Beam Position Monitoring in the 100-MHz to 500-MHz Frequency Range Using the Log-Ratio Technique*

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Abstract

A logarithmic-ratio beam position monitor (BPM) circuit has been designed that operates directly from radio frequency signals in the 100-MHz to 500-MHz frequency range. The circuit uses four logarithmic amplifiers, a pair for each channel. One amplifier per channel receives its signal input directly from a BPM electrode, while the second amplifier receives the same signal attenuated by 7-dB. The two outputs of each channel are summed together and the composite video outputs are applied to a differencing amplifier. The net result is the logarithmic-ratio position measurement derived from the two input rf signals. Paralleling the pairs of outputs from the amplifiers provides measurement accuracy that is comparable to other circuit techniques used for position measurement.

I. INTRODUCTION

Logarithmic-ratio processing of beam position monitor (BPM) signals is a viable circuit technique that has been described in several publications [1], [2], and [3]. Previously, however, an upper frequency limit of 100-MHz was imposed by the Analog Devices Model AD640 integrated circuit logarithmic amplifier that was employed for this application. Recent investigations have shown the feasibility of designing log-ratio circuits around the Plessey Semiconductor Company Model SL3522A logarithmic amplifier [4]. This device is a successive detection logarithmic/limiting, monolithic amplifier that produces a Log/Lin characteristic for input signals between +6 and -64 dBm with a linearity of 1-dB over the 100-MHz to 500-MHz frequency range. Comprising the circuit are six amplifier stages of 12-db gain each, seven detector stages, a limiting rf output buffer and a video output amplifier. For the log-ratio application the rf output buffer is disabled.

II. AMPLIFIER CHARACTERISTICS

In Figure 1, the transfer curve for a typical SL3522A amplifier is shown. The figure also shows a plot of the difference between a straight line fit to the curve and the actual amplifier response. The difference curve illustrates the sinusoidal ripple that is present in the transfer function. This ripple is a side effect of the successive approximation technique used to achieve the logarithmic response.

When two amplifiers are employed in a log-ratio circuit a large amount of ripple is produced in the position measurement response. This is illustrated by the curves of Figure 2. The measurement error resulting from this ripple ranges from 2% at the center of a cylindrical BPM probe to approximately 8% at one-fifth of the probe radius [4].

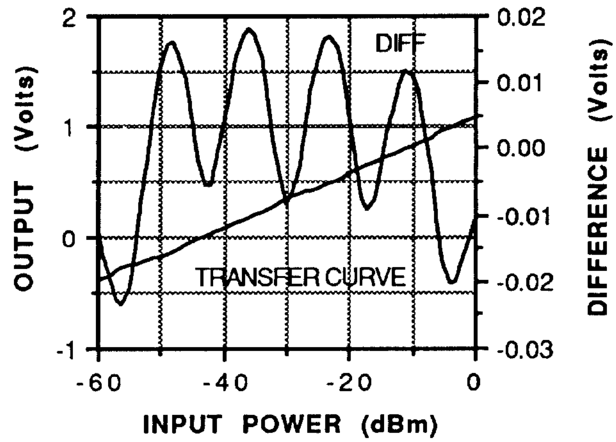

Figure 1. Transfer curve of a SL3522A amplifier and the straight line fit difference plot.

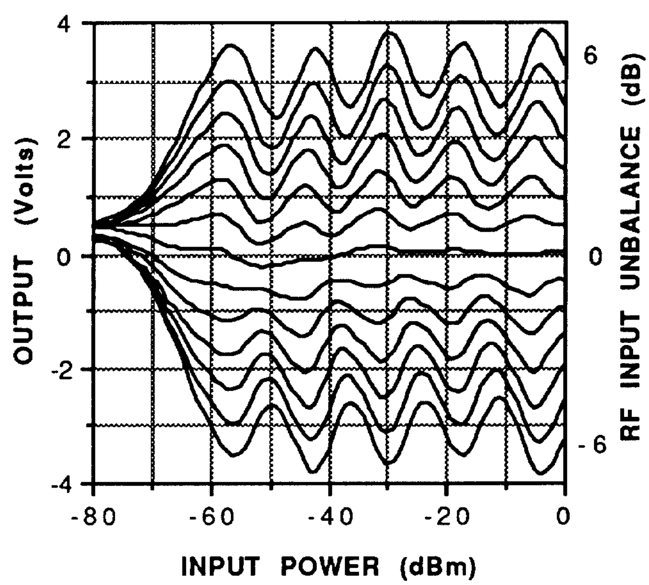

Figure 2. Response curves of the dual amplifier log-ratio circuit.

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A technique for suppressing the ripple has been suggested in Reference [3]. Two amplifiers are operated in parallel and their outputs are summed to give a composite response. One amplifier receives its signal directly from a BPM electrode, while the second receives the same signal attenuated by approximately one-half the intrastage gain, i. e., 6-dB. For this case 7-dB was found to produce the best results.

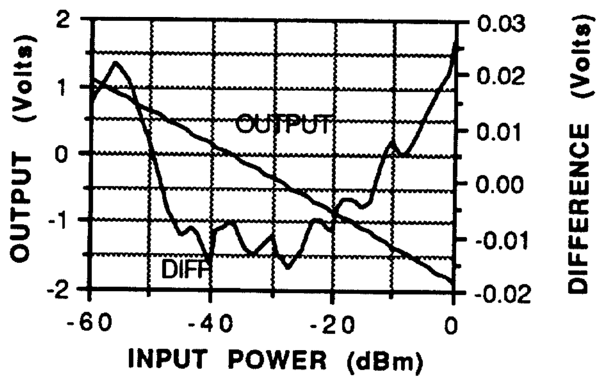

Figure 3. Transfer curve of a dual amplifier combination with the input to one amplifier attenuated 7-dB.

Figure 3 shows the transfer curve of the pair, along with the straight-line-fit difference curve. The transfer curve is more linear then that of a single amplifier and the ripple is suppressed.

To obtain the best results the circuit adjustments are important. Each amplifier has a gain and an offset adjustment. Care must be taken to match the gains and the offsets so as to equalize the transfer slopes.

III. THE QUAD-AMPLIFIER CIRCUIT

Figure 4 shows the circuit configuration for the log-ratio application. The four logarithmic amplifiers, two summing amplifiers and the differencing amplifier combine to produce a beam-position-output signal proportional to log (A/B).

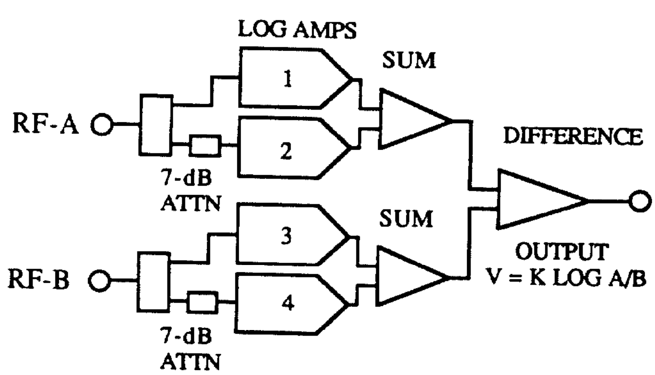

Figure 4. The quad-amplifier log-ratio circuit.

The response of the quad-circuit to 425-MHz rf signals is shown in Figure 5. On the horizontal axis, the rf input power to the A and B channels is plotted, ranging from -70 dBm to 0 dBm. The family of curves represents 13 position values corresponding to signal input ratio changes from -6-dB to + 6-dB in 1-dB steps. The center trace results when the two signals are equal (A=B). The upper traces correspond to A>B, whereas the lower traces result when A<B. Ripple in these curves has been substantially reduced by use of the quad-amplifier technique. Best operation occurs in the range of -50 dBm to -10 dBm, corresponding to a dynamic range of 100:1 in beam current. The transfer factor for the circuit is about 0.5 volts per dB.

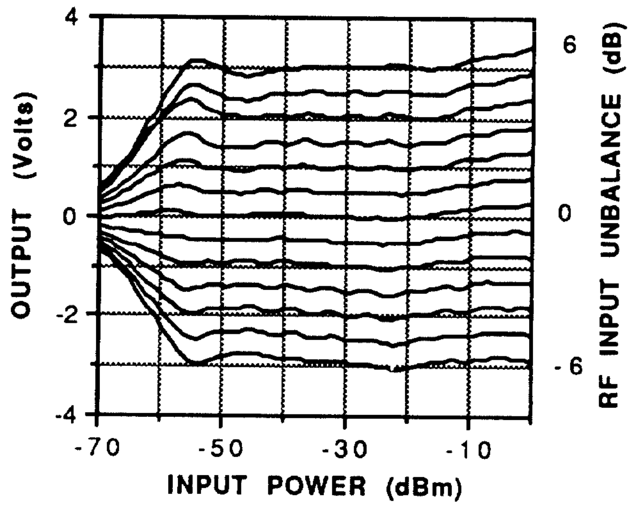

Figure 5. Response curves of the quad-amplifier log-ratio circuit.

IV. NOISE CONSIDERATIONS

Figure 6 shows the noise limited resolution characteristic of the circuit, along with a plot of the theoretical kTB resolution, for a circuit bandwidth of 2-MHz. Below -40 dBm the two curves have approximately the same slope and they

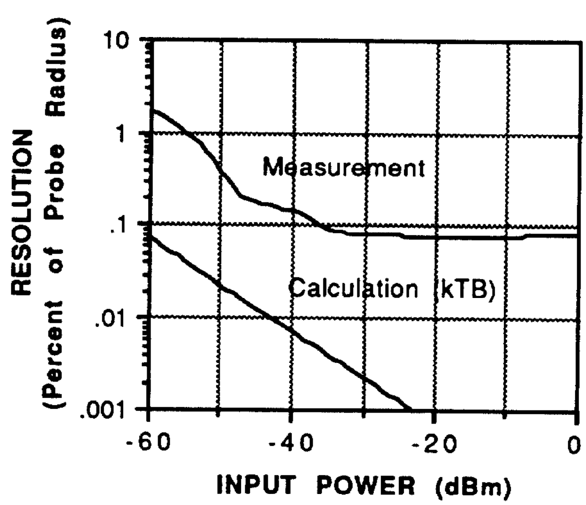

Figure 6. Resolution curve of the quad-amplifier log-ratio circuit.

are separated by about 25-dB of input power. For rf power inputs greater than -40 dBm the trend is toward a constant value of resolution. This flattening of the resolution curve is characteristic of log-ratio circuits [2], [3]. It may be caused by saturation effects that take place in the intrastage amplifiers and detectors as the input power increases.

V. CONCLUSIONS

The quad-amplifier log-ratio circuit is a viable candidate for beam position measurement in the 100-MHz to 500-MHz frequency range. Many accelerators operate at bunching frequencies in this range and they could benefit from beam position measurements using this equipment. The principle attribute of the circuit is that it can operate directly from BPM rf signals. No additional circuits such as down converters would be required.

VI. REFERENCES

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