

July 2, 1963

P. E. CHANEY ETAL

3,096,401

METHODS AND APPARATUS FOR TRANSMITTING RECORDS

Filed May 15, 1961

3 Sheets-Sheet 1

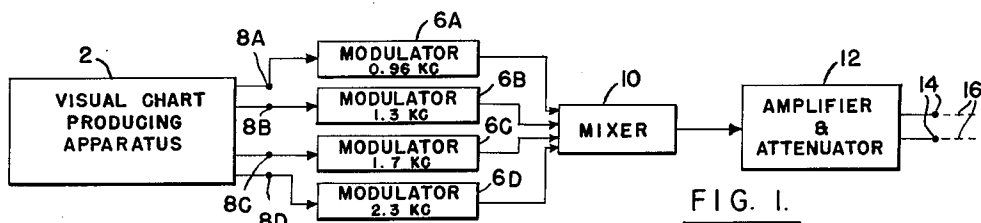


FIG. 1.

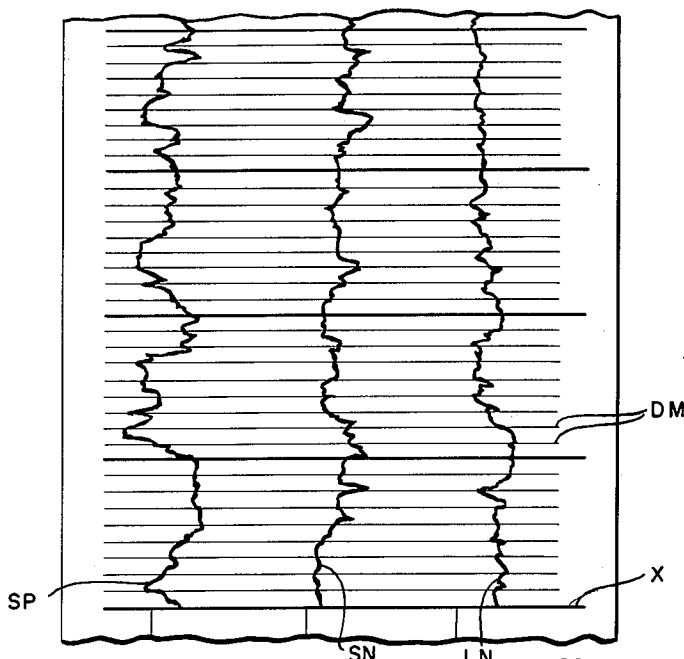


FIG. 2.

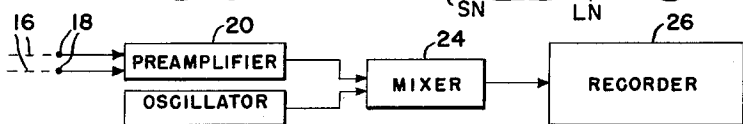


FIG. 3.

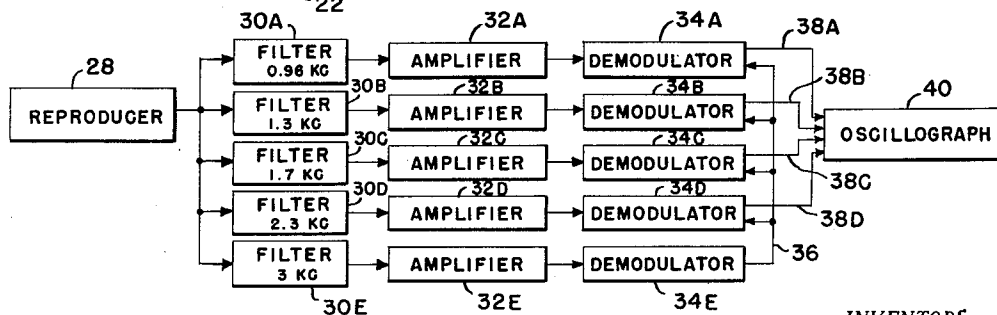


FIG. 4.

INVENTORS
PRESTON E. CHANEY
FRED M. MAYES &
JACK WEIR JONES

BY
Burrer Smith & Harding
ATTORNEYS

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P. E. CHANEY ET AL

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3 Sheets-Sheet 2

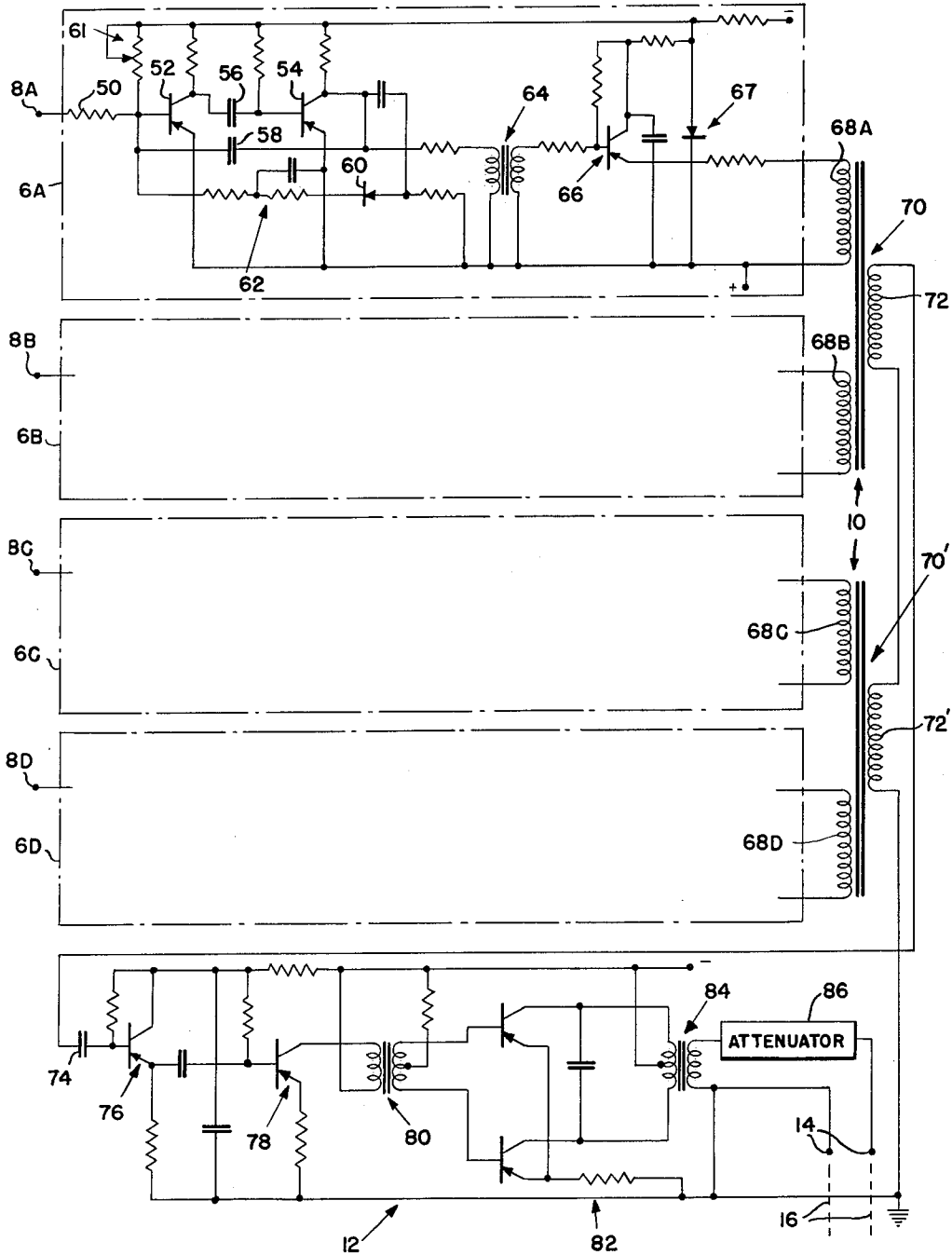


FIG. 5.

INVENTORS
PRESTON E. CHANEY
FRED M. MAYES &
JACK WEIR JONES

BY

ATTORNEYS

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P. E. CHANEY ETAL

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3 Sheets-Sheet 3

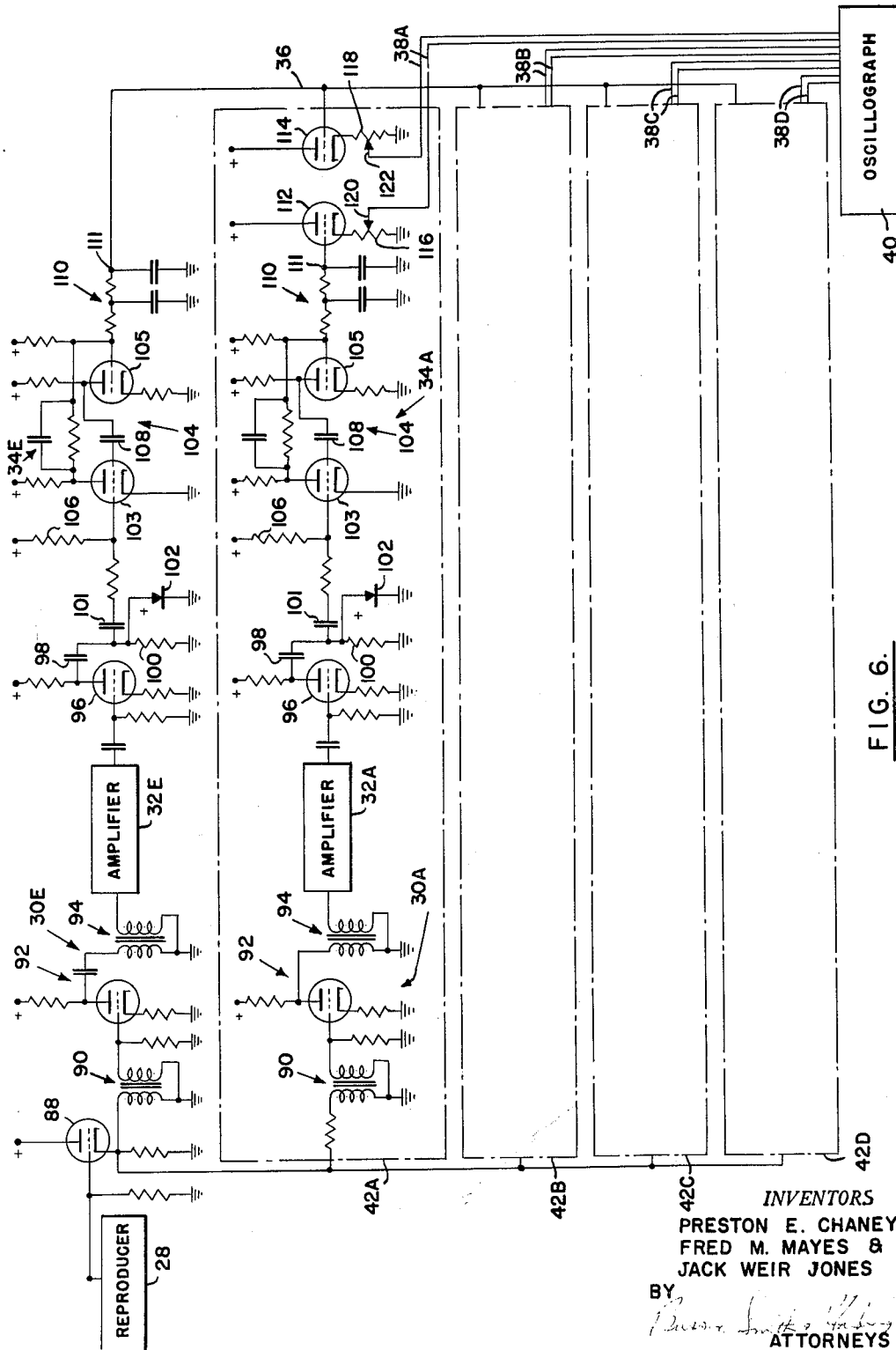


FIG. 6.

INVENTORS
PRESTON E. CHANEY
FRED M. MAYES &
JACK WEIR JONES

BY
[Signature]
ATTORNEYS

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METHODS AND APPARATUS FOR TRANSMITTING RECORDS

Preston E. Chaney, Dallas, and Fred M. Mayes and Jack Weir Jones, Richardson, Tex., assignors to Sun Oil Company, Philadelphia, Pa., a corporation of New Jersey

Filed May 15, 1961, Ser. No. 110,166
2 Claims. (Cl. 179-15)

This invention relates to methods and apparatus for transmitting records, and particularly for transmitting simultaneously a plurality of related records correlated through an independent variable such as time or depth. The invention is particularly applicable to the transmission over telephone lines of bore hole logs which are desired to be plotted against depths in bore holes.

While, as will appear hereafter, the invention is of broader applicability, it is particularly useful in the transmission of logs of various types which are to be exhibited in parallel arrangement plotted against depths at which they were made. To maintain uniformity of description, it will be directed to a particular type of problem.

Reference may be made to the application of Bennett, Chaney, Jones and Mayes, Serial No. 54,695, filed September 8, 1960. The last mentioned application refers to logging methods and apparatus disclosed in the application of Mayes and Jones, Serial No. 818,066, filed June 4, 1959. Considering the matters of the two applications just mentioned, a particular problem which is presented is the following:

A highly advantageous logging procedure is carried out by carrying on drilling utilizing a rotary drill string until a desired amount of hole has been drilled, and then, without removing the drill string from the hole, lowering therethrough a logging apparatus which is completely self-contained and which includes an electrode assembly connected to recording apparatus within a housing. The lowering, in most cases, is desirably effected merely by dropping the apparatus within the drill string. As the position of the bit is reached, a flexible electrode assembly emerges from the bit through one of the holes therein and ultimately extends below the bit with the remaining portions of the apparatus arrested above the bit within the drill stem. Typically, the electrode assembly contains a plurality of electrodes particularly arranged to provide desired logs such as those ordinarily designated as long-normal, short-normal, and self-potential logs. The recording apparatus associated with this assembly provides records in modulated pulse form, these records being recorded on magnetic tape. At the same time there are recorded on the tape what may be approximately described as time markings. These, actually, are markings corresponding to the repetitions of pulses in one of the logs. The apparatus also contains a power supply providing current for excitation of the earth in the vicinity of the logging apparatus. No connections to the surface are required.

Logging is carried out by the raising (or lowering) of the drill stem through the desired region which is to be logged. In view of the fact that an extended length of the hole cannot be logged without the removal or replacement of drill stem sections, the continuity of variations with depth of the logs which are recorded is generally repeatedly interrupted. Records are kept at the surface in the form of a log against time of the depth of the apparatus, and the surface and subsurface records may accordingly be correlated to give the logging responses in terms of depth. After the logging is completed the recording apparatus and the electrode assembly are removed, either by bringing the drill stem to the surface or by haul-

ing them up through the use of an overshot carried by a wire line insertable through the drill stem.

The foregoing is a very brief general summary of the procedure disclosed in the said Mayes and Jones application Serial No. 818,066.

The magnetic tape record which is recovered contains all of the essential data which, along with the records kept at the surface, could be used to present an ultimate visual record of the various logs, in amplitude form, plotted against depth. However, the original data is in a quite impractical form from the standpoint of what is ultimately desired, in that, the magnetic tape record, made continuously, will contain the irrelevant portions produced during rest positions of the drill stem. Furthermore, correlation with depth requires the carrying out of additional steps considering that, in its most practical form, the recording apparatus is not closely controlled as to tape speed, and actual time records are not made in the hole. Accordingly, there is desirably utilized the apparatus disclosed in the Bennett, Chaney, Jones and Mayes application, through the use of which apparatus there is producible an ultimate "clean" record of the logs in the form of amplitude traces plotted side by side against depth with omission of the irrelevant portions of the logs. Such traces are desirable for interpretation which, generally, involves comparison of logs made in several holes in the same vicinity. The apparatus last mentioned involves rerun manipulations, the final one of which produces the ultimate desired visual log.

Because of the fact that logging is an expensive procedure, not only because of the activities directly involved therein, but also because of the fact that drilling does not proceed during the actual logging, it is usually desirable to have the last mentioned visual log producing apparatus in the general vicinity where drilling is being carried out. The visual log may thus be made immediately following the logging operation and may be examined to determine whether the logging actually produced the desired results. If not, the logging may be promptly repeated.

While the visual log thus produced may be transmitted by mail to a location where detailed analysis may be made, the detailed analysis is also desirably made very promptly, and since this may require correlation of the produced log with other logs of different holes, the analysis is generally desirably made at a headquarters where complete records of an extended drilling program may be kept. Desirably, therefore, the final log is transmitted to the point of interpretation, and this may be most conveniently done over telephone lines, though it may also be done through radio transmission.

The general object of the present invention is to provide methods and apparatus whereby such transmission may be accomplished even simultaneously with the production of the final visual log by the reproducing apparatus mentioned above, though alternatively, it may be transmitted very promptly after a final visual log is made and generally examined at the drilling location. Either of these procedures is possible because of the fact that in the final log producing apparatus there is provided a magnetic record which corresponds to the final log and which is capable of producing amplitude signals corresponding to the visual logs and depth signals.

In brief, in accordance with the invention, the visual chart producing apparatus provides frequency modulated signals corresponding to the several logs and time markings. These several signals have base frequencies which are in the audio range and sufficiently spaced so that the frequency modulated signals may be separated by filtering. The audio signals may be transmitted as such over telephone lines, or, alternatively, may be used to modulate high frequency signals transmitted by radio.

While the subject matter of the present invention may

be described with reference to utilization of the apparatus of said Bennett, Chaney, Jones and Mayes application, then involving the transmission of the logs in completed form for direct visual reproduction, it will become apparent that the methods and apparatus are equally adapted to provide long distance transmission, over telephone lines or by radio, of logs in cruder form, for example as directly derived from a modulated pulse set of records on the tape made in the hole. It will also become evident that transmittable in accordance with the invention are logs made by other conventional methods utilizing surface recording and accordingly in such form that a final record is produced directly in the logging operation. Such variations involve aspects of greater simplicity. It will also be evident that the methods and apparatus may be used for the simultaneous transmission of multiple matters of information which are related to each other through a common independent variable of time, distance, or other type.

The accomplishment of the foregoing objects of the invention together with others which relate particularly to advantageous aspects of methods and apparatus, will become apparent from the following description, read in conjunction with the accompanying drawings, in which:

FIGURE 1 is a block diagram indicating the assembly of apparatus which is located at the transmission point and produces an output for distant transmission;

FIGURE 2 illustrates a portion of a visual record which is produced by the apparatus of said Bennett, Chaney, Jones and Mayes application;

FIGURE 3 is a block diagram illustrating the apparatus which is used at the receiving station to provide a magnetic record of what is transmitted;

FIGURE 4 is a block diagram of apparatus which is utilized to provide from the record made in accordance with FIGURE 3 a visual log;

FIGURE 5 is a wiring diagram illustrating the transmission apparatus shown in the block diagram of FIGURE 1; and

FIGURE 6 is a wiring diagram showing the apparatus which is indicated in the block diagram constituting FIGURE 4.

To simplify explanation of the invention, reference may be made first to FIGURE 2 which illustrates the beginning of a chart which would be made at the drilling location utilizing the visual chart producing apparatus of the Bennett, Chaney, Jones and Mayes application. This chart contains three amplitude logs which, for convenience of consistent description, may be considered a self-potential log SP, a short-normal log SN, and a long-normal log LN. Depth markings are indicated by the transverse line DM. The beginning of the actual log is indicated at X, and the straight traces therebelow represent zero lines for the respective logs, these being produced by recording galvanometer or oscillograph elements in rest position. FIGURE 2 indicates also the type of ultimate record which is desired at the receiving end of the transmission effected in accordance with the invention. As described in the Bennett, Chaney, Jones and Mayes application, the visual record constituting FIGURE 2 is produced by reproduction of a magnetic tape having a plurality of recording channels. The inputs to the galvanometer elements from this tape are of amplitude type to provide the visual traces and also the transverse sweep lines constituting the depth markings DM. These same outputs derived from the magnetic tape record are utilized to provide the inputs to the present apparatus. It will thus be seen that there are four amplitude signals provided for transmission.

Reference may now be made to FIGURE 1. There is indicated at 2 the visual chart producing apparatus which may be in the form of that described in said Bennett, Chaney, Jones and Mayes application. This provides to a set of four modulators 6A, 6B, 6C and 6D the four output signals which are delivered at the terminals 8A, 8B,

8C and 8D, respectively. It is, of course, immaterial which ones of the several signals these outputs represent, so long as a consistent convention is maintained throughout the apparatus. These outputs may simultaneously provide in the apparatus 2 the chart constituting FIGURE 2.

The modulators 6A, 6B, 6C and 6D have established base frequencies which may be typically as indicated, 0.96 kc., 1.3 kc., 1.7 kc. and 2.3 kc. These frequencies are mentioned only because they are in a readily transmittable audio range and are sufficiently spaced for convenient filter separation.

The outputs from the four modulators are combined in a mixer 10, and are then fed to an amplifier and attenuator 12 to provide a proper level for transmission through the output terminals 14 connected to a telephone line indicated at 16. Of course, if radio transmission is used, the mixed output signals at the audio frequencies may be used to modulate, in amplitude or frequency fashion, a radio frequency carrier. The transmitted signals, therefore, involve directly, or as modulation, the mixed frequency modulated audio signals derived from the modulators.

FIGURE 3 illustrates the apparatus connected to the receiving end of the transmission line 16 or radio transmission link corresponding thereto. If radio transmission is used, there will precede the input terminals 18 a conventional demodulator for recovery of the audio signals. These are fed through a conventional preamplifier 20, and mixed, in a mixer 24, with the output of a fixed frequency oscillator 22, which, consistently with the other frequency values given, may have a constant frequency output at 3 kc. As will hereafter appear, this oscillator is used for control purposes and provides correction for uncontrolled variables which may enter into the system. The output from the mixer 24 is used to record in a single tape channel of a recorder 26 the five mixed audio signals, the fifth being constituted by the output from the oscillator 22. The tape record thus produced is retained for as many visual reproductions of the information thereon as may be desired.

Continuing the general matters of the block diagrams, FIGURE 4 shows the apparatus which is then used to reproduce the magnetic tape record made by the recorder 26 to provide a visual amplitude trace record of the same form as that illustrated in FIGURE 2. There is indicated at 28 a reproducer for the tape record which may, of course, be the same as the recorder 26 with its circuits shifted for reproduction purposes. The single channel output of this reproducer 28 is fed to the set of filters 30A, 30B, 30C, 30D and 30E, corresponding in pass bands to the audio frequencies of the various modulators of the transmitting system with the addition of the filter 30E which is adapted to transmit the 3 kc. signal provided on the tape from the oscillator 22. The outputs from the several filters are respectively fed to amplifiers 32A, 32B, 32C, 32D and 32E and thence to demodulators 34A, 34B, 34C, 34D and 34E which provide recovery of the original audio signal. As indicated by the connection 36, the output of the demodulator 34E is used to control the outputs from the other demodulators, these outputs being provided at 38A, 38B, 38C and 38D to the respective galvanometer elements of a conventional oscillograph 40 to provide in amplitude visual form the three logging traces and the depth markings, to provide a record which is of the same form as that shown in FIGURE 2 and which may then be directly used for analysis which may involve comparison with other logs. The receiving apparatus may be duplicated at various geographically spaced points where interpretation is to be effected.

FIGURE 5 shows the circuitry involved in the parts of the apparatus running from the input terminals 8A, 8B, 8C and 8D to the line 16. Since the four modulators are identical except for tuning, only the modulator

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6A is detailed, the others being indicated merely by blocks. Input is provided from the terminal 8A through resistor 50 to the base of the transistor 52 which, together with a transistor 54 constitutes a multivibrator involving the criss-cross capacitor connections at 56 and 58. A direct current feedback is provided by the diode 60 and the network 62. A zero adjustment is provided in the form of a variable resistance at 61.

The multivibrator has a frequency which is controlled by the current injected into the base of the first transistor 52. The zero adjustment at 61 sets the center frequency of the multivibrator, and the direct current feedback fed around to the input base makes the output frequency deviation linearly proportional to the injected current. The result is the provision of a frequency deviation in each channel linearly proportional to the corresponding galvanometer deflection of the visual chart producing apparatus 2. The center frequencies of the multivibrators are set by suitable choices of parameters and finely adjusted by the zero adjustments. Frequency modulated outputs are thus provided.

The output of the described multivibrator is fed to the band pass telemetering filter indicated as a transformer 64, this being tuned to the center frequency of the multivibrator. The filters 64 eliminate harmonic components of the multivibrator outputs giving a very clean sinusoidal output frequency modulated in accordance with the signal injected at the corresponding terminal 8.

The output from the filter transformer 64 is fed to a transistor emitter follower 66 comprising a transistor in conventional connections, and this follower provides an input to a primary transformer winding 68A. The emitter follower prevents feeding back of the signals from one channel to another and thus prevents secondary modulation of the various modulators. A diode 67 of the usual voltage regulating type maintains constant potentials for energization of the various transistors which have been mentioned.

Mixing is accomplished through the use of the transformers 70 and 70', the former having as its primaries the windings 68A and 68B, and the latter the windings 68C and 68D. The respective secondaries 72 and 72' are connected in series and provide an input to an amplifier through capacitor 74. The arrangement of the transformers provides the mixer which has been heretofore indicated at 10.

The amplifier 12 fed through the connection 74 comprises an emitter follower stage 76, an amplifier stage 78, and a push-pull output stage 82 fed through a transformer 80. Signals are provided through the output transformer 84 to an adjustable attenuator 86 which feeds the terminals 14 connected to the line 16 or serving to provide modulation of a radio transmitter.

For adjustment and monitoring purposes the apparatus shown in FIGURE 5 has associated with it calibrating and monitoring means which, however, are of quite conventional type and need not be described in detail. Adjustments are initially made, with zero injection currents, to set the center frequencies of the modulator multivibrators, and other adjustments are made suitable to the type of transmission which is involved. The overall result is that the amplitude signals are transformed into frequency modulated audio signals as previously indicated, these being mixed for transmission.

As has already been described with reference to FIGURE 3, at the receiving end of the transmission the signals are amplified and mixed with the output of a fixed frequency oscillator, and then recorded in a single tape channel. All of the elements of this apparatus in FIGURE 3 are conventional and circuit details need not be described.

Reference may now be made to FIGURE 6 which illustrates the circuitry of the reproducing apparatus illustrated in block form in FIGURE 4.

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The reproducer 28 provides its output to a cathode follower 88 which is common to all of the frequency channels. In FIGURE 6 the channel corresponding to the 3 kc. signals is shown at the top and, as will appear, this channel has a rather special function. The other channels are, up to a point to be indicated, the same as the 3 kc. channel and these are designated generally by the blocks 42A, 42B, 42C and 42D, with the circuitry shown in detail only in the block 42A. In the two uppermost channels, because of their similarity, the corresponding elements are indicated by the same numerals. It will be understood, however, that where tuning is referred to, the various respective frequencies above described are involved. For the sake of initial description, reference will be made particularly to the uppermost 3 kc. channel.

The cathode follower 88 feeds the filter transformer 90 of the type already described, which provides its output to an amplifier 92 in turn feeding a second transformer filter 94. The last mentioned assembly constitutes the filter elements designated heretofore as 30A to 30E. Filtering is here provided to the extent that the several frequency bands are quite thoroughly separated, and to the respective amplifiers 32A to 32E, there are fed substantially pure bands respectively comprising the center frequencies and their respective deviation frequencies. The amplifiers are conventional and need not be described in detail.

The amplifier in each band feeds its output to a limiter 96, the output of which is differentiated by the series arrangement of capacitor 98 and resistor 100. The junction of these elements is clamped to ground through diode 102, with the result that only negative pulses are delivered through the capacitor connection 101.

Receiving the negative pulses is a single shot multivibrator comprising the triodes 103 and 105 with conventional connections. Triode 103 is normally conducting due to the connection of its grid to the positive supply terminal through a high resistance 106. The duration of the non-conducting condition of triode 103 is determined by the time constant of the arrangement provided by resistance 106 and capacitor 108.

As will now be apparent, each cycle of the original channel signal will throw the multivibrator 104 to its unstable state, and return to its stable state will occur after a delay determined by the time constant just mentioned. The circuit parameters of the various multivibrators are so chosen that, at least approximately, the ratio of on to off time of each multivibrator is the same at its center frequency. It will be evident that as a result of this the output from the anode of the triode 103 of each multivibrator will have an average value which is linearly proportional to the applied frequencies, and at the center frequency of the various channels the average values of the outputs will be approximately the same.

The resulting pulsations are fed to an RC filter 110 with the resulting outputs at 111 direct, though varying, current having magnitudes proportional to the frequency deviations and hence corresponding to the original amplitude signals which controlled the frequency modulation.

Up to the terminals indicated at 111 the various channels are similar except for the matters of frequency tuning mentioned above, and the other aspects dependent thereon, such as the durations of the astable state of the multivibrators. In the case of the channels 42A to 42D, the terminals 111 provide inputs to triodes 112 connected as cathode followers. In the case of the 3 kc. channel, the output 111 feeds the connection indicated at 36 heretofore, providing inputs to cathode followers 114 one of which is located in each of the channels 42A to 42D.

The resistors of the cathode followers are provided by potentiometers 116 and 118, and outputs are adjustably taken from these potentiometers through the movable contracts 120 and 122 which feed the output lines 38A to 38D running to the recording elements of the oscillograph 40. The oscillograph mirrors are thus driven by direct currents

from the filters 110 of the signal channels which direct currents are linearly related to the frequency deviations and thence to the original signals controlling the transmitter.

The reason for the 3 kc. signal may now be explained. Both the recorder 26 and the reproducer 28 are subject to variations in tape speed. Such variations would be serious in view of the fact that frequency modulation is involved at relatively low (audio) frequencies. Variations in tape speed would thus be reproduced as variations in frequency with resulting spurious amplitudes in the ultimate record. By providing the fixed frequency oscillator 22 operating at, say, 3 kc., any changes in tape speeds in the recorder and/or reproducer will produce corresponding frequency variations in this signal. Feeding it through the demodulator system will then result in variations in the direct current produced at the output terminal 111 of the filter 110 of the 3 kc. channel. By driving the galvanometers between the pairs of cathode followers, one of each of the pairs being driven in accordance with the signals to be reproduced and the other being driven from the 3 kc. signal, the effects of variations of tape speed are greatly reduced, since the 3 kc. signal and the signals at the other audio frequencies will be simultaneously affected in the same senses. Of course, this does not theoretically result in complete elimination of variations of tape speed due to the fact that various other factors enter into the picture, such as differences in the filter characteristics, etc. But there is a very considerable reduction of these effects and the net result is that they are negligible since, using well constructed recorders and reproducers the variations in tape speed are ordinarily of small magnitude.

It will be obvious from the foregoing that the apparatus described is applicable to many uses where a number of variables correlate to each other and to an independent variable are to be recorded remotely. The signals exemplified by the self-potential, short-normal and long-normal logs are typical. As has been indicated, the time markings are also reproduced, these being essentially in the form of intermittent short pulses which, however, will be of durations sufficiently long to involve a number of cycles of the frequencies transmitted. The frequency deviations are, here, of course very large, so that the galvanometer may provide sweeps completely across the record being made.

To summarize the general aspect of operation, the method which is carried out involves the derivation from variable amplitude signals of corresponding frequency modulated signals desirably in the audio range, these signals having deviations which are substantially linearly proportional to the originating amplitude signals. The frequency modulated signals may then be mixed and transmitted over wires or by radio. At the receiving end, for convenience, the frequency modulated signals are directly recorded in a signal channel. This recording may be preserved for later reproductions. In the reproducing apparatus utilizing this record, the various frequency bands are separated by filtering and demodulation is accomplished in such fashion as to recover amplitude signals which are linearly related to the frequency deviations of the frequency modulated signals. Furthermore, the reproduction is accomplished in a fashion which substantially eliminates the detrimental effects which might occur due to variations in operating speed of the recording and reproducing apparatus.

It will be evident that various changes in details may be made without departing from the invention as described in the following claims.

What is claimed is:

1. Apparatus for the simultaneous transmission of a plurality of functions of a common independent variable comprising transmitting means, means for supplying to said transmitting means a plurality of signals corresponding respectively to said functions, said transmitting means comprising means for producing in response to the first mentioned signals a plurality of frequency-modulated signals each of which corresponds to one of said first mentioned signals, and comprising means for mixing said frequency-modulated signals, means providing a transmission link receiving the mixed frequency-modulated signals and transmitting them to a point remote from said transmitting means, means at said point receiving the signals so transmitted, mixing the last mentioned signals with a fixed audio frequency signal, and recording the so mixed signals in a single record channel, means for reproducing the signals from said channel, means separating the individual signals thereof, means demodulating said frequency-modulated signals and also the signal provided at said fixed frequency to provide respective variable amplitude signals corresponding thereto, and means recording simultaneously a plurality of signals each of which corresponds respectively to the difference of amplitude of the amplitude signal derived from said signal provided at said fixed frequency and the amplitude of one of signals derived from the frequency-modulated signals.

2. Apparatus for the simultaneous transmission of a plurality of functions of a common independent variable comprising transmitting means, means for supplying to said transmitting means a plurality of signals corresponding respectively to said functions, said transmitting means comprising means for producing in response to the first mentioned signals a plurality of frequency-modulated signals each of which corresponds to one of said first mentioned signals, and comprising means for mixing said frequency-modulated signals, means providing a transmission link receiving the mixed frequency-modulated signals and transmitting them to a point remote from said transmitting means, means at said point receiving the signals so transmitted, mixing the last mentioned signals with a fixed audio frequency signal, and recording the so mixed signals in a single record channel, means for reproducing the signals from said channel, means separating the individual signals thereof, means demodulating said frequency-modulated signals and also the signal provided at said fixed frequency to provide respective variable amplitude signals corresponding thereto, said demodulating means comprising, for each of said frequency-modulated signals and said fixed frequency signal, a single shot multivibrator actuated by each cycle of said signals to produce pulses of uniform duration at the frequency of said signals and a smoothing filter receiving such pulses and providing such variable amplitude signal, and means recording simultaneously a plurality of signals each of which corresponds respectively to the difference of amplitude of the amplitude signal derived from said signal provided at said fixed frequency and the amplitude of one of signals derived from the frequency-modulated signals.

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