Pulsed 500-MHz arbitrary waveform generator

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Unipolar and bipolar arbitrary waveform generators (AWGs) are described. Starting from a single 2-ns-wide pulse, a train of 2-ns-wide, variable amplitude pulses are formed by splitting the initial pulse into multiple, equal amplitude pulses and then delaying and attenuating each of these pulses separately. By choosing the proper attenuation (pulse amplitudes) and adding the train of pulses together, an arbitrary unipolar waveform can be constructed. With the addition of a second pulse generator of opposite polarity, an arbitrary bipolar waveform can be generated.

INTRODUCTION

A variety of scientific projects require the generation of specific, tailored waveforms for applications such as the centering or aiming of charged particle beams in accelerators,[1] and compensating for instabilities in fusion devices.[2] An AWG system would consist of: (1) sensors to detect the beam or plasma location or the magnitude and phase of instabilities, (2) a computer algorithm to predict the corrective waveforms (or perturbation) to center the beam or to counter the instability, (3) a computer-controlled AWG to produce the corrective waveform, (4) an amplifier to increase the waveform amplitude to the desired level, and (5) an antenna structure to induce the corrective perturbations into the beam or plasma.

In this paper, we present a simple, reliable, 2 ns per point (500-MHz) AWG design based on techniques which can be scaled to 0.25 ns per point using currently available components. Current technology is limited to 200 MHz.[3]

I. AN UNIPOLAR ARBITRARY WAVEFORM GENERATOR

Our approach is shown in Fig. 1. The initial pulse generated by an Avantech AVH-P pulse generator is split in eight, 2-ns-wide, equal amplitude parallel pulses by an Anzac DS-309 power splitter. The generator pulse is approximately triangular. Each split line is delayed by 2 m ns. The pulses are then fed through Mini-Circuits PAS-1 electronic attenuators, and are attenuated by amounts determined by external potentiometer controls. When summed together through an Anzac DS-309 power adder, the resultant pulse is a train of 2-ns duration pulses.

With all attenuators set to zero attenuation, the waveform at the combiner output is shown in Fig. 2. To zero order, this waveform is a square wave, as expected. Waveforms with attenuator number six set to maximum attenuation, and then with attenuator numbers four and five set to maximum attenuation are shown in Figs. 3 and 4. Although

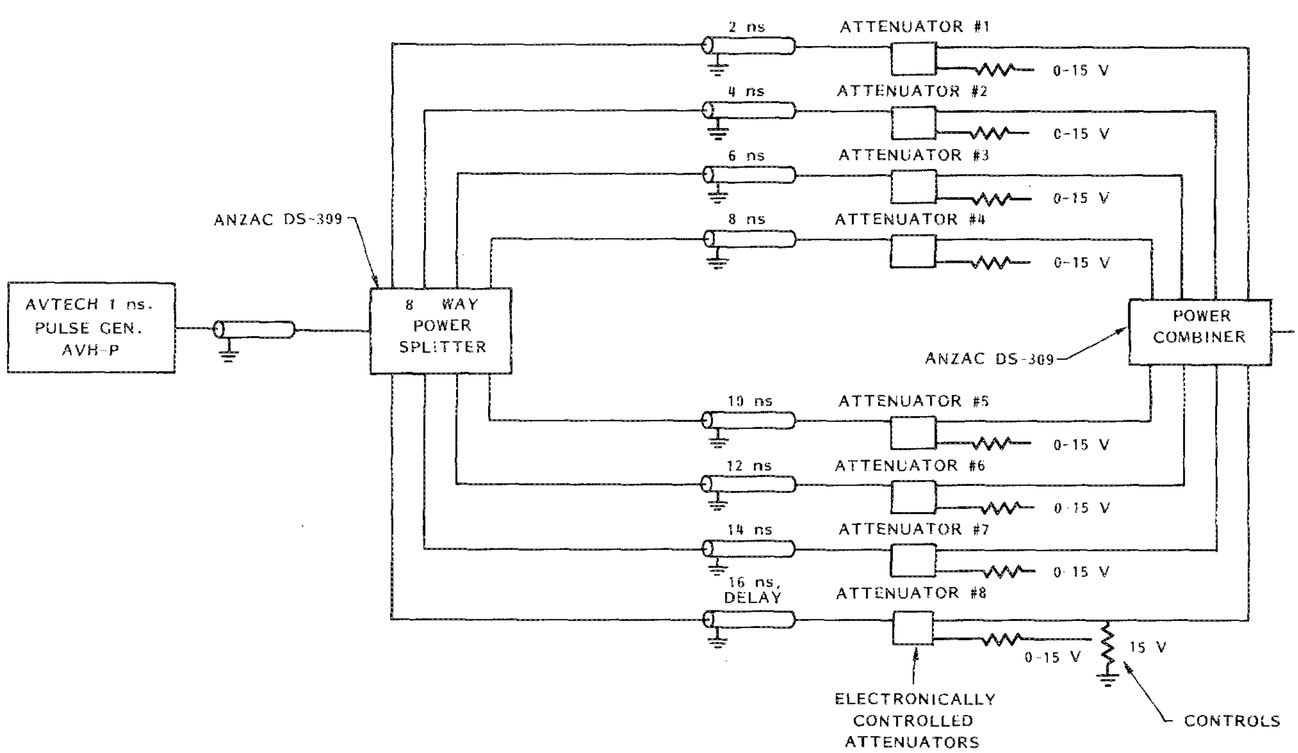

FIG. 1. Arbitrary waveform generator.

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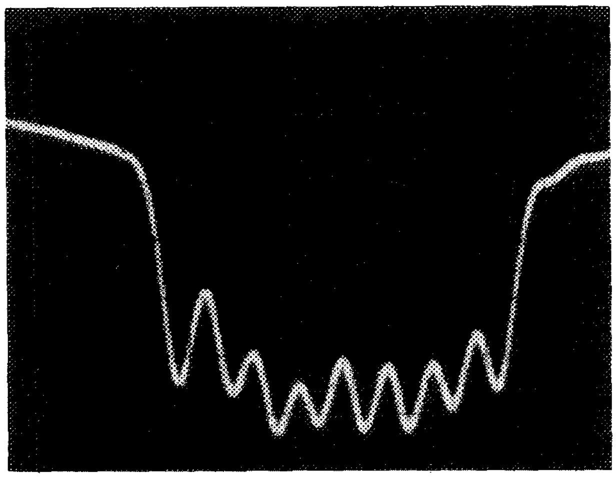

FIG. 2. Generator output with all attenuators set to 0 dB. The waveform is inverted.

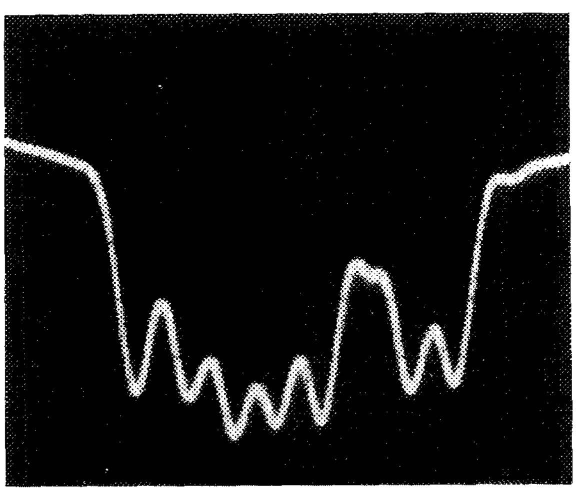

FIG. 3. Attenuator number six set to maximum attenuation, all other attenuators set to 0 dB.

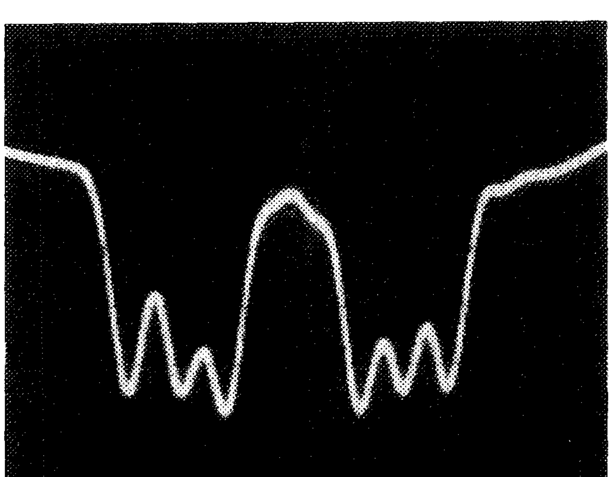

FIG. 4. Attenuators numbers four and five set to maximum attenuation with all others set to 0 dB.

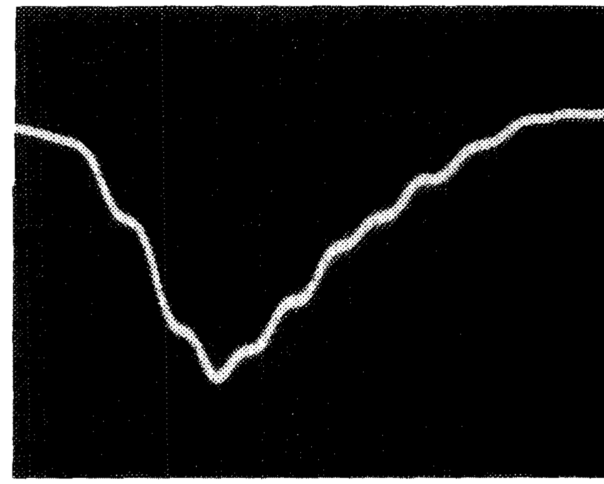

FIG. 5. Arbitrary waveform triangular pulse.

the rise times of the waveforms are somewhat distorted by the 100-MHz bandwidth of the recording oscilloscope, the oscillations are due to the shape and spacing of the generator pulses. Note that the pre- and postpulse amplitudes (i.e., lack of a flat base line) are due to the low amplitude pre- and postpulse output of the pulse generator. Since these outputs are of long (tens of ns) duration, they add to a measurable value. The waveforms do demonstrate the rapid voltage variations which can be achieved. Another example of the versatility of the AWG—an asymmetric triangular waveform—is shown in Fig. 5.

II. A BIPOLAR ARBITRARY WAVEFORM GENERATOR

A simple technique for adapting this device to bipolar operation is to add an opposite polarity square pulse to the output of the unipolar AWG. An example of the output is shown in Fig. 6. The jitter of the AWG is less than 0.5 ns.

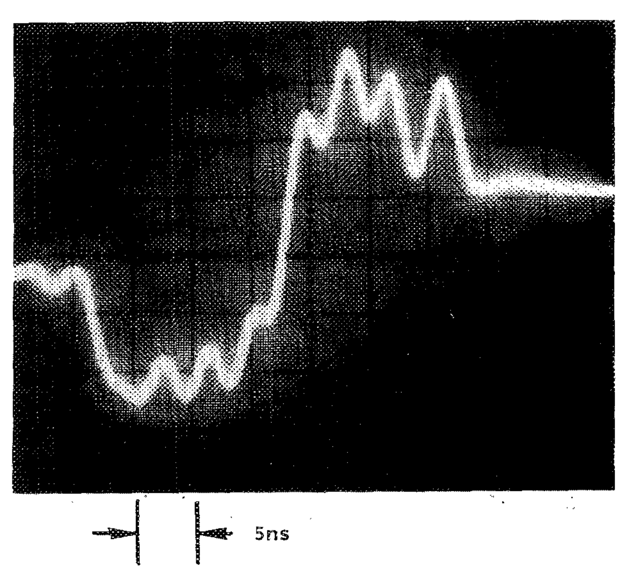

FIG. 6. A bipolar arbitrary waveform generator output.

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III. SUMMARY

Unipolar and bipolar AWGs have been demonstrated. The technique of dividing a single pulse into multiple, equal amplitude pulses which are separately attenuated and delayed and then added together has been used to construct various waveforms. An advantage of the technique is that jitter is reduced because only one (unipolar AWG) to two (bipolar AWG) pulse generators are required. The frequency of AWGs is limited by the bandwidth of available adders/splitters and attenuators and the pulse width of available pulse generators. Ideally, the output of the pulse generators would be square waveforms. The AWGs can be computer controlled by command triggering the pulse generators and installing programmable attenuators.

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[1] See, for example, J. Golden, J. Pasour, D. E. Pershing, K. Smith, F. Mako, S. Slinker, F. Mora, N. Orrick, R. Altes, A. Fliflet, P. Champney, and C. A. Kapetanakos, IEEE Trans. Nucl. Sci. **NS-30**, 2114 (1983) or Y. Cho, E. Crosbie, T. Khoe, R. Kustom, R. Martin, J. Norem, W. Praeg, K. Thompson, and G. Whitfield, IEEE Trans. Nucl. Sci. **NS-30**, 2117 (1983).

[2] D. A. Baker *et al.*, Bull. Am. Phys. Soc. **31**, 1546 (1986).

[3] See, for example, Hewlett–Packard 1986 catalog, p. 457.

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