

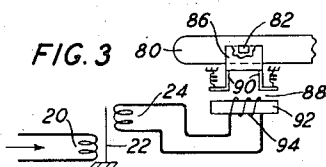
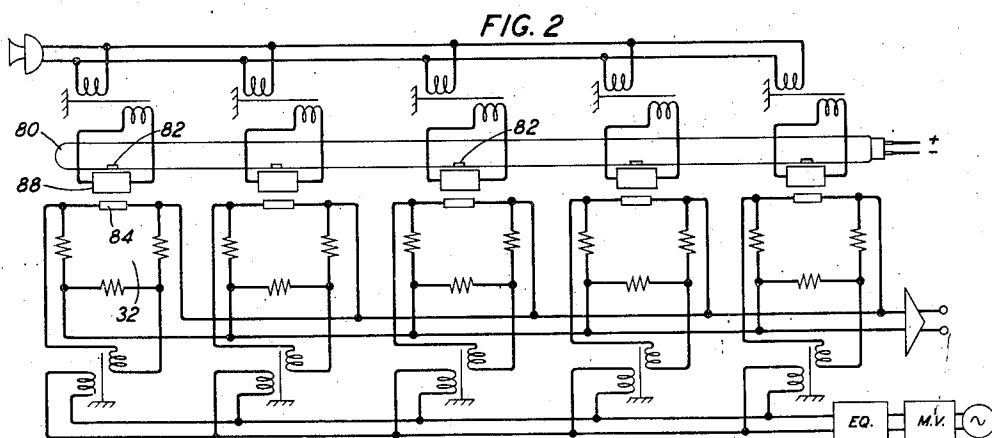
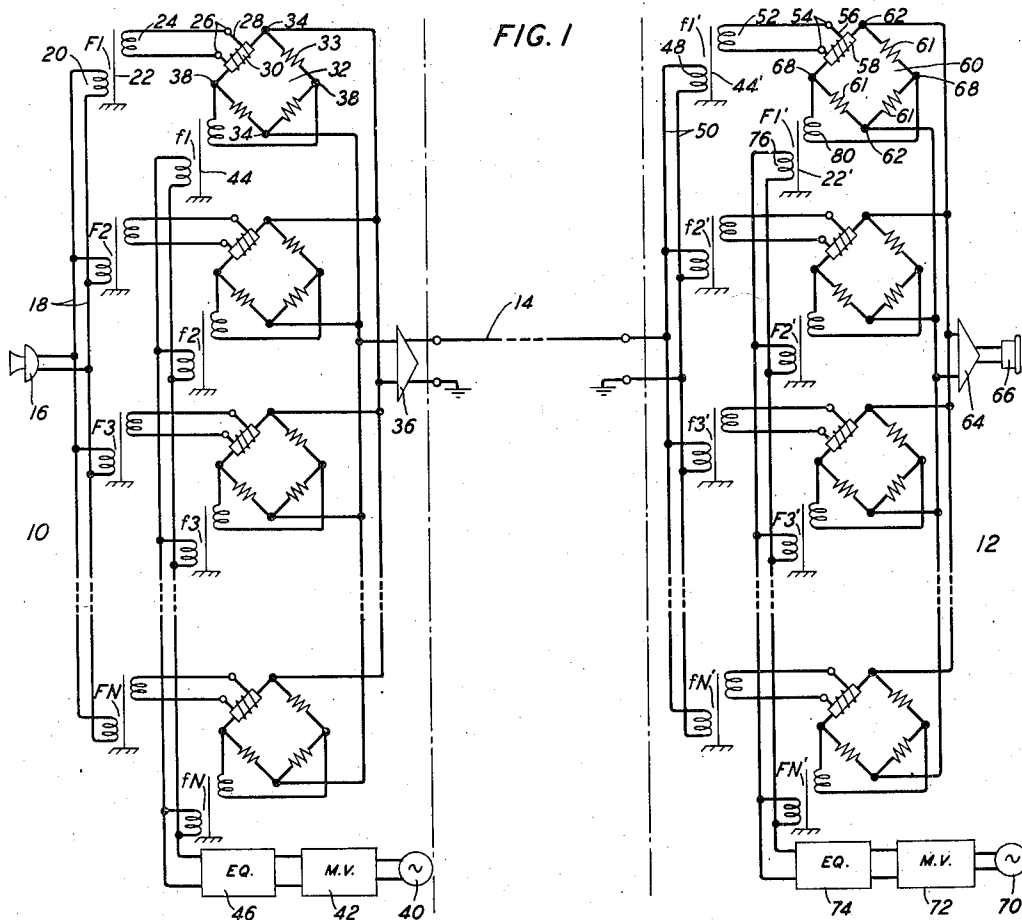
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SPEECH ANALYSIS AND SYNTHESIS SYSTEM

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SPEECH ANALYSIS AND SYNTHESIS SYSTEM

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1

This invention relates to speech analysis and synthesis.

It is already known how to analyze speech-bearing waves and to compress them into a relatively narrow band of frequencies for transmission over a transmission path or line of limited frequency band transmission properties, and to reconstruct the speech-bearing waves at the receiving end of the transmission line in order to produce at the receiving end the intelligence or message generated at the transmitting end of the line. Such arrangement has been disclosed in the present inventor's United States Patent 2,151,091 of March 21, 1939 for "Signal transmission." In the arrangements heretofore proposed, stress has been placed on a more or less complete analysis of the speech-bearing waves and the determination therefrom of control currents related to both the pitch and the amplitude frequency characteristics of the speech-bearing waves, and the transmission of these control currents (pitch-defining current and speech-band-defining currents) over the transmission line to the receiving end of the transmission line to be there effective as controls for the reconstruction or production of a more or less identical simulation of the speech-bearing waves that were analyzed at the transmitting end of the system. Such arrangements have been elaborate in structure and costly to build.

In the past, the complexity of equipment, and consequent bulk and cost thereof, resulted from the stress placed upon high quality analysis, transmission and synthesis of the complex waves involved. The assumption was also made that it would not be known at the receiving end what was being transmitted until the appropriate control currents were received at the receiving end of the system. In many instances, however, it is desirable to be able to compress the frequency range of a message into a relatively narrow band of frequencies for purposes of transmission to a receiving point at which an operator or other attendant will know the probable content of the incoming message and, consequently, will be able to supply mentally the deficiencies in what would ordinarily be considered transmission of a poor quality. Such an instance might involve troubleshooting over a telegraph line or over a submarine cable. In each of such examples, the transmission medium will be a poor one from a telephonic standpoint and yet a satisfactory one with reference to the transmission of a narrow band of low frequency currents therethrough. At one end of such a line, the operator or attendant could be equipped with a compact and inexpensive speech-analyzing set for converting the speech waves into a plurality of low-frequency signal currents respective to a corresponding plurality of component frequency bands of the sound waves, the

2

operator or attendant at the other end of the line being equipped with a compact and inexpensive synthesizing equipment for receiving the referred-to signal currents which would be employed as control currents for building up an approximate simulation of the original sound waves out of a source of broad-band audio-frequency waves.

An object of the invention is the simplification of the equipment required for speech analysis and synthesis in transmission systems.

In accordance with the invention speech-bearing waves are converted into complex electric waves which latter are divided into a plurality of component frequency bands. The division of the complex waves into the respective frequency bands may be accomplished by means of electromechanical filters or transducers each selective to a respective frequency band. The output of each transducer is delivered as heating current to the heating element of a thermo-sensitive resistance element constituting one of the arms or branches of a Wheatstone bridge arrangement. One pair of terminals of the bridge may be connected to the input of an amplifier whose output is connected to the transmission line over which the signal currents are to be transmitted. The other pair of terminals of the bridge may be connected to the output of an electromechanical filter or transducer whose input is connected to a suitable source of carrier current. The carrier current source may consist of a standard low frequency alternating current fed into a suitable multivibrator for producing an output rich in harmonics of the input current, selected harmonics being employed as carrier waves for the signal currents generated in each bridge by virtue of the variation in the resistance of the thermo-sensitive element in response to voice frequency input to the heater winding thereof. Each bridge arrangement performs a multiple function, that of rectification, filtering and modulation. The rectification or detecting action is accomplished through the heating action of the heating element inasmuch as the alternating current supplied to that element will produce a heating effect for both negative and positive pulses thereof determined by the average power of the wave. The filtering action is a result of the thermal lag characteristic of the thermo-sensitive element. The modulation action follows from disturbance from the initially balanced condition of the bridge, the change in the arms ratio of the bridge as a result of change in the resistance of the thermo-sensitive element with changes in temperature produced by the heating winding, producing corresponding variations in the carrier current taken from the bridge. The current supplied to the transmission line, therefore, will comprise the carrier wave modulated in accordance with variation in the average amplitude or intensity of the

3

component frequency band supplied to the specific bridge arrangement. Simultaneously, the same action will be occurring with reference to the different component frequency bands, whereby a corresponding number of modulated carrier waves will be transmitted over the transmission line. At the receiving end, the equipment may comprise a plurality of electromechanical filters or transducers, each of which is selective to one of the carrier frequencies. The output of each of such transducers is connected with the heater element of a thermo-sensitive resistance element constituting one or more bridges of a Wheatstone bridge arrangement. One pair of terminals of the bridge arrangement may be connected to a suitable amplifier, the output of which is connected to a telephone receiver. The other pair of terminals of the bridge may be connected through an electromechanical filter or transducer to a source of complex electric waves covering the frequency range corresponding to that selected at the transmitting end for transmission purposes. Each of the last-mentioned transducers is selective to one of the component frequency bands into which the original speech-bearing waves were divided so that in its respective associated Wheatstone bridge the particular band of frequencies is modulated in accordance with the input to the heater element of the thermo-sensitive element in the bridge. The output of each of the bridges at the receiving end will be simultaneously transmitted to the receiving device and produce in the receiving device sound waves simulating those generated or picked up at the transmitting end.

A more complete understanding of the invention will be obtained from the detailed description that follows, read with reference to the appended drawing, wherein:

Fig. 1 illustrates a transmission system embodying the principles of the present invention; and

Figs. 2 and 3 illustrate a modification of one aspect of the arrangement of Fig. 1.

With reference to Fig. 1, there is shown a one-way transmission system comprising a transmitting terminal 10, a receiving terminal 12, and an intermediate transmission medium 14, for example, a transmission line. The latter is illustrated as a single wire line with grounded return such as might be used in telegraph or submarine signal systems.

The transmitting terminal includes a sound wave energy pick-up device or microphone 16, or other source of speech-bearing waves, interconnected over a transmission path 18 with the input windings 20 of a plurality of electromechanical filters or tuned-reed type transducers $F1, F2 \dots FN$. Each of these filters is selective to a preassigned component band or subband of frequencies in the frequency range embraced by the complex electric waves into which the sound wave energy impressed on the microphone is translated by the latter. The reed 22 of magnetic material is tuned to a frequency in the component frequency band respective to the filter, for example, to the mid-frequency of the band. The output winding 24 of each filter is connected to the terminals 26 of the heater element or winding 28 for a thermo-sensitive resistance element 30, of the general type that varies in resistance in response to variations in the temperature thereof, and that comprises one arm or branch of a Wheatstone bridge arrangement 32, the other arms of which may comprise suitably proportioned conventional resistance elements

4

33. In its normal condition, that is, with no audio-frequency input to the heater winding of the respective bridge, the latter will be in balance. One pair of terminals 34 of each bridge constitute output terminals therefor, and are connected to the input terminals of an output amplifier 36. The latter may be of the so-called mechanical amplifier type, or of the electronic type, of small dimensions such as is employed in hearing aid sets. The line 14 is connected with the output terminals of the amplifier. The other pair of terminals 38 of the bridge arrangements are connected, through respective ones of a plurality of electromechanical filters or tuned-reed type transducers $f1, f2 \dots fN$, with a source of low frequency carrier currents. The latter may comprise an alternating current source 40 of a standard low frequency current, for example, 60 cycles per second, that feeds into a multivibrator 42 for generating a range of harmonics of the low frequency current, respective ones of which are selectively transmitted by the filters $f1 \dots fN$ to their respective bridges. In each of the last-mentioned filters, the reed 44 thereof of magnetic material is sharply tuned to a particular one of the harmonics. The equalizer 46 may be included for equalizing the carrier wave amplitude input to the carrier wave filters.

The receiving terminal 12 comprises a plurality of electromechanical filters or tuned-reed type transducers $f1', f2' \dots fN'$ having their input windings 48 connected to the line 14 over the common transmission path 50, and corresponding in number to and similar in design to the filters $f1 \dots fN$ at the transmitting terminal. The reed 44' of each filter $f1' \dots fN'$ is sharply tuned to a respective one of carrier waves originating at the transmitting end. Each filter output winding 52 is connected to the terminals 54 of a heater element or winding 56 for a thermo-sensitive resistance element 58, of the type whose resistance varies in response to variations in the temperature of the resistance element, the resistance element constituting one arm or branch of a Wheatstone bridge arrangement 60, the other arms of which may comprise conventional resistance elements 61'. In its normal condition, that is, with no heating current input to the heater element of the respective bridge, the latter will be in balance. One pair of terminals 62 of each bridge is connected to the input terminals of an amplifier 64, which may be of the same type as the amplifier 36, and in whose output circuit is connected a receiving device 66 for converting audio-frequency currents into sound waves corresponding thereto. The other pair of terminals 68 of each bridge 60 is connected, through a plurality of electromechanical filters or tuned-reed type transducers $F1', F2' \dots FN'$, corresponding in number and in pass-band characteristics, respectively, to the transducers $F1, F2 \dots FN$ at the transmitting terminal, to a source of broad-band audio-frequency waves. This source may comprise an alternating current source 70 of standard low frequency current, for example, 60 cycles per second, feeding into a suitable multivibrator 72 for generating the desired band of frequencies that may be equalized as to amplitude by the equalizer 74 before being impressed on the input windings 76 of the filters $F1', F2' \dots FN'$. The reed 22' is tuned to a frequency in the pass band of its respective filter, for example, to the mid-frequency of that band. Each output winding

80 is connected to the terminals 68 of its respective bridge arrangement.

In accordance with the invention, speech-bearing waves impressed on the microphone 16 are converted thereby into complex electric waves corresponding to the sound waves, the complex waves being divided into a plurality of component frequency bands, or subbands of the frequency range of the complex waves by the filters $F1 \dots FN$. In practice, the number of frequency bands, the band widths, and the portion of the entire frequency range that should be selected for transmission purposes, may range between relatively wide limits. Generally speaking, sufficient intelligibility at the receiving end will be provided if the frequency range up to about 1,500 cycles per second only is selected for purposes of transmission. If the individual component frequency bands selected are about 300 cycles wide, five such bands would be employed. The frequency selective transducers or filters divide the complex wave output of the microphone into the preassigned component frequency bands, and transmit such frequency bands to the respective heater element associated therewith. The alternating currents thus delivered to each heater element are converted into heat for varying the temperature, and, consequently, the resistance, of the thermo-sensitive element 30 in response to the variations in the average wave power content or intensity of the component frequency band input to the heater element. In effect, the heater element accomplishes a rectification of the wave input thereto inasmuch as the heating effect is produced by both the negative and positive pulses of the alternating currents. Because of the thermal lag of the thermo-sensitive resistance, the variation in its resistance may occur at a relatively low rate, that is, discriminating against frequencies above a low value. For purposes of providing a control current representative of the varying average amplitude of the respective component frequency band, a pass-band for the thermo-sensitive resistance of up to about 25 cycles per second would be sufficient. The variation in the resistance of the element 30 unbalances the respective bridge, and varies or modulates the carrier current wave supplied to the bridge in accordance with the variations in the amount of unbalance. As already noted, the carrier waves may be of very low frequency, and in the five band system premised hereinabove, the carrier waves might be of frequencies of 60, 120, 180, 240 and 300 cycles per second. Hence, there will be impressed on the input to the amplifier 36, a plurality of low frequency carrier waves each modulated in accordance with a signal wave or current characteristic or respective to the average amplitude variations of a different component band of the frequencies included in the frequency range of the complex waves impressed on the input windings of the filters $F1 \dots FN$.

At the receiving terminal, the modulated carrier waves incoming from the line 14 are impressed on the filters $f1' \dots fN'$, each transmitting the carrier wave to which it is tuned to the heater element 56 of its respective bridge arrangement. The signal wave component of the modulated carrier wave is rectified in the heater element, that is, it produces a heating effect for both positive and negative pulses thereof, causing the latter to vary the temperature and, consequently, the resistance of the thermo-sensitive element 58, in accordance with the variations in

the intensity of the signal wave component. The variations in the resistance of the element 58 unbalance the respective bridge 60 and varies or modulates the band of frequencies supplied to the bridge through the respective filter $F1'$, $F2' \dots$ or FN' , in accordance with the variations in the amount of unbalance. The output of the particular bridge 60 to the amplifier 64 will simulate, therefore, the varying amplitude-frequency characteristic of the component frequency band input to the corresponding channel at the transmitting end, and the composite input to the amplifier 64 will simulate the complex wave input selectively transmitted by the transmitting end filters $F1 \dots FN$ to their respective associated bridge arrangements. The sound wave energy produced in the receiving device 66 will correspond to that of the complex wave input supplied to the latter from the amplifier 64.

Although a one-way transmission system has been specifically described, it is obvious that the transmitting terminal 10 could be provided also with the receiving terminal equipment, and the receiving terminal 12 could be provided also with the transmitting terminal equipment, to enable two-way transmission over the line 14. In such an event, the transmitting and receiving equipments at each end of the line could be interconnected therewith through known means, for example, a hybrid coil and balancing network, or appropriate switching means be employed.

Instead of analyzing the speech-bearing waves with reference to a limited portion only of the normal frequency range, the component frequency bands may be broader than has been indicated hereinbefore. If it is desired, for example, that the system function on the basis of a frequency band width of approximately 3,600 cycles, each component frequency band may be, continuing the premise of five channels, of the order of approximately 600 cycles wide. On the other hand, it may be found desirable and of negligible effect on the intelligibility at the receiving end, to omit certain portions of the frequency range within the broad limits of a band of 3,600 cycles. For example, the component frequency bands might be of the order of 300 cycles wide, with alternate bands omitted, that is, the respective bands might be 300—600, 900—1200, 1500—1800, 2100—2400, 2700—3000. Additionally, the band widths need not be uniform and it may be found desirable to have the band widths uniform below approximately 750 cycles per second only, and to vary in a logarithmic fashion above that frequency.

Instead of a thermo-sensitive resistance element as the variable resistance arm or branch of the Wheatstone bridge arrangement, a photo-sensitive resistance element may be used. If the latter is utilized, a single light source for all of the photosensitive elements at one end of the system may be provided, a suitable shielding arrangement being included to confine the light from such source to each individual photo-sensitive element. Figs. 2 and 3 show such a modification as applied for illustrative purposes to the transmitting terminal of a system such as is shown in Fig. 1.

The light source may comprise an incandescent electric lamp 80, whose opaque bulb is provided with a plurality of light emitting windows 82, one oppositely disposed with respect to each photosensitive element 84, and normally covered by a suitable masking or shielding member 86. The latter comprises a component of an electromag-

netic light valve 88. The latter comprises the shield 86 attached to a pair of extensions 90 of magnetic material, oppositely disposed to a magnetizable core member 92 surrounded by an energizing winding 94. The terminals of the latter are connected to the output winding of a component frequency band filter. The shield 86 is normally in retracted position under control of suitable spring members. When complex electric waves corresponding to speech sound wave energy are present in the path 18, the component frequency band currents transmitted by a filter to the energizing winding of its respective valve 88, causes the shield 86 to be varied in position relative to the window 82 to permit a varying quantity of light to have access to the photo-sensitive resistance element, to vary the resistance of the latter. Such variations in resistance disturb the balance of the bridge, and result in corresponding modulation of the carrier current supplied to the respective bridge.

Reference has been made to the use of a standard low frequency current source, for example, 60 cycles per second alternating current, for providing the carrier frequencies at the transmitting terminal and for providing the source of frequencies to be operated upon by the received signal currents at the receiving terminal. An alternative source in each case, rendering the system independent of such alternating current source would be an appropriately designed buzzer that would provide the requisite range of frequencies.

In some instances, it may be possible to eliminate the use of amplifiers. In situations in which the parties at the transmitting and receiving ends of the system have arranged in advance as to the character of the message that is to be transmitted over the system, the transmission level could be very low and yet sufficient intelligibility would be contained in what is transmitted to enable the listening party to recognize that the received message either conforms to or is different from that agreed upon.

The arrangement described is one that uses components of quite small size that may be mounted or included in a comparatively compact unit of limited volume and weight, and which, once assembled, presents substantially no maintenance requirements.

Although the invention has been disclosed with reference to a specific arrangement, it will be evident to the skilled in the art that modifications may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A wave translating system comprising means for translating speech sound wave energy into complex electric waves corresponding thereto, a plurality of frequency selective devices for dividing the frequency range of said waves into a corresponding plurality of component frequency bands, a plurality of Wheatstone bridge circuits respective to said frequency selective devices, one ratio arm of each of said bridge circuits comprising a thermo-sensitive resistance, a plurality of heater elements respective to said resistances and connected with said frequency selective devices to be heated in response to the varying energy content of the component frequency band transmitted by the respective selective device, a source of carrier currents connected across one diagonal of each of said bridges, the carrier current supplied to each bridge being of a different frequency, a common output circuit connected across the other

diagonal of each bridge, the thermo-sensitive resistance in each bridge varying in resistance with variation in temperature under control of its respective heater element to unbalance the bridge to a degree varying with such variation in resistance whereby the carrier current respective to said bridge is modulated correspondingly, a transmission line connected at one end to said common output circuit, a plurality of other frequency selective devices connected to the other end of said line and each selective to one of said modulated carrier currents, a plurality of other Wheatstone bridge circuits respective to said other devices, one ratio arm of each of said other bridge circuits comprising a thermo-sensitive resistance, a plurality of other heater elements respective to said last-mentioned resistances to be heated in response to the varying energy content of the modulated carrier current transmitted by its respective selective device, a source of audio-frequency currents embracing the frequencies included in said complex electric waves, means for dividing the audio-frequency currents into component frequency bands corresponding to the first-mentioned component frequency bands and for applying said second-mentioned bands respectively to one diagonal of each of said other Wheatstone bridge circuits, and a common output circuit connected across the other diagonals of said other Wheatstone bridge circuits and including a translating device for converting audio-frequency currents into sound wave energy corresponding thereto, the thermo-sensitive resistance element in each of said other bridges varying in resistance with variation in temperature under control of its respective heater element to unbalance such bridge to a degree varying with such variation in resistance whereby the component band of frequencies respective to the bridge is varied correspondingly.

2. A wave translating system comprising a transmitting terminal, a receiving terminal, and a transmission line interconnecting said terminals; said transmitting terminal comprising a device for converting sound wave energy into audio-frequency currents corresponding thereto, a plurality of frequency selective devices for separating the frequency range of said currents into component frequency bands, a plurality of Wheatstone bridges respective to said selective devices normally in balance and adapted to be varied from such balance to a degree proportioned to the variation in energy content of the frequency band transmitted to it by its respective selective device, means for applying a different carrier current across one diagonal of each of said bridges, each carrier current being modulated in correspondence with the variation from balance of its respective bridge, and a common output circuit connected to one end of said transmission line and across the other diagonal of each of said bridges; and said receiving terminal comprising a plurality of devices respectively selective to a different one of said modulated carrier currents, a common input circuit interconnecting the other end of the transmission line and the carrier selective devices, a plurality of Wheatstone bridges respective to said carrier selective devices, normally in balance and adapted to be varied from such balance to a degree proportioned to the variation in the energy content of the modulated carrier current passed by its respective selective device, means for applying a different band of audio-frequency currents across one diagonal of each of said bridges, each of such frequency bands

being modulated in correspondence with variation from balance of its respective bridge, and a common output circuit connected across the other diagonal of each of said bridges and including a device for converting the modulated audio-frequency currents into sound wave energy corresponding thereto.

3. A speech analyzing and synthesizing system comprising a source of complex electric waves corresponding to speech, frequency selective devices for dividing the frequency range of said waves into a plurality of component frequency bands, a Wheatstone bridge respective to each of said devices, each bridge including a thermo-sensitive variable resistance as one ratio arm to be varied in resistance in response to the variation in the intensity of the respective component frequency band, means for applying a different frequency carrier current across one diagonal of each bridge to be modulated in accordance with such resistance variation, a common output circuit for the modulated carrier currents connected across the other diagonals of said bridges, a transmission line connected to said output circuit, a plurality of devices connected to said line respectively selective to said modulated currents, a Wheatstone bridge respective to each of said last-mentioned selective devices, each of said last-mentioned bridges including a thermo-sensitive variable resistance as one ratio arm to be varied in resistance responsive to the modulation component of the respective modulated carrier current, means for applying a different band of audio-frequency currents across one diagonal of each of said last-mentioned bridges to be modulated in accordance with said last-mentioned resistance variation, a common output circuit for said modulated frequency bands connected across the other diagonals of said second-mentioned bridges, and means for translating said modulated frequency bands into sound waves corresponding thereto.

4. A wave translating system comprising a source of a speech frequency band of electric waves, electromechanical devices for dividing said waves into a plurality of component frequency bands, a corresponding plurality of temperature-dependent variable resistance elements, Wheatstone bridges respectively including one of said resistance elements in one ratio arm thereof, means for varying the temperature of a respective element in accordance with a parameter of a respective component frequency band, means including other electromechanical devices for applying a carrier current of a different frequency across one diagonal of each of said bridges for modulation in accordance with variation in resistance with temperature of the resistance element of the respective bridge, and a common output circuit for the modulated carrier currents connected across the other diagonals of said bridges.

5. A wave translating system comprising a source of a speech frequency band of electric waves, electromechanical devices for selecting frequency subbands of said waves, each of said devices comprising a vibratory magnetic member having a natural frequency lying in a respective one of said subbands, an input winding for vibrating said member and an output winding in which signal waves are generated by vi-

bration of said member, thermo-sensitive resistances, Wheatstone bridges respectively including one of said resistances in one ratio arm thereof, a heating element respective to each of said resistances, said heating elements being connected respectively to one of said output windings, means for applying a carrier current of a different frequency across one diagonal of each of said bridges, and a common output circuit including the other diagonals of said bridge.

6. A wave translating system comprising a source of a plurality of carrier waves respectively modulated in accordance with signal waves characteristic of a corresponding plurality of component frequency bands of a speech frequency band of electric waves, devices respectively selective to said modulated carrier waves, a corresponding plurality of variable resistance elements, Wheatstone bridges respectively including one of said resistance elements in one ratio arm thereof, means for varying the resistance of a respective element in accordance with the signal wave component of the carrier wave, means for applying across one diagonal of each of said bridges a different component frequency band of the speech frequencies included in said speech frequency band, for modulation in response to variation in resistance of the resistance element of the respective bridge, and a common output circuit for the modulated frequency bands connected across the other diagonals of said bridges.

7. A wave translating system as claimed in claim 6 in which each selective device comprises a vibratory magnetic member tuned to a respective carrier wave, an input winding and an output winding, each variable resistance element is a thermo-sensitive resistance, and the means for varying its resistance comprises a heater element connected with the output winding of a said selective device.

8. A wave translating system comprising a bridge circuit having input terminals and having output terminals conjugate to said input terminals at balance of said bridge circuit, a source of modulated waves to be demodulated for yielding signaling waves of lower frequency, a source of other waves to be modulated with said signaling waves, means for supplying said other waves to said input terminals, and means for demodulating said first-mentioned waves, said demodulating means comprising a thermo-sensitive element connected to control the degree of unbalance of said bridge in accordance with the temperature of said element, and means for supplying to said element heating energy derived from said first-mentioned waves to the substantial exclusion of heating energy derived from said other waves, to vary the temperature of said element in accordance with the time variations of energy of said modulated waves.

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