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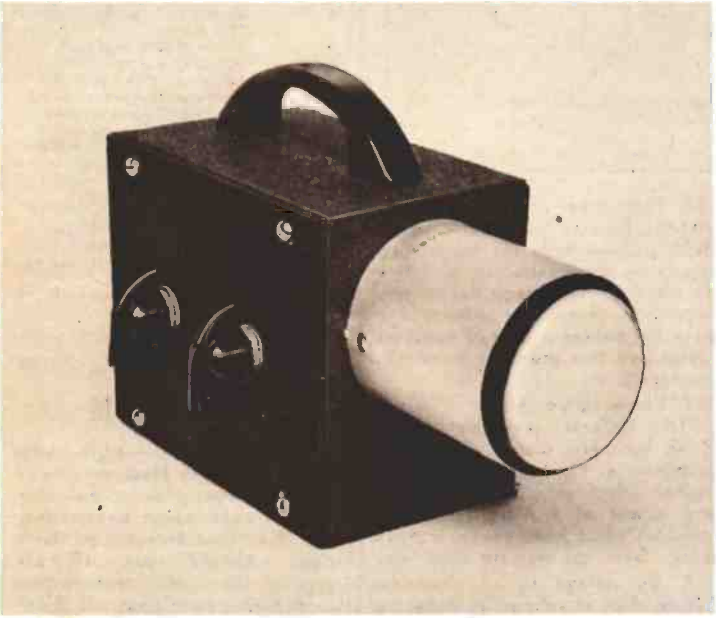
UNIQUE 'RAY GUN MONITOR CHECKS MODULATION QUALITY

'RAY GUN MONITOR



The unique unit shown above improves Ham 'phone technique by giving a positive visual indication of modulation quality. It's easy to build and can be made from a 2BP1 tube and a few inexpensive components

SIMPLE VISUAL MONITOR 'SCOPE EMPLOYS 2BP1 CATHODE-RAY TUBE

By J. H. OWENS, W2FTW

If you would like to see your voice as others hear it, and if you would like to hear your station praised by those who can't see it, take this tip to check up on the quality of your modulation. It's so easy and so positive with the new RCA 'Ray-Gun Monitor.

The modern Amateur phone station transmits with a modulated signal comparable to that of a broadcasting station. In common use are the techniques of high-frequency pre-emphasis, band-width restriction, correct phasing of non-linear voice waves, automatic modulation control, clipper-filters, compression, harmonics suppression, and other very professional engineering practices. Of course, such advanced practices require the use of elaborate test and measuring equipment, but a great amount of progress can be made with a simple cathode-ray visual indicator such as the 'Ray-Gun Monitor.

Consisting of an RCA-2BP1 CR tube, a 3" x 4" x 5" cabinet, an 807 tube shield, with several resistors, capacitors, and pieces of wire, the unit can be put together in a few hours by the average ingenious Amateur. Reference to the circuit diagram will prove that there are fewer complications involved than would be encountered in the building of a "one-tube blooper".

The 'Ray-Gun Monitor is built without a power supply to provide portability, simplicity, and low cost. By means of flexible clip-lead cables it can be attached readily to almost any amateur transmitter. A pair of alligator clips are used for connecting a source of 6.3 volts to the heater. If the heater supply is not grounded, make sure that the peak heater-to-cathode voltage on the 2BP1 does not exceed ±125 volts. A larger battery-clip goes to the transmitter ground, which is also the negative high-voltage return. One of the insulated pee-wee (red) clips connects to the unmodulated high-voltage dc, and the other one (black) goes to the modulated high-voltage supply of the plate-modulated final amplifier. RF is fed into the unit through the

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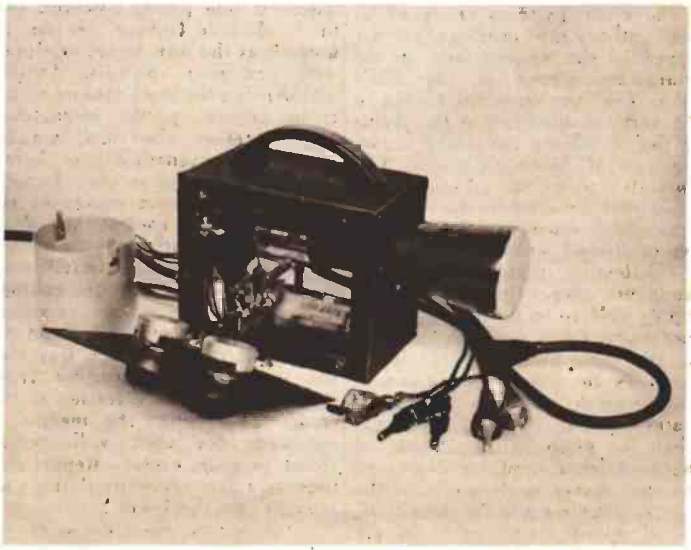
AN INTERIOR VIEW



The 'Ray Gun Monitor with its cabinet cover removed shows a logical layout of wiring and parts. It requires no power supply.

ANALYSIS OF CLASS B MODULATORS FOR AMATEUR 'PHONE APPLICATION

Brass-pounding may provide the basic interest in Amateur Radio, but "mike hounding" gives it the flavor of romance. Radiophone communication has the charm of reality—to hear the other fellow's voice as he hears yours—to speak half-way around the globe as if in person—this is a treat the whole family can enjoy.

If you haven't as yet tried 'phone, why not give it a fling? The cost is moderate, and the benefits can be very worthwhile. For instance, putting sound on your carrier will acquaint you with subjects of interest in radio-broadcasting, public address, and the other electronic arts and professions.

Where to start? Probably you are already familiar with microphone and speech amplifier circuits. The modulator is the final link in the radiophone chain, so a review of the theory and design practice of class B amplifiers is in order.

Basic Principles

A class B audio-frequency amplifier employs a pair of tubes, connected in push-pull, and biased near the point of plate-current cut-off, where the grid-voltage--plate-current characteristic starts to bend sharply. At low signal levels both tubes work together in complementary fashion, but at higher levels each tube alternately conducts and rests, and the resulting half-waves are combined in the modulation transformer to produce a composite wave which is an amplified replica of the original signal.

Objectives

One advantage of class B operation is that it provides high peak

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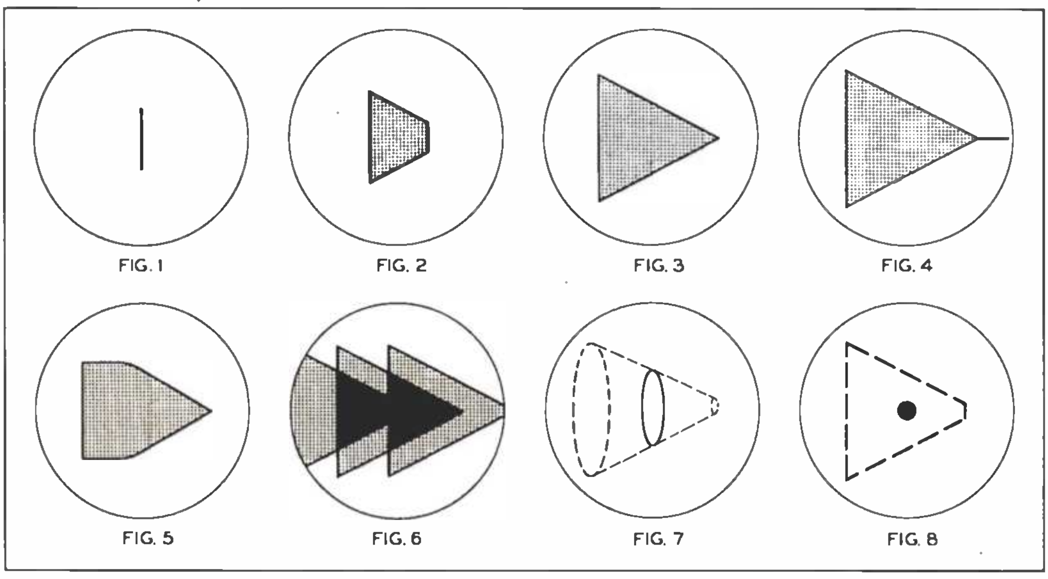
'RAY GUN SCOPE VISUAL PATTERNS



#1. Unmodulated carrier. RF on vertical-deflection plates. No ac voltage on horizontal-deflection plates. Adjust rf coupling loop so that vertical line is about one-half inch long. A thickened line indicates hum or other noise on carrier.

#2. 50% modulated carrier. Left-end vertical line is 50% longer than unmodulated line of Fig. 1. Right-end vertical line is 50% shorter than the same unmodulated vertical line. Straight diagonal lines indicate linear modulation.

#3. 100% modulated carrier. Left-end vertical line is 100% longer than unmodulated line. Right-end vertical line is 100% shorter than unmodulated vertical line. Carrier shift is present when left-end vertical line is less than twice as long as unmodulated line. If unsymmetrical speech waves are properly phased, left-end vertical line may be more than twice as high as unmodulated line, and without distortion.

#4. Overmodulated carrier. Right-end spout indicates complete disappearance of carrier on negative peaks of modulation. Bad modulation splatter results due to generation of high-frequency audio harmonics.

#5. Downward modulated carrier. Final amplifier incapable of 100% positive-peak modulation. May be due to insufficient grid drive, too much fixed bias, insufficient grid-leak bias, or low emission of final tubes.

#6. Poor power supply voltage regulation. Because the monitor obtains its dc voltage from the high-voltage supply of the transmitter, a shift in dc plate supply voltage due to poor regulation develops a difference of potential between the two horizontal plates and thus produces a series of trapezoids.

#7. Unmodulated carrier. Ellipsoidal pattern indicates some out-of-phase rf on horizontal plates. Effect is as prominent at 150 Mc as illustrated in figure. Effect very slight at 30 Mc, and absent at 4 Mc. Dashed line indicates effect when carrier is modulated. Does not indicate distortion.

#8. Dc voltage on all electrodes, but no rf or af voltage on deflecting plates. Expanded spot indicates that deflection plates are picking up some stray rf and af voltages. 100% modulation can not reduce small end of trapezoidal pattern smaller than size of spot, as indicated by dashed line.

RAY GUN MONITOR

(Continued from Page 1, Column 4)

coaxial cable from the Faraday-shield pick-up loop. One of the knobs is a brightness control and the other one is for focusing the electron beam to a tiny spot.

The visual patterns produced by this cathode-ray oscilloscope are traced by the moving spot on the fluorescent screen of the 2BP1 tube. The spot scans the screen in the vertical direction as the result of the rf voltage impressed across one pair of deflecting plates. The spot also scans the screen in the horizontal direction as the result of the audio-frequency modulator voltage impressed across the other pair of deflecting plates. When the modulator causes this class C plate supply voltage to be increased, the spot moves horizontally to one side. At the same time, the rf output increases to supply an increased voltage across the vertical deflector plates of the 2BP1. Conversely, when the plate voltage supply of the modulated amplifier decreases, the spot moves horizontally in the reverse direction. At the same time, the rf output decreases to supply a reduced voltage across the vertical-deflection plates of the 2BP1. The result is that the spot forms a trapezoid.

Construction

The utter simplicity of the 'Ray-Gun Monitor precludes a discussion of the details of fabrication. There is one point, however, that might deserve further mention inasmuch as the unit is not equipped with centering controls. Cutting and drilling the steel cabinet causes it to become partly magnetized, and, therefore, the small amount of residual magnetism may deflect the electron beam so that the spot is not in the exact center of the tube screen. To correct this condition it is only necessary to neutralize the effect of the small magnetic field produced by the cabinet. Take a horseshoe magnet, or an old PM speaker, and move it about the closed cabinet in such a way that the spot is forced further from center in the same direction as the error. Then when the magnet is removed, the spot will return closer to exact center. Repeat this process a few times until the spot is right "on the beam".

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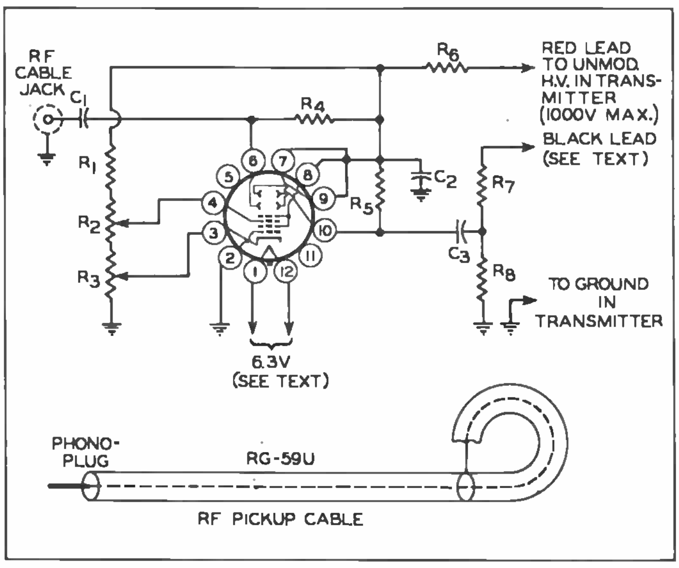
PARTS LIST

R1	1	megohm, 1 watt
R2	500,000	ohms, midget potentiometer —straight line taper preferred
R3	50,000	ohms, midget potentiometer —tone control taper preferred
R4	0.5	megohm, 1 watt
R5	3.9	megohms, 1 watt
R6	68,000	ohms, 1 watt
R7	2.2	megohms, 1 watt
R8	150,000	ohms, 1 watt
C1	0.005	µf Centralab BC-Hi-Kap or equivalent, 500 volts dc working
C2	0.1	µf paper capacitor, 1000 volts dc working
C3	0.01	µf Centralab BC-Hi-Kap or equivalent, 500 volts dc working
1		RCA 2BP1 cathode-ray tube (2")
1		Alden (Na-ald) #212FTSC diheptal socket (alternate, Amphenol #59-402-12)
1		3" x 4" x 5" metal cabinet
2		Knobs, Bud #K-575 or ICA #1125
1		Millen #80007 shield can
1		ICA #2375 or Bud #PL-247/JP-248 Plug and Jack
1		Drawer-pull or cabinet handle
2		Birnback #430 or Johnson #600 standoff insulators
2		Bud #TS-1973 or ICA #2438 terminal strips
4		Pee-Wee Clips
1		Small-size battery clip
2		Rubber clip-covers
6		Rubber grommets, ½" size
1		RG-59U coaxial cable
1 ea.		Red and black test lead cables (2 or 3 feet)
3 ea.		Pieces flexible push-back wire (2 or 3 feet)

CAUTION

Because of the high voltages present in Ham transmitters, Amateurs must exercise special care when connecting the 'Ray-Gun Monitor to their rigs. Always turn off all power from the transmitter and make sure that all filter condensers are completely discharged before making any clip lead connections. It's better to be safe than sorry!



Schematic diagram of 'Ray Gun Monitor. Connections to base pins 9 and 10 may be interchanged to reverse the pattern horizontally.

CLASS B MODULATORS

(Continued from Page 1, Column 2)

output power with respect to the no-signal input power. In the quiescent "no signal" condition, audio amplifier tubes dissipate all of the power delivered to them. As a result, if high plate voltages are used, the quiescent plate current must be kept low in order that dissipation ratings will not be exceeded under the no-signal condition.

Good plate circuit efficiency is another characteristic of class B audio amplifiers. One reason is that when the input signal level becomes appreciable, all of the plate current becomes signal plate current. Also, as a result of the grids being driven positive, the plate voltage swings all the way to the diode line on peak positive grid excursions and the peak values of plate current are, therefore, much higher than would be obtained under class A, AB, or AB_1 conditions. In the case of high-perveance tubes like RCA-811's, the voltage at the diode line is small, thus providing an efficiency factor approaching the theoretical maximum of 78.5% which would exist if the plate swing equalled the plate-supply voltage, as shown by the formula:

$$\text{Plate efficiency} = \frac{\pi}{4}\left(1 - \frac{E\,min}{E\,b}\right) 100$$

Where E min is plate voltage at diode point and E_b is the plate-supply voltage. If E min is taken as zero, the plate efficiency is equal to 78.5%.

In a practical circuit, using a pair of RCA-811's at 1500 volts and a load line of 4400 ohms (17,600 ohms plate-to-plate), the voltage at the plates (E min) would be pulled down to 70 volts on maximum signal peaks. Under these conditions, the efficiency formula would give the following results:

$$\text{Plate eff.} = \frac{\pi}{.4}\left(1 - \frac{E\,min}{E\,b}\right) 100 =$$

$$0.785 \quad (1 - (70 \div 1500)) \quad 100 =$$
$$0.785 \times 0.954 \times 100 = 75\%$$

This formula holds for pure sine-wave signals only, and does not take into account transformer losses. If considerable harmonic distortion is allowed, the efficiency can be slightly higher, but such distorted power output should not be credited as useful power output. Reputable tube manufacturers indicate conservative values of tube power output from which it is only necessary to deduct transformer losses to obtain actual amplifier power output.

Typical Operation

Although tube handbooks provide tables of typical operating data, it is frequently desirable to establish a set of conditions for a particular application that has not been previously used as an example. To illustrate the procedure, consider the combination of a 1500 volt dc power supply and a pair of 811's, but the need for only 140 watts of audio power.

To be on the safe side and provide for a slightly higher than normal amount of circuit and component losses, a conservative efficiency factor of 70% should be used. The required plate power input to a class B amplifier (P_{in}) can then be determined from its relation to the desired power output (P_o):

$$P_{in} = \frac{P_o}{0.7} = 140 \div 0.7 = 200 \text{ watts}$$

The total dc plate current (I_b) at maximum signal, with a plate-supply voltage (E_b) of 1500 then becomes

$$I_b = \frac{P_{in}}{E_b} = 200 \div 1500 = 133 \text{ ma}$$

The next step is to determine the peak value of signal plate current per tube (I_p):

$$I_p = \frac{\pi I_b}{2} = 1.57 \times 133 = 210 \text{ ma}$$

Reference to the plate family will show that 210 ma is located on the diode line at approximately 50 volts. This means that the plate swings from 1500 down to 50 volts on peak positive grid excursions, and provides a peak plate swing (E_p) of 1450 volts. The load line can now be drawn as a straight line between 1500 volts at zero plate current (E_b) and the point of intersection of 210 ma (I_p) and 50 volts (E min). The load resistance (R_L) represented by this line can be calculated as follows:

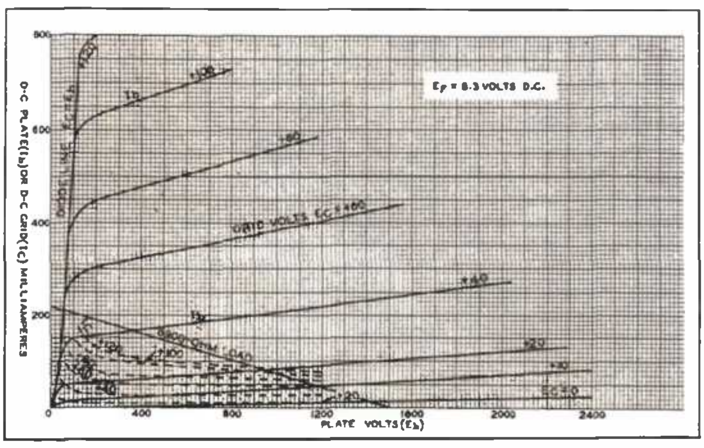
$$R_L = \frac{E_p}{I_p} = \frac{1450}{0.210} = 6900 \text{ ohms}$$

The equivalent plate-to-plate load impedance is four times the plate load per tube, or 27,600 ohms. This value of effective load resistance is optimum for the conditions set up in the problem. If a lower value is used, more power output can be obtained but the efficiency will be slightly lower. Any difference in distortion is negligible. Plate power output for a class B amplifier can now be calculated from the formula:

$$P_o = \frac{I_p\,(E_b - E\,min)}{2} =$$

$$\frac{0.210\,(1500 - 50)}{2} = 152 \text{ watts}$$

This is more than the required 140 watts and provides ample safety factor for higher than normal circuit and component losses.



Average plate characteristics of the 811. Note that emission capabilities far exceed class B amplifier requirements.

Grid-Circuit Conditions

The exact value of negative grid bias (E_c) needed is not critical. A satisfactory approximation can be obtained by dividing the plate-supply voltage by the tubes' amplification factor. In the case of 811's, which have a mu of 160, the value obtained is —9.5 volts. This value would be exact cutoff if the grid-voltage/plate-current characteristic were a straight line. In practice, this theoretical cutoff voltage is very near to the optimum bias voltage.

At plate potentials of 1250 volts or less, the 811's will operate within plate dissipation ratings without any negative grid bias. Because of this feature, they are called "zero bias modulators". High-mu tubes can be used without negative grid bias when the product of plate voltage and quiescent plate current is less than the tubes' dissipation ratings.

Again, referring to the plate family, it will be seen that a peak plate current of 210 ma is drawn at 50 plate volts when the grid goes approximately 55 volts positive. The peak a f cathode-to-grid voltage (E_g) will be 55 plus the bias voltage or close to 64 volts. To determine the grid driving power of a class B amplifier, refer to the plate family of curves and note the peak value of grid current (I_g) that flows when the plate voltage is minimum (50 volts) and when the grid voltage is at the crest of its cycle (+55 volts). It will be seen to be 70 ma. Grid driving power for two tubes (W_g) can now be ascertained by solving the equation:

$$W_g = \frac{I_g\,(E_g + E_c)}{2} =$$

$$\frac{0.07 \times 64}{2} = 2.24 \text{ watts}$$

The minimum effective resistance (R_g) of one modulator tube grid can also be determined for impedance-matching purposes. The formula is

$$R_g = \frac{E_g + E_c}{I_g} = \frac{64}{0.07} = 915 \text{ ohms}$$

Audio Power Requirements

The ratio of power input to the final amplifier and audio power output from the modulator is usually stated as 2 to 1 for 100% plate modulation. This ratio holds true only when sine-wave modulation is used, since it is based upon the relationship of voltages.

To illustrate with an example, consider a 100-watt class C amplifier drawing 100-ma from a 1000-volt plate supply. 100% modulation requires that the plate voltage be alternately doubled and reduced

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A FAMOUS PAIR—RCA-811'S

These transmitting triodes have long been the Amateurs' favorite class B modulators.

RCA 2BP1 2" OSCILLOGRAPH TUBE

2BP1 OSCILLOGRAPH TUBE 2"—Diameter Bulb

DATA

General:		
Heater, for Unipotential Cathode:		
Voltage (AC or DC)	6.3	Volts
Current	0.6	Ampere
Phosphor	No. 1	
Fluorescence	Green	
Persistence	Medium	
Focusing Method	Electrostatic	
Deflection Method	Electrostatic	
Base	Small-Shell Duodecal 12-Pin	
Mounting Position	Any	
Maximum Ratings, Design-Center Values:		
ANODE- No. 2 & GRID-No. 2 VOLTAGE	2500 max.	Volts
ANODE-No. 1 VOLTAGE	1000 max.	Volts
GRID-No. 1 VOLTAGE:		
Negative bias value	200 max.	Volts
Positive bias value	2 max.	Volts
PEAK VOLTAGE BETWEEN ANODE No. 2 AND ANY DEFLECTING ELECTRODE	500 max.	Volts
PEAK HEATER-CATHODE VOLTAGE:		
Heater negative with respect to cathode	125 max.	Volts
Heater positive with respect to cathode	125 max.	Volts
Equipment Design Ranges:		
For any anode No. 2 voltage (Eb_2) between 500 and 2500 volts		
Anode-No. 1 Voltage	15% to 28% of Eb_2	Volts
Grid-No. 1 Voltage for Visual Cutoff	0% to 6.75% of Eb_2	Volts
Anode-No. 1 Current for Any Operating Condition	—15 to +10	Microamp.
Deflection Factors:		
DJ1 & DJ2	115 to 155 V dc/in./Kv of Eb_2	
DJ3 & DJ4	74 to 100 V dc/in./Kv of Eb_2	

Examples of Use of Design Ranges:			
For anode-No. 2 voltage of	*1000*	*2000*	*Volts*
Anode-No. 1 Voltage	150-280	300-560	Volts
Grid-No. 1 Voltage for Visual Cutoff	0-67.5	0-135	Volts
Deflection Factors:			
DJ_1 & DJ_2	115-155	230-310	Volts dc/in.
DJ_3 & DJ_4	74-100	148-200	Volts dc/in.

Maximum Circuit Values:		
Grid-No. 1-Circuit Resistance	1.5 max.	Megohms
Resistance in Any Deflecting-Electrode Circuit	5.0 max.	Megohms

Amateur Net **$8.75**

Features

- High deflection sensitivity
- Good sensitivity to 150 Mc
- Sharp focus over entire screen
- Improved electron-gun with zero-current first anode
- Operates with a plate supply of only 500 volts
- Individual base-pins for all deflecting electrodes

Application Considerations

1. Focus of the electron beam is accomplished by the adjustment of anode #1 voltage with respect to anode #2 voltage.
2. Spot centering may be obtained electro-magnetically or electro-statically. If the latter is used, it may be necessary to apply to adjacent deflecting plates a voltage difference as high as 2% of the dc voltage on anode #2.
3. Brightness may be increased by a reduction of the negative bias on grid #1, or by an increase of the positive voltage on anode #2.
4. For best results, anode #2 voltage should be 500 volts or higher. 1000 volts provides a brilliant trace that is clearly visible in a well-lighted room.
5. An oscillograph circuit in a 12-page technical bulletin is available on request. Write to RCA, Commercial Engineering, Harrison, N. J.

RAY GUN MONITOR

(Continued from Page 2, Column 2)

Application

The 'Ray-Gun Monitor can also be used to show a wave-form pattern. In this use, the modulated dc voltage on the horizontal deflecting plate should be replaced with 60-cycle ac. This change can be made by connecting the clip of the horizontal deflection lead to the plate of one of the high-voltage rectifier tubes.

The 'Ray-Gun Monitor is designed for use with transmitters operating at plate voltages up to about 1000 volts. The limitation is the working voltages of the various capacitors. When the Monitor is used with higher-voltage rigs, bleeders will have to be used to reduce the voltages to which the clip-leads are attached to not over 1000 volts. The bleeders can be made up of 1-megohm, 1-watt carbon resistors. These resistors should be permanently wired in the transmitters so that the 'Ray-Gun Monitor can always be put to work in a few seconds.

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CLASS B MODULATORS

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to zero. This would require an alternating peak voltage of 1000 volts, or an RMS voltage of $1000 \div \sqrt{2}$ or 707 volts. The 1000-volt, 100-ma class C amplifier load appears to the modulator as a pure resistance of 10,000 ohms as determined from the relationship:

$$R = \frac{E_b}{I_b} = \frac{1000}{0.1} = 10{,}000 \text{ ohms}$$

The sine-wave power required to develop 707 RMS volts across 10,000 ohms can be determined from the formula:

$$\text{Watts} = \frac{E^2}{R} = 707^2 \div 10{,}000 = 50$$

If the modulating signal were a square wave, 1000 volts would still be required for 100% modulation. But in this case, the average voltage would equal the peak voltage, therefore 100 watts of square-wave audio would be required to plate-modulate 100 watts of power input to the final amplifier. This condition is almost reached when a "clipter" is used and adjusted for maximum clipping and filtering.

When voice modulation is used, the condition is again different, although 1000 peak volts of audio power is still required. The RMS voltage of an average speech wave is less than half the peak voltage. If a figure of 50% is used, for example, the RMS modulating potential would be 500 volts, and the modulation power would be $500^2 \div 10{,}000$ or 25 watts. This is why some Amateurs figure on a 4 to 1 ratio of class C input to modulator power output.

On the above basis a pair of 811's would be capable of modulating 880 watts input to a final amplifier. However, to get the 1000 peak volts for 100% modulation, the turns ratio between primary and secondary of the modulation transformer has to be reduced. As a result, the transformer reflects a lower than proper load impedance to the modulator plates. Under these conditions, the class B modulator tubes can be quickly overloaded by a sine-wave signal from a test oscillator, or a whistle, or a soft female voice—and we should never do anything that might possibly keep those purring YL's and XYL's out of our Ham Shacks.