BSC Associates Ltd

LAPC 2017

Practical application of small antennas in hardware platforms

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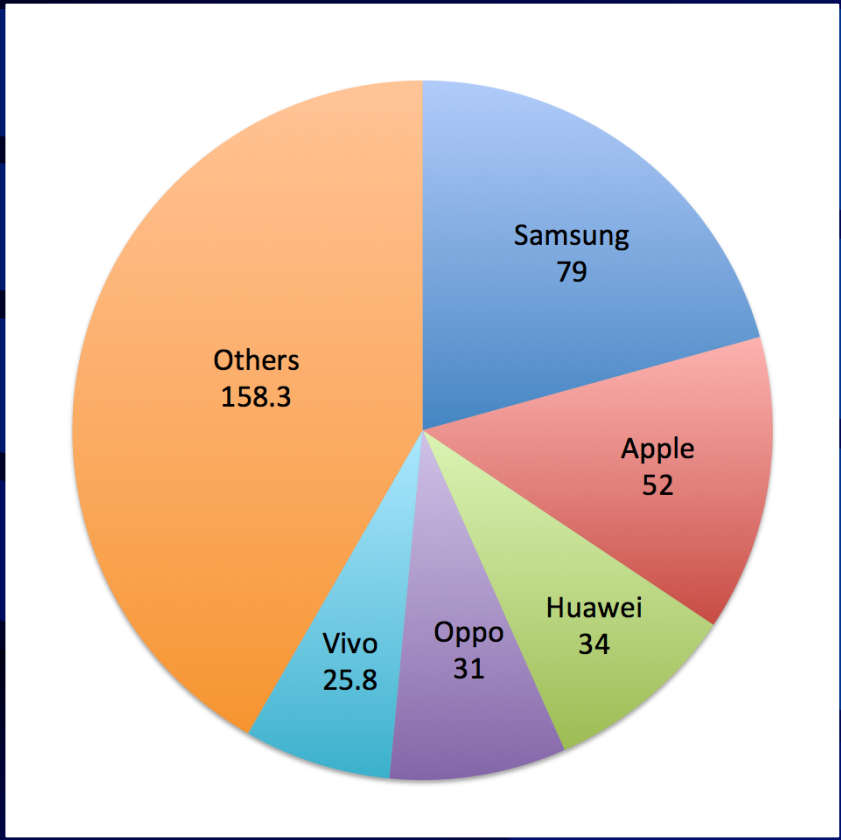
Landscape for small antennas

- Impact of the smartphone
- Impact of LTE
  - Proliferation of frequency bands
  - Cross-band aggregation
- Consolidation of the industry
- Antennas designed in-house
  - Mechanical integration
  - Software integration.

Smartphone market



Source: Gartner, May 2017

IoT

- **Things:**
  - **Static – monitoring, measuring, metering**
  - **Mobile – vehicles, goods in transit**
- **Not just things:**
  - **Animals**
  - **People**
- **Health, logistics, safety, resource management.**

Photo: Linde AG

Photo: Philips GoSafe™

Photo: BSC/eCow

Photo: PitPat

Photo: Axscend

IoT

- High efficiency antennas
  - Improve connectivity
  - Extend battery life in poor signal environments
  - May not be so important for short-range devices
- Unfriendly platforms
  - Too small
  - ID unfriendly to antennas
  - Shared with noisy hardware
- Bandwidth
  - Cellular: WIDE, multiband – even for LTE-M and NB-IoT
  - ISM (868/915/2400 MHz) Narrow, but 868-928 is wide!

The IoT antenna market

- Customers often have no RF skill or knowledge
  - Limited understanding of RF platform design
  - They have to trust the antenna vendor
- Any antenna will work – to a degree
- Balanced antennas connected by coax cables do not have reliable performance
- Reference designs : traps for the unwary
- Integrated antennas on small modules.

Disappointing

- No antenna has optimum performance unless matched on the application platform : seldom explained by vendors
- Many vendors offer poor designs and over-claim performance
  - Measured data often not provided …
    … or is measured on unspecified optimum platform
  - Performance dependent on cable configuration
  - Patterns totally unsuited to application
  - Multi-band antenna work on only one band
  - Poor implementation advice

Antenas and device size

- Bandwidth is strongly determined by platform dimensions
- For small devices the transmission loss/frequency relationship is not obvious:

  Free space loss between dipoles falls with frequency

  – this is a property of antennas, not of free space

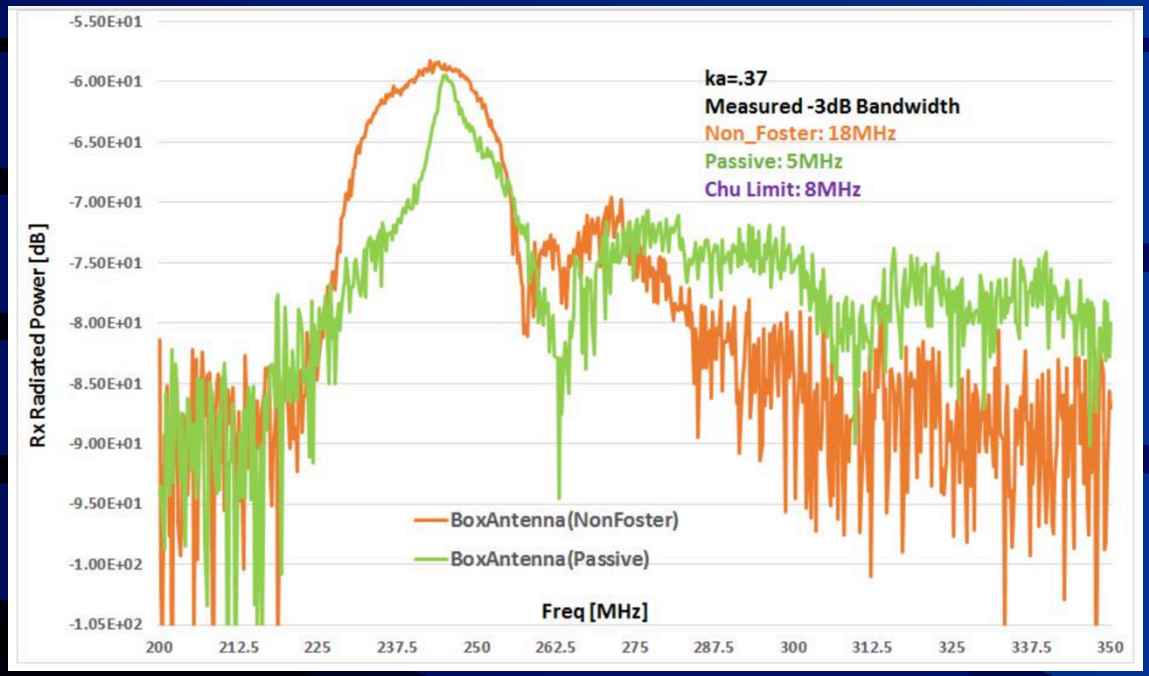
  $$\Gamma_o = (4\pi d/\lambda)^2$$

  – assumes that both antennas get larger at low frequencies
- If we freeze the dimensions of the TX and RX antenna the loss stays the same – and in practice falls because of falling efficiency
- Practical benefit is lower diffraction losses and lower wall penetration losses

Effective bandwidth

- Effective bandwidth for a small antenna is usually defined by its efficiency
  - The most important determinant is usually antenna matching
  - Bandwidth is limited by reflection loss
- Spec limit for small devices is usually regarded as RL = 6 dB (25% loss of efficiency)
- To increase TRP we may need to consider the load pull characteristics of the TX.

Small antennas – recent work



https://phys.org/news/2017-02-chu-limita-limit.html

Results reported from NIST using non-Foster matching: Chu's limit – a limit no more

(Katherine Connor, US Space and Naval Warfare Systems Pacific, Feb 2017)

See also: Shapari & Thiel, *Physical bounds for antenna radiation efficiency* https://arxiv.org/abs/1609.01761 (awaiting publication)

Small antenna configurations

- **Inverted-F – very common**
- **Dipoles – usually too large (twice size of IFA) but not dependent on platform currents**
- **Slots – useful above 2 GHz**
  - cavity-backed, loaded
- **Notches – small and simple**
- **Tees – compact omnidirectional antenna on small groundplane**
- **Patches – too large, usually dielectric-loaded**
- **Dielectric chips – just about managing (OK for some BT uses)**

IFAs, notches & slots useful for dual-band operation (eg 2.4/5GHz)

Academic papers on small antennas

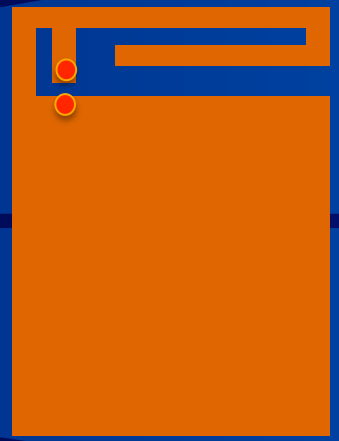
- **A huge number of engineer-hours (£$¥)are spent designing antennas that are of no practical use ...SAD**
  - **– far too large**
  - **– too complex – for too little advantage**
  - **– *defected* groundplanes – *ie* occupying both sides of the groundplane**
  - **– poorly executed measurements**
    - * often no regard for isolating measurement cables
  - **– only return loss is shown**
  - **– no critical review of results.**

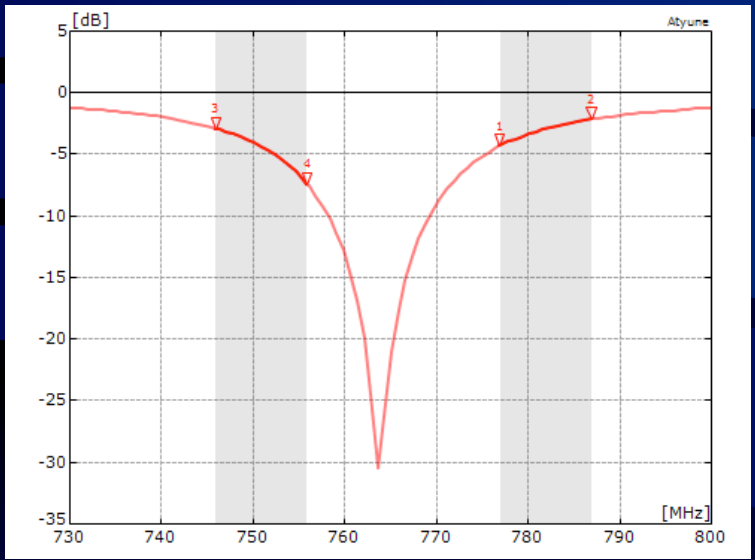
Matching

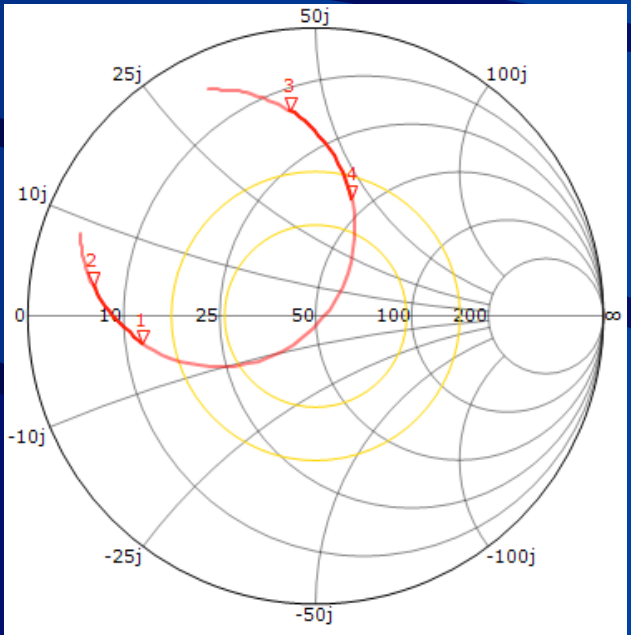
- 50 ohms is an entirely arbitrary impedance – antennas know nothing about it!
- Most small antennas provide maximum bandwidth ONLY when provided with an external matching circuit
- This becomes obvious only when we plot impedance results on a Smith chart
- External matching is easy once we capture the complex IMPEDANCE as a function of frequency
- An external matching circuit often avoids a last-minute re-spin

Inverted-F example

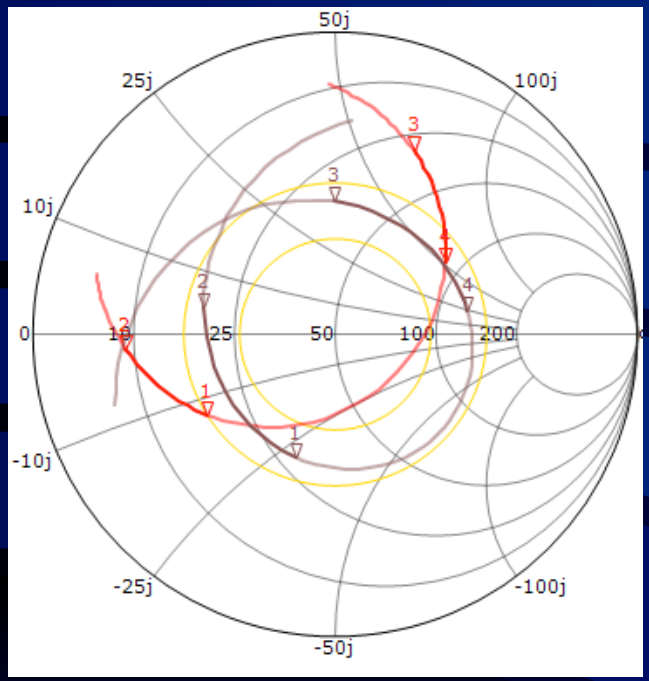
- Simple folded IFA: 10-mm high
- LTE Band 12 (746-756 / 777-787 MHz)
- PCB 65 long x 60 wide (0.19λ)

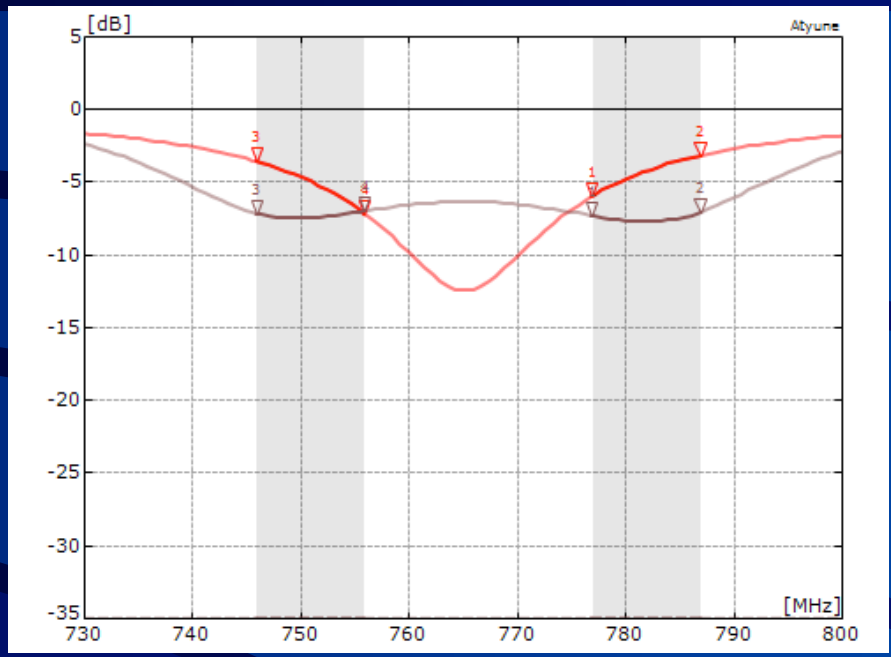


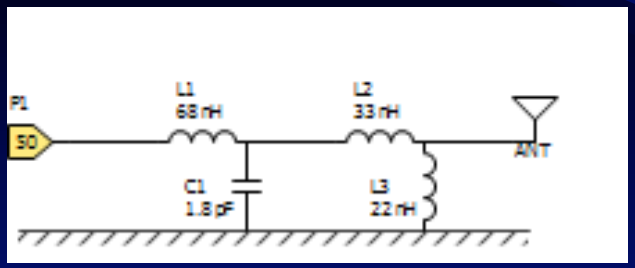




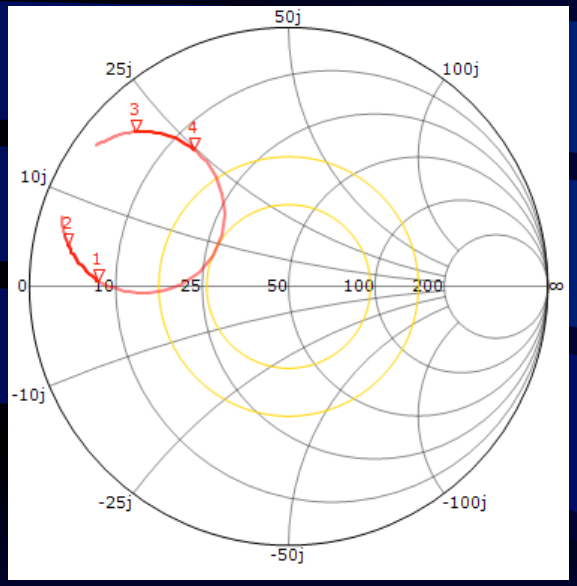
With matching network

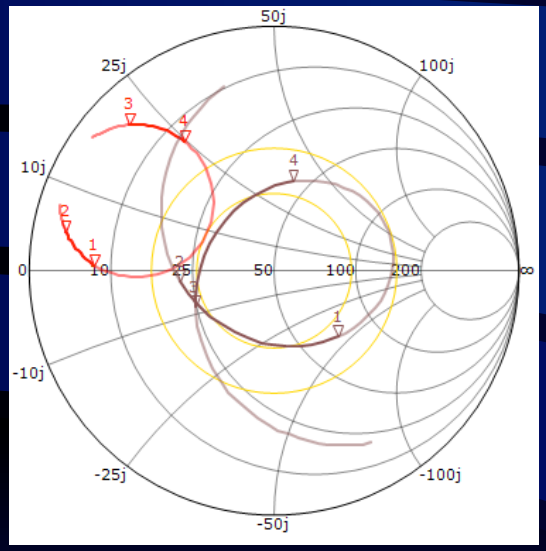






Can we do better?




50j
25j
100j
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0
10
25
50
100
200
∞
-10j
-25j
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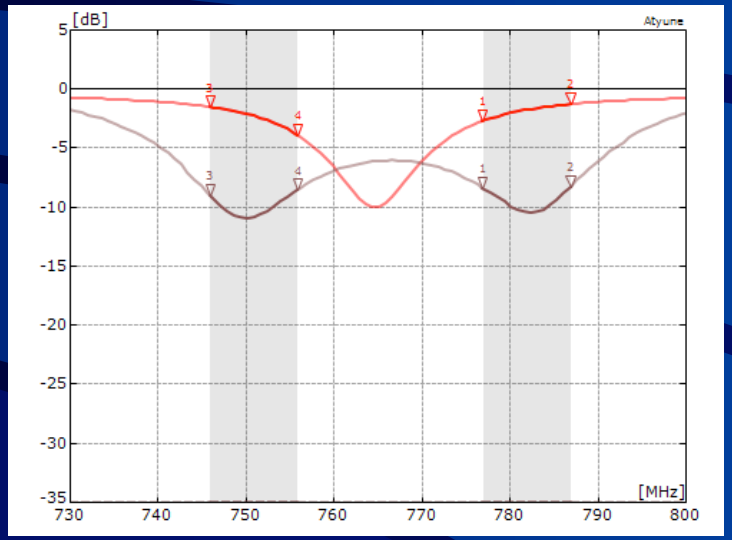
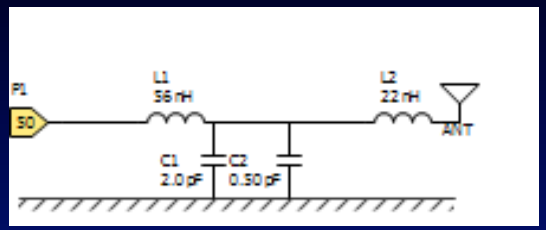
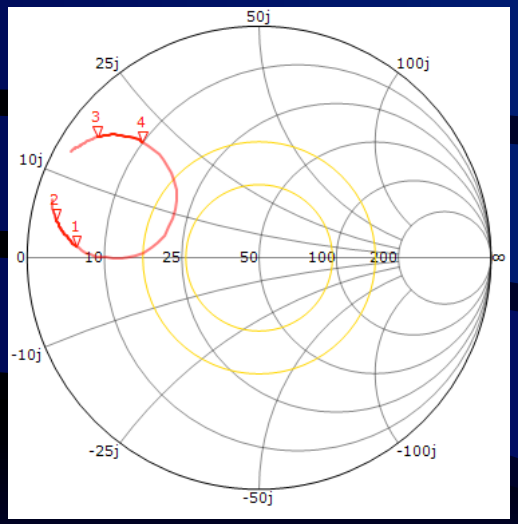
-50j


[dB]
Atyune
5
0
-5
-10
-15
-20
-25
-30
-35
[MHz]
730
740
750
760
770
780
790
800


P1
50
L1
56 nH
L2
22 nH
ANT
C1
2.0 pF
C2
0.50 pF

Go further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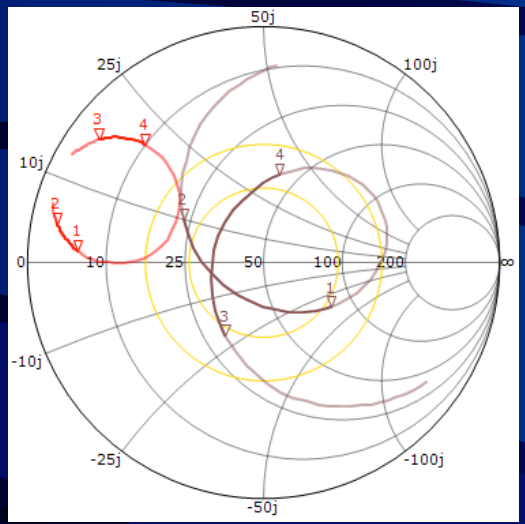
50j
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-25j
-100j
-50j
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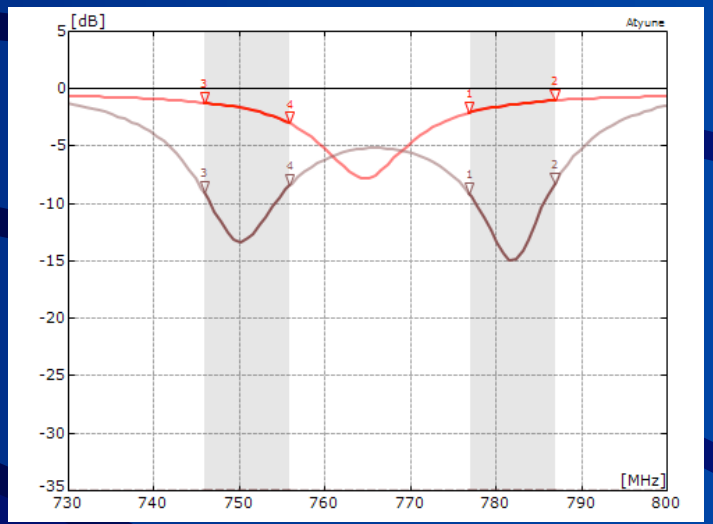
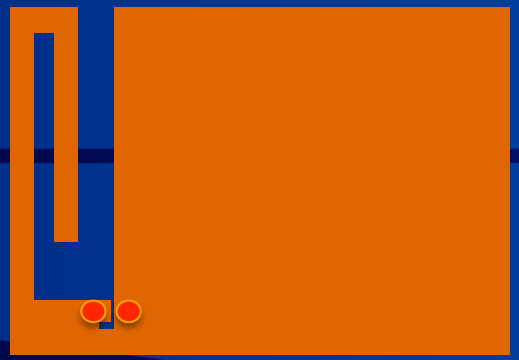
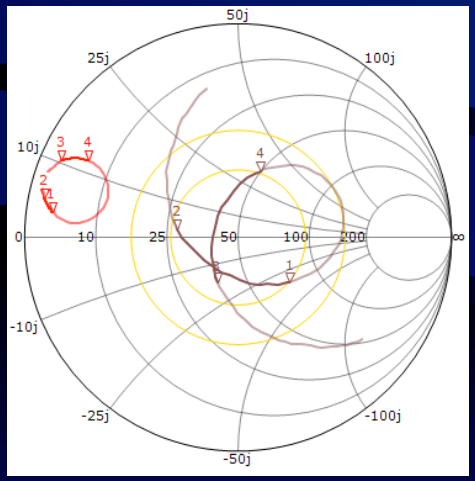
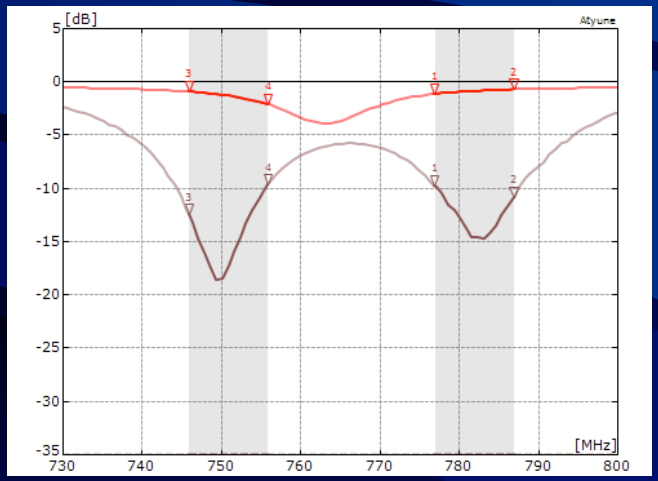
200
∞

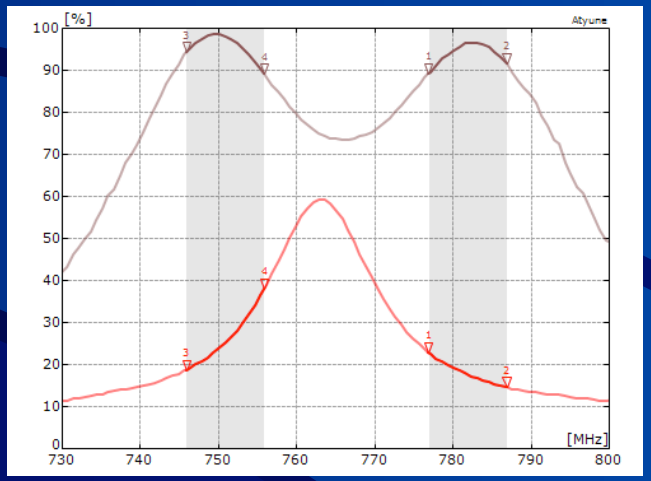

[dB]
Atyune
5
0
-5
-10
-15
-20
-25
-30
-35
730
740
750
760
770
780
790
800
[MHz]

How much further?





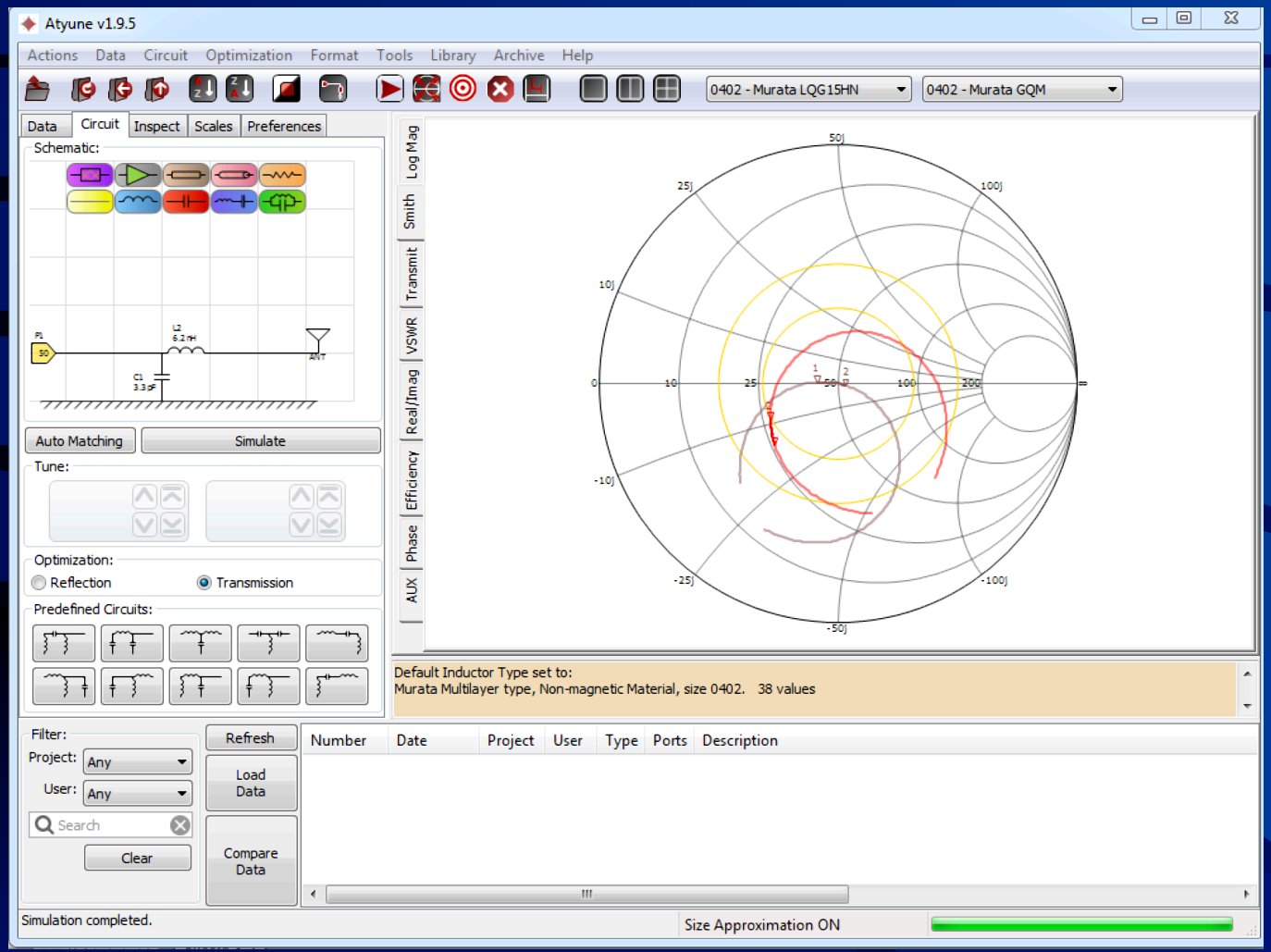




Atyune

- A fantastic tool for anyone working with small antennas
  - Basic program and functionality is FREE
  - Extended component libraries with license
  - Well documented
  - Extensive Help
  - www.atyune.com
  - Written by Devis Iellici

Example

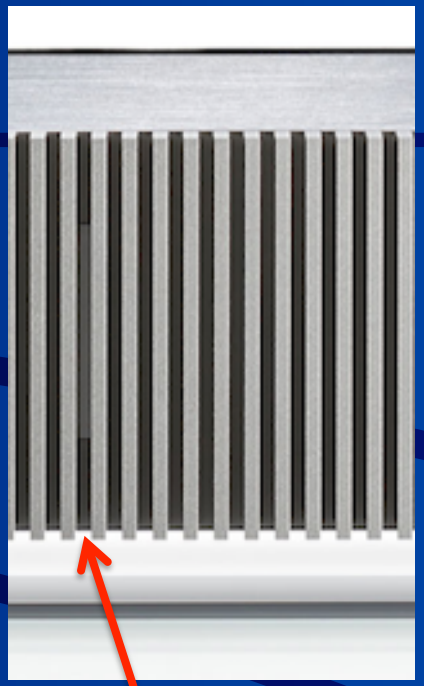

Atyune v1.9.5
Actions Data Circuit Optimization Format Tools Library Archive Help
0402 - Murata LQG15HN
0402 - Murata GQM
Data Circuit Inspect Scales Preferences
Schematic:
Auto Matching
Simulate
Tune:
Optimization:
Reflection
Transmission
Predefined Circuits:
Log Mag
Smith
Transmit
VSWR
Real/Imag
Efficiency
Phase
AUX
Default Inductor Type set to:
Murata Multilayer type, Non-magnetic Material, size 0402. 38 values
Filter:
Project: Any
User: Any
Search
Clear
Refresh
Load Data
Compare Data
Number Date Project User Type Ports Description
Simulation completed.
Size Approximation ON

A reminder that small can be big

http://www.visitcumbria.com/car/anthorn/

RNAS Anthorn, 13 masts 227m high, 19.6kHz, λ = 15.3km, h=0.014 λ

At low frequencies where antennas are very expensive structures, it may simply not be possible to build an antenna of 'normal' electrical dimensions.



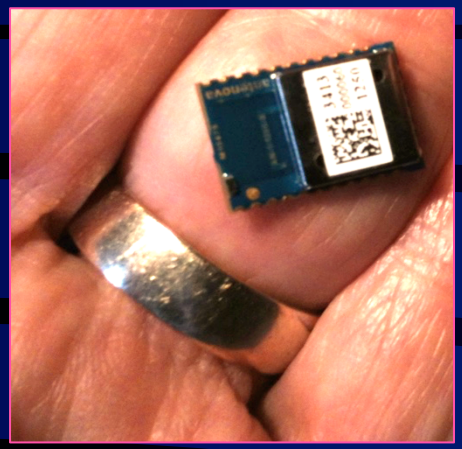
Photos: Naim Audio

The case is metal clad except for front and bottom. The front is occupied by 5 drivers (speakers). The back is a solid heatsink with fins.

Apple Play requires almost perfect 360° coverage at 2.4GHz.

Solution: Front antennas embedded between drivers and a rear microstrip-fed slot antenna in the root of the heatsink (3rd from left)

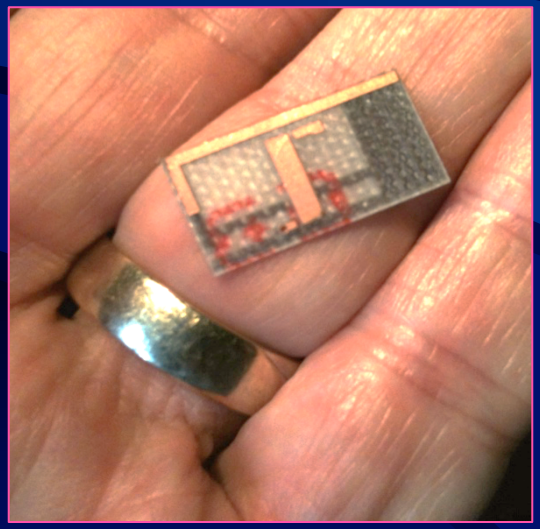
… and smaller ones

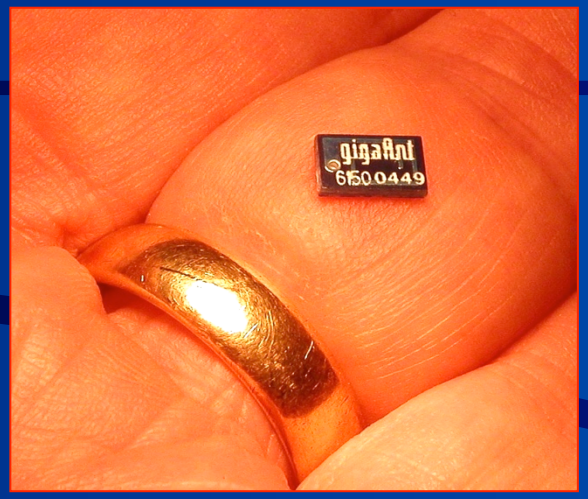


Complete GNSS antennas and receivers

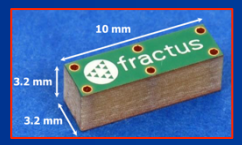
(Antenova /ublox)

Quad-band notch (BSC)





2.4GHz WiFi/BT (Antenova)



Quad-band bar (Fractus)

In summary

There's still scope for innovation in small antennas

– and in base station antennas

– more is needed!