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H. S. BLACK

2,154,888

WAVE TRANSLATION SYSTEM

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FIG. 2

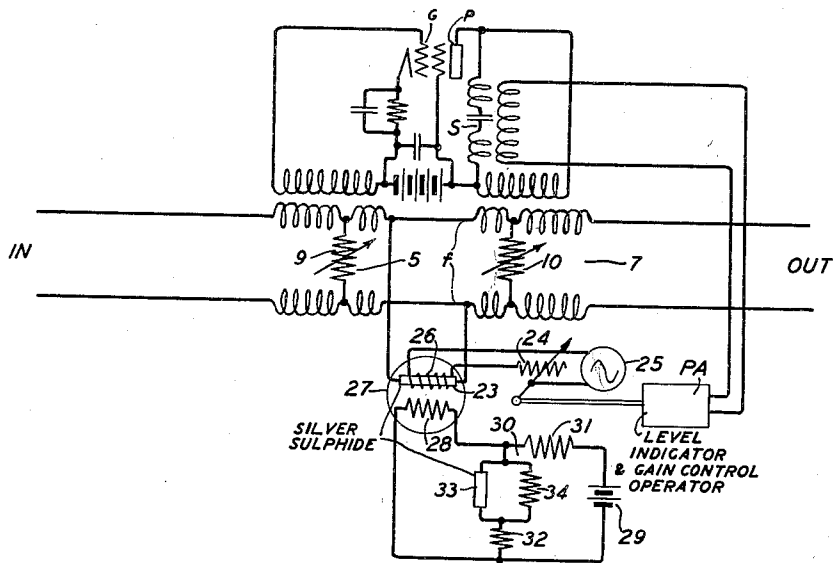
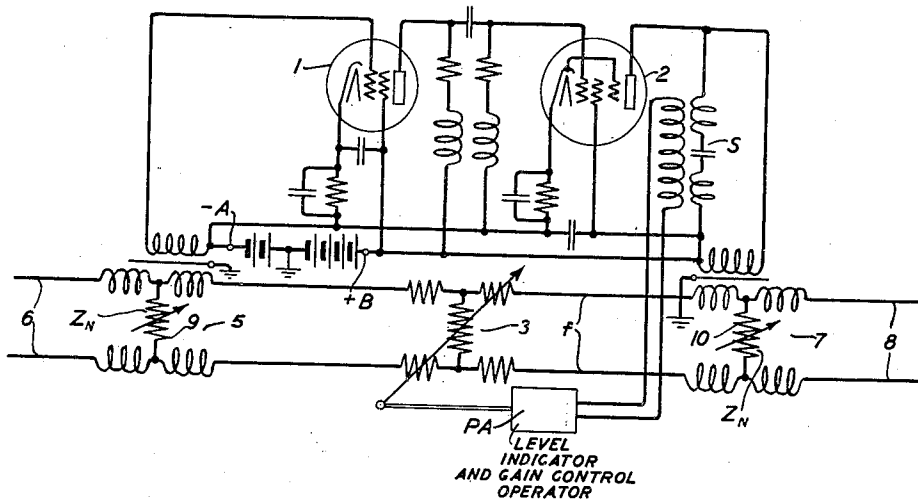


FIG. 1



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2,154,888

WAVE TRANSLATION SYSTEM

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Application March 23, 1937, Serial No. 132,559

4 Claims. (Cl. 178—44)

This application is a continuation-in-part of my copending applications Serial No. 606,871, filed April 22, 1932, for Wave translation system, now Patent No. 2,102,671, issued December 21, 1937; Serial No. 663,317, filed March 29, 1933, for Wave translation system, now Patent No. 2,131,365, issued September 27, 1938; and Serial No. 114,390, filed December 5, 1936, for Wave translation system.

This invention relates to wave translation systems, as for instance wave transmission systems involving wave amplifying means or means for increasing the power level of waves.

An object of the invention is to control transmission properties of such systems, as for example to control impedance relations, modulation, wave reflection, cross-talk, transmission efficiency or gain frequency relations or over-all phase shift effects involved in the systems.

For various purposes, as for example voice frequency ringing or signaling, or operation or control of apparatus by pilot currents, it is often desired to pick off at a point in a transmission circuit or path a portion of the energy being propagated through the path. This picking off of energy may tend to affect transmission in the circuit deleteriously.

An object of the invention is to reduce this tendency.

In accordance with the invention, this tendency can be reduced by picking off the energy at a point in the forwardly transmitting portion or μ -circuit of a stabilized feed-back amplifying device or system included in the transmission circuit or path. For example, in the case of pilot channel systems it may be desired to pick off pilot current energy at repeater points or stations, for operation of pilot current indicators or transmission gain control apparatus; and in accordance with the invention, when the repeater amplifier is of the negative feed-back type, (a type disclosed, for example, in the above-mentioned copending applications and in my article on Stabilized feedback amplifiers published in Electrical Engineering, January, 1934, pages 114 to 120), the pilot current energy can be picked off at the repeater by bridging a pilot current indicator or detector across the μ -circuit of the amplifier, for instance at a point in the latter part of the μ -circuit. A pilot current shunt at a point in the μ -circuit need not materially affect the over-all transmission, for the effects that its influence upon the transmission properties of the μ -circuit or the propagation through the μ -circuit has upon the over-all transmission

properties or propagation of the amplifier can be reduced by the negative feed-back, because with a sufficient amount of feed-back the over-all transmission properties and propagation or transmission become practically independent of the propagation through the μ -circuit. Thus if β , the propagation through the feed-back path, is stable, and unity is negligibly small in comparison to $\mu\beta$ then the effects that the influence of the pilot current bridging circuit upon the impedance, gain or transmission efficiency, phase shift, modulation, etc. of the μ -circuit, has upon such transmission properties of the amplifier are practically zero or so small as to be negligible, or immaterial.

Other objects and aspects of the invention will be apparent from the following description and claims.

Figs. 1 and 2 are diagrams of circuits embodying two forms of the invention.

The amplifier of Fig. 1 may be a stabilized feed-back amplifier of the general type disclosed, for example, in the copending applications and published article mentioned above. It comprises an amplifying path or element shown as including tandem connected vacuum tubes 1 and 2, and comprises a feed-back path f shown as including a transmission control network 3 of generalized impedances. The significance of μ , β , μ -circuit and β -circuit is as indicated in the Patent No. 2,102,671 just mentioned. The network 3 may be referred to as the β -circuit network.

An input hybrid coil 5 couples the incoming circuit 6 and the feed-back path f to the input end of the amplifying path; and an output hybrid coil 7 couples the output end of the amplifying path to the outgoing circuit 8 and the feed-back path. One of the important advantages of this type of feed-back circuit, with considerable amounts of feedback, is that the input and output impedances of the amplifier stabilize around fixed values that are independent of variations within the amplifier, its gain, or the amount of feedback, regardless of whether, in the passive condition of the amplifier, the hybrid coils are balanced, or in other words, regardless of whether the impedance Z_N of the hybrid coil net (i. e. the impedance 9 or 10 across the bridge points of the hybrid coil) is such as to give passive conjugacy (i. e., conjugacy in the absence of feed-back) between the line and the feed-back path.

With $\mu\beta$ much greater than unity the (input or output) impedance of the amplifier is equal

to the impedance of the net connected across the (input or output) hybrid coil bridge points multiplied by one plus the turns ratio t of the equality ratio or usually inequality ratio of the (input or output) hybrid coil, where t designates the turns ratio of the line and feed-back windings. Thus, assuming $\mu\beta$ is large, the impedance of the amplifier can be made to approach what is wanted as closely as can the net.

Since either an input hybrid coil or an output hybrid coil can render the amplifier input and output impedances independent of one another (regardless of whether the hybrid coil is in passive balance), it results that if an input hybrid coil is used, or an output hybrid coil is used, or both are used, the amplifier input and output impedances can be given equal values or altogether different values, at will.

Since, with considerable amounts of negative feed-back in the amplifier of Fig. 1, the impedances of network 3 will not substantially affect the amplifier input or output impedance, the network may be of any desired form suitable for controlling transmission. For example, it may be a series or shunt resistance adjustable for giving amplifier gain changes independent of frequency, or a network adjustable for giving variable equalization or changes of amplifier gain dependent on frequency.

The amplifier as so far described is that of Fig. 1 of my above-mentioned copending application Serial No. 114,390. It is noted therein as to operation of the hybrid coils in such a circuit, that when the β -circuit network 3 is a network for amplitude or phase equalization or correction of distortion (in the general manner disclosed, for example, in my above-mentioned article or Patent No. 2,102,671, or my United States Patent 1,956,547, May 1, 1934, or British Patent 371,887), the hybrid coils render the equalization independent of the flexibility of the amplifier input and output impedances, the impedances of the amplifier being adjustable through very wide ranges without affecting the equalization or distortion correction. As mentioned in the application Serial No. 114,390, this is especially noteworthy since locating the equalizing or transmission controlling network in the feedback path or β -circuit has important advantages. A number of such advantages are pointed out in that application by way of example.

The amplifier of Fig. 1 may be, for example, one of a number of line amplifiers connected in tandem, one in each of line sections such as 6 and 8 of a long transmission line. For instance, the amplifiers may be repeater amplifiers of a repeatered signal transmission line. A pilot current or tone may be transmitted over the line and picked off at the repeater or amplifier points, for example, by frequency selective circuit S which may feed pilot apparatus PA responsive to pilot current for indicating signal level and adjusting the transmission control network 3. This adjustment may regulate the amplifier gain, to compensate for changes of attenuation occurring in the line section assigned to the amplifier. These attenuation changes may be due, for example, to changes in temperature or other weather conditions to which the line section is subjected. The β -circuit network 3 may be of any suitable type, as for example, the type of the β -circuit network shown in Fig. 2 described below, or in Fig. 65 of my above-mentioned Patent No. 2,102,671 or in my above-mentioned United States Patent 1,956,547 or British Patent 371,887, or in F. A.

Brooks Patent No. 2,075,975, granted April 6, 1937, for Transmission regulation; F. B. Anderson, C. O. Mallinckrodt and A. L. Stillwell Patent No. 2,106,336, granted January 25, 1938, for Voltage or gain control; E. B. Payne Patent No. 2,075,956, granted April 6, 1937, for Electric wave transmission system; or C. O. Mallinckrodt Patent No. 2,098,968, granted November 16, 1937, for Transmission regulation.

The signal currents may be in any desired frequency range; and the pilot current or tone may be within the frequency range of the signals transmitted through the amplifiers, for example as in the case of the system shown in N. C. Norman Patent 1,918,822, July 18, 1933, or may be outside of the frequency range of the signal currents transmitted through the amplifiers, for example, as in the case of the system shown in Fig. 10 or Fig. 11 of Affel 1,511,013, October 7, 1924, E. I. Green 1,918,390, July 18, 1933, Chesnut 2,049,195, July 28, 1936, or Beyer et al. 2,066,514, January 5, 1937. The pilot apparatus PA may include level indicating means of any suitable type, as for example the type of milliammeter circuit shown in Figs. 8 and 9 of this Affel patent, and may include any suitable means for operating the gain control network, as for example means of the type disclosed in Fig. 10 or Fig. 11 of this Affel patent or in these patents to Norman, Green, Chesnut and Beyer et al.

Fig. 2 shows an amplifier similar to that of Fig. 1, but shows the β -circuit network by way of example as a thermosensitive shunt element, preferably a resistance 23 of silver sulphide or boron for controlling the gain of the amplifier. G and P in this figure, designate the first grid of the first stage and the plate of the last stage of the amplifier, and indicate that the amplifier may have any suitable number of stages. To vary the resistance, for changing the amplifier gain, the temperature of the resistance is varied. This temperature variation may be accomplished by adjusting a resistance 24 which controls heating current supplied from an alternating current or direct current power source 25 to a heating element 26 for the silver sulphide resistance 23.

Ordinarily the amount of power required to heat the silver sulphide resistance so as to produce a gain change of a few to as much as 80 to 100 decibels would not exceed a small fraction of a watt and in many instances could be as little as one milliwatt or even a fraction of a milliwatt.

Used in this manner it would often be required that the silver sulphide be stable with time and humidity. Where effects of room temperature variations tend to be objectionable, the silver sulphide resistance may be enclosed in a heat insulated chamber 27. The heat insulated container, possessing sufficient heat capacity with respect to the size and heat capacity of the silver sulphide resistance, is very helpful in reducing effects of variations in ambient or room temperatures upon the silver sulphide resistance. If desired, to compensate for effect of room temperature on operation of the silver sulphide unit, the heat insulated container can be maintained at a constant temperature, above the highest room temperature.

This could be done by a thermostatic control, but in Fig. 2 is accomplished by a chamber-heating element 28 supplied with heating current from alternating current or direct current power source 29 through a regulating network such for example as network 30. The network 30 is shown as having a series resistance arm 31 and a shunt

arm comprising a resistance 32 in series with two parallel resistances 33 and 34, resistance 33 being a silver sulphide resistance. The constants of the network depend upon the thermal and other properties of the particular silver sulphide unit 33. With the temperature of the chamber 27 elevated above the highest room temperature by the chamber-heating unit 28, if the room temperature rises the resistance of the silver sulphide element 33 falls sufficiently to reduce the heating current in the element 28 so that the temperature of the chamber 27 is held sufficiently constant.

The voltages or currents from the power supply sources 25 and 29 should be relatively stable.

Silver sulphide is preferred as the temperature responsive transmission control element because of its large (negative) temperature coefficient of resistance, constancy and uniformity of performance as disclosed more fully in J. R. Fisher-C. O. Mallinckrodt Patent No. 2,116,609, granted May 10, 1938, for Electrical transmission control. The specific form of the silver sulphide element may be, for instance, the form disclosed therein; and the preparation of the element may be, for example, as disclosed in J. R. Fisher Patent No. 2,082,102, granted June 1, 1937. Instead of having the silver sulphide element shunted across the feed-back path, it can be placed in series in the feedback path, and if it is then desired that the circuit be symmetrical (balanced to ground), two such elements can be used, one in series in each side of the feed-back path. Both can be in the same heat chamber, both heated by the same heater 26 or each heated by an individual heater such as 26.

With the gain control in the feed-back path of a stabilized feed-back amplifier, as indicated for example at 3 in Fig. 1 and at 23 in Fig. 2, reducing the gain is accomplished by correspondingly increasing the amount of negative feedback; and this improves the amplifier performance accordingly, for example reducing modulation, increasing gain stability, and, in the case of hybrid coils that are in passive unbalance, increasing the independence of the amplifier input and output impedances with respect to the impedances of the network such as 3 or 23. The gain around the feed-back loop in the amplifier of Fig. 1 or Fig. 2 may be large, as for example several times ten decibels. Since the amplifier gain practically equals the loss in the feed-back circuit and the working gain is usually appreciable, a loss is usually required in the feed-back path; and consequently, considerable loss may occur in the gain control device in the feed-back path without necessarily being a disadvantage.

The amplifier of Fig. 2, with the silver sulphide transmission control element, is the same as that of Fig. 6 of my above-mentioned copending application Serial No. 114,390, except that Fig. 2 includes frequency selective circuit S and pilot apparatus PA responsive to pilot current for indicating signal level and adjusting the β -circuit network as described above for the case of Fig. 1. In Fig. 2 the pilot apparatus operates the gain control contact of resistance 24, and this adjustment may regulate the amplifier gain to compensate for changes of attenuation occurring in the line section assigned to the amplifier, as in the case of the amplifier of Fig. 1.

The circuit S tuned to the pilot frequency or tone transmitted over the line to the amplifier of Fig. 1 or Fig. 2 picks off pilot current at a point in the transmission circuit such that dele-

terious effects upon transmission in the circuit are avoided. Any point in the μ -circuit satisfies this condition. By bridging the pilot current selective circuit across the transmission path at a point in the μ -circuit of the amplifier instead of across the output, any loss in transmission due to the pilot current shunt is prevented from affecting the over-all transmission because, with enough feed-back, the transmission is practically independent of μ . Moreover, even though the part of the μ -circuit at which the pilot current is picked off be after the last tube, the shunt does not affect the amplifier output impedance. In fact designs might even in certain instances be so arranged that the pilot energy picked off would actually exceed the pilot energy transmitted to the line or cable. Preventing the shunt from affecting the amplifier output impedance is of importance for example for preventing reflection due to mismatching of the amplifier output impedance and the attached impedance at the pilot frequency. Such mismatching might produce objectionable cross-talk, for example in the case of "staggered" carrier systems having a pilot frequency associated with one set of signals lie within the frequency band of a signal of another set of signals. Preventing any loss in transmission due to the pilot current shunt from affecting the over-all transmission is of importance for example for reasons indicated by the following considerations.

Using a pilot frequency current as a means of automatic or manual regulation of the transmission, the procedure is to adjust the repeater gain until the pilot current output is correct. Thus, if the line attenuation increases the current out of the repeater is reduced and the gain is then increased until the output is normal.

In a practical system it is usually necessary to do this while the circuit is busy. Therefore, the customary procedure is to bridge across or so associate a sharply tuned circuit with the output that only the pilot current is selected and its amplitude is then examined, usually after first having been amplified.

Not only should this bridging loss be kept low so that the full output of the repeater is used to advantage, but this bridging loss should be, for the most nearly perfect results, exactly the same for the signal frequencies as for the pilot current frequency.

To show the desirability of having these losses equal, let S and P be the signal and pilot current voltages across the line or cable at the output of the transmitting terminal. Then at the output of the first repeater let x decibels be the difference between the bridging loss of the pilot current detector at signal and pilot frequencies; for example, say that the pilot current out of the repeater is attenuated x decibels more than the signal in getting past the bridging circuit to the line. Then, if the pilot current voltage across the line at the output of the first repeater is P the signal voltage instead of being S is S up x decibels. Now, if there were n repeaters the unwanted difference in level at the output of the n th repeater would be $n x$ decibels and if n is a large number, for example several hundred to several thousand, and $n x$ is to be less than 1 decibel, so as not to overload any of the repeater amplifiers by more than 1 decibel, x has to be of the order of a few thousandths of 1 decibel or a few ten-thousandths of a decibel which is a severe requirement in the first place and would add to the expense in the second place.

This disadvantage could be overcome by changing the equalization of the repeater so as to equalize for this bridging effect as well as the line or cable. However, this has its drawbacks and it would be advantageous if the need for doing it could be eliminated.

If the repeater amplifier is a feed-back amplifier this can be done by bridging the detector or pilot channel detecting system anywhere across the μ -circuit because if μ varies, the amplification of the amplifier which is

$$\frac{\mu}{1-\mu\beta}$$

does not vary if β is stable and $\mu\beta \gg 1$. However, where it is desired that when the detected pilot current is one value the pilot current out of the amplifier always remains unchanged, this bridging shunt ordinarily should be as near the output end of the μ -circuit as practical, for example, after the output tube of the amplifier rather than across its grid, at least unless the tube is stable as to gain or is separately stabilized by local negative feed-back.

In a pilot channel system the importance of having the pilot current out of the amplifier always at the same value for a given value of the detected pilot current, and consequently the importance of having the shunt after the last tube rather than, for example, across the grid of that tube, is lessened by the fact that the next repeater would correct for this preceding one and thus the effect of variation of the gain of the last tube of this preceding amplifier would be only to overload or underload just this one amplifier by the amount that the gain of its last tube might vary. However, when the pilot current is picked off from the plate circuit of the tube instead of its grid circuit, the pilot current ordinarily is much more easily detected, since the ease of detection is greater the higher the level of the pilot current energy at the point where it is picked off.

In any case, the "Q" of the coil of the circuit for selectively picking off the pilot current, and the gain of the pilot channel detector need not be so high as when the pilot current is picked off at the amplifier output. The "Q" of the coil could be very low with the gain control operated manually or with an automatically operated gain control using, for example, air condensers or silver sulphide as indicated above. With any considerable selectivity, by just adding delay in the pilot apparatus PA, for example, as in the above-mentioned Norman patent, the apparatus would not respond to the signal (e. g. voice fluctuations) to operate the gain adjusting network. A change would have to endure without interruption for a certain short length of time before it could affect the pilot channel regulating system. Then even with a broad band system only the channels adjacent to the pilot could produce an effect and with only two or several channels their effects would be fluctuating in character. With silver sulphide or boron either of which can be used as a heat controlled resistance, this delay can be introduced and controlled by appropriate consideration and design of the thermal properties of the silver sulphide or boron units.

While the invention has been described above with especial reference to negative feed-back systems, it is applicable also to systems stabilized by positive feed-back as described in my above-mentioned Patent No. 2,102,671 and published article. For example, in the amplifier of Fig. 1 or Fig. 2, the pilot frequency can be fed back in such phase and magnitude as to increase the gain as well as the gain stability of the amplifier at the pilot frequency, and the feed-back will still reduce the effect of the shunt circuit S upon the over-all gain of the amplifier.

What is claimed is:

1. A wave translating system comprising wave amplifying means and means feeding back waves in said system in such phase and magnitude as to render the gain stability of the system greater than without feed-back, means for supplying message waves and pilot current waves to the input of the amplifier, and frequency selective means in the μ -circuit of the system exclusive of said feedback means, for selecting pilot current.

2. A wave translating system comprising a wave amplifying path, a feed-back path from the output to the input of said amplifying path for producing gain-reducing feed-back, means supplying to said amplifying path signaling waves and other waves to be amplified therein, and means exclusive of said feedback path for diverting from said amplifying path amplified energy of said other waves, to the substantial exclusion of energy of said signaling waves, at a point of said amplifying path such that said feed-back reduces the effect that the influence of said diverting means upon the transmission properties of said amplifying path has upon the over-all transmission properties of said system.

3. In a multiplex carrier telephone system, comprising a repeatered transmission line having therein an amplifier supplied with speechmodulated carrier signaling waves and pilot current waves of frequency differing from said signaling waves, said amplifier having a feedback path from its output to its input for producing negative feedback therein, pilot current level indicating means at said amplifier, and frequency selective means exclusive of said feedback path connected in the μ -circuit of said amplifier and responsive to said pilot current for operating said level indicating means.

4. In a carrier wave signaling system, an amplifier, a transmission line for supplying to said amplifier signaling waves and pilot current waves, said line being subject to attenuation changes due to varying weather conditions, and said amplifier comprising an electronic device having an anode-cathode discharge path therein, a feedback path for producing negative feed-back in said amplifier, a load circuit for said amplifier, means comprising a bridge network connecting said discharge path to said load circuit and said feed-back path, a gain control device in said feed-back path adjustable to compensate for said line attenuation changes, and means for adjusting said gain control device comprising a frequency selective circuit in shunt relation to said discharge path.

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