RADIOTRONICS

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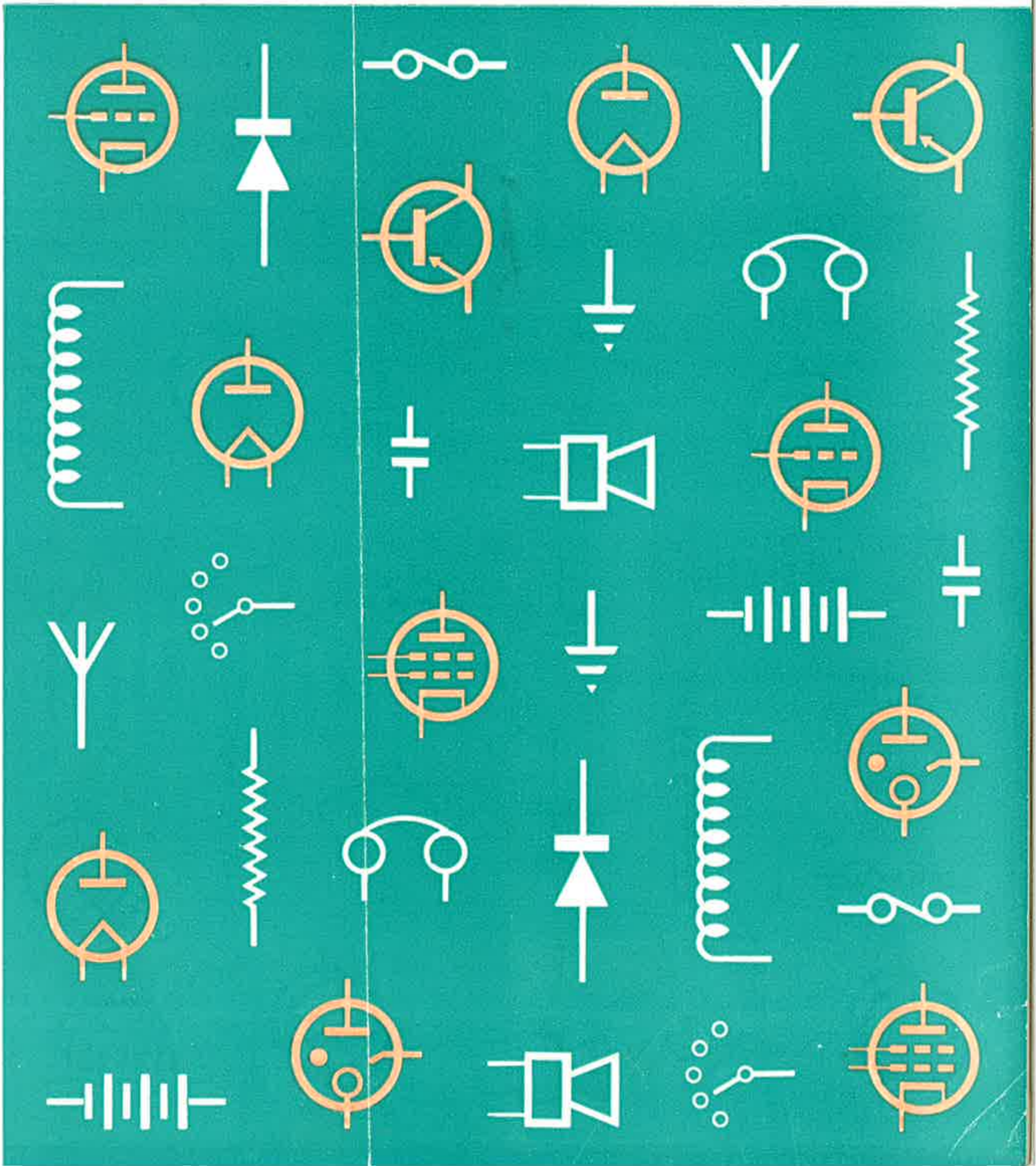

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Editor, Bernard J. Simpson

IN THIS ISSUE

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TRAVELLING WAVE TUBES FOR MICROWAVE COMMUNICATIONS NETWORK

By R. B. Coulsen, B.Sc., B.E.

The Travelling Wave Tube, invented during the last war by Kompfner, has been applied chiefly to civil communication equipments, where its broad bandwidth and high gain characteristics make possible the simultaneous transmission of several hundred telephone channels or a television signal.
After a brief description of the principles of operation, this article discusses the characteristics of TWTs of the types used in microwave communications systems.

Introduction

The travelling wave tube is a microwave amplifier characterized by an inherently broad bandwidth and relatively high gain. It was invented in England during the war, but the pressure of other work, notably on klystrons and magnetrons for radar purposes, prevented its full development and exploitation. Even now, its applications to military equipment are relatively few, and it is chiefly in the realm of civil communications that the travelling wave amplifier is coming into its own.

The steady increase in usable frequencies which has taken place since the war has permitted the design of multi-channel radio equipment capable of carrying increasing numbers of telephone channels. With the exploitation of the microwave frequency bands, several hundreds of telephone channels or a television signal may be carried. Such systems inevitably occupy very large bandwidths, and thus provide a natural application for travelling wave tube amplifiers.

The ability of a travelling wave tube to amplify effectively at uhf frequencies permits a radical simplification in communication equipments. Unlike other microwave devices, travelling wave tubes are large, thus calling for relatively less exacting dimensional tolerances and permitting the necessary emitting and power dissipating electrodes to be designed capable of giving very long lives. The reduction in the number of amplifying stages which are necessary can bring about a great increase in the overall system reliability, with consequent reduction in costs due to traffic breakdowns and attendant maintenance costs.

Principles of Operation

Basically a travelling wave tube consists of two electrical circuits: (1) a short length of waveguide having a low phase velocity, and (2) an electron beam passing down the centre of the waveguide.

The simplest waveguide with the required characteristic was used by Kompfner in his first experiments at the British Admiralty Signals Research Establishment, and has not yet been supplanted. This is a single wire wound in the form of a long helix supported inside a glass envelope. An electron beam is derived from a cathode situated one end. Accelerating voltages and focusing fields are arranged to produce a suitable beam of electrons which flows from the cathode down the centre of the helix and impinges upon the collector located at the opposite end.

Provided the proportions of the helix have been correctly chosen, a microwave signal can be coupled, either capacitatively or inductively, to the cathode end of the helix, and will propagate with only small ohmic losses to the other end. By similar coupling means, the signal is fed out of the helix and into the next stage of the amplifying equipment. If, during the passage of the signal along the helix, the electron beam is also flowing with the same velocity, there will be a transfer of energy from the electron beam to the helix, so that the signal is amplified considerably by the time it reaches the end.

Fig. 1 shows a travelling wave amplifier in schematic form. The pattern of arrows indicates the instantaneous distribution of the electric field of an electromagnetic wave travelling along the

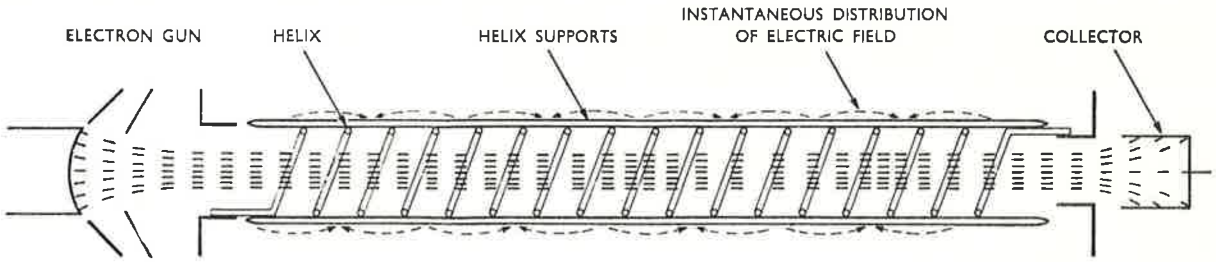


Fig. 1 — Schematic diagram of a TWT showing mechanism of beam bunching.

helix. At points corresponding to one half wave length (measured on the helix) the direction of the arrows reverses. This field pattern progresses with a phase velocity depending on the diameter and pitch of the helix. If the electrons in the beam are moving with the same velocity, it can be seen that some electrons are in an electric field which tends to oppose their motion, while others are in the opposite condition. Therefore, as the electron beam and the electromagnetic field move along together, bunching occurs as the faster electrons overtake slower electrons ahead of them. In other words a form of electrical energy is impressed on the electron beam and for this reason the beam may be considered an electrical circuit. A reciprocal condition also applies, the bunched electron beam inducing rf currents or modifying existing rf currents in the helix. In this way, the energy level of the wave along the helix is increased at the expense of the mean kinetic energy of the electrons in the beam. The electron velocity at the collector is thus lower than at the point of entry into the helix.[1]

Fig. 2 shows a typical power output travelling wave tube such as is used in the output stage of a 2000 Mc band microwave equipment. It is manufactured to the following dimensions:

Helix inside diameter	0.177"
Helix wire diameter	0.024"
Helix pitch diameter	18 turns per inch
Effective helix length	12"
Cathode diameter	0.394"
Final beam diameter	0.125"

It can be seen from these dimensions that the focus of the electron beam must be well maintained if interception of the beam by the helix is to be kept at a tolerably low level. The focus is maintained by means of a solenoid giving a longitudinal magnetic field of approximately 350 oersteds.

A travelling wave tube of this kind has an output of between 10 and 15 watts and an efficiency of approximately 20%. It has an overall gain of some 25 db. Input and output coupling to the travelling wave tube is by means of waveguide. A typical mount is shown in Fig. 3.

Travelling Wave Tube Characteristics

The three most important characteristics of a travelling wave tube are the high gain that can be obtained, the wide bandwidth over which this gain is maintained and the inherent simplicity and robustness of the device.

Theoretically there is no upper limit to the gain for which a TWT can be designed. The gain in decibels is linearly proportional to the helix length, and therefore the ultimate limit would seem to be largely a matter of mechanics.

Repeaters in a typical microwave system are separated by distances of 30 to 35 miles which, taking into account the customary antenna gains, calls for an amplification of the order of 80 to 90 db under median conditions, with a further gain margin of some 30 db to allow for fading.

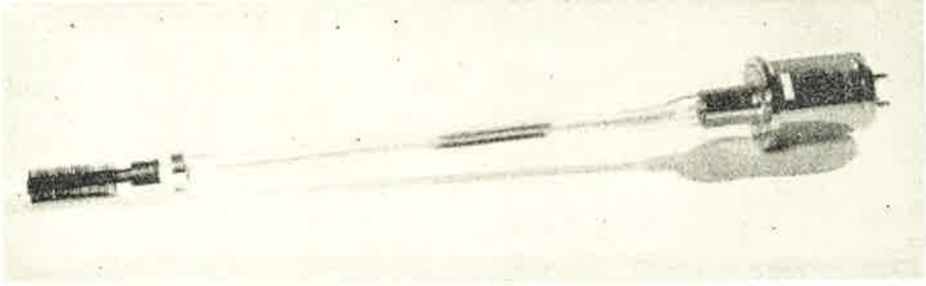


Fig. 2 — Typical power output travelling wave tube for the 2000 Mc band

It would be attractive to construct a travelling wave tube capable of this degree of amplification in a single stage, but unfortunately this is not at present practicable. The most fundamental difficulty arises from the fact that it is not possible to design a tube which combines a low noise factor with high power output. Output power tubes have a noise factor which may be as high as 30 db, whereas the associated receiver noise factor must be less than 10 db.

To avoid saturation at normal input signal levels, it is necessary to restrict the gain of the low noise input travelling wave tube. Because of these two factors it is not possible at present to design a microwave repeater, all the amplification in which is provided at radio frequency, using less than three tubes. This would comprise low noise and power output tubes and an intermediate tube which possesses certain of the qualities of each type. The necessary frequency change at the repeater can be achieved by modulating the helix of one of the tubes at the difference frequency, and selecting the desired output frequency by means of filters.

Apart from these considerations it becomes increasingly difficult to avoid self-oscillations in a tube with a gain of more than 35 db. Sometimes such oscillations are at very low power levels and extremely difficult to detect by normal methods. With a very high gain tube in a multi-channel

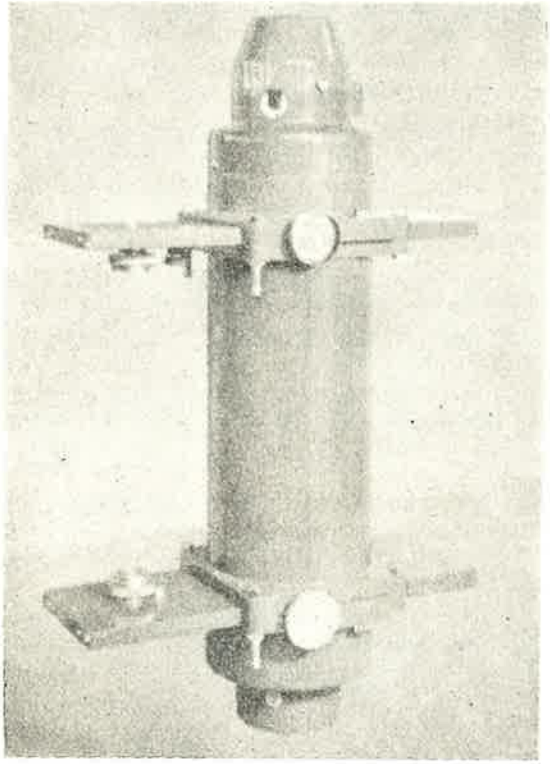


Fig. 3 — A 2000 Mc band travelling wave tube mount, showing waveguide/coaxial input and output coupling devices.

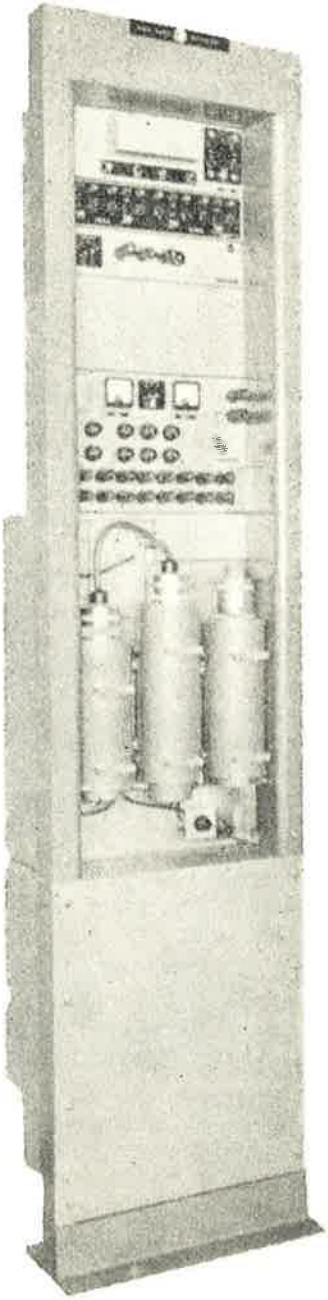
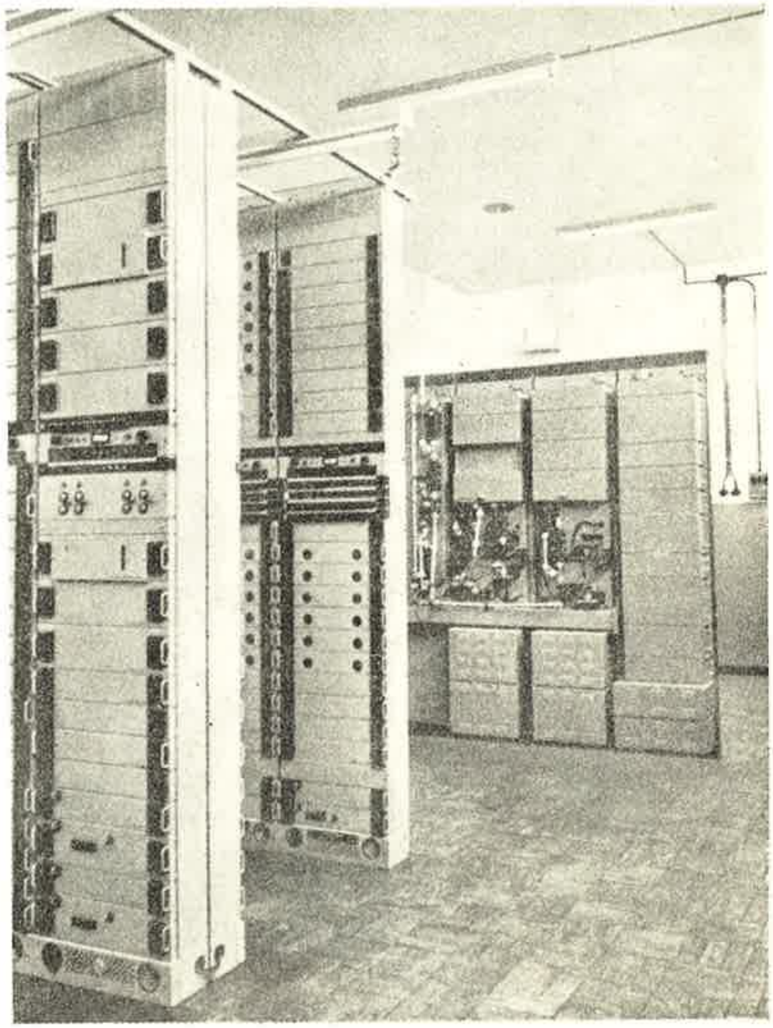


Fig. 4 — Typical 4000 Mc band all-travelling wave tube repeater.

telephone application there would be a great risk of spurious low level oscillatory power being impressed on the amplified signal, giving rise to cross-talk and noise modulation.

It will be noted in the above discussion, that nowhere has there been mention of a tuned circuit. From what has been said, it would appear that the amplifying properties of a travelling wave tube do not depend directly on the frequency of the signal. This is not the case, however, since for any helix and beam, the degree of coupling between the two circuits does depend on frequency, but not nearly to the same extent as in, say a kylstron or a triode with grid and anode tuned circuits. The chief frequency limitation is, in fact, the bandwidth of the coupling means between the external wave guides and the ends of the helix. This, to some extent, is determined by the amount of time one is prepared to spend on the problem and by one's definition of bandwidth. If the voltage standing wave ratio is required to remain below 1.5 to 1, the bandwidth is typically 10% to 15% of the centre frequency. If a vswr of 1.1 to 1 is required, 1% to 2% is a more realistic figure, and is the bandwidth used in high quality multichannel telephone relay systems.

The significance of a microwave radio repeater requiring only three tubes to provide the total amplification will not have escaped notice. Such a repeater, an example of which is shown in Fig. 4, becomes the ultimate in simplicity and the most reliable. Since the difference in receive and transmit frequencies is of the order of 200 Mc only, this change can be achieved without resorting to microwave oscillators. The frequency stability of those which are required is of a secondary order since it is only a difference frequency which is being generated.

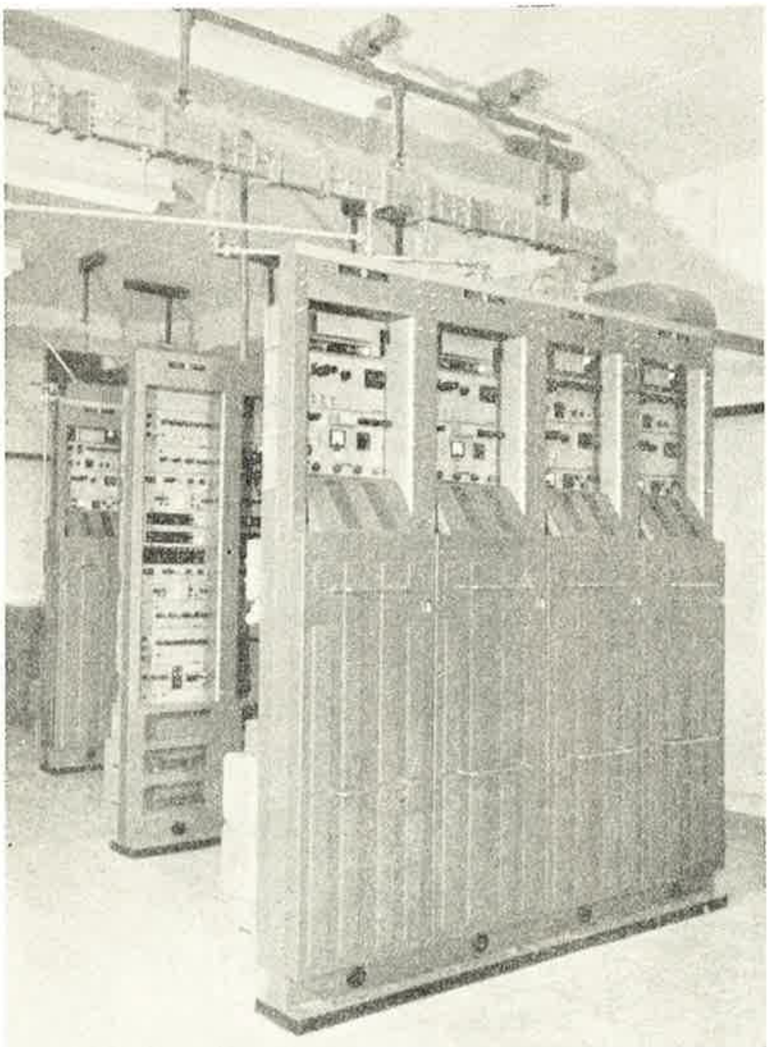


A typical 2000 Mc installation showing microwave equipment and carrier bays, at Montijo, Portugal.

While the application of TWT techniques is particularly attractive in the case of repeater equipment in microwave communications systems, as it enables all amplification to be carried out at radio frequency, nevertheless there is advantage also in using these tubes at the terminal equipment. The power gain and high power output possessed by a TWT enables a transmitter to be designed which permits the use of low level mixers, thus easing considerably the design problems where high performance is involved. Similarly, the noise figure obtainable by the use of a low noise TWT is slightly though significantly better than that obtainable by conventional crystal mixer techniques.

Once a radio link is put into service as a public utility it is of paramount importance that the service remains uninterrupted. Irrespective of system design, the greater the number of elements capable of failure the greater the probability of failure. If we consider the probability of survival of one active element after a certain time is P, then the probability of survival in the same time of an equipment consisting of three such elements is P^3. For ten elements the probability would be P^{10}. For example, for $P = 0.7$ for 10,000 hours' operation, then with three elements (TWTs) $P^3 = 0.343$ whereas with ten elements (triodes) $P^{10} = 0.02824$. This suggests that the optimum design of a repeater is one in which the number of elements is small and for which the probability of survival, P, is the highest possible.

A considerable amount of effort has been devoted to increasing the life expectancy of travelling wave tubes. They are fundamentally more reliable than other microwave devices because their relatively large dimensions avoid excessively small manufacturing tolerances and also permit the use of large emitting surfaces. That the life should be any different from other kinds of lower frequency tube is due to the use of an electron beam which by reason of its



2000 Mc travelling wave equipment at Mendlesham, near Norwich.

System Maintenance

Compared with equipments using other types of rf amplifiers, those embodying TWTs are remarkably simple to service. Because of its length, there is more chance of breakage and for this reason moderate care must be taken in handling. However, since no tuned circuits are involved, the procedure is quite straightforward, although some adjustment of the matching devices at input and output may be necessary, especially if a very low vswr is required.

Voltage and current adjustments are not excessively critical, and the first installation of a new tube can be done by maintenance personnel after a small amount of instruction, and by reference to simple monitoring devices.

It will be appreciated that for maximum performance, most of the electron beam leaving the cathode should reach the collector without impinging on the helix or other electrodes. For a power tube such intercepted current may overheat part of the helix and in the case of an extremely mis-focused beam, localized melting of the helix may occur.

length and high current density, gives rise to a long column of heavy positive ions which drift back to the cathode and tend to destroy the cathode material. In certain cases this problem can as yet only be met by the most careful manufacturing technique but in other cases, particularly for power tubes, a concave cathode can be used. This renders the problem less acute as the ions tend to collect in the middle of the electron beam where the beam potential is lowest and the cathode bombardment is therefore restricted to a small central area. Even though the active material may be completely destroyed in this region, the effect on the total electron emission is negligible. This ion bombardment can be reduced by running the collector at a lower voltage than the helix; the ions then tend to drift to the collector. In certain more recent tubes, an ion trap is introduced by providing a voltage "pump" by maintaining the accelerating anode at a voltage higher than the helix. By this and other means, lives well in excess of 10,000 hours are being obtained.

This could not happen in a low noise tube where the total beam power is very small, but the consequence of a high helix current may be a high noise factor.

High helix current will occur if the energizing current in the electro-magnet is too low, or if the TWT is misaligned so that its axis does not lie along that of the electro-magnet. To prevent this latter circumstance, a travelling wave tube intended for relay equipment is fitted with machined mounting surfaces, adjusted in the factory for current in the electromagnet is too low, or if with corresponding seating surfaces so that when a tube is installed, no alignment procedure is necessary. Fig. 5 shows a set of three tubes designed for relay equipment working in the 4,000 to 5,000 Mc band. The large diameter of the base has been so fashioned to provide an accurate seating surface. A similar surface is provided at the collector end.

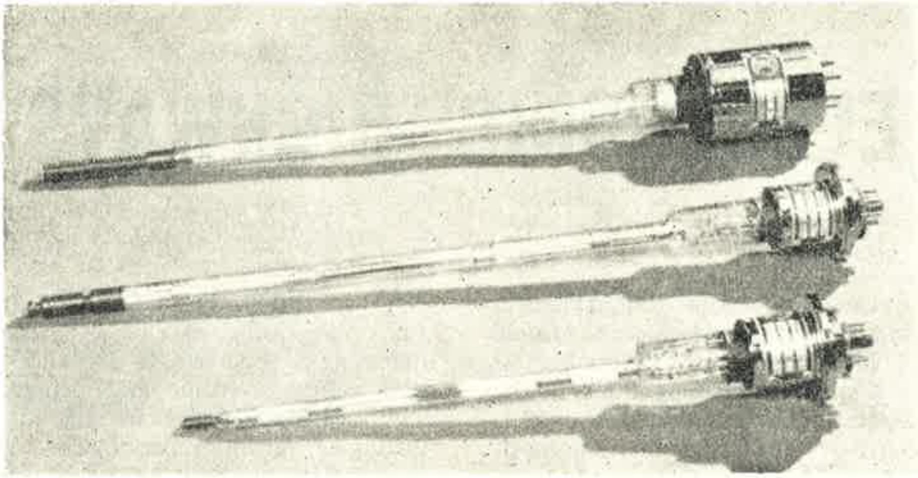


Fig. 5 — 4000 Mc band low noise, intermediate and power output travelling wave tubes. Note the machined seating surfaces at each end.

Conclusions

Installations incorporating TWT amplification are now under way in Italy, Portugal, Yugoslavia, Sweden, Norway and Australia as well as in the United Kingdom, and the application of this technique can therefore be said with truth to have progressed beyond the experimental stage. It is now generally appreciated that TWTs are ideally suited to link applications and it is becoming increasingly recognized that particularly for trans-continental high performance systems, the TWT has no effective competitor as a highly reliable amplifier of microwave signals.

[1] J. R. PIERCE: Travelling Wave Tubes', Van Nostrand, 1950.

Reprinted from "Point to Point Telecommunications", published by Marconi's Wireless Telegraph Co. Ltd., England.

NEW RELEASES

QS1215

The new EEV 90 volt miniature cold cathode voltage stabiliser, type QS1215, is designed for operation within the current limits of 1 to 40 ma and over this range the tube has a maximum regulation of 10 volts and a nominal regulation of 8 volts. Maximum striking voltage in normal lighting or total darkness is 115 volts, with an operating voltage of 86 to 92 volts at 20 ma. Maximum variation of operating voltage in the first 1,000 hours is 1%. The temperature co-efficient between −55°C and +25°C is −10mv/°C max and between +25°C and 90°C is −5mv/°C max. Radioactive material has been used in the tube to facilitate breakdown under low ambient light conditions and the maximum voltage required for striking the tube is the same in normal lighting and total darkness. The total spread in operating voltage between tubes at the nominal current of 20 ma is only 6 volts.

K359

The EEV K359 is a new rugged reflex klyston designed primarily to operate in the severe environmental conditions prevailing in airborne equipment. It is a frequency variant of the K351 for use as a local oscillator in the frequency range 8050 to 8800 Mc. Designed to operate from a resonator supply of 350 volts, the K359 gives 2 to 3 db more power than the K351, although lower voltage operation is possible.

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ELECTRONIC HIGHWAYS

The Radio Corporation of America and General Motors recently demonstrated a full-size electronic automobile guidance and warning system on a test installation on a quarter-mile-long track at the David Sarnoff Research Centre, Princeton, N.J. The basic elements of the installation consist of a series of rectangular wire loops, each about the size of a car, and a continuous guidance cable, all buried under the roadway, with a chain of transistorized detector circuits, one for each loop, located alongside the roadway. Specially-equipped driverless cars can be operated on the test track, steering themselves and automatically maintaining a safe distance behind other cars on the same track.

Directional Guidance

The guidance and control in the system fall into two components, directional control, which keeps the vehicle on a pre-determined lane by controlling the steering, and control of distance and speed, which controls the throttle opening and also gauges distance to any car ahead.

Steering control is provided through the continuous guidance cable buried under the centre of the track, and two pickup devices mounted on each vehicle. Reception and comparison of 15-kilocycle signals induced into the two pickup devices from the guidance cable produces a resultant error signal which is used to actuate the steering mechanism. When the vehicle is perfectly on track, the resultant error signal falls of course to zero; the polarity of the error signal determines the "sense" of the steering correction applied.

The continuous guidance cable can also be used to transmit voice information which can be fed to a loudspeaker in the car. Emergency announcements, bulletins on traffic and road conditions and other messages can be passed over the system to advise and instruct occupants of vehicles.

Speed Control

Control of vehicle speed and the maintenance of safe distances from other vehicles in front is afforded by the rectangular loops laid in the road-bed, with their associated transistorized detectors. Each loop forms part of an oscillatory circuit, operating at about 100 to 300 kilocycles. Passage of a vehicle over the loop detunes the circuit. The transistorized detector unit at the roadside thereupon generates two signals, which are fed to control equipment and to a third buried wire called a "tail antenna."

The tail antenna radiates a variable pulse width signal at 4.5 kilocycles to control distance or separation, and a pulse-spaced signal at 8 kilocycles for speed information. These signals are picked up by twin detector loops located at the back of the vehicle and used to control engine throttle opening, brakes and associated controls. Although not stated, it is assumed that cars with automatic transmissions are used, eliminating the complication of providing clutch and gear-shift controls.

The signals generated by the tail antenna are also picked up by the next tail antenna to the rear, a little over one car's length back along the road. These signals are then retransmitted by the next tail antenna, but at a lower level, and with the 4.5-kilocycle signal modified to indicate the addition of one car's length between the leading car and any that might be following.

It will be seen that a vehicle moving down a highway thus equipped generates what has been described as a "flying electronic tail" behind it by exciting the buried loops and actuating the control and signalling circuits. Each vehicle wipes out the preceding tail signal and generates a new one of its own. The vehicle speeds are regulated by control of the "speed" 8-kilocycle signal, possibly from a central traffic control point, and also by the 4.5-kilocycle signal which ensures reduction of speed to prevent rear-end collisions.

Application

The outline just given illustrates perhaps only the most-obvious application of the system, but the control signals from the detectors can be used in several ways. They can be used to measure speed, operate speed warnings, count traffic flow, operate traffic lights and turn roadside illumination on and off.

One problem currently being studied is the use of the system where roads are fog-bound regularly and for long periods. One idea that has been put forward is to install guidance lights in the highway surface which would change pattern or colour to signal information to drivers on road conditions and traffic ahead. This would allow drivers to speed up where it was safe to do so. This and some of the other applications would not of course require cooperating equipment in the vehicles as would the driverless control system first discussed, and could be introduced merely by installing the necessary equipment in the road bed.

One limited installation has been in use for about two years by the Nebraska Highway Department, and it is understood that further installations are planned. One interesting application will be installed at a very congested intersection, where, because speed and spacing data on cars approaching the intersection is instantly available, a special computer will be installed to programme the traffic lights at the intersection.

RCA are supplying guidance equipment also to the Federal Aviation Agency for installation at the National Aviation Facilities Experimental Centre at Atlantic City, N.J. Here the FAA will test the possibility of using the equipment for monitoring of aircraft positions and movements on the airport to assist controllers in the routing of ground traffic.

Estimates of costs on these systems are very approximate. Road control systems are estimated to cost between 5% and 10% of the total highway cost, depending on the number of lanes controlled. Vehicle equipment is estimated at between 200 and 300 dollars.

NEW RELEASES

(Continued from page 191)

7533

The 7533 is a tunable oscillator triode of the pencil type designed for use in battery-powered radiosonde applications where high efficiency, light weight, low battery drain, and small frequency drift are important considerations.

The 7533 has two resonators integral with the valve. One resonator, connected between grid and cathode, is fixed-tuned to provide relatively uniform power output over the operating frequency range. The other resonator, connected between grid and plate, is loop-coupled to a coaxial rf output terminal and can be tuned capacitively within the 1660 to 1700 Mc frequency range by means of two frequency-adjustment screws.

This type can be operated over an ambient-temperature range of $-55°$ to $+75°C$, at altitudes up to 100,000 feet without pressurization, and will withstand severe vibration. It has a maximum plate-dissipation rating of 3.6 watts.

7457

The 7457 is a new, very small, forced-air-cooled, uhf beam power valve designed specifically for applications where dependable performance under severe shock and vibration is essential. It is intended for use as an rf power amplifier, oscillator, frequency multiplier, af power amplifier, or modulator valve in compact mobile or fixed equipment.

The 7457 has a maximum cw plate input rating of 180 watts and a maximum plate dissipation of 115 watts. It can be operated with full ratings at frequencies from 960 to 1,215 Mc, and is useful up through 2,000 Mc and above. Because of its high power sensitivity and high efficiency, it can be operated with relatively low plate voltage to give large power output with small driving power.

The 7457 features a coaxial type of structure with "one-piece" electrode construction.

TIP CONDITIONING

Solder joint failure is often a result of improper care of the working element of a soldering iron — the tip. When a technician neglects the condition of the soldering iron tip used in his work, the time consumed in making circuit repairs is often appreciably increased and the reliability of the repairs is likely to be decreased.

Copper is used extensively for soldering-iron tips because of its high-volume thermal conductivity and its ease of tinning. To remain efficient, copper tips require frequent and periodic dressing. Soldering-iron tips that are made of iron-plate copper alloy are less efficient than pure copper tips, but they are more durable and require less attention.

It is important to keep in mind that soldering-iron tips must be cared for, if they are to serve efficiently and last for a reasonable length of time. The effectiveness of a soldering iron tip is greatly dependent upon how well it is tinned and the degree to which it is kept clean.

If the soldering iron tip is in serviceable condition, cleaning it with a wiping cloth frequently and keeping it well tinned is all that is required to keep it in good condition. Use a white cotton duck cloth to clean the tip; this material will leave no lint and is sufficiently coarse to clean off oxides (corrosion), enabling the tip to function properly. Avoid using ordinary rags that can leave lint on the tip of the iron. Lint can carbonize and become enmeshed in a connection; this can be a possible source of trouble.

Caution should be exercised in cleaning tips with a steel wire brush or file, since this can destroy the oxide protective coating found on some tips and reduce this effectiveness. A file should be used for retipping a bit only when excessive pitting makes it necessary.

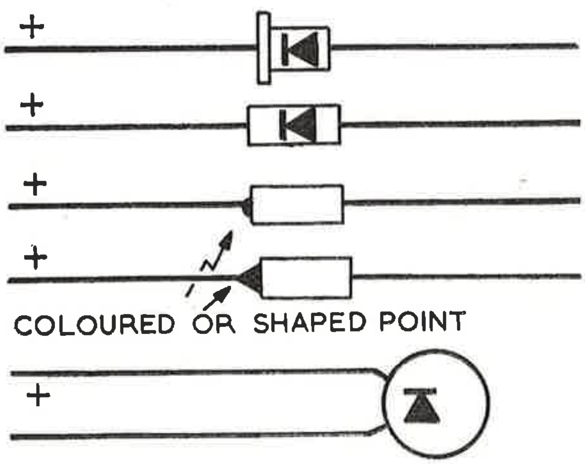
Always keep a soldering iron tip well tinned. After cleaning a tip, retin it immediately. Oxides allowed to form on the tip of the iron can reduce the effectiveness of the iron to a great extent. When storing a tip over night, see that it is well covered with solder. When putting a soldering iron into use, retin the tip as soon as it reaches operating temperature.

Allow the soldering iron to dissipate heat freely while in stand-by service; an enclosed soldering iron holder will cause over heating of the tip and result in excessive oxidation; an open or well-ventilated type of holder will contribute to the ease in which a soldering iron tip can be maintained.

SILICON RECTIFIERS

When replacing silicon rectifiers, take care to avoid subjecting them to excessive heat. Silicon rectifiers can be damaged if subjected to the direct heat of a soldering iron. Such damage may not show effects immediately but may result in a breakdown at a later date.

Application of heat to the pigtail leads of a silicon rectifier closer than one inch away from the body of the rectifier should be avoided. A heat sink, such as pliers clamped on the lead between the solder point and the body of the rectifier, should be employed during the soldering operation. Silicon rectifiers should be installed with a minimum of one inch of pigtail lead between the solder point and the body of the silicon diode.



When replacing a silicon diode rectifier, be certain that the proper polarity is observed. The polarity of the rectifier is usually marked on the body of the diode with the "diode" symbol. The diagram shows some typical silicon diodes and their polarity.

AV44

TUNGSTEN FILAMENT CONTROL DIODE

DESCRIPTION

Type AV44 is a tungsten filament control diode intended for use in ac regulator circuits. The AV44 supersedes and is unilaterally interchangeable with the AV36B; the AV44 may be used as a direct replacement for the AV36B, 29C1 and similar diodes in existing equipment, provided the necessary adjustments are made in the filament series resistor.

The AV44 retains the plate-to-filament short circuiting feature with an improved design of switch; this feature automatically protects the equipment in the event of filament failure. In addition, the use of a smaller-diameter filament has resulted in reduced filament current and a faster response time; this is a considerable advantage in some applications. The AV44 features good stability, high resistance to burn out, vibration and shock, with good life expectancy.

GENERAL DATA

Mechanical:

Mounting position	Any
Overall length	3¾" max
Seated height	3⅛" max
Diameter	1¼" max
Bulb	T9
Base	Intermediate Octal, 7 pin

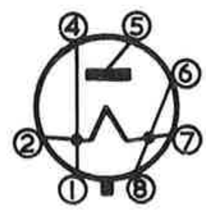
Maximum Ratings:

Filament voltage (ac or dc)	3.5 volts
Filament current	0.8 amp
DC plate voltage	250 volts

Typical Operation:

AC filament voltage	2.5 volts
AC filament current	0.72 amp
DC plate voltage	100 volts
DC plate current	0.1 ma

Socket Connections
(Bottom View)



Pins 1, 2 and 4	Filament
Pin 5	Plate
Pins 6, 7 and 8	Filament

To reduce contact resistance each end of the filament is brought out to three base pins, all of which should be used.

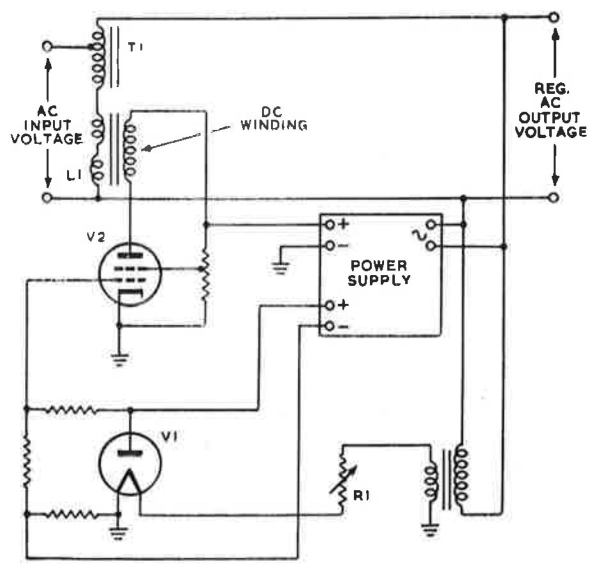


Fig. 1 — Typical Circuit using the AV44.

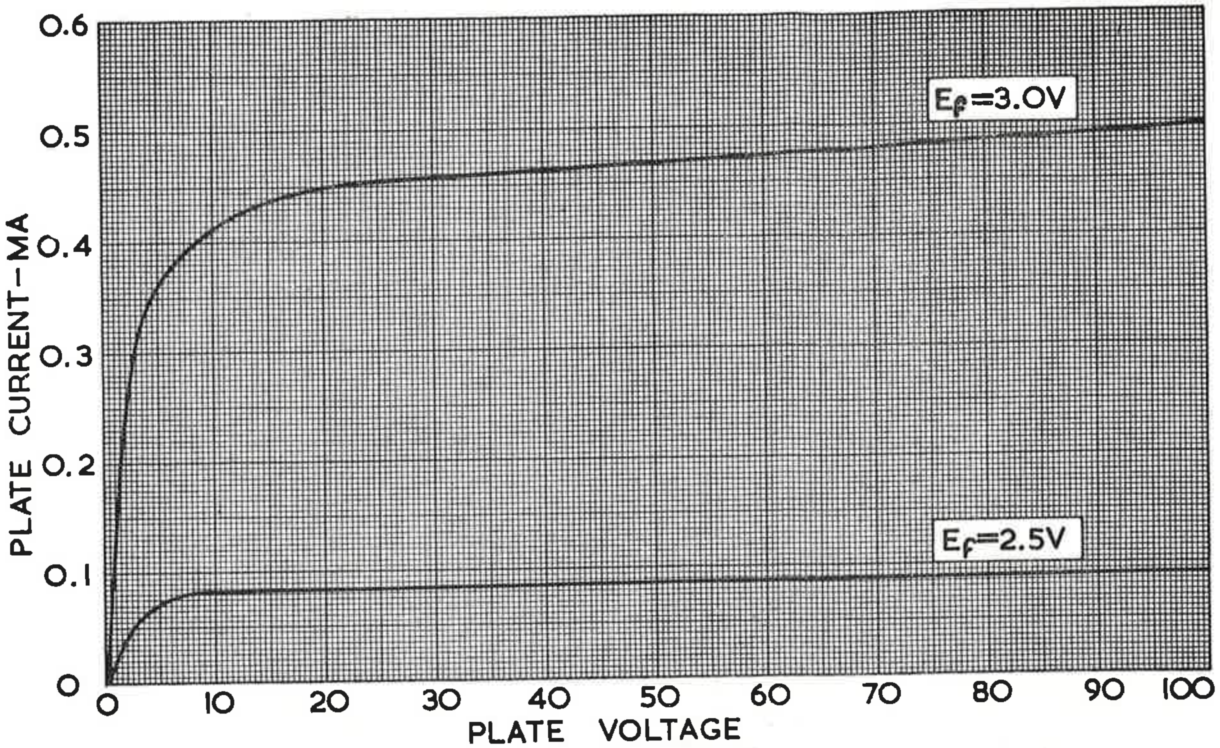


Fig. 2 — Plate Voltage/Plate Current Characteristic of the AV44.

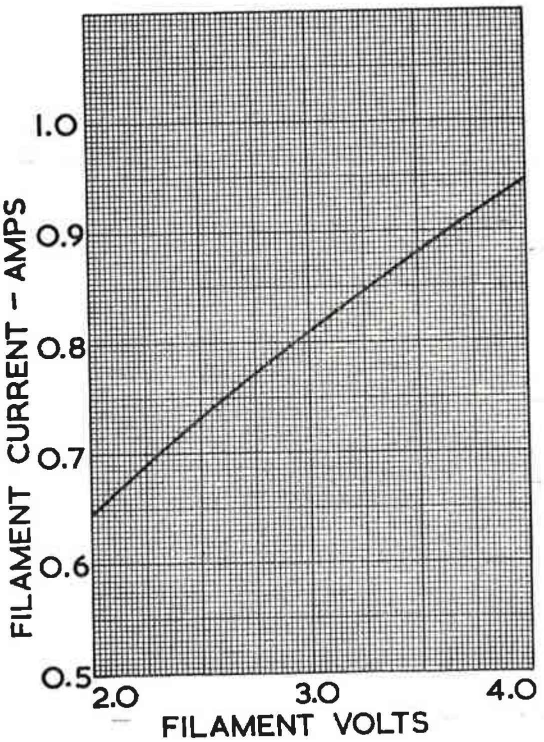


Fig. 3 — Filament Voltage/Filament Current Characteristic of the AV44.

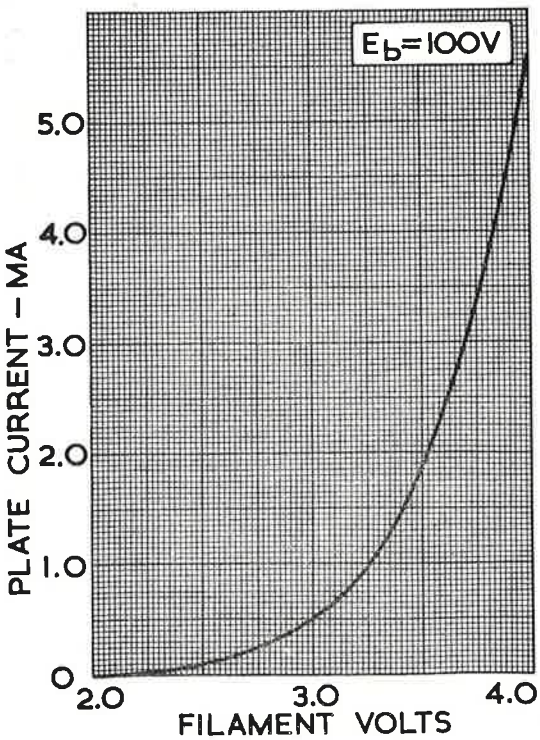


Fig. 4 — Filament Voltage/Plate Current Characteristic of the AV44.

APPLICATION DATA

AC voltage regulators generally include a sensing element which detects voltage deviations from the desired output voltage. The output of this sensing element is, after amplification, applied at some point in the circuit to minimize the initial deviation, so returning the output to the correct value.

Temperature-limited diodes having a pure tungsten filament are very satisfactory sensing elements because of their rapid change of saturated plate current with changing filament voltage. A typical circuit is shown in Fig. 1.

If the filament of an ordinary control diode open-circuits, so causing its plate current to vanish, it can be seen from the above explanation that the output voltage must rise to the maximum extent allowed by T1. This is very undesirable in certain applications, and, in the AV44 control diode, is avoided. The built-in switch shorts the plate-to-filament automatically when the filament opens, so causing the output voltage to drop to the lowest extent allowed by T1. No damage due to excessive regulator voltage can thus occur.

Typical regulators of this type will maintain the output voltage accurately to 0.5% or better over a wide range in load current, and input voltage variations. The AV44 is insensitive to frequency changes.

BOOK REVIEWS

"NUMERICAL METHODS FOR HIGH SPEED COMPUTERS" G. N. Lance, M.Sc., Ph.D., M.I.A.S., A.F.R.Ae.S. Iliffe & Sons Ltd. Size 8¾" x 5½". 166 pages.

To realise the full possibilities of which electronic computers are capable it is essential that they should be fed with information in the most suitable form. Programmers are frequently finding that classical methods of mathematical computation do not take full advantage of the facilities provided by modern automatic high speed computing machines. Because of this, research mathematicians have developed new methods of solving complicated problems, many of which are applicable only to electronic computers. To date, most of the new methods have only been published in original papers which may have a limited circulation and are not readily available. The author has collected into a single volume the most useful of these new methods, including some which he has himself developed.

Important considerations such as the degree of accuracy, the amount of storage space required and the time taken to obtain the result, have not been overlooked. The result is a thoroughly practical approach to the subject. The mathematical formulae and methods given are general in the sense that they are applicable to most modern computers, hence they are of value to every programmer irrespective of the type of machine he has at his disposal.

This book should prove invaluable to programmers, mathematicians, engineers, physicists, chemists and scientists generally who are interested in the application of electronic computers to the solution of their own particular problems.

"ELECTRONICS FOR THE BEGINNER." J. A. Stanley. Howard W. Sams & Co. Inc. Size 8½" x 5½." 190 pages.

To say that this book is a beginner's course in electronics is not only a paraphrase of the title, but a complete understatement. This is essentially a book for the beginner who wants to approach electronics from the practical rather than from the theoretical viewpoint. The book is full of electronic projects that a reader can tackle with no previous technical training at all. The copious illustrations, with step-by-step instructions, guide the novice's hands to success. This can be good fun, not only for the many teenagers who will set their first foot into electronics with this book, but for anyone who likes to use his hands and feels the attraction of electronics and all it means. If a lot of theoretical knowledge rubs off onto the exprimenter in the meantime, who is going to complain?

"SPECIAL QUALITY VALVES" Amalgamated Wireless Valve Co. Pty. Ltd. Size 10½" x 8¼". 32 pages.

This latest AWV publication deals with special ranges of valves, which, although their basic characteristics are usually similar to those of the equivalent commercial type, are especially manufactured and tested to meet exacting conditions. These valves are intended to meet the increasingly-heavy life and performance requirements inspired by industrial and other specialised applications. This booklet provides data which is invaluable to the designer and engineer. The features of these special-quality valves are outlined, with selection guides, data charts and equivalents tables. The booklet forms a comprehensive reference.

A ONE VALVE WALKIE TALKIE

With Transistorized Audio Stages

Martin L. Kaiser, W2VCG

Interested in small-sized, low-cost walkie-talkies? Then you may find the newly developed 28-megacycle unit described in this article especially suited to your requirements.

Evolved from numerous units constructed by the writer over the last decade, this walkie-talkie features a unique application of two 2N407 germanium p-n-p alloy junction transistors in combination with a 6AK5 sharp-cutoff pentode. The 2N408 transistor, readily available in Australia, is electrically identical with the 2N407, except that it has flying leads instead of a plug-in base; this arrangement is generally more popular, as no socket is required.

Under normal operating conditions, the walkie-talkie can achieve a range of about five miles; receiver sensitivity is ½ microvolt.

The 28-megacycle band was selected for the following reasons:

(1) Operation at 28 Mc permits use of a conveniently sized, easily portable antenna.

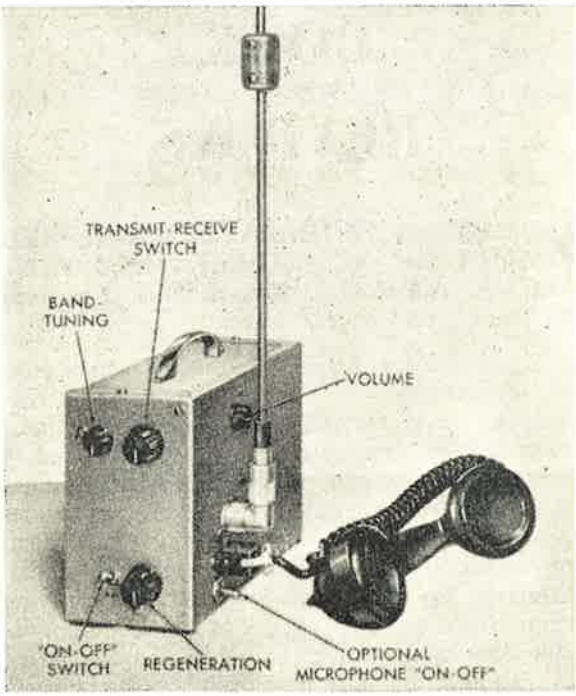
(2) On the crowded lower-frequency bands, QRM is difficult to overcome with only 1-watt output.

(3) At higher frequencies, coil placement and lead length are extremely critical, and special vhf construction procedures must be followed.

Receiver Circuit

As shown in Figure 1, a single 6AK5 valve is used in the circuits of both a superregenerative receiver and a modulated tri-tet oscillator in the transmitter. The circuit of the regenerative-type receiver is conventional.

Regeneration is obtained by feeding some of the signal from the plate coil (L6) to the grid coil (L4). The amount of regeneration is determined by the setting of R11, a 100,000-ohm potentiometer; this control is set just below the point of oscillation. This point will vary with the frequency



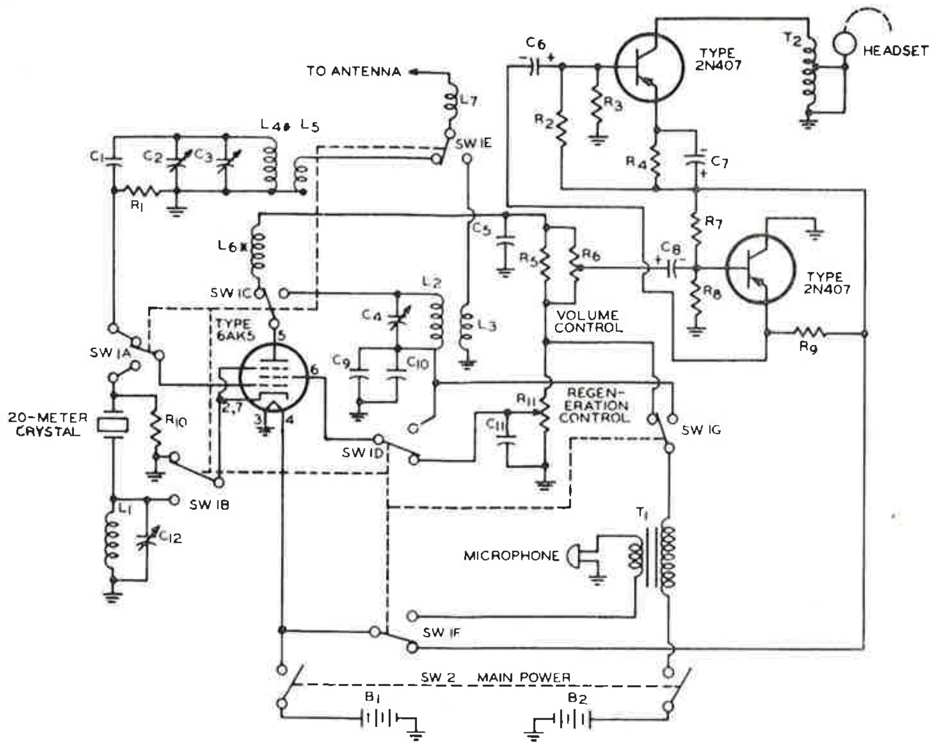


Fig. 1 — Schematic Diagram of W2VCG's One Valve Walkie-Talkie with Transistorized Audio Stages (*L4, L6 are cemented together.)

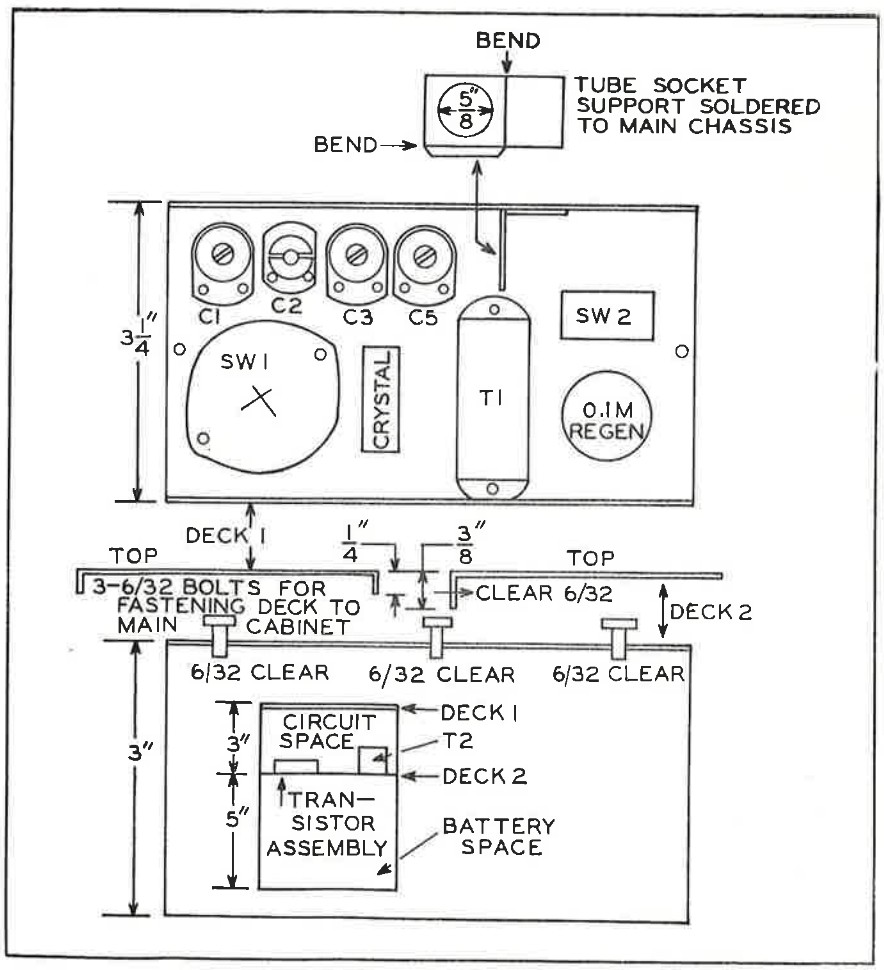


Fig. 2 — Chassis Layout for all Major Components in the Author's Walkie-Talkie.

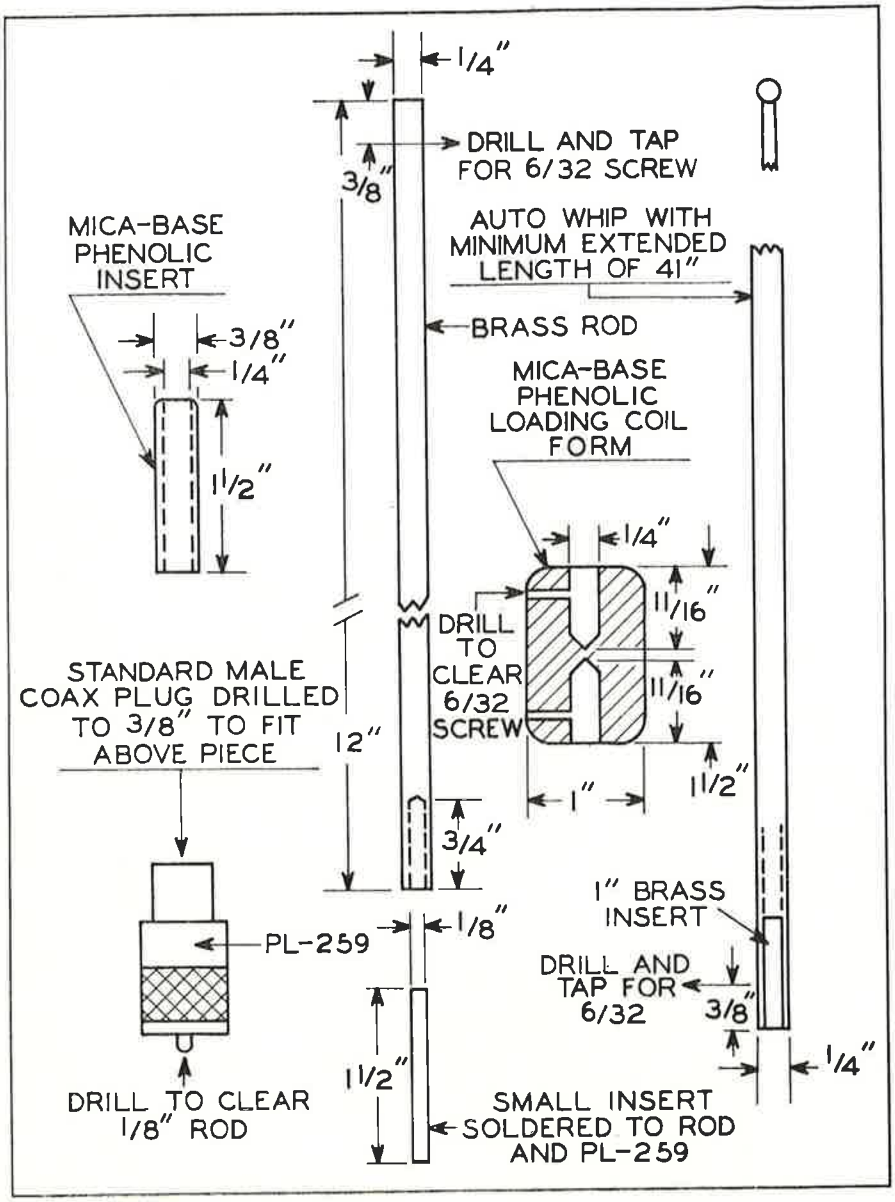


Fig. 3 — Antenna Assembly for Use with the One Valve/Two Transistor Walkie-Talkie.

to which the receiver is tuned. The audio signal appears across the plate-load resistor (R5) and the volume control (R6) and is transferred through C8 to the base of the 2N407 or 2N408 emitter-follower.

Figure 2 shows the chassis layout for all major components. After these components have been mounted, the 6AK5 socket and the TR (Transmit-Receive) switch are connected by a small cable consisting of five 4-inch wires. These wires must be connected to pins 1, 2, 4, 5, and 6 at the valve socket. Pins 2 and 7 are connected together at the socket; pin 3 is soldered to the copper support bracket. Leads carrying dc and audio frequencies are soldered to common terminals at the rear of the TR switch, while leads carrying radio frequencies (leads from pins 1, 5, and 6, for example) are soldered to common terminals of the switch nearest the valve.

After these leads are connected to the switch, all coils (L1 through L6) are mounted securely. Coil L1 should be mounted close to the crystal and, together with L2 and L3, as far as possible from metal surfaces.

Coverage of C2, the main band-tuning capacitor, can be determined experimentally, depending on the coverage required and the sharpness of tuning. A value of about 5 to 10 pf should work out alright.

After L4 is wound, the windings should be secured with coil "dope." Then, when the cement has dried, L6 is wound in the same direction and on top of L4 at the ground end. L6 is cemented securely to L4. When L4 and L6 are wired, the two outermost leads of the coil combination go to the grid and plate circuits of the 6AK5. The end of L4 nearer L6 should be grounded, and the other end connected to the grid circuit. The end of L6 nearer the ground end of L4 goes to the plate. If this wiring arrangement is not followed, the circuit will not operate.

Audio stages are wired on a separate sub-assembly, as shown in the accompanying photograph. The audio stages appear in the bottom left portion of the photo; the audio driver transformer is shown at the bottom right.

T2 is a transformer which has a 600-ohm winding with multiple taps, one of which is 75 ohms. The 600-ohm winding closely matches the impedance of the 2N407 driver, and the 75-ohm tap closely matches the impedance of a standard telephone-headset earpiece. Voltages are fed to the emitters of the transistors and the collectors held at ground potential. This arrangement permits the telephone headset to be connected in the ground lead of the output transistor. The other 2N407 is an emitter-follower which drives the low-impedance base of the audio-output stage from the high-impedance output of the 6AK5. L7 is wound with uniform spacing on the loading-coil form shown in the antenna diagram, Figure 3. It is then sprayed or painted with a heavy layer of coil dope.

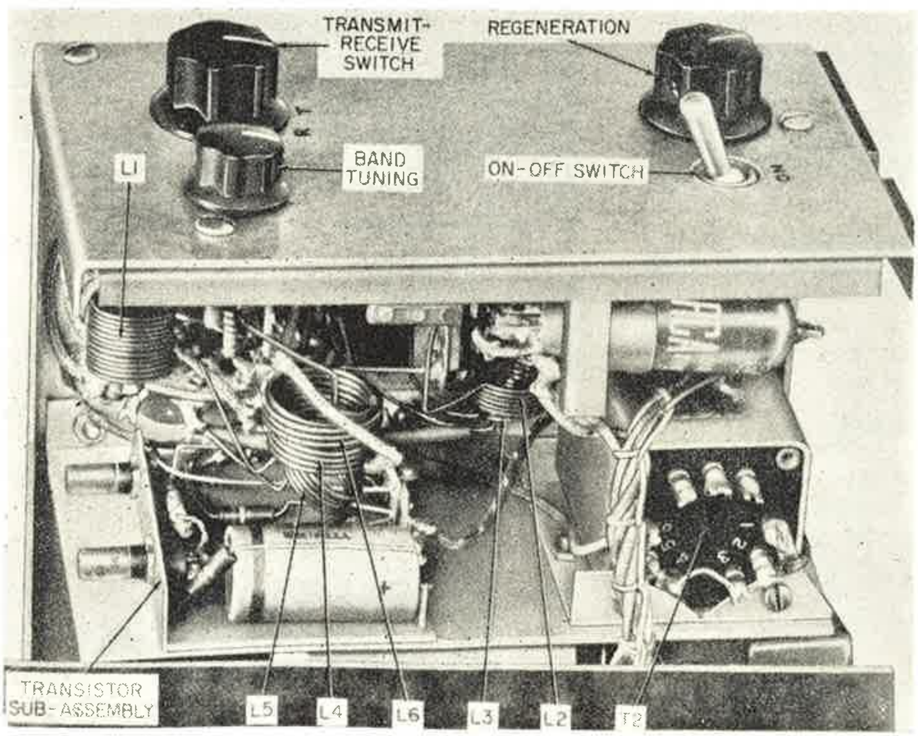
The volume control does not attenuate all the audio, but lowers it to a comfortable level. With the audio gain at maximum, there is sufficient drive to overcome practically all extraneous noise.

After the receiver is wired it should be tested and any necessary adjustment made before the transmitter circuit is wired. The battery drain during the "receive" cycle is 160 milliamperes for the A cells, and about 15 milliamperes for the B cells.

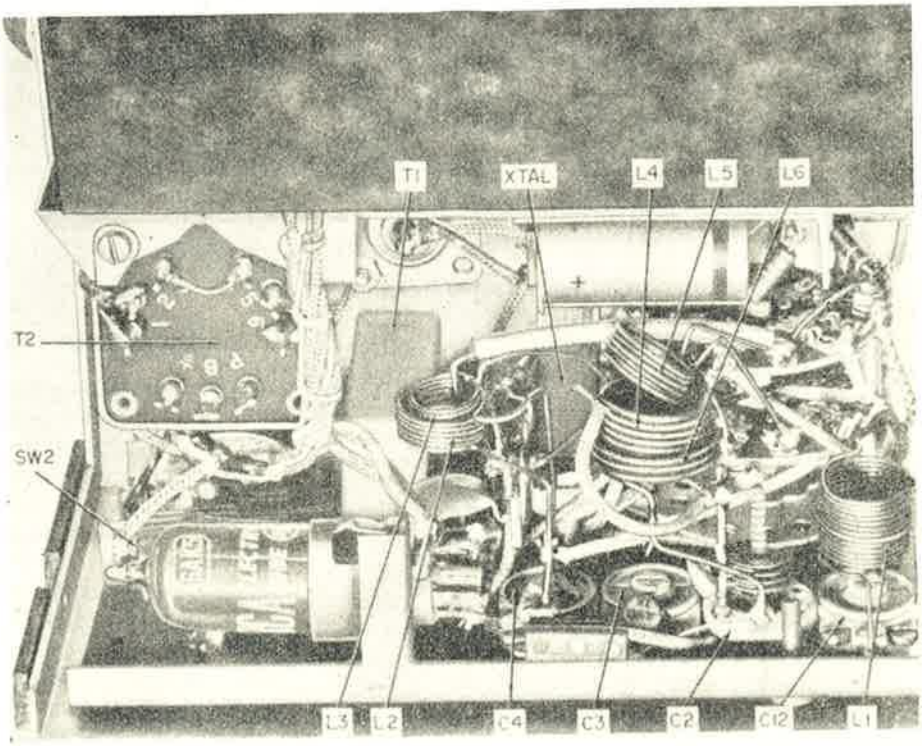
Transmitter Circuit

After the coils for the transmitter are connected it is good practice during tuning to simulate the side of the chassis by placing a piece of sheet metal next to any coil which will come within 1 inch of the case. When wiring has been completed on the transmitter section, voltages and currents should be tested. The battery drain should average 200 milliamperes for the A cells and 18 milliamperes for the B cells. (Where dry cells are used to form the A battery, the author has specified a 7.5 volt battery. When the voltage drop caused by the heavy heater current of the 6AK5 is considered, this will bring the actual voltage during operation within the valve's ratings. Should this circuit be adapted for other applications with other power supplies, the heater supply voltage may need to be adjusted accordingly. Editor.)

With the TR switch in the transmit position, the 7.5-volt supply is placed across the primary



As noted in the text, W2VCG has wired the audio stages on a separate sub-assembly. This photograph shows the audio stages at bottom left and the audio drive transformer at bottom right.



Inside view of walkie-talkie showing placement of components.

of T1, which is in series to ground through the 200-ohm microphone of the headset. This connection provides enough power transfer to modulate the unit fully. In the "receive" position, T1 has no effect on the circuit, except to increase audio choking. The transmitter should be tuned with the aid of a grid-dip meter or some other type of rf detector. To make certain the unit is crystal-controlled, remove the crystal several times while watching rf output. The output should drop to zero when the crystal is removed. C1 sets the excitation level for the crystal and is fixed at mid-range.

You need not stretch your imagination to find numerous occasions for the use of this novel walkie-talkie. In addition to providing many hours of pleasant entertainment, it can serve as a vital means of communication during emergencies.

PARTS LIST

B1	Battery, 7.5 volts, A type
B2	Battery, 67.5 volts, B type
C1	100 pf, mica
C2	5 to 10 pf, variable, see text
C3	7-45 pf, variable
C4	7-45 pf, variable
C5	0.005 μf, ceramic
C6	2 μf, 15 volts, electrolytic
C7	100 μf, 15 volts, electrolytic
C8	4 μf, 150 volts, electrolytic
C9	0.001 μf, ceramic
C10	470 pf, mica
C11	0.001 μf, ceramic
C12	7-45 pf, variable
L1	½" I.D., 14 turns No. 20
L2	½" I.D., 6 turns No. 20
L3	½" I.D., 4 turns No. 20
L4	⅝" I.D. 8 turns No. 18
L5	½" I.D., 5 turns No. 20
L6	3 turns No. 18 on L4
L7	1" I.D., 12 turns No. 20, ¾" long
R1	1.2 megohm
R2	5,600 ohms
R3	10,000 ohms
R4	220 ohms
R5	5,600 ohms
R6	100,000-ohm potentiometer
R7	47,000 ohms
R8	270,000 ohms
R9	10,000 ohms
R10	30,000 ohms
R11	100,000-ohm potentiometer
SW1	Rotary switch, eight-pole, two-position
SW2	DPST toggle switch
T1	Transformer for carbon microphone
T2	See text

(With acknowledgements to RCA)

RADIO'S SIGNALS SCATTER

The history of radio transmission is spiced every few years by some new technique of propagating radio waves from one point to another. Each such advance extends the utility and capability of radio to new applications, and broadens the technological frontiers. A relatively new technique for radio transmission is called "tropospheric forward scatter." The troposphere is the name given the airspace surrounding the earth, and reaches a height of 40-50,000 feet.

Radio waves have certain peculiarities, depending on wavelength. They are not all propagated from point to point in the same manner, but travel over entirely different distances depending on wavelength. Very-low-frequency waves with a wavelength of 1000 metres or more are propagated along the earth's surface (ground waves), for distances determined by the emitted power.

Medium-frequency waves with a wavelength of several hundred metres are the most popular broadcast waves. These medium-frequency waves are partly propagated along the earth's surface and partly reflected by the atmosphere and can be received at distances of 300 to 600 miles with, however, a poor reception zone at about 120 miles. Short waves between 80 and 15 metres are received around the entire earth even at very low transmitting powers. These waves are reflected by the upper atmospheric layers in such a manner that they span the greatest distances. These short waves can be beamed in their height and width so that it is possible to obtain a narrow angle of radiation.

As we study waves of even shorter length, we find that very-high-frequency waves between 10 and 1 metre in length behave in a similar fashion to light waves. They do not follow the curvature of the earth but can be received only within the optical range, which is determined by the height of the antenna. Beyond the horizon, vhf waves travel away from the earth straight into space. Ranges up to say 120 miles can be obtained, provided the height of the antennae is sufficient. On the other hand, however, it is possible to beam these waves almost like light waves and to obtain very narrow directive beams which strike only the target located in the directional and optical range, and cannot be received outside of this beam. These waves are therefore preferred for the transmission of communications over long distances — for telephony, broadcasting and television. For these transmissions, relay stations are provided at intervals of say 35 to 50 miles on an average.

Where the distance between the transmitter and the receiving station is so great that they cannot be brought by any means into line of sight, and if the nature of the terrain or sea located between the transmitter and the receiving station does not permit the erection of repeater stations, it is still possible to establish a connection by employing these vhf waves in scatter propagation.

Scatter Propagation

Scatter Propagation permits reliable communication over hundreds of miles at frequencies (wavelengths) that were formerly limited to essentially line-of sight distances. Tropospheric scatter propagation is particularly adaptable to frequencies above about 100 megacycles per second, and includes the so-called "microwave" frequencies. It's importance is evident when it is realized that station separations of 100 to 500 miles can be used instead of the more usual distances typical of the familiar radio-optical transmission techniques. In remote, uninhabited, and often inaccessible areas of the world, high capacity communications systems can now be built that formerly would have been impracticable.

World-wide radio transmission is as old as radio itself, but such transmissions were basically of small communication capacity — one telephone or one broadcast programme, or a few telegraph channels for each system. On special international circuits, certain techniques permit a number of simultaneous telephone conversations. The new long-distance tropospheric scatter method allows dozens of telephone channels and even television to be transmitted.

If a narrow beam of light is emitted by a searchlight, this beam of light is visible in clear air only in the direction of its rays but not from the side However, if the beam of light reaches fog, dust or clouds it will become visible because the water or dust particles refract the rays and scatter them towards all sides. Thus, a portion of the light is visible also from the side.

Electromagnetic waves of very high frequency behave in a similar manner. The scattering effect takes place in the atmosphere due to localized turbulence and variations in moisture distribution. The wave scattering from these causes is very small, but if adequate power is used in narrow beams, the scattered waves are detectable far beyond the horizon, and can be received using high-gain aerials and receivers.

At an altitude of about 18 miles there are atmospheric layers which are strongly ionized, and it is mainly at these layers that scattering occurs. Not only is the proportion of energy which is scattered very small, but it is returned in a non-uniform manner because the refracting layers in the troposphere are constantly shifting.

One method of overcoming the disadvantage of non-uniform refraction is to employ "diversity reception." Two high-gain receiving antennae are installed at some distance from each other, and used by the same receiver. In this case one of the antennae will always pickup sufficient energy to render signals intelligible, an automatic switching arrangement being used to connect at all times to the receiver that antenna which is receiving the stronger signal.

The changeover by electronic means from one antenna to the other takes place with such speed that it is imperceptible; the changeover is repeated hundreds of times a second, depending on the variations of signal strength. This ensures a constantly uniform reception, and by means of this scattered radiation it is possible to establish satisfactory communications over distances at least twice as long as the ranges which are otherwise obtainable when using waves of very high frequency.

The principles of scatter propagation have been known for several years, but the equipment necessary to produce sufficient power economically for transmission at these frequencies has only recently been developed. Power sources, as well as receivers, depended on the evolution of suitable electron valves.

WARNING

From time to time articles and circuits are printed in these pages of transmitters, transceivers, "walkie-talkies" and similar equipment. It must be pointed out that the construction and use of such equipment without the possession of an appropriate liccense from the Postmaster General's Department is an offence. Details of liccenses available can be obtained from the Department, whilst training and tuition to the standard required for qualification as an amateur operator is available from the Marconi School of Wireless and other radio schools.

AWV