Tuneable antennas for UHF-TV reception

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Adaptable and tuneable antenna technology for handsets and mobile computing products

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Overview

In this presentation we will examine:

- The performance requirements for UHF-TV antennas for portable devices
- The potential performance advantage of tuneable antennas
- The selection of tuning techniques
- Three examples of tuneable antennas for handset and Notebook platforms.

Performance requirements

MBRAI Specification for DVB-T/H (EICTA)

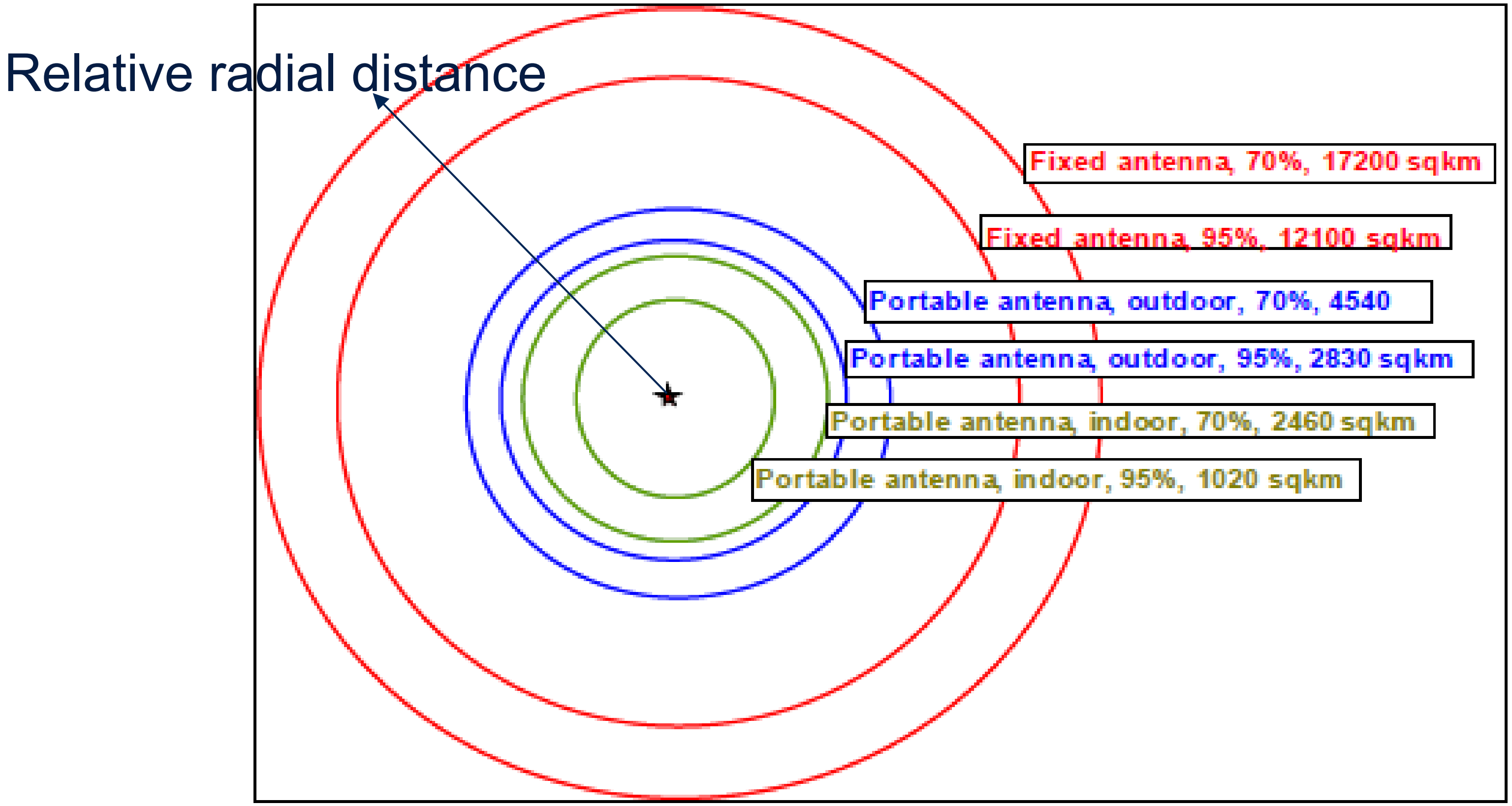
Mobile Broadband Radio Air Interface

European Information & Communications Technology Industry Association

This says, of *the antenna solution in a small hand held terminal:*

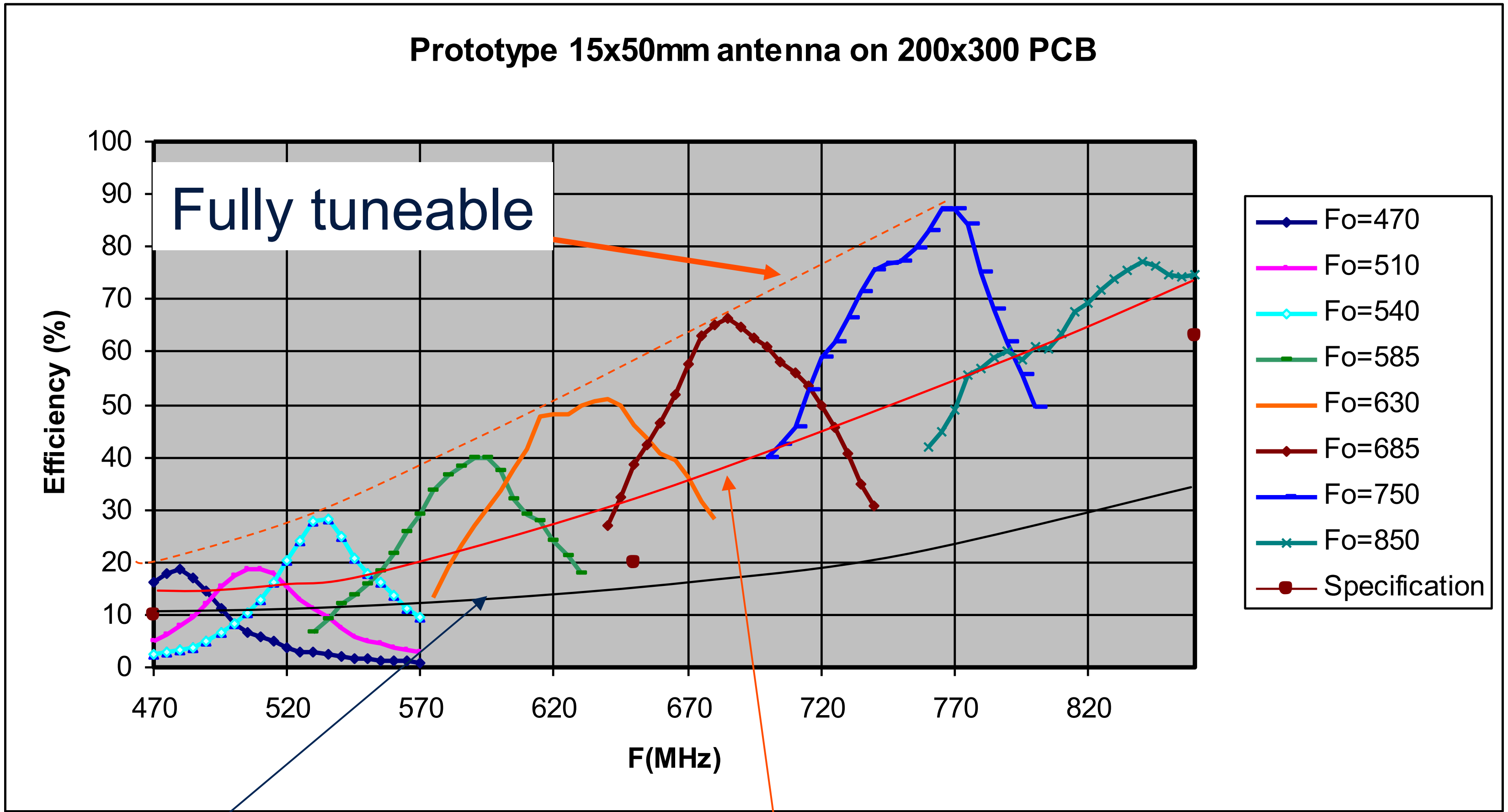
- "Current understanding of the design problem indicates that the typical antenna gain at the lowest UHF-band frequencies would be in the order of –10dBi increasing to –5dBi at the (upper) end of UHF-band. Nominal antenna gain between these frequencies can be obtained by linear interpolation."
- Similar words are used in ETSI **TR** 102 377 V1.4.1 (Jun 2009)
- There is no "specification" – the more gain we can obtain from the mobile antenna, the better the system will function.

Gain and coverage



Impact of antenna gain on effective coverage EBU, [5]

Why tune the antenna?

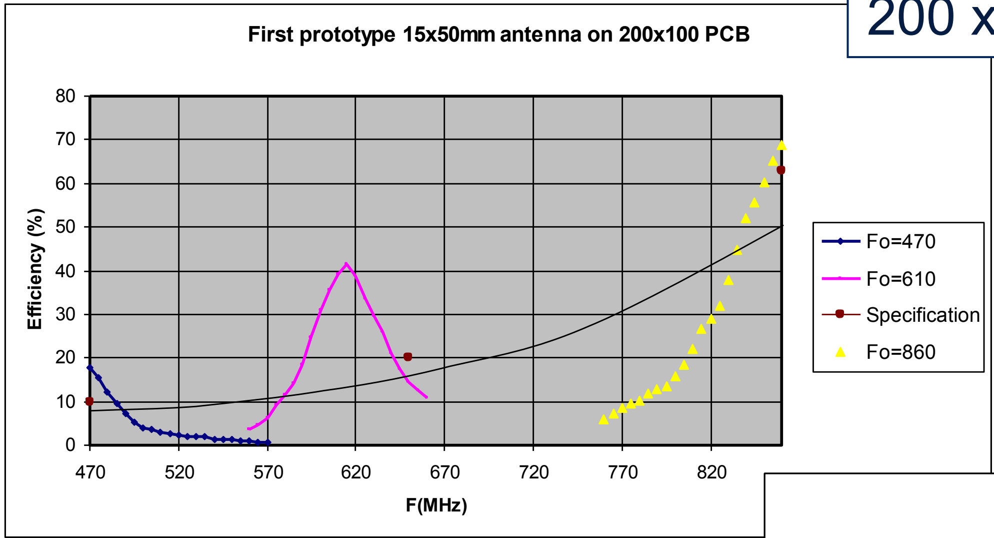


Gain suggested in ETSI TR 102 377

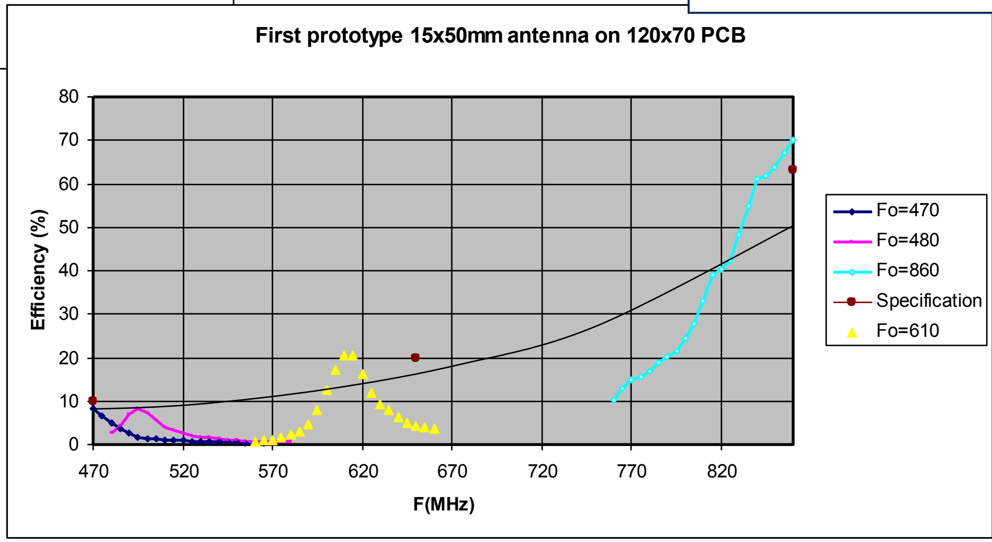
8 fixed tune points

Smaller platforms

200 x 100mm



120 x 70mm



As usual, an effective antenna depends on the presence of chassis currents and design becomes more challenging as the platform becomes smaller

Constraints on a tuneable design

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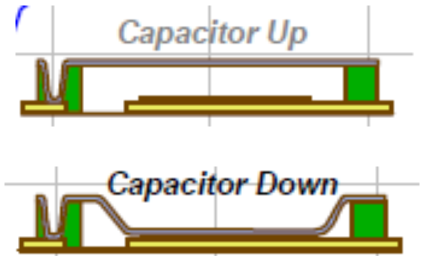
- Loss
  - The antenna will be electrically small, so losses are very important, especially at the bottom of the band
- Tuning range
  - With almost an octave to cover, the tuning system requires a very wide tuning range
- Voltage and power available for tuning are severely constrained, especially in a handset (typically <3V and a few μA).

Tuning technology

- MEMS capacitor arrays / MEMS switches+caps
  - Latest technology
  - High stray C to ground
  - Significant losses
  - High voltage required
  - Reliability/hysteresis?
- PIN diode switches + capacitors
  - Lossy
- GaAsFET switches + capacitors
  - Lossy.



Tuning technology

- BST capacitors (barium strontium titanate)
  - Lossy
  - Require high voltage
- Varactor diodes
  - Mature technology
  - Available for 4/6 volt operation
  - Some types have low ESR (0.25 ohms)
  - Problem with C_{min} if we want large C_{max}.

Circuit arrangement

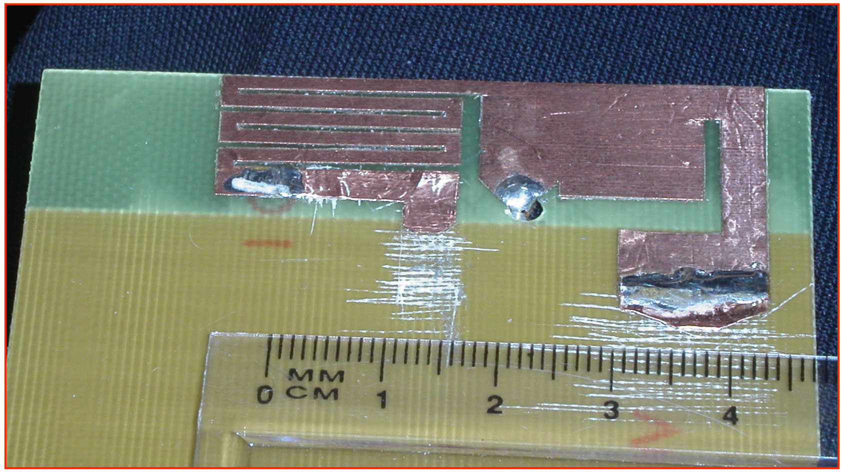
- Conventional tuning circuits:
  - Capacitively top-load radiating element
  - Provide matching circuit between antenna and receiver

One new solution

- Varactor diodes, directly/indirectly coupled to radiator
  - High ratio C_{max}/C_{min} (7) , connected in series to reduce C_{min}
  - Linear voltage doubler circuit to control from RX
- Tuning driven by C/N ratio from the receiver

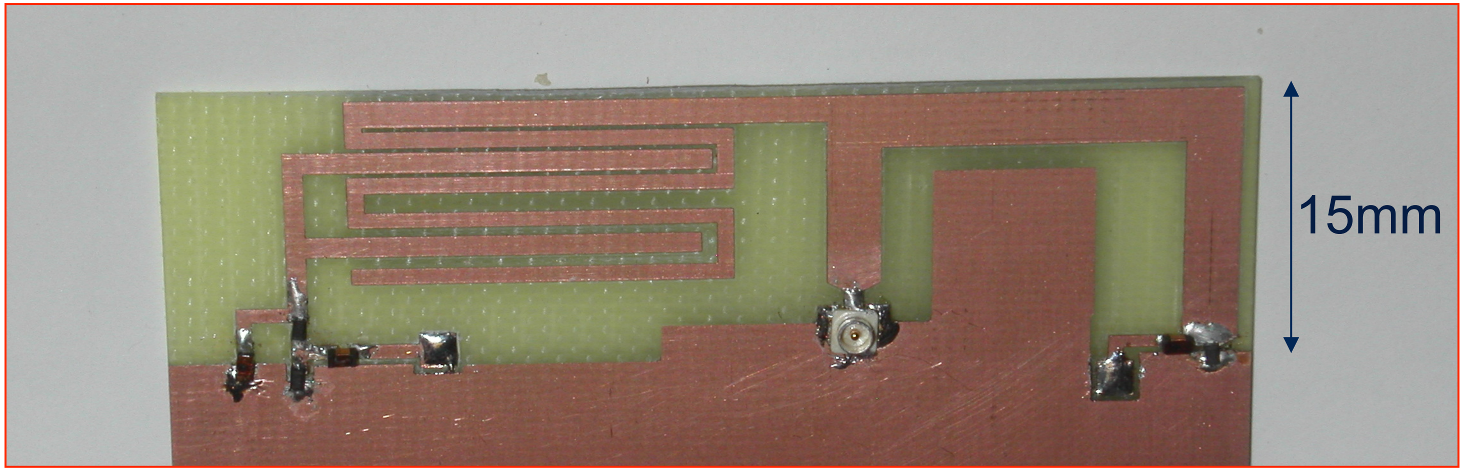
Fixed-tuned reference design

15mm x 50mm
470-860MHz



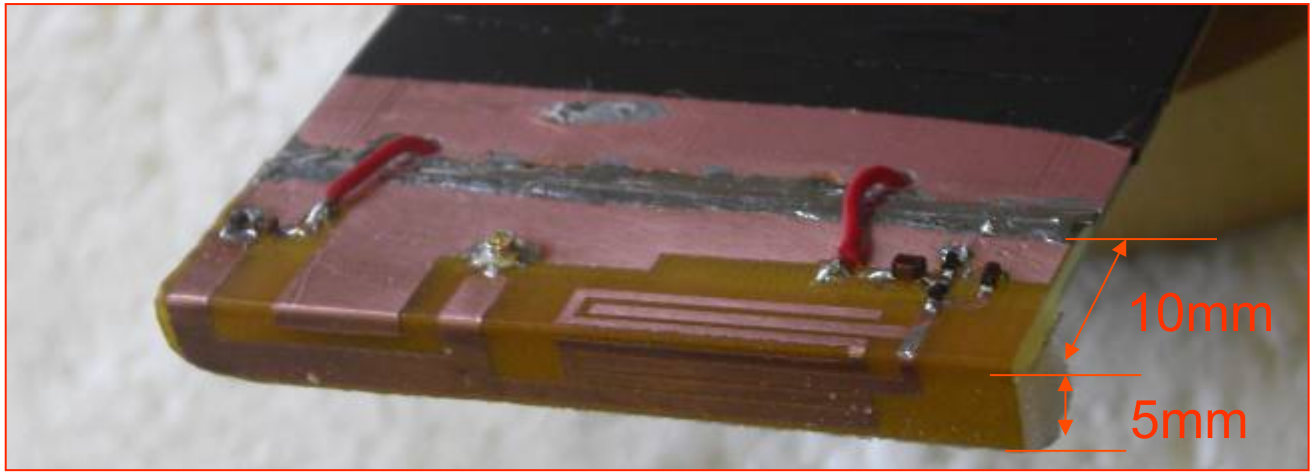
- Unconventional order of connections for an inverted-F antenna
- Dimensions reduced by more use of meandering
- Tuning by capacitive patches on FR4 substrate
  - Reasonably independent tuning/coupling controls
- Note small adjustment increments!
- The following efficiency measurements relate to this geometry.

Tuneable design



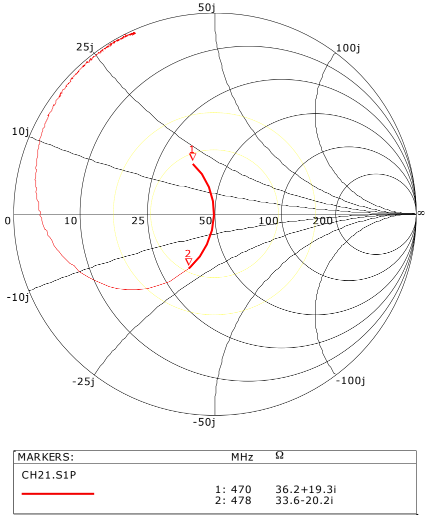
- Planar version of the current antenna with tuning varactors and DC coupling inductors
- The tuning capacitor is on the left and the coupling capacitor on the right.

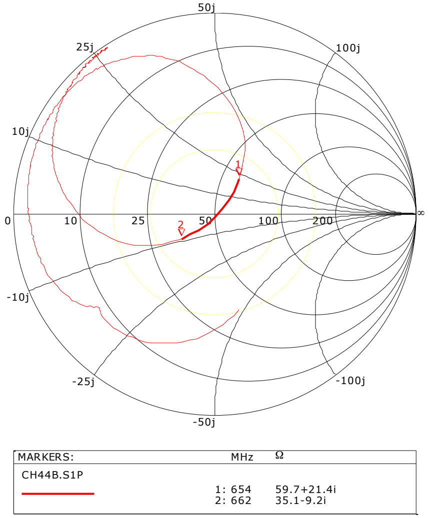
Compact tuneable antenna

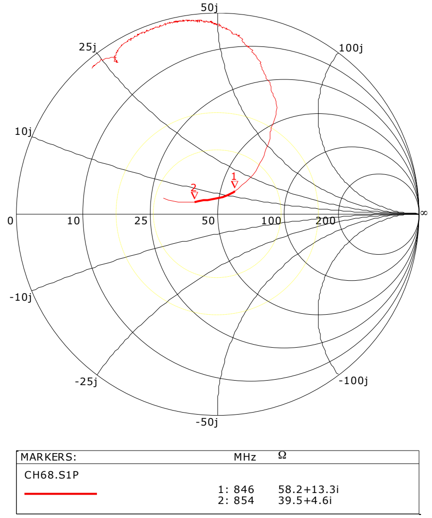


- Folded or radiator to suit space requirements of application
- Red wires connect tuning voltages to varactor diodes.

Tuneability







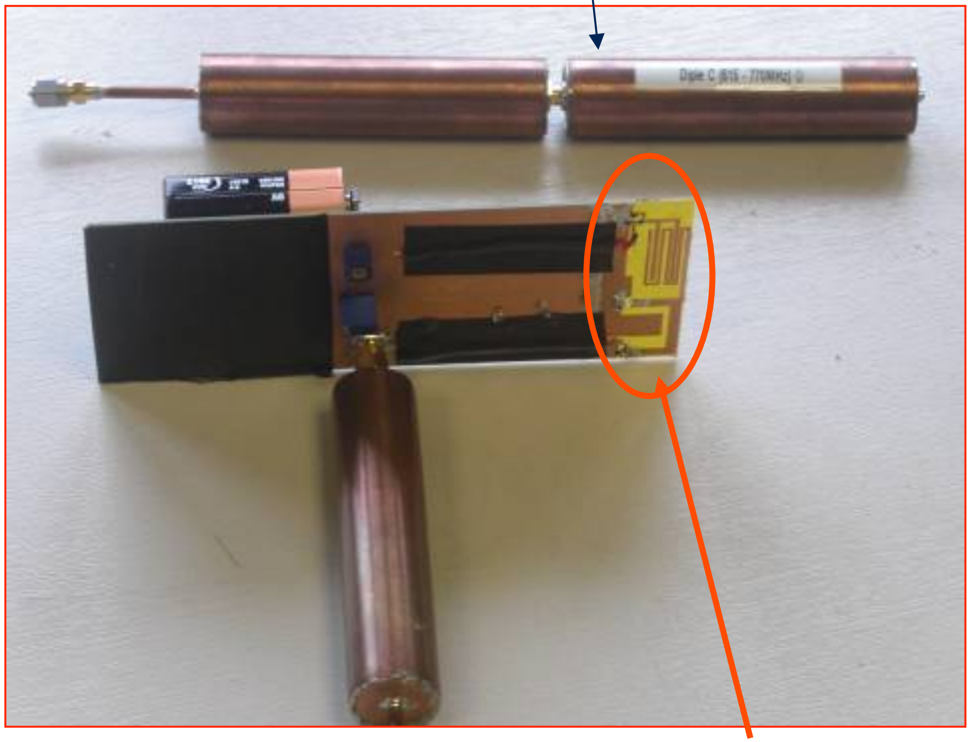
Impedance plots for the complete prototype with fitted varactor diodes at channel center frequencies of 474MHz, 658MHz and 860MHz. The effect of reduced bandwidth at lower frequencies is clearly seen.

Matching

- In this design, there is no *antenna matching circuit* – the variable reactances allow adjustment of the resonant frequency and the resistive component of the input impedance of the antenna at resonance
- An input impedance at f_c close to 50+j0 is achieved over the whole UHF-TV band without the use of inductors in the signal path, with plenty of bandwidth for an 8MHz DVB channel.

Gain: antennas for comparison

Reference Antenna



Tuneable Antenna

- The output from the antenna on the PCB is connected near the mid-line of the PCB and is decoupled using a quarter-wave sleeve choke. DC lines are taped down, close to the ground-plane
- The reference antenna is a coaxial dipole
- The cables feeding both antennas were well decoupled.

Test receiver

- Test receiver was a DiBcom 9080M single-chip receiver This feeds the varactors via a voltage-doubler circuit
- Test software was DiBcom's Advanced Monitoring Tool, which was used to measure SNR, frame errors and signal spectra
- Antennas were mounted in a clear outside environment, 1m above ground level
- Local *DVB-T* transmitter is 34km (21 miles) from the test site, transmitting 15kW eirp on Channel 40 (626MHz) with horizontal polarisation. The C-OFDM transmitter is currently operating in 2k mode using 16-QAM.

Signal spectrum: reference dipole

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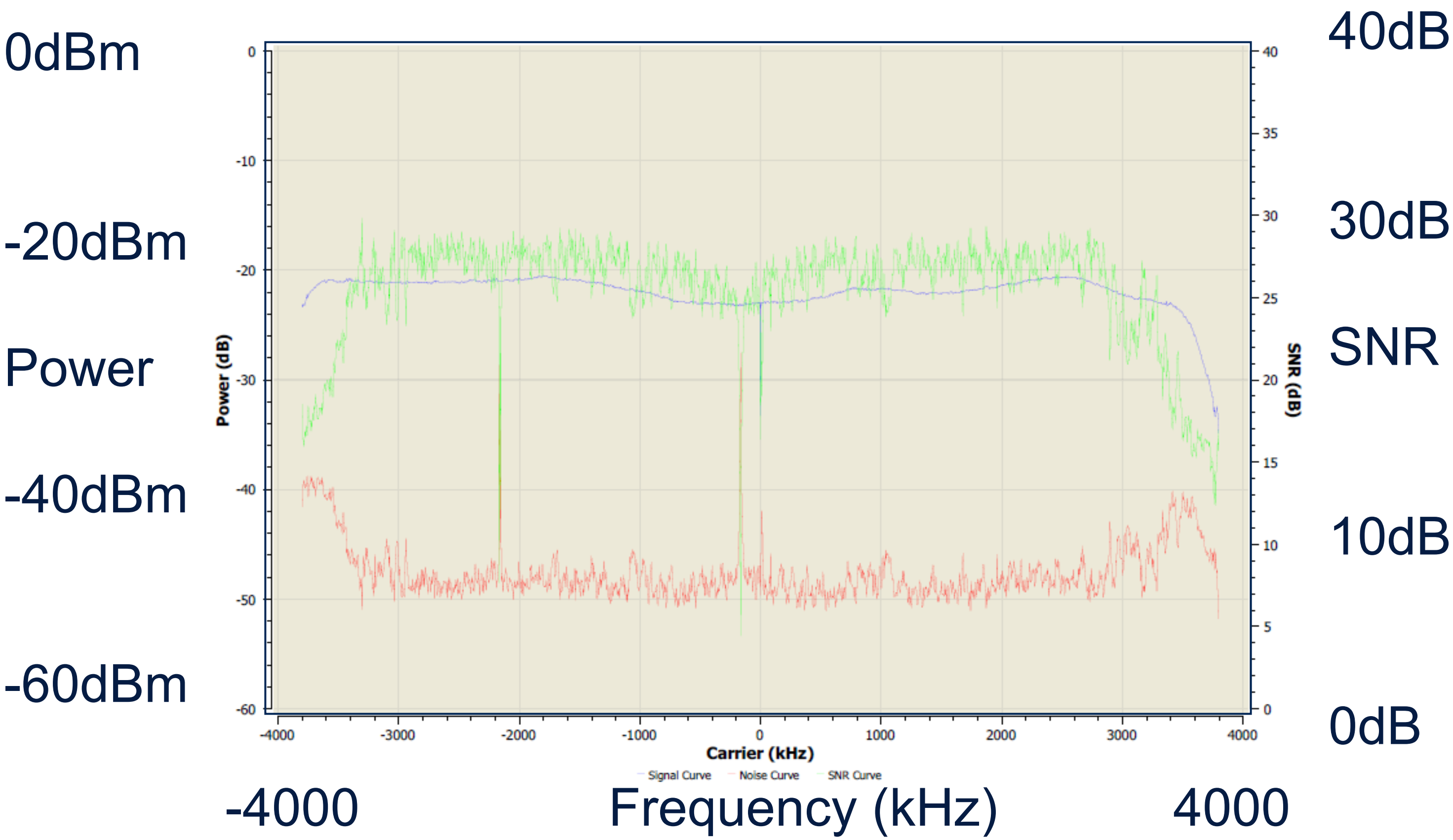

- Reference dipole: Signal, Noise and SNR

Signal spectrum: tuneable antenna

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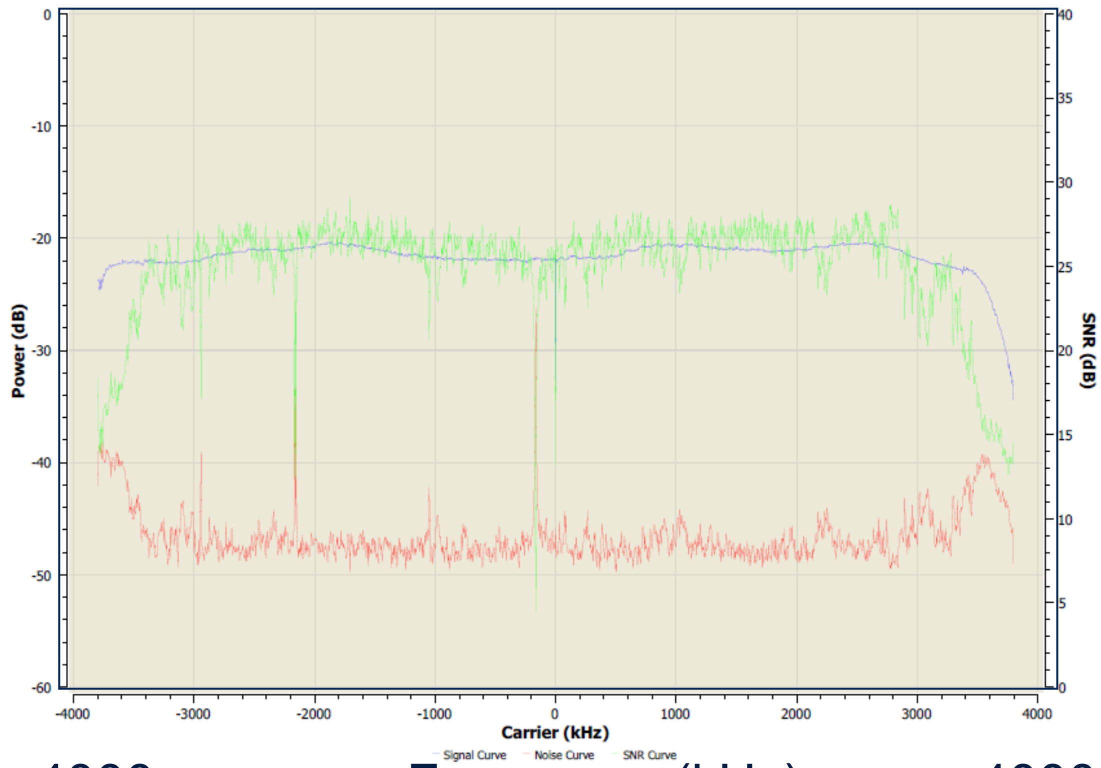
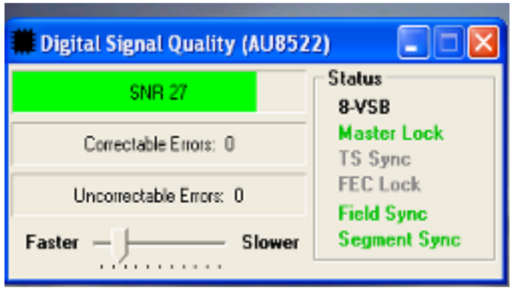


- Planar tuneable antenna: Signal, Noise and SNR

Integrated Antenna and RF Solutions

Demonstrations

HD ATSC programs in
Santa Ana, California



Antenna on pcb lying in front of 11-in laptop

Antenna pcb taped behind to lid of laptop

An integrated Notebook antenna

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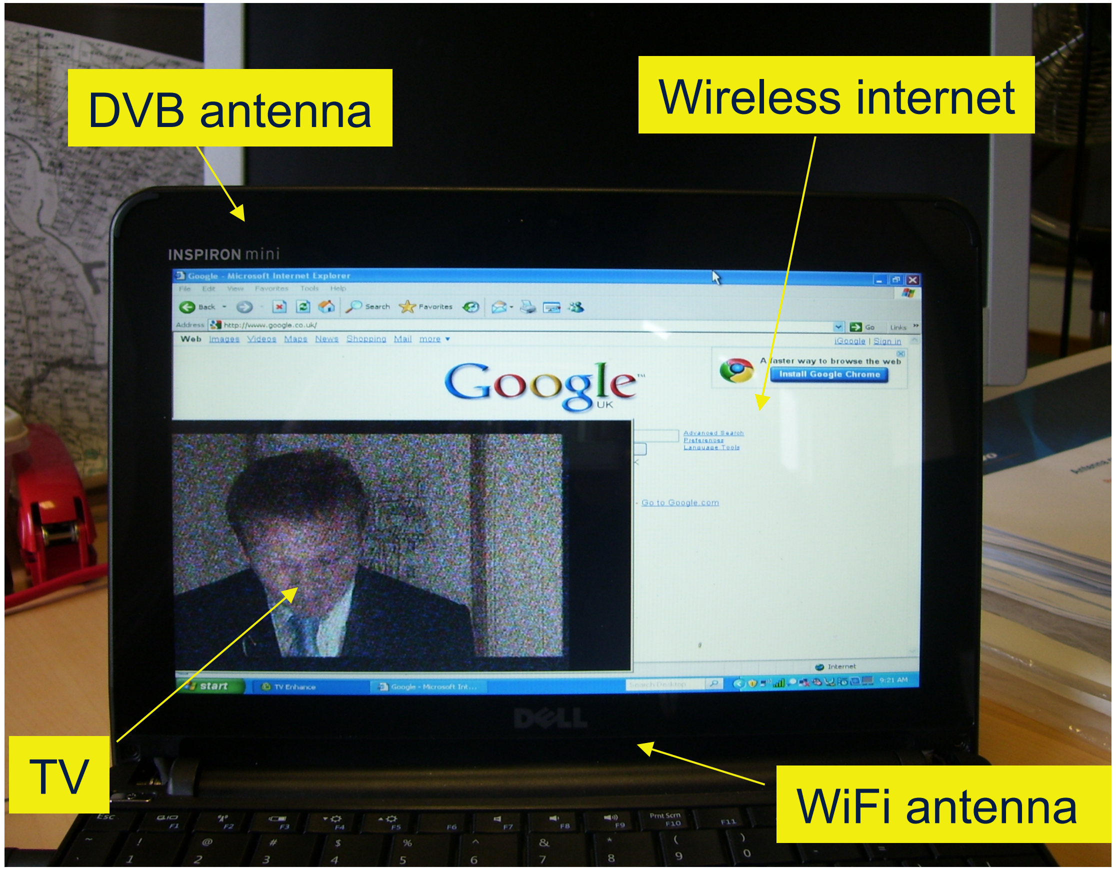
This antenna is designed to provide tunable operation across the UHF band

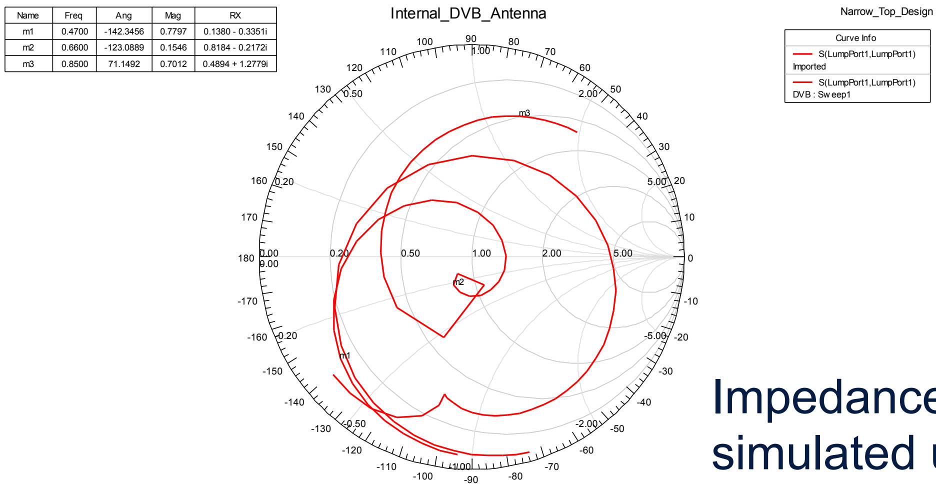
This antenna fits within the lid, above the display panel, with the cables routed along one side

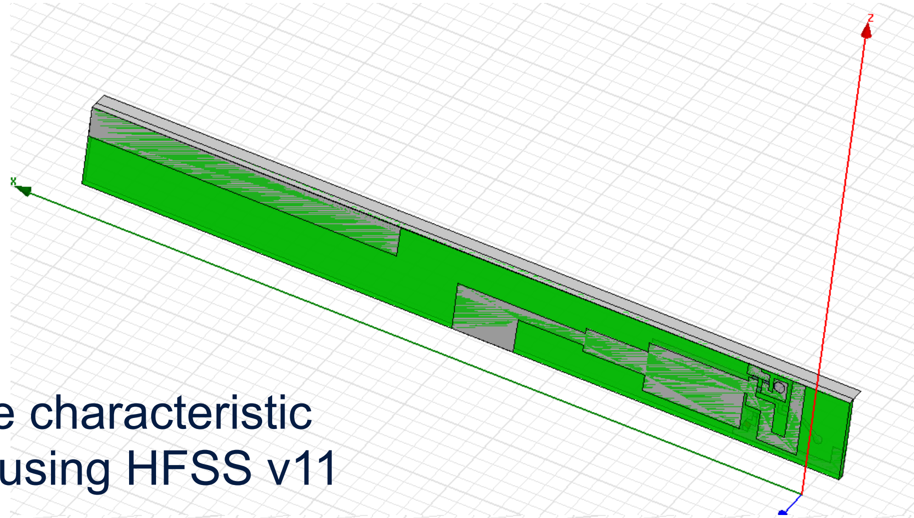
An additional insulated wire is used to provide a DC voltage to the tuneable matching circuit embedded within the antenna

Grounding is achieved by the use of a stick-down foil to the rear of the LCD housing.

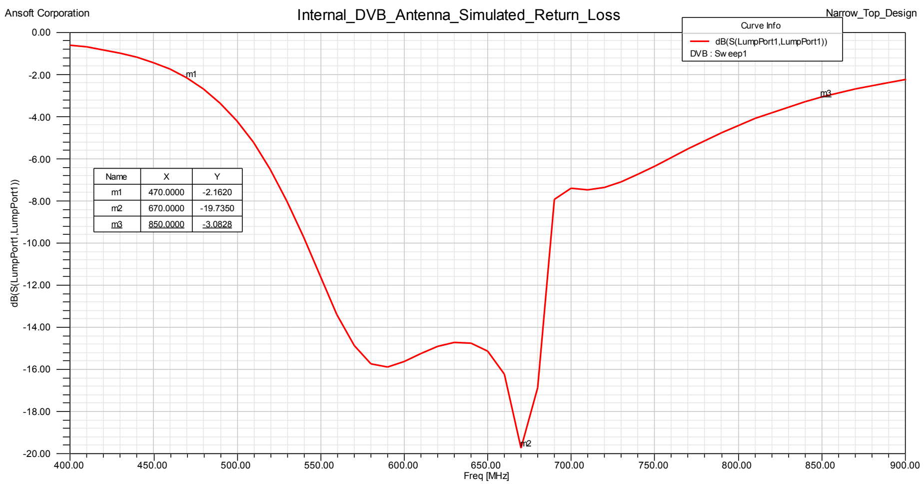


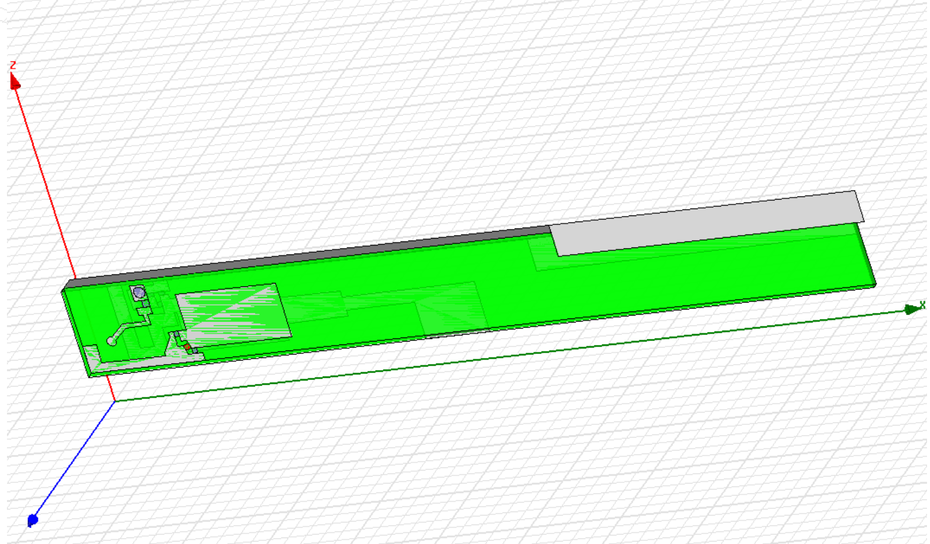
Antenna concept development





Impedance characteristic simulated using HFSS v11





Tuneable matching circuit design

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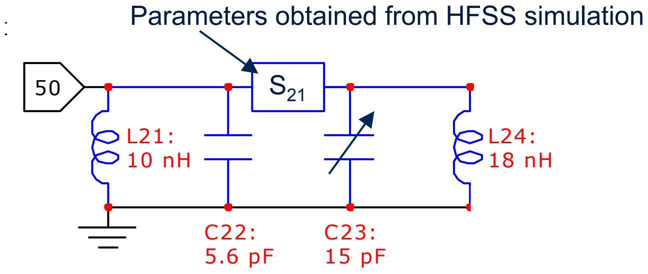
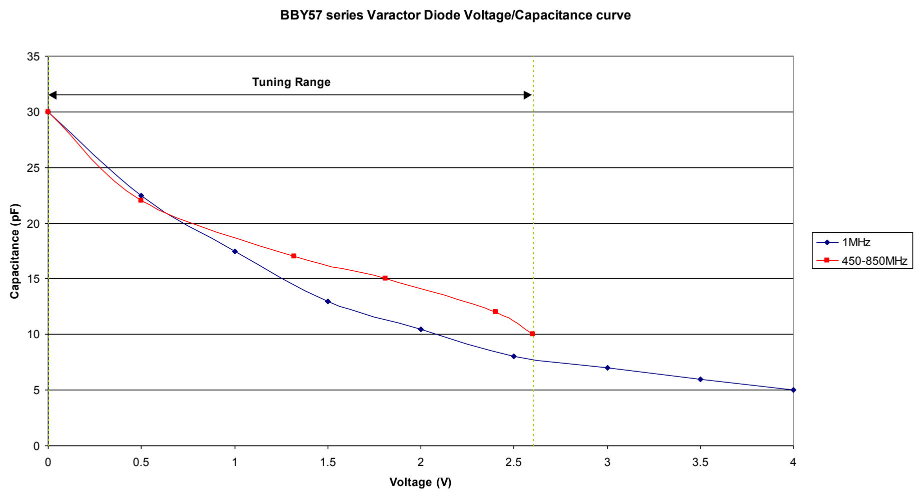
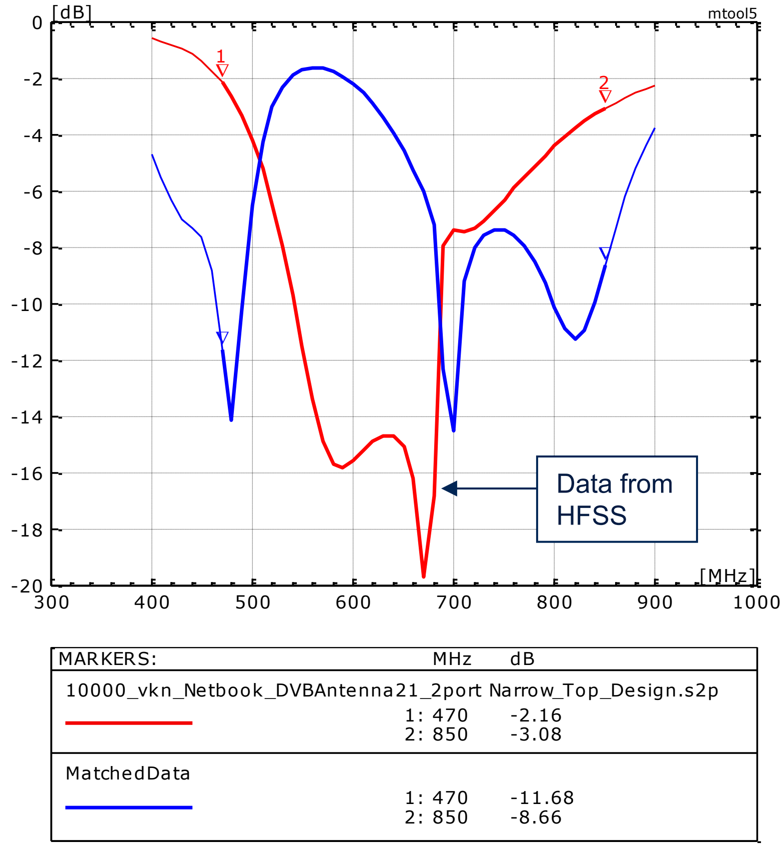


Data from the HFSS model is used to develop the matching circuit, using interactive circuit simulation software.

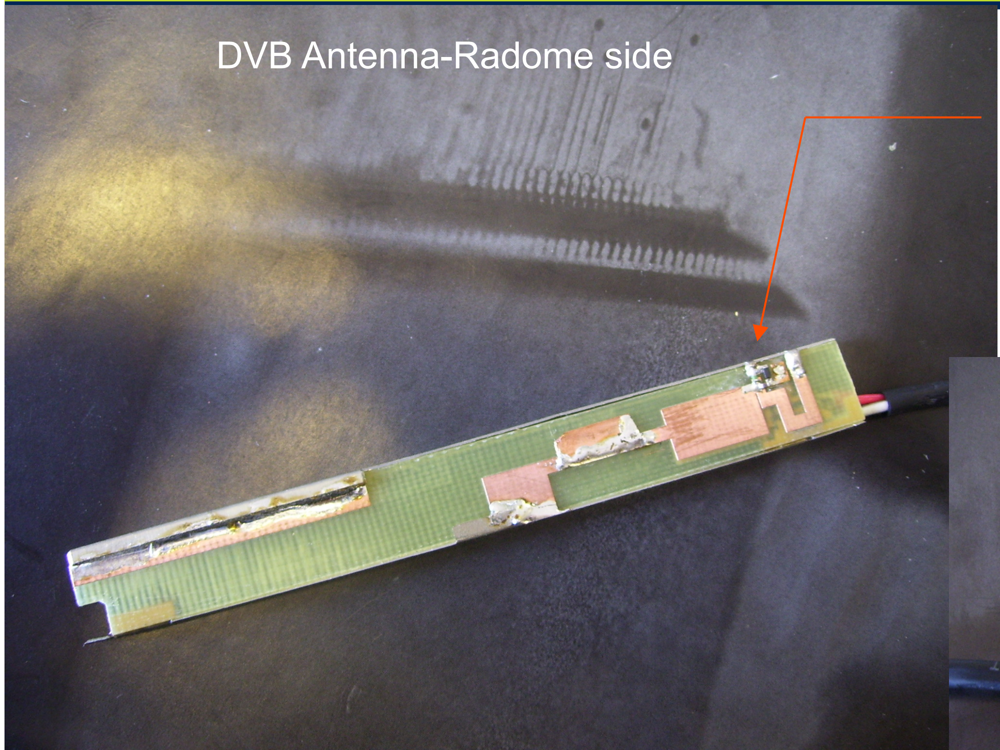
The graph below shows how the capacitance of the varactor diode varies with the applied DC control voltage.

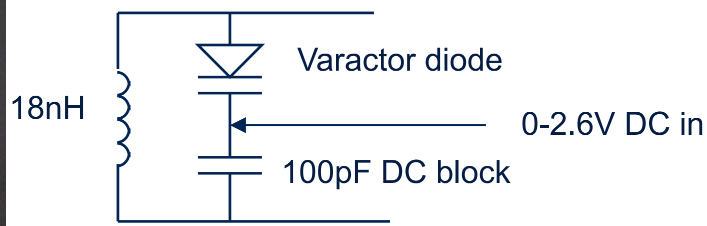


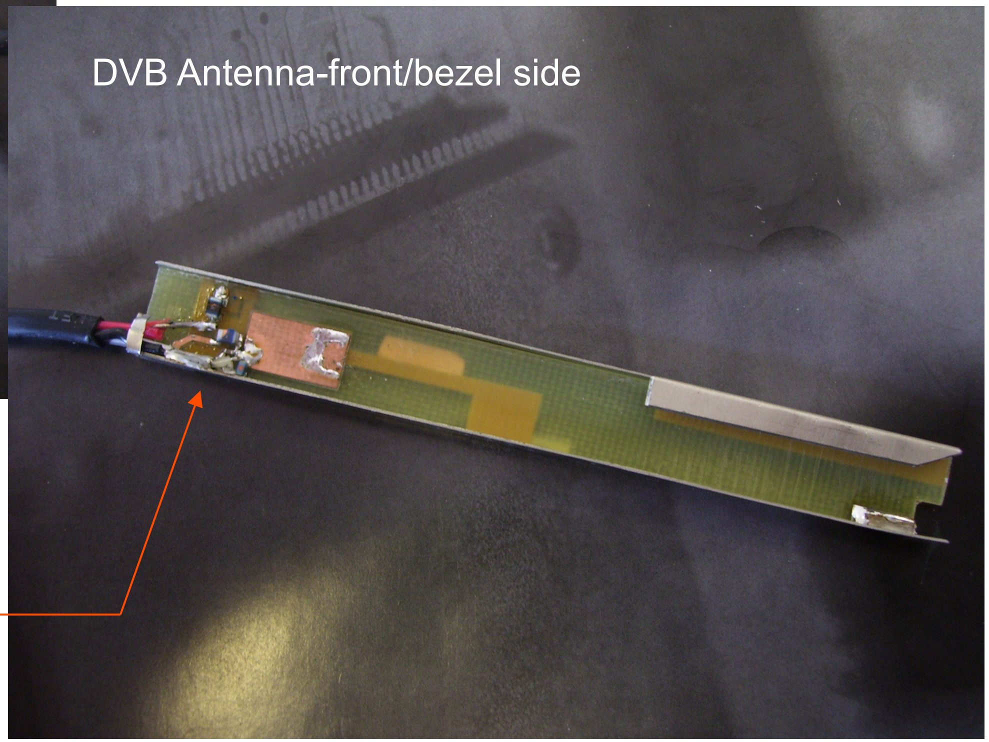
Simulated matching with varactor diode at 15pF capacitance

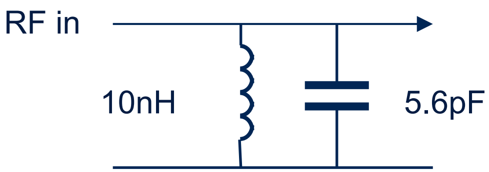


Practical design of the matching circuit

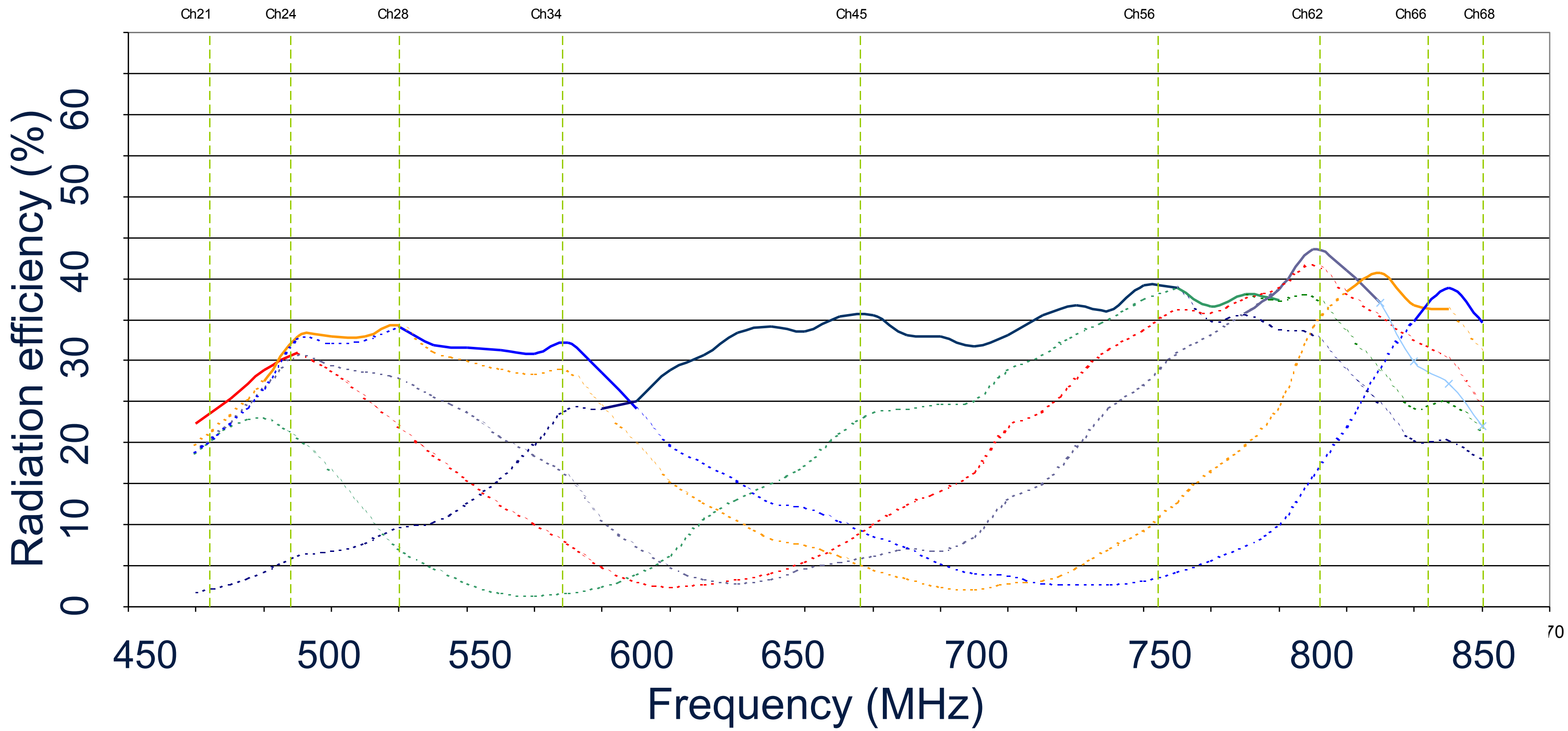






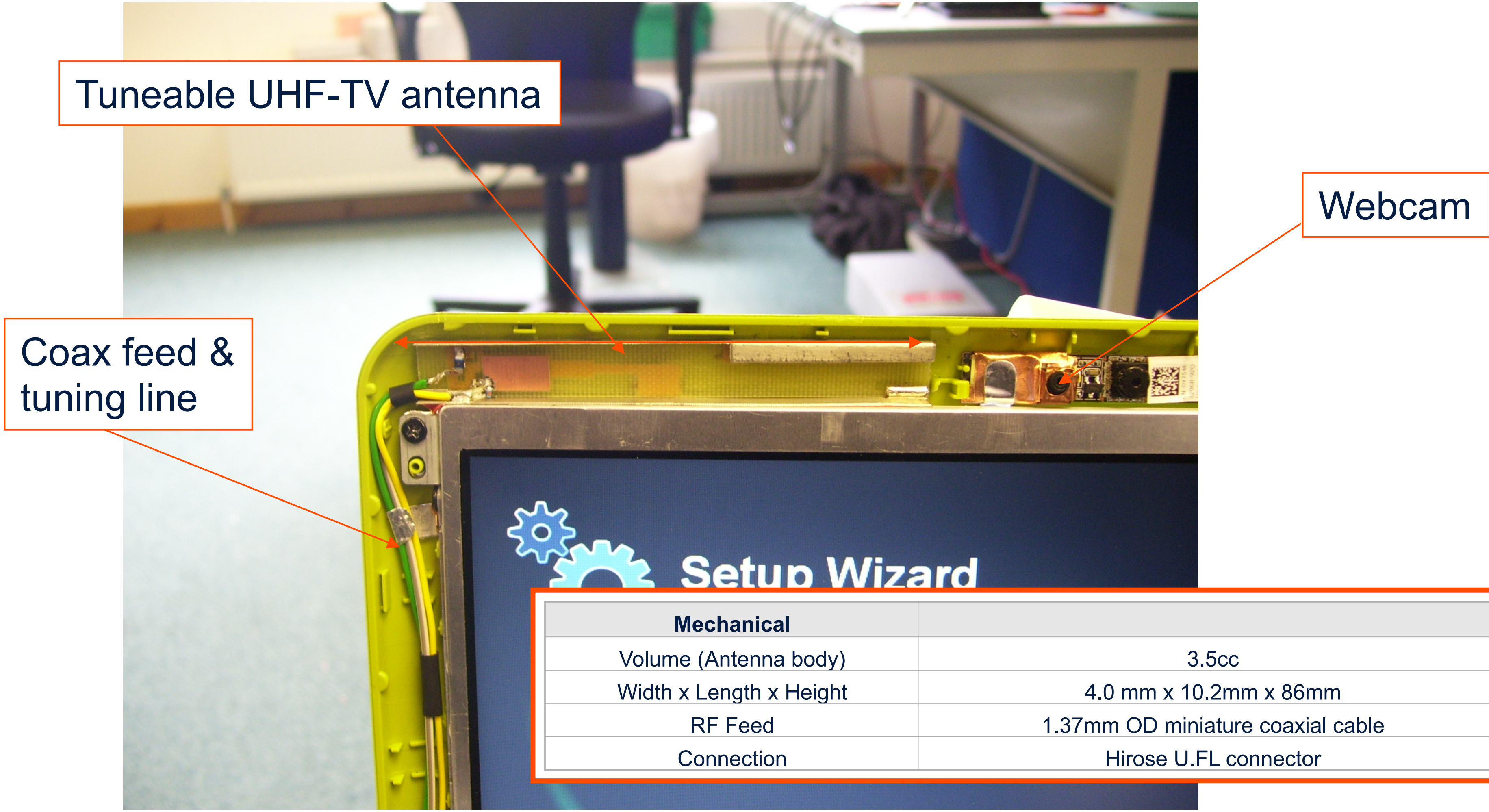


Antenna radiation efficiency



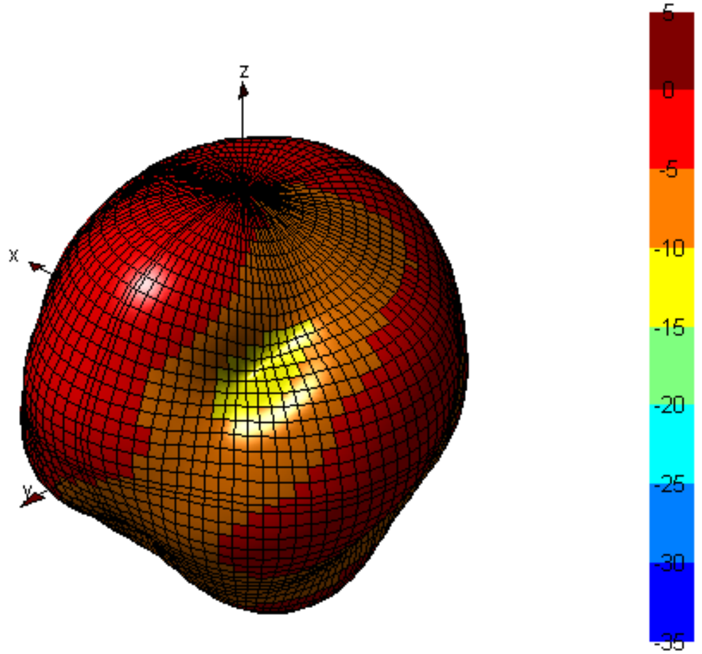
Radiation efficiency measured in SATIMO S64 for different tuning voltages

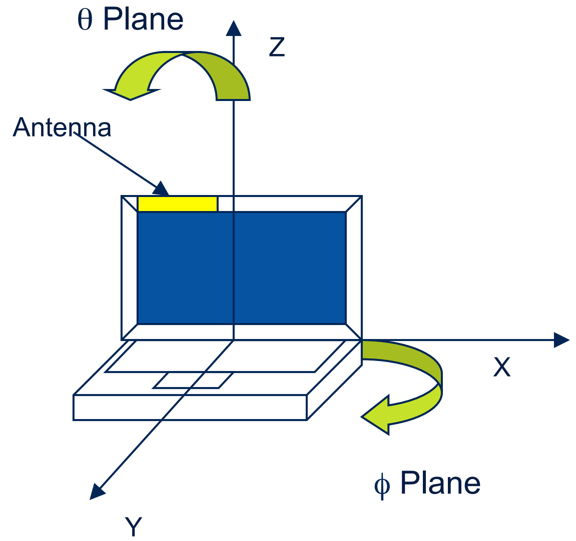
Mechanical details



Mechanical	
Volume (Antenna body)	3.5cc
Width x Length x Height	4.0 mm x 10.2mm x 86mm
RF Feed	1.37mm OD miniature coaxial cable
Connection	Hirose U.FL connector

Gain at 500MHz

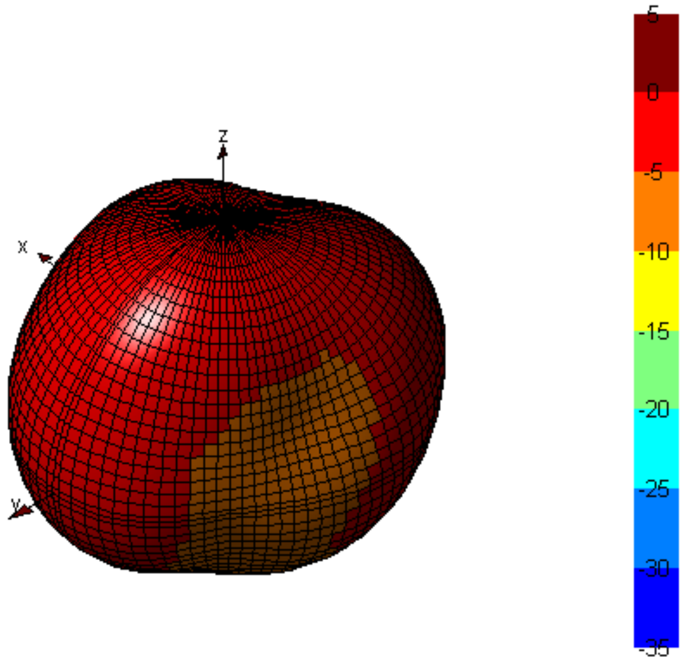




DC = 1.81V

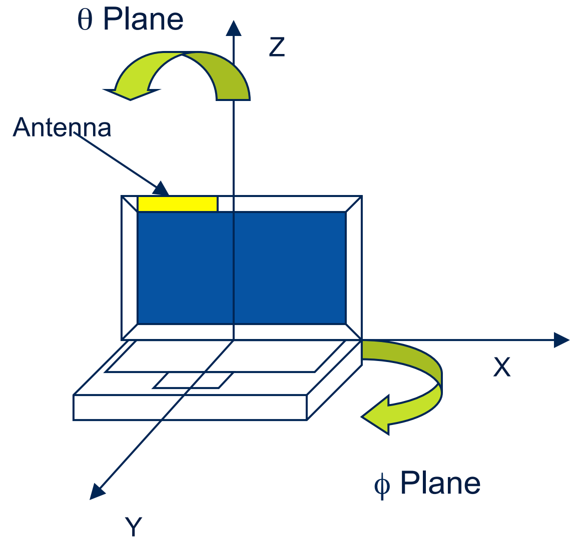
Polarisation	Peak Gain YZ	Peak Gain XY	Peak Gain XZ
Theta θ	-12.4	-5.8	-3.0
Phi φ	-1.1	-1.1	-7.5
Total	-0.8	-0.9	-2.9

Gain at 666MHz

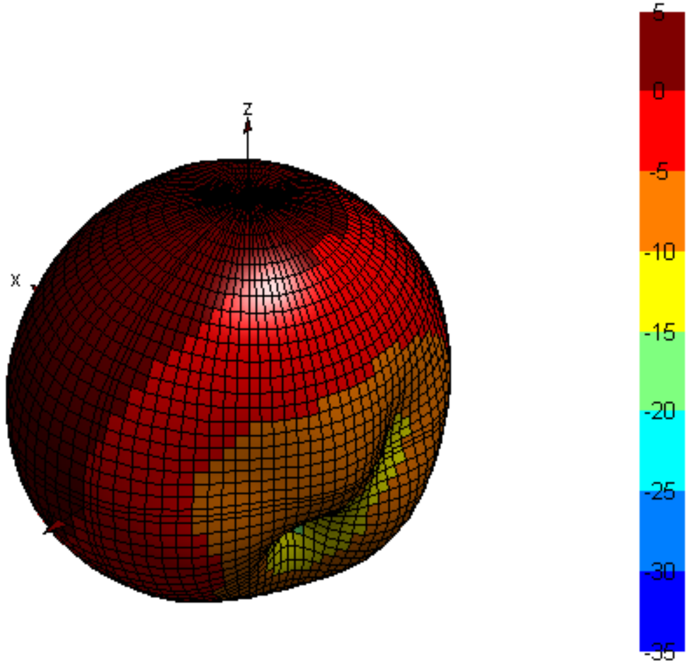


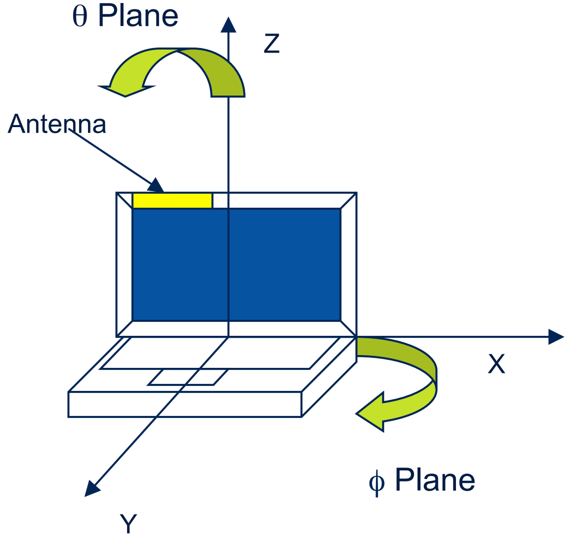
DC = 0V

Polarisation	Peak Gain YZ	Peak Gain XY	Peak Gain XZ
Theta θ	-7.6	-6.1	-1.8
Phi ϕ	-1.2	-1.7	-6.3
Total	-0.8	-0.7	-1.8



Gain at 800MHz





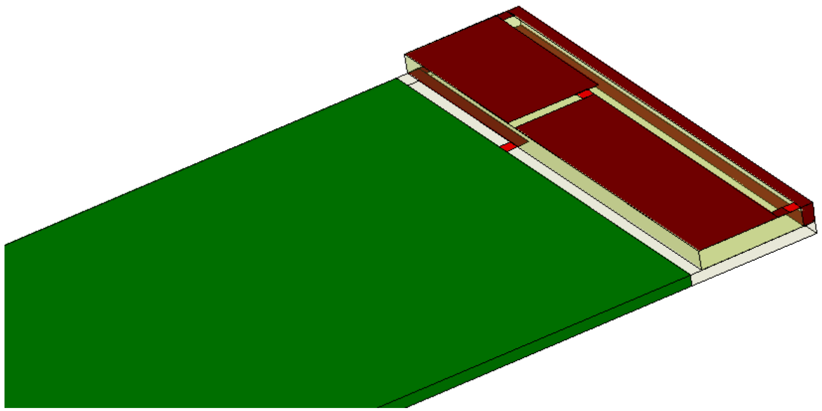
DC = 2.0V

Polarisation	Peak Gain YZ	Peak Gain XY	Peak Gain XZ
Theta θ	-6.9	-4.5	+0.3
Phi ϕ	+0.3	-0.8	-7.2
Total	+0.4	0.0	+0.4

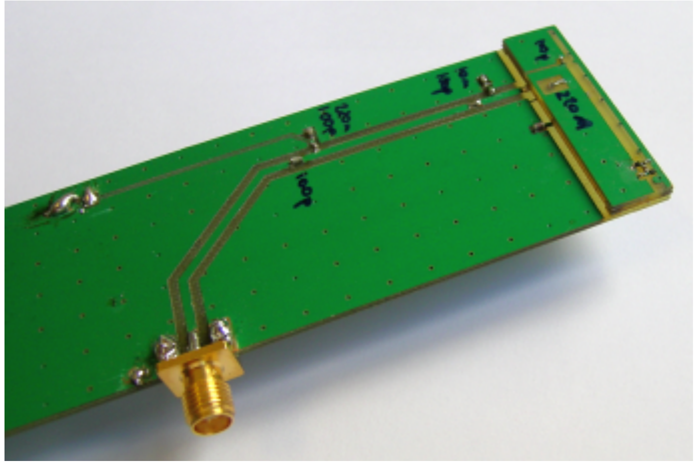
An SMT Antenna

- Small, tuneable UHF (470-862MHz) for handheld devices
- Single tuning voltage 0-3.7V
- Two varactors
- High efficiency (>30%)
- SMT (FR4 Module)

Size: 40x10x1.6mm



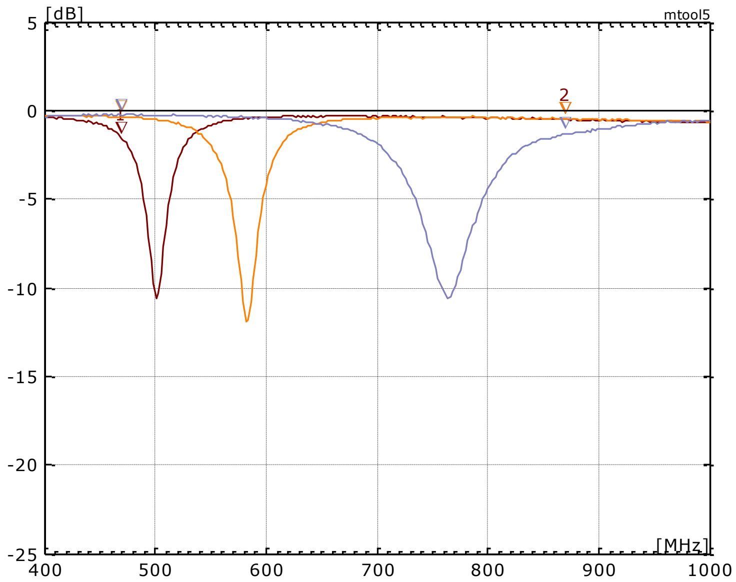
HFSS Model



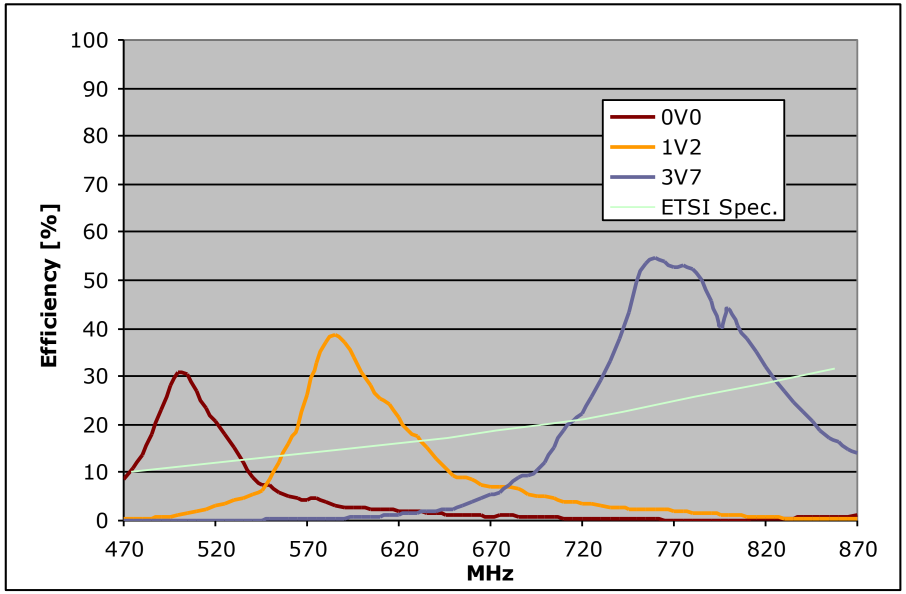
Actual prototype

Results

- Return loss and efficiency on a 120x40mm PCB



MARKERS:		MHz	dB
0V0		1: 470	-1.57
		2: 870	-0.51
1V21		1: 470	-0.38
		2: 870	-0.49
3V70		1: 470	-0.25
		2: 870	-1.34



<u>Work in progress:</u>
- Extend range at upper edge
- Reduce max voltage <2.8V

Conclusion

- A tuned solution potentially has significant advantages for a small antenna which must cover a large frequency band
- Over the UHF-TV band the advantage of continuous tuning relative to 3-bit step-tuning can be of the order of 4dB on a handset platform
- Interactive tuning provides additional benefit and involves no significant extra cost
- New technologies may out-perform the best varactor diodes, but they can't do so at the present time
- The most important design challenges for small tuned antennas for this application are the minimization of loss and the achievement of sufficient tuning range.

Note

- **The design of the double-tuned antennas described in this presentation is the subject of UK Patent Application GB 0902307.8.**
- **The authors are grateful to DiBcom SA for the loan of their DVB-T monitoring receiver and software**

References

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Thank you!

Thank you for your attention

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