FerriteCore-core5

December 10, 2022

1 Measure initial permeability

Make one or very few loop over the toroid, measure inductance and torroid dimensions.

It is vital that this measurement is done with as few turns as necessary to give a reliable and accurate reading on the measuring instrument. More turns means decreased self resonant frequency and the impedance will no longer obey the simple model

$\frac{X}{R} = \frac{\mu'}{''}$

If the inductor has appreciable flux leakage (eg a rod or low µ), then the flux leakage results in a departure from this

$\frac{X}{R} = \frac{\mu'}{''}$

Magnetic permeability μ is the ability of a magnetic material to support the formation of a magnetic field. The initial permeability μ_i is the purely amplitude permeability of the ferrite core when the magnetic field (B) is close to "zero" as shown in the below B-H curve figure.

Initial permeability describes the relative permeability of a material at low values of B (below 0.1T). The maximum value for μ in a material is frequently a factor of between 2 and 5 or more above its initial value.

The magnetic permeability μ can be interpreted as "conductivity for magnetic flux". The initial permeability is determined by the following formula, which is related to the applied magnetic material, its dimensions and shape.

$L = \frac{\mu_0 * \mu_r * N^2}{2 * \pi} * h * log_e(\frac{r_o}{r_i})$

μ_0 - magnetic constant $4 * \pi * 10^{-7}[\frac{T*m}{A}]$

src https://coil32.net/ferrite-toroid-core.html

From here we can compute μ_i

[ ]:
```
import math

# measured values with one turn over torroid.
od = 10 #mm
id = 4 #mm
width = 4 #mm, the h symbol in the formula above
turns=25 #use least turns possible to minimise self resonance effects
L=55 #uH
```

```
mu_init = L/(0.0002*width*turns**2*math.log(od/id))
print("initial magnetic permeability of the core = ", mu_init, "[gauss/oersted␣
 ↪or G/Oe]")
```

```
initial magnetic permeability of the core =  120.04923347310205 [gauss/oersted
or G/Oe]
```

2 Compute inductance factor of the core

We will use this measured initial magnetic permeability of the core to compute A_L parameter - the inductance factor of the core

$A_L = 0.2 * \mu_i * h * log_e(\frac{r_o}{r_i})$

[ ]:
```
#width is the h symbol in the formula above
al=0.2*mu_init*width*math.log(od/id)
print("Al=",al)

mu_0=4e-7*math.pi # magnetic constant
a_over_l=al/(mu_0*mu_init*1e9);
print("A/l=",a_over_l)
```

```
Al= 88.0
A/l= 0.0005833287971482491
```

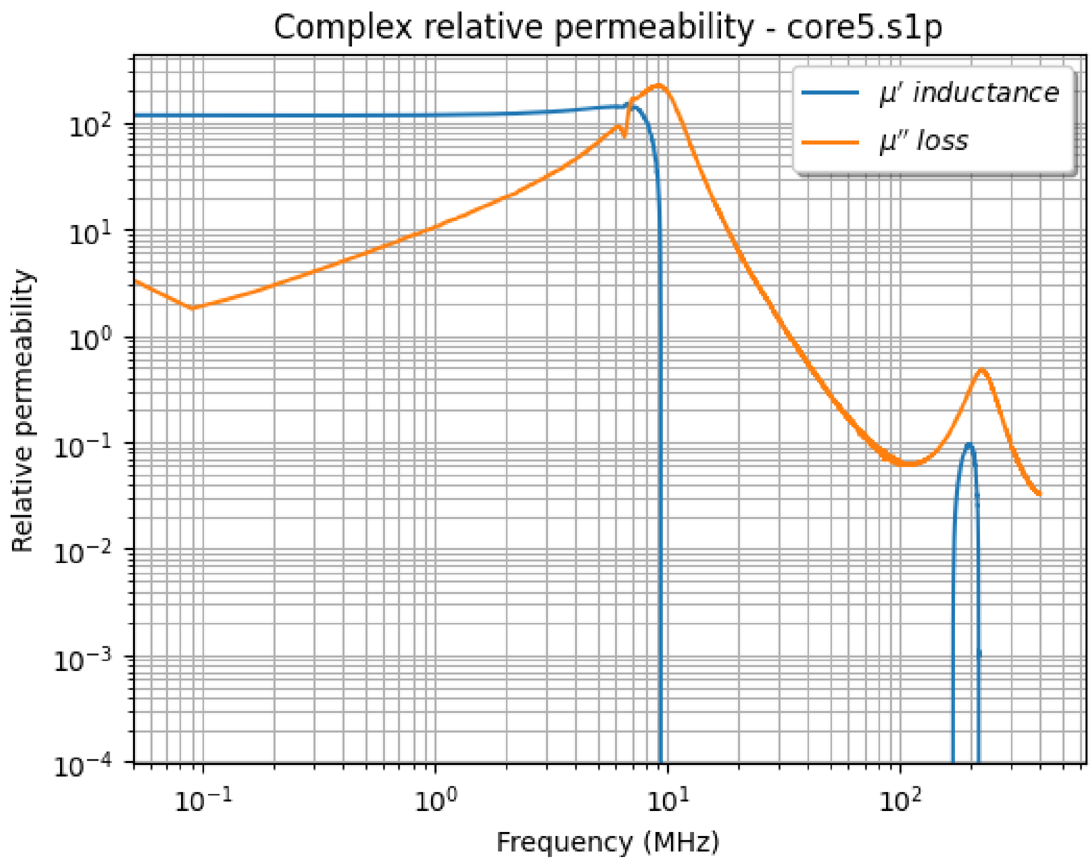
3 Take measurements of the toroid with VNA**

- Callibrate the VNA with the testing fixture
- Setup the toroid in the testing fixture
- Run nano-VNA, record measurements into *.s1p file (Touchstone file format)

[ ]:
```
import matplotlib.pyplot as plt
import skrf as rf
import numpy
import math

file1='core5.s1p'

nw1=rf.Network(file1)
mu=(nw1.z[:,0,0]/turns**2/(2*math.pi*nw1.f))/(mu_0*a_over_l)*-1j

f = plt.figure()
plt.plot(nw1.f/1e6,mu.real,label='mu1')
plt.plot(nw1.f/1e6,-mu.imag,label='mu2')
plt.xscale('log')
plt.yscale('log')
```

```
plt.legend(('$\mu\'\ inductance$','$\mu\'\'\ loss$'),loc='upper␣
↪right',shadow=True)
plt.ylim(bottom=0)
plt.xlim(left=0.05)
plt.ylabel('Relative permeability')
plt.xlabel('Frequency (MHz)')
plt.title('Complex relative permeability - {}'.format(file1))
plt.grid(True, which="both")
plt.show()
```

```
/var/folders/gf/zhqjnh3j6pl9x81ktjjv_lv40000gn/T/ipykernel_38116/2353971116.py:1
7: UserWarning: Attempted to set non-positive bottom ylim on a log-scaled axis.
Invalid limit will be ignored.
  plt.ylim(bottom=0)
```



4 Check manufacturers

Name	Site
Fair-Rite	http://www.fair-rite.com
Ferroxcube(Yageo)	http://www.yageo.com
Magnetics	http://www.mag-inc.com
Micrometals	http://www.micrometals.com
Amidon Company	http://www.amidoncorp.com

src https://www.nutsvolts.com/magazine/article/July2015_HamWorkbench

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core4.s1p appears to be material simmilar or identical material 61 https://www.fair-rite.com/61-material-data-sheet/

> A high frequency NiZn ferrite developed for a range of inductive applications up to 25 MHz. This material is also used in EMI applications for suppression of noise frequencies above 200 MHz. Excellent stability characteristics.

4.1 Saturation current

Check `Flux Density @ Field Strength` row in the datasheet. See max Oersted (H) number. This is where this material saturates. It can also be determined graphically from the Hysteresis Loop: the point where the two black lines meet at the upper-right is saturation.

$1\,Oe = \frac{1000\,A}{4\pi\,m} \approx 79.58\,A/m$

Calculate for inductor we about to wind. For example, say we have a toroidal core with a circumference of 4cm, with 10 turns on it, with 500mA. The field strength is then:

$\frac{10*0.5A}{0.04m} = 125\,A/m$

$125\,A/m * \frac{4\pi}{1000} \approx 1.57\,Oe$

This is less than the 10 Oe in the datasheet, so the core is not saturated.