Miniature High-Power Microwave Systems Based on Explosive-Driven High-Voltage Ferroelectric Generators

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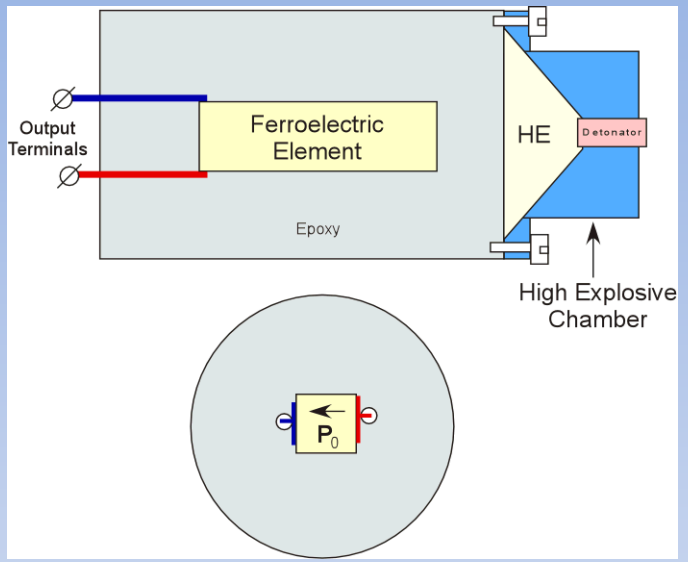
Overview

- History
- What is an FEG (Ferroelectric Generator)?
- What makes the Loki FEG HPM concept different from others?
- Three major Loki designs
- Summary

The FEG

- FEG – explosive-driven primary power source
  - Based on the shock wave depolarization of piezoelectric (ferroelectric) ceramics.
  - Explosive driver plus cylindrical polymer body, which includes potted-in ferroelectric energy-carrying element and load circuit.



Schematic of explosively driven ultrahigh-voltage ferroelectric generator developed by Loki.

LOKI INCORPORATED

History of the FEG – HPM system

- Loki testing, under SMDC SBIR and with Naval Research Laboratory collaboration, proved that an FEG using lead-zirconium-titanium (PZT) ferroelectric materials as a power source could directly drive an antenna through a peaking spark gap switch.
- Loki in-house efforts:
  - We were looking for a new power conditioning system paradigm
    - Simple
    - Designed from the start to be a single-shot system, allowed us to demand performance from components that couldn't be had from systems requiring duty cycles
  - Designed system that capitalized on the interrelated functioning of its components
    - Prime power, the FEG, has capacitive and inductive characteristics that change as PZT material is stressed by explosive shock
    - Power conditioning via miniature switch and transmission lines has capacitive and inductive characteristics that affect FEG operation and antenna operation during different parts of the overall function time

What Makes Loki's FEG – HPM System Different?

- Does not follow conventional wisdom/practices
  - Designed to fit form factor from the start, not to scale-down working bench-scale models
  - Power conditioning components designed as single-use items; overstressed far beyond acceptable limits for duty-cycle rated components
  - Simplicity is a key

Loki's Three Major FEG-HPM Designs

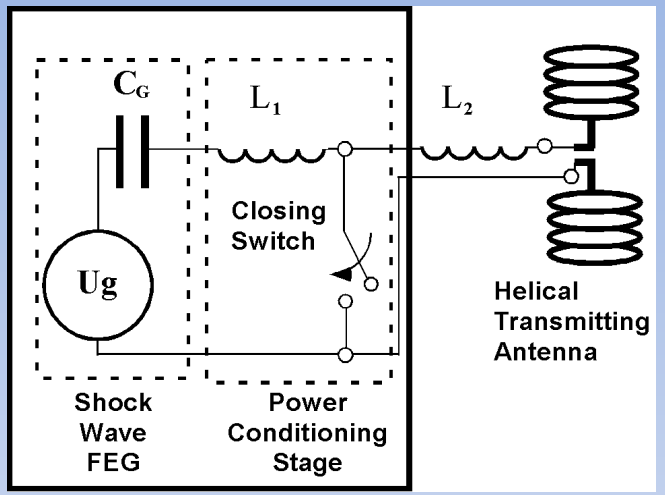
- Each of the three major Loki FEG – HPM designs uses an explosive-driven FEG as a prime power source, a miniature solid-state switch as the key component of the power conditioning subsystem, and a form-factored antenna
- The differences are in the operating points of the switches and in the type of antenna used

FEG – Miniature Switch – Helical Antenna

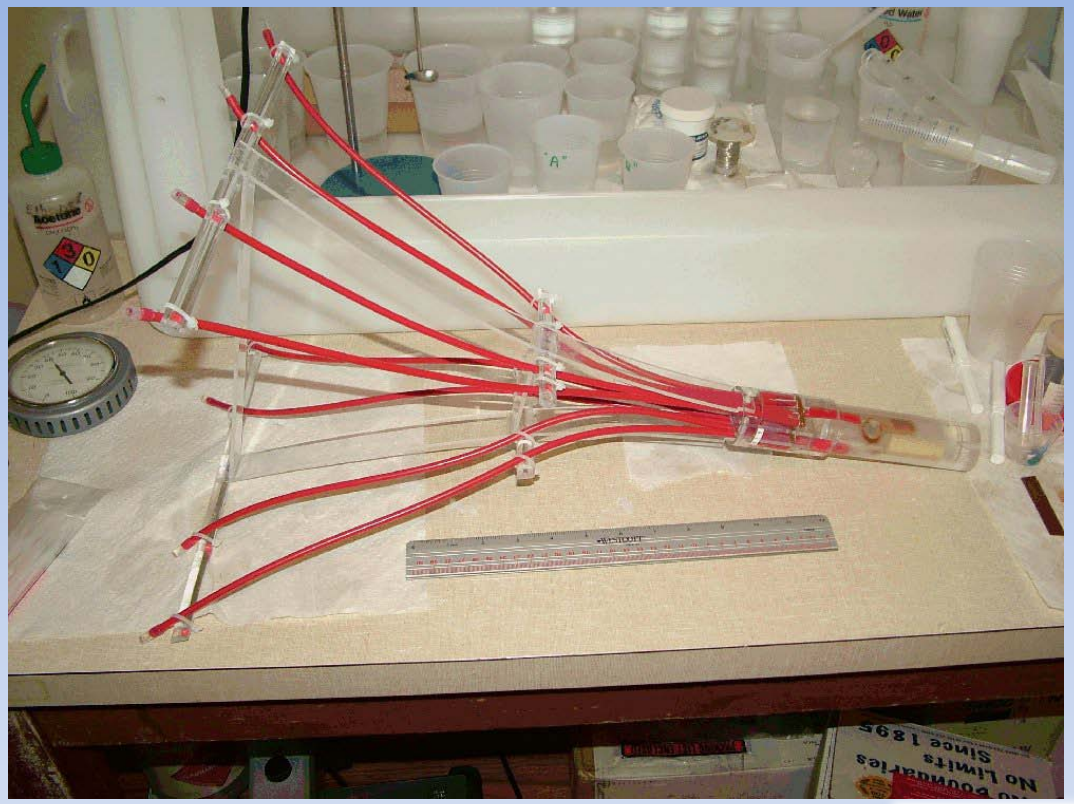
Helical antenna designed by Everett Farr (Farr Research) under contract to Loki

FEG – Miniature Switch – Helical Antenna

- Equivalent circuit shows the miniature switch acting as a closing switch across the terminals of the prime power source
- In tests at AMRDEC, electric fields were higher at 90^{o} to the antenna axis than on the axis, center frequency in the sub-100 MHz range

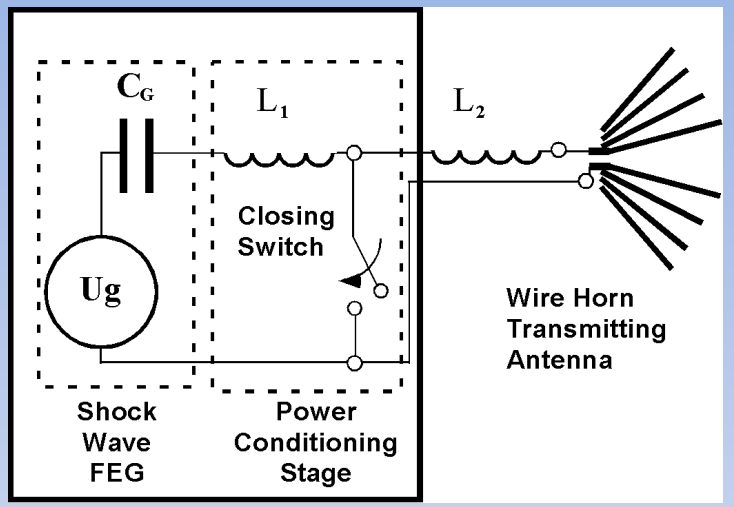


FEG – Miniature Switch – Wire Horn Antenna

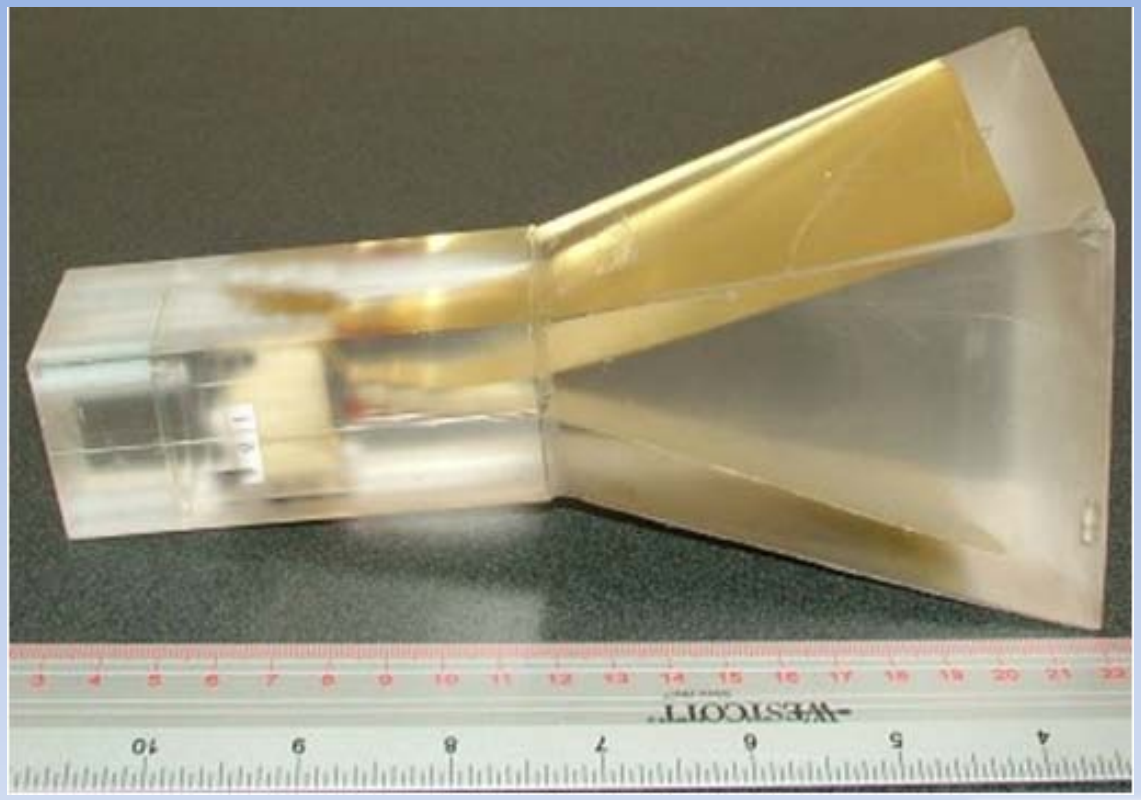


FEG – Miniature Switch – Wire Horn Antenna

- As with the helical system, equivalent circuit shows the miniature switch acting as a closing switch across the terminals of the prime power source
- In tests at AMRDEC, electric fields, as expected, were higher on the antenna axis than at 90^{o} to the axis
  - Center frequency sub-150 MHz range

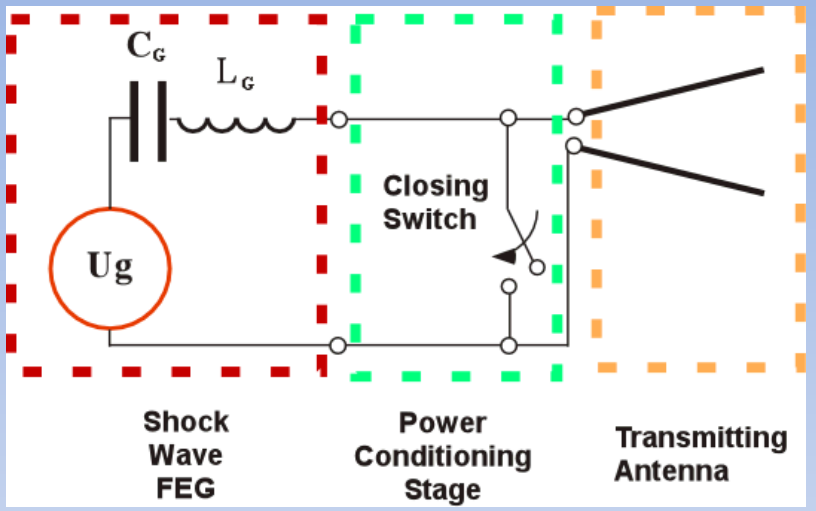


FEG – Miniature Switch – Foil Horn Antenna



FEG – Miniature Switch – Foil Horn Antenna

- As with the helical and wire horn systems, equivalent circuit shows the miniature switch acting as a closing switch across the terminals of the prime power source
- In tests at AMRDEC, electric fields were lower than for the wire horn antenna, but at a higher center frequency



Patents

[1] J. Baird and S. Shkuratov, U.S. Patent 7,560,855. “Ferroelectric Energy Generator, System, and Method”; Issued July 14, 2009 to Loki Incorporated.

[2] J. Baird and S. Shkuratov, U.S. Patent 7,999,445. “Ferroelectric Energy Generator with Voltage-Controlled Switch”; Issued August 16, 2011 to Loki Incorporated.

[3] J. Baird and S. Shkuratov, U.S. Patent 8,008,843. “Energy Generator Systems with a Voltage Controlled Switch”; Issued August 30, 2011 to Loki Incorporated.

Summary

- History of the FEG – HPM concept
- Differences between Loki designs and others
- Three major Loki FEG – HPM designs

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