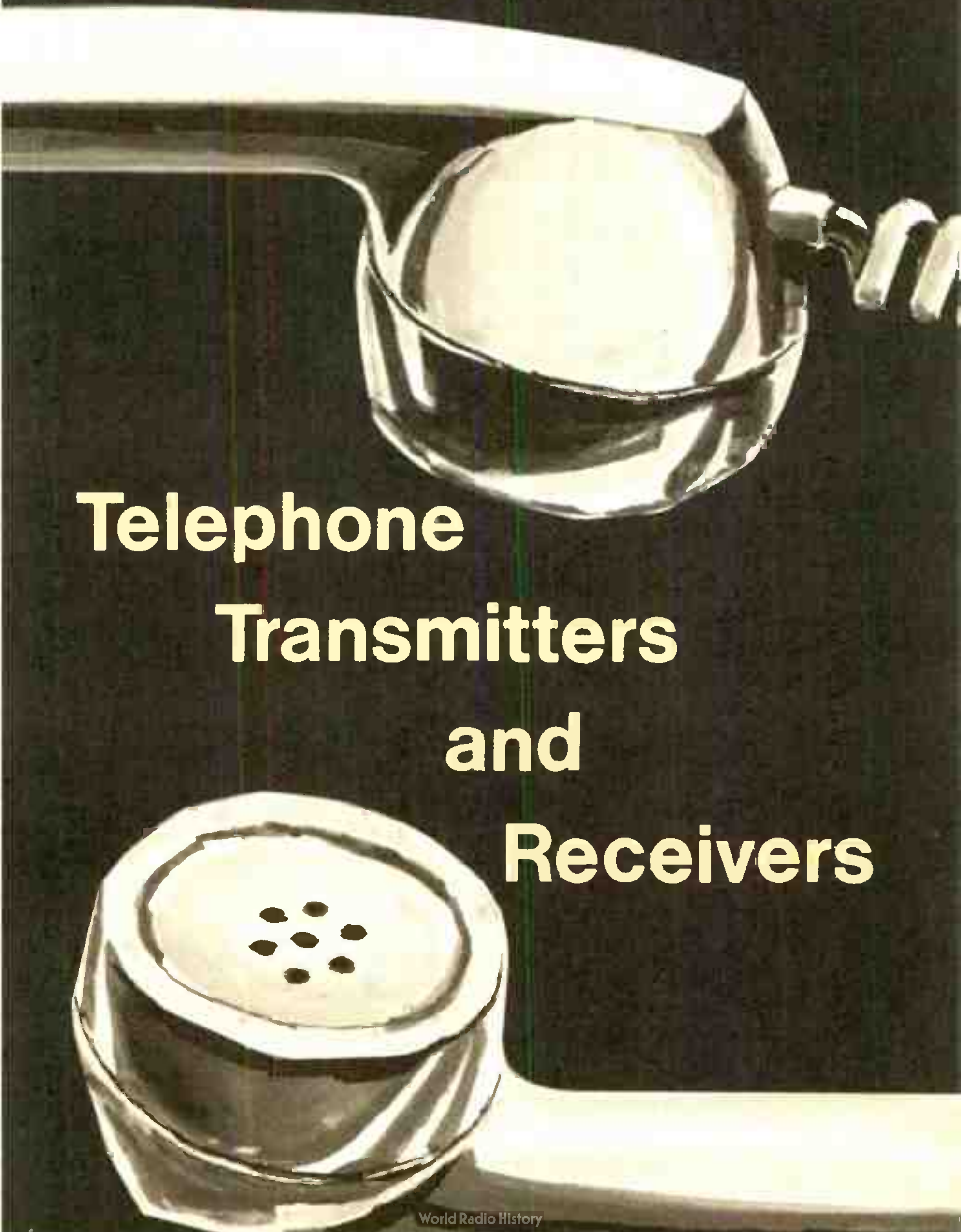
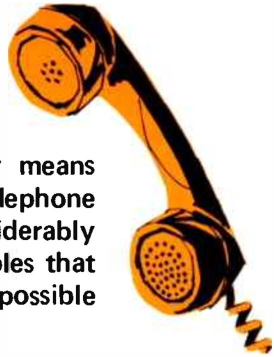
GTE LENKURT
DEMODULATOR
MAY 1974



Telephone Transmitters and Receivers



The word "telephone" literally means "sound at a distance." While telephone equipment has changed considerably over the years, the basic principles that made "sound at a distance" possible remain the same.

In telecommunications, the basic goal is the transmission of intelligence with a minimum of distortion, from the point of origin to the intended destination. This intelligence may be in the form of speech, a scene, a picture, a series of electrical signals, or a modulated electric wave. A telephone system establishes a voice communication path between any two telephones in that system. To do this successfully, the system must convert sound waves to electrical signals and back again in such a manner that the distant receiver hears the original voice sounds with a minimum of distortion. The telephone system must also establish a communication channel and transmit information over it as quickly and reliably as possible.

The difference in nature between audible sound signals and electromagnetic signals necessitates the utilization of devices or converters designed to permit passage from one medium to the other. While in theory, and to a certain extent in practice, it is possible to produce one device that converts sound to electromagnetic impulses and back, power limitations have forced the design of two separate converters. The converter that changes sound variations to corresponding electromagnetic variations is called a transmitter. The converter that changes electromagnetic variations back to corresponding sound variations is called a receiver. (See Figure 1.)

Telephone Transmitters

A telephone transmitter converts mechanical vibrations in the air to electrical "sound" vibrations in an electrical circuit. This is accomplished by varying the resistance in a portion of the transmitter in step with the incoming sound. The varying resistance causes a direct current to increase or decrease.

The simplified telephone transmitter shown in Figure 2 consists essentially of two components—a diaphragm and a capsule filled with carbon granules. The diaphragm is usually made of a stiff metallic material, and is held in place by a retaining ring. A rod connects the diaphragm to the car-

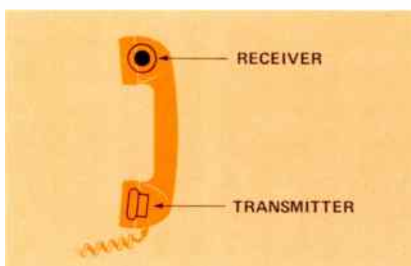


Figure 1. The transmitter and receiver in the telephone handset convert audible sound signals to electromagnetic signals, and back to audible sound.

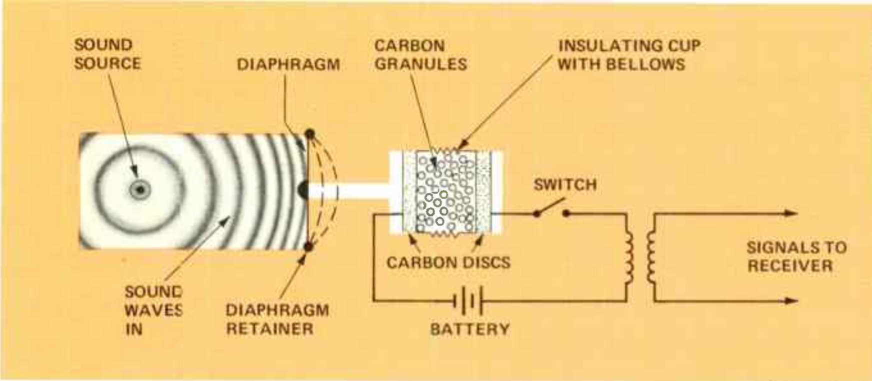


Figure 2. A simplified telephone transmitter.

bon-filled capsule. The capsule is made up of two metal-backed carbon discs held together by an insulating cup with paper bellows. The space between the discs is filled with carbon granules. Because of the action of the bellows, one disc moves freely with the diaphragm. The other disc is rigidly held. The whole capsule is part of a circuit through which direct current can flow.

The components of the transmitter change sound signals to electrical signals. Sound waves meeting the diaphragm cause it to move back and forth. These movements are transmitted to the movable carbon disc. The carbon granules between the two discs are then alternately compressed or decompressed in step with the incoming sound. The compressions and decompressions (rarefactions) vary the resistance of the granules causing the direct current (dc) in the circuit to increase or decrease. The mechanics of the resistance changes are shown in Figures 3 and 4. (While carbon granules are irregular in shape, they are shown here as round for simplicity.)

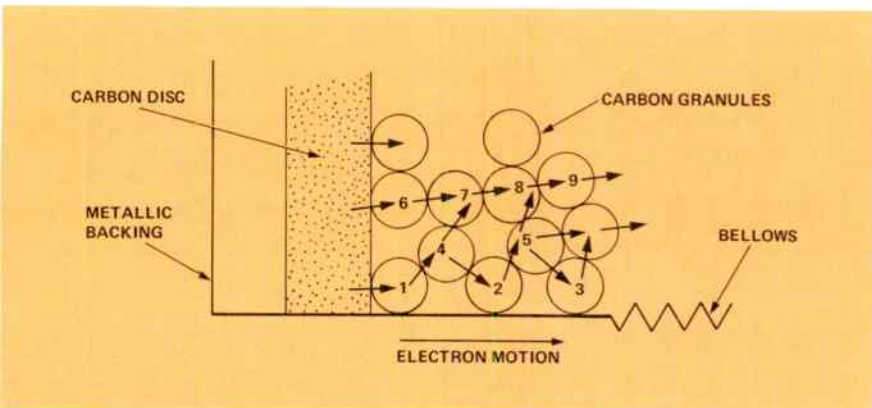


Figure 3. Carbon granules in a normal or decompressed condition within a telephone transmitter capsule.

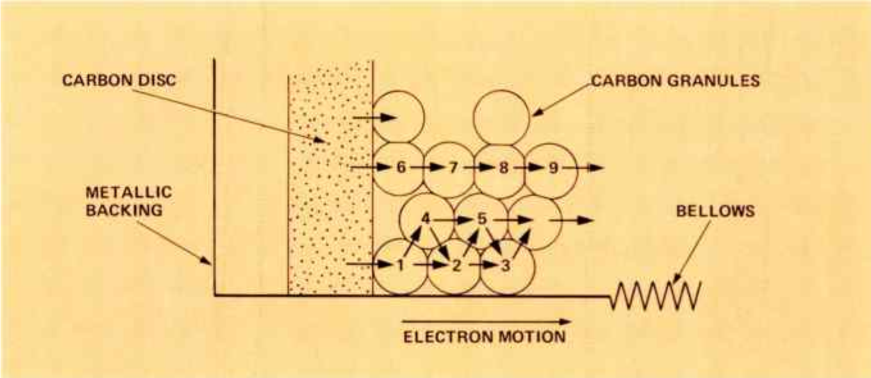


Figure 4. Carbon granules during a period of compression.

Figure 3 represents a steady-state condition with no sound meeting the diaphragm, and a steady current in the circuit. There is a possibility of several paths for the current. It can, for example, travel from the carbon disc to granule 1, 4, 2, 5, 3, etc. Figure 4 shows an instant in time when the granules are compressed by a wave. Granules 1, 2, and 3 have now come in contact, thus providing an additional path for the current. Also, granules 6, 7, 8, and 9 have been compressed so that instead of there merely existing point contacts, there are circular-area contacts between them. This increase in contact area decreases the overall resistance and thus increases the current. The high resistance caused by a decompression wave is produced when the carbon disc moves to the left (see Figure 4), allowing the granules to separate; in some cases contacts are broken and in other cases only point contacts are established. The undulating voice current (see Figure 5) produced by the compression and decompression of the carbon granules is carried by the line to the distant end where it is coupled to a receiver circuit and changed back into sound.

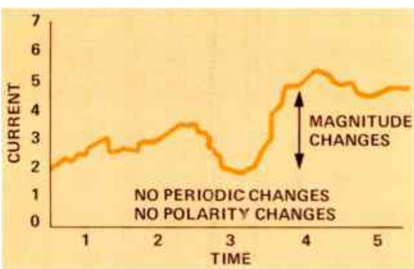


Figure 5. An undulating voice current is produced by the compression and decompression of the carbon granules in the telephone transmitter.

Telephone Receivers

A telephone receiver changes electric voice signals to audible sound by magnetically vibrating a diaphragm in step with the incoming electric voice signals. Voice signals enter the receiver circuit over a coupling coil. The signals continue to the receiver capsule, where they pass through coil windings and generate a fluctuating magnetic field. The magnetic field causes a rigid diaphragm to vibrate, thus producing an audible sound.

There are two types of receivers which are most commonly used—the biased or direct-action receiver and the polar or indirect-action receiver. In the

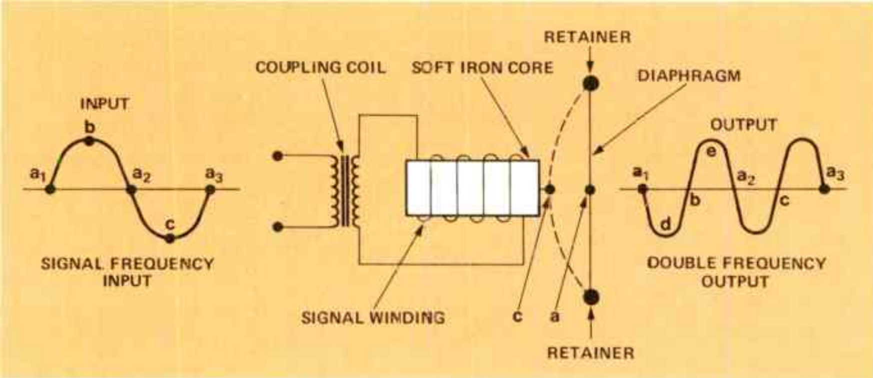


Figure 6. A receiver with no permanent magnet incurs double-frequency distortion problems.

first type, a magnetic diaphragm is directly vibrated by the fluctuating field. In the second type, the field vibrates a magnetic armature which then transmits the vibrations through a linkage to a non-magnetic diaphragm.

Direct-Action Receiver

The direct action or biased receiver has been a standard unit for many years. Its diaphragm is the link between the electric circuit and the air. The voice signals are changed into magnetic field fluctuations by two coils. These fluctuations then vibrate the magnetic diaphragm. The principal parts of the direct-action receiver are two inductive windings, the diaphragm, and a permanent magnet. The permanent magnet is used to prevent double-frequency distortion.

An example of the cause of double-frequency distortion is shown in Figure 6. The receiver in Figure 6 has no permanent magnet, the signal winding is wound around a soft iron core which becomes magnetized only while current is flowing in the winding. When a signal is introduced, the core will be magnetized during each half-cycle. The diaphragm will be attracted as the signal increases from a_1 to b; then as the signal decreases from b to a_2, the diaphragm will be released. When the diaphragm is attracted, the air experiences a decompression: when it is released, the air is compressed. Thus, while the input signal goes through a half-cycle (from zero at a_1, to maximum positive at b, and back to zero at a_2), the output goes through a complete cycle (from zero at a_1, to maximum negative or decompression at d, to zero at b, to maximum positive or compression at e, and back to zero at a_2). The series of events described above are repeated on the negative half-cycle of the input. Each input cycle, therefore produces two cycles in the output, thus creating double-frequency distortion.

The direct-action receiver shown in Figure 7 was designed to prevent double-frequency distortion. The permanent magnet biases the diaphragm in an operating region where double-frequency distortion is at a minimum. The signal windings are wound on the permanent magnet poles in such a way that a positive going pulse will weaken the poles, and a negative going pulse will strengthen the poles. When the

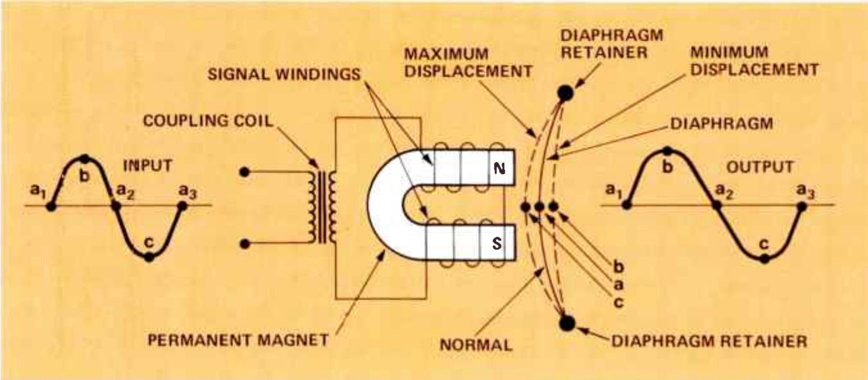


Figure 7. The use of a permanent magnet in a biased or direct-action telephone receiver prevents double frequency distortion.

input rises from a_1 to a maximum positive at b, and back to a_2, the diaphragm is released and returned, producing a compression. On the negative swing of the input signal (from a_2 to maximum negative at c, and back to a_3), the diaphragm is attracted and returned to normal, producing a decompression. This action generates an output resembling the input. The same results may be obtained by introducing a direct current into the receiver of Figure 6. However, there is a certain amount of amplitude distortion. On the negative half-cycles of the input, the diaphragm offers greater elastic resistance than on the positive half-cycles. This causes the decompressions to be weaker in amplitude than the compressions.

Indirect-Action Receiver

The indirect-action or polar receiver (shown in Figure 8) is a more recent development than the direct-action receiver; it is more sensitive and introduces considerably less distortion than the direct-action receiver. In effect, the indirect-action polar receiver is capable of discriminating the polarity

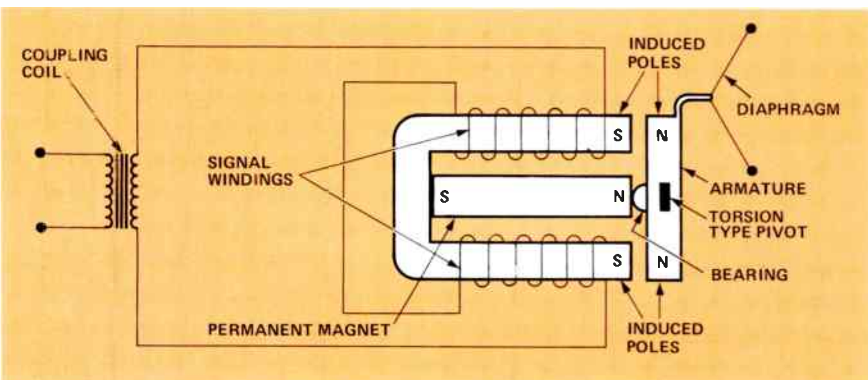


Figure 8. A polar or indirect-action telephone receiver.

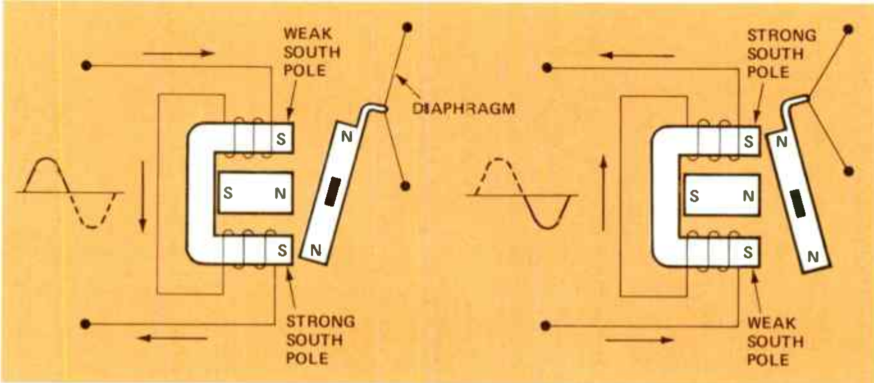


Figure 9. Polar receiver action.

of the incoming signals. The principal parts of this receiver are two signal windings, a permanent magnet, a movable armature, and a diaphragm.

The permanent magnet in Figure 8 polarizes the movable armature and the signal winding cores as indicated. The armature is held in normal position by a torsion bar and the equal attraction of the winding cores. The windings are wound so that current in one direction produces a magnetic field that aids the induced pole in one core and opposes the induced pole of the other. When the current reverses, the above effect also reverses. These unequal forces cause the armature to see-saw about its pivot and in this way, the diaphragm, which is attached to one end of the armature, moves back and forth as shown in Figure 9. One advantage of the indirect-action receiver is that the diaphragm is designed specifically for producing sound and does not have to serve the dual purpose of being a good magnetic conductor as well as a good acoustical generator. Also, less electrical energy is required because the magnetic circuit is more compact and efficient.

The various components of a telephone system can be overwhelming if one attempts to perceive them all at once; but taken individually, it becomes much easier to visualize an overall system. This is especially true today, when the business of telephony encompasses not only basic telephone principles and associated apparatus, but also other forms of telecommunications, such as video and machine communications.

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