

# Broadband Amplifier Gain Slope Equalization with a Single Passive Component

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This article describes the performance of a newly-developed component intended for amplifier gain slope equalization over frequency and temperature

With the new and increasing demand of the Internet and multimedia on the commercial side, and the broadband high data rate communications links on the aerospace

and military side, RF and microwave amplifiers are being used in many broadband applications in the 2 to 20 GHz range.

Gallium Arsenide (GaAs) monolithic microwave integrated circuit (MMIC) amplifiers lose gain with increasing temperature and increase in gain with decreasing temperature. The ratio of gain change/°C tends to increase with frequency, making it difficult to compensate the amplifiers in a chain and causing unwanted equalization effects. There are three variables which must be considered when designing GaAs amplifier lineups: gain, gain slope versus frequency, and gain variation versus temperature.

## Gain Slope Compensation Versus Frequency and Temperature

Specifications for multifunction assemblies often require positive gain slopes versus frequency, within a narrow gain window. The change in gain slope over temperature makes it difficult to fit these gain windows at all temperatures. An equalizer creates a positive slope over frequency, which only works within a limited temperature range. On the other hand, a microprocessor can set an attenuator gain control level over temperature, which works best over a limited range of frequencies. These factors define the need for a new component to help bridge this gap.

A temperature and frequency variable equalizer is a passive microwave component with an attenuation characteristic that varies as a function of frequency and temperature. The equalizer consists of a temperature variable attenuator [1] and a temperature variable filter network where resistance and component values are changed to generate different responses that vary over temperature and frequency. This absorptive temperature variable microwave gain equalizer is produced utilizing at least three different thick film thermistors, with two of these used on the attenuator and a third one used on the filter network. The temperature coefficients of the thermistors are different and are selected so that the attenuator and filter network attenuation change at a controlled rate with changes in temperature while the impedance of the gain equalizer remains significantly constant. Almost any temperature coefficient of resistance can be created for each resistor by properly selecting and mixing different inks when forming the thick film thermistors. Furthermore, the gain equalizer's characteristic responses can have either a negative or positive temperature coefficient of attenuation.

## Temperature and Frequency Variable Equalizer

The equalizer presented here is a variable microwave attenuator, wherein the attenuation changes at a controlled rate with changes in temperature and frequency, while the impedance remains significantly constant.

Gain equalizers are used in applications that require signal level control. Level control can be accomplished by either reflecting a portion of the input signal back to its source or by

PASSIVE EQUALIZER

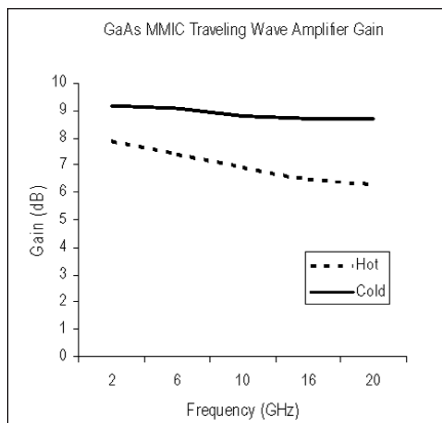


Figure 1 · Gain for a TWA from 2 GHz to 20 GHz without compensation.

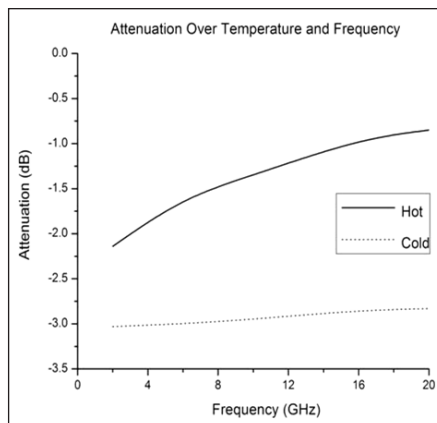


Figure 2 · Temperature and frequency variable equalizer performance from 2 GHz to 20 GHz.

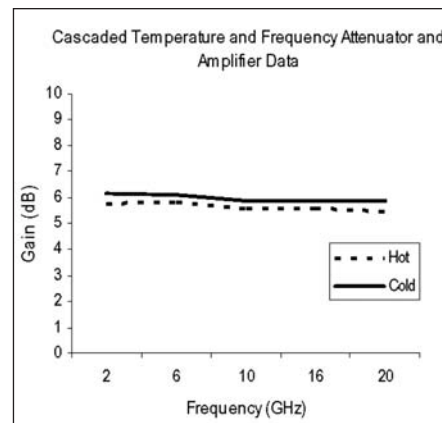


Figure 3 · Gain over frequency for a TWA from 2 GHz to 20 GHz with passive compensation.

absorbing some of the signal in the equalizer itself. The latter case is often preferred because the mismatch that results from using a reflective equalizer can create problems for other devices in the system such as nonsymmetrical two-port amplifiers. It is for this reason that absorptive passive components are more popular, particularly in microwave applications.

The important parameters of a temperature variable gain equalizer are: response as a function of frequency and temperature, return loss, and stability over time and temperature. Variations in temperature can affect various component parts of a microwave system causing differences in signal strengths at different temperatures and frequencies. Time, effort and expense goes into the components of such systems in an effort to stabilize them over various temperature and frequency ranges. This greatly increases the cost of microwave systems that must be exposed to wide temperature ranges. A gain equalizer is a passive component that solves this issue by flattening the linear increase in attenuation (decrease in gain) with frequency and temperature. In order to achieve this, the gain equalizer utilizes thermistors with resistance values that change over temperature.

It is common today to find thermistors used in many types of electronic circuits. They are often employed as temperature compensating elements in analog circuits and as detectors in temperature probes. Most thermistor applications are at frequencies of a few hundred megahertz or less. To our knowledge, there are no components utilizing the attributes of a thermistor in a microwave attenuator circuit that are usable up to 6 GHz or more for simultaneous temperature and frequency gain slope compensation.

An example of this can be demonstrated using a GaAs MMIC Traveling Wave amplifier. Figure 1 shows the gain changes over frequency for two temperatures: hot (+85° C) and cold (-55° C). Figure 2 shows attenuation data over frequency for a temperature and frequency equalizer designed by EMC Technology to compensate for these variations. The attenuation slopes over temperature are the opposite of the amplifier gain slopes. There is also less attenuation at hot and more at cold, which, when cascaded with the GaAs amplifier, keeps the gain more constant with flatter slopes.

This amplifier data is cascaded with the hot and cold data of the temperature and frequency equalizer, and the net results are presented in

Figure 3. These results show an equalized gain slope along with reduced gain change over temperature. The gain variation over frequency has changed from 1.3 dB to 0.31 dB, and over temperature from 2.4 dB to 0.42 dB over the frequency range of 2 to 20 GHz. This is a significant improvement obtained without complex gain controls.

By using the temperature and frequency equalizer, the gain variation of GaAs MMIC amplifiers is reduced to a point where it will be possible to meet gain windows that are much narrower than what has been possible in the past.

Conclusion

A passive temperature and frequency equalizer that simultaneously corrects the gain slope of an amplifier over frequency and temperature has been presented in this paper. This unique component combines a temperature variable attenuator and frequency equalizer in one small passive component. The measured data shows an impressive attenuation change over temperature and frequency over a broad frequency range. This passive equalizer reduces the complexity of microprocessor-based solutions and reduces time to market.

(continued on page 26)

References

1. EMC Technology, U.S. Patent 5,332,981. July 26, 1994.

Author Information



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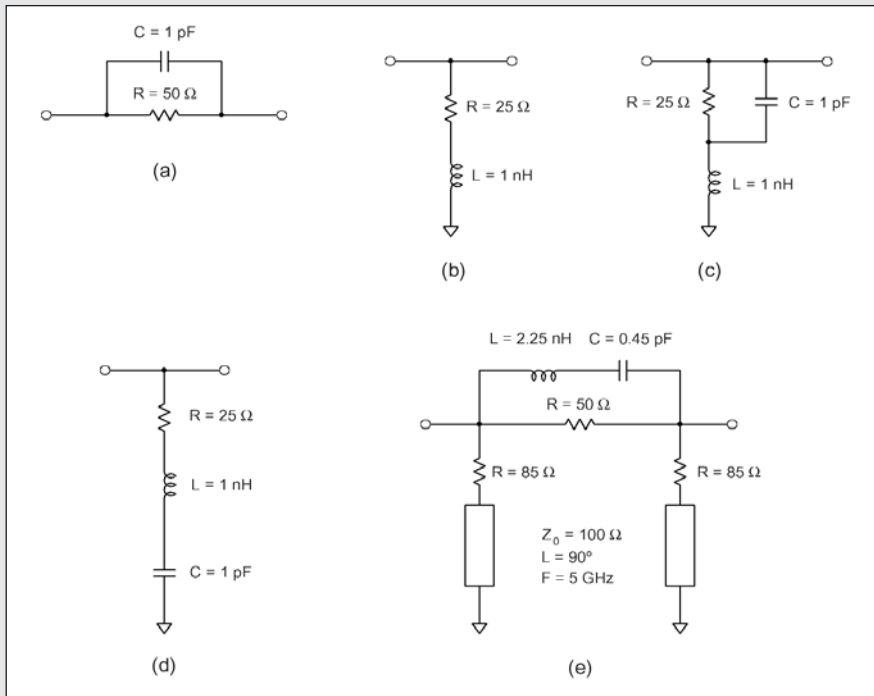
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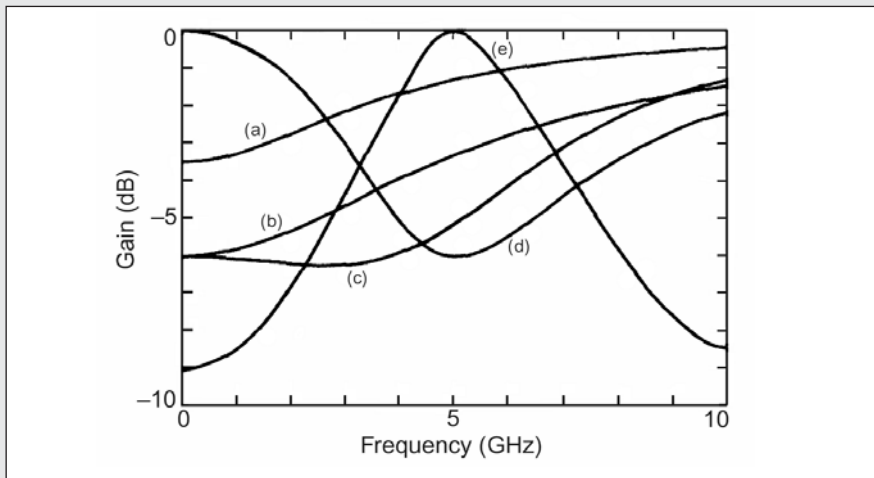
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Example Equalizer Circuits

*Microwave Circuit Design Using Linear and Nonlinear Techniques* by Vendelin, et al, includes these equalizer circuits, providing various attenuation versus frequency behaviors, as noted in the response plots.



Schematic diagrams and component values for five equalizer types.



Gain (attenuation) versus frequency for the five example equalizers.

Reference

George D. Vendelin, Anthony M. Pavio, Ulrich L. Rohde, *Microwave Circuit Design Using Linear and Nonlinear Techniques*, John Wiley & Sons, 1990, Chapter 5, Figure 5.32. (Note: 2nd ed. published in 2005).

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