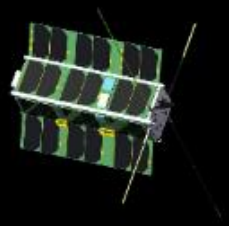
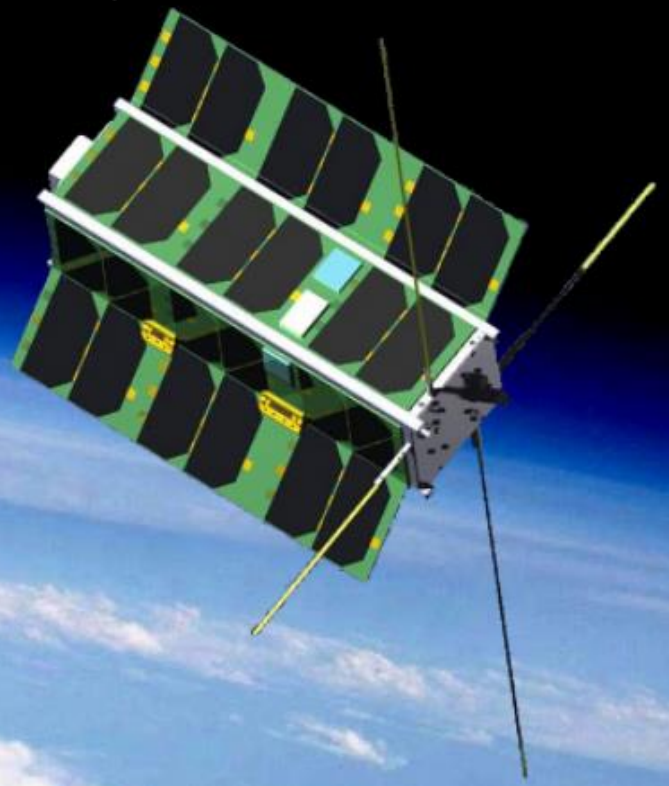


A Novel Planar Antenna for CubeSats

Jan Verwilligen
Prem Sundaramoorthy



13th Annual Summer CubeSat Developers' Workshop
Small Satellite Conference - 2016

TU Delft

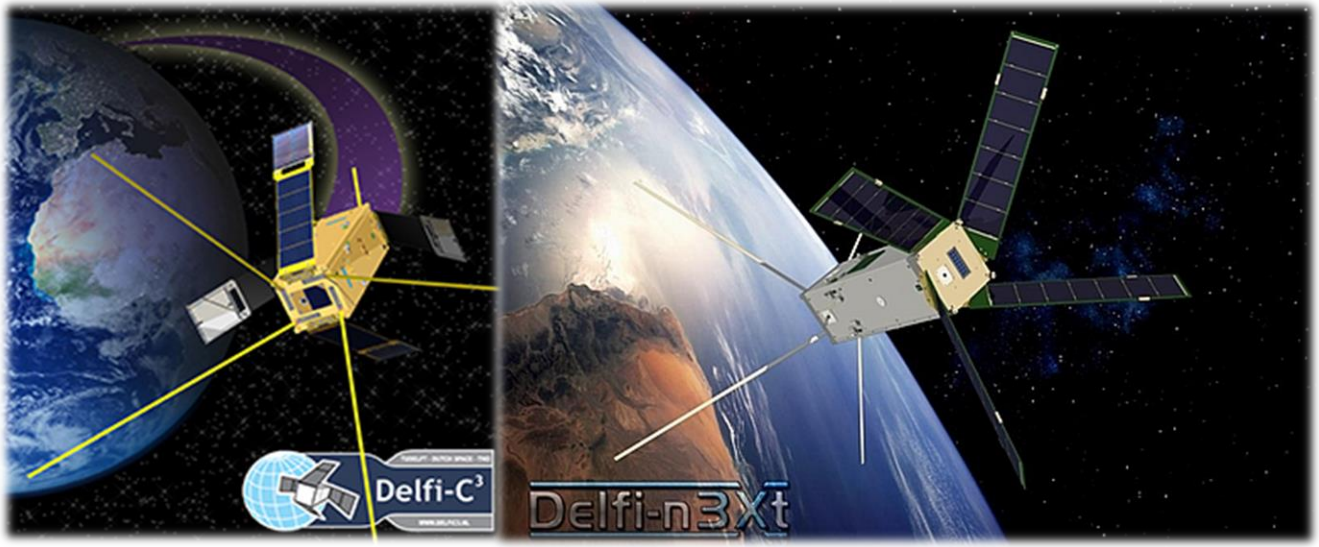
Frequency bands

- UHF and VHF for communication

  Radio amateur band

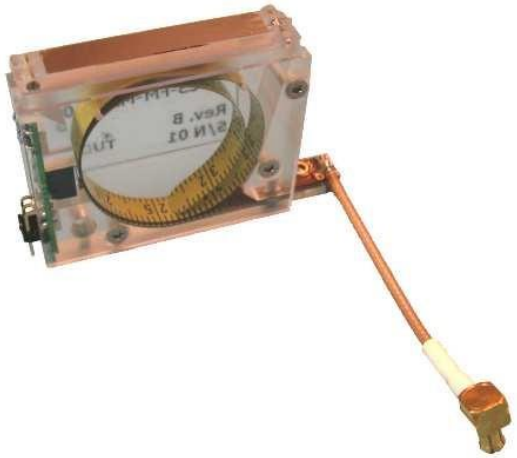
  UHF: 435 to 438 MHz ; 70 cm

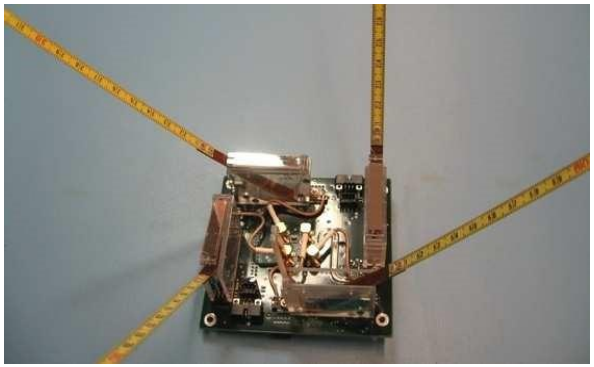
  VHF: 144 to 146 MHz ; 2 m

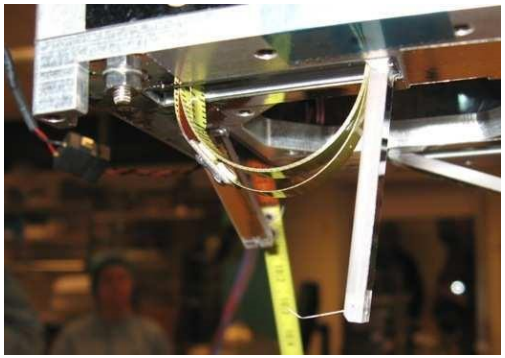


Antenna for UHF/VHF

- Wire antennas
  - Deployment mechanisms
  - Added mass
  - Added volume
  - Added complexity







Pictures from - Brouwers, Ubbels, Vaartjes, Hennepe . *Lessons Learned in Space Systems.* 59th International Astronautical Congress, Glasgow, 2008

Problem statement

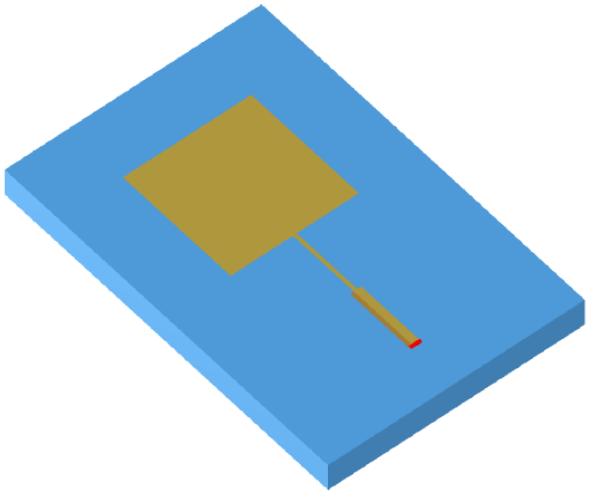
Can we develop a planar antenna for the UHF downlink?

Antenna Requirements

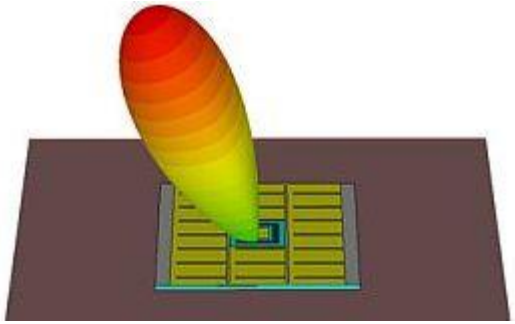
- The antenna shall be able to radiate over the UHF frequencies
- All antenna connections will have an impedance of 50 Ohm
- The size of the antenna shall not exceed the dimensions of a 3U CubeSat side panel
- The patch shall not stick out more than 4mm
- The antenna, if placed on the side, shall not be wider than 80 mm

Patch Antenna

- Quarter Wavelength Patch
  - S-band (2.4GHz) : 3.125 cm
  - UHF (436MHz) : 17.5 cm
  - GSM (900 MHz) : 8.33 cm

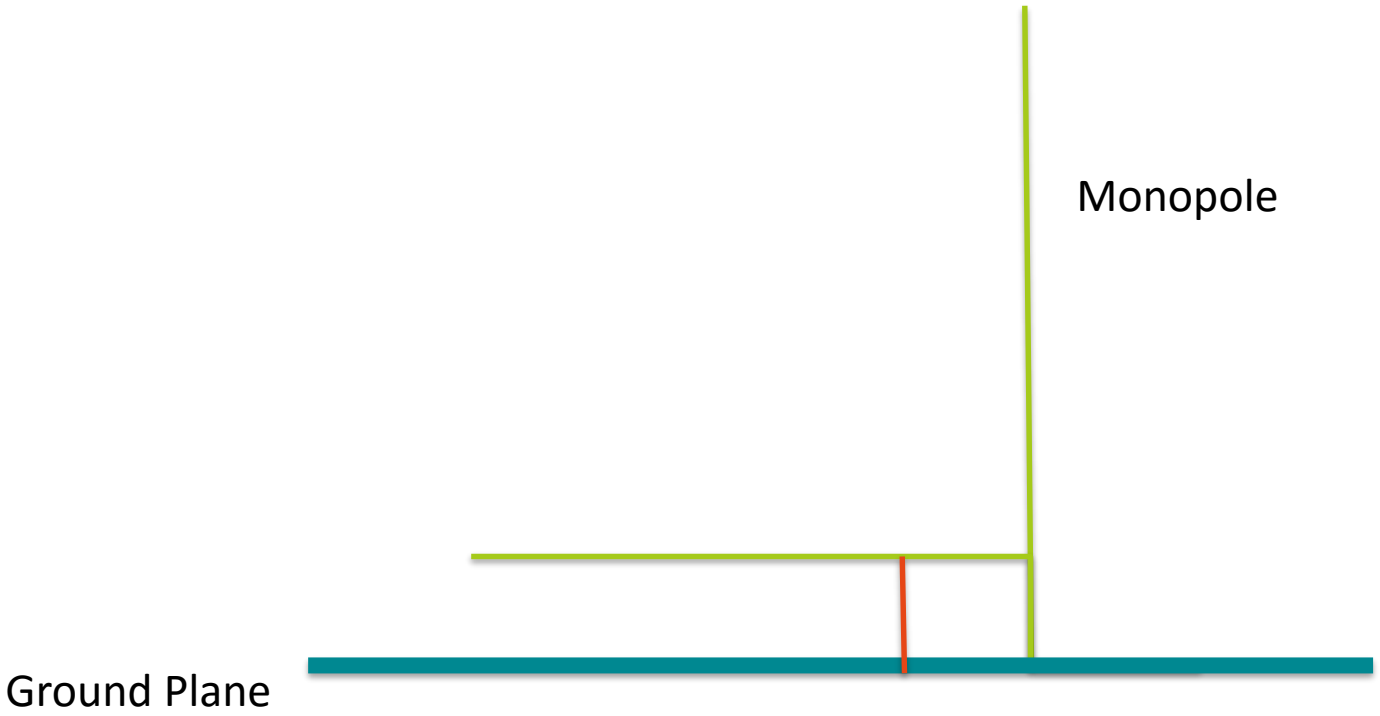


http://www.antennamagus.com/database/antennas/antenna_page.php?id=22

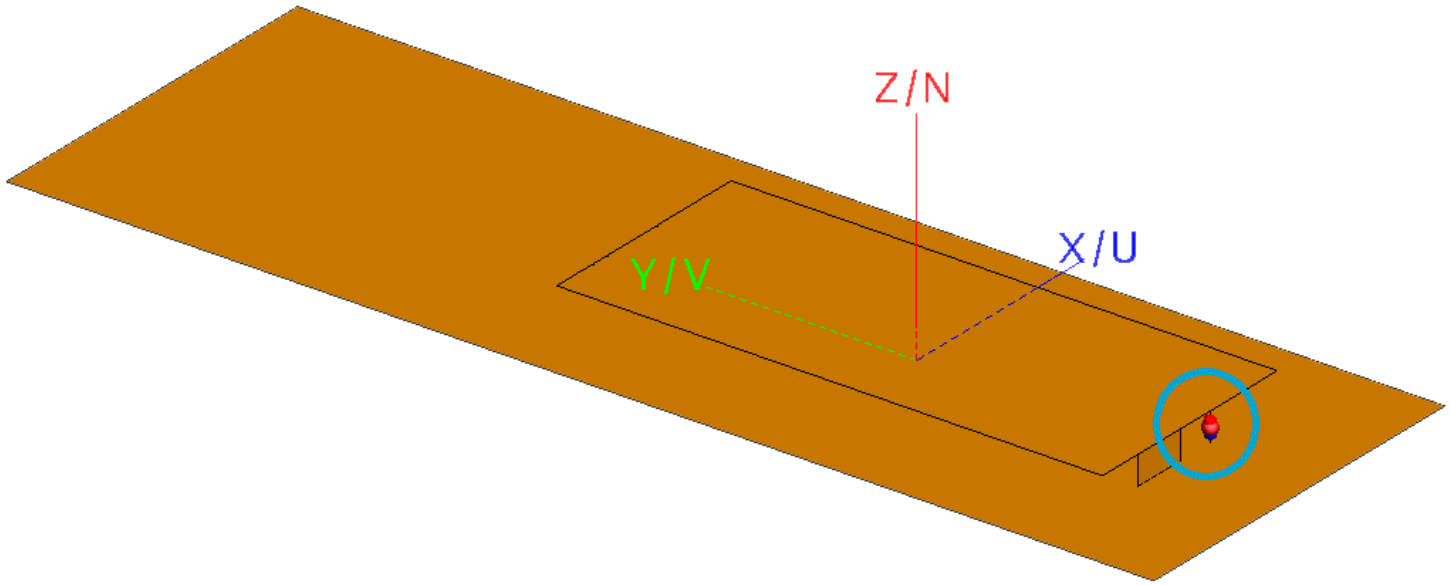


http://ahfr.dit.ie/node/26

Planar Inverted F Antenna (PIFA)



Planar Inverted F Antenna (PIFA)

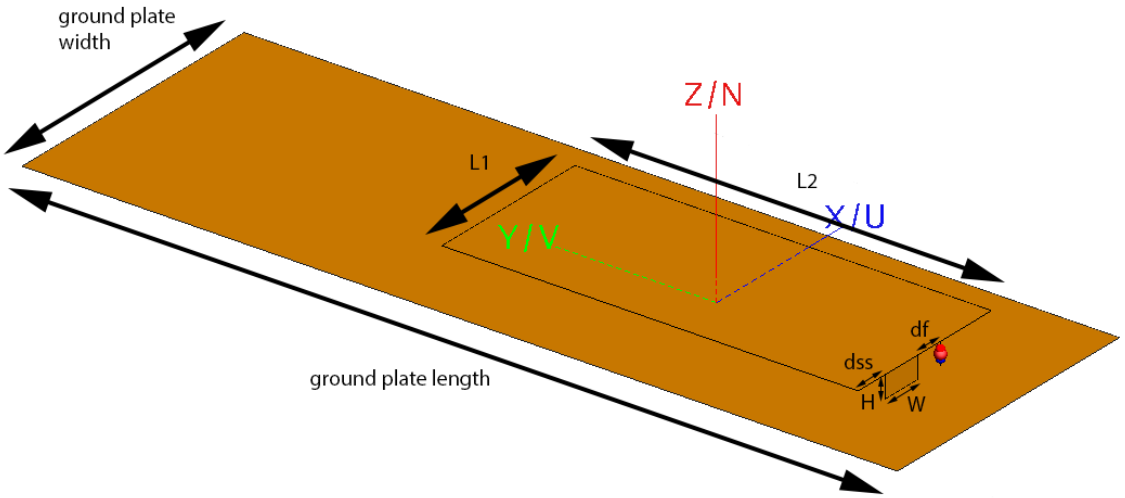


Planar Inverted F Antenna

- Design Equation

$$L_1 + L_2 + H - W = \frac{c_0}{4 f_0 \sqrt{\grave{o}_r}} = \frac{\lambda}{4\sqrt{\grave{o}_r}}$$

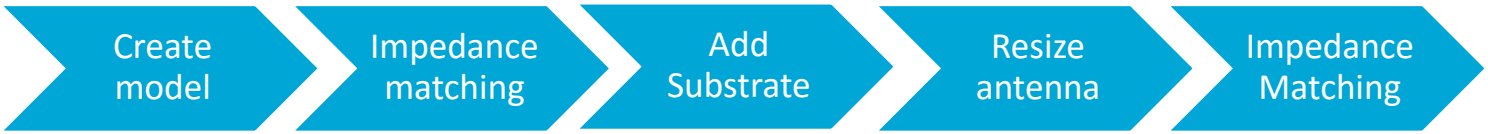
Hirasawa and Haneishi,
Analysis, Design, and Measurement of Small and Low-Profile Antennas. Artech House on Demand, 1992



Planar Inverted F Antenna

- Impedance matching
  - Maximum power transfer
  - $Z = R + jwL - j/wC$
  - Smith chart and return loss for analysis and insight

Design Process

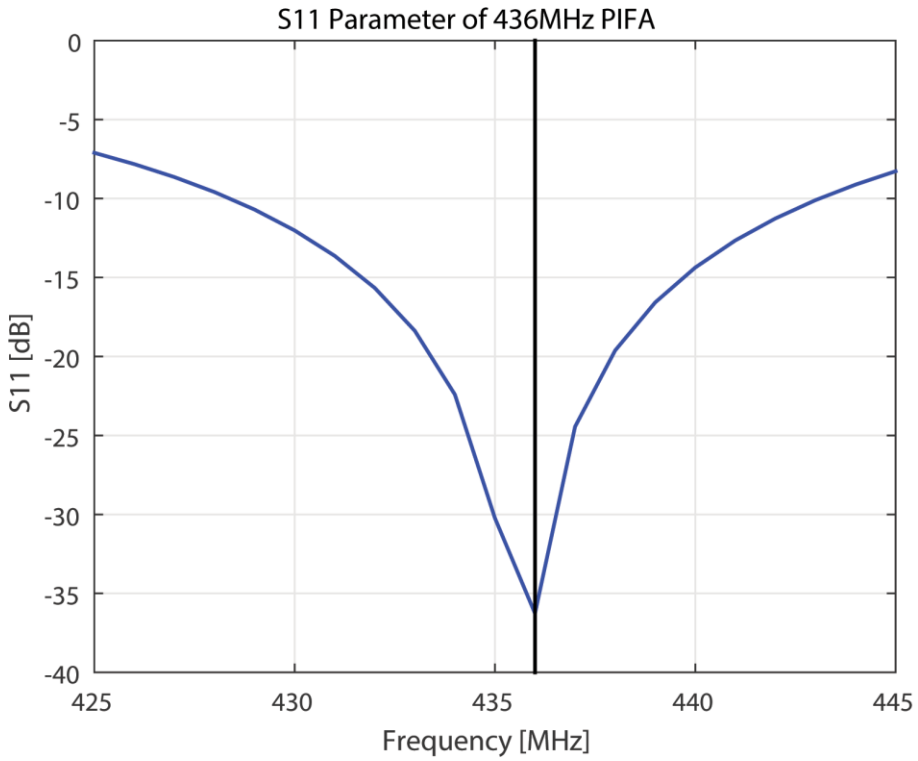


- First estimates are derived with no substrate
- Sensitivity to impedance increases with addition of substrate
- Software suite for computational electromagnetics – FEKO

(FEldberechnung für Körper mit beliebiger Oberfläche)

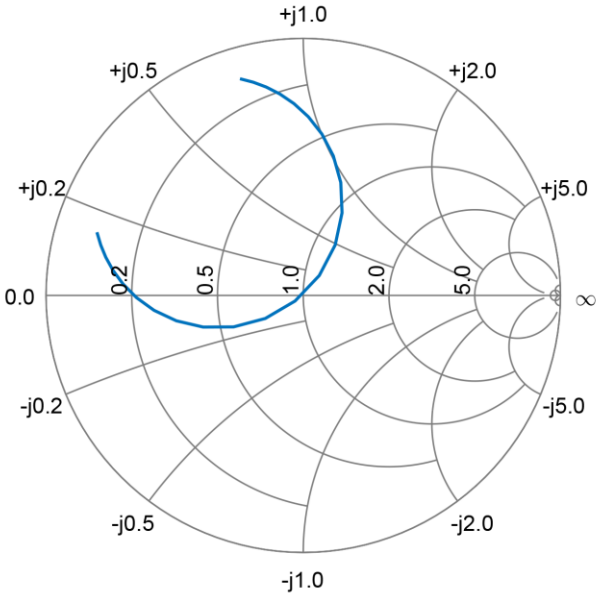
Results - Return Loss (without substrate)

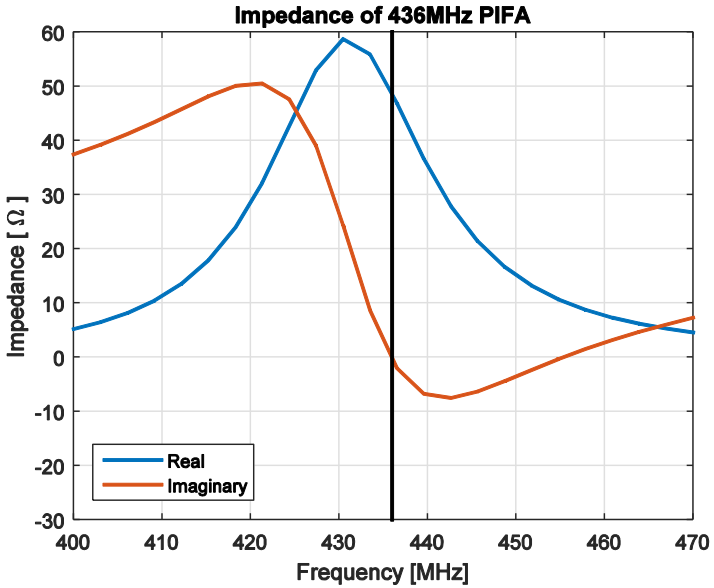
- Measure of the amount of power radiated by the antenna compared to the input power



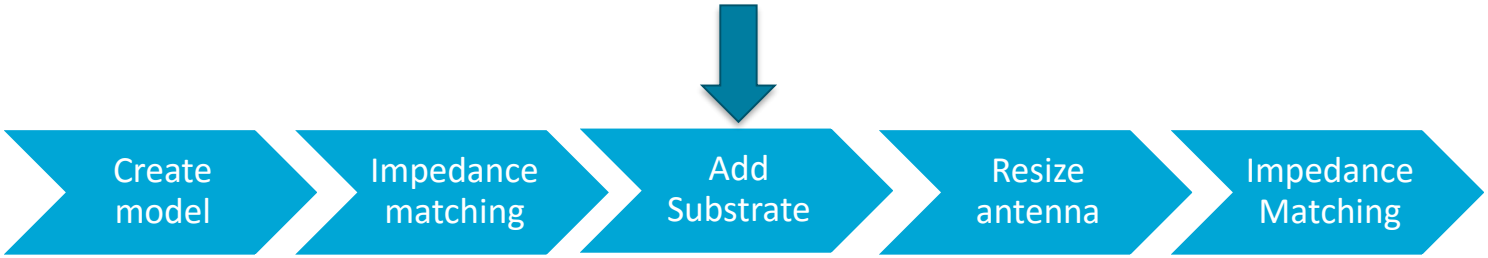
Results - Impedance Matching (without substrate)

- Antenna impedance needs to be the same as the impedance of the transmission line to maximise power transfer efficiency





Design Process

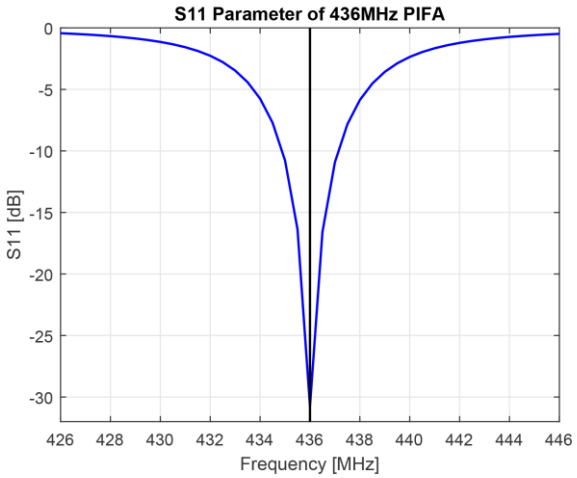


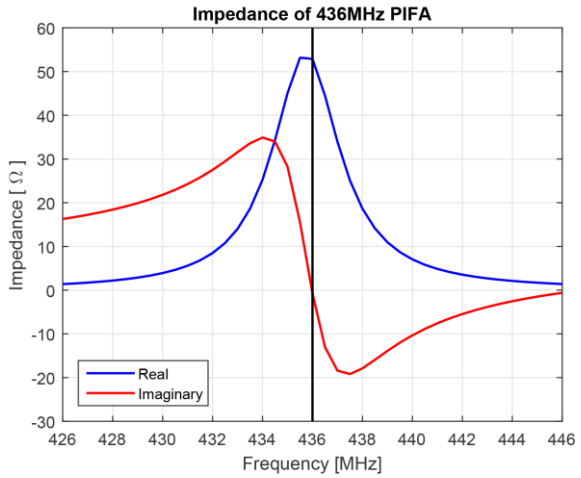
- Substrate adds physical support between patch and ground

$$L_1 + L_2 + H - W = \frac{c_0}{4 f_0 \sqrt{\grave{o}_r}} = \frac{\lambda}{4\sqrt{\grave{o}_r}}$$

- Reduces the size of the antenna
- Reduces bandwidth

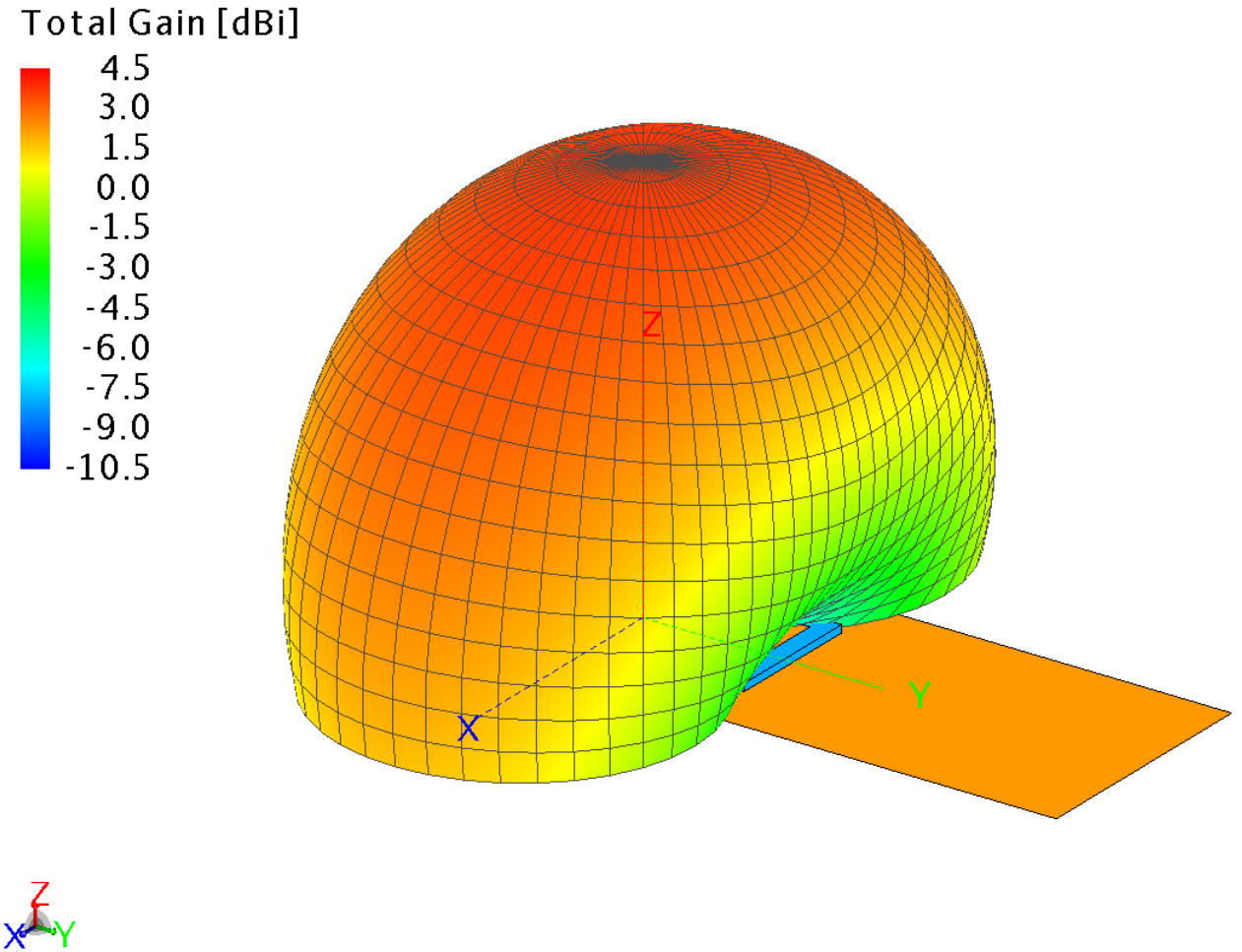
Bandwidth and Impedance





- S11 <-30dB
- Bandwidth = 2.275MHz at -10dB
- Impedance 52.9 Ohm

Radiation Pattern



Conclusions – PIFA for UHF

Performance similar to dipole antenna

Smaller (Less volume and mass)

Higher reliability

Potential to be integrated in structure

Reduction in development time

Design Optimisation needed if a slightly different centre frequency is requested

Thank you

Additional Slides

$$f_c \approx \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_0 \varepsilon_r \mu_0}}$$

$$\lambda \approx 2L\sqrt{\epsilon_r}$$
$$L \approx \lambda/2\sqrt{(\epsilon_r)}$$

W influences the input impedance