Transformer Core as a Transmission Line

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1. Introduction

There is interest in using the magnetic delay characteristics of transformer cores as a means of accessing the zero point energy (zpe) of space. This line of enquiry was initiated by Prof. Turtur's paper which suggested that EM radiation (actually antenna near-field radiation in his example) was evidence of zpe and that some zpe could be captured using delay techniques. It is perhaps unfortunate then that his proposed capacitance-loaded magnetic motor did not use magnetic delay techniques and is doomed to failure. In this present paper a transformer core is considered to be a type of waveguide supporting TE mode propagation. It is shown that for the ideal case of zero attenuation (zero core losses) the characteristic impedance (Z_0) of this transmission line is purely reactive, i.e. there is no real (resistive) component. This is unlike any conventional delay line, which is perhaps the reason why reactive Z_0 transmission lines have not been studied in any depth. It is shown here using classical transmission line theory that a line with reactive Z_0 when terminated with a reactive Z can exhibit a negative value of input resistance. It is well known that negative resistance represents an energy source, so the question must be asked how can passive components supply energy? The answer lies in Prof. Turtur's paper, and using a transformer core as a magnetic delay-line is one method of exploiting this characteristic.

2 Classical Transmission-Line Theory

Considering first a line with zero attenuation; the impedance Z_1 looking into the input of a line of electrical length θ terminated with Z_2 is given by

$$Z_1 = Z_0\left(\frac{Z_2 + jZ_0 \tan\theta}{Z_0 + jZ_2 \tan\theta}\right) \tag{1}$$

Let Z_0 be purely reactive, say jX_0. Also let the load Z_2 be purely reactive, say jX_2. Equation (1) then becomes

$$Z_1 = jX_0\left(\frac{jX_2 - X_0 \tan\theta}{jX_0 - X_2 \tan\theta}\right) \tag{2}$$

Evaluating real and imaginary parts of Z_1 yields

$$\operatorname{Re} Z_1 = \frac{X_0 \tan\theta(X_2^{\,2} - X_0^{\,2})}{X_0^{\,2} + (X_2 \tan\theta)^2} \tag{3}$$

$$\operatorname{Im} Z_1 = \frac{X_2 X_0^{\,2} + X_2 X_0^{\,2} \tan^2\theta}{X_0^{\,2} + (X_2 \tan\theta)^2} \tag{4}$$

From (3), if $X_2 < X_0$ the input impedance exhibits a negative resistance component. Thus in theory we could tune the inductive component (4) with a capacitor placed across the input terminals and obtain self oscillation, extracting power into a load resistor also present across the input. It is interesting that classical theory predicts this possibility for power generation from otherwise passive components, which may be considered as a validation for Prof. Turtur's prediction.

For a line with small attenuation equation (1) becomes

$$Z_1 = Z_0\left(\frac{Z_2 + \alpha x Z_0 + j(Z_0 + \alpha x Z_2)\tan\theta}{Z_0 + \alpha x Z_2 + j(Z_2 + \alpha x Z_0)\tan\theta}\right) \tag{5}$$

where α is the attenuation constant and x the physical length of the line. Following the same procedure as before we obtain the real component of Z_1 as

$$\mathrm{Re}\ Z1 = \frac{X_0 \tan\theta[(X_2 + \alpha x X_0)^2 - (X_0 + \alpha x X_2)^2]}{(X_0 + \alpha x X_2)^2 + (X_2 + \alpha x X_0)^2 \tan^2\theta} \tag{6}$$

As before, this is negative when $X_2 < X_0$, although it is hard to conceive of a lossy line that has purely reactive Z_0. However it is shown below that a transformer core can come close to such an ideal.

3. Magnetic Core as a Waveguide Transmission Line

The B field, hence also H, within a core is longitudinal while the E field forms concentric circles. Since for a transformer where the primary and secondary are wound on opposite sides of a ring core the core transports energy along the field direction, the core can be considered as a waveguide operating in the transverse electric (TE) mode. Within the core material the ratio of transverse E to longitudinal H is not constant, being zero at the centre and rising in value with increasing radius. Thus the core supports an infinite number of modes, unlike conventional waveguides. If we take the ratio of the E field at the surface (where the coils exist) to the internal H we can establish an impedance for the overall transport channel. Taking the core to have a circular cross section of diameter d, we know that the surface E field is related to the internal B field by

$$\pi d E = \frac{-j\omega d^2 B}{4} \tag{7}$$

which is simply equating the induced voltage to the time differential of the flux. Then since $B=\mu_R\mu_0 H$ we can obtain the impedance Z_0 as

$$Z_0 = \frac{E}{H} = \frac{j\omega\mu_R\mu_0 d}{4}$$

This is for a single length of core (like a ferrite rod) acting as a waveguide or an unbalanced line which requires a ground return. In a transformer there are two channels and we can consider this as being like a balanced line which will have twice the impedance of a single one, thus

$$Z_0 = \frac{j\omega\mu_R\mu_0 d}{2} \tag{8}$$

One may ask why (8) doesn't have the minus sign of (7) and the answer to that is found in the impedance of an inductor L being $j\omega L$ (no minus sign) but the induced voltage is $V=-L\mathrm{d}i/\mathrm{d}t$ (with minus sign).

Equation (8) shows that a transformer with separated primary and secondary coils acts like a transmission line with purely reactive impedance $X_0=\omega\mu_R\mu_0 d/2$ hence for a loss-less transformer we could expect the input resistance to become negative when the secondary is shunted with a capacitance of reactance lower than that value (note these values apply to notional one-turn coils, for N turns the value has to be factored by N^2.) This is different from the previous analysis which suggested the capacitance reactance should be lower than that of the secondary inductance $X=\omega\mu_R\mu_0 A/l$ where A is the core area and l the total closed length. It remains for experimental evidence to show which analysis is correct.

4. Conclusions

While it is probably too optimistic to expect that a transformer can self oscillate, this present analysis indicates that at the very least we should expect to obtain improved COP's by deliberately operating at a frequency where there is significant magnetic phase delay between primary and secondary and by deliberately shunting the secondary with a capacitive reactance. The fact that classical transmission line theory predicts anomalous gain of energy supports Prof. Turtur's views, and we await experimental evidence of this phenomenon.

5. Reference

"Fundamental Basics of Vacuum-energy and the Principle of the Construction of Zero-point-energy motors" by Prof. Dr. Claus W. Turtur, University of Applied Sciences Braunschweig-Wolfenbüttel. http://www.ostfalia.de/cms/de/pws/turtur/FundE/index.html