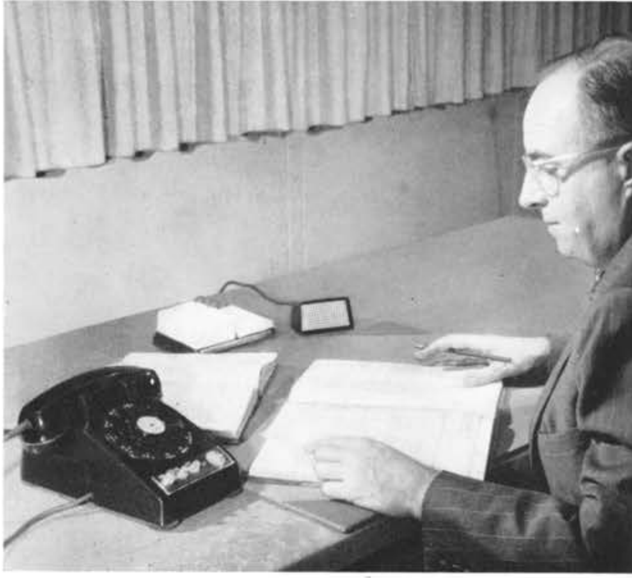
The Speakerphone



W. F. CLEMENCY

Station Apparatus Development

As the telephone has become a more and more valuable part of normal American life, the need for many new services has increased. Part of the Laboratories' responsibility, acting on the advice of the A.T.&T. Co., is to anticipate these needs and design the instruments and systems to fulfill them. One good example of this work is the Speakerphone designed to provide "hands-free" telephone service under most conditions.

Ever since the invention of the telephone, the trend of design has been to increase the ease with which a customer can carry on his telephone conversation. Following this trend a new telephone set, the Speakerphone, that provides hands-free telephony has recently been introduced for Bell System use. The customer, using the Speakerphone, talks into a transmitter about eighteen inches from his mouth, and listens to a loudspeaker about the same distance away. The customer can now readily write notes or refer to charts, reference books, and correspondence during a telephone call. He converses with the distant caller as if the latter were seated across the desk from him; this gives the user considerable freedom of movement. The Speakerphone also provides for group participation. During a call, a number of people seated closely around a desk can talk freely – the transmitter picks up the conversation and the replies are heard from the loudspeaker. This hands-free set is also of considerable value to the physically handicapped.

The location of the acoustic instruments at a greater distance away from the user as required for a hands-free telephone set makes the performance of the Speakerphone more dependent on room acoustics and room noise than that of a handset telephone. The handset is used at such close distances, about one inch for the transmitter and directly on the ear for the receiver, that the ordinary environmental acoustic conditions have little influence. As the distance between the user and the telephone instruments is increased, however, room reverberation and room noise become important. Hence the quieter and less reverberant the room, the better the Speakerphone performance.

A typical desk arrangement for the components of the Speakerphone is shown in the headpiece of this article. The housing, similar in appearance to the 500-type telephone set, contains the transmitter, ON and OFF buttons, and the loudspeaker volume control, in addition to the handset and other usual components of the 500-type set. The loudspeaker is located in the small plastic housing shown in the upper center of the headpiece. The circuit of the Speakerphone permits independent use of either the handset or the Speakerphone.

The Speakerphone is easy to use. To place a call, it is only necessary to momentarily press the ON button which lights up when the set is connected to the line. Then, when dial tone is heard from the loudspeaker, the number is dialed in the normal manner. When answering a call, the ON button is momentarily pressed, again causing it to light up, and the conversation can start. The transmitter picks up the voice of the user, and the other person is heard on the loudspeaker. The volume of the incoming speech is adjusted by turning the small knob of the volume control. At the end of the call, the OFF button is pressed, disconnecting the set from the line.

If privacy is desired during a call with the Speakerphone, or if some transmission difficulty is encountered, lifting the handset automatically transfers the call to the handset, and turns off the Speakerphone. If the handset is being used, and it is desired to transfer to the Speakerphone, the ON button is depressed while the handset is being returned to the cradle. The Speakerphone is designed for a talking distance of ten to thirty inches. The loudspeaker is placed about three feet from the transmitter and so located that the normal seated position of the user is midway between the two instruments.

In addition to the two desk instruments shown in the headpiece, an apparatus box containing amplifiers, power supply, and associated circuitry is part of the Speakerphone. The interior of this apparatus box is shown in Figure 1. This box is mounted following usual Bell System practices.

Two amplifiers, each having approximately 50-db maximum gain, are required, one for the transmitter and one for the loudspeaker. These two amplifiers are assembled on a printed circuit card which plugs into a socket in the apparatus box as shown in Figure 1. When these amplifiers require servicing, the printed circuit amplifier card can be quickly replaced. The power supply of the Speakerphone is energized from a 115-volt, 60-cps power outlet and consumes 8 watts when the Speakerphone is in use and 0.6 watt when it is in standby condition. The handset of the Speakerphone operates independently of the power supply and will perform in its normal manner in case of power line failure. The other components in the apparatus box are a relay, a hybrid coil, and input and output transformers. The instruments shown in the headpiece and the apparatus box shown in Figure 1, which together constitute the Speakerphone, are coded as the 595-type telephone set.

The basic circuit of the Speakerphone is shown in Figure 2. The hybrid coil, which is a form of Wheatstone bridge, couples the two-way telephone line to the output of the one-way transmitting amplifier and to the input of the one-way receiving amplifier, and introduces a loss between them (the output of the transmiting amplifier and the input of the receiving amplifier). As indicated in Figure 2, the unavoidable acoustical coupling through the air path between the loudspeaker and the transmitter forms a closed loop with the rest of the circuit. This closed loop, when there is power gain in it, acts as an oscillator causing the loudspeaker to produce a sustained tone called "singing". Because of this, there is an upper limit on the total permissible gain which can be used in the transmitting and receiving amplifiers.

The degree of balance between the telephone line impedance and the balancing network impedance determines the loss introduced by the hybrid coil between the output of the transmitting amplifier and the input of the receiving amplifier. If a perfect balance could be obtained at all frequencies, this loss would be infinite, and singing could not occur. The impedance of telephone lines varies considerably, however. It may be resistive, capacitive, or inductive depending on the length of loop to the central office, the length and type of trunk between central offices, and in the case of short connections,

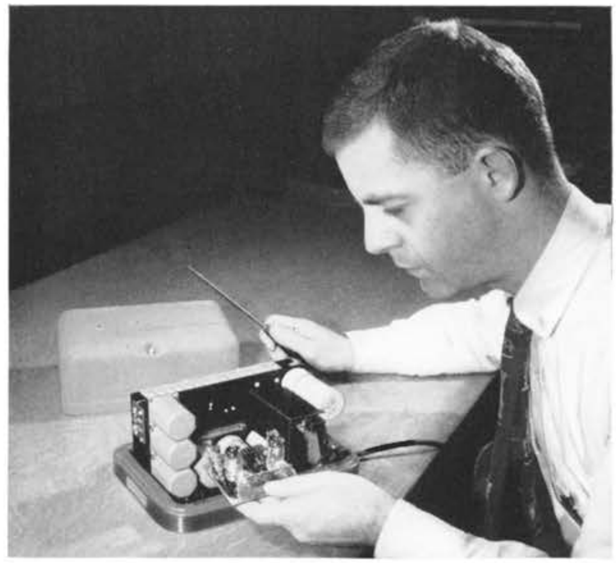


Fig. 1 — W. J. Zinsmeister replaces an amplifier card in a Speakerphone box.

also somewhat on the length of loop to the distant party. This is especially true for a line on a PBX which, on internal calls, may have a short loop, but on calls to an external telephone may have a long loop to a central office. There is, fortunately, a rough correlation between loop impedance and loop direct current. The balancing network is designed to be adjusted by this loop direct current, which produces a voltage across the terminals of the network. A varistor in the network varies its resistance in response to this voltage and regulates the impedance of the network. The network is designed to produce a better balance on long loop connections where more loudspeaker gain is required and singing becomes a limiting factor. Because both the transmitting and receiving amplifiers are in the singing loop, it is important that the gains in these amplifiers be properly apportioned.

The gain of the transmitting amplifier is adjusted at the factory so that the Speakerphone transmitting level at a talking distance of eighteen inches is somewhat below the transmitting level of the 500 set with its transmitter at about one inch from the user's lips. The loudspeaker volume control, adjustable by the user, regulates the gain in the loudspeaker amplifier circuit. With the fixed gain in the transmitting circuit, the permissible gain in the loudspeaker amplifier before singing occurs

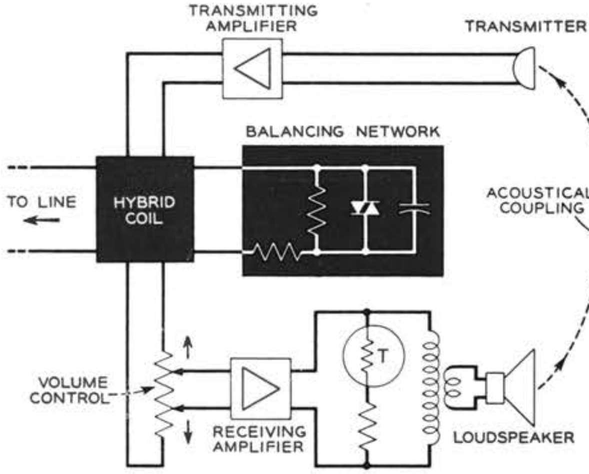


Fig. 2 — Simplified Speakerphone circuit.

is determined by the balance of the hybrid coil circuit, and the acoustical coupling between the transmitter and the loudspeaker. As shown in Figure 3, an increase in distance between the transmitter and the loudspeaker allows more gain to be used in the loudspeaker circuit. However, beyond a certain separation, further increase in the distance between the instruments moves the loudspeaker further from the listener and hence causes a decrease in the signal at his ears for the same loudspeaker circuit gain. The optimum practical arrangement is to have the user seated approximately midway between the instruments which are separated by about three feet on the desk top.

Figure 3 also indicates that the acoustical properties of the room influence the acoustical coupling between the transmitter and the loudspeaker. In reverberant rooms having very little sound absorption, the permissible gain in the loudspeaker circuit before singing occurs is less than that in a room with sound absorption resulting from acoustical treatment on the ceiling, carpet on the floors, and perhaps window drapes. The acoustical properties of the room also influence the transmitting quality of the Speakerphone.

Because the transmitter of the Speakerphone is eighteen inches from the lips instead of one inch as with the handset transmitter, the ratio of direct speech to reverberant speech, caused by reflections from the walls and other solid surfaces in the room, is less with the Speakerphone than with the handset. In a room having little sound absorption, these room echoes are a disturbing influence to the listener at the other end of the line. In direct person-to-person conversation, the binaural effect resulting from our having two ears reduces the effect of such room echoes. In rooms having good sound absorption, the echoes are reduced and Speakerphone transmission is relatively free of this reverberant quality. Furthermore, if the loudspeaker received signal is high, it is picked up by the transmitter and returned to the distant talker as a delayed sidetone of his speech. This effect, caused by the transmitter-to-loudspeaker acoustical coupling, is small in rooms having good acoustical properties. To minimize this delayed sidetone at the called customer's telephone, the loudspeaker volume should not be greater than is required for comfortable listening.

A thermistor is used in the loudspeaker amplifier to limit the volume of the sound from the loudspeaker, and to limit the voltage applied to the telephone line if the Speakerphone should sing because the volume control is advanced too high. The thermistor, designed especially for this application, is used as a variable resistance shunt across the loudspeaker transformer as shown in Figure 2. As the alternating voltage developed by the amplifier increases, the thermistor decreases in resistance and

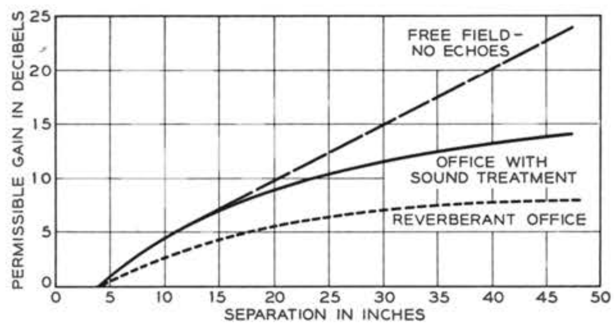
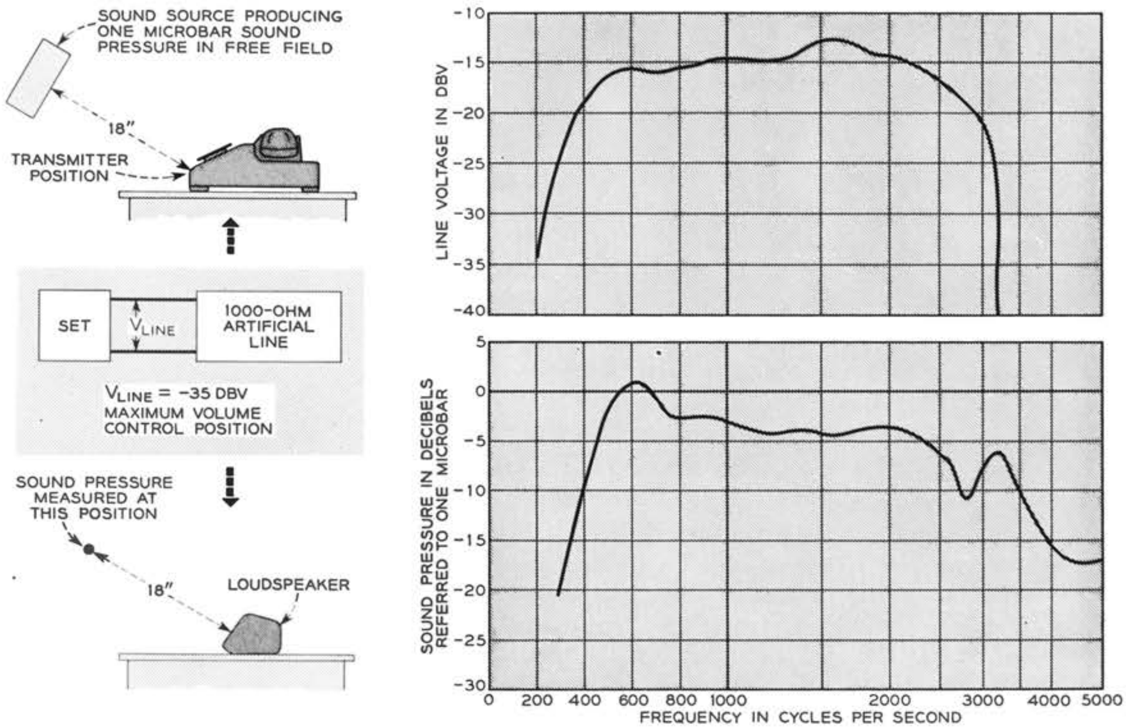


Fig. 3 — Permitted loudspeaker gain versus separation between loudspeaker and transmitter.

acts to limit the voltage. This action reduces the singing tone from a disturbing howl to a soft audible tone, and also limits the voltage applied to the line to that of the transmitted speech level. In addition, by acting as a volume limiter on received loudspeaker signals, the thermistor reduces the magnitude of the delayed sidetone at the distant telephone.

The transmitting and receiving frequency characteristics of the Speakerphone are illustrated in Figure 4. By experiment these response curves have been found to be good compromises for speech quality, for the reduction of the effects of room echoes, and for the control of the singing char-

Fig. 4 — Speakerphone frequency characteristics; top, transmitting, and bottom, receiving. Measurement details are given at the left.



acteristics of the set. The decrease of receiving response at the higher frequencies produces a more pleasant quality for speech received from a connected handset telephone over short lines without producing a serious degradation of articulation on long lines. This is due to the fact that the higher frequencies are augmented by the reflection of sound waves at the listener's head so that the response in terms of ear canal sound pressure actually rises at frequencies between 1,500 and 3,000 cycles per second. These reflections do not occur with the regular telephone receiver held close to the ear.

Ambient room noise influences the performance of the Speakerphone to a greater extent than it does the performance of the handset. This results from the greater talking distance of the Speakerphone transmitter, and the fact that the loudspeaker is heard through an open air path. With a handset, the receiver cap, when pressed against the ear, attenuates the ambient noise considerably. With the Speakerphone, the ambient room noise enters the ear with the received speech from the loudspeaker and may interfere with reception.

Greater appreciation of quietness, and the use of modern sound absorptive materials in office and home construction have made rooms having good acoustical properties quite prevalent. A recent field survey, in a business area, shows that a high percentage of Speakerphone installations are in private offices having good acoustical properties. In these offices, the Speakerphone generally provides satisfactory telephone service with the benefits of hands-free telephony and permits a small group to participate in the conversation.

THE AUTHOR

W. F. CLEMENCY joined the Research Department of the Western Electric Company in 1923. He was engaged in studies of transmitter carbon and in the development of improved methods of manufacturing this carbon. Since the incorporation of the Laboratories, he has been a member of the Apparatus Development Department and has worked on the development of telephone transmitters, receivers, and other electro-acoustical devices. He is now engaged in the application and development of loudspeaking telephone sets. Mr. Clemency received a degree in Electrical Engineering from Brooklyn Polytechnic Institute in 1934.