The Vodas *

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Since the first transatlantic radio telephone circuit was opened for service over ten years ago, an increasing number of voice-operated switching devices has been added to the international telephone network. All of these have the common purpose of preventing echo and singing effects due to arranging the facilities to give the best possible transmission, even under difficult radio conditions. Differences in the design and performance of the several types of devices suggest that the advantages and disadvantages of each be made available.

The characteristics of two types of "vodas" used on circuits connecting with the United States are described in this paper. For reference purposes, a complete list of Bell System papers relating to these devices is included.

Introduction

THE interconnection of ordinary telephone systems by means of long radio-telephone links presents some unique and interesting technical problems. Since radio noise is often severe as compared with that in wire lines, radio transmitter power capacity is relatively large and expensive, and it is in general economical to control the speech volumes so that the radio transmitter will be fully loaded and thus the effect of noise minimized for a given transmitter power rating. This volume control, to be fully effective, calls for voice-operated switching devices to suppress echoes and singing.

This paper describes the measures which have been developed for use at radio-wire junctions in the United States. They are based upon an arrangement called a "vodas." This word, devised to fill a need for verbal economy, is formed from the initial letters of the words "*v*oice-*o*perated *d*evice *a*nti-*s*inging"; and thus implies not only a suppressor of feedback or singing, but also automatic operation by voice waves.

The general principles and applications of the vodas have been discussed from time to time in various papers listed at the end of this text. The present paper goes somewhat more into detail regarding the transmission performance of the vodas, including a description of an improved form of circuit which discriminates between line noise and the syllabic characteristics of speech.

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Historical Background

The two-way problem in telephony began with the invention of the telephone itself, and was the subject of considerable pioneering activity during the latter part of the nineteenth century. The invention of the amplifier brought about new problems when applied in a repeater for two-way operation. Even before a practical repeater had been devised, inventors visualized controlling the direction of transmission through amplifiers in a line by relays controlled from switches associated with the subscribers' instruments, an idea which is in use today on airplanes and small boats and in special circuits where this type of two-way operation is practicable. It is also used by amateur radio telephone operators. But for public telephone service more rapid and automatic control of two-way conversation is preferable.

To control the direction of transmission in a manner that would meet public convenience, invention progressed through the early part of the twentieth century toward devices for switching the speech paths automatically by voice waves. During this period, long distance radio telephony was first demonstrated to be practical on a one-way basis.

From that time until the first transatlantic radio telephone circuit was placed in service on January 7, 1927, anti-singing voice-operated devices underwent a process of development aimed at meeting the requirements of two-way radio telephone service. The vodas was one result. Since 1927, improvements have been made in cheapening and simplifying the equipment and in making a vodas that will operate better on speech and not so frequently on noise. It has also been possible to arrange a vodas so as to permit using the same privacy apparatus for both directions of transmission, thereby saving the cost of duplicate apparatus.

The Radio Telephone Problem

The conditions encountered when joining two-wire two-way circuits by radio links are illustrated in Fig. 1 in which (*a*) shows a connection between two subscribers, *W* and *E*, while (*b*) shows the paths of direct transmission and echo when *E* talks. In addition to the talker and listener echoes which arise in such a connection, singing can occur around the closed circuit *CAFGDBC* if the amplification is great enough. Also, when the same frequency band is used to transmit in both directions, two cross-transmission paths *AB* and *DF* are set up, and echoes and singing can take place around the end paths *ABC* and *DFG*. Any echoes or singing are of course primarily due to reflections of energy at points of impedance irregularities in the two-wire plant, including the subscribers' telephones themselves.

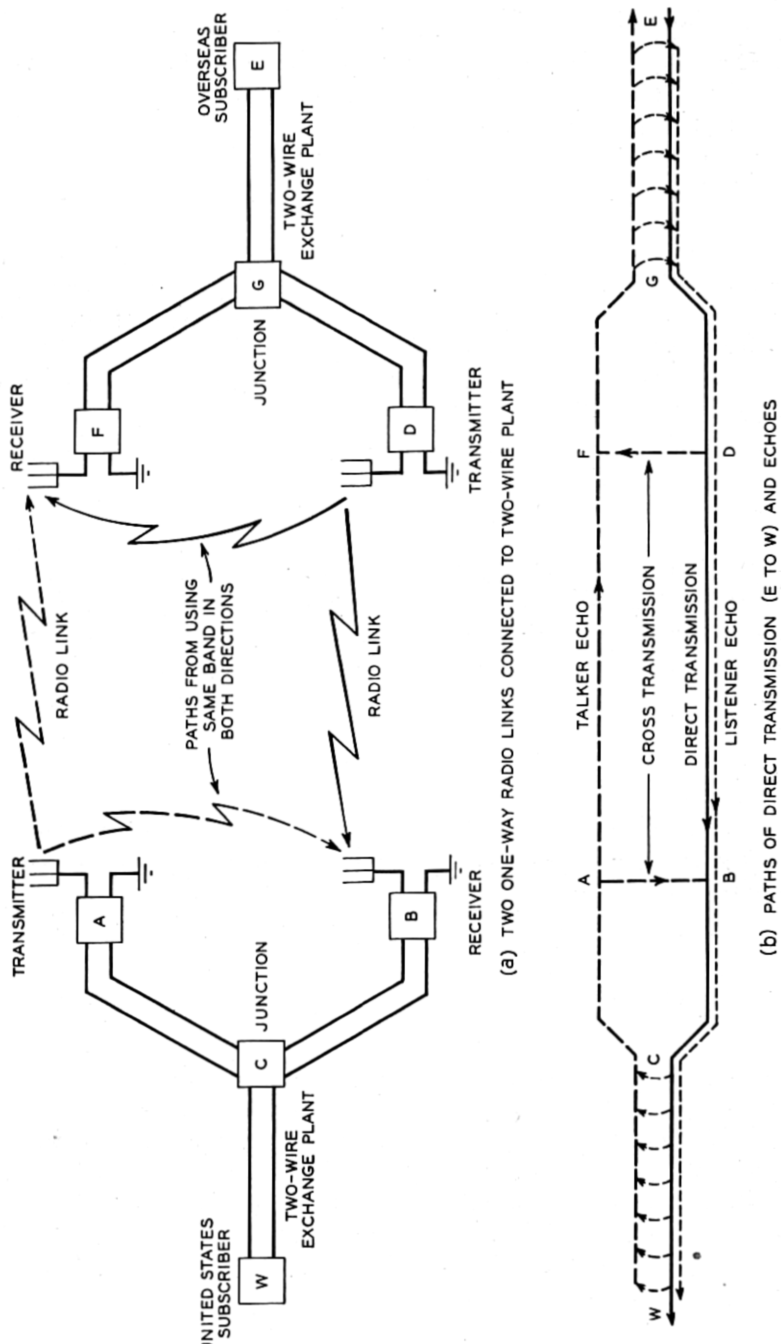

Fig. 1—Echoes in a radio telephone connection.

In wire circuits, simple hybrid coils and echo suppressors[2] are usually adequate to prevent such effects because the gains are not increased to provide for loading the circuit with energy when speech is weak, and also because the cross-transmission paths are absent. In long radio circuits, however, singing may result from the adjustments of amplification made to load the radio transmitter in case of weak speech and thus override noise, even though separate frequency bands are used in the two directions. Moreover, it is desired that the users of the service have as good transmission over the entire connection, including these radio links, as that to which they are accustomed in their own wire telephone systems, and even better transmission may be desired owing to differences in the language habits of the subscribers. Consequently, the overall transmission efficiencies of intercontinental radio circuits are sometimes better than those of the best land lines in the areas to be interconnected.

Fundamentals of Vodas Operation

A voice-operated device to suppress singing effects can be designed to have three possible arrangements:

1. The terminal can normally be blocked in one direction and connected through in the other.

2. Both directions of transmission can normally be blocked and activated in either direction but not both directions by the voice waves.

3. The circuit can remain activated in the last direction of speech and blocked in the other direction.

Where there is no noise on the transmission system under consideration any of these three arrangements will give satisfactory operation as there is then nothing to prevent making the voice-operated devices as sensitive as may be necessary to obtain full operation on weak as well as on strong voice waves. If there is any noise on the system which tends to operate the device it is necessary to make it less sensitive to avoid false operation. A point may be reached where the sensitivity is so low that the weakest parts of speech will not cause operation, and the weak consonants will be lost. The reduction in articulation has been found to be proportional to the time occupied by these lost or "clipped" sounds.[9]

If the device is located at a point in the circuit where the signal-to-noise ratio coming from one direction is poorer than that coming from the opposite direction it is obvious that a considerable advantage will be gained by using arrangement 1, since the device may be pointed in

[2] See references at end of text.

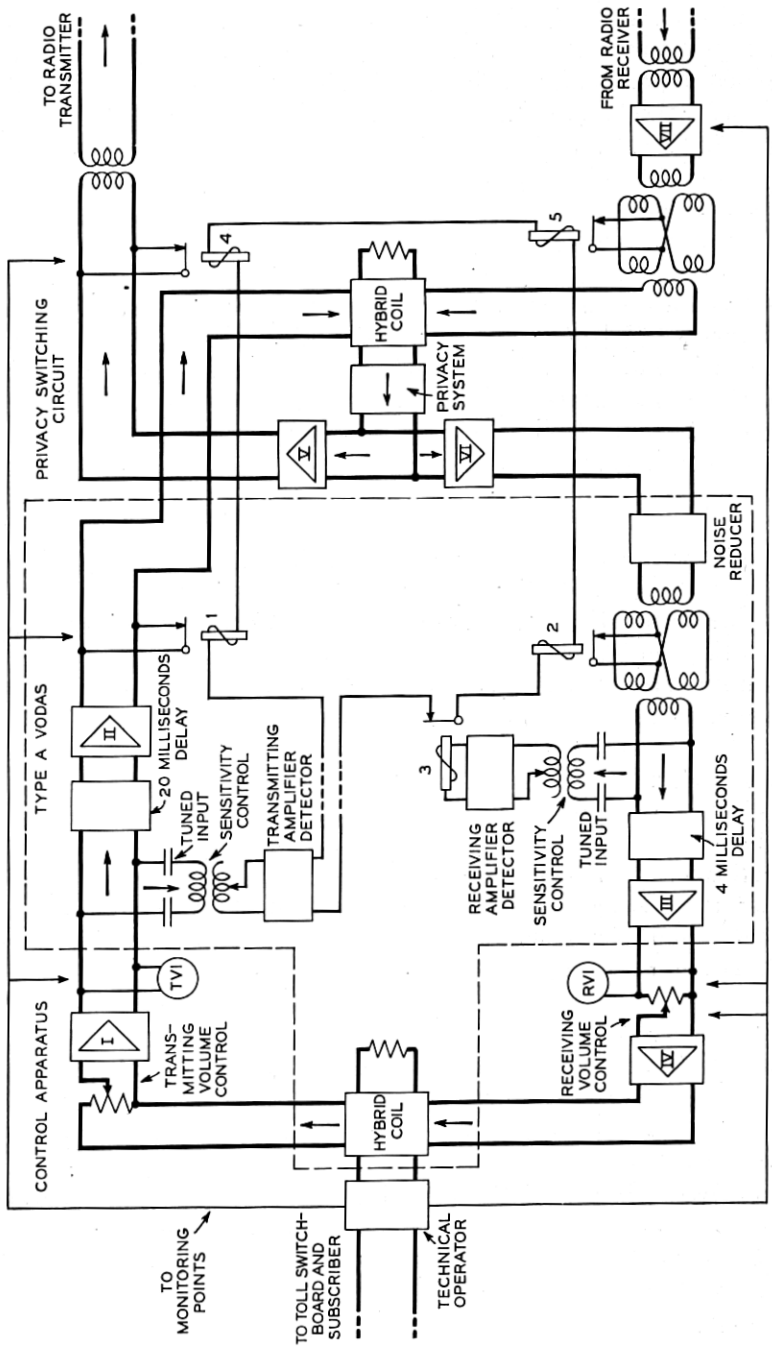

Fig. 2—Schematic of type A control terminal.

the direction in which the normally blocked path is exposed to the better signal-to-noise ratio and the normally activated path is exposed to the poorer signal-to-noise ratio. The vodas is, of course, arranged so that the normally blocked (transmitting) side is exposed to the land lines, which are usually quieter than the radio links. In the receiving side, the device can be less sensitive because there is no need for having it completely operated under control of the voice waves. All that is necessary is to have this side sensitive enough to operate in response to comparatively large voice or noise waves which might otherwise, after reflection and passage into the outbound path, result in false operation of the more sensitive side associated with this path.

In the vodas the principle of balance is used to keep the reflected currents small and thus allow the sensitivity of the normally activated device to be further reduced if necessary. Where a high degree of balance is not obtained and when noise from the radio limits the sensitivity of the receiving device it is sometimes necessary, particularly for weak outgoing volumes, to reduce the incoming volume so as to prevent echoes from operating the normally blocked transmitting side.

This echo limitation is primarily due to noise in the radio link, reflections from the two-wire plant and weak volumes from the subscribers. It is difficult to produce any large improvement in talker volumes and balance; so it would appear that the solution of the difficulty would probably come from the direction of improving radio transmission. Some benefit has also been obtained by reducing the effect of radio noise on the vodas with special devices of which the "Compandor"[17, 18] and the "Codan"[19, 20] are examples. More recently, use has been made of a new voice-controlled device called a "Noise Reducer"[21, 22] which reduces the received noise between speech sounds.

Vodas Design—Type A Control Terminal

Figure 2 shows a schematic diagram of a vodas * arranged to use the same privacy device for both transmitting and receiving. This is the type used on transatlantic and other long routes. Since the operation of this arrangement has been described before,[13] it will not be repeated here.

The diagram of the relay circuit in Fig. 3 shows how various time actions are obtained. Relays 1, 2, 4 and 5 are operated from battery B_1 when the ground contact of relay TM is opened. Thus the travel time of any relay armature is not a factor in securing fast initial

* The vodas apparatus, together with the volume control devices and technical operator's circuits, go to make up what is called a *Type A Control Terminal.*

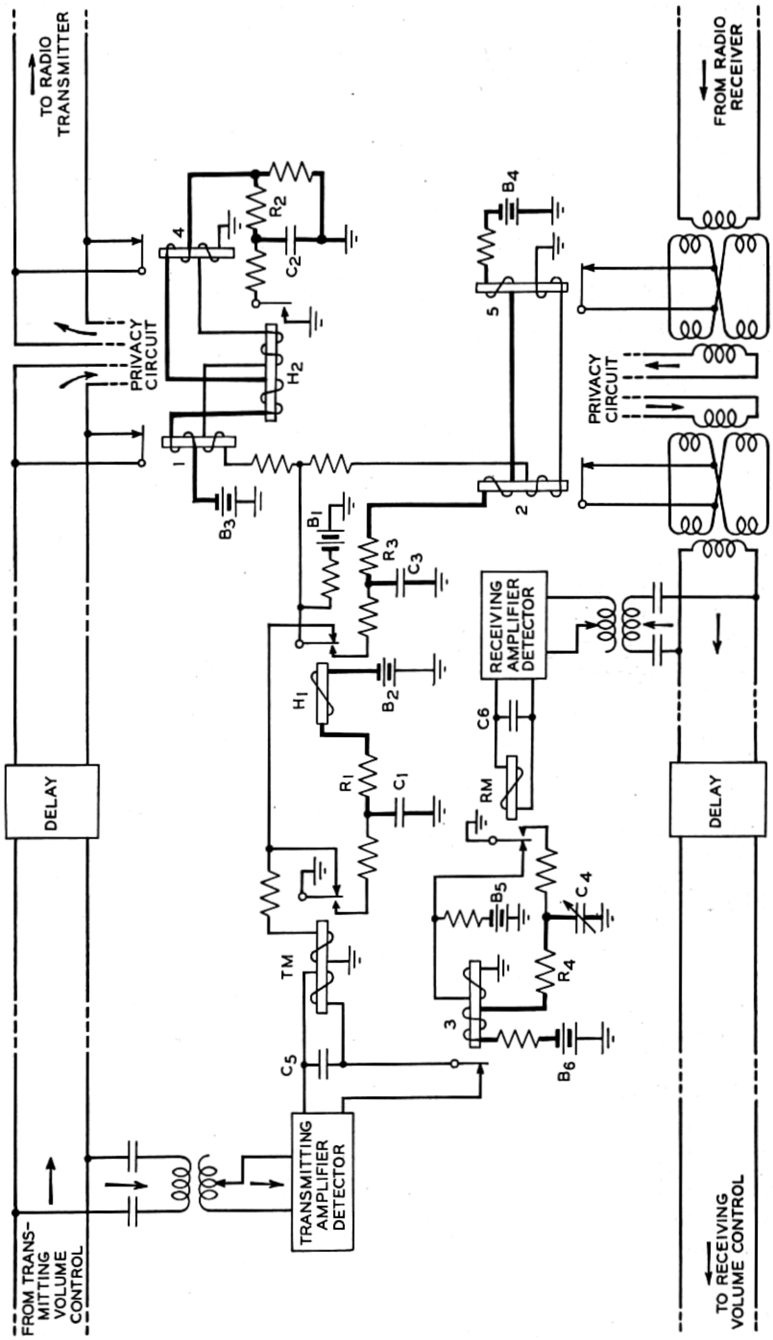

Fig. 3—Vodas relay circuits.

operation. When the armature of relay TM reaches its left-hand contact, relay H_1 operates and delays release of the relay train even if TM is at once restored to normal. H_1 is delayed in releasing by the time required to charge condenser C_1. The final release of relays 1 and 4 is then controlled by the time constant of an auxiliary circuit involving relay H_2 and condenser C_2, while that of relays 2 and 5, which is made later so as to suppress delayed echoes, is controlled by the circuit charging C_3. On the receiving side, condenser C_4 is adjustable so as to permit the technical operator to select the shortest release time for suppressing the delayed echoes in a given land line extension.

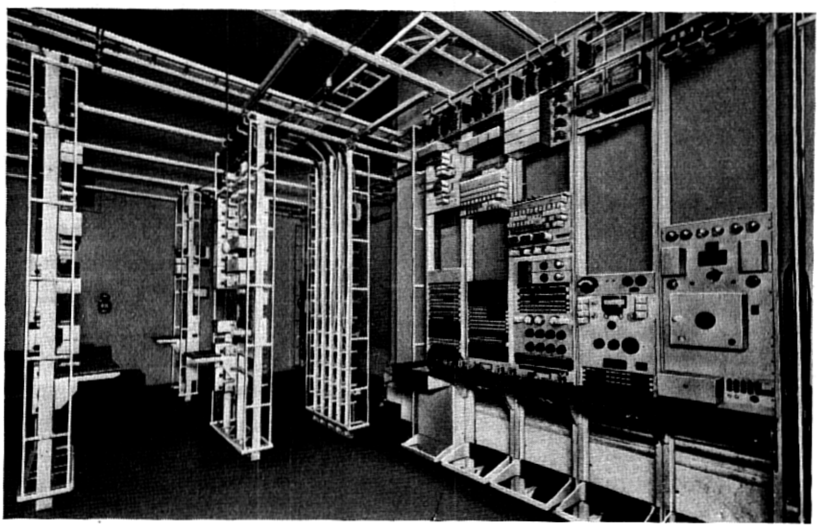

Fig. 4—Type A control terminal at San Francisco.

The vodas control terminal of the A type [8] used at New York consists of a line of technical operating positions with cross-connections to other lines of equipment containing the delay units, repeaters, vodas amplifier-detectors and privacy apparatus. Figure 4 shows an arrangement of a single terminal at San Francisco. The control bay is placed between two line testing bays on the left and two transmission testing bays on the right of the operating lineup. The distributing frame is in the center of the picture; and repeaters, ringers and privacy apparatus are shown at its left. At the extreme left is the vodas bay.

Syllabic Vodas—Type B Control Terminal

The desire for a cheaper control terminal than the Type A led to the development of a second type, known as *Type B*, in which the vodas employs the same fundamental principles. In this vodas added protection against false operation from line noise is secured by the use of a new principle in voice-operated devices, called "syllabic" operation.

It is observed that in many types of noise a large component of the long-time average power is steady. Speech, however, comes as a series of wave combinations of relatively short duration. These facts suggested a device which distinguishes between the rates of variation of the envelopes of the impressed waves. This is accomplished by a filter in the detector circuit which passes the intermodulated components of speech in the syllabic range, but suppresses those of line noise which are above or below this range.

Figure 5 shows a schematic diagram of the application of this device to a Type B control terminal. The privacy switching circuits are omitted from this drawing, as are also the circuits for delaying the release of the relays. In comparing this drawing with Fig. 2, it will be seen that relays 1, 2 and 3 perform the same functions, but the transmitting branch of the vodas consists of two portions, one a sensitive detector with a syllabic frequency filter, which on operation increases the sensitivity of the second portion.

Considering the action of Fig. 5 on transmitted speech, the output of the sensitive detector of the syllabic device is a complex function of the applied wave having intermodulated components in the range passed by the tuned input circuit, together with a d-c. component and various low frequency components set up by the syllabic nature of the speech. There are also various components of any noise waves which may be present including a d-c. component. The first step in getting rid of the noise is to pass the detector output through a repeating coil which blocks the d-c. component of both the speech and noise, but passes frequencies above about ½ cycle per second. The resulting waves enter the low-pass filter, the output of which contains frequencies between ½ and 25 cycles per second, which "syllabic range" is between the d-c. component of zero frequency and the fundamental frequency of the line noise. These syllabic frequency currents cause momentary operations of relays (*I*) and (*F*). Relay (*I*) operates when a speech wave is commencing and relay (*F*), which is poled oppositely, operates while the impulse is dying out, thus sending current out of the filter in the opposite direction. Operation of either (*I*) or (*F*) effectively inserts gain ahead of the upper detector, thereby

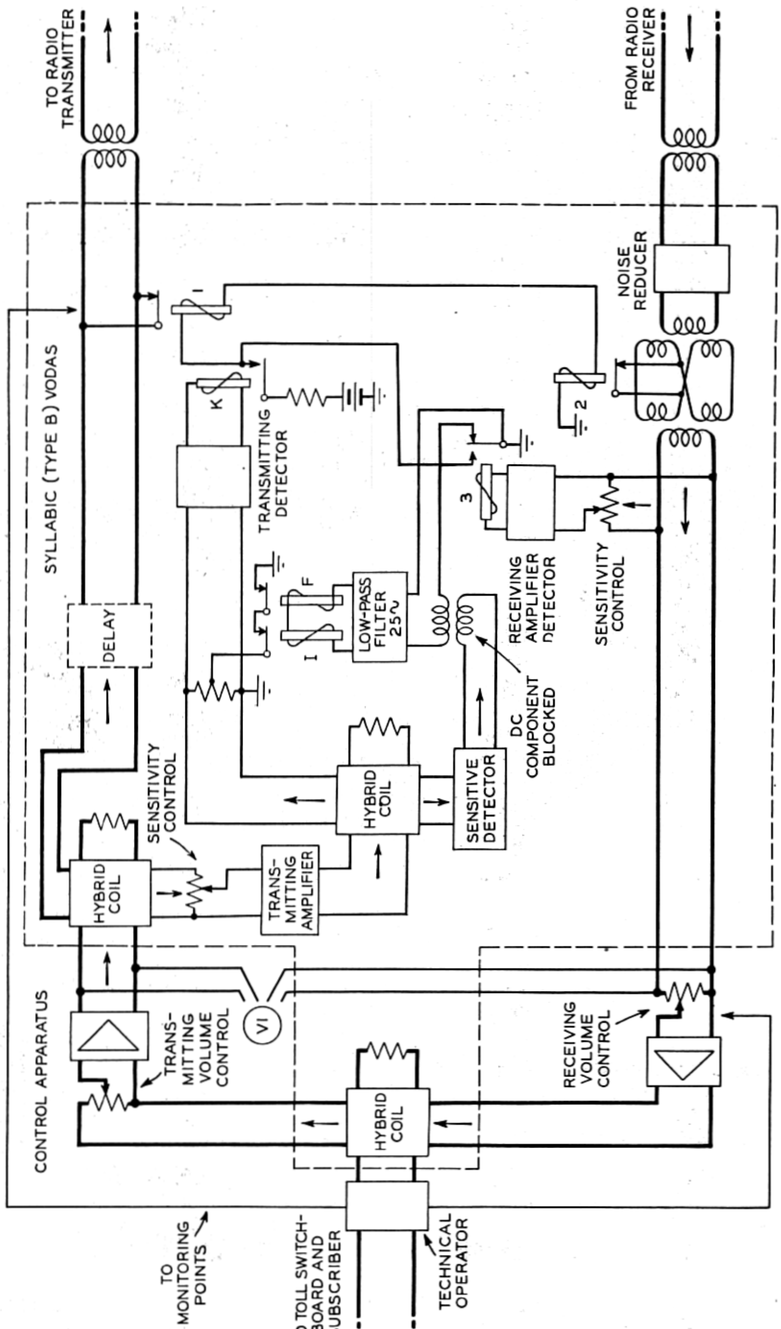

Fig. 5—Schematic of type B control terminal with syllabic vodas.

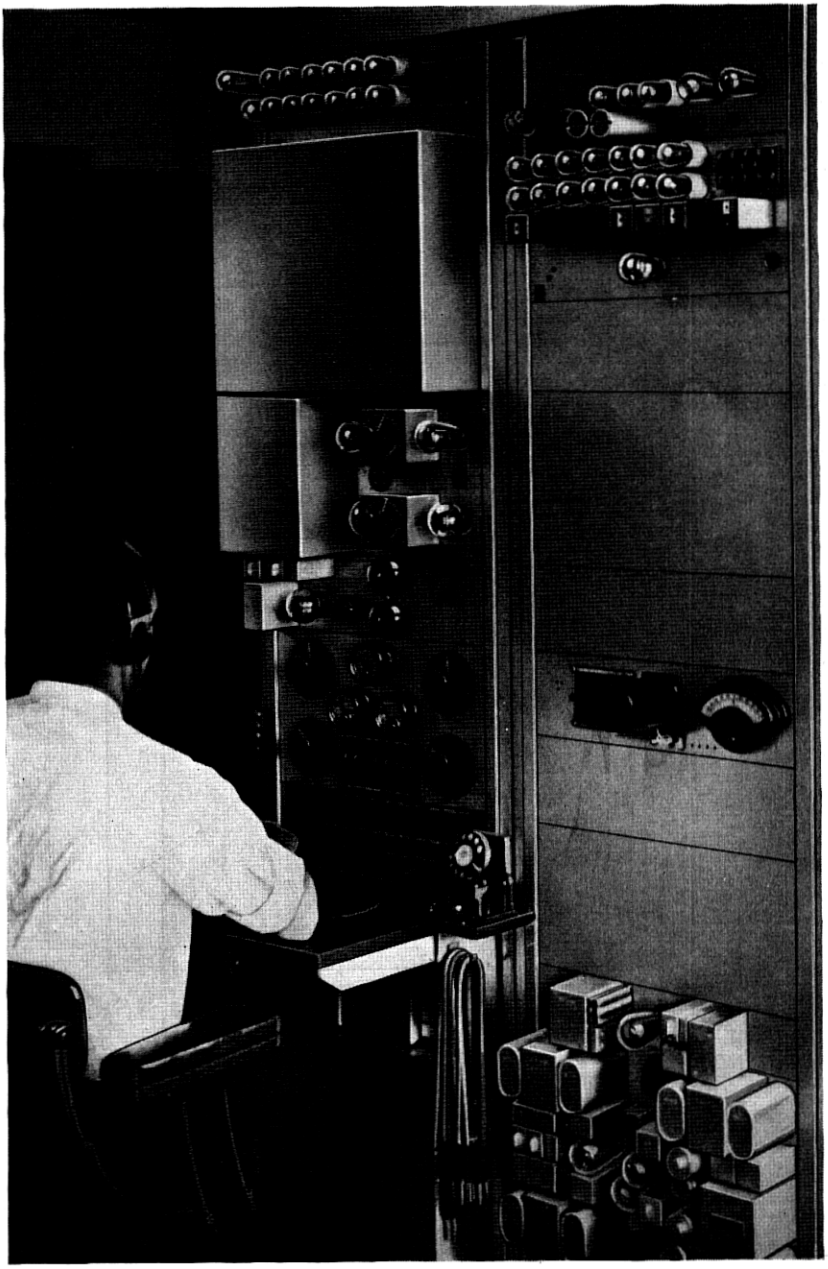

Fig. 6—Technical operator at Forked River, N. J., using a type B control terminal to establish a circuit between a steamship and a shore telephone operator.

increasing the sensitivity of relay (K), when speech is present. Even if the noise is strong enough to operate relay (K) over the upper branch when the gain is inserted, the release of relay (F) at the end of a speech sound will remove the gain and permit (K) to fall back. Thus, it is possible to work relay (K) more sensitively on weak speech than would be possible without the syllabic device.

Figure 6 shows a photograph of a B-type terminal in ship-to-shore service at Forked River, New Jersey. The vodas and volume control apparatus are in the left-hand cabinet. The right-hand cabinet contains privacy apparatus, a signaling oscillator and a vodas relay test panel.

Performance

In any system employing voice-operated devices it is necessary for the time actions to provide for to-and-fro conversation with a minimum of difficulty when the subscribers desire to reverse the direction. The electromagnetic relays used in the vodas have advantages over other types of switching arrangements which have been proposed in that they (1) operate and release at definite current values, (2) have fast operating and constant releasing times, (3) have their windings and their contacts electrically separated, thus simplifying the circuits, and (4) operate in circuits having low impedances.

The operating times of the two types of vodas are shown in Fig. 7 as a function of the strength of suddenly-applied single-frequency sine waves in the voice range. These measurements were made with a capacitance bridge.[5] The sensitivities of the two types were adjusted so that observers noted an equivalent amount of clipping. The Type A vodas was provided with a 20-millisecond delay circuit; the Type B had no delay. For the Type A vodas, the operating time is quite small and constant just above the threshold of operation.

For weak inputs the operating time of the syllabic device is determined by relay (I) and the filter, as shown in Fig. 7. As the suddenly-applied input is increased, a point is reached where the less sensitive detector operates relay (K), reducing the operating time from around 20 milliseconds to values comparable to those of the Type A.

The operation was also tested on waves formed by applying simultaneously two sine waves of equal amplitude but slightly different frequencies. These waves were recorded on an oscillograph, together with a d-c. indication of the operation of each of the vodas relays, with the sensitivities adjusted the same as for Fig. 7. The time from the beginning of a beat wave (null point) to the time of operation was measured from these oscillograms and plotted against various values of total applied voltages. Figure 8 shows the results for a 5-cycle-per-second difference between the two frequencies. Negative values of time indicate that the path was cleared before the beginning of the wave, and these occur only with the Type A vodas due to the delay circuit. The curves for frequency differences of less than 5 cycles per second show more clipping and greater differences between the devices, while those for greater frequency differences show less time clipped and less difference between the two types of vodas. In the case of weak waves it is evident that the syllabic will give less clipping

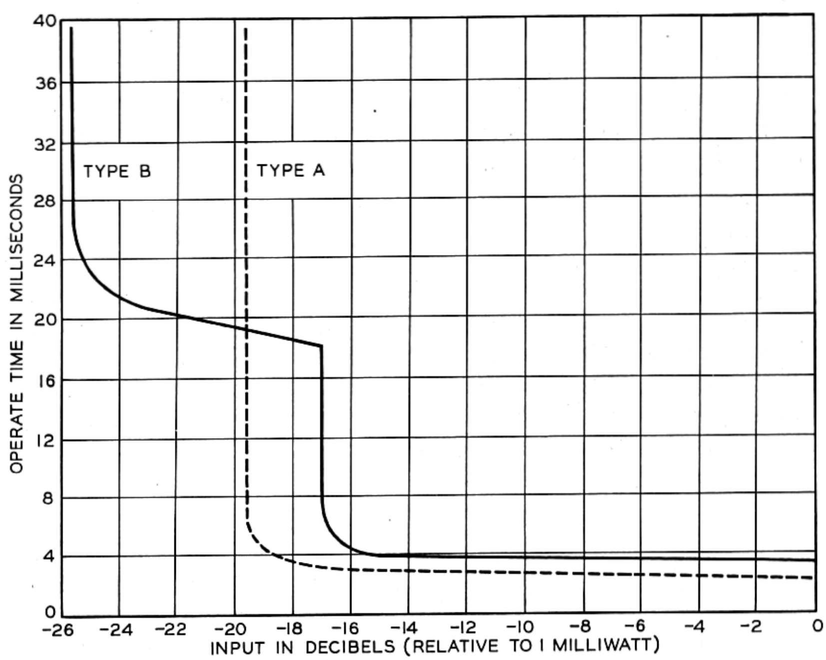

Fig. 7—Vodas operating times with sine waves suddenly applied.

because the energy of the wave does not rise to the value required to operate the Type A device until after the syllabic device has operated; and for very weak waves the Type A does not operate at all. In the case of strong waves, the Type A vodas is better due to its delay circuit. However, since the clipped time is greater on weak sounds than on strong ones, the two types give performances on speech which are judged to be equivalent.

A comparison of operation of the two types of vodas on a speech wave is shown in Fig. 9. Reading from left to right, the middle trace of this oscillogram shows the wave recorded by saying the word "six" over a telephone circuit transmitting a band of frequencies from about 800 to 2000 cycles per second, which is the range normally effective in operating the vodas. The upper trace shows the point at

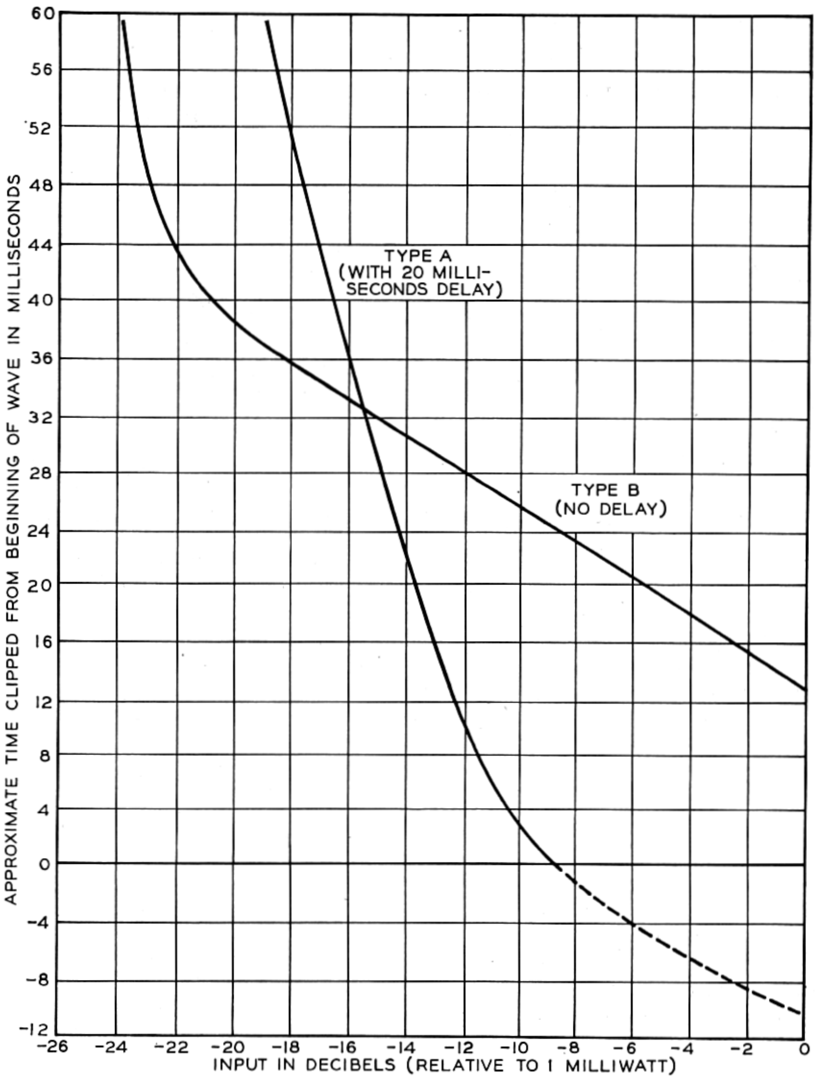

Fig. 8—Operation on a 5-C.P.S. sine wave.

which the syllabic Type B device operated and the lower trace shows the point at which the Type A device operated. Since the speech wave shown was used to operate both devices, the reduction of clipping by the delay circuit in the Type A vodas was not recorded. However, the effect of a transmission delay of 20 milliseconds is shown by subtracting 20 milliseconds from the point at which operation occurred. This is indicated on the oscillogram for both devices. It is concluded that on this wave the syllabic device without a delay circuit would give about the same clipping as the Type A vodas with its delay circuit. Figure 8 indicates that the Type A would be better for stronger speech and the Type B would be better for weaker speech. The advantage of a delay circuit in either case is evident.

It is evident from this analysis that the reason for using delay circuits is not primarily because the relays are slow in operating. When the sensitivity is limited by noise, clipping of initial consonants can occur with infinitesimal operating times. One way of reducing the clipping is to use long releasing times so that the relays remain

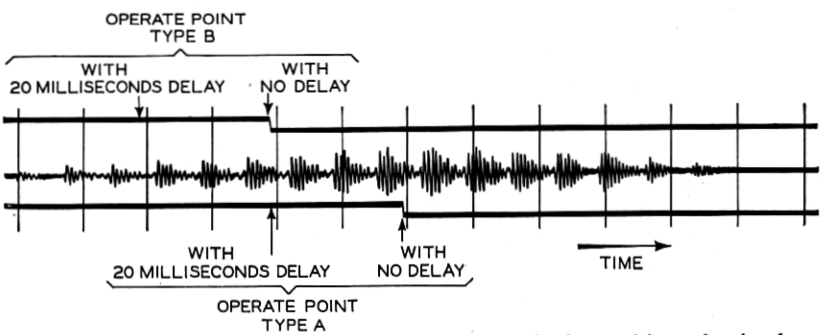

Fig. 9—Oscillogram of the word "SIX," illustrating clipping and its reduction by a delay circuit in the transmission path.

operated between syllables. This has the disadvantage of making it harder for the opposite talker to break in. To avoid this difficulty, the relays in the vodas are given releasing times that permit the distant speech to break in about one sixth of a second after a United States talker ceases to speak.

One advantage of delay circuits is to reduce the clipping of initial consonants and thus permit using short releasing times, thereby making it possible to reverse the circuit more readily. In addition, delay circuits permit using a lower relay sensitivity which has two advantages. First, more noise can be tolerated without causing false operation. Second, more received volume can be delivered without the echoes causing false operation of the normally blocked transmitting side.

The advantage of artificial delay of various amounts has been determined by using different types of normally blocked arrangements to find the relation between the delay and the sensitivity required to produce given amounts of clipping of initial sounds. The results are shown for a Type A vodas in Fig. 10. The curves for the syllabic device are similar. The set-up was arranged so that various delays could be inserted in either the transmission circuit (Delay *X*) or the relay circuit (Delay *Y*). The left ends of the curves indicate that when delay *Y* is used, that is, when the net operating time of the relay is great, a point will be reached where no reasonable increase in

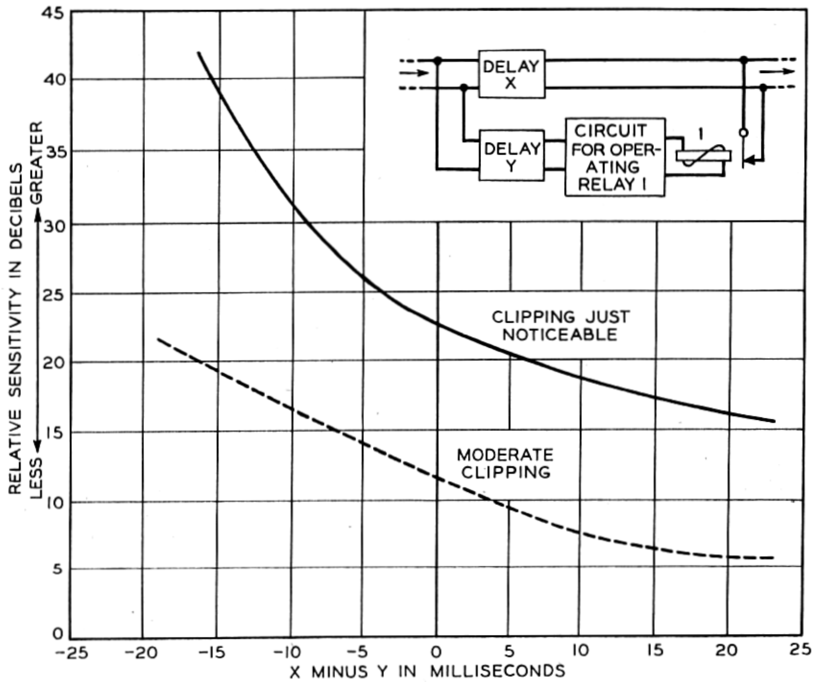

Fig. 10—Typical delay vs. sensitivity for certain clipping effects.

sensitivity is sufficient to prevent intolerable clipping. The value of 20 milliseconds of delay *X* as compared to zero is equivalent to an increase of about 5 db in sensitivity for a given amount of noticeable clipping.

A reasonable release time is of value in preventing clipping, as it causes the relays to remain operated not only for trailing weak endings of sounds, but also when the energy is temporarily reduced by intermediate consonants which may be comparable with noise. Delayed release is also important when it is required to maintain the blocked condition while delayed echoes are being dissipated. For these echoes, the hangover or release times should be constant for various applied voltages. In the vodas, the change in release time over a wide range of inputs is less than 1 per cent. Adjustments are made by varying the condensers and resistances of the auxiliary circuits shown in Fig. 3. Typical values obtained by this method are indicated in Fig. 11.

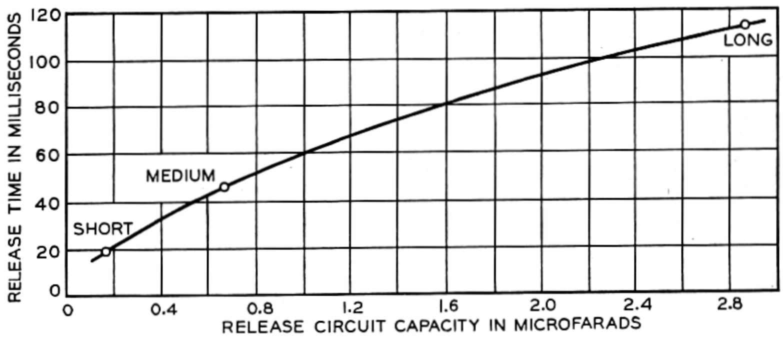

Fig. 11—Release time vs. capacitance.

The vodas amplifier-detectors have broadly tuned input circuits to exclude by frequency discrimination many of the frequencies induced by power sources and those which are unnecessary for speech operation. The sensitivity-frequency characteristic is shown on Fig. 12.

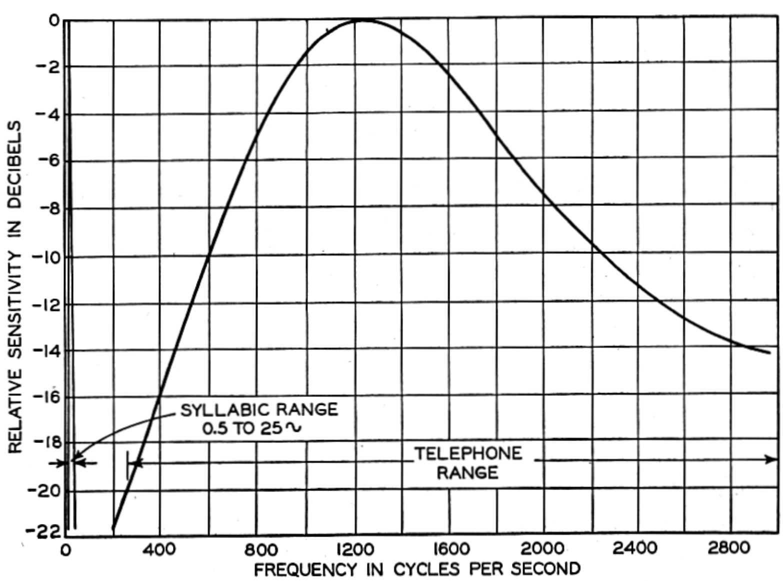

Fig. 12—Sensitivity-frequency characteristics of the vodas.

This figure also shows the relatively narrow frequency range passed by the repeating coil and syllabic frequency filter of the Type B vodas.

Operating Attendance

To insure proper operation of a vodas a technical operator [3] is in attendance. He is provided with circuits which enable him to talk and monitor on the circuit as indicated in Figs. 2 and 5. His duties include adjusting the sensitivity of the receiving relays for the particular value of radio noise existing and adjusting the transmitting and receiving speech volumes by the aid of potentiometers and volume indicators. He selects the proper hangover time and coordinates the operation of the circuit as a whole with the distant end. At times, he may be required to increase the sensitivity of the transmitting side of the vodas in the case of talkers with poor ability to operate relays or to decrease the sensitivity when weak volumes are supplied from land lines with more than the usual amount of noise.

Summary

The vodas is used in radio telephony to switch the voice paths rapidly to and fro, and thus prevent echoes and singing that would otherwise occur at unpredictable times. It is also used to save privacy apparatus by permitting the use of the same apparatus for both directions of transmission. The performance characteristics of the electromagnetic relays used in the vodas are very suitable in that they have small operating and constant releasing times.

Improved performance of the voice-operated relays in the presence of line noise can be secured by the use of a syllabic type of vodas which discriminates between the characteristic voltage-time envelopes of the noise and speech waves. Laboratory and field tests indicate that this device, even without delay circuits, gives slightly better performance on most conditions than the original vodas with delay. When provided with a transmitting delay circuit, the syllabic device is decidedly better than the older vodas.

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