(12) UK Patent Application (19) GB (11) 2 042 715 A

(21) Application No **8000805**
(22) Date of filing **10 Jan 1980**
(30) Priority data
(31) **54/012806**
(32) **8 Feb 1979**
(33) **Japan (JP)**
(43) Application published **24 Sep 1980**
(51) INT CL[3] **H04B 9/00**
(52) Domestic classification **G1A** AB C13 D10 G14 G7 P10 P18 R7 S10 S12
(56) Documents cited **None**
(58) Field of search **G1A**
(71) Applicant
Kokusai Denshin Denwa Co., Ltd., 3—2 Nishishinjuku 2-chome, Shinjuku-ku, Tokyo, Japan
(72) Inventors
Hiroharu Wakabayashi, Yasuhiko Niiro
(74) Agent
Gill, Jennings & Every

(54) Optical Repeater Monitoring System

(57) A digital optical communication system having a two-way optical transmission cable (1), with repeaters (2), between a pair of terminal stations (3A and 3B) at opposite ends of the cable is provided with a repeater monitoring system in which each repeater (2) is tested by transmitting from one of the terminal stations (3A) a repeater designation signal unique to that repeater immediately followed by the repeater test signal, each repeater having means which recognises its own designation signal and turns on an optical switch (LS) to complete an optical path between the transmission lines of the cable (1) so that the test signal at least is returned to the station (3A) by the designated repeater. The transmitted and returned test signals are compared at the terminal station 3A to determine the error rate of the digital signal in the cable. Each repeater also has means which derives a timing signal from the designation and test signals received by the repeater and which is effective to turn off the optical switch (LS), thereby breaking the return optical path, as soon as the test signal stops.

Fig. 1

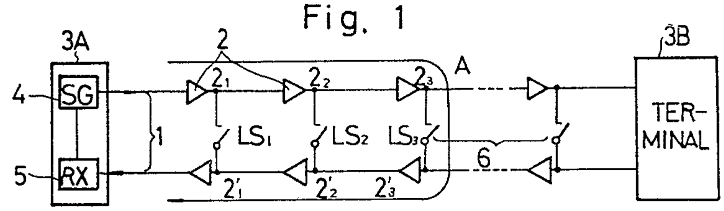

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Fig. 1

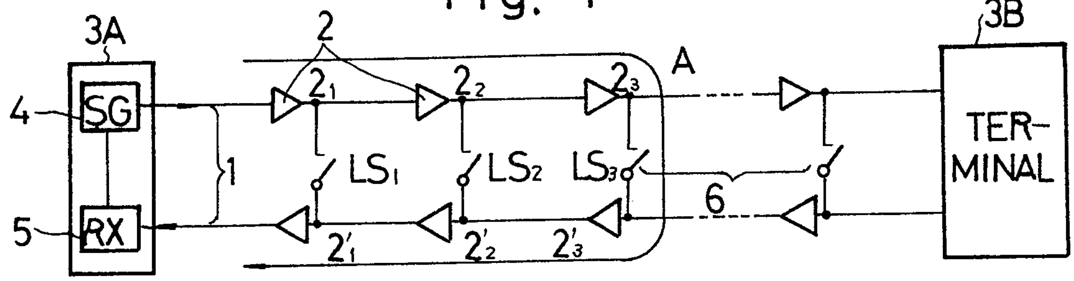


Fig. 2

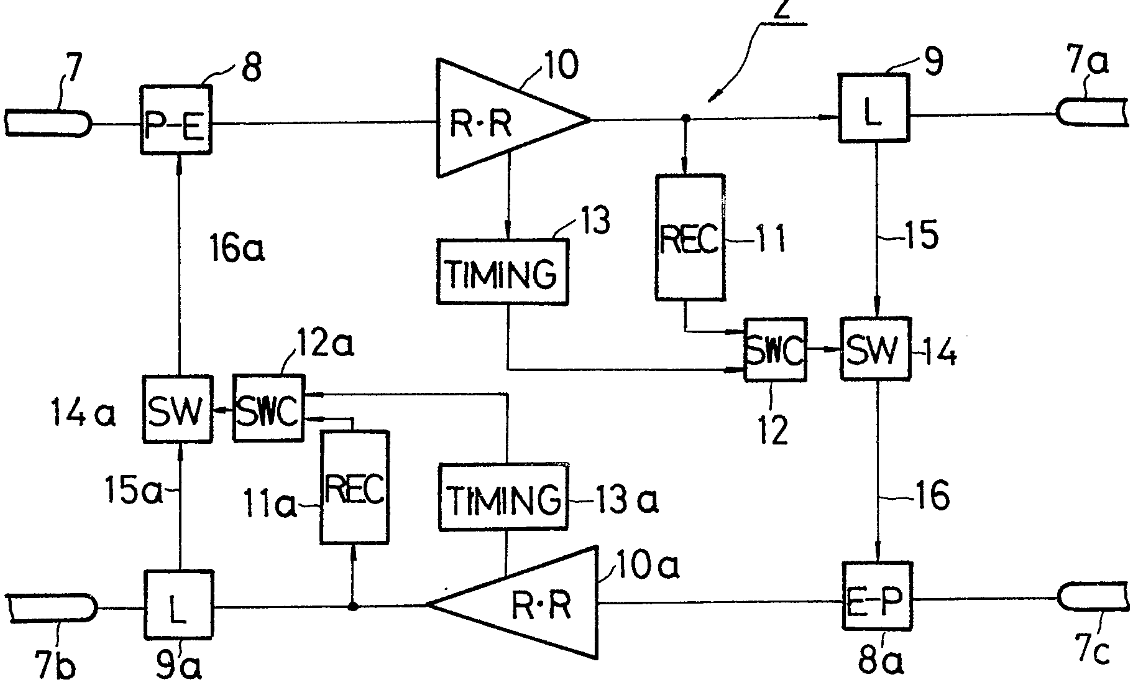
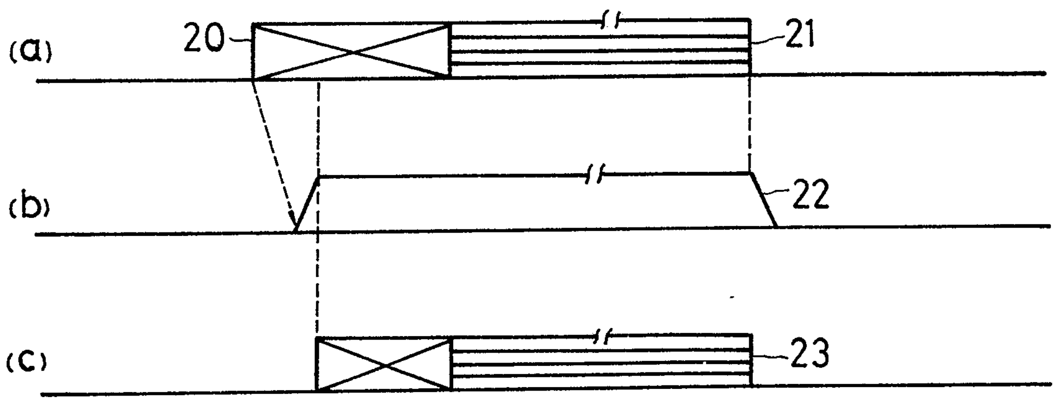


Fig. 3



SPECIFICATION

Optical Repeater Monitoring System

The present invention relates to a monitoring system for repeaters in a digital communication system utilizing an optical fibre submarine cable.

In an optical cable communication system, neither light emitter elements nor light receiver elements have satisfactory linear characteristics, and an analog system which transmits an analog signal cannot be used. Therefore, a digital transmission circuit which transmits a digital signal is presently under study for the application to an optical communication system. However, none of the monitoring systems which have previously been used in analog submarine cable systems is applicable to an optical fibre submarine cable in a digital communication system.

Some of the best known monitoring systems for onshore digital PCM communication systems are "the pulse trio system" described in "The Review of Electrical Communication Laboratories" Vol. 14, No. 1 published by Nippon Telegraph & Telephone Public Corporation, Tokyo, Japan, and "the phase detection system" or "AMI violation detecting system" described in "The Review of Electrical Communication Laboratories", Vol. 24, No. 9—10. However, these systems have the disadvantage that an interstitial cable is necessary in addition to the main communication cable in order to designate the particular repeater and/or carry a test signal to and from the repeater to be tested. If one tries to introduce such an interstitial cable monitoring system to an intercontinental optical fibre submarine cable communication system, additional repeaters for the interstitial cable are necessary since the intercontinental submarine cable will be too long to transmit without a repeater. The additional repeater or repeaters for the interstitial cable makes the communication system more complicated, and the interstitial cable must be as reliable as the main optical communication cable. Further, the system is uneconomical since the cable structure is complicated.

Various monitoring systems which do not employ interstitial cable but only the main cable have also been proposed, but none of them are free from disadvantages, some of which are as follows:—

1. Since the system is designed to return a part of the repeater designation signal itself directly as a test signal, an arbitrary test signal pattern cannot be utilized and the test signal pattern is severely restricted;

2. Since the system is designed to allocate a unique signal to the designation of each of the repeaters, it is impossible to test all the repeaters with a pattern commonly applicable to all the repeaters; and,

3. Since the system is designed to return a signal by employing an electrical circuit assembled in each repeater, the main communication route is required to have a switch connected in series therein (such as described in Japanese Patent laid open publication 51-99904). However, the electrical switch inserted in the main communication route reduces the reliability of the main communication route considerably.

With a view to solving these problems, Japanese Patent laid open publication 54-133001 discloses another system, according to which a repeater designation signal is used which is independent from the repeater test signal. When receiving the repeater designation signal, an optical switch forms a return circuit in the repeater for a predetermined duration to allow the repeater test signal to return through the return circuit. The problem with this system is that since the duration that the return circuit is formed is predetermined and is rather short, it is essential to finish the repeater test within this predetermined duration, thus causing the system to be inflexible and inconvenient in operation. Also, adverse effects are assumed for the long term stability of a time constant circuit for defining the predetermined duration.

In another prior proposal, the test signal is also returned by an optical switch (no conversion from optical energy to electrical energy is performed), but the repeater test signal doubles as the repeater designation signal and the system therefore suffers from some of the problems mentioned earlier.

With the aim of overcoming the above disadvantages and providing a new and improved optical repeater monitoring system for a digital communications system having first and second terminal stations at opposite ends of a two way optical fibre transmission cable and a number of optical repeaters at intervals along the cable, according to the present invention the repeater monitoring system comprises a digital signal generator at the first terminal station for generating and transmitting along one of the transmission lines of the cable a repeater designation signal immediately followed by a test signal, a different repeater designation signal being generated for each repeater of the communications system, an optical switch in each repeater which is arranged to close in response to recognition by the repeater of its particular designation signal, closure of the optical switch completing an optical path between the transmission lines of the cable so that the designation signal and the test signal are returned to the first terminal station from the designated repeater, and means at the first terminal station for comparing the transmitted test signal with the returned test signal to determine the error rate in the cable, the optical switch of the designated repeater being opened to break the return path on termination of a timing signal which is derived from the designation signal and the test signal by the repeater and which terminates when the test signal stops.

Some of the important features of the present invention are:—

(a) No interstitial cable is utilized for monitoring the system;

(b) The return path in each repeater is provided by an optical switch instead of an electrical switch, so that optical-to-electrical conversion is not necessary for the purpose of the monitoring;

(c) The repeater test signal is completely independent from the repeater designation signal; and,

(d) The signal return path completed by the optical switch is maintained for the entire time that the repeater test signal is transmitted, irrespective of how long the test signal lasts.

An example of an optical communication system embodying the repeater monitoring system in accordance with the present invention will now be described with reference to the accompanying drawings, in which:—

Figure 1 is a schematic representation of the communication system;

Figure 2 is a block diagram of an optical repeater which may be used in the system; and,

Figures 3(a), 3(b), and 3(c) are time charts relating to the operation of different components of the optical repeater monitoring system.

In Figure 1 the reference numeral 1 represents a two-way submarine cable made of optical fibre, the numerals 2 represent optical repeaters inserted in the submarine cable 1, and the references 3*A* and 3*B* represent land-based terminal stations connected at the extreme ends of the submarine cable 1. In the system depicted in Figure 1, each optical repeater 2 is arranged to be monitored from the terminal station 3*A*, but it will of course be understood that the system could be arranged so that each optical repeater can be monitored from the other terminal station 3*B* instead of from the station 3*A*. The reference numeral 4 represents a digital signal generator which is arranged to send out a repeater designation signal fro designating the particular repeater to be tested, and a repeater test signal which follows immediately after the designation signal. A different designation signal is, of course, allocated to each of the repeaters.

Each repeater 2 has a designation signal receiver (not shown in Figure 1) which closes an optical switch 6 upon receipt of the appropriate designation signal from the signal genèrator 4. In the example illustrated in Figure 1, the third repeater 2_3 from the station 3*A* is designated, and its associated optical switch LS_3 is therefore closed while the optical switches installed in the other repeaters are open since the other repeaters do not recognise the designation signal of the third repeater 2_3. The optical switch LS_3 is kept closed while the designated repeater 2_3 receives its designation signal and the following repeater test signal. Accordingly, the repeater test signal from the terminal 3*A* following the designation signal returns along the cable 1 to a signal receiver 5 installed at the terminal station 3*A*, the signal passing through the repeaters $2_3'$, $2_2'$, and $2_1'$ as shown by the arrow A in Figure 1. The signal receiver 5 compares the signal generated by the signal generator 4 with the corresponding signal which has returned from the designated repeater 2_3, and accordingly determines the error rate of a digital signal in the submarine cable.

In this way, it is possible to measure the error rate at each repeater 2 in an extremely simple manner. It should be appreciated that the test attern chosen for the monitoring process can be selected arbitrarily, and that all the repeaters of the communication system can be tested with the same test pattern. Further, provided that the power supply is available, the monitoring system in accordance with the invention can allocate a faulty repeater even when the cable is broken or cut.

Figure 2 is a block diagram of an embodiment of an optical repeater which can be used in carrying out the present invention. It should be noted that the repeater shown can repeat signals transmitted along the cable 1 in either direction, that is ether from the first terminal station 3*A* to the second terminal station 3*B* or vice versa. In the figure, the reference numerals 7, 7*a*, 7*b* and 7*c* depict low loss optical fibres which constitute the main communication cable on opposite sides of the repeater 2. The numeral 8 repressnts a first light receiver element which is connected to the end of the optical fibre 7 of the main cable for converting the optical energy received along the fibre 7 to an electrical signal. The first light receiver element 8 is also arranged to receive optical signals along a line 16*a* as will be described later. The electrical signal provided by the element 8 is repeated and/or amplified by a first regenerative amplifier 10, and the output from the amplifier 10 is applied to a first light emitter element 9 and a first repeater designation signal receiver 11. The first light emitter element 9 converts electrical signals to corresponding optical signals, and the major portion of the converted optical signal power is fed to the optical fibre 7*a* for onward transmission along the communication cable. The minor portion of the converted optical signal power from the emitter 9 is fed to an optical fibre path 15 which forms part of a monitoring circuit. Since only a minor portion of the optical signal power is fed to the monitoring circuit, its influence on the main communication path can be neglected. The repeater designation signal receiver 11 receives the output of the regenerative amplifier 10, and when it recognises the designation signal representing the repeater, the receiver 11 applies a control signal to a first optical switch control circuit 12 which is then turned ON. In addition the monitoring circuit includes a first timing signal detection circuit 13 which is connected to the regenerative amplifier 10 to derive a timing signal from the repeater designation signal and the repeater test signal, and to provide the timing signal to the switch control circuit 12.

When the optical switch control circuit 12 is turned ON by the designation signal receiver 11, the optical switch (shown at 14 in Figure 2) is turned ON to complete an optical path through the fibre 15 and a further optical fibre 16 to a second light receiver element 8*a* forming part of a second repeater chain 8*a*, 10*a* and 9*a* which is located between the optical fibres 7*c* and 7*b* of the main cable and which operates in the same way as the repeater chain 8, 10, and 9 but on signals transmitted in the opposite direction, i.e. from the station 3*B* towards the station 3*A*. Consequently, signals transmitted by the optical path 15, 16 when the switch 14 is ON are returned to the terminal station 3*A*, from which they originated.

The switch control circuit is held ON for as long as it receives the timing signal from the timing circuit 13. Accordingly, the optical switch 14 is held ON while the repeater receives the repeater designation signal and the repeater test signal, and the return path from the light emitter element 9 to the light receiver element 8*a* through the optical fibre 15, the optical switch 14, and the optical fibre 16 is maintained for this duration so that the designation and test signals are returned to the station 3*A* for processing by the receiver 5.

When the repeater test signal transmitted from the terminal station 3*A* stops, the timing signal applied to the switch control circuit 12 by the timing circuit 13 also stops, thereby turning the circuit OFF and resetting the optical switch 14 to OFF so that the optical return path through the repeater is disconnected. Generally speaking, the time from the stop of the test signal to the stop of the timing signal is approximately 1 μs, so the time which must be spared between two independent tests for different repeaters, i.e. the guard time, can be minimized.

As will be seen from Figure 2, in addition to the second repeater chain 8*a*, 10*a* and 9*a*, the repeater 2 has a second monitoring circuit comprising a second repeater designation signal receiver 11*a*, a second optical switch control circuit 12*a*, a second timing signal detection circuit 13*a*, a second optical switch 14*a*, and optical fibres 15*a* and 16*a* for communicating the light emitter 9*a* with the light receiving element 8 when the switch 14*a* is closed. The second monitoring circuit is provided for monitoring the repeater 2 from the opposite direction, i.e. from the terminal station 3*B*.

Figure 3 shows a time chart illustrating the sequential operation of the system in accordance with the present invention. More particularly, Figure 3(a) shows the time for which the repeater designation signal 20 and the repeater test signal 21 are transmitted from the terminal station 3*A* on land. Figure 3(b) depicts the time 22 that the optical switch circuit 14 is held ON during a monitoring cycle, i.e. from recognition of the designation signal 20 to the end of the test signal 21. Figure 3(c) illustrates the duration 23 of the signal which is returned to the station 3*A* during the monitoring cycle and comprising the latter portion of the designation signal 20 and all of the test signal 21.

The optical switch control circuits 12 and 12*a* may comprise ordinary flip-flop circuits. This facilitates the recovery from an abnormal incident by stopping the power supply when the return path is not reset by the abnormal incident. For the optical switches 14 and 14*a*, any type of mechanical optical switch may be used.

As explained above, the use of a monitoring system in accordance with the present invention in a digital optical communication system has the following advantages:—

(a) An arbitrary pattern can be used as a repeater test signal;

(b) All of the repeaters can be tested using an identical test signal pattern;

(c) The time period for testing any repeater can be designed arbitrarily;

(d) The length of the guard time between the end of a test on one repeater and the start of a test on the next repeater can be extremely short;

(e) The reliability of the main communication route is not affected by the addition of the monitoring system, since the return path in each repeater is connected or disconnected to or from the main route without disconnecting the main optical route;

(f) Upon accidental breakage of the communication cable, the monitoring system is useful for locating the breakage point, provided that the power supply is available; and,

(g) An optical switch inherently allows much larger ON-OFF ratios of optical power in comparison with any electrical or semiconductor type switch.

Claims

1. A repeater monitoring system for a digital communications system having first and second terminal stations at opposite ends of a two way optical fibre transmission cable and a number of optical repeaters at intervals along the cable, the monitoring system comprising a digital signal generator at the first terminal station for generating and transmitting along one of the transmission lines of the cable a repeater designation signal immediately followed by a test signal, a different repeater designation signal being generated for each repeater of the communications system, an optical switch in each repeater which is arranged to close in response to recognition by the repeater of its particular designation signal, closure of the optical switch completing an optical path between the transmission lines of the cable so that the designation signal and the test signal are returned to the first terminal station from the designated repeater, and means at the first terminal staion for comparing the transmitted test signal with the returned test signal to determine the error rate in the cable, the optical switch of the designated repeater being opened to break the return path on termination of a timing signal which is derived from the designation signal and

the test signal by the repeater and which terminates when the test signal stops.

2. A monitoring system according to Claim 1, in which each repeater comprises a light receiver element for converting digital optical signals received from the first terminal station along said one of the transmission lines into corresponding electrical signals, a regenerative amplifier for regenerating and amplifying the electrical signals from the light receiver element, a light emitter for reconverting the electrical signal output from the regenerative amplifier into optical signals for onward transmission along said transmission line, a timing signal circuit connected to the regenerative amplifier and responsive to the repeater designation signal and the test signal to provide a timing signal output which terminates when the test signal terminates, a designation signal detector connected to the output of the regenerative amplifier and responsive to the particular designation signal of the repeater to provide a recognition signal output, and an optical switch control circuit which is connected to receive the outputs from both the timing signal circuit and the designation signal detector and which closes the optical switch on receipt of the recognition signal and subsequently opens the switch when the timing signal stops, closure of the switch allowing a portion of the output from the light emitter to be transmitted to a second light receiver element which is also arranged to receive digital optical signals along the other transmission line of the cable and originating from the second terminal station, the second light receiver element converting its received optical signals into corresponding electrical signals which are fed through a second regenerative amplifier to a second light emitter for reconversion into optical signals for transmission along said other transmission line towards the first terminal station.

3. A monitor system according to Claim 2, in which the second terminal station has a digital signal generator and test signal comparison means similar to those at the first terminal station, and each repeater has a second optical switch, a second optical switch control circuit, a second designation signal detector, and a second timing signal circuit which are arranged so that the repeater can be monitored from the second terminal station in the same way as it can be monitored from the first terminal station, closure of the second optical switch completing an optical path which allows a portion of the output from the second light emitter to be transmitted to the first light receiver element.

4. A monitoring system according to Claim 1, substantially as described with reference to the accompanying drawings.

Printed for Her Majesty's Stationery Office by the Courier Press, Leamington Spa, 1980. Published by the Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.