INDUCTANCE COILS BASED ON GLASS-COATED CAST MICROWIRE WITH MAGNETIC COATING

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Abstract. Influence of a magnetic covering on parameters of coils from micro wire is examined.

Keywords: Micro wire, inductance, coil, magnetic covering.

INTRODUCTION

Besides inductance and accuracy, Q-factor and critical frequency are very important for inductance and microinductance coils applied in radio-frequency range (from 100 kHz up to 1000 MHz). Q-factor characterizes frequency losses at radio-components. Great value of Q-factor is important for various filtering components since it determines quality of signal filtration and value of signal amplification for filtration losses compensation. Standard Q-factor values quoted by various manufacturers of microinductances [1,2,3] lay within the range from 15 to 100 depending on inductance value and signal frequency. Critical frequency determines signal frequency below which coil reactance has inductive nature. Q-factor Q and critical frequency f_k of inductance coils are known to be determined by the following ratio: $\omega L / R$ and $1 / 2\pi\sqrt{LC}$ respectively, where ω - signal frequency, L – coil inductance, R – losses resistance, C – total coil inductance consists of winding self-capacitance and stray capacitance of leads.

Thus, improvement of microinductance performance ability can be achieved due to the reduction of resistance losses and windings self-capacitance.

Most manufacturers apply various types of magnetic cores in order to improve performance ability of microinductance. At the same time number of laps of winding is reduced depending on value of effective permeability of coil’s core. Resistance losses are reduced in proportion to number of laps of winding as well. However as a result of significant overall dimensions of coil’s core, which often exceed overall dimensions of winding, overall dimensions and stray capacitance of microinductances are increased and additional magnetic losses proportional to core size take place. Net effect related to application of magnetic cores is not so significant. Operating frequency range of microinductance is constricted.

Theoretical studies. Theoretical and applied studies of development of microinductance with improved performance ability have shown that solution of the said problems can be achieved applying microwire with magnetic coating. The equation which allows to obtain parameters of microinductance based on such microwire has been derived. Value of additional linear inductance Ls and insertion linear resistance of losses Rs can be obtained with help of equation of complex impedance, inserted by magnetic coating:

$$Z = \frac{k}{2\pi \cdot r_1 r_2 \sigma_1} \cdot \frac{(Y_1(kr_1)r_1 - Y(kr_2)r_2)(J_0(kr_2) - J_0(kr_1)) - (J_1(kr_1)r_1 - J(kr_2)r_2)(Y_0(kr_2) - Y_0(kr_1))}{Y_1(kr_1)\cdot J_1(kr_2) - Y_1(kr_2)\cdot J_1(kr_1)} \qquad (13)$$

where $Ls = \mathrm{Im}(Z/\omega)$, $Rs = \mathrm{Re}\,Z$, additional inductance and inserted resistance obtained with help of real and imaginary part of complex impedance; $k = \sqrt{-i\omega\mu\sigma}$ - medium propagation factor, ω- circular frequency, μ, σ, r_1, r_2, - permeability, conductivity, outer radius of microwire insulation and coating respectively, J_0, J_1, Y_0, Y_1 - Bessel function of first and second genus respectively.

Results and Discussion. Results of calculation of linear inductance and resistance inserted by magnetic coating with thickness 0,1 µm and permeability µ=100 in case of copper-based microwire of various diameters are shown in table 2.

Table 2. Linear parameters of microwire with magnetic coating.

Core diameter, µm	**diameter of coating, µm**	**Signal frequency, MHz**	**Linear resistance of core, Ohm**	**Linear inductance of core, µH**	**Inserted resistance of core, Ohm**	**Inserted inductance of core, µH**
8	13	1	349	0,05	7.10^{-6}	0,3
		100	349	0,05	7.10^{-4}	0,3
		1000	426	0,05	7,2	0,3
12	25	1	155	0,05	$3{,}75.10^{-6}$	0,16
		100	155	0,05	$3{,}75.10^{-4}$	0,16
		1000	252	0,034	4,1	0,16
12	20	1	155	0,05	$4{,}7.10^{-6}$	0,2
		100	155	0,05	$4{,}7.10^{-4}$	0,2
		1000	252	0,034	5,38	0,2

Compare of self and inserted linear inductance shows that inserted linear inductance is a few times greater than self one. Compare of self and inserted linear losses resistance shows that inserted losses resistance insignificantly increases overall losses. Thus, magnetic coating allows to significantly reduce number of laps of microinductance coil winding. Since self-resistance of losses is proportionally reduced, Q-factor of microinductance coil is increased the same way.

Frequency dependencies of inserted linear inductance and resistance in case of various coating thickness are shown on Fig. 1 and 2. Since nature of the dependencies shows that at small thickness of coating value of inserted inductance doesn't depend on frequency, inserted reactance ωL will be directly proportional to frequency and thickness of magnetic coating. The second graph shows linear dependence of inserted resistance on logarithm of frequency. It is followed from the mentioned graphs that Q-factor has extreme at a definite frequency depending on coating thickness. Fig. 3 shows dependence of Q-factor of inductance coil on thickness of magnetic coating at different values of coating conductivity. It is followed from these graphs that there is a maximum of Q-factor on a given frequency at a definite coating thickness, and materials with great specific resistance (smaller conductivity) should be used in order to increase Q-factor.

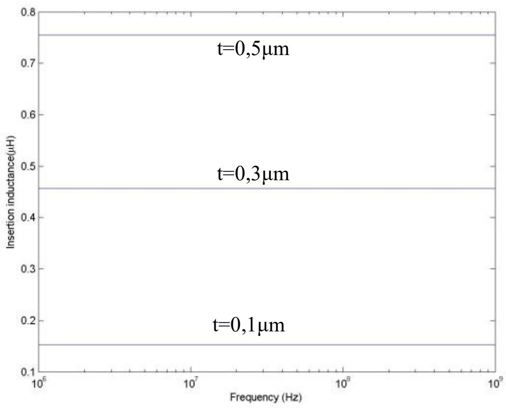

Fig. 1. Frequency dependence of inserted inductance on frequency and thickness of magnetic coating.

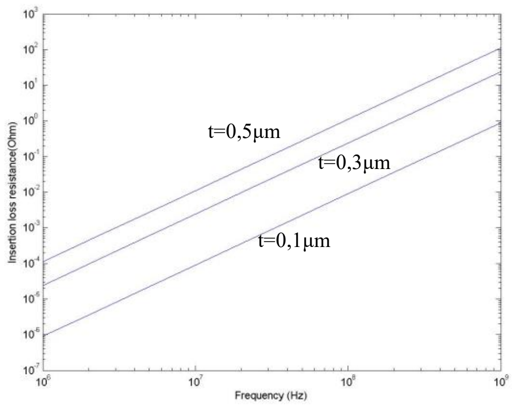

Fig. 2. Frequency dependence of inserted resistance on frequency and thickness of magnetic coating.

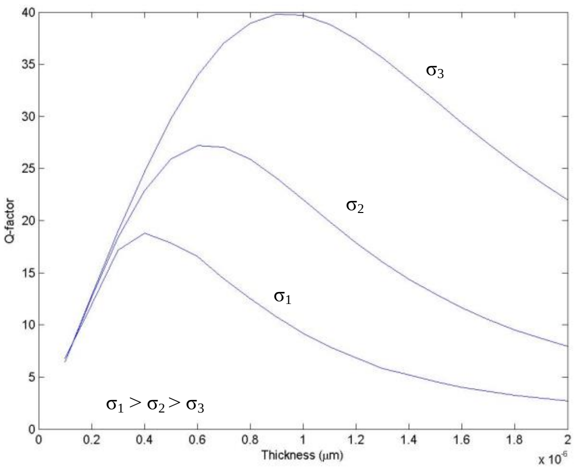

Fig. 3. Dependence of Q-factor of inductance coil on coating thickness at frequency 100 MHz while using coatings with different conductivity

Actual inductance increase is even greater since at presence of magnetic coating inter-inductance between laps of winding also increases. This fact hasn't been taken into account while studying impact of inserted inductance and resistance. Reduction of radial dimensions of winding takes place due to the reduction of laps of winding. Most researchers [4] state directly proportional dependence of coil self-capacitance on its radial dimensions (external diameter of winding). Thus reduction of coil's radial dimensions results in broadening of frequency range of micro-inductance coil application. It's very important for micro-inductance coil with great nominal value.

CONCLUSION

Application of magnetic coating is very promising for increase of micro-coil's inductance. It allows to improve performance abilities of micro-coils such as Q-factor and operating frequency range. Maximal Q-factor in a given frequency range can be achieved by adjusting thickness of magnetic coating.

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