Operational Characteristics of a High-Power Plasma Limiter – Measurements and Modeling

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INTRODUCTION

High-power microwave limiters are widely used as protection units in wireless communication devices, radars, electronic warfare systems, and other applications [1]. The limiters are designed to allow low-power signals to pass through, while strongly attenuating those with power above a certain threshold and protecting the circuitry from potential disruption or destruction. Aiming to improve the functionality and performance of conventional solid-state limiters (which feature p-i-n-, Schottky diodes, and FETs), a resonator plasma-based limiter was introduced in [2] and later revisited in [3]. Recently, in [4], that limiter was examined using full-wave electromagnetic modeling, backed by the characterization of microwave plasma proposed in [5]. In this paper, we report on experimental and computational studies of the plasma limiter [2] that provide additional insights into its operational characteristics and demonstrate its effectiveness and robustness.

METHODOLOGY

A general view, the interior, and the internal design of the plasma limiter are shown in Figures 1(a), 1(b), and 1(c), respectively. The full geometric characterization of the device is given in [4]. The resonator has been fabricated by copper machining. The ceramic gas discharge tube is a hermetically sealed gas-filled cell integrated with the resonator. The gas ionizes in response to a high electric field, acting as a protective high-power switch.

Measurements of the *S*-parameters of the limiter (in the presence and absence of plasma) were carried out in an experimental setup (Figure 2) which resembles the original described

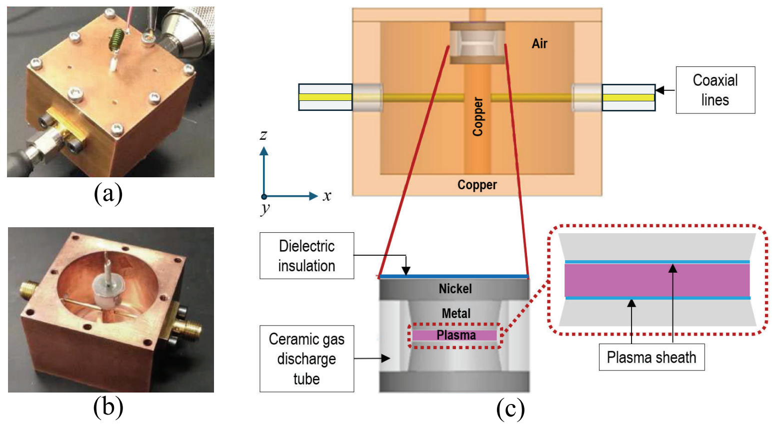


Figure 1. High-power plasma limiter: assembled device [2] (a), view of its interior [2] (b), and the layout of its internal structure (with the plasma cell zoomed in) (c).

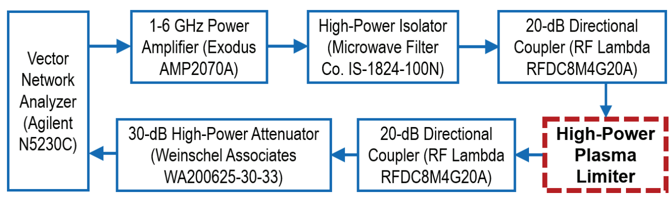


Figure 2. Flow chart of the high-power measurement setup.

in [2]. The system is characterized by a resonance near 2.3 GHz [2]-[4]. Unlike [2], this study performs measurements with Neon over a wider frequency range (1.0-3.0 GHz).

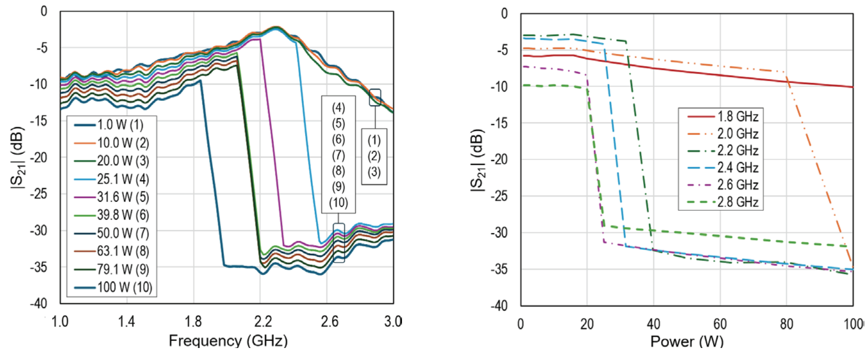
RESULTS

Figure 3 shows the measured magnitude of the transmission coefficient $|S_{21}|$ versus frequency (for different values of input power) and versus input power (at various operating frequencies). The curves reveal the breakdown effect caused by plasma ignition at high power. The signal is transmitted through the limiter when it is at low power, but plasma emerges at power levels near 25 W for 2.3 GHz. Higher powers of up to 100 W result in a shift of the breakdown to 1.85 GHz. Attenuation is very strong (below -30 dB). The limiter's performance is stable and robust; when the power drops below the level required to sustain plasma, the transmission through the limiter returns to the "pre-plasma" levels. The observed ripples are likely due to the power amplifier in the measurement setup.

Operational characteristics of the plasma limiter were also studied with the use of a verified computer model built for the FDTD simulator *QuickWave* [6]. Figure 4 reveals that the electric field, as anticipated, is highly uniform in the capacitive gap. When the plasma ignites, a further increase in the input power leads to a rise in the field magnitude in the sheath, but, due to the increase of plasma conductivity, not inside the plasma itself.

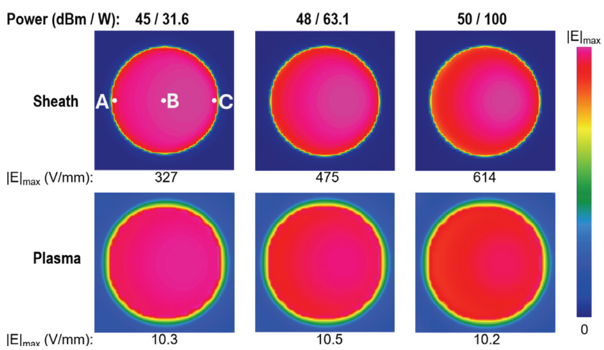
CONCLUSION

In the reported computational and experimental study of the high-power limiter containing sustained plasma, we have provided additional insight into the frequency selective and



(a) (b)

Figure 3. Measured transmission coefficient $|S_{21}|$ as a function of frequency (for different input powers) (a) and input power (for different frequencies) (b); gas: Neon; pressure: 30 Torr.



Power (W)	31.6			63.1			100.0		
Point	A	B	C	A	B	C	A	B	C
Sheath	298	327	308	412	472	437	507	607	555
Plasma	10.0	10.2	10.3	10.1	10.1	10.5	9.6	9.6	10.2

Figure 4. Relative patterns of the electric field (in the *xy*-plane) and its magnitude |E| at points A, B, C in the central plane through the plasma and in the sheath for variable input power.

widely tunable performance of the device. The stability and efficiency of the limiter are ensured by an exceptionally high level of uniformity of the electric field in the capacitive gap of the plasma cell.

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