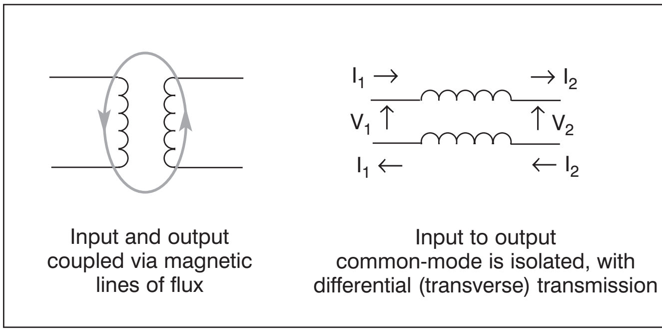
Transmission Line Transformer Basics

Gary A. Breed
Publisher

A particular class of RF transformers with excellent bandwidth and low loss is the *transmission line transformer*. This note provides an engineer's first description of such transformers and points out the differences between transmission line transformers and conventional flux-coupled transformers.

The value of transmission line transformers in RF circuits and systems is that extremely low losses (a fraction of a dB) can be obtained over bandwidths of two or more decades. Other transformer types may match the low loss over a narrow bandwidth, or they may exhibit wide bandwidth, but have 1 dB or more loss. The low loss of transmission line transformers makes them especially useful in high power circuits.

The transmission line transformer operates by transmitting energy via the transverse transmission line mode. It does not rely on the coupling of magnetic flux lines like a conventional transformer. Figure 1 shows the simplest illustration of this difference. In the transmission line transformer, the purpose of the windings is to eliminate (reduce as much as possible) common-mode currents from the input to the output. With input and output isolated in this manner, the voltages at the input and output can be treated as being independent of one another.

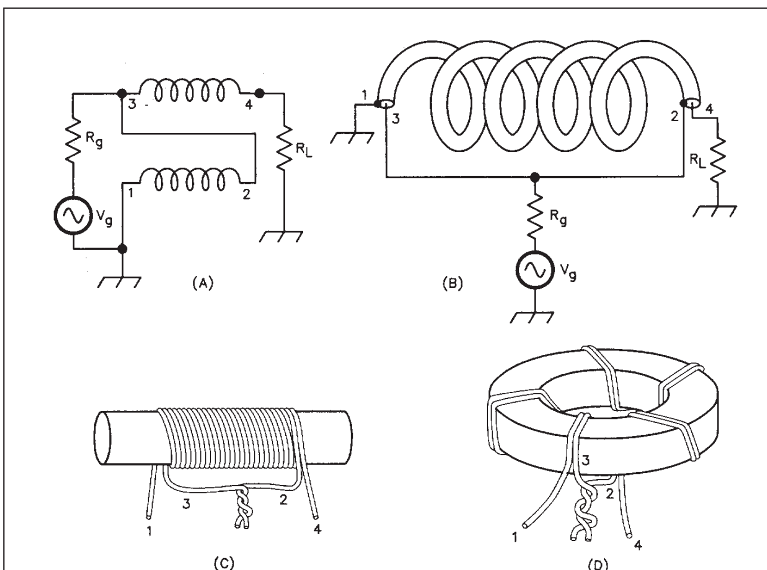


■ Figure 1. A conventional transformer (left) compared to the basic transmission line transformer section (right).

Figure 2 shows a simple transformer which has an impedance transformation ratio of 4:1 [1]. This is a Ruthroff design [2], one of the classic transmission line transformer types. In this circuit, two voltages are summed to get twice the voltage at the output. Since we must have conservation of energy in any system, R_L must be four time the value of R_S in order for the voltage ratio to be two.

Also, for this transformer to operate satisfactorily, the phase difference of the voltage fed from terminal 2 to terminal 3 must not differ much from the incident voltage. This means that the physical length of the transmission line must be very short in terms of wavelength.

We also need to maintain the required isolation from input to output in order add the delayed voltage at 2 "back on itself" at 3. This isolation is obtained by forming the transmission line (coaxial cable or closely spaced parallel wires) into an inductance. Inductance is maximum with a magnetic core of iron powder or ferrite material, as shown in Figure 2(c) and (d).



■ Figure 2. Four diagrams of a Ruthroff type 1:4 unbalanced-to-unbalanced transformer: (a) schematic, (b) coaxial cable schematic, (c) rod core pictorial, and (d) toroid core pictorial (from [1]).

This short introduction cannot fully explain the operation of transmission line transformers, but it illustrates its basic properties and operating principles. ■

References

1. Jerry Sevick, *Transmission Line Transformers*, Noble Publishing Corp., 1996.
2. C.L. Ruthroff, "Some Broad-Band Transformers," *Proc. IRE*, Vol. 47, Aug 1959, pp. 1337-1342.