interstage 50-ohm terminator for vhf converters

Many mixers and preamplifiers require a 50-ohm load — here's a circuit for providing a wideband resistive termination with minimum insertion loss

When cascading modules for receiving systems, it is often necessary to make sure that a particular stage is presented with a reasonably precise 50-ohm termination, over a relatively broad range of frequencies. One such requirement involves terminating a low-noise preamplifier which, although unconditionally stable at the operating frequency, is potentially unstable out-of-band. The highly reactive termination presented by a bandpass filter, operated off resonance, may cause the amplifier to oscillate at some undefined frequency, significantly degrading system noise figure and intermodulation performance. Another problem involves the image-frequency termination of double-balanced mixers. It has been shown that, to maximize a mixer's dynamic range, the i-f port must be properly matched – not only at the signal frequency, but also at any multiple-response frequencies appearing at the i-f.[1]

One method for obtaining a broadband interstage impedance match is based on the use of resistive attenuators between various stages.[2] Unfortunately, this approach introduces additional system losses which tend to degrade overall sensitivity. Another solution uses *interstage duplexers* which shunt the undesired frequency into a 50-ohm load.[3] This practice, however, is applicable only when the frequency of the undesired response is known and is well removed from the signal frequency. The circuit in **fig. 1** overcomes these shortcomings: It appears *virtually* lossless at the signal frequency and provides a wideband 50-ohm termination to any other frequency components which are present (limited only by the reactive nature of the load resistors at microwave frequencies). Additionally, this network provides the desired degree of interstage *selectivity*, as a function of the component values chosen.

The circuit of **fig. 1** is by no means original; it was brought to my attention by Gary Frey, W6KJD, who first encountered it in a commercial receiver design. Gary and I have both used the circuit extensively in vhf and uhf transmit and receive converters with considerable success.

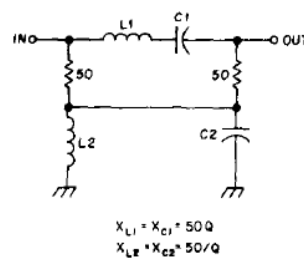

fig. 1. Vhf terminator which provides a wideband 50-ohm termination with minimum insertion loss. Component values are based on desired circuit Q, as discussed in the text. Equivalent circuits at resonance, and above and below resonance, are shown in fig. 2.

circuit operation

In the circuit of **fig. 1** capacitor C1 and inductor L1 form a series-resonant circuit at the operating frequency, while C2 and L2 are parallel resonant. At resonance the impedance of L1-C1 is at a minimum, the impedance of L2-C2 is maximum, and the signal path from input to output appears as a short circuit across the two 50-ohm

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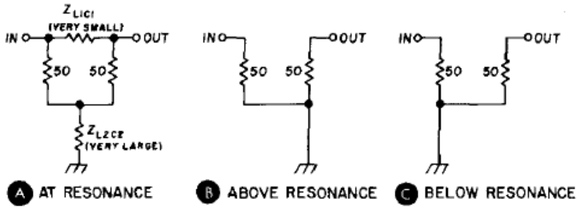

fig. 2. Equivalent circuit of the 50-ohm vhf terminator at resonance (A), above resonance (B), and below resonance (C).

resistors, as shown in **fig. 2A**. Thus the insertion loss of the network at resonance is minimal (due primarily to component losses in the resonant circuits).

At frequencies far above resonance, capacitors C1 and C2 appear as short circuits, and inductors L1 and L2 appear open. Thus the circuit is equivalent to that shown in **fig. 2B**, with input and output isolated from one another, and each port terminated in a 50-ohm load.

Well below the resonant frequency, both capacitors appear open, the two inductors may be thought of as short circuits, and the equivalent circuit of **fig. 2C** applies. Again, maximum isolation exists between the two ports, and each is terminated in 50 ohms.

A less clearly defined condition exists at frequencies slightly removed from resonance. Isolation is incomplete and the transfer coefficient is a function of circuit Q. Thus the selectivity characteristics of a single-pole band-pass filter are achieved. However, non-propagated signal components are not reflected, as would be the case with a simple resonant circuit. Rather, they are absorbed by the 50-ohm loads, giving the interstage network its wide-band terminating properties. Since reflected waves are not evident from either port, bilateral out-of-band isolation has been achieved.

determining circuit Q

Assuming minimum dissipative losses in the reactive components, circuit Q is primarily a function of the ratio of the reactances at resonance to the terminating impedance (50-ohms in this case). Selecting a desired circuit Q, component reactances at resonance are found from:

$$X_{L1} = X_{C1} = 50Q$$

$$X_{L2} = X_{C2} = 50/Q$$

Ideally, any desired circuit Q could be selected, and component values derived. Practical considerations, however, restrict practical values of Q to 10 or less. Higher Q is possible if passband insertion loss is not a significant consideration, but this usually requires that variable capacitors be used to set the network to resonance at the desired frequency. With lower values of Q, fixed components of standard values may be used with minimum circuit degradation.

The required Q is a function of the amount of out-of-band isolation which is desired, as well as the frequency separation between the signal and spurious components. It is useful to relate isolation requirements to ripple bandwidth, which is defined as center frequency divided by Q. As a rule of thumb, isolation is 10 dB for frequency components separated from resonance by ±3BW and 20 dB of isolation is achieved at the center frequency ±10BW.

In receiving converters, when terminating the i-f port of a balanced mixer, the rf feedthrough, LO feedthrough, and image frequency components may be separated from the i-f signal frequency by an order of magnitude or more. In such cases a Q of one may be entirely adequate to effectively isolate all spurious components. (Incidentally, a Q of unity is the only case for which C1 = C2 and L1 = L2).

Improperly terminated uhf preamplifiers, on the other hand, often tend to oscillate in the vhf spectrum (a common occurrence with Microcomm's RA-70, 432-MHz preamplifier, for example). Therefore, the terminator following a preamplifier should exhibit relatively high Q so it will provide adequate isolation at the frequency of potential instability, thus suppressing oscillation. An acceptable compromise seems to favor a Q of about 5. Insertion loss thus remains low (fractions of a dB), selectivity is moderate, and components have practical values and are non-critical.

Table 1 lists actual component values for terminators operating at various i-f and rf frequencies of interest to radio amateurs, assuming a circuit Q of 5. At the lower frequencies the circuits may be built successfully by using disc capacitors and either miniature molded rf chokes or hand-wound toroidal inductors. In the uhf region, the use of chip capacitors and microstripline inductors seems more appropriate. Of course, as frequency is increased, lead lengths must be kept to a minimum.

table 1. Interstage 50-ohm terminator component values (Q = 5) for various vhf and uhf amateur bands.

	frequency (MHz)						
	10.7	28	50	144	222	432	1296
L1 (nH)	3720	1420	796	276	179	92	30.7
C1 (pF)	59.5	22.7	12.7	4.4	2.9	1.5	0.5
L2 (nH)	149	56.8	31.8	11.1	7.2	3.7	1.2
C2 (pF)	1490	568	318	111	71.7	36.8	12.3

acknowledgements

I wish to thank Gary Frey, W6KJD, for bringing this terminator circuit to my attention, explaining its operation to me, and calculating the component values presented in **table 1**. And I owe a special thanks to Stan Savage, W6ABN; his frustration in fighting oscillations in not one, but two Microcomm preamplifiers, convinced me of the importance of providing an effective, broadband impedance match.

references

1. Peter Will, "Reactive Loads — The Big Mixer Menace," *Microwaves*, April, 1971, page 38.
2. Edward L. Meade, Jr., K1AGB, "Using the Double-Balanced Mixer in VHF Converters," *QST*, March, 1975, page 12.
3. Doug DeMaw, W1CER, "His Eminence — The Receiver," *QST*, June, 1976, page 27.

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