A Novel Planar Antenna for CubeSats

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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

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://ahfr.dit.ie/node/26
Planar Inverted F Antenna (PIFA)

Monopole

Ground Plane
Planar Inverted F Antenna (PIFA)
Planar Inverted F Antenna

- Design Equation

\[ L_1 + L_2 + H - W = \frac{c_0}{4 f_0 \sqrt{\epsilon_r}} = \frac{\lambda}{4 \sqrt{\epsilon_r}} \]

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

*(FEIdberechnung 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

\[ L_1 + L_2 + H - W = \frac{c_0}{4 f_0 \sqrt{\lambda}} = \frac{\lambda}{4 \sqrt{\lambda}} \]

- Reduces the size of the antenna

- Reduces bandwidth
Bandwidth and Impedance

- $S11 < -30\text{dB}$
- Bandwidth $= 2.275\text{MHz} \text{ at } -10\text{dB}$
- Impedance $52.9\ \text{Ohm}$
Radiation Pattern

Total Gain [dBi]

-10.5
-9.0
-7.5
-6.0
-4.5
-3.0
-1.5
0.0
1.5
3.0
4.5

X
Y
Z
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
\[ f_c \approx \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_0 \varepsilon_r \mu_0}} \]

\[ \lambda \approx 2L\sqrt{\varepsilon_r} \]

\[ L \approx \frac{\lambda}{2\sqrt{\varepsilon_r}} \]

\( W \) influences the input impedance