

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
12 September 2002 (12.09.2002)

PCT

(10) International Publication Number
WO 02/071655 A2

- (51) International Patent Classification⁷: **H04B 10/10**
- (21) International Application Number: PCT/GB02/00139
- (22) International Filing Date: 14 January 2002 (14.01.2002)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
2001105766/09 1 March 2001 (01.03.2001) RU
- (71) Applicant (*for all designated States except US*): **SCEPTRE COMMUNICATIONS LIMITED** [GB/GB]; Singleton Court, Wonastow Road, Monmouth NP25 5JA (GB).
- (72) Inventors; and
- (75) Inventors/Applicants (*for US only*): **NIKIFOROV, Evgeny Alexeevich** [RU/RU]; 10-1 apt 100, Proezd, Borisovsky, Moscow 115563 (RU). **POBEDONOSTEV, Konstantin Alexandrovich** [RU/RU]; Apt 35, Energetcheskaya Street 9, Moscow 111116 (RU). **CHERNOPLEKOV, Anatoly Nikiforovich** [RU/RU]; 14-4, apt 54, S. Lazo Street, Moscow 111398 (RU). **TOLSTYKH, Evgeny Matveevich** [RU/RU]; Block 116, 4, apt 50, Lyubertsy Kirova Street, Moscow Region 140002 (RU). **GORDIENKO, Vladimir Nikolaevich** [RU/RU]; 25-1, apt 4, Moscow Plakhanova Street, Moscow (RU).
- (74) Agent: **MURGITROYD & COMPANY**; Scotland House, 165-169 Scotland Street, Glasgow G5 8PL (GB).
- (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Published:**
— *without international search report and to be republished upon receipt of that report*
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*

(54) Title: WIRELESS DUPLEX OPTICAL COMMUNICATION SYSTEM

(57) **Abstract:** A wireless optical communication systems using two optical transceivers located at the opposite ends of an optical communication line. The optical communication system can be either two-element, when each of the said transceivers contains one optical transmitter (emitter) and one optical receiver, or it can be four-element, where each of the said transceivers contains two optical transmitters and two optical receivers. The output of each of the optical transmitters is a diverging beam of incoherent electromagnetic radiation arranged to have a cross sectional diameter which is larger than the cross sectional diameter of the respective optical receiver at that point on the communication line at which the respective optical receiver is situated. The invention reduces the probability of communication failure, higher noise resistance, and lowers operation and production costs.



WO 02/071655 A2

1 WIRELESS DUPLEX OPTICAL COMMUNICATION SYSTEM

2

3 The invention relates to wireless optical
4 communication systems and can be used in digital
5 communication systems, in particular for wireless
6 information exchange, e.g. between computers that
7 are moving in relation to each other, or are divided
8 by a barrier impeding the use of wireless
9 communication means.

10

11 An optical communication system is known, which uses
12 two terminals located on the ends of an optical
13 communication line formed thereby. Each terminal
14 includes a combination of laser transmitters, which
15 emit a set of laser beams carrying information
16 signals received at the other terminal which are
17 summed up incoherently. However such systems must
18 use laser transmitters in order to operate for long
19 periods, these are expensive and technically
20 complex.

21

1 An optical communication system is known, which
2 provides for wireless information exchange and
3 contains the transmitting and receiving components
4 made in the form of an optical transmitter and an
5 optical receiver. The problem with this known system
6 is that environmental conditions influence the
7 stability of communication, when high rates of
8 information transmission, and long range
9 communication are required. In addition such
10 optical communication systems have a short service
11 life with rather high production and operation
12 costs.

13

14 Among the environmental conditions that degrade
15 communication there are:

16

- 17 1. Atmospheric phenomena, such as fog, rain, snow.
18 These conditions lead to attenuation of the
19 signal in the communication line.
- 20 2. Deformations and slow vibrations of buildings
21 and structures, where optical receivers and
22 optical transmitters (emitters) are installed.
23 These result in a loss or partial reduction of
24 the received signal level due to broken mutual
25 pointing of the optical receivers and optical
26 transmitters (emitters) at the opposite
27 communication points.
- 28 3. Crossing of the communication lines by non-
29 transparent objects, e.g. birds, which can
30 bring about sharp short-time weakening of the
31 signal.

1 4. Position error and change of the angle at which
2 the beam arrives at the optical receiver
3 aperture.

4 5. When the beam passes through convection
5 currents caused by heat from the sun, for
6 example, fluctuations of the light capacity on
7 the photodiode of the optical receiver can
8 result causing poor communication quality
9 where large beam amplitudes are required.

10

11 The present invention is at least in part aimed at
12 minimising the communication quality reduction that
13 result from the above factors as well as providing a
14 system that is cheap to produce and run.

15

16 In accordance with the present invention there is
17 provided apparatus for wireless duplex
18 communication, comprising, a first optical
19 transceiver having a first optical transmitter and a
20 first optical receiver, a second optical transceiver
21 having a first optical transmitter and a first
22 optical receiver, the first and second optical
23 transceivers being located at the opposite end of an
24 optical communication line formed thereby, wherein
25 the output of each of the optical transmitters is a
26 diverging beam of incoherent electromagnetic
27 radiation arranged to have a cross sectional
28 diameter which is larger than the cross sectional
29 diameter of the respective optical receiver at that
30 point on the communication line at which the
31 respective optical receiver is situated.

1 Preferably, the optical transmitter comprises a
2 light emitting diode the incoherent electromagnetic
3 radiation.

4 Preferably, the optical transmitter comprises the
5 LED and further comprises at least one optical
6 condenser lens, the input to the optical condenser
7 lens being provided by the LED and the output of the
8 optical transmitter being provided by the optical
9 condenser.

10 Preferably, the optical receiver consists of an
11 optical condenser lens, diaphragm and photodiode,
12 wherein the diaphragm is installed in the focal
13 plane of the optical condenser lens.

14 Preferably the distance Δ between the photodiode and
15 the diaphragm situated in the focal plane of the
16 optical condenser lens is defined by the formula

17 $\Delta = b F / D_c$, where

18 b - diameter of the light-sensitive site of the
19 photodiode,

20 D_c - diameter of the optical condenser lens.

21

22 Preferably, the input of the optical condenser is
23 the input of the optical receiver, and the output of
24 the photodiode is the output of the first optical
25 receiver.

26

27 Preferably the beam angle θ characterizing of the
28 first optical transmitter and the first optical
29 receiver of each of the said transceivers is defined
30 from the following condition:

1 $\tan 2\theta = a / F$, where

2 a - diameter of the diaphragm aperture;

3 F - focal distance of the optical condenser measured
4 from the lens of the optical condenser to the centre
5 of the stop aperture.

6 Preferably, the beam angle is between 30 and 60
7 angular minutes.

8 Preferably, the distance between the optical
9 transmitter and optical receiver of a transceiver is
10 greater than or equal to $d/2$, where $d = 30\text{cm}$.

11 Optionally $d=60\text{cm}$.

12 Preferably an input of the optical transmitter of
13 the first transceiver is connected to an output of a
14 converter through a modulator, and an output of the
15 optical receiver of the first transceivers is
16 connected to an input of a demodulator, the output
17 thereof being connected to an input of a converter.

18 Preferably, an input of the optical transmitter of
19 the second transceiver is connected to an output of
20 a converter through a modulator, and an output of
21 the optical receiver of the second transceivers is
22 connected to an input of a demodulators, the output
23 thereof being connected to the input of a converter.

24

25 Preferably, the converter is made in the form of a
26 transformer, which transforms the signals of the
27 input discrete information into a coded signal using
28 the Manchester code during transmission, and which
29 is capable of a reverse transformation of signals

1 coming from the outputs of the respective
2 demodulators during reception.

3 Preferably, each optical transceiver further
4 comprises a second optical transmitter and a second
5 optical receiver.

6 Preferably, said transceivers are connected to the
7 input of the respective demodulators through a
8 summator.

9 Preferably, the input of the second optical
10 transmitter of each of the transceivers is connected
11 to the output of the respective modulator, and the
12 outputs of the first and second optical receivers is
13 connected to the input of the respective demodulator
14 through a summator.

15

16 In one embodiment of the present invention, the
17 optical system is a two-element system, which uses
18 one optical transmitter (optical emitter) and one
19 optical receiver in each optical transceiver thereby
20 forming two communication channels. When a two-
21 element optical transceiver is used, the spacing of
22 the optical transmitter and the optical receiver
23 creates its own route of beam transmission for each
24 beam of the duplex wireless optical communication
25 line and therefore creates two communication
26 channels. The probability of simultaneous emergence
27 of conditions for maximum deviation of the beam in
28 both transmission directions and thus the
29 probability of simultaneous communication failure in

1 both channels, is reduced as compared to the case of
2 transmission along a single, common route.

3

4 In another embodiment of the present invention, the
5 optical system is a four-element system. In this
6 case, each of the said transceivers is equipped with
7 a second optical transmitter and a second optical
8 receiver similar to the first optical transmitter
9 and the first optical receiver, which will together
10 form four communication channels. In this
11 embodiment, the optical transmitters and receivers
12 of each transceiver are spaced on a plane
13 perpendicular to their optical axes in relation to
14 the straight line connecting their optical axes on
15 the plane.

16

17 The optical transmitters and receivers of the first
18 transceiver are arranged in the following order:
19 first optical receiver;
20 first optical transmitter;
21 second optical receiver; and
22 second optical transmitter.

23

24 In the second transceiver in relation to the first
25 transceiver, the optical transmitters and receivers
26 are arranged in the following order:
27 first optical transmitter;
28 first optical receiver;
29 second optical transmitter; and
30 second optical receiver.

31

1 It will be appreciated that the order of the first
2 and the second transceivers could be reversed.

3

4 The spacing between each component of each
5 transceiver is defined as being $d/2$, where $d = 30\text{cm}$.
6 It has been found that this value represents a value
7 below which the probability of protection against
8 failures in the system reduces in cases where the
9 line of sight between the transmitter and receiver
10 is obscured by non-transparent objects or where
11 errors in the angle of arrival of the light beam to
12 the optical receiver have occurred or where the beam
13 passes through turbulent atmosphere.

14

15 The outputs of the photodiodes of the first and
16 second optical receivers of each of the said
17 transceivers are connected to the input of the
18 respective demodulator through a summator. The
19 outputs of the second optical transmitter in each of
20 the said transceivers are connected to the relevant
21 modulator.

22

23 The invention will now be described by way of
24 example only with reference to the accompanying
25 drawings in which:

26

27 Fig. 1 shows a first embodiment of the present
28 invention having a pair of two-element transceivers
29 Fig. 1 also shows the location (spacing) of the
30 optical transmitters (optical emitters) and the
31 optical receivers of the transceivers as well as the

1 transmission geometry of optical beams emitted by
2 the optical transmitters;

3

4 Fig. 2 shows a second embodiment of the present
5 invention having two four-element transceivers, the
6 location (spacing) of the optical transmitters
7 (optical emitters) and the optical receivers in the
8 optical communication system is also shown along
9 with the transmission geometry of optical beams
10 emitted by the optical transmitters;

11

12 Fig. 3 is a flow chart of the optical communication
13 system for two-element transceivers of Fig. 1;

14

15 Fig. 4 is a flow chart of the optical communication
16 system for four-element transceivers of Fig 2; and

17

18 Fig. 5 shows an optical receiver (location of the
19 optical receiver elements) used in the embodiment of
20 the present invention illustrated in Figs. 1 to 4.

21

22 Referring to Figs. 1 and 3, the wireless optical
23 duplex communication system uses two-element
24 transceivers each of which are connected to an
25 optical transceiver 3 and 5, a modulator 23 and 25,
26 a demodulator 27 and 29 and a converter 39 and 41.
27 The combination of optical transceiver, modulator,
28 demodulator and converter is referred to as a semi-
29 set. The first 3 and second 5 optical transceivers
30 are located facing each other at the opposite ends
31 of the optical communication line formed
32 therebetween. The converters 39 and 41 are connected

1 to the digital information exchange network
2 (transmission and reception) (not shown). Since the
3 system is duplex, and the operations of information
4 transmission and reception from one semi-set to the
5 other are the same in both directions, the
6 information transmission process will be explained
7 with reference to the communication line (channel)
8 from the first semi-set to the second with two-
9 element transceivers 3 and 5. The input information
10 (input discrete signal) comes to a converter 39 of
11 the first semi-set connected to the first optical
12 transceiver 3, where it is coded utilising
13 Manchester-type code. The input information is then
14 fed at pre-defined logical levels to Modulator 23
15 which controls the emission of LED 43a which is part
16 of the optical transmitter (optical emitter) 9 in
17 such a way that during transmission of logical "1"
18 light pulses are emitted in the first half of the
19 given clock interval, and during transmission of
20 logical "0" light pulses are transmitted in the
21 second half of the given clock interval. The signal
22 emitted by LED 43a comes to optical condenser 37a of
23 the first optical transmitter 9. The optical
24 condenser 37a forms the beam angle of the optical
25 transmitter 9 (optical emitter) to be between 30 and
26 60 angular minutes.

27
28 Manchester-type coding is used, because it ensures
29 resistance to impulse noise and reduces the
30 probability of false alarms at the signal/noise
31 ratios found in devices of this type. In the
32 Manchester-type code the leading edge of the signal,

1 is used for coding unities and zeros. During such
2 coding, the bit period (time to transmit one bit of
3 data) is divided into two parts. Information is
4 coded by potential differences happening in the
5 middle of each bit period. A unity is coded by a
6 change from the low level to the high one, and zero
7 by the reverse change. At the beginning of each bit
8 period, there may be a service signal drop, if
9 several unities or zeros are to be transmitted.
10 Since the signal is changed at least once per bit
11 period such a code possesses good self-synchronizing
12 qualities and advantageously, allows the use of two
13 signal levels for data transmission.

14
15 The optical radiation of the first optical
16 transmitter 9 of the first transceiver 3 irradiates
17 the optical condenser 37c of the first optical
18 receiver 15 of the second transceiver 5, see beam A
19 in Fig. 1). The optical energy collected by the
20 optical condenser 37c of the first optical receiver
21 13 of the second transceiver 5 is directed through a
22 stop or diaphragm aperture 45 (Fig.5) to a
23 photodiode 35a. Thereafter, it is transformed into
24 an electric signal, and then directed to demodulator
25 29. The optical condenser of the optical receiver 35
26 forms an angular beam of between 30 and 60 angular
27 minutes. In the demodulator 29 of the second
28 transceiver 5 the signal is transformed into logical
29 levels of the Manchester-type code and is fed to
30 converter 41 where it is transformed into an
31 information signal in accordance with the

1 requirements of the network protocols and directed
2 to the information transmission digital network.

3

4 To reduce the probability of communication failures
5 in case communication lines are crossed by non-
6 transparent objects, the optical receiver and
7 optical transmitter of each semi-set are spaced
8 apart on a plane perpendicular to their optical axes
9 to a distance of $d/2$ where $d = 30$ cm. This reduces
10 the probability of simultaneous failure in both
11 channels of the duplex communication line.

12

13 When a two-element optical transceiver, as described
14 with reference to Figs. 1 and 3, is used, the
15 spacing of the optical devices creates a separate
16 route of beam transmission for each channel of the
17 duplex communication line (beam A, beam B in Fig.
18 1). The probability of simultaneous emergence of
19 conditions for the maximum beam deviation in both
20 routes of transmission, and, thus, the probability
21 of a simultaneous communication failure in both
22 channels, is reduced as compared to the case of
23 transmission along a common route.

24

25 The present invention, with two-element transceivers
26 using two routes (two communication channels) of
27 beam transmission (beams A, B in Fig. 1) provides
28 for integral summation of signals by two spaced beam
29 transmission routes. The integral summation thus
30 formed in the communication system realizes the
31 information transmission, reception and processing
32 scheme, in which simultaneous failures in both

1 channels are possible only in case of simultaneous
2 communication failures in both beam transmission
3 routes.

4

5 A special optical scheme is used for each of the
6 optical receivers (Fig. 5), in which a diaphragm or
7 stop aperture 45 is installed in the focal plane of
8 the lens 37, forming the visual angle of the optical
9 receiver (the beam angle). Angle θ characterizing
10 the beam angle is defined from the condition

11

12 **$\tan 2\theta = a / F$**

13

14 Where

15 **a** is the diaphragm aperture diameter.

16 **F** is the focal distance of the optical condenser
17 measured from the optical condenser lens to the
18 centre of the diaphragm aperture.

19

20 The optical scheme sets the maximum and minimum beam
21 angle for transmission and, in conjunction with the
22 diaphragm 45, reduces the density of the light flow
23 on the photodiode surface and consequently increases
24 the operation resource of LED.

25

26 The photodiode 35 is located behind the diaphragm 45
27 at distance Δ providing for reduced density of the
28 light flow falling on the photodiode, without
29 reducing the value of the light capacity of the said
30 flow, where

31

32 **$\Delta = b F / D_c$** .

1

2 where

3 **b** is the diameter of the light sensitive photodiode
4 site.5 **D_c** is the diameter of the optical condenser lens.

6

7 To remove the effect of deformations and slow
8 vibrations of buildings and structures, the beam
9 angle of optical transmitters (beam divergence) and
10 receivers (visual angle) is standardized. Allowable
11 values of the beam angle of the optical transmitters
12 and receivers are limited to maximum and minimum
13 values and are selected using the above equation to
14 be between 30 and 60 angular minutes in this
15 example. In a typical example, an infra-red beam
16 having a frequency of 340000 GHz and wavelength of
17 850 nm is created having a beam diameter of 10m at a
18 distance of 1.5Km from its source.

19

20 In general, the minimum value of the beam angle is a
21 practical limit which ensures the absence of
22 communication failures in case of an error of mutual
23 angular pointing caused by deformations and slow
24 vibrations of buildings or position errors and
25 change of the angle of arrival of the light beam to
26 the aperture of the optical receiver when the beam
27 passes through turbulent atmosphere. The maximum
28 beam angle value is set to provide sufficient power
29 in the communications line to allow effective
30 communication.

1 In an optical communication system where four-
2 element optical transceivers 103, 105 are used (Fig.
3 2, 4), each consisting of the first optical
4 transmitter 109, the first optical receiver 107, the
5 second optical transmitter 117, and the second
6 optical receiver 119 are located as shown in Fig. 2
7 and are similar to the optical transmitters and
8 optical receivers of the two-element transceivers 3,
9 5.

10 The information transmission process is as follows,
11 and, since the system is duplex and the operations
12 of information transmission from one transceiver to
13 the other are the same in both directions, the
14 information transmission process will be described
15 with reference to the communication channel from the
16 first transceiver 103 to the second transceiver 105
17 (Fig. 2, 4).

18 The information (signal) comes to converter 139 of
19 the first optical transceiver 103, where it is coded
20 using the Manchester-type code and then fed to
21 Modulator M1 123 of first optical transceiver 103 to
22 control emission of LED 143a and 143b of the first
23 and second optical transmitters 109 and 117 through
24 respective optical condensers 137a, 137c in such a
25 way that during transmission of logical "1" light
26 impulses are emitted in the first half of the given
27 clock interval, and during transmission of logical
28 "0" light impulses are transmitted in the second
29 half. Optical condensers 137a and 137c of the first
30 and second optical transmitters 109 and 117
31 respectively, form the beam angle of each optical

1 transmitter (optical emitter) at between 30 and 60
2 angular minutes. Manchester-type coding is used as
3 shown above, because it ensures resistance to
4 impulse noise and reduces the probability of false
5 alarm. The optical radiation of each of the optical
6 transmitters 109 and 117 irradiates optical
7 condensers 137b and 137d of the first and second
8 optical receivers 111 and 119 of the second optical
9 transceiver 105 (beams C,D,E and F in Fig.2). The
10 optical energy collected by the optical condensers
11 37 (fig.5) is directed through the respective
12 diaphragm apertures 45 to respective photodiodes
13 35, transformed into electric signals summed later
14 in electronic summator $\Sigma 2$ 133 of the second optical
15 transceiver 105. The summator implements the
16 information transmission and processing scheme. A
17 failure of information transmission through the
18 communication channel is possible only where a
19 simultaneous failure in all four beam spreading
20 routes has occurred.

21

22 Optical condensers 137b and 137d form the beam angle
23 of the respective optical receivers between 30 and
24 60 angular minutes, and angle θ characterizing the
25 beam angle is also defined from the condition

26
$$\tan 2\theta = a / F,$$

27 the optical receivers in the four-element system
28 being similar to those in the two-element system.

1 In the proposed four-element system, integral
2 summation of signals coming through the four beam
3 transmission routes is made, which makes it possible
4 to realize an information transmission and
5 processing scheme that prevents failure of
6 information transmission through the said
7 communication channels except in case of
8 simultaneous failures in all the four beam
9 transmission routes.

10 In demodulator 129 of the second optical transceiver
11 105 the signal from the $\Sigma 2$ summator 133a output is
12 transformed into the logical levels of the
13 Manchester-type code and fed to converter K2 of the
14 second optical transceiver 105, where it is
15 transformed into signals meeting the network
16 protocol requirements and channeled to the digital
17 information (consumer) network.

18 If we regard the four-element information
19 transmission and reception system as a whole (two
20 transceivers and four respective transmitters and
21 four receivers), its realization allows for the
22 formation of an integral summing system (since
23 summation due to the beam transmission geometry
24 shown in Fig. 2 is made in each communication
25 channel: optical transmitter - optical receiver),
26 which embodies the information transmission and
27 processing system, where a simultaneous failure in
28 all the channels is possible only in case of
29 simultaneous failures in eight beam transmission
30 routes (beams C, D, E, F. G. H, I and J in Fig. 2).

1 Thus, due to the design of the wireless optical
2 duplex communication system and the use of the
3 Manchester-type code, resistance to impulse noise is
4 increased, and the probability of false alarm is
5 lowered. In addition, the present invention
6 incorporates a data confirmation routine in which
7 confirmation that data has been received at a
8 transceiver is provided by sending a separate data
9 stream in the opposite direction in a different
10 vector space. This is achieved by attaching a
11 characteristic group of symbols to the data packet.
12 The receipt of these symbols is acknowledged by the
13 transmission of an acknowledgement to the data
14 packet transmitter. Where receipt of the data
15 packet has not been acknowledged, transmission of
16 the original data package will be repeated.

17 Beam angle selection makes it possible to prevent
18 communication failures in case of a mutual angular
19 pointing error where the necessary energy potential
20 in the communication line is available. Spacing of
21 the optical transmitters and receivers at each end
22 (point) of the communication line reduces the
23 probability of failures, when the line is crossed by
24 nontransparent objects. The use of a special optical
25 receiver circuit helps reduce the density of the
26 light flow on the photodiode surface and increases
27 the LED operation resource.

28 The embodiments of the present invention shown above
29 use LEDs as incoherent light sources. Incoherent
30 light sources have a number of advantages over laser

1 (or coherent) sources for use in communications
2 systems.

3 The radiation spectrum width of a laser is many
4 times smaller than that of an incoherent light
5 source and the spectral emission width in the
6 atmosphere can correspond to the typical laser
7 radiation spectrum width. Therefore attenuation of
8 the laser beam by atmospheric conditions can be
9 severe. The larger spectrum width of the incoherent
10 light source greatly decreases the likelihood of
11 high attenuation. Therefore, in laser
12 communications systems (depending upon the
13 temperature of the laser, where the wavelength
14 depends upon temperature) attenuation values can
15 exist that correspond to maximum atmospheric
16 spectral emission values, whereas in incoherent
17 systems, such as LED systems, the much larger
18 spectrum width obviates this problem.

19 In addition, LEDs are much cheaper than lasers to
20 manufacture and unlike lasers, are safe even for
21 personnel located in close proximity to the optical
22 transmitters (emitters). In particular, where high
23 power lasers are used to increase the range over
24 which a communications system can operate, there is
25 an increased health risk to people caught in the
26 beam path. There is no associated health risk with
27 incoherent or LED systems.

28 Operation costs are also lowered, since the mutual
29 pointing procedure is simplified because the beam
30 angle is wide enough to remove the need for highly

1 accurate pointing of the transmitter at the receiver
2 and the requirements for the structures upon which
3 the optical transmitters and receivers are installed
4 are less strict.

5

6 The use of incoherent light sources means that
7 interference between signals in the present
8 invention is minimised.

9

10 The apparatus in accordance with the present
11 invention can have an optical path length of 3000m.

12

13 Improvements and modifications may be incorporated
14 without deviating from the scope of the invention.

1 **Claims**

- 2 1. Apparatus for wireless duplex communication,
3 comprising, a first optical transceiver having a
4 first optical transmitter and a first optical
5 receiver, a second optical transceiver having a
6 first optical transmitter and a first optical
7 receiver, the first and second optical transceivers
8 being located at the opposite end of an optical
9 communication line formed thereby, wherein the
10 output of each of the optical transmitters is a
11 diverging beam of incoherent electromagnetic
12 radiation arranged to have a cross sectional
13 diameter which is larger than the cross sectional
14 diameter of the respective optical receiver at that
15 point on the communication line at which the
16 respective optical receiver is situated.
- 17 2. An apparatus as claimed in Claim 1 wherein the
18 optical transmitter comprises a light emitting diode
19 which provides the diverging beam of incoherent
20 electromagnetic radiation.
- 21 3. Apparatus as claimed in claim 2 wherein the
22 optical transmitter comprises the LED and further
23 comprises at least one optical condenser lens, the
24 input to the optical condenser lens being provided
25 by the LED and the output of the optical transmitter
26 being provided by the optical condenser.
- 27 4. Apparatus as claimed in any preceding claim
28 wherein the optical receiver consists of an optical
29 condenser lens, diaphragm and photodiode, wherein

1 the diaphragm is installed in the focal plane of the
2 optical condenser lens.

3 5. Apparatus as claimed in claim 4 wherein the
4 distance Δ between the photodiode and the diaphragm
5 situated in the focal plane of the optical condenser
6 lens is defined by the formula

7 $\Delta = b F / D_c$, where

8 b - diameter of the light-sensitive site of the
9 photodiode,

10 D_c - diameter of the optical condenser lens.

11 F - Focal distance of the optical condenser measured
12 from the lens of the optical condenser to the centre
13 of the stop aperture.

14

15 6. Apparatus as claimed in claim 4 or claim 5
16 wherein the input of the optical condenser is the
17 input of the optical receiver, and the output of the
18 photodiode is the output of the first optical
19 receiver.

20

21 7. Apparatus as claimed in any preceding claim
22 wherein the beam angle θ characterizing of the first
23 optical transmitter and the first optical receiver
24 of each of the said transceivers is defined from the
25 following condition:

26 $\tan 2\theta = a / F$, where

27 a - diameter of the diaphragm aperture;

28 F - focal distance of the optical condenser measured
29 from the lens of the optical condenser to the centre
30 of the stop aperture.

1

2 8. Apparatus as claimed in claim 7 wherein the
3 beam angle is between 30 and 60 angular minutes.

4

5 9. Apparatus as claimed in any preceding claim
6 wherein the distance between the optical transmitter
7 and optical receiver of a transceiver is greater
8 than or equal to $d/2$, where $d = 30\text{cm}$.

9 10. An apparatus as claimed in any preceding Claim
10 wherein an input of the optical transmitter of the
11 first transceiver is connected to an output of a
12 converter through a modulator, and an output of the
13 optical receiver of the first transceivers is
14 connected to an input of a demodulator, the output
15 thereof being connected to an input of a converter.

16 11. An apparatus as claimed in any preceding claim
17 wherein an input of the optical transmitter of the
18 second transceiver is connected to an output of a
19 converter through a modulator, and an output of the
20 optical receiver of the second transceivers is
21 connected to an input of a demodulators, the output
22 thereof being connected to the input of a converter.

23

24 12. Apparatus as claimed in claim 10 or claim 11
25 wherein the converter is made in the form of a
26 transformer, which transforms the signals of the
27 input discrete information into a coded signal using
28 the Manchester code during transmission, and which
29 is capable of a reverse transformation of signals

1 coming from the outputs of the respective
2 demodulators during reception.

3 13. Apparatus as claimed in any preceding claim
4 wherein each optical transceiver further comprises a
5 second optical transmitter and a second optical
6 receiver.

7 13. Apparatus as claimed in any of claims 10 to 12
8 wherein said transceivers are connected to the input
9 of the respective demodulators through a summator.

10 14. Apparatus as claimed in claim 12 or claim 13
11 wherein the input of the second optical transmitter
12 of each of the transceivers is connected to the
13 output of the respective modulator, and the outputs
14 of the first and second optical receivers is
15 connected to the input of the respective demodulator
16 through a summator.

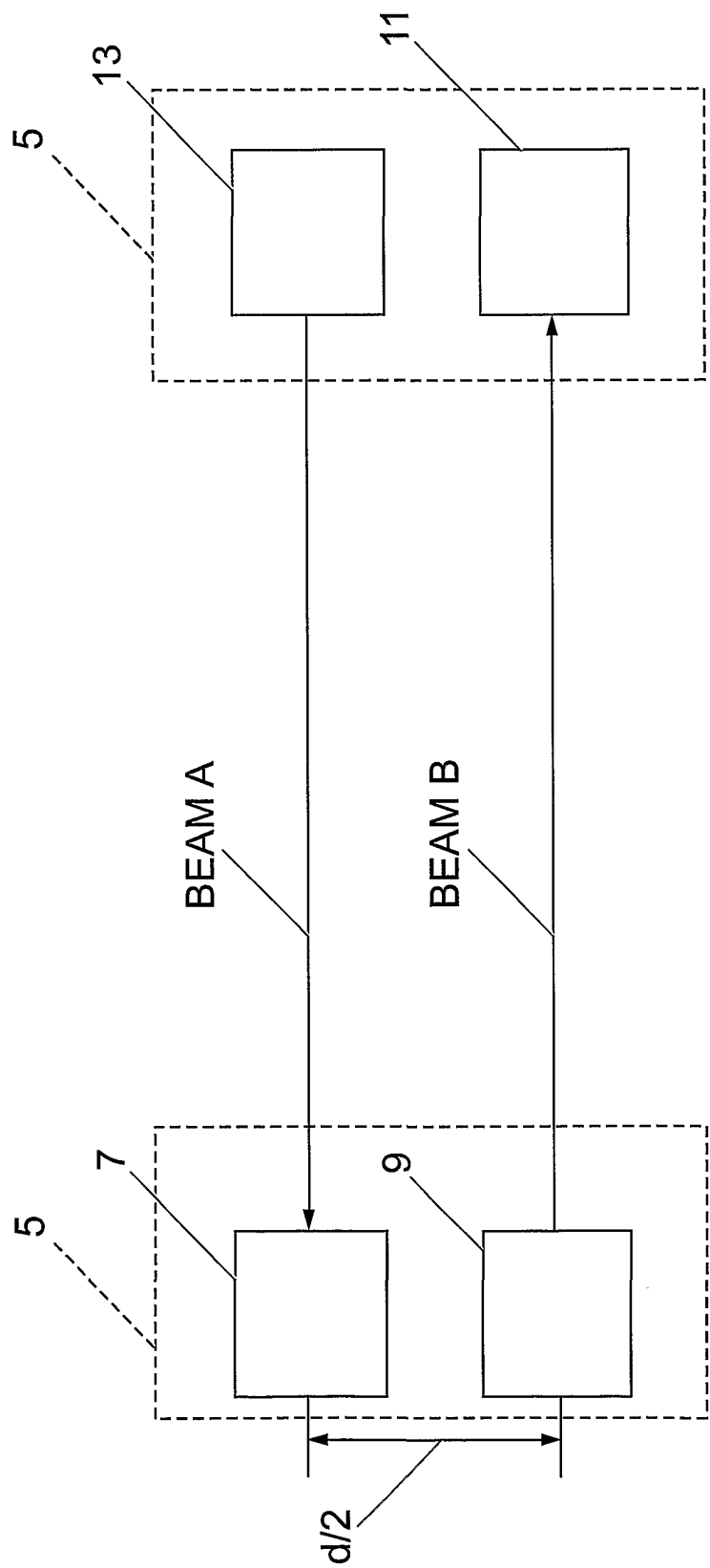


Fig. 1

2 / 5

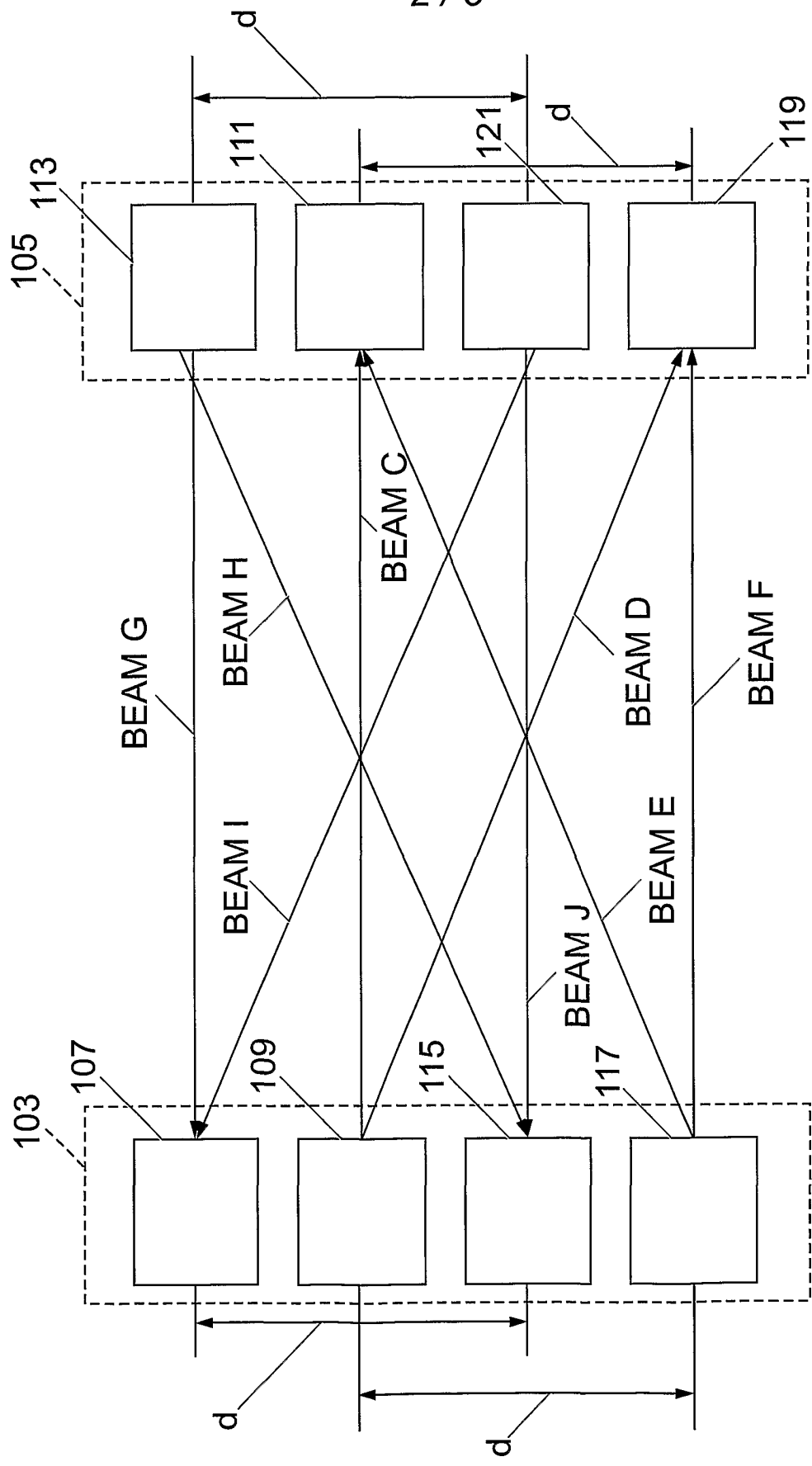


Fig. 2

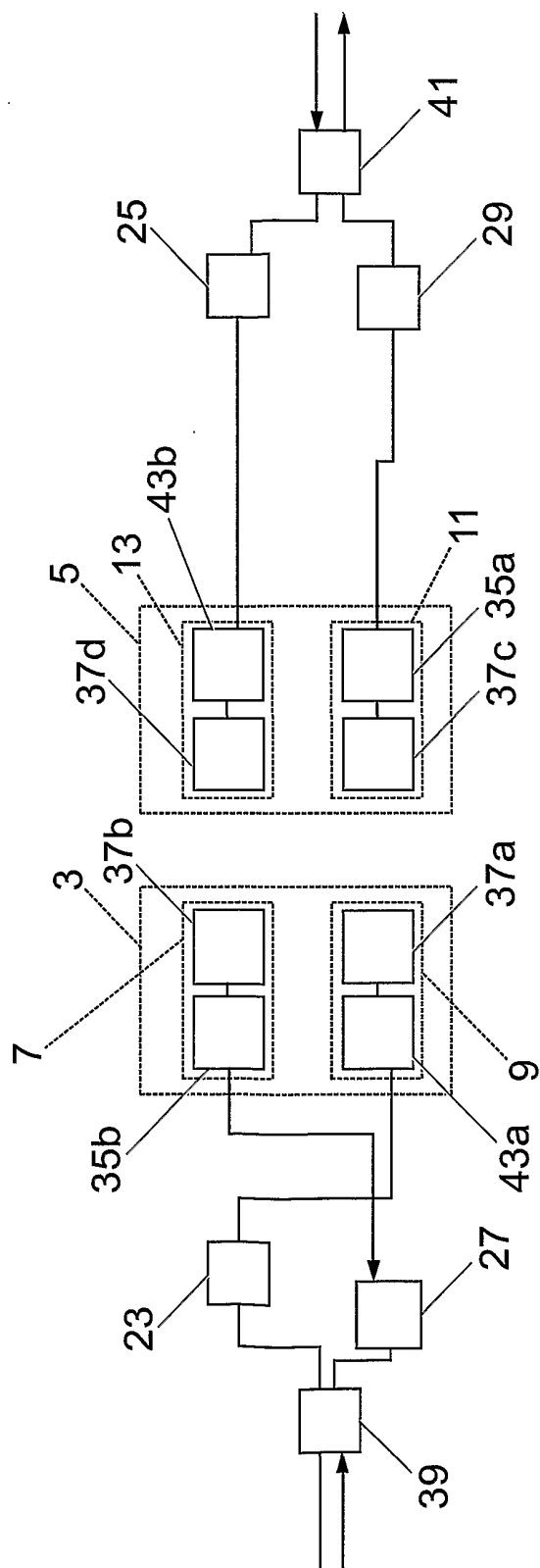


Fig. 3

4 / 5

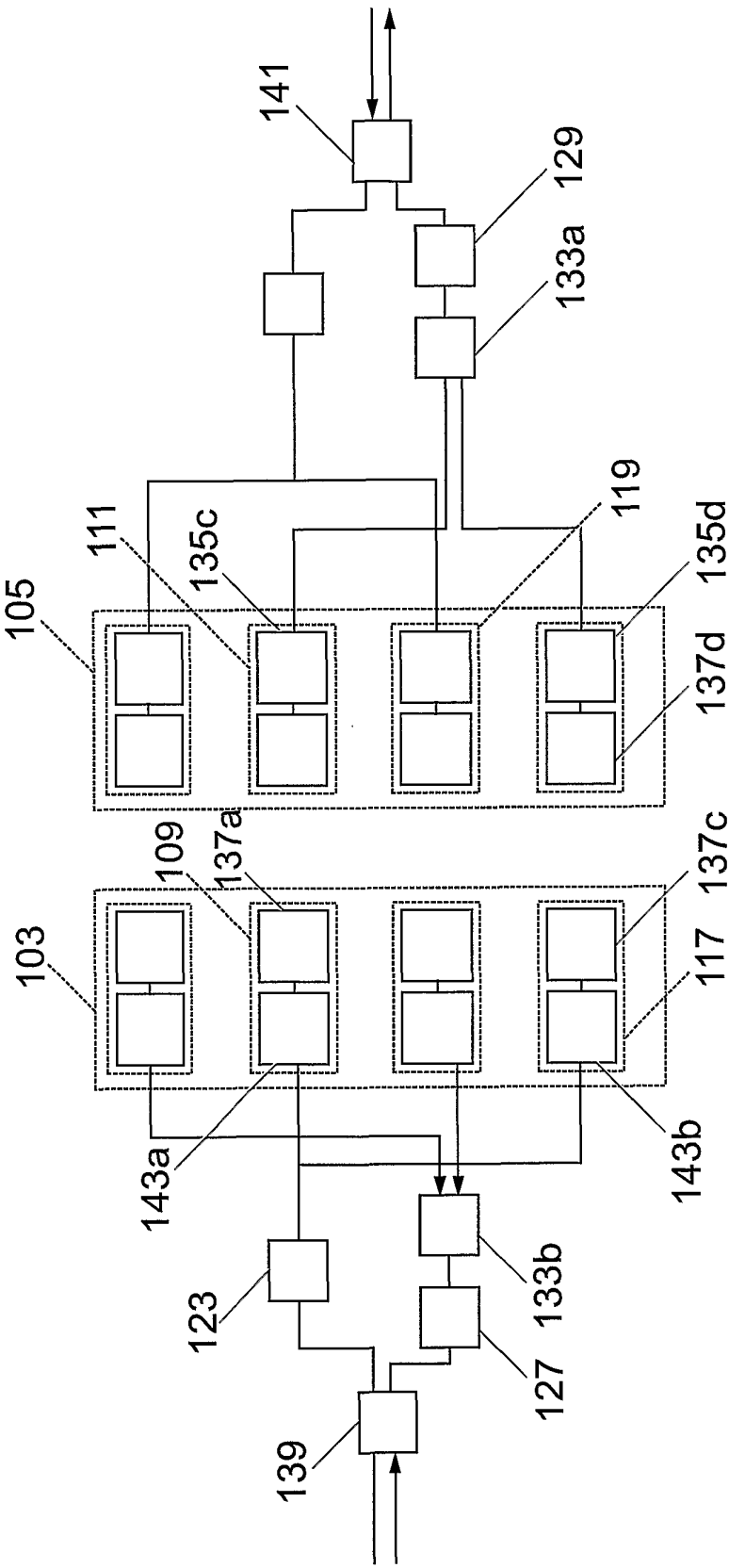


Fig. 4

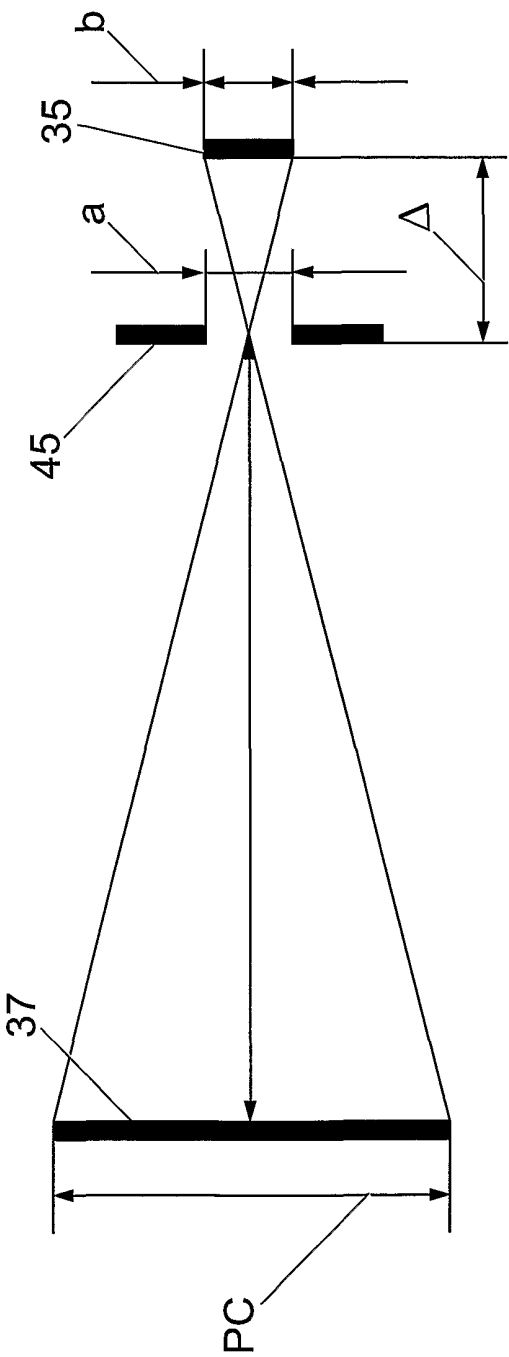


Fig. 5