PULSED BEAMLESS HIGH POWER MICROWAVE (HPM) SOURCE WITH INTEGRATED ANTENNA

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Abstract

A self-contained High Power Microwave (HPM) source with a peak power of 2.2 GW in the frequency range of 150-550 MHz is addressed. This source utilizes a coaxial electrodynamic structure, excited by two precisely synchronized high-pressure spark gaps. A Transverse Electromagnetic (TEM) horn antenna is used to direct and focus the HPM radiation. A field pattern converter, doubling as an impedance matching device, is used for matching the TEM-horn antenna to the electrodynamic structure. The field pattern converter and impedance matching device is integrated with a TEM-horn antenna. This design reduces the overall HPM source length (including antenna) to 165 cm and the diameter to 152 mm.

I. INTRODUCTION

Beamless HPM sources are ideally suited for the generation of single GW HPM pulses with spectral content in the frequency range of 0.1-1.1 GHz.

These sources are designed around a coaxial electrodynamic structure, excited by several high-pressure spark gaps. Their operation is precisely synchronized, which phase locks the E-fields excited in the structure. The spark-gaps generates broad radiation frequency spectrum. The number of exciter spark-gaps is defined by the output RF power and energy requirements for the HPM source.

Since these HPM sources use a TEM-horn antenna, there is a requirement for a field pattern converter, which also doubles as a matching device. Usually, there is a design requirement to minimize the diameter and length of these sources. In view of this, the impedance matching and converter devices used in these sources have been made an integral part of the source's antenna. This approach was utilized for designing a self-contained beamless HPM source operating in the 150-550 MHz frequency band. The peak radiated RF power of this source was measured to be 2.2 GW at 20 m with a pulse length of 8-12 ns.

II. SELF-CONTAINED BEAMLESS HPM SOURCE DESIGN

Figure 1 shows the design of a beamless HPM source integrated with a TEM-horn antenna.
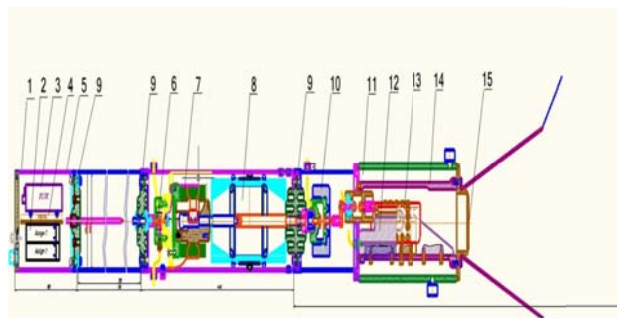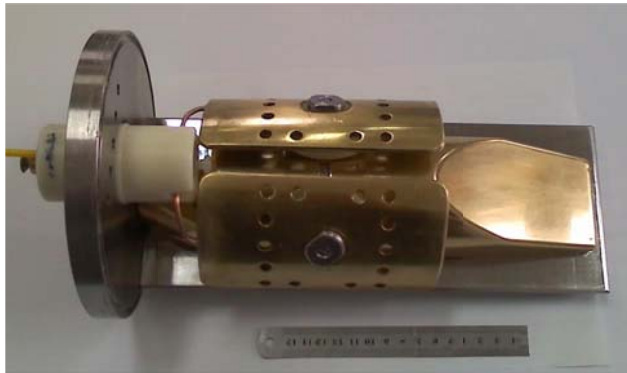

Figure 1. Self-contained beamless HPM source integrated with field pattern converter and antenna. 1- cylindrical case; 2-battery; 3-DC-DC converter; 4-control circuit; 5 - capacitor 0.9 µF/25kV; 6 - capacitor switching spark gap; 7 - is step-up transformer; 8- high-voltage pulse capacitor 300 pF/0.5 MV; 9 - centering insulators; 10 -peaking spark-gap; 11 - coaxial electrodynamic structure; 12 - exciter spark-gap array; 13 – EM field pattern converter; 14 - TEM horn; and 15 - coupling window.

This modification employs a capacitor-based energy source, while an alternate design utilizes an explosive-driven magnetic flux compressor (FCG) as the energy source.

The self-contained HPM source with the capacitor energy storage contains three basic units: 1) capacitor charging unit, 2) high-voltage unit with capacitor storage, and 3) HPM exciter integrated with an antenna. The charger unit employs two 12V batteries (12) connected in series. The charger unit drives a DC-DC converter (3) to produce 30kV, which is used to charge custom-designed pulsed coaxial 0.9 µF/30kV capacitors (15). This capacitor is discharged through the spark-gap (6) and the primary coil of the step-up transformer (7) producing 500-550 kV in the transformer's secondary coil, which is used to charge a coaxial 300 pF pulsed capacitor. The high voltage pulse drives two exciter spark gaps, mounted

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14. ABSTRACT
A self-contained High Power Microwave (HPM) Source With a peak power of 2.2 GW in the frequency range of 150-550 MHz is addressed.

15. SUBJECT TERMS

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inside the electrodynamic structure (12), through the peaking spark-gaps (10). General views of the precisely phased high-pressure exciter spark-gaps are shown in Figure 2.

(a)

(b)

Figure 2 (a, b). General view of the exciter spark gap unit with field pattern converter: a) general view of the exciter spark-gaps with field pattern converter. b) exciter spark-gaps integrated with the TEM-horn flatline section.

Precisely synchronized operation of both high-pressure SF_6 – filled spark-gaps excites the coaxial electrodynamic structure (11) and drives the input of the field patten converter unit elements (13) and (14). The field patten converter unit includes the initial section of TEM-horn (14) and the coaxial electrode (13) of the electrodynamic structure (11). This design allows the field pattern converter to be an integral part of antenna and to influence its radiative characteristics. General views of the HPM source with the field pattern converter integrated with its antenna are shown in Figure 3 and Figure 4.

Figure 3. General view of HPM source with a field pattern converter integrated in the TEM-horn antenna
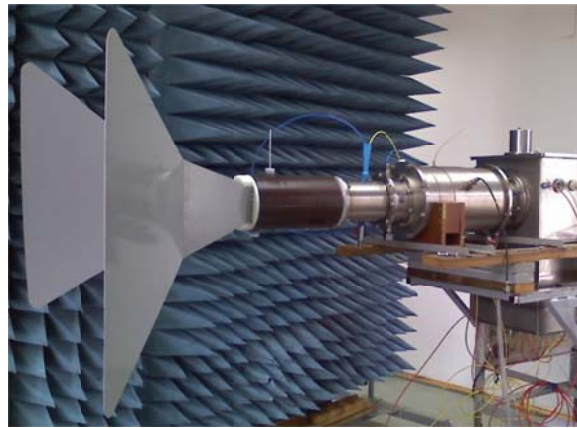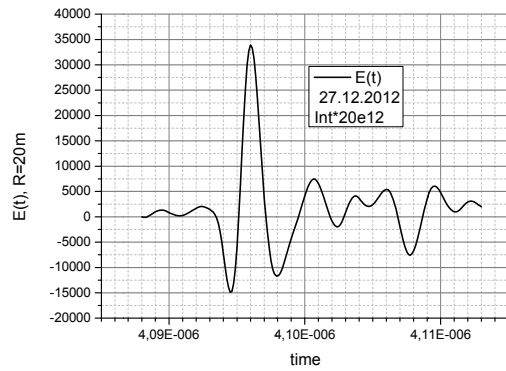

Figure 4. General view of the HPM source installed at the test stand

Utilization of this kind of field pattern converter and impedance matching device reduces the overall length of the HPM source and the electromagnetic wave path losses.
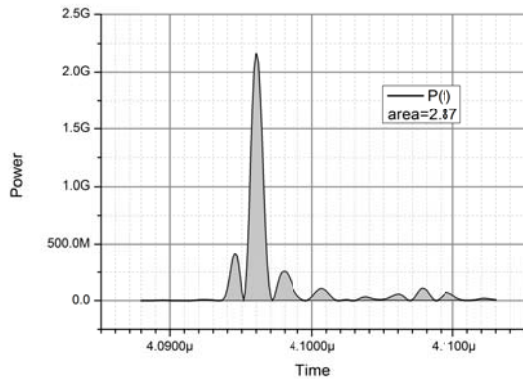
III. EXPERIMENTAL VERIFICATION

It has been experimentally demonstrated that the maximal radiated peak power of this HPM source to be 2.2 GW and the RF energy in the pulse to be 2.87J. The electric field was measured in the far field region using a D-Dot (Prodyn AD-70) sensor terminated with integrator, which was used to calculate the radiated power taking into account system losses.

The time-domain waveforms of E-field and RF power are shown in Figures 5 (a,b).

a)

b)

Figure. 5 (a, b): a) is measured E-field at 20m distance. E*R = 654 kV, b) is RF power time domain waveform. Total RF energy is 2.87J (Antenna gain G=7.1dB).

The time domain waveform's integrated signal, as recorded by the AD-70 D-Dot sensor, and its wavelet spectrum are shown in Figure 6 and Figure 7

Figure 6. Digital Storage Oscilloscope screenshot recording signal from HPM source with TEM-horn antenna. Yellow trace – D-Dot AD-70 waveform, violet trace –integrated signal. Green trace – signal spectrum (100 MHz horizontal 5 dB vertical scales).
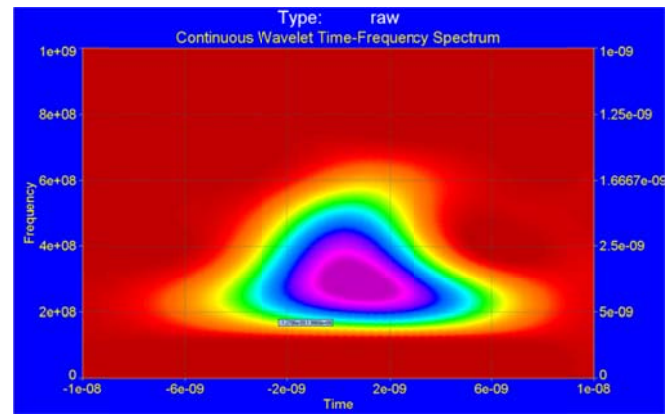

Figure 7. A wavelet spectrum of the received signal at 20m range.

IV. SUMMARY

A self-contained beamless HPM source with a capacitor-based power supply has been designed, developed and experimentally tested.

The source relies on the high-precision phasing of multiple gas filled spark-gaps, allowing it to achieve the E*R product of 654 kV in the frequency range 150-550 MHz at 20 m distance from the transmitter antenna. The source's overall length and RF losses were minimized by integrating the field pattern converter and impedance matching unit with the TEM-horn antenna. This allowed the source to produce 2.87 J of energy per pulse and peak power of 2.2 GW. The HPM source is electronically-controlled and can operate in the single-burst operational regime with the number of burst sub-pulses being defined by the storage capacitor specifications.

V. REFERENCES:

[1] G.D. Krauss, Antennas, Mc Graw-Hill, Inc. 1988.