

ADJUSTABLE MM-WAVE GAIN EQUALIZERS

Growing demand for higher communication bandwidths has led to considerable development of systems operating at millimeter-wave frequencies. These systems have, in turn, stimulated research and development efforts of 26 to 40 GHz components such as TWT and solid-state amplifiers and phase shifters. These novel components often suffer from bandwidth limitations due to variations in the gain-frequency response. Gain equalizers are used to correct the gain-frequency response of complex communication systems in order to increase serviceable bandwidth. While the need for this gain-frequency correction in mm-wave systems is great, field-adjustable mm-wave gain equalizers for 26 to 40 GHz frequencies have not been available. In response to these new markets and technological trends, Aeroflex/Inmet has re-

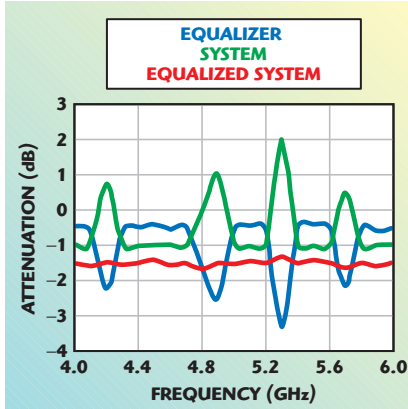
cently developed field-adjustable gain-equalizer technology optimized specifically for mm-wave applications.

To introduce gain-equalization at millimeter-wave frequencies, critical qualities such as versatility and high dependability must be met. The technology must utilize precise and stable mechanisms used in the tuning elements or tuners. Aeroflex/Inmet has 30 years of experience developing all types of fixed, adjustable and field-adjustable gain equalizers with broadband coverage for various military and commercial applications.

DESIGN OF mm-WAVE EQUALIZER PACKAGE

Gain equalizers are classified by the type of correction they provide, namely slope, parabolic and ripple equalizers (as shown in **Figure 1**). Equalizers can also be divided into fixed

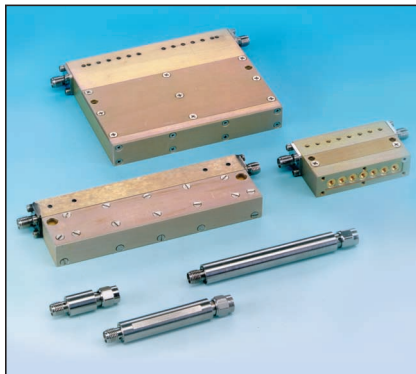
Fig. 1 Gain-frequency correction in a complex communication system.



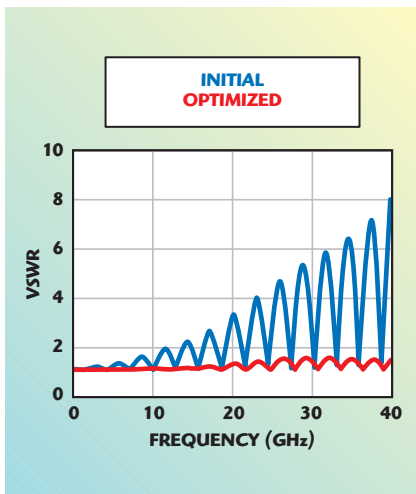
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(tubular) and adjustable (rectangular) models based on the end user's ability to modify the shape of the gain correction and the gain-equalizer form factor (some examples of which are shown in **Figure 2**).

The use of existing gain-equalizer technology was limited at higher frequencies by the higher mode cut-off in the SMA transmission lines, tuning filters and other coaxial elements, which had been proportionally scaled for optimal operation below 26.5 GHz. The first step in realizing a mm-wave equalizer was the development of a rectangular package with a long coaxial transmission line. The coaxial line accommodates the placement of multiple tuning elements while maintaining low reflection characteristics up to 40 GHz. This helps support various types of correction curves with minimum additional parasitic loss. In addition, the transmission line is robust with respect to environmental stress conditions as described by MIL-STD-202 standards.



▲ Fig. 2 Examples of gain equalizers.

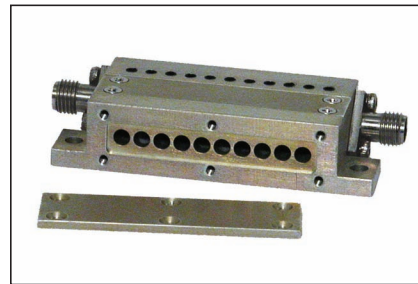


▲ Fig. 3 Initial and optimized VSWR using a compensating step.

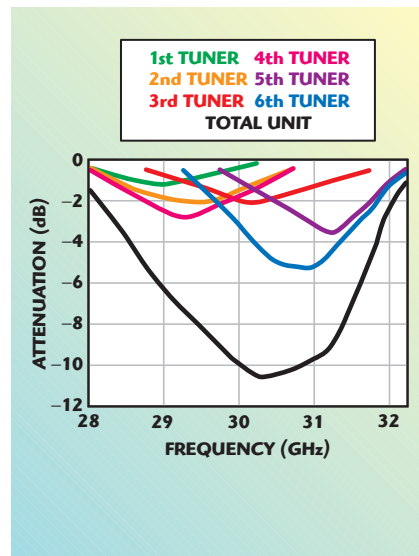
To achieve low reflection characteristics, the design of a 2.5"-long coaxial transmission line and its transitions to 40 GHz 2.9 mm connectors was optimized with the help of a 3-D electromagnetic simulator. The length of the compensation step between the center conductor and outer conductor of the 2.92 mm bead was optimized in order to reduce coupling capacitance, as illustrated in **Figure 3**. The developed package allowed installation of up to 10 tuning elements and the use of 2.9 mm and 2.4 mm connectors, as shown in **Figure 4**.

40 GHz TUNING ELEMENTS

Equalization of the gain-frequency response is addressed by frequency- and amplitude-adjustable tuning elements that resonate at uncoupled frequencies. By carefully selecting the full-width half-maximum (FWHM) bandwidth, the resonance frequency and the magnitude of the loss (or quality factor) from every individual tuner element, it is possible to build



▲ Fig. 4 The equalizer's rectangular package.

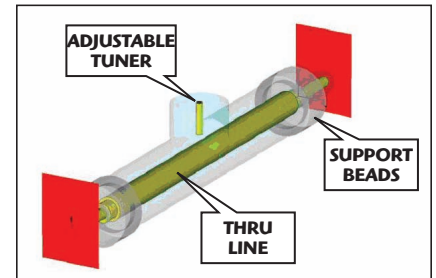


▲ Fig. 5 Example of a Ka-band parabolic equalizer's performance.

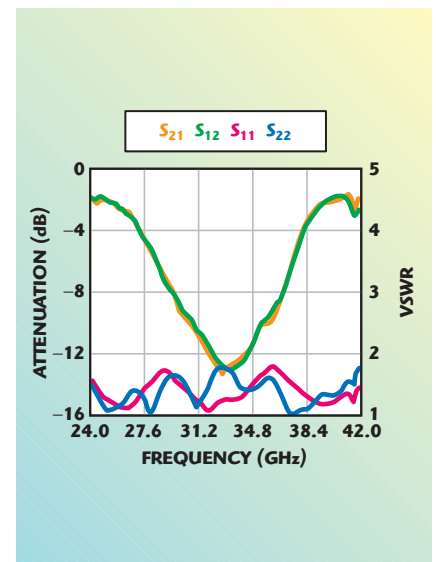
various types of complicated correction curves. The slope and parabolic type equalizers for 26 to 40 GHz applications require the use of wide and medium-band tuners with FWHM bandwidths of ~3 and ~1 GHz, respectively. Narrow-band tuners with a FWHM bandwidth of less than 300 MHz can be utilized to generate a ripple-type equalizer.

An example of a Ka-band parabolic equalizer constructed using six medium- and wideband tuning elements (tuners) is shown in **Figure 5**. The resonant frequency and the magnitude of the individual tuners are set to oppose the gain bumps in the equalized system. The modification of tuning elements to operate up and above 40 GHz was complicated by the need to scale most of the piece parts by half, while still meeting the demanding requirements of precise and robust operation of the tuning screws.

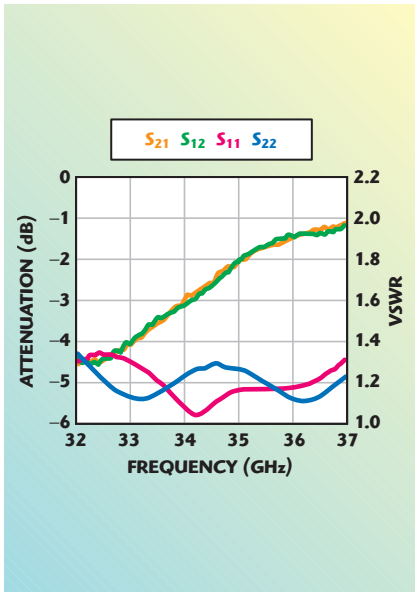
A complete 3-D electrical model used for development of a 40 GHz tuner is shown in **Figure 6**. The di-



▲ Fig. 6 3-D electrical model used in the 40 GHz tuner development.



▲ Fig. 7 Fully adjustable 10 dB parabolic-slope equalizer's performance.



▲ Fig. 8 A 4 dB negative-slope equalizer's performance.

mensions of the coupling cavity, length and diameter of the resistive element and the locations of the tuners were all optimized for maximum versatility and highest TEM-mode frequency of operation.

EXPERIMENTAL DATA

The new technology was demonstrated across the entire 26 to 40 GHz band using a fully adjustable 10 dB parabolic-slope equalizer (see **Figure 7**), as well as a 4 dB negative-slope equalizer (see **Figure 8**).

Most parabolic curves and linear slopes up to 15 dB are achievable across the broader 26 to 42 GHz band or within a selected sub-band. In addition to the linear and parabolic equalizers with slopes less than 15 dB as described above, this technology has also been applied successfully

to extremely narrow-band ripple equalizers (120 MHz). Several prototype units exceeding the end-user's system requirements have already been delivered.

CONCLUSION

Adjustable-slope gain-equalizer technology suitable for flattening frequency response in 26 to 42 GHz TWT transmitter systems has been designed, demonstrated and delivered to engineers working at millimeter-wave frequencies. The new technology provides fully adjustable mm-wave equalizers of linear, parabolic and ripple-removal types.

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