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NOISE IN IMAGE DISSECTOR TUBES

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Noise in image dissector tubes may be divided into two general classifications: (1) spurious noise which can be avoided or minimized by careful design, and (2) fundamental noise which cannot be avoided.

Spurious noise may be caused by ion feedback, hum pickup, deflection coil current pickup, etc., and can be expected to be low in amplitude in a properly designed and properly operated tube.

Fundamental noise, on the other hand, is inherently present and must be considered in any practical dissector application. Fortunately, the theory of the dissector tube is so simple that it is relatively easy to compute the fundamental noise limitations.

The fundamental noise can be divided into three types: (1) statistical fluctuation of the dark current, i.e. thermonic emission from the photocathode (2) statistical fluctuation of the signal current emitted from the photocathode as a result of a flux input signal, and (3) statistical fluctuations of the secondary emission multiplication process in the multiplier dynodes.

Noise from the first two sources can be computed from the well known shot law:

$$i_{nk}^2 = 2\, e\, I_k\, \Delta f$$

where

I_k = The d-c current entering the dissector defining aperture, emitted from a corresponding photocathode area as chosen by the deflection fields and aperture size.

i_{nk} = rms noise component of I_k

e = charge on the electron = 1.6×10^{-19} coulomb

Δf = noise bandwidth in cps

If I_k is the magnitude of the dark current, then i_{nk} is the dark noise current; if I_k is the signal current only, then i_{nk} is the so-called noise-in-signal current; and if I_k is the total current, i_{nk} is the total noise current.

For most dissector applications the dark current and dark noise current are both negligible compared to the signal current and noise-in-signal current and can be neglected. However, for some applications it is convenient to know that the dark (thermionic) emission from an S-1 photocathode normally lies between 3×10^{-13} and 3×10^{-12} amperes/cm^2 and for an S-11 or an S-20 photocathode it normally lies between 10^{-15} and 10^{-14} amperes/cm^2. These figures will permit a dark noise current estimation if desired.

Considering now the multiplier anode output circuit, the d-c anode current, I_a, is derived from the d-c cathode current, I_k, by multiplying by the current amplification, μ, of the electron multiplier structure, thus:

$$I_a = \mu I_k$$

where the subscript "a" refers to the multiplier anode output circuit.

The corresponding noise current in the anode circuit, i_{na}, is obtained by multiplying the cathode noise current, i_{nk}, by two factors: first, the current amplification, μ, and second, the factor $[\sigma/(\sigma-1)]^{1/2}$ where σ is the gain/stage of the electron multiplier[1]. This latter factor accounts for the third type of fundamental noise listed previously, namely that due to fluctuations of the secondary emission ratio.

The anode circuit noise current is then

$$i_{na} = \mu \left[\frac{\sigma}{\sigma-1}\right]^{1/2} i_{nk}$$

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[1] See, for example, Spangenberg, "Vacuum Tubes", McGraw Hill Book Company, New York, 1948, p 320 ff. With $\sigma \cong 3$ in the usual ITT multipliers, the noise increase due to secondary emission is $[3/2]^{1/2} = 1.22 = 22\%$.

and the relationship between i_{na} and I_a is

$$i_{na}^2 = 2e\mu I_a \quad \Delta f\, \sigma/(\sigma - 1)$$

Comparing this final equation for anode noise current with the basic shot law shows that anode noise in a dissector tube acts as if it were shot noise generated by unit charges having an amplitude of

$$e\,\mu\,\sigma/(\sigma - 1)$$

or approximately μ times the unit charge, e. This is an easy way to remember the relationship for anode circuit noise.

In an actual operating dissector all of the necessary parameters above can be readily determined experimentally with the exception of the noise bandwidth, Δf. This bandwidth may be estimated from the approximate relationship

$$\Delta f \simeq (1/2\,\Delta t)$$

where

Δt = time taken to scan across one single aperture width.

It can be seen that dissector noise varies as the square root of the scan speed, i. e. as the square root of the scan frequency for a given scanned area. Slow scan speeds are necessary for low noise and clearly a compromise must always be made between resolution and signal-to-noise ratio.

Further discussions of dissectors or dissector-type operation may be found in the references on the following page.

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