Project #1: Printed Patch, Linear Polarization, 1.85 GHz

1. Design parameters
    - $f_0 = 1.85$ GHz
    - $\Delta f / f_0 > 1\%$ (VSWR $\leq$ 2.0)
    - $Z_{in} = 50\ \ \Omega$, at $f_0 = 1.85$ GHz
    - Polarization: Linear
    - Pattern: single lobe (SLL below –20 dB), half-power beamwidths al least 90 deg.

2. Substrate parameters
    - $\varepsilon_r = 2.2$ - relative dielectric permittivity
    - $h = 0.14$ cm – height;
    - $\tan\delta = 0.001$ - substrate dielectric loss
    - maximum substrate area 10×10 cm.

3. Feed

    Microstrip line, $Z_c = 50\ \ \Omega$

Additional requirements:

Give full geometrical description of the design.

Give full details of the numerical simulations: edge and segment lengths, mesh convergence error.

Plot the principal-plane radiation patterns at the central frequency and at the begin/end frequencies of the band of operation. Plot the 3D pattern at the central frequency. Plot the polarization patterns at the center frequency.

Plot the input impedance (real and imaginary parts).

Plot the SWR vs. frequency in the desired band of operation.

Project #2: Printed Patch, Linear Polarization, 3.00 GHz

4. Design parameters
   - $f_0 = 1.85$ GHz
   - $\Delta f / f_0 > 1\%$ (VSWR $\leq$ 2.0)
   - $Z_{in} = 50\ \ \Omega$, at $f_0 = 1.85$ GHz
   - Polarization: Linear
   - Pattern: single lobe (SLL below –20 dB), half-power beamwidths at least 120 deg.

5. Substrate parameters
   - $\varepsilon_r = 4.4$ - relative dielectric permittivity
   - $h = 0.14$ cm – height;
   - $\tan\delta = 0.005$ - substrate dielectric loss
   - maximum substrate area 15×10 cm.

6. Feed

   Microstrip line, $Z_c = 50\ \ \Omega$

Additional requirements:

Give full geometrical description of the design.

Give full details of the numerical simulations: edge and segment lengths, mesh convergence error.

Plot the principal-plane radiation patterns at the central frequency and at the begin/end frequencies of the band of operation. Plot the 3D pattern at the central frequency. Plot the polarization patterns at the center frequency.

Plot the input impedance (real and imaginary parts).

Plot the SWR vs. frequency in the desired band of operation.

Project #3: Printed Patch, Circular Polarization, 10 GHz

1. Design parameters
   - $f_0 = 10$ GHz
   - $\Delta f / f_0 > 1\%$ (VSWR $\leq$ 2.0)
   - $Z_{in}\ (f_0 = 10\ \text{GHz}) = 50\ \ \Omega$
   - Polarization: Right-hand Circular
   - Pattern: single lobe (SLL below –20 dB), half-power beamwidths al least 120 deg.

2. Substrate parameters
   - $\varepsilon_r = 4.2$ - dielectric constant
   - $h = 0.05$ cm - height
   - $\tan\delta = 0.001$ - dielectric losses
   - maximum substrate area 2×2 cm.

3. Feed
   Microstrip line, $Z_c = 50\ \ \Omega$

Additional requirements:

Give full geometrical description of the design.

Give full details of the numerical simulations: edge and segment lengths, mesh convergence error.

Plot the principal-plane radiation patterns at the central frequency and at the begin/end frequencies of the band of operation. Plot the 3D pattern at the central frequency. Plot the polarization patterns at the center frequency.

Plot axial ratio vs. frequency in the frequency band of operation.

Plot the input impedance (real and imaginary parts).

Plot the SWR vs. frequency in the desired band of operation.

Project #4: GPS Printed Antenna, Coaxial Feed, Circular Polarization

1. Design parameters
   - $f_0 = 1575.42$ MHz
   - $\Delta f = 2.046$ (VSWR $\leq$ 2.0)
   - $Z_{in}\ (f_0) = 50\ \ \Omega$
   - Polarization: Right-hand Circular
   - Pattern: single lobe (SLL below –12 dB), half-power beamwidths no more than 120 deg.

2. Substrate parameters
   - $\varepsilon_r = 2.2$ - dielectric constant
   - $h = 0.14$ cm - height
   - $\tan\delta = 0.001$ - dielectric losses
   - maximum substrate area 2×2 cm.

3. Feed

   Coaxial probe, $Z_c = 50\ \ \Omega$

Additional requirements:

Give full geometrical description of the design.

Give full details of the numerical simulations: edge and segment lengths, mesh convergence error.

Plot the principal-plane radiation patterns at the central frequency and at the begin/end frequencies of the band of operation. Plot the 3D pattern at the central frequency. Plot the polarization patterns at the center frequency.

Plot axial ratio vs. frequency in the frequency band of operation.

Plot the input impedance (real and imaginary parts).

Plot the SWR vs. frequency in the desired band of operation.

Project #5: X-band Horn

Design an X-band (8.2 to 12.4 GHz) pyramidal horn antenna with an optimum gain at $f_0 = 10$ GHz. The horn is fed by a standard X-band waveguide WR-90 (cross-section is 0.9×0.4 inches^2 or 23×10 mm^2). The overall length from the horn's imaginary vertex to the center of the aperture is $R_0 = 10\lambda$ (same in both planes).

- Determine the aperture dimensions.
- Give the antenna gain (in dB).
- Determine the aperture efficiency (in %). Assume that the conductor, dielectric and reflection losses are negligible.
- Calculate the HPBW in the *H*-plane and the *E*-plane.
- Design the horn for SWR $\leq$ 1.5 in the whole band of operation.

Verify design with simulations.

Additional requirements:

Give full geometrical description of the design.

Give full details of the numerical simulations: edge and segment lengths, mesh convergence error.

Plot the principal-plane radiation patterns at the central frequency and at the begin/end frequencies of the band of operation. Plot the 3D pattern at the central frequency. Plot the polarization patterns at the center frequency.

Plot the feed waveguide wave impedance for the dominant mode in the whole band of operation.

Plot the SWR vs. frequency in the desired band of operation.

Project #6: C-band Horn

Design a C-band (3.95-5.85 GHz) pyramidal horn antenna with optimum gain $G = 20$ dBi at $f_0 = 4.9$ GHz. The horn is fed by a standard rectangular waveguide WR 187 with a cross-section 4.755×2.215 cm^2.

- Determine the aperture dimensions and the remaining horn dimensions such as R_E and R_H.
- Give the antenna gain (in dBi).
- Determine the aperture efficiency (in %). Assume that the conductor, dielectric and reflection losses are negligible.
- Calculate the HPBW in the *H*-plane and the *E*-plane.
- Design the horn for SWR $\leq$ 1.5 in the whole band of operation.

Verify design with simulations.

Additional requirements:

Give full geometrical description of the design.

Give details of the numerical simulations: edge and segment lengths, mesh convergence error.

Plot the principal-plane radiation patterns at the central frequency and at the begin/end frequencies of the band of operation. Plot the 3D pattern at the central frequency. Plot the polarization patterns at the center frequency.

Plot the feed waveguide wave impedance for the dominant mode in the whole band of operation.

Plot the SWR vs. frequency in the desired band of operation.

Project #7: Inverted F Antenna for a PCS Handset

Design an inverted F antenna to fit on a box of size $13\times 6.5\times 2$ cm^3. The operating frequency band is from 1850 to 1990 MHz. SWR must be below 2 in the whole frequency band. Maximum gain must be larger than or equal to 1.8 dBi. Polarization is linear.

Additional requirements:

Give full geometrical and material description of the design.

Give full details of the numerical simulations: edge and segment lengths, mesh convergence error.

Plot the principal-plane radiation patterns at the central frequency and at the begin/end frequencies of the band of operation. Plot the 3D pattern at the central frequency. Plot the polarization patterns at the center frequency.

Plot the input impedance (real and imaginary parts).

Plot the SWR vs. frequency in the desired band of operation.

Note: The antenna must be designed together with the box.

Project #8: Inverted F Antenna for a GSM Handsets

Design an inverted F antenna to fit on a box of size $13\times6.5\times2\ \text{cm}^3$. The operating frequency band is from 880 to 925 MHz. SWR must be below 2 in the whole frequency band. Maximum gain must be larger than or equal to 1.8 dBi. Polarization is linear.

Additional requirements:

Give full geometrical and material description of the design.

Give details of the numerical simulations: edge and segment lengths, mesh convergence error.

Plot the principal-plane radiation patterns at the central frequency and at the begin/end frequencies of the band of operation. Plot the 3D pattern at the central frequency. Plot the polarization patterns at the center frequency.

Plot the input impedance (real and imaginary parts).

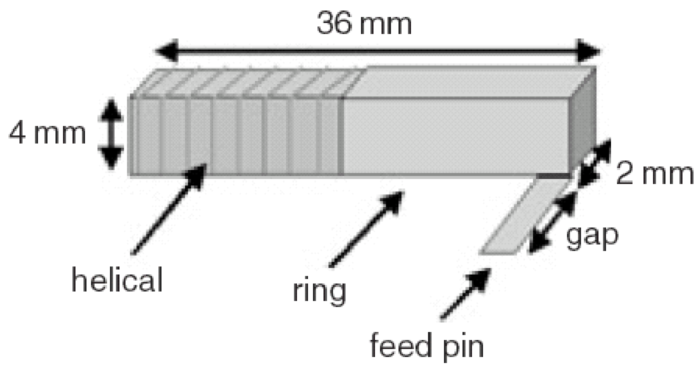
Plot the SWR vs. frequency in the desired band of operation.

Note: The antenna must be designed together with the box.

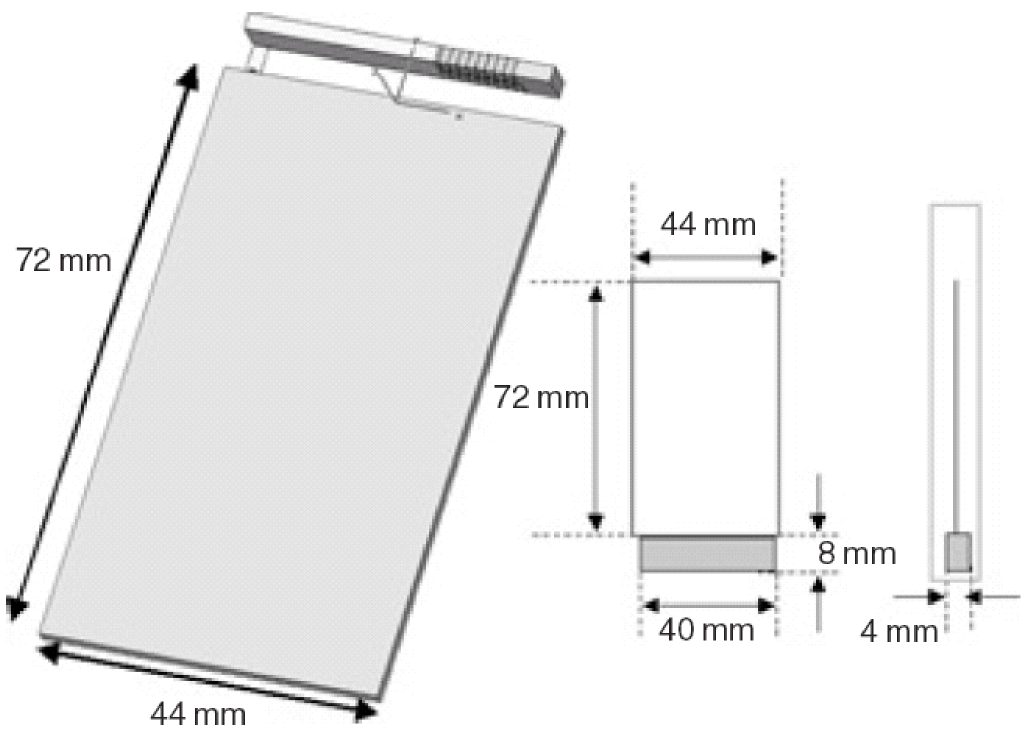
Project #9: Low-Profile Ring-Helix GPS Antenna
(requires professional FEKO license)

In January 2006, a low-profile ring-helix antenna has been proposed by M. Tzortzakakis and R.J. Langley in *Electronics Lett.*, vol. 42, No. 1. The sketch below shows the antenna and the PCB (printed circuit board) it is mounted above. Assume the PCB is a metallic box. The original design aims at multi-band performance.

Here, we require that this design is modified and optimized for good performance (return loss less than –10 dB) in the GSM band, 880 to 925 MHz. Its performance in other bands is unimportant.



a



Additional requirements:

Give full geometrical and material description of the design.

Give full details of the numerical simulations: edge and segment lengths, mesh convergence error.

Plot the principal-plane radiation patterns at the central frequency and at the begin/end frequencies of the band of operation. Plot the 3D pattern at the central frequency. Plot the polarization patterns at the center frequency.

Plot the input impedance (real and imaginary parts).

Plot the SWR vs. frequency in the desired band of operation.

Project #10: TV Receiving Yagi-Uda Antenna

Design a 7-element Yagi-Uda array at $f_0 = 500$ MHz and bandwidth greater than or equal to 3 %. SWR must be less than 2 (with respect to 50 Ω) and the maximum gain must be greater than 12 dBi in the whole band of operation. Front-to-back-lobe ratio must be larger than 20 dB.

Additional requirements:

Give full geometrical and material description of the design.

Give full details of the numerical simulations: edge and segment lengths, mesh convergence error.

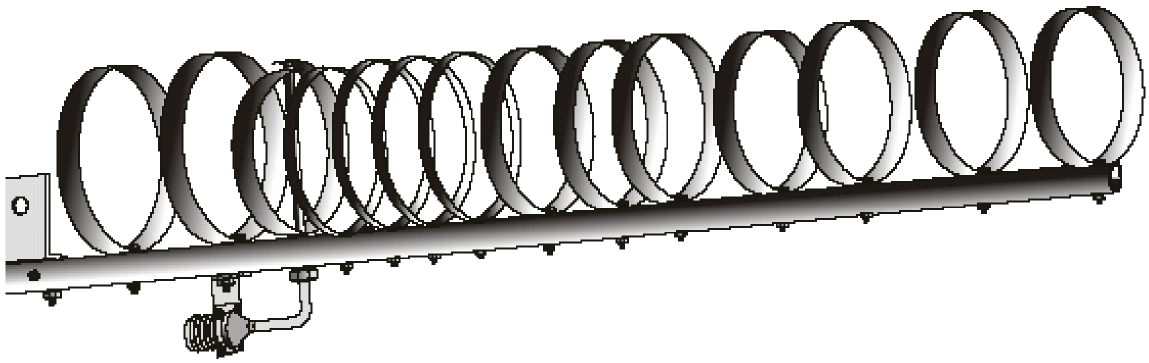
Plot the principal-plane radiation patterns at the central frequency and at the begin/end frequencies of the band of operation. Report gain at these three frequencies. Plot the 3D pattern at the central frequency. Plot the polarization patterns at the center frequency.

Plot the input impedance (real and imaginary parts).

Plot the SWR vs. frequency in the desired band of operation.

Project #11: Loop Yagi-Uda Array

A Yagi-Uda array can be constructed not only from dipoles but also from loops. A 14-element loop Yagi-Uda antenna is shown below.



Design this antenna to operate in the frequency band from 1.26 to 1.30 GHz for a SWR below 1.8 (with respect to 50 Ω) and a maximum gain of 15 dBi or more along boresight. The front-to-back-lobe ratio must be larger than or equal to 20 dB.

Additional requirements:

Give full geometrical and material description of the design.

Give full details of the numerical simulations: edge and segment lengths, mesh convergence error.

Plot the principal-plane radiation patterns at the central frequency and at the begin/end frequencies of the band of operation. Report gain at these three frequencies. Plot the 3D pattern at the central frequency. Plot the polarization patterns at the center frequency.

Plot the input impedance (real and imaginary parts).

Plot the SWR vs. frequency in the desired band of operation.

Project #12: Printed Planar Antenna for UWB Applications

1- Design parameters:
   - Covering a bandwidth of 3.1-10.6 GHz (VSWR < 2, or S11 < -10dB)
   - Acceptable maximum gain: G > 2dB in the specified bandwidth

2- Substrate parameters:
   - $\varepsilon_r = 2.1$- relative dielectric permittivity
   - $h = 0.787$ mm - height
   - Maximum Area: 10.65×34 mm

3- Feed:
   - Microstrip line, $Z_C = 50\ \Omega$

Additional requirements:

Give full geometrical and material description of the design.

Give full details of the numerical simulations: edge and segment lengths, mesh convergence error.

Plot the principal-plane radiation patterns at the central frequency and at the begin/end frequencies of the band of operation. Report gain at these three frequencies. Plot the 3D pattern at the central frequency..

Plot the input impedance (real and imaginary parts).

Plot the SWR vs. frequency in the desired band of operation.

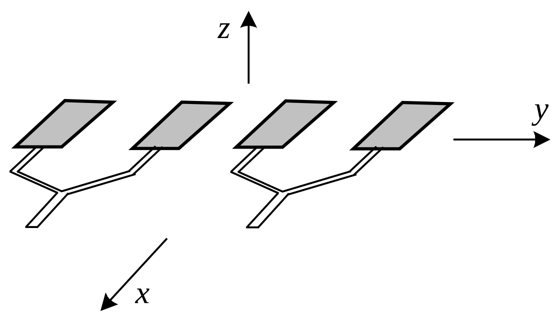
Project #13: Printed Planar Antenna and Array

A. Design a rectangular printed patch antenna.

1. Design parameters
   $f_0 = 10$ GHz
   $\Delta f / f_0 > 1\%$ (VSWR < 1.5)
   $Z_{in}(f_0) = 50\ \ \Omega$
2. Substrate parameters
   $\varepsilon_r = 4.2$ - dielectric constant;
   $h = 0.1$ cm - height;
   $\tan\delta = 0.0001$ - dielectric losses
3. Feeding
   Microstrip line, $Z_c = 50\ \ \Omega$

Plot the principal-plane radiation patterns at the central frequency and at the edges of the band. Plot the 3D pattern at the center frequency. Plot the polarization pattern at the central frequency. Plot the input impedance vs. frequency in the desired bandwidth.

B. Design a broadside linear array consisting of identical patches, same as designed in A.



1. Determine the spacing *d* and the number of elements *N*, so that the *HPBW* is less than 5° in the H-plane (yz -plane) and the SLL is less than –22 dB.
2. Calculate the directivity of the array factor.

<u>Software for fast patch and array calulations</u>: (Sainati) *patchd.exe, patch9.exe, hwpatch.exe, arraycal.exe*, (Balanis) *ARRAYS.m*

Project #14: CPW-fed Broadband Antenna, 3.1-10.6 GHz

1. Design parameters
   - Bandwidth ≈ 3.1-10.6 GHz (VSWR < 2.0)
   - Pattern: single lobe (SLL below –20 dB), half-power beam widths at least 120 deg.

2. Substrate parameters
   relative dielectric permittivity $\varepsilon_r = 4.4$
   substrate height (should be commercially available) $h_{\max} = 1.6$ mm
   maximum substrate area 7×7 cm.

3. Feed
   CPW, $Z_c = 50\ \Omega$

Give full geometrical description of the design.

Give full details of the numerical simulations: edge and segment lengths, mesh convergence error.

Plot the principal-plane radiation patterns at the central frequency and at the begin/end frequencies of the band of operation. Plot the 3D pattern at the central frequency.

Plot the input impedance (real and imaginary parts).

Plot the SWR vs. frequency in the desired band of operation.

Reference:
H.-D. Chen, H.-M. Chen and W.-S. Chen, "Planar CPW-fed sleeve monopole antenna for ultra-wideband operation," *IEE Proc.-Microw. Antennas Propag.*, Vol. 152, No. 6, December 2005, pp. 491-494.

Project #15: LTE Inverted F Antenna

The LTE inverted F antenna is to be designed on FR4 substrate. This is to be an electrically small antenna, i.e., $ka < 0.5$. The antenna must fit in a 115x60x10 mm^3 casing. The operating frequency: is 2.60 GHz with a bandwidth of 150 MHz. Gain ≥ 1.6 dBi. SWR ≤ 2.

References:

Qinjiang Rao and Dong Wang, "A compact dual-port diversity antenna for long-term evolution handheld devices," *IEEE Transactions on Vehicular Technology*, vol. 59, no. 3, March 2010.

Gopinath Gampala, Oliver Stäbler, Thomas Hager and C. J. Reddy, "Compact antenna for LTE mobile phone applications," *Microwave Journal*, March 11, 2012.

Review Projects (includes a report and a 40-minute lecture)

Suggested Topics:

The Fundamental Limitations of Small Antennas

Review of Smart Antenna Technology in Modern Wireless Communications

Review of Ultra-wideband Antenna Technology for Wireless Communications

Review of Antennas for Biomedical Microwave Imaging

NOTE:
BONUS OF 10 % TO THE MARK OF THE PROJECT IS GIVEN TO STUDENTS WHO FABRICATE THEIR ANTENNA.