Lossless Diplexers for Mixer Applications

by

Chris Trask / N7ZWY
Sonoran Radio Research
P.O. Box 25240
Tempe, AZ 85285-5240

Senior Member IEEE

Email: christrask@earthlink.net
16 July 2009
Revised 18 July 2009

Introduction

When using diode ring mixers, the intermodulation distortion (IMD) performance is highly dependent upon the load and source impedances seen by the three ports (RF, LO, and IF). Any mismatch of these ports will cause signal energy to be reflected back to the mixer, where it will interact with the other signals and produce additional IMD products.

One could terminate the ports with wideband amplifiers, but in most cases this is impractical due to any number of reasons. One in particular is the case of an IF amplifier in a receiver, where some degree of selectivity immediately after the mixer is desired so as to reduce the possibility of IMD products in the amplifier. In such cases, it would be desireable that a lossless circuit be employed that will pass the desired spectrum and terminate the undesired signals, while at the same time presenting a constant impedance at the input to satisfy the needs of the mixer. Such a circuit is commonly refered to as a diplexer.

Distributed Element Diplexers

At microwave frequencies, a simple diplexer such as being considered here can be realized by way of an in-phase power divider, a Magic-T, and a piece of transmission line that is a half wavelenth long at the centre frequency of the desired band, as shown in Fig. 1. At the centre frequency, the signal at the first input of the Magic-T is equal in amplitude and opposite in phase to the signal at the second input . Thus, the signal will appear at the difference output port, while at the same time signals that are equal in amplitude and phase will appear at the summation port. Obviously, there will be a degree of summation and difference over a wide band, but the concept is fairly simple. Diplexers of this sort will have multiple difference and summation port resonances at odd and even integral half-wavelengths of the transmission line.

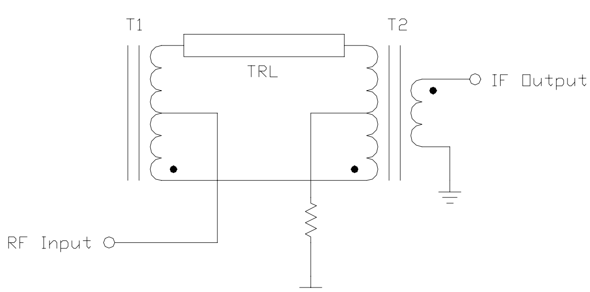

Fig. 1 - Distributed Lossless Diplexer

Lumped Element Diplexers

At lower frequencies, distributed elements become impractical due to their physical size, so lumped elements are employed. The transmission line of Fig. 1 is now replaced with a lumped element 2-pole allpass network, as shown in Fig. 2. The hybrid transformer T_1 is a simple 2CT:1 wideband transformer, such as a Mini-Circuits T4-1 or T4-6T. An equally suitable transformer can be made with a trifilar twist of wire wound on a suitable ferrite or powdered iron core.

The 2-winding inductor L_1 may appear to be fairly simple, however in order to work properly the coupling coefficient between the windings is much less than unity, so making L_1 by way or a twisted pair on a fixed core or a variable coil form (much preferred) is not very practical. There are various methods of transposing the all-pass network into other forms that

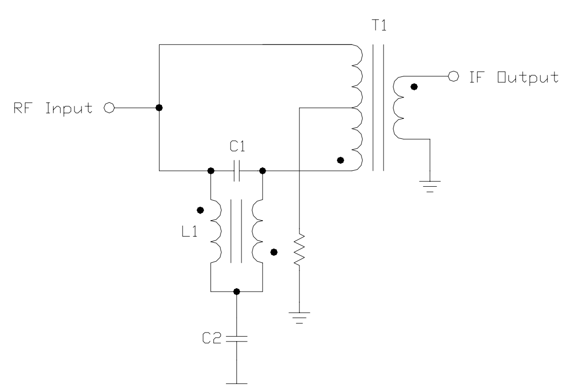

Fig. 2 - Lumped Element Lossless Diplexer

are reasonably practical, and the one that I have found to be the least expensive and easiest to use is that of Fig. 3. Here, the 2-winding inductor L_1 has close to unity coupling, so it is easily made by way of a twisted pair on a variable coil form. The single inductor L_2 is also variable, and it's value is such that it can usually be purchased as a commercial part.

To calculate the element values, we begin by first determining the damping factor k:

$$k = \frac{1}{Q} = \frac{BW}{f_0} \tag{1}$$

where BW is the 3dB bandwidth and f_0 is the centre frequency of the desired band. We now derive the intermediate values L and C:

$$L = \frac{k\,2\,R_L}{\omega} \tag{2}$$

$$C = \frac{1}{L\,\omega^2} \tag{3}$$

where R_L is the diplexer load resistance and ω is the frequency in radians/second:

$$\omega = 2\pi f \tag{4}$$

Now, the values of the two-winding inductor L_1 and capacitor C_1 are found by way of:

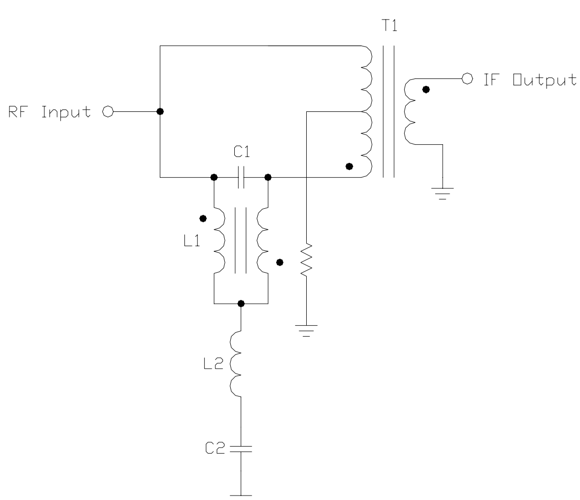

Fig. 3 - Practical Lossless Diplexer

$$L_1 = \frac{L}{2} \tag{5}$$

$$C_1 = \frac{C}{2} \tag{6}$$

We now define an additional pair of intermediate values L_A and C_A, which are:

$$L_A = \left(1 - k^2\right)\frac{L_1}{2} \tag{7}$$

$$C_A = \frac{L}{4\,R_L^{\,2}} \tag{8}$$

which now let us determine the values of inductor L_2 and capacitor C_2 by way of:

$$L_2 = L_1 + L_A \tag{9}$$

$$C_2 = 2\,C_A \tag{10}$$

Alignment

Tuning this circuit is quite simple. With a signal generator set to the desired centre frequency and connected to the input,and an oscilloscope connected to the lower end of the primary winding ot T_2, open (or remove) capacitor C_2 and adjust inductor L_1 for a minimum signal voltage. Restore capacitor C_2, short capacitor C_1, and adjust inductor L_2 for a minimum signal voltage. Remove the short across capacitor C_2. Now, connect the oscilloscope to the circuit output and adjust inductors L_1 and L_2 slightly to obtain a peak voltage reading.

References

1. Schauman, R., M.S. Ghausi, and K.R. Laker, *Design of Analog Filters: Passive, Active RC, and Switched Capacitors*, Prentice-Hall, 1990
2. Blinchikoff, H.J. and A.I. Zverev, *Filtering in the Time and Frequency Domains*, Kreiger, 1987.