High Power Microwave Generation with Nonlinear Transmission Lines

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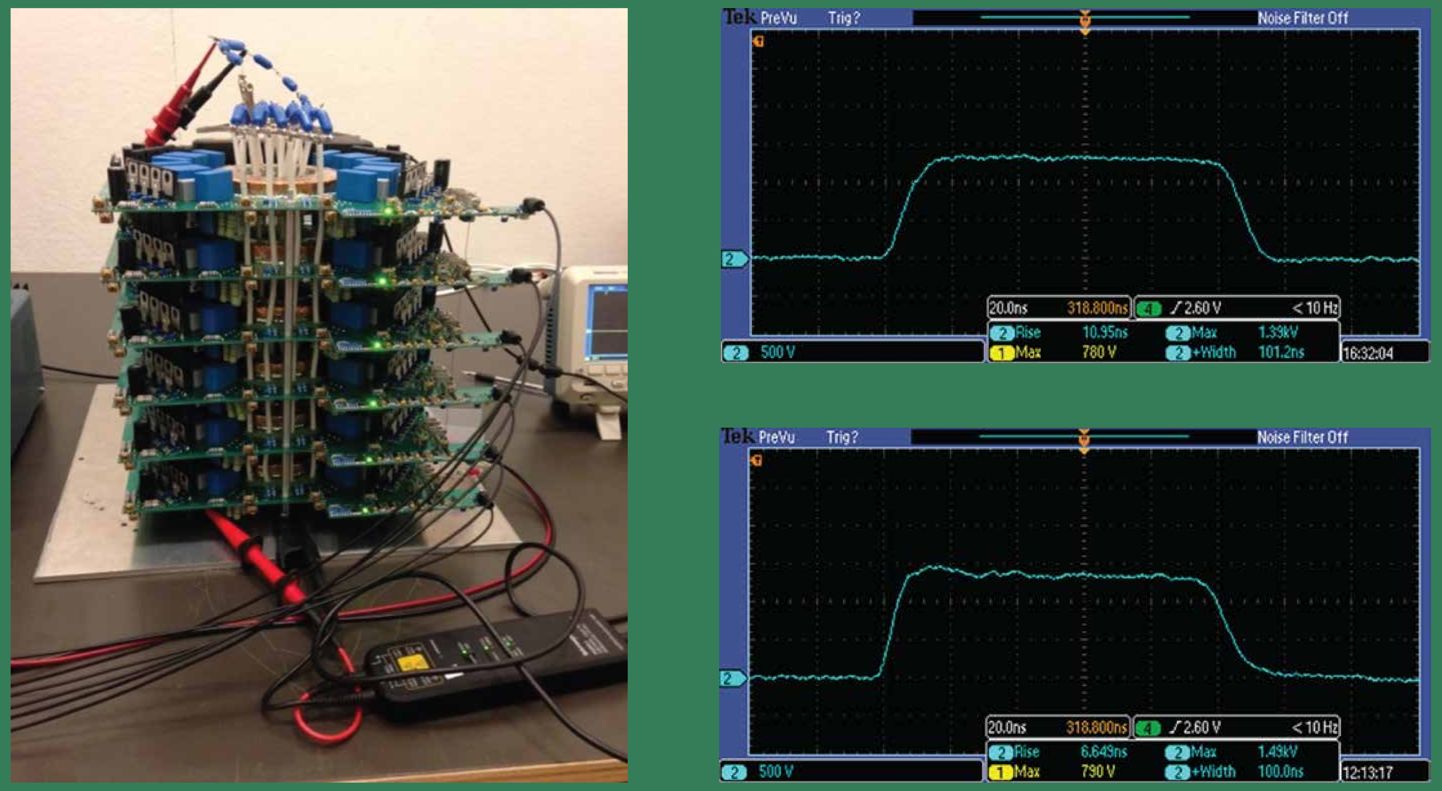
EAGLE HARBOR TECHNOLOGIES

Introduction

Eagle Harbor Technologies, Inc. (EHT) is investigating the generation of high power microwaves using the EHT Nanosecond Pulser (NSP) and nonlinear transmission lines (NLTLs). The EHT NSP provides independent control of the output voltage (20 kV), pulse width (20 – 200 ns), and pulse repetition frequency (up to 100 kHz) and is used to drive two different NLTLs. The gyromagnetic NLTL produces RF around 2 GHz. EHT has constructed a test setup including solenoid for producing an axial field. Experimental results, including RF measurements with a D-dot probe, will be presented. The second NLTL is based on the nonlinear properties of high voltage, Schottky diodes and produces RF at a lower frequency. Rise time sharpening and RF experimental data and modeling results will be presented.

EHT Inductive Adder

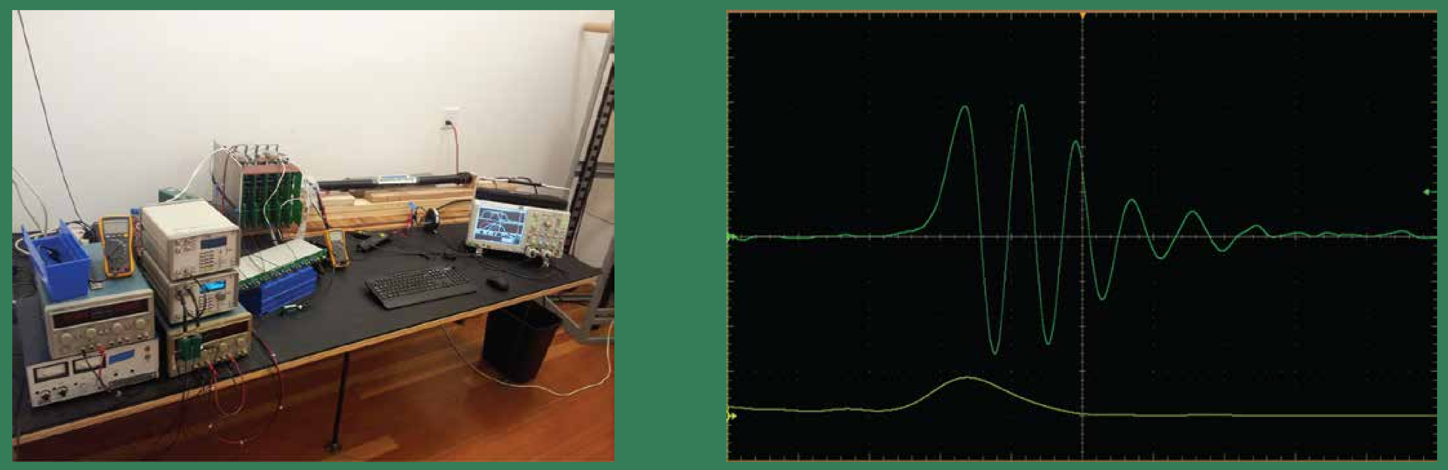
Most gyromagnetic NLTLs are designed with 25-50 Ω impedance that must be driven with sub-10 ns rise time. EHT is leveraging nanosecond pulser components, which can operate at high pulse repetition frequency (PRF), to build an inductive adder that is capable of driving these low impedance loads with fast rise times. EHT has built a six board stack that can operate at 10 kV, with adjustable pulse width, fast rise time, and PRF. This circuit topology can be easily scaled to drive NLTLs with 25-50 Ω impedance at higher voltage with sub-10 ns rise time.



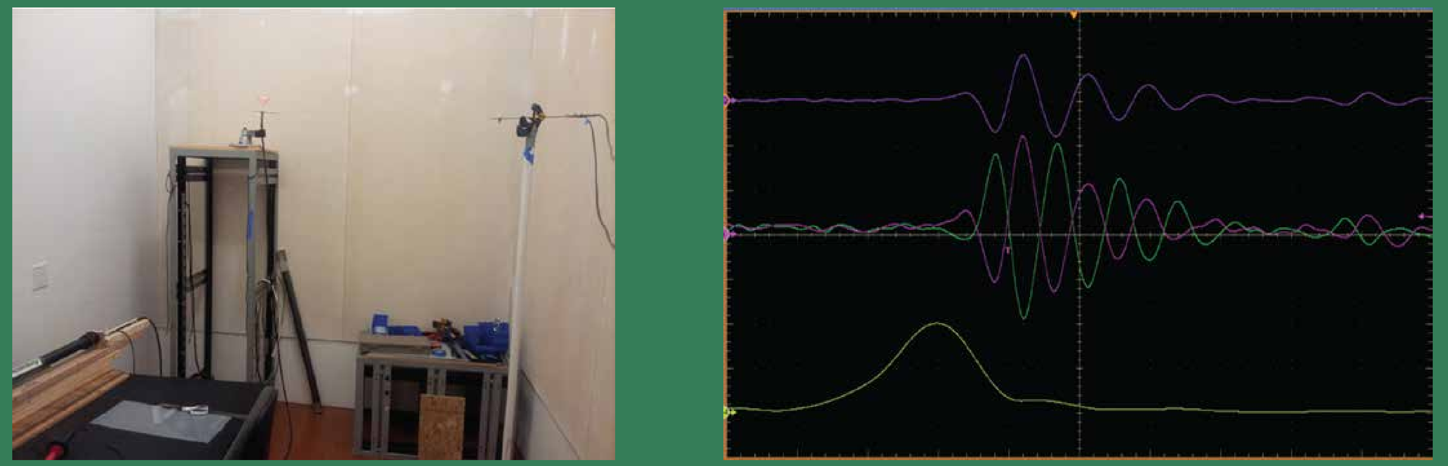
Left: 10 kV inductive adder. Top Right: 10 kV - 100 ns pulse into resistive 50 Ω load with 6.6 ns rise time. Bottom Right: 10 kV - 100 ns pulse into resistive 25 Ω load with 11 ns rise time.

RF Production with NLTL

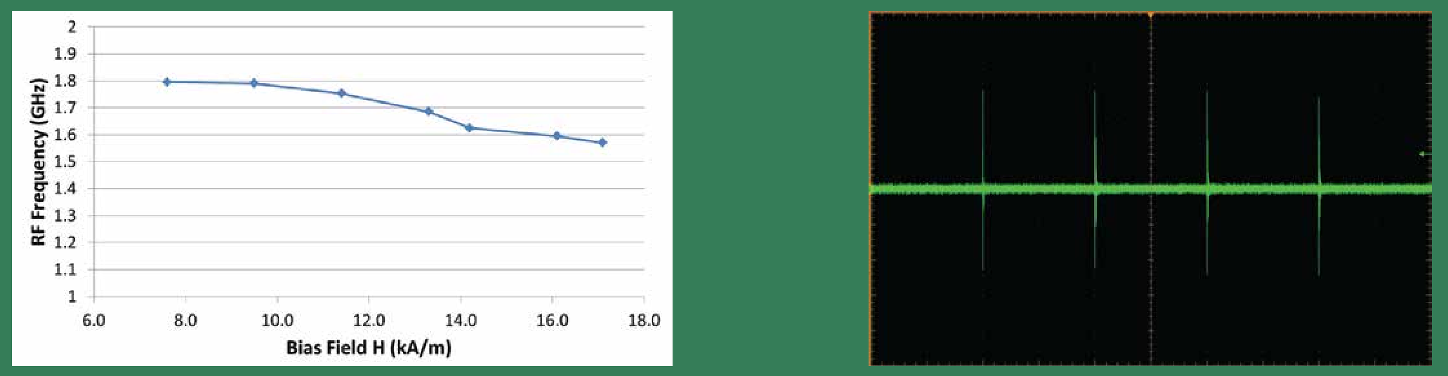
EHT has demonstrated RF production by driving the gyromagnetic NLTL with a 10 kV inductive adder. The RF output of the NLTL was measured with a capacitive voltage probe (CVP) and a D-dot probe in the far-field.



Left: Experimental setup showing the 50 Ohm pulse driver, the NLTL, and the CVP at the output of the NLTL. Right: CVP output (green) with 12.6 [kA/m] bias field. Horizontal scale 740 ps/div, vertical scale 3333 V/div. An FFT of the signal (yellow) has a peak at ~ 1.7 GHz. FFT scale is 25 mV/div vertical and 500 MHz/div horizontal.



Left: Experimental setup with D-dot in far-field of monocone antenna. Right: From top to bottom signal names: Math 2, Ch3 (purple), Ch4 (green), Math4. Math2 = Ch3 – Ch4, Math4 = FFT(Math2). Vertical scale: Math2 = 2V/div, Math4 = 100mV/div, Ch3&Ch4 = 500 mV/div. Horizontal scale is 750 ps/div for signals and 500 MHz/div for FFT.



Left: NLTL RF output frequency as a function of magnetic bias field. Right: CVP output with 12.6 [kA/m] bias field. Burst of 4 pulses at 100 kHz. Horizontal scale 5 μs/div, vertical scale 3333 V/div.

Acknowledgment

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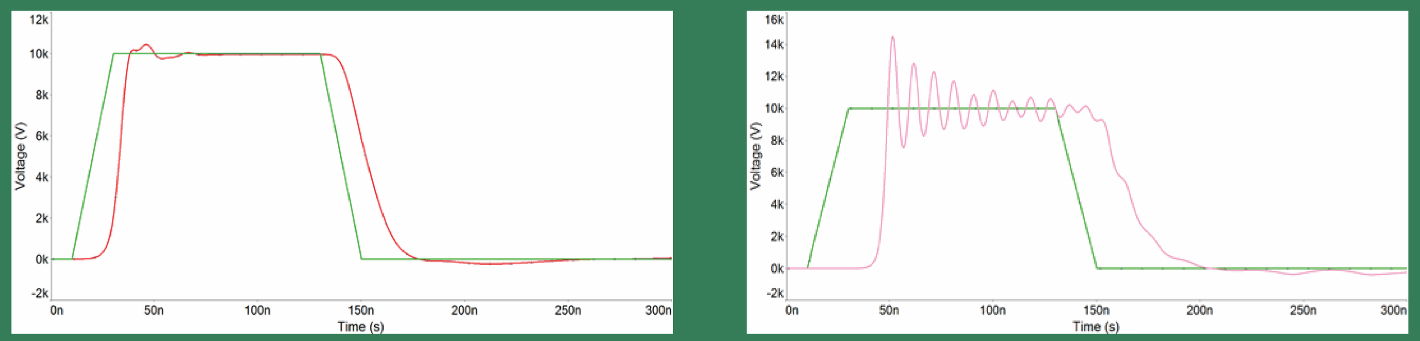
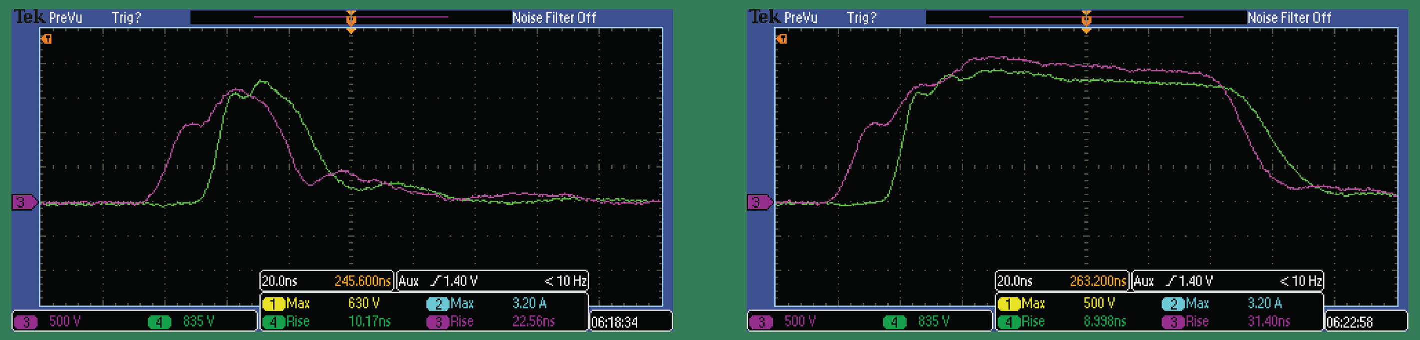
Lumped-element NLTL

EHT is investigating lumped-element NLTLs with off-the-shelf components. SPICE modeling showed that the pulse rise time could be improved to below 10 ns. A 10 kV NLTL with 20 elements was built and tested, which produced sub-10 ns rise time at 82-86% efficiency.



Left: SPICE model showing pulse sharpening from 16 ns to 8.4 ns.
Right: 100 MHz RF with lumped-element NLTL.

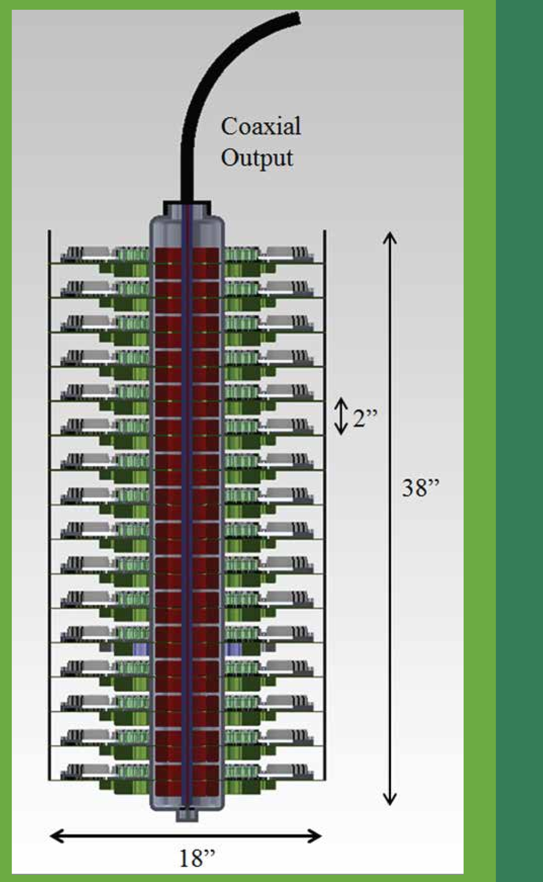


NLTL input and output for 40 ns (right) and 120 ns pulse (left).

Conclusion

EHT has constructed a 10 kV inductive adder that has adjustable pulse width and PRF and has tested it into resistive loads. This inductive adder has been used to drive a gyromagnetic NLTL to produce RF near 2 GHz over a range of parameters. EHT has built a lumped-element NLTL and demonstrated efficient rise time reduction.

EHT is in the process of building an testing a 20 kV inductive adder that will be capable of driving low impedance NTLTs with adjustable pulse widths and continuous wave PRF over 100 kHz.



Design of 20 kV inductive adder that EHT is constructing.

For more info: http://www.eagleharbortech.com/