2-18 GHZ LOGARITHMIC AMPLIFICATION COMPONENTRY

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ABSTRACT

Two microwave logarithmic amplifier designs are described. First is a dual channel extended dynamic range Detector Logarithmic Video Amplifier (DLVA) design to cover the 2 - 18 GHz frequency band. The DLVA was developed to achieve state-of-the-art accuracy over 65 dB dynamic range, while providing excellent amplitude and phase tracking between the two channels. Amplitude and phase tracking of ±1 dB and ±5 degrees have been achieved, respectively. Second is a Successive Detection Logarithmic Amplifier (SDLA) design to cover the 2 - 6 GHz frequency range. The SDLA was developed to achieve state-of-the-art pulse processing capability. Rise time of 8 ns and recovery time of 30 nsec have been achieved over 70 dB of dynamic range.

INTRODUCTION

This paper presents the design, fabrication and experimental results of two microwave logarithmic amplifiers. First is a dual-channel detector logarithmic video amplifier operating over the full 2 - 18 GHz band. Broadband GaAs MMIC amplifier and Si monolithic Logarithmic Video Amplifiers (LVA) have been used in the design to obtain a dynamic range of 70 dB, a rise time of 15 ns and a recovery time of <1 µs. Excellent amplitude and phase tracking of ±1 dB and ±5 degrees, respectively, has been achieved between the two channels. The overall size of the dual-channel amplifier is 3" x 4" x 0.75". Secondly, a successive detection logarithmic amplifier covering the 2 - 6 GHz frequency range is presented. The unit maintains excellent sensitivity and dynamic range while providing state-of-the-art pulse performance. Rise times and recovery times of 8 nsec and 30 nsec, respectively, have been achieved over a 70 dB dynamic range while responding to input signal levels as low as -65 dBm. Monolithic GaAs amplifiers and a unique detector/limiter design is used to achieve state-of-the-art performance.

DUAL-CHANNEL 2 - 18 GHZ DETECTOR LOGARITHMIC VIDEO AMPLIFIER

Design

The DLVA is designed using monolithic GaAs MMIC amplifiers and Si monolithic logarithmic video amplifiers (LVA). Since it is an extended dynamic range design a parallel detection approach is utilized [Figure 1]. Referring to Figure 1, the input feeds into power divider, C1, and is divided into two equal amplitude outputs, A and B.

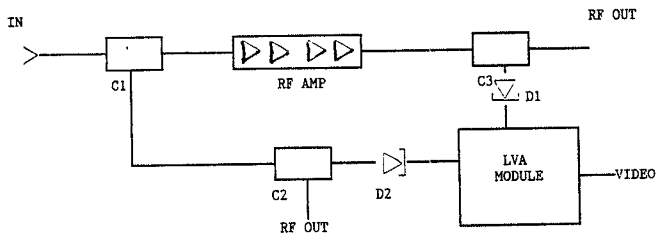

Figure 1. Block Diagram of a Wide Dynamic Range DLVA.

Output "D" provides an RF output. The other output of C1, path "B", is amplified and fed into power divider C3. One output, E, is detected and fed into the LVA module. The amplification in this path is required to increase the sensitivity of the detector. The additional output, F, provides amplified RF output with low input signal levels. The outputs of the two LVA's inside the LVA module are summed together to provide a logarithmic video output over the full dynamic range.

Experimental Results

DLVA prototypes were fabricated using the design approach described above. Measurements were taken on RF bandwidth, dynamic range, linearity, pulse response and channel to channel tracking. Test results are presented below.

Bandwidth And Dynamic Range

The units were measured over the full 2 - 18 GHz bandwidth. A plot of the video output response vs. frequency at stepped power levels from -65 to +0 dBm is shown in Figure 2. This figure shows frequency flatness of ±2.5 dB over the full 2 - 18 GHz bandwidth while maintaining a minimum dynamic range of 70 dB. Over the 6 - 14 GHz frequency band the DLVA's frequency flatness improves to ±<1 dB as shown in Figure 2. Further improvement of frequency flatness can be achieved by reducing the RF amplifier gain ripple.

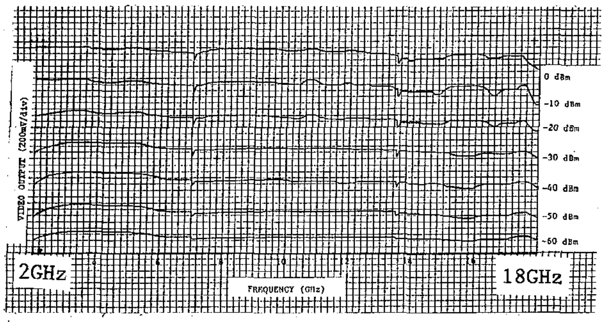

Figure 2. Extended Range DLVA Output Vs. Frequency and Power.

Slope And Linearity

A plot of the video output response vs. RF input power at 8 GHz is shown in Figure 3. This plot shows a video slope of 12.5 mV/dB. The best fit straight line slope variation over frequency was measured to be less than ±7%. A plot of the video output deviation from the calculated best fit straight line is shown in Figure 4. A deviation of less than ±1.0 dB from an ideal response has been achieved.

Pulse Response

Pulse response of the DLVA at 8 GHz over the full dynamic range is shown in Figure 5. It can be seen from Figure 5 that the rise time is less than 15 ns over the full dynamic range. Also, the recovery time is less than 300 ns with input power levels up to -20 dBm, and less than 1 μs with power levels up to +8 dBm. Minimal pulse overshoot and ringing are also obtained over the full dynamic range.

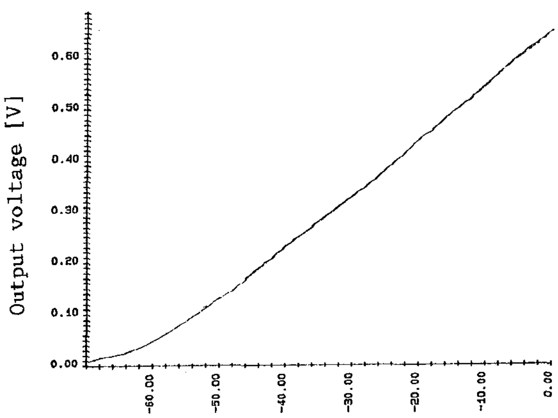

Figure 3. Log Video Output Slope Vs. Input Power.

The TSS of the device was measured to be -64 dBm. This corresponds very well with the calculated TSS of -64.5 dBm.

Dual Channel Tracking

A photograph of the dual-channel DLVA is shown in Figure 6. A single device (3" x 4") contains two complete extended dynamic range 2-18 GHz DLVA's. Additional available outputs are the direct and amplified RF outputs. Tracking between the two video channels and corresponding RF outputs was measured. The video tracking between DLVA's is shown in Figure 7. This figure shows excellent tracking of <±0.5 dB over 65 dB of dynamic range. The low end deviation is a result of differences in sensitivity of the lowest power logging stage.

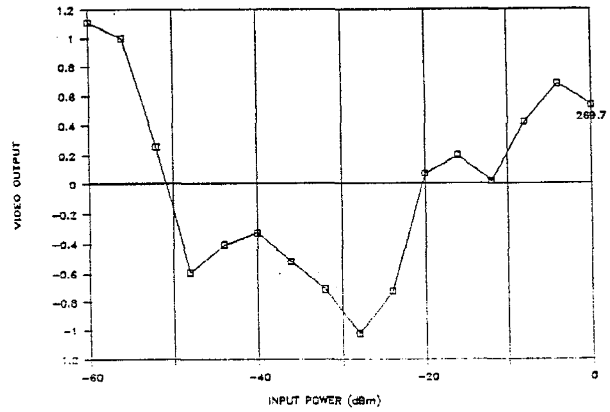

Figure 4. 8 GHz Logarithmic Transfer Function.

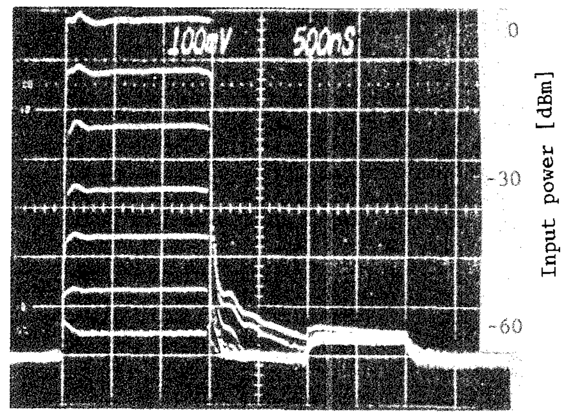

Figure 5. Pulse Performance.

RF output phase and amplitude tracking was also measured between channels. The results showed better than ±5 deg. phase tracking and <±1 dB amplitude tracking over the full 2 - 18 GHz frequency range.

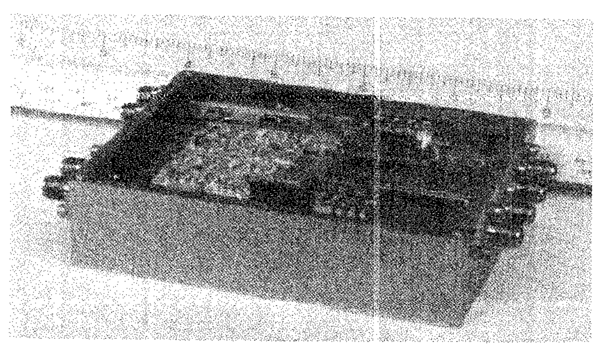

Figure 6. Photograph of the Dual Channel DLVA.

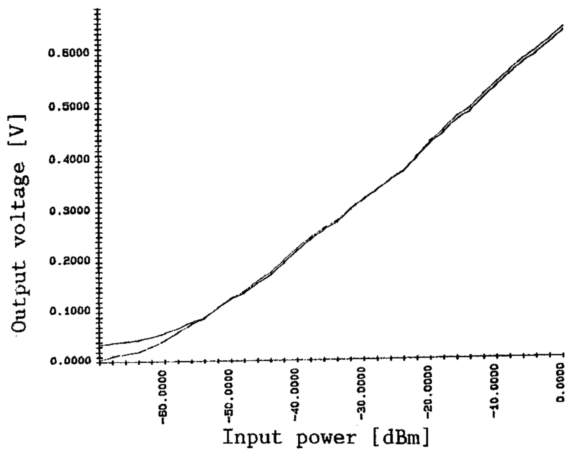

Figure 7. Dual Channel Tracking at 10 GHz.

2 - 6 GHz SUCCESSIVE DETECTION LOGARITHMIC AMPLIFIER

A block diagram of the 2 - 6 GHz SDLA is shown in Figure 8. The SDLA described utilizes a six stage design. Each amplifier stage consists of a single GaAs MMIC amplifier with approximately 10 dB gain. Off of the output of each stage is a unique Schottky barrier diode detector configuration which greatly reduces frequency roll-off caused by the diode's junction capacitance. A detector is also placed on the SDLA input to increase the upper end of the dynamic range response. Full power supply regulation is provided with an operating bias voltage of ±12 VDC to ±15 VDC. Temperature compensation is incorporated into the design by providing temperature dependent supply voltage to the MMIC amplifiers to stabilize gain and video amplifier gain and offset control to hold the video output constant. Thin Film construction is used to fabricate the RF portion of the SDLA, while Thick Film is used for the power supply regulation and video amplifier sections. The entire circuitry is housed in a 2.1" X 1.75" X 0.4" Kovar housing. [Figure 9]

Experimental Results

Measurements were taken on RF bandwidth, dynamic range, linearity, video slope, and pulse response. The results of the measurements are presented below.

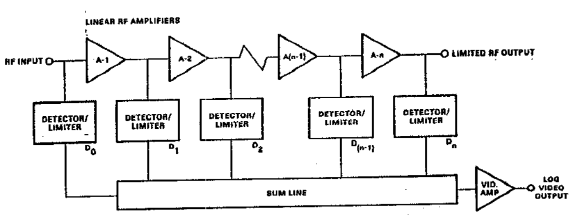

Figure 8. SDLA Block Diagram.

Bandwidth and Dynamic Range

The performance of the SDLA was measured over the full 2 to 6 GHz bandwidth. A plot of the video output response vs. frequency at stepped power levels from -60 dBm to +10 dBm is shown in Figure 10. This Figure shows the frequency flatness to be ±2 dB over the full 2 to 6 GHz frequency range while maintaining a minimum dynamic range of 70 dB.

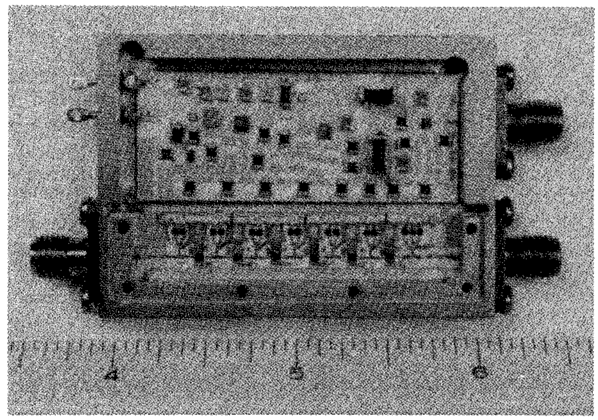

Figure 9. 2 - 6 GHz SDLA.

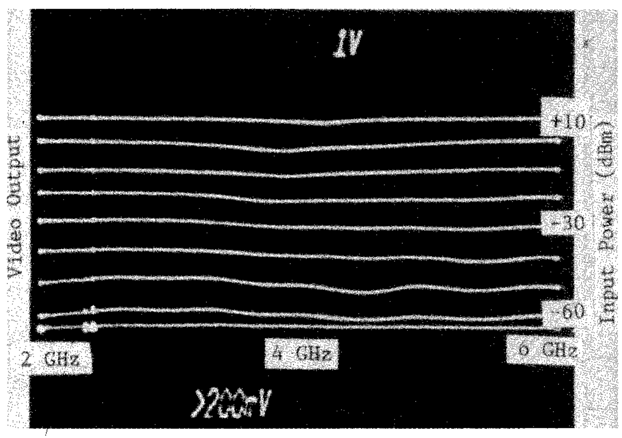

Figure 10. SDLA Frequency Response.

Slope and Linearity

The video amplifier gain was adjusted to provide a nominal log video slope of 10 mV/dB. The linearity was then measured at each frequency. The linearity is the deviation of the measured data compared to the best fit straight line of the same data. A typical linearity plot is shown in Figure 11. This is a plot of the unit's deviation, in dB, from a ideal transfer function measured at 4 GHz. The deviation is shown to be < ±0.6 dB over the full 70 dB of dynamic range. The SDLA maintains better than ±1.3 dB linearity over the full frequency and dynamic range. The variation of the best fit straight line over frequency was measured to be < ±4.0%.

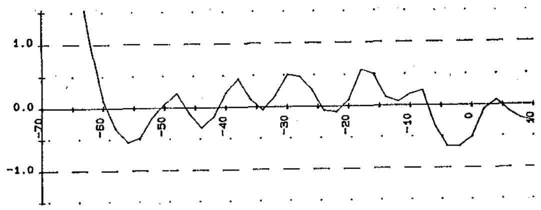

Figure 11. 4 GHz Linearity Plot.

Pulse Performance

One of the main advantages a SDLA has over a DLVA is pulse performance. With this in mind the SDLA's pulse response was carefully designed and measured. A plot of the pulse response to an input pulse, stepped in power from -60 dBm to +10 dBm by 10 dB steps, is shown in figure 12. This plot shows the excellent pulse fidelity that is achieved with a SDLA. The rise time was measured to be 8 nsec worst case over the full 70 dB of dynamic range. The recovery time is measured to be 30 nsec also over the full dynamic range. Pulse overshoot, ringing and droop are minimal. Minimum pulse widths of 20 nsec can be processed with full accuracy. TSS was measured to be -65 dBm.

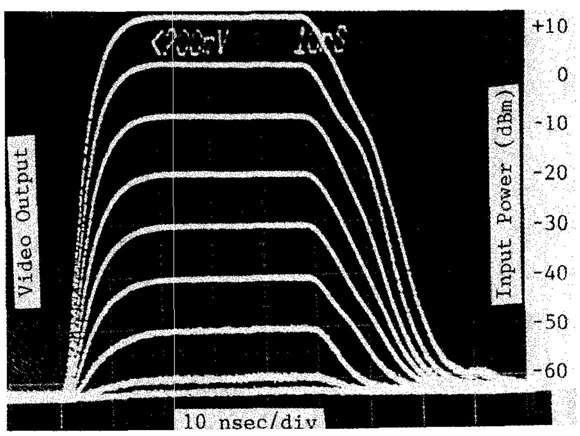

Figure 12. SDLA Pulse Response.

Input/Output VSWR

The input and output maintained better than a 2:1 match over the 2 to 6 GHz frequency range.

CONCLUSIONS

A state-of-the-art performance dual-channel DLVA having a 70 dB dynamic range, a rise time of 15 ns, a recovery time of <1 μs and an excellent amplitude and phase tracking has been presented. GaAs and Si monolithic circuits have been used to achieve this performance in a small size.

A 2 to 6 GHz successive detection logarithmic amplifier has been designed and fabricated. Measured results show far superior pulse and dynamic range performance when compared to a DLVA. A minimum dynamic range of 70 dB has been achieved over the full 2 to 6 GHz bandwidth while maintaining a sensitivity of -65 dBm. Worst case pulse rise and recovery times were 8 nsec and 30 nsec, respectively, over the full input dynamic and frequency ranges. Maximum use of monolithic circuitry provided small size of 2.1" X 1.75" X 0.4".

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