# Correspondence

## Klystron Noise

In my paper "Crystal Checker for Balanced Mixers"[1] I gave data on the excess noise of typical klystrons. Since that paper was prepared, further data has been obtained that permits an expansion of Fig. 6.

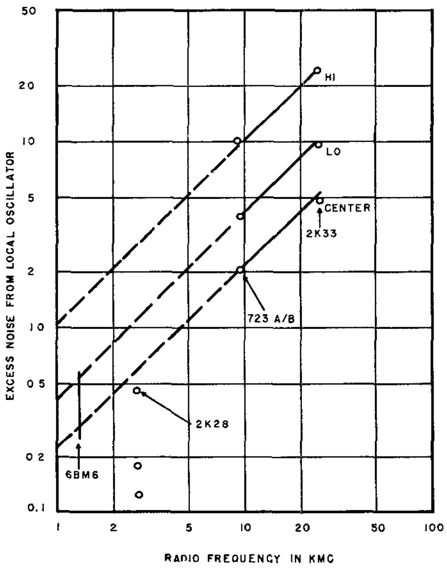


Fig. 1—30-mc excess noise of typical klystrons. (Same as Fig. 6 of original paper except for addition of 2K28 data.)

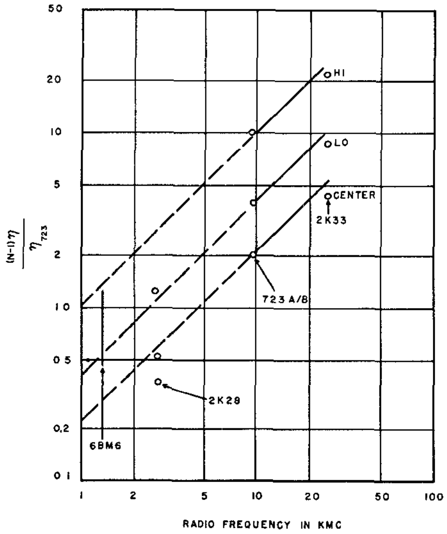


Fig. 2—30-mc excess noise of typical klystrons multiplied by the efficiency ratio $\eta/\eta_{723}$.

Measurements were made on a 2K28 at 2800 mc. Fig. 1 is a revision of Fig. 6 to show the new data. It is seen that the new points fall below the interpolated curves given originally, although the relative vertical spacings are about the same as those predicted by interpolation. The data in Fig. 1 seem to fit the empirical relationship

$$N - 1 \cong K \frac{f}{\eta},$$

where $N-1$ is the excess noise power at a particular intermediate frequency, $K$ is a constant, and $\eta$ is the efficiency of converting beam power to cw power.

If one arbitrarily multiplies the data in Fig. 1 by the ratio of the efficiency of the particular klystron to that of the 723A/B, the nearly linear relationship of Fig. 2 is obtained.

If the empirical relation is valid, Fig. 2 can be used to predict the approximate performance of other klystrons by spotting the operating frequency on the figure, or an extension thereof, and multiplying by the ratio of efficiencies, $\eta_{723}/\eta$.

P. D. Strum
Applied Electronics Section
Airborne Instruments Lab.
Mineola, N. Y.

[1] *Trans. I.R.E.*, vol. MTT-2, pp. 10–15; July, 1954.

## A Practical Method of Locating Waveguide Discontinuities

In the maintenance of ultra-high frequency equipments utilizing waveguide, one of the more difficult troubles to diagnose and correct is that of the high standing wave ratio. The question always arises as to whether the antenna or the waveguide is at fault. Sometimes a visual inspection of the transmission system will disclose the difficulty. Too often, however, the physical layout of the system makes a close inspection impractical. The construction of many antennas, also, does not permit an examination of the radio frequency components without a complex mechanical disassembly, costly in terms of man-hours.

It is desirable, therefore, to determine the approximate location of the discontinuity electronically. On those equipments having a continuously variable-frequency transmitter, a frequency measuring device, and a waveguide probe for sampling the standing wave, this can be done quite easily. On other equipments these features can be simulated by installing, at the transmitter end of the line, a waveguide section equipped with probes for inserting the signal of a variable-frequency, calibrated, test oscillator and for sampling the standing wave.

The usual analysis of a standing wave requires the movement of the probe along the slotted waveguide; the detected voltage progresses through maximum and minimum values in accordance with the standing wave pattern.

If, however, the probe is left at a fixed position and the frequency is varied, the standing wave will move past the probe, its detected voltage rising and falling in the same manner as the *guide* wavelength changes with frequency. It will be shown that the frequency change necessary to move the standing wave a specific number of wavelengths is a function of the distance from the probe to the discontinuity causing the standing wave.

If we let $N$ equal the number of half-guide wavelengths between the probe and the discontinuity, and let $L$ represent the physical distance from the probe to the discontinuity, then

$$N = \frac{2L}{\lambda_g}. \tag{1}$$

Now, if the operating frequency is increased sufficiently to bring one more half-guide wavelength into the distance, $L$, then

$$N + 1 = \frac{2L}{\lambda'_g}. \tag{2}$$

Subtracting (1) from (2) and rearranging, we have

$$L = \frac{\lambda_g \lambda'_g}{2(\lambda_g - \lambda'_g)}. \tag{3}$$

In making use of this phenomenon to locate a serious discontinuity in a waveguide transmission system, we must determine the guide wavelengths that will give us two successive maxima (or minima) of the standing wave at a fixed probe location, as the frequency is varied.

The guide wavelength is a function of frequency which can be evaluated from the identity

$$\lambda_g = \frac{c}{\sqrt{f^2 - \left(\frac{c}{2b}\right)^2}}, \tag{4}$$

in which

$c$ is free space velocity of propagation,
$f$ is operating frequency,
$b$ is wide inside dimension of the waveguide.

Thus, we are approaching a practical solution to the problem, since the frequencies required to give two successive maxima (or minima) of the standing wave are measurable. Once the frequencies are determined, they are converted to wavelengths in (4); the wavelengths, in turn, are used in (3) to give the distance from the probe to the discontinuity.

In practice, frequency is measured with a calibrated echo box or wave meter. Standing wave voltage is measured with a vacuum tube volt meter equipped with radio frequency probe. (Calibration of this instrument is not necessary since only relative readings of voltage are required to establish the maximum and minimum positions of the standing wave.) If possible, the detector of the vacuum tube voltmeter should be con-

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nected directly to the waveguide probe in order to minimize the effect of standing waves between the probe and the detector.

Enough readings of maximum and minimum voltage and their respective frequencies are taken to establish the cyclic recurrence of the standing wave. Computation of $L$ for several sets of data gives a check on the accuracy of measurement as well as a means of "averaging out" any discrepancies.

This technique is subject to several limitations, among them the following:

*Accuracy of frequency measurement*—For accurate results, the frequency must be measured exactly. This is particularly true on long waveguide runs ($L$) where the change in guide wavelength between standing wave maxima is very small. Since exact frequency measurement with field equipment is very difficult, this is a primary source of error.

*Complexity of the standing wave*—Minor reflections, present in all practical waveguide installations, tend to shift the maxima and minima of the main standing wave, thus leading to errors in the determination of the pertinent frequencies. A broad frequency spectrum of the oscillator, which normally attends a high standing wave ratio, will also complicate the standing wave, resulting in more difficult analysis. In severe cases of complex standing waves, it may be necessary to plot carefully a curve of standing wave voltage versus frequency to identify properly the maxima and minima resulting from the main discontinuity. In these cases, it is desirable to use a larger constant than one in (2), that is, to shift the standing wave several half-guide wavelengths, rather than one. Eq. (3) must then be modified accordingly.

Using field test equipment, in experiments on $L$-band radar, accuracies of a few inches at fifteen feet and a few feet at seventy feet have been achieved. With the use of laboratory instruments, greater aecuracy can be expected.

In general, the accuracy of the results depends upon how severe the main discontinuity is, and upon how well the rest of the system performs, in other words, upon how simple the standing wave is. The chief value of the technique is its ability to isolate the trouble to the antenna or to a specific section of the waveguide.

OAKLEY T. NEAU
1121 Liku St.
Lanikai, Hawaii

# Contributors

Helmut M. Altschuler (S'47–A'49–M'54) was born in Germany, in 1922. He received the B.E.E. degree in 1947 and the M.E.E. degree in 1949 from the Polytechnic Institute of Brooklyn, where he is continuing his graduate studies at the present time.

H. M. ALTSCHULER

In 1947–48 Mr. Altschuler held a Research Fellowship at the Microwave Research Institute of the Polytechnic Institute of Brooklyn, and since then has been employed there, now in the capacity of research associate. His work has been concerned chiefly with the development of impedance meters, microwave measurement techniques, and equivalent network representations.

Mr. Altschuler is a member of Sigma Xi and Eta Kappa Nu.

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Henry L. Bachman (S'51–A'52) was born in Brooklyn, N. Y., on April 29, 1930. He received the B.E.E. degree in 1951 and M.E.E. degree in 1954 from the Polytechnic Institute of Brooklyn.

H. L. BACHMAN

Mr. Bachman has been employed since 1951 as an engineer by the Wheeler Laboratories, where he has specialized in microwave antennas and transmission lines.

He is a member of Eta Kappa Nu and Tau Beta Pi, and an associate of Sigma Xi.

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Paul A. Crandell (A'52) was graduated from Boston College in 1951 with the degree Bachelor of Science in physics. He then joined the Raytheon Manufacturing Company where he spent 18 months in the Power Tube Division as a development engineer.

P. A. CRANDELL

In 1952 Mr. Crandell joined the Laboratory for Electronics in Boston, Mass., where he is now engaged in microwave development problems associated with "Ground Controlled Approach Equipment."

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Harvel N. Dawirs (S'49–A'52) was born in Colorado, on July 10, 1920. He received his B.S. in electrical engineering in 1942 from Colorado State College of Agriculture and Mechanic Arts, and his M.S. in mathematics from Ohio State University in 1952.

H. N. DAWIRS

From 1942 to 1946 Mr. Dawirs worked in the engineering departments of a number of Westinghouse plants. From 1946 until 1948 he worked in the research department of the Curtiss Wright Corporation, Columbus plant; and since 1948 he has been with the Antenna Laboratory of the Ohio State University Research Foundation, in Columbus, Ohio.

He is a member of Pi Mu Epsilon.

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Arthur E. Harrison (A'41–SM'45) was born on January 20, 1908, at San Luis Obispo, California. He received the B.S. degree in electrical engineering from the University of California in 1936.

A. E. HARRISON

From 1936 to 1939 he was a teaching fellow at the California Institute of Technology, receiving the M.S. degree in 1937, followed by the Ph.D. degree in 1940. From 1940 to 1946, Professor Harrison was employed by the Sperry Gyroscope Company in the Klystron Development Laboratory. He joined the staff of Princeton University in 1946 as assistant professor of electrical engineering. In September, 1948, Dr. Harrison joined the faculty of the University of Washington, where he is professor of electrical engineering.

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Wilbur L. Pritchard (A'45–M'48–SM'52) received the B.E.E. degree from the City College of the City of New York in 1943, and did further graduate study at M.I.T. between 1948 and 1951.

W. L. PRITCHARD

From 1943 to 1946 Mr. Pritchard was an engineer with the Philco Radio and Television Corporation, where he was engaged first in development of airborne radar systems and later of home radios and phonographs. From there he joined the Raytheon Manufacturing Company as senior engineer,