Balun Transformers

A Balun is a device which converts balanced impedance to unbalanced and vice versa. In addition, baluns can also provide impedance transformation, hence the name Balun Transformers.
The following sections describe the properties of various commercially available baluns.

Types of Transformers

Following are the most commonly available balun transformers:

I. Ruthroff[1] Balun Transformers.

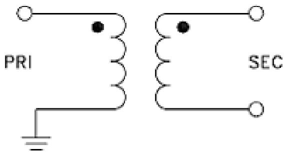


Figure 1a

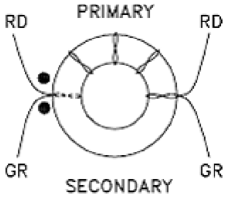


Figure 1b

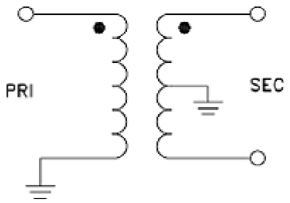
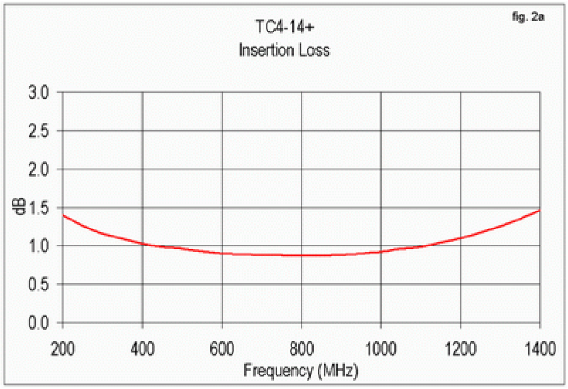
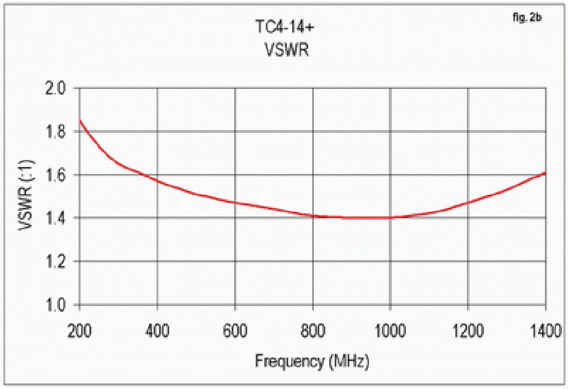


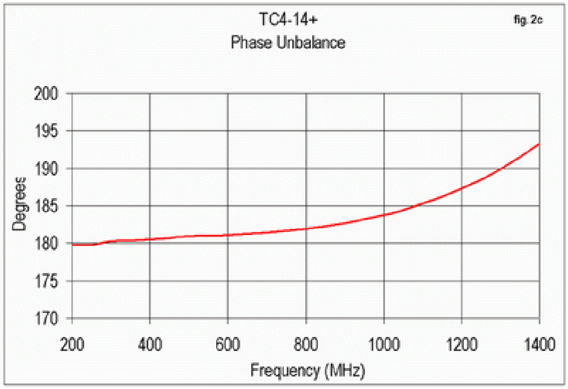
Figure 1c

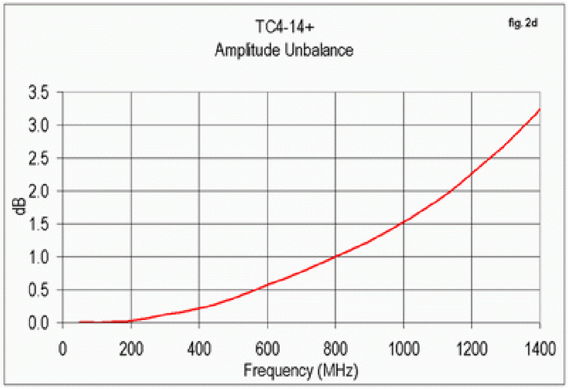
In the most common form, these use a pair of twisted magnet wire wound around a ferrite or powdered iron core.**Figure 1(a)** shows an equivalent circuit of the balun, and **Figure 1b** shows its actual implementation. Baluns of this type provide multi decade bandwidth and are generally limited to frequencies below 1.5 GHz. They also provide isolation from primary to secondary, and can provide a variety of impedance ratios. The higher the impedance ratio, lower the bandwidth. Variations are constructed with secondary center tap, **Figure 1(c)**.

Figure 2, shows performance of such a Balun, having 1:4 impedance ratio and center-tapped secondary. (Model TC4-14+)









II. Guanella^2 or Transmission line transformers

As frequency of operation increases, insertion loss of Ruthroff transformers increases; so also unbalance and VSWR. Transmission line transformers overcome these limitations.

Figure 3(a) shows the equivalent circuit of a 1:1 balun. Figure 3(b) its implementation in simplest form. Figure 3(c) is its alternate implementation. Figure 3(d) shows a 1:4 balun.
Transmission line transformers provide very wide bandwidth and operate up to 3 GHz and higher.

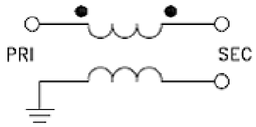


Figure 3(a)

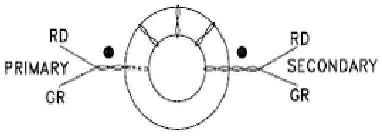


Figure 3(b)

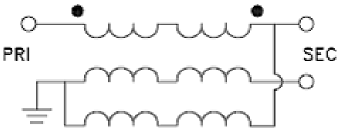


Figure 3(c)

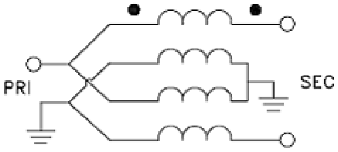
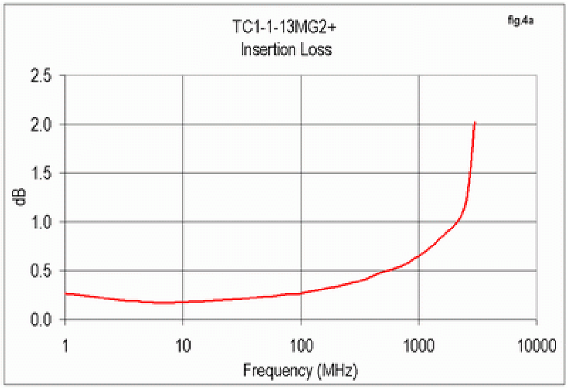
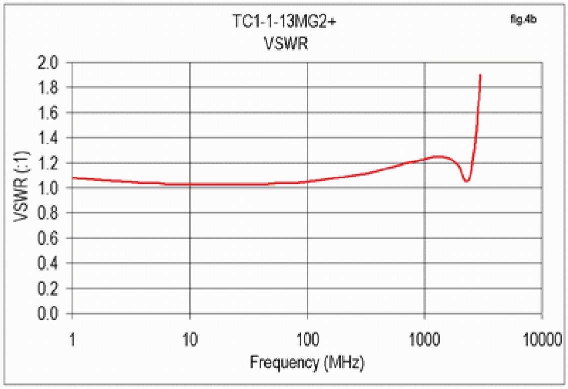
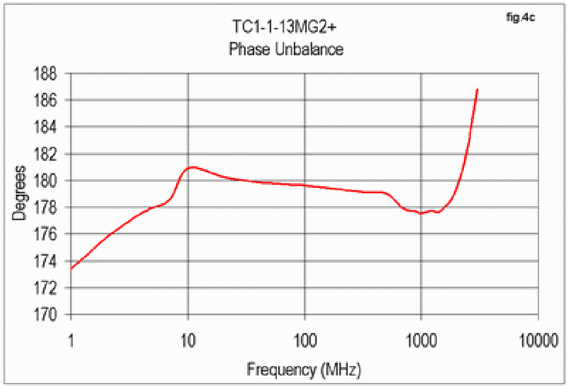


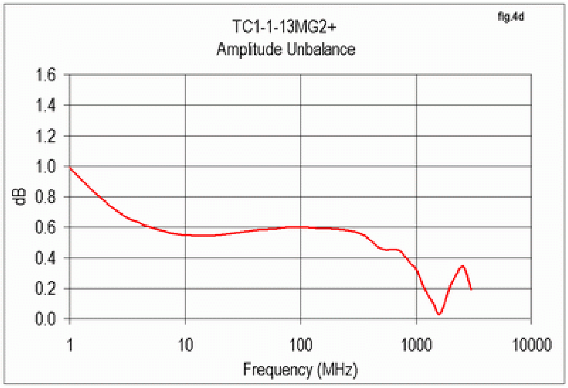
Figure 3(d)

Figure 4 shows the performance characteristics of a transmission line balun implemented in LTCC. [(Model TC1-1-13MG2+)](#)









III. Marchand Balun^3 Transformers

Transmission line transformers do not provide isolation from primary to secondary. When such isolation is essential for the performance of the circuit, external DC blocks need to be used. Marchand Balun overcomes this problem. Fig 5 shows its schematic.

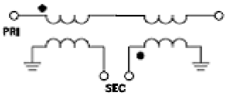
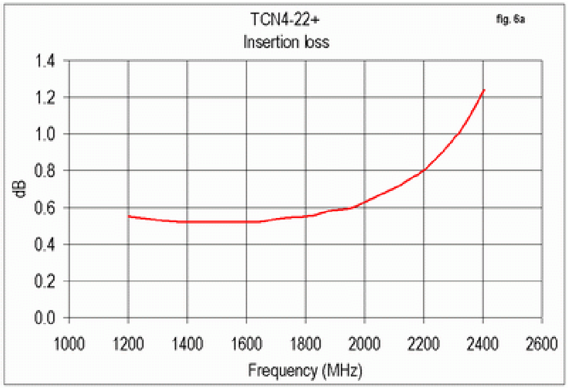
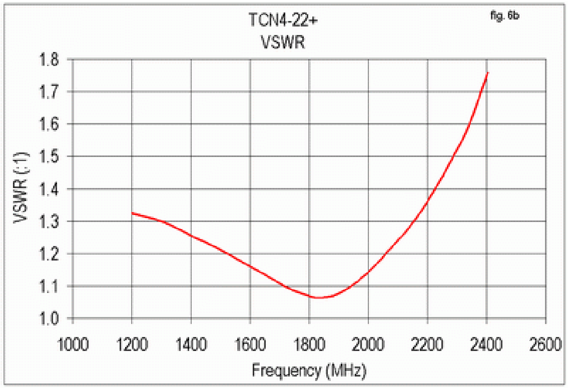
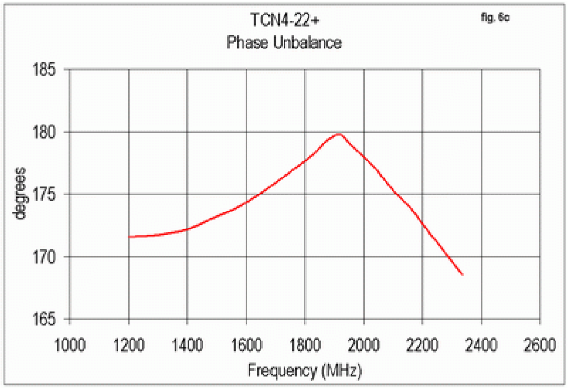


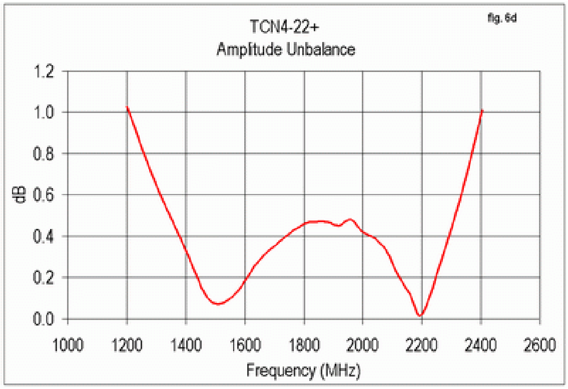
Figure 5

In its original form it used coax/cavities and was very bulky. Over years of research, it was implemented in microstrip and in recent years in LTCC (Example: Some Mini-Circuits models with prefix TCN and NCS). LTCC baluns are very compact (such as 1206 or 0805 size). Commercial Marchand baluns operate above 600 MHz. Theoretically, they can provide any impedance ratio, but commercially available baluns are generally limited to 1:1, 1:2, 1:3 and 1:4 ratios. Figure 6 shows the performance of a Balun implemented in LTCC, (Model TCN4-22+) In addition to being compact, LTCC baluns also provide stable performance over a wide temperature range such as -55° to 100°C.









Characterization at arbitrary impedances

Balun transformers are generally characterized in 50 or 75 ohm systems until now due to the limitation of the test instrumentation. Thanks to the availability of impedance transforming capabilities of the new network analyzers (such as Agilent's ENA/PNA series), it is possible to characterize them at any other impedances.

Explanation of terms used

Insertion Loss

Prior to the availability of modern network analyzers, the baluns were connected back to back and the insertion losses of two baluns were measured together. Insertion loss of a single balun was calculated by dividing the measured loss by two.

In recent years, baluns are characterized as 3 port networks, like a two-way 180° splitter. As the impedance at the secondary ports is generally not 50 ohms, impedance transformation is essential to do an accurate measurement. One method is to use resistive matching pads at the secondary[4] for that purpose. In this method insertion losses from primary dot to secondary dot and primary dot to secondary (after subtracting loss of matching pad and 3 dB for loss due to theoretical split) are measured. The average of these two losses is specified as insertion loss.

New network analyzers such as Agilent's PNA series provide impedance transformation and port extension capabilities and hence there is no need to add resistive matching pads. This also enables measurement for any user-specified input and output impedances.

Unbalance- Amplitude and Phase

In an ideal Balun, with input at primary (unbalanced port), the output voltage at the two secondary ports should be identical in amplitude but differ in phase by 180°. In practical Baluns there is always a difference, amplitude unbalance (expressed in dB) and phase (deviation from 180°) expressed in degrees. The set up used for charactering a balun as a 3-port network, provides two insertion losses (primary dot to secondary dot and primary dot to secondary). The difference of these two powers in dB is called amplitude unbalance. The phase angle deviation from 180° between the secondary ports is phase unbalance.

Input Return Loss

When the secondary is terminated in its ideal impedance, the return loss measured at the primary is the input return loss. It is a measure of the effectiveness of the balun in transforming impedance.

References:

1) Ruthroff, C.L., "Some Broadband Transformers," Proc IRE, vol 47, August 1959, pp 1337-1342

2) Guanella, G., " New Method of Impedance Matching in Radio-Frequency Circuits", Brown Boveri Review, September 1944, pp. 327-329

3) Marchand, N., "Transmission-Line Conversion transformers", Electronics, Vol 17, December 1944, pp 142-145

4) Mini-Circuits Application Note, "How RF Transformers work and How they are measured," Click here to review this article