INFRARED TELEMETRY AND ITS IMPACT IN RURAL AREAS AND DEVELOPING COUNTRIES

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ABSTRACT -- Infrared telemetry is a special form of biomedical telemetry for remote sensing of physiological parameters, patient location and drug delivery. Due to the intrinsic properties of infrared radiation, practically restricting medical infrared telemetry to indoor applications, the major aim of medical infrared telemetry differs from that of radiotelemetry. The major property of radiotelemetry, the reduction of the impediment of the patient by the measuring equipment, is even better realized by infrared telemetry due to the extremely small system size and weight. Nevertheless infrared telemetry has its special value for the cost reduction effect both on the patient care and equipment side, as well as the simple solution of the electrical safety problem. This renders infrared telemetry also suitable for applications in remote (rural) areas and in developing countries. Progress achieved in the field during the past 3 to 4 years will likely lead to an extensive commercial supply of infrared telemetry equipment in the near future but technology is simple enough to be realized locally by hospital departments.

INTRODUCTION:

Infrared telemetry (IR telemetry), a new technology, whose early developments date back only about 10 years, is facing increasing interest in the U.S.A., Japan and Australia, after an astonishing growth in Europe. This fast growth (the number of publications has increased by a factor of 20 in two years time) has many reasons. Yet two of the reasons, namely the potential reduction of patient care cost by introduction of IR telemetry, and the elimination of electrical safety problems are especially significant for developing countries.

The great potential of IR telemetry was recognized by the European Commission about 4 years ago and subsequently strongly supported by financing a concerted action on IR telemetry between several European countries. For a possible broad application of IR telemetry, this action brought the necessary development and breakthrough. The begining efforts were published in Kimmich and Bornhausen, 1983, whereas subsequent progress was documented in numerous papers, many of which in the following proceedings: Kimmich and Klewe, 1984; Kimmich, Weller, Erdmann and Bornhausen, 1985; and Kimmich and Neuman, 1987.

It is the purpose of this publication to investigate the state of the art of IR telemetry and show the advantages of the method for application in developing countries.

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HISTORICAL DEVELOPMENT:

Light telemetry was proposed 20 years ago (Kimmich, 1969) but early IR systems remained unpublished because the transmission distance was very small and in addition transmission was only possible along line of sight. First publications of IR telemetry systems (Weller and Levis, 1976; Weller, 1977) still showed very severe limitations, and research therefore often concentrated on patient location systems, with an IR receiver on the patient side instead of an IR transmitter (Weller, 1978). Specialized, limited applications of IR telemetry, e.g. for transmission from pressure chambers (Dyson et al., 1981) or in perinataology (Neuman et al., 1984) were described but a real breakthrough of IR telemetry was only achieved by the idea of detecting reflected IR light, rather than using line of sight transmission (see principle of IR transmission). The study on IR propagation and reflection properties by Kimmich and Klijn (1979) formed, together with the availability of substantially improved IR diodes (LED's and receivers), the basis for many of the systems published in the proceedings as mentioned in the introduction.

PRINCIPLE OF IR TELEMETRY:

An IR telemetry system is basically identical to a radiotelemetry system with the exception of the IR link instead of the the RF link (figure 1).

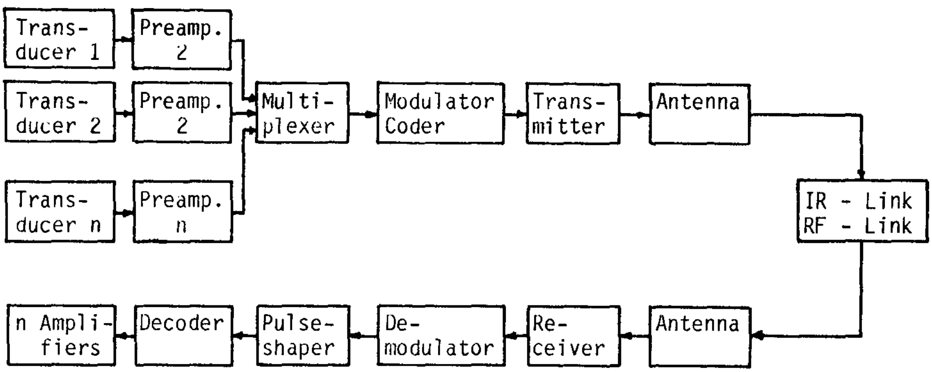

Figure 1: Block schematic of a biomedical telemetry system, both with IR - link and with radio frequency link.

The intrinsic properties of IR propagation, however, have great influence on the design of the remaining elements of IR telemetry systems, namely:

- The design of both the IR transmitter and the IR receiver is extremely simple and these elements are built up of only a few electronic elements, demonstrated by the basic circuits of a transmitter (figure 2) and a receiver (figure 3).

- Generally there is no need for a transmitting and/or receiving antenna. The sometimes required receiving filter (to prevent penetration of visible light into the receiver) is also cheap and requires no special designing or frequency adjustment, as known from RF telemetry.

- Modulation and multiplexing (required for multichannel operation) is often also simpler. The accuracy of signal transfer is much better in IR transmission, so that complex methods such as pulse-code-modulation can generally be avoided.

- In radiotelemetry, the design of the preamplifiers is difficult, due to the vicinity of an RF emitting source, and often determines the overall accuracy of a radiotelemetry system. Obviously RF power is also influencing IR telemetry preamplifiers but not more than the preamplifiers of any other biomedical equipment.

- Similar considerations are true for the elements on the receiving side (decoder, demodulator, signal shaper, amplifiers).

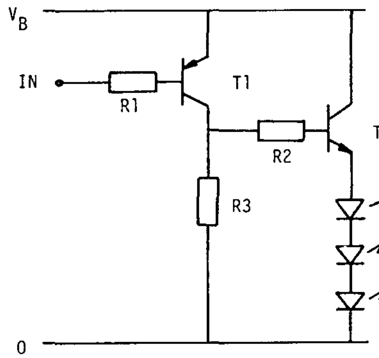

Figure 2: Basic circuit of an IR transmitter

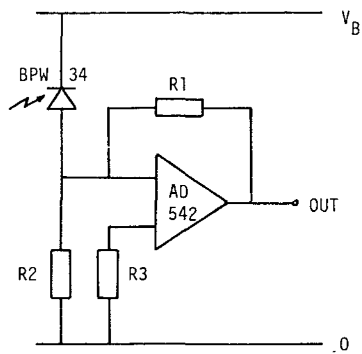

Figure 3: Basic circuit of an IR receiver

PRINCIPLE OF IR TRANSMISSION:

The IR transmission link is the most complex element of an IR telemetry system and therefore needs close consideration.

Infrared light, as used for biomedical telemetry, has a wavelength of approximately 950 nm, corresponding to a frequency of about 315 THz. Such high frequencies are stricly transmitted along line of sight. As mentioned earlier, this is not suitable for medical telemetry. Therefore the effect of reflection of IR light at almost any obstacle is used. Contrary to radiotelemetry where correct radiation may be hampered by reflections, which cause interference and nulls, interference patterns due to optical reflections are small in comparison with the size of the receiving antenna or sensor, respectively. The use of reflected light rather than direct radiation gives the first important restriction for operation of an IR telemetry system. The transmission system must be confined by IR reflecting obstacles. Practically this means that IR applications relying on reflections are restricted to indoor applications. Most materials used in buildings reflect IR sufficiently. Operation of IR systems is possible in rooms up to a size of approximately 10 by 10 by 4 meters with currently available IR emitting diodes. According to the size of the room, indirect signals are received with 10 to 20 dB less than direct signals at a distance of 2 meters (figure 4). For further details see Kimmich and Klijn, 1979.

Whereas direct signals vary much with the distance between transmitter and receiver, the room is fairly equally illuminated by indirect IR light.

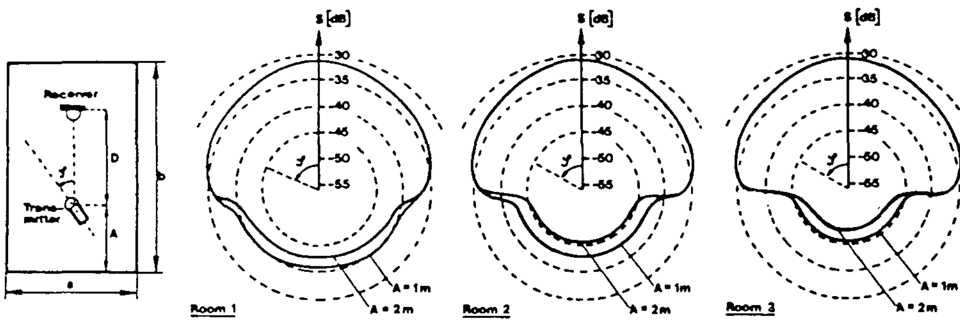

Figure 4: Receiving signal strength (S) as a function of the angle between the optical axis of the transmitter and the interconnecting line transmitter/receiver, measured in three rooms: room 1 (3 by 5 by 2.7 m), room 2 (6 by 8 by 2.7 m) and room 3 (8 by 10 by 2.6 m).

By preventing direct illumination of the receiver, the dynamic range of the received signal can be reduced substantially to very small values. IR transmission is thus safely possible also under difficult circumstances of shielding, and does not show any directive properties, contrary to most commercial IR remote control systems, such as for television sets.

Materials (mainly glass) that do not reflect IR may be used on up to two sides of the room, generally referred to as IRTA (IR Transmission Area), but do reduce the maximum possible size of an IRTA. The problem can be circumvented by placing active electronic reflectors onto such non-reflecting materials. Even more, it is possible to divide large rooms into smaller subunits by placing active electronic reflectors at the borders of the subunits. For further details see Kimmich and Klijn, 1985; 1987.

OPERATION OF SEVERAL TRANSMITTERS IN A SINGLE ROOM (IRTA):

This is probably the most complicated and complex aspect of IR telemetry. Whereas IR can be emitted at different discrete wavelengths, there still does not exist a method to sufficiently discriminate IR light of different wavelength at the receiving side. On the other hand, it is possible to switch the IR carrier up to a frequency of 1 to several MHz. Therefore IR telemetry systems generally operate in a pulse position, code modulation (PPM/CM) mode. Due to the bad efficiency of IR light emitting diodes (IR-LED's) as well as to save battery power, duty cycles of 1 to 100 up to 1 to 1000 are generally incorporated. Even so, a total bandwidth of approx. 1 to 50 kHz is available for signal transfer. It is thus possible to share this bandwidth with several users (patient transmitters), if a way of synchronization of the different IR transmitters is available. Practically this is realized with tow-way systems, in other words, each transmitter is also equipped with an IR receiver (which is easily achieved due to the simple circuitry), obtaining a synchronization pulse from time to time, either from a master patient unit, or from a separate transmitter in the IR receiver station.

Much of the effort directed towards development of IR telemetry systems was used to find an optimal solution for this problem of simultaneous operation of several transmitters in a single IRTA. The proposed solutions are quite astonishing allowing, for example, free exchange of patients equipped with IR telemetry transmitters between different IRTA's within a hospital. Detailed discussion of the solutions of this problem are found in Kimmich, Weller and Mancini, 1987; Mancini, Weller and Kimmich, 1987, Bedini, Franchi and Mancini, 1987; Franchi, Bedini and Mancini, 1987 and Klewe, 1987.

ADVANTAGES AND DISADVANTAGES OF IR TELEMETRY:

Comparison of IR telemetry must be with radiotelemetry on one side and conventional equipment on the other side. By comparing the two telemetric methods, it becomes clear that the advantages and disadvantages are such that radiotelemetry does not compete with IR telemetry. In contrary, both systems are complimentary. Here some of the most important advantages and disadvantages of IR telemetry:

Disadvantages of IR telemetry:
- The transmission range is restricted to a small area, generally a room.
- Multiple transmitter operation in a single room requires a complexity of electronic circuitry which is manyfold to that of the main parts of IR telemetry (coder, multiplexer, transmitter).

Advantages of IR telemetry:
- Identical IR systems can be used in all IRTA's, in other words there is no frequency allocation problem.
- Very safe operation. There is practically no interference from other IR telemetry systems, nor from RF telemetry equipment or other RF sources.
- Equipment is small, light and cheap.
- Battery operation lasts much longer (practically from several days up to several months (or even a year), while using simple commercial 9-volt batteries.

Disadvantages of IR telemetry as compared to conventional equipment:
- A major disadvantage is the need of changing (or recharging) batteries from time to time (approx. every month).

Advantages of IR telemetry as compared to conventional equipment:
- Certain freedom of motion of the patient, e.g. it is not necessary to disconnect the patient for certain cares (X-rays, toilet use, etc.).
- Substantial improvement of patient's safety. (Reduction of risk of electrical shock to practically zero).
- Substantial cost reduction, mainly on the equipment side (simple, cheap preamplifiers in spite of the improved patient safety) but also on the care side: Free access to the patient during operations and intensive care, less connections and disconnections of the patient to monitoring equipment, resulting in work reduction and in substantially improved safety of monitoring of physiological variables.

DISCUSSION:

IR telemetry is a new technology. Its development is certainly not yet finished, but its is already clear that with IR telemetry many problems can be solved, problems for which radiotelemetry or starage telemetry was not suited. This is especially true for applications inside of buildings, where the use of radiotelemetry often showed practical problems with frequent loss of signal. Infrared can, however, not only circumvent these problems in the hospital sphere but represents a cost effective alternative. Even more, it may also represent a cost effective alternative to conventional (wirebound) equipment because it decouples the patient from the mains in the simplest and cheapest way. This renders IR telemetry suitable not only for academic hospitals but also for home use, for rural (remote) areas and in developing countries.

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TELEMETRIA DE INFRAVERMELHO E SEU IMPACTO EM ÁREAS RURAIS E PAÍSES EM DESENVOLVIMENTO

RESUMO--Telemetria de infravermelho é uma forma especial de telemetria biomédica para sensoriamento remoto de parâmetros fisiológicos, localização de pacientes e distribuição de drogas. Devido às propriedades intrínsecas da radiação infravermelha, praticamente restringindo a telemetria de infravermelho em medicina a aplicações em ambientes fechados, o propósito mais importante da telemetria de infravermelho em medicina difere daquele de radiotelemetria. A principal propriedade de radiotelemetria, a redução do impedimento do paciente por equipamentos de medições, é muito melhor conseguida com telemetria de infravermelho devido a pequeno porte do sistema e a seu peso. Contudo, a telemetria de infravermelho tem seu valor especial para o efeito de redução de custo tanto no cuidado com o paciente e equipamento auxiliar, como na solução simples do problema de segurança elétrica. Isto torna a telemetria de infravermelho capaz de também ser utilizada em aplicações em áreas rurais remotas e em países em desenvolvimento. O progresso obtido no campo durante os últimos 3 ou 4 anos irá certamente provocar um extenso suprimento - comercial de equipamentos para telemetria de infravermelho num futuro próximo e tecnologicamente é bastante simples de ser implementada localmente por departamentos de hospitais.