Signalite

200

NOISE TUBES AND MINIATURE NOISE SOURCES

for use in noise figure test equipment and for monitoring system receiver sensitivities

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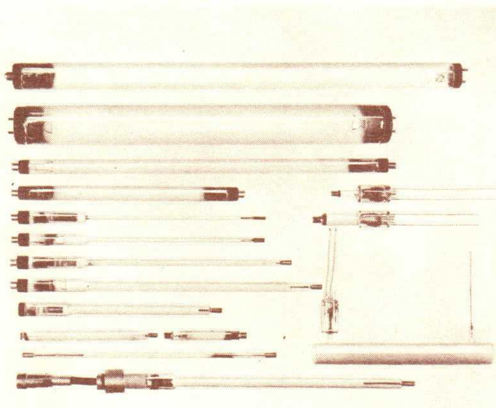
1.0 INTRODUCTION

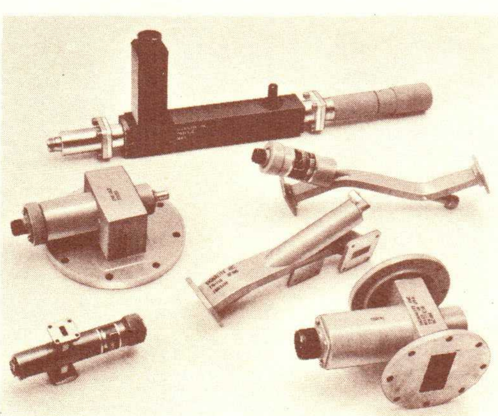
This "200" brochure is a summary of the history, fundamentals, characteristics and application information on gas discharge noise tubes and noise sources. The Signalite gas discharge source is the element in a microwave rf system which makes possible accurate measurements of the noise figure of the receiver or its components. The requirements of a device used for making such noise figure measurements include broad bandwidth inherent in the active element, stability, ease of operation and long life. When the gas discharge noise tube is mounted and terminated normally it presents a "white signal" of constant intensity over a bandwidth limited only by the system or mount. In general, the range of usefulness of these noise sources permits measurements of noise figures from about 2 to 30 db. Existing mountings provide a useful frequency range of approximately 100 MHz to 100 GHz.



2.0 DEFINITIONS

NOISE SOURCE TUBE OR NOISE TUBE

An electron tube filled with a rare gas, generally argon or neon, and operated in a positive column discharge mode at currents normally from 35 to 250 mA.



NOISE SOURCE OR NOISE GENERATOR

A noise tube mounted in an appropriate waveguide or coaxial mount. The noise tube and/or the noise source should meet the following general requirements:

a) When not operating, it should present a low insertion loss and VSWR to the system.

b) When operating, it should provide an adequate signal level.

c) Its output should be frequency independent, or at least known, over the prescribed bandwidth.

d) Its output should exhibit minimum spurious oscillations.

Lists of available noise tubes and noise sources are given in Appendices I, II, & III.

3.0 HISTORY

From W. W. Mumford's original work in 1949[1] to about 1952 [2]-[5] the predominant effort was on the understanding of the basic gas discharge phenomena and on some preliminary attempts to make absolute measurements based on the use of modified Dicke [6] radiometers. The accuracy of these measurements probably was of the order of .5 to 1 db. Since the agreement with existing theory [7] appeared to be within the error of measurement, no significant attempt was made to improve the accuracy. From about 1953 to 1962, additional measurements [8]-[14] were made on various tubes at differing frequencies and at varied tube currents. When all of these measurements were reduced to a common set of conditions, the net result and the existing theory all agreed within a spread of ±.5 db for argon S-band tubes. An average value of 15.2 db was used until about 1959 for all argon tubes, independent of tube diameter, gas pressure and coupling efficiency in the mounts. In 1959, values appropriate to the variety of tube diameters and gas pressures were published and have been included in all subsequent specifications.

The measurement setups presently at Signalite for making excess noise ratio, insertion loss and VSWR measurements were initiated in 1954.

In January of 1962 NBS Boulder [15] completed the first phase, X-band (WR-90), of a program of making accurate radiometer hot body load noise measurements. In 1965 a Ku-band (WR-62) service was announced [16], an S-band (WR-284) service is now available [17]. This program had been started in late 1955 and is continuing. [18–19 & 22]

These NBS measurements were generally one order of magnitude better in tolerances than any previous absolute measurement.

4.0 BASIC DISCUSSION

A gas discharge noise source is basically a fundamental device which provides a stable source of random white noise covering the entire rf and microwave spectrum.

4.1 NOISE POWER

The available noise power from a gas discharge noise tube is essentially kTeB power coupled to the guide from the positive column of the discharge, where k is Boltzmann's constant, Te is the effective electron temperature of the discharge, and B is the bandwidth. To some extent Te can be approximated by the method of von Engel and Steenbeck [7].

In microwave power measurements consideration is given to the noise temperature, Tn, which when multiplied by k gives the power per unit bandwidth of a noise source. Tn is determined by comparison of the noise source against a thermal load [18]. Appropriate corrections [20] must be made if the noise of the tube only is desired. Some earlier work tended to indicate that Tn for a normal gas discharge tube was nearly equal to Te [2]-[5], [8]-[13]. Such an approximation recently [21] has been shown to have limited usefulness, however, and the noise temperature of an individual noise tube or complete noise source should be measured rather than calculated for accurate results.

4.2 EXCESS NOISE RATIO

The important characteristic in microwave measurements is the ratio of the difference between operating and non-operating temperatures to the non-operating temperature (the latter assumed to be 290 K), namely the ratio $\frac{T_n - 290}{290}$, where T_n also is in

K. When expressed in db, this number is called the Excess Noise Ratio (Nr—1):

$$(Nr - 1) = 10 \log \frac{(T_n - 1)}{290}$$

At the usual pressures and operating currents (Nr —1) for an argon tube is approximately 15.5 db and for neon is approximately 18.0 db. The exact value for any noise source is influenced by the tube radius and pressure, and to some degree by current. [21]

The available noise from any given tube in mount combination depends as much on the characteristics of the mount and the method of coupling the tube into the mount as on any tube parameter. See Section 6.2 for the characteristics of the various types of mounting methods.

4.3 NOISE FIGURE & Y-FACTOR

The noise figure of any network is defined as the ratio of signal to noise at the input to the signal to noise at the output. [22-23]

$$F = [S_i/N_i] \ / \ [S_0/N_0] \qquad (1)$$

where F = noise figure (a ratio), S_i = signal at input, N_i = noise at input, S_0 = signal at output, and N_0 = noise at output.

If a gas discharge noise source is used as an input signal, then

$$S_i = BP_{ns}, \qquad (2)$$

where B is the bandwidth and P is the power delivered by the noise source per unit bandwidth. When the gas noise source is turned off the noise at the input is thermal noise, or

$$N_i = kT_0B \qquad (3)$$

where k = Boltzmann's constant and T_0 = the reference temperature, 290 K. The signal output of the device, S_0 can be written

$$S_0 = (S_0 + N_0) - N_0 \qquad (4)$$

In this case $(S_0 + N_0)$ is the noise-tube-on condition and N_0 is the noise-tube-off condition. Therefore,

$$S_0 = P_{on} - P_{off}. \qquad (5)$$

Equations (2) through (5) may be substituted in (1):

$$F = \left[\frac{BP_{ns}}{kT_0B}\right]\left[\frac{P_{off}}{P_{on}-P_{off}}\right] \qquad (6)$$

From Section 4.2 and from Equation (6) above it can be seen that the first term of Equation (6) is the excess noise ratio of the noise source, therefore,

$$\frac{BP_{ns}}{kT_0B} = \frac{T_n}{T_0} - 1 = \frac{T_n - 290}{290} \qquad (7)$$

The "Y-factor" is defined as the ratio between two power output measurements, the first with the noise source on and the second with the noise source off. The first measurement of this ratio includes the room temperature noise as well as the excess noise. Therefore the second term of Equation (6) above can be expressed in terms of the Y factor:

$$\frac{P_{off}}{P_{on}-P_{off}} = \frac{1}{\frac{P_{on}}{P_{off}} - 1} = \frac{1}{Y-1} \qquad (8)$$

Combining Equations (6), (7) and (8), we then obtain the noise figure of the system being measured as follows:

$$F = \left[\frac{T_n - 290}{290}\right]\left[\frac{1}{Y-1}\right] \qquad (9)$$

, or

$$(F)\ db = 10 \log \left[\frac{T_n - 290}{290}\right] - 10 \log (Y\text{-}1) \qquad (9a)$$

This last equation says that the noise figure of the system being measured is simply the excess noise ratio of the noise source in db minus the value of (Y —1), in db, as determined from a (Y) db to (Y —1) db conversion. We now have the noise figure of the receiver defined in terms of all known quantities.

Note that effects of overall bandwidth are not included in the above calculations although image responses in improperly filtered systems could be of significant value. Also the temperature of the termination in the "off" condition may be other than 290 K. For extremely accurate measurements (better than ± .01 db), a correction is required to Equation (9a) [24].

5.0 OPERATIONAL FACTORS

5.1 TYPES OF OPERATION

5.1.1 DC with filamentary cathode tubes: The DC supply of Figure 1 is fed to the tube through an inductance, L, and current limiting resistances, R_1 and R_2. Upon closing the starting switch, SW, current flows through the inductance, resistance R_2 and the tube cathode all in series. When the switch is opened, the collapse of the magnetic field in L provides a high voltage spike which ionizes the gas in the tube and establishes the discharge from anode to cathode. The current is then limited by R_1 to the rated value. SW must be capable of fast break operation and of withstanding the high peak voltage developed.

The circuit of Figure 2 provides an electronic method of providing the starting spike and is applicable where switch life is a problem. The pentode or beam tube acts like the switch of Figure 1, interrupting the current flow in L when the cut-off bias switch is closed. The resultant voltage spike developed is impressed across the noise source. The current is limited by R_3 to rated value. Capacitor C flattens the pulse peak and assists in initiating the discharge. C must not be large enough to lower the voltage spike below the firing voltage of the tube and must be of a high voltage rating. Current through the beam tube is adjusted by R_4 to provide rated current.

5.1.2 Pulse operation with hollow cathode tubes which operate for hundred of millions of starts in the circuit of Figure 3:

This circuit includes provision for driving the grid of the switch tube with pulses, thus pulsing the noise output. For high repetition rates and for control of pulse shape, the addition of the turn-off tube, V_2, (Figure 3 vs Figure 2), is necessary to insure extinguishing of the noise tube current.

5.1.3 DC or pulse operation with tubes which have indirectly heated cathodes: this type of tube may be used with circuit of Figure 1 modified to include a continuous filament voltage. Also circuits Figure 2 and 3 may be utilized again with the same modification.

5.1.4 Figure 4 is a typical DC circuit in which no starting spike is provided but in which the high voltage is provided by a separate high voltage low current supply and in which the operating current condition is provided from the main or lower voltage supply. This circuit is useful for either filamentary or indirectly heated cathode tubes.

5.1.5 Starting by repetitive pulsing to provide a lower starting voltage for filamentary and hollow cathode tubes is illustrated in Figure 5. A train of pulses at a typical repetition rate of 30 to 50 pps is maintained until the tube operates. When tube conduction begins the start button is released and normal dc operation continues.

5.1.6 Grounded anode operation: for all previous methods of operation and cathode types the polarity can be reversed when desirable so the anode may be operated grounded. In the circuit of Figure 1, under reversed polarity conditions, choke L would be moved to the negative leg as would limiting resistor R_1. Similar modifications would be made to circuits of Figures 2, 3 and 4.

The advantage of operating with a grounded anode is that the anode potential then is distributed down the length of the tube by the metal tube holder part of the mount and the starting voltage is decreased from 10% to as much as 50% depending upon the particular tube type and mounting arrangement.

5.1.7 AC with filamentary cathodes: When operation directly from an AC source is desired and AC modulation of the noise is not objectionable, the circuit of Figure 6 is suitable. Transformer T must provide a voltage high enough to strike the discharge. L may be included in the transformer as leakage reactance but should be of a size to limit the average tube current to the specified value. SW can be eliminated if the secondary voltage of T is made high enough to provide a cold start without filament preheat.

Operation of a single ended tube in this circuit will result in excessive anode heating with probable failure of anode seal.

5.2 OPERATIONAL PARAMETERS

5.2.1 In the circuits of Figures 1 and 2, tubes with filamentary cathodes generally require from 700 to 2500 V starting spikes, operate at currents from 50 to 250 mAdc and exhibit operating tube drops of the order of 40 to 150 Vdc. Their life under conditions of essentially continuous operation, with only occasional starts, is generally in excess of 8,000 hours and may be as high as 20,000 hours. Their life under pulse conditions is short.

5.2.2 In the circuit of Figure 3, tubes with hollow cathodes designed principally for pulse operation usually require starting spikes of 700 to 3000 V, operate at peak currents from 75 to 175 ma, and have tube drops from 100 to 250 V. Under pulse conditions with duty cycles up to 50%, their life is typically 2000-5000 hours.

In general, under intermittent DC conditions, they have adequate life of at least 500-1000 hours.

5.2.3 In the circuits of Figures 1-4 tubes with indirectly heated cathodes can be operated with very long life under either dc or pulse conditions. This particular cathode assembly utilizes an electrostatic shield around the cathode resulting in minimum ion bombardment of the active cathode surface area. The coated area is such that the maximum current density for any tube of this type is ultra-conservative. These tubes generally require starting spikes of the order of 500-2000 volts, operate typically from 35-200 mAdc or 50-150 ma pulse, and have tube drops from 40-200 volts. Under intermittent dc conditions, life is generally in excess of 10,000 hours and may be as high as 50,000 hours. Under pulse conditions, at duty cycles up to 50%, their life is typically 3000-7000 hours.

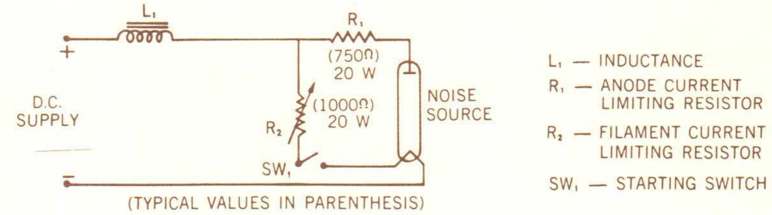


Figure 1 Typical starting circuit for DC-operated tubes

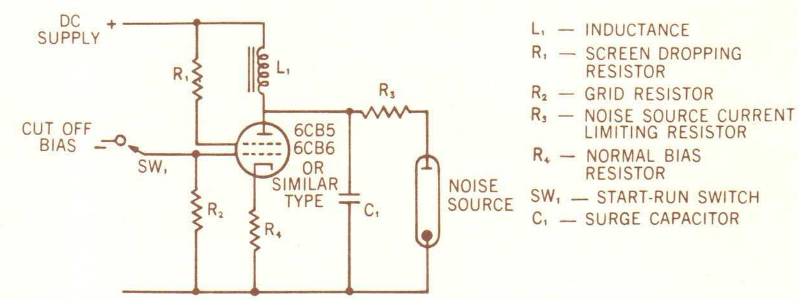


Figure 2 Alternate starting circuit capable of being pulsed

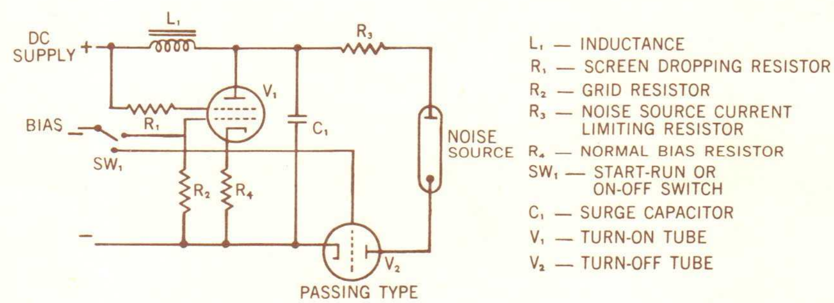


Figure 3 Typical driving circuit for pulse-operated tubes

5.2.4 As mentioned in Section 5.1.6 the grounded anode operation method of Figure 5 reduces all starting voltage requirements.

5.2.5 AC tubes operated in the circuit of Figure 6 under 60 to 400 cps sine wave conditions generally require starting voltages of the order of 1000 to 2500 Vac, operate at currents from 100 to 250 mAac and exhibit tube drops of the order of 40 to 150 Vac. Typical life under 60 cps conditions is 100-1000 hours, depending on circuit parameters.

5.3 IONIZATION TIME

Because of the presence of the rare gas, there is a finite time required for the discharge to become stable in any gas discharge noise tube. In argon filled tubes, the discharge will normally become stable in from 50 to 150 us after the completion of the starting spike. For neon these times are of the order of 80 to 300 us.

These times may be modified drastically by the circuit however. If there is appreciable ringing in the circuit, or if the supply voltage is only slightly greater than the tube operating voltage at the rated current, the time for a tube to establish a stable discharge may be much longer. In general, by proper circuit design, these indicated times can be attained for any of the types of operation mentioned above.

This ionization time is an important factor in making pulsed noise figure measurements (See Section 6.4).

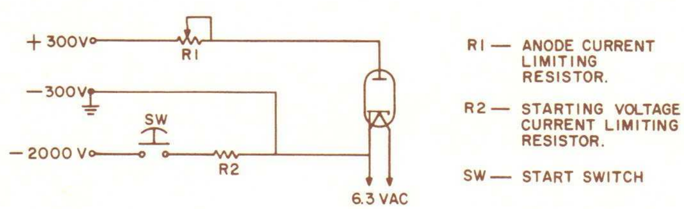


Figure 4 Typical DC High Voltage Starting Circuit

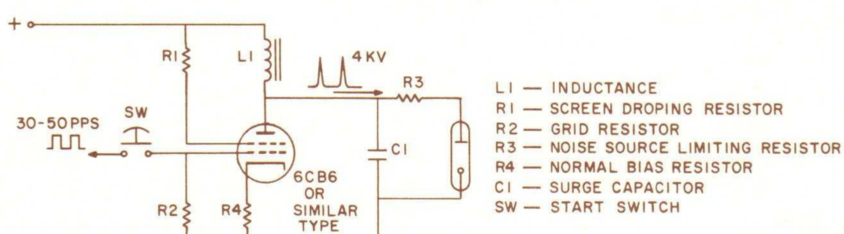


Figure 5 Typical Repetitive Pulse Starting Circuit For DC Operation

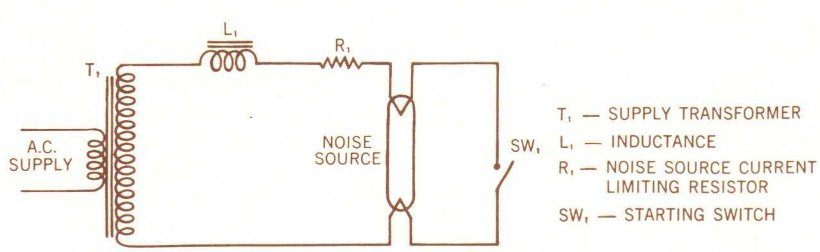


Figure 6 Typical AC-operation circuit

5.4 DEIONIZATION TIME

Again because of the presence of the rare gases, these tubes have finite deionization times. In argon at 200 mA plate current and at 20 mm pressure, the deionization time are of the order of 70 to 300 μs, depending on tube diameter. In neon at the same current and pressure, deionization times are normally from 150 to 500μs. These deionization times can be improved by the application of a slight negative voltage when the tube is being turned off, in a pulse application for example. The deionization times generally increase with current.

6.0 MICROWAVE CHARACTERISTICS

6.1 GENERAL CONSIDERATIONS

The level of the excess noise ratio which can be attained from any noise source is determined by the available excess noise ratio from the noise source itself and by the coupling of the noise source in the mount. The available excess noise ratio from the noise source is determined principally by the type of gas and the pressure and, to some small extent, by the tube current. The coupling in the mount is determined by the insertion angle of the tube through the mount, by the type of gas fill, and by the ratio of the tube diameter to the maximum guide dimension [4]. The coupling also is affected by the gas pressure and the tube current. The user has control in general only over the tube current. The mounting is so important that the success with which any combination of noise source, mount and termination meets the requirements at the end of Section 1.0 depends as much on the mounting method as on any other single feature. Some typical waveguide and coaxial mounts are shown in Appendix IV.

6.2 MOUNTING METHODS

The most common mounting methods and their relative advantages and disadvantages include:

a) 0° to 30° E-plane Insertion; Advantages: extremely broadband (within the tolerances of the excess noise ratio specified for tube-and-mount this style of mounting yields a frequency independent noise source), very low VSWR, very low non-operating insertion loss, high operating insertion loss (therefore, very little reduction in the available excess noise ratio [20] from the noise source itself); Disadvantages: relatively large size, high voltage starting spike, and relatively high tube drop.

b) 90° E-plane Insertion, Transmission Type; Advantages: fair VSWR, very small size, low voltage starting spike, low tube drop and low non-operating insertion loss; Disadvantages: low operating insertion loss (therefore, appreciable reduction in the available excess noise ratio) and relatively narrow bandwidth (approximately 10 to 20%).

c) 90° E-plane Insertion, Shorted Type; Advantages: small size, low voltage starting spike, low tube drop and high operating insertion loss (therefore negligible reduction in the available excess noise ratio); Disadvantages: poor VSWR, very narrow bandwidth (the order of 5 to 10%).

d) 90° H-plane Insertion, Transmision Type; Advantages: low non-operating insertion loss, fairly small size, good non-operating VSWR, moderate voltage starting spike and tube drop; Disadvantages: poor operating VSWR, low operating insertion loss (with resultant reduction in available excess noise ratio), and very narrow bandwidth.

e) Coaxial, Helix Coupled; Advantages: permits use of the noise tubes originally designed for waveguide bands down into the UHF region, relatively broadband, good operating insertion loss, relatively good operating VSWR, fair non-operating insertion loss and VSWR in the prescribed bands; Disadvantages: relatively large size, high voltage starting spike and relatively high tube drop.

f) Coaxial, Direct Coupled; the advantages and disadvantages of this type are the same as for the helix coupling except that the direct coupling approach, with the toroidal cross section tube family used in this approach, presents much lower non-operating insertion loss than the helix coupling approach. Since these types are almost all transmission types used directly in front of the receiver the low non-operating insertion loss serves two advantages. First there is less attenuation of the incoming signal during system operation and secondly there is no correction necessary to the available excess noise ratio as a result of significant non-operating loss. [20]

6.3 COMPARATIVE NOISE MEASUREMENTS

Comparative noise measurements are made by Signalite in a test system shown schematically in Figure 7. Since these measurements depend ultimately on the stability of the gain set, and this stability can be checked by visual observation of the output meter over a period of time long compared with the measurement time, the tolerances to which Signalite excess noise ratio specifications are written are at least five times wider than the system capability.

6.4 SYSTEM NOISE FIGURE MEASUREMENTS

Noise figure has been summarized completely by Mumford & Scheibe [23], and reviewed in Section 4.3. Our discussion here will be concerned only with precautions to be taken with pulsed noise sources in making noise figure measurements.

The voltage and current curves of Figure 8 show typical pulsed tube performance as a function of time. The voltage across the tube rises to a very high value at which point the tube breaks down. The voltage then falls to almost zero and eventually

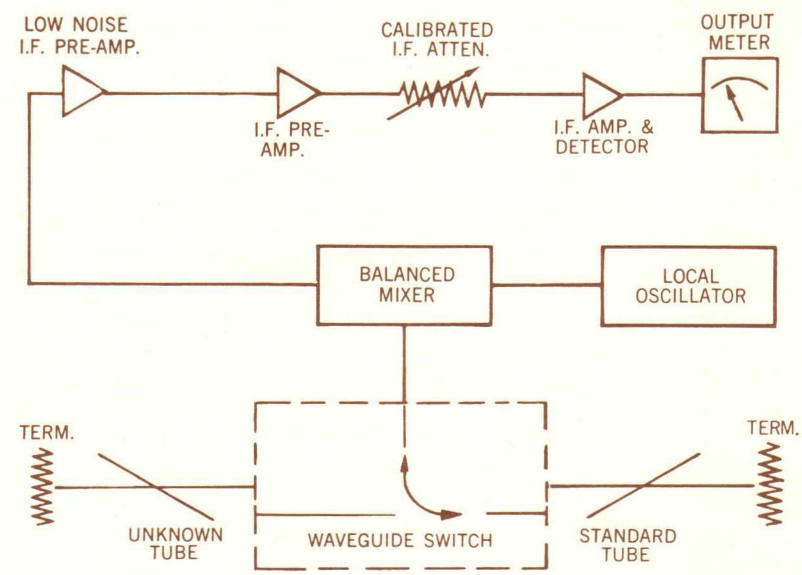


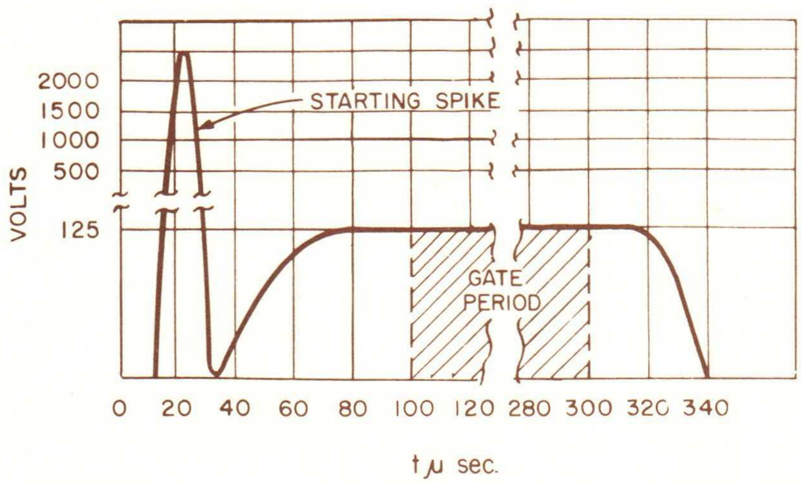
Figure 7 Schematic diagram of set-up for measuring excess noise ratio.

stabilizes at the tube drop after several tens of microseconds (See Section 5.3). The current usually stabilizes faster than the tube drop.

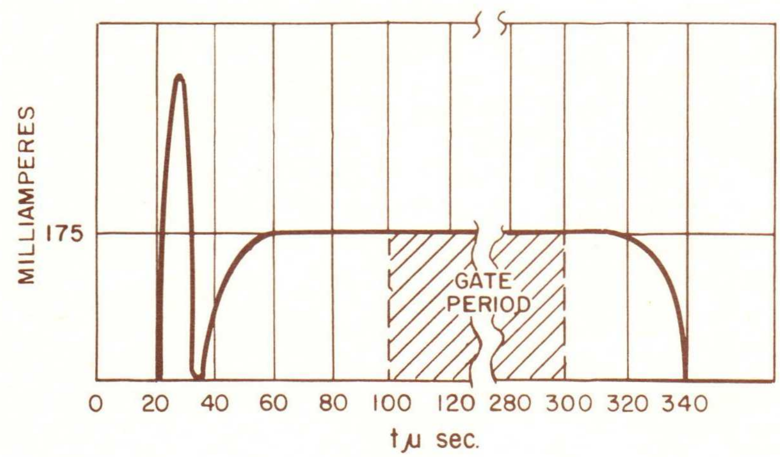
If the "on" time of the receiver gating period starts too soon then there will be a fraction of the total gate period during which the noise power will not have the rated noise output of the tube at the given current because the tube drop, and consequently the field in the positive column, will not have been stabilized. Whenever possible, therefore, the total gating period should be long, ideally a few hundred microseconds and the initiation of the gating period should be delayed as long as possible following the high voltage starting spike.

Another consideration is that the gating period during which the receiver looks at the cold, non-operating, noise source should be as long as possible after the main transmitter pulse (for a unit being used in the transmitter arm through a directional coupler) so that the lapsed time definitely as long compared with the deionization time of the tube (Section 5.4)

Finally use of a noise source for which there is the smallest possible difference between operating and non-operating match is important when the noise source is the element being viewed as the cold reference for the system.



8a: Voltage vs: Time



8b: Current vs: Time

Figure 8 Typical Voltage and Current Curves for TD-72 pulse type tube (Argon).

6.5 VARIATIONS WITH TUBE CURRENT

Since a change in current causes a slight change in tube drop, and thereby a slight change in the field in the positive column, there is a small correction to the excess noise ratio of a tube as a result of actual change in effective electron temperature. Further, there is an additional small change to the available excess noise ratio from tube-in-mount as a result of the changing insertion loss caused by the change in current.

6.5.1 Noise vs current: For most noise tubes there is a change in $(N_r - 1)$ with current of —.003 to —.005 db/mA. The curves of Figures 9 to 13 present actual data of the change in excess noise ratio as a function of tube current for representative types, both argon and neon. The data are presented for current values both higher and lower than the respective rated tube currents for the purpose of showing the user the detailed variation around the rated currents. The presentation of the data at higher than rated currents does not imply recommended operation at these currents. Since these noise tubes are extremely reproducible [13] the user may consider these curves as true indications of the performance of any particular tube.

6.5.2 Tube drop vs current: The variation in tube drop with current for representative types is presented in Figures 14 to 18.

6.5.3 Insertion loss vs current: Nominal values of operating and non-operating insertion loss for argon noise tubes in specific waveguide mounts are given in Table 1. The tube to tube variation for operating insertion loss values of less than 20 db is ± .2 — .6 db, for values of from 20 — 30 db is ± .4 — 1.0 db, and for values of greater than 30 db is ± 1 — 3 db.

7.0 GENERAL OPERATING NOTES

7.1 POLARITY

Since all noise sources are polarized devices, except those specifically designated for ac operation, they should never be operated in reverse. Under conditions of reverse operation the life will be extremely short with failure due to anode seal breakage as the result of excess heating.

7.2 AMBIENT TEMPERATURES

All rare gas filled noise tubes can be operated over a temperature range of −55° to + 125°C. Some noise sources cannot be operated over this range because built-in shorting plates or terminations may present temperature dependent characteristics.

7.3 VIBRATION AND SHOCK

In general noise sources are satisfactory under vibration and shock, with the smaller units being the best. Since there exists such a large variety of sizes and shapes, the user should determine the vibration and shock ratings of the individual unit he is planning to use.

7.4 LIFE

The life of a noise tube depends principally upon the type of cathode, the mode of operation (CW or pulse) and the gas pressure. Under CW conditions the indirectly heated cathodes exhibit extremely long life because their surface area is such that the current density is ultra-conservative. Similarly the filamentary cathodes are conservatively rated with respect to current density.

Under pulse conditions again the indirectly heated cathodes have very long life this time for two reasons. The first is the lower starting spike required in a tube with this style cathode and resultant drastically reduced ion bombardment of the cathode during the starting spike. The second is the conservative design with respect to the current density. The hollow cathodes exhibit good life under pulse conditions because the design of these cathodes causes the cathode coating which is sputtered during the starting spike to be re-deposited on another part of the cathode and thus not be lost. Filamentary cathodes typically last only a few hundred thousand discharges of normal starting spikes. In a typical pulsed noise figure set-up operating at the rate of 500 pps for example, one hundred thousand discharges are achieved in less than an hour. Therefore this type cathode definitely is not recommended for pulse operation.

The principle mode of failure of gas discharge noise tubes is loss of cathode coating with consequent increase in tube drop and starting voltage. The second failure mode is reduction in gas pressure with consequent change in tube drop and excess noise ratio.

Fortunately the change in tube drop and starting voltage occur long before there is any significant change in gas pressure so a general set of criteria for end of life include the following:

1) In the case of filamentary or indirectly heated cathodes if the starting voltage increases by 20% or if the tube drop increases by 10%, end of life may be considered as having been reached. Within this period of time negligible change in excess noise ratio will have taken place. For most argon tubes with indirectly heated cathodes, operated DC, this time is in excess of 10,000 hours and may be as long as 50,000 hours and when operated pulse, 3000-7000 hours. For most argon tubes with filamentary cathodes, operated DC, this time is in excess of 8,000 hours and may be as long as 20,000 hours.

   For neon tubes with either type of cathodes the above times generally are decreased by a factor of 2.

2) For argon tubes with hollow cathodes, operated pulse, the life is typically 2000-5000 hours; for neon hollow cathode tubes typically 1000-2000 hours.

3) AC tubes with a filamentary cathode at each end operating under 60 or 400 Hz sine wave conditions usually are rated for 100 hours of operation but typically have life times of the order of 500-1000 hours with as little as .05 to .1 db change in excess noise ratio.

7.5 FACTORS AFFECTING TYPE OF SOURCE TO BE USED

The two major use areas for gas discharge noise sources are in noise figure test equipment and in microwave system receiver sensitivity monitoring. This subject is reviewed under Section 9, APPLICATIONS, but a discussion of the requirements of noise sources used in test equipment vs those for system operation is pertinent for adequate understanding of operating these devices.

7.5.1 Bandwidth and size: In test equipment broad bandwidth usually is necessary. Further, size, current drain and starting voltages usually are not limitations, therefore in almost all test equipment the 10° E-plane mounting (Section 6.2a) or the coaxial mounting (Sections 6.2e and f) generally is used. In system operation, however, bandwidths of 5 to 15%, minimum size and weight, lowest possible voltage and current drain and maximum resistance to all type of external environments are typical requirements. Therefore, the 90° E-plane, either transmission or shorted, and the direct coupled coax types of mounting are preferred depending upon the detailed requirements. In special cases 90° E-plane units can be made as small as three to four flange thicknesses in guide length and no larger in outside dimensions than a basic flange.

7.5.2 Transmission vs shorted type (location in system): The choice of transmission or shorted type of mount depends upon location in the system. This location generally is determined by the amount of excess noise necessary to perform the monitoring function, the position of the actual components whose noise figure is to be monitored and the amount of rf leakage back to the noise source. If the noise figure of the components to be monitored is high, 10-30 db, for example, then the use of a system with a directional coupler might be unacceptable because of the low resultant noise available from the directional coupler and the subsequent insensitivity of the readout with resultant loss in sensitivity in the entire monitoring system. Conversely use of a transmission type directly in front of a receiver is determined by the acceptability of the level of cold insertion loss of the noise source.

The position of the noise source in the system also will be determined by the actual components being measured. A unit mounted on a directional coupler in the transmitter arm in a radar set would then be monitoring the effective noise figure not only of the receiver but of all switching elements between the receiver and the transmitter in addition. A transmission type unit directly in front of the receiver would be monitoring the noise figure of the mixer and subsequent pre-amps, amplifiers and read-out of which the dominant factors would be the mixer and first pre-amp.

7.5.3 RF leakage: An important criterion could be the amount of rf leakage to the tube. A discharge can be created in most gas discharge noise tubes by coupling of peak powers of the order of 1-10 kw into the tube. Therefore to use a noise source on a 12 db directional coupler in the transmitter arm of a 100 kw peak system, for example, might not prove satisfactory as the unit might be partially ionized during the supposed "off" period by the coupling of transmitter power into the noise tube. In such types of applications the noise source must be used in the receiver arm.

7.6 ANODE GROUNDED

Under Section 5.1.6 mention was made of the resultant lower starting voltages when noise sources are operated with the anode grounded. This lower starting voltage results from distribution of the ground plane along the length of the tube so that the actual field is from cathode (high negative voltage) to a positive ground which is only a short distance away. This approach is particularly useful in system applications where a major criterion for the system is minimum useable voltage throughout.

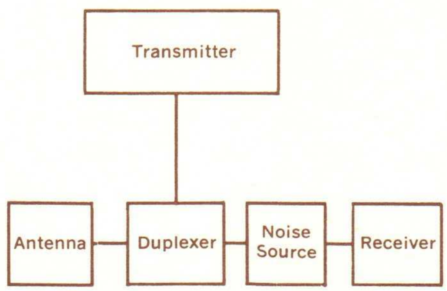
9.0 APPLICATIONS

9.1 The basic use of noise sources is the DETERMINATION OF THE NOISE FIGURE of a component or system. This determination stems from the relation: (F) = (Nr −1) − (Y −1), where (F) is the system noise figure, (Nr −1) is the excess noise ratio of the noise generator, (Y) is the output meter reading, $Y = \text{antilog}\,\frac{(Y)}{10}$, and the parenthetical terms in the relation are in db. See Section 4.3 for complete discussion.

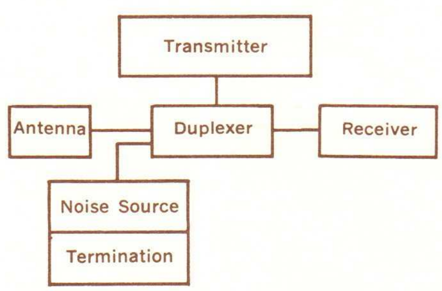
9.2 Noise sources are the basic component of NOISE FIGURE TEST SETS. Commercial models exist which are complete with the noise source and mount, the driver supply (either modulated or DC), IF, video and output, so that all this is necessary to obtain noise figure to connect the device in question to the test set and read the answer.

9.3 Noise sources frequently are used as BUILT-IN RECEIVER MONITORS directly in a radar system.

9.3.1 Directly in the RECEIVER ARM between the receiver and duplexer in which case a transmission mount is used.



9.3.2 In the ANTENNA ARM via a switch or directional coupler, in which case the noise source is a terminated or shorted one.



9.3.3 In general, because the discharge can be initiated by sufficiently high levels of RF power, the method of 9.3.1 is used for high power systems, and the method of 9.3.2 is used for low or medium power systems. (See Section 7.5)

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TABLE 1: COLD AND HOT INSERTION LOSS FOR ARGON NOISE SOURCES

Band	Type	Mount and Meas't. Freq. (GHz)	Typical Insertion Loss (db)					
			Ib = 0	125	150	175	200	250mAdc
S	TD-12 -38	WR-284, 10°E; 3.3	.12	12.3	13.5	14.0	14.5	15.1
C	TD-10 -39	WR-187, 10°E; 5.5	.11	14.8	16.9	17.3	18.8	20.8
J	TD-10 -39	WR-137, 10°E; 7.0	.16	20.4	22.8	23.8	25.4	28.1
X	TD-40	WR-90, 10°E; 9.0	.18	18.2	20.8	22.8	24.4	26.0
X	TD-11 -72	WR-90, 10°E; 9.0	.06	23.2	25.7	27.6	29.5	32.2
Ku	TD-18 -41	WR-62, 10°E; 16.0	.07	32.0	37.9	44.1	51.0	54.5
K	TD-13 -42	WR-42, 10°E; 24.0	.10	25.8	31.7	37.8	44.0	57.5

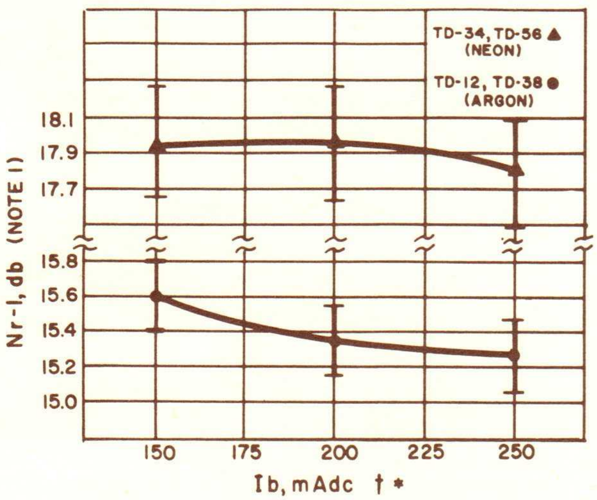

Figure 9 Noise vs. tube current for S-band noise sources

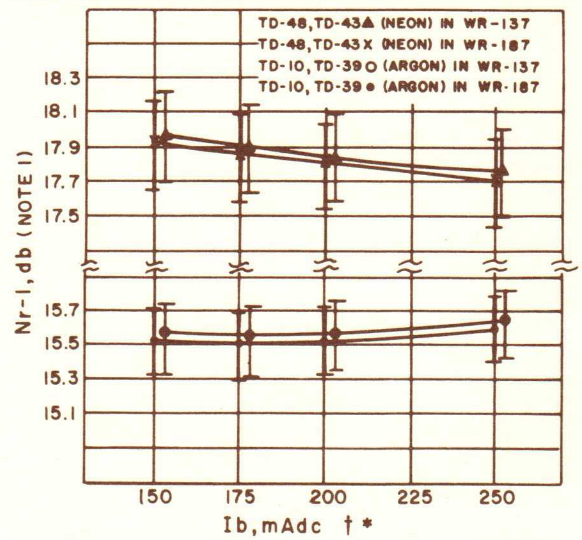

Figure 10 Noise vs. tube current for C- and J-band noise sources

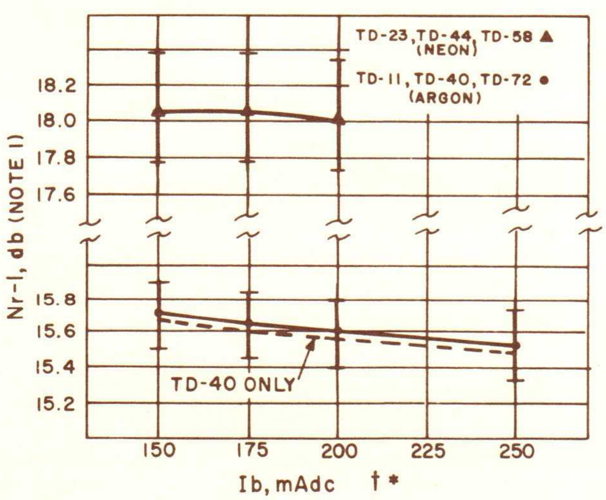

Figure 11 Noise vs. tube current for X-band noise sources

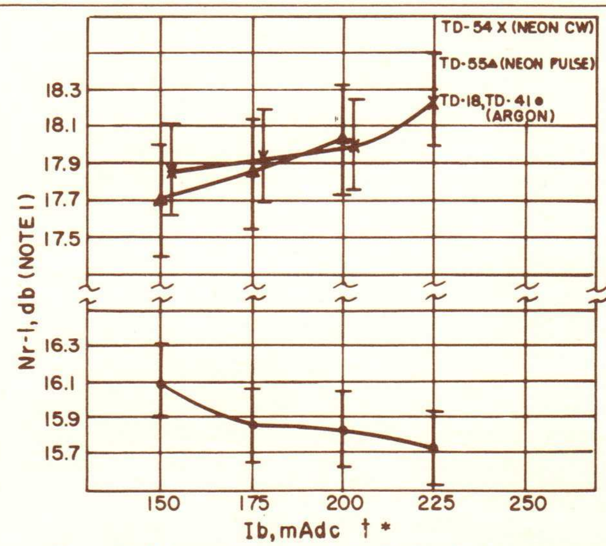

Figure 12 Noise vs. tube current for Ku-band noise sources

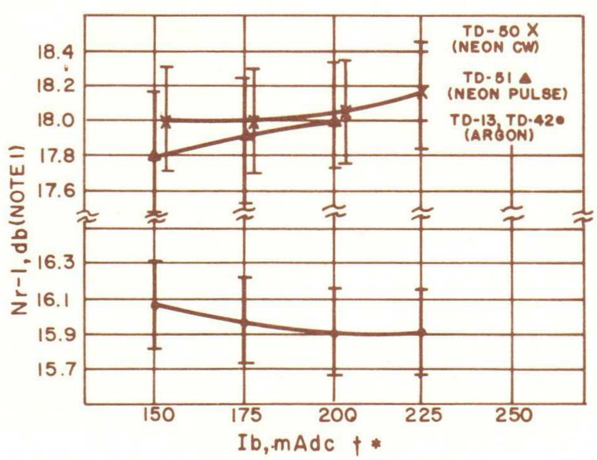

Figure 13 Noise vs. tube current for K-band noise sources

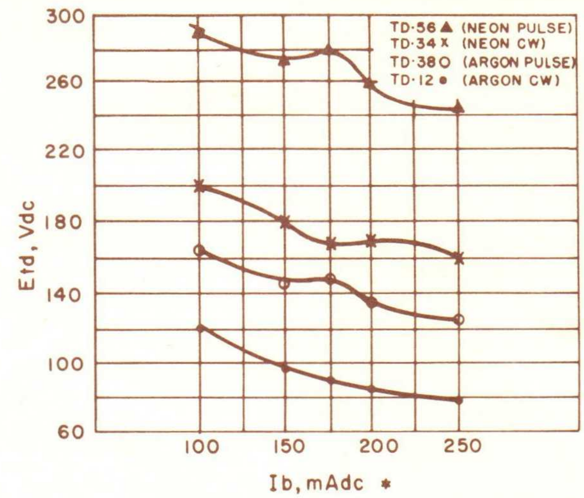

Figure 14 Tube drop vs. tube current for S-band noise sources

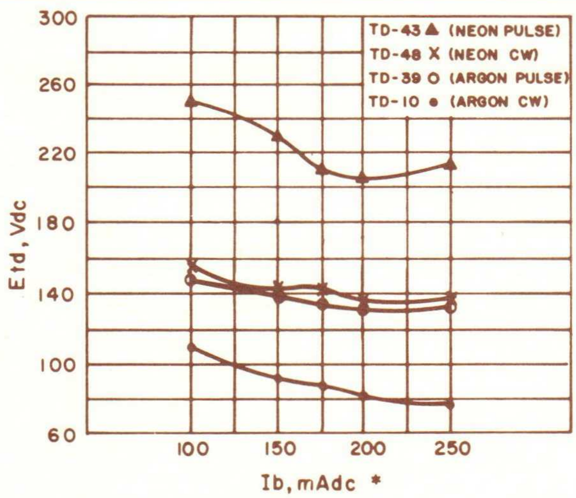

Figure 15 Tube drop vs. tube current C- and J-band for noise sources

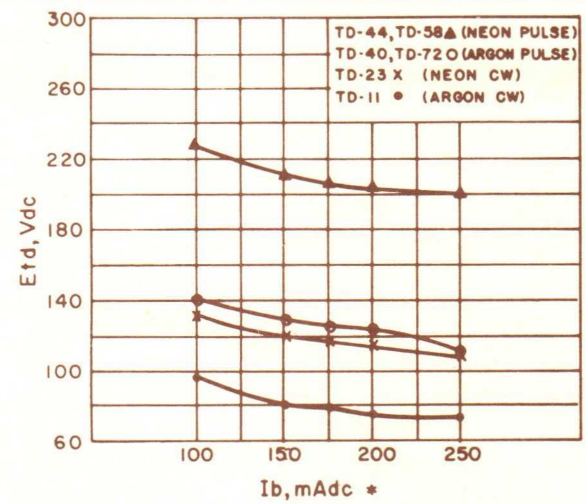

Figure 16 Tube drop vs. tube current for X-band noise sources

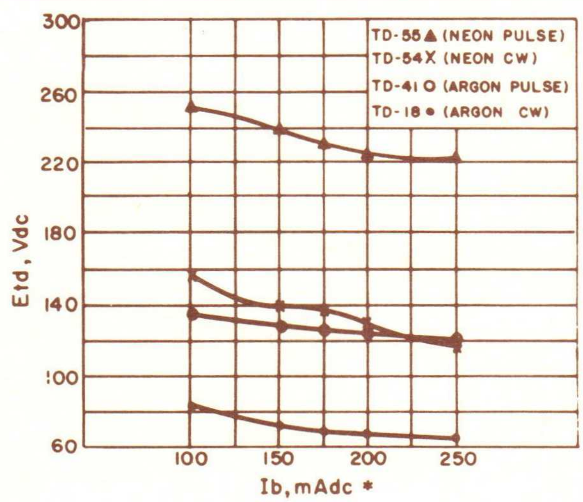

Figure 17 Tube drop vs. tube current for Ku-band noise sources

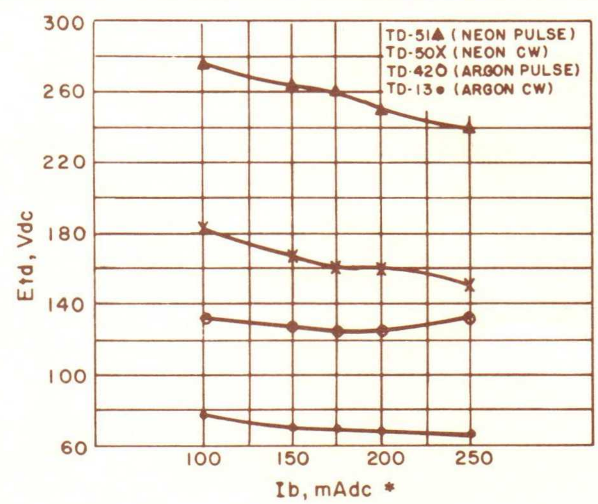

Figure 18 Tube drop vs. tube current for K-band noise sources

NOTES:

† Center values are appropriate for both the CW and pulse types. Tolerances are shown for CW types only. For tolerances on pulse types, see individual tube spec sheets.

* Presentation of data at currents higher than the rated currents does not imply recommended use at these currents but is provided only for customer information.

All data are tube-in-mount data.

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APPENDIX I

SIGNALITE-GAS NOISE TUBES WITH FILAMENTARY OR HOLLOW CATHODE

Freq. Range, GHz	Band	Wave-guide	Signalite/ EIA Type Numbers	Outline (Note 1)	Mount Type	Recm'd. Mode of Operation (Note 2)	Maximum Starting Voltage Spike, KV	Anode Current, mAdc (Note 3)	Tube Drop, Vdc (Note 3)	Tube-in-Mount Excess Noise Ratio, db (Note 3, 4)
1.12 to 1.70	L	WR-650	TD-21/6881	1	90°H	D.C.	4.0	250	65	15.2**
			TD-62/7992	1	90°H	D.C.	4.5	250	(145)	18.0**
			TD-33/7147	1a	90°H	A.C., D.C.	4.0	250	75	15.2**
			TD-29/7101	1a	90°H	A.C., D.C.	4.5	250	130	18.0**
			TD-49	1	90°H	PULSE*	4.0	200	125	15.2**
			TD-75	1	90°H	PULSE*	4.5	200	235	18.0**
			TD-91	S	10°E	D.C.	7.0	250	230	15.2**
2.60 to 3.95	S	WR-284	TD-12/6358	2	10°E	D.C.	2.7	250	80	15.20
			TD-34/7148	2	10°E	D.C.	2.7	250	165	17.80
			TD-31	2a	10°E	A.C., D.C.	2.7	250	85	15.20
			TD-32	2a	10°E	A.C., D.C.	2.7	250	170	17.80
			TD-22/6782	S	90°H	A.C., D.C.	2.5	250	45	8.85
			TD-38/8151	2	10°E	PULSE*	3.3	200	145	15.35
			TD-56/8286	2	10°E	PULSE*	3.5	200	265	17.90
			TD-82	S	90°E	D.C.	0.9	75	55	18.50
3.30 to 4.90	S	WR-229	TD-24	S	10°E	A.C., D.C.	2.5	250	65	15.30
			TD-30	S	10°E	A.C., D.C.	2.5	250	110	17.80
3.95 to 5.85	C(G)	WR-187	TD-10/6356	3	10°E	D.C.	3.1	250	75	15.60
			TD-48/7989	3	10°E	D.C.	2.7	250	135	17.70
			TD-39/7999	3	10°E	PULSE*	3.5	175	140	15.50
			TD-43/8287	3	10°E	PULSE*	3.5	175	210	17.85
			TD-83	S	90°E	D.C.	0.9	100	55	18.90
5.85 to 8.20	X(J)	WR-137	TD-10/6356	3	10°E	D.C.	3.1	250	75	15.65
			TD-48/7989	3	10°E	D.C.	3.5	250	135	17.75
			TD-39/7999	3	10°E	PULSE*	3.5	175	140	15.55
			TD-43/8287	3	10°E	PULSE*	3.5	175	210	17.90
			TD-67/8288	3	15°E	PULSE*	3.5	150	225	18.00
8.20 to 12.40	X	WR-90	TD-11/6357	4	10°E	D.C.	2.7	200	75	15.50
			TD-23/6882	4	10°E	D.C.	2.7	200	115	18.00
			TD-40/8152	4	10°E	PULSE*	3.3	175	125	15.52
			TD-72/8059	4	10°E	PULSE*	3.3	175	128	15.56
			TD-44/7988	4	10°E	PULSE*	3.5	175	205	17.90
			TD-58/8293	4	10°E	PULSE*	3.5	175	208	18.00
			TD-73	S	90°E	D.C.	0.9	100	54	14.50
			TD-114	S	10°E	D.C.	2.7	200	90	15.30
			TD-93B	S	90°E	PULSE*	0.9	100	165	14.50
12.40 to 18.00	KU	WR-62	TD-18/6684	5	10°E	D.C.	2.7	200	67	15.80
			TD-54/7991	5	10°E	D.C.	2.7	200	130	18.00
			TD-46	S	20°E	A.C., D.C.	(1.2)	100	35	15.2**
			TD-41/8030	5	10°E	PULSE*	3.3	175	125	15.85
			TD-55/8290	5	10°E	PULSE*	3.5	175	230	17.85
			TD-92	5	10°E	PULSE*	3.3	175	125	15.65
18.00 to 26.50	K	WR-42	TD-13/6359	6	10°E	D.C.	2.7	200	68	15.90
			TD-50/7990	6	10°E	D.C.	2.7	200	157	18.05
			TD-42/8031	6	10°E	PULSE*	3.3	175	125	16.00
			TD-51/8291	6	10°E	PULSE*	3.5	175	260	17.90
			TD-81	S	10°E	PULSE*	3.3	150	130	16.15
26.50 to 40.00	KA	WR-28	TD-76/7993	7	10°E	D.C.	2.7	125	130	(16.25)
			TD-77/8292	7a	10°E	PULSE*	3.0	100	175	(16.25)
33.00 to 50.00	Q	WR-22	XD-972	8	10°E	D.C.	3.0	(30)	(200)	(16.0)
50.00 to 75.00	V	WR-15	XD-972	8	10°E	D.C.	3.0	(30)	(200)	(16.0)
60.00 to 90.00	E	WR-12	XD-972	8	10°E	D.C.	3.0	(30)	(200)	(16.0)

Note 1: Outlines are shown on pp. 16 and 17. "S" means special; these types are shown individually. "a" and "b" indicate variations.

Note 2: D.C. operation — Cathode at one end only.
A.C. and D.C. operation — Cathodes at both ends
Pulse operation — Cathode at one end specially designed for pulse operation.

Note 3: Anode current and tube drop are D.C. values. Values in parenthesis are tentative.

Note 4: The Excess Noise Ratio in db is $10 \log\left(\frac{T_e}{290} - 1\right)$. For tolerances, see individual type specifications.

*If the anode current during the "on time" of a square pulse (of greater than 100 microsec. duration) is nominally the same as the rated D.C. anode current, the tube drop during this period will be approximately the same as the rated D.C. tube drop.

**Excess noise ratio of tube only.

APPENDIX II
SIGNALITE NOISE SOURCES WITH INDIRECTLY HEATED CATHODE TUBES

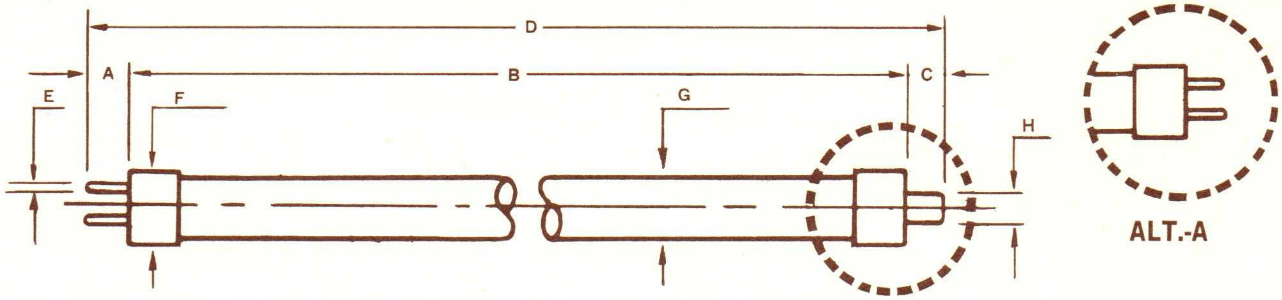
Band (1)	Signalite Part No.	Former Tucor Designation	Frequency Range (GHz)	Excess Noise Ratio (db)	Operating Voltage (2) (Nominal)	Operating Current (ma)	Striking Voltage	Circuit Length (3) (Inches)	Mounting	Circuit
VHF	TN-46	T44V3C	0.2-0.25	18.5	200	30	1500	15-1/2	Helical Coupling	7/8" coax.
UHF	TN-47	T44U2D	0.56-0.64	19.0	325	50	2000	16-1/2	Direct Coupling	7/8" coax.
	TN-48	T44U3D	0.425±20%	18.5		75	2000	10	Helical Coupling	Type N
L	TN-51	T44L1C	1.0-2.0	20.1	200	50	1900	8-15/16	Direct Coupling	7/8" coax.
	TN-52	T44L1D	1.0-2.0	20.1	200	50	1900	10-3/8	Direct Coupling	7/8" coax.
	TN-54	T44L6C	1.0-2.0	20.5	200	50	1900	17-5/16	Direct Coupling	Type N
	TN-55	T44L8D	1.0-2.0	20.1	200	50	1900	9-9/16	Direct Coupling	7/8" coax.
	TN-57	T44L11D	1.28-1.35	20.5	225	50	1900	12-9/16	Direct Coupling	7/8" coax.
S	TN-60	T44S1D	2.0-4.0	18.5	200	50	1900	10-3/8	Direct Coupling	7/8" coax.
	TN-64	T44S6A	2.7-2.9	18.5	35	60	450	3-3/4	90°E	RG-75/U
	TN-65	T44S7A	3.4-3.6	18.3	40	75	600	2-1/2	90°E	RG-75/U
	TN-71	T44S14A	2.9-3.1	18.5	35	75	450	3-5/8	90°E	RG-75/U
	TN-72	T44S15A	2.7-2.9	18.5	35	75	450	3-3/32	90°E	RG-75/U
	TN-73	T44S16A	2.7-2.9	18.5	35	75	450	3-3/32	90°E	RG-75/U
	TN-74	T44S17A	2.7-2.9	18.5	35	60	450	3-3/4	90°E	RG-75/U
	TN-75	T44S18A	3.1-3.5	18.3	40	75	600	2-5/8	90°E	RG-75/U
C	TN-76	T44C1A	5.3-6.0	18.5	60	150	700	2	90°E	RG-49/U
	TN-77	T44C1B	5.3-6.0	13.5	60	150	700	3-1/2	90°E	RG-49/U
	TN-78	T44C2A	5.45-5.82	18.5	60	150	700	2-3/4	90°E	RG-95/U
	TN-82	T44C11B	5.3-6.0	13.5	60	150	700	3-9/16	90°E	RG-49/U
H	TN-83	T44H1A	7.5-8.6	18.5	60	75	800	1-9/16	90°E	RG-51/U
	TN-84	T44H1B	7.5-8.6	15.0	55	100	800	2-1/2	90°E	RG-51/U
X	TN-94	T44X3A	8.9-9.1	18.5	50	60	950	1-5/8	90°E	RG-67/U
	TN-95	T44X3B	8.5-9.6	14.5	50	100	950	2-1/2	90°E	RG-67/U
	TN-97	T44X8A	8.5-9.6	18.5	50	75	950	1-5/8	90°E	RG-67/U
	TN-101	T44X12B	8.5-9.6	14.5	50	100	950	2-1/4	90°E	RG-52/U
	TN-124	——	10.0-11.0	13.0	50	50	1000	2-1/2	90°E	RG-52/U
Ku(K)	TN-102	T44K1A	15.0-16.5	18.5	60	40	1200	1-1/2	90°E	RG-67/U
	TN-103	T44K1B	12.4-18.0	18.5	140	50	2000	7-1/2	0°E	RG-107/U
	TN-104	T44K5B	15.0-16.6	12.5	95	50	1000	1-5/8	90°E	RG-91/U
	TN-128	——	12.0-14.0	13.5	50	50	1000	2	90°E	RG-91/U
K(P)	TN-106	T44P1B	18.0-26.5	18.5	175	50	1900	6-7/16	0°E	RG-66/U
	TN-125	——	22.0-23.0	12.5	65	50	1500	2-1/4	90°E	RG-53/U
Ka(Q)	TN-107	T44Q1B	26.5-40.0	18.0	140	40	2500	5-1/8	0°E	RG-96/U
	TN-109	T44Q4B	34.0-36.0	18.0	140	35	2500	7-3/8	0°E	RG-96/U
	TN-126	——	31.0-32.0	13.3	75	50	1500	2-1/4	90°E	RG-96/U
R	TN-111	T44R1B	50.0-75.0	18.2	230	30	2500	4-5/8	0°E	RG-98/U

REPLACEABLE INDIRECTLY HEATED CATHODE TUBES

Band	Signalite Part No.	Former Tucor Designation	Frequency Range (GHz)	Excess Noise Ratio (db)	Operating Voltage (Nominal)	Operating Current (ma)	Striking Voltage	Nominal Filament Current @ 6.3 In Amps	Used In Mount
S	TD-124	T44S7	3.4-3.6	18.3	40	75	600	1.25	TN-65
	TD-129	T44S14	2.9-3.1	18.5	35	75	450	1.25	TN-71
	TD-121	T44S15	2.7-2.9	18.5	35	75	450	1.25	TN-72
X	TD-126	T44X7	8.2-12.4	15.6	90	100	1500	1.25	TN-130

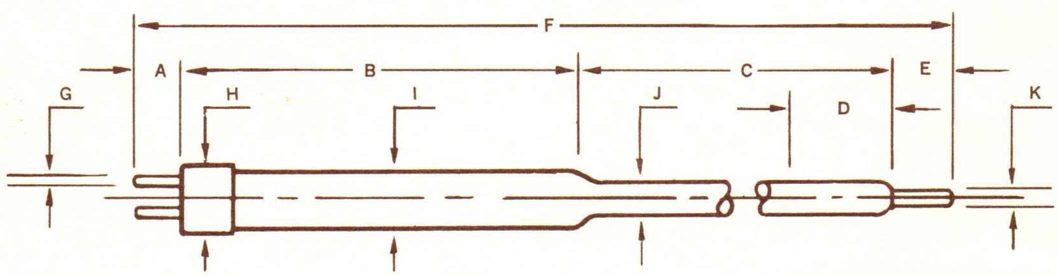
(1) Units at higher frequencies can be furnished upon request.
(2) Negative voltage pulse applied to cathode.
(3) Various types of combinations of connections are available upon request.

OUTLINE DRAWINGS



Outline Number:	1		2		3	
Frequency (GHz):	1.12 — 1.70		2.60 — 3.95		3.95 — 5.85 5.85 — 8.20	
Dimensions	Min.	Max.	Min.	Max.	Min.	Max.
A	.260	.325	.260	.325	.260	.325
B	—	—	16.937	17.437	13.875	14.375
C	—	½	.310	.360	.270	.320
D	14⅝	15	17.625	18.000	14.375	15.000

Outline Number:	1		2		3	
Frequency (GHz):	1.12 — 1.70		2.60 — 3.95		3.95 — 5.85 5.85 — 8.20	
Dimensions	Min.	Max.	Min.	Max.	Min.	Max.
E	.090	.105	.090	.105	.090	.105
F	1.350	1.435	—	.990	—	.555
G	1.475	1.550	.975	1.050	.547	.579
H	—	3/16	.305	.325	.245	.265

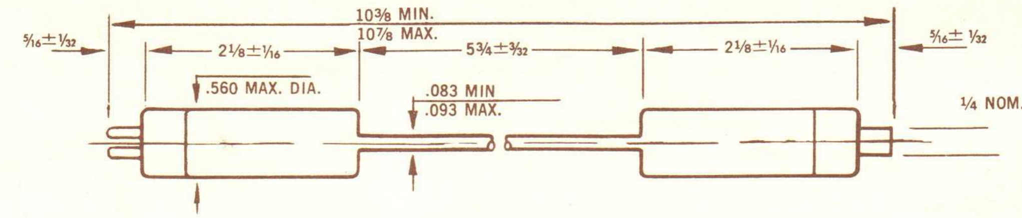


Outline Number:	4		5		6	
Frequency (GHz):	8.2 — 12.4		12.4 — 18.0		18.0 — 26.5	
Dimensions	Min.	Max.	Min.	Max.	Min.	Max.
A	.260	.325	.260	.325	.260	.325
B	—	2.750	—	2.750	—	2.750
C	8.625	—	7.375	—	6.187	—
D	—	1.500*	—	1.25**	—	1.25***
E	—	.500	—	.500	—	.500
F	11.937	12.250	10.875	11.250	9.687	10.000

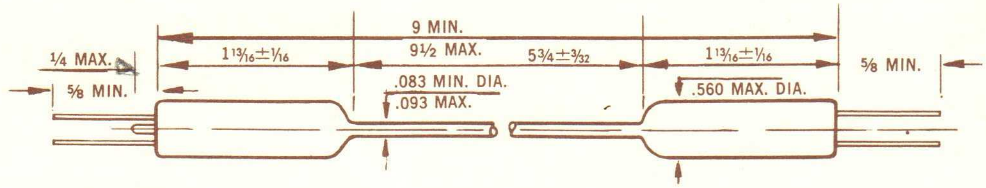
Outline Number:	4		5		6	
Frequency (GHz):	8.2 — 12.4		12.4 — 18.0		18.0 — 26.5	
Dimensions	Min.	Max.	Min.	Max.	Min.	Max.
G	.090	.105	.090	.105	.090	.105
H	—	.555	—	.555	—	.555
I	—	.550	—	.500	—	.500
J	.370	.380	.235	.265	.160	.194
K	—	.187	—	.187	—	.187

* = .380 max., no min., dimensions on diameter for this length of tube
** = .265 max., no min., dimensions on diameter for this length of tube.
*** = .194 max., no min., dimensions on diameter for this length of tube.

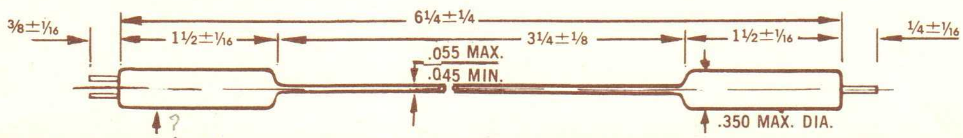
Outline 7

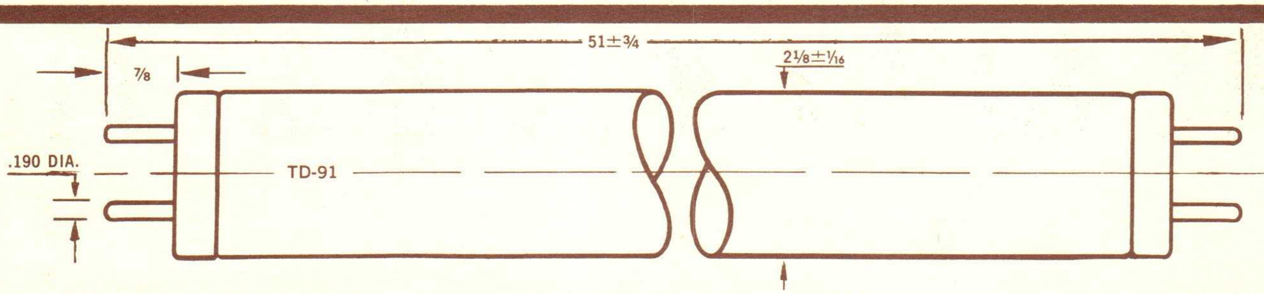


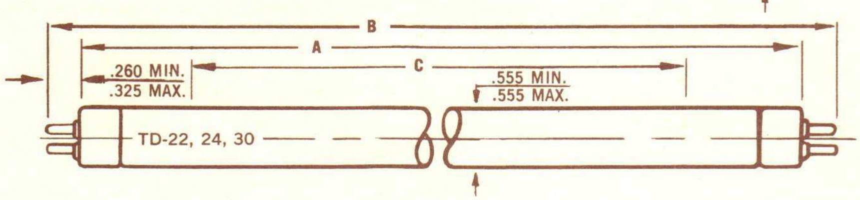
Outline 7A



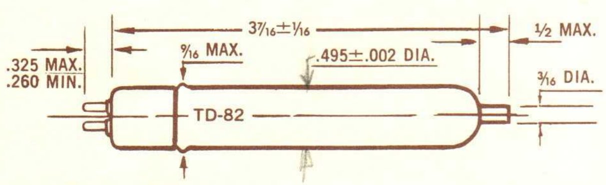
Outline 8

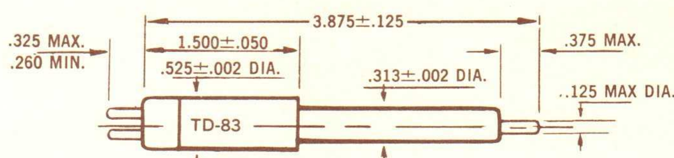


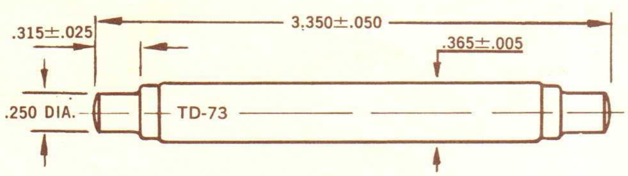


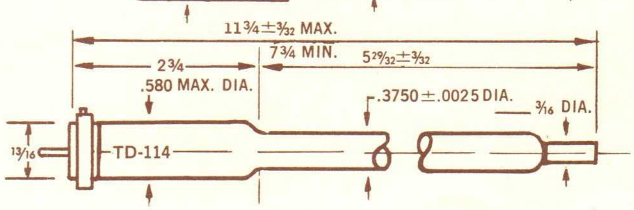


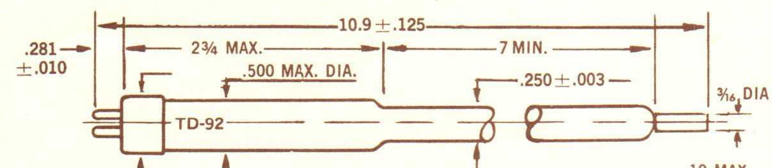
	A		B		C
	MAX.	MIN.	MAX.	MIN.	
TD-22	8 19/32	8 3/16	9 3/16	8 13/16	6 NOM.
TD-24 TD-30	11⅜ NOM.		11 13/16±¼		8⅜ NOM.

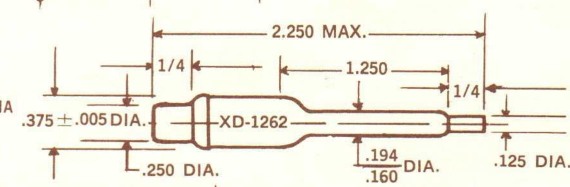


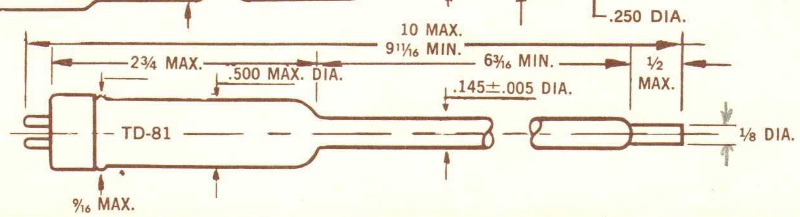












SPECIALS

July 1974.