Oct. 22, 1940.

R. R. RIESZ

2,219,021

FREQUENCY CHANGING

Filed June 30, 1939

3 Sheets-Sheet 1

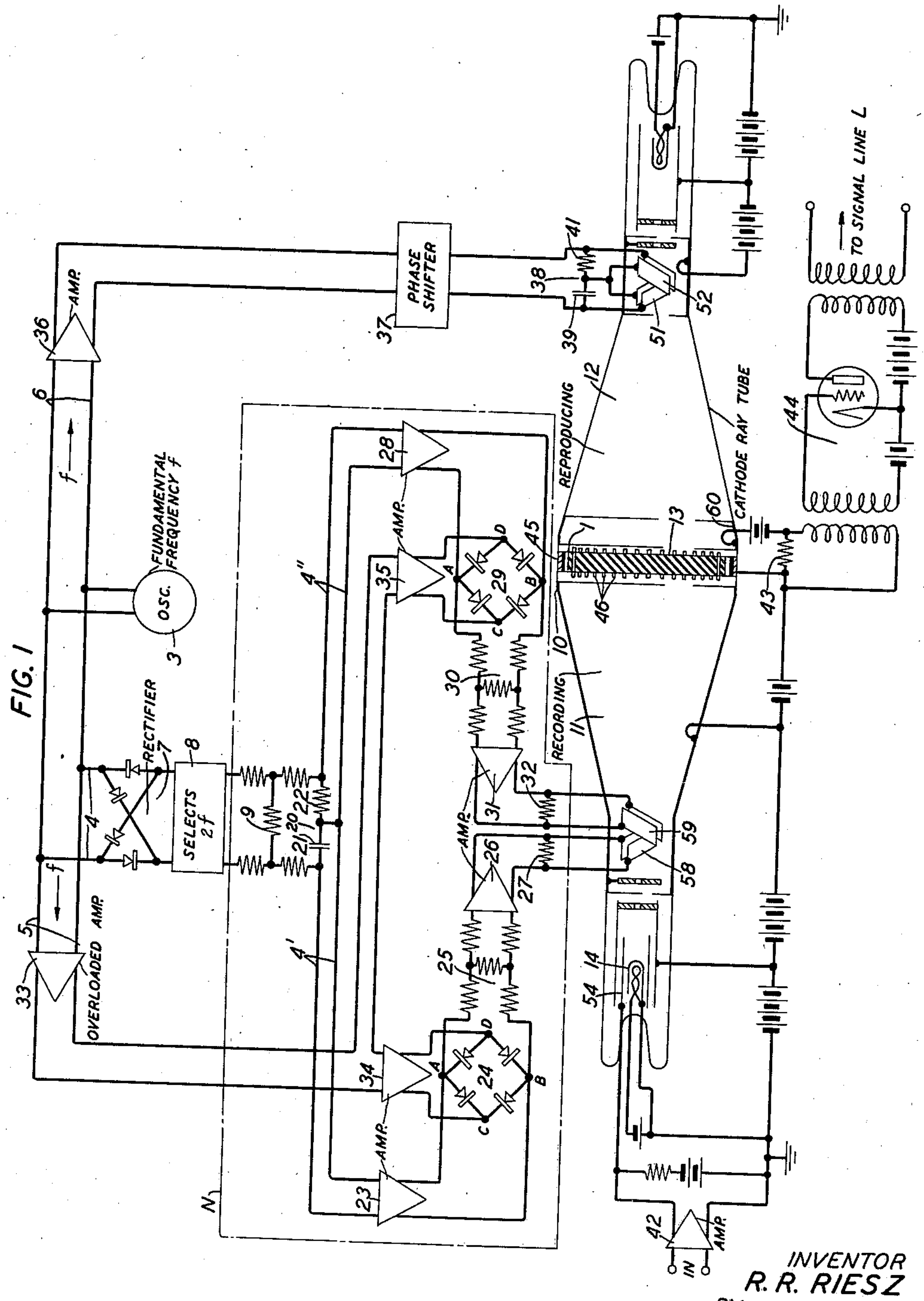

FIG. 1

INVENTOR
R. R. RIESZ
BY
Earl C. Laughlin
ATTORNEY

FREQUENCY CHANGING

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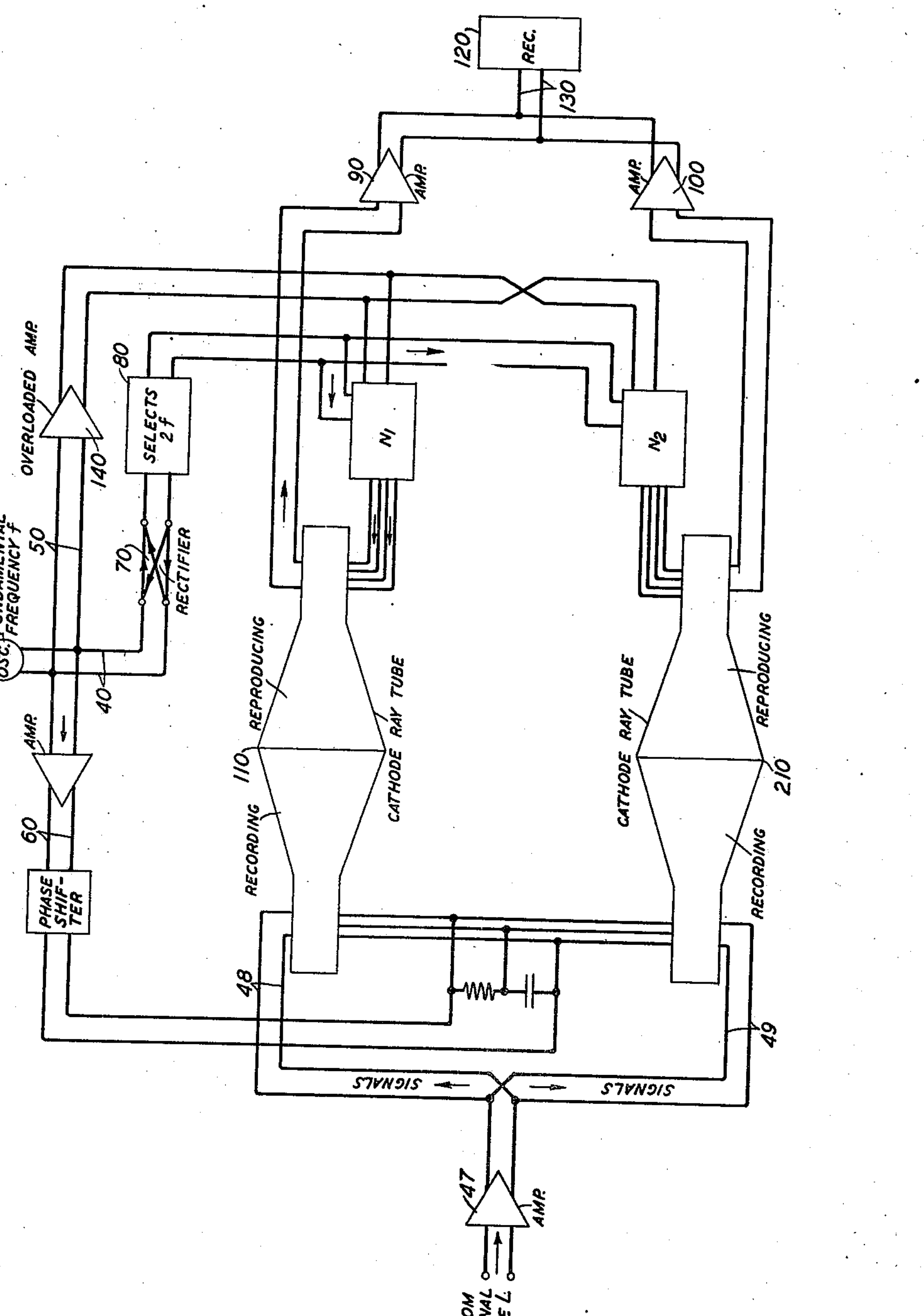

FIG. 2

INVENTOR
R. R. RIESZ
BY
Earl C. Laughlin
ATTORNEY

Oct. 22, 1940.

R. R. RIESZ

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3 Sheets-Sheet 3

FIG. 3

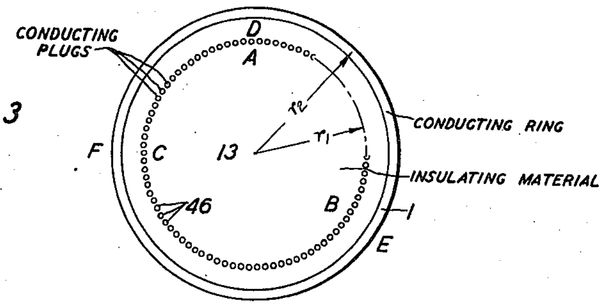
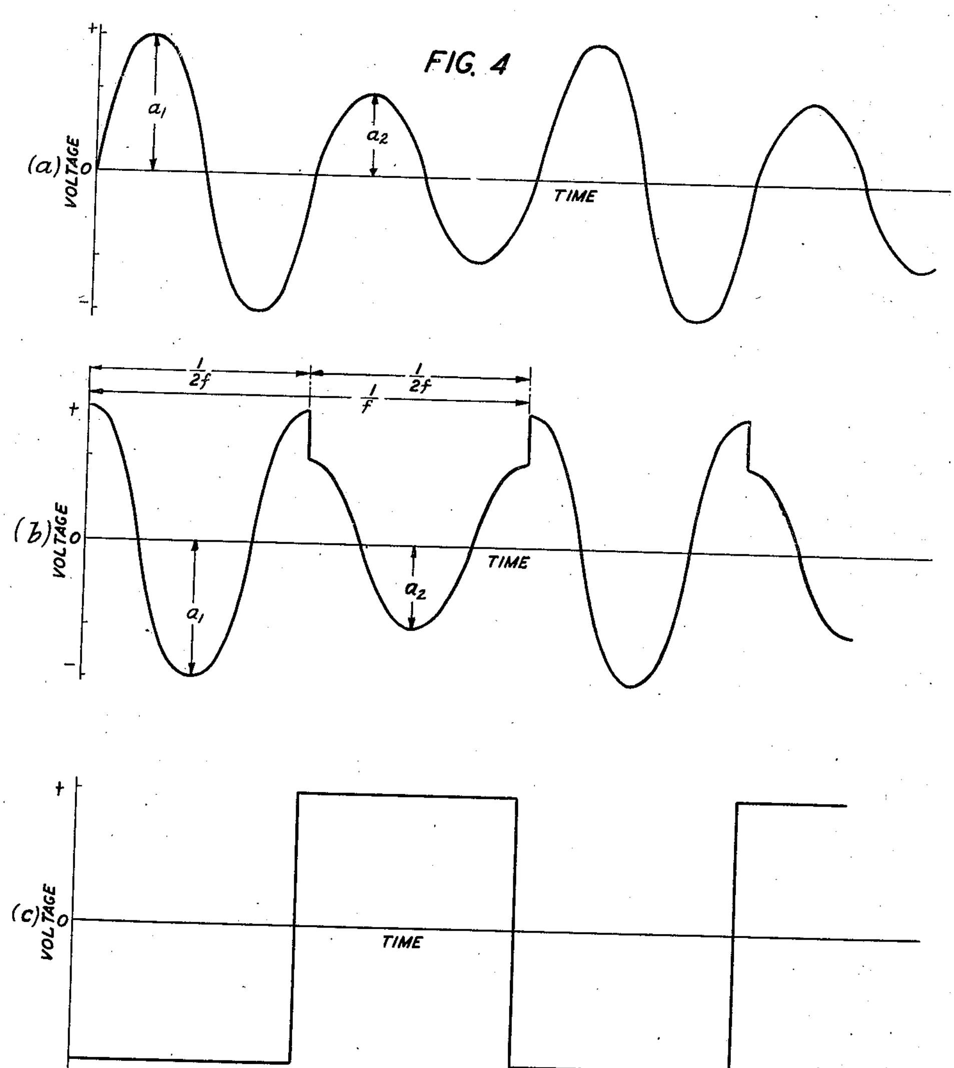


FIG. 4



INVENTOR
R. R. RIESZ
BY
Earl C. Laughlin
ATTORNEY

Patented Oct. 22, 1940 2,219,021

UNITED STATES PATENT OFFICE

2,219,021

FREQUENCY CHANGING

Robert R. Riesz, Mount Vernon, N. Y., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

Application June 30, 1939, Serial No. 282,021

11 Claims. (Cl. 178—44)

This invention relates to frequency changers and particularly to frequency changers employing electrostatic recorders and reproducers.

An object of the invention is to change the frequency range of an alternating current signal wave.

Another object is to effectively reduce the width of the frequency band required for the transmission of an alternating current signal wave.

A more specific object is to effectively compress the frequency range of an alternating current signal wave prior to transmitting it over a signaling path, and at a receiving point to expand the received wave to restore it to its original frequency range.

Another object is to electrostatically record signal variations at a given rate, and to reproduce the recorded variations at a different rate.

These objects are attained in accordance with the invention by the use of specially designed cathode ray electrostatic recording and reproducing devices at the sending and receiving stations of a signaling system, for example, a speech wave signaling system. In one embodiment, a cathode ray electrostatic recording and reproducing device at the sending station operates to chop up an alternating current wave representing speech or other signals of a periodic character to be transmitted, into a series of equal short elements on a time basis the time interval of chopping being equal to the fundamental period of the original signal or an integral multiple or submultiple thereof, to eliminate alternate signal elements of the waves and to stretch out the remaining elements on a time scale so as to double their duration and thus effectively to halve the total signal frequency range. The signal wave so modified is transmitted over a signal transmission line, and at the receiving station two similar cathode ray devices operate alternately to reproduce each of the received signal elements at twice the speed at which it is received so that each frequency therein is restored to its original value, the two reproduced portions of each signal segment being laid down side by side so that there are no silent gaps in the final reproduced signals.

The invention will be better understood from the following detailed description thereof when read in conjunction with the accompanying drawings, in which:

Figs. 1 and 2 show respectively the transmitting and receiving stations of a signaling system embodying the invention; and

Figs. 3 and 4 show respectively a diagram and curves illustrating the construction and operation of apparatus shown in Figs. 1 and 2.

The cathode ray electrostatic recording and reproducing devices employed in the system of the invention may be of the general type disclosed in the copending patent application of R. R. Riesz and H. S. Wertz, Serial No. 145,442, filed May 29, 1937. Briefly described, the cathode ray device disclosed in that application comprises an evacuated enclosure divided into two compartments or chambers by a plate or disc of insulating material which includes a number of elements in the form of plugs, fine wires or cylinders of a metallic conducting material, insulated from each other, extending through the disc perpendicular to its plane and arranged in a circle near the periphery of the disc, acting as a target for electron beams produced by an electron gun mechanism in each chamber moving in a circular path over the respective ends of the metallic plugs. The electron beam in one chamber, which is modulated by signals to be recorded, in passage over the ends of the plugs places electrostatic charges thereon which are proportional to the signal variations. The electron beam in the other chamber, which is arranged to move in synchronism but in an out-of-phase relationship with the recording beam, by secondary emission action removes the charges previously placed on the plugs in the target by the recording beam. A conducting ring in the reproducing chamber collects the secondary electrons from the target in this process, the rate of emission depending upon the charges so that the fluctuation of the secondary emission current in the conducting ring will be a copy of the signal waves modulating the recording beam.

The use of such cathode ray devices to accomplish the purposes of the invention requires modification of the target within each cathode ray tube and modification of the control circuits exterior to the tubes for controlling the deflection of the electron beams within the tubes.

The modification of the target in each cathode ray device and the recording and reproducing process in accordance with the present invention are illustrated diagrammatically in Fig. 3 which shows a plan view of the target. Referring to Fig. 3, as in the case of the target illustrated in Figs. 1 and 2 of the aforementioned copending patent application, the target consists of a circular plate or disc **13** of insulating material and a row of plugs or wires **46** of conducting material, insulated from each other, extending through the insulating disc perpendicular to the plane thereof, spaced around an inner circle (of average radius r_1). In addition, the target 13 includes an outer ring 1 of (metallic) conducting material of average radius r_2, which may be connected to the metal ring 45 surrounding the target 13, as shown in Fig. 1, and which is separated from the inner circular row of metal plugs 46 by the insulating material of the disc 13.

For each cathode ray tube used, the electron beam deflecting circuits to be described in connection with Figs. 1 and 2, which control the electron gun mechanism in the recording and reproducing chambers, are designed to make the electron beam in either the recording or the reproducing chamber traverse at a given angular velocity altenately the circular path ABC of radius r_1 and the circular path DEF of larger radius r_2 on the face of the target in that chamber, and to make the electron beam in the other chamber of the tube traverse at a different angular velocity a circular path of radius r_1, equivalent to the circular path ABC, on the opposite face of the target in the latter chamber, continuously.

In the case where the electron beam in the recording chamber traverses alternately the circular paths ABC and DEF on the target, it is effective during the time intervals only in which it moves over the path ABC to place electrostatic charges on the ends of the plugs 46 in that chamber, to make an electrostatic record of the signal variations modulating the beam during those time intervals, but is ineffective to make any electrostatic record during the alternate equal time intervals in which it is passing over the circular path DEF, because it then impinges on the conducting ring 1. Thus the portions of the signal variations modulating the beam during these latter time intervals are effectively eliminated. For that case, the electron beam in the reproducing chamber continuously traverses the equivalent circular path ABC over the other ends of the plugs 46 in the latter chamber, but with an angular velocity equal to one-half that of the recording beam, and reproduces the electrostatic record of signal variations previously placed on these plugs by the recording beam during the alternate time intervals in which it passes over the path ABC, in the manner described in detail in the aforementioned copending patent application. Conversely, when the electron beam in the recording chamber continuously traverses the path ABC on the face of the target in that chamber, it makes a continuous electrostatic record on the plugs 46 of the signal variations modulating the recording beam during each revolution, and the delayed beam in the reproducing chamber alternately traverses the circular paths ABC and DEF with an angular velocity which is twice that of the recording beam so that those signal variations recorded on the plugs 46 are reproduced in alternate revolutions of the recording beam.

In a preferred embodiment of the signaling system of the invention illustrated in Figs. 1 and 2, the beam deflecting circuits associated with the single cathode ray tube 10, employed at the sending station of Fig. 1, are designed to make the recording beam alternately traverse the circular paths ABC and DEF on one side of the target in a time of

$$\frac{1}{2f}$$

second for each revolution, where f is the fundamental frequency produced by the controlling harmonic producing oscillator and is equal to the fundamental frequency of the signal wave or an integral submultiple thereof, and to make the reproducing beam continuously traverse an equivalent circular path ABC on the reproducing side of the target in a time of

$$\frac{1}{f}$$

second, that is, in twice the time that the recording beam traverses the equivalent path, and the beam deflecting circuits associated with each of the two cathode ray devices 110 and 210 at the receiving station of Fig. 2 are designed to make the recording beam continuously traverse the circular path ABC in a time of

$$\frac{1}{f}$$

second for each revolution and to make the reproducing beam alternately traverse the equivalent circular path ABC and the path DEF on the other side of the target in a time of

$$\frac{1}{2f}$$

second for each revolution, that is, in one-half the time taken by the recording beam at the reproducing end.

Referring to Fig. 1, the electron beam deflecting circuits for controlling the electron gun mechanisms in the recording and reproducing chambers of the single cathode ray tube 10 include an oscillator, indicated by the box 3, which may be of any of the well-known types for producing an alternating current sine wave of a given fundamental frequency f. The output of the oscillator 3 is connected in parallel to the inputs of three control circuits 4, 5 and 6.

The control circuit 4 includes in order full-wave rectifier 7, the selective circuit 8, a resistance loss pad 9 of fixed value, a phase splitting network 20 consisting of the condenser 21 and resistance 22 in series shunting the branch circuit 4, and two equivalent parallel branch circuits 4′ and 4″, respectively connected across the condenser 21 and the resistance 22 of the phase splitting network 20. The branch circuit 4′ comprises in order the buffer amplifier 23 of high input impedance, the variable loss pad 24, the resistance loss pad 25 of fixed value, the amplifier 26 and the shunt resistance 27 connected across the output of amplifier 26, the terminals of the resistance 27 being connected across one pair of deflecting plates 58 of the electron gun mechanism in the recording chamber 11 of the cathode ray device 10. Similarly, the branch circuit 4″ comprises in order the buffer amplifier 28, the variable loss pad 29, the resistance loss pad 30 of fixed value, the amplifier 31 and the shunt resistance 32 the terminals of which are connected across the other pair of deflecting plates 59 of the electron gun mechanism in the recording chamber 11 of the cathode ray device.

Each of the variable loss pads 24 and 29 consists of four copper-oxide rectifier units connected in a balanced bridge circuit, one diagonal AB of each bridge circuit being connected across the branch circuit 4′ or 4″.

The copper-oxide units in the pads 24, 29 are so poled that when biasing current from the amplifiers 34, 35 is supplied so as to flow from C to D, the copper-oxide rectifier units provide a low loss to current from the amplifiers **23**, **28** and so permit the transmission of a relatively large voltage to the input of the amplifiers **26**, **31** but that when biasing current is supplied so as to flow from D to C the loss provided to current from the amplifiers **23**, **28** is increased to a relatively high value and the amplitude of the voltage transmitted to the input of the amplifiers **26**, **31** is correspondingly decreased. Due to the balance of the copper-oxide bridges, no current from the amplifiers **34**, **35** will flow in the branch circuits **4′**, **4″** provided the amplitude of the voltage supplied by the amplifiers **34**, **35**, is large compared with that supplied by the amplifiers **23**, **28**.

The current for biasing the variable loss pads is supplied from the oscillator **3** through the control circuit **5** including in order the overloaded amplifier **33** and the amplifiers **34** and **35** having their inputs connected in series across the output of overloaded amplifier **33** and their outputs respectively connected across the diagonals CD of the variable loss pads **24** and **29**, in a manner which will be described later.

The third control circuit **6** connected across the output of oscillator **3** comprises in order the amplifier **36**, the phase shifter **37** and the phase splitting network **38** comprising the condenser **39** and the resistance **41** in series, shunted across the output of the phase shifter **37**, the terminals of the condenser **39** and the terminals of the resistatnce **41** being respectively connected across the pairs **51** and **52** of deflecting plates of the electron gun mechanism in the reproducing chamber **12** of the cathode ray device **10**.

The alternating current signals to be transmitted, applied at the "IN" terminals of the cathode ray device **10** are amplified in amplifier **42**, and the amplified signals in the output of that amplifier are applied through an input circuit identical with that disclosed in the aforementioned copending patent application, between the modulating element **54** and the cathode **14** in the recording chamber **11** of the tube, and modulate the intensity of the recording electron beam of the tube in accordance with the signal variations in a manner similar to that described in the specification of that application.

The movement of the recording beam alternately over the ends of the plugs **46** in the circular path ABC and over the conducting ring **1** in the path DEF on the recording side of the target **13** in tube **10**, at an angular velocity of one revolution for each

$$\frac{1}{2f}$$

second is obtained by applying to the respective pairs **58**, **59** of deflecting plates in the recording chamber **11** of the cathode ray tube **10** voltage waves respectively, such as shown in the curves of Fig. 4(*a*) and Fig. 4(*b*). As indicated in Fig. 4(*a*), for

$$\frac{1}{2f}$$

second, where f is the fundamental frequency of the wave generated by oscillator **3**, the voltage wave applied to one pair **58** or **59** of deflecting plates is a sine wave of frequency $2f$ and maximum amplitude a_1, and for the next

$$\frac{1}{2f}$$

second the wave is changed to a sine wave of the frequency $2f$ and of a smaller maximum amplitude a_2, this cycle being continuously repeated. As shown in Fig. 4(*b*), a similar voltage wave is applied to the other pair of deflecting plates **58**, **59**, but, as indicated, the latter wave is 90 degrees out of phase with respect to the wave applied to the first pair of deflecting plates.

The required quadrature voltages, applied to the respective pairs of deflecting plates **58**, **59**, are derived from the wave of fundamental frequency f generated by the oscillator **3** through the branch circuits **4** and **5** in the following manner.

The sine wave of the fundamental frequency f from the oscillator **3** passing into the input of control circuit **4** is rectified in the full wave rectifier **7** and then is transmitted through the selective network **8** tuned to pass the frequency $2f$. The sine wave of the frequency $2f$ in the output of the selective network **8** passes through the fixed loss resistance pad **9** and is impressed across the phase splitting network **20** which operates to split the applied voltage wave into two portions of equal amplitude but 90 degrees out of phase. One of these voltage waves taken off across the terminals of the condenser **21** passes over branch circuit **4′** through a high input impedance buffer amplifier stage **23** and then through the variable loss pad **24**, the fixed loss resistance pad **25** and amplifier **26** to the shunt resistance element **27**, the voltage drop in that resistance being applied across the pair **58** of deflecting plates of tube **10**. The other portion of the voltage wave picked off across the terminals of the resistance element **22** of the phase splitting network **20** passes over branch circuit **4″** through the high input impedance buffer amplifier **28**, the variable loss pad **29**, the resistance loss pad **30** and amplifier **31** to shunt resistance **32** producing a voltage drop therein of the same magnitude as the voltage drop produced by the other portion of the waves in the shunt resistance **27** but 90 degrees out of phase therewith, which voltage is applied to the other pair **59** of deflecting plates in the recording chamber of the cathode ray tube.

The change in the amplitudes of the voltages applied to the two pairs of deflecting plates in the recording chamber of the tube from a relatively high value a_1 to a lower value a_2 during successive time intervals of

$$\frac{1}{2f}$$

second, as indicated by the curves of Fig. 4(*a*) and Fig. 4(*b*) is obtained by means of the variable loss pads **24** and **29** in the respective branch circuits **4′** and **4″** under control of the control circuit **5** in the following manner:

The sine wave of fundamental frequency f passing into the circuit **5** from the output of oscillator **3** is impressed upon the overloaded amplifier **33** which operates to change the wave into a square-topped wave of the same fundamental frequency, such as shown in Fig. 4(*c*). Alternative types of overloaded amplifiers which may be used for this purpose are disclosed in Figs. 1 and 2 of Meacham Patent 2,022,969, issued December 3, 1935.

The resulting square-topped wave is supplied through the pair of amplifiers **34** and **35** to the respective diagonals CD of the modulator bridges **24** and **29**, respectively. As these bridges work into resistance circuits (resistance pads **25** and **30**, respectively), the applied square-topped biasing waves operate cyclically to reverse the direction of the biasing current through the copper-oxide rectifiers in these bridge circuits so as to change the loss provided thereby in the branch circuits 4′, 4″, between high and low values so that the amplitudes of the currents 90 degrees out of phase passing to the amplifiers 26 and 31 in branch circuits 4′ and 4″, respectively, change every cycle between the values a_1 and a_2 as shown in the curves of Fig. 4(*a*) and Fig. 4(*b*). The particular phase at which the change in amplitude takes place determines the point on the circumference of the circular path ABC traced by the recording electron beam at which the radius changes from r_1 to r_2, as indicated in Fig. 3. To obtain the required operation of the modulators 24 and 29 it is necessary that the amplitude of the voltages applied across the diagonal AB thereof from the output of the amplifiers 23 and 28, respectively, be small compared with the amplitude of the square-topped waves supplied to the diagonals CD of the modulator bridges from the output of amplifiers 34 and 35. This can be obtained by suitable selection of the impedance values of the apparatus in the circuits 4 and 5, and by suitably adjusting the gain of the amplifiers.

The voltages required to be applied to the pairs 51, 52 of deflecting plates in the reproducing chamber 12 of the cathode ray tube 10 to cause the reproducing electron beam to continuously trace a circular path of radius r_1, over the ends of metallic plugs 46, on the reproducing side of the target 13, in a time of

$$\frac{1}{f}$$

per revolution, and with the proper synchronized phase relation with respect to the recording electron beam in the recording chamber to reproduce the recorded signal variations, are derived from the wave of fundamental frequency f generated by the oscillator 3 in the following manner.

A sine wave of the frequency f is transmitted by the oscillator 3 into the branch circuit 6 in which it is amplified by the amplifier 36. The amplified waves pass through the phase shifter 37, which is adjusted to give the required lag in the voltage wave transmitted through branch circuit 6 behind the voltage wave transmitted through control branch circuit 4, so that, referring to Fig. 3, the reproducing electron beam begins to traverse its circular path ABC over the plugs 46 on the reproducing side of the target at the same instant the recording beam starts to traverse its circular path ABC on the recording side of the target, both beams rotating in the same direction. The output of the phase shifter 37 is impressed on the phase splitting network 38 which operates to split the applied voltage wave into two components 90 degrees out of phase, one component taken off from the terminals of the condenser 39 being applied across the pair 51 of deflecting plates, and the other component taken off across the terminals of the resistance 41 being applied across the other pair of deflecting plates 52 of the electron gun mechanism in the reproducing chamber.

The effect of the recording electron beam, traversing at a time per revolution of

$$\frac{1}{2f}$$

second alternately the active circular path ABC and the inactive circular path DEF on the target 13 under control of the voltages applied to the deflecting plates in the recording chamber in the manner described, is to split up the signals modulating the beam into equal elements on a time basis, alternate elements of which (those modulating the beam in the time intervals in which it traverses path DEF over conducting ring 1) are discarded, and the remaining alternate elements being electrostatically recorded on the plugs 46 in the path ABC of the beam. The effect of the reproducing beam traversing, under control of the voltages applied to the deflecting plates in the reproducing chamber as described, the active circular path ABC over the other ends of the plugs 46, continuously with an angular velocity

$$\left(\frac{1}{f}\text{ second per revolution}\right)$$

which is half that of the recording beam, is that the recorded signal elements will be reproduced in such manner that they are stretched out to twice their original duration each occupying the same time interval formerly occupied by it and the succeeding discarded signal segment.

The reproduced signal elements collected by the collecting electrode 60 are impressed across the resistance 43 on the input circuit of the vacuum tube amplifier 44 and the amplified signal elements, which now occupy only one-half the total signal frequency range formerly occupied by the original signals impressed on the "IN" terminal of the cathode ray device 10, are transmitted over the transmission line L to the receiving station illustrated in Fig. 2.

In the receiving station of Fig. 2, two cathode ray tubes 110, 210, shown diagrammatically because each is identical with the device 10 employed at the sending station, are used for first recording and then reproducing the signal elements received over the line L. Two cathode ray devices are employed because it is desired to reproduce each signal element twice in order to fill the gaps which would otherwise occur in the reproduced signals due to the fact that each alternate signal element or interval was eliminated at the sending station.

The incoming distorted signal elements are amplified by the amplifier 47 and portions of the amplified waves are diverted into the parallel circuits 48 and 49. These portions of the waves are respectively applied between the modulating element and the cathode element (not shown) of the cathode ray tubes 110 and 210 by input circuits (not shown) similar to that employed with the cathode ray tube 10 at the sending station, to modulate the intensity of the electron beam generated by the electron gun mechanism in the recording chamber of each tube in accordance with the variations in the applied signal elements.

It is desired to have the recording electron beam in each of the tubes 110, 210 continuously trace out a circular path ABC of radius r_1 over the ends of the conducting plugs in the circular row on the target in the recording chamber with a frequency f or a time of revolution of

$$\frac{1}{f}$$

second, in order to have each beam make a continuous electrostatic record which is an exact copy of the incoming signal segments reproduced in the reproducing chamber 12 of the cathode ray device 10 at the sending station. Therefore, an electron beam deflection control circuit 60 including in order an amplifier, a phase shifter and a phase splitting network, identical with the control branch circuit 6 associated with the reproducing deflection plates of the cathode ray tube 10 at the sending station, is used for deriving the required voltages 90 degrees out of phase applied to the two pairs of deflection plates (not shown) in the recording chamber of each of the tubes 110, 210.

It is desired that the electron beam generated in the reproducing chamber of each of the tubes 110, 210 operates to cause all of the signal elements recorded on the conducting plugs 46 while the recording beam traces the circular path ABC, to be reproduced but in a time of

$$\frac{1}{2f}$$

second per revolution. As the recording is done in a time of

$$\frac{1}{f}$$

second per revolution, it is apparent that the value of each frequency in the reproduced signal elements in that case would be double the value as recorded, which would mean that all of the frequencies in the reproduced signal segment are restored to the values they had originally at the sending station.

This is accomplished by employing for controlling the deflection voltages applied to the pairs of deflecting plates in the reproducing chamber of each tube, the circuits 40 and 50, the elements in the control circuits for each tube being identical with those in the control circuits 4 and 5 employed for controlling the recording operation in the similar tube 10 at the sending station, so that the reproducing electron beam in each tube 110, 210 alternately traverses in the time of

$$\frac{1}{2f}$$

second per revolution the circular path ABC over the plugs 46 on the target in which interval it is effective to reproduce the recorded signal variations, and the circular path DEF over the conducting ring 1 of the target in which interval it is not effective to reproduce anything.

The control circuit 40 associated with the reproducing deflecting plates of the tubes 110 and 210, as indicated, comprises a full-wave rectifier 70 for rectifying the sine wave of fundamental frequency f supplied by the oscillator 300, similar to the oscillator 3 at the sending station, a selective circuit 80 for selecting a sine wave of the frequency $2f$ from the output of the rectifier 70, and parallel circuits indicated by the boxes N_1 and N_2 each identical with the circuit shown within the dot-dash box N in Fig. 1, respectively connecting the output of the selective circuit 80 to the two pairs of deflecting plates in the respective tubes 110, 210. The control circuit 50 comprises the overloaded amplifier 140 for changing the sine wave of frequency f received from the oscillator 300 to a square-topped wave of the same frequency, which is applied in parallel through amplifiers to properly bias variable loss pads within the boxes N_1 and N_2, respectively, corresponding to the amplifiers 34 and 35 and the copper-oxide rectifier bridges 24 and 29 within the box N in Fig. 1.

The control circuits 40 and 50 operate in a manner similar to that described for the similar circuits 4 and 5 of Fig. 1 to make the deflection voltages applied to the reproducing plates of the tubes 110, 210 such that the reproducing electron beam in each tube alternately traverses the circular paths ABC and DEF in alternate time intervals of

$$\frac{1}{2f}$$

second each so that it will reproduce in transmission over the path ABC all the signal segments previously recorded on the plugs 46 by the recording beams but with each frequency therein doubled so that it is restored to the value it originally had at the sending station.

The connection between the overloaded amplifier 140 and the circuits within the box N_2 only are crossed, as indicated, to cause the square-topped control wave to be applied 180 degrees out of phase to the variable loss pads in circuits N_1 and N_2 respectively, so that each tube 110 and 210 reproduces the same signal segments for alternate time intervals lasting

$$\frac{1}{2f}$$

second each.

The reproduced signal segments are taken off from the reproducing chamber of the cathode ray tube 110 by an outgoing circuit including an amplifier 90, and the alternate reproduced signal segments are taken off from the reproducing chamber of the cathode ray tube 210 by an outgoing circuit including an amplifier 100, in a manner similar to that described for the cathode ray tube 10 at the sending station of Fig. 1, and the amplified signal segments, the frequencies of which are now increased to the original values which they had at the input of the cathode ray tube 10 at the sending station of Fig 1, are combined in a common circuit 130 leading to a suitable receiving device 120 as indicated. The signaling wave impressed on the receiving signaling device 120 will contain only the alternate speech segments recorded at the sending station, but each of these segments is reproduced twice consecutively so that the signals as reproduced by the receiving device 120 will contain no silent gaps.

The phase of the wave of fundamental frequency f received from the oscillator 3 at the sending station and the oscillator 300 at the receiving station is preferably made adjustable by any suitable means so that the relative points in the cycle at which the speech waves are switched or interrupted are the same at the sending and receiving ends of the system.

In a modification of the circuit illustrated and described, the fundamental frequency f, determining the rate at which the speech or other signal wave of slowly varying fundamental frequency and wave shape is chopped up, may be derived directly from the fundamental frequency of a speaker's voice instead of being generated by the auxiliary oscillators 3 and 300 as described. In an unvoiced sound, where the voice has no finite fundamental frequency, the rate of interruption may be determined by an oscillator having the average frequency of the speaker's voice.

It is apparent that the amount of reduction in the frequency range of the signals transmitted in a system, such as described, may be made any desired fraction of the original frequency range by varying the number of cathode ray tubes employed at the receiving station and utilizing different harmonics of the frequency f to control the deflection voltages of the single cathode ray tube at the sending station. Where a frequency reduction of 2 to 1 is desired, two cathode ray tubes operating in alternation would be employed at the receiving station and the harmonic 2*f* would be selected by selective circuit **8**, as indicated. Where a reduction of 3 to 1 is required, three cathode ray tubes operating in sequence would be employed at the receiving station and the harmonic 3*f* would be selected at the sending station, and where a 4 to 1 reduction is desired, four cathode ray tubes operating in sequence would be employed, and the harmonic 4*f* would be selected at the sending station, and so on. However, in the case where an odd harmonic is required to be selected by the selective circuit **8** at the sending station, the full wave rectifier **7** would be eliminated.

Other modifications of the circuits which have been illustrated and described which are within the spirit and scope of the invention will be apparent to persons skilled in the art.

What is claimed is:

1. A method of changing the form of a message wave, which consists in chopping it up into a number of segments on a time basis, discarding certain segments, electrostatically recording the remaining segments at a given speed, and reproducing the recorded message segments at a lower speed, whereby the total frequency range occupied by the reproduced message components is reduced.

2. The method of reducing the width of the frequency band required for transmitting an alternating current signal wave, which consists in chopping up the wave into a plurality of small portions on a time basis, eliminating certain of said portions, electrostatically recording the remaining portions at a given speed, reproducing the recorded portions of the signal waves at a lower speed whereby each frequency in the reproduced signal portions is reduced to a fraction of its original value, transmitting the reproduced signals so modified over a transmission medium, and restoring the frequencies of the transmitted wave to their original values at a receiving point.

3. The method of reducing the frequency range required for transmitting an alternating current signal wave, which consists in chopping up the wave into a plurality of small intervals on a time basis, eliminating alternate intervals, electrostatically recording the remaining intervals of said waves at a given time rate, reproducing the recorded intervals at half the speed of recording, whereby the duration of each interval is stretched out by a factor of two and the total frequency range occupied by the reproduced signal intervals is halved, transmitting the reproduced signals so modified over a transmission medium, and at a receiving point electrostatically recording the received signals at the same speed as received, and reproducing the recorded signals at twice the speed of recording whereby the frequency components therein are restored to their original values.

4. A frequency changing system comprising means for generating an alternating current signal wave containing a wide range of frequencies, a cathode ray device for producing an electrostatic record of separated portions of said wave on a time basis while discarding the intervening portions, and for reproducing the recorded portions at such a time rate compared to the speed of recording that the value of each frequency of the reproduced waves bears a desired ratio to its original value.

5. The method of communication which consists in chopping up an alternating current message wave into a large number of small fragments on a time basis, selecting a sufficient number of said fragments to insure intelligibility of the message when the fragments are reproduced, while eliminating the remaining fragments, electrostatically recording the selected fragments at a given speed, reproducing the fragments at a lower speed such that each frequency therein and the total frequency range occupied by each fragment is reduced by a desired amount, transmitting the reproduced message fragments and at a receiving point electrostatically recording the received fragment at the same speed as received, and reproducing the resulting record at such speed as to restore the message components to their original frequency value.

6. A frequency reducing system comprising a source of alternating current signal waves of a wide range of frequencies, means to chop up the wave produced by said source into a plurality of small equal portions on a time basis, means to produce an electrostatic record of every alternate portion of said waves while discarding the intermediate portions, and means to reproduce the recorded portions at such a time rate that each frequency therein is reduced to a desired fraction of its original value, whereby the total frequency range of said signal waves is effectively compressed.

7. The system of claim 6, in which the recording and reproducing means comprise a single cathode ray device.

8. In a communication system comprising a sending and a receiving station connected by a signal transmission medium, said sending station comprising a source of signal waves comprising a wide band of frequencies, a cathod ray device for producing an electrostatic record of portions of said waves spaced apart with respect to time while discarding the intermediate portions of the waves, means for reproducing said record at a slower rate than the recording rate to decrease the signal frequencies from their original values, and means to transmit the reproduced signals to said medium, said receiving station comprising means for reproducing the portions of the signal waves received over said medium in such manner as to restore the frequencies therein to their original values.

9. A communication system comprising a sending station and a receiving station joined by a signal transmission medium, said transmitting station comprising a source of alternating current signal waves, means for eliminating separated portions of the signal on a time scale and for electrostatically recording the intermediate portions, and means for reproducing and transmitting to said medium the recorded portions in such manner that each successive transmitted signal portion is stretched out so that it occupies the time interval formerly occupied by it and the succeeding eliminated portion together, said receiving station comprising means for restoring the modified signal portions received over said medium to their normal time intervals, and means for replacing each signal portion eliminated at the transmitting station with a copy of the preceding retained signal portion so that the final signal wave is continuous.

10. A communication system comprising at a transmitting station a complex wave message source, means for eliminating alternate time intervals of the message wave received from said source and retaining other intervals, means for electrostatically recording the retained portions

of the message and means for reproducing and transmitting to a receiving station the recorded portions at a rate different from the recording rate, and means at said receiving station for restoring the transmitted portions to their normal time intervals.

11. The system of claim 6 in which the chopping up, recording and reproducing means comprises a single cathode ray device comprising an evacuated enclosure divided into two chambers each containing an electron beam generating apparatus, separated by a target consisting of a disc including a ring of conducting material and a parallel circular row of small plugs of conducting material insulated from each other, extending through the target perpendicular to its plane, separated from said ring by insulating material, means to modulate the intensity of the beam generated in one chamber with said alternating current signal wages, means to cause the latter beam to revolve at a given angular velocity alternately in circular paths over the ends of said plugs in said one chamber, to make an electrostatic record of the signal variations modulating the beam during that interval, and over said conducting ring, the signal variations modulating the beams during the alternate time intervals in which it moves over the conducting ring being thereby eliminated, means to cause the electron beam generated in the other chamber to revolve at a lower angular velocity and with the required delay with respect to the first beam, continuously in a circular path over the other ends of said plug in said other chamber, to reproduce all record of signal variations previously made on said plugs by said first beam, each frequency in the reproduced signals being thereby reduced with respect to its original value and the total frequency range occupied by the reproduced signals being less than that of the original signals.

ROBERT R. RIESZ.