PULSED HIGH POWER MICROWAVE (HPM) OSCILLATOR WITH PHASING CAPABILITY

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Abstract

A pulsed, beamless HPM oscillator is described. The oscillator operates in the frequency band of 120-600 MHz and has a peak RF power of 1.8 GW. The oscillator produces bursts of HPM pulses having a length of 8-10 ns, containing 3 individual pulses, each having rise times on the order of 200 ps. The oscillator uses a custom-designed dipole antenna array to focus and radiate the device's output RF energy. The referenced proprietary antenna array provides higher directivity in the operational frequency band and is specifically more efficient in the low-frequency portion of the radiated spectrum when compared to conventional Transverse Electric Mode (TEM) antennas having the same physical dimensions.

The oscillator described above is a part of a phased multi HPM source system, capable of producing 12 GW of radiated RF power.

I. INTRODUCTION

Compact broadband oscillators are available now that are capable of radiating single pulse of HPM at power levels of several GW. These oscillators have demonstrated the capability to generate repetitive, rapid fire pulses in operational regimes of interest. To meet operational requirements for further increases in RF power by single pulsed and/or repetitively pulsed rapid-fire sources, the coherent addition of RF power from several oscillator elements is necessary. Similarly, the prevention of RF breakdown is also an essential requirement in these operational regimes, which is also made possible by using this broadband antenna design. A beamless HPM pulse oscillator has been designed and experimentally verified to satisfy the above requirements. The oscillator is capable of producing an 8-10ns, 1.8GW HPM burst. The individual pulses in a burst had a pulse length of 2-3 ns with a risetime on the order of 200 ps, which is by far lower than the response time of even advanced receiver protection devices and limiters. The HPM oscillator operates in the 120-600 MHz frequency band and uses a dipole phased array antenna with a reflector mirror. This array is very efficient in the operational spectrum's lower frequencies and is much more efficient than a classical TEM horn antenna of the same dimensions. The antenna's geometry is tailored to prevent RF breakdown at the 2 GW radiated power level in an open air environment in both single and repetitive rapid-fire operational regimes.

The oscillator's design allows one to phase lock up to twelve (12) oscillator units, which enables it to radiate up to 12 GW of RF power in both single pulse and repetitive rapid-fire burst operational modes.

II. DESIGN OF BEAMLESS HPM OSCILLATOR WITH PHASED ANTENNA ARRAY

The design of a beamless HPM oscillator operating in the frequency band of 120-600 MHz with its dipole phased antenna array is shown in Figure 1.

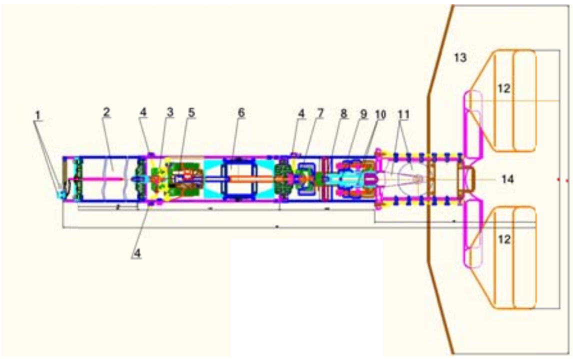

Figure 1. Design of beamless HPM oscillator, operating in the repetitive rapid-fire or single HPM pulses or bursts with dipole phased antenna array: In Figure 1. 1- input of capacitor charging voltage and control signal; 2 - low voltage capacitor storage; 3 - switching spark-gap; 4 - gas feed and purge lines; 5 - pulsed step-up transformer; 6 -high-voltage storage capacitor; 7 - peaking pulsed spark-gap; 8 - coaxial electrodynamic structure (EDS); 9 - EDS central electrode; 10 - exciter spark-gap units; 11 – field pattern converter and impedance matching device; 12 - phased dipole antennas; 13 - antenna mirror; and 14 - dielectric window.

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14. ABSTRACT

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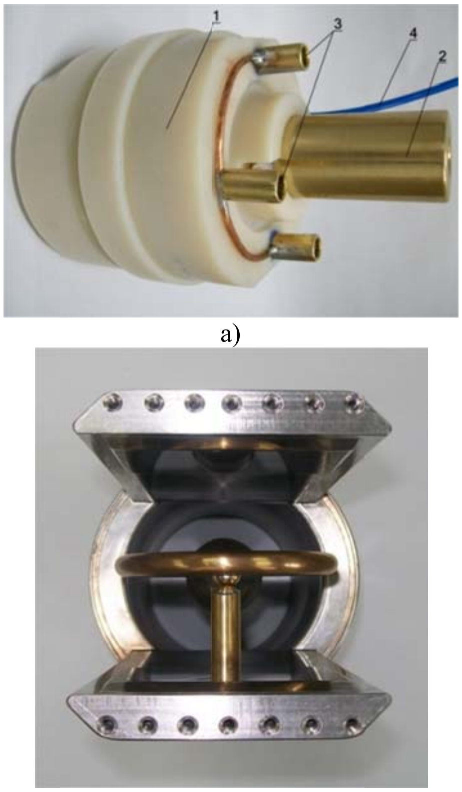
The HPM oscillator design contains the following main elements: The 0.9 uF/35 kV storage pulse capacitor (2) is charged through the feed (1) from the 35 kV prime power supply. The capacitor (2) output is connected to the switching spark-gap (3) operating in the continuous purge mode through the gas lines (4). Once the spark gap (3) is triggered, the capacitor (2) discharges through the primary coil of step-up pulsed transformer (5) (with a turns ratio of 17). The secondary coil of the transformer (5) is connected to the 300 nF/500kV pulse capacitor (6). This capacitor is discharged, then, through the high-pressure peaking spark-gap (7) and the two high-pressure exciter spark-gaps (10).

The exciter spark-gaps are mounted inside the common EDS (8) and are precisely synchronized. This feature enables the coherent addition of the excited TEM waves. The produced RF power is then fed to the input of the field pattern converter and impedance matching device (11). The general view of the exciter spark-gap units connected to a field pattern converter and impedance matching device is shown in Figure 2 (a,b).



a)

b)

Figure 2 (a, b). a) general view of the exciter spark-gap unit: 1 is dielectric case; 2 is coaxial EDS central electrode; 3 are high-voltage feed electrodes; 4 is gas feed line; b) is field pattern converter and impedance matching device, connected to the EDS.

The HPM oscillator utilizes a phased dipole antenna array with a reflector mirror. Its design and general view are depicted in Figures 3 and 4 respectively.

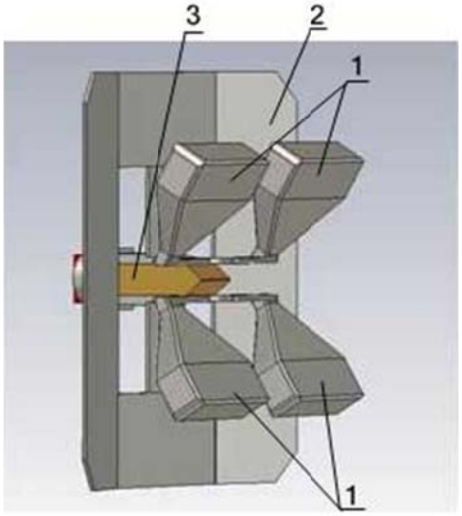


Figure 3. Phased dipole array design: 1 are dipoles; 2 is reflector mirror; 3 is field pattern converter and impedance matching device

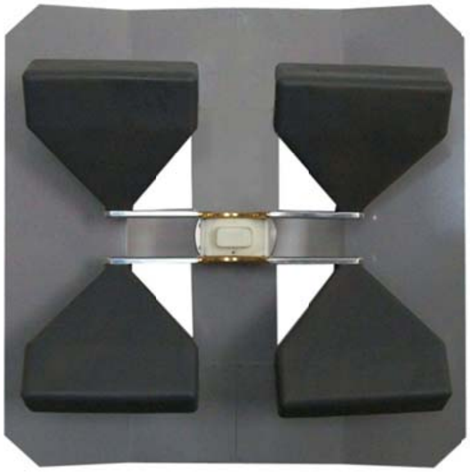


Figure 4. Phased antenna array general view

The antenna dimensions, including reflector mirror and balun are: width is 100 cm; height is 110 cm; and depth is 51 cm. Its beam pattern in the E- and H- field planes at 300 MHz frequency are shown in Figures 5 and 6 respectively. The antenna gain is 11 dB at this frequency.

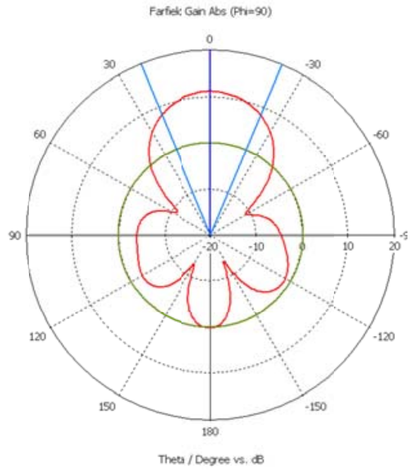


Figure 5. Beam pattern of the dipole phased antenna array with a reflector mirror in E-plane at 300 MHz, Antenna gain is 11 dB.

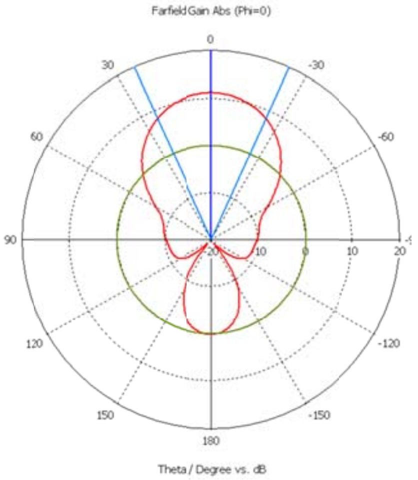


Figure 6. Beam pattern of the dipole phased antenna array with a reflector mirror in H- plane at 300 MHz.

III. HPM OSCILLATOR EXPERIMENTAL VERIFICATION

The pulsed beamless HPM source with a phased dipole antenna array has been demonstrated to radiate 1.1 GW of RF peak power. These values were recorded at a distance of 20 m from the source antenna and in the 3-pulse burst operational regime. The RF energy achieved in the pulse was 2.9 J. The E*R product, (i.e. describes the E-field strength produced by the source as a function of range) was equal to 581 kV. The fields were measured using a D-Dot probe (Prodyn AD-70) with the integrator at 20 m range. The single pulse waveform and its wavelet spectrum are shown in Figures 7 and 8, respectively.

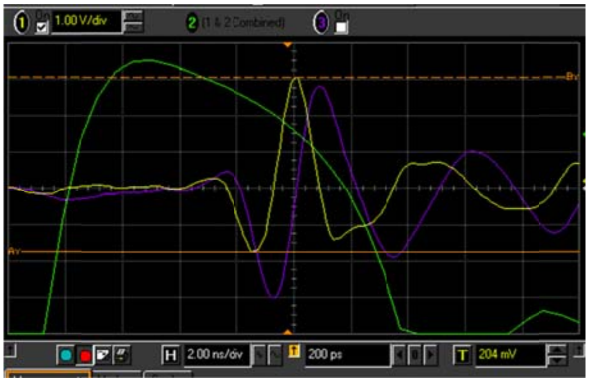


Figure 7. Individual pulse waveform recorded by a digital storage oscilloscope: yellow trace is the received signal from the D-Dot probe, the blue trace is an integrated E-field waveform, and the green trace is signal energy spectrum;

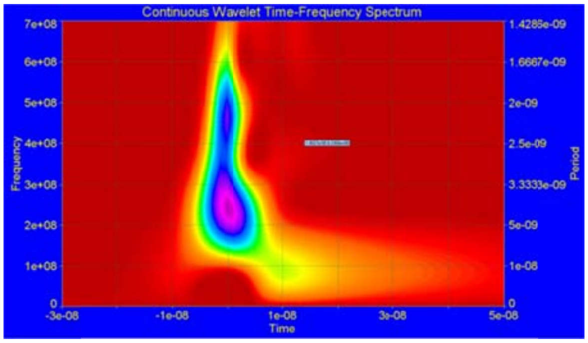


Figure 8. The individual pulse wavelet spectrum

The recorded waveforms describe a single pulse, which corresponds to the three-pulse burst operational regime. The pulse magnitudes are limited only by the power capabilities of the prime power sources and the capacitors charging rate. Provided these characteristics are optimized, the peak power of each pulse in the burst mode can be increased to 2 GW.

IV. SUMMARY

A beamless compact HPM oscillator with a proprietary phased antenna array has been designed and experimentally verified. The oscillator is capable of producing bursts of 3 pulses with 1.1 GW peak power and 2.9 J of radiated RF energy in a burst as recorded at 20 m distance from the transmitter antenna. The burst length is 8-10 ns with an individual sub-pulse length of 2-3 ns. The individual sub-pulse risetimes are on the order of 200 ps, which is by far lower than the response time of even advanced receiver protection devices and limiters. The E*R product value for this oscillator is 581 kV with a radiated spectrum residing in the range of 120-600 MHz. A phased dipole antenna array with a reflector mirror has been designed for this oscillator. This design is more efficient than a classical TEM-horn antenna, especially in the lower portion of the operational spectrum. This antenna design ensures efficient operation in the GW-power level regime, while capable of supporting bursts of 3-4 pulses with 8-10 ns total burst length, without RF breakdown related energy losses. The antenna array requires no special protective measures to prevent RF breakdown.

The designed oscillator can be used as an element in a phase-locked HPM system, consisting of up to 12 HPM oscillator units. This approach enables the development of an HPM source operating in a repetitive rapid-fire or single burst mode in 120-600 MHz frequency range, producing up to 12 GW RF output power.

V. REFERENCES

[1] M. Zhuk, Yu. B. Molochkov, “Design of lense scanning, broadband antennas and feeder devices”. Moscow: Energia, 1973.