Embedded antennas for IoT

Adapting the Nordic Thingy:91 antenna to your cellular IoT design

Nordic Partner Webinar
with Fractus Antennas
October 2019
Duration: approx 45 mins
Today’s host

Dr. Jaume Anguera

- Chief Scientist and Co-Founder at Fractus Antennas
- Inventor of Virtual Antenna™ Technology, 2008
- Author more than 130 granted patents and author of more than 220 papers (IEEE, EE, ...)
- 20 years of experience in antenna design for the wireless industry
- Named to the European Inventor Award, 2014
- Technology Pioneer, World Economic Forum, 2005
- Associate Professor at Universitat Ramon LLull (Antenna Engineering)
Practicalities

- Duration: 45 mins
- Questions are encouraged!
- Please type your question in the Questions tab on the right sidebar
- All questions are anonymous
- We will answer questions towards the end
- All questions will be answered in a written Q&A shared a few days after the webinar
- Please use DevZone if you have further questions
Content

- Brief on Nordic Thingy:91
- Fractus Antennas present the TRIO mXTEND™ embedded antenna and how you can adapt it for your cellular IoT designs
- Q&A
What is Nordic Thingy:91?

- An ‘out-of-the-box’ rapid prototyping kit for cIoT
- Supports LTE-M/NB-IoT and GPS
- Ships with a eSIM
- Supports Bluetooth Low Energy
- Lots of other sensors etc.
- Comes with a sophisticated application ready to go
- Dev tools and SDK
Nordic Thingy:91 hardware
Embedded Antennas for IoT

Adapting the Nordic Thingy:91 Antenna to your cellular IoT Design

Dr. Jaume Anguera,
Chief Scientist
FRACTUS ANTENNAS

October 2019
Index

- About Virtual Antenna™
- Antenna Architecture for Nordic Thingy:91 based on nRF9160
- Adapting Nordic Thingy:91 design to your c-IoT Device
- Other form-factors
- Conclusions
Radio Frequency Architecture in the Nordic Thingy:91
Virtual Antenna™

One antenna.
Any band.
Any device.

Faster, Cheaper, Easier.

FRACTUS ANTENNAS
About Virtual Antenna™

Use the same antenna in every device, regardless of the form factor. Change platform by just changing the matching network.

Use the same antenna for every frequency band, even for multiple of them all together (multiband design). Change protocol and frequency by just changing the matching network.
About Virtual Antenna™

Virtual Antenna™: the latest generation of miniature, multiband, multipurpose chip antenna components for sub 6 GHz cellular/IoT

A game changing technology
NN Products – Virtual Antenna™ boosters

Mobile + GNSS

IoT Smart Tracking

https://www.fractusantennas.com/files/AN_FR01-S4-210_Mobile_GNSS.pdf
Virtual Antenna™ in the Nordic Thingy:91

TRIO mXTEND™ chip antenna component: 30 mm x 3 mm x 1 mm (h)

Clearance area

Feeding Port #1
For Thingy:91, port #1 supports LTE + GPS

Feeding Port #2

Space for filtering purposes

Ground plane

https://www.fractusantennas.com/files/AN_FR01-S4-210_Thingy91.pdf
Antenna Architecture for Nordic Thingy:91 Platforms

LTE bands B2, B3, B4, B8, B12, B13, B20 and B28 (700-960 MHz + 1710-2200 MHz LTE band support) + GPS: reconfigurable antenna system

TRIO mXTEND™ chip antenna component
Antenna Architecture for Nordic Thingy:91 Platforms

Matching networks:
- 698-748MHz
- 746-803MHz
- 791-849MHz & 1710-2200MHz
- 824-894MHz
- 880-960MHz
- 1575MHz

TRIO mXTEND™ chip antenna component
Antenna Architecture for Nordic Thingy:91 Platforms

nRF9160

MATCHING networks

698-748MHz
746-803MHz
791-849MHz & 1710-2200MHz
824-894MHz
880-960MHz
1575MHz

TRIO mXTEND™ chip antenna component
Antenna Architecture for Nordic Thingy:91 Platforms

QM12038 GPIO Control
CLT1 CLT2 CLT3 GND VDD

Matching networks
- 698-748MHz
- 746-803MHz
- 791-849MHz & 1710-2200MHz
- 824-894MHz
- 880-960MHz
- 1575MHz

TRIO mXTEND™ chip antenna component
Antenna Architecture for Nordic Thingy:91 Platforms

- **nRF9160**
- **TRIO mXTEND™ chip antenna component**

**Device Connections**:
- **nRF9160** to **QM12038**: GPIO Control, Matching networks (698-748MHz, 746-803MHz, 791-849MHz, 1710-2200MHz, 824-894MHz, 880-960MHz)
- **CLT1, CLT2, CLT3**
- **GPS**
- **TRIO mXTEND™ chip antenna component**
Antenna Architecture for Nordic Thingy:91 Platforms

QM12038

GPIO Control

CLT1
CLT2
CLT3
GND
VDD

QM12038

Matching networks

698-748MHz
746-803MHz
791-849MHz & 1710-2200MHz
824-894MHz
880-960MHz
1575MHz

nRF9160

LTE

GPS

QM14501

TRIO mXTEND™ chip antenna component
Antenna Architecture for Nordic Thingy:91 Platforms

nRF9160

QM14501: Low noise amplifier with integrated SAW filter at the output

All schematics available at Nordic Semiconductor web
Matching Networks

<table>
<thead>
<tr>
<th>STATE</th>
<th>Frequency band</th>
<th>Matching Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF5</td>
<td>698-748MHz &amp; 1710-2200MHz</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>Z1 (L6)</td>
<td>5.1nH</td>
<td>LQW03AW5N1J00</td>
</tr>
<tr>
<td>Z2 (C10)</td>
<td>5.5pF</td>
<td>GJM0332C1H5R5WB01</td>
</tr>
<tr>
<td>RF7</td>
<td>746-803MHz</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>Z1 (L7)</td>
<td>4.7nH</td>
<td>LQW03AW4N7J00</td>
</tr>
<tr>
<td>Z2 (R10)</td>
<td>0Ω</td>
<td>-</td>
</tr>
<tr>
<td>RF8</td>
<td>791-849MHz</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>Z1 (C11)</td>
<td>9.2pF</td>
<td>GJM0332C1E9R2WB01</td>
</tr>
<tr>
<td>Z2 (L5)</td>
<td>6.2nH</td>
<td>LQW03AW6N2J00</td>
</tr>
<tr>
<td>RF3</td>
<td>824-894MHz</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>Z1 (C12)</td>
<td>1.5pF</td>
<td>GJM0334C1E1R5WB01</td>
</tr>
<tr>
<td>RF1</td>
<td>880-960MHz</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>Z1 (C9)</td>
<td>2.5pF</td>
<td>GJM0335C1E2R5WB01</td>
</tr>
<tr>
<td>Z2 (L4)</td>
<td>Open circuit</td>
<td>-</td>
</tr>
<tr>
<td>RF4</td>
<td>GPS (1575MHz)</td>
<td><img src="image" alt="Diagram" /></td>
</tr>
<tr>
<td>Z1 (L3)</td>
<td>2.9nH</td>
<td>LQW03AW2N9C00</td>
</tr>
<tr>
<td>Z2 (C13)</td>
<td>3.9pF</td>
<td>GJM0333C1E3R9WB01</td>
</tr>
<tr>
<td>RF2&amp;6</td>
<td>available for other bands</td>
<td>empty</td>
</tr>
</tbody>
</table>
About the Switch

Features:
- Excellent insertion loss and isolation performance
  - 0.5dB Typ IL, Band 5
  - 40dB Typ Isolation, Band 5
- Multi-Band operation 700MHz to 2700MHz
- GPIO compatible to 1.8V typ (1.3V min)
- Power handling +32dBm, 50Ω
- Compact 2mm x 2mm, Module package
- No DC blocking capacitors required (unless external DC is applied to the RF ports)
Considerations on the TRIO mXTEND™ chip antenna

TRIO mXTEND™ chip antenna component

Clearance area

<table>
<thead>
<tr>
<th>Component</th>
<th>Value</th>
<th>Part Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z1 (C15)</td>
<td>0.3pF</td>
<td>GJM1555C1HR30WB01 (Q\text{\textsubscript{min}}=570)</td>
</tr>
<tr>
<td>Z2 (L8)</td>
<td>15nH</td>
<td>LQW18AN15NG80 (Q\text{\textsubscript{min}}=78)</td>
</tr>
</tbody>
</table>

- This is a filter used to optimize antenna performance
- In order to optimize efficiency, the inductor is SMD 0603 and the capacitor SMD 0402
- Murata components are used. Other brands can be used as long as they keep the same quality factor (Q)
Adapting Nordic Thingy:91 design to your c-IoT Device
Video Tutorials

Easy. In only 3 simple steps you can obtain high antenna performance in the smallest space ever.

https://www.fractusantennas.com/tutorials/

STEP 1
Place the antenna component

STEP 2
Design your matching network

STEP 3
Test your device

Video #1
Video #2
Video #3
On its starter configuration, Thingy:91 has been optimized for a small platform following these general guidelines:

- **Minimum recommended PCB size:** 50 mm x 50 mm
- **Keep one continuous RF ground plane layer**
- **Place the TRIO mXTEND™ chip antenna component** close to a **corner of the PCB**
- **Include a feeding line** 1mm width as close to the **corner** as possible
- **Leave a ground clearance** (area free of any component or conductive traces) of at least 40 mm x 12 mm. This clearance area applies to all layers
- **Include the nRF9160 front end module from Nordic Semiconductor** close to the **antenna matching network layout**
- **Include pads compatible with 0201 SMD components** for the matching networks as close as possible to the feeding point
- **Transmission lines** connecting the switch with matching networks and nRF9160 should have a characteristic impedance of **50 Ω**
Design Guidelines (II)
Design Guidelines (III): Do-not rules

**Clearance Area**
- Avoid small clearance area
- Avoid traces on the clearance area

**Antenna placement**
- Avoid placing the antenna in the middle of the ground plane

**Antenna feeding**
- Avoid the feeding at the center of the ground plane

**Distance RF module and antenna**
- Avoid long distances between the TRIO mXTEND™ chip antenna and the nRF9160 module
Transmission lines connecting the antenna with switch #2, matching networks with the switches, and switch #1 with the nRF9160 module, must present a 50 Ω characteristic impedance.
Design Guidelines (V): 50 Ω transmission lines

NI-AWR Software Txline calculator: A free and interactive calculator for the analysis and synthesis of transmission-line structures
Design Guidelines (VI): About Inductors and Capacitors

- Do I need to know something else besides L or C value?

Yes, Q matters!!

- The largest the Q, the better
- Low Q may result in poor performance
- SMD 0201/0402/0603
- Tight tolerance (2%, 3%)

Vendors provide software applications to analyze the Q value across frequency

## Design Guidelines (VII): Matching Networks

<table>
<thead>
<tr>
<th>STATE</th>
<th>Frequency band</th>
<th>Matching Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF5</td>
<td>698-748MHz &amp; 1710-2200MHz</td>
<td><img src="image1" alt="Matching Network Diagram" /></td>
</tr>
<tr>
<td></td>
<td><strong>Component</strong></td>
<td><strong>Value</strong></td>
</tr>
<tr>
<td></td>
<td>Z1 (L6)</td>
<td>5.1nH</td>
</tr>
<tr>
<td></td>
<td>Z2 (C10)</td>
<td>5.5pF</td>
</tr>
<tr>
<td>RF7</td>
<td>746-803MHz</td>
<td><img src="image2" alt="Matching Network Diagram" /></td>
</tr>
<tr>
<td></td>
<td><strong>Component</strong></td>
<td><strong>Value</strong></td>
</tr>
<tr>
<td></td>
<td>Z1 (L7)</td>
<td>4.7nH</td>
</tr>
<tr>
<td></td>
<td>Z2 (R10)</td>
<td>0Ω</td>
</tr>
<tr>
<td>RF8</td>
<td>791-849MHz</td>
<td><img src="image3" alt="Matching Network Diagram" /></td>
</tr>
<tr>
<td></td>
<td><strong>Component</strong></td>
<td><strong>Value</strong></td>
</tr>
<tr>
<td></td>
<td>Z1 (C11)</td>
<td>9.2pF</td>
</tr>
<tr>
<td></td>
<td>Z2 (L5)</td>
<td>6.2nH</td>
</tr>
<tr>
<td>RF3</td>
<td>824-894MHz</td>
<td><img src="image4" alt="Matching Network Diagram" /></td>
</tr>
<tr>
<td></td>
<td><strong>Component</strong></td>
<td><strong>Value</strong></td>
</tr>
<tr>
<td></td>
<td>Z1 (C12)</td>
<td>1.5pF</td>
</tr>
<tr>
<td>RF1</td>
<td>880-960MHz</td>
<td><img src="image5" alt="Matching Network Diagram" /></td>
</tr>
<tr>
<td></td>
<td><strong>Component</strong></td>
<td><strong>Value</strong></td>
</tr>
<tr>
<td></td>
<td>Z1 (C9)</td>
<td>2.5pF</td>
</tr>
<tr>
<td></td>
<td>Z2 (L4)</td>
<td>Open circuit</td>
</tr>
<tr>
<td>RF4</td>
<td>GPS (1575MHz)</td>
<td><img src="image6" alt="Matching Network Diagram" /></td>
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<tr>
<td></td>
<td><strong>Component</strong></td>
<td><strong>Value</strong></td>
</tr>
<tr>
<td></td>
<td>Z1 (L3)</td>
<td>2.9nH</td>
</tr>
<tr>
<td></td>
<td>Z2 (C13)</td>
<td>3.9pF</td>
</tr>
<tr>
<td>RF2&amp;6</td>
<td>available for other bands</td>
<td>empty</td>
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</table>
Technical Features of Nordic Thingy:91

<table>
<thead>
<tr>
<th>Technical features</th>
<th>698 – 748 MHz</th>
<th>746-803 MHz</th>
<th>791-849 MHz</th>
<th>824-894 MHz</th>
<th>880-960 MHz</th>
<th>1575 MHz</th>
<th>1710-2220MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Efficiency</td>
<td>10.0%</td>
<td>12.0%</td>
<td>14.8%</td>
<td>19.0%</td>
<td>20.2%</td>
<td>20.6%</td>
<td>49.9%</td>
</tr>
<tr>
<td>VSWR</td>
<td>&lt; 3:1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiation Pattern</td>
<td>Omnidirectional</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polarization</td>
<td>Linear</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight (approx.)</td>
<td>0.25 g.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature</td>
<td>-40 to + 120 °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Impedance</td>
<td>50 Ω</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total efficiency: \( \frac{P_{\text{rad}}}{P_{\text{av}}} = \eta_f \eta_r \left(1 - |S_{11}|^2\right) \)
Designing your Matching Network (I)

This corresponds to the LTE port of the nRF9160 module.
Designing your Matching Network (II)

• For **devices housed in plastic/ruber cases**, the value of L/C component of the **matching networks** may be need to be **readjusted** to compensate the frequency shift of the case

• A **library of S-parameters** are available at FRACTUS ANTENNAS for **other platform sizes**
NN Wireless Fast Track

Your Antenna Design, Free of Charge, In 24h

1. Fill out the form
2. Reply to email
3. Get free design in 24h

Off-the-shelf and tiny Virtual Antenna™ component specially selected for your application by the NN Engineering Team.

https://www.fractusantennas.com/fast-track-project/
Conclusions

- **Virtual Antenna™ Technology**: off-the-shelf antenna product, small, multi-band, and pick & place (SMD component)
- **Thingy:91 by Nordic Semiconductor** is a multi-sensor prototyping kit ideal for kick starting cellular IoT projects
- **Thingy:91 with the TRIO mXTEND™ embedded antenna** will help cellular IoT designers to develop new applications fast and easy

**APPLICATIONS:**
- Logistics and asset
- Tracking
- Smart city
- Smart agriculture
- Predictive maintenance & industrial
- Wearables & medical
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