Panel: Noise in Microwave Transmission Applications of Gunn and IMPATT Diodes

ON THE CIRCUIT-DEVICE INTERFACE IN IMPATT-DIODE APPLICATIONS

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Summary of Introductory Statement

The avalanche process in an IMPATT-diode is inherently noisy. On the other hand the IMPATT-diode has the highest C.W. power capabilities, compared with the other active solid-state microwave devices. Therefore, several applications can only be realized using IMPATT-devices and must be designed in such a way that the noise is acceptable.

Let us first consider the noise generation in an IMPATT-diode. The noise is due to the random character of the avalanche process and is, in principle, shot noise. However, due to the large multiplication factor this shot noise is amplified. Every deviation from equilibrium will grow at a fast rate, depending on the intrinsic response time τ_i. This intrinsic response time (1) is closely related to the ionisation rates and the transit time through the avalanche region. Therefore τ_i depends on the semiconductor used and the doping profile. It appears that for a given value of the drift space transit angle GaAs diodes are less noisy than Si p^+-n diodes, which are better than Si n^+-p diodes, all at small signal levels. By chosing a relatively long transit-angle in the drift space, the noise can be minimized somewhat (2).

At increasing signal levels the noise increases steeply. This is due to the fact that the current bunches, generated in the avalanche process, have to build up from the very low current levels between the pulses. Due to the pioneering work of Convert (C.S.F.) and Hines (M.A.) the noise in IMPATT-diodes at large signal levels is now well understood (3). The current minima between the bunches can be raised due to minority carrier storage, tunelling or ionisation in the drift space, so as to decrease the noise at high signal levels. It is known, however, that in the latter case, at least in Si diodes, the efficiency is deteriorated by the same effect (4).

We now consider the device-circuit interaction in the various applications. In a high-Q cavity stabilized oscillator the noise properties of the diode can be screened off. To show an example: in a transmission cavity stabilized oscillator (Kurokawa circuit) the f.m. noise can be as low as 0.2 Hz_{rms} in a 100 Hz band, which is lower than required for application as a local oscillator in a radio relay link. Also the long term stability requirements can be met, using special materials and constructions. At the signal levels required, no parasitic oscillations occur. However, at higher signal levels the noise at about half the oscillation frequency can be amplified parametrically. As Hines already pointed out these effects can be studied using a theory as given in ref. (3) and a systematic consideration of the device/circuit interaction is given in (5), giving some idea of the impedance that should be presented to the diode near the subharmonics. Furthermore, low-frequency oscillations can be excited when at large signal levels the quasistatic I-V characteristic obtains a region with a negative slope (4).

In electronically tuneable oscillators the high Q cavity cannot be used so the noise properties of the diode become more and more dominant. Here, of course, is a possibility for trade-off which is not yet systematically studied.

The next important application is in an injection locked oscillator. In this case the diode noise near the carrier is suppressed. However, in radio relay systems low noise is needed over a large bandwidth so that the diode noise still plays an important role. The noise behavior of a locked oscillator can be studied again on the basis of the theory in ref. (3). preliminary results of such a study will be shown. Also in an amplifier precautions have to be taken for subharmonic oscillations. With precautions the injection locked amplifier can be applied at medium signal levels ($\approx$15 dB gain at input levels of 10-50 mW) in radio relay links.

As a reflection type amplifier the diode noise cannot be influenced, because either a large bandwidth (P.C.M.) or a high power is needed. However, here the high noise power levels can be tolerated in many cases since the signal levels are also high.

References:

1) J. J. Goedbloed: "Determination of the intrinsic response time of semi-conductor avalanches", Solid-State Electr. 15, 635-647, 1972.
2) J. J. Goedbloed: "Noise in IMPATT-diode oscillators", Philips Res. Repts., Suppl. 7, 1973, Chapter 6.
3) J. J. Goedbloed and M. T. Vlaardingerbroek, "Noise in IMPATT-diode oscillators at large signal levels", IEEE Trans. ED-21, 342-351, 1974.
4) B.B. v. Iperen, "Efficiency limitations by transverse instability", Proc. IEEE Letters, 62, 284, 1974.
5) J.J. Goedbloed and H. Tjassens, "Parasitic oscillations in IMPATT-diode oscillators", Proc. 4th Europ. Microw. Conf. Montreux, page 328-332, 1974.