April 9, 1946. P. BERNSTEIN 2,397,913

MULTIPLEX RADIO SYSTEM OF THE CARRIER FREQUENCY SHIFT TYPE

Filed July 19, 1944

Fig. 1.

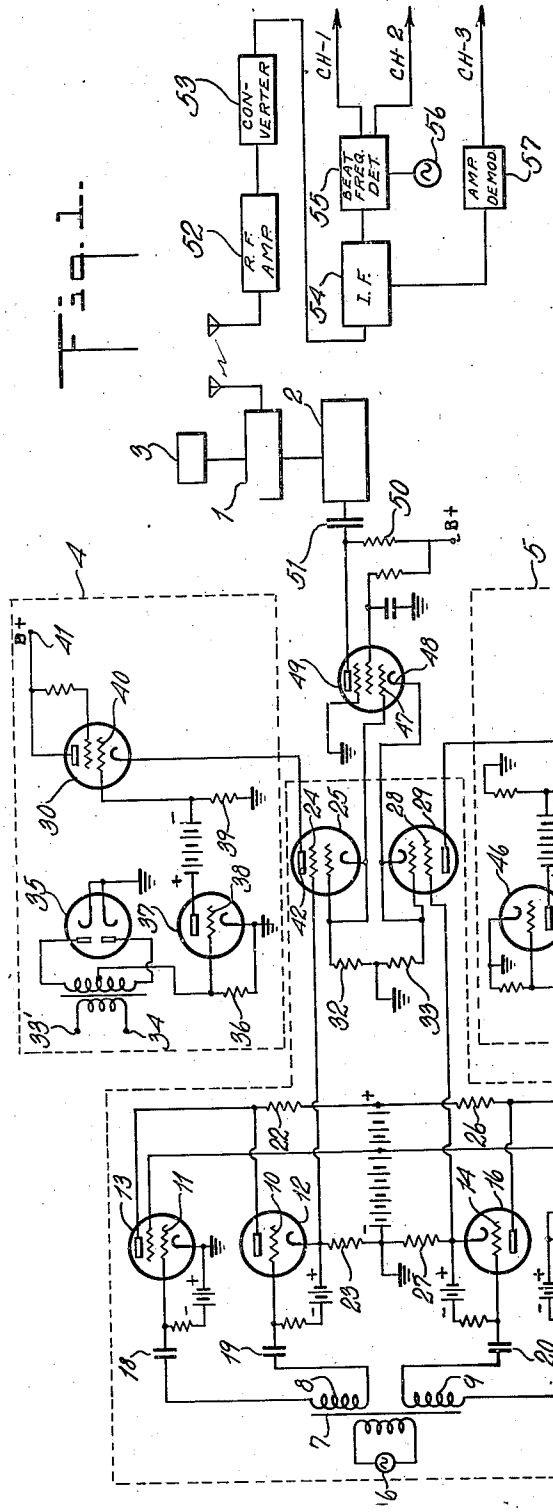
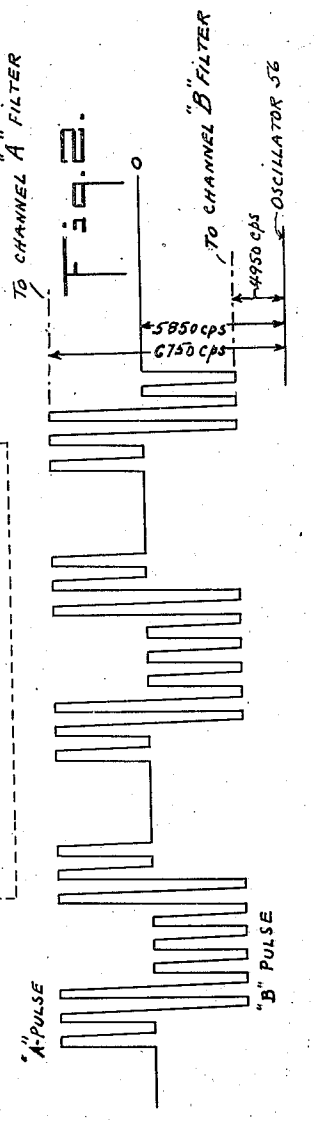



Fig. 2.

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Patented Apr. 9, 1946

2,397,913

# UNITED STATES PATENT OFFICE

2,397,913

## MULTIPLEX RADIO SYSTEM OF THE CARRIER FREQUENCY SHIFT TYPE

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Application July 19, 1944, Serial No. 545,629

10 Claims. (Cl. 250—9)

This invention relates to multiplex radio systems and more especially to such systems using carrier frequency shift.

One of the principal objects is to extend the usefulness of an existing radio service transmitter by fully employing the frequency tolerance limits of the normal assigned service frequency of the transmitter.

Another principal object is to provide a method of operating an existing radio service transmitter by the carrier frequency shift method, whereby it is possible to key the transmitter to two or more channels simultaneously, without the usual loss of power, and without the phase distortion and troublesome side bands encountered with well-known modulated-tone multiplex methods.

A further object is to provide an improved shift-control arrangement for multiplex radio transmitters of the carrier frequency shift type.

A feature of the invention relates to an electronic tube switching arrangement for controlling the effectiveness of a plurality of carrier frequency shift channels.

A further feature relates to the novel organization, arrangement and relative interconnection of parts which cooperate to provide an improved and highly flexible multiplex radio service system.

Other features and advantages not specifically enumerated will be apparent after a consideration of the following detailed descriptions and the appended claims.

In the drawing which represents one preferred embodiment,

Fig. 1 is a schematic wiring diagram of a transmitter and receiver system embodying the inventive features.

Fig. 2 is an explanatory wave diagram applicable to Fig. 1.

Referring to Fig. 1, the transmitter portion of the system comprises any well-known type of radio service transmitter 1, which generates a carrier having an assigned service frequency with certain fixed frequency tolerances on either side of the assigned frequency. Associated with the transmitter is an arrangement 2, for shifting the carrier frequency between fixed limits under control of signals to be transmitted. Transmitter 1 has also associated therewith amplitude modulation equipment 3, whereby another signal can be simultaneously transmitted by amplitude modulation of the frequency shifted carrier. For a detailed description of the arrangements 2 and 3, reference may be had to application Serial No. 498,278, filed August 12, 1943.

In accordance with the present invention, the carrier shift device 2 is arranged to be keyed by two separate message channels 4 and 5. For this purpose, the channel 4 is arranged to shift the carrier frequency of the transmitter 1 a predetermined amount above its normal assigned frequency; while channel 5 is arranged to shift the carrier frequency a predetermined amount below its normal assigned frequency. Each of the channels 4 and 5 is controlled at a predetermined frequency rate by means of a common master oscillator 6, whose frequency determines the rate at which the transmitter 1 is shifted in frequency. For example, the normal assigned frequency of transmitter 1 may be 10,000 k. c., and the oscillator 6 may operate at a frequency of 0.9 k. c.

The control oscillator 6 is connected to the primary of the audio frequency transformer 7 which has two similar secondaries 8 and 9. The secondary 8 has its opposite ends connected respectively to the control grids 10, 11, of the gas triode 12 and the vacuum-tube amplifier 13. Likewise, the secondary 9 has its ends connected to the grids 14, 15, of gas triode 16 and vacuum-tube amplifier 17. Tubes 12 and 16 may for example be of the 884 Thyratron type, while tubes 13 and 17 may be of the beam power type such as a 6L6. The secondaries 8 and 9 are connected to the respective grids through condensers 18, 19, 20 and 21. Each pair of tubes 12, 13, and 16, 17, acts respectively on the half waves from source 6 to convert them into square-topped pulses as indicated in Fig. 2. The transformer secondaries are so phased that they excite the grids 11 and 14 in like phase; and they excite the grids 10 and 15 also in like phase but 180 degrees displaced with respect to the excitation of grids 11 and 14. Consequently, when a positive pulse is impressed on grids 11 and 14, a negative pulse is simultaneously impressed on grids 10 and 15. With a positive pulse on grid 11, the plate current of tube 13 will rise and cause an increase in voltage drop in the plate load resistor 22. This also causes a decrease in the plate voltage applied to the gas triode 12 to such an extent that the plate current thereof is extinguished. This abrupt break in the conductivity of tube 12 is further accelerated by the fact that at the same time the negative pulse is applied to grid 10. The plate-to-cathode return circuit of tube 12 includes a resistor 23, and the voltage drop in this resistor provides the normal positive D. C. potential for the second grid 24 of a tetrode amplifier tube 25, the first grid of which is connected directly to the cathode. Thus, tubes 12 and 13 cooperate to control the "on" and

"off" D. C. voltage applied to the grid 24 of tube 25. At the same time the foregoing action is taking place, a positive impulse is being applied to grid 14 and a negative pulse to grid 15. At a result, the plate current of tube 17 decreases and the drop in resistance 26 decreases, causing the plate potential of tube 16 to rise to striking level whereby current flows through resistor 27. This applies a positive D. C. potential to the second grid 28 of the tetrode amplifier tube 29. In other words, the 0.9 k. c. control signal from source 6 causes the grids 24 and 28 of tubes 25 and 29 to be alternately and recurrently keyed "on" and "off" in synchronism with the half waves from source 6.

However, the plate conductivity of each of the tubes 25 and 29 is also dependent upon the application of plate potential thereto. For this purpose, the plate potential for tube 25 is applied through the plate-to-cathode space of another tetrode 30 and likewise the plate potential for tube 29 is applied through the plate-to-cathode space of a similar tetrode 31. If tubes 30 and 31 are at plate current cutoff, no plate potential is applied to the respective tubes 25 and 29 with the result that no voltage appears across the cathode load resistors 32 or 33. The tubes 30 and 31 are in the respective keying control channels 4 and 5. Thus, when a keyed tone is applied to the input terminals 33', 34 of channel 4, it is rectified in the full-wave rectifier 35, and this rectified voltage flows through resistor 36 in the grid circuit of the triode 37, causing the grid 38 thereof to be negatively biassed to plate current cutoff. Under this condition, no voltage is developed across the load resistor 39. Consequently, no bias is applied to the control grid 40 of tube 30. Under this condition, plate current flows through tube 30 and applies a steady D. C. positive potential from power supply terminal 41 to the plate 42. This application of potential causes current to flow through resistor 32 but only during the half cycle of the shift-control frequency from source 6 that appears on the grid 24. During the "space" intervals of the keying channel 4 when no tone is present at the terminals 33' and 34, no rectification occurs in tube 35, hence there is no bias drop across resistor 36. Therefore, plate current flows through tube 37 and produces a voltage drop across resistor 39 of sufficient magnitude to block the plate current through tubes 30 and 25, regardless of the fact that positive pulses of voltage may be applied to the grid 24. Summarizing the above description, when a keyed tone signal appears at terminals 33' and 34, the current pulses from control source 6 produce voltage drops across resistor 32 at the rate of 0.9 k. c. per second. This action occurs during the "mark" intervals of a channel 4. During the "space" intervals of this channel, no voltage drops appear across resistor 32.

A similar action occurs when a keyed tone is applied to the input terminals 43, 44, of channel 5. These signals being rectified in the full-wave rectifier 45, to control the cutoff bias of tube 46, similar to tube 37, and consequently the cutoff bias of tube 31. Therefore, a "mark" signal in channel 5 produces a voltage drop across resistor 33. When the channels 4 and 5 are on "space" i. e., no tone signals are applied to the input terminals thereof, no voltage drops appear across the respective resistors 32 and 33, and transmitter 1 remains at its normal assigned frequency.

The resistors 32 and 33 are connected in balanced relation across the control grid 47 and cathode 48 of a vacuum-tube amplifier 49 which, for example, may be of a pentode type. Therefore, when both channels 4 and 5 are on space, the bias on control grid 47 is slightly negative and plate current flows through tube 49 to develop a corresponding voltage across the coupling resistor 50, which voltage is applied through a small coupling condenser 51 to the frequency shifter device 2 as described in said application Serial No. 498,278, filed August 12, 1943. The device 2 responds to these potentials to maintain the carrier frequency of the transmitter 1 at its normal assigned frequency. The extent of frequency shift in the carrier is related to the amount of plate current flowing through tube 49. Therefore, when channel 4 is receiving a "mark" signal, the voltage drops across resistor 32, occurring at the rate of 0.9 k. c. per second, trigger the control grid 47 in a positive direction thus causing the frequency shifter 2 to shift the carrier to a higher frequency above its normal assigned frequency and then back to its assigned frequency at a rate of 0.9 k. c. per second. When channel 4 is receiving a space signal and channel 5 is receiving a mark signal, the voltage drops across resistor 33 produce negative bias pulses on the control grid 47, thus shifting the carrier frequency below its normal assigned frequency and back to its normal assigned frequency at the shift rate of 0.9 k. c. per second.

When both channels 4 and 5 are simultaneously receiving mark signals, voltage drops are alternately produced across resistors 32 and 33 of opposite polarity at the rate of 0.9 k. c. per second, causing grid 47 to swing positive and negative alternately and shifting the normal service frequency of the transmitter 1 to frequencies above and below the said normal frequency at the frequency shift rate of 0.9 k. c. per second.

As described in detail in said application Serial No. 498,278, the frequency shifted carrier of the transmitter 1 may simultaneously be amplitude modulated from a suitable source 3 representing a third signal.

At the receiver the shifted frequency carrier is applied to an R. F. amplifier 52, and then to a frequency converter 53, such as ordinarily used in superheterodyne receiving systems. The resultant intermediate frequency signal is applied to the usual intermediate frequency amplifier 54, and the output thereof is applied to a suitable beat detector 55, which is supplied with local oscillations beating frequency from the source 56 as is well-known in the art. Oscillator 56 may be such that two beat frequencies e. g., 4950 and 6750 C. P. S., are alternately produced in the output of device 55. These beat frequencies can be passed through suitable filters and applied to respective signal producing or indicating devices. For the purpose of detecting the amplitude modulations originating at device 3 in the transmitter, a portion of the output of amplifier 54 can be applied to a suitable amplitude demodulating detector 57 of any well-known type, whereby the amplitude modulations representing the third signal can be applied to a separate indicating or reproducing device.

Fig. 2 illustrates diagrammatically the manner of separating the two beat frequency channels at the receiver. An inspection of this figure will show that "A" indicates that the channel 4 frequency is 900 C. P. S. above the normal carrier

frequency and appears as a 6750 C. P. S. beat. "B" indicates that the channel 5 frequency is 900 C. P. S. below the normal carrier frequency and appears as a 4950 C. P. S. beat. Channel 4 is thus illustrated as producing keying dots at a speed of 300 C. P. S. (750 words per minute Continental code). Each dot pulse is broken up into three segments representing the frequency shift rate of 900 C. P. S. Each segment therefore, will contain roughly three and one-half cycles of the 6750 C. P. S. channel 4 beat frequency. Likewise, channel 5 is illustrated as producing keying dots at a speed of 150 C. P. S. (375 words per minute Continental code). Each dot pulse is broken up into six segments representing the shift rate of 900 C. P. S. Each segment, therefore, will contain roughly two and one-half cycles of the 4950 C. P. S. channel 5 beat frequency. It will be understood that the frequencies mentioned in the foregoing description serve merely for purposes of illustration. The rate of shift frequency, the frequency range or limits of the service carrier, the beat frequencies, and the keying speeds can be changed to suit any desired service conditions. If desired, the rate of shift frequency can also be shifted by other keyed pulses to multiply the number of channels. If the full tolerance range of the assigned service frequency of the transmitter 1 is utilized, it is possible to key as many as five channels or more simultaneously from the same transmitter without the usual loss of power and without the phase distortion and troublesome side bands encountered in modulated tone multiplex methods.

Various changes and modifications may be made without departing from the spirit and scope of the invention.

What I claim is:

1. In combination, a radio service transmitter, a plurality of signalling channels, a frequency shifter for shifting the carrier frequency of said transmitter in opposite senses and respectively in accordance with signals from said channels, a pair of grid-controlled tubes one for each channel for effectively associating each channel with the frequency shifter, a control oscillator, means connecting said oscillator in common to said pair of tubes whereby said tubes are alternately and recurrently conditioned for plate current conduction regardless of the signal condition in each channel, and means connecting each tube of said pair to its associated channel so that its conductivity is completed under control of the signal condition in the associated channel.

2. In combination a radio service transmitter, a plurality of signalling channels, a frequency shifter for shifting the carrier frequency of said transmitter in opposite senses and respectively in accordance with signals from said channels, a grid-controlled tube for controlling said shifter, means to bias the control grid of said tube in one sense to vary the frequency shifter in a like sense, means to bias said control grid in an opposite sense to vary the frequency shifter in the same sense, each of said bias means including a grid-controlled electron tube associated with one of said channels and having means for exciting a grid thereof alternately and recurrently with a potential tending to render the tube plate conductive, and means controlled by a respective signal channel for applying a D. C. potential to the plate of the associated tube to complete the plate conductivity thereof.

3. In combination a radio service transmitter, a plurality of signalling channels, a frequency shifter for shifting the carrier frequency of said transmitter in opposite senses and respectively in accordance with signals from said channels, a master control oscillator, a first pair of grid-controlled electron tubes, a second pair of grid-controlled electron tubes, means connecting said oscillator to said pairs of tubes whereby one pair responds to positive half waves from the oscillator and the other pair responds to negative half waves from the oscillator, a third pair of grid-controlled tubes having their plate current control grids connected in opposed phase relation to the cathodes of corresponding tubes in each of said first and second pairs so that the plate currents of said third pair of tubes are keyed alternately "on" and "off", means to apply a D. C. plate potential to one tube of said third pair under control of the first signal channel, and means to apply a D. C. plate potential to the other tube in said third pair under control of said second signal channel whereby each tube of said third pair becomes plate conductive only on the coincident application of said D. C. plate potential and the application of an "on" keying potential applied to its plate current control grid, and means to control said frequency shifter by the respective plate currents of each of said third pair of tubes and thereby controlling the operating frequency of said transmitter.

4. The combination according to claim 3 in which said first pair of grid-controlled tubes comprises a vacuum tube and a gas tube of the Thyratron type, the control grids of which are connected in opposite phase to said oscillator, and said second pair of grid-controlled tubes also comprises a vacuum tube and a gas tube of the Thyratron type the control grids of which are connected in opposite phase to said oscillator, the control grid of the vacuum tube in the first pair being excited in like phase with the control grid of the gas tube in the second pair, and the control grid of the gas tube in the first pair being excited in like phase with the control grid of the vacuum tube in the second pair.

5. In combination a master control oscillator, a pair of grid-controlled gas tubes of the Thyratron type, means for exciting the control grids of said tubes in opposite phase from said oscillator, a first resistor in the cathode load circuit of the first tube, a second resistor in the cathode load circuit of the second tube, a first grid-controlled vacuum tube, a second grid-controlled vacuum tube each vacuum tube having a plate current control grid, means connecting the first vacuum tube to the cathode of the first gas tube whereby the voltage developed in said first load resistor is applied to the said control grid of the first vacuum tube, means connecting the said control grid of the second vacuum tube to the cathode of said second gas tube whereby the voltage developed in said second load resistor is applied to said control grid of said second vacuum tube, a first signalling channel, a second signalling channel, means controlled by the signal condition in said first channel for applying a D. C. operating plate potential to the plate of said first vacuum tube, means responsive to the signal condition in the second channel for applying a D. C. operating plate potential to the plate of the said second vacuum tube, a radio transmitter having a normal assigned carrier frequency, a frequency shifter for shifting the carrier frequency of said transmitter, and means for controlling the said shifter in accordance with the relative plate conductivities of said vacuum tubes.

6. The combination according to claim 5 in which said pair of vacuum tubes are connected across the input electrodes of another grid-controlled vacuum tube the plate current of which controls said frequency shifter.

7. The combination according to claim 5 in which said pair of vacuum tubes each has a cathode load resistor and the resistors are connected in opposed phase relation across the input electrodes of another grid-controlled vacuum tube the plate current of which controls said frequency shifter.

8. The combination according to claim 5 in which said transmitter is also connected to an amplitude modulator whereby the frequency shifted carrier is amplitude modulated under control of a third signal channel.

9. In combination a pair of signalling channels each including a tone signal source, rectifiers for the tone signals, and a control grid electron tube whose plate current flows only when a rectified signal is present; a pair of grid-controlled vacuum tubes one for each of said channels each having its plate potential supplied in series through the plate-to-cathode path of the electron tube in the associated one of said channels, a master control oscillator, means alternately and recurrently to apply D. C. keying potential to a control grid of each of said pair of tubes whereby each tube passes plate current only when a rectified signal is present in the associated channel and its control grid is keyed on, another grid-controlled tube having its input electrodes connected in opposite phase relation to said pair of tubes whereby the plate current in one of said pair of tubes biasses said grid in one direction and plate current flow in the other of said pair of tubes biasses said grid in the opposite direction, a frequency shifter controlled by the plate current of said other tube, and a radio transmitter whose carrier frequency is shifted under control of said frequency shifter.

10. In combination a source of master control oscillations, a transformer having a pair of secondaries, means connected to one secondary to convert the positive half waves of said source into square-topped pulses, means connected to the other secondary to convert the negative half waves from said source into square-topped pulses each of said means including a grid-controlled gas tube of the Thyratron type and a grid-controlled vacuum tube with a common plate load resistor for controlling the "on" and "off" plate striking voltage of the gas tube, another pair of grid-controlled vacuum tubes having their control grids connected in opposite phase relation to the load circuits of said gas tubes, a third grid-controlled tube having its plate current control electrodes connected in opposite phase relation to the load circuits of said second pair of vacuum tubes, a frequency shifter connected to the plate circuit of said third tube, a radio transmitter connected to said frequency shifter so as to have its operating frequency shifted thereby, a first signalling channel for controlling the D. C. plate potential of one tube of said second pair of tubes, and another signalling channel for controlling the D. C. plate potential of the other tube of said second pair of tubes.

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