July 16, 1946. S. W. SEELEY 2,403,957

MULTIPLE PROGRAM SYSTEM

Filed Sept. 29, 1942 2 Sheets-Sheet 1

Fig. 1.

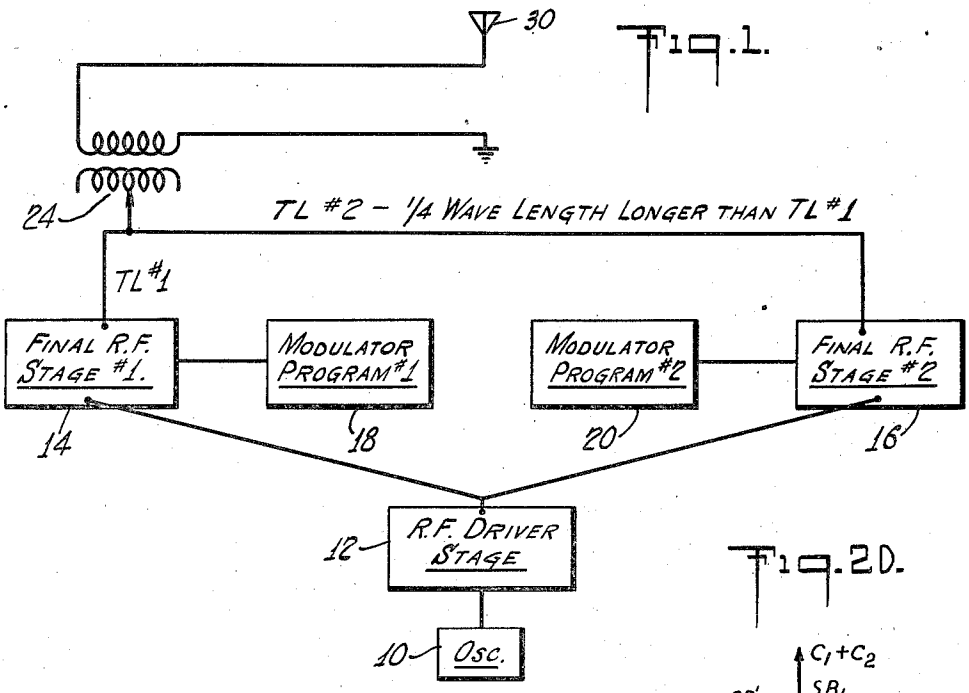


Fig. 2A.

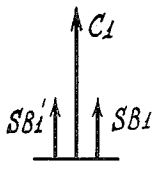


Fig. 2B.

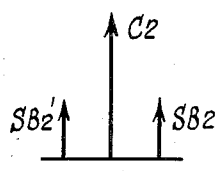


Fig. 2D.

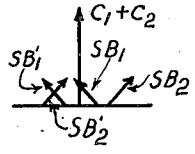


Fig. 2C.

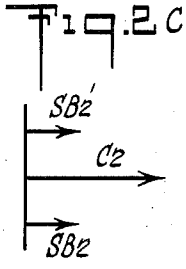
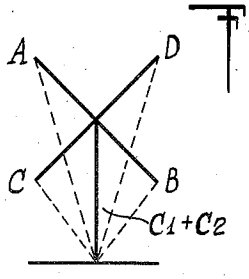


Fig. 2E.



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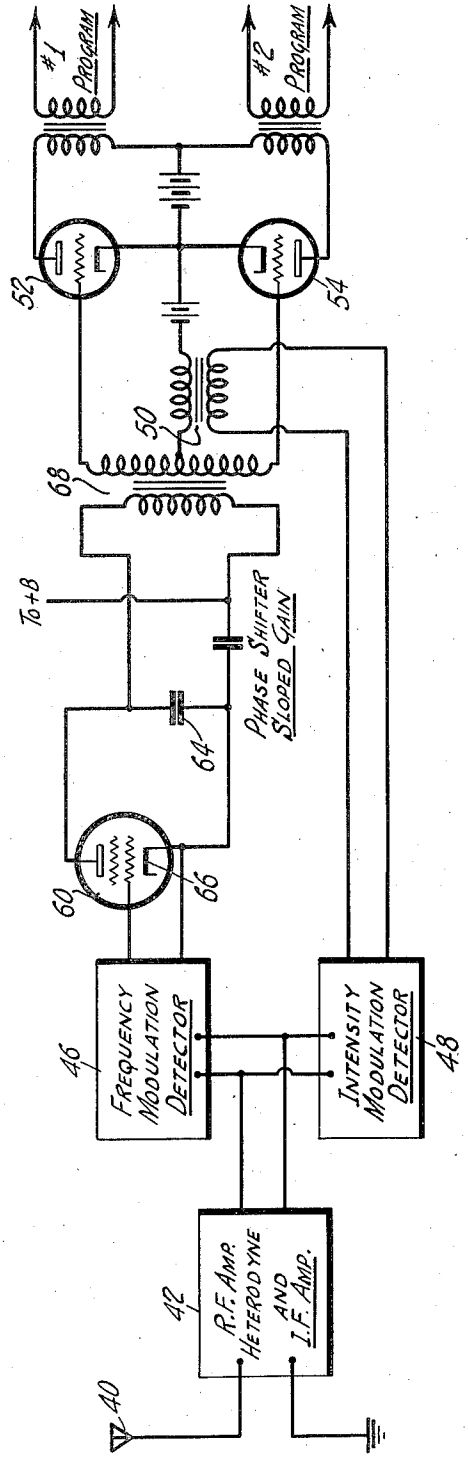


Fig. 3.

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MULTIPLE PROGRAM SYSTEM

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Application September 29, 1942, Serial No. 460,040

12 Claims. (Cl. 179—15)

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This application discloses a new and improved method of and means for modulating or controlling carrier wave energy in accordance with a plurality of signals of the same or different character.

An object of this invention then is to provide a new and improved means for sending by means of a single carrier at least two distinct and different messages or signals of any nature which may or may not be represented by voltages or currents in the same or different or overlapping bands in the frequency spectrum.

Systems of this general nature are known in the prior art. However, in all known systems complex circuit arrangements are used at the transmitter and at the receiver. Moreover, in the known systems at the receiver an unmodulated or pure carrier must be obtained and phase displaced portions thereof mixed with the received wave to separate the several messages one from the other.

An object of my invention is to provide a receiver wherein demodulation is accomplished without the use of a pure carrier used as outlined above. This greatly simplifies the receiver system.

In describing my invention in detail, reference will be made to the attached drawings, wherein Figure 1 illustrates mostly by block diagram a transmitter arranged in accordance with my invention.

Figures 2A and 2E are graphs showing the nature of the carrier and side bands resulting from modulation of carrier energy by two signals and sending out the same in accordance with my invention.

Figure 3 illustrates schematically and partly by rectangles a receiver arranged in accordance with my invention.

In my new and improved transmitter as illustrated in Figure 1, oscillations from a source 10 are amplified in a driver stage 12, and, if desired, increased in frequency. Voltages of the desired amplitude and carrier frequency are fed from the final stage in 12 to two amplifier stages 14 and 16.

The amplifier in 14 is designated Final R.-F. stage #1 and herein the carrier supplied to 14 from 12 is modulated in accordance with a #1 program of the desired nature originating in source 18.

In a like or similar manner the carrier in stage #2 of unit 16 is modulated by a #2 program of the desired nature originating in 20.

It will be understood that the modulated stages

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in 14 and 16 may be the last stage or may be followed by additional amplifier stages.

The modulated carrier with the #1 program is fed to the combining circuit 24 by a line TL #1. The modulated carrier with #2 program is fed to the combining circuit by way of a line TL #2 which is ¼ or an odd multiple of ¼ wave length longer than the line TL #1.

The two modulated carriers accordingly reach the antenna 30 shifted in phase about 90°. The nature and relation of the carriers and side bands are shown graphically in Figures 2A and 2E.

In Figure 2A is shown the output of the output stage in 14. This output comprises a carrier C1 and upper and lower side bands SB1 and SB1'.

In Figure 2B is shown the output of the output stage in 16. This output comprises a carrier C2 and upper and lower side bands SB2 and SB2'.

Since the output of the last stage in 16 reaches the circuit 24 over a line that is longer by $\lambda/4$ (where λ is the output wave length) than the path over which the output of stage 14 reaches circuit 24, the carrier and side bands from the stage in 16 are shifted about 90° as indicated in Figure 2C.

The displaced voltages as fed to the antenna 30 by lines TL #1 and TL #2 will be related as indicated in Figure 2D. The carriers combine to provide a resultant or new carrier C1+C2 which is modulated along one locus, say A—B, by the #1 program and along the other locus C—D, by the #2 program.

The result of the combination as shown in Figure 2E is that each program on the carrier is part phase modulated and part intensity modulated.

Notice, however, that the phase modulation is reversed in the two programs. This means that as the absolute intensity due to one program is approaching maximum, the frequency is lower than normal, and when it is approaching a maximum due to modulation of the other program, the frequency is higher than normal. In other words, the phase modulation produces a frequency shift 90° ahead of intensity modulation from one program and 90° behind the intensity modulation from the other program.

Thus, if the frequency modulation is extracted from one program and combined with the intensity modulation subtracted from the same program by shifting all audio due to frequency modulation 90° ahead, the frequency modulation and intensity modulation of one program will add and audio due to frequency modulation and intensity modulation of the other program will buck

leaving a pure program, say #1, whereas if the audio due to phase modulation (frequency modulation) of either program is shifted 90° behind and then combined with the audio due to intensity modulation of either program, the result will be pure #2 program.

Since frequency modulation due to phase modulation is proportional to the rate of change of the phase with respect to time, it can be seen that the higher modulating frequencies produce a greater degree of frequency modulation. In other words, the amount of frequency modulation is directly proportional to the modulating frequency. This calls for a "sloped" audio amplifier. This can very easily be combined with the phase shifter since both devices call for a high resistance in series with a reactance.

In Figure 3 I have shown a receiver incorporating the novel features described above including means to provide the necessary relative phase shift between the demodulation components derived by subjecting the resultant modulated carrier to an amplitude demodulation and frequency demodulation process.

In Figure 3 the carrier is picked up at **40** and amplified, and, if desired, reduced in frequency and further amplified in **42**.

The resulting intermediate frequency carrier is fed to a frequency modulated wave demodulator **46** and an amplitude modulated wave demodulator **48**.

The demodulator in **46** may be of the type disclosed in my United States Patent No. 2,121,103 or of the Conrad type. The demodulator in **48** may be of any approved type, of which there are many.

The output of the demodulator **48** is fed to the primary winding of a transformer **50**, the secondary winding of which feeds the voltages in phase to the grids of program separator and amplifier tubes **52** and **54**.

The demodulation components from **46** are fed to the control grid of a tube **60** of high plate impedance. This tube is of high plate impedance as compared to the impedance of condenser **64** at all useful audio frequencies. Thus, the voltage appearing across **64** is in quadrature with that applied to the grid of tube **60** and the magnitude of the voltages across **64** relative to their amplitudes on the grid of tube **60** are inversely proportional to their frequency. Thus, the voltages across **64** are of the proper magnitude and phase to coincide exactly with the phase modulation of the radio-frequency envelope received on antenna **40**.

These voltages are fed to the transformer **66** and thence in opposite phase to the grids of tubes **52** and **54**. The voltages from the intensity modulation detector **48** are fed by transformer **50** to the grids of tubes **52** and **54** in parallel. Thus, the detected phase modulation components of one program will add to the detected intensity modulation component voltages of that same program on the grid of the tube, say **52**, but will cancel each other on the grid of the tube **54**.

The detected phase and intensity modulation of the other program will add at the grid of tube **54** while cancelling at the grid of tube **52**. Thus, the output of tube **52** will consist entirely of one program and the output of tube **54** will be purely the other program.

It is, of course, realized that the system must include means to keep the amplitudes of the components fed to the tubes **52** and **54** from tube **60** and detector **48** of like amplitude. Intensity adjusting means may be included in **46** or at the input of **60** or in **48**. Preferably this means is included in **48** to control the intensity of the energy before or after or during the time it is being acted on by the intensity demodulator in **48**.

It will also be understood that the circuits feeding the radio-frequency stages #1 and #2 to the antenna are diagrammatic only and in practice means is provided to prevent the output of each stage from reacting through the couplings on the other stage.

What is claimed is:

1. In apparatus of the class described, a source of oscillations of carrier wave frequency, a plurality of amplifier stages each coupled to said source to be excited in phase by energy from said source, a source of control or modulating energy coupled to each amplifier stage, a transmission element, and a circuit for each amplifier coupling the respective amplifiers to said transmission element, said circuits being so constructed and arranged as to produce a displacement of phase between the wave controlled or modulated energies fed by the amplifiers to the transmission element.

2. In apparatus of the class described, wave receiving and amplifying means, a plurality of signal output circuits, a wave length modulated wave demodulator having an input coupled to said means and an output coupled to each signal output circuit, an amplitude modulated wave demodulator having an input coupled to said means and an output coupled to each signal output circuit, and means for introducing a phase displacement in the voltage supplied from one of said demodulators to each signal output circuit.

3. The method of signalling with carrier energy two portions of like phase which have been modulated each by a different signal and the modulated portions transmitted in phase displaced relation which includes these steps, receiving said energy so modulated, subjecting one portion of the received energy to an amplitude demodulation process, subjecting another portion of the received wave energy to a frequency demodulation process, combining output resulting from the frequency demodulation process in relatively phase advanced relation with output derived from the amplitude demodulation process to derive one of said two currents, and combining output derived from said frequency demodulation process in relatively phase retarded relation with output derived from said amplitude demodulation process to derive the other of said two currents.

4. The method of signalling by means of carrier wave energy and at least two currents corresponding to different signals which includes the following steps, modulating portions of said carrier wave of like phase in accordance with the respective currents, transmitting said portions in phase displaced relation as a new carrier, receiving said new carrier, subjecting the carrier to an amplitude demodulation process and to a frequency demodulation process, combining output resulting from the frequency demodulation process in relatively phase advanced relation with output derived from the amplitude demodulation process to derive one of said two currents, and combining output derived from said frequency demodulation process in relatively phase retarded relation with output derived from said amplitude demodulation process to derive the other of said two currents.

5. In a signalling system, a wave energy amplifier, a frequency modulation detector coupled to

said wave energy amplifier, an intensity modulation detector coupled to said wave energy amplifier, a balanced modulation combiner coupled to both detectors, and two output circuits coupled to said balanced modulation combiner.

6. In apparatus of the class described, a source of oscillations of carrier wave frequency, two modulator stages each having an input coupled to said source to be excited by oscillations therefrom of like phase, said modulators each having an output, a first source of control or modulating energy coupled to one modulator stage, a second source of control or modulating energy, distinct and separate from said first source, coupled to the other modulator stage, a transmission element, a first line coupling the output of one modulator to said transmission element, a second line of a length which exceeds the length of said first line by about $\lambda/4$ coupling the output of the other modulator to said transmission element to feed the modulated wave energies from the modulator stages to the transmission element, said second line being electrically about $\lambda/4$ longer than said first line thereby serving to produce a phase quadrature relation between the energy fed to the transmission element over one line and the energy fed to said transmission element over the other line.

7. The method of signalling by means of carrier wave energy and at least two currents corresponding to different signals which includes these steps, modulating portions of said carrier wave energy of like phase in accordance with the respective currents, relatively shifting the phases of the modulated wave energy portions about 90° and transmitting the same.

8. The method of signalling with carrier energy comprising two portions which have been modulated each by a different signal and the portions displaced in phase about 90° and transmitted which includes these steps, receiving said energy so modulated, subjecting one portion of the received energy to an amplitude demodulation process and another portion of the received energy to a frequency demodulation process, retarding the phase of the components resulting from the frequency demodulation process about 90°, combining the phase retarded components resulting from the frequency demodulation process with the components resulting from the amplitude demodulation process to derive one of said two currents, and reversing and combining said phase retarded components resulting from said frequency demodulation process with the components resulting from amplitude demodulation process to derive the other of said two currents.

9. In a signalling system, a wave receiver including an amplifier, a wave length modulated wave demodulator having an output and having an input coupled to said amplifier, an amplitude modulated wave demodulator having an output and having an input coupled to said amplifier, two electron discharge tubes each having input electrodes and output electrodes, an individual output circuit coupled to the output electrodes of each tube, an input circuit coupling the input electrodes of said tubes in pushpull relation, a second input circuit coupling the input electrodes of said tubes in parallel, a phase shifter and voltage correction circuit coupling the output of said first demodulator to said pushpull input circuit and a coupling between the output of said second demodulator and said parallel input circuit.

10. In a signalling system, a wave receiver including an amplifier, a wave length modulated wave demodulator having an output and having an input coupled to said amplifier, an amplitude modulated wave demodulator having an output and having an input coupled to said amplifier, two electron discharge tubes each having input electrodes and output electrodes, an individual output circuit coupled to the output electrodes of each tube, a transformer having a primary winding and having a secondary winding coupling the input electrodes of said tubes in pushpull relation, a second transformer having a primary winding and having a secondary winding coupling the input electrodes of said tubes in parallel, connections coupling the output of one of said demodulators to one of said primary windings, connections coupling the output of the other demodulator to the other of said primary windings, and a phase shifter in one of said connections.

11. A system as recited in claim 9 wherein said phase shifter and voltage correction circuit includes an electron discharge device of high plate impedance coupled at its input to the output of the wave length demodulator and coupled at its output to the said pushpull input circuit with a condenser of relative low impedance effectively in shunt to this device's output.

12. Apparatus as recited in claim 2 wherein said one of said demodulators is the wave length modulation demodulator and wherein said last named means is a tube of high plate impedance coupled at its input to said wave length modulated wave demodulator and coupled at its output to each signal output circuit, with a condenser of relatively low impedance effectively in shunt to the tube's output.

STUART W. SEELEY.