TAOGLAS®

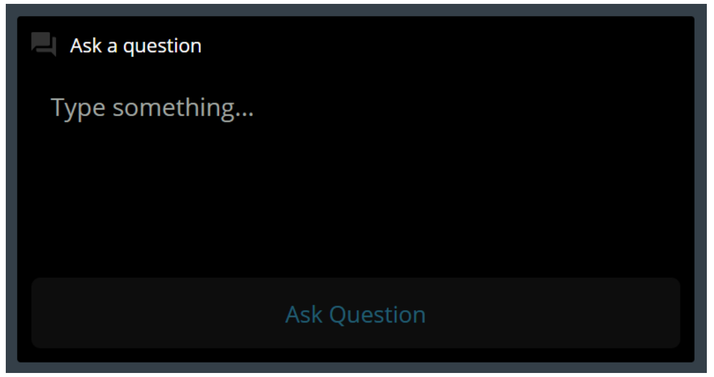
NORDIC® SEMICONDUCTOR

Cellular Antenna Certification

May 25, 2022

Practicalities

- Duration: 50-60 mins
- Questions are encouraged!
- Please type questions in the top of the right sidebar
  - All questions are anonymous
  - Try to keep them relevant to the topic
- We will answer questions towards the end
- The chat is not anonymous, and should **not** be used for questions
- If you have more questions:
  - Go to DevZone for Nordic related questions
  - Go to Taoglas website www.taoglas.com
- A recording of the webinar will be available together with the presentation at webinars.nordicsemi.com



{ DevZone

Speaker Intro

Baha Badran
Global Head of Engineering

Patrick Frank
Principal RF Engineer

Agenda

1. About Taoglas
2. Cellular Certification
3. Antenna Integration
4. Designing for TIS
5. Preparation for Certification
6. Q&A

Delivering Trusted Technology

Focused on best-in-class, high-performance antenna and RF design with advanced positioning, imaging, audio and artificial intelligence technologies, ***Taoglas*** has unique expertise in integrating and commercializing highly complex technology solutions.

Design and Expertise

We have enabled thousands of successful IoT/M2M hardware and software projects globally since 2004

Innovation

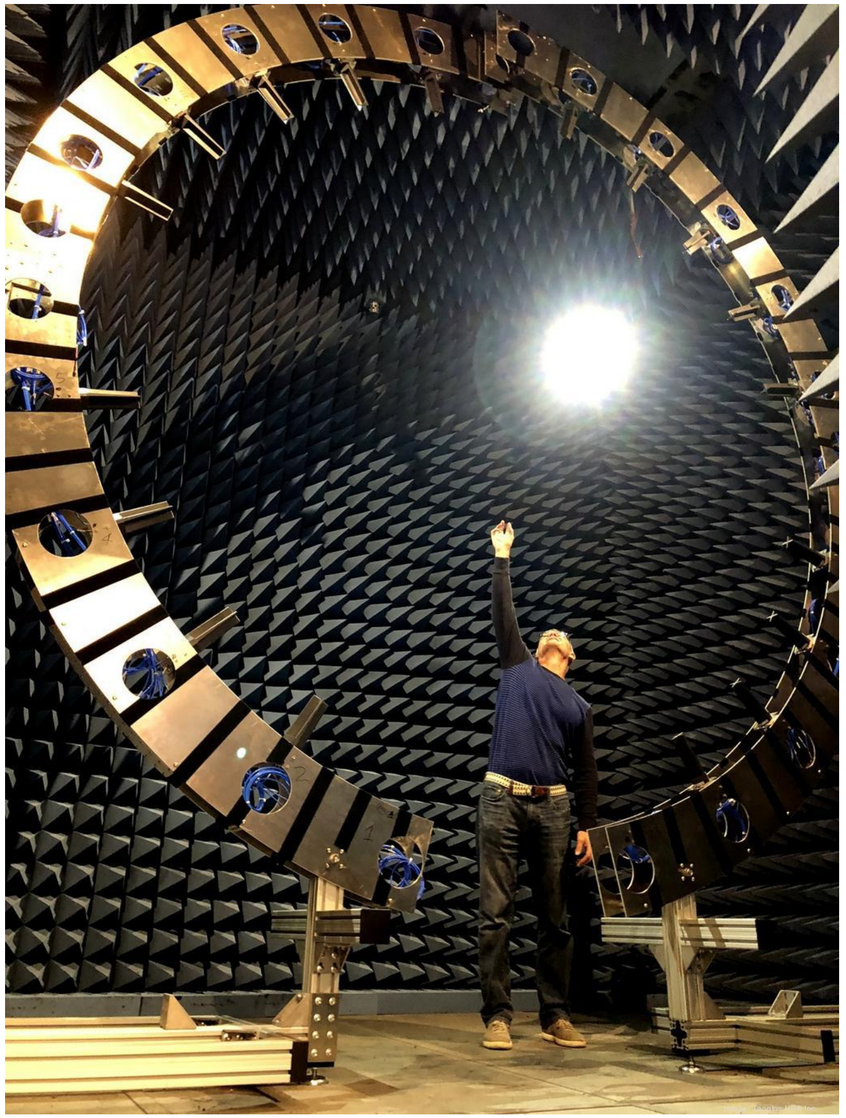
We drive innovation on the road to 5G, unmanned autonomy and IoT.
90 patents approved and 120+ pending

Global Presence

Currently, over 430+ employees based in design and manufacturing centers spread across the globe

Customer support

Located close to customers globally with the latest test, design and support services



Satimo 24 SGL, 400 – 6000MHz Chamber in Minneapolis, USA

Taoglas Centers of Excellence

San Diego, USA
Full RF Test Labs ACCD Division, Engineering and Sales

Minneapolis, USA
R&D Test Lab, Engineering and Sales

Florida, USA
Engineering

Enniscorthy, Ireland
Full Test Lab, Engineering and Sales

Dublin, Ireland
Full Test Lab, Engineering and Sales

Gdansk, Poland
Engineering

Tainan, Taiwan
Taoglas Manufacturing and Engineering

Taoyuan, Taiwan
Full RF Test Lab, Environmental Test Lab, Engineering and Sales

Shanghai, China
Full RF Test Lab, Engineering and Sales

Australia, Brisbane
Engineering and Sales

Cellular Certification

Basics & Terminology

Regional…

- Every market is different!
- Modular certifications go a long way
- Nordic has good references:

https://www.nordicsemi.com/Products/Low-power-cellular-IoT/nRF9160-Certifications

https://blog.nordicsemi.com/getconnected/certifying-a-cellular-iot-device

Specifically…

- Regulatory certification:
  - Inter-device/Inter-system Coexistence
  - Safety (RF and otherwise)
  - Basic functionality
- Industry cellular certification:
  - Enable inter-operator roaming
  - Baseline performance measurements
- Carrier certification:
  - More rigorous network behavior testing
  - Enforced performance metrics

- Spurious Emissions
- RF Safety (SAR, MPE)
- Immunity

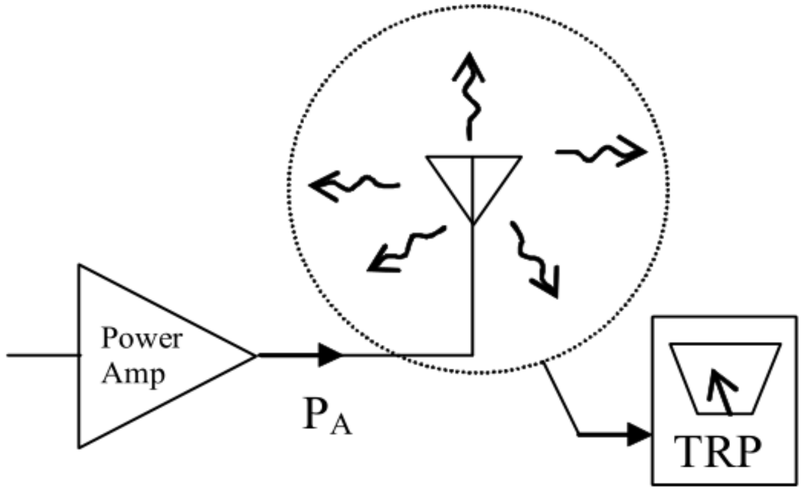
- Network interoperability testing
- SIM Card interoperability
- ***Over-the-Air (OTA) Measurements***

- Network connection testing
- ***OTA performance requirements***

OTA: TRP

- TRP = Total Radiated Power
- Radiated power given set input power
- Highly dependent on antenna *total efficiency*

FIGURE E-2 TRP



Credit: CTIA OTA Test Plan V3.8.1

$$TRPWatts = Power_{Total} = Power_{Conducted}\, Efficiency_{Antenna}$$

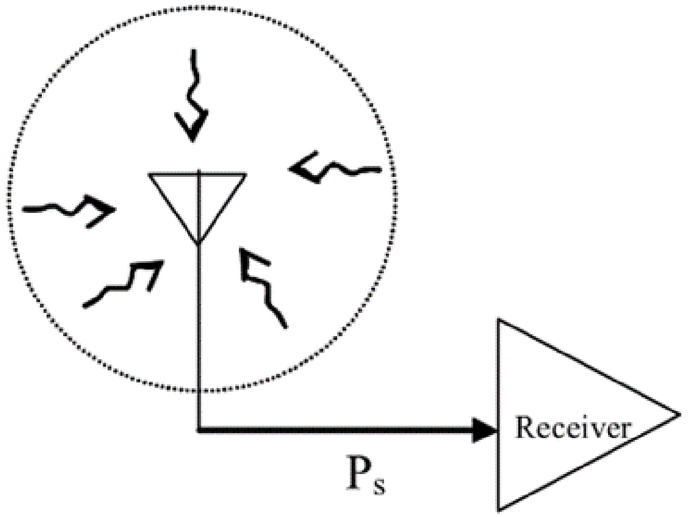
$$TRP_{dBm} = Power_{Total,dBm} = Power_{Conducted,dBm} - Efficiency_{Antenna,dB}$$

$$TRP_{dBm} = Power_{Total,dBm} = Power_{Conducted,dBm} - LOSS_{tline,dB} - LOSS_{mismatch,dB} - Rad\ Efficiency_{Antenna,dB}$$

OTA: TIS

- TIS = Total Isotropic sensitivity
- Dependent on antenna *total efficiency*
- TIS is *also* highly influenced by interference

FIGURE E-1 TIS



Credit: CTIA OTA Test Plan V3.8.1

$$TIS = \frac{4\pi}{\int_{\theta=0}^{\pi}\int_{\varphi=0}^{2\pi}\left[\frac{1}{EIS_{\theta}(\theta,\varphi)}+\frac{1}{EIS_{\varphi}(\theta,\varphi)}\right]\sin(\theta)\,d\varphi d\theta}$$

where $EIS_x(\theta,\varphi) = P_S G_{x,EUT}(\theta,\varphi)$

$$TIS \cong \frac{P_S}{\eta_{antenna} P_{interference}}$$

Sample OTA Requirements

Requirement		LTE Cat 1+	LTE Cat-M1 (Power Class 3)	LTE Cat-M1, Small Form-factor
TRP	Band 2	+20 dBm	+20 dBm	+12 dBm
	Band 4	+20 dBm	+20 dBm	+12 dBm
	Band 12	+18 dBm	+18 dBm	+10 dBm
TIS	Band 2	-91 dBm	-96 dBm	-88 dBm
	Band 4	-93 dBm	-98 dBm	-90 dBm
	Band 12	-91 dBm	-93 dBm	-85 dBm

- **Each carrier has their own requirements (if any) – ask your carrier!!!**
- Some variations of OTA requirements for new classes
- Small form-factor devices (< 107mm in length) have a lower bar
- Power Class 5 TRP requirements = 3 dB lower than Power Class 3
- Contact your carrier – yours may have different requirements
- Ref: https://iotdevices.att.com/

Antenna Integration

Designing for TRP

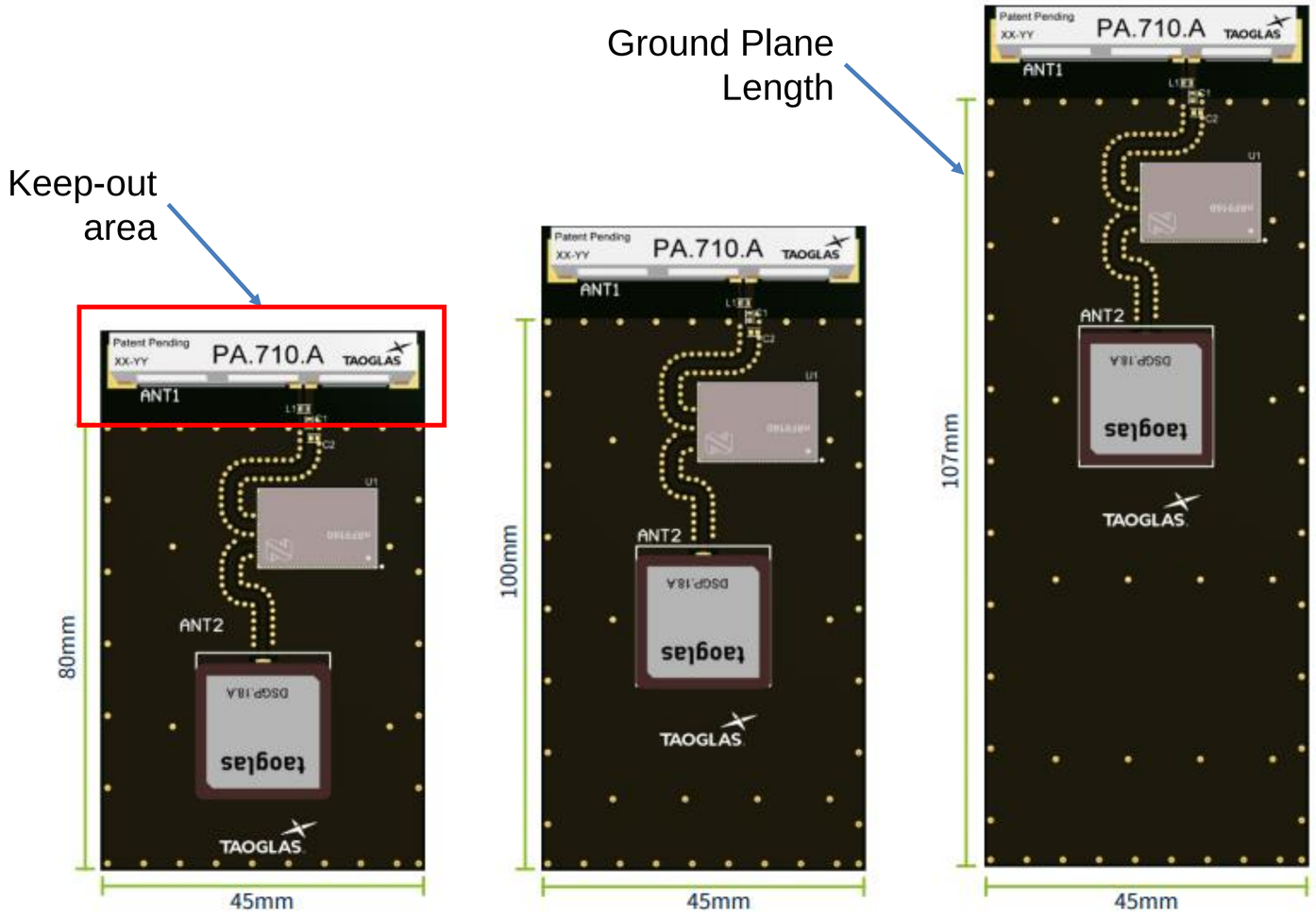
Typical Examples

Key Considerations

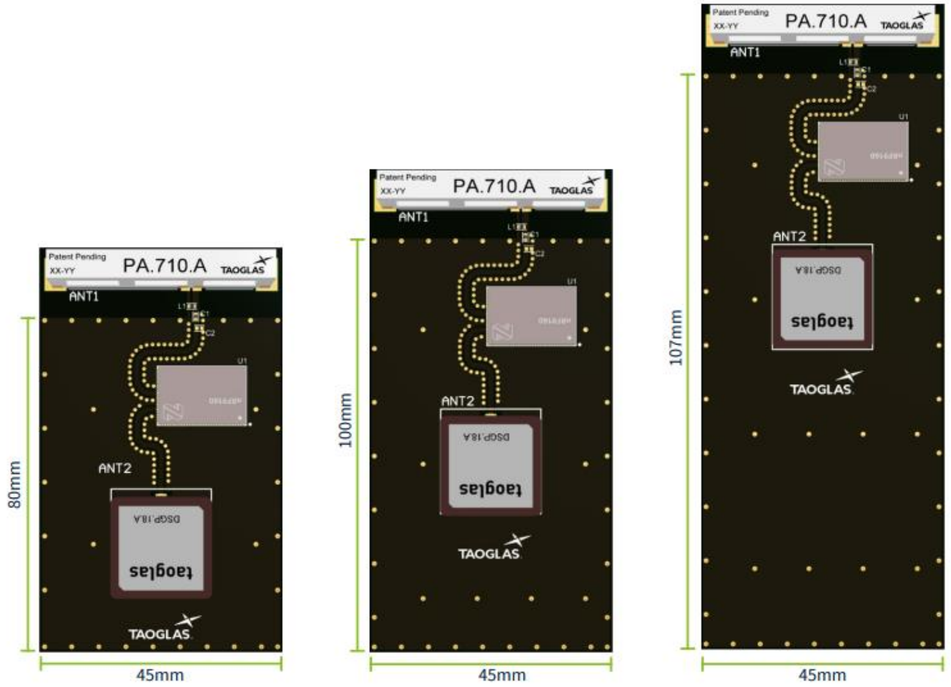
- Ground Plane Length
- Keep Out Areas
- Proximity to Metal

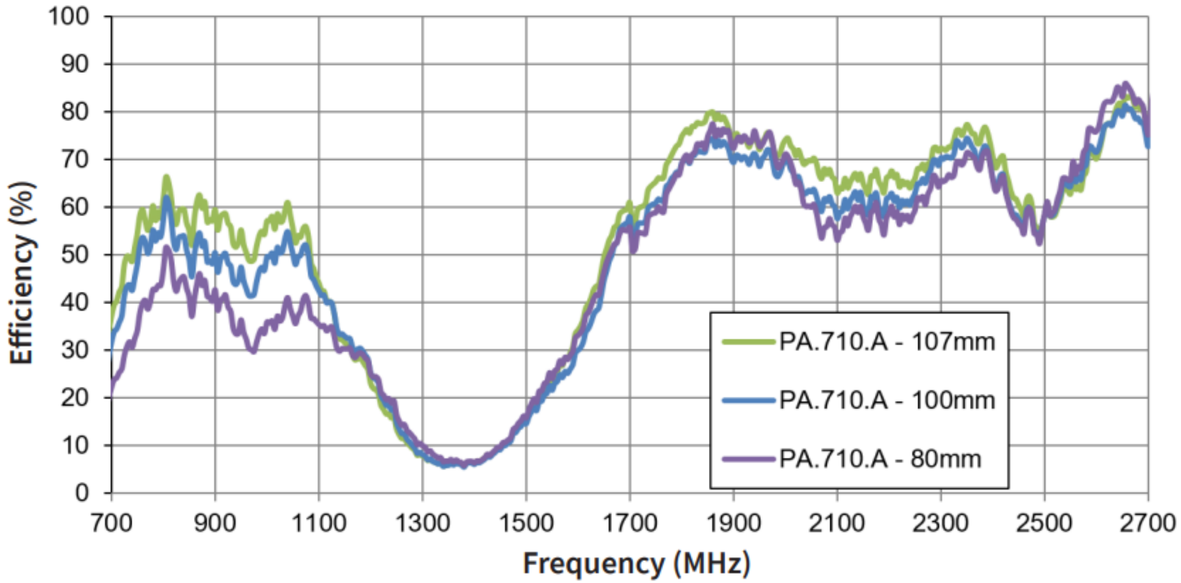
Ground Plane Length

- #1 most common issue for antenna performance
- **Target**: ¼ free-space wavelength



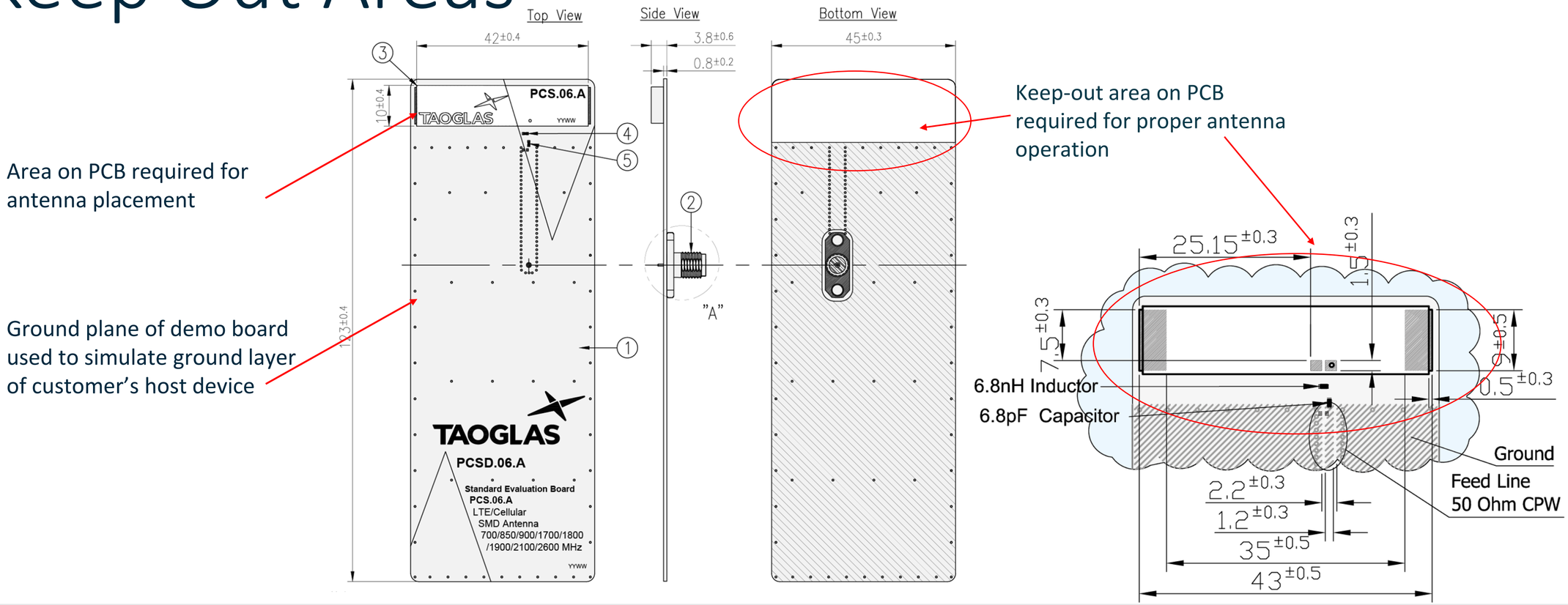
Ground Plane Size





- Performance of on-board antennas depends on ground plane length
- Efficiency AND Bandwidth decrease rapidly as ground plane length drops below ¼-wavelength
- 699MHz → ¼ wave =~ 107mm

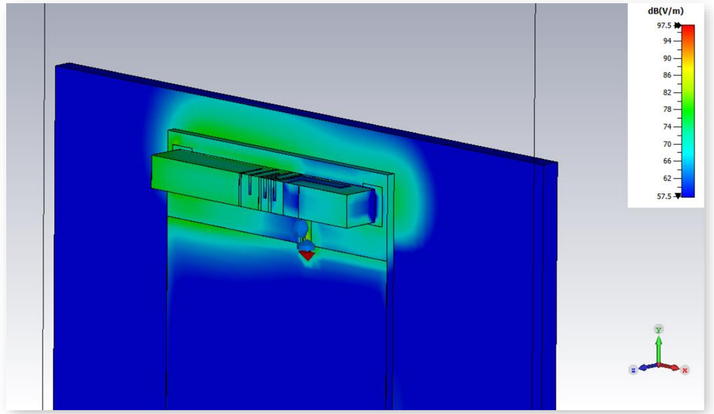
Keep Out Areas

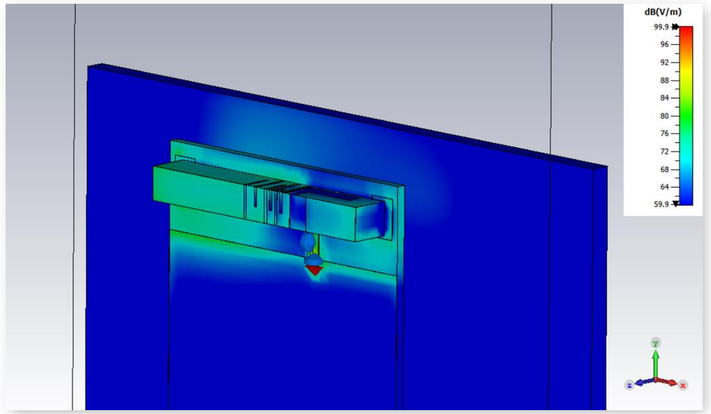


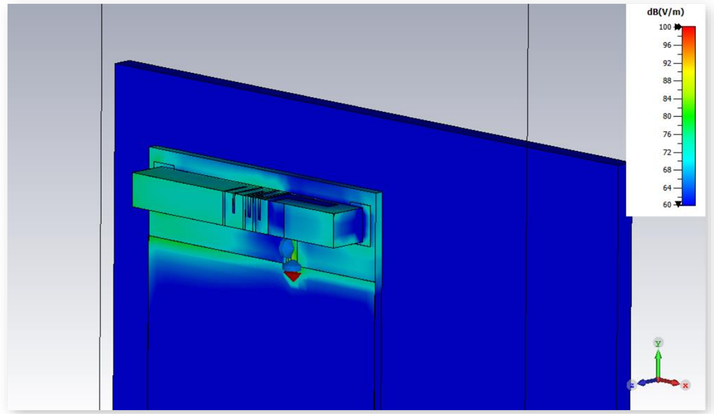
- Maintaining the "keep-out area" is key to achieving good performance
- The antenna has a physical volume, i.e. dimensions associated with it
- The realized antenna performance requires a VOLUME greater than the size of the antenna
- Follow the datasheet!

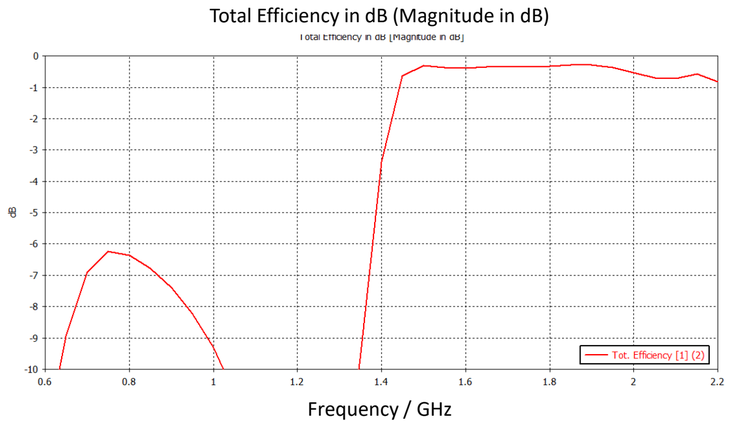
Proximity to Metal

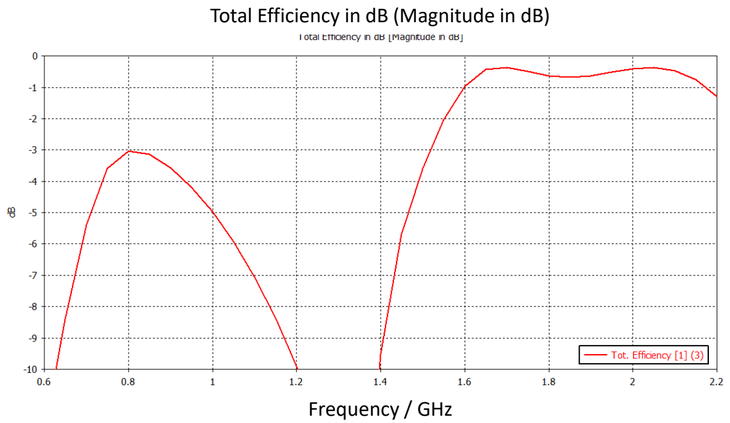
Keep-out area is 3D! Target > 20mm for cellular

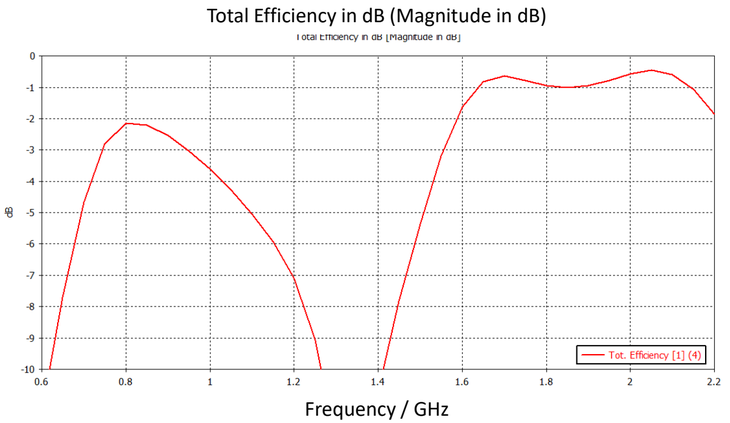








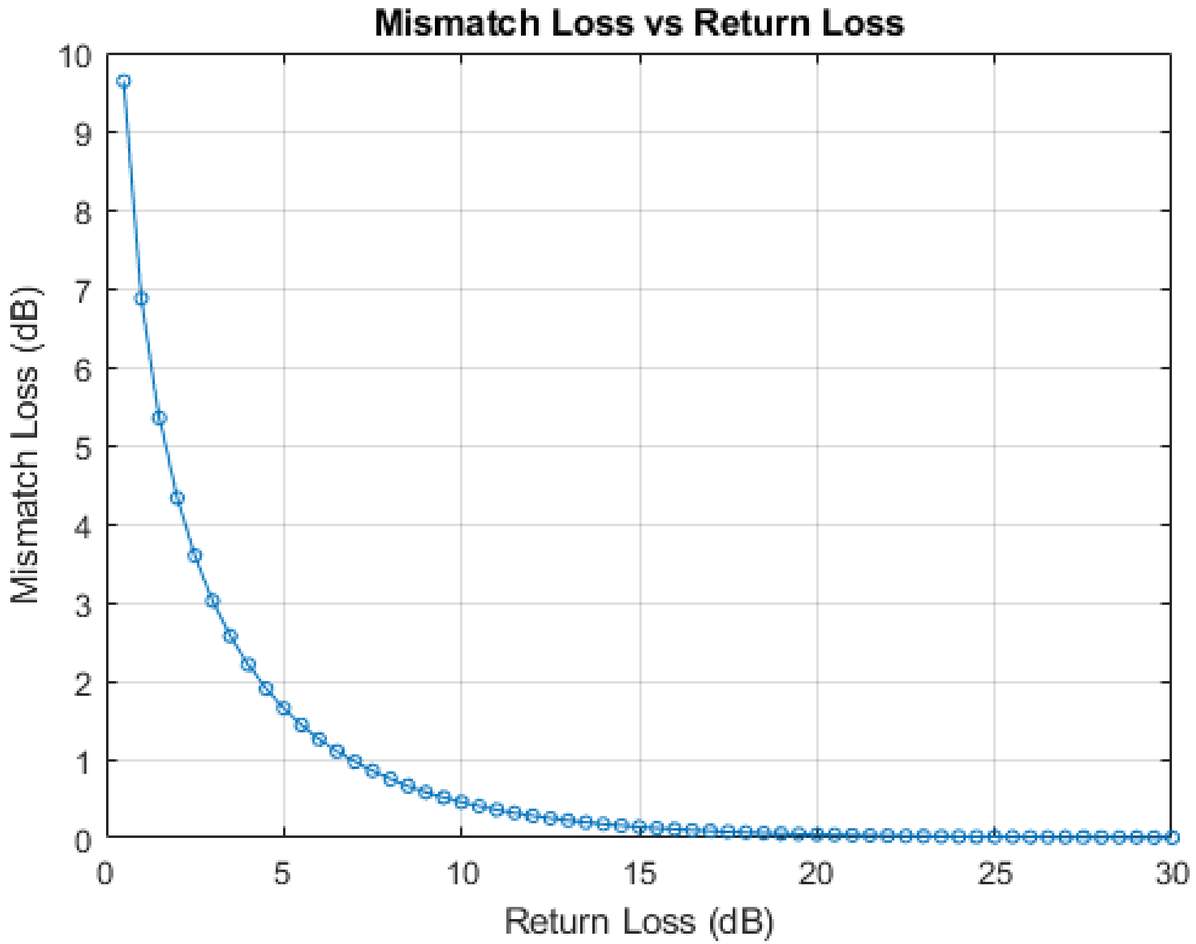




- Placing antennas over large sheets of metal requires much more than 20mm of clearance, unless using a monopole!

Impedance Matching

- Make sure the antenna (and all transmission lines) are impedance-matched
- Target 6dB return loss or better – diminishing returns after 10 dB
- If already matched to 10 dB return loss and TRP/efficiency is STILL low…there are other problems

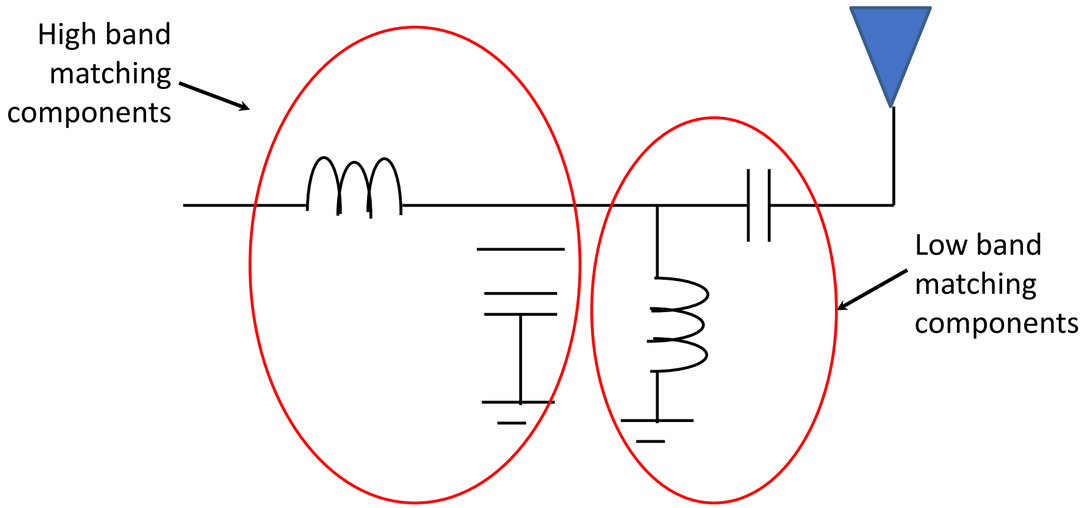


Impedance Matching Concept

There are many antenna types and many impedance matching schemes, so a common approach for multiband antennas is highlighted here as an example

Using a 4-component matching circuit:

- Assign two components to match the low band resonance; this acts as a high pass filter
- Assign 2 components to match the high band resonance; this acts as a low pass filter



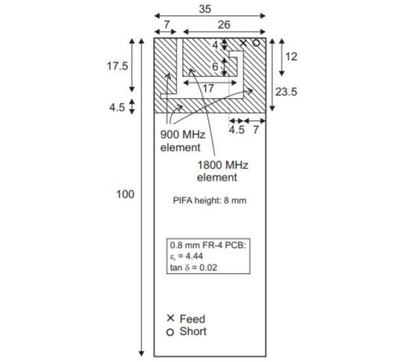
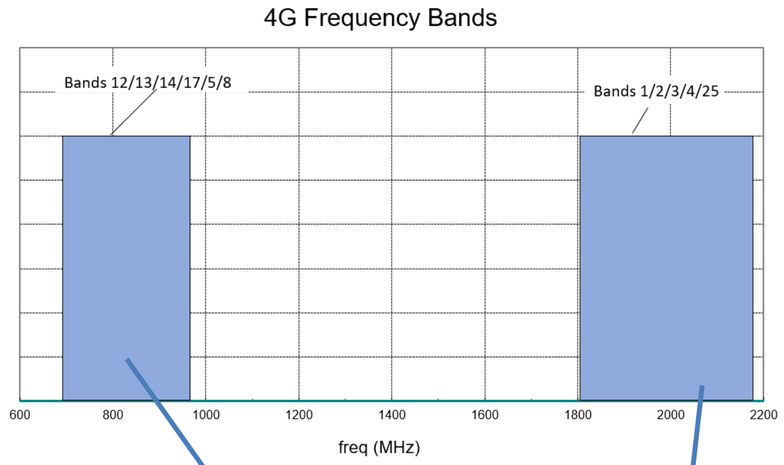
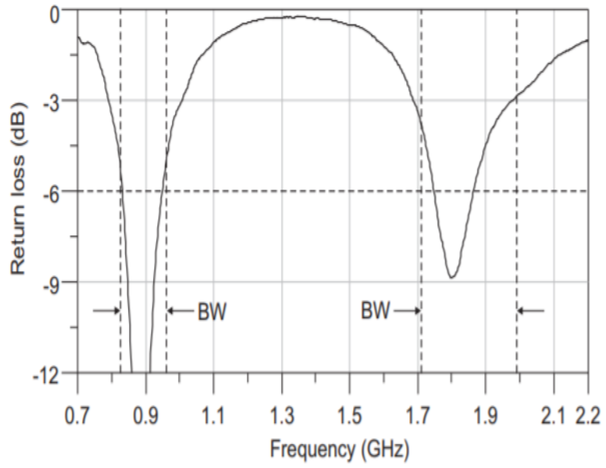


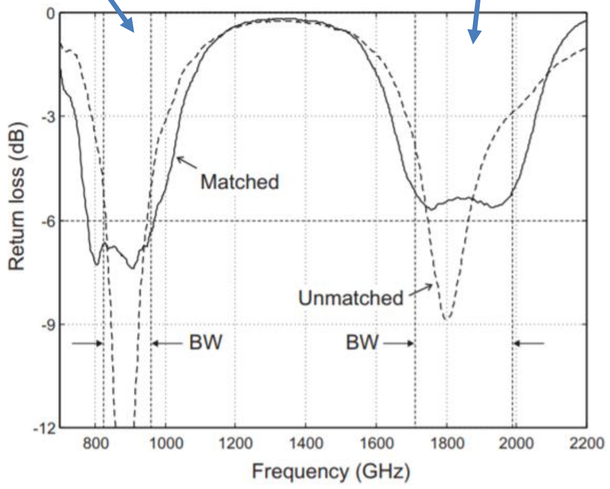
Figure 1. Layout of terminal antenna. All measures in mm.



Before Matching

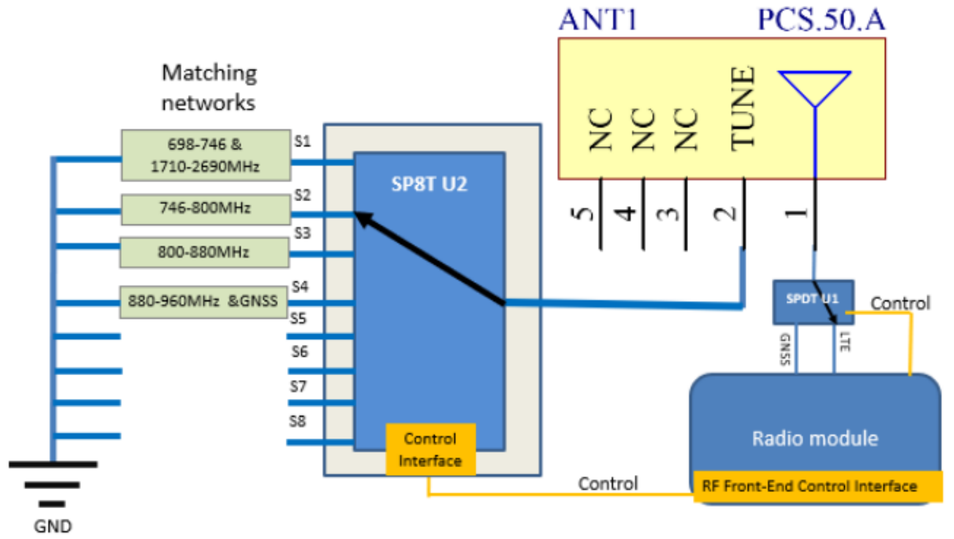


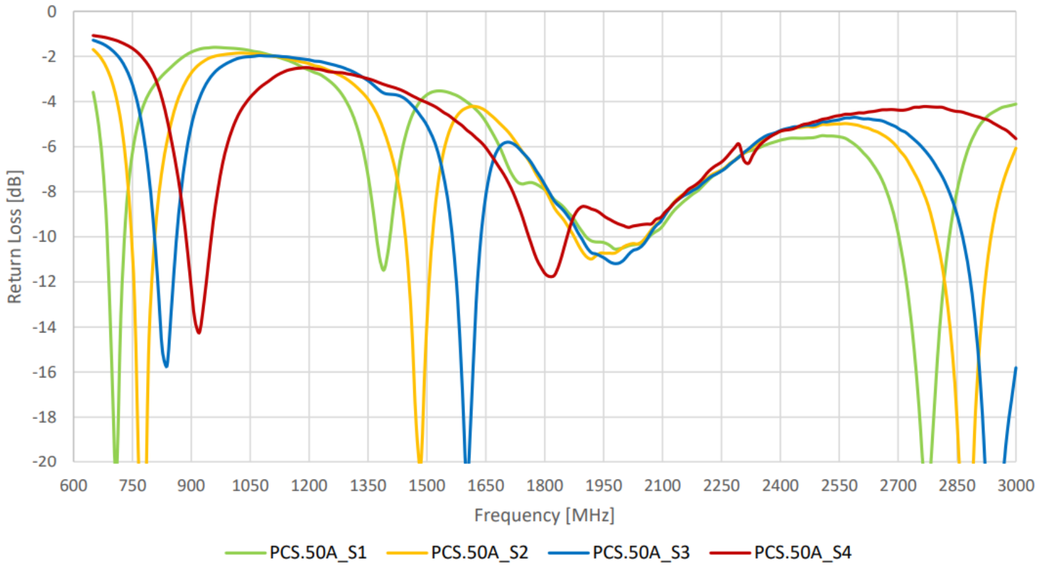
After Matching



Dynamic Tuning

- As antenna volume shrinks, so does bandwidth
- Dynamic tuning allows a smaller bandwidth to “cover” more bands than if statically-tuned
- Solid-state switch network adjusts tuning “on the fly”

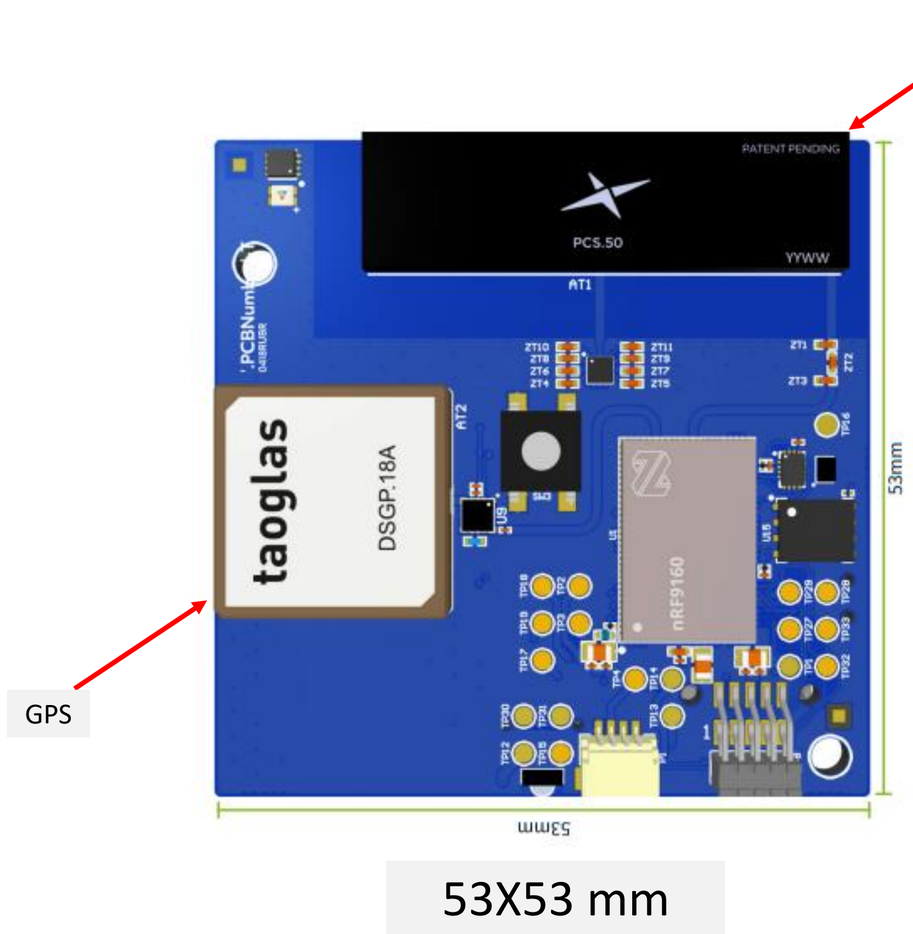




Dynamic Tuning – Nordic Thingy:91

- Taoglas’ PCS.50 + Nordic’s nRF9160 support dynamic tuning
  - Nordic nRF9160 module supports antenna tuning control
  - Taoglas PCS.50A supports aperture tuning (700-2700 MHz).

PCS.50



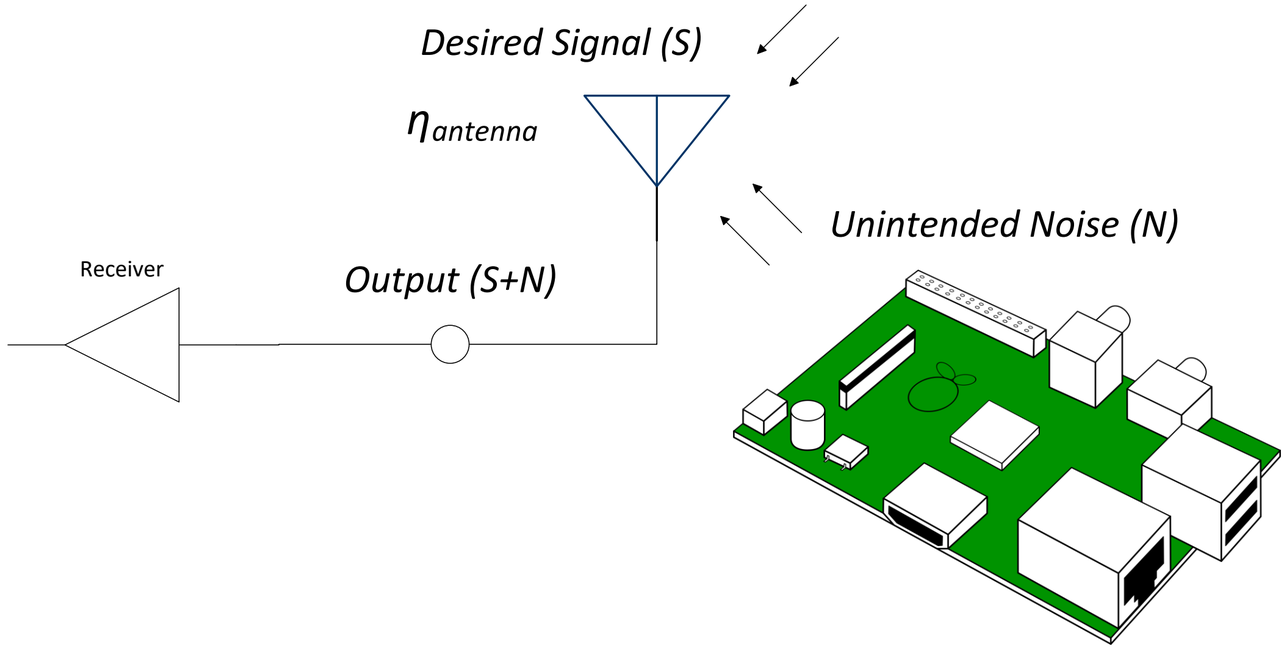
53X53 mm

Design for TIS

RF Noise/Interference Mitigation

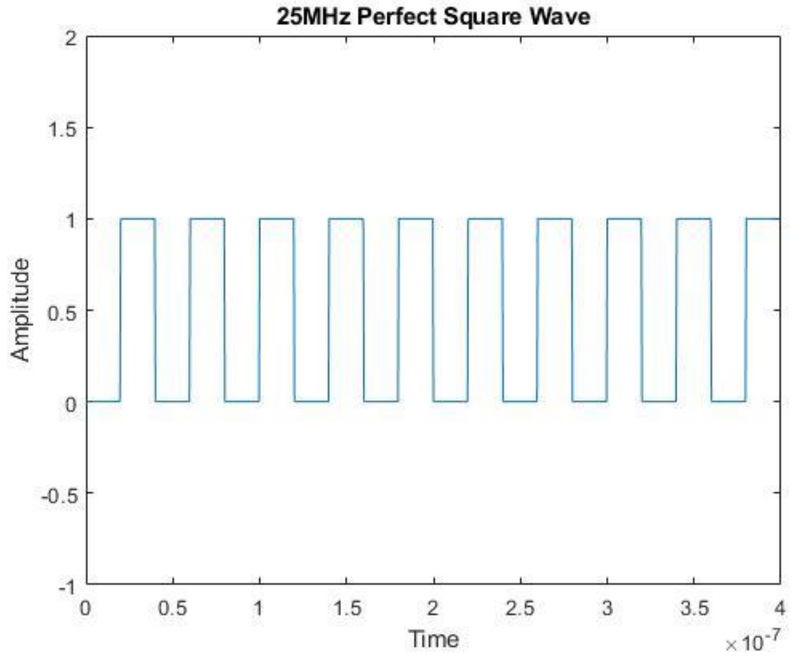
How noise affects TIS

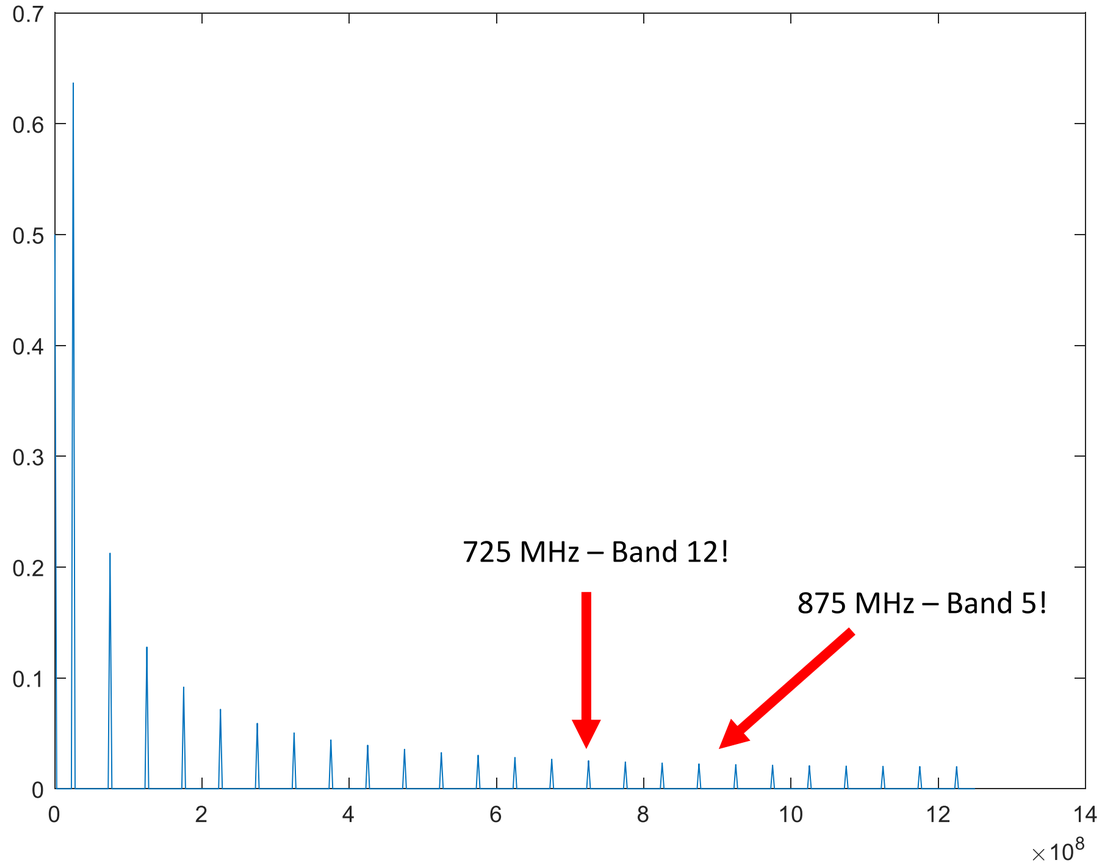
- Electro-magnetic noise (often cause by power supply) can be emitted from the device itself and received by its own antenna.
  - This is called *self interference*.
- EMC issue!
  - Mitigated using same methods, but power levels are lower



Noise: Narrowband

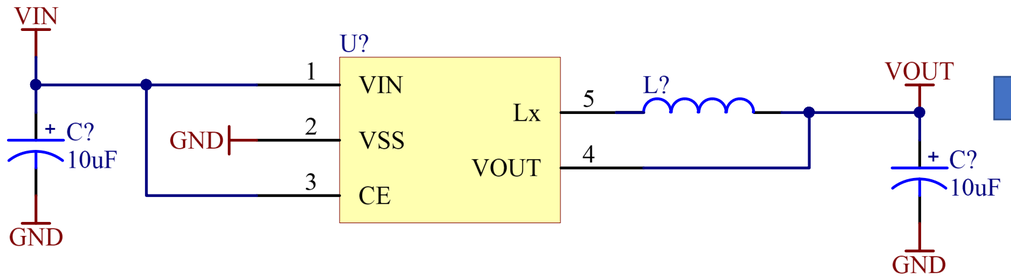
- Narrowband generates CW-like interferers
- Real signals have jitter, real rise & fall times: both odd and even harmonics

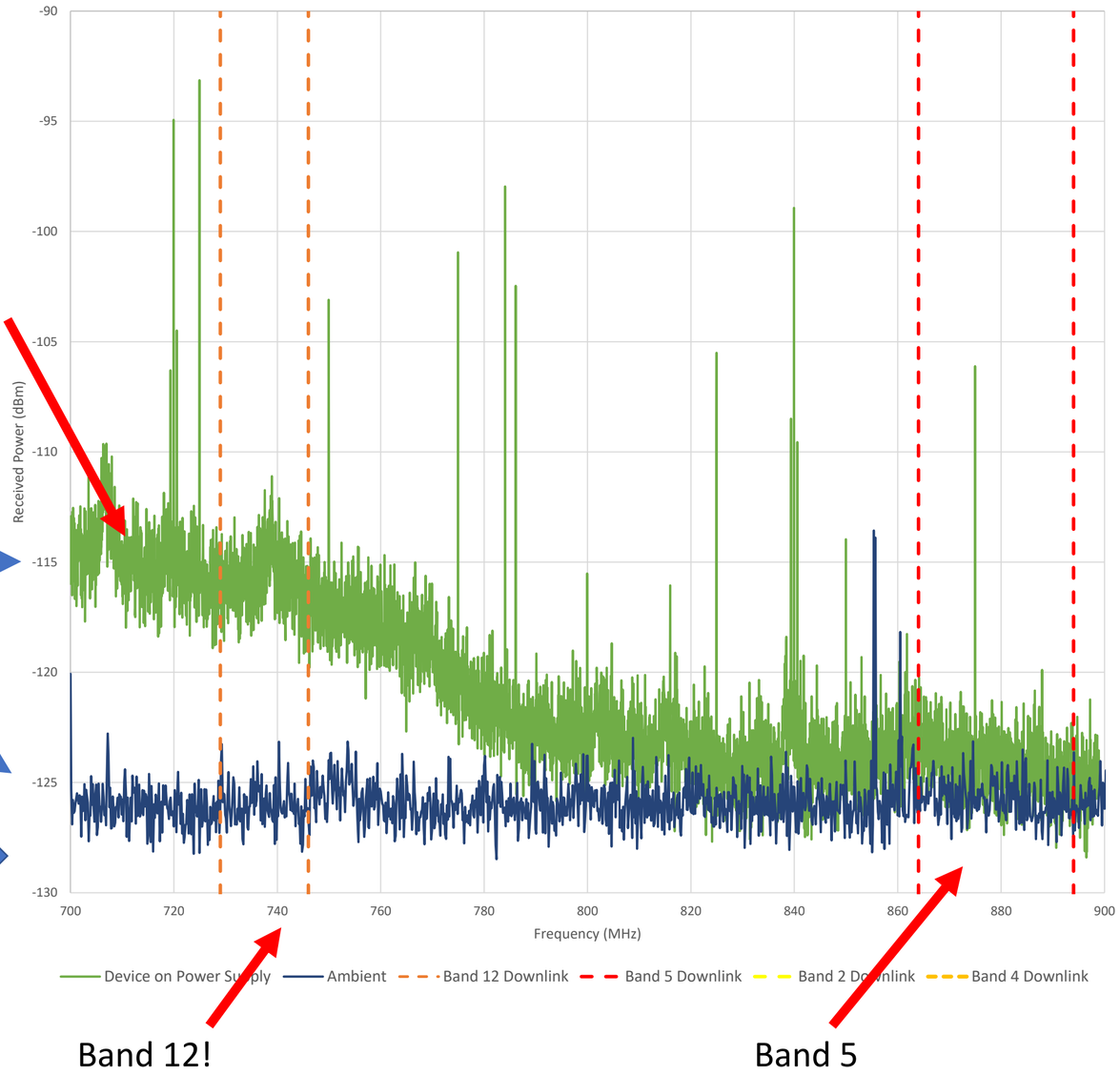




Noise: Broadband

- Broadband: high-speed data bus or switch-mode power supply (SMPS)
- Acts like thermal noise from the receiver's perspective
- More stringent requirements…





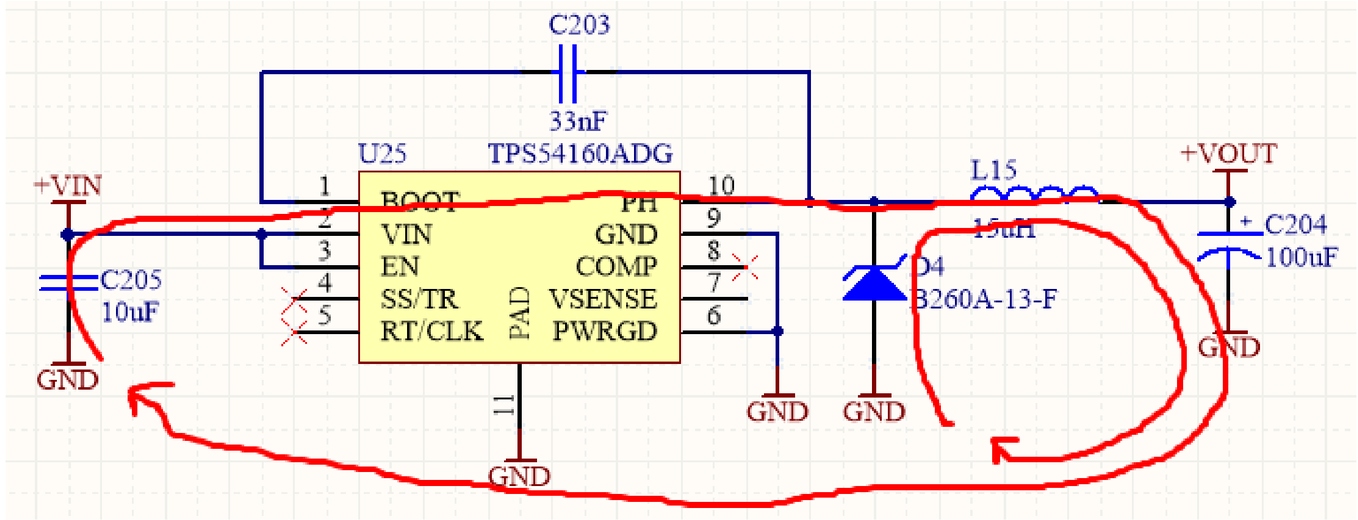
Self-Interference Requirements

- Performance targets can be estimated for self-interference
- Narrowband systems like GSM are equally sensitive to narrowband and broadband interference
- OFDM systems like LTE are less sensitive to narrowband but more sensitive to broadband interference

Technology	Maximum Narrowband Interferer Power	Maximum Broadband Interferer Power
GSM/GPRS (2G)	-108 dBm	-108 dBm
LTE (4G)	-82 dBm	-117 dBm

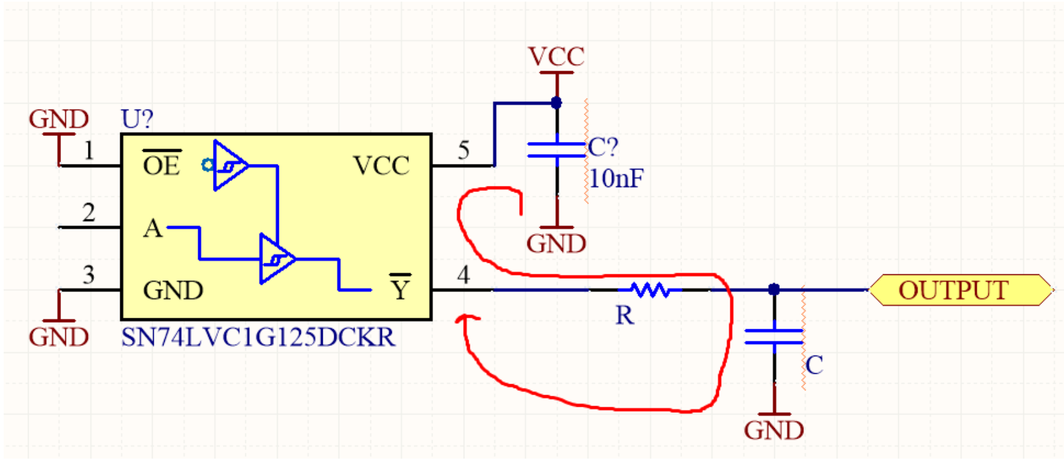
Mitigating SMPS Noise

- Ensure tight switching loop PCB layout
- Make sure switching loop has clean and clear return path **(and does not change reference plane!)**
  - Typically, two loops: minimize area of both!
- Plan for shielding SMPS
- Add high-frequency capacitors to both input & output to minimize broadband area.



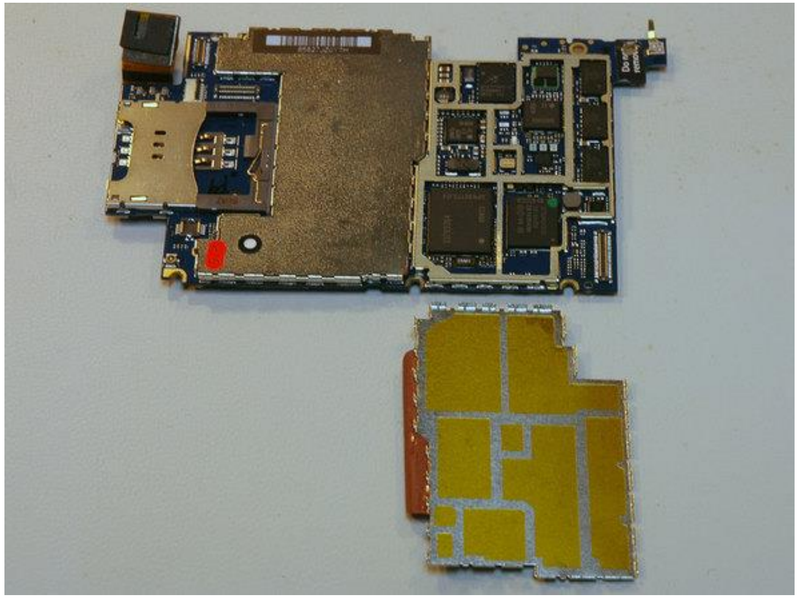
Mitigating Digital Switching Noise

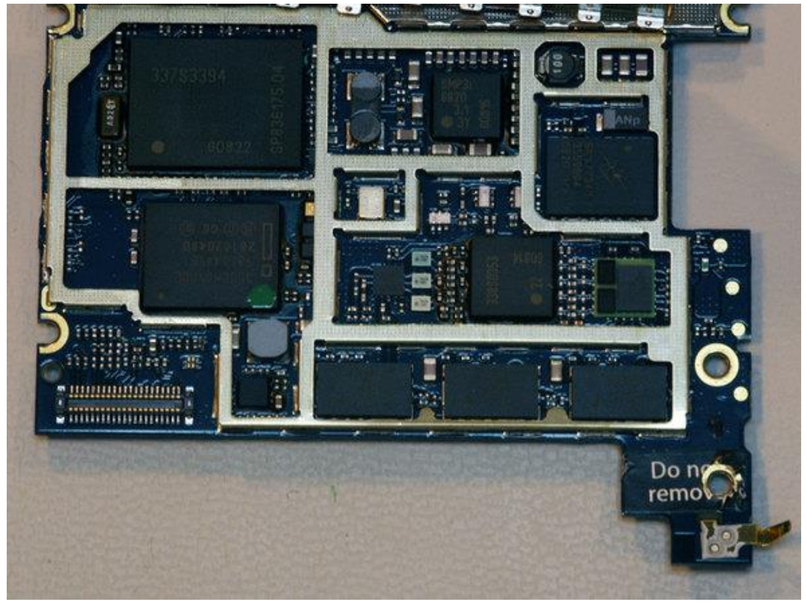
- Power supply bypassing!
- The “full” loop includes the power supply
- Keep impedance of the bypassing/”Power Distribution Network” (PDN) low at the fundamental and harmonic frequencies
- Keep PCB trace routing clean – good ground planes and layer transitions



Shielding

- Plan for shielding around high-frequency digital electronics and switch-mode power supplies
- Shields should be connected directly to the PCB ground planes
- Minimize openings/gaps/apertures in shields



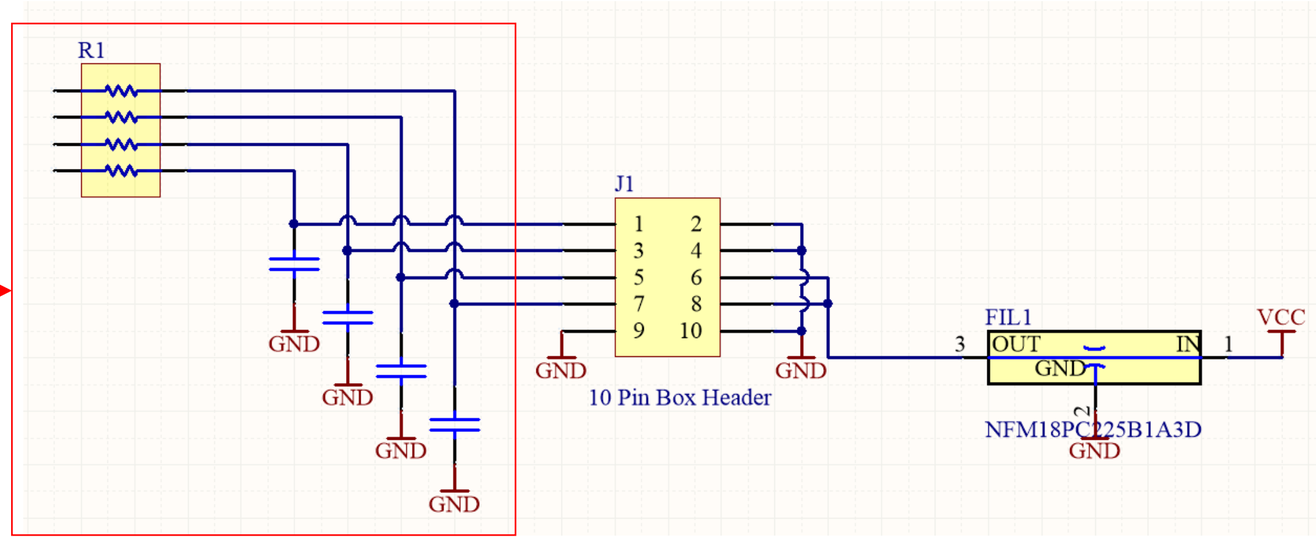


Interfaces

- Pay close attention to off-board interfaces
  - Cables, connectors, board-to-boards
- Power & Differential Lines: common-mode choke
- Single-Ended Lines: RC or LC filtering

Power & Differential Lines

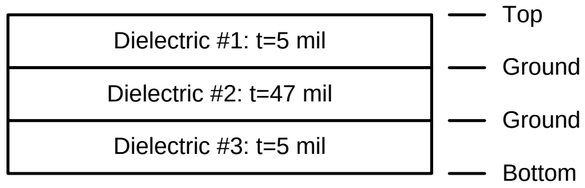
Single-Ended Digital Lines



PCB Stack-ups & Other Notes

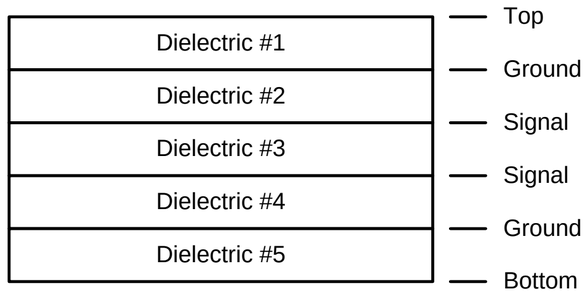
- At least one ground plane
- Stitch grounds together! At board edge and throughout the board
- If using power plane/pours: couple tightly to ground plane
- Examples are presented below. Every implementation will be different, so always check!

Substrate Stack-Up: 4-layer



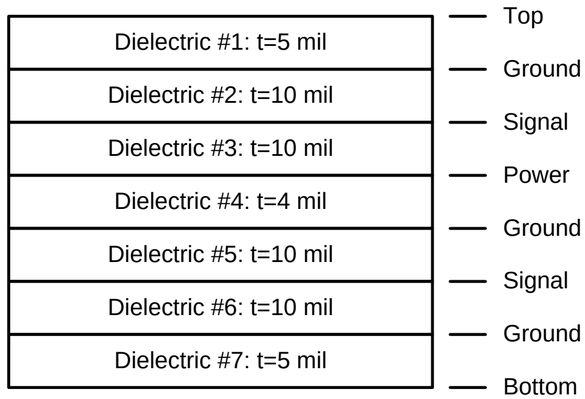
Using two ground planes allows clean routing on top & bottom: no worry about routing across a break in the reference plane

Substrate Stack-Up: 6-layer



Keeping the ground planes from the 4-layer, we can add two signal layers in the middle. These signal layers are well-shielded!

Substrate Stack-Up: 8-layer



Keeping two signal layers but adds a power layer. Good for high-speed designs. Internal signals are shielded and provided with clean reference planes.

Design for Test

How to make your test lab like you

- Don’t interfere with the LTE modem module operation
    - Turn it on and let it run in its default state
- Don’t let it fall asleep
- Enable auto-registration
- Enable auto-answer (when applicable)
- Provide test lab AT command access
- … #1 solution: instructions!

Pretesting

- “Pretesting” or “Precertification testing” is a shortened form of testing, focused on high-risk areas
- A great way to gain confidence (or identify problems) early
- TRP and TIS are tested but often shortened
  - TIS: mid channel only
  - TRP: reduced spatial sampling (15° → 30°)
  - No Intermediate Channel testing
- Radiated Spurious Emissions
  - Intentional Radiator – harmonics of transmitted signal
  - Unintentional Radiator – radio off, 30MHz – 1GHz
- Perform as soon as you have a functional unit!

Recap

Take-aways

- Identify your target markets & carriers early
- Talk to your target carriers early (if known)
- Design for TRP
  - Ground plane/device size is critical
  - Give your antenna volume
- Design for TIS
  - Design for low emissions
- Test early
- Reach out to Taoglas & Nordic for help

More Information

- Antenna Integration Application Note
- Taoglas/Nordic Web Release
- Nordic Partner Program: Taoglas
- nRF9160 Antenna and RF Interface Guidelines
- HW files reference layout and BOM (nRF9160 DK, Thingy:91)

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Q&A

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