Sevick's Transmission Line Transformers

Theory and practice
5th Edition

The long awaited revision of the classic book *Transmission Line Transformers*, by Jerry Sevick, is now in its fifth edition and has been updated and reorganised by Raymond Mack to provide communication engineers with a clear technical presentation of both the theory and practical applications of the transmission of radio communication.

Sevick's Transmission Line Transformers: Theory and Practice, *5th Edition* reviews the underlying principles that promote a better understanding of transmission line transformers. Ideal for academics and practicing engineers, this edition is divided into two clear parts for easy reference. Part one is a review of the theory and new concepts, including a discussion on the magnetic properties that affect the core of a transmission line transformer. Part two essentially focuses on the "practice" element of the book title. This section has been updated to reflect the significant changes in component suppliers over the 30 years since the first edition of the book.

Highlights of this title include the coverage of substantial background theory, recent work on fractional ratio transformers and high power Balun designs, and provides updated sources for transformer materials to reflect mergers, sales, and business failures over the past 20 years. There is also expanded coverage of commercial sources of low impedance coaxial cable; expanded construction hints for purpose built rectangular parallel transmission lines; plus an updated test equipment chapter to reflect modern computer based experimenter grade test equipment sources. Ray has leveraged his experience with ferrite materials for switching power to explain the performance characteristics of the ferrite materials used for RF power transmission line transformers.

Raymond A. Mack, W5IFS, received his Electrical Engineering degree, with emphasis on biomedical engineering, from Purdue University in 1975. His career in medical devices covered clinical chemistry analyzers, heart pacemakers, electro-surgery, and infant warming therapy. From 1999 he worked in digital television for eight years and is now working in the oil and gas industry at National Oilwell Varco. Ray has worked for QEX magazine for 12 years as a technical proofreader, editor, writes a column on software defined radio, and has authored *Switching Power Supplies Demystified*. Ray's interests include alternative energy using switching power design, microwave system design, software defined radio, and DSP.

Jerry Sevick, W2FMI—renowned for his research and publications related to short vertical antennas and transmission line transformers—passed away in 2009. Jerry was a graduate of Wayne State University and later graduated from Harvard University with a doctorate in Applied Physics. In 1956, he joined AT&T Bell Laboratories and supervised groups working in high-frequency transistor and integrated-circuit engineering; later, he served as Director of Technical Relations at the company. During his career, he undertook the characterization and design of transformers for low impedance applications, resulting in this book, originally published in 1987.

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Mack and Sevick

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Raymond A. Mack and Jerry Sevick

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Chapter 1
Transformer Basics

1.1 Introduction

There are two basic methods for constructing broadband impedance matching transformers. One employs the conventional magnetically coupled transformer that transmits energy to the output circuit by flux linkage; the other uses a transmission line transformer to transmit energy by transverse transmission line mode. Conventional transformers have been constructed to perform over wide bandwidths by exploiting high magnetic efficiency of modern materials. Losses on the order of 1 dB can exist over a range from a few kilohertz to over 200 MHz. Throughout a considerable portion of this range, the losses are only 0.2 dB. Transmission line transformers exhibit far wider bandwidths and much greater efficiencies. The stray inductances and interwinding capacitances are generally absorbed into the characteristic impedance of the transmission line. The flux is effectively canceled out in the core with a transmission line transformer, so extremely high efficiencies are possible over large portions of the passband—losses of only 0.02–0.04 dB with certain core materials.

A full model of a conventional transformer is presented in Figure 1-1. Multiple parasitic elements are affecting both low and high frequency operation. Low frequency operation is controlled by the magnetizing inductance (L_M) in parallel with the ideal transformer. As frequency decreases, the current flows mostly through the low impedance inductance (L_M) rather than the ideal transformer. High frequency operation is governed by the capacitances (C_P, C_S, and C_{PS}), leakage inductances (L_P and L_S), and core losses (R_C). As frequency increases, the output voltage and current become out of phase and the losses of the core increase. R_P and R_S are the copper losses of the respective windings. They increase with increasing frequency due to skin effect. R_P and R_S also increase with increasing temperature, so higher power applications will have higher losses.

Figure 1-2 shows the construction of two conventional transformers on a double "U" core. The windings are physically separated on the core in the first example, so the only linkage from primary to secondary occurs through the shared flux in the core. C_P and C_S in the model occur because each turn of the winding is in proximity to the adjacent turns. A very small capacitance exists between each pair of turns, and each capacitor is in series with the next one around the winding. The capacitance can be quite small, but a capacitor of only 10 pF has an impedance

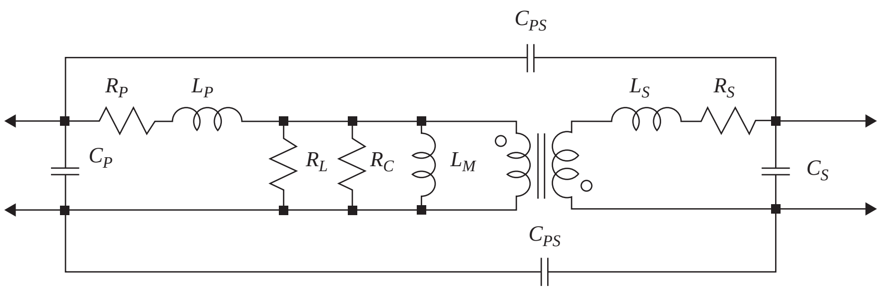

Figure 1-1 *The schematic shows a complete model of a magnetically coupled transformer.*

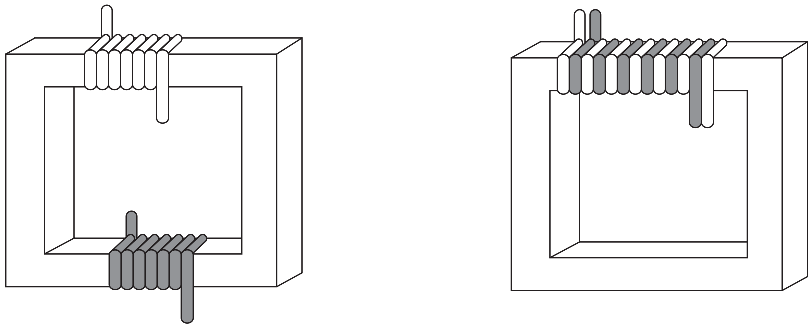

Figure 1-2 *Two different methods of magnetically coupled transformer construction: (Left) This transformer minimizes capacitive coupling with all coupling by magnetic flux. (Right) This transformer has coupling by both capacitance and magnetic flux.*

of 159 at 100 MHz. Another method of transformer design in the figure winds the secondary on top of the primary. This construction reduces L_P and L_S but increases C_{PS}. The other advantage of this construction is that flux linkage is improved at higher frequencies where the transformer tends to look more like an air core transformer with an absorber in the middle.

A basic transmission line transformer with an unbalanced input and a balanced load is illustrated in Figure 1-3. Two pieces of equal length transmission line are connected in parallel at the input side and in series on the output side. If a transmission line is terminated in its characteristic impedance, the input side appears to be Z_0 regardless of the length of the transmission line (within limits). In the example in Figure 1-3, Z_0 and each half of the load are 100 Ω. The impedance on the input side is 50 Ω because we have two 100 Ω impedances in parallel.

Oliver Heaviside used Maxwell's equations in the late nineteenth century to develop the mathematical expressions for transmission lines. Those equations show that the load is isolated from the input on a transmission line that is longer than about 0.1 wavelength. At that point, the distributed inductance and distributed

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