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INSTANTANEOUS TYPE TIME COMPRESSORS AND EXPANDERS FOR
PULSE TIME MODULATION TRANSMISSION SYSTEMS

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2 Sheets-Sheet 1

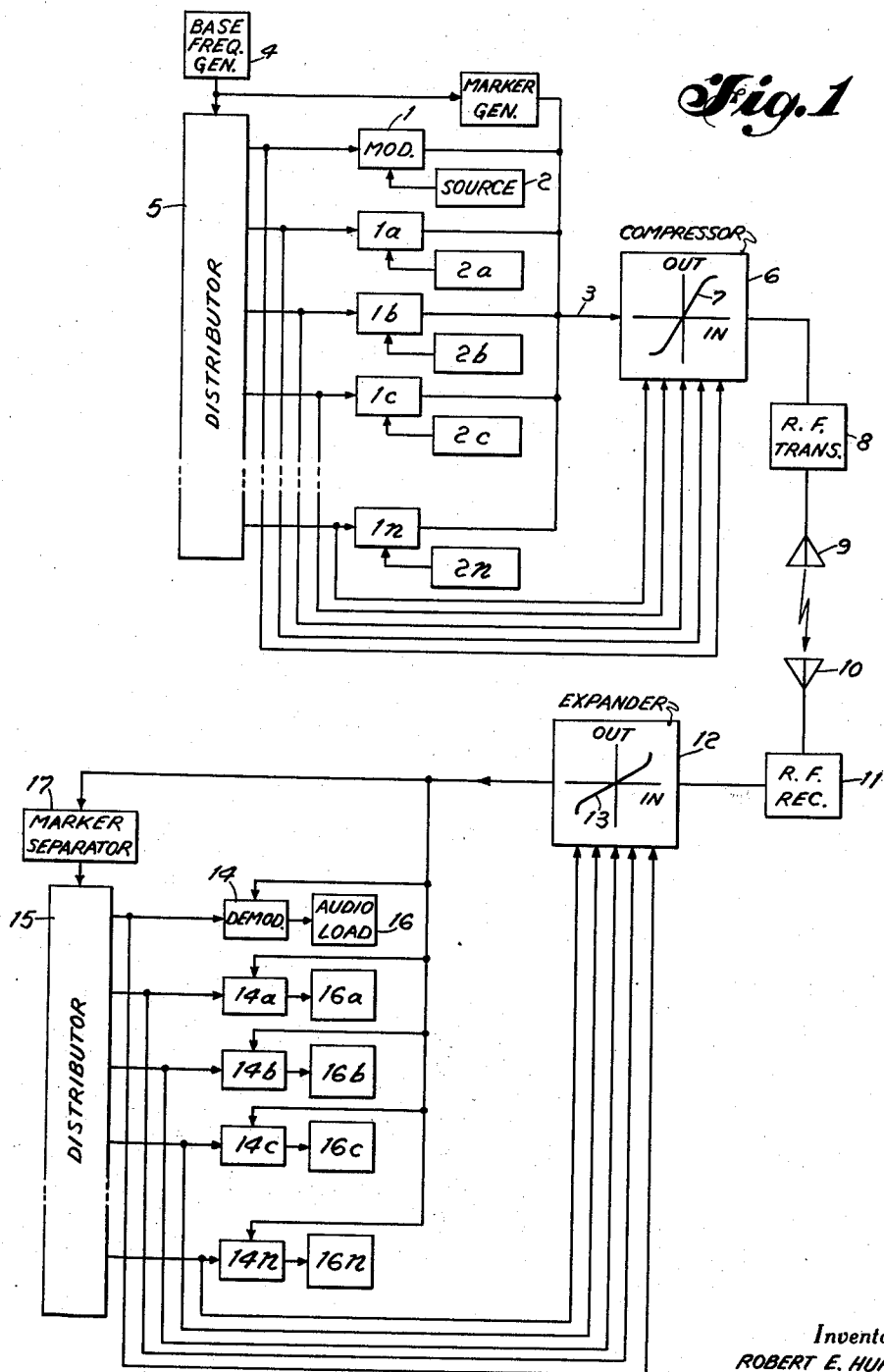


Fig. 1

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Fig. 2

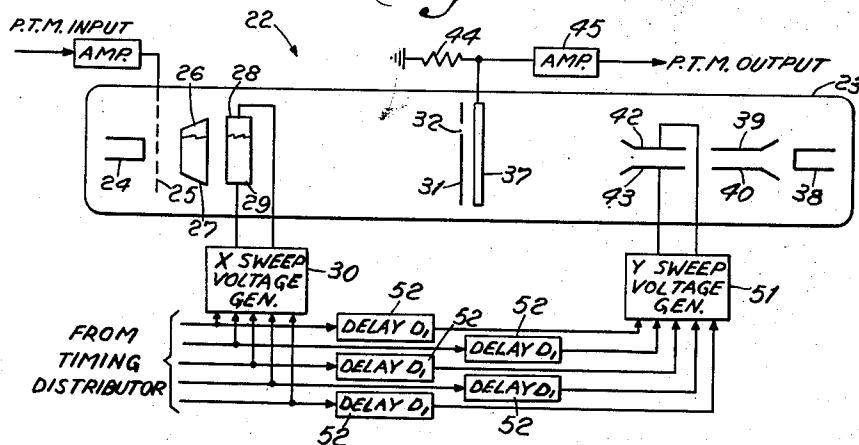


Fig. 4

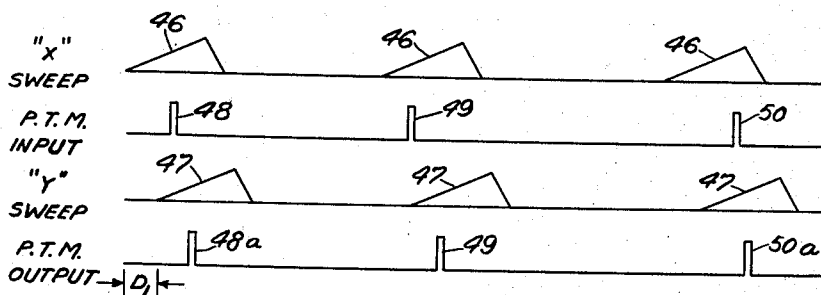


Fig. 3

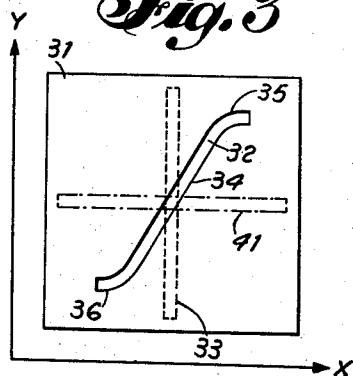
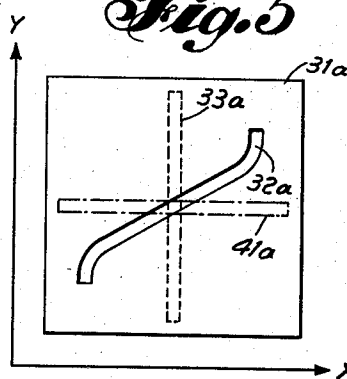


Fig. 5



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INSTANTANEOUS TYPE TIME COMPRESSORS AND EXPANDERS FOR PULSE TIME MODULATION TRANSMISSION SYSTEMS

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15 Claims. (Cl. 179-15)

This invention relates to message transmission systems, and more especially it relates to improved compressors and expanders for such systems of the pulse time modulation kind, hereinafter referred to as PTM systems.

As is well known, for many reasons, it is desirable in certain kinds of transmission systems to employ so-called compandor combinations. Such compandors comprise a volume compressor at the transmitter and a complementary expander at the receiver. Various forms of such compandors have been proposed heretofore for different kinds of transmission, for example transmission of amplitude modulation, by frequency modulation, by pulse count modulation, and the like. However, the present invention is directed primarily to a novel and improved instantaneous type compandor for systems employing the principle of pulse time modulation. In such systems the transmission of intelligence is effected by translating the originating audio frequency signals, such for example as voice frequency signals, into sampled time pulses whose time position is changed to represent the wave shape of the audio frequency signal envelope. Such a system is well suited to multiplex transmission since it is possible to interleave the PTM pulses so as more efficiently and reliably to operate over radio frequency transmission links and the like. However, with such PTM systems special problems arise which render the usual compandor arrangement not always satisfactory.

Accordingly, one of the principal objects of this invention is to provide a compressor device and also an expander device which are specially well suited for use in PTM systems.

A feature of the invention relates to an instantaneous type compressor or to an instantaneous type expander wherein the compression or expanding function is controlled by a sweepable substantially inertialess cathode ray beam, thus providing a minimum attack and decay time.

Another feature relates to an instantaneous type compressor or to an instantaneous type expander wherein the desired compressing or expanding function is controlled by a sweepable cathode ray beam and a specially designed electron mask which forms part of the cathode ray tube. The mask is so designed with respect to the shape and sweeping action of the cathode ray beam so as to impart directly to the output of the cathode ray tube the desired signal compression or signal expansion.

A further feature relates to a novel instantaneous compandor for PTM signals employing as the compandor control a novel construction of cathode ray tube.

A still further feature relates to the novel method of compressing or expanding the time deviation of pulse time modulation pulses by storing the pulse time modulation pulses on a storage surface in a predetermined graph-

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like configuration or array of elemental storage areas, and then electronically reading the stored pulse time modulation pulses to produce a PTM signal output having the desired compression or expansion.

An additional feature relates to the employment of the novel cathode ray tube mentioned above as an instantaneous type compressor or an instantaneous type expander for a multichannel PTM pulse train applied thereto.

Other features and advantages will appear from the ensuing descriptions, the appended claims, and the attached drawing.

In the drawing, which shows by way of example one preferred embodiment,

Fig. 1 is a schematic block diagram of a PTM system embodying the compressor and expander units according to the invention;

Fig. 2 is a schematic diagram of the cathode ray tube compressor or expander according to the invention;

Fig. 3 is a face view of the compressor mask shown in edge view in Fig. 2;

Fig. 4 shows a series of graphs used in explaining the operation of the invention; and

Fig. 5 is a face view of the mask when the device of Fig. 2 is used as an expander.

Referring to Fig. 1, there is disclosed therein a multichannel communication system employing a compressor and an expander in accordance with the invention. The multiplexer end of the system includes a plurality of PTM modulators 1 of any well-known kind, such for example as described in U.S. Patent 2,485,591. Each modulator produces a series of pulses representing by their time position the amplitude of the signals of modulating sources 2. The outputs of modulators 1 are coupled to a common point 3 for multiplexing into a PTM pulse train. The time of occurrence of each channel PTM pulse is determined by the base frequency generator 4 and the delay line timing distributor 5. The generator 4 also times the production of a synchronizing or marker pulse repetitious at the frequency of the output of generator 4. Thus, at point 3 the channel PTM pulses are interleaved in time between successive marker pulses to produce a plurality of pulse trains repetitious at the frequency of generator 4. The PTM pulses of each signal channel occupy a given time of the pulse train. This given time is the maximum time deviation of the PTM pulses, said maximum time deviation being proportional to the maximum amplitude of the modulating signal. A guard time can be provided between adjacent channels. The PTM pulse trains are then impressed upon a compressor unit 6 according to the invention, and to be described in connection with Figs. 2-4. For the present, suffice it to say that the unit 6 maintains the time deviation of the pulse time modulation pulses at its output within a predetermined time deviation proportional to a given volume range. Thus the general characteristic of the compressor 6 has to be such that most of the time deviations proportional to modulating signal amplitude are concentrated in the early part of the pulse time modulation pulse time deviations. One way of doing this is to decrease the time deviations of the successive sampled amplitudes of the modulating signal in a such a way that the successive decreased time deviations follow a predetermined characteristic. The curve relating instantaneous input signal time deviation to instantaneous output time deviation of the compressor may be according to any predetermined characteristic, such for example as that repre-

sented by the graph 7. The pulses which have had their time deviations compressed are then transmitted over any suitable radio frequency link transmitter 8 of known design, and then impressed upon the transmitting antenna 9.

The signals are picked up by a suitable receiving antenna 10 and are impressed upon any well-known radio receiver 11 for detecting the time deviations of the pulse time modulation pulses. These pulse time modulation pulses are then passed through an expander 12 which has a characteristic 13 relating instantaneous input time deviation to instantaneous output time deviation, which characteristic is complementary or inverse to the characteristic 7 of the compressor. In other words, the characteristic curve 13 may be considered the same as the characteristic curve 7 but rotated through 180°, the axis of rotation being the straight portions of the curves.

The PTM pulse train with pulses, the time deviation of which has been expanded is then coupled to a plurality of any well-known demodulators 14. Demodulators 14 under control of the timing pulses of delay line distributor 15 separates its corresponding channel pulse from the pulse train and converts the PTM pulses into intelligence signals. This operation is described in said U.S. Patent 2,485,591 and gives an example of one type of demodulator that may be employed in conjunction with my novel compandor. The outputs of demodulators 14 are coupled to their respective channel loads 16.

The timing of the outputs of distributor 15 is synchronized with the transmitter base frequency generator 4 by the synchronizing or marker signal. This marker signal is detected in marker separator 17 which supplies a synchronized signal to distributor 15 for the appropriate timed distribution to the demodulators 14.

Referring to Figs. 2-4, a description will now be given of the compressor unit 6. Since the expander unit 12 is of the same construction as the unit 6, it will only be necessary to explain in detail the construction and operation of the compressor unit. In general the unit 6 comprises the cathode ray tube 22 (see Fig. 2) having the usual evacuated enclosing bulb 23 with any well known electron gun 24 located at one end thereof. Mounted in relatively closely spaced relation to the gun is the control grid 25 upon which the PTM signals are impressed. Located in the path of the electrons passed by grid 25 is a pair of spaced plates 26, 27 which extend parallel to each other and to the plane of the sheet of drawing. These plates are connected to a suitable direct current potential source (not shown) so as to form the electron stream from the gun into a sheet-like beam, the plane of which is parallel to the sheet of the drawing. In front of the sheet-forming plates are the usual beam deflecting plates 28, 29 which can be connected to any well-known source of sweep voltage 30 for deflecting the sheet beam in a direction perpendicular to the plane of the drawing, which direction for convenience of description will be referred to herein as the X direction.

Mounted in front of the plates 28, 29 is an apertured electron mask 31 which may be a metal plate having an electron transparent slit 32 of a contour which is the same as or bears a definite configurational relation to the above-mentioned characteristic curve 7. In order to show the relation between the sheet-like electron beam and the slit 32, the beam is represented in Fig. 3 by the dotted cross-sectional outline 33, and for convenience of description will be referred to as the recording beam. Preferably the slit 32 has a substantially linear central region 34 terminating in symmetrical curved end regions 35, 36.

Located in closely spaced parallelism with the mask 31 is a signal storage plate 37 which may be in the form of a dielectric sheet having the surface thereof facing the gun 24 provided with a special secondary emission coating and having the opposite surface provided with a

conductive coating so that when the beam passes through the slit 32 and strikes the storage plate at any given point, it sets up at that point an electrostatic storage charge. Since such storage electrodes are well-known in the art, such as in television pickup tubes, electrostatic signal storage cathode ray tubes, and the like, detailed description thereof is not necessary herein. Suffice it to say that the charge which is localized at any given elemental area of the storage surface, as determined by the intersection of the beam 33 and the slit 32, will remain stored at that elemental area until it is read or discharged by a second sheet-like electron beam, referred to as the reading beam.

It will be clear from the foregoing that the beam 33 where it intersects the electron-transparent slit 32 scans the storage plate 37 in a line which has the same shape as the said slit. Preferably the control grid 25 is, in the absence of PTM pulses, biased to plate current cut-off so that in the absence of a PTM pulse no corresponding charge is stored on plate 37. However, when the grid 25 is energized by time-spaced PTM pulses, those pulses are stored as electrostatic dots on the plate 37 and the array or succession of such dots will be along the path defined by the shape of slit 32.

Located at the opposite end of the tube 22 is another electron gun 38 which constitutes the reading gun. It is provided with a pair of spaced plates 39, 40 similar to plates 26, 27 to form the electrons from gun 38 into a sheet-like beam. In a general sense it is required only that the plane of beam 41 is not parallel to the plane of beam 33. Preferably, however, the plane of beam 41 is perpendicular to the sheet of the drawing or in other words lies in the X plane and hence is perpendicular to the plane of beam 33. The reading beam is represented schematically in Fig. 3 by the dot-dash cross-sectional outline 41 in its preferred form. Located in front of the sheet-forming plates 39, 40 are a pair of beam deflecting plates 42, 43 for deflecting beam 41 perpendicular to the X plane or in other words in the Y direction. The storage plate 37 is connected to ground through a suitable resistor 44 which is connected to the input of a suitable amplifier 45 whose output is connected to the transmitter 8 (Fig. 1). Therefore, as the beam 41 sweeps across the stored charges on plate 37, it generates pulses corresponding to the location of those charges in the given configuration defined by slit 32. Deflection plates 42 and 43 and forming plates 39 and 40 would be disposed at a given angle to deflection plates 28 and 29 and forming plates 26 and 27 to provide the more general orientation of beams 41 and 33.

It should be noted that the beam 41 is continuously "On" even though the control grid 25 of the recording gun is keyed on only in response to an impressed PTM pulse. Preferably, however, there is a predetermined time delay D_1 between the recording sweep of beam 33 and the reading sweep of beam 41. This relation is shown in the graphs of Fig. 4. In that figure the sawtooth waves 46 represent the sweep voltage for sweeping the recording beam and the sawtooth waves 47 represent the sweep voltage for the reading beam timed for operation on one signal channel, the delay between the two sweeps being indicated by the designation D_1 . The repetition rate of waves 46 and 47 are equal to the repetition rate of the individual channel pulses being operated on. The typical PTM input pulses for one channel are represented by the numerals 48, 49, 50 and the corresponding PTM output pulses are represented by the numerals 48a, 49a, 50a. It will be clear from the foregoing, therefore, that because of the slope of the slit 32, and because of the intersectional relation between that slit and the reading and recording beams, the time deviation of successive PTM pulses will be compressed and maintained with a predetermined time distribution as determined by the shape of the slit 32.

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The waveforms of Fig. 4 are for one channel. It must be remembered that the compressor of this invention operates on the time deviation of the channel pulses of a multi-channel pulse train in sequence. Thus, for each channel the sweep generators 30 and 51 must be triggered to produce a sweep waveform having a repetition frequency equal to the channel repetition frequency and having a period equal to at least to the maximum deviation of the channel pulse. Preferably the period of the sweep waveform is slightly greater than the maximum deviation of the channel pulse. The triggering or timing pulses for the compressor and expander are derived from the channel taps of distributors 5 and 15, respectively, as indicated in Fig. 1. The timing signals are directly coupled to sweep generator 30 of Fig. 2 and through delay lines 52 to sweep generator 51. Thus, these timing signals will trigger the production of sweep waveforms coincident with the maximum channel deviation of the channel signals of the multiplex pulse train, thereby enabling the compressor and expander of this invention to operate thereon.

The expander unit 12 at the receiver is of the same construction as slit 32a of unit 6 of the transmitter except that the mask 31a, Fig. 5, in the expander is complementary to slit 32 of mask 31. The recording beam 33a and the reading beam 41a when used in the expander have the same preferred relationship as beams 33 and 41 of the compressor. In other respects the expander unit is identical with the compressor unit. In view of the inverse or complementary relation between the slit 32 of the compressor and the slit 32a of the expander, the complementary expansion of the time deviation of the pulse time modulation pulses is obtained at the output of the unit 12, thus restoring the PTM pulses applied to the demodulators 14 to their original time deviation relation.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

What is claimed is:

1. An instantaneous type compressor of the time deviation of pulse time modulation pulses for pulse time modulation systems and the like comprising means to store the pulse time modulation pulses on a storage surface in the form of energy including means in juxtaposition to said storage surface to confine the storage of said energy on said storage surface in a given configuration correlated with the desired compression of the time deviation of the pulse time modulation pulse, and means to electronically scan said stored energy to produce corresponding output pulse time modulation pulses having the desired time compression.

2. An instantaneous type expander of the time deviation of pulse time modulation pulses for pulse time modulation systems and the like comprising means to store the pulse time modulation pulses on a storage surface in the form of energy including means in juxtaposition to said storage surface to confine the storage of said energy on said storage surface in a given configuration correlated with the desired expansion of the time deviation of the pulse time modulation pulses, and means to electronically scan said stored energy to produce corresponding output pulse time modulation pulses having the desired time expansion.

3. An instantaneous type compandor combination for pulse time modulation transmission systems comprising at the transmitter means to store the pulse time modulation pulses on a storage surface in the form of energy including means in juxtaposition to said storage surface to confine the storage of said energy on said storage surface in a first given configuration correlated with the desired compression of the time deviation of the pulse time modulation pulses, means to electronically scan said

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stored energy to produce corresponding output pulse time modulation pulses having the desired time compression, and means to transmit said time compressed pulses, and at the receiver means to receive said time compressed pulses, means to store said time compressed pulses on a storage surface in the form of energy including means in juxtaposition to said storage surface to confine the storage of said energy on said storage surface in a second given configuration complementary to said first configuration, and means to electronically scan said stored energy at said receiver to reproduce the original pulse time modulation pulses with their original time deviated relations.

4. An instantaneous type compressor of the time deviation of pulse time modulation pulses for pulse time modulation systems and the like comprising an electrostatic storage surface, a mask having a slit of a predetermined configuration therethrough correlated with the desired compression of the time deviation of the pulse time modulation pulses, said mask being disposed in juxtaposition to said storage surface, means to record the pulse time modulation pulses as corresponding charges on said storage surface through said slit with the successive charges following the configuration of said slit, and means for electronically reading said charges stored on said storage surface to produce output pulse time modulation pulses having the desired time compression.

5. A compressor according to claim 4, in which means are provided to produce a predetermined time delay between the recording of said pulse time modulation pulses and the electronic reading thereof.

6. An instantaneous type expander of the time deviation of pulse time modulation pulses for pulse time modulation systems and the like comprising an electrostatic storage surface, a mask having a slit of a predetermined configuration therethrough correlated with the desired expansion of the time deviation of the pulse time modulation pulses, said mask being disposed in juxtaposition to said storage surface, means to record the pulse time modulation pulses as corresponding charges on said storage surface through said slit with the successive charges following the configuration of said slit, and means for electronically reading said charges stored on said storage surface to produce output pulse time modulation pulses having the desired time expansion.

7. An instantaneous type compandor combination for pulse time modulation transmission systems comprising at the transmitter a first electronic storage surface, a first mask having a slit of a predetermined configuration therethrough correlated with the desired compression of the time deviation of the pulse time modulation pulses, said first mask being disposed in juxtaposition to the first storage surface, means to record the pulse time modulation pulses to be transmitted as corresponding charges on said first storage surface through said slit in said first mask with the successive charges following the configuration of said slit, means for electronically reading said charges on said first storage surface to produce output pulse time modulation pulses with the desired time compression, means coupled to said reading means to transmit said compressed pulse time modulation pulses, and at the receiver means to receive said compressed pulse time modulation pulses, a second electrostatic storage surface, a second mask having a slit of predetermined configuration therethrough correlated with the required expansion of the time deviation of the pulse time modulation pulses to be complementary to the compression of the time deviation of the pulse time modulation pulses, said second mask being disposed in juxtaposition to said second storage surface, means to record said compressed pulse time modulation pulses as corresponding charges on said second mask with the successive charges following the configuration of said slit of said second mask, and means for electronically reading said charges on said second storage surface to produce pulse time modulation pulses having

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the same time deviation as the pulse time modulation pulses prior to time compression.

8. An instantaneous type compandor device for pulse time modulation systems and the like comprising a cathode ray tube having a first electron gun, a control grid for said gun upon which pulse time modulation pulses for transmission are impressed, means to shape the controlled electron stream from said gun into a sheet-like beam, means to deflect said sheet-like beam into a direction perpendicular to the plane of said beam, an electrostatic storage surface upon which the beam impinges, a mask in the path of said beam before it impinges on said surface, said mask having an electron transparent slit of a predetermined configuration correlated with the desired compression of the time deviation of the pulse time modulation pulses, and another electron gun for reading the stored charges on said surface in time delay relation to the recording thereof.

9. A compandor device according to claim 8, in which the said other electron gun is provided with means for forming the electron beam therefrom into a sheet-like beam in a plane substantially perpendicular to the first mentioned beam, and means for deflecting the sheet-like beam from said other gun in a direction perpendicular to the plane thereof.

10. An instantaneous type device for varying the time deviation of pulse time modulation pulses in pulse time modulation systems and the like comprising a cathode ray tube having means to develop a recording cathode ray beam of sheet-like shape, means to deflect said beam in a direction normal to the cross-sectional length of the beam, an electrostatic storage surface, an apertured electron mask located between said deflecting means and said surface, said mask having an electron transparent portion defining a configurational shape correlated with the desired time deviation of pulse time modulation pulses whereby the scanning thereof by said recording beam produces stored electrostatic dots on said surface along said electron transparent portion, and electronic means to read said stored dots to produce a corresponding series of output pulse time modulation signals having the desired time deviated relations.

11. A device according to claim 10, in which the means to develop said recording beam comprises an electron gun having means to scan said surface in an X direction, and the means for electronically reading said stored dots comprises another electron gun having means to scan said surface in a Y direction.

12. An instantaneous type compandor for pulse transmission systems comprising a compressor of the time deviation of pulse time modulation pulses including a first cathode ray tube having a first electron gun and a second electron gun, means to form the beam from the first gun into a sheet-like beam for recording, means for forming the beam from the second gun into a sheet-like beam for reading, the planes of said sheet-like beams being mutually perpendicular, an electrostatic recording plate having a recording surface located between said guns, means to sweep the first sheet-like beam in one direction across said surface, means to sweep the second sheet-like beam across said surface in a direction perpendicular to that of the first beam, a control grid for keying the first beam on and off by the pulses the time deviation of which is to be compressed, an electron permeable mask between the first gun and said surface, said mask having an aperture which is electron transparent and having a configuration which is correlated with the desired time compression characteristic, and a pulse expander for receiving the time compressed pulses, said expander having a time expansion characteristic complementary to the time compression characteristic of the compressor, said expander having a cathode ray tube substantially the same as said first cathode ray tube and including a similar electron transparent mask but with the aperture thereof oriented with respect to its associated recording and reading beams

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so as to produce the desired complementary time expansion of the output pulses from the expander.

13. An instantaneous type time compressor for multi-channel pulse time modulation signals having a synchronizing signal and a plurality of channel signals comprising a cathode ray tube having means to develop a recording cathode ray beam of sheet-like shape, means to deflect said beam in synchronism with each of said channel signals in a direction normal to the cross-sectional length of the beam, an electrostatic storage surface, an apertured electron mask located between said deflecting means and said surface, said mask having an electron transparent portion defining a configurational shape correlated with the desired signal compression whereby the scanning thereof by said recording beam produces stored electrostatic dots on said surface along said electron transparent portion, and electronic means in synchronism with each of said channel signals to read said stored dots to produce a corresponding series of output pulse time modulation signals having the desired signal compression.

14. An instantaneous type time expander for multi-channel pulse time modulation signals having a synchronizing signal and a plurality of channel signals comprising a cathode ray tube having means to develop a recording cathode ray beam of sheet-like shape, means to deflect said beam in synchronism with each of said channel signals in a direction normal to the cross-sectional length of the beam, an electrostatic storage surface, an apertured electron mask located between said deflecting means and said surface, said mask having an electron transparent portion defining a configurational shape correlated with the desired signal expansion whereby the scanning thereof by said recording beam produces stored electrostatic dots on said surface along said electron transparent portion, and electronic means in synchronism with each of said channel signals to read said stored dots to produce a corresponding series of output pulse time modulation signals having the desired signal expansion.

15. An instantaneous type compandor for multichannel pulse time modulation transmission systems wherein the intelligence is carried by a pulse train having a synchronizing signal and a plurality of signal channels comprising a compressor of the time deviation of pulse time modulation pulses including a first cathode ray tube having a first electron gun and a second electron gun, means to form the beam from the first gun into a sheet-like beam for recording, means for forming the beam from the second gun into a sheet-like beam for reading, the planes of said sheet-like beams being mutually perpendicular, an electrostatic recording plate having a recording surface located between said guns, means to sweep the first sheet-like beam in one direction across said surface in synchronism with each of said signal channels, means to sweep the second sheet-like beam across said surface in a direction perpendicular to that of said first beam in synchronism with each of said signal channels, means to delay the initiation of the sweep of said second beam with respect to said first beam, a control grid for keying the first beam on and off by the pulses the time deviation of which is to be compressed, an electron permeable mask between the first gun and said surface, said mask having an aperture which is electron transparent and having a configuration which is correlated with the desired time compression characteristic, and an expander of the time deviation of pulse time modulation pulses for receiving the time compressed pulses including a second cathode ray tube having a third electron gun and a fourth electron gun, means to form the beam from the third gun into a sheet-like beam for recording, means for forming the beam from the fourth gun into a sheet-like beam for reading, the planes of said sheet-like beams being mutually perpendicular, an electrostatic recording plate having a recording surface located between said guns, means to sweep the third sheet-like beam in one direction across said surface in synchronism with each of

said signal channels, means to sweep the fourth sheet-like beam across said surface in a direction perpendicular to that of said third beam in synchronism with each of said signal channels, means to delay the initiation of the sweep of said fourth beam with respect to said third beam, a control grid for keying the third beam on and off by the pulses the time deviation of which is to be expanded, an electron permeable mask between the third gun and said surface, said mask having an aperture which is electron transparent and having a configuration which is correlated with a time expansion characteristic complementary to the time compression characteristic of said compressor.

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References Cited in the file of this patent

UNITED STATES PATENTS

2,189,898	Hartley	Feb. 13, 1940
2,219,021	Riesz	Oct. 22, 1940
2,516,886	Labin et al.	Aug. 1, 1950
2,629,771	Anderson et al.	Feb. 24, 1953
2,768,352	Von Sivers et al.	Oct. 23, 1956
2,795,650	Levine	June 11, 1957