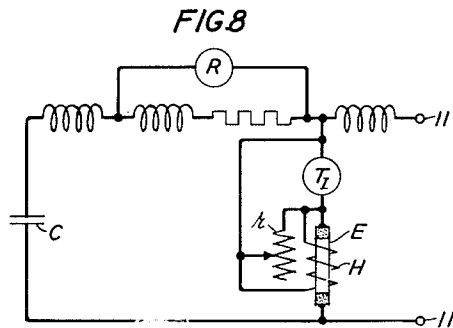
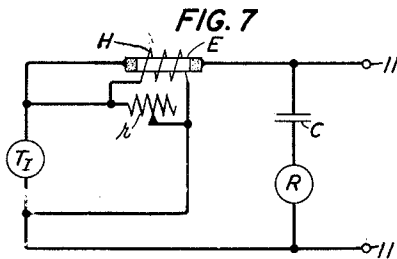
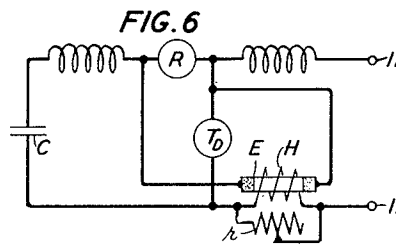
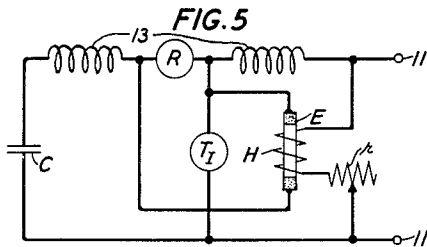
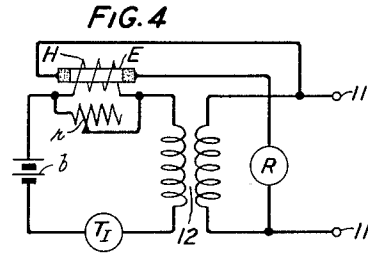
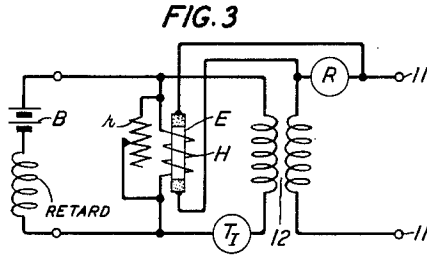
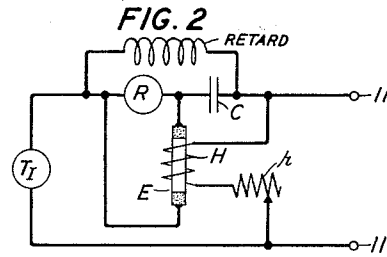
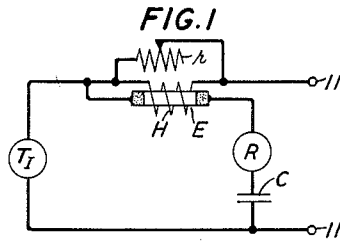
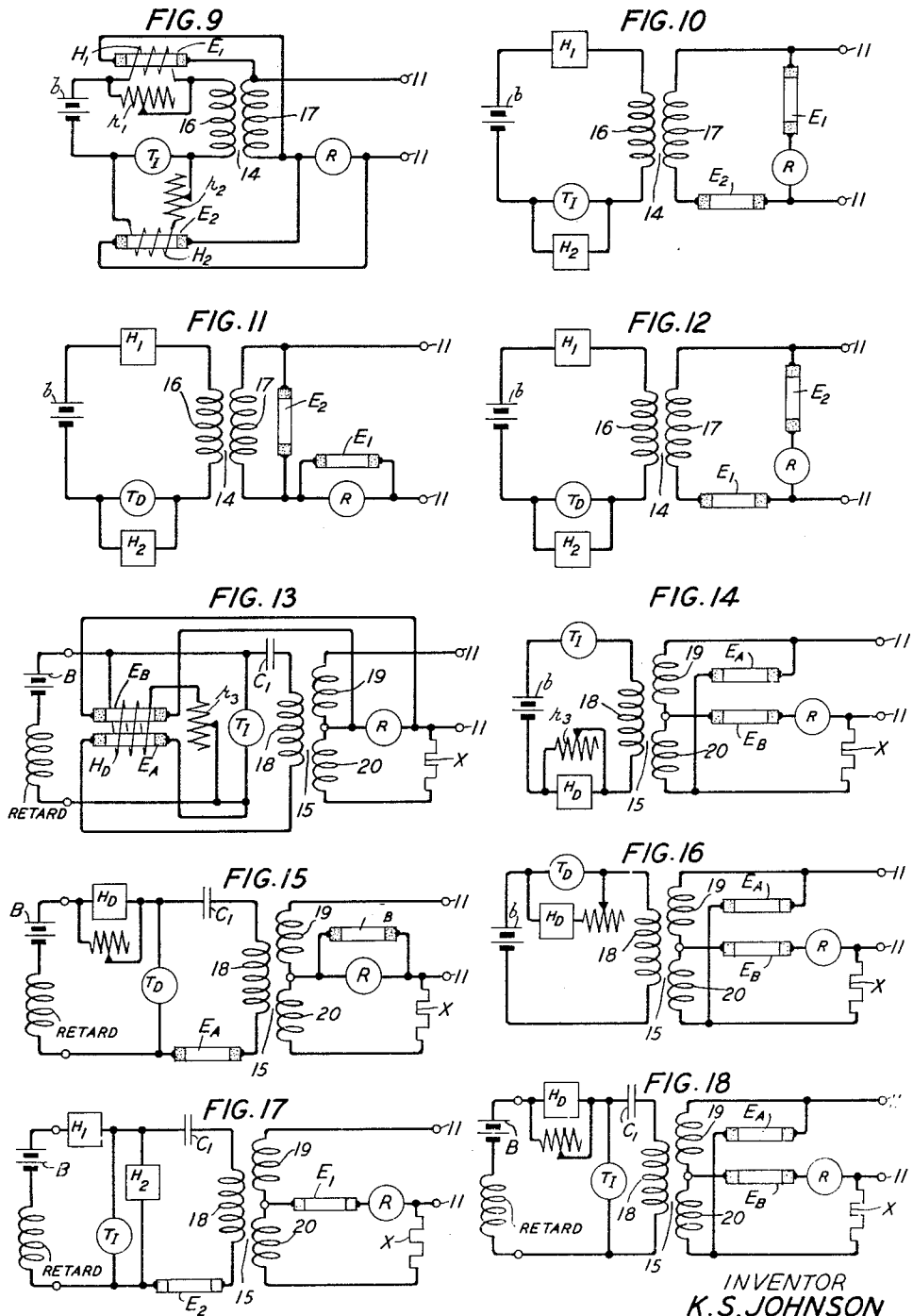




INVENTOR
K. S. JOHNSON
BY
Robert J. Huskey
ATTORNEY



June 30, 1942.

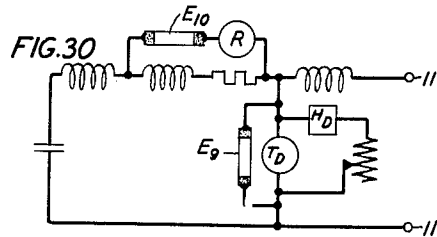
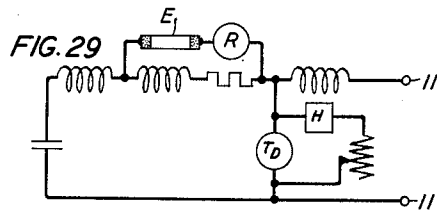
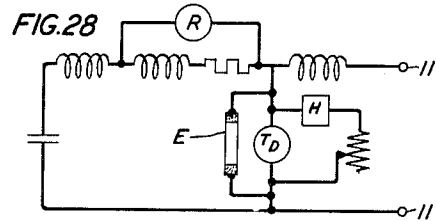
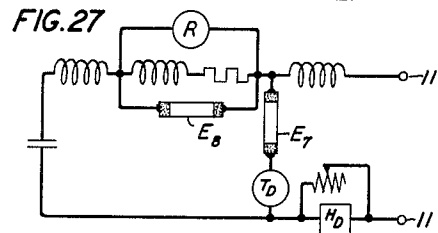
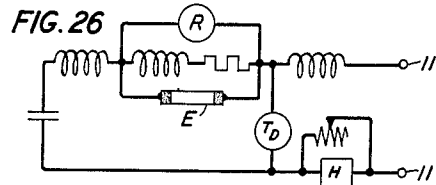
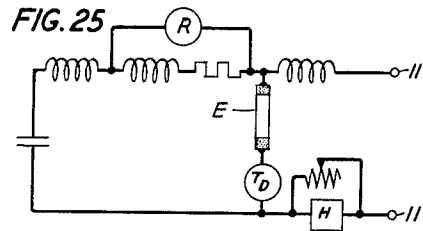
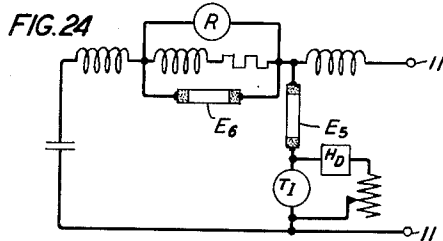
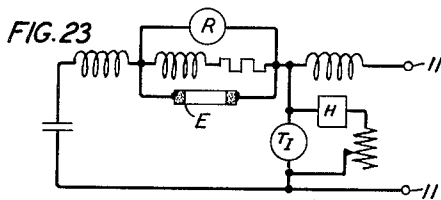
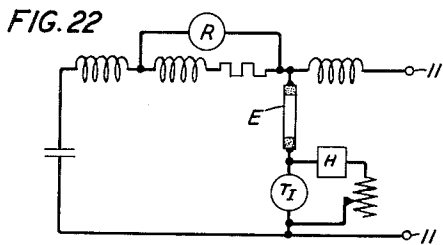
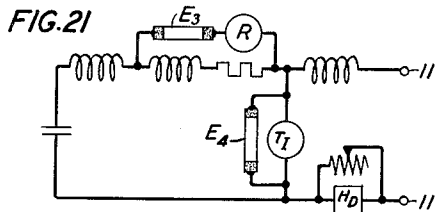
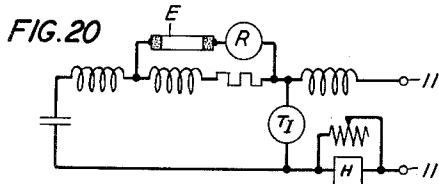
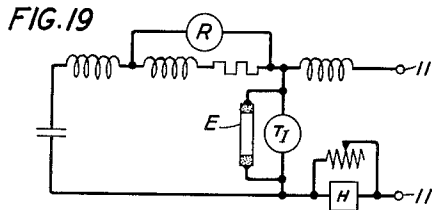
K. S. JOHNSON

2,287,998

TELEPHONE CIRCUIT

Filed June 10, 1939

6 Sheets-Sheet 3



INVENTOR
K. S. JOHNSON
BY
Robert J. Fluskey
ATTORNEY

June 30, 1942.

K. S. JOHNSON

2,287,998

TELEPHONE CIRCUIT

Filed June 10, 1939

6 Sheets-Sheet 4

FIG.31

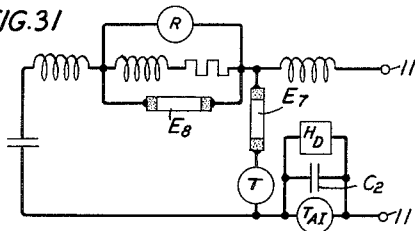


FIG. 32

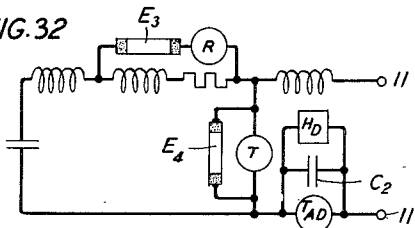


FIG. 33

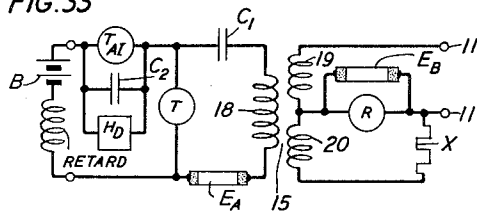


FIG.34

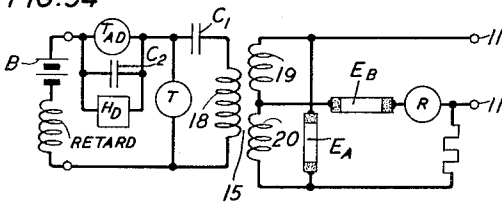


FIG.35

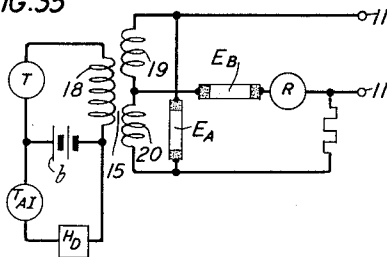


FIG.36

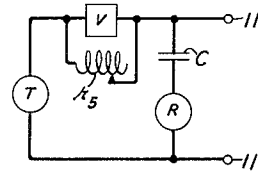


FIG.37

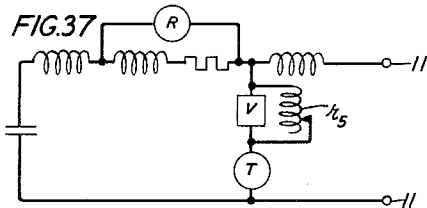


FIG.38

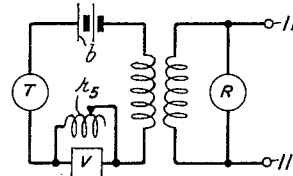


FIG. 39

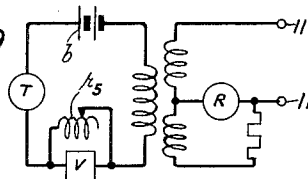


FIG. 45

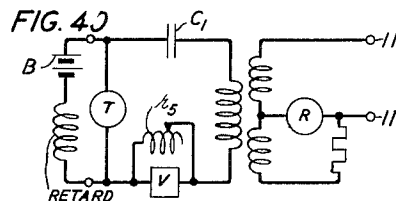
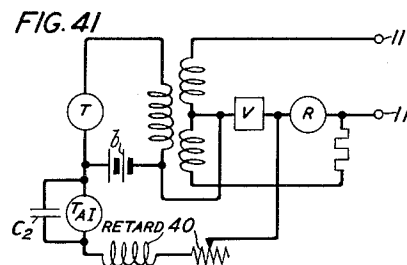
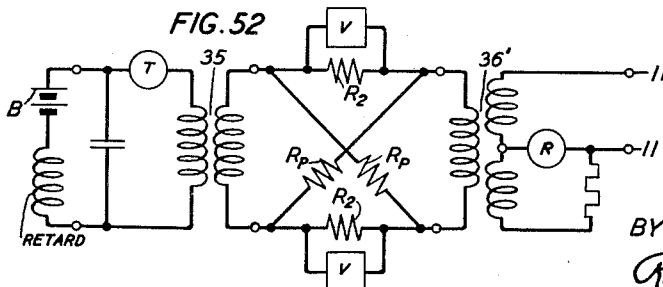
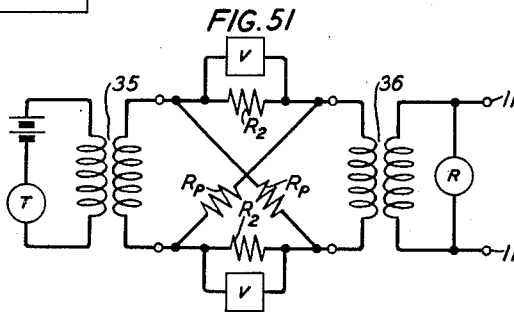
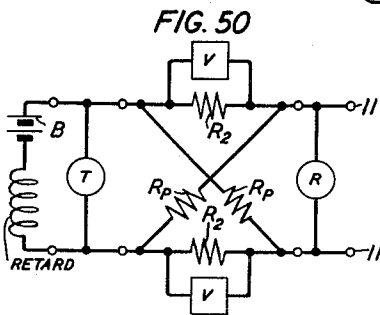
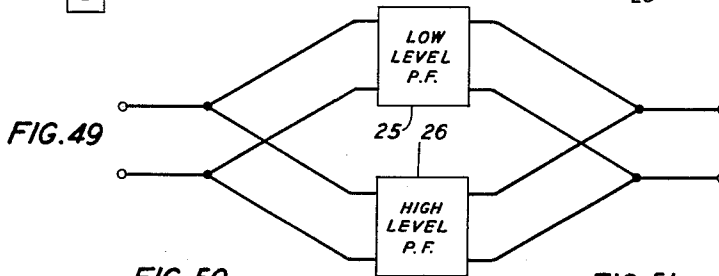
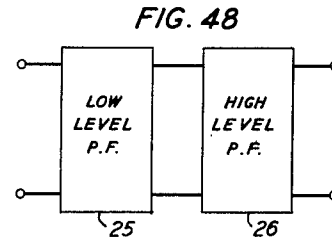
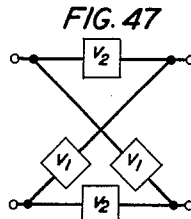
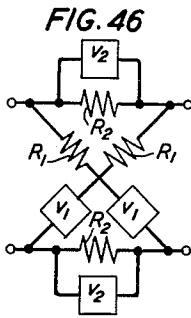
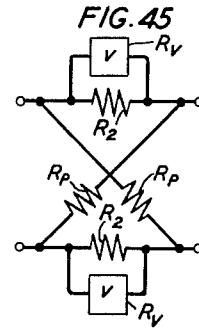
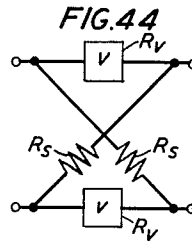
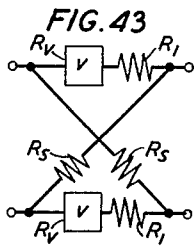
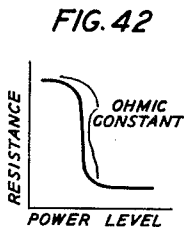


FIG. 41



INVENTOR
BY **K.S. JOHNSON**
Robert J. Fluskey
ATTORNEY



INVENTOR
K.S. JOHNSON
BY
Robert J. Fluskey
ATTORNEY

UNITED STATES PATENT OFFICE

2,287,998

TELEPHONE CIRCUIT

Kenneth S. Johnson, South Orange, N. J., assign-
or to Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application June 10, 1939, Serial No. 278,411

14 Claims. (Cl. 179—81)

This invention relates to telephone set circuits and more particularly to circuits for subscriber substation sets and for telephone operators' sets.

Circuits for subscriber substation and for operators' sets may be of two types, variable or invariable. An ideal variable circuit may be described or defined as follows: a circuit so arranged that, when transmitting, the receiving element or receiver is actually or effectively, that is, from an electrical standpoint, removed from the circuit, and, when receiving, the transmitting element or transmitter is actually or effectively removed from the circuit, so that, during transmitting, side-tone will not be developed in the receiving circuit and receiver and so that, during receiving, weak currents caused by room or other noises effective to agitate the transmitter will not interfere with the weak currents or signals incoming to the receiver, is called a variable circuit. On the other hand, however, one still has a variable circuit, but not an ideal variable circuit, if, on transmitting, the receiving efficiency is caused to be greatly reduced or reduced to a preassigned degree, and, if, on receiving, the efficiency of transmitting is greatly reduced or reduced to a preassigned degree. The invariable circuit, on the other hand, is one in which the circuit is identically the same electrically whether voice currents are being transmitted or received. If by receiving efficiency we mean the proportion of the power incoming to the substation circuit that is dissipated in the receiving element, i. e., the telephone receiver, and if by transmitting efficiency we mean the proportion of the power generated by the transmitting element, i. e., the telephone transmitter, that appears at the line terminals of the substation circuit, with the variable circuit the transmission efficiency is much higher than with the invariable circuit. This would be so, of course, since the actual or effective removal in a variable circuit of the receiving circuit from the substation circuit during transmission, reduces or eliminates any transmission losses in the receiving circuit, and means a higher proportion of the power generated at the transmitter appearing at the line terminals of the substation circuit, than in the case of the invariable circuit in which the receiving circuit is neither actually or effectively removed from the substation circuit during the transmitting operation, and there is no reduction or elimination of transmission losses therein.

The invariable circuit may be a side-tone circuit or an anti-side tone circuit. With the

former, when voice or other currents are generated in the transmitting circuit, some of the generated energy is transferred to and dissipated in the receiving circuit. With the latter, there is in the ideal case no power dissipated in the receiving circuit and receiver when an electromotive force is developed in the transmitter. The anti-side tone circuit giving the most favorable results up to the present time has been of the type utilizing a Wheatstone bridge or balancing network disclosed in many patents to G. A. Campbell and shown in great variety in a paper entitled, "Maximum output networks for telephone substation and repeater circuits," by G. A. Campbell and R. M. Foster, in vol. 39 (1920), Transactions of the American Institute of Electrical Engineers, pages 231 to 280. Although an anti-side tone invariable circuit can theoretically be so designed as to have the same efficiency as a side-tone invariable circuit, actually under most commercial conditions, the efficiency will be slightly lower because the two conjugacy conditions, that is, of no current in the receiver when transmitting and no current in the balancing network when receiving, cannot rigorously be met for all of the different line conditions, frequencies, and the like factors, encountered in commercial telephone practice. In any event, the receiving and transmitting efficiencies in a system using invariable circuits are very much less than those in a system using appropriately arranged variable circuits.

There has been a need for some time for a variable circuit for subscriber substation sets and operators' sets that is simple in character, certain in operation, inexpensive, reproducible in characteristics, operable without amplification on the currents flowing in the substation or operator's circuit, and that obviates the necessity for an anti-side tone circuit of the Campbell type, or, if the latter is used, improves its effectiveness.

An object of the invention is to satisfy this need.

In accordance with the invention, one or more resistance elements or one or more networks of resistance elements are associated with the receiver, or with the transmitter, or with both, of a substation or an operator's set circuit to render the transmitter ineffective as a transmitting element during the receiving or listening condition of the circuit, thereby reducing or eliminating the effect of room or the like noises; and to render the receiver ineffective as a transmission receiving element during the transmit-

ting or talking condition, whereby side-tone in the receiver is reduced or eliminated.

The resistance elements are of the type in which the exceeding of a critical temperature, voltage or current, or in which a change in temperature, voltage or current within preassigned limits, produces a sharp and rapid change in the resistance of the element which returns to its initial value when the critical point is no longer exceeded, or the change in one direction is reversed in the other direction and to the initial condition, and which is capable of repeating the cycle a great number of times.

Such non-linear resistance-current characteristic or non-linear resistance-temperature characteristic elements may be, for example, of silver sulphide, or of uranium oxide, for example, in the form of a bead of uranium oxide in a glass binder, which have negative temperature coefficients of resistance; or, of finely divided chromium oxide in a binder of sodium silicate, which has a positive temperature coefficient of resistance, and which is disclosed in H. L. B. Gould and B. A. Kingsbury Patent No. 2,278,072, issued March 31, 1942; or, of carbon-coated quartz spheres in cellulose acetate, which has a positive temperature coefficient of resistance, and which is disclosed in G. L. Pearson Patent No. 2,258,958, issued Oct. 14, 1941.

Although these materials may be heated either directly, i. e., by passing current therethrough, or indirectly, i. e., by heating in an oven or with a heating coil, and, in the direct heating process, either direct current or alternating current may be used, in certain cases, direct heating with alternating current may be preferred to heating with direct current, and in other cases, indirect heating of the variable resistance element will be found to give the desired results. When the variable resistance element is indirectly heated, a greater time may be required for the desired resistance change than when the element is directly heated, i. e., for the same amount of power input or change in power input to the element or the element and heater, but, in either case, the greater the power input, or the change in power input, the higher the speed in the change of the resistance condition of the element.

In accordance with the invention, furthermore, the variable resistance element associated with the transmitter, or the receiver, or both, of the telephone substation or operator's circuit set, may have a negative temperature coefficient of resistance or a positive temperature coefficient of resistance, hereinafter designated as negative resistance element and positive resistance element, respectively, and a heater coil or element or heater elements are associated with the transmitter whereby, under the control of the transmitter, the resistance condition of the variable resistance element or elements may be adjusted to a predetermined extent from an initial or normal condition, either of high resistance or of low resistance. For certain circuit arrangements, when the variable resistance element or elements are of the negative resistance type, the transmitter used in the circuit should be of the type that increases in resistance from its quiet or non-talking resistance upon agitation by the user's sound waves; while for the same circuit arrangements using a variable resistance element or elements of the positive resistance type, the transmitter used in the circuit arrangement should be of the type that decreases in resistance from its quiet or non-talking resistance upon agi-

tation by the user's sound waves. In other circuit arrangements, however, embodying a negative resistance element or elements, it will be more expedient to utilize a transmitter of the decreasing resistance type; and in other circuit arrangements, incorporating a positive resistance element or elements, it will be more expedient to employ a transmitter of the increasing resistance type.

In accordance with this invention, the temperature-controlled variable resistance element may be associated with the transmitter only, and either in series or in parallel therewith; or be associated with the receiver only, and either in series or in parallel therewith, the heater coil or element being connected in series or in parallel with the transmitter; or one variable resistance element may be connected in series with the transmitter and another in parallel with the receiver, or one in parallel with the transmitter and the other in series with the receiver, the heater coil or element being connected in series or in parallel with the transmitter. Instead of a single heater coil or element for the variable resistance elements, when two are associated with the telephone set circuit, a separate heater coil or element may be provided for each variable resistance element.

In accordance with the invention, also, a telephone set circuit including a transmitter, a receiver, and one or more variable resistance elements associated therewith, may include an auxiliary transmitter or voice energy-controlled variable resistance device. This auxiliary transmitter may be of the type that increases in resistance on change from its quiet condition to its talking condition, or of the type that decreases in resistance under such circumstances. The variable resistance element may be a negative resistance element or a positive resistance element, or an element whose variation in resistance is dependent on current flow or potential drop rather than temperature change. The change in resistance of the auxiliary transmitter functions to alter the initial resistance condition of the variable resistance element to that desired in the particular circuit.

The invention embraces, also, the utilization in a telephone set circuit of one or more variable resistor elements that experience non-linear changes in resistance with change in current flow therethrough or potential thereacross, or a network or networks of such elements, associated with the transmitter, or the receiver, or both, so that during transmitting the receiver may be free of side-tone, and/or during receiving the receiver may be free of interference resulting from room or other noises effective on the transmitter.

A more complete understanding of this invention will be obtained from the detailed description which follows, taken in conjunction with the appended drawings, wherein, in accordance with this invention:

Fig. 1 shows a telephone set circuit comprising a transmitter and a receiver in parallel across the circuit line terminals, with a temperature-controlled resistance element in series with the receiver, and a heater coil for the element, the heating current varying with the talking current flowing therethrough;

Fig. 2 shows another telephone set circuit in which the receiver and transmitter are connected in series across the line terminals, the temperature-controlled element is in parallel with the

receiver, and the heater coil therefor is connected across the line terminals so that its heating effect is regulated by change in the potential across the line terminals;

Fig. 3 shows a common battery telephone set circuit including an induction coil, the temperature-controlled element being connected in parallel with the receiver on the line terminals side of the induction coil, and the heater coil being connected in parallel with the series connection of the transmitter and an induction coil winding on the talking current supply terminals side of the induction coil;

Fig. 4 shows a local battery telephone set circuit including an induction coil, with the temperature-controlled element in series with the receiver on the line terminals side of the induction coil, and the heater coil for the element connected in series with the battery, the transmitter and an induction coil winding;

Figs. 5 and 6 show common battery telephone set circuits with the temperature-controlled element connected in parallel with the receiver in each circuit, but with the heater coil therefor connected in Fig. 5 across the line terminals, and in Fig. 6 in series with the transmitter and a winding of the induction coil, the transmitter in Fig. 6 being of the type that decreases in resistance when talked into;

Fig. 7 shows a telephone set circuit in which the resistance element is connected in series with the transmitter across the line terminals and the heater coil therefor is connected in parallel with the transmitter;

Fig. 8 shows an anti-side tone telephone set circuit in which the resistance element and its heater coil are associated with the transmitter as in Fig. 7;

Figs. 9, 10, 11 and 12 disclose local battery telephone set circuits comprising a transmitter, a receiver and induction coil with the receiver connected on the line terminals side and the transmitter on the battery side of the induction coil, two temperature-controlled variable resistance elements being included in each circuit with a separate heater coil for each resistance element. One resistance element is connected in series with the receiver and the other in parallel therewith, the heater coils therefor being connected in series and in parallel with the transmitter, which, in Figs. 9 and 10, is of the type increasing in resistance when spoken into, and in Figs. 11 and 12 is of the type decreasing in resistance when spoken into;

Fig. 13 shows a common battery, anti-side tone telephone set circuit embodying two temperature-controlled variable resistance elements, one connected in parallel with the receiver and the other connected in parallel with the transmitter, a single heater coil for the two resistance elements being connected in parallel with the transmitter and across the talking current supply terminals;

Fig. 14 shows a local battery anti-side tone telephone set circuit, embodying two temperature-controlled variable resistance elements, one in series with the receiver and the other in parallel with the induction coil windings on the line terminals side of the induction coil, the single heater coil for the resistance elements being connected in series with the transmitter;

Fig. 15 shows a circuit similar to that of Fig. 13 except that it embodies a transmitter that decreases in resistance when talked into, and the heater coil is connected in series with the trans-

mitter across the talking current supply terminals;

Fig. 16 shows a circuit similar to that of Fig. 14 except that the transmitter is of the type that decreases in resistance when talked into, and the heater coil is connected in parallel with the transmitter;

Fig. 17 shows a common battery, anti-side tone circuit embodying two variable resistance elements, with a separate heater coil for each, one being connected in parallel and the other in series with the transmitter across the talking current supply terminals;

Fig. 18 shows a common battery, anti-side tone telephone set circuit embodying a pair of variable resistance elements with a single heater coil therefor connected in series with the transmitter across the talking current supply terminals;

Fig. 19 shows a common battery, anti-side tone telephone set circuit embodying a temperature-controlled variable resistance element connected in shunt with the transmitter, and the heater coil for the element connected in series with the transmitter and one induction coil winding across the line terminals;

Fig. 20 shows the circuit of Fig. 19 except that the resistance element is connected in series with the receiver;

Fig. 21 shows a circuit that combines the arrangements of Figs. 19 and 20, with a single heater coil for the two resistance elements;

Fig. 22 shows the circuit of Fig. 19 except that the resistance element is connected in series with the transmitter, and the heater coil for the element is connected in parallel with the transmitter;

Fig. 23 shows the circuit of Fig. 22 except that the resistance element is connected in parallel with the receiver;

Fig. 24 shows a circuit that combines the arrangements of Figs. 22 and 23, except that the heater coil for the two resistance elements is connected in parallel with the transmitter;

Figs. 25, 26 and 27 show the same circuit arrangements as those of Figs. 22, 23 and 24, respectively, except that the transmitter is of the type that decreases in resistance when talked into, and the heater coil is connected in series with the transmitter instead of in parallel therewith;

Figs. 28, 29 and 30 show the same circuit arrangements as those of Figs. 19, 20 and 21, respectively, except that the transmitter is of the type that decreases in resistance when talked into, and the heater coil is connected in parallel with the transmitter rather than in series;

Fig. 31 shows a common battery, anti-side tone telephone set circuit embodying two temperature-controlled variable resistance elements, one in parallel with the receiver and another in series with the transmitter, and a single heater coil for the elements, an auxiliary transmitter being connected in parallel with the heater coil and adapted to function as an auxiliary variable resistance device;

Fig. 32 shows the same circuit as Fig. 31 except that the resistance elements are in series and in parallel with the receiver and transmitter, respectively, and the auxiliary transmitter is of the type that decreases in resistance when talked into;

Figs. 33 and 34 show circuits similar to those of Figs. 15 and 18, respectively, embodying an auxiliary transmitter in parallel with the heater coil;

Fig. 35 shows a circuit similar to that of Fig. 14, embodying an auxiliary transmitter;

Fig. 36 shows a telephone set circuit embodying a variable resistance element in series with the transmitter, the resistance element being of the type experiencing a sharp change in resistance with change in potential thereacross, change of current flow therethrough, or the maintaining of a heating current flow therethrough;

Fig. 37 shows a common battery, anti-side tone telephone set circuit embodying the variable resistance element of Fig. 36 in its transmitting circuit;

Fig. 38 shows a local battery telephone set circuit in which the variable resistance element of Fig. 36 is included in the transmitting circuit;

Fig. 39 shows an anti-side tone circuit otherwise the same as Fig. 38;

Fig. 40 shows a common battery, anti-side tone circuit otherwise the same as Fig. 39;

Fig. 41 shows a local battery, anti-side tone telephone set circuit embodying the variable resistance element of Fig. 36, and an auxiliary transmitter functioning as an auxiliary variable resistance device;

Fig. 42 shows a typical resistance-power level characteristic curve for the variable resistance element such as embodied in Fig. 36;

Figs. 43 to 47 show networks embodying variable resistance elements and linear resistances, that constitute low level or high level pass filter sections;

Figs. 48 and 49 show how a low level and a high level pass filter section of the types shown in Figs. 43 to 47 may be connected to provide a band-pass wave filter and a band level elimination filter, respectively;

Fig. 50 shows a telephone set circuit embodying a high level pass filter, such as that of Fig. 45, isolating the transmitter from the receiver so that low level room noises are not transmitted to the receiver, but the high level voice currents pass to the line terminals of the circuit;

Fig. 51 shows a local battery telephone set circuit embodying a filter of the type shown in Fig. 45 and coupled to the transmitter and receiver through transformers;

Fig. 52 shows a common battery, anti-side tone telephone set circuit embodying a filter of the type shown in Fig. 45;

Fig. 53 shows a telephone set circuit in which the receiver is isolated from the transmitter and the line terminals by a low level pass filter of the type shown in Fig. 43;

Fig. 54 shows a local battery telephone set circuit with the receiver in one diagonal of a level pass filter, balanced for high levels or intensities but unbalanced for low levels or intensities;

Fig. 55 shows a common battery, anti-side tone telephone set circuit embodying the low level pass filter of Figs. 53 and 54;

Fig. 56 shows a local battery, anti-side tone telephone set circuit embodying the low level filter of Figs. 53 to 55;

Fig. 57 shows an operator's telephone set circuit in which the features of Figs. 40, 52 and 56 have been embodied; and

Fig. 58 shows a common battery telephone set circuit embodying a low level pass filter associated with the receiver, and a high level pass filter associated with the transmitter.

The telephone set circuits to be described specifically hereinafter, and incorporating tempera-

ture-controlled variable resistance elements may be classified as follows:

1. Circuits in which a heater coil or element is connected in series with the transmitter of the set and in which a variable resistance element is associated (a) with the transmitter, being effectively in parallel therewith; or, (b) with the receiver, being effectively in series therewith; or, (c) with both the transmitter and receiver, one variable resistance element being effectively in parallel with the transmitter, and another variable resistance element being effectively in series with the receiver.

2. Circuits in which a heater coil or element is connected in parallel with the transmitter of the set and in which a variable resistance element is associated (a) with the transmitter, being effectively in series therewith; or, (b) with the receiver, being effectively in parallel therewith; or, (c) with both the transmitter and receiver, one resistance element being effectively in series with the transmitter, and a second variable resistance element being effectively in parallel with the receiver.

3. Circuits in which a heater element is connected in series with the transmitter of the set and the variable resistance element is associated (a) with the transmitter, being effectively in series therewith; or, (b) with the receiver, being effectively in parallel therewith; or, (c) with both the transmitter and receiver, one variable resistance element being connected effectively in series with the transmitter, and a second variable resistance element being connected effectively in parallel with the receiver.

4. Circuits in which a heater element is connected in parallel with the transmitter and in which the variable resistance element is associated (a) with the transmitter, being effectively in parallel therewith; or, (b) with the receiver, being effectively in series therewith; or, (c) with both the transmitter and receiver, one variable resistance element being effectively in parallel with the transmitter, and a second variable resistance element being effectively in series with the receiver.

In these circuits the transmitter may be one of the type that increases in resistance upon change from its quiet condition when it is talked into or agitated by sound waves or it may be of the type that decreases in resistance under such circumstances. In the circuits of classes 1 and 2, when the transmitter is of the increasing resistance type the variable resistance elements should be of the type that have a negative temperature coefficient of resistance, and when the transmitter is of the decreasing type, the variable resistance elements should be of the type having a positive temperature coefficient of resistance. For the circuits of classes 3 and 4, when the transmitter is of the increasing resistance type, the variable resistance elements should be of the type having a positive temperature coefficient of resistance, and when the transmitter is of the decreasing resistance type, the variable resistance elements should be of the type having a negative temperature coefficient of resistance.

In circuits in which two variable resistance elements are used, a separate heater coil or element may be provided for each variable resistance element; one coil may be connected in series with the transmitter and the other connected in parallel therewith. In circuits of this type, one resistance element will normally be in

a high resistance condition and the other resistance element in a low resistance condition. When the circuit is being used for transmitting, the resistance element in its high resistance condition will assume its low resistance condition and the resistance element in its low resistance condition will assume its high resistance condition.

5. Circuits in which a transmitter, auxiliary to that provided for transmitting voice sounds, is provided for controlling, in whole or in part, the resistance condition of the variable resistance element or elements associated with the circuits.

6. Circuits in which the variable resistance element or elements are not temperature controlled, or, if so, are self-controlled, that is, directly heated.

The telephone substation circuits of Figs. 1 to 8 have a single variable resistance element E associated with the transmitter or the receiver of the set, the resistance of the element E being variable non-linearly with temperature variation, and, for purposes of specific description until otherwise indicated, being of the type having a negative temperature coefficient of resistance; and, preferably, having such a characteristic that it presents a high resistance when at a temperature below a certain critical value, but, as the temperature is increased to and above such critical value, the resistance drops to a very low value, returning to its original high resistance condition when the temperature is lowered below the critical point, and being capable of indefinite repetitions of the process. Such a material is silver sulphide, disclosed in J. R. Fisher Patent 2,091,259, issued August 31, 1937, J. R. Fisher Patent 2,082,102, issued June 1, 1937, J. R. Fisher-C. O. Mallinckrodt Patent 2,116,600, issued May 10, 1938, and R. O. Grisdale Patent 2,079,690, issued May 11, 1937. In Figs. 1 to 6, the element E is in series or in parallel with the receiver; in Figs. 7 and 8, the element E is in series with the transmitter.

The substation circuit of Fig. 1 embodies a transmitter T_r , i. e., a transmitter, e. g., of the granular carbon type, that increases in resistance on change from its quiet condition to its agitated condition when talked into; a receiver R; a condenser C for keeping direct current out of the receiver circuit; a heater coil or element H for the resistance element E; a rheostat r associated with the heater coil; and substation or line terminals 11, 11 for connection with a telephone line. In the circuit of Fig. 1, talking current is obtained from a central office through terminals 11. In Figs. 1 to 8, like elements bear corresponding identifying characters. The element E is controlled essentially by the variation in direct current flowing through the transmitter circuit as the transmitter changes in resistance from its quiet to its agitated or talked-into condition. In this circuit, when the transmitter is talked into, its resistance increases and the direct current decreases. For the normal or receiving condition of the circuit, rheostat r has been adjusted so that the heating effect of heater H is such that element E is at a temperature above its resistance breakdown point and a low resistance is in series with the receiver R; then, when the transmitter resistance increases during transmitting, the decreased flow of direct current through the heater H causes the element E to cool down to a temperature below its breakdown temperature whereby the element E assumes its

high resistance condition, and a high resistance effectively has been placed in series with the receiver reducing or eliminating side-tone in the receiver. When the user ceases talking, the heater and element E return to their initial conditions.

In Fig. 2, the transmitter and receiver are in series across the line terminals, with the heater connected across the line terminals and the element E in shunt with the receiver. In the normal condition of the circuit, i. e., receiving or listening, the heater H adjustment is such that element E is in its high resistance condition; when the transmitter is talked into, its resistance increases, the voltage across the heater increases, its heating effect is increased and the element E is caused to assume its low resistance condition effectively shunting the receiver, reducing or eliminating side-tone in the receiver.

In Fig. 3, a common battery telephone set circuit, an induction coil 12 is included; the receiver R is connected in series with one winding across the terminals 11; and the transmitter is connected in a local series circuit comprising the other winding of the induction coil, a common battery B, and a retard coil having substantial resistance. This circuit is one that can be made efficient for a low resistance transmitter, e. g., a 50-ohm transmitter. The heater H is connected effectively in shunt of the transmitter, and the element E is connected in shunt of the receiver. This circuit functions similarly to that of Fig. 2.

The circuit of Fig. 4 is a local battery circuit, the transmitter T_r being in a local series circuit with talking-current battery b , one winding of the induction coil 12, and heater H. The element E is in series with the receiver. The circuit functions similarly to that of Fig. 1.

The circuit of Fig. 5 is adapted for common battery supply of talking current, includes a two-winding induction coil 13, has the element E connected in shunt with the receiver, and the heater H connected across the line terminals 11. In the normal or receiving condition of the circuit, the heater is adjusted so that the temperature of the element E is such that it is in its high resistance condition. When the transmitter is talked into, its resistance increases, the power absorbed by the heater increases, and the temperature of element E is raised to cause it to assume its low resistance condition, effectively to shunt the receiver, and reduce or eliminate side-tone therein. When talking ceases, the initial conditions are re-established.

The circuit of Fig. 6 is the same as that of Fig. 5 except that the heater H is connected in series with a transmitter T_b , i. e., a transmitter whose resistance decreases on change from its quiet condition to its agitated or talked-into condition, and one winding of the induction coil 13 across terminals 11. In the normal or receiving condition of the circuit, the adjustment of the heater H is such that the element E is in its high resistance condition. When the transmitter T_b is talked into by the user, its resistance decreases causing more power to be absorbed by the heater, and the element E caused to assume its low resistance condition, whereby side-tone is shunted or by-passed around the receiver. When talking ceases, the element E and heater H return to their initial conditions.

In each of Figs. 1 to 6, the element E is associated with the receiving circuit to reduce or eliminate side-tone in the receiver when the transmitting circuit is being utilized. In Figs. 7 and 8,

the circuits are ones in which the element E is associated with the transmitting circuit so that there will result a reduction or elimination of interfering currents in the receiving circuit during the normal or listening condition of the set circuit, because of room or other noises that the transmitter might tend to pick up.

The circuit of Fig. 7 is the same as that of Fig. 1 except that the heater H is now connected in parallel with the transmitter T₁ and the element E is connected in series with the transmitter across the line terminals 11. During the normal or listening condition, the adjustment of heater H is such that element E is in its high resistance condition, hence currents resulting from room or the like noises acting on the transmitter meet a maximum impedance, and their effect on the receiver is reduced or precluded. When the transmitter is talked into, its resistance increases, more power is absorbed by the heater and element E is caused to assume its low resistance condition, whereby an efficient transmitting circuit is provided. On cessation of speech by the user, heater H and element E return to their initial conditions.

Fig. 8 shows a common battery, anti-side tone substation circuit rendered more effective as to reduction of interference because of room and the like noises, by use of essentially the same variable resistance element arrangement of Fig. 7. Except for element E and associated heater, the circuit of Fig. 8 is the same as that of Fig. 1 of J. W. Gooderham Patent 1,901,958, issued March 21, 1933.

Telephone set circuit arrangements will now be described in which temperature-controlled variable resistance elements are employed for disabling the transmitter or effectively removing it from the circuit during receiving, so that room or other noises acting on the transmitter do not produce interfering currents in the receiver, and for disabling the receiver or effectively removing it from circuit when the transmitter is actuated by voice frequency sound waves.

In each of the circuit arrangements of Figs. 9 to 18, two variable resistance elements of the same type as element E of Figs. 1 to 8 are employed. One of the two is connected directly either in series or in shunt with the receiver, while the other is connected either directly or effectively in series or in parallel with the transmitter. In Figs. 9 to 12 and 17, the variable resistance elements are designated E₁ and E₂, and a separate heater coil or element is provided for each element, the heaters being designated H₁ and H₂, respectively, with associated rheostats r₁ and r₂, the heater H₁ being connected in series with the transmitter and the heater H₂ in parallel with the transmitter. In Figs. 13 to 16 and 18, a single heater coil or element H₃ and associated rheostat r₃ is provided for the two variable resistance elements, the latter being designated E_A and E_B. In the circuits of Figs. 9 to 12, 14 and 16, talking current is supplied by a local battery b, and in the circuits of Figs. 13, 15, 17 and 18, the talking-current supply is similar to that of the circuit of Fig. 3. The circuits of Figs. 9 to 12 embody two-winding transformers or induction coils 14; and those of Figs. 13 to 18, embody the three-winding transformer or induction coil 15 and balancing resistance X, to provide an anti-side tone circuit in accordance with G. A. Campbell Patent 1,254,472, issued January 22, 1918.

In the circuit of Fig. 9, the transmitter T₁ is connected in a local series circuit comprising the

battery b, the transmitter, one winding 16 of the transformer 14, and heater H₁, with heater H₂ shunted across the transmitter. The receiver R and the other winding 17 of the transformer 14 are connected in series across the terminals 11. Element E₁ is in shunt with winding 17, and element E₂ is connected in shunt with the receiver.

In the normal or receiving condition of the circuit, element E₁ is in its low resistance condition and element E₂ is in its high resistance condition, i. e., the heaters H₁ and H₂ are so adjusted that the appropriate temperature condition exists. Room or other noises acting on the transmitter are ineffective with reference to the receiving circuit and the receiver because element E₁ effectively short-circuits the transformer, or the transmitter branch of the set circuit. Since element E₂ is in its high resistance condition, incoming voice currents or signals are reproduced without interference in the receiver. When the transmitter T₁ is talked into by the user, its resistance increases, the power absorbed by heater H₁ decreases and that absorbed by heater H₂ increases whereby the temperatures of elements E₁ and E₂ are caused to change so that element E₁ assumes its high resistance condition and element E₂ assumes its low resistance condition; thus eliminating the short-circuit effect of the shunt resistance which exists on the winding 17, providing a shunt around the receiver to reduce or eliminate side-tone, and permitting substantially the entire voltage generated across winding 17 to be impressed on terminals 11. When talking ceases, the circuit returns to its initial status. The circuit described, it is evident, is equivalent to an ideal variable station circuit both on transmitting and receiving.

The circuit of Fig. 10 is the same as that of Fig. 9 except that element E₁ is connected in series with the receiver across the terminals and element E₂ is connected in series with winding 17 across the terminals 11. For the normal or listening condition, the heaters H₁ and H₂ will be adjusted so that elements E₁ and E₂ are in their low resistance condition and high resistance condition, respectively. An efficient low resistance path through the receiver is provided for incoming voice currents, and a high resistance exists in series with the winding 17 so that currents induced therein because of room or other noises acting on the transmitter are ineffective on the receiver. During transmitting, the increase in transmitter resistance causes a reversal in the resistance condition of elements E₁ and E₂, the high resistance of the element E₁ minimizing side-tone in the receiver, and the low resistance of element E₂ providing an efficient transmitting path across the terminals 11.

The circuit of Fig. 11 is the same as that of Fig. 9 except that a transmitter T₂ replaces the transmitter T₁, and the elements E₁ and E₂ are reversed in position from that of the same elements in Fig. 9. Although the operation of this circuit is believed to be obvious in the light of the previous description, it may be pointed out that in the normal or receiving condition, elements E₁ and E₂ are in their high and low resistance conditions, respectively; and that when the transmitter is talked into, its resistance decreases, increasing the power absorbed by heater H₁ and decreasing that absorbed by heater H₂, whereby elements E₁ and E₂ assume their low and high resistance conditions, respectively, returning to their initial conditions when talking ceases.

The circuit of Fig. 12 is the same as that of Fig. 10 except that a transmitter T_b replaces the transmitter T_r , and the locations of the elements E_1 and E_2 are reversed, the effect of which on the operation of the circuit will be evident from the description with reference to Figs. 9, 10 and 11. For each of the circuits of Figs. 11 and 12, interfering currents arising from room or other noises are minimized with respect to the receiver during receiving, and side-tone is reduced or eliminated in the receiver during transmitting.

In the circuit of Fig. 13, the elements E_A and E_B are connected in series with the transmitter and in parallel with the receiver, respectively, and for the normal or receiving condition of the set are in their high resistance conditions. During transmitting, the transmitter resistance increases, the power absorbed by heater H_D increases, and elements E_A and E_B are caused to assume their low resistance conditions, returning to their initial conditions when talking ceases; and, in each condition, having the above-noted effects with reference to room and other noises and side-tone. This circuit, it will be observed, is doubly anti-side tone in that it has the normal anti-side tone action of the Wheatstone bridge or balancing network arrangement of Campbell, and, furthermore, has the receiver, during transmitting, shunted by the low resistance of element E_B . This latter effect is, of course, independent of the value of the impedance of the telephone line that may be connected to the line terminals. Condenser C_1 isolates the battery B from transformer winding 13, but is of low impedance to voice currents generated by the transmitter. The circuit of Fig. 15 is the same as that of Fig. 13 except that a transmitter T_b replaces the transmitter T_r , and in order that the circuit may function with respect to room and other noises and side-tone as does Fig. 13, the heater H_b is connected in series with the transmitter T_b and battery B . In Fig. 13, the heater H_b is connected in parallel with the transmitter T_r . In the normal or receiving condition of the circuit of Fig. 15, elements E_A and E_B are in their high resistance condition; during transmitting, they are caused to assume their low resistance condition.

In the circuit of Fig. 14, the heater H_b is connected in series with battery b , the transmitter T_r and one winding 13 of the transformer 15. Element E_A is connected in shunt with the series-connected windings 19, 20 of the transformer, and element E_B is connected in series with the receiver and winding 19 across the line terminals. In the normal or listening condition of the circuit, elements E_A and E_B have been caused to assume their low resistance conditions; during transmitting, the decreased power absorbed by the heater H_b causes the elements E_A and E_B to assume their high resistance conditions. Hence, interference with receiving from room or the like noises, and side-tone during transmitting are controlled as already pointed out herein. The circuit of Fig. 16 is the same as that of Fig. 14, but since the transmitter T_b is employed instead of the transmitter T_r , the heater H_b is connected in parallel with the transmitter T_b . The effects with respect to room noise and side-tone during receiving and transmitting will be the same in the circuit of Fig. 16 as in the circuit of Fig. 14. The circuit of Fig. 18 is the same as that of Fig. 14 except that the transmitter current supply is from a common battery B through a high resistance retard coil rather than from a local bat-

tery. The action of the circuit of Fig. 18 is otherwise essentially equivalent to that of Fig. 14.

The circuit configuration of Fig. 17 is the same as that of Fig. 13 except that two heaters H_1 and H_2 are associated with the elements E_1 and E_2 . In the normal or receiving condition of the circuit, elements E_1 and E_2 are in their low resistance condition and high resistance condition, respectively. When the transmitter T_r is talked into, the additional power absorbed by heater H_2 and the lessened power absorbed by heater H_1 result in elements E_1 and E_2 assuming their high and low resistance conditions, respectively. For one operating condition of the circuit, room and other noises are rendered ineffective with respect to the receiver and, for the other, side-tone is rendered ineffective with respect to the receiver.

To recapitulate at this point, telephone set circuits have been described that fall into the following classes, as already defined in this specification:

Fig.—	Class	Fig.—	Class	Fig.—	Class
1.....	1(b)	7.....	2(a)	13.....	2(c)
2.....	2(b)	8.....	2(a)	14.....	1(c)
3.....	2(b)	9.....	1(a)+2(b)	15.....	3(c)
4.....	1(b)	10.....	1(b)+2(a)	16.....	4(c)
5.....	2(b)	11.....	3(b)+4(a)	17.....	1(b)+2(a)
6.....	3(b)	12.....	3(a)+4(b)	18.....	1(c)

In Figs. 19 to 30, there is illustrated the manner in which this invention, in its various aspects as defined hereinabove in classes 1, 2, 3 and 4, may be applied to a telephone set circuit of the type disclosed in J. W. Gooderham Patent 1,901,958, issued March 21, 1933, for example, Fig. 1. In Figs. 19, 22, 25 and 28, a single variable resistance element E is associated with the circuit, and, specifically, with the transmitter of the circuit; in Figs. 20, 23, 26 and 29, a single variable resistance element E is associated with the circuit, and, specifically, with the receiver of the circuit; and, in Figs. 21, 24, 27 and 30, two variable resistance elements are associated with the circuit, one with the receiver and one with the transmitter; in each circuit, a single heater coil or element H or H_D , with associated rheostat, is provided.

As already defined in this specification, the circuits of Figs. 19 to 30 may be classified as follows:

Fig.—	Class	Fig.—	Class	Fig.—	Class
19.....	1(a)	23.....	2(b)	27.....	3(c)
20.....	1(b)	24.....	2(c)	28.....	4(a)
21.....	1(c)	25.....	3(a)	29.....	4(b)
22.....	2(a)	26.....	3(b)	30.....	4(c)

In the circuits of Figs. 19 and 20, for the normal or listening condition of the circuit, the element E would be in its low resistance condition, changing to its high resistance condition when the transmitter T_r is talked into. The arrangement of Fig. 19 is such that, during receiving the transmitter is effectively by-passed, hence the effectiveness of the circuit in excluding interfering currents resulting from room and other noises acting on the transmitter, is increased. In the case of Fig. 20, the circuit becomes doubly anti-side tone in character because, during transmitting, the element E is in its high resistance condition. The circuit of Fig. 21 combines the features of Figs. 19 and 20, a variable resistance element E_3 being connected in series with

the receiver, and an element E_4 in parallel with the transmitter T_1 .

In the circuits of Figs. 22 and 23, for the normal or receiving condition of the set circuit, the elements E are in their high resistance condition. During transmitting, however, they are caused to assume their low resistance conditions as a result of change in the heater condition with change in the transmitter resistance. The circuit of Fig. 22 is rendered more effective in the exclusion of room noise effects from the receiver during receiving; that of Fig. 23, more effective in excluding side-tone from the receiver during transmitting; that of Fig. 24, more effective in each respect by virtue of the use of two elements E_5 and E_6 .

In the circuits of Figs. 25 to 30, respectively, a transmitter T_b is utilized in place of a transmitter T_1 . In Figs. 25 and 26, the element E , during the normal or receiving condition of the circuit, is in its high resistance condition; during transmitting, however, it is caused to become of low resistance, hence, in the circuit of Fig. 25, the use of the element E adds to the effectiveness of the circuit in the exclusion of room noise effects from the receiver during receiving, and in the circuit of Fig. 26, the use of the element E adds to the effectiveness of the circuit in excluding side-tone from the receiver during transmitting. The circuit of Fig. 27 combines these advantages, utilizing elements E_7 and E_8 .

In the circuits of Figs. 28 and 29, during the normal or receiving condition of the set circuit, the element E is in its low resistance condition and during transmitting is caused to change to its high resistance condition, resulting in the advantages attained with the circuits of Figs. 19 and 20. The circuit of Fig. 30 combines the features of the circuits of Figs. 28 and 29, utilizing elements E_9 and E_{10} .

In the circuit arrangements described with reference to Figs. 1 to 30, the transmitter T_1 may be replaced by a transmitter T_b , or the transmitter T_b may be replaced by a transmitter T_1 , with the circuit functioning in the manner described if at the same time the variable resistance element E of negative temperature coefficient of resistance in the particular circuit is replaced by a variable resistance element having a positive temperature coefficient of resistance that varies non-linearly with temperature, i. e., in which for a portion at least of the resistance-temperature characteristic, a large increase in resistance is produced by a small increase in temperature, or by changes in temperature over a preassigned range. If the initial circuit arrangement were one embodying a transmitter T_1 or T_b and a variable resistance element having a positive temperature coefficient of resistance, the transmitter T_1 or T_b may be replaced by a transmitter T_b or T_1 , respectively, with the positive coefficient elements being replaced by negative temperature coefficient elements.

To design a transmitter that will give large changes in resistance between the talking and the listening conditions of the telephone set circuit, and one that, at the same time, will give, for example, a good quality of reproduction, is more difficult than to construct simply a "transmitter" whose quality of reproduction is of negligible importance, but whose essential function is to have a large percentage change in resistance between its quiet and its talking or talked-into condition. In accordance with this inven-

tion, an auxiliary transmitter whose resistance-changing function is its essential function is associated with a telephone set circuit. Either two transmitters with separate diaphragms, but each of which is acted upon by the user's vocal output, may be used; or, a single sound wave actuated diaphragm may be used, but it may have two transmitter buttons or microphonic elements associated with the diaphragm, variation of the resistance of one button being in accordance with the sound waves and for the purpose of translating them into electric current variations to be transmitted, and the variation in resistance of the other button being for the purpose already stated.

Circuits incorporating this feature of an auxiliary transmitter are shown in Figs. 31 to 35, and fall into the above-noted class 5. Each circuit comprises a transmitter T for translating the circuit-user's vocal output into voice currents to be transmitted to the party at the other end of the telephone line, the resistance-change characteristic of the transmitter from its quiet to its talking condition being a matter of indifference, the design of the transmitter being primarily with respect to the quality of reproduction; a receiver R ; a three-winding induction coil or transformer, including balancing resistance; line terminals 11 ; two variable resistance elements of the same type as elements E , E_1 , E_2 , E_A or E_B , and bearing the same identifying symbols as the corresponding elements in Figs. 27, 15, 21, 18 and 14, respectively; a heater H_b , common to the variable resistance elements associated with receiver and transmitting circuits; an auxiliary transmitter T_{A1} or T_{A2} , connected in parallel with the heater H_b except in Fig. 35; and, except in Fig. 35, a condenser C_2 , bypassing around the auxiliary transmitter voice currents generated by transmitter T .

The circuit of Fig. 31 is the same as that of Fig. 27 except that the transmitter T replaces transmitter T_b ; and except that, in the circuit of Fig. 31, the transmitter T_{A1} , that is, one that increases in resistance upon change from its quiet to its agitated condition, and the condenser C_2 are connected in parallel with the heater H_b . The circuits of Figs. 33 and 15 are related in the same respects.

The circuit of Fig. 32 is the same as that of Fig. 21 except that the transmitter T replaces transmitter T_1 ; and except that, in the circuit of Fig. 32, the transmitter T_{A2} , that is, one that decreases in resistance upon change from its quiet to its agitated condition, and the condenser C_2 are connected in parallel with the heater H_b . The circuits of Figs. 34 and 18 are related in the same respects.

The circuit of Fig. 35 is the same as that of Fig. 14 except that the transmitter T_{A1} is connected in series with the local battery b and the heater H_b , and the transmitter T replaces transmitter T_1 and is in the local series circuit of battery b and winding 18.

In the normal or listening condition of the circuit of Fig. 31, elements E_7 and E_8 are in their high resistance condition; hence, an efficient receiving and an inefficient transmitting circuit exist. When the user speaks or transmits, agitation of transmitter T_{A1} results in its increasing in resistance. The potential drop across the heater H_b increases, the elements E_7 and E_8 are decreased in resistance, the receiver is effectively removed from the circuit and an efficient transmitting circuit is established. When talking

ceases, the initial condition of the circuit is re-established. Whatever increase or decrease occurs in the resistance of transmitter T upon change from its quiet to its agitated condition, may be allowed for in transmitter T_{AI}, or, in the case of Figs. 32 and 34, in transmitter T_{AD}. It will be evident from the description with reference to Fig. 31 and what has preceded this how the circuits of Figs. 32 to 35 operate.

In constructing a telephone set circuit such as has been described, prior art practice in the choice of transmitter, receiver, induction coil or transformer, blocking condensers, local battery or central office battery voltage, may be followed. The impedance relations that should be present for most efficient transmitting and receiving for variable and invariable circuits, and for side tone and anti-side tone circuits, are outlined in the inventor's book: "Transmission Circuits for Telephonic Communication," published by D. Van Nostrand Company, Inc., New York, N. Y., and particularly chapter X thereof, "Substation circuits."

The thermosensitive variable resistance device or element E may, by way of example, be a silver sulphide unit, the characteristics of which are well known. The temperature-resistance relation of silver-sulphide is given approximately by:

$$R = R_0 e^{-.05t}$$

where, R_0 is the resistance before the assumed change of temperature t degrees centigrade occurs, and R is the resistance after this temperature change has occurred. This relation holds for all temperatures between 0° C. and 179° C. At the latter temperature, the resistance falls to about one-fortieth of its former value for an increase of less than 1° C. The coefficient as given by the above formula is such that the resistance of a given sample falls to half its former value by a temperature rise of about 14° C. The resistance-frequency characteristic is such that the resistance is constant with frequency from at least the audible range up to at least 2000 kilocycles. The resistance-change time lag depends on the size of the resistance element, the amount of power available to heat it, and the facilities provided to cool it; to obtain an element with a preassigned time lag is merely a matter of design.

By way of example, the thermosensitive variable resistance element may comprise a silver-sulphide wire of approximately 7 mils and about three-eighths inch in length. Connection with the ends of the silver-sulphide wire may be made with one mil platinum leads. The heater wire is wound around the silver sulphide wire, with a layer of suitable insulating material therebetween, for example, aluminum oxide. The element may be mounted inside of a glass envelope or tube, which may be evacuated, or may contain air or other gas at desired pressure.

The silver sulphide wire is prepared as follows: The platinum leads are fused to the ends of a length of silver wire. The wire unit is placed in a closed glass jar containing a few grams of sulphur powder. The jar, in turn, is placed in a furnace and heated at 170° C. for an hour, and finally raised to 200° C. for about ten minutes so that all of the silver may be reduced to Ag₂S, the platinum leads being unaffected by the sulphur vapor. Any excess sulphur present may be removed by heating the silver sulphide unit in a clear glass tube at about 400° C. while a stream of pure nitrogen gas is passing; a small

amount of silver foil may be placed in the tube to absorb the free sulphur as it is vaporized. By preselection of the length and the diameter of the silver wire, a silver sulphide unit having a desired static resistance, i. e., resistance at room temperature with no current flowing through the silver sulphide, may be obtained.

As a specific illustration of the application of thermosensitive variable resistance elements to a telephone set circuit, consider the following calculations with reference to the circuit arrangement of Fig. 14. The elements E_A, E_B are silver sulphide elements such as described above, having a static resistance of approximately 10⁶ ohms, but, for power inputs between approximately .0035 watt and .07 watt, varying in resistance from about 100,000 ohms down to about ten ohms, substantially along a straight line on a logarithmic plot of resistance versus power input to the heater of the silver sulphide unit. If the battery b is a 6 volt battery, and the heat H_D is a four ohm heater, and the transmitter T_I has a quiet resistance of about 40 ohms, the current flow in the series circuit of battery, heater, transformer primary, and transmitter is about .135 ampere. The power dissipated in the heater will be about .073 watt, and the resistance of the elements E_A, E_B will be about eight ohms. Under such conditions, the low resistance E_B in series with the receiver R affords a high efficiency receiving circuit, and the low resistance of E_A effectively prevents room or other noises acting on the transmitter T from introducing side tone in the receiver R.

If a moderately loud talker speaks into the transmitter T_I, its talking resistance will be substantially greater than its quiet resistance, for example, it might rise to 54 ohms. The direct current flow in the transmitter local circuit would then fall to about .103 ampere, and the power dissipated in the heater would be approximately .042 watt. The resistance of elements E_A and E_B under the reduced heating condition would rise to about 100 ohms. If a very loud talker speaks into the transmitter T_I, the change in the transmitter resistance from its quiet resistance might be of the order of 100 per centum. A rise of transmitter resistance to, say, 83 ohms would reduce the direct current flow in the transmitter local circuit to about .069 ampere, and the power dissipated in the heater to about .019 watt. Under such circumstances, the resistances of elements E_A and E_B would rise to about 1700 ohms. During talking, therefore, additional resistance is effectively introduced in series with the receiver R, and the effective short circuit of the transmitting circuit is eliminated by the increased resistance of E_A. The amount of side tone present in the receiver R during talking by the user of the telephone set circuit will be substantially reduced, while an efficient transmitting circuit is established.

As a further specific illustration of the application of thermosensitive variable resistance elements to a telephone circuit, consider the following calculations with reference to the circuit arrangement of Fig. 33. The direct current path for this circuit is battery B, transmitter T_{AI} in parallel with the heater H_D, transmitter T, retard coil, battery B. If it is assumed that battery B is of a potential of 24 volts, the resistance of the retard coil is 200 ohms, the resistance of transmitter T is 50 ohms, the resistance of the heater is 500 ohms, and the quiet or non-talking condition resistance of transmitter T_{AI}

is 40 ohms, then, for the listening condition of the circuit, the current drain on the battery would be about .084 ampere, the voltage drop across the heater about 3.1 volts, the power consumed in the heater about .019 watt, and the resistances of elements E_A and E_B would be about 1700 ohms. A relatively high resistance is in series with the alternating current circuit of transmitter T, and a relatively high resistance is in shunt with the receiver R. Room or other weak noises acting on the transmitter T during listening by the user of the set circuit are ineffective to produce any appreciable current flow in the transmitter circuit that might appear in the receiver. The telephone signals incoming to the set circuit through the line terminals are reproduced in the receiver R substantially unaffected by the presence of element E_B .

When the user of the circuit of Fig. 33 talks into the transmitter T, the resistance of the transmitter T_{AR} is caused to increase from that of its quiet condition. If the user speaks at a moderately loud level, the increase in resistance might be of the order of 50 per centum. This would reduce the direct current flow in the circuit to about .079 ampere, increasing the potential drop across the heater H_p to about 4.25 volts, and the power dissipated in the heater to about .036 watt. Under this heating condition, elements E_A , E_B would have a resistance of about 190 ohms. If the user of the circuit of Fig. 33 speaks at a very loud level, the increase in resistance of transmitter T_{AR} from its quiet resistance might be of the order of 100 per centum. In the latter event, the current drain on the battery would become about .0735 ampere, increasing the potential drop across the heater to about 5.2 volts and the power dissipated in the heater to about .054 watt, whereby elements E_A , E_B would be lowered in resistance to about 28 ohms. The substantial decrease in the resistance of E_A renders the alternating current circuit of transmitter T highly efficient; and the substantial decrease in the resistance of element E_B during talking provides a very low resistance path around the receiver R so that side tone in the receiver is substantially reduced.

In the succeeding figures constituting other embodiments of the invention and comprising the above-noted class 6, the resistance element V is one of the type or of a material having a rapid and sharp change in resistance from a high to a low value or vice versa when a critical current therethrough is realized, or when a given current is maintained sufficiently long to change the temperature of the element by a predetermined amount at which altered temperature the element undergoes a rapid and sharp change in resistance. This element V may be a unit comprising a mixture of carborundum, clay and graphite, disclosed in K. B. McEachron Patent 1,822,742, issued September 8, 1931, and known commercially as "Thyrite"; or, a unit comprising a copper-oxide rectifier unit; or, a unit of a semiconductor, such as boron, silver sulphide, uranium oxide, or the like. Devices such as gas-filled tubes and photoconductive cells will also give, when shunted by a finite resistance, essentially the characteristics of such a unit.

In Fig. 36, an elementary substation circuit is shown in which the element V is connected in series with the transmitter across the line terminals to which the telephone line would be

connected and through which talking current for the transmitter would be obtained. The appropriate or requisite initial bias on the element V, to provide high resistance in series with the transmitter, is made possible by the adjustable resistive inductance r_s in shunt of the element V. When talking into the transmitter, relatively large alternating current voltages are generated to which the impedance of the element V will be of relatively low value. Upon receiving, however, the impedance of the element V will be of relatively high value to the relatively low incoming voice or signal currents, thereby effectively reducing the efficiency of the transmitting circuit for room and other noises and preventing the latter from providing interfering currents in the receiving circuit. Since this is a parallel type of circuit, the receiving efficiency is actually increased over that of the circuit without the element V, since the transmitter impedance is effectively high under these conditions. If the transmitter is of the type that decreases in resistance on change from its quiet to its talking condition, there will be an increase in direct current flowing through the element V, tending to reduce the impedance of the element V faster than would be possible by the alternating currents alone, such increase in direct current being dependent in part on the length of the talking loop. Figs. 37 to 40, like Fig. 36, show substation circuits embodying a resistance element V in series with the transmitter; the circuits of Figs. 37 and 40 are of the common battery type and those of Figs. 38 and 39 of the local battery type. The circuits of Figs. 37, 39 and 40 include Campbell-type anti-side tone circuits, that of Fig. 37 being similar to that of Fig. 8 and that of Figs. 39 and 40 being similar to that of Fig. 13. In Figs. 36 and 38, there is no provision against side-tone due to voice currents generated in the transmitting circuit; in Figs. 37, 39 and 40, the anti-side tone circuit arrangement affords some protection, at least, against side-tone.

The circuit of Fig. 41 is a local battery circuit incorporating a Campbell-type anti-side tone circuit arrangement, and a variable resistance element V connected in series with the receiver, one transformer winding and the line terminals. A transmitter T_{AR} is connected in a series circuit with battery b , a retardation coil, a variable resistance 40 and the element V, whereby, during talking, the change in resistance of auxiliary transmitter T_{AR} , causes the element V to become of high impedance as a result of decreased current flow therethrough. The normal or listening condition of the circuit finds element V in a low impedance condition.

The resistance characteristic of units or devices such as the element V is that of a relatively high constant or ohmic type of resistance at all low electric inputs. This resistance rapidly decreases as the electrical input is increased until at relatively high inputs the resistance has become an extremely low constant or ohmic type of resistance. This type of characteristic is illustrated in Fig. 42. The element V may be incorporated in what may be called a level or intensity filter, in contrast to the usual wave or frequency filter. In such a level or intensity filter, the element V balances a bridge network at either high or low intensities or levels of electrical input, and will produce, therefore, infinite attenuation at all frequencies under these conditions. On the other hand, at the inverse intensities or levels (low or

high) the level filters will produce negligibly small attenuation at all frequencies. Some simple types of intensity filter sections are shown in Figs. 43 to 47. Referring to Fig. 43, let it be assumed that at low input levels or intensities, $R_v + R_1 = R_s$, where R_v is the resistance of element V, and R_1 and R_s are the resistances of substantially linear current-resistance characteristic resistance elements. The bridge network will be balanced and the filter section will give infinite attenuation for all of the low intensity levels at which R_v has the value that will satisfy the above relation. At high levels, however, R_v rapidly approaches a low resistance, as indicated in Fig. 42, and the resultant attenuation of the section will be greatly reduced. The minimum attenuation would occur for these high levels if R_1 had originally been made equal to zero, in which case the value of the minimum attenuation would be determined simply by the ratio of R_s to the low constant ohmic resistance of R_v . This structure, then, when operating as described, may be called a high level pass filter. Its maximum discrimination would be that existing in the limiting case referred to above, i. e., when $R_1 = 0$. In this case, the high level filter section would reduce to the form shown in Fig. 44. The same physical structures as are shown in Figs. 43 and 44 obviously can be made to provide a low level pass filter section by selection of constants so that the bridge or lattice is balanced at the high constant ohmic resistance value of the elements V.

The same general approach applies to the level filter section shown in Fig. 45. As in the case of Fig. 43, this lattice network can be balanced at either high or low levels, resulting in either a low level or a high level pass filter section, as desired. If maximum discrimination is wanted, the resistance R_2 would be omitted, and the structure would reduce essentially to that shown in Fig. 44. The practical choice between the filter sections of Figs. 43 and 45 depends in part upon the relative resistances of the elements V and the desired characteristic impedance of the filter section. The characteristic impedance of that shown in Fig. 43 is $\sqrt{R_s(R_1 + R_v)}$, and that of Fig. 45 is $\sqrt{R_p R_v R_2 / (R_v + R_2)}$, where R_p and R_2 represent the resistances of the linear resistance-current elements of the network. Even though the elements V do not have identically the same resistances, the section will still have its two image impedances equal to each other.

The lattice section of Fig. 46 may be proportioned so as to be balanced at either the high or low levels at which the elements V_1 and V_2 are ohmic, but, in general, the balanced condition would not exist at intermediate intensities. The amount of this attenuation at intermediate levels depends upon the relations between R_1 , R_{v1} , R_2 and R_{v2} , where R_{v1} and R_{v2} are the resistances of elements V_1 and V_2 . If R_1 is made equal to zero and R_2 is made infinite, the structure of Fig. 46 would reduce to that of Fig. 47. This structure may be readily proportioned to have a constant—either finite or infinite—attenuation at all levels or intensities with a constant but relatively high characteristic impedance at low intensities, and a low but constant characteristic impedance at high intensities or levels.

In the same way that a section of a low and a high-pass wave or frequency filter can be put in tandem to produce a band-pass wave or frequency filter, a section of a low level pass filter may be put in series or in tandem with a high

level pass filter to produce a band level pass filter. Such an arrangement is shown in schematic in Fig. 48, in which section 25 has high attenuation for high levels, and section 26 is balanced or has high attenuation for low levels. Only energy lying between the two level cut-offs will be transmitted through the entire structure with small attenuation, and all other levels will be effectually attenuated. A band level pass filter can be constructed using two or more sections in tandem, each having the same general configuration, but one of the sections being balanced so that it has a low level cut-off and the other section being balanced for a high level cut-off. By proper selection of the cut-off points a level band of preassigned width is obtainable.

In the same way, and analogous to the practice of wave or frequency filters, the low and the high level pass sections described may be put in parallel to give a structure that is essentially a band level elimination filter. These might be sections of the types shown in Figs. 43, 45 and 46, and might comprise two or more sections of the same general configuration. An illustration of such a band level elimination filter is shown in schematic in Fig. 49.

The low level and high level filters described hereinabove may be used advantageously in place of the simple series or shunt connected variable resistance elements. This fact is due primarily to the possibility of producing, in effect, infinite attenuation at either high or low electrical energy levels.

In Fig. 50, there is shown an elementary substation in which marked discrimination can be obtained between the low intensity electrical energy levels produced by room and the like noises and the high intensity electrical energy levels produced when the transmitter is actuated by the voice. The transmitter is isolated from the receiver and line by a high level pass filter of the type shown in Fig. 45. The filter section is balanced for low values of alternating current electromotive force encountered when the circuit is in the normal or receiving, i. e., listening, condition, thus, in effect disabling the transmitter with respect to room and the like noises. The value of R_2 should be slightly greater than R_p . When the transmitter is talked into, however, the alternating current electromotive force generated breaks down the resistance of the elements V to such an extent that the bridge reduces essentially to the two shunt resistances R_p acting in parallel across T. A more elaborate form of the circuit of Fig. 50 is shown in Fig. 51 wherein the level pass filter section is coupled by an induction coil or transformer 35 to the local circuit for the transmitter and coupled by an induction coil or transformer 36 to the line terminals across which the receiver is connected. This circuit operates in the same manner as that of Fig. 50. In Fig. 52, the circuit arrangement is substantially the same as that of Fig. 51 except that a common battery source B of talking current is indicated, and a Campbell-type anti-side tone circuit arrangement is included using a three-winding transformer 36'.

In Fig. 53 there is shown an elementary substation circuit in which the receiver is isolated from the transmitter and line by a low level pass filter of the type shown in Fig. 43. The value of R_1 is slightly lower than that of R_s . In other words, this filter section is balanced for large or high level electromotive forces at its terminals. That is, for the large electromotive forces gen-

erated when the transmitter is talked into, the resistances of the elements V are substantially zero, and the bridge is proportioned to be balanced under such conditions, resulting in an efficient anti-side tone performance that is independent of the line impedance and providing a type of anti-side tone circuit effective as a result of the intensity of speech rather than as a result of a Wheatstone bridge type of balance. For low level electrical energy, however, such as would be represented by voice or signal energy incoming to the substation circuit the filter section is unbalanced, and the receiving efficiency is not appreciably impaired by the presence of the filter section.

In the local battery substation circuit of Fig. 54, the receiver is connected to the rest of the circuit by a filter section similar to that of Fig. 53. As in the latter figure, the filter section is balanced for the relatively high intensities or levels occurring while the transmitter is being talked into, but is unbalanced for and readily passes the relatively weak intensities or levels of the incoming voice or signal currents during the listening condition of the circuit.

In Fig. 55, there is shown a common battery substation circuit employing the anti-side tone arrangement of the Gooderham patent and, in addition, the low level pass filter section of Figs. 53 and 54. This circuit is doubly anti-side tone in that it has the usual Wheatstone bridge type of balance, tending to give anti-side tone coupled with a level filter. If, on transmitting, there is a large unbalance between the telephone line and the substation network, resulting in large voltages being impressed across the terminals of the filter section, the latter will be effectively balanced to any such high voltages and greatly attenuate them before they can be effective on the receiver. On the other hand, during receiving, the section is unbalanced and the circuit acts essentially as if the filter section were not present.

The substation circuit of Fig. 56 is a local battery arrangement embodying the filter section arrangement of Figs. 53, 54 and 55. The circuit is also doubly anti-side tone in that it is balanced for high potentials across the terminals of the level filter section, and in that the circuit embodies the Campbell-type anti-side tone arrangement employing a network to balance the line.

The circuit of Fig. 57 represents an operator's set circuit in which the features of Figs. 40, 52 and 56 have been incorporated. In other words, there is first a variable resistance element V in series with the transmitter so that the transmitting circuit will effectively discriminate against weak sounds, such as room noises. Secondly, the transmitter branch is effectively isolated, during the receiving or the listening condition, by a high level pass filter section, i. e., a network that is balanced for low values of electromotive force impressed on its terminals, transformer-coupled to the transmitter-branch and to the receiving circuit. Thirdly, the receiver is effectively isolated from the transmitting circuit by a low level filter that is balanced for large electromotive forces across its terminals. In addition, the circuit includes the balancing network anti-side tone arrangement of the Campbell patent.

Fig. 58 shows a common battery substation circuit incorporating the feature of a low level pass filter section associated with the receiver R and effectively balanced for high values of electromotive force, and the feature of a high level pass filter associated with its transmitter T

and effectively balanced for low values of electromotive force.

In practice, telephone set circuits usually include parts that, for a complete understanding of this invention, it has not been necessary to show in the circuit arrangements of the drawings, for example: a switchhook and switching springs, or other switching means; signaling or ringer means; a calling device or dial, when the circuit is to be used in an automatic telephone system. These may be supplied, of course, in accordance with the telephone practice with reference to telephone set circuits.

What is claimed is:

1. A telephone set circuit comprising a transmitting circuit including a transmitter, a receiving circuit including a receiver, and variable resistance means in said receiving circuit for reducing the side tone that would be produced in said receiver during talking into said transmitter, the resistance of which means varies non-linearly with its temperature.

2. A telephone set circuit comprising a transmitting circuit including a transmitter, a receiving circuit including a receiver, and variable resistance means in said receiving circuit for reducing side tone that would be produced in said receiver during talking into said transmitter, the resistance of which means varies non-linearly with its temperature, the temperature of said resistance means varying with variation in the resistance of the transmitter on change from its quiet to its talking condition or vice versa.

3. A telephone set circuit comprising a transmitting circuit including a transmitter, a receiving circuit including a receiver, and variable resistance means in said receiving circuit whose resistance varies non-linearly with its temperature, said resistance means being adjusted in resistance for talking and listening conditions of the circuit so that current variations in said transmitting circuit resulting from variation in the transmitter resistance have a reduced side tone effect in said receiver.

4. A telephone set circuit comprising a transmitting circuit including a transmitter, a receiving circuit including a receiver, and an auxiliary transmitter in said transmitting circuit operated by the user's vocal output simultaneously with said first-mentioned transmitter but not contributing to the voice currents to be transmitted.

5. A telephone set circuit comprising a transmitting circuit including a transmitter, a receiving circuit including a receiver, variable resistance means whose resistance varies non-linearly with current flow therethrough, said means being included in said receiving circuit, and an auxiliary transmitter in said transmitting circuit adapted to have a preassigned change in its resistance on change from its quiet to its agitated condition when the user of the circuit speaks.

6. A telephone set circuit comprising a transmitting circuit including a transmitter, a receiving circuit including a receiver, variable resistance means included in said receiving circuit for variation in resistance non-linearly with variation in temperature, means for varying the temperature of said variable resistance means, and an auxiliary transmitter in said transmitting circuit for regulating the temperature varying effect of said temperature varying means.

7. In combination, a transmitting circuit including a transmitter, a receiving circuit including a receiver, the two circuits being so related that during talking into said transmitter side

tone is produced in said receiver, and resistance means in said receiving circuit to reduce the amount of said side tone, said resistance means varying in resistance in a non-linear manner with its variation in temperature, the temperature of said resistance means altering with change in the direct current flow in the transmitting circuit when the user talks into the transmitter.

8. In a telephone station, line terminals for connecting said station to telephone conductors leading to another telephone station, a transmitting circuit including a transmitter, a receiving circuit including a receiver, said circuits being connected to said terminals and being so related that sound waves acting on said transmitter tend to cause side tone in said receiver, and variable resistance means in the receiving circuit to reduce the amount of side tone when the user talks into said transmitter, said means having such a resistance-temperature characteristic that over a preassigned range of temperatures it changes from one resistance condition to a relatively greatly different resistance condition.

9. A telephone set circuit comprising a transmitting circuit including a transmitter, a receiving circuit including a receiver, a resistance element whose resistance varies in a non-linear manner with respect to its temperature, said element being included in said receiving circuit, and a heating coil for said element, said element being adjusted in resistance for talking and receiving conditions of the set circuit so that current variations resulting from variations in transmitter resistance produce reduced side tone in said receiver.

10. A telephone set circuit comprising a transmitting circuit including a transmitter, a receiving circuit including a receiver, a resistance element whose resistance varies in a preassigned manner with respect to its temperature variation and which is in said receiving circuit, a second such resistance element in said transmitting circuit, and means for maintaining said resistances at preassigned values for the talking and listening periods of use of such circuit, whereby side-tone in said receiver is reduced to a preassigned degree during the talking period.

11. A telephone set circuit comprising a transmitting circuit including a transmitter, a receiving circuit including a receiver, means for applying direct current to said transmitting circuit, a resistance element in said receiving circuit and whose resistance varies in a preassigned manner with its variation in temperature, and heating means for said resistance element, said heating

means being in the transmitter direct current circuit, said transmitter having a different resistance in talking condition than in quiet condition, the change in direct current through the transmitter when the transmitter is being talked into causing a change in the heating effect of said heating means on said resistance element to alter the latter's resistance effectively to prevent current flow in the receiving circuit because of current flow in the transmitting circuit.

12. A telephone set circuit comprising a receiver, a transmitter, line terminals and a pair of resistance elements each varying non-linearly in resistance with variation in its temperature, one of said resistance elements being connected in circuit with said receiver and the other in circuit with said transmitter, said resistance elements being adjusted in resistance for talking and listening conditions of the circuit so that current variations in said transmitting circuit resulting from variation in the transmitter resistance have a reduced side tone effect in said receiver.

13. A telephone set circuit comprising a receiving circuit including a receiver, a transmitting circuit including a transmitter, line terminals to which said circuits are connected, a pair of resistance elements each varying in resistance in a non-linear manner with variation in its temperature for reducing the effect that agitation of the transmitter tends to have on said receiver during transmitting and receiving, and a single heating means for said resistance elements, said heating means being connected in series with said transmitter, and one of said resistance elements being connected in a series circuit with said transmitter and the other being connected in shunt with said receiver.

14. A telephone set circuit comprising a transmitter, a receiver, a multiwinding transformer, a pair of resistance elements, each element being variable in resistance in a preassigned manner with respect to variation in its temperature, means for regulating the temperature of said resistance elements, and line terminals, said transmitter being connected in a local circuit with one winding of said transformer, said receiver and one of said resistance elements being connected in series with a second winding of said transformer across the line terminals, a third transformer winding being connected in shunt of the series-connected receiver and resistance element, and the second resistance element being connected in shunt of series-connected second and third windings of said transformer.

KENNETH S. JOHNSON.