Oct. 25, 1949. E. LABIN ET AL 2,485,611

BROADCASTING SYSTEM

Filed April 7, 1944 5 Sheets-Sheet 1

Fig. 1.

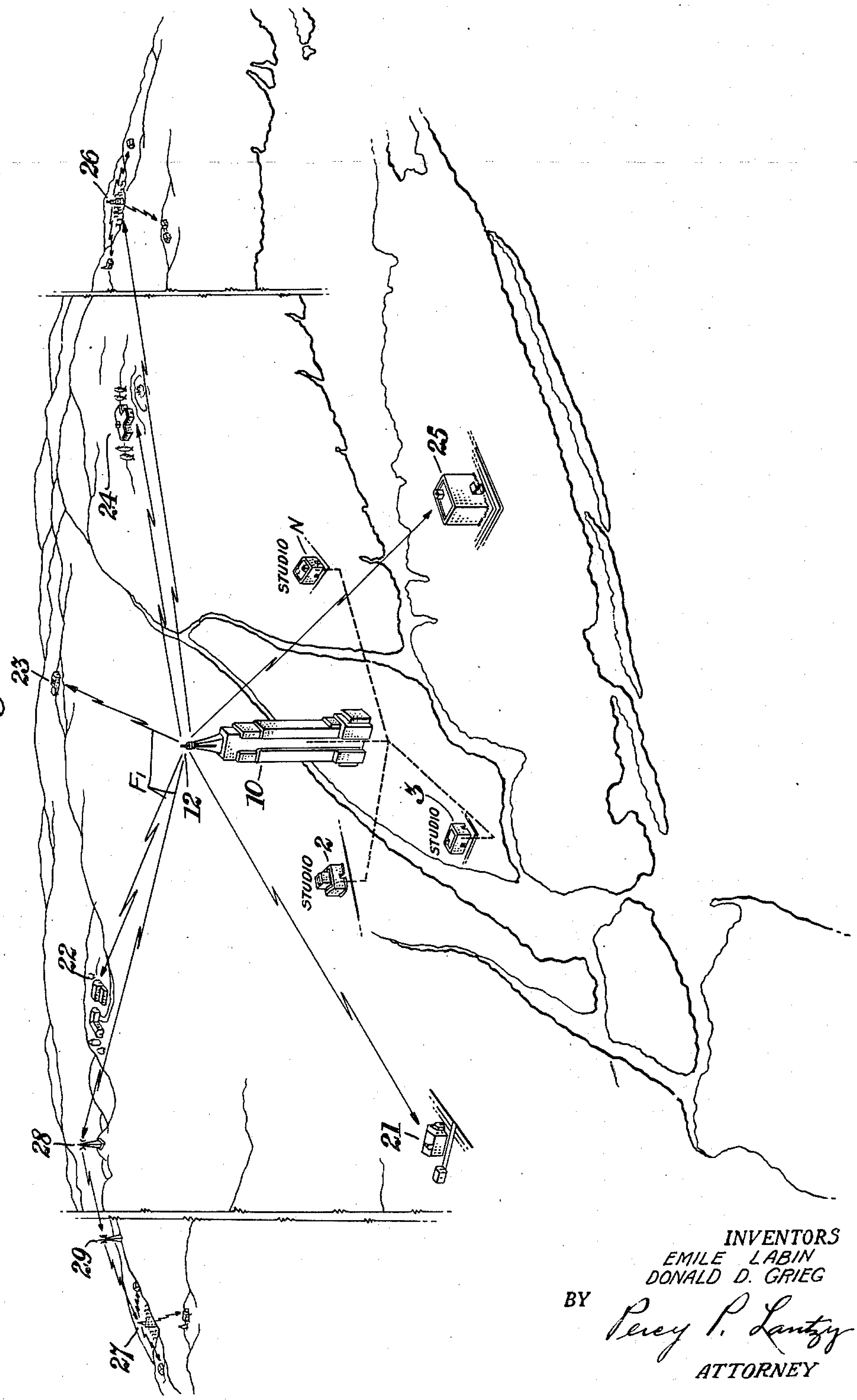

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Fig. 2.

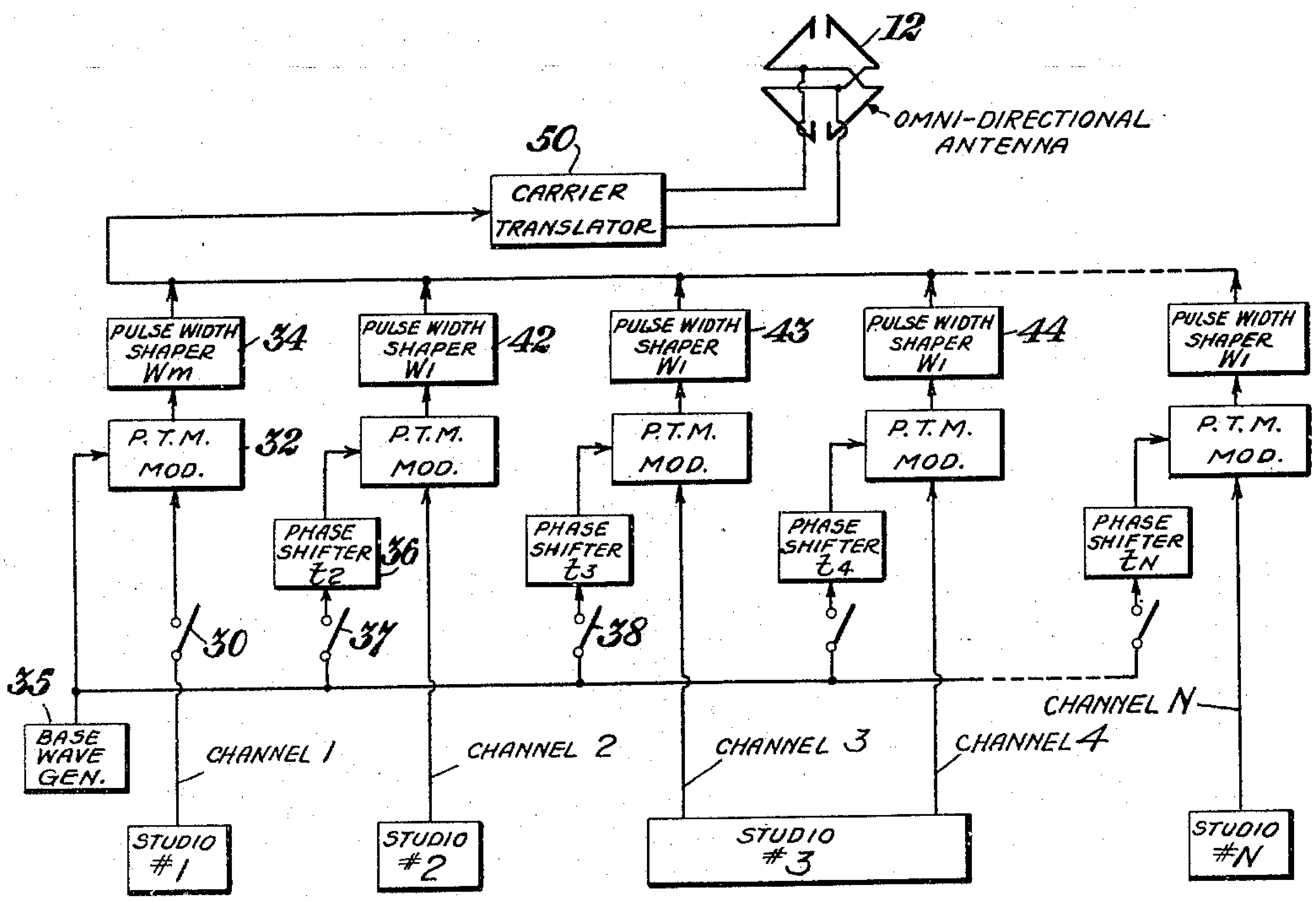

Fig. 2A.

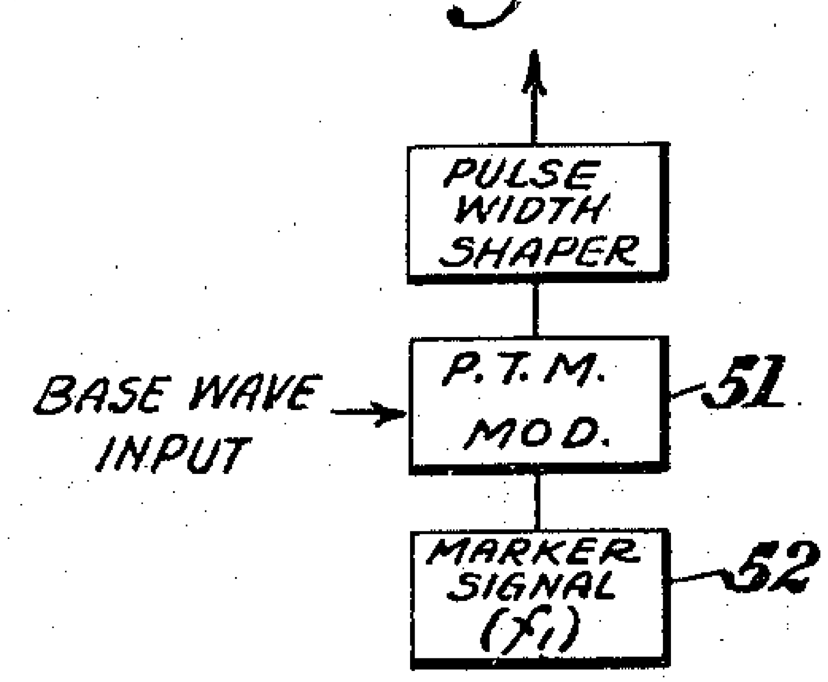

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Fig. 3.

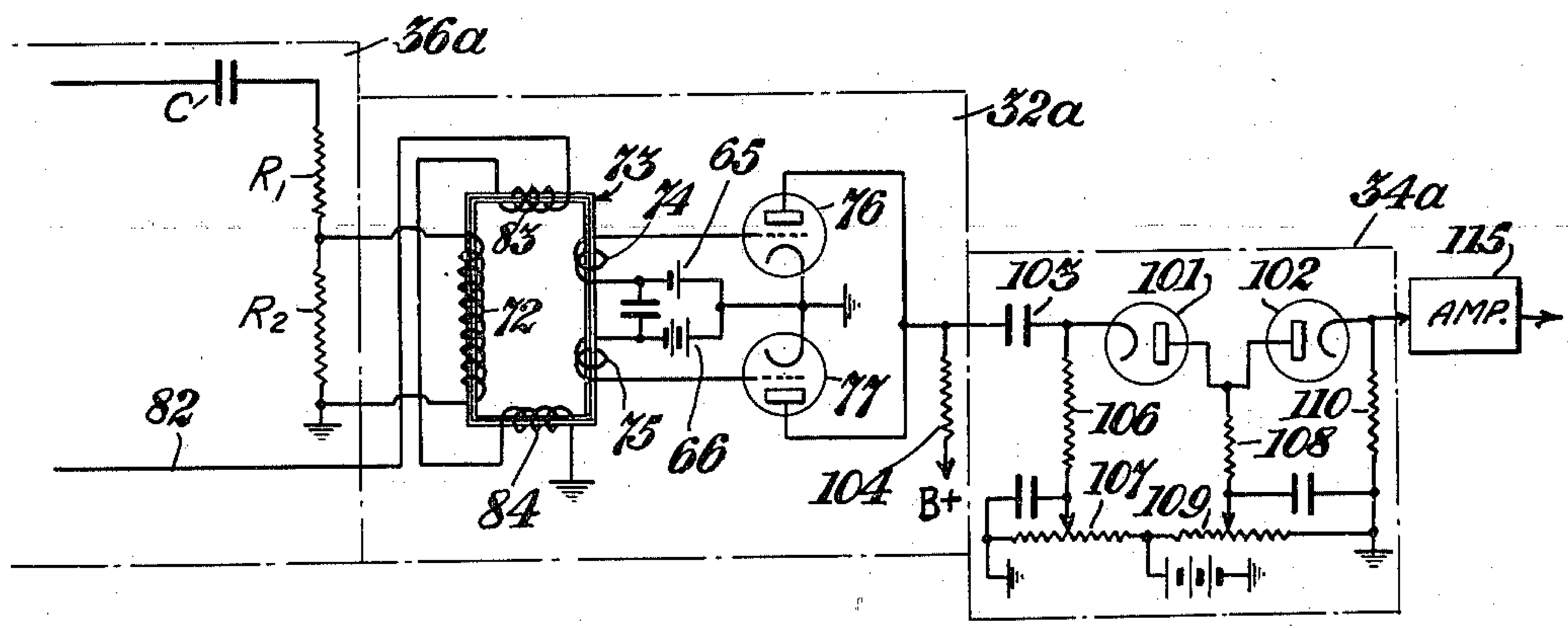

Fig. 4.

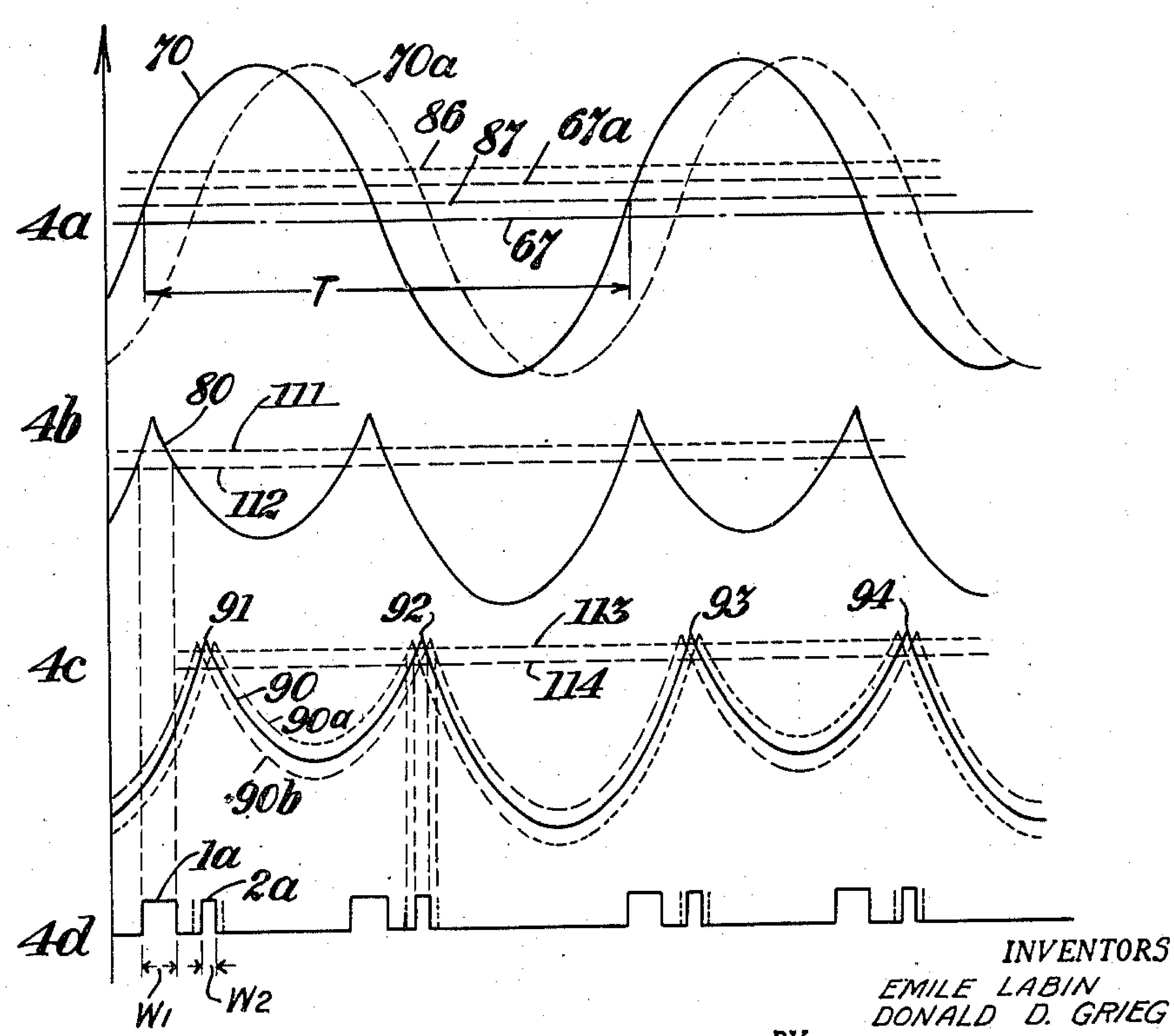

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Fig. 5.

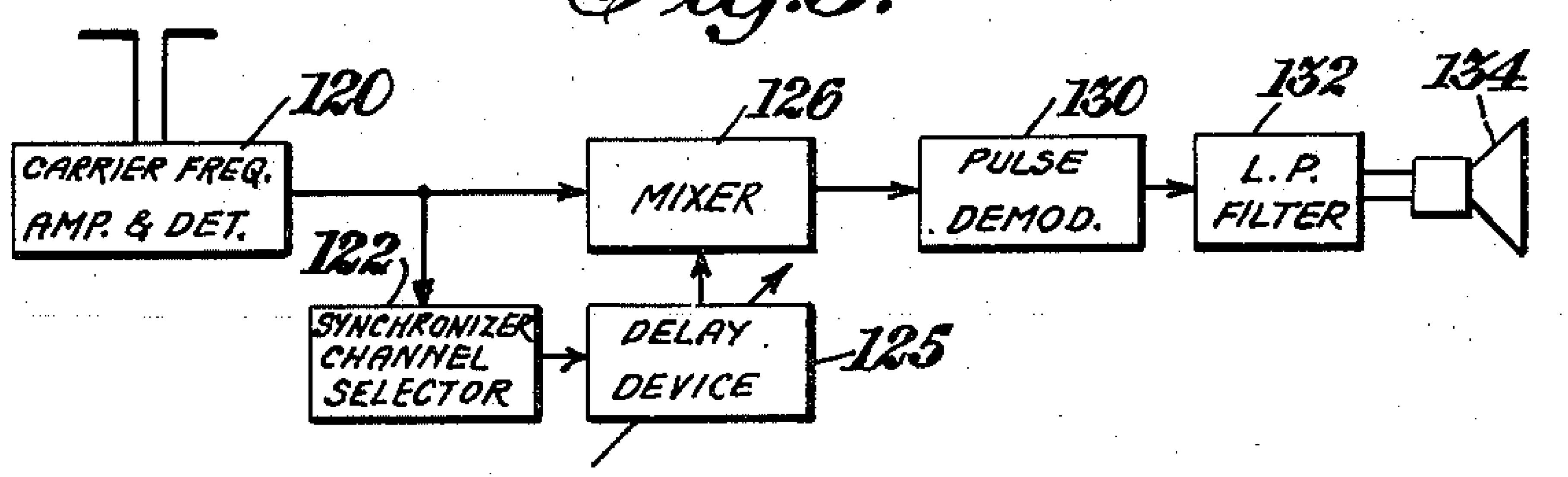


Fig. 5A.

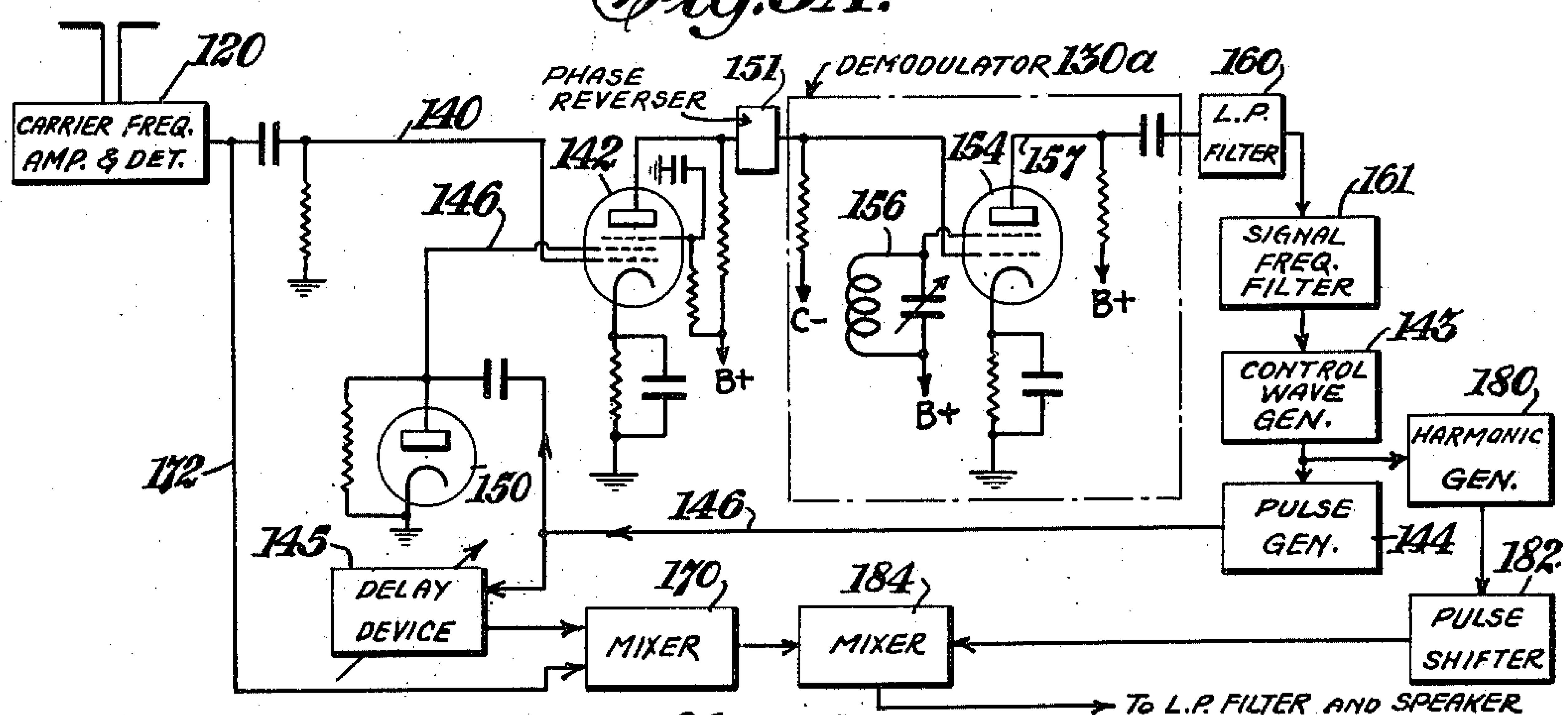
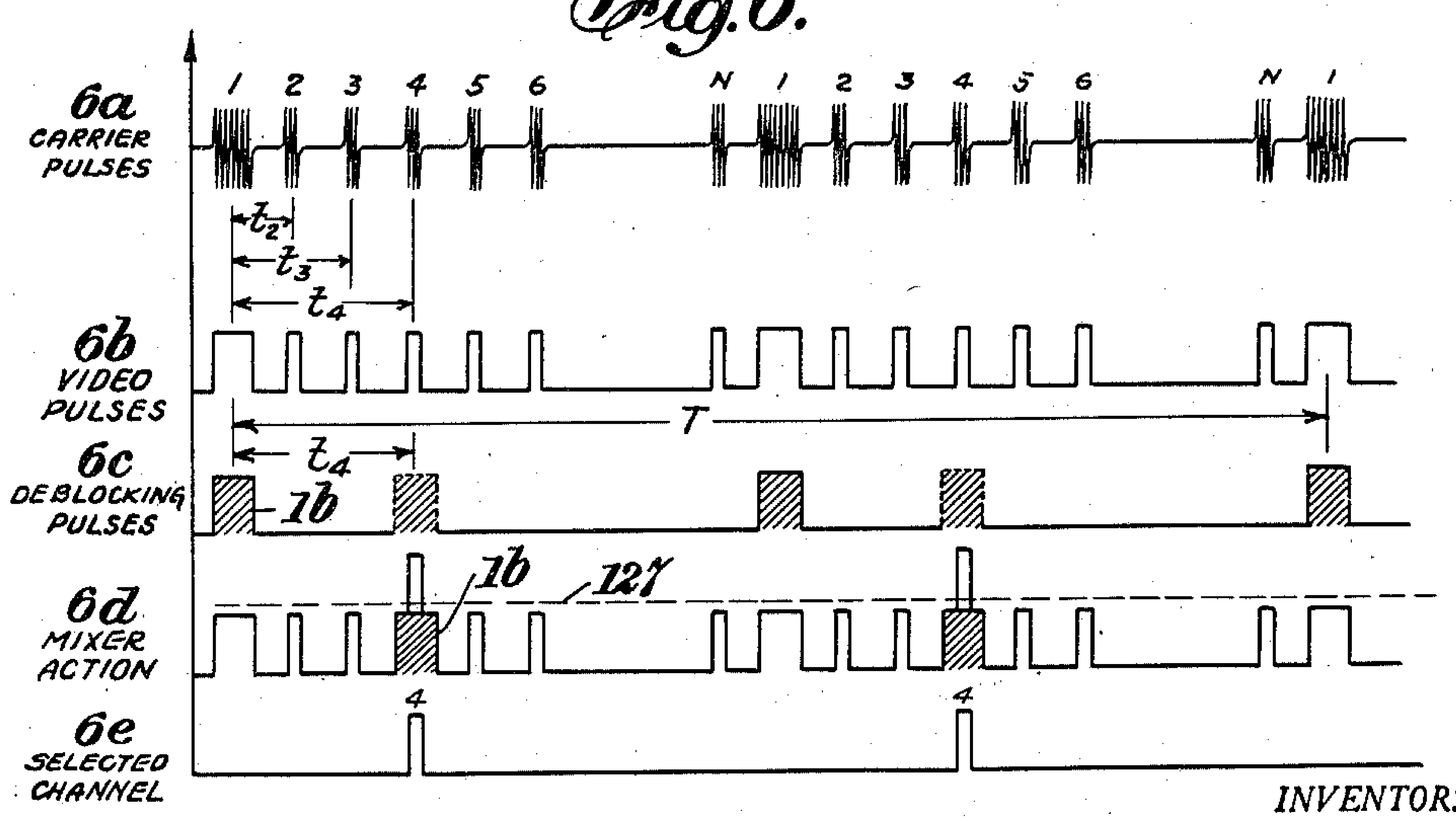


Fig. 6.



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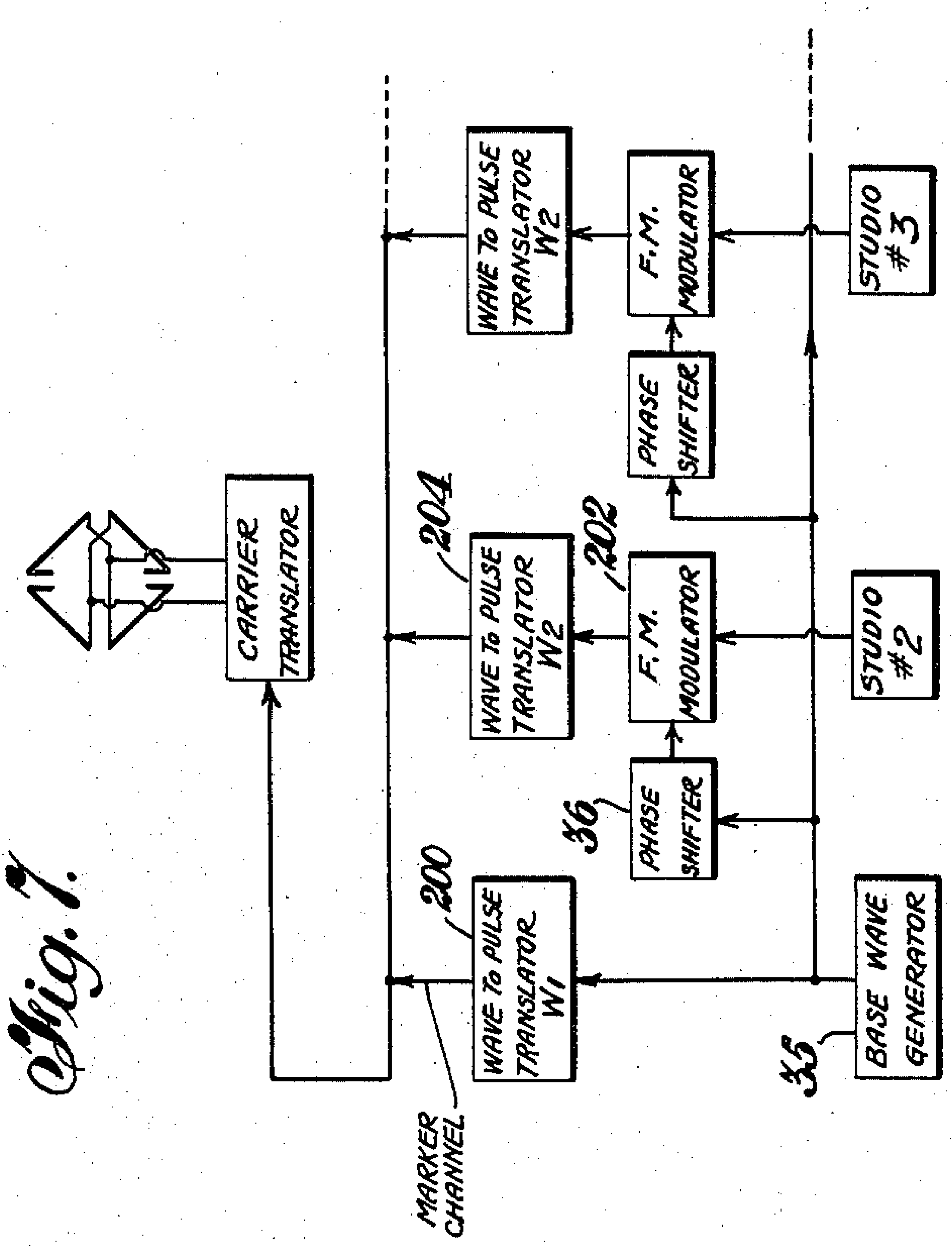

Fig. 7.

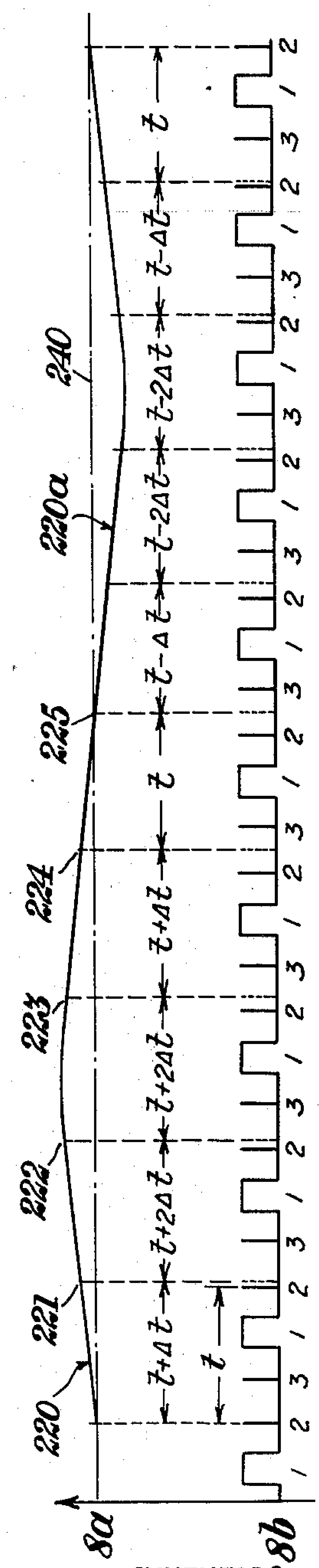

Fig. 8.

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UNITED STATES PATENT OFFICE

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BROADCASTING SYSTEM

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Application April 7, 1944, Serial No. 529,932

3 Claims. (Cl. 250—9)

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This invention relates to radio broadcasting systems and more particularly to radio multichannel broadcasting in the ultra-high frequencies and the selective reception of such transmitted channels.

The ultra-high frequency broadcasting system known as FM (frequency modulation) is being developed along the same lines as the standard low frequency AM (amplitude modulation) broadcasting systems. The method used is the following: In the larger centers of population, New York city for example, the studios of the several broadcasting stations are situated conveniently to the program originating sources. From these studios the programs are transmitted by line to the respective transmitting stations which are located primarily for maximum populated area coverage and which transmit on individual authorized frequencies. At the receiving end the listener, of course, separates the various stations by frequency tuning.

While this system of broadcasting has proved entirely satisfactory for the lower frequencies, the same advantages do not necessarily follow at the higher frequencies. In fact, at these higher frequencies several major disadvantages arise. To give a few examples:

There can only be a limited number of optimum transmitting locations about the area to be served by the broadcaster, and since height of the transmitting antenna in such area is all important at the higher frequencies, those stations not possessing these important locations are at a serious disadvantage with respect to their competitors. In New York city for example, there is only one Empire State building dominating in height the entire city and centrally located. The broadcasting company controlling this location enjoys, therefore, a monopoly which even a considerably larger amount of power at other locations cannot overcome.

The multiplicity of transmitting equipment required is an additional disadvantage. At the higher frequencies the broadcast coverage area is limited to horizontal distance which practically limits the range to about 20 to 30 miles. In order to link areas at distances greater than this, and to extend the networks on nationwide scale, it has been envisaged to use relay stations linking the important service areas. However, with the existing multiplicity of transmitting stations a consequent multiplicity of relay stations will be required which would entail considerable economic waste aside from the technical problem of duplication of the optimum of relay location.

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The listener's receiver in an area served by the several broadcasting stations is also at a distinct disadvantage with the existing system. With the various transmitting stations located at different compass points with respect to the receiving location, it is not possible for a single simple receiving antenna to be operated at maximum efficiency due to the problem of reflections from nearby buildings. This is especially true with facsimile and television, although not much less so with music and voice broadcasting. The practical elimination of these reflective effects entails the use of a directive antenna. Hence, in order to receive all the stations, in addition to the normal receiving tuning, a definitely impractical rotation of the antenna or a switching antenna system is necessary. This problem alone makes it virtually imperative that all stations for a given area be located geographically as close together as possible.

In addition to the above-mentioned disadvantages there are still others such as the duplication of transmitting apparatus and transmitting antenna systems, and the reduced efficiency of duplicate operation.

It is an object of this invention to provide a multi-channel broadcasting system which overcomes the above-mentioned disadvantages of existing and other heretofore proposed broadcasting systems.

Another object is to provide a multi-channel broadcasting system incorporating the unique advantages of ultra-high frequency pulse transmission.

Another object is to provide a method and means for multi-channel broadcasting over a common carrier frequency and for selectively receiving at points in the vicinity of the broadcasting station any desired one of a plurality of channels.

A further object of the invention is to provide a method and means for synchronizing receivers to the transmission sequence of the signals of a multi-channel transmission system.

Still another object of the invention is to provide a relatively simple and inexpensive ultra-high frequency receiver for selective reception of the channels transmitted on a common carrier frequency with the signals thereof interleaved with the signals of other channels.

A feature of the invention is the character of channel transmission. Each channel is represented by a train of pulses timed to interleave in sequence with pulses of other channels to form a single train of pulses. The pulses of one of the channels are modulated with an identifying characteristic distinct from the pulse characteristics of other channels for synchronizing receivers to the transmission sequence of the channels. The pulses of the other channels, and the pulses of the identified channel if desired, are modulated in some manner, such as the time relation of the pulses of the respective channels, according to intelligence to be conveyed thereby. The identifying characteristic may involve the shape of the pulses or it may comprise a frequency signal selected outside of the frequency band of the intelligence with which the channels are modulated.

It is acknowledged that a system has been proposed heretofore for multiplex communication between two points by interleaving the signals of a plurality of channels, the signal of each channel varying in amplitude according to intelligence for such channel. The receiver for that multiplex system was synchronized to the transmitting sequence by including a further channel, the amplitude of which was made greater than the average maximum amplitude of the other channels. That type of multi-channel transmission, however, has a number of disadvantages among which are the following: The transmitter-rereiver circuits, for example, must have accurate linear characteristics to avoid intermodulation and distortion. Because of the amplitude modulation feature of such system, limiters cannot be used for minimizing interference, and the maximum signal-to-noise ratio obtainable for the expenditure in band width cannot be realized, and further, the average power required varies. In the case of "fading" present in AM systems, the effects thereof are amplified through all repeaters which may be used to extend the range of the system thereby necessitating the use of A. V. C. circuits. The receiving circuits must also have accurate linear characteristics.

According to the pulse modulating principles of our invention, we overcome the disadvantages present in amplitude modulation systems since modulation of intelligence by our invention involves the time relation of the pulses as distinct from amplitude, while the synchronizing signals utilize pulse shape or time modulation outside the frequency band of the intelligence with which the channels are modulated.

The interleaved channel pulses are broadcast according to our invention over an antenna located at a vantage point such as at the top of the highest building of a city or on a tower located at some other high elevation within the area to be served. The antenna preferably is of the omni-directional type although it may have certain directional characteristics if desired. Certain channels may be assigned to local studios located within the area of the broadcasting station and others may be assigned to national broadcasting chains. All of the channels are broadcast in the form of pulses interleaved in a single train at a common carrier frequency. This clearly permits the broadcasting of a plurality of different programs from one high point so that receivers located within the range of the station may be equipped with directional antennas arranged in alignment with the antenna of the transmitting station. The directional antenna of the receivers may be fixed in position and the tuning for different programs effected by time selection of the channels, the time selection being based upon the timing of the synchronizing channel. This selection of stations by time relation is, of course, independent of the carrier frequency used. Thus, a simple and universal tuning mechanism may be used which remains unchanged regardless of the band of frequencies used for the broadcast system. The receiving antenna, of course, need not be directional but for best reception with a minimum of reflection interference from buildings and the like, the directional type will, in most cases, be preferred. Furthermore, the directional receiving antenna need not be fixed on one broadcasting antenna but may be adjustable for alignment with other broadcasting sources.

A further feature is that intermodulation due to lack of sufficient frequency selectivity is avoided by the use of the time sequence of channels.

The above and other objects and features of the invention will become more apparent upon consideration of the following detailed description to be read in connection with the accompanying drawings, in which:

Fig. 1 is a diagrammatic panoramic view of New York city and vicinity illustrating the centralized multi-channel broadcasting principle of our invention;

Fig. 2 is a block diagram of a multi-channel broadcastng system utilizing pulse width as the distinguishing characteristic for the synchronizing channel;

Fig. 2A is a block diagram illustrating the synchronizing channel portion of a modified multi-channel broadcasting system;

Fig. 3 is a schematic wiring diagram of a phase shifter, time modulator and pulse width shaper for one of the channels of the system of Fig. 2;

Fig. 4 is a graphical illustration used in explaining the operation of the circuit of Fig. 3;

Fig. 5 is a block diagram of a radio receiver capable of selectively receiving channels transmitted by the system of Fig. 2;

Fig. 5A is a modified form of radio receiver for use with the modified broadcasting system illustrated by Fig. 2A;

Fig. 6 is a graphical illustration used in explaining the receiving operations of Figs. 5 and 5A;

Fig. 7 is a block diagram of another modified form of multi-channel broadcasting system employing pulse frequency modulation; and

Fig. 8 is a graphical illustration used in explaining the multi-channel transmission of Fig. 7.

Referring to the panoramic view of New York city and vicinity shown in Fig. 1, the multi-channel broadcasting station is shown located, for illustrative purposes, in the Empire State building **10** which affords the highest centralized location for the broadcasting antenna **12**. The antenna may be of any known omni-directional type. The building may house several of the studios while other studios and sources of signals may be located in still other buildings as indicated at **2**, **3** and N, each studio being connected by line to the control room of the broadcasting station. By this arrangement a number of programs is supplied for modulation of different trains of pulses which, when properly timed, interleave in sequence to form a single train of pulses to modulate a single transmitter for simultaneous transmission at a common carrier frequency F_1 over antenna **12**. Thus each studio, rather than being identified by an individual transmitting frequency, is represented by a train of pulses interleaved in time position with the pulses carrying programs from other studios. Listeners at receiving points such as **21**, **22**, **23**, **24** and **25** tune their respective receivers by time channels rather than frequency to choose a desired one of the programs transmitted.

In addition to the selective reception, the multi-channel transmission may be relayed by repeated broadcasting stations where the receiving antenna thereof is in visual alignment with the transmitter antenna 12 as indicated at 26. If the repeater broadcasting station is beyond range as indicated at 27, relay repeaters such as indicated at 28 and 29 may be located at appropriate points in-between. The repeater broadcasting systems rebroadcast the channel pulses after amplification either at the same or at different carrier frequency, as the case may require.

In Fig. 2, the separate studios are shown connected by lines to one or more pulse modulating channels of the system. Studio 1, for example, is shown connected through switch 30 to channel 1 which includes a modulator 32 indicated, for example, as P. T. M. (pulse time modulator) coupled to a pulse width shaper 34. The modulator 32 is controlled by a base wave produced by generator 35. The additional pulse modulating channels are also controlled by the base wave from generator 35 but the timing thereof is controlled by individual phase shifters as indicated at 36 for channel 2, the difference in timing with respect to channel 1 being indicated by the symbols t_2, t_3, etc. The modulation of the pulses of each channel may be controlled by an appropriate switching arrangement as indicated at 37 and 38. The synchronizing pulses of channel 1 may or may not be modulated with program intelligence as may be inferred from the use of switcn 30. For conservation of space in the train of channel pulses, it is best to maintain the synchronizing pulses free of programs for with a program the time modulation thereof would also vary the deblocking pulses in a like manner. This would, therefore, require much greater interval between the pulses of adjacent channels, otherwise "cross-talk" might result.

Since one of the channels is to be used for synchronizing the receivers, as one method it is necessary to characterize the pulses thereof with a width distinct from the width of the pulses of other channels. In Fig. 2, this is accomplished by differently shaping the width of the pulses for channel 1. This is done by adjusting the pulse width shaper 34 to a width different from the pulse widths determined by the pulse width shapers 42, 43, etc. This method of identifying the synchronizing pulses is clearly shown by curve 6a of Fig. 6. The pulses of channel 1 are considerably wider than the pulses of the other channels which, in this case, comprise a given narrow width. The interleaved train of channel pulses produced at the outputs of the shapers 34, 42, 43, etc., is applied to a carrier translator 50 for translation to a common carrier frequency to be transmitted over omni-directional antenna 12. The antenna shown is of the type disclosed in U. S. patent to A. Alford, 2,283,897.

Studio 3 is shown in Fig. 2 to be connected to two different channels. This is to indicate that a given studio may have more than one channel for broadcasting purposes. It will also be understood, in this connection, that while in existing broadcasting systems programs are generally transmitted for voice and musical programs, other types of intelligence may also be transmitted. For example, pulses may be transmitted in this manner as facsimile signals, the pulses being used directly as the facsimile build-up characters. The transmitted pulses may also constitute a sound track for television as well as synchronizing pulses required for controlling the line and frame scanning in facsimile and television transmission. In addition, the two channels may serve for binaural sound transmission for a single program.

The multi-channel broadcasting system may be provided with synchronizing signals by means other than characterizing the shape of the pulses. In Fig. 2A, a synchronizing channel is shown which may be substituted for the synchronizing channel 1 in Fig. 2. The modulator 32a is supplied with signals of frequency f_1 from source 52. This frequency is selected outside the frequency band of the intelligence with which channel 1 and the other channels are modulated. If desired, the frequency of the signal may be selected within the lower and upper band limits of the intelligence frequency but, in that case, each studio channel would require a filter for removing the selected frequency from the intelligence. It is to be understood, however, that where we specify that the synchronizing signal is selected outside of the intelligence, we intend to include a selection arrangement of this character.

Fig. 3 shows a circuit of one form of P. T. M. modulator 32a such as may be employed in the channels of the systems of Figs. 2 and 2A, together with a phase shifter 36a and a pulse width shaper 34a. The phase shifter 36a comprises a condenser-resistor network C—R_1R_2, the relative values of which determine the phase shift of the base wave applied thereto from base wave generator 35, Fig. 2. Assuming that there is no phase shift of the base wave required as in the case of channel 1, then the wave may be regarded as of the phase position indicated by wave 70 in curve 4a, Fig. 4, when applied to primary coil 72 of the coupling transformer 73.

The modulator circuit includes two secondary coils 74 and 75 coupled to the control grids of two vacuum tubes 76 and 77 in push-pull arrangement similar to a full-wave rectifier. The modulator amplifies and, in effect, full-wave rectifies the wave 70, curve 4a, Fig. 4, to obtain a cusper wave 80, curve 4b. Curve 4c shows the cusper wave 90 for channel 2 determined in time position by the phase position 70a, curve 4a, of the base wave.

Time modulation of the cusper wave is produced by applying the signal intelligence over input connection 82, with respect to ground, to primary coils 83 and 84 on the transformer 73. While the rectification of these waves may be symmetrical relative to zero axis 67, it is shown for purposes of illustration as being offset by different biasing potentials 65 and 66. This gives the effect of an offset axis 67a about which modulation takes place. The signal intelligence operates, in effect, to vary the wave 70 relative to its offset axis 67a as regards the full-wave rectification. This relative variation between the wave and the zero axis thereof is illustrated in curve 4a by the upper and lower modulation limits 86 and 87. When the input signal varies the relative relation between the offset axis 67a and the wave 70 as indicated by limit 86, the cusper wave 90, for example, is displaced as shown by the broken line 90a, and when varied to the opposite limit 87 it is displaced as shown by broken line 90b. It will be observed that the signal wave thus varies the time positions of the cusps 91, 92, 93 and 94 in push-pull manner toward and away from each other thereby decreasing or increasing the time interval between successive cusps.

For transmission purposes, the cusps are clipped from the wave and, if desired, may be shaped to form substantially rectangular pulses. A suitable shaper circuit is shown at **34a**, Fig. 3, it being understood, however, that other known shapers may be used instead. By providing each channel with a shaper circuit of this character, the shape of the pulses of each channel may be controlled.

The shaper **34a** may be of any known character capable of clipping between two desired levels, but preferably is of the character disclosed in our copending application, Serial No. 437,530, filed April 3, 1942. It comprises a double diode clipping circuit wherein the plates of the two diodes **101** and **102** are connected together and the cathode of tube **101** is connected through coupling condenser **103** across the load resistor **104** of the modulator **32a** The cathode of diode **101** is connected through a resistor **106** to a potentiometer **107**. The plates of the two tubes are connected through a resistor **108** to a second potentiometer **109**. The cathode of the tube **102** is connected through a resistor **110** to ground.

The two diodes **101** and **102** operate together as a gate clipper for clipping the cusper wave **80**, for example, between limit levels **111** and **112**, curve **4b**, the width of the gate being controlled by the adjustment of potentiometer **107** and the position of the gate relative to the wave is controlled by adjustment of the potentiometer **109**. The gate position of the clipping levels **111** and **112** on wave **80**, produces a pulse of the width W_1, curve **4d**. The pulse **1a** of curve **4d** is shown to be amplified, it being understood that the pulse width shapers may include one or more amplifying stages as indicated at **115**.

For channel 2, the cusper wave **90** is clipped at gate levels **113** and **114** as indicated in curve **4c**. These different gate levels are effected by adjusting potentiometer **109**. This gate clipping results in the pulse width W_2 which is less than the width W_1. It will thus be clear that by proper adjustment of the shaper circuits, the pulses of any channel such as channel **1** may be made distinctive from the pulses of the other channels. This distinction in width is shown in curve **6a**, Fig. 6, the wider pulses of channel **1** being used as synchronizing pulses for the receivers.

Referring to Fig. 5, we have shown in block diagram a receiver of the character synchronizable to the transmission sequence of the channel pulses by means of the distinction in pulse width between the synchronizing channel and the other channels of the system. The receiver includes a carrier frequency amplifier and detector **120** whereby the carrier pulses of curve **6a** are translated into the video pulse form of curve **6b**. The video pulses are applied to a synchronizing channel selector **122** which, in this case, may be a pulse width discriminator of any known type.

If desired, a pulse width discriminator of the character disclosed in our copending application, Serial No. 437,072, filed May 15, 1943, now Patent No. 2,440,278, may be employed. This width discriminator includes a resonant circuit which is shock-excitable in response to the leading and trailing edges of the pulses and a damping circuit having a vacuum tube connected across the resonant circuit for damping out the oscillatory energy following one or two undulations, as the case may be. The output from the circuit is provided with a threshold clipper stage which is adjustable to pass energy in response to undulations produced from pulses of a width corresponding to the tuning of the resonant circuit. Should the pulses be of a width different from one-half the period of the frequency to which the circuit is tuned, the undulations thereof will be less than that required to produce conduction in the threshold clipper stage. Thus, pulses varying in width from the desired width are blocked, pulse energy being passed by the clipper stage only in response to undulations produced from pulses of the desired width.

The output pulse energy from the synchronizer channel selector **122** is applied to an adjustable delay device **125** which, preferably is of a known form of pulse translation type of delay circuit, whereby the pulse energy may be adjusted in time with reference to the timing of the synchronizing pulses. The retarded pulse energy of the device **125** is applied to a mixer **126** to which is also applied the video pulse output of the detector **120**. It will be understood, of course, that the pulse output of the selector **122** may be shaped to provide a pulse of a width corresponding to the total time "space" occupied by the pulses of each channel throughout the maximum limits of modulation thereof. This output pulse energy **1b** which we call "deblocking" pulses is shown by curve **6c**. Retardation of the pulse energy is shown to be an amount t_4 thereby aligning the deblocking pulses **1b**, as shown in broken line, with the pulses of channel **4**. Curve **6d** represents the mixer action whereby the deblocking pulse **1b** lifts the pulses of channel **4** above the threshold level **127** of the mixer **126**. Thus, the mixer passes only pulses of channel **4** to the demodulator **130**. The demodulator **130** may be, in the case of P. T. M. modulation, of the character disclosed at **130a** in Fig. 5A, whereby the pulse displacement is translated into amplitude modulated pulses and applied to filter **132** where the envelope energy of the pulses is obtained for application to the speaker **134**.

The receiver circuit of Fig. 5A is a modification of the receiver of Fig. 5, adapted for synchronization by a synchronizing signal of the character employed by the transmitter circuit of Fig. 2A. The video output of the detector **120** is fed over line **140** to a mixer tube **142**. At the same time, deblocking pulses from a pulse generator **144** are fed over line **146** to a second grid of the tube **142**. The pulse generator **144** is controlled by the control wave produced by generator **143** whose period of operation is slightly greater than the period T of base wave **70** employed at the transmitter (see wave **4a**, Fig. 4, and wave **6b**, Fig. 6). These deblocking pulses serve to produce in conjunction with the incoming pulses timed to add thereto an ouput series of pulses from tube **142**. Assume, for example, that pulses of channel **1** of curve **6a** are applied over line **140**, the deblocking oscillator will operate to produce a plurality of rectangular pulses such as **1b** of curve **6c** timed in spaced relation according to the pulses of channel **1**. Tube **142** is also biased in the proper manner so that only the boosted pulses of channel **1** appear in the output thereof, A. D. C. restorer rectifier tube **150** may be provided across the input from deblocking oscillator **144** to eliminate the effect of variation of the peak value of the incoming deblocking pulses and thus provide a proper level to work with the mixer circuit of tube **142** to leave only the desired channel pulses in the output of the tube 142.

The output pulses from tube 142 have the same cadence frequency T as the original modulated pulses produced at the transmitter, Fig. 2. The pulses of the plate circuit of tube 142 are applied through a phase reverser 151 to the control grid of the demodulator tube 154 and cause tube circuit 156 connected to the screen grid of the tube to oscillate at a desired frequency producing in the output circuit 157 a combined wave in the form of a combination of the wave generated in the circuit 156 and the incoming pulses from tube 142. The circuit 156 is preferably tuned to some harmonic of the cadence frequency as determined by the period T, curve 6*b*, so that as the pulses are displaced due to modulation signals the output pulses of tube 154 will be raised to different levels depending upon their time displacement. Accordingly, in the output of tube 154 will appear a modulation envelope of pulses carrying signal modulations according to the amplitude measurements thereof. For a further understanding of the principles of this type of demodulator, reference may be had to the copending application of D. D. Grieg, Serial No. 459,959, filed September 28, 1942, now Patent No. 2,416,306.

A low-pass filter 160 is provided to by-pass the high frequency pulse components and pass on the modulation frequencies that define the signal envelope. The channel synchronizing signal is passed over filter 161 tuned to pass only the synchronizing frequency such as f_1, Fig. 2A, which in turn serves to synchronize the operation of the control wave generator 143. Since the pulses of channel 1 are modulated with the synchronizing signal frequency f_1, the generator 143 will be controlled thereby and the deblocking pulse output of generator 144, which may be of the "cusper" type the same as modulator 32*a*, Fig. 3, with suitable shaper, is timed to continuously deblock the pulses of channel 1. In the absence of a synchronizing frequency signal on the pulses passed by the tube 142, no synchronizing pulse energy will be passed by the filter 161 and the control wave generator 143 will continue to operate at a frequency slightly different from the cadence frequency T. The wave output of generator 143 will thus continue to cause the channel pulses to be deblocked in rotation until the pulses of the channel carrying the synchronizing frequency signal f_1 are deblocked, whereupon the generator 143 is brought into synchronism.

For channel selecting, the deblocking pulses of generator 144 are applied to adjustable delay device 145, whereby the pulses are retarded a selected amount such as t_4, for example, for deblocking pulses of channel 4. The retarded pulse energy is applied to mixer 170 together with channel pulses over connection 172. The channel pulses passed by the mixer may then be applied to a reproducing circuit such as indicated at 130 (which may be of the type shown at 130*a*, Fig. 5A), 132 and 134 of Fig. 5. Since the control generator 143 is synchronized to the transmitter, alternatively for demodulation, the output of generator 143 shown in Fig. 5A may be applied to a harmonic generator 180 the output of which is suitably phased at 182 and applied to mixer 184 together with channel pulses from mixer 170. The channel pulses are thus translated into amplitude modulated pulses according to their occurrence on the harmonic wave as more particularly described in the aforementioned copending application, Serial No. 459,959.

In Fig. 7, a broadcasting system according to the principles of our invention is shown wherein the pulses are modulated according to frequency or recurrence rate, that is, the modulating signal causes a variation in the time interval between successive pulses according to the instantaneous value of the signal. This type of modulation we call P. F. M. (pulse frequency modulation). The system of Fig. 7 is along the same lines of the system shown in Fig 2. A base wave generator 35 is employed to control the timing of the pulses for the different channels. The timing between channels is controlled by a series of phase shifters such as phase shifter 36 for channel 2. Channel 1, in this embodiment, is not provided with a modulator since the pulses of this channel are used as synchronizing pulses only. The base wave from generator 35 is translated directly into pulses of the desired width by a suitable wave-to-pulse translator 200. The base wave after having been shifted the desired amount by shifter 36 is applied to the FM modulator 202 for channel 2. The output of the modulator is applied to a translator 204 which may be similar to the translator 200 except that it is arranged to shape the pulses to a width different from the width of the synchronizing pulses. The additional channels of the system follow the arrangement of the channel 2. Thus, an output of channel pulses similar to those shown in curve 6*a* of Fig. 6 will be produced by the system of Fig. 7. Such a curve is shown for three channels, for example, by curve 8*b*, of Fig. 8.

For selective reception, a receiver of the character shown in Fig. 5 is employed, the demodulator in such case being an integrator circuit measuring the variation in average value of the pulses with modulation.

To illustrate further the fact that P. F. M. modulation may be applied to pulses in a multichannel system, the pulses of channel 2 in curve 8*b* are shown modulated according to the principles of P. F. M. modulation by a signal wave 220 shown by curve 8*a*, Fig. 8. The limits of pulse displacement according to the principles of P. F. M. modulation are selected so that the modulation will not interfere with the pulses of adjacent channels. The frequency modulation of the pulses caused by the signal 220 is indicated by the broken line positions of the pulses of channel 2. Assuming that a normal interval of t exists between the pulses of channel 2 in the absence of modulation, then as a positive signal is applied as shown at point 221 on wave 220, the pulse corresponding to such instantaneous signal value will be spaced from the preceding pulse by an interval $t+\Delta t$. Should the signal value increase a corresponding amount from point 221 to 222, the interval between the channel pulses occurring at these two points is $t+2\Delta t$. At the next point 223 of pulse occurrence on the curve the signal value is shown to be the same as at 222, therefore the interval between points 222 and 223 will also be $t+2\Delta t$. A decrease in the signal value to pulse recurrence point 224 will decrease the interval proportionately as indicated by the interval $t+\Delta t$. Since the next pulse occurrence point 225 is substantially at zero signal value, the interval between points 224 and 225 will be t representing zero potential for the signal. A swing of the signal in the negative direction causes the intervals between pulses to decrease as shown for the negative portion 220*a* of the signal wave. During this oscillation of the signal wave, it will be noted that the variation in pulse spacing causes the pulses to be displaced from normal positions throughout the cycle until the wave returns to the zero center line **240**. By controlling the limits of signal swings or by limiting the degree of FM modulation of P. the base wave at the transmitter, the pulses can be maintained within the allotted limits between pulses of adjacent channels in the train of pulses.

From the foregoing description, it is readily apparent that our invention provides maximum usage of the optimum transmitting location of each service area. Rather than a single station at each location, many stations or studios may now have equal advantage of such a location thereby resulting in improved and more uniform service to the public.

Furthermore, greater efficiency and lower cost operation results due to the elimination of the duplication of transmitter and antenna installation as required by the present existing system. The relative simplicity of the pulse method of modulation, aside from the question of multiplexing, allows further economy in operation. This is especially true at the very high frequencies where transmitting equipment such as magnetrons and Klystrons must be used.

An objection might be raised relative to the excessive band width required for the pulse method of transmission. However, in actuality the band width necessary for equivalent transmission, is equal to, or even somewhat less than that required for existing FM broadcasting. Assume that a top audio frequency of 14 or 15 kc./sec. is required for high fidelity transmission. Since the ratio of pulse frequency to the highest modulation frequency for the pulse system may be assumed of the order of four, the fundamental pulse frequency required is approximately 50 kc./sec. This allows a timing of 20 microseconds between the pulses of each channel. If it is further assumed, as a hypothetical example, that a total of ten channels are required, which is probably an adequate number for servicing a given broadcast area, a maximum timing of two microseconds is allowed between pulses of adjacent channels. This time interval must include the pulse width as well as the modulation displacement. In order to achieve a satisfactory signal-to-noise ratio, a pulse build-up time in the neighborhood of 0.25 microsecond would be required, which would necessitate a modulation band width of approximately 1.4 megacycles. For double sideband R. F. transmission the total required band width for the ten channels would thus be 2.8 megacycles.

In the case of frequency modulation, for the same top audio frequency mentioned previously, current practice is to utilize a modulation index of five with a modulation swing of ±75 kc., requiring an R. F. band width of 0.25 megacycle per channel. For the total of ten channels plus the frequency guard channels, a total of approximately 3.0 megacycles band width is required. Thus it is seen that the band width necessary for both the pulse and FM systems of modulation for ten channels is of substantially the same order of magnitude.

There are further advantages to be mentioned for the pulse broadcast system. At the receiving location no R. F. tuning is required of the receiver since a common carrier frequency is used for all stations. A fixed carrier frequency tuned receiver may thus be used, and since station selection takes place after detection, a simpler and

more economical receiving system may be utilized as hereinbefore described. Furthermore, there is no antenna problem arising from the reflection effects from nearby buildings because of the single transmission point. Thus a simple fixed directive antenna can be used for receiving all stations.

An important advantage of the multiplex broadcast method is the simplicity of relaying. A nationwide broadcast relay system linking the important service areas may be built-up in which one series of stations operating at a common carrier frequency provides the relay requirements for the several different broadcasting stations or studios. In the case of FM, as many separate and duplicating relay networks would be required as there are stations. Thus, for the example of ten broadcast stations given previously, ten separate relay nets for FM would be necessary as compared to a single network for the pulse system. In addition, of course, aside from the economies realized by avoiding duplication by means of pulse multiplexing, there are the inherent advantages to be gained from the fact that the pulse method is particularly adapted for relaying operation.

While we have described above the principles of our invention in connection with specific apparatus and particular modifications thereof, it is to be clearly understood that this description is made only by way of example and not as a limitation on our invention and the scope of the accompanying claims.

We claim:

1. A broadcasting system comprising a transmitting antenna mounted at a vantage point to transmit energy over a designated area, means for producing a plurality of series of signal pulses, each series constituting a separate signal channel, means for interleaving all of said series of pulses, means for modulating the signal pulses of each channel according to the intelligence to be transmitted during their respective channels, means for modulating a carrier wave of a given frequency with the resultant pulse train, means for feeding the modulated carrier wave to the transmitting antenna for radiation of energy therefrom, a plurality of separate points for producing signals to provide the aforesaid intelligence modulation of the signal pulses; and a receiver comprising means for receiving signals of said given carrier frequency over a directive receiving antenna aligned to receive from said transmitting antenna, means for removing the carrier frequency from said received signals to reproduce the signal pulses, adjustable selecting means for separating the signal pulses of a desired channel, demodulating means for translating the modulation of the selected separated signal pulses into another form of modulation, and a utilization device responsive to said other form of modulation.

2. A broadcasting system according to claim 1 wherein characteristic synchronizing pulses separate the signal pulses into cyclically recurring groups, and means in the adjustable selecting means of the receiver responsive to the synchronizing pulses.

3. The method of broadcasting from a plurality of studios a plurality of signal channels over a single carrier frequency comprising the following steps: producing a plurality of groups of cyclically recurring signal pulses, each recurring pulse constituting a separate signal channel, modulating the pulses of each channel to vary the time positions thereof according to the intelligence for their respective channels, transmitting signals

from the studios for producing the aforesaid time modulation of the pulses, modulating a carrier wave of a given frequency with the resultant pulse train, radiating omni-directionally the modulated carrier wave from a common vantage point, directively receiving the radiated wave substantially in alignment with the point of radiation of the modulated carrier wave, removing the carrier frequency to reproduce the signal pulses, selecting the pulses of a desired channel, separating the pulses of said desired channel, and demodulating the time modulated pulses.

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