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References

1 ASH, E. A.: 'Surface wave grating reflectors and resonators'. IEEE symposium on microwave theory and techniques, Newport Beach, Calif., 1970
2 STAPLES, E. J., SCHOENWALD, J., ROSENFELD, R. C., and HARTMAN, C. S.: 'UHF surface acoustic wave resonators'. Proceedings of IEEE ultrasonics symposium, Milwaukee, 1974, pp. 245–252
3 SCHOENWALD, J. S., ROSENFELD, R. C., and STAPLES, E. J.: 'Surface wave cavity and resonator characteristics—VHF to L band'. Proceedings of IEEE ultrasonics symposium, Milwaukee, 1974, pp. 253–256
4 LI, R. C. M., WILLIAMSON, R. C., FLANDERS, D. C., and ALUSOW, J. A.: 'On the performance and limitations of the surface wave resonator using grooved reflectors'. Proceedings of IEEE ultrasonics symposium, Milwaukee, 1974, pp. 257–262
5 LAKIN, K. M., JOSEPH, T., and PENUNURI, D.: 'Planar surface acoustic-wave resonators'. Proceedings of IEEE ultrasonics symposium, Milwaukee, 1974, pp. 263–267
6 MASON, I. M., CHAMBERS, J., and LAGASSE, P. E.: 'Spatial harmonic analysis of the multistrip coupler'. Proceedings of IEEE ultrasonics symposium, Monterey, 1973, pp. 159–162
7 INGEBRITSEN, K. A.: 'A normal mode representation of surface wave multistrip couplers'. Proceedings of IEEE ultrasonics symposium, Monterey, 1973, pp. 163–167
8 DE LA RUE, R. M., HUMPHRYES, R. F., MASON, I. M., and ASH, E. A.: 'Acoustic-surface-wave amplitude and phase measurements using laser probe', *Proc. IEE*, 1972, **119**, (2), pp. 117–126
9 KOGELNIK, H., and LI, T.: 'Laser beams and resonators', *Proc. Inst. Elec. Electron. Eng.*, 1966, **54**, pp. 1312–1328

ZENER-DIODE NOISE GENERATORS

Indexing terms: Noise generators, Zener diodes

Zener diodes operated in the breakdown region have been investigated as transfer noise standards in the r.f. region. A close correlation has been found between the variation in excess noise ratio (e.n.r., dB) and the temperature coefficient of Zener diodes. In particular, diodes having zero temperature coefficient of voltage also have zero temperature coefficient of e.n.r.

Zener diodes operated in the reverse breakdown region have been suggested as noise sources by Susans.[1] With the aim of constructing high-stability noise transfer standards at 30 MHz, the performance of Zener diodes as noise sources has been investigated. Measurements of the absolute noise level were made with a Dicke-type switched radiometer by substituting the noise generator under test for a temperature-limited thermionic diode on the same arm of the radiometer, with a high-stability carbon-lamp noise source[2] on the balancing arm. The amount of attenuation (in decibels) necessary in front of the noise generators under test to return to a balance set by the thermionic diode, plus the e.n.r. of the thermionic diode, is the e.n.r. of the generator under test. The measured noise outputs of a number of different-voltage Zener diodes are shown in Fig. 1.*

As is known, there are two different mechanisms for Zener-diode operation, the division being at about 6 V breakdown voltage. The ' Zener ' effect operates below 6 V, and the ' avalanche ' effect above. This transfer of mode of operation is manifested in Fig. 1 by the change in curvature of e.n.r. against Zener voltage, the inflection point representing the changeover. If the temperature coefficients of Zener diodes are plotted against Zener voltage,[3] the resulting curve is very similar in shape to that of Fig. 1, suggesting a close link between these two phenomena.

* It should be noted that the e.n.r. of Fig. 1 does not represent the maximum available noise from the diodes, because at the operating current the diode dynamic resistance is about 10 Ω, and, to avoid sharply tuned (narrowband) impedance matching to 50 Ω, a 39 Ω resistor was placed in series with the r.f. impedance of the diodes

Since, for the present application, maximum stability rather than maximum noise output is required, diodes near 6 V are used. As Fig. 1 shows, the e.n.r. is a function of the Zener voltage, so diodes with near-zero temperature coefficients are selected. It has been confirmed by measurement that diodes below 6 V reduce their noise output, whereas diodes above 6 V increase their noise output with increasing temperature. Since the slope of the curve in Fig. 1 near the inflection point is about 12 dB/V, if a diode with a temperature coefficient of say +0·01 %/°C is found, its noise output will increase by about 0·0072 dB/°C, rendering it suitable as a laboratory (or interlaboratory) transfer noise standard when operated from a constant-current source.

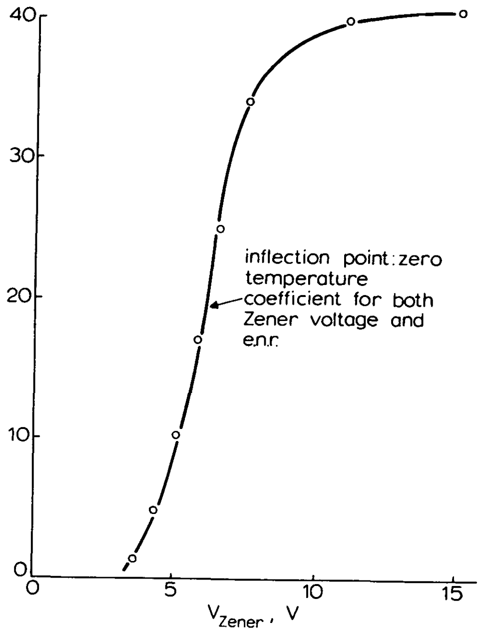

Fig. 1 *Excess-noise-ratio against Zener voltage for number of Zener diodes at 3 mA current*
Measured at 30 MHz

Fig. 1 is in conflict with the empirical formula of Susans.[4] However, his formula is claimed to fit results measured in the v.h.f. and u.h.f. ranges. It is interesting to note, that for low-voltage Zener diodes, the noise generated increases monotonically with reverse current, whereas, for high-voltage diodes, the maximum noise is generated near the threshold avalanche point, and decreases with current. For 6·2 V Zener diodes, a ' hump ' has been observed in the noise-output/current characteristics, indicating an intermediate condition between the two differing characteristics.

In conclusion, it has been found that the e.n.r. of Zener diodes is a function of the Zener voltage, and therefore for maximum stability in noise output diodes of near-zero temperature coefficient, i.e. near 6 V, should be used.

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References

1 SUSANS, D. E.: 'Noise calibrator for v.h.f. and u.h.f. field-strength-measuring receivers', *Electron. Lett.*, 1967, 3, pp. 354–355
2 HOLLWAY, D. L., and SOMLO, P. I.: 'Stable broadband variable noise source for microwave radiometry', *ibid.*, 1968, 4, pp. 24–25
3 MILLMAN, J., and HALKIAS, C. C.: 'Electronic devices and circuits' (McGraw-Hill), p. 144
4 SUSANS, D. E.: 'Semiconductor-diode v.h.f. and u.h.f. noise sources', *Electron. Lett.*, 1968, 4, pp. 72–73