

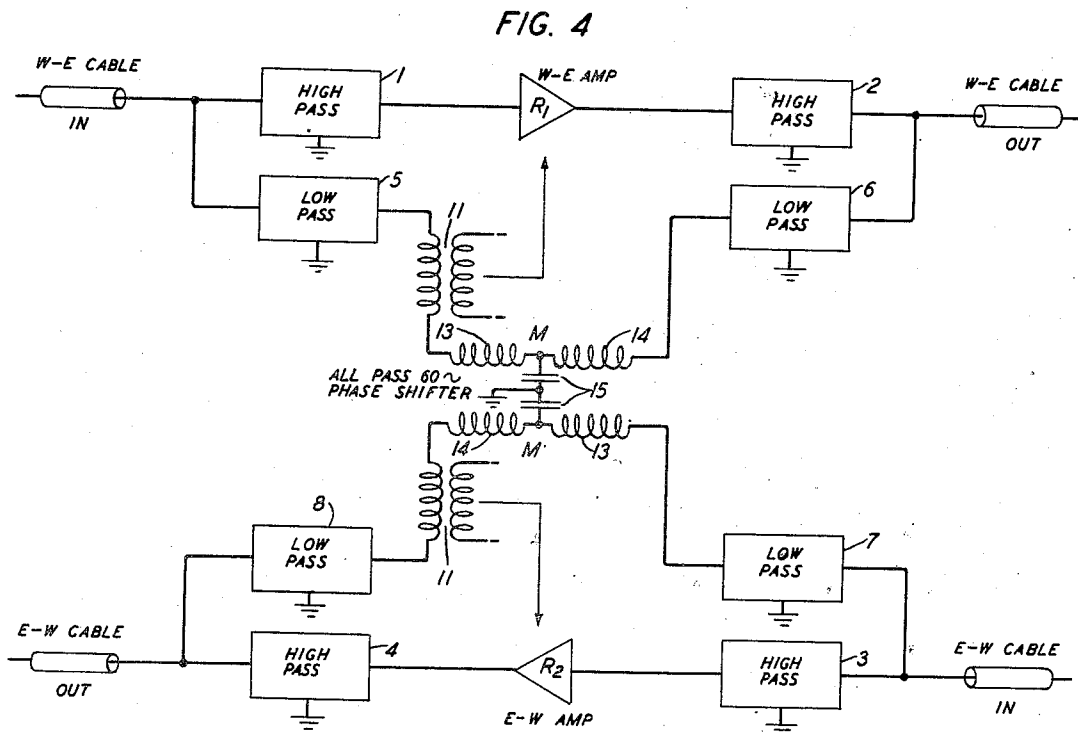
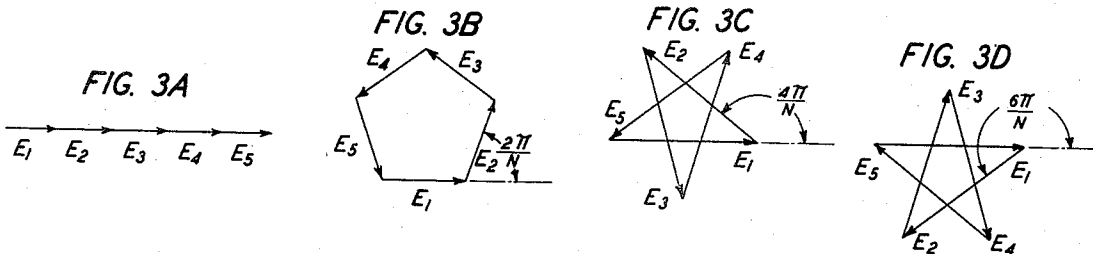
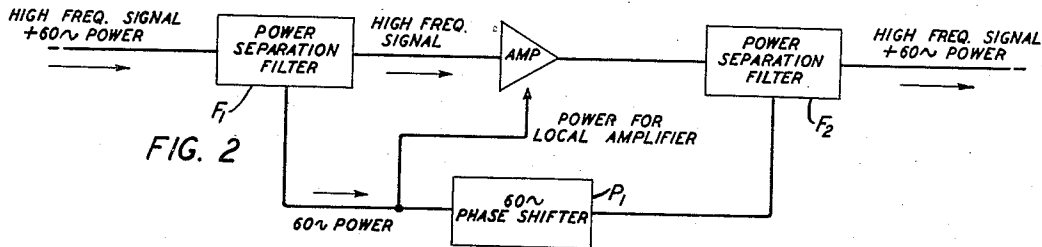
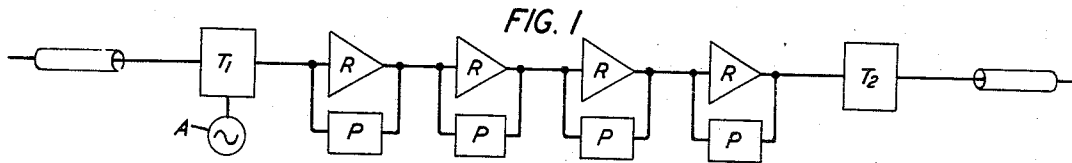
June 26, 1945.

W. R. BENNETT

2,379,211

DISTORTION CORRECTION IN WAVE TRANSMISSION

Filed June 13, 1942



INVENTOR
W. R. BENNETT
BY *H. A. Burgess*
ATTORNEY

UNITED STATES PATENT OFFICE

2,379,211

DISTORTION CORRECTION IN WAVE
TRANSMISSION

William R. Bennett, Summit, N. J., assignor to
Bell Telephone Laboratories, Incorporated,
New York, N. Y., a corporation of New York

Application June 13, 1942, Serial No. 446,965

7 Claims. (Cl. 178—44)

This invention relates to communication systems and more especially, though not exclusively, to such system as are identified as broad-band television circuits or as carrier telephone circuits in which latter case a plurality of channels are used on a single transmission medium for sending out independent messages. One type of circuit of this kind, for example, would be that known as the coaxial conductor. The invention also relates to any systems of the nature described in which a large number of repeaters are connected in tandem.

In spite of the great care which is used in the design and manufacture of repeaters on such lines there is present in the output of any one repeater a certain small amount of modulation product. While the amount of modulation in any one repeater may be small, if the system comprises a large number of repeaters in tandem, such as several hundred, then the cumulative effect may become substantial.

In certain of such systems the power for operating the repeaters is transmitted to the repeaters in the form of alternating current power, such as 60-cycle power, over the signal line itself. For example, in the case of a coaxial cable the 60-cycle power required for each repeater of a group may be supplied from a single source of power connected between the central conductor and the sheath of the coaxial cable. Due to nonlinearities in the line and in the amplifiers this superposition of power on the signal currents gives rise to modulation products involving the signal and the power frequencies. These, while small for any one repeater, may add up to troublesome amounts for a series of repeaters, especially in circuits where the requirements are severe as in television circuits. Thus, if the power frequency is 60 cycles per second and a typical signal frequency is represented by f the frequencies $f \pm 60$, $f \pm 120$, $f \pm 180$, etc., are produced and cause distortion of the received signal. Since the phase shift of the line may be quite small at 60 cycles per second and the spread of phase shift over the band $f \pm 60$, $f \pm 120$, etc., may also be very small, contributions to a particular modulation product from different points in a multirepeater system supplied from the same power source may act very nearly in phase and give a fairly large resultant value.

The purpose of this invention is to reduce the total alternating current power modulation so arising from a series of repeaters and is accomplished by inserting phase shift in the power circuit. It is further accomplished by introducing

the phase shift on the power supply itself without a similar or corresponding phase shift in the signal currents. Broadly, this is brought about by separating out the power at the input of a repeater, introducing the shift in this power and adding the thus shifted power to the line at the output of the said repeater for transmission to the next repeater.

The invention will be better understood by reference to the following specification and the accompanying drawing in which:

Fig. 1 shows a transmission line with a group of repeaters connected in tandem, the line carrying both the signal currents and the alternating current power for the repeaters;

Fig. 2 is a diagram showing the general method of shifting the phase of the power at any one repeater station without shifting the phase of the signal;

Figs. 3A to 3D are vector diagrams to assist in an understanding of the invention; and

Fig. 4 shows an arrangement for inserting phase shift of the power supply at a coaxial repeater point on a circuit comprising an incoming and an outgoing coaxial.

Referring more specifically to Fig. 1 there is shown a transmitting station T_1 and a receiving station T_2 joined by a transmission line such as a coaxial cable. This line from T_1 to T_2 may constitute a whole transmission circuit or a section of it only, it being understood that there may be additional sections coming into T_1 and going out from T_2 . Associated also with the line at some suitable point, such as station T_1 , is a source A of alternating current power to be used for supplying the necessary power to the group of repeaters shown between stations T_1 and T_2 . This power may be at any suitable frequency such as the commercial frequency of 60 cycles and may be transmitted in the same direction as the signaling direction or the reverse. Associated with each repeater in the group is a phase shifting device P the purpose of which will be more clearly understood from the following.

While the phase shift of the power supply at each of the repeater stations may be brought about at a number of points and in a number of different manners, a convenient place to insert the desired phase shift is in a power by-pass circuit at the individual repeaters. This is shown in more detail in Fig. 2 which represents the connections at any one repeater point. In front of the amplifier or repeater there is a power separation filter F_1 by which the 60-cycle power is separated from the signal band. Some of the thus

separated power is used for supplying the repeater. The remainder passes through a phase shifter P_1 and then is reintroduced at the output of the repeater through another appropriate filter F_2 so that from there on the power is shifted by a desired angle with respect to the incoming power.

The phase shifter P_1 may be of any suitable form but preferably should be one having low loss at the power frequency. An electrical network of the all-pass type with impedance matching that of the power circuit may be used. Coils and condensers of the phase shifter must obviously be designed to withstand the voltages and currents used in the power circuit.

Considering the case of two fundamental frequencies p and q producing the modulation product $p \pm mq$, it is to be noted that if the phase of q is shifted by an amount θ without changing the phase of p , the phase of the modulation product is in general shifted by $\pm m\theta$. Hence if we try to balance modulation products from two sources we should find that the proper phase shift at the q frequency for suppression of $p \pm q$ is 180 degrees while that for $p \pm 2q$ is 90 degrees. Hence for the $p \pm 60$ and $p \pm 120$ cycle side-bands appearing on the line we should not expect to balance out both the 60 and the 120 cycle side-bands by a single phase shifter. My plan of securing a simultaneous reduction of all power side-bands is based on the insertion of suitable phase shifts at each of certain repeaters—preferably each repeater—of a group supplied by one source of power. Thus, if there are N repeater sections in the group and all modulate equally, then a phase shift of

$$\frac{2\pi}{N}$$

radians at 60 cycles inserted at each repeater would make the N vectors representing the contributions to 60-cycle side-band add in the form of a closed polygon of N sides to give zero for the sum, as shown in Fig. 3B for the case of five repeaters, instead of along a straight line to give N times the amplitude of one, as in Fig. 3A. At the same time the phase angle between successive contributions to the 120-cycle side-bands would become twice as great or equal to

$$\frac{4\pi}{N}$$

and these would also form an N -sided closed polygon as in Fig. 3C. Likewise the 180-cycle side-band contributions add at an angle of

$$\frac{6\pi}{N}$$

and form a closed polygon as in Fig. 3D.

In accordance with the above the $p \pm Nq$ side-band would undergo a phase shift

$$N \left(\frac{2\pi}{N} \right)$$

or 2π and obviously these side-band contributions would add in phase, but if the number of repeaters in the group is reasonably high, the Nq side-band would be of a sufficiently high order so that its amplitude would be reduced sufficiently to meet engineering requirements.

The above principles may be applied to any communication lines of the type noted above. As a more specific illustration, however, its application is shown in Fig. 4 to a pair of coaxial cables, one for transmission of signal in the west-east direction and one in the east-west direction, the two cables being adjacent to each other, at

least at the repeater points. In front of and after each of the repeaters R_1 and R_2 high-pass filters 1, 2 and 3, 4 are introduced to keep the power frequencies out of the repeaters. By-passing each of the repeaters there are shown two low-pass filters 5, 6 and 7, 8 which prevent the signal frequencies from entering the by-pass circuits but permit the alternating current power to pass freely. In each by-pass path there is introduced a transfer 11, the secondary of which supplies the necessary amount of power for its repeater. Included in each by-pass are also inductances 13 and 14, mutually coupled, and capacitance 15, with a midcapacitance ground, the whole constituting a phase-shifting network of low loss. In this particular system, it will be observed that the 60-cycle power is transmitted over the central conductors of the two coaxial cables while the communication circuits are derived between each central conductor and its sheath.

The invention has been described in terms of quite specific arrangements, but it is to be understood that variations may be introduced without departing from the spirit of my invention. Thus, while in general I would prefer to introduce phase shift at each of the repeater points in a group, it may be desirable in some cases, especially where the number of repeaters is large, to subdivide these into smaller groups and have a single phase shift for each of these smaller groups, the shift in phase obviously being larger by a suitable factor than where the shift is divided among all the repeaters. Also, while the invention has been described in terms of a completely closed polygon as in Fig. 3B, it is apparent that appreciable gain in reduction of the power side-bands will be present even though the vector polygon is not completely closed and such modification in the application of my invention is to be contemplated.

What is claimed is:

1. In a communication line comprising a group of spaced repeaters in tandem with alternating current power supplied to the repeaters from one point and transmitted over the communication line with the signals, the method of reducing power side-band modulation on the signal wave which consists in introducing phase shift in the power supply at various points on the communication line.

2. In a communication line comprising a group of spaced repeaters in tandem with alternating current power supplied to the repeaters from one point and transmitted over the communication line with the signals, the method of reducing power side-band modulation on the signal wave which consists in introducing phase shift in the power supply at each of a plurality of the repeaters.

3. The method defined in claim 2 including the step of shifting in the same direction the phase of the power current applied to each of said repeaters.

4. The method defined in claim 2 including the step of shifting in the same direction the phase of the power current applied to each of said repeaters by approximately the angle

$$\frac{2\pi}{N}$$

where N is the number of repeaters in the group.

5. In a communication line for transmitting signals, including a group of spaced signal repeaters in tandem and a source of alternating current power at a point on the line for trans-

mission together with the signals over the line to said repeaters for energizing said repeaters, means at a plurality of repeater points to introduce in the alternating power currents a phase shift of proper angular magnitude to reduce power sideband modulation on the signal.

6. The invention according to claim 5, in which said means comprises means for shifting the phase of said alternating power currents at each repeater progressively through the angle

$$\frac{2\pi}{N}$$

where N is the number of points at which the phase shift is introduced.

7. In a communication line for transmitting signals, including a group of spaced signal re-

peaters in tandem and a source of alternating current power at a point on the line for transmission together with the signals over the line to said repeaters for energizing said repeaters, means at the input side of each repeater to take off the power currents from said line, means to shift the phase of the power currents taken off through the angle

$$\frac{2\pi}{N}$$

and means to reapply the phase shifted power currents to said line beyond the respective repeater, the quantity N being the number of repeaters supplied by power over said line from one point.

WILLIAM R. BENNETT.