The probability density of Y may be written by inspection as

$$p(Y) = \frac{1}{M} \exp\left(-\frac{Y}{M}\right).$$

The error rate is given by

$$p(e) = \int_0^\infty p(V)dV \int_V^\infty p(Y)dY$$

$$= \int_0^\infty \mathfrak{L}_V^{-1}[(ar+1)^{1-M}(Mr+ar+1)^{-1}]dV$$

$$\cdot \exp(-V/M)$$

$$= [(ar+1)^{1-M}(Mr+ar+1)^{-1}]_{r=1/M}$$

$$= [(a/M+1)^{1-M}(a/M+2)^{-1}]$$

or, in terms of the original notation

$$p(e) = (S_0T/Mn_0 + 1)^{1-M}(S_0T/Mn_0 + 2)^{-1} \quad (23)$$

which at low probability of error (large signal to noise ratio) is approximately

$$p(e) \sim M^M(S_0T/n_0)^{-M}, \quad S_0T \gg Mn_0.$$

The decibel loss at low error rate caused by the no[ise] being completely correlated is given in Table II. T[he] loss in decibels at a fixed error rate, when only a pa[rt] of the noise arises from a common source, will be som[e]what less than the tabulated values. In this connecti[on] it may be pointed out that switch diversity is not subje[ct] to perturbing effects due to correlated noise since on[ly] one receiver is operative at any instant.

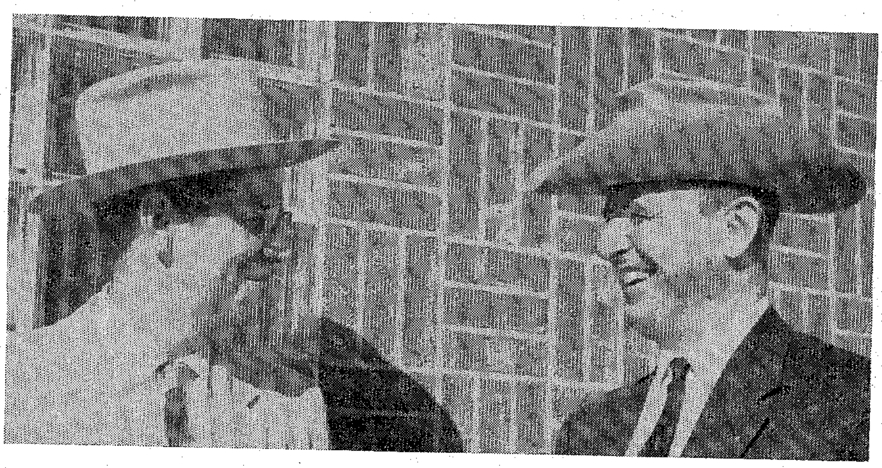
TABLE II
LOSS CAUSED BY COMPLETELY CORRELATED NOISE

M	2	3	4	5	6	8	1[0]
db loss	0.62	1.44	2.16	2.79	3.34	4.27	5.0[…]

ACKNOWLEDGMENT

Mrs. Margaret D. Hill performed part of the ha[nd] calculation and prepared the two figures.

Correspondence



The President Smiles*

We, the IRE members of Texas, found the January, 1958 PROCEEDINGS to be of poor taste and offensive in one respect. This is, the picture of our respected President for 1958 on page 2.

We have taken steps to correct this error. Enclosed is a picture of Mr. Fink which will meet with the approval of all Texans. No man can be appreciated in Texas unless he wears a "ten-gallon" hat or owns a few hundred oil wells.

In the picture, Floyd Crum, (left), Chairman of the Beaumont-Port Arthur Section, has just presented Mr. Fink with a "ten-gallon Texas hat," thus protecting the dignity due Mr. Fink by all Texans.

The smiling face of Mr. Fink, in contrast with the glum and despondent picture that was presented in the January issue of PROCEEDINGS, attests to the service which the Beaumont-Port Arthur Section has rendered the IRE.

WES ECKLES
Fellowship Chairman
Beaumont-Port Arthur Section

* Received by the IRE, January 22, 1958.

WWV Standard Frequency Transmissions*

Since October 9, 1957, the Nation[al] Bureau of Standards radio stations WW[V] and WWVH have been maintained as co[n]stant as possible with respect to atomic fr[e]quency standards maintained and operat[ed] by the Boulder Laboratories, National Bu[]reau of Standards. On October 9, 1957, th[e] USA Frequency Standard was 1.4 parts [in] 10^9 high with respect to the frequency derived from the UT 2 second (provision[al] value) as determined by the U. S. Na[val] Observatory. The atomic frequency stand[]ards remain constant and are known to b[e] constant to 1 part in 10^9 or better. Th[e] broadcast frequency can be further co[r]rected with respect to the USA Frequen[cy] Standard as indicated in the table opposi[te]. This correction is *not* with respect to the cu[r]rent value of frequency based on UT 2. [A] minus sign indicates that the broadcast fre[]quency was low.

The WWV and WWVH time signals [are] synchronized; however, they may gradua[lly] depart from UT 2 (mean solar time correct[ed] for polar variation and annual fluctuation [in] the rotation of the earth). Corrections [are] *determined and published by the U. S. Na[val]* Observatory.

* Received by the IRE, March 13, 1958.

WWV and WWVH time signals are maintained in close agreement with UT 2 by making step adjustments in time of precisely plus or minus 20 msec on Wednesdays at 1900 UT when necessary; one minus step adjustment was made at WWV and WWVH on December 11, 1957, January 15, 1958, and February 5 and 19, 1958.

WWV Frequency†

	Parts in 10^9		
Day	Dec., 1957 1500 UT	Jan., 1958 1500 UT	Feb., 1958 1500 UT
1	−4.8	−3.4	−2.6
2	−4.9	−3.3	−2.5
3	−4.9	−3.2	−2.5
4	−5.0	−3.1	−2.5
5	−5.0	−3.0	−2.5
6	−5.0	−2.9	−2.4
7	−4.9	−2.9	−2.3
8	−4.9	−2.8	−2.3
9	−4.9	−2.8	−2.2
10	−4.8	−2.8	−2.2
11	−4.7	−2.7	−2.2
12	−4.6	−2.6	−2.2‡
13	−4.4	−2.6	−2.1
14	−4.3	−2.6	−2.1
15	−4.2	−2.6	−2.1
16	−4.1	−2.7	−2.1
17	−4.1	−2.7	−2.1
18	−4.0	−2.7	−2.1
19	−4.0	−2.7	−2.2‡
20	−3.9	−2.7	−2.2
21	−3.8	−2.8	−2.3
22	−3.8	−2.8	−2.3
23	−3.8	−2.9	−2.3
24	−3.7	−2.9	−2.3
25	−3.7	−2.9	−2.4
26	−3.7	−2.9	−2.4‡
27	−3.7	−2.9	−2.5
28	−3.7	−2.9	−2.5
29	−3.6	−2.8	
30	−3.6	−2.8	
31	−3.6	−2.7	

† WWVH frequency is synchronized with that of WWV.

‡ Decrease in frequency of 0.5×10^{-9} at 1900 UT at WWV.

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Natl. Bur. of Standards
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A New Type of Low-Noise Electron Gun for Microwave Tubes*

During an investigation of noise reduction in backward-wave amplifiers which was conducted at the Hughes Research Laboratories, a series of experiments was undertaken to study the effects on beam noisiness of radical changes in the dc potential distribution in the immediate vicinity of the cathode. In particular, the diode region of an electron gun was designed to allow manipulation of electron emission and flow at exceedingly low potentials and thus to permit examination of the underlying assumptions and validity of existing one-dimensional noise theories.

These experiments, performed in 1956 and early 1957, resulted in a cascade backward-wave amplifier with a noise figure lower than 4 db at S band, as described at the Fifteenth Annual Electron Tube Research Conference.[1] Since that time the results have been reproduced on a number of tubes; tube noise figures in the vicinity of 3.5 db have been measured in several instances. Here the purpose is to formally announce these results and to briefly comment on the type of low-noise electron gun which has evolved from this work.

The basic features of the gun are 1) emission which originates predominantly from the edge and side of the cathode, and 2) a potential profile for these edge electrons which, in the cathode region, departs drastically from the usual (approximately Fry-Langmuir) potential distribution. We are led to the concept of *linear edge current* (as measured in terms of current per unit length of available cathode edge) as being a key design parameter for these low-noise guns, as distinguished from uniform current *density* which, on the basis of one-dimensional noise theories, is regarded as a controlling factor in the performance of conventional low-noise guns.

It is evident that the basic noise quantities in the beam (velocity and current fluctuations and their correlation) were being manipulated in the very low potential region of the gun near the cathode. Indeed, the unusual potential profile permits a possible drifting action at very low mean velocities or, more probably, a gradual acceleration of the beam through an extended region where the thermal velocity spread is large. It should be noted that Saito[2] has recently measured some correlation in typical beams and Siegman, Watkins, and Hsieh[3] have shown that such a correlation can develop on a one-dimensional beam as it is accelerated along the Fry-Langmuir potential profile from the potential minimum to a potential of several tenths of a volt. Thus one might expect to find an enhancement of this correlation and consequently a further reduction in the theoretically predicted minimum noise figure as a result of the unique potential profile characteristic of this gun.

Another possible explanation lies in a reduction of initial kinetic noise voltage by virtue of the edge emission mechanism, as proposed at the Tube Research Conference.[1] The particular combination of geometry and electric fields which produces the edge emission also gives rise to the distorted potential configuration, and vice versa. Therefore it has not yet been possible to experimentally determine which of these features is really the essential one.

Current research is being devoted to the frequency-scaling characteristics of the noise reduction mechanism. It is planned to describe in detail the operation of the gun and its relation to existing noise theories in a future paper.

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Hughes Aircraft Co.
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* Received by the IRE, February 17, 1958.

[1] M. R. Currie and D. C. Forster, "New results on noise in electron beams," presented at the Fifteenth Annual Electron Tube Research Conference, Berkeley, Calif.; June, 1957.

[2] S. Saito, "Determination of the Correlation Ratio π/S of the Noise in an Electron Beam," M.I.T., Res. Lab. of Electronics, Cambridge, Mass., Quarterly Progress Rept., pp. 29, 30; October 15, 1957.

[3] A. E. Siegman, D. A. Watkins, and H. Hsieh, "Density-function calculations of noise propagation on an accelerated multivelocity electron beam," *J. Appl. Phys.*, vol. 28, pp. 1138–1148; October, 1957.

S-Band Traveling-Wave Tube with Noise Figure Below 4 DB*

In the preceding letter Currie reports noise figures below 4 db obtained at S band with a backward-wave amplifier. His tube uses an annular cathode with a resulting hollow electron beam. Experiments have been undertaken at Bell Telephone Laboratories to see whether comparable noise performance could be obtained in a conventional, low-noise traveling-wave tube employing the usual type of cathode, *i.e.*, one having a plane circular emitting surface. The electrode configuration and voltage profile, however, were similar to those used by Currie. The main observation to be reported is the achievement of noise figures as low as 3.5 db.

The test vehicle employed was an S-band amplifier in which reproducible noise figures of 4.8–5.0 db had been observed previously. Initial experiments were confined to changes in the gun configuration. They gave no over-all improvement in noise figure but indicated best performance at lower currents. In order to provide more gain at the lower current, the helix pitch was decreased to give a γa of 1.7. This change, together with the more important changes in the cathode region, yielded tubes in which the 3.5-db noise figure was observed. The changes in the cathode region included operation of the beam forming electrode at a positive potential giving rise to enhanced electron emission from the cathode edge and thereby to a somewhat hollow beam.[1] The voltage configuration of the other electrodes was similar to that used by Currie in that it produced a low velocity drift region near the cathode.

Operating parameters of the original and modified versions of the tube are given in Table I.

TABLE I

Parameter	Original Version of S-Band Tube	Modified Version
I_k (microamps)	500	60
V_{helix} (volts)	560	200
γa	1.05	1.7
Cathode diameter (inches)	0.025	0.025
Helix TPI	100	160
Helix ID (inches)	0.051	0.051
Gain (db)	22	20
F_{opt} (db) at 600 gauss	4.8	4.3
F_{opt} (db) at 1600 gauss	4.8	3.5

It should be noted that the lowest value of noise figure was obtained with a magnetic field strength considerably higher than that required for focusing alone. This effect has also been observed by Currie. To date one tube with a 3.5-db noise figure and two tubes with 3.8-db noise figures have been made. In all cases the noise figure improved with increasing magnetic field strength, the observed slope up to 1600 gauss being approximately 0.1 db/100 gauss with little or no improvement beyond. The noise figure

* Received by the IRE, February 17, 1958.

[1] The hollow nature of the beam was confirmed experimentally in a demountable system by K. J. Harker using a pin-hole probe in conjunction with a 2:1 enlarged version of the gun.