# A DOPPLER RADAR USING A GUNN DIODE BOTH AS A TRANSMITTER OSCILLATOR AND A RECEIVER MIXER

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## Introduction

A simple and low cost doppler radar can be constructed by using a Gunn diode both as a transmitter oscillator and a receiver mixer. The radar has neither a mixer diode nor a circulator.

This paper presents analytical and experimental results of the doppler radar. A burglar alarm using the radar has been developed.

## Analysis

The Gunn oscillator acts as a self-excited microwave mixer when (a) the incoming signal level is very weak, or $P_{in}/P_{out} < (\triangle f/f \cdot Q_e)^2$, [1,2] and as a phase locked oscillator when (b) the signal level is very strong, or $P_{in}/P_{out} > (\triangle f/f \cdot Q_e)^2$.[3] The oscillator can not act as a mixer in(b), but as a radar receiver in (a) and also in (b).

### Case (a). $P_{in}/P_{out} < (\triangle f/f \cdot Q_e)^2$

In this case, we can analyze the radar actions by a small signal method.[4] In order to obtain the differential conductance, we have approximated the V – I characteristic of a Gunn diode by straight lines as shown in Fig. 1. The equivalent circuit of the mixer is shown in Fig.2.

Conversion gain L ($=P_{IF}$ output/$P_{signal}$ input) and the IF output admittance $y_\beta$ are given by

$$L = \frac{4R_e(y_a)R_e(y_b)}{\left[R_e(y_\beta + y_b)\right]^2} \cdot \frac{|g_1|^2}{|g_0+y_a|^2} \qquad (1)$$

$$y_\beta = g_0 - \frac{|g_1|^2}{g_0 + y_a} \qquad (2)$$

where $g_0$ and $g_1$ are the zero and the first order term of the differential conductance, respectively, and $y_a$ and $y_b$ are the microwave and IF load admittance. We see from numerical calculations that the IF output conductance $R_e(y_\beta)$ is negative and the conversion gain L is greater than unity (Fig. 3).

We obtained 20dB of conversion gain in experiment, where X - band Gunn oscillator was used and IF frequency was 70 MHz.[2] Noise figure was as large as 40 dB.

### Case (b). $P_{in}/P_{out} > (\triangle f/f \cdot Q_e)^2$

Radar actions can be analyzed by use of equivalent load admittance. When the target with reflection coefficient $\rho$ is moving away from the oscillator with velocity v, the oscillator performances are given by the equations[5]

$$-\frac{G_d+jB_d}{C\omega_a} = j\left(\frac{\omega}{\omega_a} - \frac{\omega_a}{\omega}\right) + \frac{1}{Q_a} + \frac{g+jb}{Q_e} \qquad (3)$$

$$g + jb = \frac{1 - \rho e^{-j\frac{2\omega}{C}(\ell_0 + vt)}}{1 + \rho e^{-j\frac{2\omega}{C}(\ell_0 + vt)}} \qquad (4)$$

where the quasi-static condition is used under the assumption that the external Q or $Q_e$ is smaller than $\pi C/2v$.

The relative excursion of load conductance and that of the oscillation frequency from those at $\rho = 0$ are given as follows

$$\frac{\triangle G}{G} = -2\,|\rho|\cos\theta \qquad (5)$$

$$\frac{\triangle f}{f} = \frac{|\rho|\sin\theta}{Q_e} \qquad (6)$$

$$\theta = \arg(\rho) - \frac{2\omega}{C}(\ell_0 + vt) \qquad (7)$$

where it is assumed that unloaded Q or $Q_a$ is much larger than $Q_e$, $B_d = 0$ and $|\rho| \ll 1$.

$D_c$ current is expressed as a linearly increasing function of the load conductance.[6] Let us define the sensitivity S by

$$S = \frac{\triangle I/I_0}{\triangle G/G} \qquad (> 0) \qquad (8)$$

where $\triangle I/I_0$ is the relative dc current excursion corresponding to $\triangle G$. From Eqs.(5) and (8), $\triangle I/I_0$ is written by

$$\frac{\triangle I}{I_0} = -\,2S\,|\rho|\cos\theta \qquad (9)$$

Eqs. (5) and (9) are plotted by solid lines in Fig. 4. Experimentally obtained values of $I_0$ and f are given by dots and circles.

The dc current varies periodically, and the period is the same as that of the doppler shifted signal $[T = (2fv/C)^{-1}]$.

Maximum excursion of dc current $\triangle I_M$, obtained in X - band Gunn oscillator (LD4027, NEC) are given in Fig. 5 as a function of $|\rho|$. Dc current excursion can be expressed as a linearly increasing function of $|\rho|$ or $\triangle G$, as seen from Eq. (9).

## Application

A burglar alarm with the radar has been developed. A Gunn diode oscillator is used not only as a transmitter oscillator but as a receiver mixer. The block diagram of the alarm is shown in Fig. 6. The oscillator is usually operated under the condition of case (b) because of the large value of NF. Typical data are listed in Table 1.

## Conclusion

A doppler radar using a Gunn diode both as a transmitter oscillator and a receiver mixer has been examined analytically and experimentally. It can be operated regardless of the incoming signal level. A burglar alarm using the radar has been developed.

## Acknowledgement

The authors wish to thank Drs. M. Uenohara, H. Murakami, K. Ayaki and K. Sekido for their encouragement and guidance.

Table 1. Typical performance data of a Gunn diode burglar alarm.

| | |
|---|---|
| Frequency (GHz) | 9.2 - 10.2 |
| Output power (mW) | 17 |
| Bias voltage (V) | -9 |
| Dc current (mA) | 300 |
| Sensitivity S | 0.05 |
| Detectable range (m)* | 50 |

* used a parabolic antenna of 25 cm diameter.

## References


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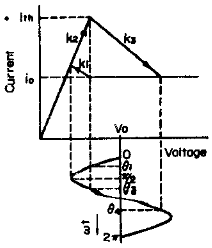


Fig.1 Model of Gunn diode dynamic current-voltage characteristic.

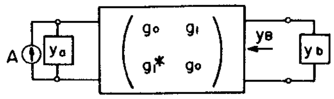

Fig.2 Equivalent circuit of self-excited mixer.

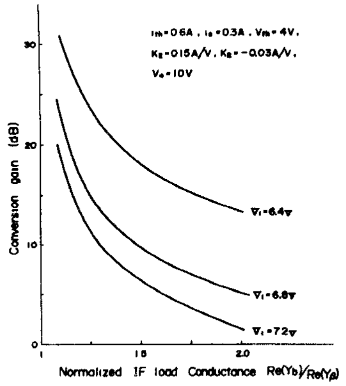


Fig.3 Conversion gain L as a function of ac voltage $V_1$ and normalized IF load conductance $Re(y_b)/Re(y_\beta)$.

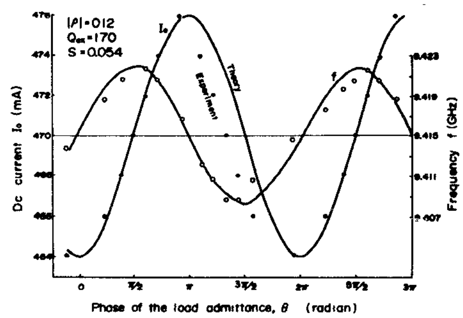


Fig.4 Oscillation frequency f, and dc current $I_o$, as a function of phase θ.

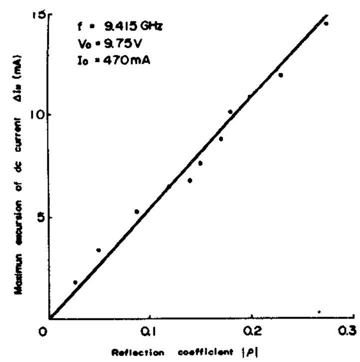


Fig.5 Maximum excursion of dc current as a function of reflection coefficient |ρ|.

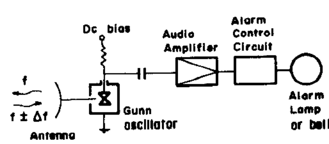


Fig.6 Block diagram of a Gunn diode burglar alarm.