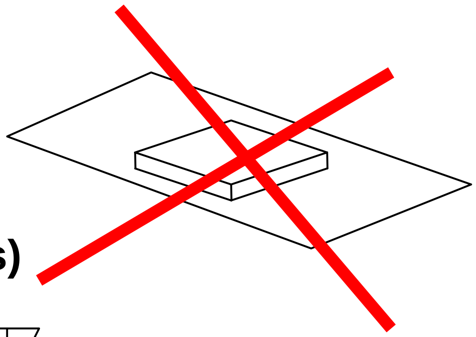
Application Notes
Antenna Issues

2005-02-25/TS

Antenna characterization

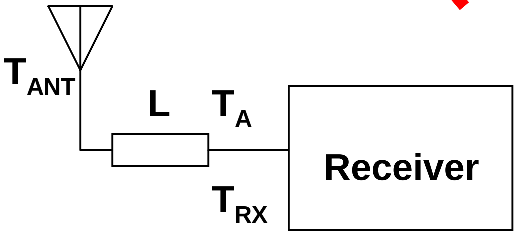
Axial Ratio (AR)

- Describes the quality of the Circular polarization
- GPS signal is RHCP (Right Hand Circularly Polarized)
- Patch: Avoid unsymmetrical GND planes (AR degrades)



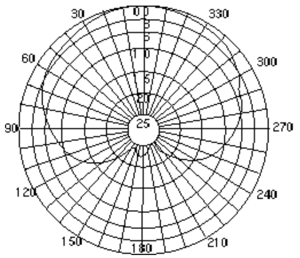
Radiation Efficiency

- Describes the loss of the antenna element itself
- Typically 0dB ... –6dB, bigger size is usually better



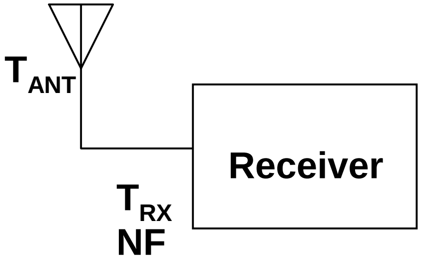
Antenna Directivity

- Generally referred to as Radiation Pattern
- Scales the received signal level
- Patch: Depends on ground plane size, bigger is better



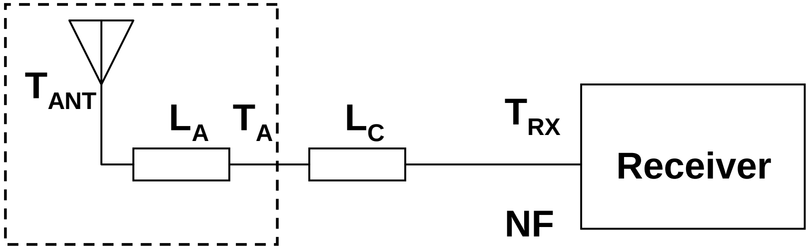
Antenna Noise Temperature T_{ANT}

- Average noise integrated over all angles
- Sky is effectively very cold, earth is warm
- E.g. with good antenna T_{ANT} = 70 K (Patch outside)
- GPS simulator: $T_{ANT} = T_O$ = 295 K



Passive & Active Antenna

Passive antenna

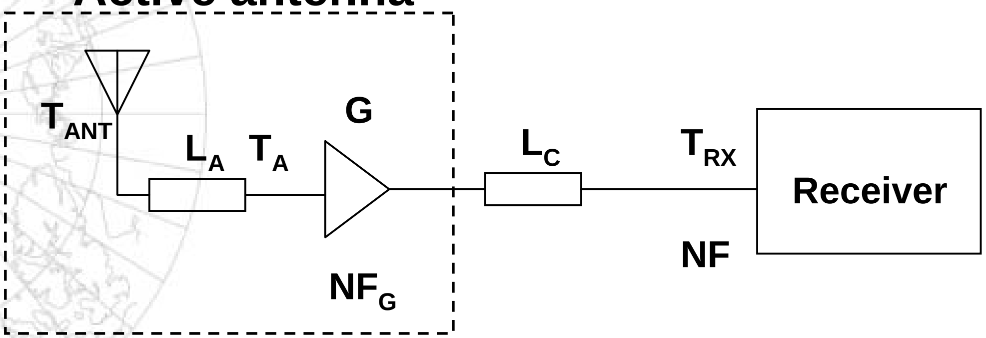


L_A = antenna element loss
L_C = cable loss

$NF_{TOT} = L_A + L_A * L_C + NF * (L_A + L_C)$ (plain numbers, not dB)

Additional cable loss (L_C) between antenna and receiver degrades the NF of the receiver. Keep L_C at minimum, preferably <1dB.

Active antenna



L_A = antenna element loss
L_C = cable loss

$NF_{TOT} = L_A + NF_G * L_A + L_C /(G + 1/ L_A)$ (plain numbers, not dB)

Amplifier (active antenna) compensates for the cable loss L_C

smart positioning

Live signal vs. Simulator

LIVE SIGNAL WITH PATCH ANTENNA (How much signal is there actually?)

Signal power from a satellite at high elevation + antenna directivity

- C = -126 dBm + 5 dBi = -121 dBm

Receiver Noise power

- Source is good antenna: $T_{ANT} = T_O = 70$ K (Patch outside)
- Receiver NF = 2 dB -> $T_{RX} = 172$ K
- System Noise Temperature $T_{SYS} = T_{RX} + T_{ANT} = 242$ K
- Normalized Noise Power N = -199 dBm/Hz-K + 10*log(242 K) dB = -175 dBm/Hz

⇒ C/N = (- 121 + 175) dBHz = 54 dBHz (Calibrated at the antenna input)

- Note that the calibration point may differ, some receivers like iTrax calculate C/N at the raw data after the correlator

SIMULATOR ENVIRONMENT (What is 54dBHz in simulator use?)

C/N = 54dBHz

Receiver Noise power

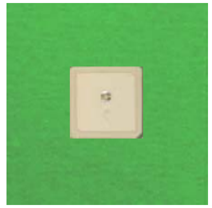
- Source is GPS simulator: $T_{ANT} = T_O = 295$ K
- Room Temperature Noise Power $N_0 = -174$ dBm/Hz
- Receiver NF = 2dB -> N = -172 dBm/Hz

Signal power, nominal

⇒ C = 54dBHz – 172dBm/Hz = -118dBm

Fastrax

Antenna comparison

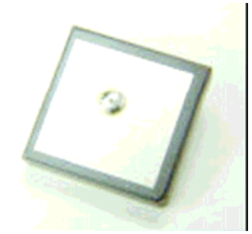




	25x25mm Patch on 70x70mm GND	18x18mm Patch on 25x25mm GND	18x18mm Patch on 25x50mm GND	Sarantel Helix	ACX Multilayer Chip Antenna	Monopole	Dipole
Axial Ratio	1	1	10	1	N/A	N/A	N/A
Front-to-back Ratio	15dB	1dB	1dB	15dB	-	-	-
Radiation Efficiency	90 %	75 %	75 %	25 %	75 %	80 %	100 %
Antenna Gain							
Up	+5dBi	+1dBi	+1dBi	-2dBi	0dBi	+1dBi	+2dBi
Horizon	-3dBi	-7dBi	-7dBi	-7dBi	-2dBi	-	-
Down	-10dBi	0dBi	0dB	-17dBi	0dBi	-	-
Antenna Noise Temperat	70K	180K	180K	250K	180K	180K	150K
GND Dependent	Yes	Yes	Yes	No	Yes*	Yes	No
Polarization	RHCP	RHCP	Linear	RHCP	Linear	Linear	Linear
Polarization Mismatch	0dB	0dB	-3dB	0dB	-3dB	-3dB	-3dB
Max S/N (dBHz)	54	50	47	45	47	46	47

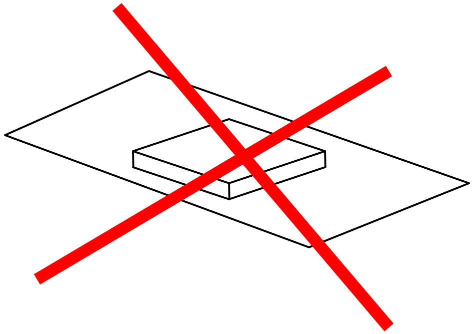
*** = Near field sensitive, performance depends on installation**

Patch antenna



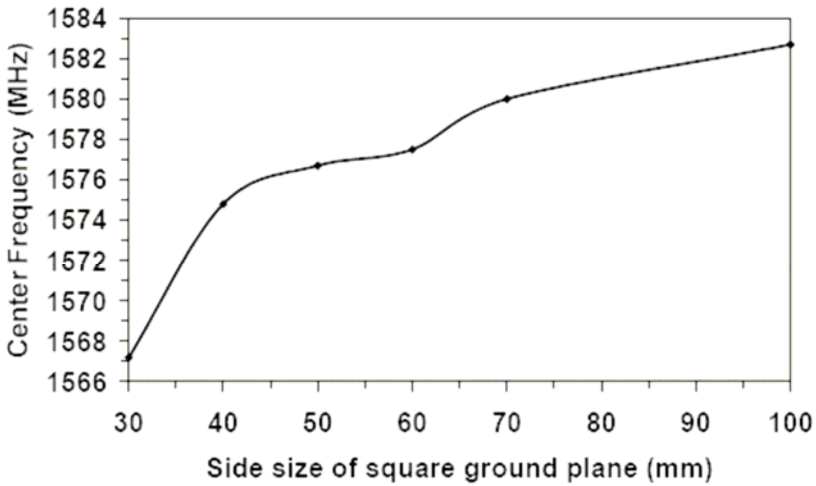
Patch antenna element

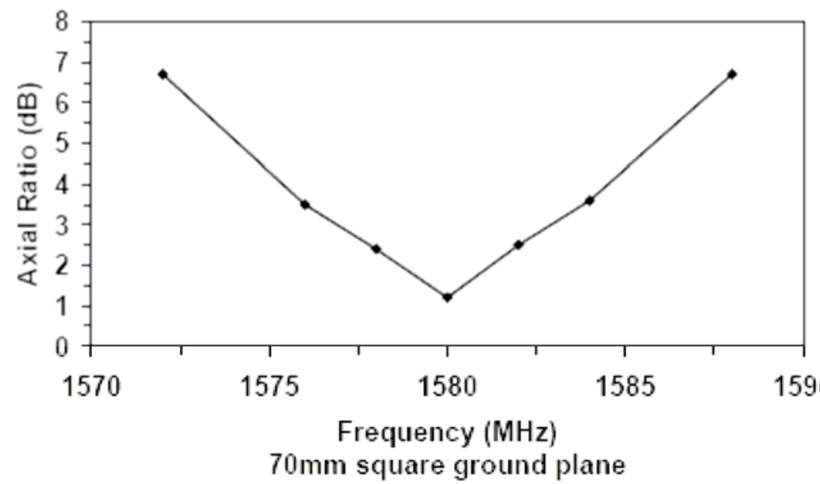
- Most popular GPS antenna
- Requires a symmetrical ground plane
  - Ground plane size affects directivity & resonance frequency
  - The element must be specified for the specific ground plane size
  - Plastic cover (radome) tends to shift the resonance about 3…5MHz down
  - Circular polarization is generated by a 90 degree phase offset between two orthogonal resonances
    - Ground plane symmetry is required for good Axial Ratio (AR) of the Circular Polarization
    - *Avoid unsymmetrical ground planes*

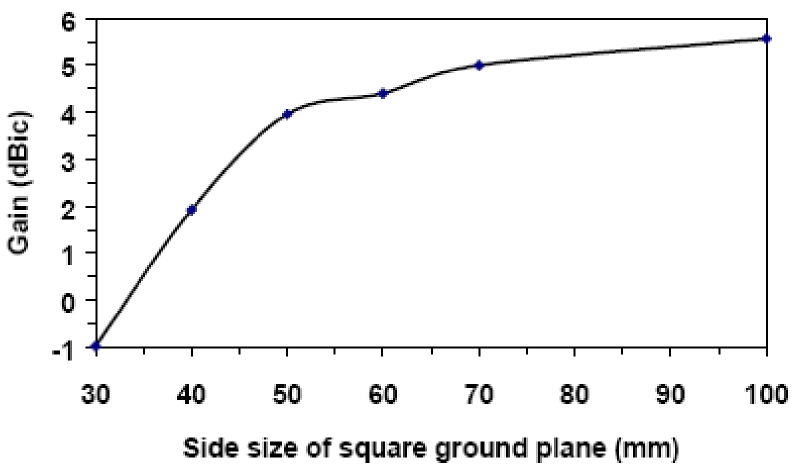


Patch antenna

Patch antenna element (Data: Inpaq I4)







EMI Issue

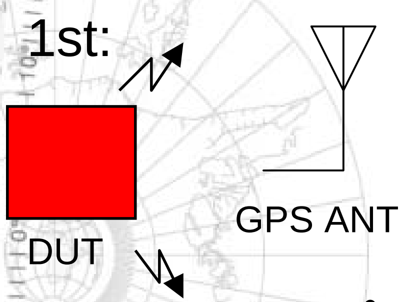
EMI issue with GPS

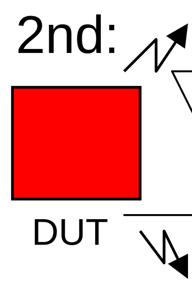
- External host processor may emit noise up to GPS L1 frequency
  - E.g. PDA & High speed CPU bus traffic
  - Nearby GPS antenna picks up the EMI noise
  - External noise degrades GPS signal levels due to increased noise floor
  - End effect: reduced sensitivity & acquisition & number of Satellites, increased HDOP, degraded accuracy; even total blockage of GPS signals

EMI Issue

Is there an EMI problem in my design?

- **EMI level can be checked easily with any existing Host CPU hardware:**
  - **Use the Evaluation Kit with the GPS Workbench (WB) and move the GPS antenna from free space close to the intended position in the application; the host CPU should be running with high load**
  - **Check if the WB shows a significant change in the receivers Automatic Gain Control (AGC) settings between free space & application**





=>

I [rf-adc]	Q [rf-adc]	I-Meas [%]	Q-Meas [%]
E-1	E-1	38.9	38.9
E-0	E-0	34.1	34.1
C-1	C-1	37.5	37.5
8-2	8-2	38.0	37.9

System | Gain Control | iTrax

  - **Note that a change seems not to be linear between coarse gain steps**
  - **Coarse step is 8dB denoted by the 1st HEX number 0, 8, C, E, F**
  - **Fine step is 2dB denoted by the 2nd number 0,1,…7**
  - **An AGC change by several fine or coarse steps indicates a noise floor increase and therefore EMI problem**
- **Avoid EMI problem by shielding the host CPU & Memory & Bus**

Internal EMI

Local Oscillator (LO) leakage

- EMI problem can be caused internally, especially when the GPS antenna is close to the module:
  - The RF down-converter uses direct down-conversion to base-band signal
  - Thus LO-signal is on the L1 GPS frequency band
  - The LO-signal may leak from the power supply and from all I/O pins back again to the GPS antenna causing problems
  - Follow the instructions in the Technical Description of the receiver
    - At least 4-layer PCB with a solid GND plane
    - I/O filtered with serial resistors placed close to the module
    - Power supply pins decoupled with a capacitor placed close to the module