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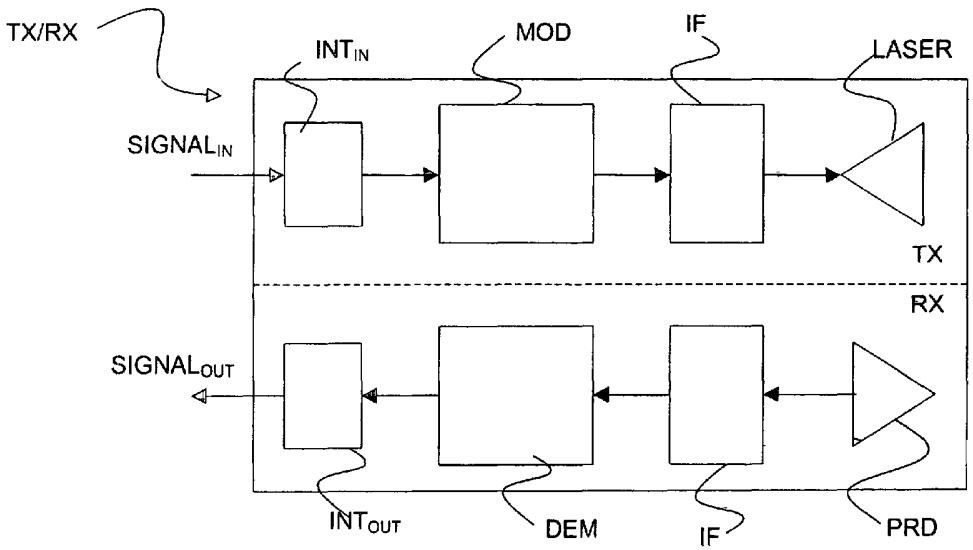
(54) Title: OPTICAL COMMUNICATION SYSTEM WITH CONSTANT POWER TYPE MODULATION



(57) Abstract: A telecommunications system for optical transmissions, in particular optical transmissions in air or via optical fiber is described. The underlying idea of this invention consists basically in use of the data/ signal to be transmitted in order to modulate an IF sub-carrier which in turn modulates the laser. Therefore, the laser source is not modulated directly by the data signal but by an IF carrier that makes it possible to shift and, using a particular modulation technique, to reduce the band occupied. Accordingly, the modulation scheme used is of the OQPSK, FM type or any other type of constant power modulation scheme. The system is particularly immune to external interferences.

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OPTICAL COMMUNICATION SYSTEM WITH CONSTANT POWER TYPE MODULATION

DESCRIPTION

This invention relates to the field of optical transmission and refers in particular to a new system for wireless transmission of laser signals that is particularly immune to external interferences so that the photo-detection diode is immune to low frequency components.

In the transmission field, wireless optical communication based on the transmission of digital signals on beams of light through the atmosphere or "free space" is already known. The beams of light are transmitted by lasers, suitably focused on photo-sensitive detectors. The receivers of the wireless optical systems are lenses or mirrors that act as collectors for the stream of photons that carry the signal and as processors of the digital stream.

Typically, a system for wireless optical communications includes a pair of receiver-transmitters located at a certain distance from each other so as to form a visible link.

As opposed to fiber-based optical systems, wireless optical connections, due to their nature, are particularly sensitive to external interferences. External interferences may be of various types: atmospheric phenomena (for example rain or fog), constant power light sources (for example the sun) or non-constant power light sources (for example discharge lights and headlights).

The common objective of wireless optical systems in air is to improve the general sturdiness of the system and to render this immune to external interferences.

In known systems, each receiver-transmitter for wireless optical transmissions includes an interface to receive a signal to be transmitted in air. The signal received and to be wireless transmitted is set simply to NRZ (Non Return to Zero) coding format, i.e., the laser is modulated ON-OFF directly by the signal to be transmitted (as in fiber-based systems). In reception, a photo-detector diode detects the laser signal received and

recovers the base-band signal which is supplied to an output interface. In other words, the data are applied directly on the laser. The band of the signal extends downwards with a consequent increase in noise at the receiver, in particular noise due to external causes.

The known solution is simple and does not necessarily require an amplification stage. However, while in laser systems that use optical fiber as means of transmission, the power received is constant, wireless systems are characterized by considerable variations in the level of the signal received due, for example, to the distances involved and to attenuation of transmission medium to be ascribed principally to atmospheric phenomena. In conventional wireless optical systems, error correctors (CRC) must be used, in the same way as for fiber-based optical systems.

One of the drawbacks of known solutions is the impossibility of direct transmission of linear signals, such as for example multi-level signals (HDB3) or video signals.

In conventional ON/OFF systems, it is more difficult to recover the signal because it is the amplitude that must recover the signal.

Therefore, the main purpose of this invention is to provide a method of transmission, a transmission system and a reception-transmission device for laser transmission/reception (particularly, but not exclusively, in air) that solves the afore-mentioned problems and assures immunity of the photo-detection receiver to low frequency components.

A further purpose is to provide a laser transmission/reception method and device (particularly, but not exclusively, in air) able to provide an automatic control system of ample dynamics of the type normally used in radio links.

A further purpose is to provide a method and a device for wireless laser transmission/reception that permit ON/OFF modulation of the laser with the signal at a certain IF frequency with a duty cycle of 50% and therefore maximum transmission efficiency.

These and other purposes are achieved by means of a method and a receiver-transmitter with the characteristics indicated, respectively, in claims 1 and 11. This invention also includes a system, as claimed in claim 17. Further advantageous characteristics of the invention are indicated in the dependent claims. All the claims are an integral part of this description.

The underlying idea of this invention consists basically in using the data to be transmitted to modulate an IF sub-carrier which in turn, modulates the laser. Therefore, the laser source is not modulated directly by the data signal but by an IF carrier that makes it possible to shift and, using a particular modulation technique, to reduce the band occupied. Use of optical modulation schemes of saturated systems with a similar behavior to that of modulation systems applicable to a laser is necessary.

The invention will certainly be clear in the light of the detailed description that follows, which is provided as a non limiting example, to be read referring to the attached table of drawings in which:

- Fig. 1 is a schematic illustration of a telecommunications system for wireless optical transmissions;
- Fig. 2 is also a schematic illustration of a receiver-transmitter appliance according to the known technique; and
- Fig. 3 is a schematic illustration of a receiver-transmitter appliance according to this invention.

Fig. 1 shows a telecommunications system for wireless optical transmission. The system includes a first receiver-transmitter TX/RX1 and a second receiver-transmitter TX/RX2 located at a certain distance from each other but always in line of sight. The first receiver-transmitter TX/RX1 receives in input the signal to be transmitted ($SIGNAL_{IN}$) and emits a laser beam that carries the signal. The laser beam that carries the signal is received by the second receiver-transmitter TX/RX2 which provides the original signal ($SIGNAL_{OUT}$) in output. Air is inserted between the first and second receiver-transmitter, as opposed to fiber-based systems in which the means of transmission is in fact the optical fiber. As

mentioned above, this fact results in high-level sensitivity of the system to external interferences.

Fig. 2 is a schematic illustration of a receiver-transmitter according to the known technique. The laser (LASER) is ON/OFF modulated directly by the data signal, as happens basically in fiber-based systems. In other words, the data are applied directly to the laser. In fact, the data (or rather the signal) to be transmitted is sent to the input of an input interface INT_{IN} and is then processed by a Base Band processing block BB. The output of the block BB is sent to the input of the laser. The reception side RX is more or less specular to the transmission side TX and includes a photo-detector diode PRD (or a similar laser signal reception device), a Base Band processing block BB and an output interface INT_{OUT} that makes the signal compatible with any appliances downstream of the receiver-transmitter.

In this invention, the laser is always modulated ON/OFF but the laser is modulated by a carrier which is modulated by the signals to be transmitted. In other words, the signal to be transmitted is not applied directly to the laser, as in known solutions, but is passed through a carrier which is first of all modulated by the data signal: the resulting signal modulates the laser. The aforesaid promotes packeting of the signal in a determined band and therefore permits filtering of the resulting electrical signal (after conversion of the signal from optical to electric at the receiver), facilitating reconstruction and improving the signal/noise ratio.

Fig. 3 is a schematic illustration of a receiver-transmitter according to this invention. According to the invention, the receiver-transmitter includes, on the transmission side TX: an input interface INT_{IN} to receive the signals $SIGNAL_{IN}$ to be transmitted; a modulator MOD to modulate the input signal; a block IF for Intermediate Frequency modulation of a sub-carrier that drives the laser light emission optical device. In transmission, the block IF amplifies the signal sufficiently to saturate the laser light emission optical device. The receiver-transmitter according to this

invention includes, on the reception side RX: a laser detection diode PRD, a block IF, a demodulator DEM and an output interface to make the signals compatible with a standardized format.

The IF block in reception acts basically as a filter in order to remove all signals that are at constant power or which are not in the frequency bands where the signal required is not present. In this block, the sub-carrier IF is recovered and the signal is amplified. Conveniently, amplification is carried out using a variable gain amplifier.

Therefore, this invention adopts modulation schemes similar to those used in conventional radio links in order to improve laser performance. The laser is modulated with modulation systems that shift the band up (the band is not used from continuous current to initial MHz), reduce the band occupied and facilitate extraction of the data, thereby promoting improved immunity and sensitivity results.

As the modulation scheme must be applied to the laser (which is not linear), it must be a constant power modulation scheme. According to this invention, a carrier modulation scheme is used that permits ON/OFF modulation of the laser; in this invention, the laser is modulated ON/OFF by the intermediate frequency.

Conveniently, the constant power modulation scheme used is OQPSK, Off-Set Quadrature Phase-Shift Keying, which modulates the sub-carrier IF which, in turn, modulates the laser ON/OFF. This makes it possible to shift the band of the signal up, (that is to say no longer starting from low frequencies); therefore, it is easier to distinguish between the signal and environmental noise or other disturbances in reception. As is known, PSK modulation is a modulation technique that uses the input signal to modulate the phase of the carrier and a simple and effective way of increasing the number of symbols in the transmission without increasing the band. In QPSK modulation, the phase of the carrier is modulated so as to obtain four possible values, corresponding to the symbols transmitted (00, 01, 10, 11). Lastly, one of the advantages of OQPSK modulation is that all signal transitions are reduced in order to

maintain constant the trajectories around radius circles, thus permitting further reduction in the spectrum when non-linear power amplifiers are used.

A further advantage stemming from use of analogue type modulation (FM or other) is that of also being able to accept linear signals in input, for example video or multi-level signals (for example, HDB3). Therefore, in other words, the input to the receiver-transmitter appliance of this invention may consist of digital signals and/or analogue signals (therefore data signals and/or video signals).

FM modulation can be used as an alternative to OQPSK modulation. Generally, it can be said that the modulation schemes that can be used are those that can pass through limitation stages, that is to say robust modulation schemes in which the carrier is limited but without any degradation of the information associated to the signal. The information is not in the amplitude of the signal but in the phase or frequency; modulation does not depend on the amplitude but on the phase (or frequency) of the sub-carrier used. In this way, the information can be easily recovered even if passed through the laser which causes distortions.

Referring once again to the modulation used, this must be a modulation applied to the carrier that can be transferred to non-linear systems. Using FM type modulation, for example, it is possible to broadcast a video signal with a wireless laser system over relatively long distances without converting the signal to digital but simply passing directly from an analogue transport system and FM modulating the carrier.

For a better generality of this invention, non-essential parts and components for the invention are not described in detail, principally the optical transmission and reception part. Obviously, the optical components used, in particular those of the transmission part, should be of high quality in order to avoid interference which could cause, in the spot broadened by distance, gaps in the light signal in the power received of tens of dB. For a complete description, but without restricting the scope

of this invention, the laser used has an operation wavelength of 850 or 911 nM (1st window). The APD used is highly sensitive, with supply voltage of approx. 200V (for example, the type used in photon counters). The power supply of the APD (not illustrated in Fig. 3) is current-limited to few mA; also, the inverse voltage is corrected in relation to operating temperature in order to maintain maximum reception efficiency.

Although this invention has been described only with reference to optical transmissions in air, it can be used entirely and with advantage also for optical fiber transmissions. Therefore, the protection of this patent application is to be intended as extended also to this type of technology.

A new transmission system, a new method of transmission and a new receiver-transmitter have been described and illustrated that achieve all the purposes and advantages indicated above. However, many changes, modifications, variations and other uses and applications of this invention will be clear to technicians skilled in the art, after considering the description and drawings attached which describe preferred embodiments. However, all the changes, modifications, variations and other uses and applications of this invention not going outside of the scope of the invention are considered as covered by this invention.

CLAIMS

1. Method for the transmission and reception of signals in a telecommunications system for optical transmission whereby, in transmission, the method includes the following steps:

- receiving in input (INT_{IN}) a signal ($SIGNAL_{IN}$) to be transmitted optically;
- processing (MOD, IF) the signal received; and
- supplying a laser light emitter device (LASER) with the signal processed,

characterized in that the step of processing the signal received in input includes a step of digital modulation (MOD) of the signal received applying a constant power type modulation scheme.

2. Method according to claim 1, characterized in that the step of processing phase of the signal received, includes the step of modulation (IF) of an Intermediate Frequency sub-carrier, for ON/OFF modulation of the laser light emitting device (LASER).

3. Method according to claim 1 or 2, characterized in that the step of digital modulation of the signal received using a constant power type modulation scheme includes the step of modulation based on an OQPSK type scheme.

4. Method according to claim 1 or 2, characterized in that the step of digital modulation of the signal received according to a constant power type modulation scheme includes the step of modulation based on an FM type scheme.

5. Method according to any of the previous claims, characterized in that the step of reception of a signal to be transmitted optically includes the phase of receiving a digital and/or analogue signal.

6. Method according to any of the previous claims, characterized in that, in reception, it includes the step of demodulation of the signal transmitted optically according to a constant power type modulation scheme.

7. Method according to claim 6, characterized in that, upstream of the demodulation phase, it includes the steps of recovering, through filtering, the Intermediate Frequency sub-carrier and of amplification.

8. Method according to claim 7, characterized in that the step of amplification includes the step of variable gain amplification.

9. Method according to any of the previous claims, characterized in that the means of transmission is basically air for the transmission of optical signals in free space.

10. Method according to any of the claims 1-8, characterized in that the means of transmission is optical fiber.

11. Receiver-transmitter for the transmission and reception of optical signals including a laser emitting device, characterized in that it includes, on the transmission side, a modulator (MOD) for digital modulation of the signal to be transmitted according to a constant power type modulation scheme and, on the reception side, a demodulator (DEM) for demodulation of the signal transmitted optically in air according to a constant power type demodulation scheme.

12. Receiver-transmitter according to claim 11, characterized in that the modulation/demodulation schemes are of the OQPSK or FM or other constant power type.

13. Receiver-transmitter according to any of claims 11-12, characterized in that, in transmission, it includes a block (IF) for IF modulation of a sub-carrier able to drive the laser emitting device and, in reception, a further block (IF) for recovery of the IF sub-carrier and amplification at Intermediate Frequency.

14. Receiver-transmitter according to any of claims 11-13, characterized in that it includes input and output interfaces (INT_{IN}, INT_{OUT}) to receive and emit digital and/or analogue signals respectively.

15. Receiver-transmitter according to any of claims 11-14, characterized by the fact that the means of transmission is basically air for the transmission/reception of optical signals in free space.

16. Receiver-transmitter according to any of claims 11-14, characterized by the fact that the means of transmission is optical fiber.

17. Telecommunication system for wireless optical transmission, characterized in that it includes at least a first and a second receiver-transmitter according to any of the claims 11-16, located at a certain distance from each other.

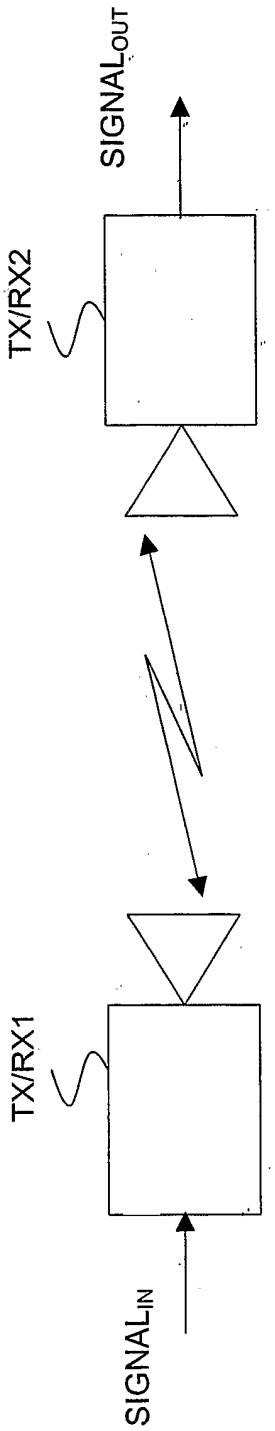

Fig. 1

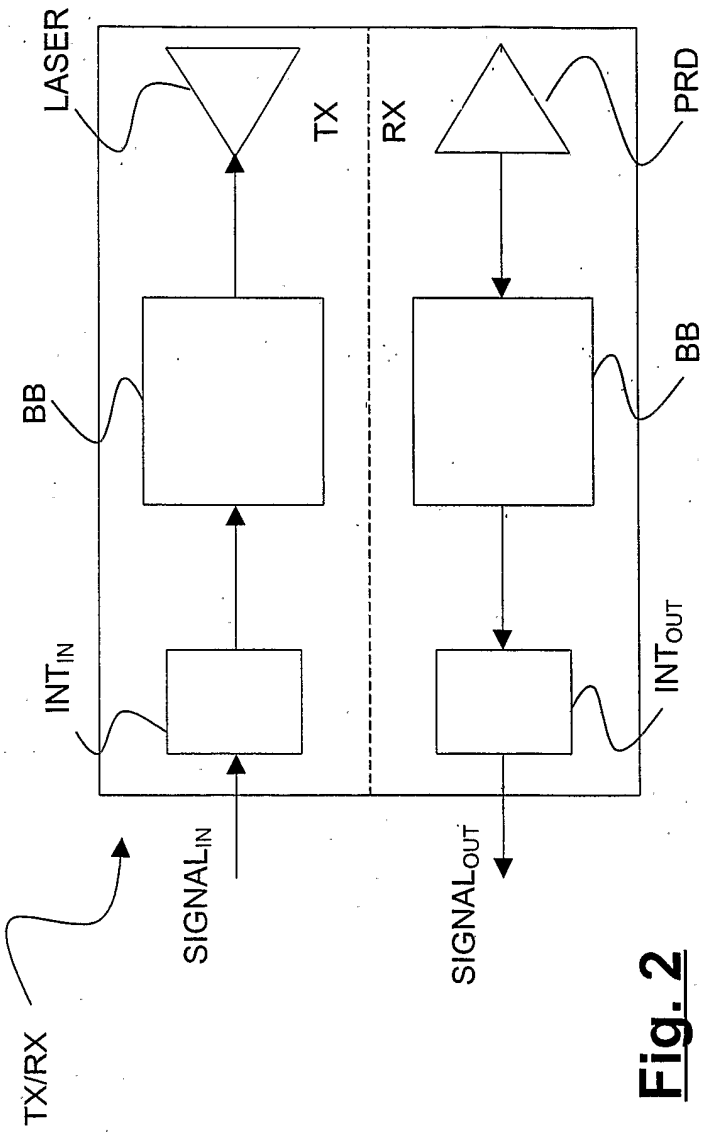

Fig. 2

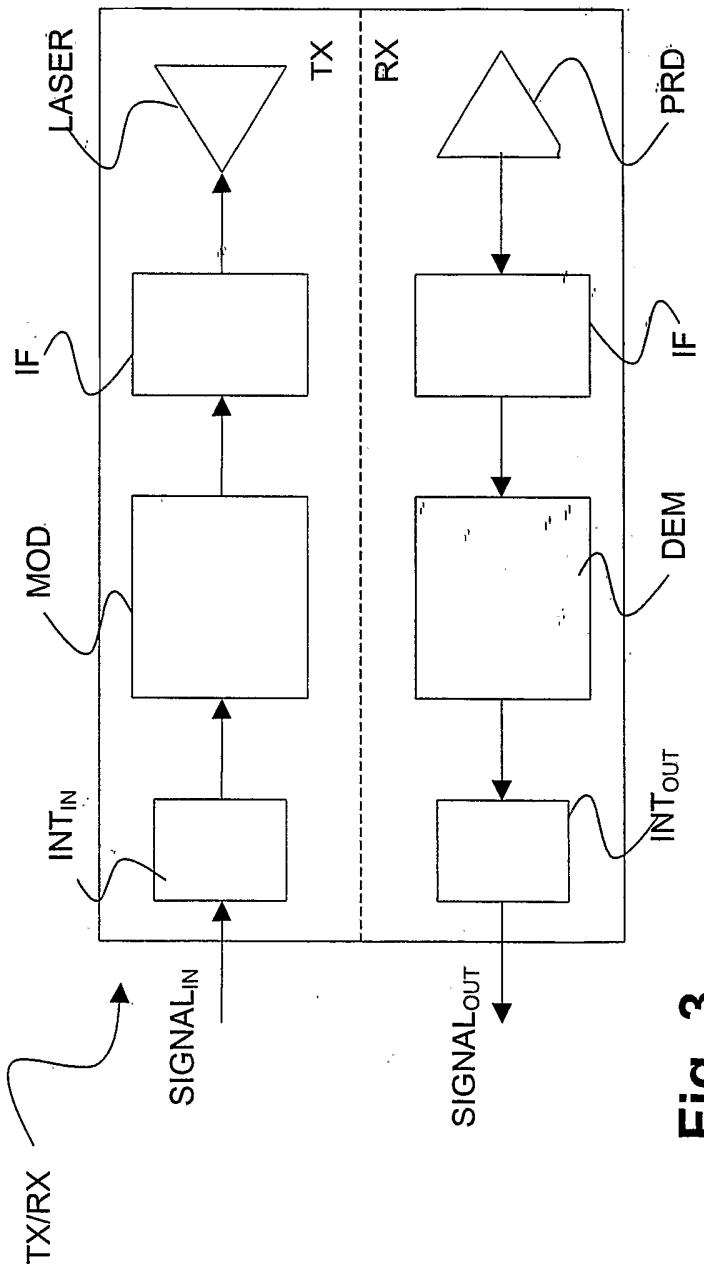
TX/RX
SIGNAL$_{IN}$
INT$_{IN}$
MOD
IF
LASER
TX
RX
PRD
IF
DEM
INT$_{OUT}$
SIGNAL$_{OUT}$

Fig. 3

INTERNATIONAL SEARCH REPORT

PCT/IB 03/02920

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B10/155

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
PAJ, EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 63 190436 A (MATSUSHITA ELECTRIC IND CO LTD) 8 August 1988 (1988-08-08) abstract; figure 1	1-17
X	US 2002/030877 A1 (WAY WINSTON ET AL) 14 March 2002 (2002-03-14) page 5, paragraph 56 -page 5, paragraph 58; figures 1A,4A	1-17
X	US 2001/021228 A1 (NOJIMA KAZUHIRO) 13 September 2001 (2001-09-13) page 5, paragraph 56 -page 5, paragraph 58; figures 1A,4A	1,4-6
A	page 1, paragraph 13; figure 1	2,3,7-17

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 898 389 A (MATSUSHITA ELECTRIC IND CO LTD) 24 February 1999 (1999-02-24)	1
A	page 4, paragraph 24; figure 1 page 9, paragraph 78	2-17

INTERNATIONAL SEARCH REPORT

PCT/IB 03/02920

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 63190436 A	08-08-1988	NONE	
US 2002030877 A1	14-03-2002	US 6525857 B1	25-02-2003
		AU 4181001 A	17-09-2001
		AU 4198901 A	17-09-2001
		EP 1264424 A2	11-12-2002
		WO 0167647 A2	13-09-2001
		WO 0167648 A2	13-09-2001
		US 2002114034 A1	22-08-2002
		US 2003025961 A1	06-02-2003
		US 2003180047 A1	25-09-2003
		US 2002067523 A1	06-06-2002
US 2001021228 A1	13-09-2001	JP 2001251144 A	14-09-2001
EP 0898389 A	24-02-1999	JP 11331089 A	30-11-1999
		EP 0898389 A2	24-02-1999
		TW 384575 B	11-03-2000
		US 6335814 B1	01-01-2002
		US 2002033987 A1	21-03-2002