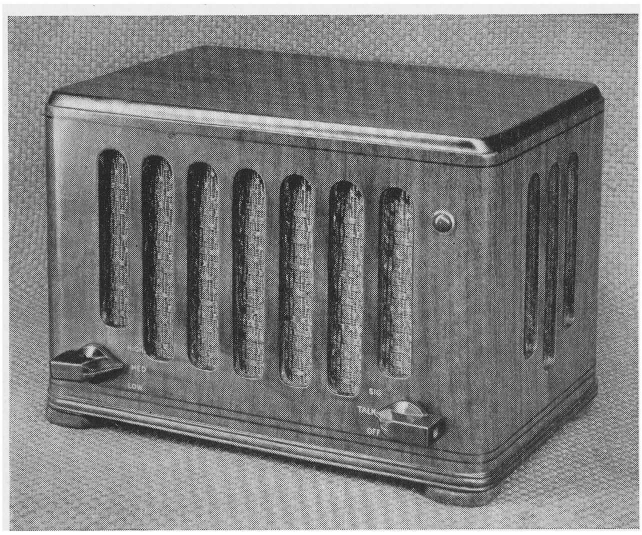


A Loud-Speaking Telephone System

By ALFRED HERCKMANS
Station Instrumentalities

THE 2-A Key Telephone System has been recently developed as an adjunct to regular telephone service to provide direct intercommunication by means of a loud speaker and distant talking telephone set at one end of the circuit and a regular handset at the other end. With this arrangement an executive, for example, may talk with his secretary as if she were across the desk from him.

The major part of the apparatus at the master station is housed in the small cabinet shown in the photograph at the head of this article. This is called the 321 telephone set. It is designed for setting on the desk at some convenient place in front of the user, and is operated by the three-position switch at the lower right. A similar switch at the lower left provides volume adjustment for the loud speaker, but requires only occasional adjustment. Both loud speaker and microphone are behind the grill work. An amplifier is required in addition to this cabinet, and is arranged in a box that may be mounted beneath the desk or elsewhere as desired. A regular telephone, or one normally provided for main station or P.B.X. service, may be arranged for alternative use with the loud-speaker-microphone set, when for privacy reasons the loud-speaking feature is not wanted. The circuit arrangement of the system is shown in Figure 1.

The master station calls the secondary station by operating the control switch to the non-locking signal position, which sounds a buzzer at the secondary station. The switch returns to the talk position when released, and when the handset at the secondary station is lifted, relay G at the master station is operated. This relay removes a short-circuit across the input to the amplifier, and as soon as the switch is turned to the talk position, connects battery to the microphone, a 638A transmitter, and lights the lamp. The secondary station calls by operating a key to sound a buzzer at the master station. The rest of the operation is the same as when the master station calls.

The provision of such a set has been difficult because of the inherent likelihood of "singing" in any arrangement of this sort. Whenever a microphone and receiver are closely associated, through being connected to the same circuit and having an acoustic coupling path between them, sustained oscillations called "singing" are apt to be set up because of the inherent gain of the microphone. Any acoustic output from the receiver is picked up by the microphone, amplified, and returned to the receiver through the electrical coupling. Whenever the gain of the microphone is greater than the loss around this closed path, there is usually a rapid building up of the volume that makes the set inoperative. Such a singing condition is a potential possibility in any telephone set, but where a loud speaker with an additional amplifier is used, its avoidance is very difficult.

Such singing can be avoided by keeping the path to either the receiver or transmitter open at all times—the receiver being opened during transmission, and the transmitter during

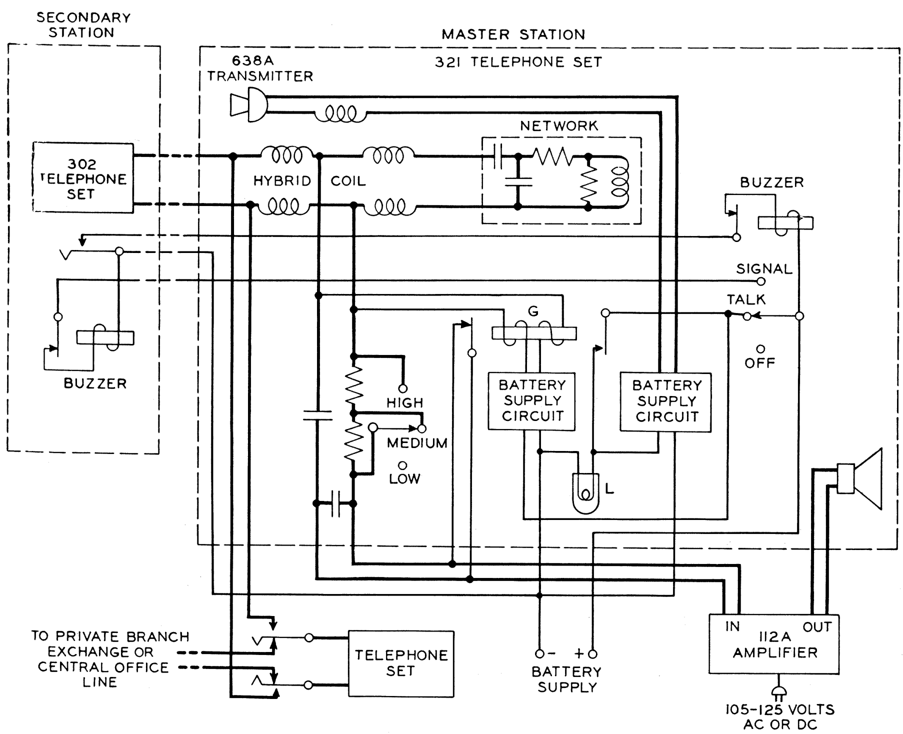


Fig. 1—Schematic of the 321 telephone set with associated amplifier and hand telephone set together with the telephone set and buzzer at the secondary station

reception. This may be done manually with a "press-to-talk" switch, or automatically with a voice-operated relay, and loud-speaking sets incorporating this feature have been developed and used. Such sets are spoken of as being of the "variable" type, transmission being in only one direction at a time, while the new 321 set is of the "invariable" type, requiring no switching operations during a connection. Its successful development has required very careful attention to a number of factors.

The important requirement of an "invariable" set is that there be a large loss around the local circuit from receiver to microphone and back to receiver that does not affect either the transmitting or receiving paths alone. This loss is secured to a considerable extent by the hybrid coil that electrically couples the microphone and receiver to the line. It is indicated in the upper left of Figure 1. Speech energy from the secondary station passes readily through the bridged connection to the amplifier, some of it reaching the coupled microphone circuit. Speech energy from the microphone, on the other hand, passes readily to the outgoing circuit through the coupling of the hybrid coil, but very little of it passes through the bridged connection to the amplifier and loud speaker.

Associated with the hybrid coil is a balancing network which should have an impedance the same as that of the line, and the effectiveness of the coil largely depends on the accuracy of this balance. Because the 321 telephone set is designed for use with a very short line, the balancing network used simulates the impedance of a short line terminated in a subscriber set. A loss of about 17 db has been obtained across the hybrid coil from transmitter to receiver.

Since the user will ordinarily be about three feet from the loud speaker and microphone, the output of the loud speaker must be relatively large, while for the same reason the microphone must be sensitive enough to act on relatively small inputs. Since the loud speaker is physically very near the microphone, the likelihood of singing is greatly increased by this discrepancy in normal operating levels. A satisfactory solution can be obtained only by a careful correlation of the efficiencies and losses of every element that enters into the circuit, and by a careful arrangement of the relative positions of loud speaker and microphone.

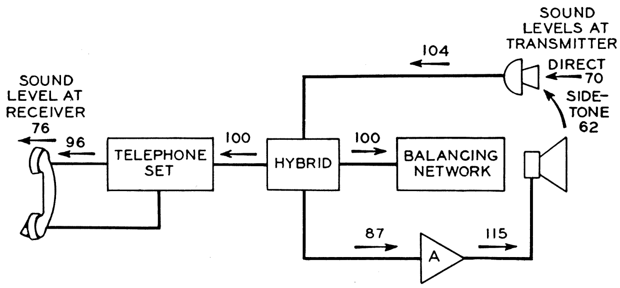


Fig. 2—Speech power distribution when master station is talking. Numbers over arrows indicate sound levels

The net gain around the local circuit is not the same at all frequencies, generally having pronounced peaks, and it is at these peak frequencies that singing occurs. It is this fact that makes careful positioning of the instruments important. The output of the loud speaker does not travel equally in all directions at all frequencies. The higher frequencies are projected for the most part straight ahead, and only the low frequencies have sufficient energy at wide angles to produce singing. By facing the microphone and loud speaker in the same direction, therefore, the danger of the system singing at high frequencies can be considerably decreased.

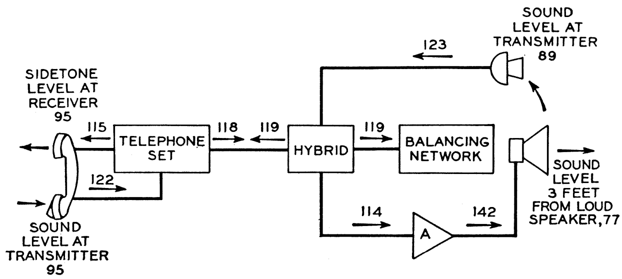


Fig. 3—Speech power distribution when secondary station is talking. Numbers over arrows indicate sound levels

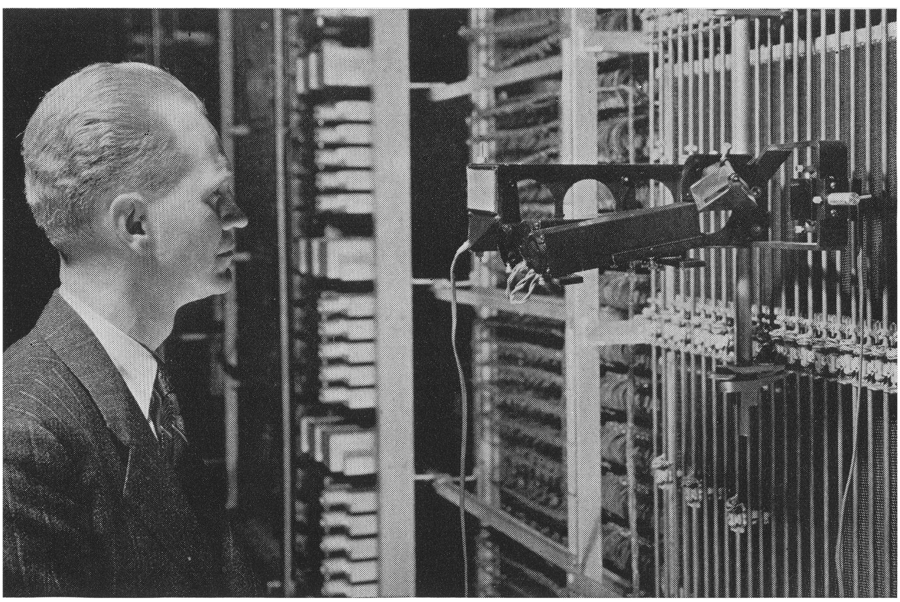
Singing will occur, of course, only at a frequency at which the returned current is in phase with the directly transmitted current at the microphone. If the current returned by the microphone reaches the loud speaker terminals in phase opposition to the originating current at this point, for example, there will be a reduction rather than an increase in output volume at the particular frequency. This phase relation, of course, depends on the delay in the circulating path, which is partly electrical and partly due to the transit time of sound waves from loud speaker to microphone, which varies with the length of path. By moving the loud speaker, or microphone, inward or outward with respect to the front of the cabinet, the length of path may be changed. Advantage has been taken of this fact in the 321 set to greatly reduce the danger of singing. The positions of microphone and loud speaker have been adjusted so that at the frequencies at which singing would be most likely to occur, the delay is such as to approach an out-of-phase condition at the loud speaker.

The acoustic and electrical levels at various points of the circuit when the master station is talking are indicated in Figure 2. The acoustic levels are in terms of sound level in db above 10^{-16} watts per square cm., and the electrical levels are in db above 10^{-16} watts. The electrical level represents the total energy in the circuit, while the sound level represents the intensity of energy. It is assumed that with the speaker three feet from the microphone and speech at ordinary conversational level, the sound level at the microphone will be 70 db. After passing through the microphone, this becomes 104 db in electrical units at the input to the hybrid coil. On the branch going to the line, there is a 4-db loss, giving 100 db on the line, and another 4 db through the coil at the secondary station, giving 96 db to the handset receiver. The equivalent sound level at the output of the receiver is 76 db, which is ample for good reception.

In the singing path across the hybrid coil to the loud-speaker branch, the loss of 17 db results in a level of 87 db. This is increased to 115 db by the amplifier, and, after passing through the loud speaker, results in an audible acoustic level at the ear of the speaker. Since he is talking at a considerably higher level, however, this is merely a hearing of his own voice at considerably reduced level and is imperceptible. Because of the control of the length of the path between loud speaker and microphone, and the directional characteristics of the loud speaker, the level at the microphone of this returned sound is 8 db below the directly received sound that produced it. Around this singing path there is thus an 8-db net loss instead of a gain, and singing will not occur.

An equivalent diagram giving the conditions when the secondary station is transmitting is shown in Figure 3. Because of the closeness of the mouth to the handset transmitter, the electrical level is 122. With 4-db loss through the hybrid coil of the secondary station, this becomes 118 db on the line, 18 db higher than for the other direction of transmission. A 4-db loss through the hybrid coil of the 321 set gives 114 db to the amplifier, and the 28-db gain of the amplifier gives 142 db to the loud speaker. This results in 77-db acoustic level at the listener's ear.

With any such loud-speaking system, the signal-to-noise ratio is always less for the direction of transmission of Figure 2, than for the other direction, because of the greater distance of the mouth from the microphone, and thus the lower level of the speech at the microphone in relation to the entering noise. Under ordinary room noise conditions, however, the transmission from master to secondary is about equivalent to that obtained with the latest type telephone sets over a long telephone connection.



T. F. Osmer, using a vibrometer, observes the effect of the operation of a nearby elevator rod on the relative motion between a brush on a stationary rod and its terminal. Simultaneously the noise generated by this relative motion is also measured