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Infrared wireless DSSS system for indoor data communication links

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ABSTRACT

A low Complexity system of optical links using indoor unguided infrared channels and Direct-Sequence Code Division Multiple Access is presented. Direct Sequence Spread Spectrum techniques improve performance of optical unguided links with background illumination noise, and multipath propagation. It also allows several users to use Code Division Multiple Access, to share the same Infrared Channel. In the system designed, optical Infrared carrier is Intensity Modulated (IM) by a Direct-Sequence Spread Spectrum electrical signal, driving the optical emitter. Infrared Radiation is directly detected (DD) by receiver photodiode.

Keywords: Direct Sequence Spread Spectrum (DSSS), Infrared wireless communications, noise rejection

1. INTRODUCTION

Communication via Optical Infrared Indoor Channel has became a viable alternative to the traditional means of information exchanging exchange which presents different advantages and problems:

- Infrared Radiation is confine by walls and obstacles so it is possible use different system in near room without interference.
- Unguided Infrared Optical Channel presents higher path loss than de radio frequency channel and introduces worse noise characteristics[1].
- Depending on Field of View (FOV) of the optical receiver, the multipropagation phenomenon may spread de impulse response of the channel increasing the Intersimbol Interference (ISI)[1 2]. And this reduces the communication data frequency.
- Artificial illuminations in home, office and industrial environments are very important contributors to interference in optical receivers, because they produce radiation in the range of infrared spectrum.

Direct-sequence spread spectrum is based on multiplying a narrowband data signal with a baud rate R, by a broadband spreading sequence with baud rate (often known as *chip rate*) R_{ss}. As the spreading sequence is coded following a pseudo-noise algorithm, only the receiver synchronized to that code would obtain the original narrowband signal. For another receiver using a non-synchronized replica of the code, or a different sequence, the signal delivered to the decision stage will be almost white or colored noise. The ratio between the baud rate and the chip rate is known as *process gain* (*PG*). The larger the *PG* the higher performance of communication system[3].

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Use of Direct Sequence Spread spectrum improves the Infrared link in several ways :

- Interference due to artificial illumination (incandescent or fluorescent) and other Infrared systems (such as remote TV control) present in the same room are rejected, because they are incorrelated with communication frame and are bandlimited. This is because one characteristic of Spread Spectrum is a high rejection to incorrelated bandlimited interference[4].
- Multipath propagation produces arrivals of the same information in different time instant. Spread Spectrum systems introduce attenuation to the delayed signals reducing their influence in the received signal. Result of this is a reduction of Inter Symbol Interference and a higher allowed data frequency.
- It allows a channel capacity improvement, because different users are able work simultaneously in the same spectrum range and in the same time interval without interference between then, by Code Division Multiple Access (CDMA). This is no possible with other access methods as TDMA or FDMA[5].

This method may be applied in different configurations of optical links to improve their characteristics. In point to point links emitter and receiver are oriented one to other. In Ceiling Satellite system all terminal in the room are oriented to a main hub in the ceiling. And in diffuse structure all system are communicated by reflections in the room. figure 1 shows some examples of these optical communications systems.

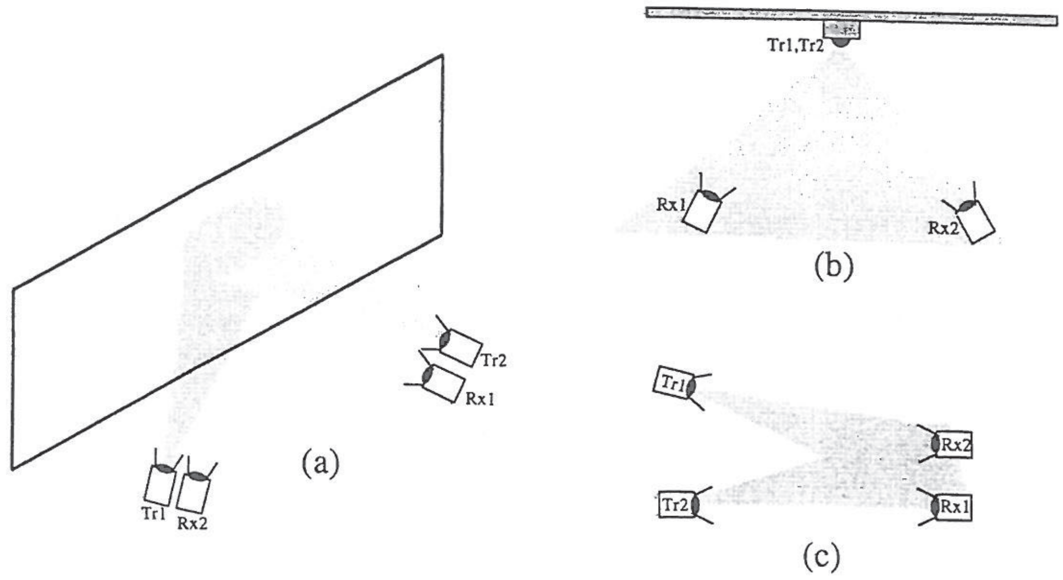


Figure 1. Configuration of optical **a)** Quasidiffuse, **b)** Ceiling satellite, **c)** Point to point links

2. SYSTEM DESCRIPTION

User's modems (figure2) carry out data at 64 Kb/s bit rate, that have been selected because it is the base of Synchronous and Plesiochronous Multiplexing Hierarchies.

Data signal is direct sequence spread using a spreading signal generated by an MLS code[6] with a length of 255 chips. This signal consist on a pseudo noise sequence, generated by a linear 8 bits length shift register with different feedback combinations according to the different users codes. The chips clock frequency is 16.384 MHz so as to obtain approximately 24 dB of process Gain. With 8 bits linear shift register, only four different MLS sequences can be obtained with adequate crosscorrelation properties.

Maximal Length Sequences generation and spreading processes is made by means of Programmable Logic Devices (ALTERA 7000 Family), this structure allows to modify the spreading code to another families (Hadamard, Bi-orthogonal....) without any further modification to the emitter circuit. The optical emitters are MONOCROM Laser modules of 5 mW (Tr1) and 20 mW (Tr2) of peak power. User's interface is synchronous at 64 Kb/s with NRZ code.

In figure 2 we can see the scheme of the global system with the programmable device and Laser module in the emitter circuit, and the APD and synchronization block in the receiver.

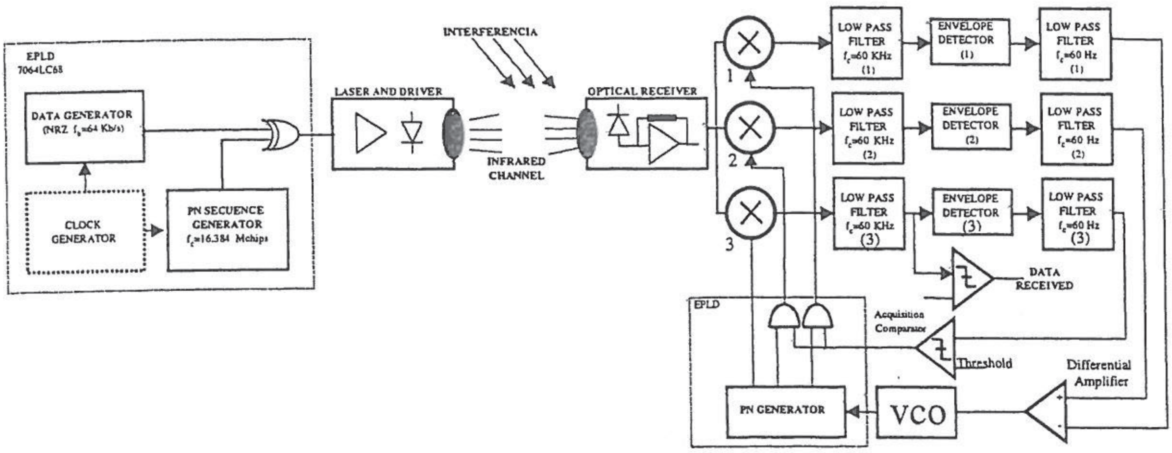


Figure 2. Block diagrams of Spread Spectrum emitter and receiver

The optical receiver uses a Hamamatsu Avalanche Photodiode (APD) S-3884-01 biasing at 80 V. It has an avalanche gain around 100. APD is followed by SE5212 transimpedance preamplifier with 7.2 KΩ trans-resistance. An optical lens with diameter of 7 cm is used to increase the area of receiver up to 7696 mm^2 . In this way it introduce a 37 dB optical gain and a FOV of 18°.

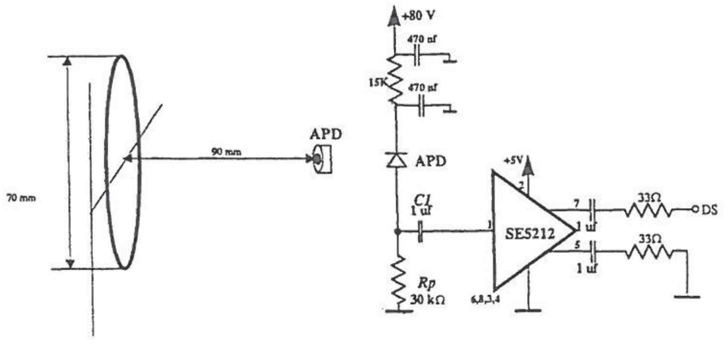


Figure 3. Optical Receiver

3. SYNCHRONIZATION

The main and more complicate block is the Synchronization stage in the receiver. It performs two separate and consecutive processes :

- **Pseudo Noise Sequence acquisition:** it generates a pseudo noise sequence at the same frequency that the received sequence. This is performed with a sliding series correlator who generates a Pseudo Noise Sequence with a frequency a bit different than in the transmitter. This produces a continuous displacement between emitted and generated by series correlator Sequence, there is a moment in that this displacement make two sequences to have the same phase and then the acquisition is get and start the next process. In figure 4 we can see the scheme of a sliding series correlator.

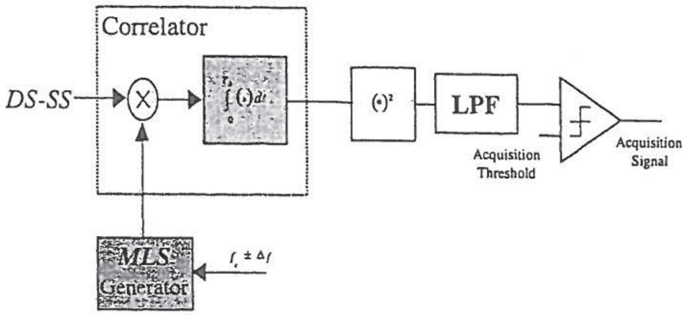


Figure 4. Sliding series correlator scheme

- **Tracking process:** once the received and generated sequences are in phase the system have to maintain it, this performs by a Delay Locked Loop (DLL). It is based on the correlation of received sequence with an advance and delayed version of the local generated sequence. The subtraction of both correlations produces an error curve that controls the Voltage Controlled Oscillator that generates the clock signal to the local sequence generator. Figure 5 shows the general circuit of a DLL.

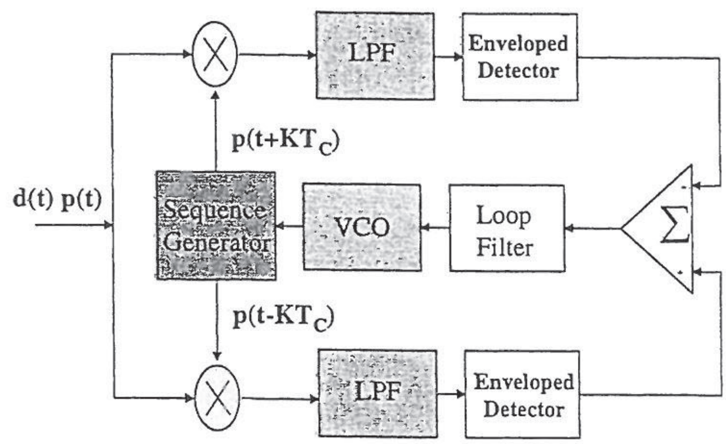


Figure 5. DLL circuit

Graphic in figure 6 shows the error curve generated in DLL out. Left figure is the ideal curve and right plot is the re curve obtained in the prototype. If the error value goes out of the central line synchronization have been lost and acquisiti process have to start again.

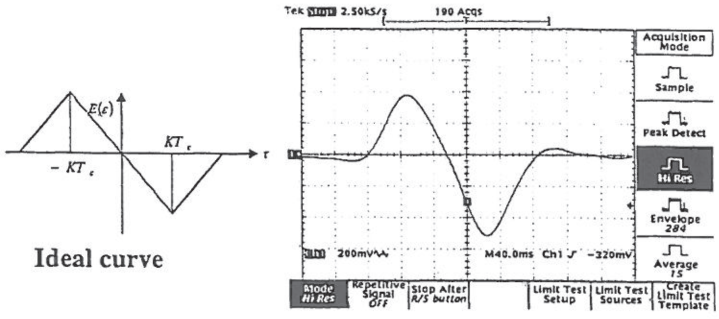


Figure 6. DLL curve

The acquisition of PN tracking is performed by a sliding series correlator, which correspond to branch 3 of receiver figure 2. The free run frequency of the receiver's Voltage Control Oscillator (VCO) in figure 2 is imposed to be less than ± Hz, according with bandwidth of correlator low pass filter. This frequency produces the slide of the local generated sequence the receiver, over the direct sequence signal received. Correlation between them is maximal in coincidence of phase of b sequences. In this condition data are recovered after the band pass filter (3) showed in figure 2 , and the acquisition compara input signal is greater than threshold voltage. At that moment synchronization process changes to tracking mode.

Tracking mode is performed by a DLL composed by branches 1 and 2 in figure 2. Tracking operations start when comparator output signal is greater than threshold level, that is synchronization condition. Mixer 1 in figure 2 operates with chip advanced local sequence, while mixer 2 uses one chip delayed local sequence. Both signals are switch on at the beginn of tracking operations. If synchronization is lost (voltage in acquisition comparator is below threshold level), tracking mod disconnected and acquisition mode starts again.

4. RESULTS

As experimental test two diffuse links of different emitted power have been implemented in this work. In that way link make interference in the other. The optical emitters' powers were 5 mW (Tr1) and 20 mW (Tr2). Emitters and recei were pointed to the wall at 5 m separation distance as can be seen in figure 7.

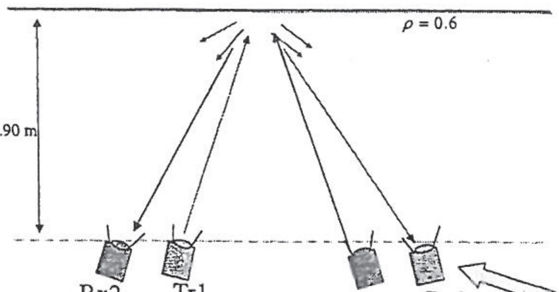


Figure 7. Configuration of experimental test

Radiations from both emitters share the same illumination area on the wall surface. The fluorescent lamps distribution on ceiling (8 x 40 Watts) produces a -60 dBm noise power over receiver bandwidth. Worst case is represented by a 5 mW link with the interference of the 20 mW emitter and -60 dBm noise ought to illuminations. In this case, power at the output of transimpedance amplifier, received from corresponding transmitter, is -42.2 dBm without interference and -36 dBm with both emitters (with interference).

Figure 8 shows the Spectral Power Density (SPD) of the DS-SS signal.

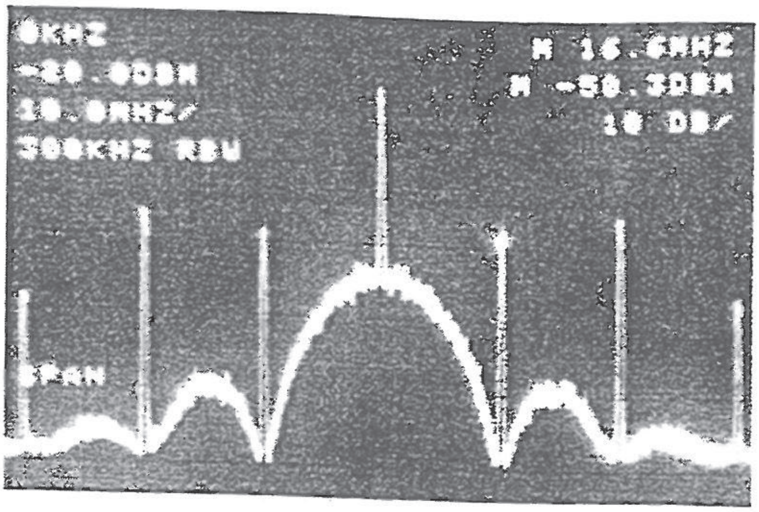
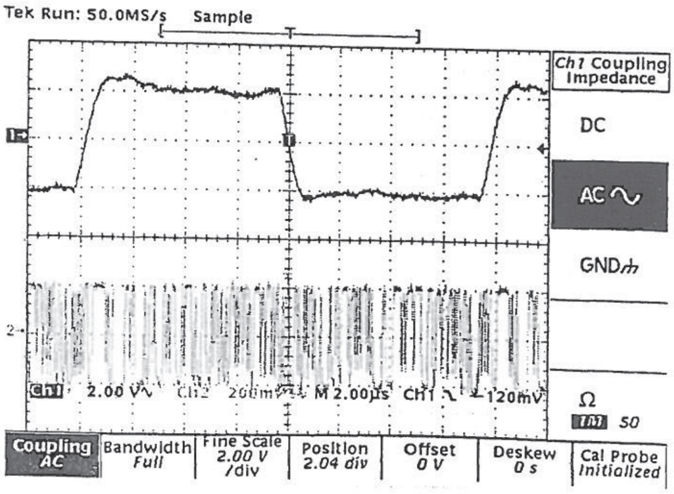


Figure 8. SPD of the DS-SS transmitted signal

In Figure 9 is represented a non interfered link. The received signal is the Pseudo Noise Sequence modulated by de data sequence.



Channel 1: recovered data **Channel 2:** received DS signal

Figure 9. Received signal without interference

In the next graphic (figure 10) we can see the effect of illumination over the optical link. As we mentioned before, spread spectrum systems have a better performance in presence of narrowband interference. This is shown by the improvement of signal to noise ratio in the output of reception circuit.

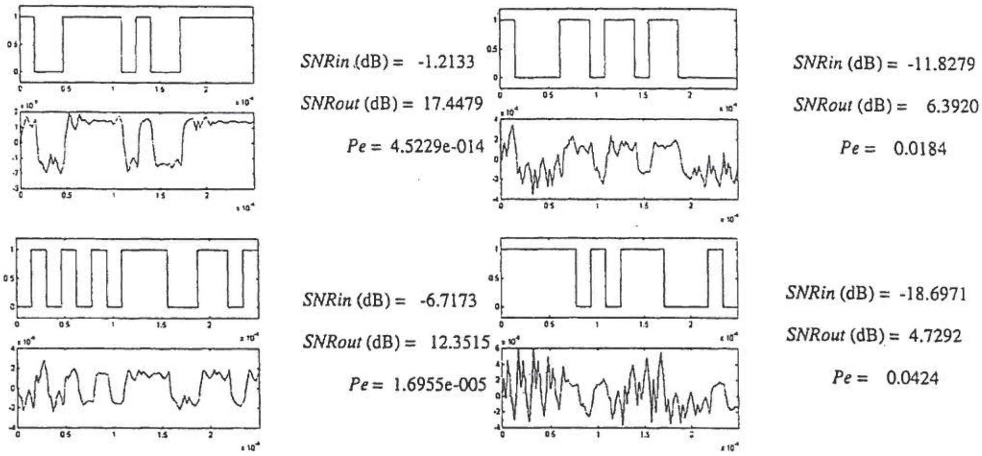


Figure 10. System response on presence of illumination interference

Figure 11 shows the electrical signal at transimpedance amplifier output (oscilloscope channel 1) and recovered data (oscilloscope channel 2) in the case of the interfered link explained below (5mW link with a 20 mW interference). In this case the pseudo noise sequence generated at the transmitter can not be appreciated in the received signal because of the noise and interference.

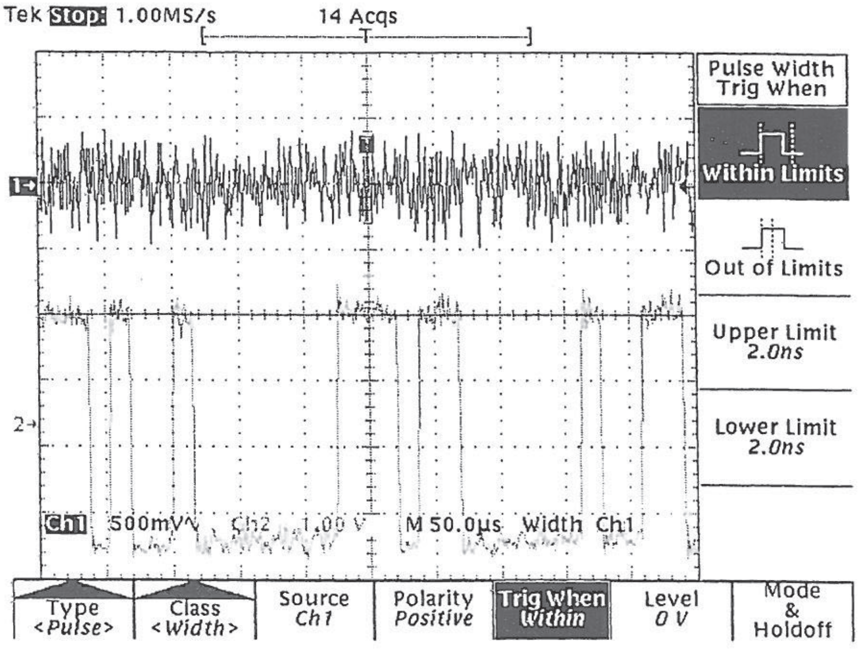


Figure 11. Received signal and detected data with noise and interference

This prototype was developed using laser beam. Therefore, to eyes save condition, Lasers should be changed by LED according standard [2], or some device to destroy the spatial coherence of lasers should be used.

5. CONCLUTIONS

We have see that use of Spread Spectrum in infrared Channel improves its characteristics versus illumination interference and multipropagation. Besides it introduces the possibility of CDMA that allow two or more systems work simultaneously in the same spectrum range without interference between then.

This system can be used in multiple applications as for example:

- Intelligent home: where each electronic device at home (TV, washing machine) communicates with a central control by means of an optical channel with a specific CDMA code.
- Multilingual conference room: In this case each language is transmitted in a different CDMA channel.
- Telephony and audio channels in aircraft avoiding cable installations.
- Wireless LAN using a CDMA as medium access control (MAC)

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