DESIGN NOTES

Wideband UHF/Microwave Active Isolators

Jiri Polivka
Spacek Labs

Ferrite isolators are common design components in many RF and microwave systems. They ensure good matching between mismatched components, often covering octave frequency bands. However, at UHF and for extremely wide bandwidths, ferrite devices are not available.

An active isolator can solve the problem, utilizing a wideband MMIC amplifier and one or two attenuators to reduce its gain while offering a high reverse isolation and good impedance match over a wide band.

Introduction

Ferrite isolators are common in RF and microwave (even optical-fiber) systems. They isolate mismatch-sensitive components like filters and amplifiers from mismatched ones by their lack of reciprocity: in the forward direction they have a small loss, while in the reverse direction the loss (isolation) is much larger: this ratio is from <0.5 dB forward loss to >20 dB reverse isolation. Ferrite isolators and circulators are commercially available for up to octave bandwidths, including versions for high power.

The author had a project that required a number of isolators that needed to cover 0.4 to 1.8 GHz. Such isolators in ferrite version are not available today. The required bandwidth exceeds one octave, and at UHF, the ferrite devices need special composition and a low-intensity magnetic field.

The only option was to design a device capable of isolator function. An active isolator was developed using commercially available MMIC amplifiers with high gain that is constant over the bandwidth, along with SMT attenuators (Figure 1). The idea was to connect the attenuator and amplifier so the forward gain becomes close to zero while reverse isolation will be >20 dB. This concept is not new; the author recalls reading an old article on "active circulators" using discrete transistor amplifiers.

Active Isolator Design

Wideband MMIC amplifiers are easy to find. RF MicroDevices, Mini-Circuits, Agilent, Sirenza and many other manufacturers offer a big selection. There are, however, other aspects than gain to be considered. Cascading a MMIC amplifier and an attenuator looks
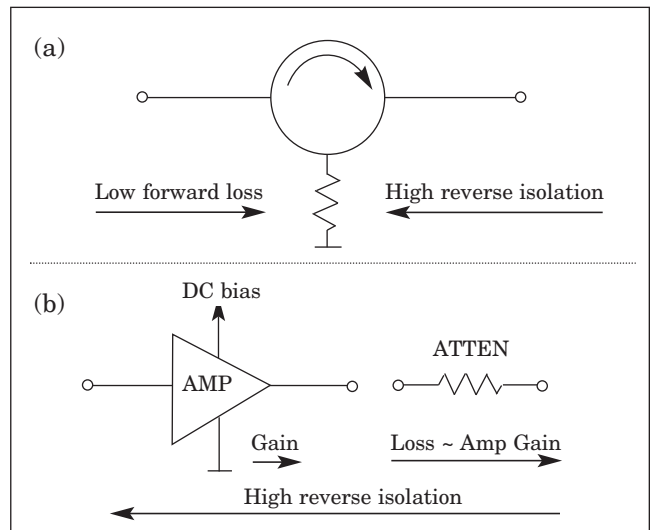

Figure 1 · (a) Passive (ferrite) isolator; (b) active isolator using a MMIC amplifier and attenuator.

easy—the finished circuit can have ±1 or 2 dB gain/loss over the 0.4 to 1.8 GHz bandwidth. But there are some problems to deal with:

Noise Figure—Where noise figure is important, a low-noise MMIC amplifier should be connected before the attenuator, so the assembly has a NF determined almost solely by the MMIC amplifier. Still, a ferrite isolator with <0.5 dB insertion loss is better, since the forward loss is its NF.

Also, locating the attenuator at the end of the combination, the "active isolator" may reach its output power compression level too easily. Finally, some MMIC amplifiers, while having a low NF, are not well matched at input, other types have mismatched outputs.

Linearity—Amplifier linearity is usually defined by the P_{1dB} power level. This quantity is also frequency dependent. Low-cost MMICs designed for low-level operation typically have P_{1dB} around +15 dBm, with higher-power versions up to +27 dBm. Very low NF MMICs, however, often have P_{1dB} at 0 to +6 dBm. Therefore, where P_{1dB} is important, the attenuator should be located before MMIC amplifier, but this will increase the device noise figure.
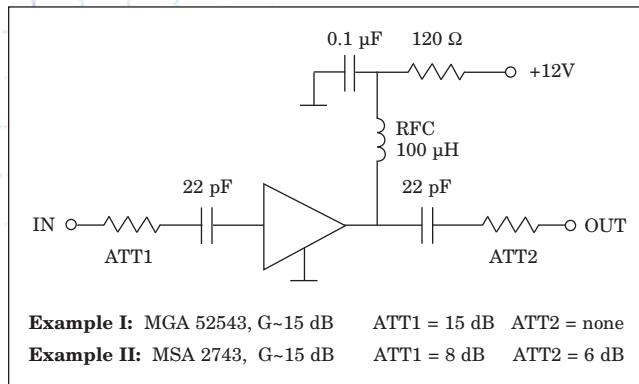
Input and Output Matching—Many MMICs do not

Figure 2 · Example active isolator circuit.

Figure 3 · Measured performance of a UHF ferrite isolator (~570-870 MHz) compared to an active isolator. Noise figure measurements are not included.

have perfect matching to 50 ohms nominal impedance. For instance, AH-4 high dynamic range MMIC usable from 0.25 to 6 GHz offers 12-13 dB of gain and 2.7 dB noise figure. With +21 dBm for P_{1dB} it is a very good universal amplifier. Its input return loss is, however, only 8 dB, and 15 dB for output. Such a MMIC can be best used as an active isolator with an attenuator added to input. This will save its high P_{1dB} but the noise figure will rise to ~15 dB.

Design Examples

For the author's application, two MMIC-attenuator combinations (Figure 2) were tested that meet the requirements for a moderate NF, moderate P_{1dB}, good isolation and input/output matching.

Active Isolator I—The Agilent MGA 52543 was chosen for its ~15 dB gain, and the 15 dB attenuator was connected before it. The complete device has a forward loss of 0.5 to 1.0 dB over 0.4 to 1.8 GHz while the isolation was ~35 dB min. Input and output return loss is ~13 dB and ~10 dB respectively. The noise figure is ~18 dB, and the P_{1dB} is +10 dBm, both acceptable for the particular application. DC bias is +12 V, 30 mA.

Active Isolator II—Agilent MSA 2743 was chosen for its ~15 dB gain, and the attenuation was divided between input and output: 8 dB before, and 6 dB after the amplifier. Mini-Circuits LAT-*x* MMIC attenuators were used. The complete device has a small gain, 1 to 2 dB over the band, with isolation of >33 dB and return loss at both input and output >15 dB. Noise figure is ~13 dB and P_{1dB} is +8 dBm, acceptable for the application. DC bias is +12 V, 70 mA.

As a comparison, a UHF ferrite isolator covering 570-870 MHz was measured, and achieves just 18 dB of isolation while its input and output match is comparable with the active isolators (Figure 3).
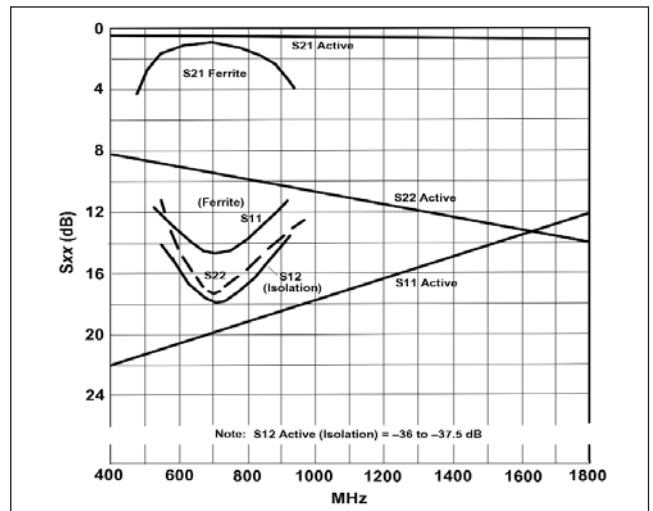
Conclusion

An active isolator is a useful solution for controlling impedance-related problems in systems at VHF/UHF frequencies and over wide bandwidths, where ferrite isolators or circulators are unavailable or expensive. For these applications, the simple described circuit is easy to design and operate. Perhaps MMIC designers would consider offering an integrated version on the market, mainly for the wide bands at VHF and UHF, and soon for UWB applications.

For low-signal level applications like the author's, the low cost of designing an active isolator may make it the preferred solution, even in the case of a narrower bandwidth. However, designers must consider the potentially degraded noise figure or P_{1dB} point.

The author may be reached by e-mail at: jpolivka@spaceklabs.com

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2. Mini-Circuits RF/IF Designer's Guide, 2001.
3. Hewlett-Packard (Now Agilent) RFIC Designer's Guide, 1997.
4. W-J Communications, AH-4 Data Sheet, Sep. 2000.

[*Readers may find the following article useful—ed.*]

5. Charles Wenzel, "Low Frequency Circulator/Isolator Uses No Ferrite or Magnet," *RF Design*, July 1991. Can be viewed at the Wenzel Associates Web site: http://www.wenzel.com/pdffiles/RFDesign3.pdf