# MODEL 161A
# VACUUM TUBE VOLTMETER

# OPERATION MANUAL

KIKUSUI ELECTRONICS CORP.

# 1. INTRODUCTION

The Model 161A is a compact, high sensitivity, AC voltmeter to indicate mean value of AC voltage. Employing stable feedback amplifier and germanium-diode full-wave rectifier circuit, this equipment measures over a wide range, from 1 millivolt (-60 dBm) to 500 volts (+50 dBm) divided in 10 steps (10 dB per step), and its frequency response expands from 5 Hz to 1 MHz. The direct reading meter indicator is calibrated in RMS values.

## 2. SPECIFICATIONS

| | | |
|---|---|---|
| Type | Mean value indication type | |
| Power Requirement | _____ Volts, 50/60 Hz approx. 21VA | |
| Dimensions | 150 (W) x 200 (H) x 140 (D) mm | |
| (Max.) | 160 (W) x 213 (H) x 168 (D) mm | |
| Weight | Approx. 3.8 kg | |
| Meter | Length of scale 105 mm. | |
| | Sensitivity 100 μA | |
| Tube used | 6AU6 (T) | 2 |
| | 6U8 or 6 BL8 | 1 |
| | 6X4 | 1 |
| | (SD-34) | 2 |
| Accessories supplied | Model 941B Terminal Adaptor | 1 |
| | Operation Manual | 1 |
| | Test Data | 1 |
| Scale | Calibrated in RMS with sine wave voltage. Calibration in both volt and decibel (0 dB equals to 1 mW into 600 ohms). | |
| Input Terminal | UHF-type receptacle and GND terminal spaced at 19 mm (3/4"). UHF-type receptacle accepts both UHF-type and M-type plugs. | |

| | | |
|---|---|---|
| Input Impedance | 1 MΩ shunted by 25 pF ± 2 pF in all ranges. | |
| Maximum Input Voltage | AC component | 500 Vrms<br>± 710 V peak |
| | DC component | ± 400 V |
| Ranges | 10 ranges. 0~15/50/150/500 mV and 1.5/5/15/50/150/500 V rms, or -40/-30/-20/-10/0/10/20/30/40/50 dBm. | |
| Accuracy | ±3% of full scale at 1 kHz. | |
| Stability | ±2% of full scale at 1 kHz against ±10% change in line voltage | |
| Frequency Response | 7 Hz-700 kHz ±10% against 1 kHz<br>10 Hz - 500 kHz ±5% against 1 kHz<br>20 Hz - 250 kHz ±3% against 1 kHz | |
| Noise | Less than 1% of full scale with input terminal short-circuited. | |
| Output Terminal | Spaced at 19 mm (3/4") interval. | |
| Voltage | Approx. 2.5 volts RMS in full scale. | |
| Distortion | Approx. 3% in full scale | |
| S/N | Approx. 35 dB in full scale | |

At 1000 Hz 1.5 volts range

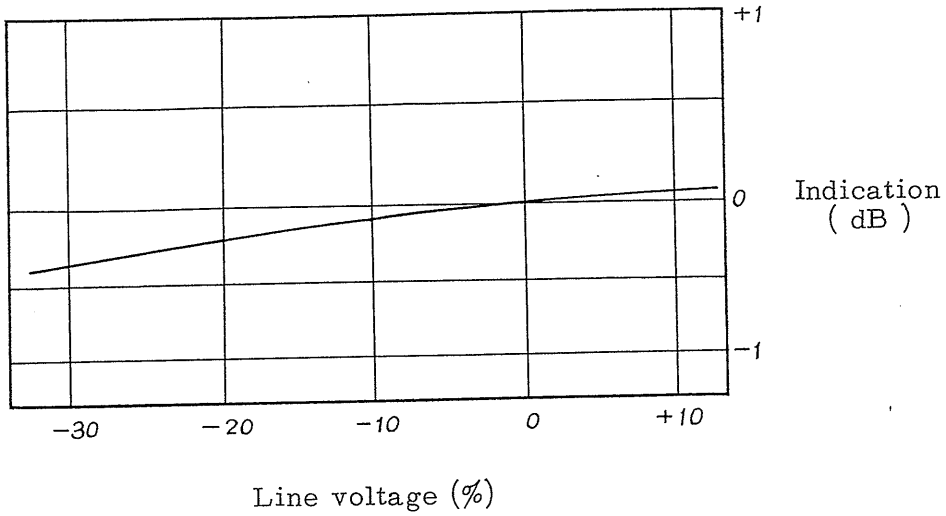



Fig. 1 Change in meter indication for change in line voltage

# 3. OPERATION

The standard model works on rated value 50 to 60 Hz power line. As shown in Figure 1, the meter indication is little affected by variation in power line voltage. However, it is preferred that the line voltage is maintained within ±5 % of rated value for longer life expectancy.

## 3.1 Explanation for Panel

POWER — A toggle switch to turn the power ON or OFF. Turning this switch upward, the power is applied, and the dial of the range switch is illuminated. For about 20 seconds after this switch is turned on, the meter pointer may swing irregularly. Also, for about a few seconds after this switch is turned OFF, the same may happen.

RANGE — This is a black-colored dial on the center of the panel. The figures on the dial have following meanings:

Figures on external circumference: These figures indicate full scale voltages.

Orange colored figures indicate voltages in millivolts and transparent figures indicate voltage in volts.

Figures on internal circumference: ___

These figures indicate center scale voltages in dBm. (Explanation on dBm will appear in later section.)

As this dial is turned clockwide, it steps for higher voltage range. In measurement, it is preferred that the dial is first set in high voltage range, then gradually switched for lower voltage range until an appropriate indication is obtained so that excessive input to the equipment can be avoided.

INPUT

This is a UHF-type receptacle to apply the voltage to be measured. This receptacle accepts either UHF-type plug or M-type plug. Also, a banana plug can be used for connection to center conductor of the receptacle. In addition, a standard 2-pole banana plug with 3/4 inch spacing can be used for

simultaneous connections to both input and ground terminals.

Furthermore, UHF-type receptacle accepts type 941B Terminal Adaptor. This terminal adaptor, similarly to GND terminal, can hold any of banana plug, spade lug, alligator clip, 2 mm (0.08 inch) prod, and wires less than 2 mm diameter.

External conductor of UHF-type receptacle and GND terminal are connected to the panel and chassis of the equipment.

In series to input terminal, a DC blocking capacitor of 600 WV oil capacitor is connected. Input impedance had been adjusted to 1 megohm with a shunt capacitance of 25 $\pm$ 2 pF and is constant in all ranges.

OUTPUT

These terminals are used when this equipment is used as an amplifier. Similarly to Type-941B Terminal Adaptor, these terminals can hold any of banana plug, spade lug, alligator clip, 2 mm (0.08-inch), prod, and wires less than 2 mm

diameter. A standard 2 pole banana plug is also convenient.

This equipment can perform both as a voltmeter and as an amplifier simultaneously. However, if load impedance is too low, several deficiciencies are caused as follows.

When resistive component of the load impedance is too low, the lower end of frequency response is sacrificed in the output circuit. However, the frequency response up to output circuit is not affected.

When capacitive component of the load impedance is dominant, the higher end of frequency response is significantly affected, Figure 2 shows an example of the effect of capacitance connected to the output terminals on the frequency response of the amplifier. However, this effect

may vary among each voltmeter and as to power line voltage.

Output terminals deliver 2.5 volts output when meter indication is full scale.

Since this equipment employs a negative feed-back circuit utililizing the current flowing in the meter, when certain load is connected, distortion and S/N characteristic may also be deteriorated.

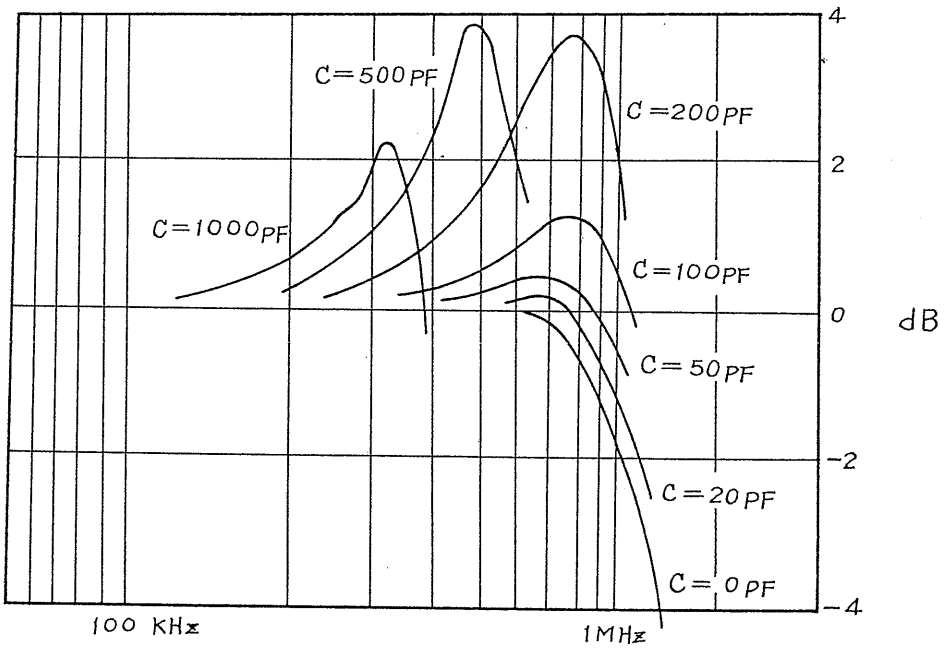



Fig. 2 Effect of capacitive load on frequency response

Meter Scale

The meter indicator of this equipment has three scales as follows:

1. Upper scale is calibrated from 0 to 50. This scale is read when range switch is set in any one of 50, 500 mV and 5, 50, 500 volt ranges.
   The figure 50 means 50 mV when range switch is placed in 500 mV position, and so on.
   Example: If meter indication is 37 with range switch placed in 500 mV position, the measured voltage is 370 mV or 0.37 volt.

2. Middle scale is calibrated from 0 to 15. This scale is read when range switch is set in any one of 15, 150 mV and 1.5, 15, 150 volt ranges.
   The meaning of the figures is same as explained above.

3. Lower scale is calibrated in dBm. This scale is read when it is required to measure dBm value (explanation on dBm will appear in later section).
   The same scale is used for all ranges.

The dBm value of the measured voltage can be obtained simply by adding the dBm value indicated on the dial to the meter indication

Example: With range switch placed in 30 dBm (50 volt) range, if meter indication is 5.5 on dBm scale, the dBm value of the measured voltage is:

$$5.5 + 30 = 35.5 \text{ dBm}$$

Example: In this condition, if range switch is turned to 40 dBm (150 volt) range, meter pointer now indicates -4.5 on dBm scale. The dBm value is then;

$$-4.5 + 40 = 40 - 4.5 = 35.5 \text{ dBm}$$

Example: With range switch placed in -20 dBm (150 mV) range, if meter indication is 3 on dBm scale, the measured voltage is:

$$3 + (-20) = 3 - 20 = -17 \text{ dBm}$$

Example: In this condition, if range switch is turned to - 10 dBm (500 mV) range, meter pointer now indicates -7 on dBm scale. The dBm value is therefore:

$$-7 + (-10) = -(7 + 10) = -17 \text{ dBm}$$

## 3.2 Errors Caused by Distorted Waveforms

This equipment is a voltmeter to indicate "mean value indicator" of the measured AC voltage, however, the scale is calibrated in RMS value. Table 1 shows several examples.

Table 1 -- Comparison of actual RMS values with indication of Model 161A

| Waveform of Measured Voltage | Calculated RMS value | Indication of Model 161A |
|---|---|---|
| Purely sinusoidal (100% fundamental) | 100% | 100% |
| 100% fundamental + 10% 2nd harmonic | 100.5 | 100 |
| 100% fundamental + 20% 2nd harmonic | 102 | 100 ~ 102 |
| 100% fundamental + 50% 2nd harmonic | 112 | 100 ~ 110 |
| 100% fundamental + 10% 3rd harmonic | 100.5 | 96 ~ 104 |
| 100% fundamental + 20% 3rd harmonic | 102 | 94 ~ 108 |
| 100% fundamental + 50% 3rd harmonic | 112 | 90 ~ 116 |

## 3.3 Measurement of AC Current

This equipment can also be used to measure AC current. In measurement, a known resistor is connected in series to the AC current circuit, and a voltage drop across such resistor is measured. The current is calculated by formula:

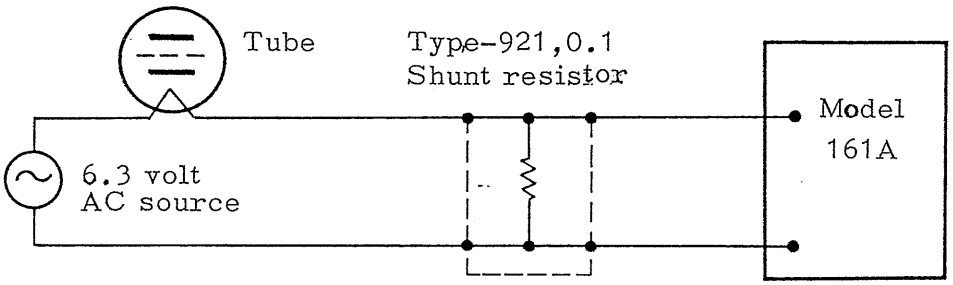
$$I = E/R$$

In this measurement, it should be noted that GND terminal of this equipment is connected to the panel and chassis.

Type-921 Shunt Resistors are available upon your separate order for your convenience in measurement of currents. These are precision resistors and their banana plugs fit to the input terminals of this equipment. Resistance values of 0.1ohm, 1ohm, 10ohms, 100ohms, 1000ohms, and in addition, 4ohms, 8ohms, 15ohms, and 600ohms, are available.

Example: How about to measure heater current of a tube with rating of 6.3 volts 0.3 amps. Using Type-921, 0.1 Shunt Resistor, a precision 0.1ohm resistor, meter indication of 29 millivolts

is read off in the connections as shown in Figure 3. Then, heater current is:




$$I = \frac{29 \times 10^{-3}}{0.1} = 290 \times 10^{-3} A = 290 mA$$

Figure 3. Measurement of Heater Current

3.4 Utilization as output meter

If voltage E impressed upon the both ends of a certain impedance X is measured, the apparent power VA in the impedance X can be obtained by $VA = E^2/X$. If the impedance X is the pure resistance R at this time, the power P consumed within the R is $P = E^2/R$. Since this instrument is provided with the dBm scale, the power can be, as described in the separate section, read in decibel as it is, in case of R = 600ohms. Also, if such decibel conversion charts as Fig. 4 and 5 are utilized, the power can be read in decibel by adding a determined number to be obtained from the charts even in case that the load resistance is lohm ~ 10ohm.

Type 921 shunt resistors include 4ohms, 8ohms, 15ohms of the same resistance values as the voice coil impedance of the speaker that is ordinarily used, and can be put to use as the load resistors of small capacity (0.3W), so that this instrument can be utilized as an output meter.

# 4. USING DECIBEL CONVERSION CHARTS

## 4.1 Decibel . dB suffix . dBm

Bell (B) is a unit given to a common logarithm of a ratio of two values of power with base of 10, and decibel (dB) is one tenth of bell.

Decibel is therefore defined by following formula:

$$dB = 10 \log_{10} \frac{P_2}{P_1}$$

Herein, if impedances at which P1 and P2 are measured are equal, ratio of power simultaneously gives ratio of voltage or current, and formulas:

$$dB = 20 \log_{10} \frac{E_2}{E_1}$$

$$dB = 20 \log_{10} \frac{I_1}{I_2}$$

are obtained.

For example, if input voltage of an amplifier is 10 millivolts and output is 10 volts, its amplification is 10/0.01 or 1000. In decibels,

$$\text{Amplification} = 20 \log_{10} \frac{10\,V}{10\,mV} = 60 \text{ decibels}$$

In RF signal generators, output voltage is expressed in decibels in reference to 1 microvolt. For example, 10 millivolts is

$$10\text{mV} = 20 \log_{10} \frac{10\text{mV}}{1\ \mu\text{V}} = 80 \text{ decibels}$$

dBm is a unit given to a value of power as compared to 1 milliwatt assuming an impedance of 60 ohms. Therefore, 0 dBm equals:

0 dBm = 1 milliwatt into 600 ohms

= 0.775 volts across 600 ohms

= 1.291 mA through 600 ohms

The meter indicator of this equipment is calibrated in dBm, therefore, in order to obtain decibel value with other reference than 1 milliwatt into 600 ohms, a constant figure should be added or subtracted from the meter indication. Such figure can be obtained using Figures 4 and 5. Figure 4 is convert ratio of voltages, currents, or powers into decibels.

Example 1: How many decibels is 5 milliwatts as referred to 1 milliwatt?

Ratio 5 mW/1 mW = 5 is obtained, and 7 dB is obtained as shown by dotted lines

in Figure 4.

Example 2: How many decibels are 50 milliwatts and 500 milliwatts as referred to 1 milliwatts ?

When ratio is more than 10 or less than C.1, the relation shown in Table 2 is used, and decibel values are obtained as follows.

500mW = 50 mW x 10 = 7 dB + 10 dB = 17 dB

500 mW = 5 mW x 100 = 7 dB + 20 dB = 27 dB

Example 3: How many decibels is 15 mV as compared to 1 volt.

15 mV/1 V = 1.5 x 0.01 = 3.5 dB + (-40) dB = -36.5 dB

TABLE 2

| Ratio | | Decibel Power ratio | Voltage or current ratio |
|---|---|---|---|
| 10000 | $= 1 \times 10^{4}$ | 40 dB | 80 dB |
| 1000 | $= 1 \times 10^{3}$ | 30 dB | 60 dB |
| 100 | $= 1 \times 10^{2}$ | 20 dB | 40 dB |
| 10 | $= 1 \times 10$ | 10 dB | 20 dB |
| 1 | $= 1 \times 10^{0}$ | 0 dB | 0 dB |
| 0.1 | $= 1 \times 10^{-1}$ | -10 dB | -20 dB |
| 0.01 | $= 1 \times 10^{-2}$ | -20 dB | -40 dB |
| 0.001 | $= 1 \times 10^{-3}$ | -30 dB | -60 dB |
| 0.0001 | $= 1 \times 10^{-4}$ | -40 dB | -80 dB |

Figure 5 is used in obtaining power value converting dBm reading on the meter indicator.

Example 1: Measuring a voltage across voice coil of 8-ohms speaker, an indication of -4.8 dBm is obtained on the meter. Then, what is the power delivered to the speaker in milliwatt ? In Figure 5, a figure +18.8 is obtained as shown by dotted line. This figure is added to meter indication,

$$-4.8 + 18.8 = +14 \text{ dB}$$

Then, using Figure 4, -14 dB can be converted into 25 milliwatts.

Example 2: How many volts of voltage is required to deliver a power of 1 watt into a 10-kiloohm load ?

1 watt is equal to 1000 milliwatts and is 30 dB as referred to 1 milliwatt.

In Figure 5, a figure - 12.2 is obtained. Then, meter indication should be 30 - (-12.2) = 42.2 dBm to deliver 1 watt into 10 kiloohm load.

The indication 42.2 dBm is 2.2 dBm in range of 40 dBm (0 ~ 150 volt) and equal to 100 volts.

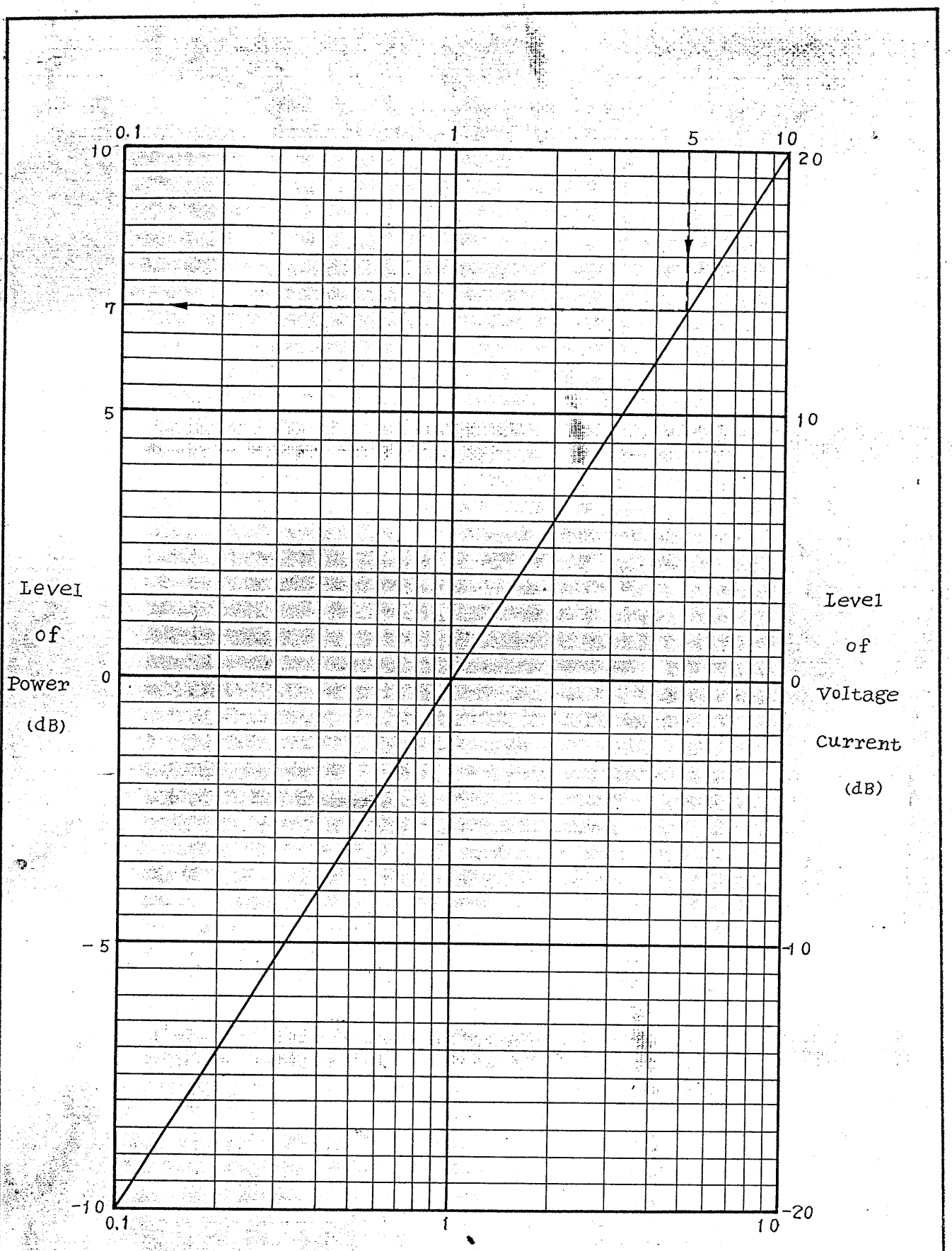

0.1
1
5
10
10
7
5
0
-5
-10
20
10
0
-10
-20
0.1
1
10
Level of Power (dB)
Level of Voltage Current (dB)
Ratio of Voltage Current Or power

Fig 4