A 6.5 GHz-11.5 GHz Source Using a Grid Amplifier with a Twist Reflector

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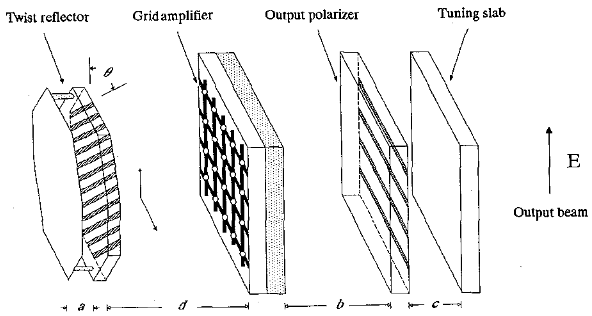
***Abstract*—We have constructed and tested an oscillator using a grid amplifier with external feedback from a twist reflector. The twist reflector serves two functions—it changes the output polarization to match the input, and its position sets the feedback phase. This permits a wider tuning range than has been possible with previous grid oscillators. The source could be continuously tuned from 8.2 GHz to 11.0 GHz by moving the twist reflector. By moving the polarizer and mirror in the twist reflector independently, a 1.8-to-1 frequency range from 6.5 GHz to 11.5 GHz was achieved. The peak effective radiated power was 6.3 W at 9.9 GHz.**

I. Introduction

In the grid oscillators that have been reported [1]–[3], much of the feedback is from the metal structure that contains the transistors. This makes it difficult to vary the feedback phase, and has limited the tuning range to 13% [1]. On the other hand, in grid amplifiers [4], the input and output are isolated by being cross-polarized. In addition, a 100-element HBT grid amplifier has shown a 27% gain bandwidth [5]. This suggests that we could make an oscillator with a wider tuning range by providing a grid amplifier with external feedback, and varying the phase. Fig. 1 shows the approach. Power from the output of the grid amplifier is fed back to the input by the twist reflector to sustain the oscillation. The output beam radiates from the other side.



	dielectric constant (ϵ_r)	Physical length (mm)	Electrical length at 10 GHz, degrees
a	1	3	36
b	1	15	180
c	1	10	120
▩	10.5	3.81	148
□	2.2	3.18	57

Fig. 1. The external feedback oscillator. The twist reflector that provides the feedback replaces the input polarizer in a normal grid amplifier [5]. The distance between the amplifier surface and the twist reflector, d, was varied to change the oscillation frequency.

II. Feedback

Obtaining sustained oscillations from a grid amplifier—which is open-loop stable—requires the introduction of appropriate feedback from output to input. The feedback circuit must serve two functions. First, it must convert some fraction of the vertically-polarized output beam into a horizontally-polarized input beam. Second, it should satisfy the oscillation criteria. That is, the feedback signal must have zero phase and should be large enough to sustain oscillations. A twist reflector meets these requirements. A twist reflector reflects a wave in a different polarization [6], [7]. The feedback phase can be set to any value by adjusting the spacing between the grid amplifier and the twist reflector.

The twist reflector consists of a metal-strip polarizer and a mirror separated by a quarter wavelength. The metal strips of the polarizer are inclined at a 45° angle to the electric field of a normally incident plane wave. We can resolve the incident field into a component that is parallel to the strips, and an equal component perpendicular to the strips. The parallel component is reflected at the strip plane, and the perpendicular component is reflected at the mirror plane, with an extra half-wavelength path delay. The resultant reflected beam is polarized orthogonal to the incoming beam. The effect is similar to a transmission half-wave plate in optical systems [8].

The twist reflector can be modelled for any incident polarization. An ideal polarizer can be described in terms of a four-port scattering matrix. The ports are 1) vertical polarization front side, 2) vertical back side, 3) horizontal front, and 4)

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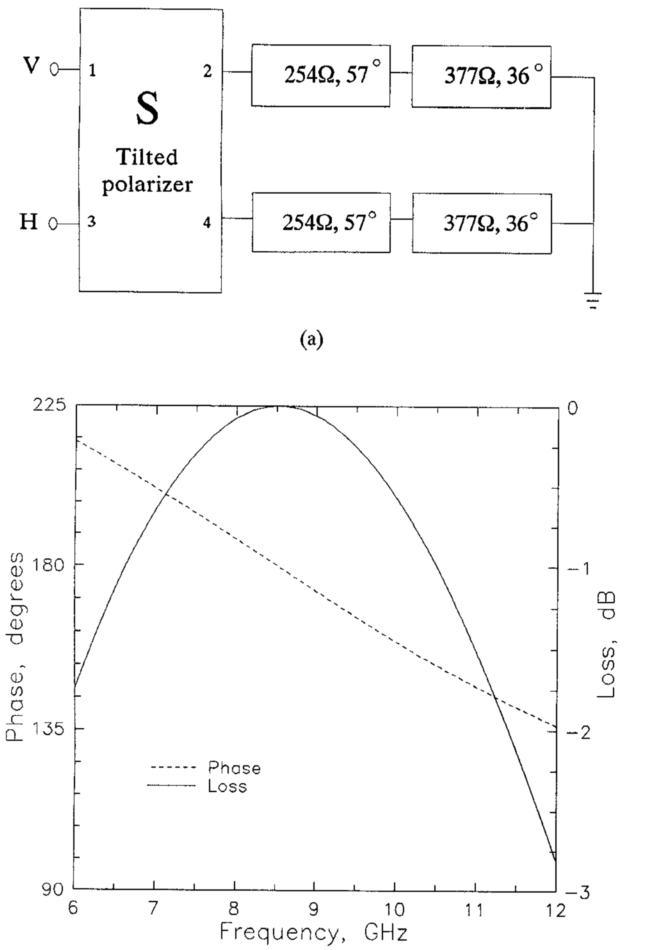


(b)

Fig. 2. (a) Representing the twist reflector by a transmission-line equivalent circuit. The polarizer scattering matrix is given in (1) The 254-Ω transmission line represents the Duroid substrate, and the 377-Ω transmission line is for the air gap between the substrate and the mirror. (b) Conversion loss and phase for the twist reflector.

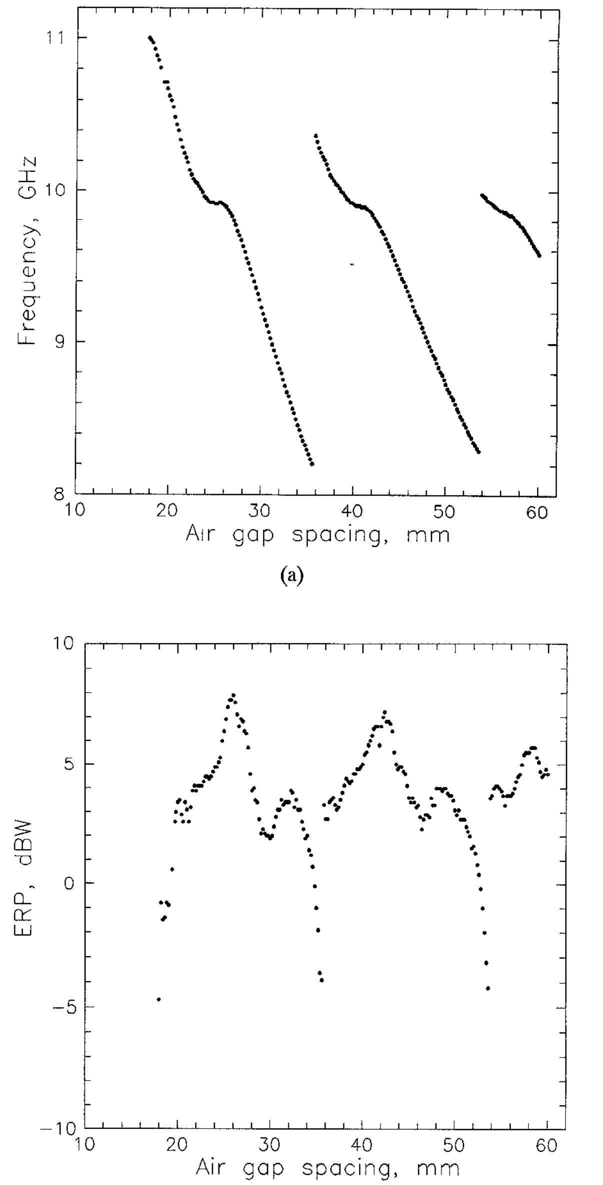
horizontal back.

$$S = \begin{pmatrix} -\cos^2\theta & \sin^2\theta & -\sin\theta\cos\theta & -\sin\theta\cos\theta \\ \sin^2\theta & -\cos^2\theta & -\sin\theta\cos\theta & -\sin\theta\cos\theta \\ -\sin\theta\cos\theta & -\sin\theta\cos\theta & -\sin^2\theta & \cos^2\theta \\ -\sin\theta\cos\theta & -\sin\theta\cos\theta & \cos^2\theta & -\sin^2\theta \end{pmatrix} \tag{1}$$

where θ is the angle between the strips and the incident polarization. The strip polarizer is on a 3.18-mm thick Duroid substrate ($\epsilon_r = 2.2$). An air gap of 3 mm separated the polarizer and the mirror. Fig. 2(a) shows a transmission-line model, and Fig. 2(b) shows the predicted polarization conversion loss. It is less than 1 dB over a 1.6-to-1 frequency range.

III. Tuning

The oscillator tuned smoothly between 8.2 GHz and 11.0 GHz by changing the spacing of the grid amplifier and the twist reflector (Fig. 3(a)). This is close to the gain bandwidth of the amplifier grid, 8.5 GHz to 11.2 GHz [5]. The frequency shows a half-wavelength period from higher-order longitudinal modes. The effective radiated power (ERP) varied from −5 dBW to 8 dBW (Fig. 3(b)). The ERP also shows a half-wavelength period. The maximum ERP was 6.3 W at 9.9 GHz. We did not measure the radiation pattern, so we do not know the total radiated power. However, we can estimate it by assuming that the directivity is given by $D = 4\pi A/\lambda^2$, where A is the grid area, 64 cm^2. With this assumption, the directivity is 19.4 dB, and the total radiated power is 72 mW. The grid was biased at 3.5 V and 530 mA, so that the efficiency would be 3.9%.



(b)

Fig. 3. Tuning the oscillator by changing the distance between the grid amplifier and the twist reflector (dimension d in Fig. 1(a). (a) Frequency. (b) ERP.

Fig. 4 shows the effect of changing the angle of the polarizer between 25° and 75°. The frequency changes by less than 3%, but the power changes over a 13 dB range. This makes sense, because changing the polarizer angle changes the strength of the feedback much more than the phase. We also tried different spacings between the polarizer and the mirror. This

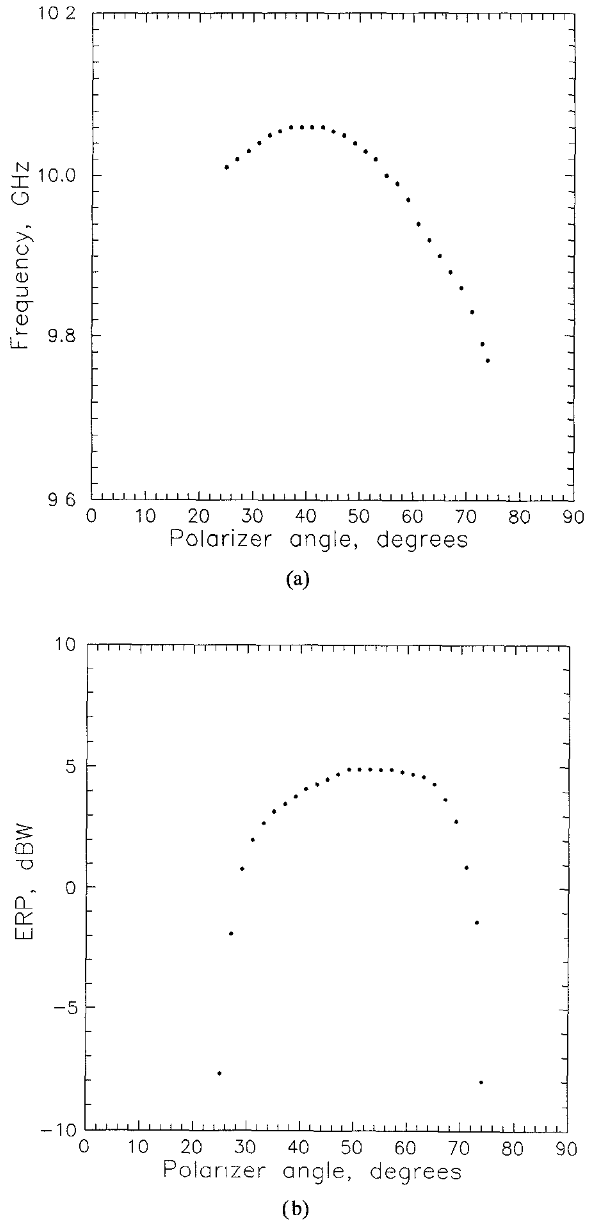


Fig. 4. Varying the polarizer angle. (a) Frequency. (b) Power. The distance between the amplifier grid and the twist reflector was 24 mm.

changes the optimum frequency for the twist reflector. We saw oscillation frequencies over the entire range from 6.5 GHz to 11.5 GHz.

IV. Conclusion

We have demonstrated a new oscillator based on a grid amplifier with external feedback from a twist reflector. This source is tunable from 6.5 GHz to 11.5 GHz, with a peak ERP of 6.3 W. The wide tuning range results from the broad gain bandwidth of the amplifier and the large frequency range of the twist reflector. In this study, the frequency was tuned by adjusting the twist reflector mechanically, but it would be desirable to have a means of electronic tuning for frequency modulation. Mader *et al.* have used a varactor diode grid for tuning an oscillator grid [9]. This suggests that a diode grid be incorporated into the twist reflector for electronic tuning.

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Moonil Kim, (S'91–M'93) for a photograph and biography, see this issue, p. 1770.

Emilio A. Sovero, for a photograph and biography, see this issue, p. 1771.

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