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RCA-8379

TRAVELING-WAVE TUBE

4.5 db Noise Figure

**Low-Noise Amplifier Type
for Receiver Applications
2320 to 2680 Mc**

31 db Gain

RCA-8379 is a low-noise, low-level traveling-wave amplifier tube of the helix-transmission-line type. Operating in the frequency range from 2320 to 2680 Mc, the 8379 is intended for use in the input stage of radar, scatter propagation, and other microwave receivers, and in if amplifier service. Characteristics of the 8379 include a noise figure of 4.5 db and a gain of approximately 31 db.

Featured in the design of the 8379 is a special type of electron gun. This gun deamplifies noise generated in the electron beam with the result that a low noise figure is obtained over the entire operating frequency range of the tube without readjustment of tube operating conditions. In addition, the use of a metal shell allows the rf-input and rf-output transducers to be permanently set in position during manufacture of the tube for optimum performance.

PRINCIPLES OF OPERATION

The structural arrangement of the 8379, shown in Fig.1, incorporates an electron gun which produces an electron beam; a helix transmission line (slow-wave structure) which propagates a microwave signal in a manner that permits interaction between the beam and the signal; a collector which removes the unused beam energy; transducers which introduce and remove the signal; and an attenuator which isolates the input and output sections of the slow-wave structure to prevent oscillations. All of the components mentioned above, with the exception of the transducers, are contained within an evacuated glass envelope. The input and output transducers, with their semirigid 50-ohm coaxial lines, are adjusted and locked in position within the metal shell to insure proper location with respect to the helix. The metal shell also facilitates mounting of the tube in the magnetic field required to focus the electron beam. The magnetic field may be provided by a permanent magnet, or by a solenoid as illustrated in Fig.1.

The amplification provided by a traveling-wave tube is produced by interaction of the electron beam and the signal on the slow-wave structure (helix) in the following manner. The velocity of the electron beam entering the helix from the gun is determined by the dc helix voltage. A strong magnetic field whose axis coincides with the axis of the helix confines the electrons to a cylindrical beam whose diameter approaches the inside diameter of the helix. A signal wave introduced onto the helix at the end nearest the gun travels circumferentially along the helix at approximately the velocity of light, although its velocity in the axial, or beam, direction is reduced by the pitch-to-circumference ratio of the helix. When the helix voltage is properly adjusted, the velocity of the beam electrons is made slightly greater than the axial velocity of the rf signal.

The electric field produced by the rf signal moving along the helix affects the velocity of the electrons in the beam in such a manner that beam velocity is slightly reduced by the time the beam reaches the end of the helix. This deceleration of the beam is accompanied by a transfer of beam energy to rf electric-field energy, with the result that the signal is amplified.

GENERAL DATA

Electrical:

Heater, for Unipotential Cathode:

Voltage (AC or DC)	5.0 ± 5%	volts
Current at 5 volts	0.65	amp

Starting Current: The maximum instantaneous starting current must never exceed 4.0 amperes even momentarily.

Cathode Heating Time	1 min.	minute
Frequency Range	2320-2680	Mc
Cold Insertion Loss	60 min.	db

Mechanical:

Mounting Position	Any
Cooling	Natural
Maximum Overall Length	19.50"
Shell Diameter	1.375" ± 0.005"
Base	Octal 8-Pin
Collector Connector	Special Banana Jack (See page 3)

RADIO CORPORATION OF AMERICA
Electronic Components and Devices Harrison, N. J.

SCHEMATIC ARRANGEMENT OF TYPE 8379
WITH ASSOCIATED SOLENOID

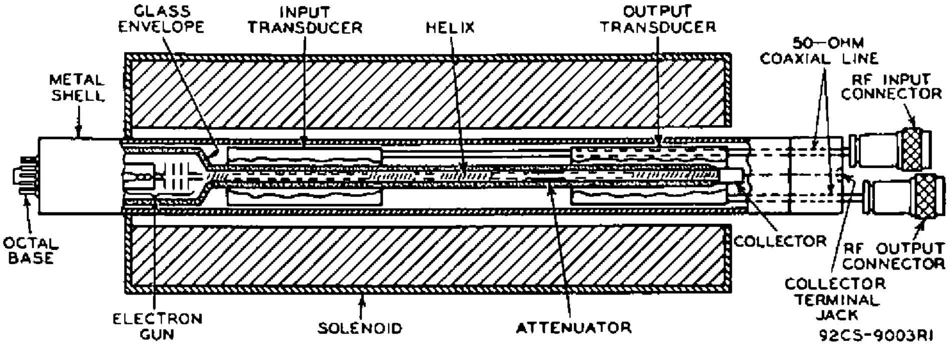

Fig.1

RF Connectors:

Input	Type N Plug (UG-18 B/U)
Output	Type N Plug (UG-18 B/U)
Weight	1-1/2 lbs

Maximum and Minimum Ratings, *Absolute-Maximum Values:*[a]

DC Collector Voltage	800	max.	volts
DC Helix Voltage	500	max.	volts
DC Grid-No.4 Voltage	500	max.	volts
DC Grid-No.3 Voltage	300	max.	volts
DC Grid-No.2 Voltage	75	max.	volts
DC Grid-No.1 Voltage	20	max.	volts
DC Collector Current	500	max.	μa
DC Helix Current	5[b]	max.	μa
DC Cathode Current	500	max.	μa
Magnetic Field Strength	650[c]	min.	gauss
RF Power Input:			
Peak	500	max.	watts
Average	1.0	max.	watts
Metal-Shell Temperature (At hottest point)	175	max.	°C

Typical Operation at 2500 Mc:

DC Collector Voltage	600	volts
DC Helix Voltage	375	volts
DC Grid-No.4 Voltage	325	volts
DC Grid-No.3 Voltage	70	volts
DC Grid-No.2 Voltage (Approx.)	10	volts
DC Grid-No.1 Voltage	10	volts
DC Collector Current	150	μa
DC Helix Current	0.5	μa
DC Grid-No.4 Current DC Grid-No.3 Current DC Grid-No.2 Current DC Grid-No.1 Current	each less than 1 μa	
Magnetic Field Strength	850[d]	gauss
Gain (Low Level)	31	db
Power Output (Saturated)	1.0	mw
Noise Figure	4.5	db

Characteristics Range Values for Equipment Design:

	Note	*Min.*	*Max.*	
Heater Current	1	0.45	0.85	amp
Input VSWR:				
Non-Operating	2,3	-	1.3	
Operating	1,4	-	1.5	
Output VSWR:				
Non-Operating	2	-	1.5	
Operating	1,4	-	3	
DC Helix Voltage	1,4	335	405	volts
DC Grid-No.4 Voltage	1,4	150	400	volts
DC Grid-No.3 Voltage	1,4	25	100	volts
Saturated Power Output	1,4	1.0	-	mw
Small-Signal Gain	1,4	28	34	db
Noise Figure	1,4	-	5.0	db

Note 1: With heater voltage of 5.0 volts.

Note 2: With no electrode voltages applied.

Note 3: Any tube having a non-operating input VSWR higher than 1.3 but less than 1.5 may be considered acceptable if the operating VSWR is less than 1.5.

Note 4: With electrode voltages and magnetic focusing field adjusted for minimum noise figure at 2500 Mc.

OPERATING CONSIDERATIONS

The *rated values for collector voltage, helix voltage, grid-No.4 voltage, and grid-No.3 voltage are high enough to be dangerous to the user.* Care should be taken during adjustment of circuits,

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[a] The *maximum ratings* in the tabulated data are established in accordance with the following definition of the *Absolute-Maximum Rating System* for rating electron devices.

Absolute-Maximum ratings are limiting values of operating and environmental conditions applicable to any electron device of a specified type as defined by its published data, and should not be exceeded under the worst probable conditions.

The device manufacturer chooses these values to provide acceptable serviceability of the device, taking no responsibility for equipment variations, environment variations, and the effects of changes in operating conditions due to variations in device characteristics.

The equipment manufacturer should design so that initially and throughout life no Absolute-Maximum value for the intended service is exceeded with any device under the worst probable operating conditions with respect to supply-voltage variation, equipment component variation, equipment control adjustment, load variation, signal variation, environmental conditions, and variations in device characteristics.

[b] During alignment of the tube in the magnetic focusing field, the helix current may exceed this value for short periods, but should never exceed 10 μa.

[c] This value of field strength will focus the electron beam, but noise figure will not be optimum.

[d] Typical peak value for RCA Solenoid, Type MW4901 (See Fig.2).

especially when exposed circuit parts are at high dc potential.

The *power supply* for the 8379 should be capable of holding ripple voltage sufficiently low to prevent phase distortion, and should have adequate regulation to prevent a change in operating conditions which might increase the noise figure. Provision should be made for monitoring helix current, collector current, and cathode current.

The rated *heater voltage* of 5.0 volts should be applied for at least 1 minute to allow the cathode to reach normal operating temperature before voltages are applied to the other electrodes.

The *magnetic field* required for focusing the electron beam of the 8379 may be obtained from a solenoid such as the RCA-MW4901 or equivalent. The field must have a distribution as shown in Fig.2. A uniform field provided by a solenoid or permanent magnet of at least 800 gauss starting 2 inches from the groove near the base end of the metal shell and continuing for at least nine inches along the tube axis can provide equivalent focusing.

CHARACTERISTICS OF RCA-MW4901 SOLENOID

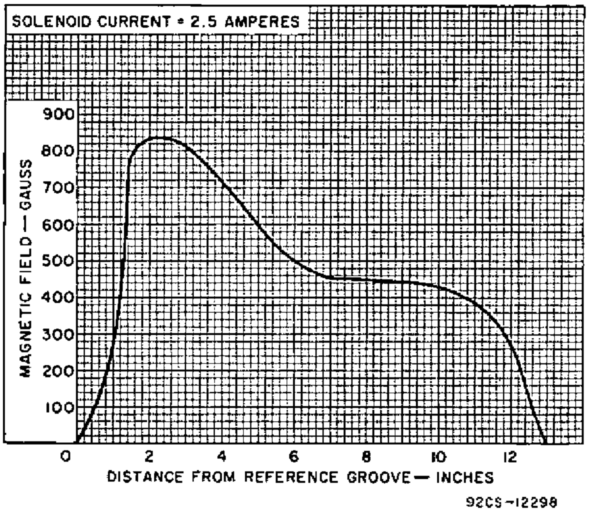


Fig.2

Mounting. The magnetic focusing device used with the 8379 should provide means both for centering the tube in the magnetic field and for locking the tube in position. Provision should be made for natural circulation of air around the tube.

The circumferential groove in the metal shell near the base end of the 8379 is designed to receive a resilient ring used with a clamping device to hold the tube longitudinally in its magnetic focusing field.

A keyway is provided to permit accurate angular location of the 8379 in its magnetic focusing field, and locking the tube against rotation.

After the tube has been inserted in the magnetic focusing field and locked in position, attach an octal socket to the tube base and make connections to the collector jack and to the rf-input and rf-output connectors.

The *base pins* of the 8379 fit a standard octal 8-contact socket. Connection to the *collector terminal connector* may be made with a banana-type plug similar to a Raytheon Test Jack 27-1594G21 fitted with an insulator from an HH Smith Type 211 banana plug. Both *rf-input and rf-output terminals* of the 8379 employ semirigid 50-ohm coaxial lines having type N UG-18B/U connectors.

Initial Alignment Procedure

Apply rated heater voltage to the 8379 for one minute. Then connect operating voltages as shown under *Typical Operation* to all other tube electrodes except grid No.2. Grid-No.2 voltage may then be applied, and increased until cathode current reaches approximately 50 microamperes.

If the tube is incorrectly aligned within the magnetic field, some of the beam current will be drawn to the helix and increase the helix current. The axial alignment of the 8379 within the magnetic focusing field should then be adjusted to produce a minimum value of helix current. Grid-No.2 voltage should then be increased until collector current is approximately 150 microamperes. Readjust alignment of the tube and magnetic focusing field until a minimum value of helix current is again obtained. Helix current of the 8379 when properly aligned in the magnetic focusing field is usually less than one microampere. Collector current should be checked to see if it is essentially the same as cathode current. Such a condition is another indication that the tube is properly aligned in the magnetic field. If a solenoid is used to supply the magnetic focusing field, check the solenoid current and readjust it, if necessary, to obtain the specified field-strength value.

The above alignment procedure need not be repeated so long as the adjustments are not disturbed.

Lowest-Noise-Figure Adjustment Procedure

In order to operate the 8379 at the lowest noise figure, it is necessary to adjust the electrode voltages as follows: With the 8379 connected in its circuit, and with either noise input or signal input, adjust the helix voltage to give maximum output at the operating frequency. This value of helix voltage simultaneously produces optimum tube gain and lowest noise figure. Next, with no input signal, vary dc grid-No.1, grid-No.3, and grid-No.4 supply voltages alternately until the receiver output reaches a minimum value. The voltages are now adjusted to operate the 8379 at its lowest noise figure for the particular frequency to which the equipment is tuned. If the strength of the magnetic focusing field changes, it will be necessary to repeat the above adjustment procedure with regard to grid-No.1, grid-No.3, and grid-No.4 voltage.

Noise Figure

Noise figure of an amplifier or a tube is fundamentally a measure of the noise added to the signal by the amplifier or tube, i.e., the ratio of the total noise power delivered by the device to its output termination to the portion thereof arising from noise developed by the input termination.

NOISE AND GAIN CHARACTERISTICS

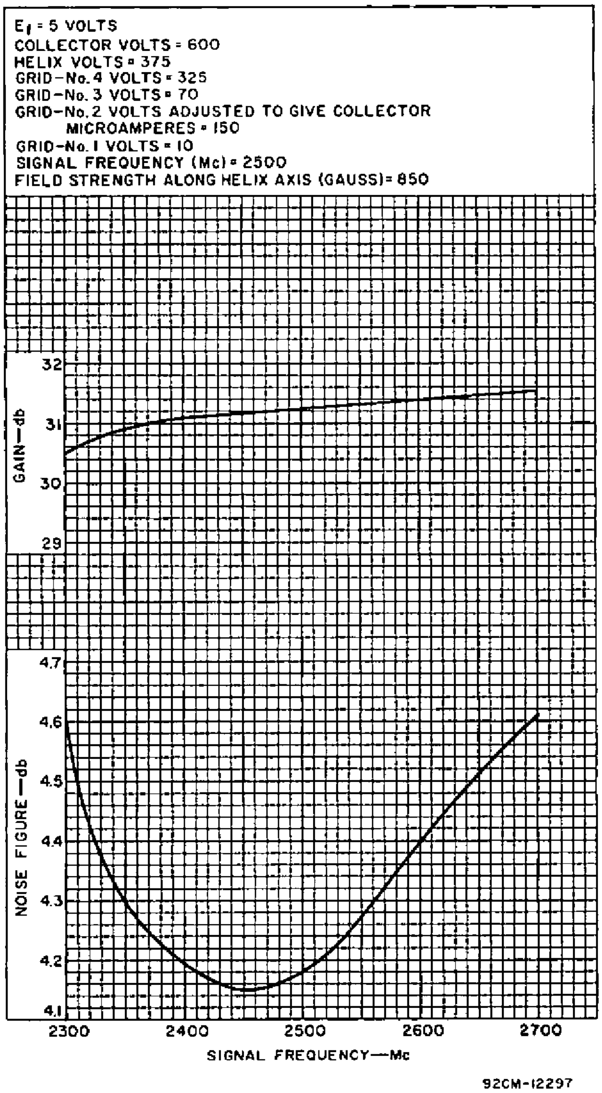


Fig.3

The noise figure (F) expressed as a power ratio may be written as

$$F = \frac{\frac{S_i}{N_i}}{\frac{S_o}{N_o}} \text{ or } \frac{S_i}{S_o} \cdot \frac{N_o}{N_i} \qquad (1)$$

where S_i = signal input power to device

S_o = signal output power delivered by device

N_i = noise power developed by input termination of device

N_o = noise power delivered by device to output termination

Since $\frac{S_o}{S_i}$ is equal to the gain (G) of the device, Eq.(1) becomes

$$F = \frac{1}{G} \cdot \frac{N_o}{N_i} \qquad (2)$$

The values for G and N_o can be measured. The value for N_i is calculated from the relation

$$N_i = kTB$$

where k = 1.38×10^{-23} joules/°K (Boltzman's constant)

T = absolute temperature of noise signal source in °K

B = bandwidth of device in cycles/second

Determination of Noise Figure

The noise-figure values in this bulletin were determined using the equipment arrangement of Fig.4, in the following manner:

The operating conditions of the 8379 were adjusted to provide lowest noise figure. Then, with the gas-tube noise source operating and with approximately 40 db of rf attenuation inserted between the noise source and the 8379, the receiver gain was adjusted to provide a convenient value of output. Next, the 40 db of rf attenuation between the noise source and the 8379 was removed and the precision if attenuator was adjusted to add attenuation until the receiver output reached its previous value with 40 db of rf attenuation. The power ratio equivalent to the if attenuation thus added is inversely proportional to the noise generated in the traveling-wave tube.

The power ratio corresponding to the added if attenuation, the effective noise-temperature ratio of the noise source, the insertion loss of the noise source, and the circuit loss between the noise source and the input to the traveling-wave tube all enter into the measurement of noise figure, as follows:

$$F = \frac{\left(\frac{T_B}{T_o} - 1\right) \left(\frac{L - 1}{L}\right)}{(A)\ (Y-1)} \qquad (3)$$

where $\frac{T_B}{T_o}$ = effective noise-temperature ratio of gas-tube noise source

L = the power ratio corresponding to the noise-source insertion loss

A = the power ratio equivalent to the circuit loss between noise source and 8379

Y = power ratio corresponding to the attenuation added in precision if attenuator

The value of the first term in the numerator of Eq.(3) is equivalent to 15.28 db for an argon-bulb waveguide-type noise source. This type does

BLOCK DIAGRAM FOR NOISE-FIGURE MEASUREMENTS

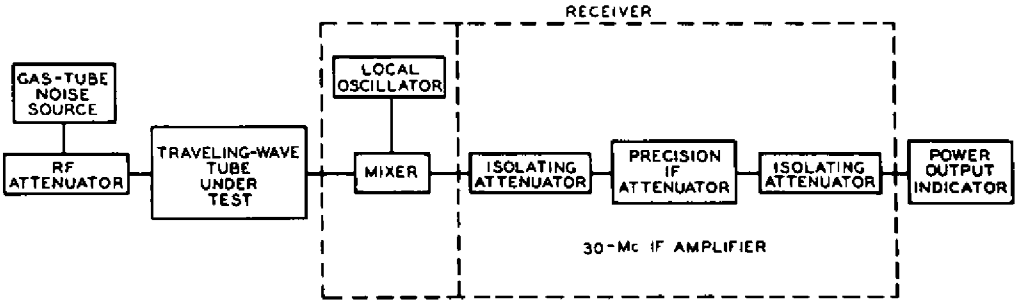


Fig.4

not require any temperature compensation. The values of A and L for the equipment used are equivalent to 0.54 db and 15 db, respectively.

Converting these db values into power ratios and substituting them in Eq.(3) gives

$$F = \frac{28.9}{(Y-1)} \tag{4}$$

To express Eq.(4) in decibels, it is necessary to take 10 times the common logarithm of the power ratio. Hence,

$$F \text{ (in db)} = 10 \log_{10} \left(\frac{28.9}{Y-1}\right) \tag{5}$$

The value determined from Eq.(5) includes both tube noise and receiver noise. The relative effect due to receiver noise can be determined from

$$F_{1,2} = F_1 + \frac{F_2 - 1}{G_1} \tag{6}$$

where $F_{1,2}$ is noise figure of two networks in cascade

F_1 is noise figure of first network (consisting of traveling-wave tube)

F_2 is noise figure of second network

G_1 is the gain of the first network

In this equation, all values are expressed as power ratios.

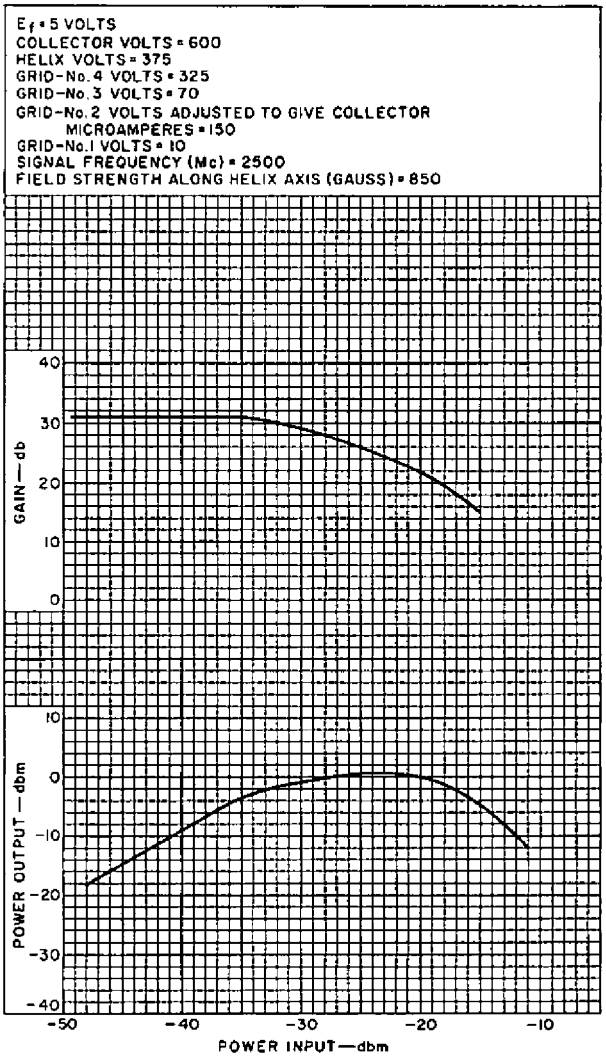
If F_2 is small or if G_1 is large, the value of the second term becomes so small that it can be neglected. In measurements on the 8379 F_2 was equal to a power ratio of 20, and G_1 was equal to a power gain of 1000. Consequently, the second term in Eq.(6) was equal to a power ratio of 0.02 as compared to a power ratio of about 2.8 for F_1. Hence, the contribution by the second network to the measured noise figure is negligible.

Similarly, in terms of decibels, the contribution by the second network to the measured noise figure is less than 0.02 db.

Preamplifier in Radar Receivers

In the usual type of radar system, a portion of the transmitter pulse leaks through the TR tube to the crystal mixer in the receiver, overloads the crystal, and gradually impairs its performance. If, however, the crystal is preceded by the 8379 in a preamplifier stage, the traveling-wave tube serves as a crystal-protection device because of its saturation characteristic shown in Fig.5. From this curve, it will be

SATURATION CHARACTERISTICS



92CM-12296

Fig.5

noted that the saturated power output of the 8379 is about 1milliwatt which will not harm the crystal. Therefore, the spike-leakage limit of the TR tube can be eased and thus eliminate the need for supplying "keep-alive" voltage to the TR tube. Furthermore, the ability of the 8379 to withstand an rf peak power input of as much as 500 watts or an average power input of as much as 1 watt makes it possible to employ a TR tube with lower attenuation.

Additional advantages offered by the 8379 in a preamplifier stage include: (1) reduction of the overall noise figure of the radar receiver; (2) improved receiver recovery time; (3) better TR tube life, and (4) reduction of local oscillator radiation. All of these advantages contribute to improved radar-system operation.

Phase-Sensitive Applications

When the 8379 is used in a phase-sensitive radar system or in a microwave relay system where frequency-modulated information is amplified, even a small amount of phase distortion can adversely affect performance. The following table shows for each tube electrode the values of rms ripple voltage which will cause a peak-to-peak change inrf phase of approximately 1 degree.

Tube Electrode	Typical Operating DC Volts	Approx. RMS Ripple Volts For Peak-to-Peak Phase Shift of 1°
Grid No.1	10	0.1
Grid No.2	10	0.1
Grid No.3	70	0.5
Grid No.4	325	3.5
Helix	375	0.024
Collector	600	6.7

For the RCA Solenoid Type MW4901 operated at 90 volts dc, a peak-to-peak change in rf phase of approximately 1° will be caused by an rms ripple voltage of 7.7 volts.

Input Matching Considerations

In general, the *voltage standing wave ratio* (VSWR) will increase as the electron-beam current of the tube is increased. This "hot VSWR" is a direct function of gain and can be attributed to reflections of the amplified wave at a discontinuity along the slow-wave structure. In contrast, the VSWR with no voltages applied to the tube, is referred to as the "cold VSWR". This "cold VSWR" determines the transfer of input signal energy to the helix and, therefore, the noise figure of the 8379 is not degraded by the "hot VSWR". In general, it will be found that when the input to the 8379 is adjusted for optimum matching under "cold" conditions, the same adjustment will provide optimum matching under "hot" conditions. Fig.6 shows a typical input-matching characteristic of the 8379 under "cold" conditions.

INPUT-MATCHING CHARACTERISTIC

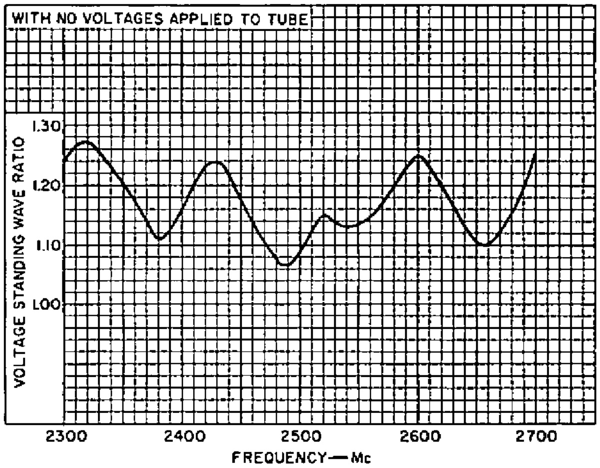


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Fig.6

Notes On Associated Microwave Circuitry

A low-noise traveling-wave tube used in a superheterodyne circuit will cause a 3 db degradation in noise figure unless a filter is used at the output of the traveling-wave tube to remove noise generated at the image frequency.

Whenever the output of the 8379 is connected to a filter, signals in the reject band of the filter are reflected back into the tube. As these signals travel back through the tube, they suffer little attenuation until they are absorbed by the attenuator. Should there be appreciable reflection from the attenuator or another discontinuity inside the traveling-wave tube, oscillations may occur, depending on the gain within the tube from the attenuator or discontinuity to the output end of the tube.

The 8379 is designed to be short-circuit stable, i.e., the power reflected from a short-circuited output termination will be insufficient to cause oscillation when the 8379 is operating at a normal value of beam current. If the beam current is increased sufficiently above this value, the gain of the tube will increase until oscillation takes place.

When a high-gain microwave amplifier tube such as the traveling-wave tube is employed, special care must be taken to prevent distortion or oscillations resulting from feedback through circuitry external to the tube. Some types of filters may show satisfactory attenuation characteristics in and near the frequency band of interest. However, oscillations can still occur due to "holes" in the filter characteristic at frequencies outside the band of interest. Attenuation of filters should therefore be checked over wide bands and the holes, if any, can then be filled by supplementary, simple filters.

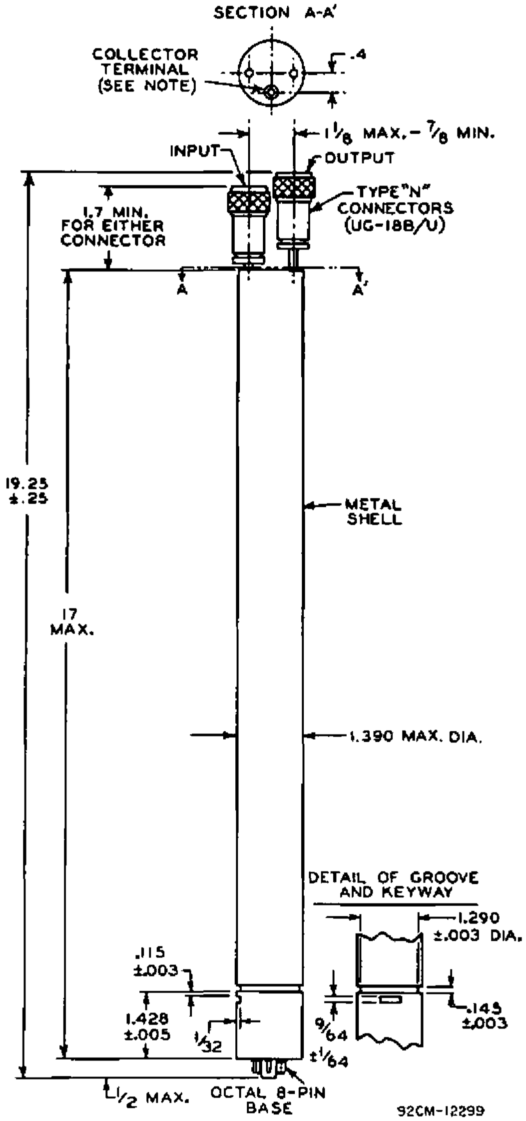
REFERENCES

J. R. Pierce, *"Traveling-Wave Tubes"*, D. Van Nostrand Co., Inc.

R. W. Peter, *"Low-Noise Traveling-Wave Amplifier"*, RCA Review, September, 1952.

W. W. Mumford, *"A Broad-Band Microwave Noise Source"*, Bell System Technical Journal, October, 1949.

DIMENSIONAL OUTLINE

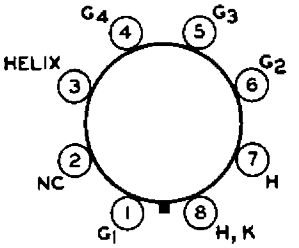


Dimensions in Inches

NOTE: SPECIAL BANANA JACK—MATES WITH RAYTHEON TEST JACK 27-1594G21 FITTED WITH AN INSULATOR FROM AN HH SMITH TYPE 211 BANANA PLUG.

SOCKET CONNECTIONS

Bottom View



Pin 1 – Grid No. 1
Pin 2 – No Connection
Pin 3 – Helix
Pin 4 – Grid No. 4
Pin 5 – Grid No. 3
Pin 6 – Grid No. 2
Pin 7 – Heater
Pin 8 – Heater, Cathode