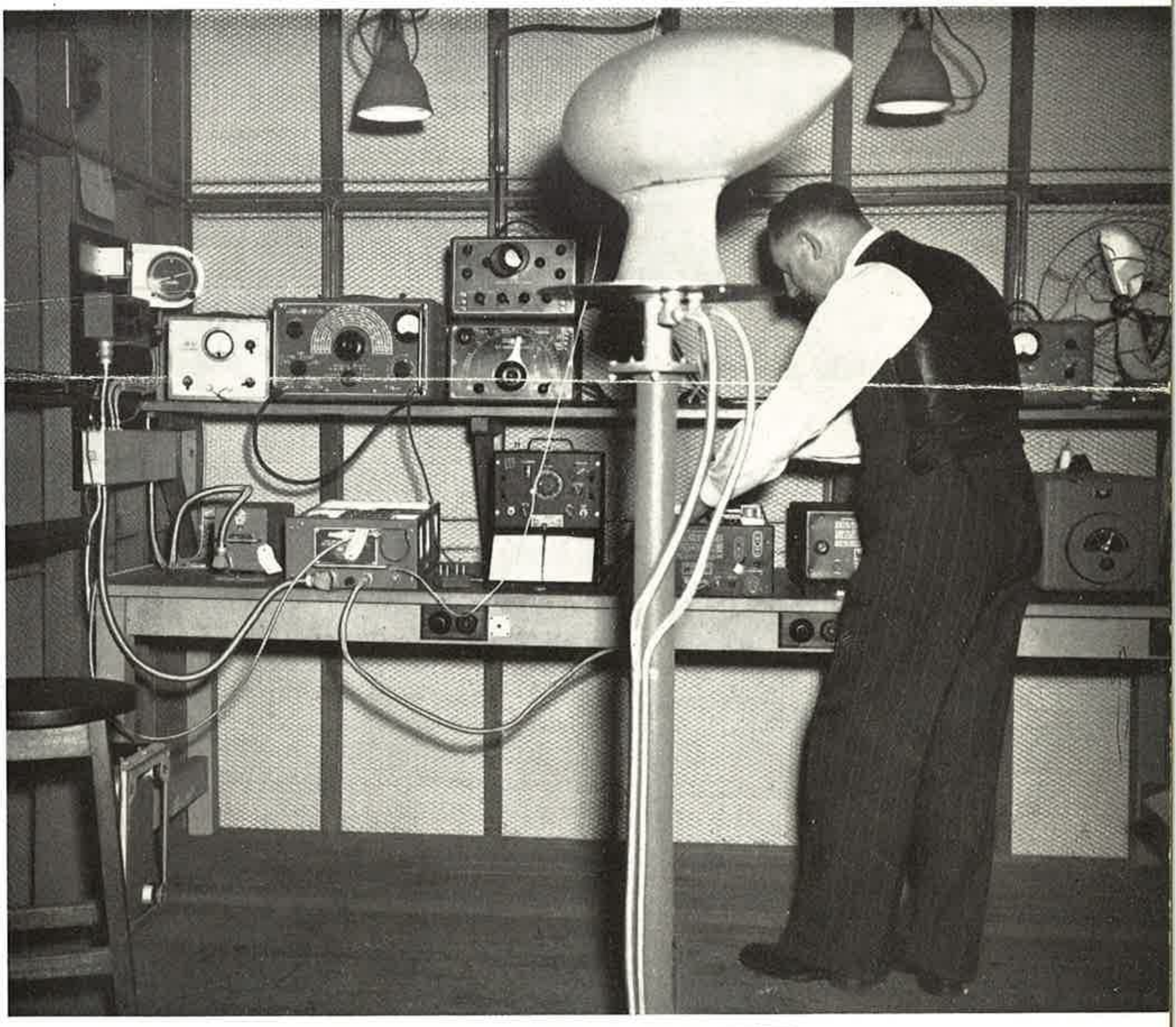
Radiotronics

AN A.W.V. TECHNICAL PUBLICATION DEVOTED TO RADIOTRONS AND THEIR APPLICATION

Number 144
AUGUST, 1950



Servicing Airborne Electronic Equipment

RESEARCH • DESIGN • MANUFACTURE

Number 144 **August, 1950**

RADIOTRONICS

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CONTENTS

COMMUNICATION RECEIVER DESIGN.
A highly informative article will appear on this ever-topical subject in the next issue of Radiotronics.

[Radiotronics for 1950 will be dated as follows: No. 141, February; No. 142, April; No. 143, June; No. 144, August; No. 145, October; No. 146, December.]

All communications should be directed in Australia to—
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See also Report #5 on R106 — "Playthrough Reduction."

CIRCUIT LABORATORY REPORT **NUMBER 4.**

Radiotron Reflex Receiver *RD34*

In Radiotronics 140 (November-December 1949) a description of an economy straight 4 valve receiver RD33 using types 6A8-G, 6AR7-GT, KT61 and 5Y3-GT was published. Although the receiver RD33 has a performance adequate for the majority of suburban locations, experience has shown that in all straight 4 valve receivers the a-f response must be deliberately restricted, as in the RD33, to avoid flutter, while a reasonably large signal input, according to the standards of country listening, is required to drive the output valve to full output. In the case of the above receiver, it will be seen from the a.v.c. curve, shown on page 100 of Radiotronics 140, that approximately 250 μV input is required to give an a-f output of 1 watt, which may be regarded as the lowest acceptable maximum output for a small a.c. receiver.

In the receiver RD34 the same valve types are used except that the rectifier is a type 6X5-GT, but by reflexing, the above limitations are avoided while a considerable improvement has been obtained in overall performance. An input of less than 20 μV gives an a-f output of 1 watt, and advantage has been taken of the increased a-f gain available to apply negative feedback for distortion reduction and tone compensation. From the point of view of sensitivity, tone and distortion, receiver RD34 compares more than favourably with many pre-war 5 valve console receivers.

These improvements, however, have been obtained at the cost of a small increase in the number of components compared with the straight set, and some difficulties in filtering and layout. The sensitivity is high—about 5 μV averaged over the broadcast band—and proper care is required to avoid regeneration in the restricted layouts usually employed for 4 valve receivers. Three experimental receivers have been built using different layouts and components, and all operated satisfactorily, but it is stressed that the recommendations made throughout should be closely followed.

Screen reflexing

A feature of the reflex circuit used is that the audio signal obtained by demodulating the i-f output of the 6AR7-GT is returned to the control grid and an amplified a-f output is obtained from the screen circuit. The 6AR7-GT thus operates as a pentode amplifier at intermediate frequencies and as a triode amplifier, using the screen as a triode plate, at audio frequencies. In this way, an appreciable reduction in playthrough can be obtained in the case of the 6AR7-GT for a given overall i-f and a-f gain, compared to that obtainable with plate reflexing.

Another advantage is that the screen voltages of the converter and i-f valves can be separately adjusted for optimum operation without using additional components. It is necessary, however, that the screen by-passing should be adequate to avoid i-f regeneration.

Playthrough

Reflex receivers as a class, unless very carefully designed, are liable to unpleasant inherent effects when the volume control is near its minimum setting. On a strong station there is always some playthrough and as the volume control is turned up the volume usually decreases to a minimum accompanied by high distortion. In this receiver the combination of screen reflexing and negative feedback reduces to a low level both playthrough (less than 0.1 milliwatt with an input of 50,000 μV modulated 30% at 400 c/s) and distortion.

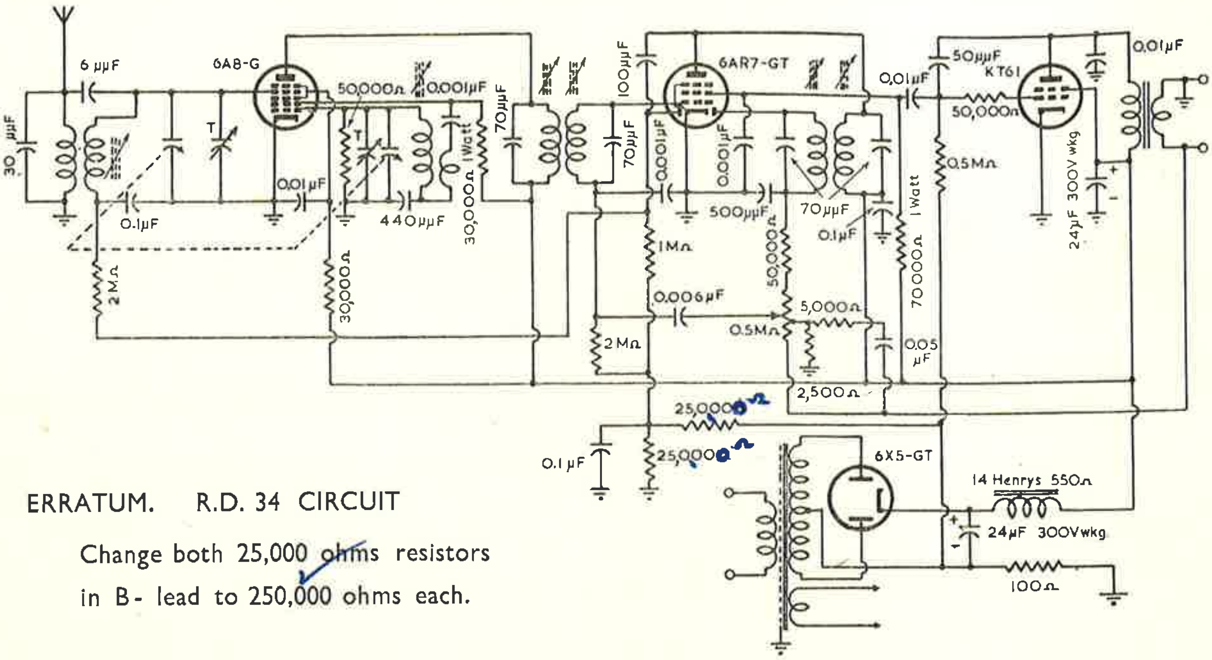
It is not possible to use negative feedback effectively if full a.v.c. is applied to the reflexed valve because a strong signal then reduces the a-f gain, which in turn reduces the feedback. Under these conditions feedback is available on weak signals when it is not needed, but very much reduced on strong signals for which it is required.

On the other hand, if no a.v.c. is used on the reflexed valve, the a-f voltage developed across the diode load by a strong signal is considerably greater than the bias of the reflexed valve, and when the volume control is turned to its maximum setting, the grid is driven positive, giving heavy damping on the input circuit. This leads to a relaxation oscillation or "bubbling".

In this receiver a fraction (one ninth only) of the developed a.v.c. voltage is applied to the reflexed valve. This amount is sufficiently small to have little effect on the feedback available on strong stations, but at the same time is adequate to prevent bubbling in normal use.

The design of each section of this receiver affects the other sections, in that sensitivity, playthrough, a.v.c. and audio characteristics are all interdependent and it is recommended that no changes be made to the circuit which affect the balance of these characteristics.

Contributed by the Circuit Design Laboratory,
Valve Works, Ashfield.



ERRATUM. R.D. 34 CIRCUIT

Change both 25,000 ohms resistors in B- lead to 250,000 ohms each.

Fig. 1.—Circuit of Reflex Receiver RD34. Component values shown are in megohms and microfarads unless otherwise indicated.

Reproduction

The a-f response has been modified to suit a typical 5 inch speaker and a small cabinet (10″ × 7″ × 6″) and because of their small size a considerable amount of bass boosting is used.

Three curves are given, showing the a-f response with the volume control arm at the tap, 20 db up from the tap and at maximum. The volume with the arm at the tap is adjusted to the lowest normal listening level by means of the 2,500 ohm resistor connected between tap and ground and consequently this setting has maximum bass boosting.

The curve taken with the arm 20 db up from the tap gives the a-f response at normal listening levels. It has bass boosting and a high frequency response to cover the upper range of frequencies normally transmitted. At higher frequencies the response is cut as sharply as possible to decrease noise and distortion products—whether from the record, the transmitter or the receiver, particularly sideband screaming while the receiver is being tuned. Because of the high frequency attenuation due to the i-f selectivity (10 db at 5 Kc/s) there is in any case little to be gained from having any appreciable a-f response above 5 Kc/s.

With the volume control at its maximum setting the high frequency response is reduced. This automatic tone control action is desirable because if the volume control is turned to maximum to receive a weak station it will remove some of the noise which always accompanies weak signals. On the other hand, if the control is at maximum on a strong station the automatic tone control effect minimizes any distortion due to overloading.

Sensitivity and noise

The 5 μV sensitivity is sufficient for almost any purpose and the receiver should perform well in country districts remote from broadcasting stations. The a.v.c. curve, Fig. 2, shows that the output from the receiver rises rapidly to 2 watts (maximum undistorted output) with increasing signal input, and the signal-to-noise ratio also increases almost at the maximum possible rate of 20 db for each 20 db increase of signal over the lower-input section of the a.v.c. curve.

Circuit details

(i) The by-pass capacitors in the reflex circuit are larger than usual (0.001 μF) for the following reason:—

Without a large by-pass on the cold side of the second i-f transformer secondary, some "screaming" is experienced on one sideband if strong stations are tuned-in with the volume control at maximum. The associated 50,000 ohm filter resistor has been reduced to the lowest possible value without regeneration occurring. This resistor is wired in series with the diode load rather than in series with the audio coupling capacitor (the more usual position in reflex circuits) because in this way the high frequency phase shift is reduced when the volume control is turned to zero, and less trouble is encountered with high frequency peaks in the a-f response.

(ii) The a.v.c. by-pass at the junction of the two 0.25 megohm resistors is required to remove hum from the voltage applied to the 6AR7-GT grid and also to remove audio frequencies which would otherwise considerably increase the playthrough on strong signals.

(iii) The plate-to-grid feedback on the KT61 is necessary to prevent high frequency instability due to the large amount of negative feedback which is used when the volume control is set to minimum. Because of this capacitor a grid stopper must be used to prevent parasitic oscillation—it is desirable in any case to ensure that this trouble does not occur in production.

(iv) The 6AR7-GT screen resistor is a 1 watt type although the dissipation is less than 0.2 watt. A large resistor is used because previous experience has shown that in such a position resistors are more prone to fail than usual. Half-watt resistors may be used when the dissipation is not specified.

(v) Padder feedback is not essential. The oscillator coil was designed to give a reasonably flat grid-current characteristic with the circuit shown, but any circuit and coil which will give satisfactory grid current can be used. It is, however, desirable to keep the oscillator plate voltage well below the permissible maximum value of 200 volts for the following reason:—

To obtain a low level of playthrough on strong signals it is essential for the i-f voltage applied to the grid of the reflexed valve to be kept to the lowest possible level, and for a given signal input this means that the gain of the converter must be as small as possible. Since at low signal input this gain must be high for good sensitivity a very effective a.v.c. characteristic is required.

This is obtained firstly by taking the a.v.c. voltage from the primary of the second i-f transformer where the voltage is higher than on the secondary, and secondly by operating the 6A8-G under conditions which give maximum gain reduction for a given control grid bias.

With the 6A8-G it is found that the conversion transconductance is very dependent on oscillator plate voltage when high negative bias values are applied to the control grid, e.g. with a control grid bias of −27 volts, the conversion conductance is reduced from about 6 micromhos to 1 micromho when the oscillator plate voltage is changed from 200 to 100 volts. On the other hand when the control grid bias is small, changes in the voltage applied to the oscillator plate have little effect on the conversion transconductance.

Thus a reduction of oscillator plate voltage for a constant value of oscillator grid current gives greater a.v.c. control by the 6A8-G and consequently less playthrough, although the initial sensitivity of the receiver is almost unchanged.

(vi) **The hum level** of the receiver is low. With the volume control at its minimum setting the

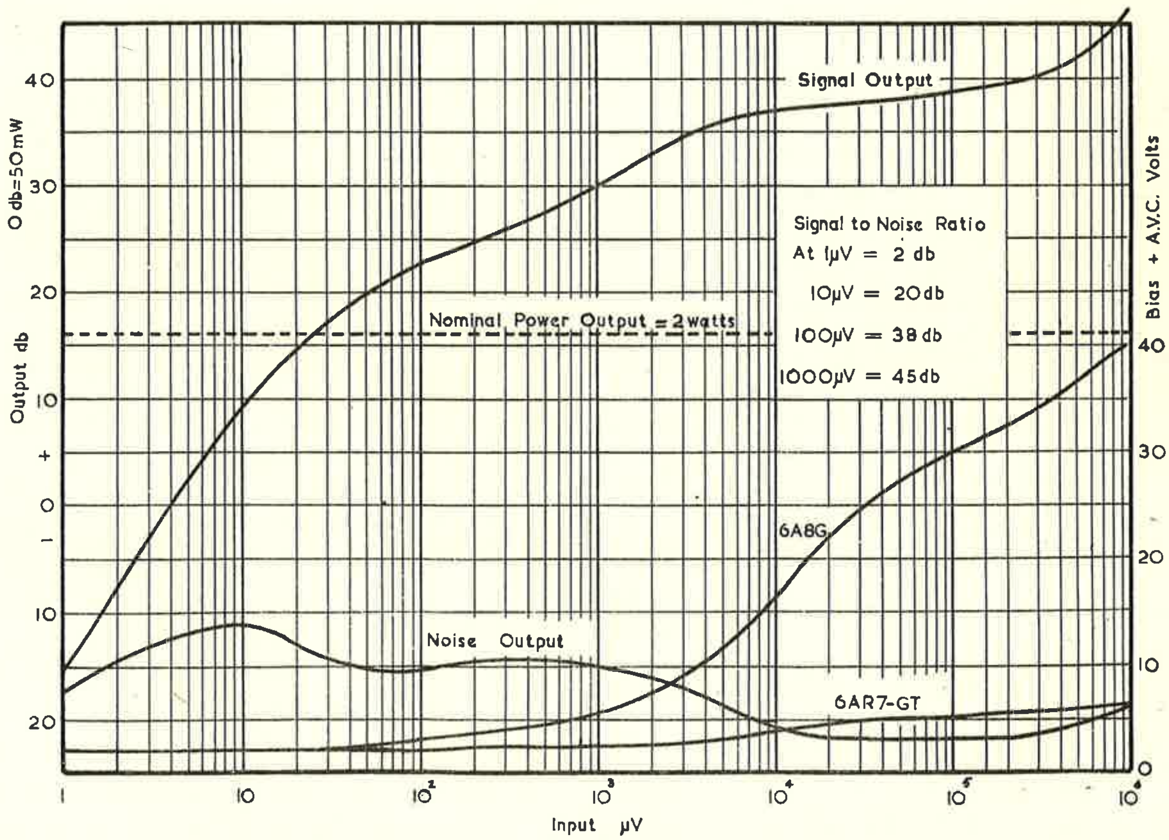


Fig. 2.—Curves of signal and noise output and a.v.c. voltages vs. signal input voltage.

a-f gain reduction due to feedback is nearly ten times, so that hum is almost inaudible. As the control is turned up the hum level increases but not to the extent of becoming noticeable under normal listening conditions. From the a.v.c. curve it will be seen that with a 1 mV input applied to the receiver the noise output (including modulation and residual hum) of the receiver is 45 db below the a-f output from a 30% modulated carrier. If it is desired to use resistive filtering to obtain a cost reduction, the residual hum will be greater and in general will not be acceptable for critical listeners.

(vii) The loudspeaker is an M.S.P. Jensen AC30 with 7,000 ohm primary and 3 ohm voice coil. With different voice coil impedances changes in the feedback constants may be required and it is probable that a higher impedance would necessitate a voltage divider to prevent instability. This will be dealt with in Circuit Lab. Report No. 5. In general, it will be found that an increase in capacitance of the 0.05 μF capacitor in the feedback circuit will decrease the frequency of maximum bass boost, and an increase in the size of the 5,000 ohm resistor will decrease the amount of feedback and thus of frequency compensation.

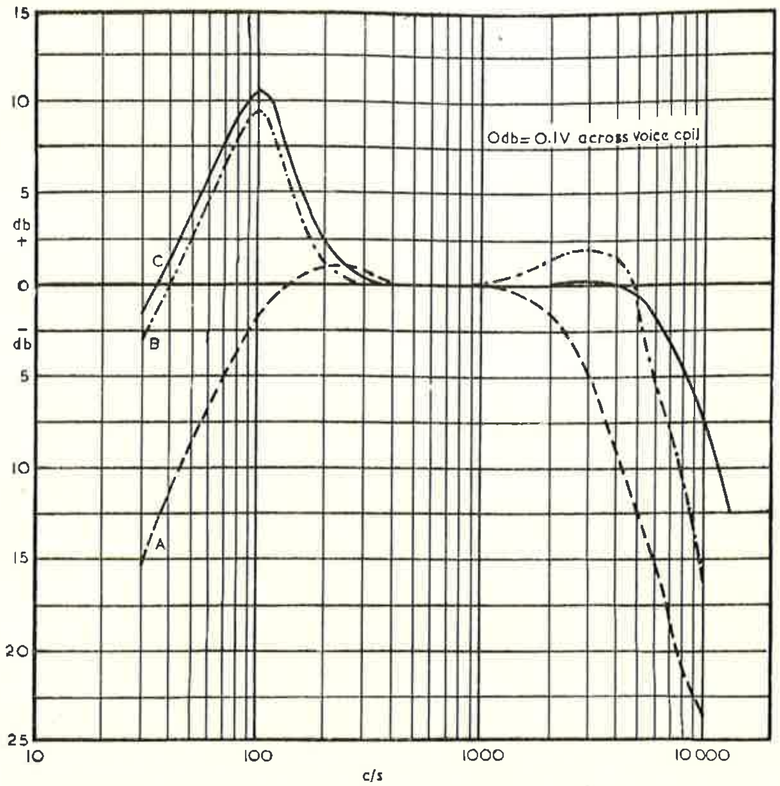


Fig. 3.—Frequency response of a-f section of receiver RD34 with no signal input to aerial.
A with volume control at maximum.
B with volume control 20 db up from tap.
C with volume control at tap.

Components

The coils and i-f transformers used in the receiver are of good quality and of a type which could be duplicated reasonably cheaply for production purposes. The i-f transformers are slug tuned and have a Q of 100 and fixed tuning capacitances of 70 μμF.

The aerial coil is a Vega type VC1 which has a secondary Q of 125 at 600 Kc/s and 120 at 1400 Kc/s. The 30 μμF capacitor and stray capacitance across the primary tune it slightly lower than the intermediate frequency. This avoids the condition in which an aerial of some particular capacitance tunes the aerial primary to the intermediate frequency and makes the receiver unstable, particularly towards the low frequency end of the band.

The oscillator coil is wound of 36 B. & S. D.C.C. wire on a $\frac{15}{32}''$ paxolin former with an adjustable iron core, $\frac{3}{8}''$ diameter by $\frac{1}{2}''$ long. The secondary consists of two $\frac{3}{16}''$ pies of 45 and 52 turns spaced $\frac{3}{16}''$ apart, and the primary is a single 45 turn $\frac{3}{16}''$ pie underneath the 52 turn pie of the secondary.

This type of coil was used to obtain a large amount of coupling between primary and secondary, but any type of winding can be used provided that the oscillator grid current is maintained over the band at approximately the figures quoted.

Layout

As stressed earlier, the receiver is dependent on good layout for successful operation. The features requiring most care are:

(i) The plate circuit of the 6AR7-GT must be isolated as far as possible from all other sections of the receiver. By-pass capacitors can be placed to provide shielding for the plate lead, the 100 μμF a.v.c. capacitor and the hot ends of the a.v.c. diode load and series a.v.c. resistor. This removes the need for shields in the receiver.

(ii) The 6A8-G input circuit must be placed to avoid coupling from the i-f channel, and if the aerial lead approaches any part of the i-f amplifier, shielded wire will probably be required.

(iii) The lead and components from the volume control to the cold end of the first i-f transformer secondary must be kept away from the plate circuit of the 6AR7-GT to avoid regeneration.

TEST RESULTS.

1. **Sensitivity (for 50 mW output)**

	400 c/s	455 Kc/s	600 Kc/s	1000 Kc/s	1400 Kc/s
KT61 grid (mV)	480 (no feedback)				
6AR7-GT grid (mV)	40 (no feedback)				
6AR7-GT diode plate (mV)		350			
6AR7-GT grid (mV)*		2.3			
6A8-G grid (μV)		39	42	44	43
Aerial (μV)			6.5	4.1	3.5
Image Ratio†			220	100	66
Noise sensitivity (μV)‡			1.5	1.3	1.2
$I_{osc.\ grid}$ (μA)			450	520	490

* Measured with 100 μμF dummy antenna.
† Measured at 10 μV.
‡ 30% modulated input required to give equal signal and noise power output.

2. **Selectivity at 1000 Kc/s**

Times down	2 (6 db)	10 (20 db)	10^3 (60 db)	10^4 (80 db)
Bandwidth (Kc/s)	6.5	15	41	55

3. **Distortion vs. Output**
(1 mV input at 1000 Kc/s, modulated 30% at 400 c/s)

Output (watts)	0.05	0.5	1.0	1.5	2.0
Total Distortion (%)	2.1	3.0	4.8	6.5	10

4. **Distortion vs. Signal Input**
(50 mW output; 1000 Kc/s input 30% modulated at 400 c/s)

Input (mV)	1	10	100	250	500	750	1000
Total distortion (%)	2.1	3.5	4.5	3.4	3.7	6.8	11

5. **Distortion vs. Modulation Depth**
(50 mW output; 1 mV input at 1000 Kc/s, modulated at 400 c/s)

Modulation (%)	20	40	60	80	100
Total distortion (%)	1.6	2.5	3.0	4.2	5.1

6. **Slump performance**
Mains voltage reduced to give E_f = 5.5 V r.m.s.
Aerial sensitivity (1,000 Kc/s) = 8 μV
A-F output for 10% distortion = 1.2 watts
Oscillator grid current (1000 Kc/s) = 450 μA.

7. **Voltage and Current Analysis**
Mains voltage 240 V r.m.s.; no signal; all voltages measured to chassis with 500 ohm/volt meter* on 400 volt range, except for bias voltages, which can be checked only with a V.T.V.M.

	Plate	Screen	Osc. Plate	Bias
6A8-G				
Voltage (V)	190	73	98	−2.0
Current (mA)	2.0	3.8	2.5	—
6AR7-GT				
Voltage	190	70	—	−2.0
Current	5.5	1.5	—	—
KT61				
Voltage	180	190	—	−4.0
Current	23	3.5	—	—

6X5-GT
190 V r.m.s. per plate.

* Avometer, model 7.

Radiotron Type 5675

U-H-F Medium-Mu Triode

(Grounded-Grid Type)

(Reprinted by courtesy of Radio Corporation of America)

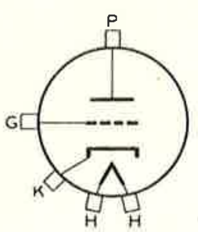
Actual Size.

Data contained herein is published for general information. No stocks of these valves are at present held in Australia.

Type 5675 is a medium-mu triode for use in grounded-grid circuits at frequencies up to 3000 megacycles/sec. As a local oscillator, it is capable of giving a power output of 475 milliwatts at 1700 megacycles, and about 50 milliwatts at 3000 megacycles. The valve is less than $2\frac{3}{8}$ inches long with a diameter except for the grid flange of only $\frac{1}{4}$ inch.

Featured in the 5675 is the "pencil-type" construction which not only meets requirements as to minimum transit time, low lead inductance, and low interelectrode capacitances, but also provides other desirable design features such as small size, light weight, low heater wattage, good thermal stability, and convenience of use in equipment design.

TERMINAL CONNECTIONS



H: HEATER
K: CATHODE
G: GRID
P: PLATE

The coaxial-electrode structure employed is of the double-ended type in which the plate cylinder and cathode cylinder extend outward from each side of the grid flange. The latter is particularly effective in isolating the plate from the cathode in grounded-grid circuits. Although designed for use in circuits of the coaxial-cylinder type, the 5675 is also suitable for use in circuits of the line type and lumped-circuit type.

GENERAL DATA

Electrical:

Heater, for Unipotential Cathode:		
Voltage (a.c. or d.c.)	6.3	volts
Current	0.135	ampere
Direct Interelectrode Capacitances:		
Grid to Plate	1.3	μμF
Grid to Cathode	2.3	μμF
Plate to Cathode	0.09 max.	μμF
Characteristics, Class A_1 Amplifier:		
Plate Voltage	135	volts
Cathode-Bias Resistor	68	ohms
Amplification Factor	20	
Plate Resistance	3225	ohms
Transconductance	6200	μmhos
Plate Current	24	mA

Mechanical:

Mounting Position .... Any

Dimensions and Terminal Connections .... See Outline Drawing

OSCILLATOR — Class C

Maximum ratings, *Absolute Values:*

D.C. Plate Voltage	165 max.	volts
D.C. Grid Voltage	–90 max.	volts
D.C. Cathode Current	30 max.	mA
D.C. Grid Current	8 max.	mA
Plate Input	5 max.	watts
Plate Dissipation•	5 max.	watts
Peak Heater-Cathode Voltage:		
Heater negative with respect to cathode	90 max.	volts
Heater positive with respect to cathode	90 max.	volts
Plate Seal Temperature	175 max.	°C

Typical Operation as Grounded-Grid Oscillator at 1700 Mc/s*

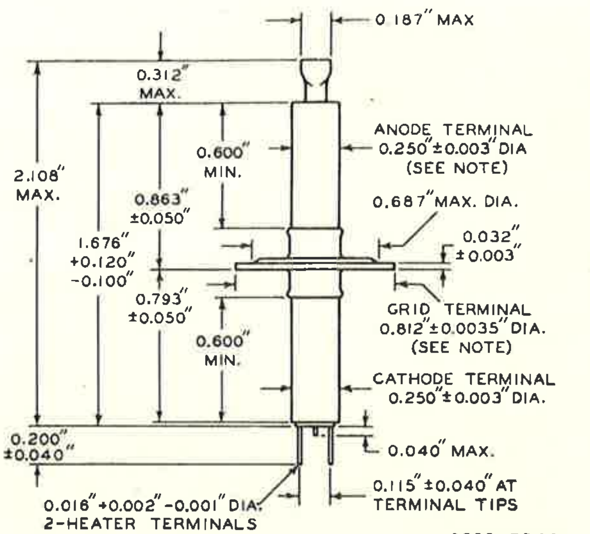
D.C. Plate Voltage	120	volts
D.C. Grid Voltage	–8	volts
From a grid resistor of	2000	ohms
D.C. Plate Current	25	mA
D.C. Grid Current (Approx.)	4	mA
Power Output (Approx.)	475	milliwatts

CHARACTERISTICS RANGE VALUES FOR EQUIPMENT DESIGN

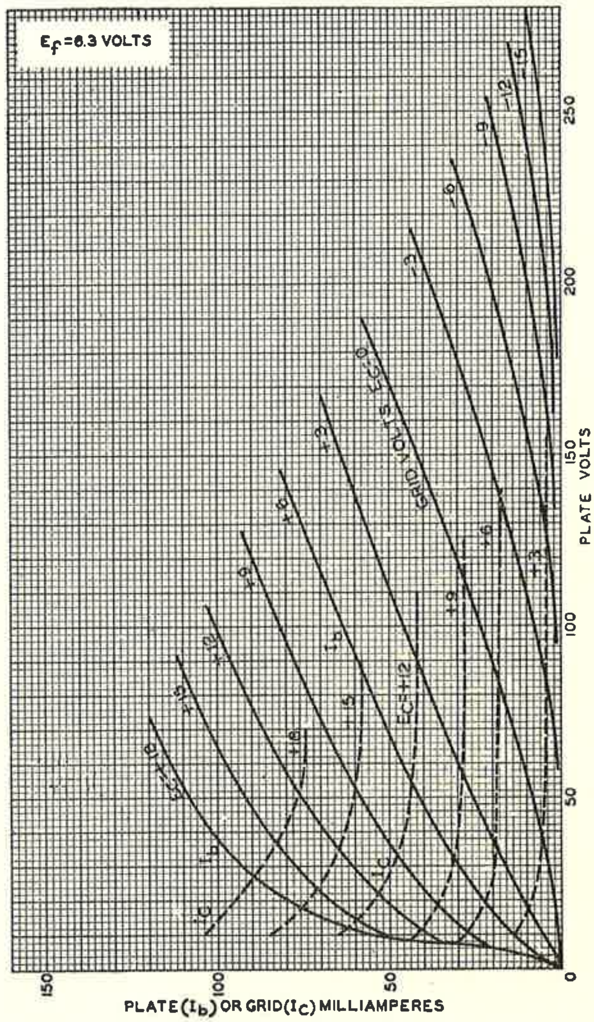
	Note	Min.	Av.	Max.	
Heater Current	1	0.125	0.135	0.145	ampere
Grid-to-Plate Capacitance	–	1.1	1.3	1.5	μμF
Grid-to-Cathode Capacitance	–	2.0	2.3	2.6	μμF
Plate-to-Cathode Capacitance	–	–	–	0.09	μμF

Note 1: With 6.3 volts a.c. or d.c. on heater.

DIMENSIONAL OUTLINE



NOTE: MAX. ECCENTRICITY OF ℄ (AXIS) OF ANODE TERMINAL OR GRID-TERMINAL FLANGE WITH RESPECT TO THE ℄ (AXIS) OF THE CATHODE TERMINAL IS 0.008".



Average Plate Characteristics of Type 5675.

Installation and application

The 5675 may be mounted in any position. Connections to the cathode cylinder, grid disc, and plate cylinder should be made by flexible spring contacts only. The connectors must make firm, large-surface contact, yet must be sufficiently flexible so that no part of the valve is subjected to strain. Unless this recommendation is observed, the glass-to-metal seals may be damaged.

The *heater* leads of the 5675 fit the Cinch socket No. 54A11953. They should not be soldered to circuit elements. The heat of the soldering operation may crack the glass seals of the heater leads and damage the valve.

The *cathode* should preferably be connected to one side of the heater. When, in some circuit designs, the heater is not connected directly to the cathode, precautions must be taken to hold the peak heater-cathode voltage to the maximum values shown in the tabulated data.

• In applications where the plate dissipation exceeds 2.5 watts, it is important that a large area of contact be provided between the plate cylinder and the terminal to provide adequate heat conduction.

* At 3000 Mc/s and with full ratings, a useful power output of approximately 50 milliwatts may be obtained.

RCA RECEIVING TUBE MANUAL

It is desired to bring to the notice of readers that stocks of the RCA Receiving Tube Manual (R.C.15) are now exhausted.

Of this article Col. Gaither says, "The form of presentation may be somewhat different than that of the usual treatise." To which we add, and how! and how delightfully so. Col. Gaither might have added to his title "Techniques without Tears." We hope you enjoy this as much as we did on first reading it.

Col. Gaither is present Eucom Communications Chief.

Radio Propagation

and the Use of Antennas

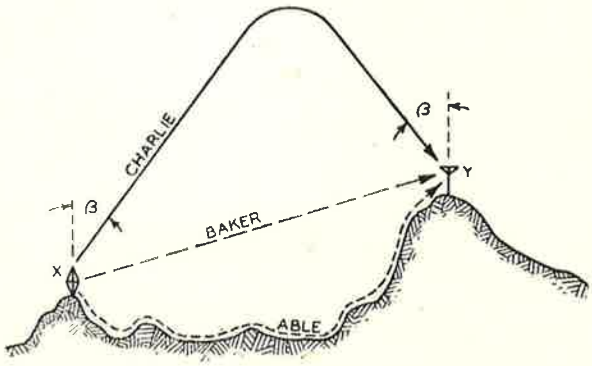


Fig. 1

By Lt.-Col. LOREN E. GAITHER.

"If it's going to happen, it's going to happen; if not . . . it sometimes does anyway!" — (Anon.).

One often wonders if some of our military agencies and an appreciable number of communications personnel are not inclined to have this same, quixotic opinion of radio propagation.

Before proceeding, however, may we excuse the hot-shot technicians and the long hairs who can inhale while saying, "integrate the equation and . . .," not that we intend to belittle or fail to recognize their ability; we simply wish to interest only those of the Armed Forces and others who do not give a tinker's damn about the technical aspects of radio but who are sometimes confronted with the problem of making a radio circuit work. It is our contention that operations personnel and supervisors too often overlook the simple rules of radio propagation and throw away hours of communications by incorrect usage of antennas. It should be common "horse-sense" to understand that, if an antenna does not transmit energy in a given direction, it isn't the fault of the radio set per se! This brings us to two important quasi-theorems:

a. If an antenna doesn't transmit in a desired direction, turn it around so that it does. This is the old mountain-Mohammed routine, but it is often overlooked by the faithful.

b. If, at a given frequency, a radio propagation path does not exist between points X and Y, no action short of rolling out the prayer rugs—or changing to a suitable frequency—will establish radio contact.

Reprinted from "Signals" (July-August, 1949) by courtesy of the Armed Forces Communications Association, U.S.A.

If we consider theorem b. above, we find ourselves concerned with the mechanics of radio propagation, a most complicated mechanism, but fortunately one adaptable to rule-of-the-thumb application. From our viewpoint we will agree that we are not interested in inverse distance fields, nor will we be interested in knowing the electronic density of the sporadic E layer above Pea Ridge, Arkansas, at 0101 on 16th August, 1941, but we shall be interested in knowing why a perfectly good radio channel, one we have been using all afternoon for 100 per cent. transmission, suddenly fades out. The approved solution may be that the late afternoon sun's rays have decreased in intensity to such a degree that the upper atmospheric regions have lost their ability to return the rays to earth. And so, instead of transmitting a requisition for four more tons of Form 36-B-O-O-O to Base Section, we suddenly start warming poor Uncle Snazzy's spirit; which at the moment happens to be wandering midway between the fourth and fifth psychic planes, someplace in the vicinity of Pluto.

We most certainly should be interested in knowing how radio signals travel from X to Y; all of which brings us to the low habit of referring to Fig. 1. If our transmitter has sufficient power perhaps we can use path Able. If the path of least resistance is Baker, we may use path Baker. If neither Able nor Baker will work we may, in some cases, use path

Charlie by selecting a proper frequency. Of course we will not overlook the possibility of signals arriving at the same instant over paths Able, Baker, and Charlie. If this happens we normally expect great trouble in the form of rapid fading of the signals. For a first approximation may we state that Able and Baker are rather solid citizens but Charlie is quite a lackadaisical rake; here to-day and gone to-morrow!

Let us examine path Able in detail. We will not call this path "ground wave propagation." Actually the wave travels in contact with the ground and the characteristics of the ground are controlling factors in determining whether or not we can successfully use the "ground-wave" for communication. If, for example, we find ourselves in the North Country where, so I've been told, it's fine for women and dogs, but hell on men and radio, we may find that low frequency, ground wave propagation is virtually the only means communicating with Fort Blow, back of the mountains. All right, if we are so smart, where can we, and where can we not, use Path Able?

Noises

Permit us, right here, a defensive statement or two before we stick out our neck. "Noise Level" may upset our very best calculations in a few cases. If, for example, an electrical storm has the sky all lit up like father on Christmas Eve we may find a high noise-level over-riding our strong signal-level; and so no communications. If not that, Joe Giezel may decide to denude his cheeks (by Schick) with the same net result . . . all noise and no signals. We can protect ourselves to some degree by plotting average expected noise for a given location and so to Fig. 2. Here we optimistically combine atmospheric noise, cosmic noise, man-made noise in a pseudo-military area, receiver noise, and antenna noise into four simple curves for good and poor locations and we state that at a given frequency, subject to variations of local storms, we expect to find these noise levels (in microvolts per meter or, let us say, for simplicity, in units) in all regions of approximately 30 to 50 degrees of latitude, north or south. Correction factors for other latitudes are listed above, Fig. 2.

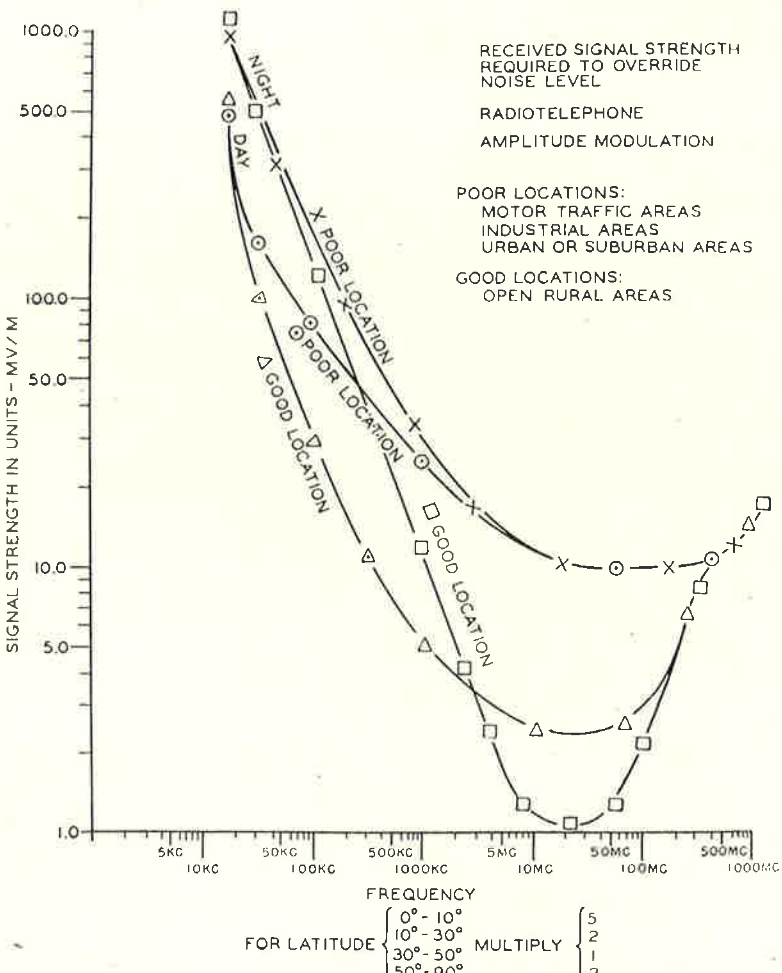


Fig. 2

Signal and noise levels

The first, or should we say basic, requirement for communications is the necessity of the signal-level over-riding the noise-level; therefore, the approximate data in Fig. 2 gives us the all important starting point. For any frequency we may read the noise level expected and then observe other factors to ascertain if the path will be workable with the equipment we have on hand.

To effect the final solution of our ground wave propagation problem we will need the information given in Figures 3 and 4. The important, general information we get from Fig. 3, at first glance, is the observation that ground wave propagation over earth is not feasible above 5,000 kilocycles, except for very short distances in the order of one tenth mile to ten miles, depending upon our power output. To say this another way, *frequencies above 5.0 Mc/s (megacycles) are virtually useless with military field equipment for covering distances in excess of ten miles by use of the ground wave.*

The second most important, quick information we can glean from Fig. 3 is to note that the lower the frequency, the better the propagation using ground wave only.

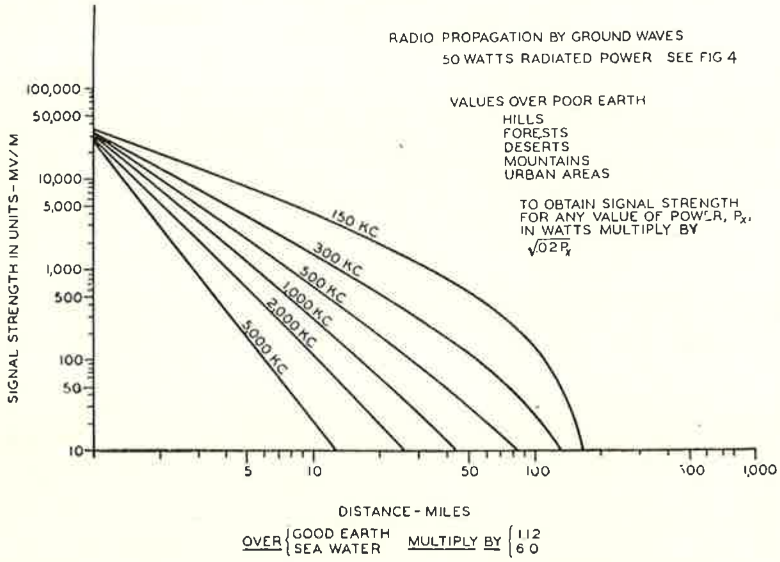


Fig. 3

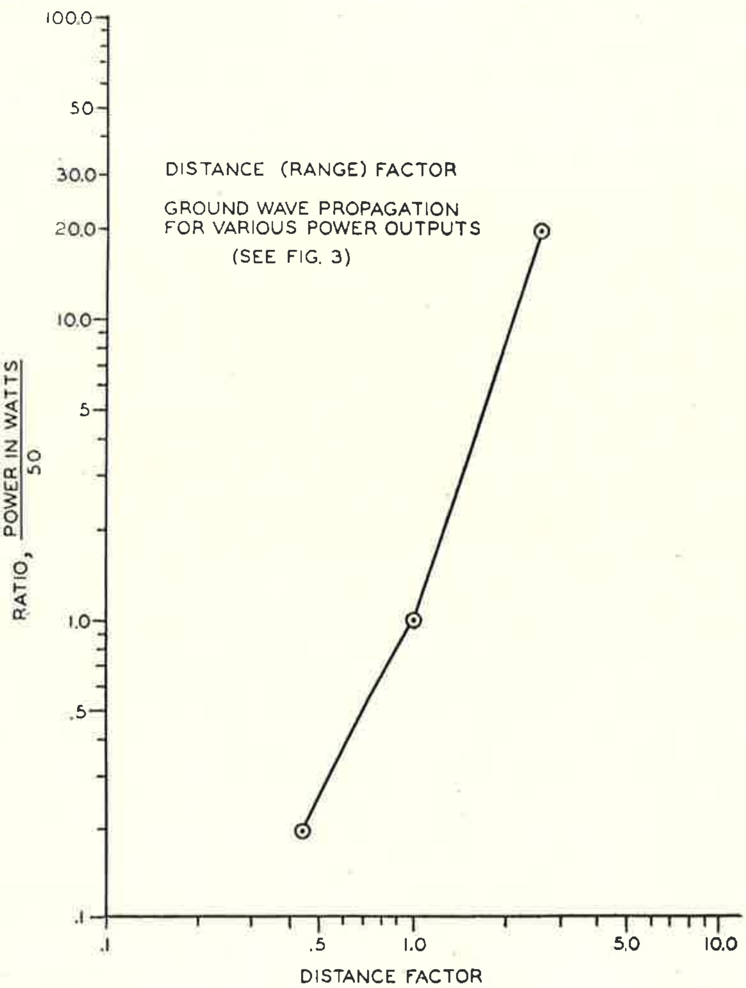
At this point, assuming one has studied Figs. 3 and 4; to those who have become discouraged, to those who may suspect that ground wave propagation is generally less efficient than a yak-cart, may we reiterate that it is sometimes the only way one can maintain contact. In any event "leave" us observe two examples.

Or else

Suppose the General wishes to communicate by radiotelephone with a station 80 miles distant. The receiving station is located behind a range of mountains. Sky Wave Propagation has failed. The receiving site has an approximate latitude of 70°. The intervening terrain consists of low, rocky hills. We do not have specific knowledge of receiving conditions at the receiver so we assume a poor location as a factor of safety. Our transmitter and antenna has a radiated power output of 40 watts.

Since the required frequency is the factor we wish to calculate, we cannot immediately use Fig. 2 but we may study Figures 3 and 4. Here we note that the distance must be, in effect, increased by reason of the actual transmitter radiated output being 40 watts instead of the 50 watts, which was the basis of the plotted data. Our power ratio is therefore $\frac{40}{50}$ or .8. Selecting this value on the vertical scale of Fig. 4 we read .85 on the horizontal.

Fig. 4



But if we use .85 × 80 miles = 68 miles, this distance will not have any significance, for it is a shorter distance instead of a longer distance. The

$$\text{distance } \frac{80}{.85} = 94 \text{ miles does have}$$

significance. In decreasing power we, in effect, increase distance. This 94 miles is the "apparent" distance upon which we must base our analysis. Now, from 3 we note that approximately 450 Kc/s will be the minimum frequency we may use for a 94 mile path providing we can get satisfactory reception with a 10 unit signal strength. Fig. 2, for a 450 Kc/s signal, at night, in a poor location, indicates we will need a 50 unit signal strength but the "latitude factor"

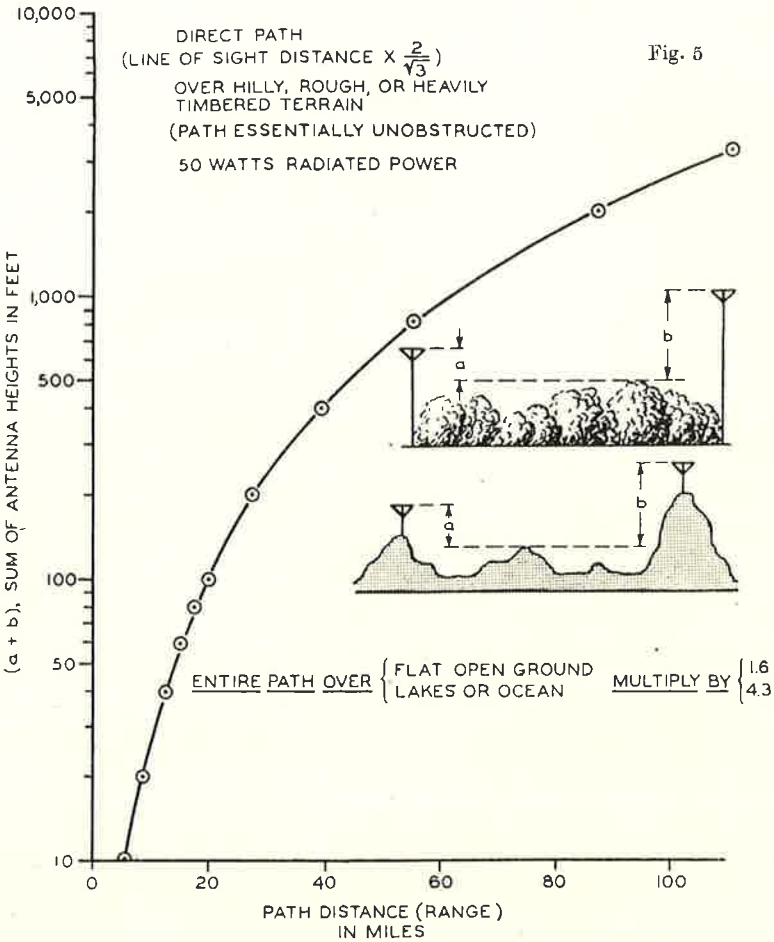


Fig. 5

One final observation of Figures 3 and 4 is in order. The curves were not plotted for signal strengths lower than 10 units for two reasons. A ten unit signal strength is about the minimum necessary for satisfactory radiotelephone operation, and furthermore, most military situations will predicate this level in order to over-ride noise. Radio telegraph will usually give us ranges much greater than those indicated but, in any event, we may be certain of the calculated ranges being reliable under virtually any condition excepting severe atmospheric storms or extreme man-made interference.

So much for path Able.

Considering path Baker, this is the path we define when we say, "The line of sight path." This statement, the way we usually use it, is slightly in error since most of our v-h-f (very high frequency) transmission paths are in excess of the actual line of sight distance. If we wish to be approximately correct we will call this path the direct path and we will agree that this path will always work unless the ray is absorbed or reflected by something encountered along the path.

listed in Fig. 2 allows us a factor of .2 thus, 50 × .2 = the number of units required, and so having examined both the noise level and the signal strength, we are confident our selection of 450 Kc/s will work under the stated conditions. A higher frequency will not permit ground wave propagation.

For a second example, suppose we have a radiotelephone transmitter capable of radiating 1,000 watts on a fixed frequency of 2,000 Kc/s and we wish to know the maximum communicating range from Island I, latitude 8° south, over sea-water to a receiving station on a ship. Good receiving conditions are known to exist on the ship. Figure 2 will indicate for night operation, a required signal strength of about 27.5 units (5.5 times the latitude factor of 5). Fig. 3 will indicate a working range of 108 miles (18.0 miles from the chart multiplied by the factor 6 noted at the bottom of the figure) under the stated conditions for a 50 watt transmitter. For our 1,000 watt solution we observe from 4, a means of obtaining our power factor; namely for a power ratio of 1,000 divided by 50, or 20, a factor 2.5,

Thus;

108 miles times 2.5 equals 270 miles—our final solution and our range.

The preceding statement is not true! We admit this because some guardhouse lawyer may protest that he can stand on Hill 301 with a one-thousandth watt transmitter and not be heard on top of Old Baldy, the top of which is visible over yon, far horizon. For the last time, may we ask that our statements be considered in the light of everyday usage of common military item of equipment. From now on, if a statement is essentially correct, we will not deviate to explain the exceptions.

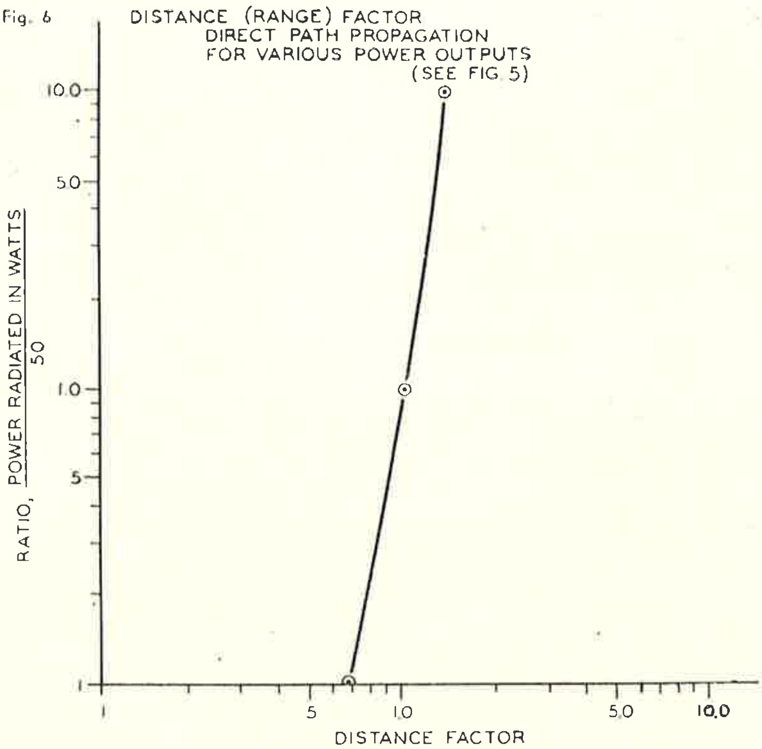
All right! We insist that the direct path, Baker, will always work unless the ray is absorbed or reflected by something encountered along the path. Would you believe it that a certain AN/TRC circuit in Western France skimmed along over the top of a dense forest; and would you believe it that this circuit became inoperative for a short time following dawn and for a short time before dusk; and would you believe it that this occurred every day and every day; the reason being that crows would fly back to their roosts during the evening thus interposing a very effective, absorbing screen for a few minutes! Perhaps this isn't a true story, but surely it is of reasonable basis!

On reflection

If we are using very high frequency (v-h-f) we may be certain that objects the size of airplanes will reflect an appreciable amount of energy and for this reason we will endeavour to locate our terminals away from landing strips. If we cannot transmit through a hill, directly in front of us, we may be able to bounce enough energy off a mountain at the side of our path to contact the station on the other side of the hill. These are interesting observations but we must not lose sight of the basic premise that Baker must be an unobstructed "bee-line" from transmitter to receiver. Very confining, we agree; for we observe that even if we had unlimited power and two antenna poles ten thousand feet high for path Baker, we could only erect the poles 280 miles apart and maintain contact for, if installed a greater distance apart, the ground would "belly-up" and cut off the direct path and thus absorb the rays.

Another observation is that a v-h-f set with a short antenna in a row-boat, drifting on a river, will be effectively out of sight, behind the curvature of the earth, to a similar set placed on a sand-bar, when the row-boat is approximately three miles downstream. Thus, antenna placement becomes, obviously, of vital concern in planning direct propagation. Figure 5 will give us more information than an elaborate written description. So, with a bow to Figure 5, we state that this diagram will answer all problems using path Baker. One must merely remember that the path must be—we repeat—must be unobstructed. If one is willing to gamble a bit, we will allow one to increase these distances by a factor of 1.6 for transmission over plains or meadows, and we will be most generous to the Navy and allow an increase in distance by a factor of 4.3 for direct propagation over salt water. This in effect permits one to transmit beyond the curvature of the earth under favourable conditions using path Baker. From the viewpoint of long distance communication, however, we admit that Baker is useless, and we remind one that Able is also useless for frequencies above 5 kilocycles. (And to the die-hards of the kilocycle per second school, an acknowledgment that we know it—why don't you mind your own business!)

Fig. 6



Here's Charlie

Now that we have decided that both Able and Baker are virtually useless for military field usage over appreciable distances, we come to that most brilliant performer, that old ace in the hole, that erraticϕ! æ ϕ? Charlie!

Path Charlie is known as sky wave propagation. If one wishes to determine if Charlie will work, one must calculate a baker's dozen of factors, any one of which may prevent the sky wave path from working. Here, however, we propose to blithely disregard a host of things and give the simple data on sky wave propagation and gamble that we will be right 85 per cent. of the time! Before we consider the omnipotent diagrams, we shall need a few concepts of the path.

Wild "something" yonder

To travel from X to Y by path Charlie, it should be noted that the path leaves the transmitting site and arrives at the receiving site at the same vertical angle. It should also be observed that the ray is bent back to earth at the middle of the path. These are the two fundamentals. If the ray does not leave the transmitting site at the correct angle and if our receiving antenna is not receptive to waves arriving at the correct angle, transmission is nil or inferior. If "something" doesn't bend the ray back to earth we cannot use the path. It now should be manifest that we must use the correct frequency; that our transmitting antennas should have the ability of "squirting" all of our power in the direction of the receiving station at the optimum vertical angle; that our receiving antennas should have maximum response in the desired azimuth and at the desired vertical angle, and, if possible, the additional ability to reject all signals arriving from other directions or vertical angles. These elements are subject to design or selection. The one thing in the hands of chance (or prediction) is the "something" which effects the return of the radio wave to earth.

In the outer atmospheric shell of the earth we have the same physical conditions existing as are found in fluorescent lamps and neon signs. The condition of a near vacuum with the presence of small amounts of gaseous elements exists in both the tubes and the outer atmosphere. And, for the record, I would like to be the first to predict some enterprising advertising agent's spectacular sign for "Sziltch's Bubble Gum" being projected in the sky in flaming letters two thousand miles in width, visible from Bombay to the Top of the Mark, for when this rarefied atmosphere is subjected to a high electrical potential, it may be made to glow like a full moon on a dark night. If it is subjected to energy bombardment from outer space (from the sun) it will also glow, creating the northern lights, or it may, at lower intensities, actually not glow but merely bend certain radio waves back to earth.

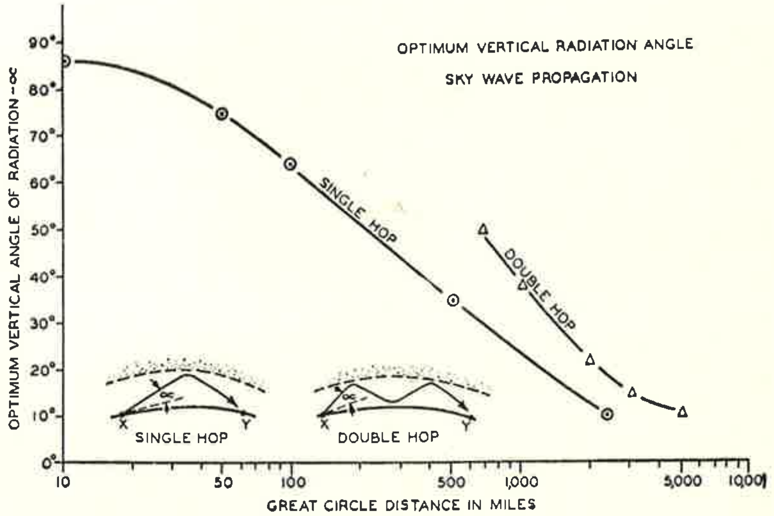
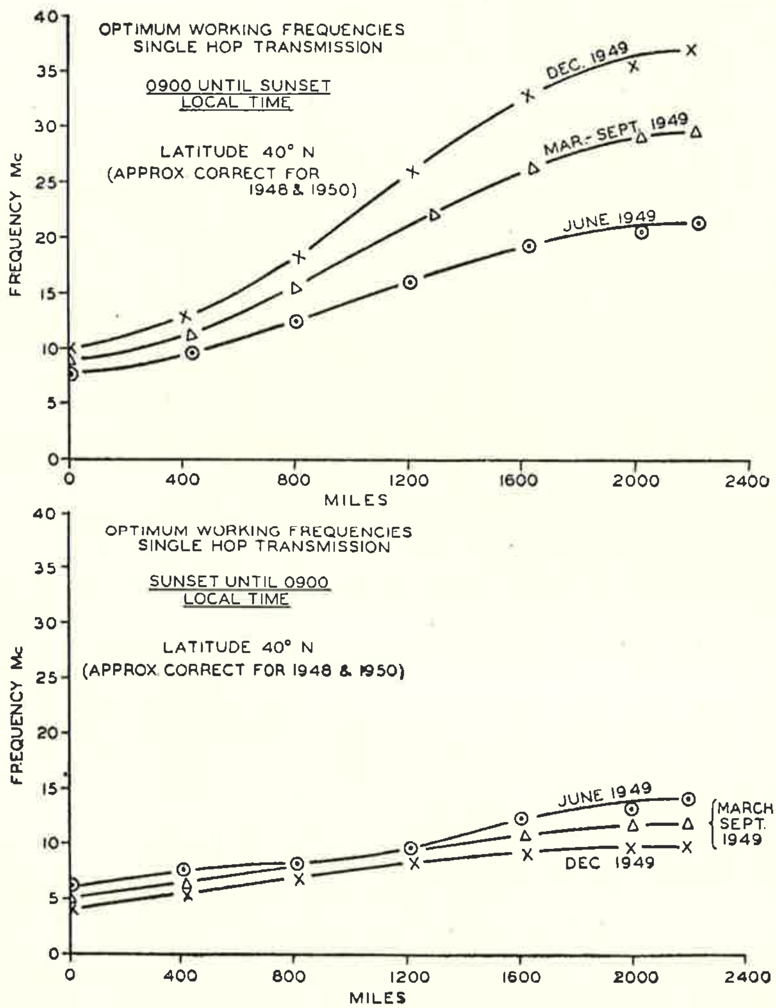


Fig. 7

Fig. 8


H-F hard to reflect

One fact we must accept: the more severe the bombardment the more the bending. Thus at noon of a given day we find the maximum bombardment of energy from the sun striking the atmosphere directly above us and we expect certain high radio frequencies to be reflected back to earth frequencies which will not be reflected back to earth at midnight of the same day. Since experience will indicate that a highly active entity is harder to deflect from a straight line than a slow, languid entity we may suppose that the higher frequencies will be harder to deflect by the ionosphere, and so it is.

Daily and seasonal cycles

The ionosphere, by the way, is the name given to the outer atmospheric shell responsible for deflecting the radio waves back to earth. The ionosphere at noon will bend back much higher frequencies than it will at night and, by reason of the sun being the prime mover of the ionosphere's reflecting power, it should be evident that there will be a difference in the degree of bending, contrasting winter with summer as well as day with night. A marked difference is also observed between periods of sun spot maximums and sun spot minimums.

All of this may be consolidated into an idea of daily, seasonal, and yearly variations, repeating in cycles, which are most certainly predictable providing we have observed the behaviour of the ionosphere long enough to collect the necessary prediction data. The Radio Propagation Unit working under the direction of the Chief Signal Officer and the Central Radio Propagation Laboratory of the National Bureau of Standards are two agencies who have been interested in this work for many years. In brief, in war or peace, someone published the information necessary for basic radio propagation predictions.

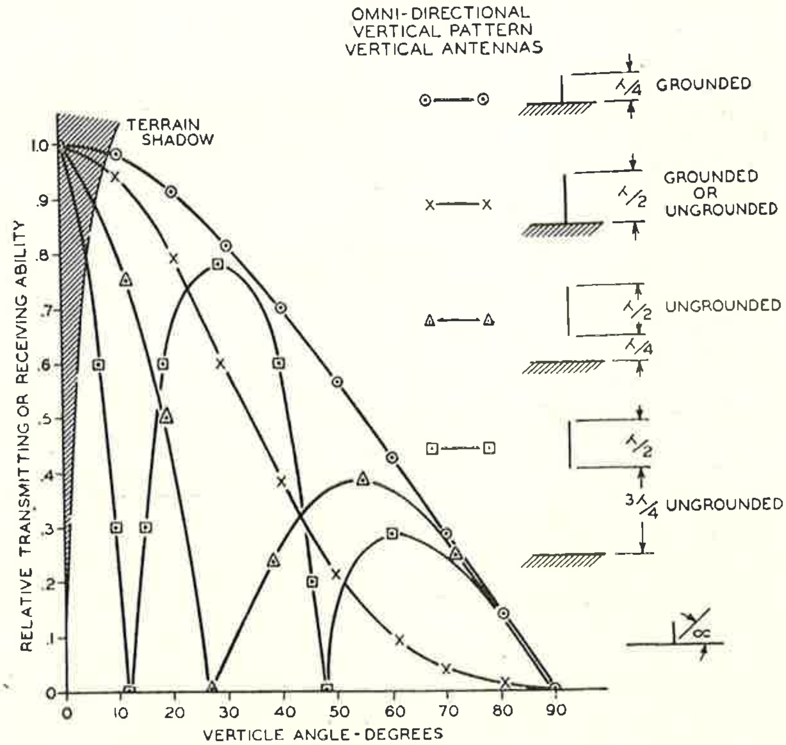


Fig. 9

If an accurate prediction is desired, up to three months in advance, the CRPL Series D predictions may be obtained from the National Bureau of Standards or from the Department of the Army, Navy, or Air Force and the problem may be calculated quite easily. If one is merely interested in rule-of-the-thumb prediction, may we "sell" Figures 7 and 8. These figures should be fairly accurate for the distances shown in the northern hemisphere at a latitude of from 30 to 50 degrees for the period of the next two years.

The information in Figures 7 and 8 should be self-evident.

Actually the frequencies given in Figure 8 are average optimum working frequencies and are the best, average selections (not forgetting the more accurate and calculable CRPL Series D results) regardless of our transmitter power, our receiver sensitivity, or the type of service—telephone, code, teletypewriter, etc.

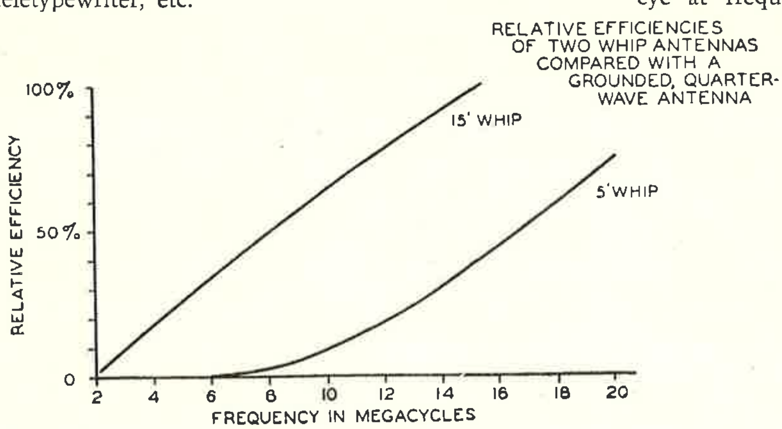


Fig. 10

If this graph is followed there will be obtained the best results possible. (Even so, the circuit may not be workable due to other factors!)

Actually there are sporadic periods when ionospheric storms, atmospheric or man-made noise, and/or absorption will absolutely prevent sky wave communication. Nevertheless, we insist these rough predictions are very much better than a guess and should serve as a guide in deciding if an unsatisfactory frequency is too high or too low. For the purposes of this article we will agree that the maximum value of frequency we may use is only ten per cent. higher than the optimum frequency shown in Figure 8.

In other words, we must look with a jaundiced eye at frequencies higher than the optimum frequency. We will be most quick to change to a higher frequency, though, in the event our unsatisfactory frequency is lower than the optimum. To be doubly certain that we are not misunderstood may we say this again in this way, "Stay as close to the optimum working frequency as possible, realizing that one can go either too far above or too far below for satisfactory operation, and realizing that one usually cannot go much higher than optimum but quite often one may go an appreciable degree lower." One, in addition, should remember the following important rules regarding use of sky wave propagation:

(a) Sky wave propagation is questionable or useless below 3,000 kilocycles during daylight hours.

(b) For the next few years sky wave propagation will normally be non-existent above 25,000 kilocycles during summer daylight hours and above 40,000 kilocycles during winter daylight hours. (Maximum night frequencies, are as explained before, much lower.)

(c) Never use sky wave propagation if ground wave or direct path propagation will work.

The remainder of this article will consist of a brief discussion of radio antennas. We would like to drum up an avid appreciation of antennas and we would like to present some practical and assimilable data. This data will not be of interest to those who have a sound, operational knowledge of antenna theory since all of the information expounded in this article may be found in the usual handbooks. The form of presentation and the emphasis upon certain elements may be, however, somewhat different than that of the usual treatise.

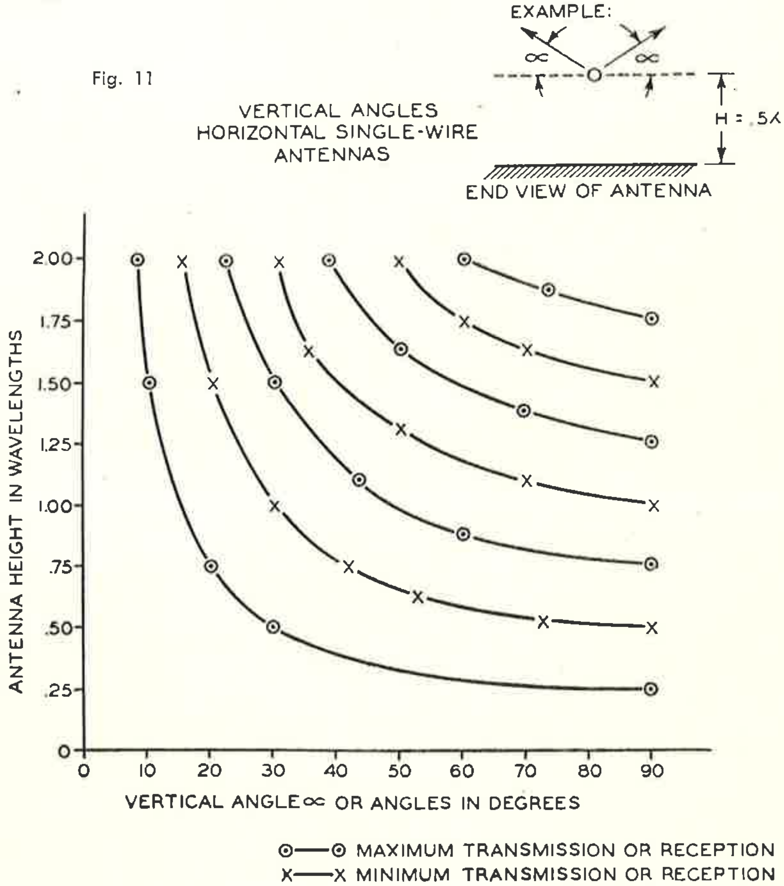
Antenna design neglected

The radio antenna is often considered to be part of a radio set. We could be wrong . . . the matter seems to be one of relativity . . . but we are much inclined to feel that the antenna is infinitely more important than the radio set. Our observation is that the design engineer's interest comes to an abrupt end at the antenna terminals. He snubs the antenna with the verve of a Long Island matron fluffing off the country cousin from Four Forks.

Tucked away in a certain radio handbook we find the bland statement, "Commercial radio antennas are designed to exhibit as much as 22 db. gain." This statement might be easily passed over without one appreciating the magnitude of a 22 decibel gain. This is a power gain of 158. This is terocious and don't bother to look up the word—it is one of our own coining and should extend the usable, upper limits of Hollywood's adjectival spectrum! Given a 40 kilowatt transmitter, exciting an antenna designed to exhibit a power gain of 22 decibels, the transmitter appears to have an output of 6,320 kilowatts viewed from the receiving end of the path! This same degree of gain may also be incorporated into the receiving antenna, thus bringing electrocution by remote control within the realm of possibility! The startling feature of this power increase appears when we state that it may be accomplished with virtually nothing more than some wire, a few poles, and a few insulators. Perhaps, before we allow our public relation complex to hypnotize our customers, it will be advisable to define the limits of this utopia. It shall be necessary, first, to define one basic premise.

The half wavelength antenna is fundamental. The simplest antenna, though like Aesop with the camel, we may not always observe the whole of the beast. Physically, we may not see a half wavelength in a short whip antenna, but we may be certain that the entire half wavelength is there, either coiled up electrically into a loading inductance, or partly supplied by some ground connection hokuspocus called "the image."

Fig. 11



Half-wave formula

This isn't too important to us except from one angle. We correctly state that electrically our antenna must consist of one or more half wavelengths —the more the better. We may string these half-wave elements end to end or we may arrange them in some sort of a fancy bird-cage with the same thought in mind; the more the better. The thing to give us pause is the physical length of this half wavelength along a wire suspended above the earth in the usual fashion for antennas. A good, approximate formula for the length of the half-wave, along a wire, in feet, is 468 divided by the frequency in megacycles.

As an example, the shortest wire length for an antenna, not connected to ground, that will operate on 1,000 kilocycles (1 megacycle) is 468/1 or 468 feet and, although a small pasture will accommodate this antenna, it would look a bit silly mounted on a jeep . . . so what do we do if we wish to operate at this frequency in a jeep? We simply wind most of the antenna into a coil, a fifteen foot end protruding electrically, and we call it a whip antenna. The fact that we have lost most of the radiating efficiency in the process and are requiring a small boy to do a man's work is blithely ignored. We end up with a thousand dollar radio working through a ten-cent antenna . . . at best a compromise and maybe an admission that we have been neglecting antenna research for research on more complicated equipments.

For the happy medium

Perhaps if we would spend a little more effort in developing radiators of increased efficiency we could expect increased reliability with smaller sets. We admit we could possibly carry this idea to the extreme where we would be using a ten-cent radio with a thousand dollar antenna. We contend this also would be stupid; somewhere there is a reasonable balance between the two factors. We are way to the left of centre at the present date.

The one basic premise we set out to define in the paragraph above is rather effectively screened by a bit of propaganda. The premise is, actually, the appreciation of the size of antenna half wave elements. With present day techniques, antenna arrays with sizeable gains may be constructed for little cost in a limited space using very high, ultra high, and super high frequencies by reason of the physical dimensions of the half wave falling between the limits of fifteen feet and a fraction of an inch for these frequencies. An extreme case would be the consideration of the size of a half wave for 30 kilocycles (.03 megacycles). For this frequency the length of the simple antenna would be 15,600 feet and dimensions alone would make the construction of an array of many of these half-wave elements a project of Herculean proportions. A further appreciation of the basic half-wave antenna predicates that the entire half wave length should be electrically exposed if we are to expect good radiating efficiency; we must not expect good results if we resort to electrical tricks to utilize a physical length of antenna which is only a fraction of a half wave in length.

Now that we have presented a bit of sales talk on antennas, may we discuss their usage.

Many military situations, especially those of mobile operation, require the use of short antennas with omni-directional characteristics. In other words, we desire 360 degree azimuthal coverage from our transmitting site and the ability to receive signals from any direction with the same degree of efficiency. To accomplish this we usually select a single, vertical radiator such as a whip, a tower, or a vertical wire. Of course, we should realize that with this ability to transmit or receive equally well in all directions we sacrifice the opportunity to beam or concentrate all of our radiation in a desired direction. It is in those situations wherein we only need to transmit in a given direction that we goof off with lackadaisical operation using omni-directional antennas when we actually have the time and the materials to construct a directional antenna.

Whip limitations

We also expect our whip antenna to accomplish many things without one thought of its limitations. We operate it at the lower end of the high frequency band and wonder why we do not get better results. As previously explained, all of the antenna isn't in sight. Only part of it is radiating and the

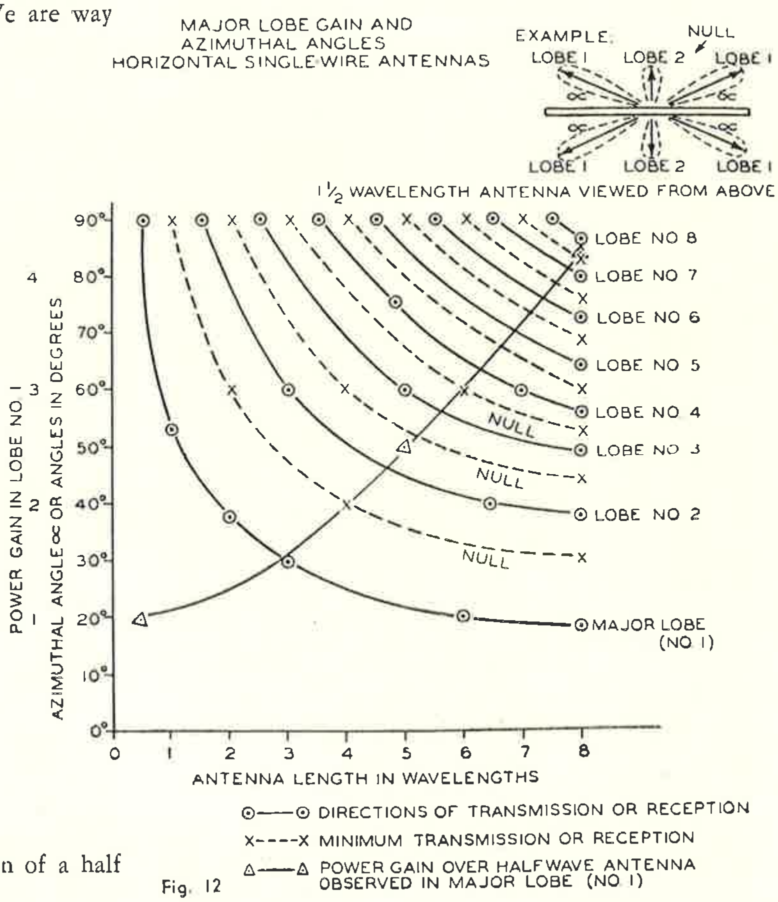


Fig. 12

greater portion of our available energy is wasted in heating up the set or the ground. Please look at Figure 10. We also may be surprised to learn that the vertical antenna is useful for only low or even very low angles of radiation. A review of Figure 7 and a quick glance at Figure 9 will clarify this entire consideration.

We note that a vertical half-wave antenna does not radiate well at vertical angles greater than forty degrees. We must never disregard the low radiation (or reception) angle of a vertical antenna; yet we do! From Figure 7 we note the optimum vertical angle is about 75° for sky wave transmission over a fifty mile path, such as a jungle path wherein we have complete absorption of the ground and direct waves. We now suspect that a vertical antenna will be worthless for this application and we are correct. Figures 9 and 10 furnish us with factual data relative to the vertical angle efficiencies of vertical half-wave antennas and vertical fractional-wave whips. This information, plus that of Figure 7, should take us a long way toward solution of sky wave propagation problems using vertical grounded and ungrounded antennas.

For ground or direct wave propagation we may assume that our best vertical angle of propagation is zero and Figures 3, 6, and 9 will yield essential data to those who wish to carefully study and evaluate the information. In general, vertical antennas are useful for ground wave, most direct wave, and long-distance sky wave paths; verticals are usually unsatisfactory for short and medium distance sky wave paths.

Polarization tricks

At this point polarization rears its ugly head and its importance should be recognized. A rather spectacular demonstration of the importance of polarization may be performed with two half-wave antennas of the same length. When one is excited at its natural or resonant frequency as a transmitting antenna and the other has a small light bulb inserted in the centre of the antenna, thus becoming a receiving antenna, we find, when the latter is brought into proximity with the transmitting antenna that the light bulb will glow brightly when the antennas are parallel, but the light bulb will not glow when the antennas are at right angles to each other, no matter where in space we place either or both of them. This demonstration is impressive and, once observed, will probably prevent one from making the mistake of using a vertical antenna at one end of a path and a horizontal antenna at the other. Please remember, transmitting and receiving antennas should always be parallel to each other—long distance, multi-hop transmission engineers disregard this statement; consult the nearest soothsayer holding a valid union card.

Reciprocity

When antennas are operated in proximity to the ground, say within a ten wavelength distance we observe a change in the vertical angle of radiation with a change in the height above ground due to an image effect. This applies to all antennas, grounded or ungrounded. Incidentally, we repeat the statement that, at a given frequency, if an antenna has one or more peculiar characteristics for transmitting, it has exactly the same characteristics for receiving . . . and vice versa. This is the important reciprocity theorem and is a very helpful tool in analyzing antenna phenomena.

We mention the image effect of the ground on an antenna although this actually has nothing to do with usage of antennas; it is rather one of the basic principles. Whenever we physically ground an antenna or whenever an antenna is near the ground there appears to be, from all points of observation above the ground, a mirror image of the antenna in the ground. For example if we erect a vertical one-quarter wavelength antenna above the ground and physically connect the bottom of the antenna to ground, from all points in space we observe another quarter wave extending into the ground from the end of the actual antenna. These two quarter-waves form, in effect, a one-half wave-length antenna. The advantage of this connection is the opportunity to operate a short length of antenna on a frequency exactly one half of its normal, resonant or natural frequency. The disadvantage of this connection is the appreciable increase in absorption losses noted when we place an antenna, particularly a transmitting antenna, in close proximity to the earth.

Horizontal misuse

Horizontal antennas are probably the most misused element in radio communication. In the first place they are virtually worthless for ground wave propagation. Why? . . . Because a horizontal antenna is horizontally polarized, meaning that it operates only with horizontally polarized waves and the earth short circuits a horizontally polarized wave when the wave attempts to travel along the earth. To those who object, we defend this statement as being true within the limits of efficient communication practices.

Horizontal antennas have very definite azimuthal directions and very definite vertical angles in which they do and do not operate, no matter whether used for transmitting or receiving. The azimuthal directions with respect to the antenna depend upon the length of the single wire antenna or upon the number and configuration of the several antennas in an array. The azimuthal direction normally is not influenced by the height above ground. The height above ground is, nevertheless, the normal, governing factor in defining the vertical angle or angles. We cannot discuss antenna arrays in this article but we invite attention to Figures 11 and 12. We have attempted to extract the germ from the whole treatise of single wire antennas and present the information in a useful form to one who may wish to operate correctly without knowing the full reason why. If one does not limit the operation of horizontal antennas by these general rules, or, should we bluntly say, if one attempts to operate without knowing what one is doing, the results will have a fifty per cent. chance of being lousy.

With apologies for the liberties and short-cuts taken in this article we sincerely hope that we have prepared a brief, usable handbook in the form of the encompassed figures and graphs. We sincerely believe that careful evaluation of the graphs will accomplish much more than all the yakety-yak we have written on this paper.

New RCA Releases

Radiotron type 5890— is a low-current beam pentode of the remote-cutoff type intended particularly for the voltage regulation of high-voltage d.c. power supplies. It has a maximum d.c. plate-voltage rating of 30,000 volts, a maximum d.c. plate-current rating of 500 microamperes, and a maximum plate-dissipation rating of 10 watts.

The high-voltage insulation required in the 5890 for its intended service is obtained by the use of a double-ended structure utilizing a suitably designed electron gun which consists of a thermionic cathode and three grids. The plate connection is made to a small cap at the end of the bulb. Tubular in shape, the 5890 has a length of $6\frac{1}{2}$ inches and a diameter of $1\frac{1}{2}$ inches. It is provided with a small-shell duodecal 7-pin base.

Radiotron type 7MP7— is a new, seven-inch, cathode-ray tube of the magnetic-deflection and magnetic-focus type having a long - persistence, cascade (two-layer) screen. It is intended primarily for pulse-modulated applications, such as radar indicator service, and replaces the 7BP7-A in new equipment design.

The 7MP7 utilizes a limiting aperture at the end of the electron gun to provide greater effective resolution especially when the tube is operated at high beam current as in pulse-modulated service. Other features of the 7MP7 include a face plate of television quality, a neck diameter of $1\frac{7}{16}$ inches, and a small-shell duodecal 5-pin base.

New Publications

We have recently received from Iliffe and Sons Ltd., a complimentary copy of "The Williamson Amplifier". This is a 36 page reprint of a series of articles that appeared in "Wireless World", written by D. Williamson on the subject of high quality amplifier design. Readers of "Radiotronics" will remember that the Australian version of this amplifier, known as A515, achieved considerable popularity here and elsewhere.

It was a happy thought to publish in one handy-sized booklet these interesting articles. Included are the various versions of the original amplifier together with details of such additional equipment as tone controls, preamplifiers with record compensation, and a suitable radio frequency amplifier and detector. Moderately priced, this publication will be well received by a wide circle of amateurs and engineers alike.

An excellent compilation of data on radio valves has recently been published by Bernards (Publishers) Ltd. of London. This work, the "International Radio Tube Encyclopaedia", runs to some 400 pages and lists approximately 15,000 types of valves. The instruction data has been translated into many foreign languages—14 in all—making it a reference useful almost anywhere in the world.

For the radio serviceman, confronted with a wide variety of valves, both new and obsolete, this book will prove a boon, enabling obscure types to be recognised and suitable substitutions made where the original is unprocurable.

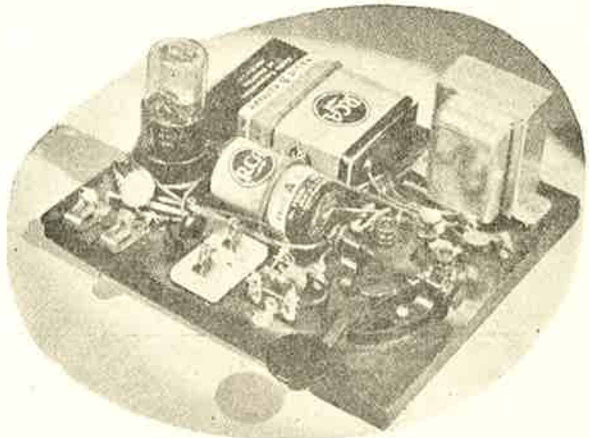
To simplify the process of locating the desired data, the book has been divided into ten sections, the largest being the receiving valve section. This publication is heartily recommended to the industry in general, as a valuable source of "hard-to-get" material. Our copy received with the compliments of the Editor, Bernard A. Babini.

A new edition of the A.W.V. Radiotron Characteristics Chart covering receiving valves is now available on request to "Radiotronics" subscribers. This 12 page booklet has been completely revised to include all valves recently released. An amended Substitution Chart included therein will be of assistance when a replacement for an unprocurable valve is sought.

A Simple Code-Practice Unit for the Novice

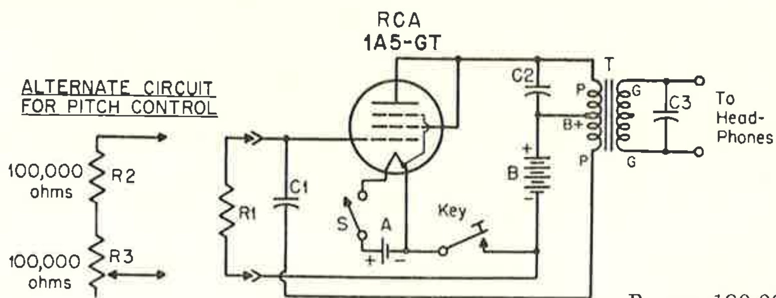
By KEN BUCKLIN

RCA Tube Department



Practice with a soldering iron is as important to the newcomer entering amateur radio as learning the code. The code practice oscillator described helps to accomplish both purposes. It is essential to prepare for the inevitable code test and to develop a good fist; it serves as a practical experiment for the novice; and after the new call letters have been issued, the parts can be put to other useful purposes.

The code oscillator is mounted on a wood board and is complete except for headphones. A 1½-volt radio "A" cell serves to heat the 50-milliampere filament of the 1A5-GT, and a very small 45-volt "B" battery is adequate to supply power to the plate of the valve, which draws only ½ milliampere. The transformer and circuit were chosen to provide good volume for the phones at low battery drain.



The 1A5-GT is a pentode, connected as a triode (with screen tied to plate) in a Hartley-type oscillator circuit. When the transformer is mounted, washers or some other type spacers should be used to provide clearance between the base of the transformer and the baseboard for the transformer leads. The batteries are held with wires fastened to the baseboard by means of soldering lugs and woodscrews. The connections to the 1½-volt battery are soldered. A standard snap-type battery plug is used for the 45-volt battery.

Pitch control

No provision was made in this model for changing the tone of the oscillator, but a pitch or frequency control can be added if desired. This control is a 100,000-ohm potentiometer (such as an ordinary volume control) which, in series with a 100,000-ohm fixed resistor, replaces the 180,000-ohm resistor. An on-off switch on the pitch control may replace the knife switch (*S*).

With this code practice oscillator, several headphones may be used in series, or an amplifier may be connected in place of the phones. The tone is very good, and is much more pleasing and realistic than that obtained with a buzzer.

PARTS LIST

R_1 = 180,000 ohms, 0.5 watt

R_2 = 100,000 ohms, 0.5 watt

R_3 = Pitch control potentiometer, 100,000 ohms, 0.5 watt

C_1, C_3 = 0.005 μF

C_2 = 0.001 μF

S = SPST knife switch

T = Audio interstage transformer, push-pull plates to push-pull grids

A = "A" battery, 1½ volts

B = "B" battery, 45 volts

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TESTING AUDIO AMPLIFIERS WITH SQUARE WAVES

By K. A. SIMONS
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The first question that must be answered before anything is said about *how* square waves can be used for testing audio amplifiers is: *Why* should they be used? Sine-wave testing is a well-established procedure. It gives the desired results. Why bother developing a new method? What advantages does square-wave testing have? A comparison of the two methods may help to answer these questions.

TESTING PROCEDURE

Sine-Wave Testing

Equipment:

1. Audio Oscillator
2. Attenuator
3. Output Meter

Procedure:

1. Connect output of Oscillator to input of Amplifier through Attenuator.
2. Set Attenuator so Amplifier does not overload.
3. Hold input constant and measure output voltage at a number of frequencies over the Amplifier's range.

Results:

1. A frequency response curve may be plotted by drawing a smooth curve through the measured points.
2. This curve actually shows the response of the Amplifier only at the measured points. Any irregularities between points, or spurious oscillations outside of the range of measurement will not show up.

Square-Wave Testing

Equipment:

1. Square-Wave Generator
2. Attenuator
3. Oscilloscope

Procedure:

1. Connect output of Generator to input of Amplifier through Attenuator.
2. Set Attenuator so Amplifier doesn't overload.
3. Observe the shape of the oscilloscope trace for square-wave input at only two frequencies, one low, one high.

Results:

1. The two patterns on the Oscilloscope screen may be traced or photographed.
2. These two patterns give a *complete* indication of the performance of the Amplifier, including any irregularities, and any oscillations outside of its normal range.

In the first place it should be clearly understood that square-waves are used primarily for checking the characteristics of an amplifier that are usually tested by measuring its frequency response with sine-wave input. Square-waves offer no advantages for measurements of power output or distortion, and a sine-wave test would still be used for these tests. Therefore the comparison must be made entirely between square-wave testing and sine-wave frequency response measurement.

Advantages of Square-Wave Testing

1. It is *Faster*. A complete test is made by measuring at only two frequencies.
2. It is more *Sensitive* to small variations. Two amplifiers whose sine-wave frequency response is almost identical may have very different square-wave responses.
3. It tells a more *Complete* story. When hum, motor-boating, or parasitic oscillations occur they may be rapidly identified and their cause located.
4. The effect of any circuit *Changes*, such as the operation of tone controls or the adjustment of compensating networks, can be observed instantly without any tedious curve plotting.

* Reprinted from RCA Radio Service News (Jan.-Feb. 1947) by courtesy of Radio Corporation of America.

Fundamentals of square-wave testing

The time-graph of a typical square-wave voltage is shown in Figure 1 (a). This voltage stays constant at plus 0.1 volt for half of each one-thousandth of a second, changes very suddenly to minus 0.1 volt and stays there for the other half, repeating this cycle over and over again. When a voltage like this is applied to the input of an amplifier, the shape of the amplifier's output voltage (as seen on an oscilloscope) will depend on two things:

1. The characteristics of the amplifier.
2. The frequency of the square-wave.

Since the former is of primary importance it is necessary to find some way of minimizing the effect of the square-wave's frequency on the results. Perhaps the best way to see how this can be done is to consider a typical case.

If the voltage shown in Fig. 1 (a) were applied to the input of an audio amplifier which had a gain of about 100, and a frequency response which fell off smoothly at the high end, its output voltage would probably look very much like Fig. 1 (b).

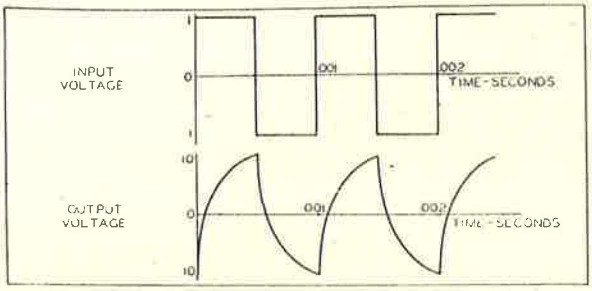

Fig. 1.
The response of a typical amplifier to a 1000 cycle square wave.

Immediately following each rapid change in input voltage, the output voltage changes in the same general manner, but more slowly. Exactly how long it takes the output voltage to complete its change is determined by the amplifier's characteristics. Whether this change is completed before the next change starts is determined by the frequency of the square-wave.

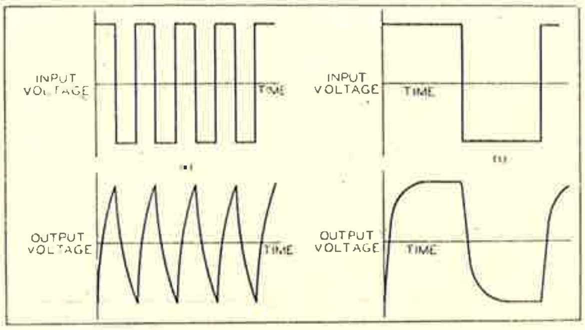

Fig. 2.
The response of the same amplifier to 2000 cycle (a) and 500 cycle (b) waves.

Figure 2 shows how the output voltage of this same amplifier would change for square-wave inputs at two other frequencies. To show the comparison most clearly, all of these graphs are plotted with the same time-scale as was used in Fig. 1. Notice that the output voltage of the amplifier takes the same length of time to complete its rise, regardless of the frequency of the applied square wave. This rise is shown most clearly, however, if the square-wave's frequency is made just low enough so that the output voltage has finished changing before the next change in input voltage occurs.

Succession of voltage "steps"

Having decided that the frequency of a square wave is not of critical importance in relation to the response of the amplifier it is testing, it seems logical to look around for a way of analyzing amplifier response in some way which does not involve frequency. This can be done by making use of the idea of a voltage "step".

A voltage "step" occurs when a voltage, which has had one value for a considerable length of time, changes suddenly to another value and stays there for a while. A simple example of a voltage step occurs when a battery is suddenly connected to a circuit, as shown in Fig. 3. The voltage, which was zero for some time before the closing of the switch, suddenly rises to the battery voltage and stays there.

Any square-wave voltage is simply a succession of positive and negative voltage steps following each other at equal intervals. If enough time is allowed between steps so that the effect of one on the output

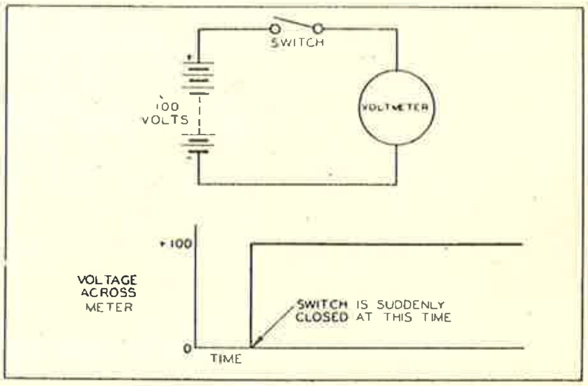

Fig. 3.
A voltage "step."

voltage has died away before the next one occurs, the output voltage change following each step will have the same shape as if that were the only step that was applied to the amplifier. This reduces the analysis of output wave forms to a fairly simple procedure:

1. Learn to recognize the response of a number of simple circuits to a voltage *step*.
2. Obtain on an oscilloscope the square-wave response of the amplifier under test, adjusting the frequency of the square wave so that each change is completed before the next one starts.
3. Compare the response following a sudden change in the square wave with the step response of various circuits, and select the circuit to which that amplifier is most nearly equivalent.

Step response of a few simple circuits

Fig. 4 shows the response of a few simple combinations of Resistance, Capacitance, and Inductance to a step voltage, together with their sine-wave frequency response curves for comparison. Certain general statements can be made (concerning these circuits only).

1. When a voltage step is applied to those

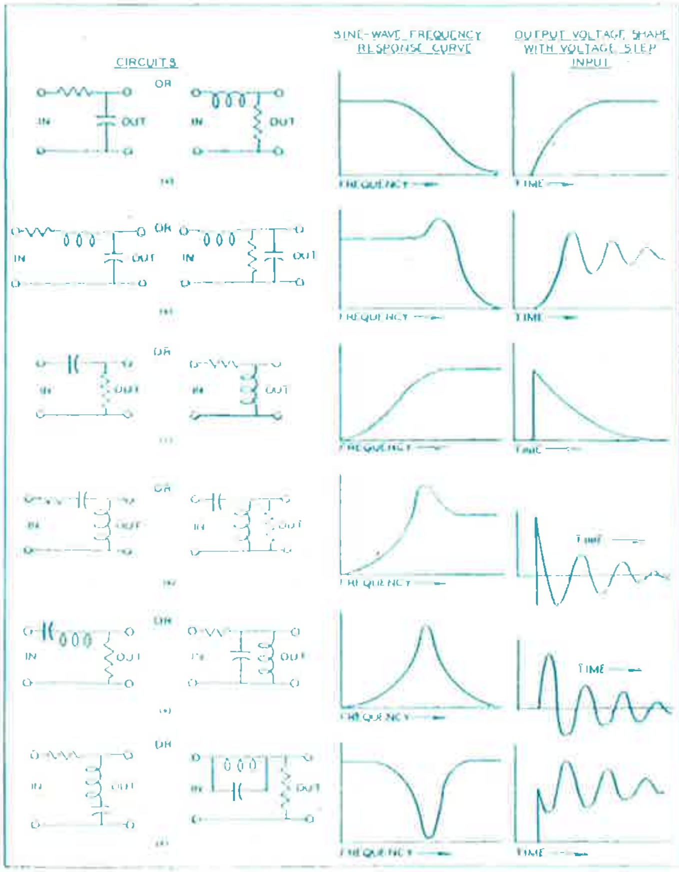

Fig. 4. Frequency response curves and response to a voltage step for simple circuits.

circuits which pass *high frequencies* (*c*, *d* and *f*) the output voltage follows the sudden rise in input voltage.

2. When a voltage step is applied to those circuits which pass *low frequencies* (*a*, *b* and *f*) the output voltage follows the shift in the average value of the input voltage.
3. When a voltage step is applied to those circuits which have a peak (*b*, *d*, *e* and *f*) response or a dip at a certain frequency, the output voltage tends to oscillate at the resonant frequency of the circuit.

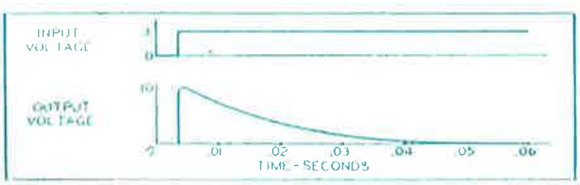

Fig. 5.
Response of the same amplifier to a voltage "step" and a longer time scale.

Why two square-wave frequencies are needed

When a voltage step is applied to an a-f amplifier, the output voltage *rises* to a steady value in a way that depends on the *high-frequency* response of the amplifier, and then *falls* slowly to zero in a way that depends on the *low-frequency* response.

If, for example, the output voltage of the amplifier previously discussed was observed for a longer period following a voltage step, it would probably behave very much as shown in Figure 5.

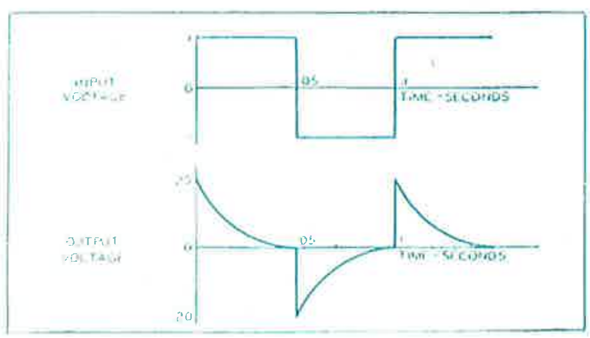

Fig. 6.
Response of the same amplifier to a 10-cycle square wave.

This response could be observed by applying a 10-cycle square wave to the amplifier's input. The resulting output would look like Fig. 6.

Thus, to obtain a complete test on the performance of an amplifier two square-wave tests are needed.

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