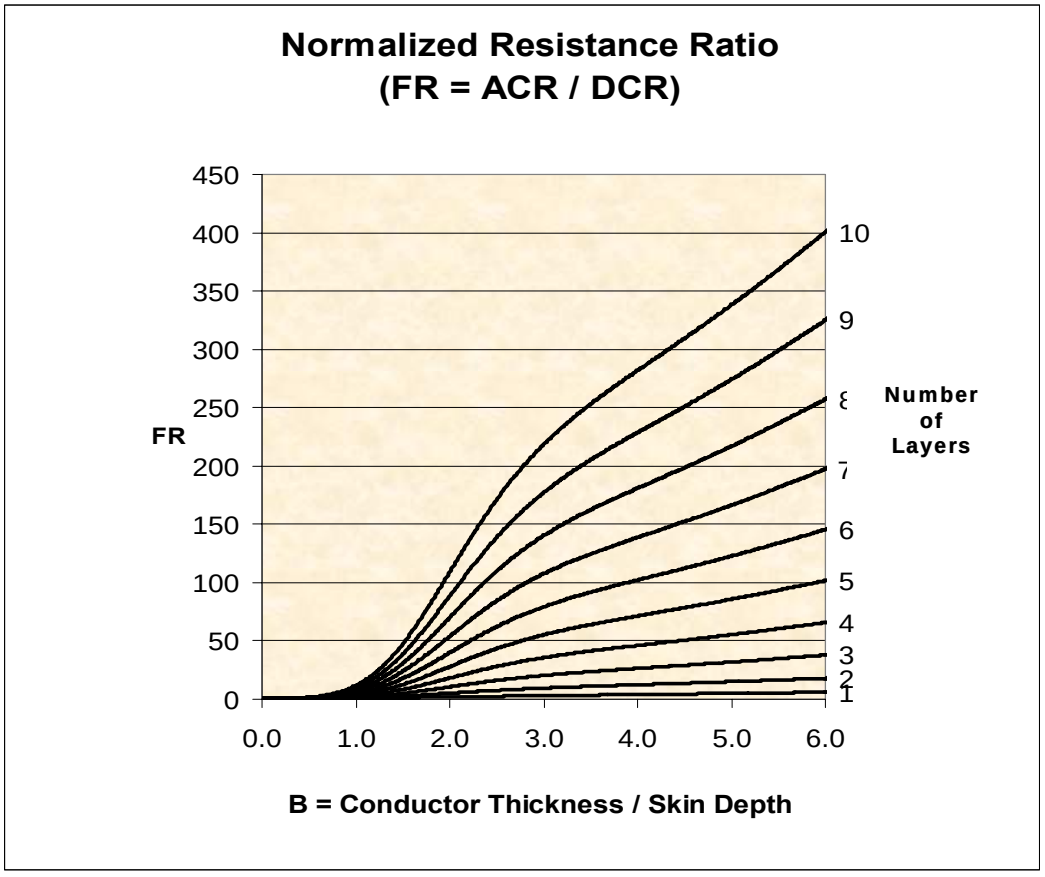
Magnetic Winding Optimization using Hyper-X Magnetic Technology ™

Introduction

This white paper introduces a novel magnetic coil technology that can significantly reduce dissipation and improve efficiency of magnetic components by optimizing winding parameters. As consumer demands and system requirements continue to push the need for smaller components, optimization of magnetic windings becomes a critical step to achieve overall system miniaturization. Hyper-X Magnetic Technology ™ ("Hyper-XMT") is a patent-pending method to achieve these goals.

Historical Method

For more than 35 years, transformer designers have used Dowell's FR analysis to evaluate the dissipation of possible winding configurations. FR is defined to be the ratio of AC resistance to DC resistance, and a plot of FR for various winding portions demonstrates that lowest FR is achieved for single layer construction:



P. L. Dowell, "Effects of Eddy Currents in Transformer Windings", Proceedings of the IEEE, Vol. 113, No. 8, August 1966 [incorporated herein by reference]

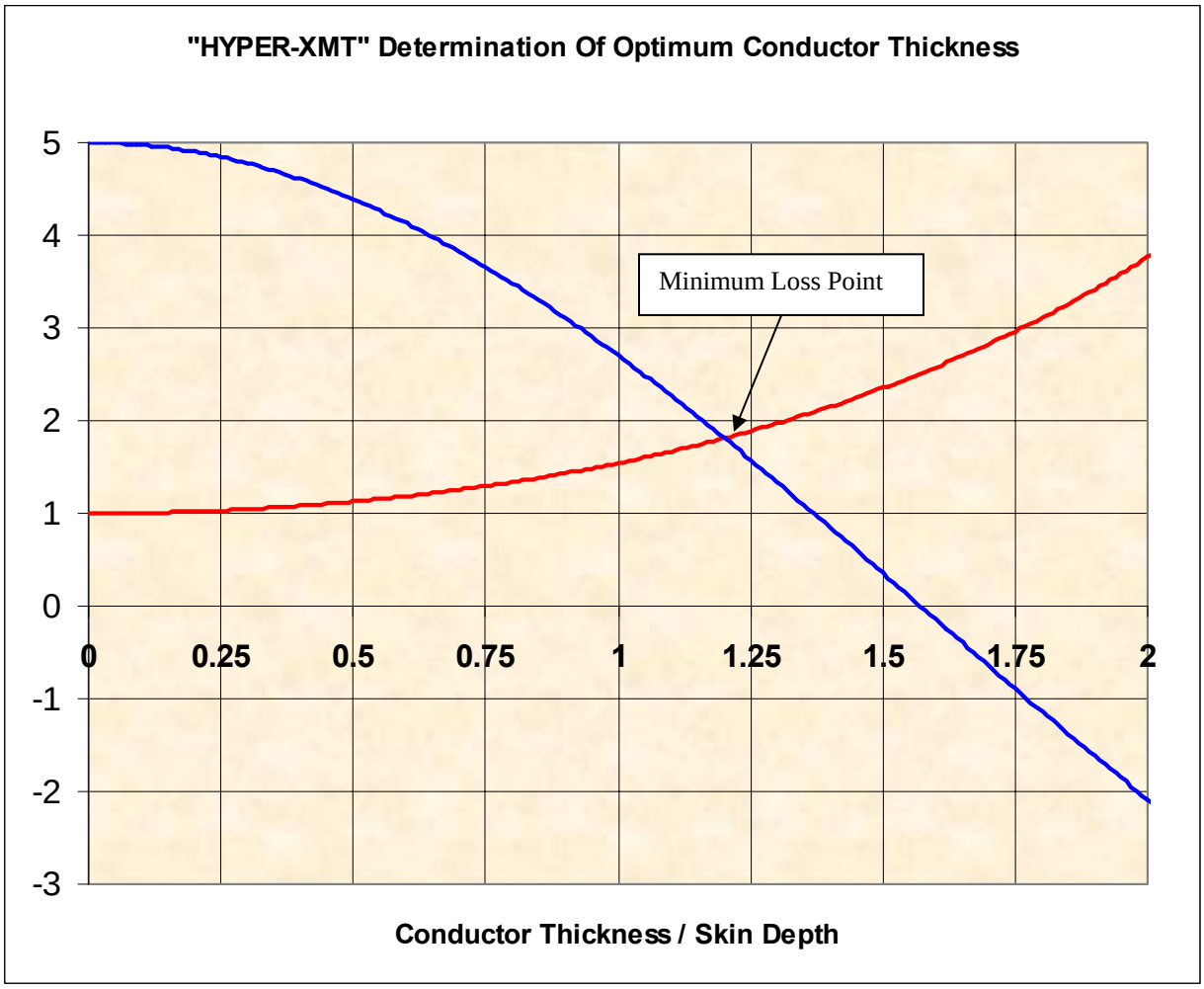
Although the concept of resistance ratio has been readily embraced by transformer designers, this technique obscures the view of minimal loss configurations. For example, minimum loss is not achieved for minimum FR. Further, since Dowell's analysis is based on the specific case of in-

phase winding currents exclusively, evaluation of losses for phase displaced winding current harmonics is challenging.

For these reasons, Tabtronics focused on finding the analytical eddy current solution for general excitation conditions of magnitude and phase. This problem is complex and closed form solutions have not been found despite much industry and academic interest.

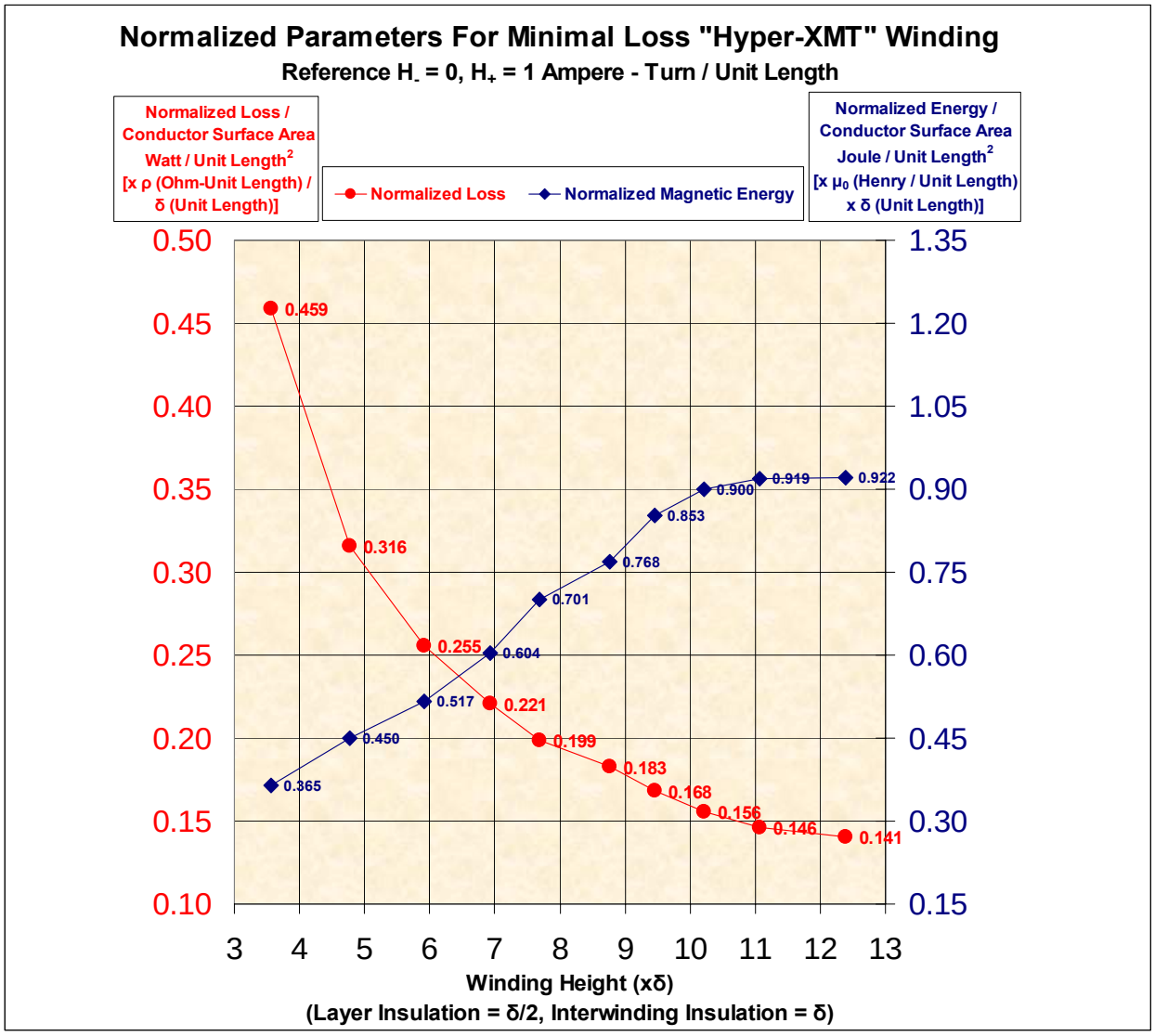
The "Hyper-XMT" Method

Innovative derivations by Tabtronics have yielded general analytical solutions of dissipation and energy for arbitrary magnitude and phase. For the first time, general analytical conditions for minimum loss have been derived. This technology is called Hyper-X Magnetic Technology ™. It is named for the minimum loss condition for in-phase winding currents which follows the intersection of hyperbolic cosine and cosine functions:



Winding Optimization

For a given frequency harmonic, Hyper-X Magnetic Technology ™ can determine the preferred conductor configuration for each layer which minimizes analytical losses. Additionally, "Hyper-XMT" has been combined with computer iteration to determine the specific winding design (turns and conductor thicknesses for each layer) that yields minimum analytical dissipation. Using normalized densities of dissipation, magnetic energy, and electric energy, the resultant parameters for the minimum loss "Hyper-XMT" construction can be readily estimated for any winding:



Since Hyper-X Magnetic Technology ™ can optimize each coil layer, coil dissipation can be more uniformly distributed over a multiple layer coil to prevent unacceptable thermal gradients. Typical loss reductions range from 12% to over 50% depending upon the application specifics. Additionally, "Hyper-XMT" can be applied to the Fourier harmonic components of a complex wave shape to determine the preferred winding design which minimizes total analytical losses. As a result, magnetic components can be made smaller and more efficient.

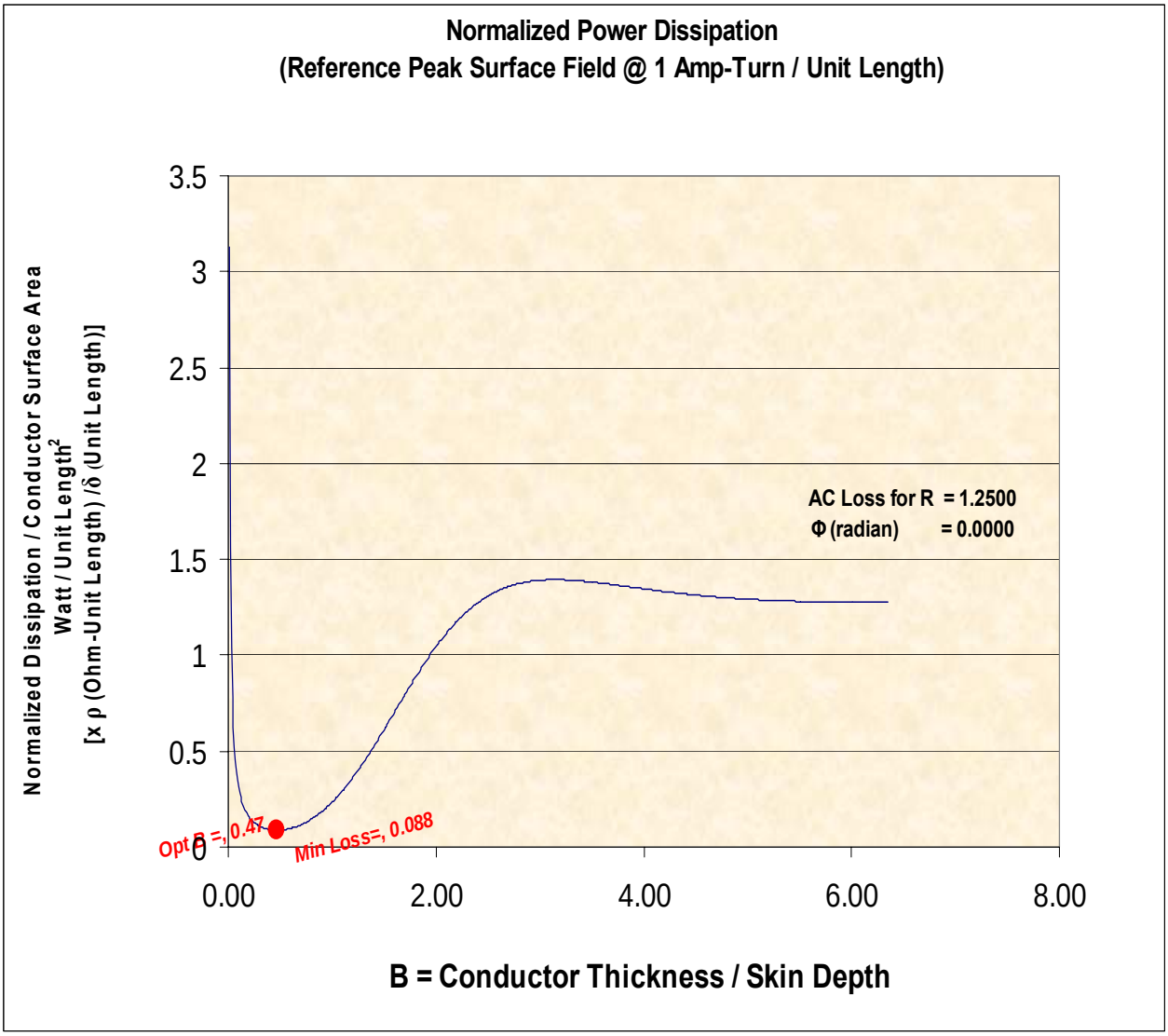
Selective Optimization

Hyper-X Magnetic Technology ™ can also be applied to individual layer(s) of a multiple layer coil to reduce dissipation selectively as illustrated in the following example:

Given:

- Application frequency of 400 Hz (implies a 0.13 inch skin depth).
- Coil having 5 layers of # 10 SQ in winding portion.

Applying "Hyper-XMT" to the 5th layer only causes a significant reduction in winding loss (7%) as well as a reduction in total winding weight (12%).



Benefits

In summary, Hyper-X Magnetic Technology ™ provides the following benefits:

- ø *Provides analytical solution for power dissipation and energy storage based upon general conditions;*
- ø *Provides effective means to consider effects of current (magnetic field) phase disparity;*
- ø *Specifies the conductor geometry that achieves minimum analytical loss in a given layer;*
- ø *Using computer iteration, the specific turns and thickness for each layer that yields minimum loss can now be found for any given number of layers;*
- ø *By normalizing loss, magnetic energy, and electric energy, the resultant parameters for this minimum loss construction can be readily estimated for any winding;*
- ø *Using Fourier decomposition of complex wave shapes, the preferred winding design which minimizes total analytical harmonic losses can now be found.*

These improvements can be applied to

- ø *High frequency applications;*
- ø *Low frequency applications involving large conductor thickness, large layer count, or harmonic current components;*
- ø *Cases of winding current (or surface magnetic field) phase shift.*

Why Tabtronics Inc.

Tabtronics specializes in creating and commercializing advanced technology for electromagnetic components. The company's technology is relied upon by military, avionics, and high technology customers.

Tabtronics has 25 years experience in direct manufacture of electromagnetic components, and also licenses its technology to other manufacturers and system integrators. The firm's continuing focus is the development of innovative methods to concentrate more power into smaller components.

TABTRONICS
thinking big. designing small. magnetics to the highest power.

For more information, or assistance with specific applications, please visit www.tabtronics.com, or contact Tabtronics Incorporated, PO Box 128, Geneseo, NY 14454-0128, 1-888-876-6424, FAX 585-243-3831.