Microstrip Inductor Design and Implementation

Abdullah Eroglu

Department of Engineering, RF/Microwave Laboratory
Indiana University – Purdue University Fort Wayne, Fort Wayne, IN 46814, USA
eroglua@ipfw.edu

Abstract: Design, simulation, and implementation of microstrip spiral inductors for RF applications at the high frequency (HF) range are given. The simplified lumped element equivalent model parameters for spiral inductor are used to obtain the initial physical dimensions for the design. The spiral inductor is then simulated with planar electromagnetic simulator, Sonnet, using the geometry constructed with the physical dimensions obtained for the desired inductance value. The parametric study of the spiral inductor is conducted to investigate the variation on its quality factor, self resonance frequency and inductance value. The spiral inductor is then implemented on a 100mil Alumina substrate and measured in the laboratory. The measurement and simulation results are found to be close.

Keywords: Microstrip, spiral, inductor, RF, HF.

1. Introduction

There is an increasing demand in the area of radio frequency applications to use the cost effective planar inductors. Spiral type planar inductors are widely used in the design of power amplifiers, oscillators, microwave switches, combiners, and splitters, etc. There have been numerous publications on spiral inductor design at microwave frequencies [1-3]. Equivalent models have been reported when spiral inductor is implemented on a Si material [4-5]. However, publications on the design of spiral inductors at HF (3MHz –30MHz) range for RF applications are very limited or none according to author's knowledge. HF range is a common frequency range that is used for ISM (Industrial, scientific, and medical) applications. Spiral inductors, when used in ISM applications, must be designed to handle power at the range of several kilowatts. They should still demonstrate good thermal characteristics, required inductance value and low loss under such high power. Any change in the component values in RF system affects the performance and can cause catastrophic failures. This can be prevented by using a material which has good thermal characteristics as a substrate and accurate design technique to design and implement the spiral inductor at the HF range.

In this paper, a practical design method for spiral inductor is proposed using the simplified lumped element equivalent model. The model is used to obtain the physical dimensions of the spiral inductor for the desired inductance value. The physical dimensions are then used to construct the geometry in the planar electromagnetic simulator, Sonnet. Planar electromagnetic simulator, Sonnet, is also used to characterize the spiral inductor with conducting parametric by varying the trace width and spacing. The parametric study is used to understand the effect on the quality factor, inductance value, and self resonance frequency of the inductor. Spiral inductor is then built using Alumina substrate and measured in the laboratory. The simulation results and measurement results are found to be close.

2. **Design and Implementation of Spiral Inductor**

The equivalent model for the spiral inductor that will be used to obtain physical dimensions is shown in Fig. 1a. Fig. 1b illustrates the microstrip model that will be implemented. Microstrip spiral inductor is a rectangular spiral inductor with rounded edges. Rounded edges increase the effective arcing distance between traces.

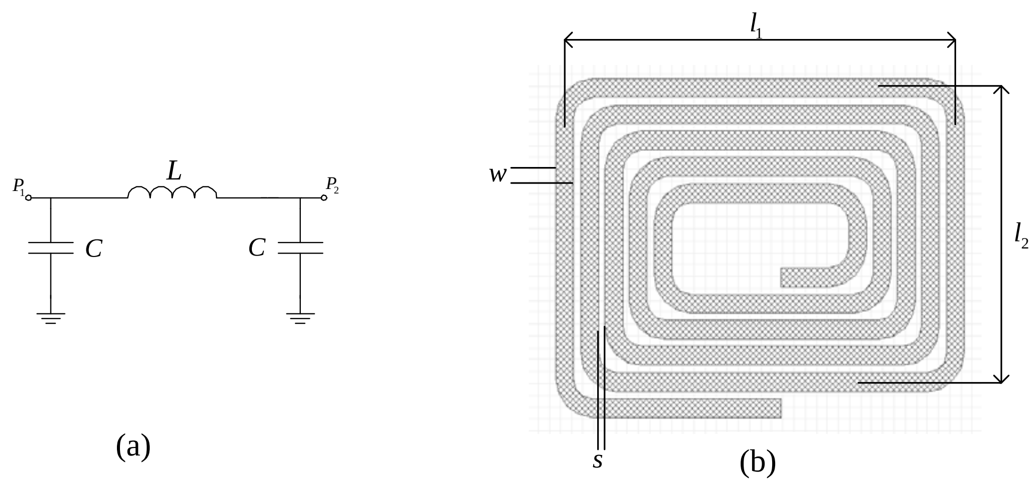

Fig. 1. (a)Two-port lumped-element equivalent circuit for spiral inductor. (b) Microstrip model of the spiral inductor.

The width of the trace, w, the length of the outside edges l_1 and l_2, and the spacing between the traces, s are the physical dimensions of the spiral inductor. In Figure 1a, L is the series inductance of the spiral, and C is the substrate capacitance. This model ignores the losses in the substrate and the conductor. The desired effective value of the spiral inductance is 590nH. The physical dimensions that give the effective inductance value of 590nH using the equivalent circuit in Fig. 1a is given in Table 1.

Table 1. Physcial dimensions of the spiral inductor.

Trace Width w	Spacing s	Horizontal Trace Length l_1	Vertical Trace Length l_2	Copper Thickness t	
80	30	1870	1450	4.2	
Dielectric Material	**Dielectric Permittivity** ε_r	**Dielectric Thickness** h	**Number of Turns** n	**Bridge Height** h_b	**Bridge Width** w_b
Al_2O_3	9.8	100	6.375	100	350

3. **Measurement and Simulation Results**

When the structure given in Fig 1b is simulated using the dimensions given in Table 1, the simulated value of the spiral inductance is found to be 588.6nH at 13.56MHz. Parametric study of the spiral inductor is conducted by varying the trace width and the spacing between traces. The effect on its quality factor, self resonance frequency and self inductance value is recorded. The results are illustrated between Figures 2-4.

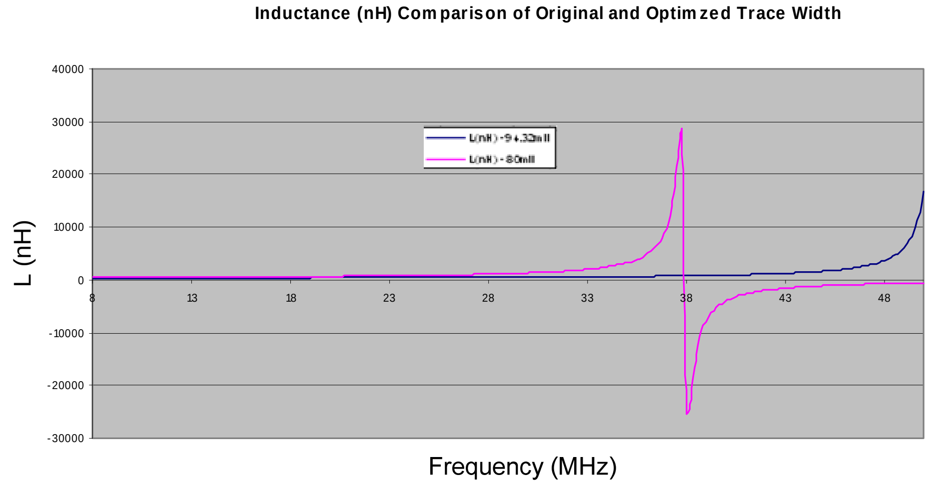

Fig . 2. Effect of trace width and spacing on self resonance.

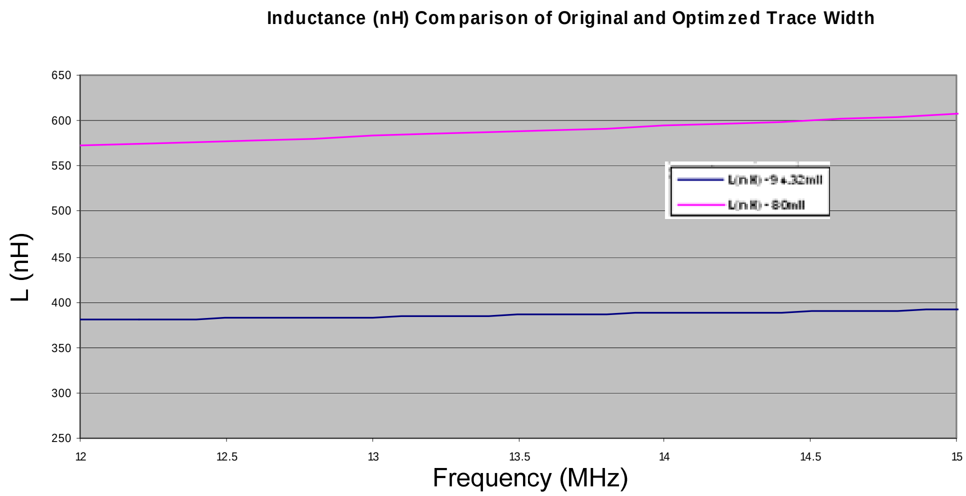

Fig . 3. Effect of trace width and spacing on self inductance.

It has been observed that self resonance frequency of the inductor increases significantly by increasing the trace width and reducing spacing between each trace. The original simulated spiral inductor trace width and spacing were 80mil, and 30mil respectively. The optimized values of the spiral inductor trace width and spacing that give higher self resonant frequency are 94.32mil, and 15.68mil, respectively. Figures 2-4 compares the performance of the spiral inductor for these two cases. We also note that measured value of the spiral inductance when trace width is 80mil and spacing is 30mil is found to be 594.91nH. The final version of the spiral inductor that is built is shown in Fig. 5.

4. Conclusions

Microstrip spiral inductor using simplified equivalent circuit is designed, simulated, built and measured at the HF range for high power RF applications. The parametric study of the spiral is conducted using planar electromagnetic simulator, Sonnet. It has been shown that the self resonant frequency of the spiral inductor can be increased by increasing the trace width and reducing the spacing between each trace. Increased self resonant frequency is very important feature for several RF applications. The measured and simulation results are found to be very close. The results of this work can be used in RF applications at HF range where high power is needed.

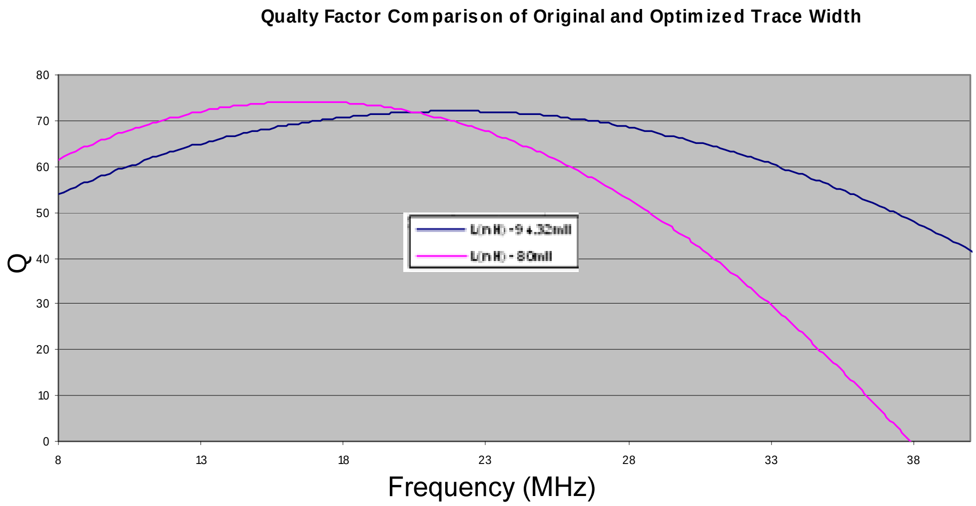

Fig . 4**.** Effect of trace width and spacing on quality factor.

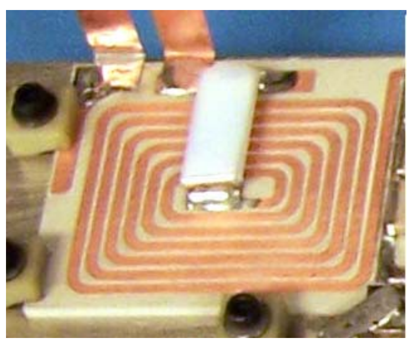

Fig . 5**.** Built and measured spiral inductor.

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