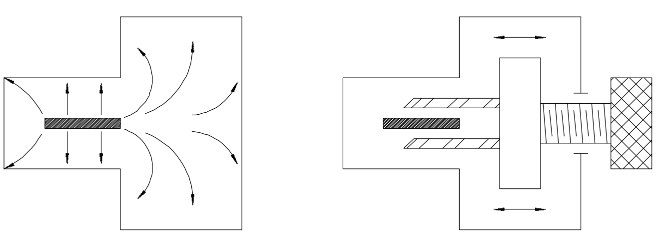
RF & MICROWAVE VARIABLE ATTENUATORS DC - 18.0 GHz GENERAL INFORMATION

Microwave Coaxial Ferrite Attenuators

A variable attenuator placed between a signal source and a load can be used to control the signal power transmitted to the load. The power transmitted to the load can be varied manually or electronically from nearly the full power of the source to as little a millionth of a percent of the source power (-80 dB) depending on the frequency of operation.

Merrimac coaxial variable attenuators are two-port devices ideally suitable for adjusting power delivered to loads through RF coaxial transmission paths. Merrimac's catalog microwave attenuator units normally employ ridged or coaxial transmission lines wherein the electro-magnetic field surrounding the center conductor is loaded by vanes of ferrite or other lossy elements. The relative degree of intrusion of the lossy elements is correlated with a calibrated dial or other measurement device. Thus, overall attenuation may be inferred by the angular position of a shaft relative to a given index mark.

The penetration of the lossy materials into the electro-magnetic field dissipates RF energy in direct proportional to the extent of immersion of the material into the field. The lossy vanes are mounted to a graphite carrier block which provides both a thermal path to conduct the heat generated within the vanes to the outer shell of the attenuator and a dry lubricant for the adjustable vane assembly. Figure 1 illustrates the basic concept.



Rectangular Coaxial Design showing Electromagnetic Field.

Representative Cross-Section showing Sliding Block with Vanes.

Figure 1. Ferrite Attenuator Design

Merrimac offers a broad assortment of variable attenuators for various bandwidths, attenuation levels, dissipation capacities, mechanical drives and packages for frequencies between DC and 18.0 GHz.

Four standard drive mechanisms serve most system and instrumentation needs :

1) Micrometer drive suitable for calibration requirements;
2) Non-translating screw or knob drive engraved in dB for precision attenuation measurements;
3) Turns counting dial or knob drive suitable for calibration;
4)) Accurate dial drive engraved in dB for precision attenuation measurements.

Special Attenuator Requirements

Many variable attenuator microwave applications require performance optimized to provide precision performance across specific narrow bandwidths. Merrimac variable attenuators normally provide superior performance over narrow bandwidths as may be seen in the performance characteristic graphs included in this catalog.

Catalog items can be modified or specially tuned to provide higher attenuation levels, flatter response, lower insertion loss and VSWR according to the application's special requirements. Call for details and typical curves for a particular frequency band.

Specially designed items requiring miniaturization, different connectors, drives and mounting features are also available on special order.

Variable Attenuators Below 500 MHz

Merrimac attenuators below 500 MHz include those with manual knob or slotted screw adjustments and electronically controlled units with either digital or analog control.

Compensated Bridged Tee Network Attenuators

Compensated bridged tee network attenuators are continuously variable attenuators utilizing compensated bridged tee networks to vary signal power as illustrated in Figure 2. These well matched, conservatively rated devices are designed for DC to VHF in the manually variable models (AR, ARM and ARS series) and HF to UHF in electronic type (ARE series).

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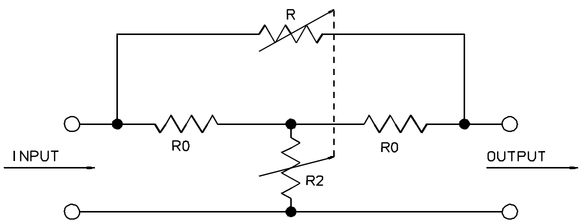

Figure 2. Compensated Bridged Tee Design

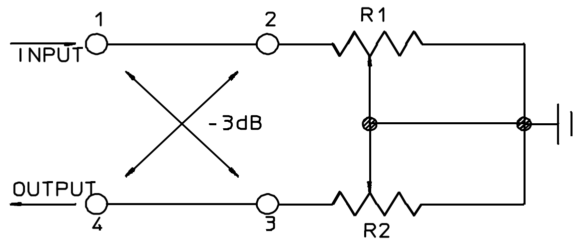

Figure 3. Quadrature Hybrid based Design

Frequency Limitations

The highest usable frequency for a manually adjustable attenuator depends primarily on how much impedance mismatch is tolerable. As signal frequency increases, wavelength decreases. As wavelength decreases, the fixed, finite dimensions of the attenuator's circuit elements become progressively larger in proportion to the wavelength.

As a result, the ratio of capacitive to inductive reactance changes with increasing frequency thus altering the impedance. This, in turn, leads to an impedance mismatch that tends to increase with frequency. At some point the mismatch will become unacceptable and that point defines the unit's highest usable frequency.

The highest usable frequency for electronically controlled attenuators is principally determined by the junction capacitance of the series diode. The smaller the physical size of the diode, the lower the capacitance and the higher the frequency at which it will be useful.However, with decreasing size comes decreased heat dissipation capacity. Thus, there is a tradeoff between upper frequency bound and power handling capacity.

The low frequency limit of electronically controlled attenuators is determined by the de-coupling chokes. Flatness may thus be improved by bandwidth reduction or by using a smaller diode junction. Although attenuation flatness (with varying frequency) is not normally specified, units selected or designed for a flatness of 1 dB, for example, can be obtained on special order.

Quadrature Hybrid Based Attenuators

Quadrature hybrid based attenuators are manually controlled attenuators used for narrowband leveling and control applications. The chief advantages of this design approach are flat attenuation and minimal phase shift variations. This approach uses a quadrature hybrid linked to a pair of variable, tracking resistors, as shown in Figure 3.

Changing the resistance values alters the mismatch. This modifies the response from ''complete'' absorption to ''complete'' reflection of the input signal. Thus, the output level is varied by approximately 20 dB while maintaining a good match at both the input and output.

An additional benefit of this approach is that the bandwidth limitation is about 25% due to the quadrature hybrid. High frequency operation is limited by stray capacitance and asymmetries in the variable element. Response flatness is a function of the band pass characteristics of the quadrature hybrid and may be improved by using a broadband unit.

Electronically Variable Attenuators

Electronically variable attenuators are continuously variable attenuators used for applications requiring automatic signal leveling and control, amplitude modulation, remote signal control, etc. The simplest realization is a balanced mixer circuit in which the diodes are biased over the linear portion of their characteristic curve. The disadvantage of this approach is that the impedance ''seen'' by the signal source changes with the bias.

A quadrature hybrid as shown in Figure 4 may be used to eliminate this problem at the cost of decreased bandwidth. With the configuration shown, modifying the bias or control current through the pair of tracking diodes causes variations in their RF impedances changing from ''complete'' absorption to ''complete'' reflection of an incident RF signal.

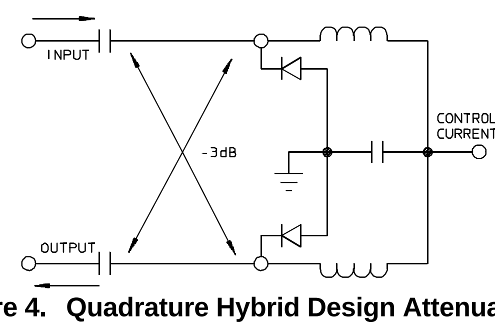

Figure 4. Quadrature Hybrid Design Attenuator

The overall performance of these designs depends critically on the precise tracking of the series and shunt variable elements. The low frequency limit is set by the values of the coupling capacitors, the core materials used for the decoupling chokes and the diode junctions. The high frequency limit is determined by stray capacitance and inductance, diode junction capacitance and resonances in the decoupling chokes. This type of attenuator (AEF and AFF series) can be supplied at frequencies from audio to microwave.

Digital Attenuators

The standard catalog AD series digital attenuators are switched pad attenuators designed to be driven directly by TTL. They accept straight binary input and produce monotonically increasing RF attenuation. Diode switches are used to route the signal through the appropriate resistive pads. For applications requiring attenuation of signals that include DC, relays are substituted for the diode switches at the cost of reduced switching speed. When isolation from switching transients is a requirement, it is important to cancel out their effects using quadrature hybrid switch sections or a similar balanced approach. Many such digital switches are available and can be supplied on special order.

Parameter Definitions

Attenuation Range - The difference in dB between the maximum and minimum obtainable attenuation. The minimum obtainable attenuation is normally the basic insertion loss.

Attenuation Flatness - The difference in dB between minimum and maximum attenuation at a given attenuation setting over the specified frequency range at ambient temperature (unless otherwise specified).

An attenuation flatness specification of 0.5 dB or 5% (whichever is greater) is typical for a 0 to 30 dB model. This means that when set at 10 dB, the maximum attenuation variation is 0.5 dB over the frequency range. However, when the same unit is set at 30 dB, the attenuation variation can be as high as 5% of the level set, i.e., 1.5 dB.

Insertion Loss - The loss in dB of the attenuator when set at the minimum attenuation position.

VSWR - The VSWR at either port at any attenuation setting with the other port terminated with a perfectly matched load.

Calibration Accuracy - The maximum deviation in dB between attenuation obtained and that shown by the unit's attenuation indicator assuming zero setting error. In a step attenuator, for example, if the selector were set to 10 dB and actual attenuation provided was 10.1 dB at one frequency and 9.9 dB at another, the calibration accuracy would be ±0.1 dB. In a continuously variable attenuator with an analog type indicator, the assumption is that the dial is set "exactly" to the attenuation desired; an ideal condition which excludes the additive error effects of "precision" and resetability.

Resetability - The difference in dB between a desired attenuation *setting* and that actually obtained. This is contrasted with "calibration accuracy" as defined above. Resetability is a measure of precision in the mechanical apparatus used to adjust the attenuator. In a step attenuator, mechanical detents provide digital increments and perfect resetability results. In continuously variable, attenuators provided with analog type indicators such as micrometers or verniers, resetability depends on factors such as backlash in gearing and "mechanical hysteresis." In general, the more turns of a micrometer it requires to cover the entire attenuation range, the better is the resolution on small deviations and the better is the resetability.

Here is an example of how to determine resetability. Assume an attenuator is equipped with a micrometer which provides 100 turns from end to end of the attenuation range. Assume further that each turn of the micrometer is divided into 50 increments. Finally, assume that because of gear clearance and other factors that the attenuation does not change until the micrometer is moved one tenth of one of those increments. The resultant resetability would therefore be 1/100 x 1/50 x 1/10 = 1/50,000. In this example the resetability would be 0.002%. In the case of a micrometer-equipped attenuator, the resetability is usually much better than the calibration accuracy because of the resolution provided.

In an electronically controlled attenuator, resetability depends on the resolution of the device that adjusts the control current.

Power - The capacity of the attenuator in watts to pass CW power through it under matched load conditions.

Reliability

Merrimac variable attenuators have been designed in accord with MIL-A-24215A. Certain models have been qualified to this military specification.

MTBF calculations performed in accord with MIL-HDBK-217B can be provided for reliability estimates. Merrimac has provided the highest reliability components possible consistent with catalog-based items. Models have quality factors monitored to MIL-I-45208A or MIL-Q-9858A Quality Control Level as may be required by your application.

For higher levels of reliability, Merrimac can provide attenuators with Hi-Rel connectors at additional cost. Other environmental services such as high temperature exposure (bake), burn in, vibration, etc. are available.

Calibration Data

All variable attenuators driven with micrometer or turns counting dial drives can be calibrated at specified frequencies upon request.

To order calibrated models, the center operating frequency must be specified when ordering. The maximum anticipated operating attenuation level at that frequency must also be specified. A calibration chart showing attenuation versus micrometer or turns dial setting will accompany the attenuator when shipped.

Merrimac standard catalog models are calibrated at the attenuation increments shown in Table 1.

Table 1

Standard Catalog Attenuator Calibration Increments

Unit Attenuation Range In dB				
0 - 20	**0 - 40**	**0 - 50**	**0 - 60**	**0 - 80**
1	1	1	1	1
2	2	2	2	2
3	3	3	3	3
4	4	4	4	4
5	5	5	5	5
10	10	10	10	10
15	15	15	15	20
20	20	20	20	30
	25	25	30	40
	30	30	40	50
	35	40	50	60
	40	50	60	70
				80

Attenuation Ranges (dB)

Contact Merrimac if other attenuation increments are required. Calibrated models with dials permanently engraved in dB are also available.

Panel Mounting Provisions

In addition to the attenuators shown in this catalog that are expressly designed for panel mounting, Merrimac can supply most of its attenuators with provision and hardware for panel mounting. Inquire at the factory regarding availability of special units custom designed for your application.

The miniature screw slot drive models and certain screw driven, non translating models are available as optional panel mountable and non-panel mountable styles. They are essentially identical except that the necessary mounting hardware, as illustrated in each panel mountable outline drawing, is provided with the panel mountable models.

All knob driven models and turns counting dial models are panel mountable and are delivered with the necessary mounting hardware.

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