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FEM analysis of the magnetic closed type RF integrated inductor

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1. Introduction

Recently, RF lumped-element devices are demanded strongly in application of hand-held mobile communication equipme nts. Many workers have been reported RF integrated inductor as well as air cores. In order to achieve the high Q value, they removed backside of substrate by micro machining process [1] and also another MEMS-like approach such as levitated structure [2]. These approaches are capable of suppressing the parasitic effects, but low reproducibility and high cost problems remain. To solve this problem, we have been proposing the application of magnetic materials [3],[4]. Our uni que idea is to apply patterning of magnetic film enables to enhance resonance frequency of magnetic film (0.7 GHz for $Co_{85}Nb_{12}Zr_3$ with Ms=10 kG and Hk=10 Oe) and to reduce eddy current losses.

We performed 3D-FEM simulations to find optimum design of the ferromagnetic RF integrated inductor having magnetic closed circuit design. In this paper, we discuss details based on the change of electrical potential energy and equivalent circuit parameter.

2. Structure & design

The HFSS (v. 8.5 by Ansoft. Co.) simulation program have been used to study the application of patterned magnetic films i n RF integrated inductors aimed for mobile handset applications. In the modelin g, mesh planes divided the magnetic films and the coil lines into 0.2 and 0.5 micron which is thinner than skin depth at 2 GHz. As well, frequency dependent complex permeability was pre-calculated based on L.L.G. equation a nd put into the simulation.

The L, R, Q values were extracted from S para meters of simulation results [5].

Fig.1 shows the cross-sectional of air-core, magnetic matched, magnetic mismatched a nd magnetic closed design investigated in this work. The 4-turn spiral, 20 microns wide, 2 m icorns thick and 3 m icons Ga p, microns of Cu and 20 microns wide, 3 micron s gap, 0.2 thickness of $Co_{85}Nb_{12}Zr_3$ (at.%) was u sed as magnetic layer, 1 m thick SiO_2 was us ed as insulator.

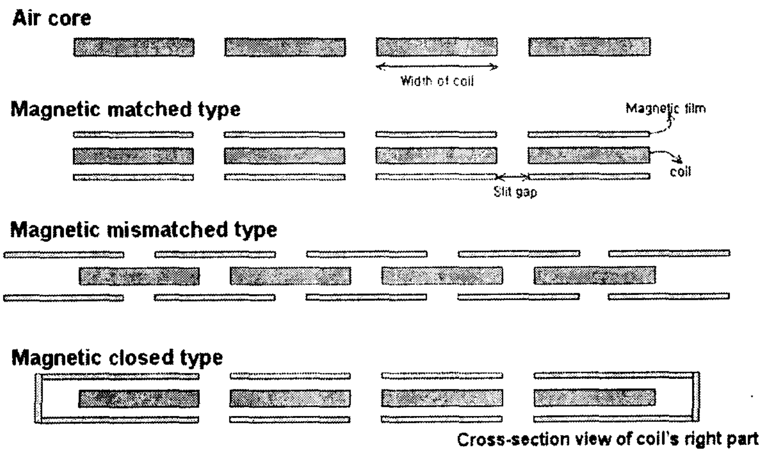

Fig. 1. Schematic description for various kinds of inductor structure

3. Results & discussion

The 20 microns as coil width was chosen because same width and gap 3 microns of magnetic film has 128 of effective permeability value (effective permeability 100 is the condition of 35% enhanced inductance from air-core value [6]). The 3 microns as coil gap was selected from simulation results (but, not reported here).

As shown in Tab. 1., magnetic closed design show the best property because of low resistance and 29.1% of enhanced inductance from air-core compare with another design. We believed that loss mechanism was related with different potential energy by electric force between each coils and up & down side magnetic films. In case of mag. mismatched design shown un-uniform distribution of electric field from fig.2. (b) than mag. matched design. These sandwich type inductors have low capacitance value between coil and magnetic film (it was revealed by our previous work [5]), but each turn of coils have

Tab. 1. Calculated L, R, Q value of various designed inductor at 2 GHz

At 2 GHz	Air-core	Mag. matched	Mag. mismatched	Mag. closed
L (n H)	4.36	5.00	4.59	5.63
R (ohm)	5.46	9.44	10.28	8.39
Q	10.3	6.8	5.7	8.6

different electric potential value because of different position and length. In other words, mag. mismatched design was electrically connected between each coils by magnetic films such as 'bridge'. Also we investigated uniformity of electric field distribution of mag. closed design in the same way. There is only one structural difference that whether got closed on the edge sides of coils between mag. matched (a) and mag. closed (c) designs. This magnetic film of edge wall did role of electric bridge, thus up and down side magnetic film's electric potential energy gap was adjusted small value.

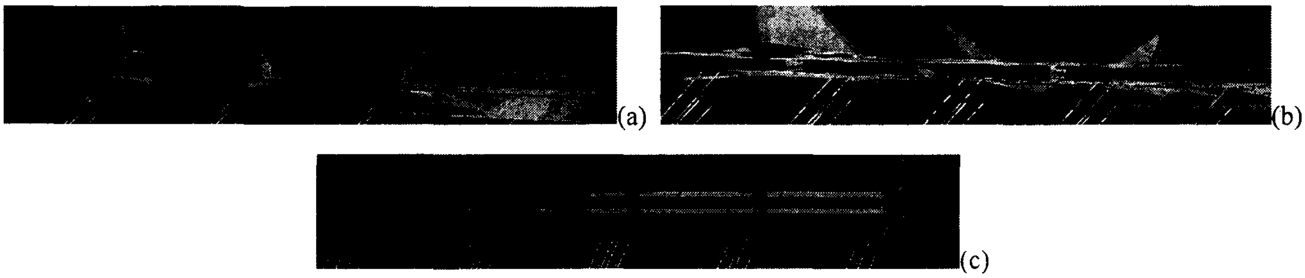

Fig. 2. Electric field distribution of (a) mag. matched (b) mag. mismatched (c) mag. closed design inductor

From the R (5.46 ohms) of air-core in tab. 1, we could conjecture resistance by the coil proximity effect. DC resistance was 1.8 ohm. Remained 3.66 ohms consist of eddy current loss (Cu skin depth is about 1.5 micron at 2 GHz) and loss by proximity effect, if it is consider 2 microns thickness of coil, eddy current loss was small. It means that 20 microns width of coil is wide it leads to increase the resistance. Optimization of Cu coil width and thickness work should be completed necessarily, so it is studying present.

4. Conclusion

Various inductor structures were investigated L, R, Q value by FEM analysis. Mag. closed design shows 5.63 nH of L, 8.39 ohms of R and 8.6 of Q at 2 GHz. Low potential energy gap between up and down side magnetic films by electrical connection of closed edge side was achieved and leaded low loss generation. However, it is need that additional research for optimization of width and thickness of coil because resistances are acting intricately.

5. Reference

[1] J.M. Lopez-Villegas, J. Samitier, C. Cane, IEEE Trans. Microwave Theory & Technique, Vol. 48, No. 1, 76-83 (2000)

[2] J-B. Yoon, C-H. Han, E-S. Yoon, C-K. Kim, 1999 IEDM Technical Digest, 753-756 (1999)

[3] M. Yamaguchi, K. Suezawa, K. I. Arai, Y. Takahashi, S. Kikuchi, Y. Shimada, W. D. Li, S. Tanabe, and K. Ito, Journal of Applied Physics, 85 (1999), 7919-7922.

[4] S. Bae, D-H Shin, C-S Kim, S-R Ryu, S-E Nam, J-S Song, M Yamaguchi, H-J Kim, INTERMAG Europe 2002, DQ-08, Digest of Technical Papers (2002)

[5] T. kuribara, M. Yamaguchi, K. Arai, INTERMAG Europe 2002, DQ-01, Digest of Technical Papers (2002)

[6] S. Tanabe, Y. Shiraki, K. Itoh, M. Yamaguchi, K. Arai, IEEE Trans. Magnetics, Vol. 35, No. 5, 3580-3582 (1999)