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## Analysis of Eddy Current Distribution in High Frequency Coaxial Transformer with Faraday Shield.

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**Abstract**— This paper presents the analysis and measurement results for a high frequency (HF) coaxial transformer with Faraday shield. The simulation results demonstrate that the magnetic flux and eddy current distribution are not impacted by the inclusion of a Faraday shield. The Faraday shield's maximum eddy current density is less than 17% of the maximum density found in the secondary windings.

### I. INTRODUCTION

Electrical isolation of switching mode power supplies can be facilitated by employing high frequency transformers in the design. The input power source and the output of the power supply are coupled together by the magnetic field. Practical transformers are not ideal and have leakage inductances and a capacitance between the primary and secondary windings. The capacitance couples HF noise from the primary winding to the secondary winding [1]. A Faraday shield, which is formed by placing a grounded conductor between the two windings, can eliminate the HF noise coupling. Ideally the shield should not influence the magnetic coupling, but should eliminate the capacitive coupling between windings when the shield is grounded. The shielding coil may exhibit, at higher frequencies, an eddy-current loss caused by leakage flux. The location and thickness of the shield should be designed in such a way as to minimize the impact of eddy current loss and the insertion loss which is caused by coupling capacitance between the primary and secondary windings.

### II. COAXIAL TRANSFORMER WITH FARADAY SHIELD

The basic structure of the coaxial transformer and its HF equivalent circuit [2], with Faraday shield, is shown in Fig. 1. The outer copper tube is used as a primary winding, the wires inside are used as a secondary winding and the copper tube in between the primary and the secondary windings represents the Faraday shield. This shielded coaxial transformer is suitable for HF operation, has negligible capacitive coupling between the primary and secondary windings and has low insertion loss, a 50% reduction in the insertion loss compared to the case without a shield.

### III. COMPUTATION AND EXPERIMENT RESULTS

In this coaxial transformer, the shielding layer is made of a single layer of thin copper tube which has the same structural configuration as the primary winding. Figure 2 shows the eddy-current distribution in both windings and the shielding coil, where the excitation source is applied to the primary winding. The numerical simulation results indicate that the eddy-current density in the shielding coil is relatively small compared with the eddy-current in the secondary windings. The maximum eddy current density in the Faraday shield is  $<5\text{A/cm}^2$ , while the maximum eddy current density in the secondary windings is  $>30.0\text{A/cm}^2$ . The maximum eddy current density in the Faraday shield was found to be less than 17% of the density observed in the secondary winding. Therefore, the power loss in the Faraday shield can be neglected. Both eddy current and magnetic flux

distributions in the transformer windings with the Faraday shield remain the same as the current distribution without the Faraday shield, which indicates that the Faraday shield does not have a major impact on the transformer's operation and influence the magnetic flux coupling and field distribution.

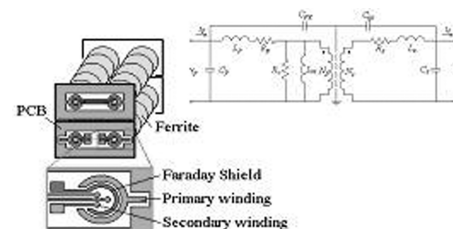
The transformer with Faraday shield has been tested with a load using a single switch forward resonant converter configuration. A 1.144 MHz switching frequency is used to investigate the characteristic of the transformer. The measured waveforms for an operating frequency of 1.144 MHz are illustrated in the full paper where the waveform is measured between the gate and the source of the switching MOSFET.

### IV. CONCLUSION

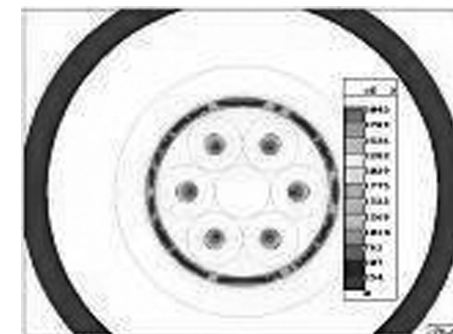
A HF coaxial transformer with shielding coil has been constructed and tested. The numerical and experimental results show that the Faraday shield had no effect on the magnetic coupling coefficient, and the flux and eddy current distributions in the coaxial HF transformer. The maximum eddy current density in the Faraday shield was found to be less than 17% compared with the density in the secondary winding.

[1] Laszlo Tihanyi, "Electromagnetic compatibility in power electronics", The IEEE Press, 1995.

[2] J. Lu, F. P. Dawson and S. Yamada, "Application and analysis of adjustable profile high frequency switch mode transformer having a U-shaped winding structure", IEEE Trans. on Magnetics, Vol. 34. No. 4, July 1998, pp1345-1347.



**Fig. 1 High frequency coaxial transformer and its equivalent circuits with Faraday shield (E field shielding)**



**Fig. 3 Eddy current distribution in the HF coaxial transformer with Faraday shield at an operating frequency of 1MHz.**