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Swiss Space Summer Camp 2016

Antenna Design

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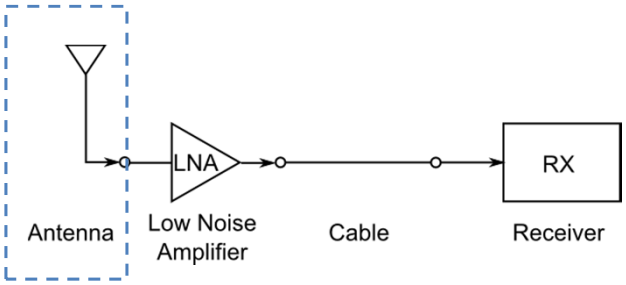
System block diagram

Simple ground station

- Only receiver path will be implemented
- Four main functional blocks
- Main objectives:
  - Receive signals from LEO satellites and ISS with reasonable quality
  - Simple to build and operate (no special technical skill needed)



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Receiving antenna

Requirements

- Omnidirectional directivity
- Circular polarisation
- Feedpoint impedance 50 Ohm
- Reasonable gain and efficiency
- Not to heavy
- Simple to build and test

…it might not be the right solution.

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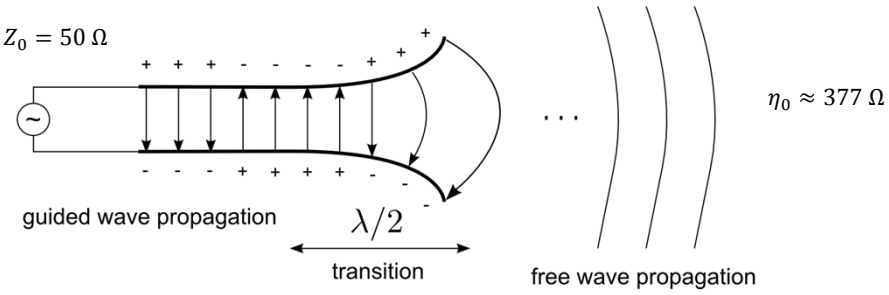
What is an antenne?

- Impedance transducer ($Z_0 \leftrightarrow \eta_0$)
- Wave filter ($c_0 = f\lambda$)

"world of circuit theorie" (Kirchhoff)

"world of fields and waves" (Maxwell)



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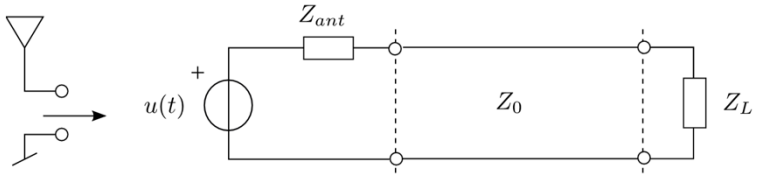
Power flow

Antenna (Thévenin Source) | Transmission line (e.g. Coaxial Cable) | Load



$P_{ant} = S_i\, A_e$

$P_{ant} \rightarrow P_{cable} = (1 - |\Gamma|^2) P_{ant}$

$P_{refl} = |\Gamma|^2 P_{ant}$ ← $\Gamma = \frac{Z_0 - Z_{ant}}{Z_0 + Z_{ant}}$

A_e: effective area (m^2)
S_i: power density of incident wave (W/m^2)
Γ : reflection coefficient

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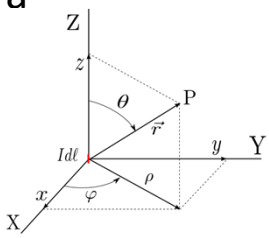
Electromagnetic field of a basic current element

- The electromagnetic field close to the current element is complex (reactive field) [1].
- Far from the current element, the field reduces to the radiation field.



$$E_r = \frac{Id\ell}{2\pi} e^{-jkr} \left(\frac{\eta}{r^2} + \frac{1}{j\omega\varepsilon r^3} \right) \cos(\Theta)$$

$$E_\Theta = \frac{Id\ell}{4\pi} e^{-jkr} \left(\frac{j\omega\mu}{r} + \frac{\eta}{r^2} + \frac{1}{j\omega\varepsilon r^3} \right) \sin(\Theta)$$

$$H_\varphi = \frac{Id\ell}{4\pi} e^{-jkr} \left(\frac{jk}{r} + \frac{1}{r^2} \right) \sin(\Theta)$$

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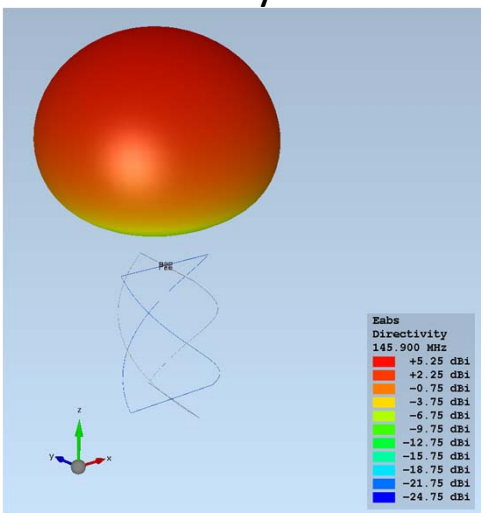
Directivity of an antenna



- Directivity is the ratio of maximum radiation intensity to average radiation intensity [1].
- The unit dBi means the antenna gain must be referenced to an isotropic radiator.
- The simulated model is a quadrifilar helical antenna. It shows a back-fire behaviour.

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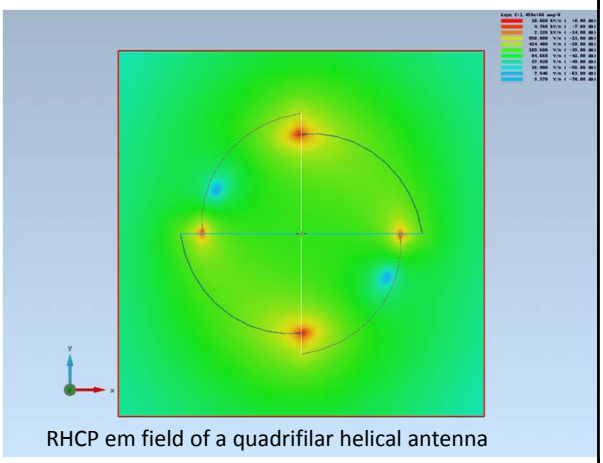
Polarisation of the electromagnetic wave

- Linear polarisation of the em wave places a constraint on trans-mitter and receiver antenna alignment.
- For satellite links one or both antenna may be moving.
- Circular polarisation is used on at least one end.



RHCP em field of a quadrifilar helical antenna

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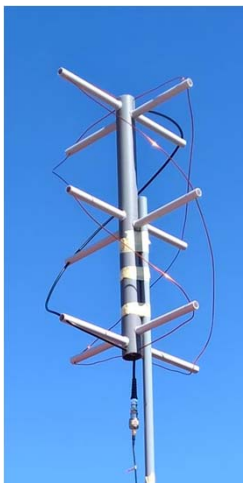
Quadrifilar helical antenna



- The QHA is first published in 1968 by Kilgus [2].
- Our construction is based on guidelines described in a paper by Ruperto, W3KH [3].
- Two twisted wire frames are placed upon each other at right angles and are connected to the antenna cable at the top.
- We build a “self-phasing” QHA with two unequal loops and an “infinite” balun (**bal**anced / **un**balanced transformer).

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Assembly and Test Instructions

- The following slides describe the various steps for assembling and testing the quadrifilar helical antenna

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Calculating the leg sizes

- The antenna shall be tuned to a single frequency.

$$f_0 = 145.9\ MHz$$

- Calculate the wavelength.

$$\lambda = \frac{c}{f_0} = \frac{3 \cdot 10^8\ m/s}{145.9\ MHz} = 2.056\ m$$

- Calculate the various dimensions for the antenna segments.

Big Loop	**Small Loop**
$Height = 0.26\ \lambda$	$Height = 0.238\ \lambda$
$Diameter = 0.173\ \lambda$	$Diameter = 0.156\ \lambda$
$Leg\ size = 0.56\ \lambda$	$Leg\ size = 0.508\ \lambda$

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Preparing the material

- The antenna mast may be a pvc tube with a diameter of 40 mm.
- The cross arms are pvc tubes with a diameter of 16 mm.
- The copper wire or element diameter shall be $\approx 0.088\ \lambda$.
- Cut 1 big loop leg size length + 10cm of RG-58 cable for the balun (which is also the fourth helix leg).
- Cut 1 big loop leg size length of copper wire.
- Cut 2 small loop leg size length of copper wire.

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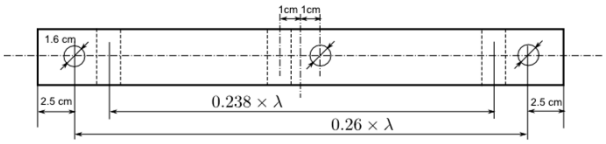
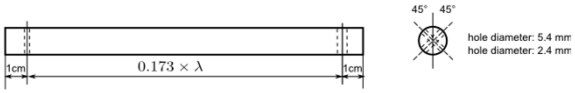
Mechanical drawings

Mast

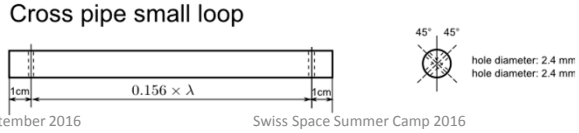
bottom center top



Cross pipe big loop



Cross pipe small loop



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Constructing the frame

- Insert the cross arms through the holes, starting from the bottom with a longer arm (big loop) followed by a shorter one (small loop).
- Make sure both sides extending are the same length.
- After all arms have been adjusted and checked, fix them with adhesive and let it dry.

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Wiring the antenna

- Strip the enamel wire thoroughly and tin the ends.
- Feed the wires and cable through the holes. Bend the wires only absolutely necessary to smoothly fit trough the cross arms.
- For RHCP you wind the helices ***counterclockwise*** as viewed from the top.

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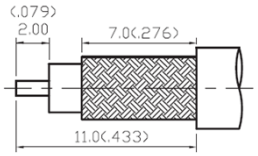
Preparing the Soldering

- Carefully remove on both ends of the RG-58 cable the jacket and part of the braid and insulation according to the figure.
- Remove at the bottom side 10cm away from the cable end carefully only the coax jacket. Don't harm the braid.
- Solder the connections as shown in the wiring diagram on next slide.



STRIPPING DIMENSION

Dimensions : Millimeters (Inches)

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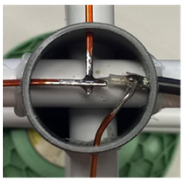
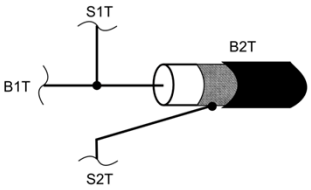
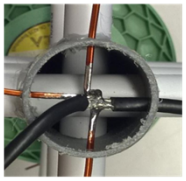
Soldering



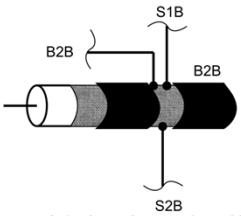
Top View



S1T: small leg 1 top
S2T: small leg 2 top
B1T: big leg 1 top
B2T: big leg 2 top (coax. cable)



Bottom View



S1B: small leg 1 bottom
S2B: small leg 2 bottom
B1B: big leg 1 bottom
B2B: big leg 2 bottom (coax. cable)

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Mounting the sma connector

- Slip a 3cm length of heatshrink tubing onto the bottom end of coax cable.
- Assemble the SMA female connector onto the end of the coaxial cable using the crimp tool.
- Finally shrink the tubing using a heat gun.

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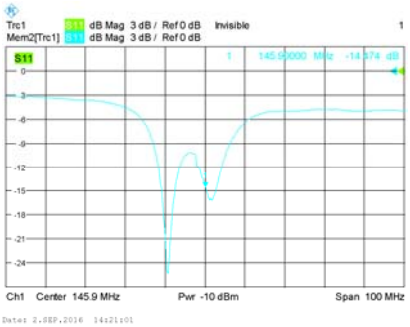
Measuring the performance (1/2)

- Mount the Antenna onto a wooden mast and fix it with sticky tape.
- Measure by means of the vector network analyser (vna) the scattering parameter S_{11}.
- The scattering parameter S_{11} describes the reflexion coefficient:

$$S_{11} = 10\ log_{10}(|\Gamma|^2)$$



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Measuring the performance (2/2)

- Store the measurement as png-file for later documentation.
- Read out the S_{11} value at resonant frequency.
- Read out the antenna bandwidth for which the S_{11} value is less than – 10 dB.
- If you touch the antenna by hand, what happens? Do you have an explanation for it?
- Document your observations and thoughts.

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References

[1] C.A. Balanis, "*Antenna Theory. Analysis and Design*", 4th ed. Hoboken, New Jersey: John Wiley & Sons, 2016.

[2] C.C. Kilgus, "Resonant Quadrafilar Helix," IEEE Trans. Antennas Propag. , AP-17, pp. 349–351, May 1969.

[3] E. F. Ruperto, "The W3KH Quadrifilar Helix Antenna," QST, pp. 30-34, Aug. 1996.