Technical Training

Low Frequency Antenna Design

LF Antenna Design

- Custom Antenna Design
  - There are many reasons why integrators may wish to make their own Low Frequency antennas:
    - The application needs special sized antennas
    - The antennas must be built into structures/equipment
    - The field needs to be more localized
    - Larger loops are needed to cover a wide area (road loops)
  - Another reason may be to achieve a greater reading distance but integrators are advised that reader antenna size is only one factor. Factors that influence read range include:
    - The size and shape of the tag's antenna
    - The size and shape of the reader's antenna
    - Environmental noise
    - The transmitter power (limited by legislation)

LF Antenna Design

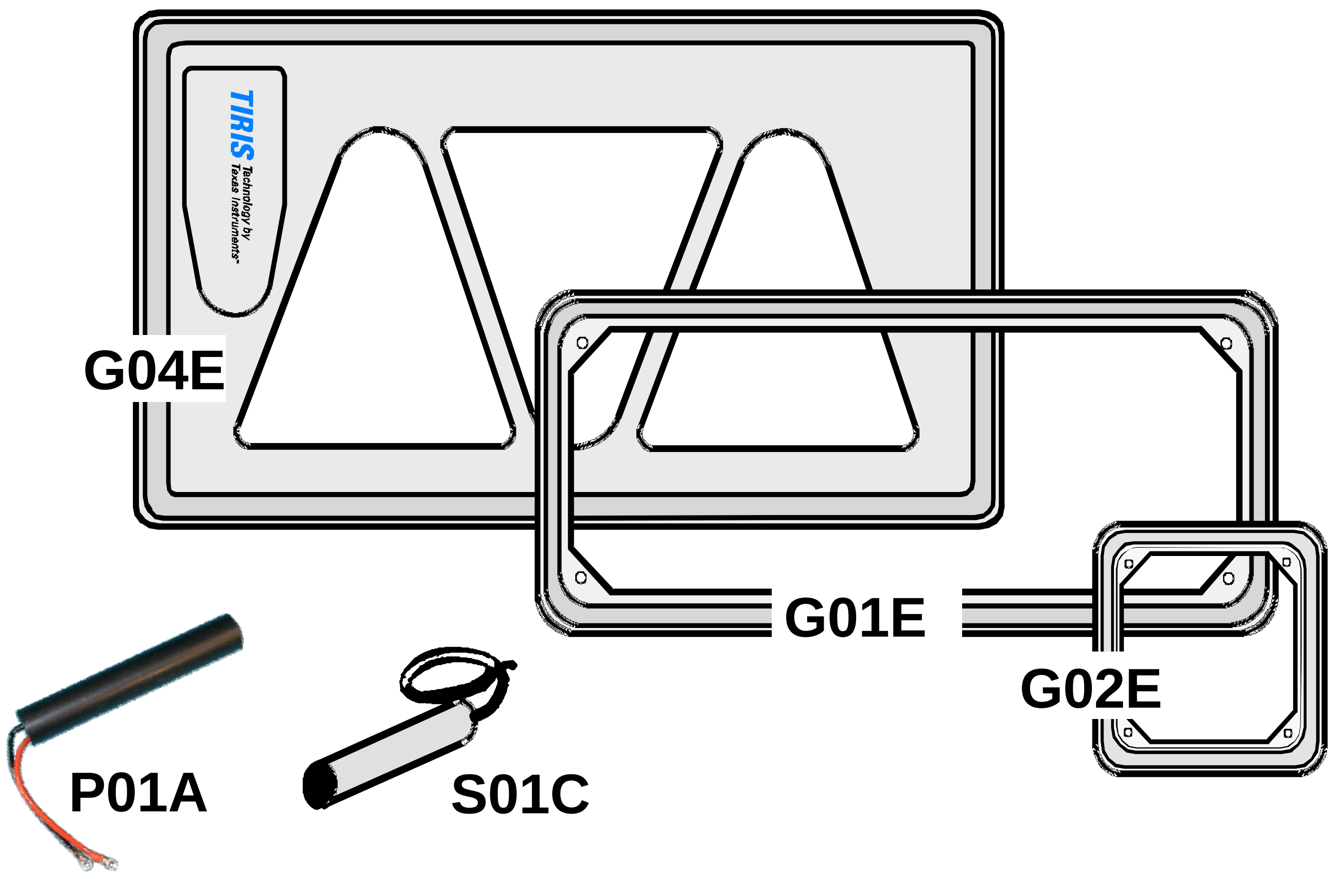
- Custom Antenna Design
  - What intending antenna designers should keep in mind is:

WARNING

Increasing the antenna size doesn't automatically lead to an increase in a tag's reading performance - it may go down. Even if it were possible to fully charge a tag at long range, the battery-free tag may not have a strong enough signal to respond back over the same distance. More usually the tag doesn't have the necessary 6 dB signal difference to be heard above the increased noise resulting from the poorer signal-to-noise ratio of the larger antenna

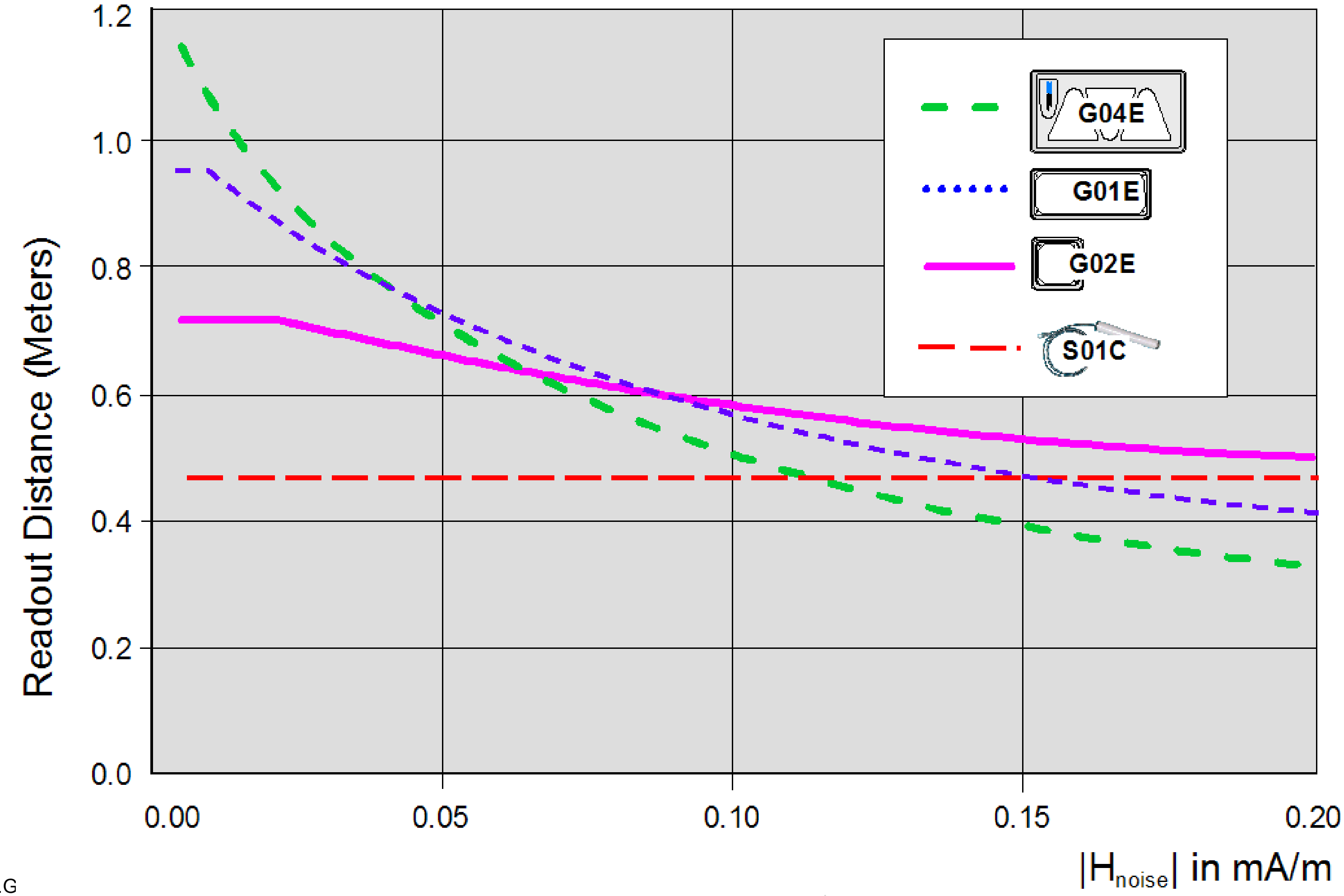
LF Antenna Design

- Standard Antennas



LF Antenna Design

- Readout Distance with Noise Vs Antenna Size



LF Antenna Design

- Resonant Frequency Calculation
  - Antennas for TI’s LF RFID readers must resonate at a frequency of 134.2 kHz

$$f_{(res)} = \frac{1}{2\pi\sqrt{LC}}$$

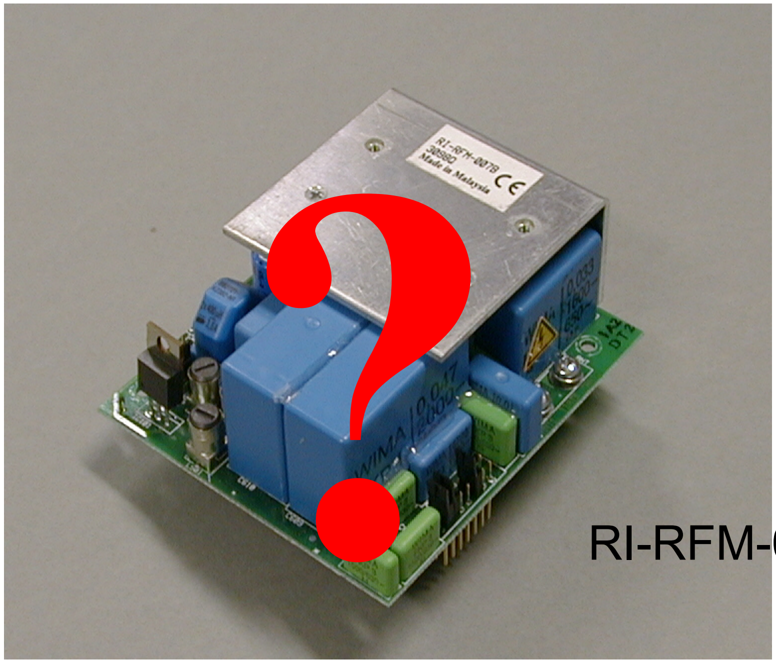
INDUCTANCE

CAPACITANCE

  - Each reader has a resonant circuit of a certain capacitance – all that is required of an antenna loop is to supply the inductance, e.g. 27 µH. If the inductance is within limits and the resistance is the correct value, the antenna will work.

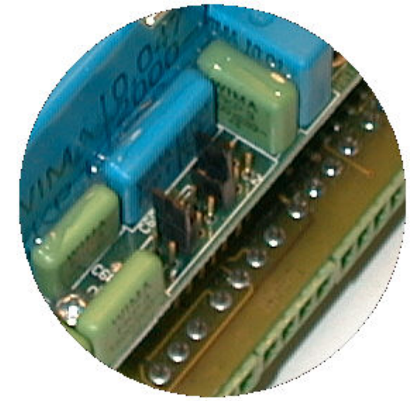
LF Antenna Design

- The Power RF Module Antenna Requirements

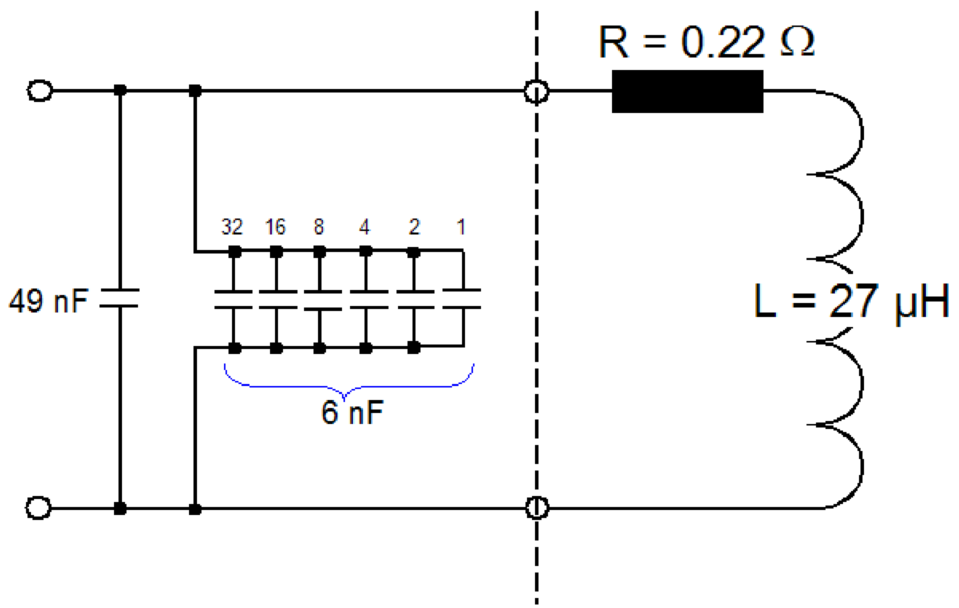


RI-RFM-007B

LF Antenna Design



- RI-RFM-007B expects its antenna to have:
  - an Inductance (L) between 25.5 µH and 28.5 µH
    - Within this range, the on-board tuning can be used

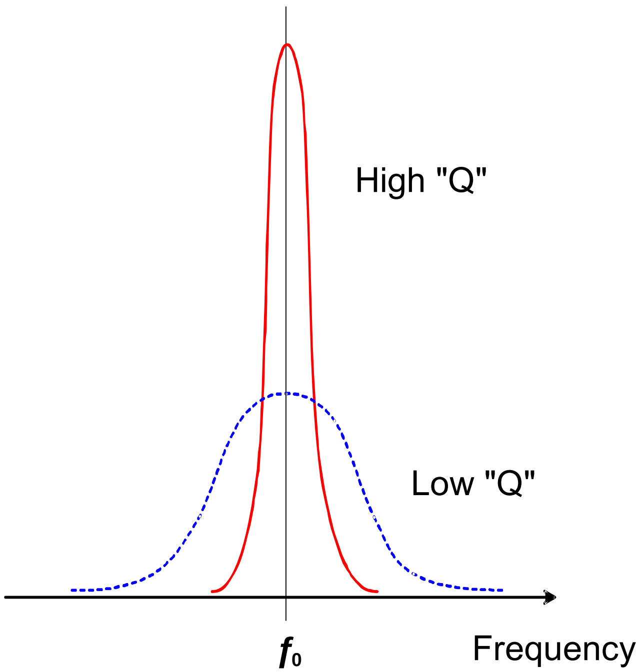


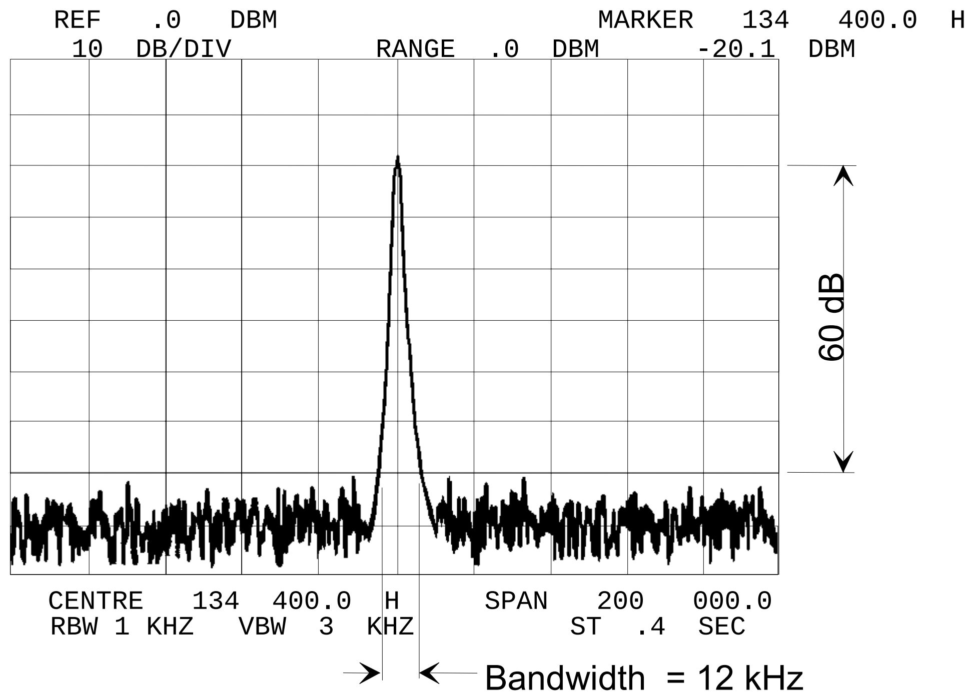
$$C = \frac{1}{(2\pi f)^2 L}$$

L (µH)	C(nF)
28.5	49
28.0	50
27.5	51
27.0	52
26.5	53
26.0	54
25.5	55

LF Antenna Design

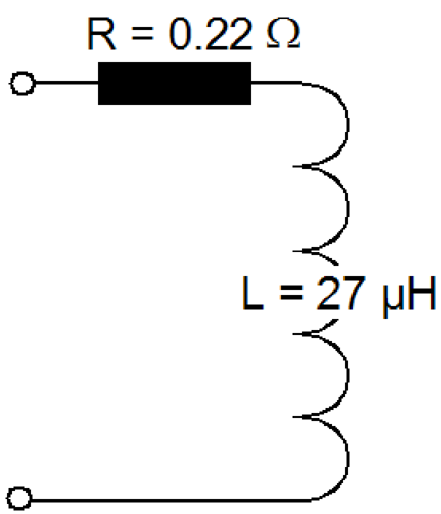
- RI-RFM-007B expects its antenna to have:
  - a high quality factor (**Q**) [typically 100]
    - A high Q gives increased performance
    - Increased immunity to noise





LF Antenna Design

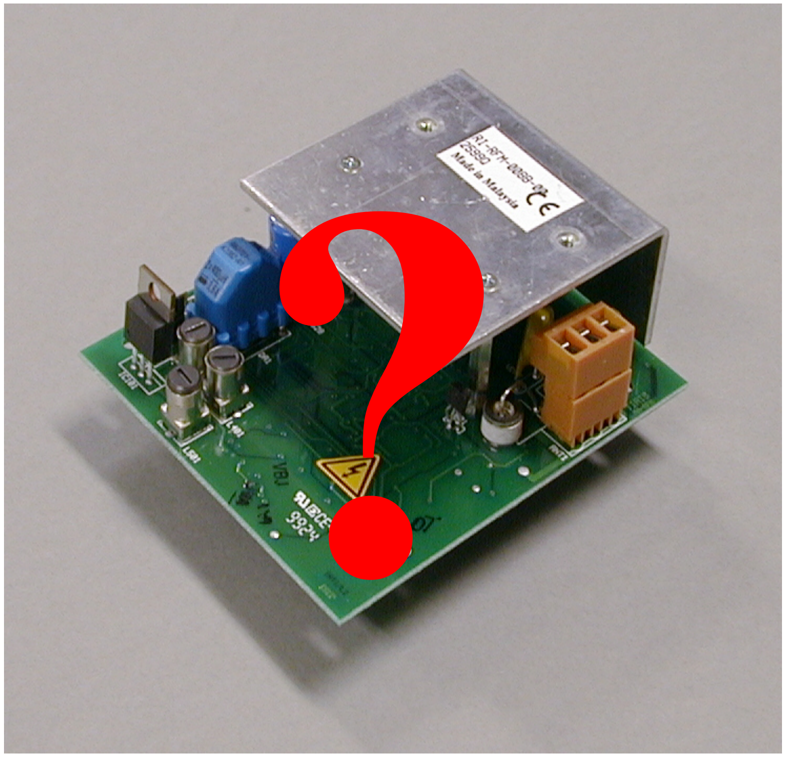
- RI-RFM-007B also expects its antenna to have:
  – a low resistance (R) [typically < 0.3 Ohm]
    - As the resistance rises, the Q factor drops and performance is less.

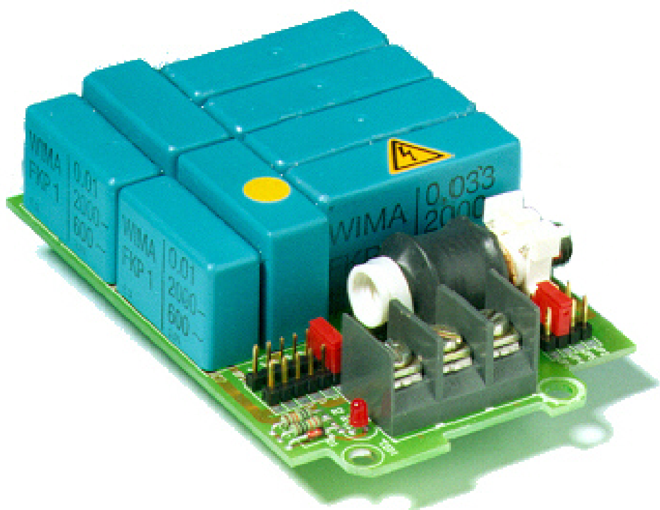


$$Q = \frac{(2\pi f)^2 L}{R} = 103$$

LF Antenna Design

- RI-RFM-008B Remote Antenna Module





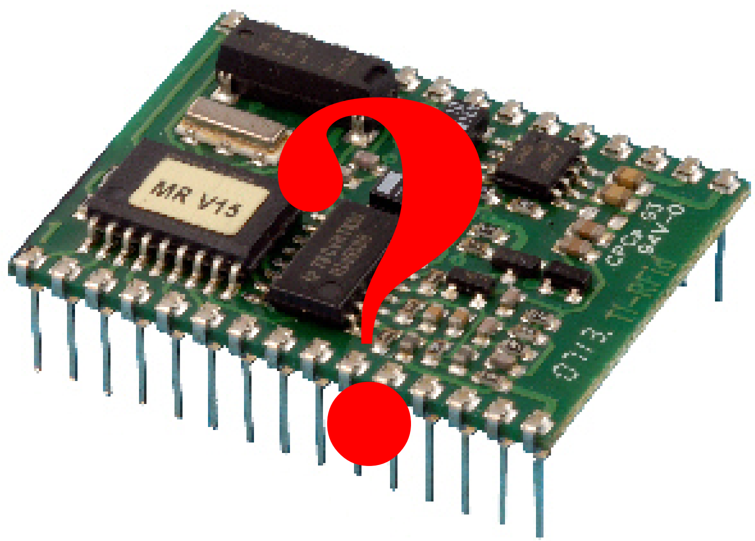
Tuning Board
(RI-ACC-008B)

LF Antenna Design

- The RI-ACC-008B tuning board expects antennas to have:
  - Inductances between 12 µH and 80 µH
    - Within this range, the Tuning-board will match antennas
    - Inductances outside this range are not recommended
  - quality factors (Q) between 30 and 100
  - low resistances (R) [typically < 0.3 Ohm]
  - tuned to resonance

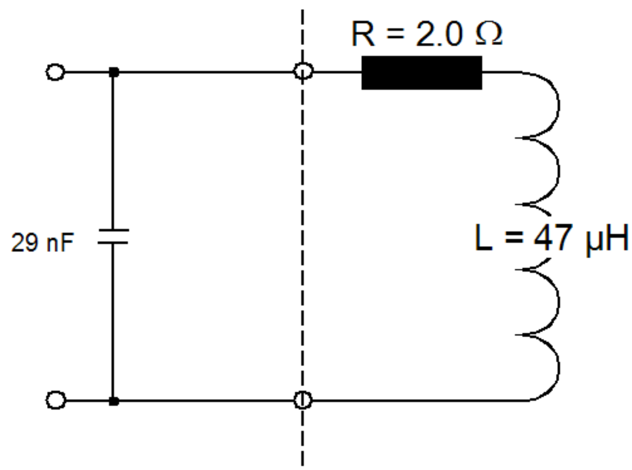
LF Antenna Design

- MicroReader Antenna Requirements



LF Antenna Design

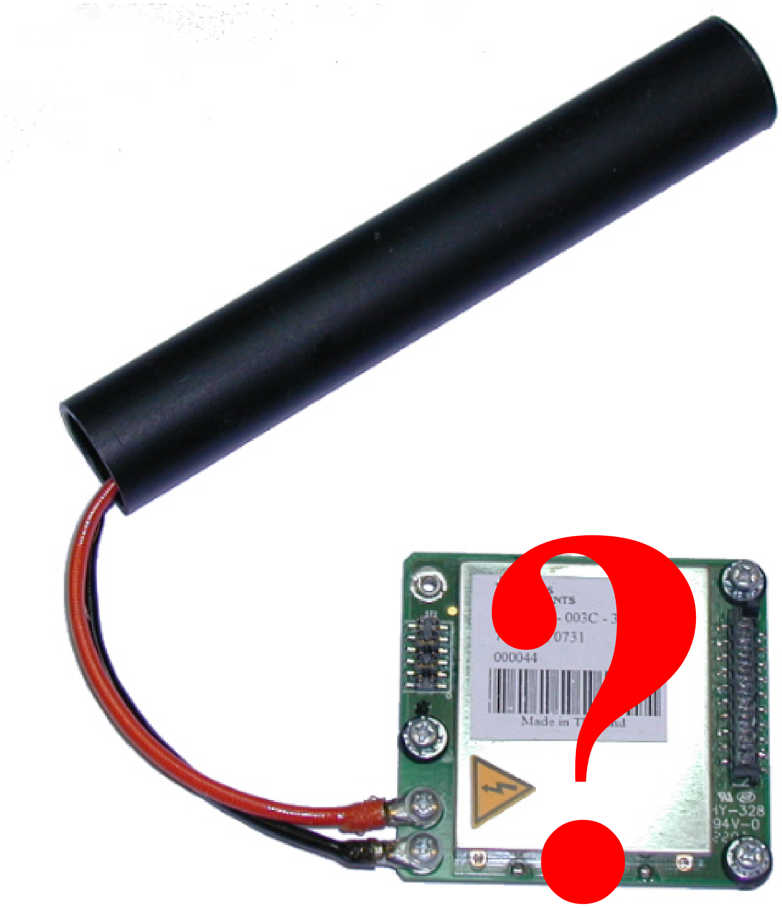
- The MicroReader expects its antenna to have:
  - an Inductance between 46 µH and 48 µH [typ. 47 µH]
    - Within this range, the Antenna will be matched



  - a quality factor typically Q < 20
  - a higher resistance [typically 2 ~ 2.5 Ohm]

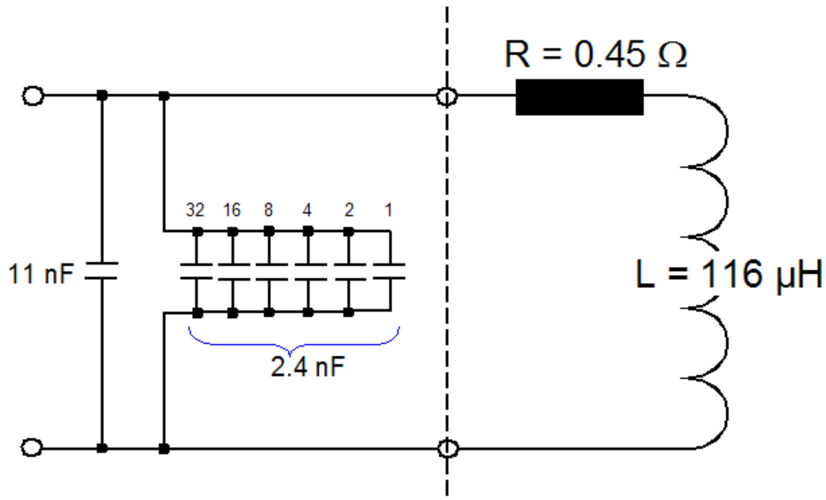
LF Antenna Design

- The Mini-RF Module Requirements:



LF Antenna Design

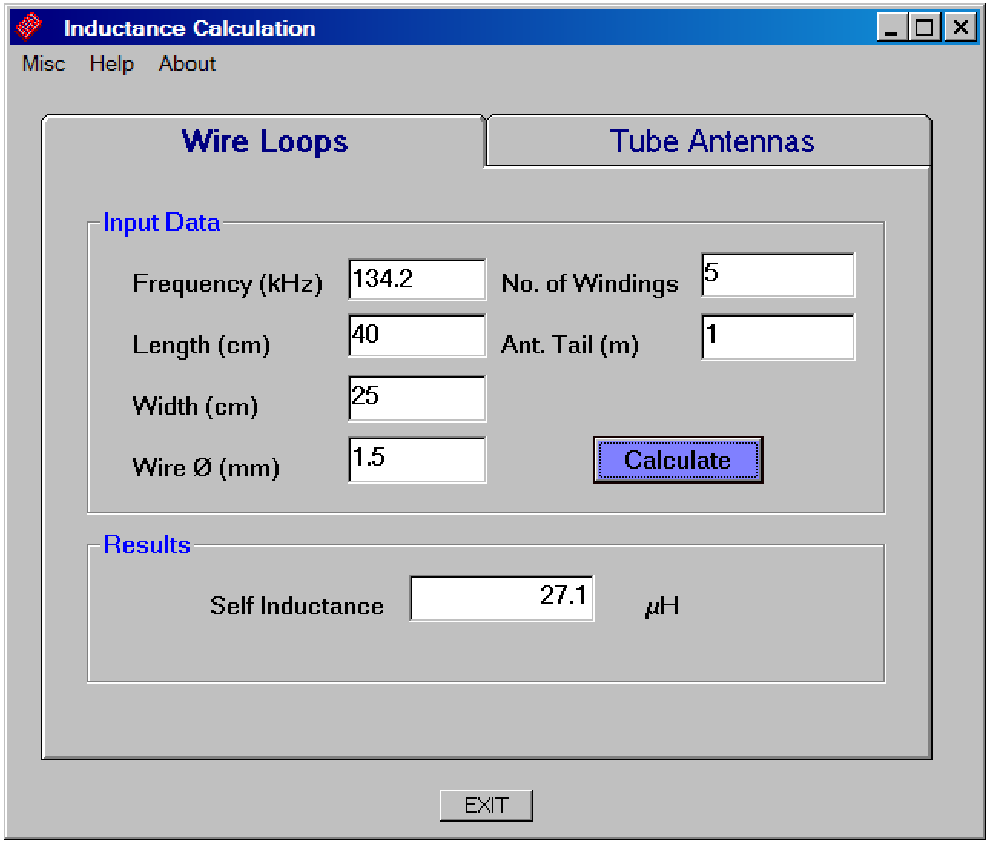
- The Mini-RF Module expects its antenna to have:
  - an Inductance (**L**) between 115 µH and 117 µH [typ. 116 µH]
    - Within this range, the Antenna will be matched



  - a high quality factor [typically Q = 200]
  - a low resistance [typically < 0.5 Ohms]

LF Antenna Design

- Checking the Inductance (Calculated)
  - Using “ADU.exe”

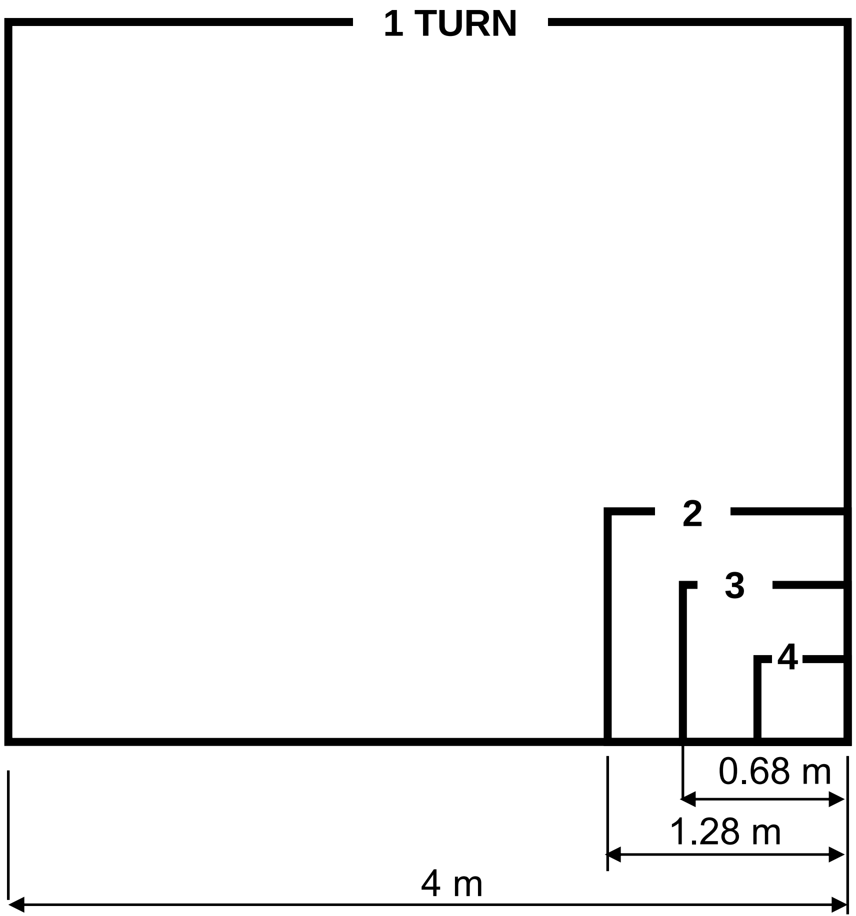


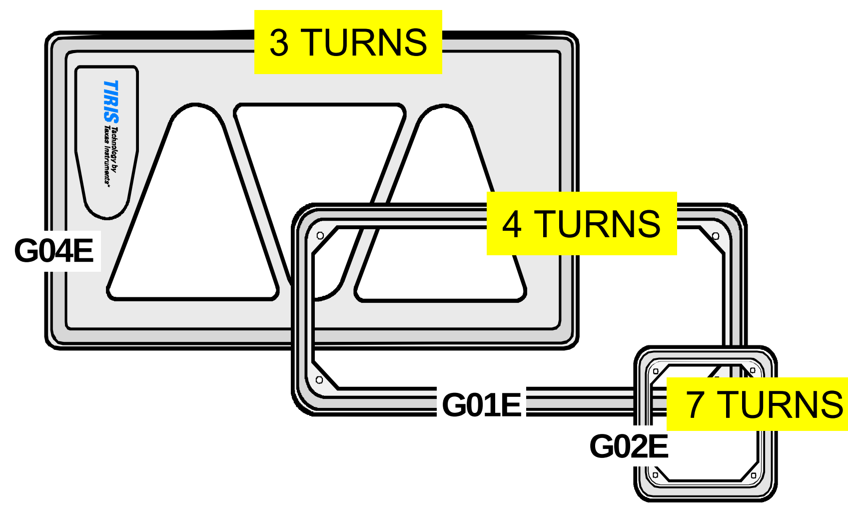
LF Antenna Design

- Checking the Inductance (Measured)
  - **Choosing an LCR Meter**
    - Frequency of operation not critical
    - Must read in the µH range (ideally a resolution of 0.1 µH)
    - Must be portable (battery operated)
    - Must be robust

LF Antenna Design

- Antennas Size vs. 27 µH Inductance





LF Antenna Design

- Quality Factor
  - The Quality (Q) Factor is a measure of the effectiveness of an antenna.
  - A high Q antenna will output a higher field strength than a low Q antenna for the same input power.
  - A high Q antenna is also a filter and will reject signals outside the bandwidth.
  - Unfortunately, the higher the Q, the more easily the antenna is de-tuned by the presence of metal.
  - The MicroReader is intended for low Q antennas that are mounted next to the metal cylinders of door and ignition locks

LF Antenna Design

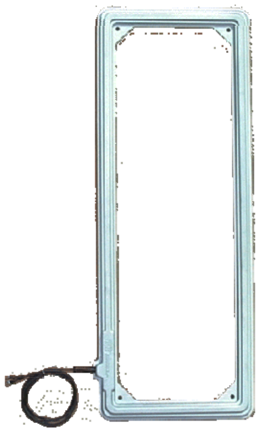
- Quality Factor Calculation
  - The Quality (Q) Factor of an antenna is given by

$$Q = \frac{2\pi f L}{R}$$

  - Where
    - π = 3.142
    - f = 134200 Hz (134.2 kHz)
    - L = Self inductance (henry)
    - R = Resistance @ 134.2 kHz
  - Although the resistance should be measured at 134.2 kHz because of the increasing skin effect with frequency – nevertheless this formula will give a good approximation of the Q when R is measured as a DC resistance

LF Antenna Design

- Quality Factor Examples



Standard TIRIS G01E

f = 134200 hertz
π = 3.142
L = 0.0000275 henry
R = 0.22 Ω

MicroReader Low-Q Antenna

f = 134200 hertz
π = 3.142
L = 0.000048 henry
R = 2.3 Ω

$$Q = \frac{2 \times 3.142 \times 134200 \times 0.0000275}{0.22}$$

Q = 105

$$Q = \frac{2 \times 3.142 \times 1342000 \times 0.000048}{2.3}$$

Q = 18

LF Antenna Design

- Litze wire
  - At RF frequencies the AC current in a wire is only flowing in the outer ‘skin’ because the centre of the wire is disturbed by eddy currents . As frequency increases the wire’s impedance increases. The formula below gives a reasonable approximation of the depth of this skin:

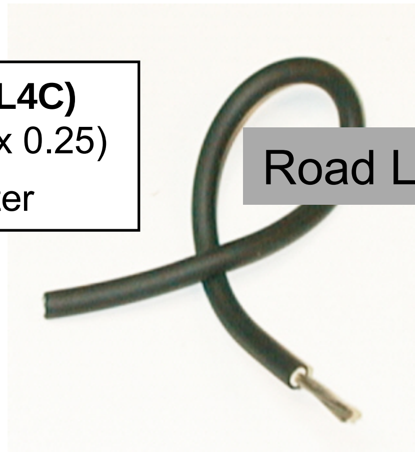
$$\frac{0.064}{\sqrt{f_{res}\,(\mathrm{Hz})}} \qquad \text{e.g.} \quad \frac{0.064}{\sqrt{134200}} = 0.17\ \mathrm{mm}$$

  - To maintain a high Q, it is importance to keep the resistance low and Litze wire is a low resistance wire because it is composed of hundreds of individually insulated wires, each around 2 × skin depth and covered in a thin silk sheaf.
  - It is ideal for small antennas, as it is compact and low resistance.
  - On the downside though, Litze wire is expensive, difficult to work and tends to be brittle. There are few suppliers.
  - It is not recommended for larger (lower Q) antennas where it has few advantages over regular wire.

LF Antenna Design

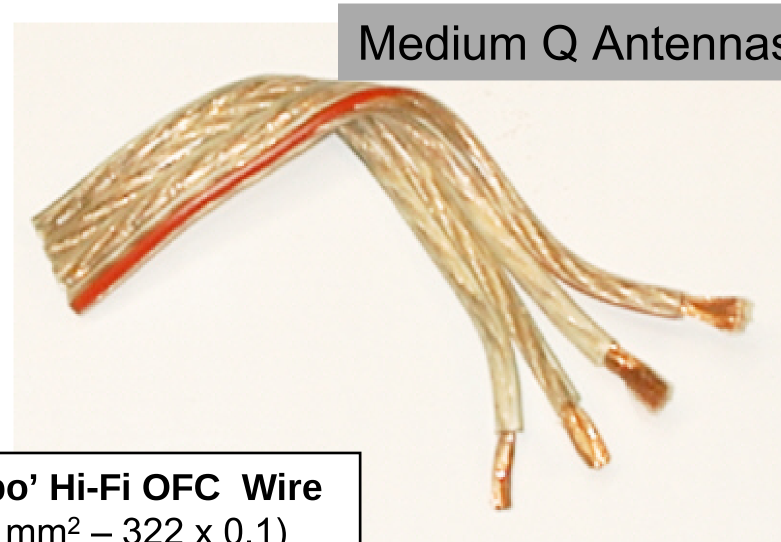
- Which wire?

Road Loops



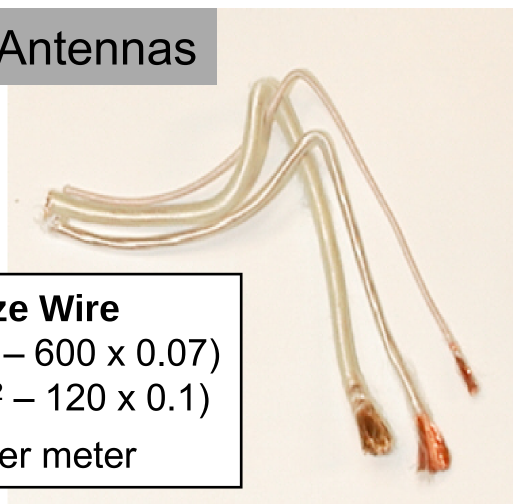
Coil Wire (CL4C)
(2.5 mm² – 50 x 0.25)
1x per meter

Medium Q Antennas



'Jumbo' Hi-Fi OFC Wire
(2.5 mm² – 322 x 0.1)
2x per meter

High Q Antennas



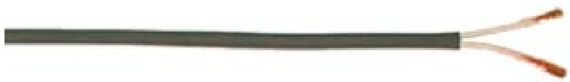
Litze Wire
(2.5 mm² – 600 x 0.07)
(1.5 mm² – 120 x 0.1)
6x per meter

Low Q Antennas

Polyurethene Coated Copper 0.2mm (36 AWG)
x/15 metre

LF Antenna Design

- Antenna Tails
  - It is important that the two wires of the tail are tight together. In this way any signals cancel. If they are apart they will radiate.



  - **HEAT SHRINK**
    - Expensive, protective but less flexible

  - **PLASTIC BRAID**
    - Easier to apply and cheaper than heat shrink

  - **FIGURE OF EIGHT**
    - No action necessary but has a joint at the loop

  - **TWISTED**
    - Effective but adds extra wire (inductance)

  - Keep tails as short as possible as the extra resistance lowers the Q (and performance). Each meter of twin cable adds 0.5 µH. When extending standard tails, any more than 3 m will require external capacitance to tune to resonance.

LF Antenna Design

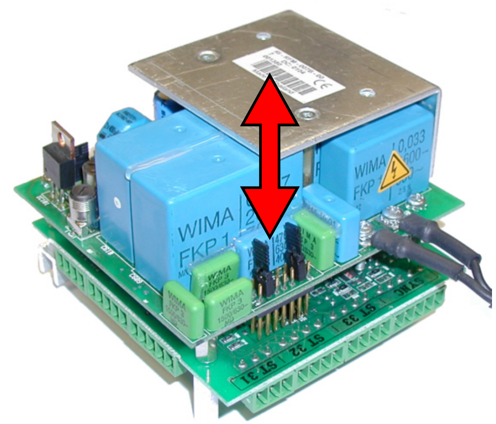
- Tuning Antennas to Resonance

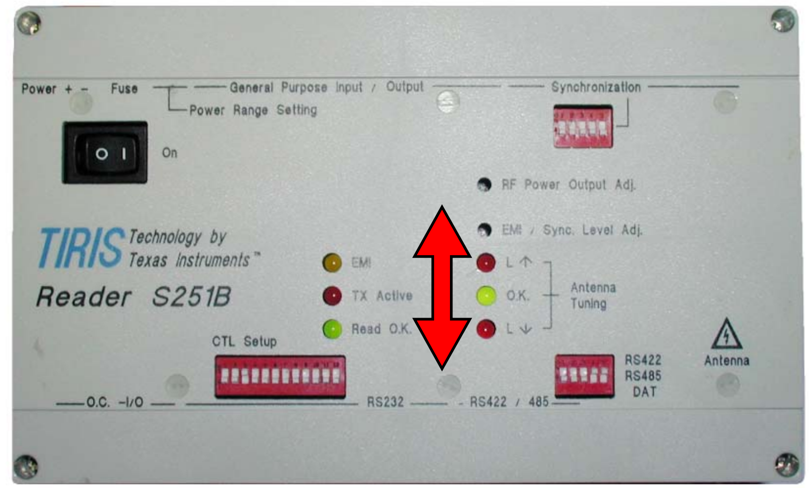
  – The Antenna Tuning Indicator greatly simplifies the tuning of antennas

Antenna Tuning Indicator (RI-ACC-ATI2)

LF Antenna Design

- Antenna will not Tune





All jumpers in / L↓
Inductance too Low
Antenna close to metal?
Increase size of loop
Make antenna narrower
Add capacitance in **Parallel**

All Jumpers out / L↑
Inductance too high
Extension added to antenna tail?
Reduce size of loop
Make antenna more square
Add capacitance in **Series**

LF Antenna Design

- Resonant Frequency Formula

$$f_{(res)} = \frac{1}{2\pi\sqrt{LC}}$$

INDUCTANCE

CAPACITANCE

  – If the inductance is too high, adding capacitance in series, or in the case of the inductance being too low, adding capacitance in parallel, will bring the antenna back into tuning range.

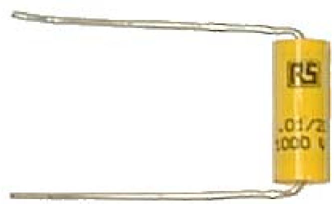
LF Antenna Design

- Extending the Reader' Tuning Range

Inductance (µH)	Capacitance (µF)	Inductance (µH)	Capacitance (µF)
51.0	0.060	25.0	0.004
48.0	0.067	24.5	0.005
45.0	0.076	24.0	0.007
43.0	0.089	23.5	0.008
41.0	0.100	23.0	0.009
40.0	0.110	22.5	0.010
39.0	0.120	22.0	0.012
38.0	0.130	21.5	0.013
37.0	0.140	21.0	0.015
36.0	0.160	20.5	0.017
35.0	0.180	20.0	0.018
34.0	0.200	19.5	0.020
33.5	0.220	19.0	0.022
33.0	0.230	18.5	0.024
32.5	0.260	18.0	0.026
32.0	0.280	17.5	0.028
31.5	0.310	17.0	0.031
31.0	0.350	16.5	0.033
30.5	0.400	16.0	0.036
30.0	0.470	15.5	0.038
29.5	0.560	15.0	0.042
29.0	0.700	14.5	0.045

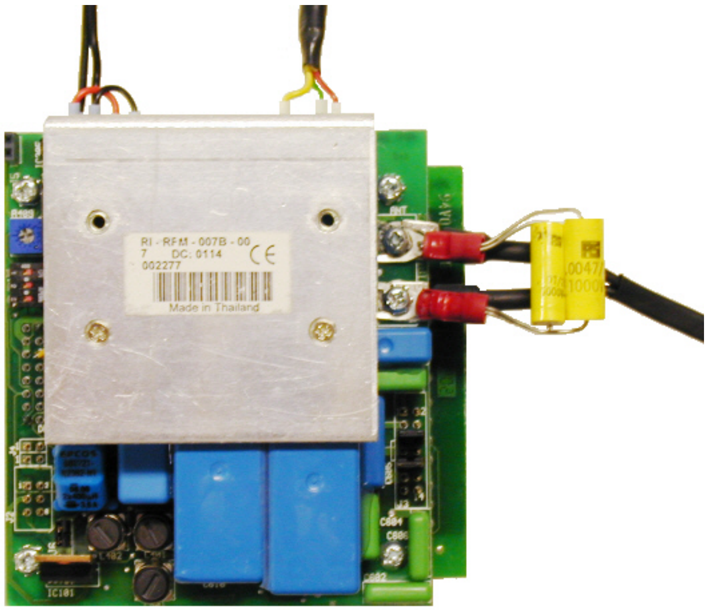
Series Capacitance

Parallel Capacitance

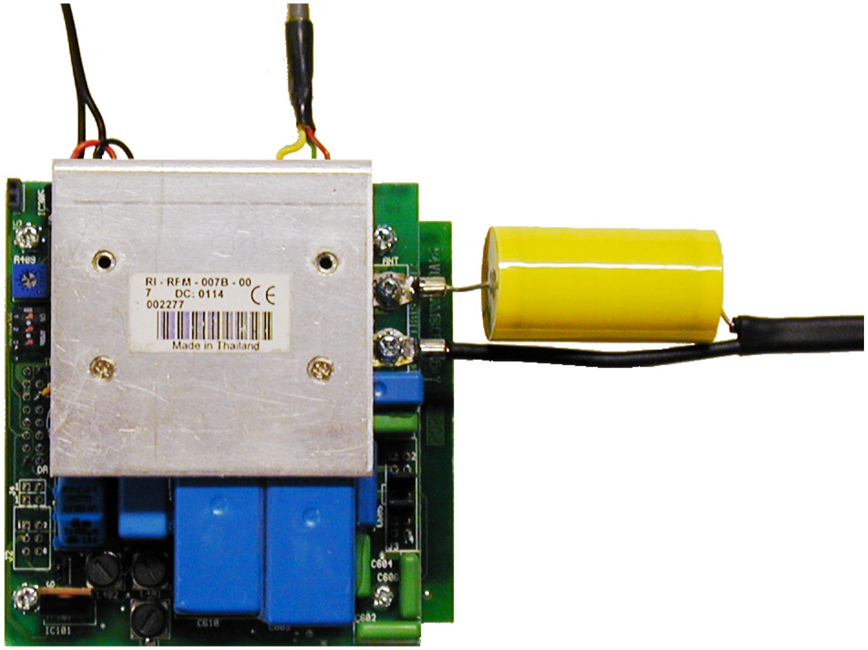


LF Antenna Design

- Extending the Reader' Tuning Range



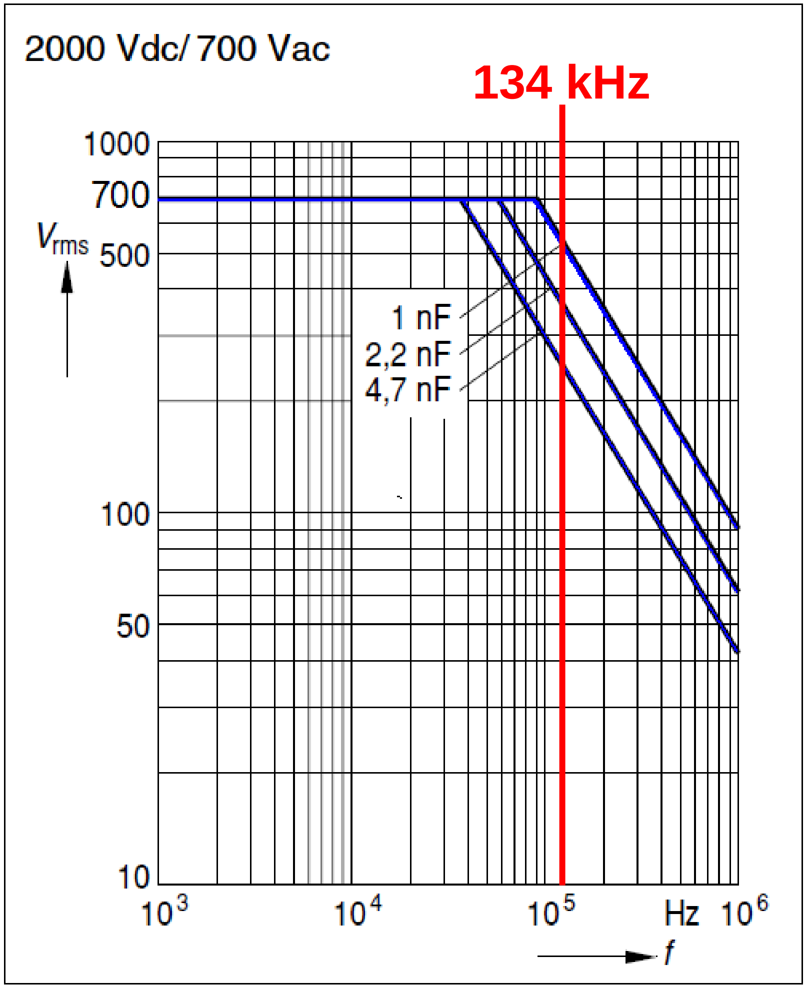
Capacitance in parallel to correct low inductance.



Capacitance in series to Correct high inductance.

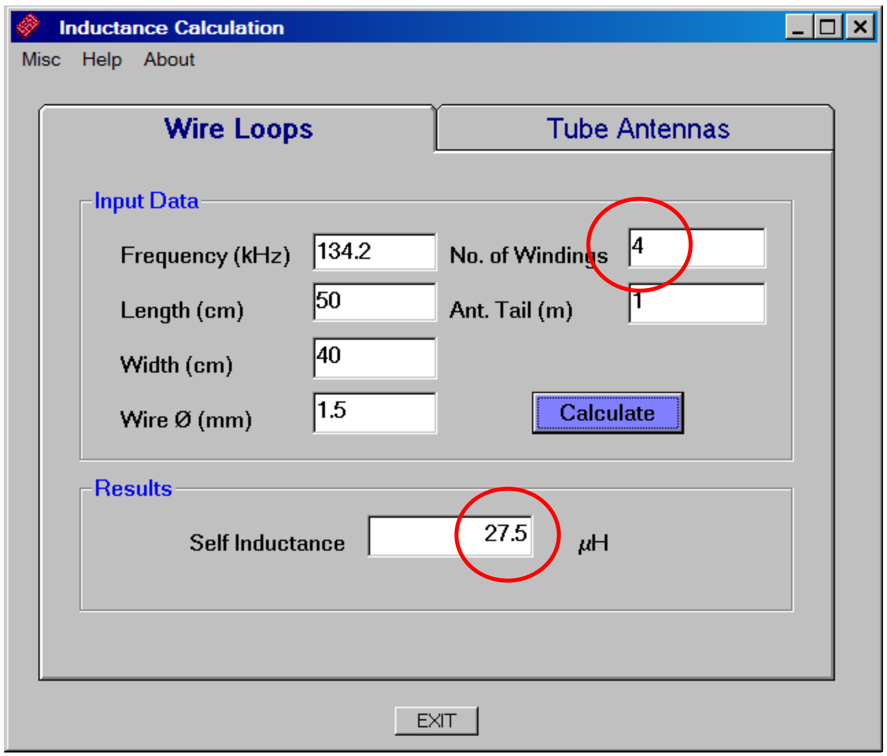
LF Antenna Design

- Extending the Inductance Range
  - High Voltage Polypropylene are capacitors required
  - The maximum voltage of these capacitors falls off sharply at 134 kHz



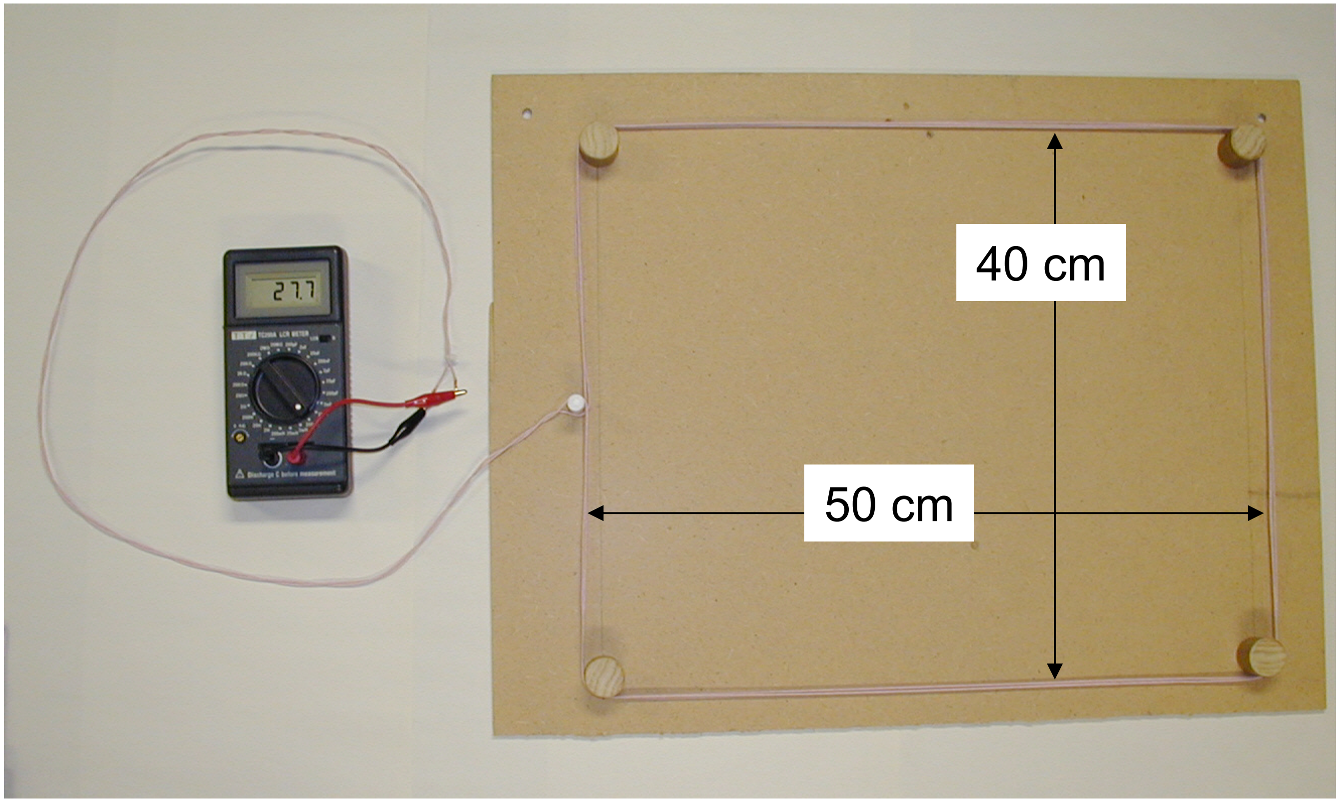
LF Antenna Design

- Worked Example
  - Make a 50-cm × 40-cm using 1.5 mm^2 Litze wire
    - Use ADU.exe to model the antenna



LF Antenna Design

– Make a former for your prototype and check the inductance.



– If the inductance is out – adjust the size of the loop.

LF Antenna Design

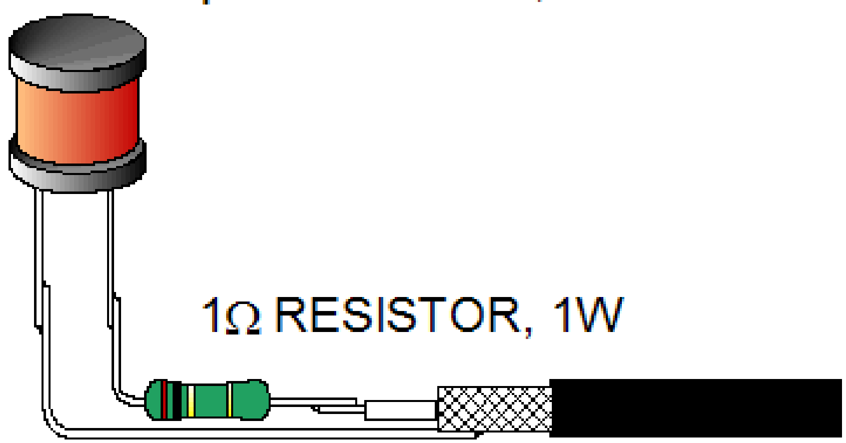
- MicroReader Antenna Designs
  - The Microreader requires 47 µH , low Q antennas. As Texas Instruments doesn't sell a separate antenna suitable for this product, details of four MicroReader antenna designs follow

Antenna	Size (mm)	Turns	Q	L (µH)	Range with 32 mm Tag
1	10Ø	n/a	17	47	40 mm
2	40Ø	28	14	47	110 mm
3	75Ø	15	18	47	160 mm
4	200 x 200	8	20	47	270 mm

  - Each antenna will be described in the following slides

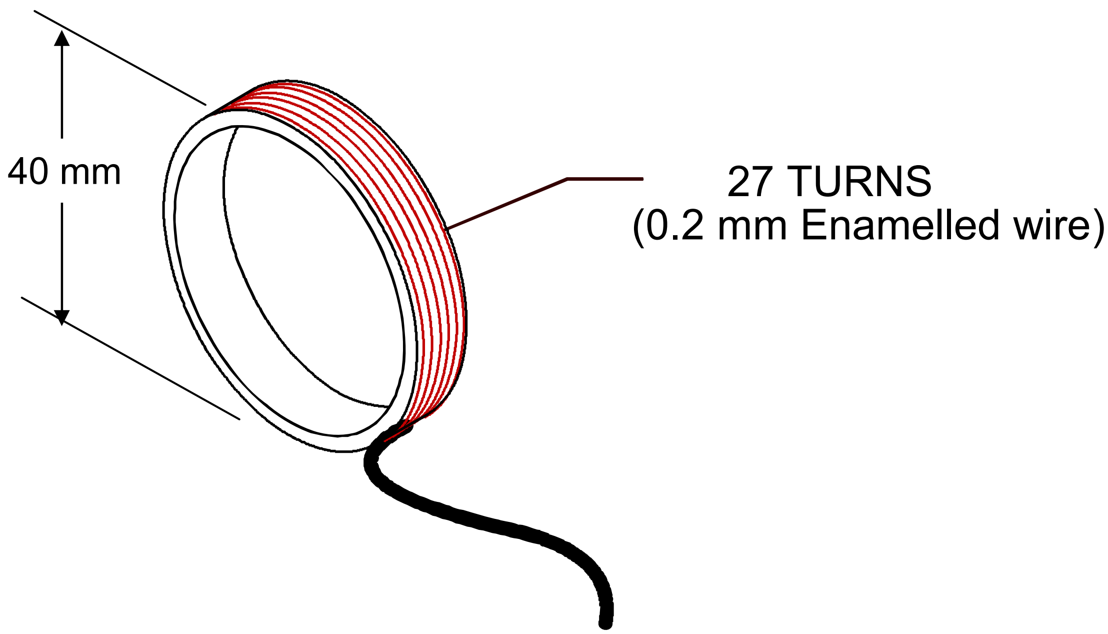
LF Antenna Design

- (1) Ferrite Cored Antenna
  - Uses catalogue parts
  - Gives localized field



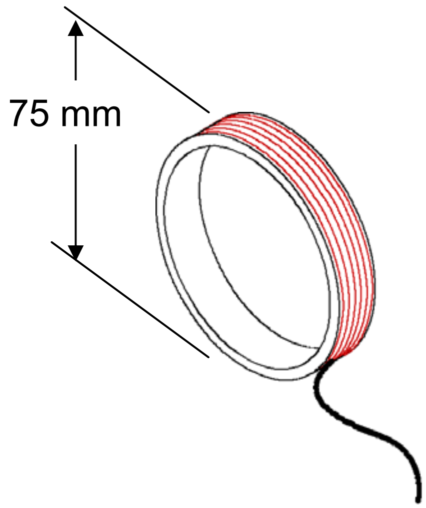
LF Antenna Design

- (2) 40Ø Antenna
  - Constructed around 40 mm plastic pipe



LF Antenna Design

- (3) 75Ø Antenna



- Wind 15 turns (item 1) around a 75 Ø former.
- Cross over the start and finish wire with approximately 50 mm free ends and secure with a small piece of tape
- Separate the braid and main conductor of the cable (item 3) wrap the loop ends 3 times around the braid and conductors respectively and solder the joints. Polarity is not important
- Tightly bind the solder joints and lead together using cloth tape

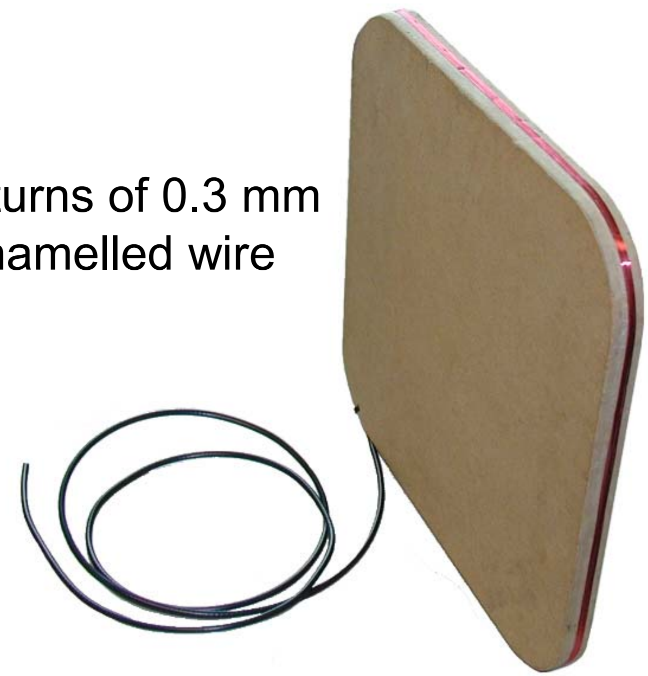
Parts List

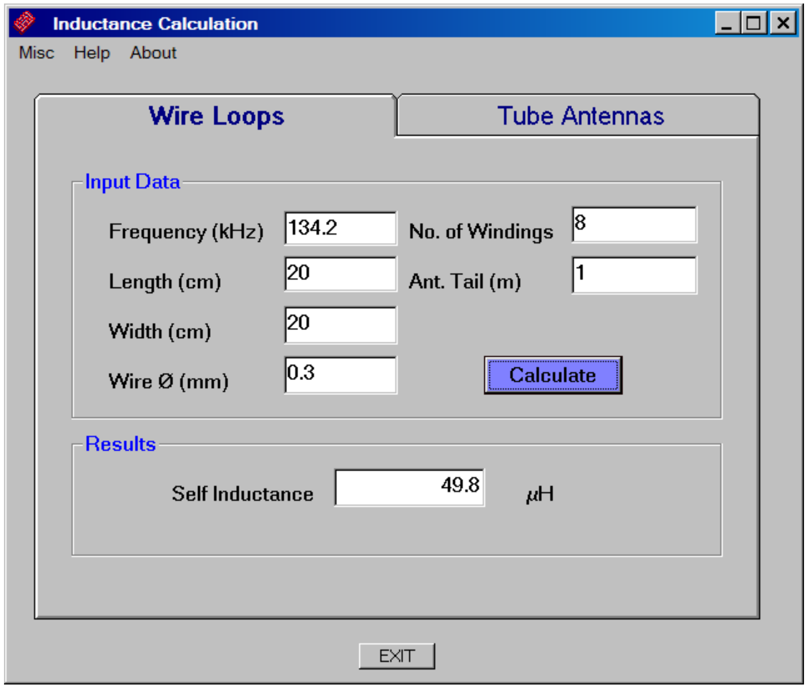
Item	Description	Qty	RS Part
1	Enameled copper wire, 0.2 mm	1.1g	357-918
2	Cloth tape, 12 mm wide	120 mm	512-301
3	Screened antenna lead	1 m	388-259

LF Antenna Design

- (4) 200 mm x 200 mm Antenna
  - Produced around an MDF former
    - Use double sided tape to retain the fine wire during construction

8 turns of 0.3 mm Enamelled wire





- Inductance is high because the Program doesn't allow for the radiused corners