

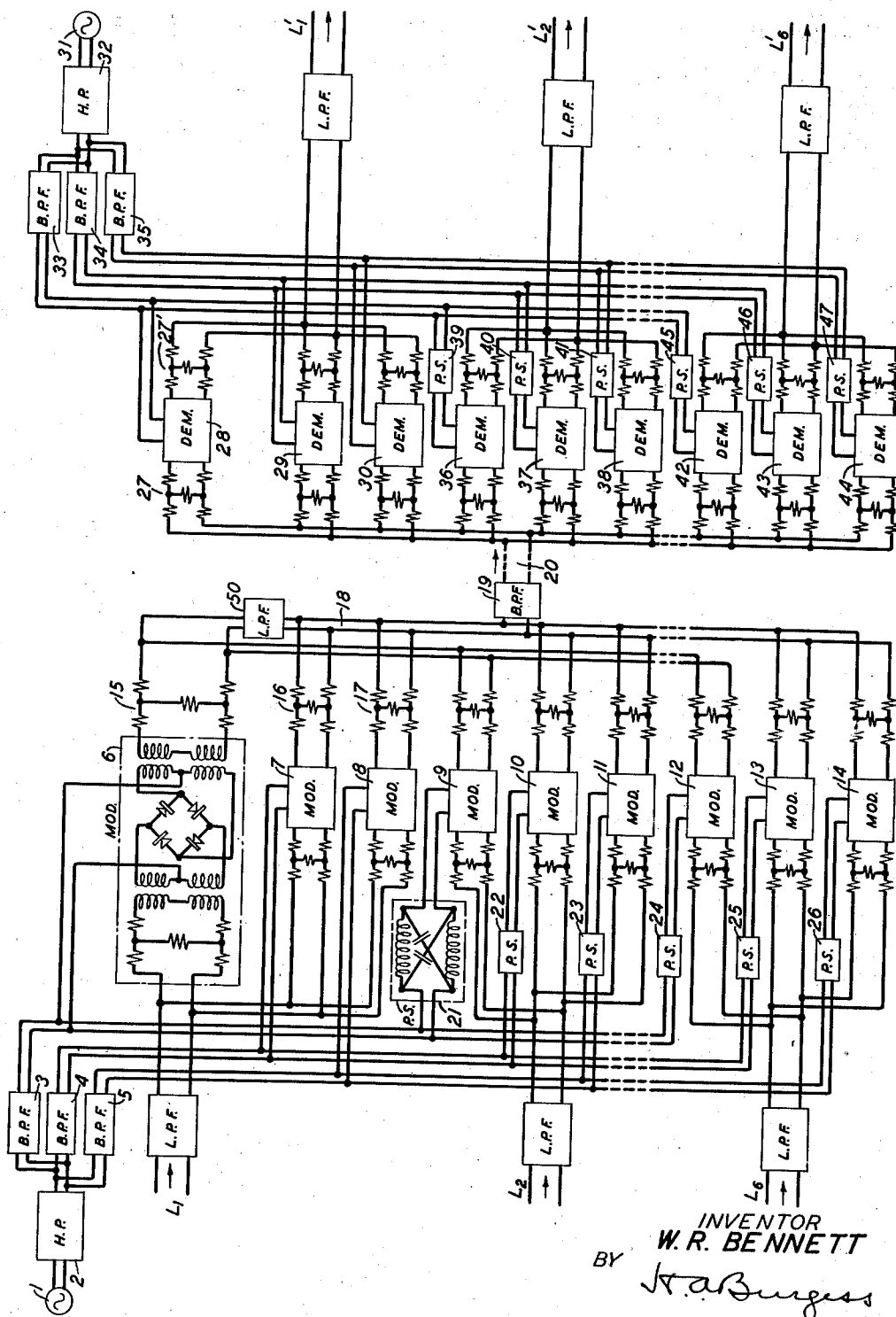
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MULTIPLEX TRANSMISSION WITH PHASE DISCRIMINATION

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MULTIPLEX TRANSMISSION WITH PHASE DISCRIMINATION

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The present invention relates to multiplex transmission of signals, such as speech, television or other types of signals, on the basis of time division or phase relation.

Systems of this general type are disclosed in my prior application Serial No. 221,298, filed July 26, 1938, issued as United States Patent 2,213,938, September 3, 1940, and an application of E. Peterson Serial No. 221,297, filed July 26, 1938, issued as United States Patent 2,213,941, September 3, 1940. In those systems side-bands representing a plurality of signals are produced and transmitted based on waves harmonically related in frequency. These waves harmonically related in frequency are in effect in those systems modulated in different phase by the successive signals and the signals are separated and separately received at the receiving end by virtue of these differences in phase. In the Peterson application the harmonically related waves are applied as a group to as many modulating circuits as there are signals to be transmitted, with a progressive shift in the phase of the waves as they are supplied to the successive modulating circuits. Carrier waves of the same frequency are thus modulated in successive phase by the different signals to be transmitted.

The present invention is in the nature of an improvement upon the type of system disclosed in the prior applications referred to in that a separate modulator is, according to the present invention, provided for the carrying out of each modulating process between a given signal wave and a given carrier frequency. While this results in the use of a greater number of modulators, the design of the individual modulators is simplified because of the less rigid requirements. A system according to the invention avoids the necessity of securing product modulation over the range of amplitudes present in a frequency range in which maxima of varying heights occur and in which the side-band output should be proportional to instantaneous carrier amplitude over the entire range.

In a system according to the present invention for N channels, $N/2$ carriers are required. The signal from each channel is modulated with each of the $N/2$ carriers in $N/2$ independent modulators so that the total number of modulators required in a transmitting terminal is $N^2/2$. A like number of demodulators is required for receiving. The modulators should be of a type in which the unmodulated carrier component is suppressed in the output. The necessary phase shifts between waves of the same carrier frequency supplied to

the modulators for the different channels can be accomplished by single frequency phase shifters which are preferably of the all-pass constant resistance type, thereby minimizing interaction effects among the carrier circuits.

The nature of the invention and its various objects will be made clear from the following detailed description taken in connection with the accompanying drawing, the single figure of which shows a complete one-way multiplex system comprising for illustration six signal channels, although it will be apparent that the invention is not limited to any particular number of channels.

In the drawing, lines $L_1, L_2 \dots L_6$ are shown at the left for transmitting messages simultaneously over the multiplex line 20 to the corresponding signaling circuits $L_1', L_2' \dots L_6'$ shown at the right. These lines may be telephone lines or circuits for transmitting any other suitable types of signals, such as television, or they may serve for transmitting speech subbands divided out of a single speech wave for privacy transmission in the manner disclosed in an application of Mathes-Peterson-Dudley Serial No. 229,236, filed September 10, 1938, issued as United States Patent 2,213,320, September 3, 1940.

On the basis of a six-channel system, three carrier waves are required. These are derived from the alternating current source 1, feeding harmonic producer 2 from the output of which three adjacent harmonics are selected by the band-pass filters 3, 4 and 5 for supply to the various modulators. The circuit L_1 is connected in common to three modulators 6, 7 and 8 which may all be of the same type indicated specifically in the case of modulator 6. This circuit is of the double balanced type in which neither the wave in the circuit L_1 nor the carrier wave is allowed to pass through into the output circuit but only the side-bands are transmitted. This modulator is shown as comprising a ring of solid element rectifiers preferably of copper oxide and is of a type well known in the art.

The modulator 6 is supplied by a carrier wave from filter 3 while modulators 7 and 8 are supplied with carrier waves respectively from filters 4 and 5. The signals on the line L_1 , therefore, modulate three carrier waves of different frequencies in three separate modulators and the resulting side-bands are supplied through resistance pads 15, 16 and 17 to the transmitting branch 18. Similar separating pads are used on the input sides of the modulators as shown.

Signals on line L_2 are supplied to a group of three modulators 9, 10 and 11. Modulator 9 is

supplied with carrier waves from filter 3 which pass through a phase shift network 21 before application to the modulator. Similarly, modulators 10 and 11 are supplied with phase shifted carrier waves from, respectively, filters 4 and 5 through phase shifters 22 and 23, respectively. Thus signals on line L₂ modulate carrier waves of the same carrier frequencies as do the signals on the line L₁ but in different phase.

In similar manner the signals on each of the succeeding lines, down to and including line L₆, modulate waves of these same three carrier frequencies but in progressive phase. The modulators for line L₆ are shown at 12, 13 and 14 and the phase shifters at 24, 25 and 26. The output side-bands from all of the eighteen modulators pass through individual resistance pads to the common outgoing branch 18 from which they pass through band-pass filter 19 to the transmitting line 20. Band filter 19 should have linear phase shift throughout the transmission band and should have such a pass band as to enable all of the pairs of side-bands from the modulators 6 to 14 to pass through to the line 20 with uniform attenuation and should effectively suppress all frequencies both lower and higher than the range of frequencies embraced by these side-bands as a group.

A low-pass filter 50 may be necessary to eliminate side-bands of harmonics of the wave from filter 3 where the frequency relations are such that these side-bands would overlap the frequency range of the wanted side-bands from the other modulators, such as 7 or 8, using higher carrier frequencies. This filter is included in common in the outputs of all of the modulators using the frequency passed by filter 3, assumed to be the lowest of the three carriers. A similar filter could, of course, be used in the case of the other modulators. Care should be taken, of course, to make the time of transmission the same in all branches.

The receiving circuit is entirely analogous to the transmitting circuit and comprises resistance pads 27 and 27' and demodulators 28 to 44, inclusive, each of which may be similar to the modulator 6. A source of fundamental frequency waves 31 is shown at this terminal, although it may be preferable to transmit some of the waves from the source 1 to the receiving terminal for synchronizing purposes. The wave of fundamental frequency is applied to the harmonic producer 32 from the output of which three adjacent harmonics are selected by the band-pass filters 33, 34 and 35 for application to the various demodulators. These three waves are applied to the demodulators 28, 29 and 30 without shift of phase and it is assumed that the carrier waves so applied are in identically the same phase as the corresponding waves supplied to the modulators 6, 7 and 8 at the transmitting end except for the necessary allowance for phase shift in the transmitting medium between the two stations. This being the case, of all the received waves that are applied to the demodulators 28, 29 and 30, only those side-bands coming from modulators 6, 7 and 8 will reproduce the signals in the line L₁' for the reason that all of the other side-bands produce output signal components which neutralize one another because of their phase differences, as is more fully explained in the Bennett and Peterson patents above referred to.

The three carrier waves from band filters 33, 34 and 35 are applied to the demodulators 36,

37 and 38 through phase shifters 39, 40 and 41, respectively, so as to bring the waves applied to these demodulators in phase with the waves applied to the transmitting modulators 9, 10 and 11 except for phase shift in the transmitting medium. Similarly, phase shifters 45, 46 and 47 produce the necessary phase shifts in the carrier waves applied to the final group of demodulators 42, 43 and 44 to produce phase coincidence between the carrier waves applied at the receiver and those applied at the transmitter to the corresponding modulators 12, 13 and 14. Consequently, the signals from line L₂ are reproduced exclusively in the line L₂' and those in the other transmitting lines are reproduced exclusively in the corresponding receiving lines including line L₆'.

It has been shown that a six-channel system requires three carrier waves and as many separate modulators per channel as there are carrier frequencies or in this case eighteen modulators. The rule stated above that the number of carrier frequencies is one-half the number of channels does not preclude the use of an odd number of channels, since obviously one of the channels may be left blank giving five channels instead of six, if desired. The number of carrier frequencies in this case would still obviously be three. The values of the phase shifts necessary can be ascertained from the following table, where f is the lowest carrier frequency used and q is the frequency spacing between carriers, the phase in each case being referred to the phase of the carrier in channel 1:

Table of phase shifts for N-channel system

Carrier	Frequency	f	$f+q$	$f+2q$	$f+3q$
Phase shift in carrier.	(Channel 1.	0	0	0	0
	Channel 2.	π/N	$3\pi/N$	$5\pi/N$	$7\pi/N$
	Channel 3.	$2\pi/N$	$6\pi/N$	$10\pi/N$	$14\pi/N$
	Channel 4.	$3\pi/N$	$9\pi/N$	$15\pi/N$	$21\pi/N$

Thus in a six-channel system, the three demodulating carriers for the second channel differ in phase by 30 degrees, 90 degrees and 150 degrees, respectively, from the corresponding three modulating carriers of the first channel. Therefore, the demodulated components received in the second channel from the three pairs of side-bands transmitted from the first channel have phases +30 degrees, -30 degrees, +90 degrees, -90 degrees, +150 degrees, -150 degrees with respect to the phases they would have if detected by carriers in phase with the modulating carriers. The six detected components thus cancel in pairs, i. e., the +30 degree and -150 degree; the -30 degree and +150 degree, and the +90 degree and -90 degree components differ in phase by 180 degrees and the resultant in each case vanishes. Similar results hold for reception in channels 3, 4, 5 and 6.

The invention is not to be construed as limited to the specific circuits that have been disclosed nor to the specific numerical values or other magnitudes but is of general application and may be modified within the scope and spirit of the following claims.

What is claimed is:

1. In a multiplex signaling system, a plurality of signal sources, means to produce carrier waves of a plurality of frequencies, modulators connected to said signal sources and supplied with said carrier waves for producing signal modulated waves for transmission, each signal source

being connected in common to a plurality of modulators equal in number to the number of said carrier waves, each of said plurality of modulators common to a given signal source being supplied with a carrier wave of a different frequency, whereby carrier waves of like frequencies are separately modulated by signals from the respective sources, and means for shifting the phase of each carrier by progressive amounts before it is supplied to the respective modulators.

2. A multiplex signaling system for transmitting N different message waves simultaneously comprising $N^2/2$ modulators, $N/2$ sources of carrier waves of different frequency, means to impress each message wave in common on $N/2$ of said modulators as a group, means to impress a carrier wave of a different frequency on each of the $N/2$ modulators of said group, means to impress others of said message waves individually on other groups of said modulators each group containing $N/2$ modulators, means to supply carrier waves of the same set of $N/2$ different frequencies to the respective modulators in each group, means to shift the phase of each carrier wave progressively before it is supplied to modulators of the successive groups, and means to transmit the sidebands resulting from the modulators in common over said system.

3. A multiplex signaling system according to claim 2 including a receiving station comprising N groups of $N/2$ demodulators, a separate receiving line connected to the outputs of the demodulators of each group, means to impress a carrier wave of a different frequency on each demodulator in a group, and means to make each such carrier wave agree in frequency and phase with the carrier wave impressed on the corresponding modulator.

4. In the multiplex transmission of a plurality

of message waves, a plurality of carrier wave sources of different frequencies harmonically related, groups of modulators each comprising a modulator per carrier frequency, one such group for each message wave, means to cause each modulator in any one group to modulate a carrier wave of a different frequency by the same message wave and the modulators in the separate groups to modulate said carrier waves by respectively different message waves from group to group, and means to shift the phase of each carrier wave progressively from group to group.

5. In multiplex transmission, a plurality of message sending circuits at a transmitting station and a corresponding plurality of message receiving circuits at a receiving station, at each station sources of carrier waves of different frequencies harmonically related, the wave sources at the separate stations having the same respective frequencies and phases, means at the transmitting station to modulate each carrier wave by the same message wave in separate circuits in each of a succession of phases of the carrier waves, and means at the receiving station to demodulate the received message modulated carrier waves with carrier waves corresponding in frequency and phase with those used for modulation at the transmitting station, whereby each message is recovered and reproduced in a separate one of said receiving circuits, said modulating means comprising a separate modulator for modulating each carrier wave in each of its phases by each message wave and said demodulating means comprising a separate demodulator for demodulating received waves with each carrier wave in each of its phases for each of the separately recovered message waves.

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