A 1-Watt, 38-GHz Monolithic Grid Oscillator

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Abstract– **We have demonstrated a monolithic grid oscillator that shows 1 watt of effective transmitter power at 38 GHz. Use of a wire twist reflector as an external feedback element added to a successful monolithic grid amplifier allows a tuning range from 37.5 GHz to 41 GHz. Impedance matching is accomplished by a double-slug tuner and the movable backshort of the twist reflector.**

I. MOTIVATION

Two very common frequency generation circuits are Gunn oscillators and frequency converters. Traditional Gunn oscillator circuits feed a resonator with a Gunn diode operating in the limited space charge mode. Powers of less than 1 watt are achievable using such devices with efficiencies around 20% [1] at Ka-band. Tuning a Gunn oscillator is accomplished by tuning its resonator, and achieving higher powers than a few hundred milliwatts at Ka-band requires a power amplifier. Adding an amplifier to the oscillator circuit degrades the net generation efficiency considerably. Traditional frequency converters require a stable low-frequency oscillator and resonant circuit to provide efficient frequency conversion. Step recovery diodes provide efficient frequency conversion, but tuning the oscillator requires tuning both the low-frequency source and the output resonator. Achieving higher powers again requires a power amplifier, degrading the net system efficiency.

Quasi-optical oscillators offer the advantages that significantly higher output powers can be achieved readily with a comparatively wide tuning range [2]. Quasi-optical oscillators combine the outputs of an array of many oscillators together in free-space, allowing for a combining loss that is independent of the number of oscillators. As a consequence, the achievable power from a quasi-optical oscillator scales linearly with the area of the oscillator array. By designing a stable gain stage, and then adding a tunable feedback network externally, a quasi-optical oscillator can operate over a wide tuning range [2]. This work shows a quasi-optical oscillator that delivers 18 watts EIRP at 38 GHz, and is tunable over a range from 37.5 GHz to 41 GHz.

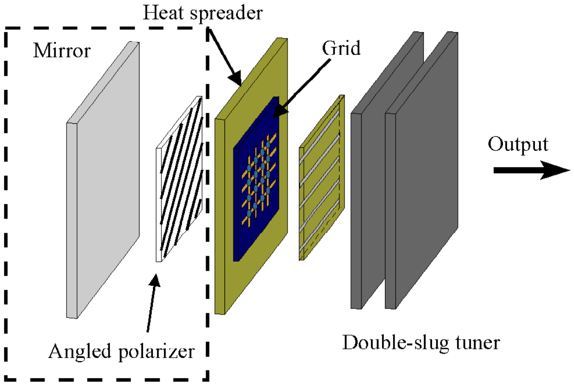

Figure 1. Grid oscillator setup. The double-slug tuner at the output of the oscillator provides output matching.

II. TOPOLOGY

The layout of the grid oscillator is shown in Figure 1.

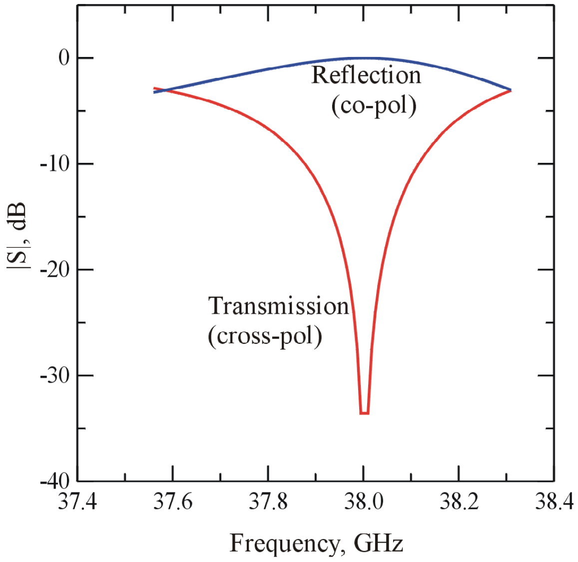

Figure 2. Scattering parameters for the twist reflector. The rapidly changing co-polarized reflection can be used to impedance match the gain stage.

Gain is provided by a grid amplifier that consists of 256 amplification cells [3]. Input to the grid is polarized horizontally; output is polarized vertically. Feedback is added to the grid amplifier by inserting a twist reflector to rotate the polarization of the output beam back to the input polarization. The dashed box of Figure 1 shows the twist reflector. Its components are a movable backshort and a wire polarizer. With the tilt angle of the polarizer set at 45° with respect to the incident beam, strongest coupling from horizontally to vertical polarization occurs at the frequency for which the back-short offset is $\lambda/4$. Simulation of a twist reflector (shown in Figure 2) shows that its cross-polarized transmission is less sensitive to back-short positioning than its co-polarized reflection. As a consequence, the position of the backshort can be used to impedance match the input side of the gain stage. Changes in transmission phase that result from back-short translation can be compensated by translation of the entire twist reflector structure. Impedance matching at the output side of the gain stage is accomplished by a double-slug tuner made of duroid. At the frequency for which the thickness of the duroid slabs is equal to $\lambda/4$, the area of the Smith chart that the double-slug arrangement can tune is a circle centered at the origin with a radius given by $(\epsilon_r - 1)/(\epsilon_r + 1)$.

The twist reflector is modeled by an ideal polarization splitter, followed by polarizers backed by a short. The polarization splitter divides the incident beam into a component with its electric field parallel to the polarizer traces, and another component with its electric field perpendicular to the polarizer traces. The scattering matrix for the splitter is given in (1) below. Ansoft's HFSS generates a scattering matrix for the polarizers that can is used in a circuit simulator in conjunction with the polarization splitter.

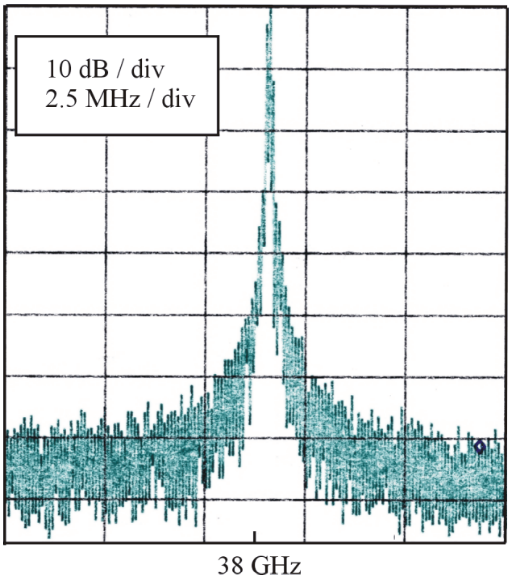

Figure 3. Spectrum of the grid oscillator tuned to 38 GHz. The noise is approximately -106 dBc/Hz at 1 MHz offset.

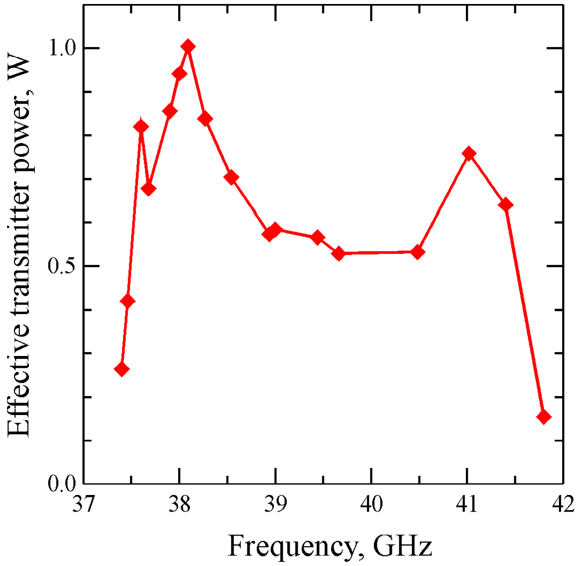

Figure 4. Effective transmitter power against frequency. The peak power out is 1 W at 38 GHz.

$$S = \begin{pmatrix} 0 & \cos(\theta) & 0 & \sin(\theta) \\ \cos(\theta) & 0 & -\sin(\theta) & 0 \\ 0 & -\sin(\theta) & 0 & \cos(\theta) \\ \sin(\theta) & 0 & \cos(\theta) & 0 \end{pmatrix} \tag{1}$$

where θ is the angle of the polarizer wires with respect to the incident beam. Figure 2 shows an analysis of the twist reflector.

III. MEASUREMENTS

Figure 3 shows a free-running spectrum of the oscillator at 38 GHz. An approximate noise measurement shows -106 dBc/Hz at 1 MHz offset from the carrier. The effective transmitter power [4], defined as

$$P_t = \frac{EIRP \cdot \lambda^2}{4\pi A}$$

where A is the geometrical area of the array, is plotted against frequency in Figure 4. The tuning range of the oscillator extends from 37.5 GHz to 41 GHz. Figure 5 shows a plot of the DC-to-RF efficiency, treating the RF output power as the effective transmitter power. The oscillator's E and H-plane patterns are

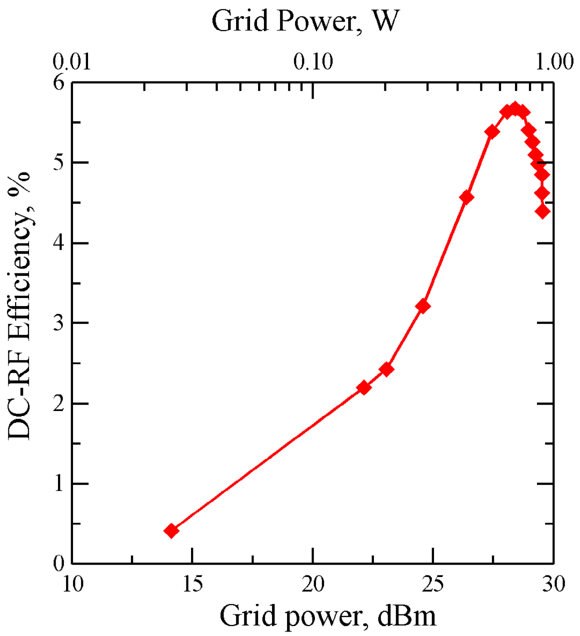

Figure 5. DC-RF efficiency at 38 GHz. The RF power is treated as the effective transmitter power.

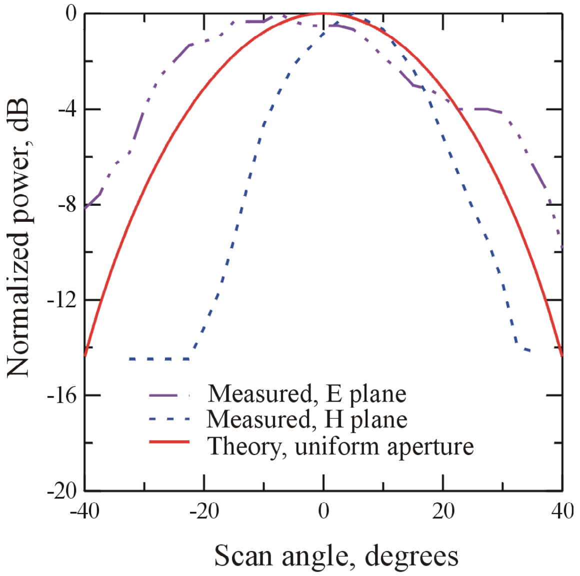

Figure 6. E and H-plane patterns compared to the far-field pattern of a uniformly illuminated aperture in an absorbing plane.

shown in Figure 6, compared to the diffraction pattern of a uniformly illuminated aperture in an absorbing plane. Some of the differences between the H-plane pattern may be explained by the additional elements through which the output beam radiates. The simple diffraction model assumes no additional scatterers, resulting in a pattern given by

$$E(x,y,z) = \frac{j\cos^2(\theta/2)}{\lambda r}\int_S E(x',y')e^{jk\sin(\theta)y'}\,dx'dy' \tag{2}$$

where $E(x',y')$ is the field in the aperture, and $E(x,y,z)$ is the far-field pattern.

IV. Conclusion

We have demonstrated a 38-GHz, 1-W monolithic grid oscillator that has a tuning range from 37.5 GHz to 41 GHz. Work is currently under way that will allow electronic tuning of the oscillator, enabling it to be phase locked to improve the phase noise performance. The oscillator's peak measured EIRP is 18 Watts.

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