Improvement of the Film Transformer Characteristics

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Abstract — Previously, we have proposed a thin film transformer. The operating principle of this transformer is based on the skin effect. Thereby, its weight and size are extremely small but its operating frequency having high efficiency is limited only to high frequency region. In order to remove this fault, we employ the thin ferrite tiles which have been sandwiched between the film conductors. As a result, we succeeded in widening the operating frequency range about 100 times compared with those of original one.

I .INTRODUCTION

In order to develop a small size and light weight high frequency transformer for DC to DC converter use, we have previously proposed a coreless transformer utilizing the skin effect of the adjacent current carrying conductors [1]. 15W output power was obtained by the coreless transformer having only 7g weight [2]. Satisfactory result of the coreless transformer spurred to exploit a film transformer, which was fabricated by the photo etching technique. When we installed our film transformer to a push-pull type DC to DC converter, 11w output power was obtained with 72% overall efficiency [3]. This record is fairly good comparing with those of the other similar type of converters [4,5]. However, we have found that magnetizing inductance of the film transformer is too small to use the DC to DC converters instead of the conventional core type transformers. In the other words, the coreless film transformer is light and small so that it is possible to realize a light weight DC to DC power supply. However, it is difficult to replace the conventional core type transformers because of the film transformer's peak frequency characteristics, i.e., useful operating frequency range of the film transformer is extremely narrow for practical use.

In the present paper, it is revealed that the film transformer sandwiched by the ferrite tiles yields about 70 times larger self inductance and gives about 100 times wider useful operating frequency range comparing with those of the original coreless film transformer. Thus, we have succeeded in improving the characteristics of film transformer by means of a simple sandwich structure.

II .EXPERIMENTAL

A. Basic principle and structure

Figure 1(a) shows a typical core type conventional transformer which utilizes the magnetic flux linking the conductors wound around the magnetic core. The proposal coreless transformer utilizes the magnetic flux enclosing the current carrying conductors as shown in Fig. 1(b) [1,2]. Because of this, the internal inductances of the primary and secondary coils should be small in order to obtain higher coupling. This can be accomplished by the skin effect at high frequency. Thus, the coreless transformer should be operated only in the higher frequency range. To utilize the same operating principle in a flat surface, the primal and secondary conductors are arranged alternatively on a film base surface. Figure 2(a) shows a coaxial circular shape film transformer. The connection of the coils are shown in Fig. 2(b). Further details of the film transformer are presented in [3].

B. Improvement

The operation of film transformer is based on the skin effect between the adjacent coils. Therefore, it is difficult to obtain similar characteristics with the conventional core type transformers. However, consideration of the magnetic flux path on the film transformer reveals a method of improvement. As shown in Fig. 2(a), when alternating current is flowing through the primary coil, at some instance, the magnetic flux starts from the center to outer on the top surface and returns from outer to center on the under surface of the film transformer. To enhance the coupling, one of the simplest ways is to increase the permeability of magnetic flux path. Thus, a sandwich structure employing ferrite tiles constitutes a reasonable magnetic flux path. The film transformer exhibits the

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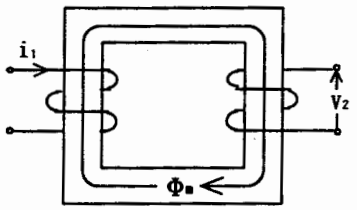
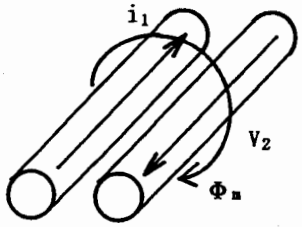
good characteristics at high frequency but poor characteristics at low frequency because of the skin effect. In order to improve the lower frequency characteristics of the film transformer, the ferrite tiles have to display high permeability characteristic at lower frequency and behave like air at higher frequency. This means that the ferrite tiles for microwave absorption are suitable for this purpose.

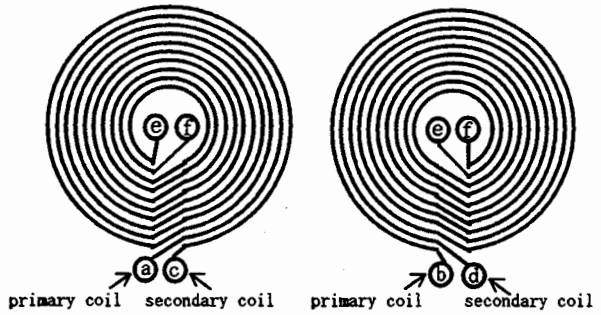


(a)

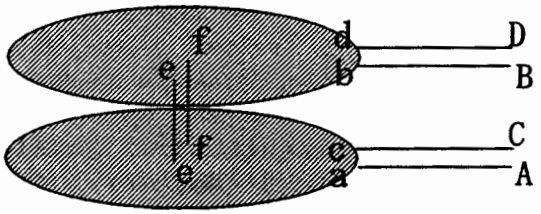


(b)

Fig.1. Principle of transformer operation. (a) Conventional core type transformer, and (b) film transformer.



(a)



(b)

Fig.2. An example of the film transformer. (a) Coaxial circular type film transformer, (b) way of coil connection for 2 layer.

C. Characteristics

We built a trial film transformer from copper coated polyimide film by the chemical etching processes. Specification of this transformer is listed in table 1. The employed ferrite tiles are the microwave absorption type fabricated by the Hitachi ferrite company.

Figure 3 shows the ratio of transformation characteristics. Figure 4 shows the efficiency vs. frequency characteristics at pure resistive loads. From the results in Figs. 3 and 4, it is obvious that the characteristics of the film transformer are fairly improved by the simple sandwich structure. It must be noted that the peak frequencies of the transformer ratio and efficiency take the similar values of the original one. This is because the magnetizing inductance changes with frequency, as shown in Fig. 5.

TABLE I
SPECIFICATION OF A TRIAL TRANSFORMER

Shape	circular coaxial type with 2 layer
Outer diameter	60mm
Turns	primary 17, secondary 17
Coil width	1.3mm
Coil thickness	17 μ m
Polyimide thickness	65 μ m
Space between the coils	0.3mm

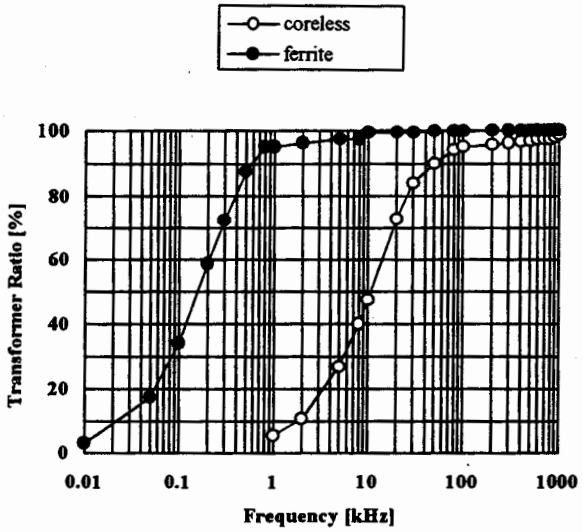


Fig.3. The frequency characteristics of ratio of transformation, which corresponds to the coupling factor at high frequency. The symbols ● and ○ denote the sandwiched by ferrite tiles and the original coreless film transformers, respectively.

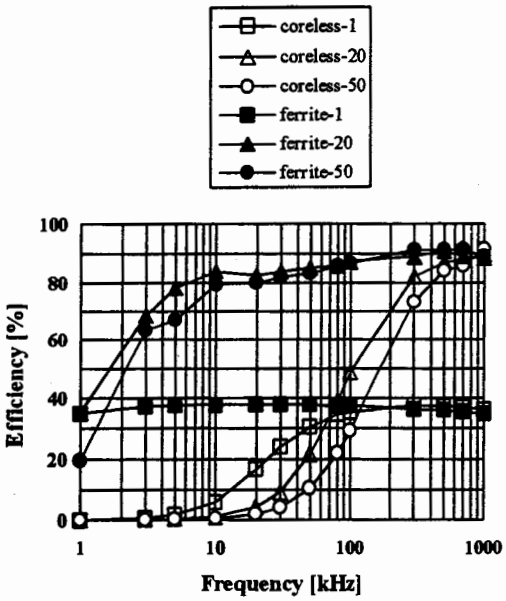


Fig.4. The frequency characteristics of efficiency. The symbols ● and ○ denote the sandwiched by ferrite tiles and original coreless film transformers, respectively. 1,20 and 50 in the figure refer to the load resistance value in Ohms.

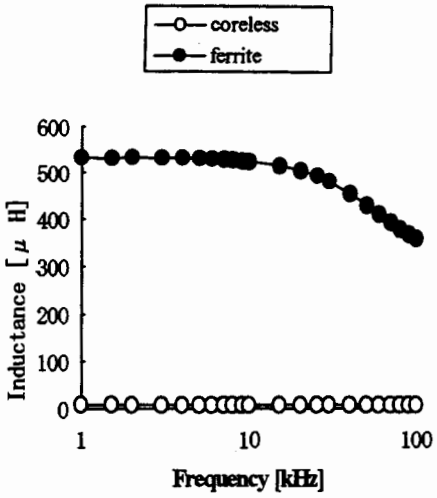


Fig.5. The frequency characteristics of magnetizing inductance. The symbols ● and ○ denote the sandwiched by ferrite tiles and original coreless film transformers, respectively.

Ⅲ.CONCLUSION

As shown, we have succeeded in improving the frequency characteristics of the film transformer by employing the thin ferrite tiles. Particularly, low frequency characteristics were dramatically improved by the way of high permeability ferrite tiles. Thus, it is possible to replace the conventional transformer by our thin film shape transformer for DC to DC converters use.

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