Antennas for RFIC Transmitter and Receiver
Part I : Loop Antennas

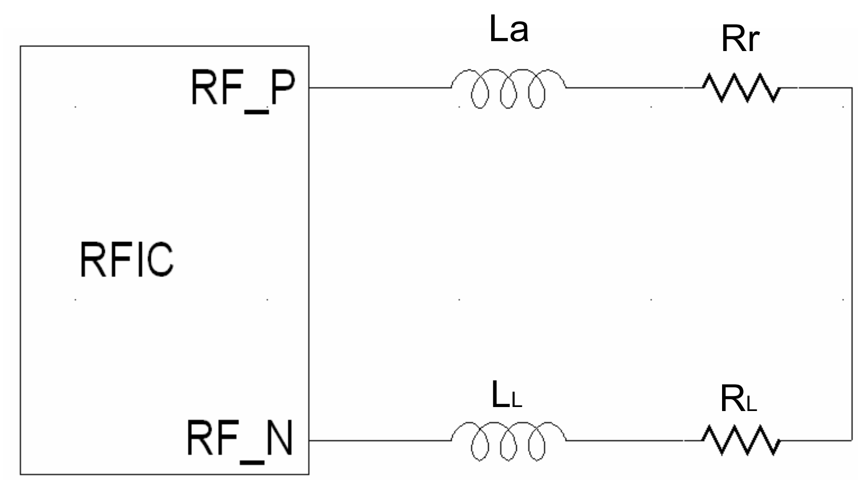
Efficiency of Small Loop Antenna

Small size printed loop antenna is widely used in many applications for RFIC transmitters and receivers. The efficiency of a loop antenna becomes a key issue for the performance of the radio, and the antenna design has become more and more important.

Since most loop antennas are very small in size, design of a loop antenna with acceptable efficiency is important.

Impedance of small loop antenna

a. Simplified Equivalent Circuit



The loop antenna input impedance Zin is given by:

$Zin=(Rr + R_L) + j2\pi f(La + Ll)\ \Omega$

Rr---------------Radiation resistance
R_L---------------Loss resistance of loop conductor (Dissipative Resistance)
La---------------Loop antenna inductance
L_L----------------Loop conductor inductance

a. Radiation Resistance, Rr

The radiation resistance of a small printed circuit board loop with area *A* at a frequency whose wavelength is λ is given by:

$Rr=320\pi^4(A^2/\lambda^4)$..........(1)

b. Dissipative resistance

The dissipative resistance in the loop, ignoring dielectric loss, is given in terms of the loop perimeter, *P*, the trace width, *w*, the magnetic permeability, $\mu = 400\pi$ nH/meter, the conductivity, σ (5.8×10^7 mohs/meter for copper is typical), and the frequency, *f*.

$R_L=(P/2w)\sqrt{\pi f\mu/\sigma}$..........(2)

The inductance of the loop is given in terms of the perimeter, *P*, the area, *A*, the trace width, *w*, and the magnetic permeability, μ.

$L=(\mu P/2\pi)\ln(8A/Pw)$..........(3)

Antenna efficiency = $Rr \;/\; Rr + R_L \approx Rr / R_L$

To increase the efficiency, we need to increase the Re and reduce R_L.

Increase the antenna dimension or frequency will increase the antenna efficiency.

Example of a small loop antenna of 25mm by 32mm, width is 0.9mm. Fig 1

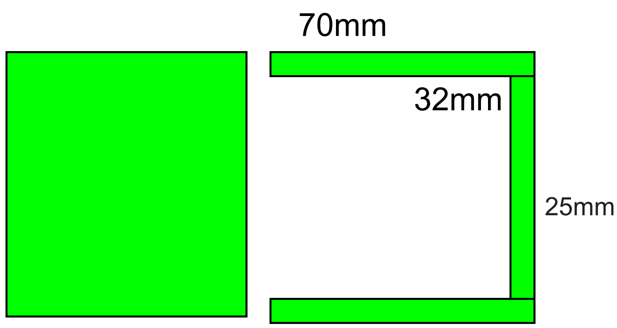


Fig.1

For 315MHz we can get

$Rr=0.025\Omega$

$R_L=0.3\Omega$

$L=95nH$

Antenna efficiency is about 8%.

For 433MHz we can get:

R_r=0.093Ω

R_L=0.35Ω

L =95nH

Antenna efficiency is about 27%

From this result we can understand, to make the antenna more efficient, the dimension of the antenna should be as large as possible. With the same PCB size, the recommended antenna pattern is showed on Fig. 2

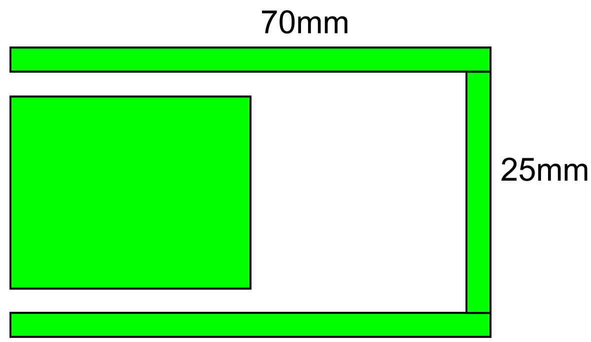
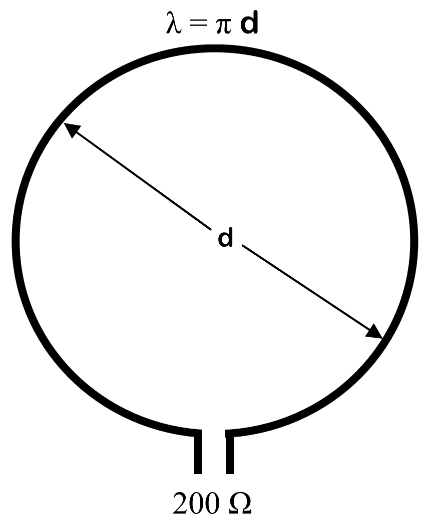


Fig.2

Comparison between monopole antenna and small loop antenna:

	¼ wave monopole	Printed small loop
Antenna Gain (dB)	-3 ~ -4	-15 ~ -20
Antenna	Resistive	Inductive
Matching Circuit	No need	Capacitive
Antenna impedance	Low	High
Required RF power For the same ERP	1	1.5—2

Example of Small Loop Antenna



1. Round Loop Antenna

   C= πd =λ…………….(4)

   Rr≈200 Ω…………….(5)

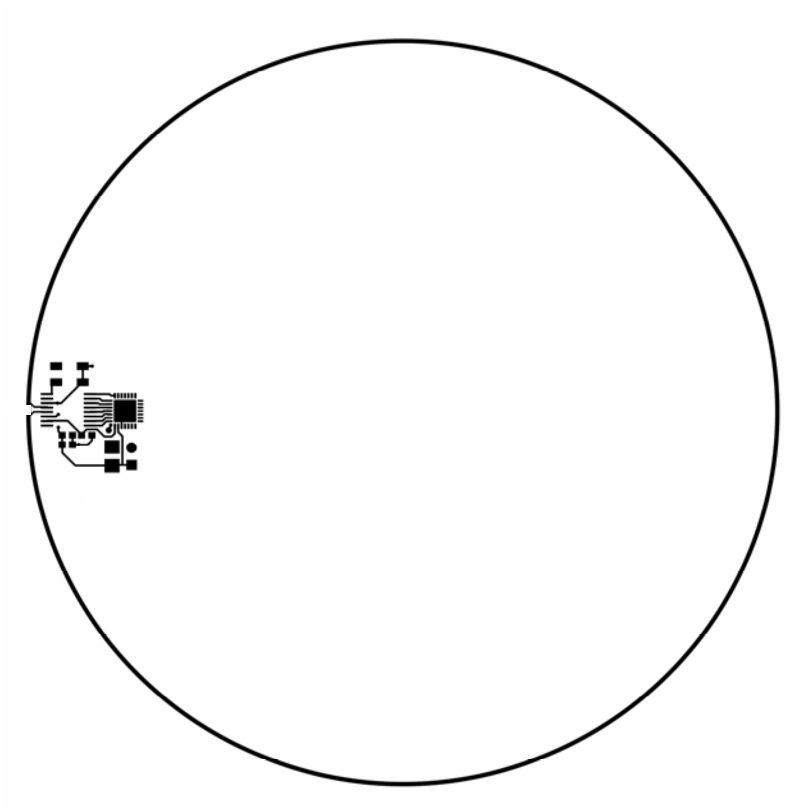
Example of Round Loop Antenna for 868MHz

F=868MHz, λ=0.34m

From equation (4)

d= λ/π=0.34/3.14=0.0108m≈11cm

The 868MHz round loop antenna is showed on Fig. 3



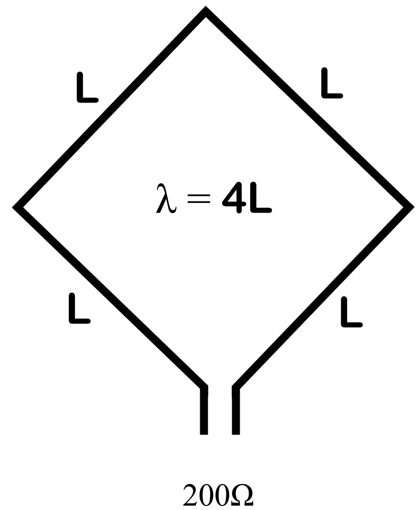
I ----------------------------- 11cm ----------------------------- I

Fig. 3 Round loop antenna for 868MHz

2. Square Loop Antenna

   C=4L= λ……………...….(6)

   Rr≈200 Ω………….….(7)



Example of Square Loop Antenna for 916MHz

F=916MHz   λ=0.33m

From equation (7)

L= λ/4=0.33/4=0.081m≈8.1cm

The 916MHz square loop antenna is showed on Fig. 4

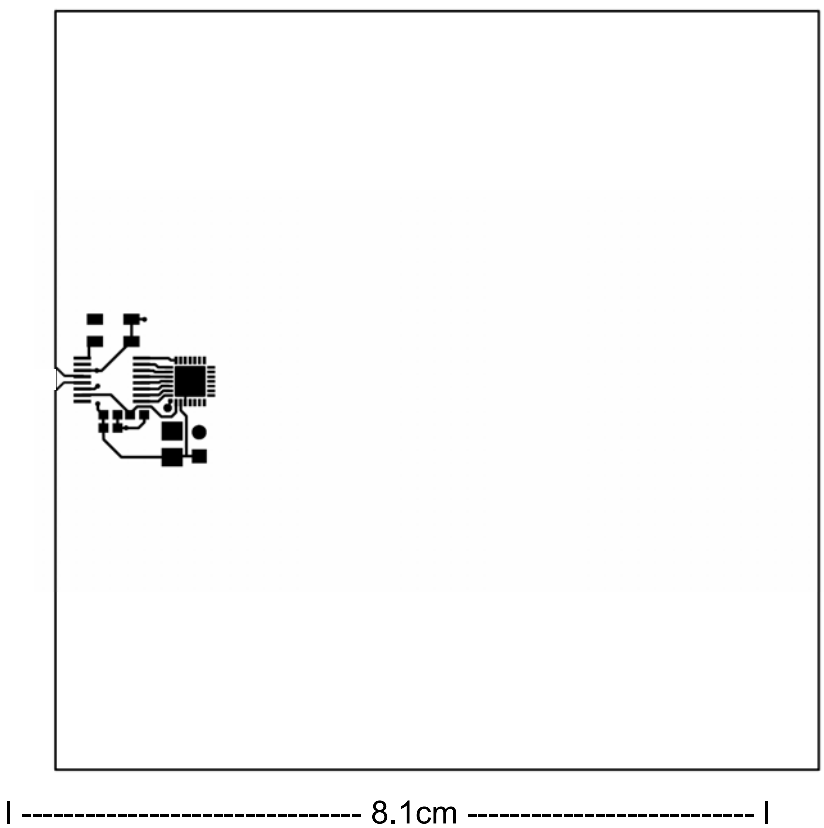


Fig. 4 Square Loop Antenna for 916MHz

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