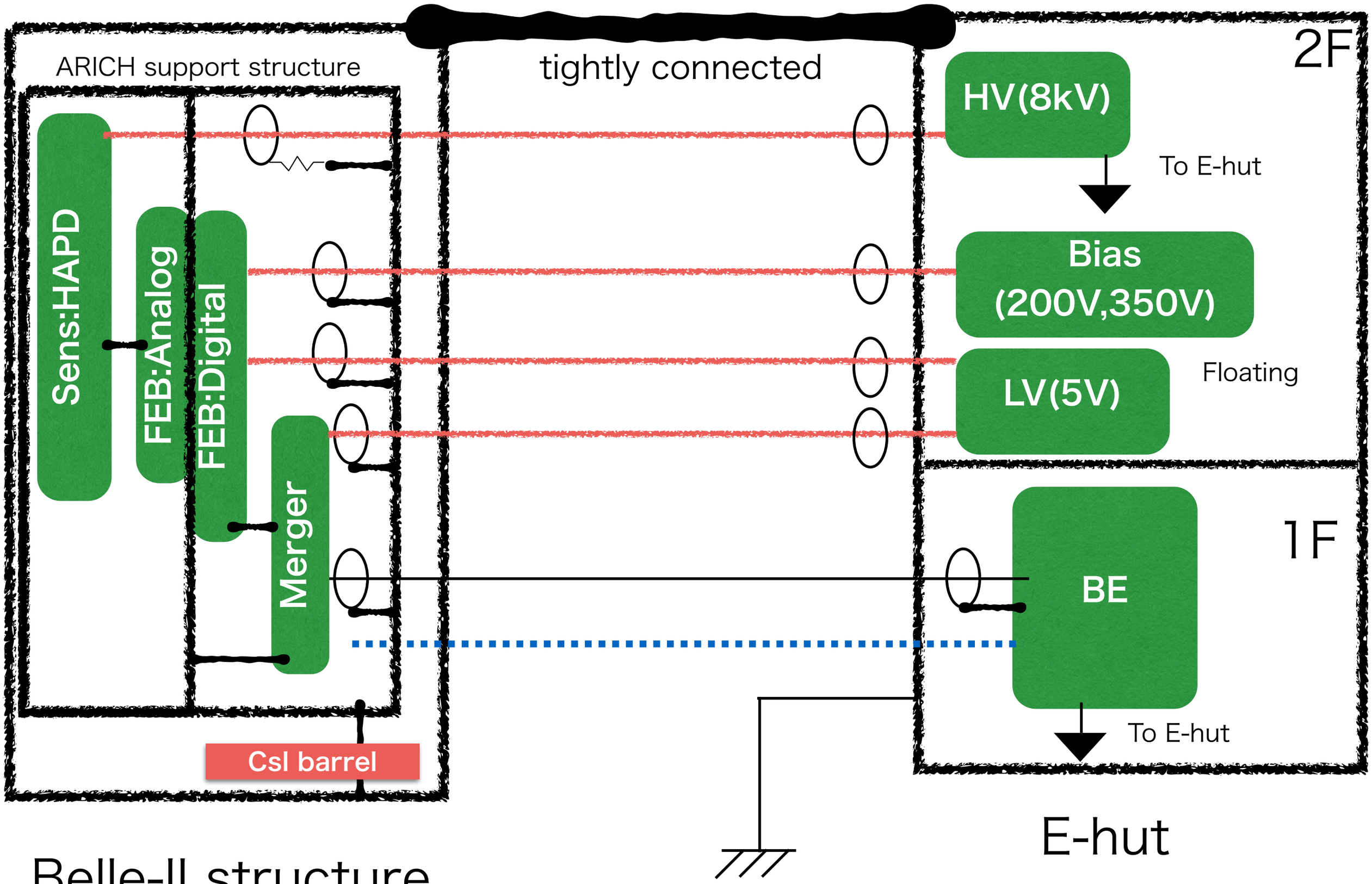
KLM grounding/shielding scheme@2015



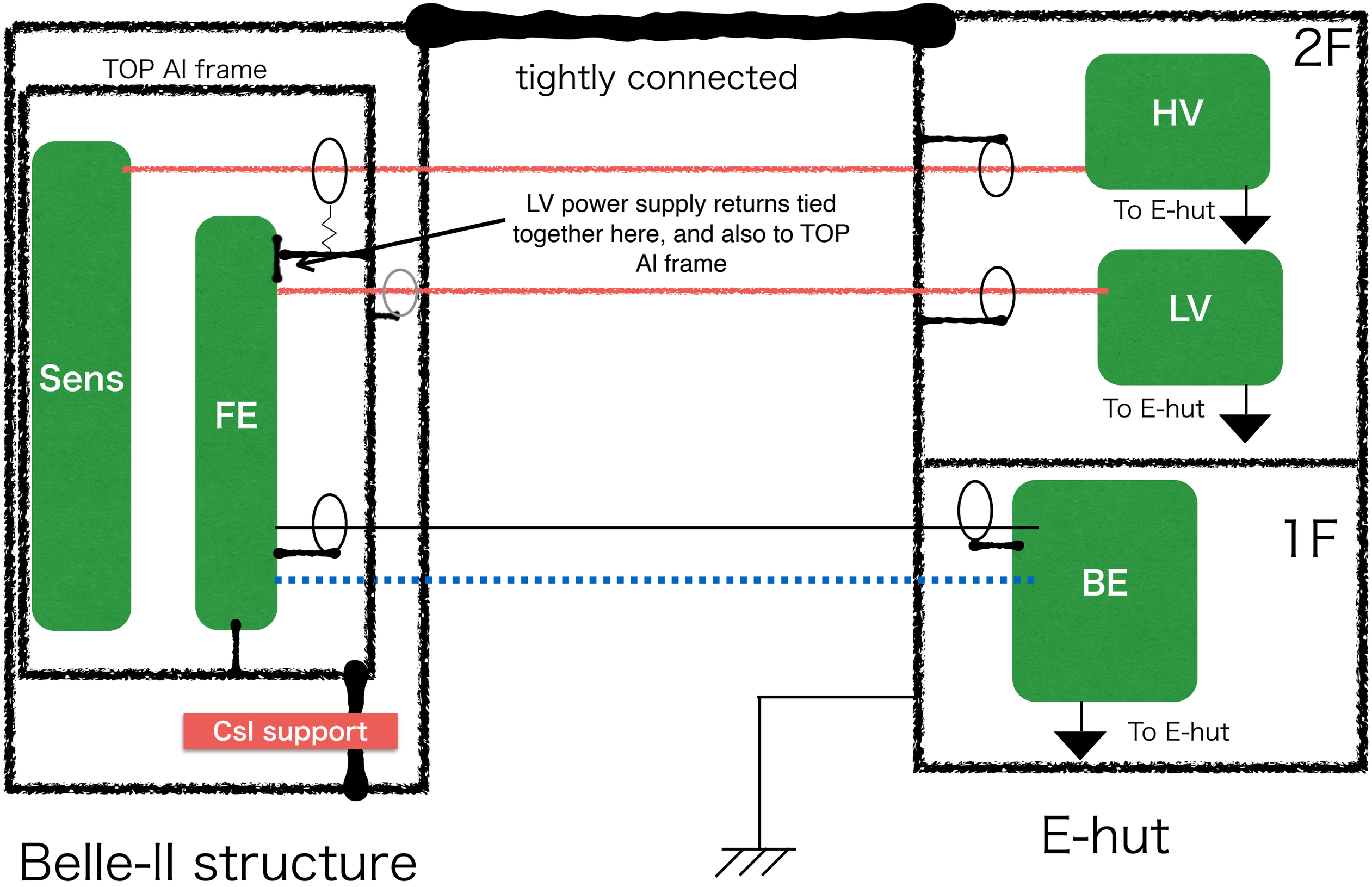
ECL grounding/shielding scheme@2014



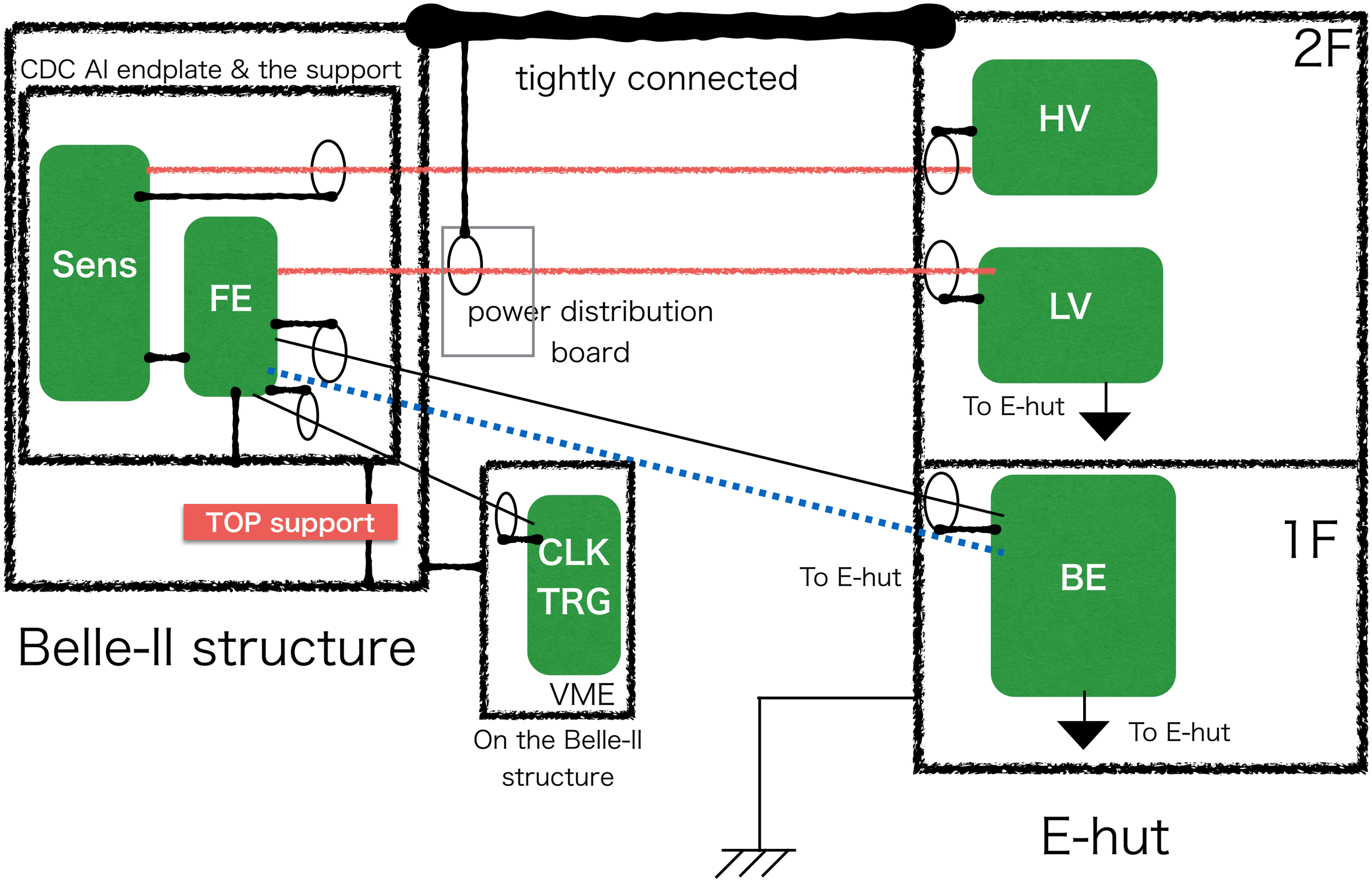
ARICH grounding/shielding scheme@2015



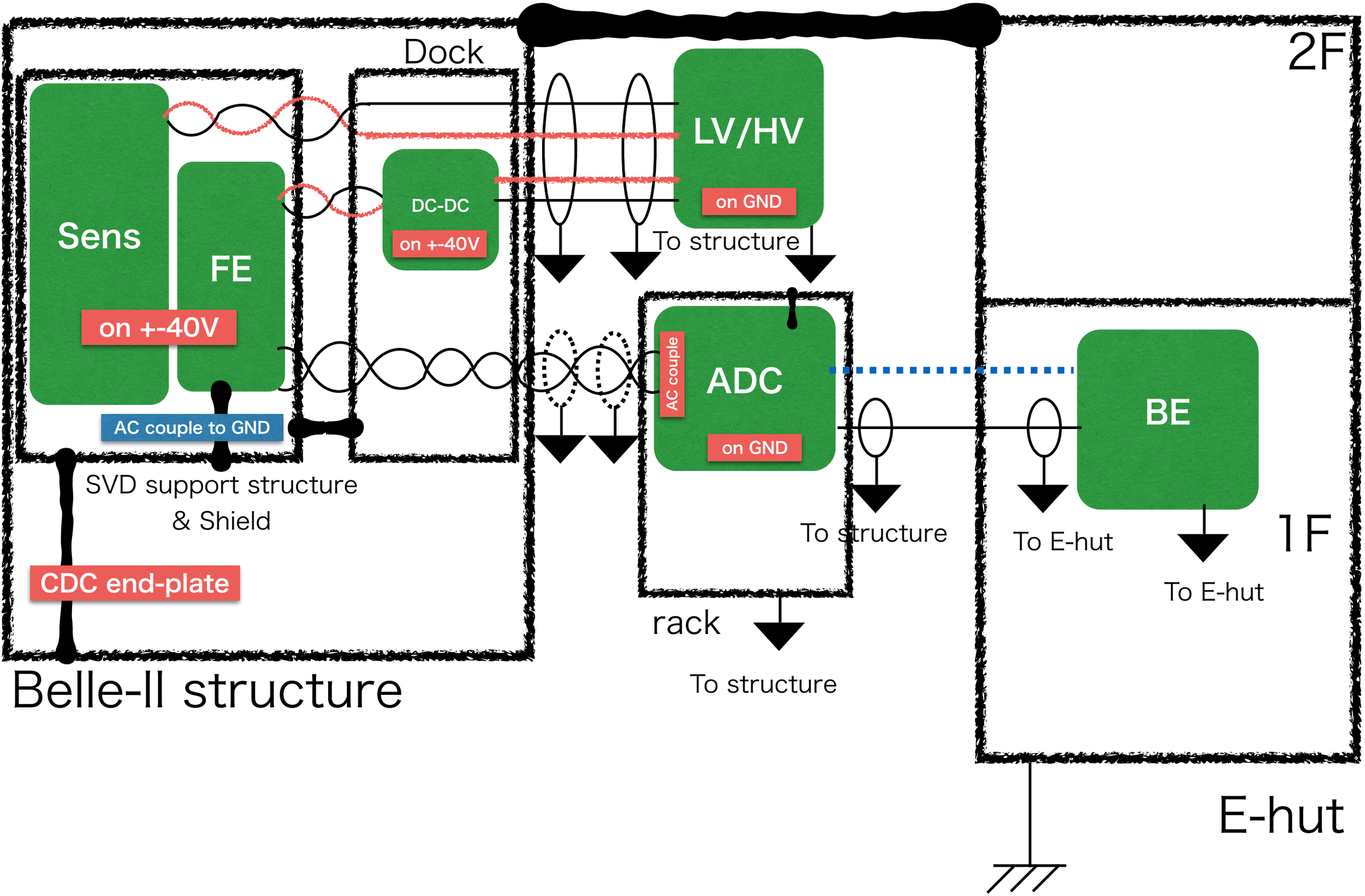
TOP grounding/shielding scheme@2015



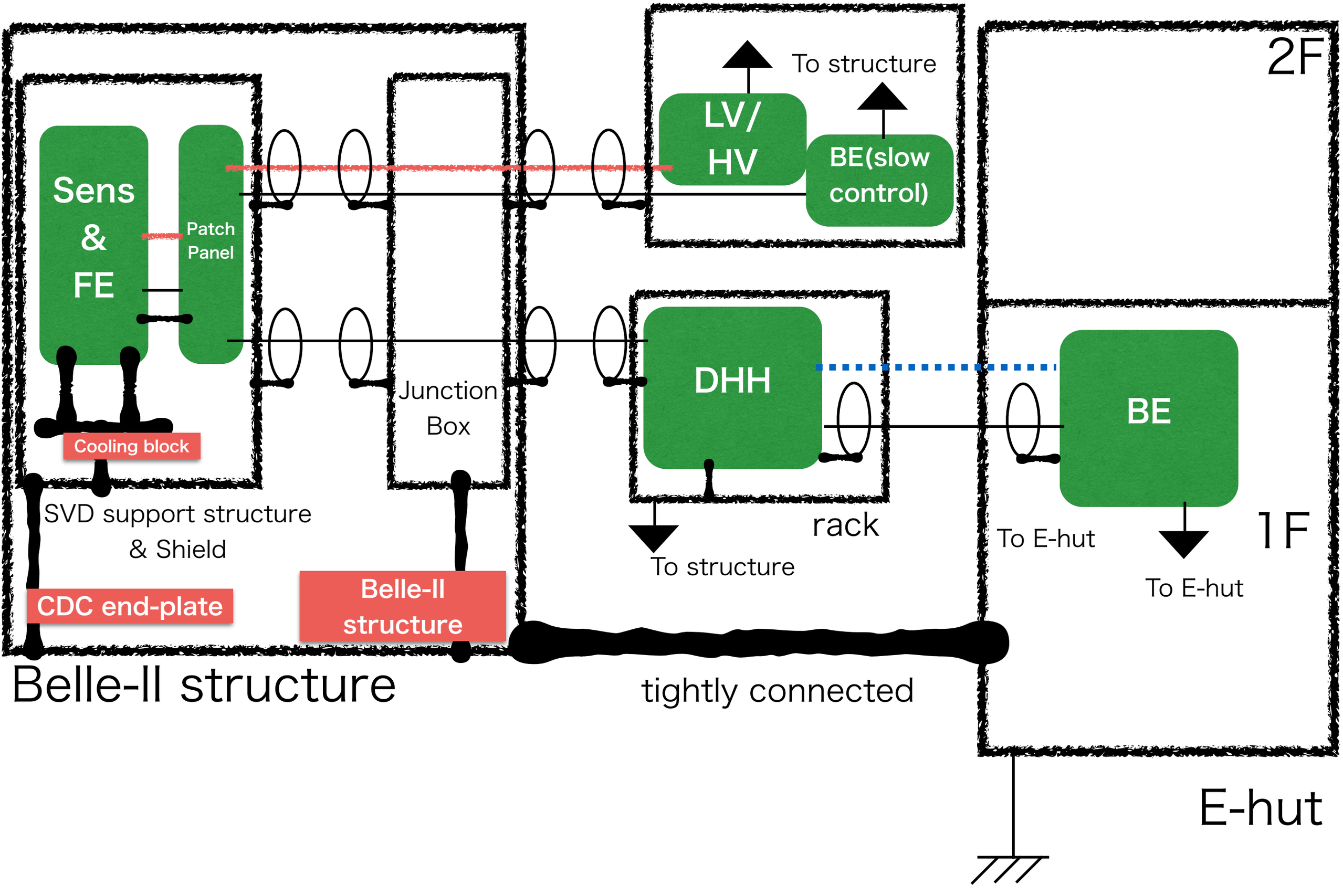
CDC grounding/shielding scheme@2015



SVD grounding/shielding scheme@2015



PXD grounding/shielding scheme@2015



possible solutons

- Out sourcing

- Using TIA lab. in Europe