Wireless infrared and UWB impulse radio systems

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- Wireless optical and RF systems
- Indoor and outdoor wireless optical systems
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- Wireless optical and IR-UWB systems
- Evolution, coexistence and convergence
- Conclussions

Why wireless optical?

There is no real competition between RF and Wireless Optical systems, for the most extended applications (WLAN, WPAN, sensor interconnection….) RF systems are well established, cheap and robust.

BUT…..

There are some specific scenarios in which RF systems are not suitable (or simply IR are competitive) because

• They produce (and are affected) by EM interferences (airplane and satellite on-board communications, nuclear facilities, hospitals)
• As they require legal procedures to be installed, they are confined to some frequencies and the bandwidth becomes a scarce recourse.
• They can be intercepted (and/or detected) by other users and communications can result non-secure (unless using extremly time-consuming algorithms)

Why wireless optical?

WHAT DO WIRELESS INFRARED COMMUNICATIONS OFFER?

- They neither produce, nor are affected by EM interferences, so they can be used in EM restricted scenarios and in others (in-house applications, sensor networking) in which interferences are present now (and even more in the future…..)
- They do not require legal procedures to be installed (by the moment) so you have all the bandwidth you can manage (as, for example, for last-mile access or building interconnection)
- They can be intercepted (especially in Line-Of-Sight communications) but is not easy to access data without detection, even without codification (so, almost all baud rate becomes real throughput)
- There are now available (and cheap!!) commercial devices and well established standards offering good performances (tens of Mbytes for indoor networking, hundreds of Mbytes for outdoor access)

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Wireless optical and RF systems

IR Vs. RF WIRELESS TRANSMISSION

Properties	IR	Classical RF
• legal requirements for channel allocation	No	Yes (*)
· Multipath Fading	No	Yes
· Transmission through walls and obstacles	No	Yes
· Multipath dispersion	Yes	Yes
· Dominant noise source	iIlumination / Other users	Other users
· Propagation losses	Very High	High

Wireless optical and RF systems

COMPARISON – IR/802.11/BLUETOOTH

- IrDA
  - A built-in port, low power, low cost, very secure, no interference
  - Line of sight, 1 meter (IrDA IR)
  - Suitable for daily constant PDA network access
  - Available from 115 kb/s to 16 Mb/s
- 802.11a/b/g
  - Long distance, real time connection.
  - High power consumption
  - Unsecured (unless well protected)
  - Interference
  - Available from 11 to 53 Mb/s
- Bluetooth (someone defined it as "…a solution looking for a problem")
  - Medium distance, medium power consumption.
  - Less secure than IR, interference, interoperability issues.
  - Technology is getting mature as applications are growing
  - Available on 1Mb/s (other systems on the way)

Wireless optical and RF systems

Infrared and radio physical media differ in a number of ways that have significant implications for multiple-access techniques:

- Infrared cannot pass through walls or other opaque barriers, making it possible to reuse the same infrared bandwidth in each room of a building.

- It is not practical to perform homodyne or heterodyne detection of the infrared carrier, and DD must be employed. If a DD system employs multiple infrared carriers, these must be separated by optical filtering prior to DD.

- The short wavelength of infrared makes it possible to achieve high angular resolution in an angle-diversity receiver,

- Achieving a high SNR is usually the greatest challenge in infrared system design. Achievement of high average-power efficiency with IM favors the use of waveforms having a short duty cycle.

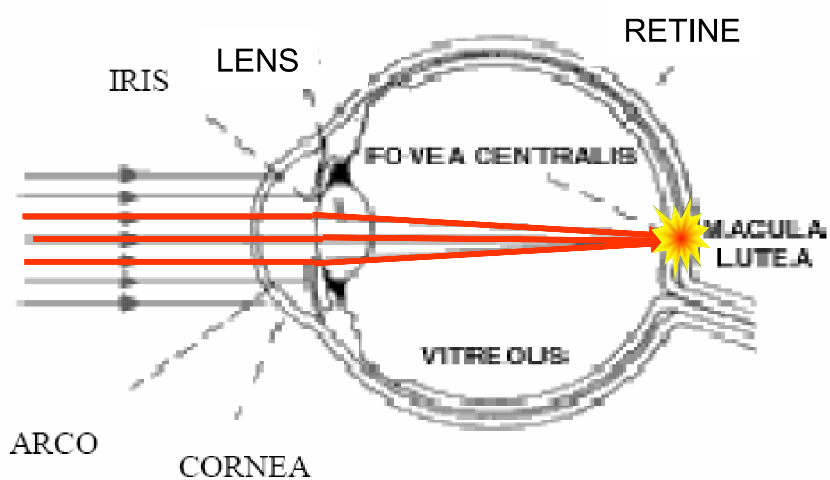
- The SNR of a DD receiver is proportional to the square of the received optical Power.

Wireless optical and RF systems

SECURITY: LASER BEAM EYE HAZARD

IRED are considered to be safe in almost all cases, and they are used in most in-house or on-board applications. But laser diodes has to be controlled because of thier spatial an phase coherence

Visible and *IR-A* wavelengths of light are transmitted through the cornea and lens of the eye, and are absorbed mostly by the retina. The visible and IR-A portions of the spectrum (400-1200 nm) are often referred to as the *"Retinal Hazard Region"* because these wavelengths of light can damage the retina.



The maximum permisible exposure as a function of the wavelength and the optical power is regulated by ANSI Standard Z136.1-1993*

*available from the Laser Institute of America. http://www.laserinstitute.org/

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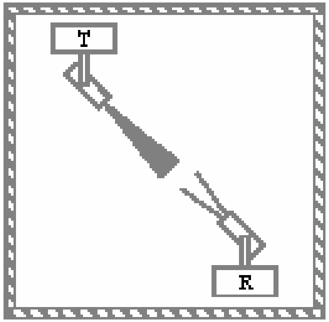
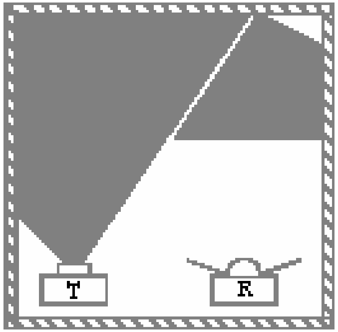
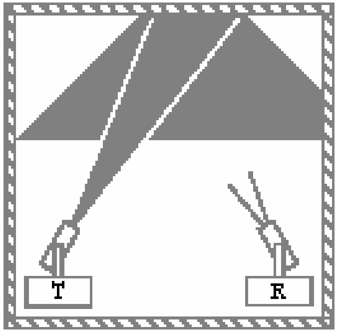
Indoor and outdoor wireless optical systems

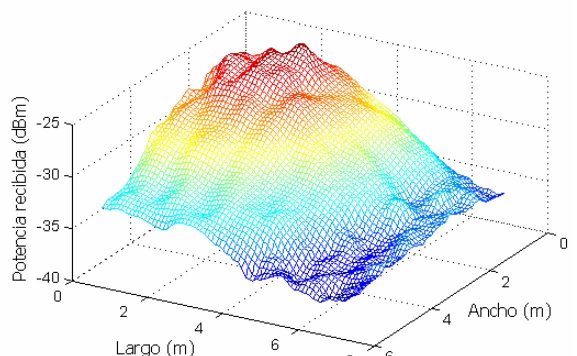
IR LINKS BY REFLECTION

LOS	diffusion	quasi-diffusion









Indoor and outdoor wireless optical systems

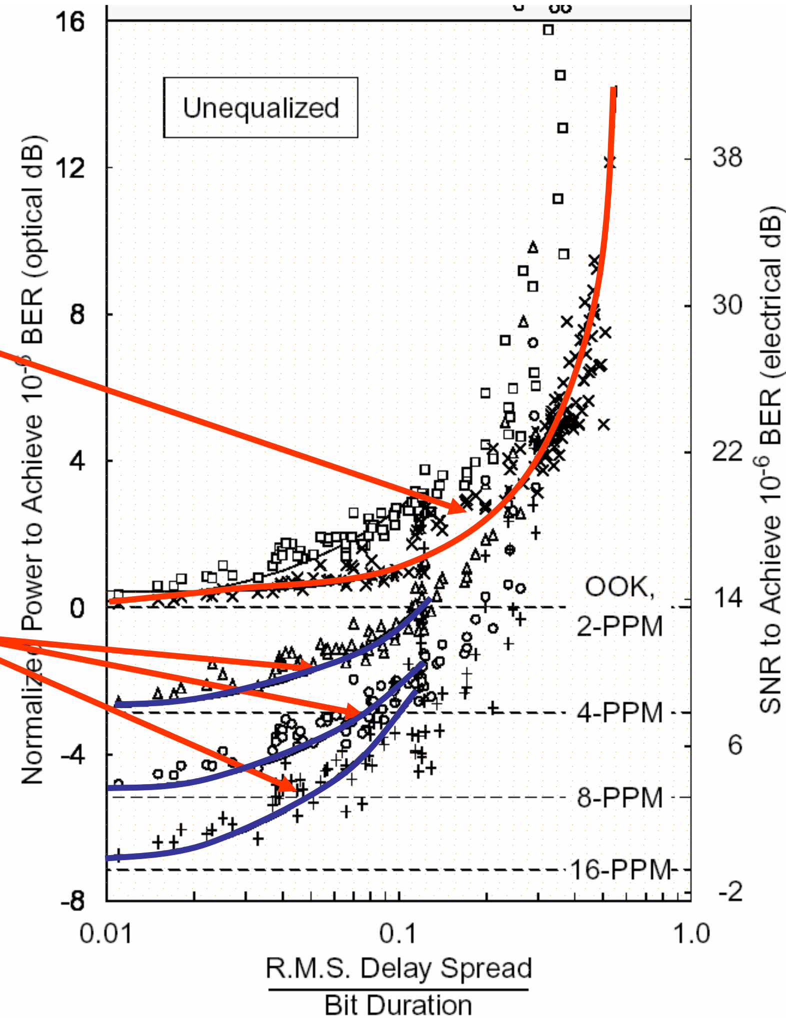
IEEE 802.3 (Ethernet) by using infrared links

Cable replacement
And system interconnection

Wireless optical and IR-UWB systems

MODULATION TECHNIQUES

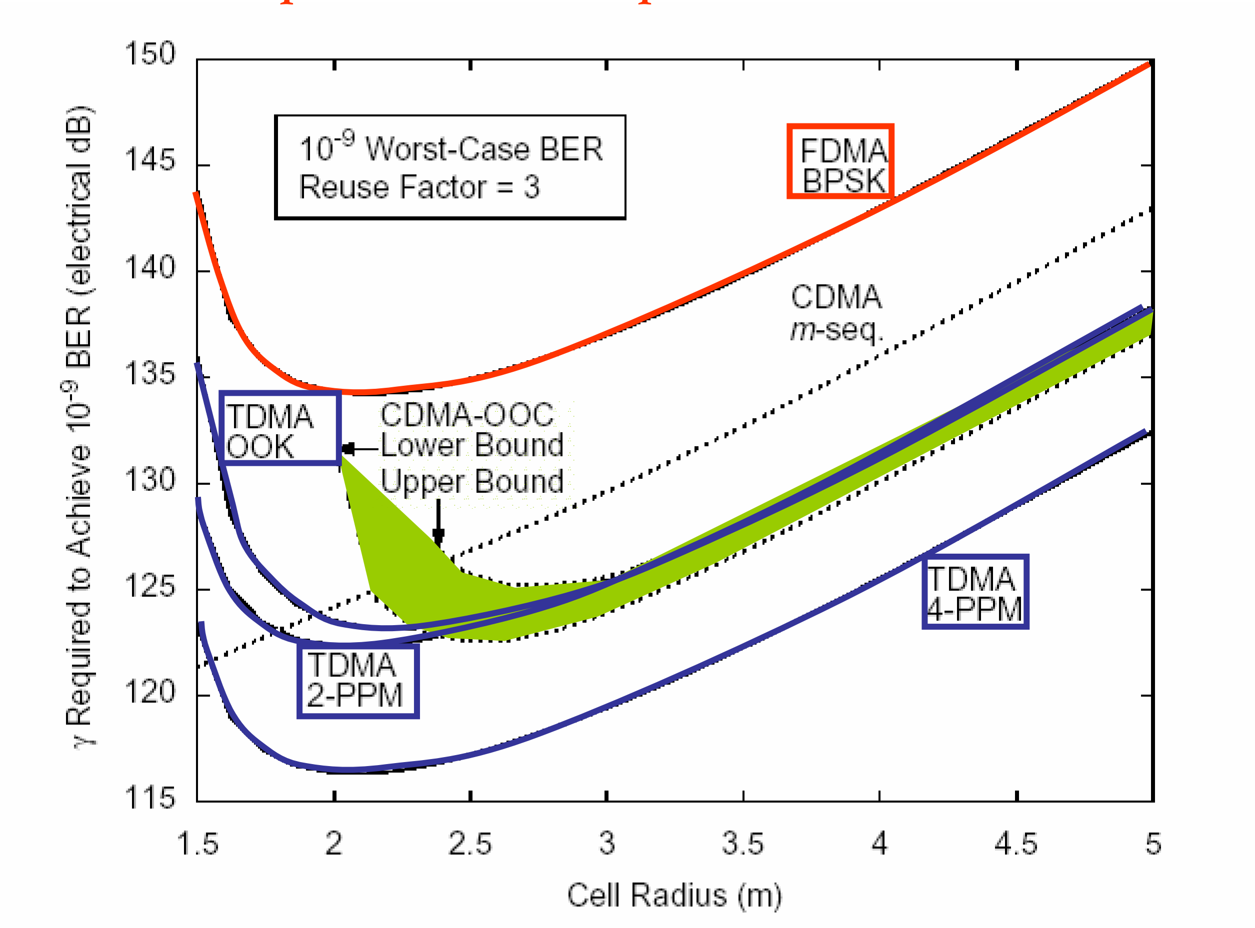
Modulation Scheme	Normalized Average Power Requirement (optical dB)	Normalized Bandwidth Requirement
OOK, NRZ	0	1
OOK, RZ, duty cycle γ	$5 \log_{10}\gamma$	$\frac{1}{\gamma}$
N BPSK subcarriers	$1.5 + 5 \log_{10}N$	2
N QPSK subcarriers	$1.5 + 5 \log_{10}N$	1
L-PPM (soft decisions)	$-5 \log_{10}\left(\frac{L \log_2 L}{2}\right)$	$\frac{L}{\log_2 L}$
L-PPM (hard decisions)	$-5 \log_{10}\left(\frac{L \log_2 L}{4}\right)$	$\frac{L}{\log_2 L}$
L-DPPM (hard decisions)	$-5 \log_{10}\left[\frac{(L+1) \log_2 L}{8}\right]$	$\frac{L+1}{2 \log_2 L}$



Source J. Kahn, J. Barry, Wireless Infrared Communications Proceedings IEEE, Jun 1997

Indoor and outdoor wireless optical systems

Theoretical performance comparison of reuse schemes

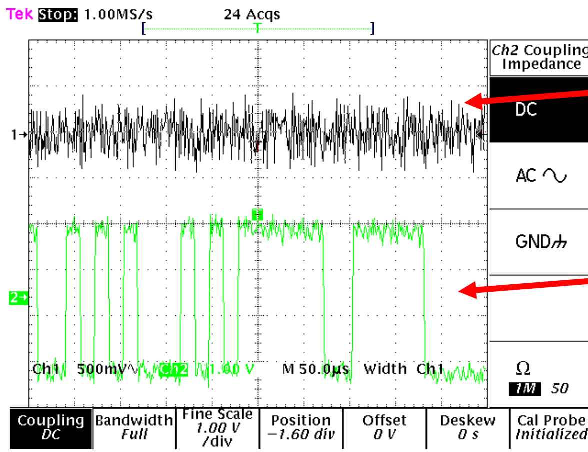


Diffuse transmission is employed, and the throughput in each cell is 10 Mb/s. The factor γ is equal to the SNR for unit optical path gain, and is proportional to the square of the transmitted optical power.

Indoor and outdoor wireless optical systems

WIRELESS OPTICAL-DSSS

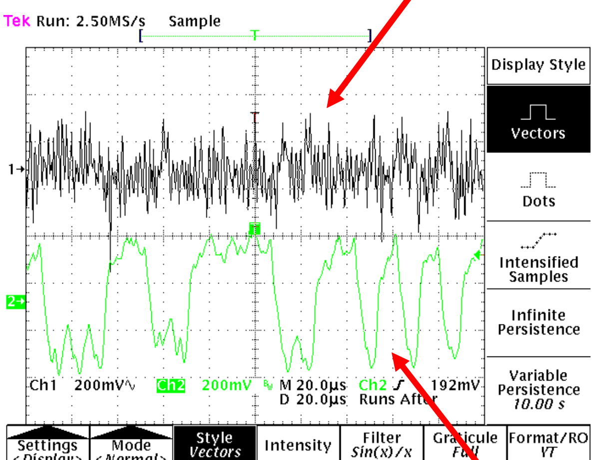
Receivers based on different photodiodes (previous to filtering)



Spread signal (SNR=0 dB)

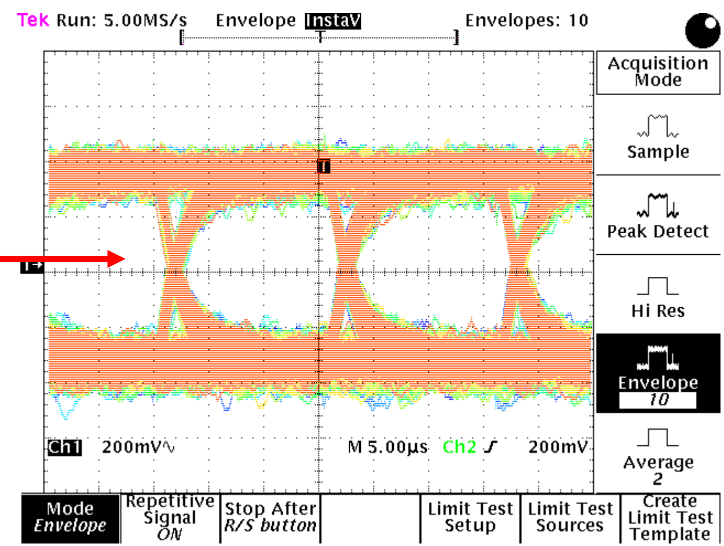
Recovered signal (APD photodiode)

Spread signal (SNR=3 dB)



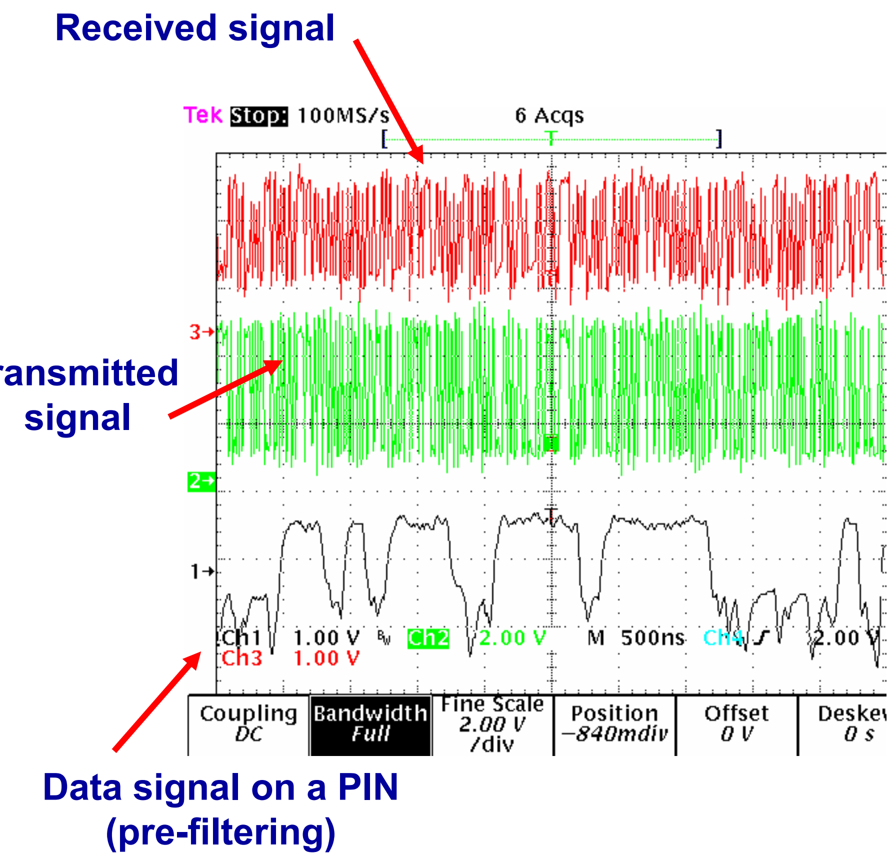
Recovered signal (PIN photodiode)

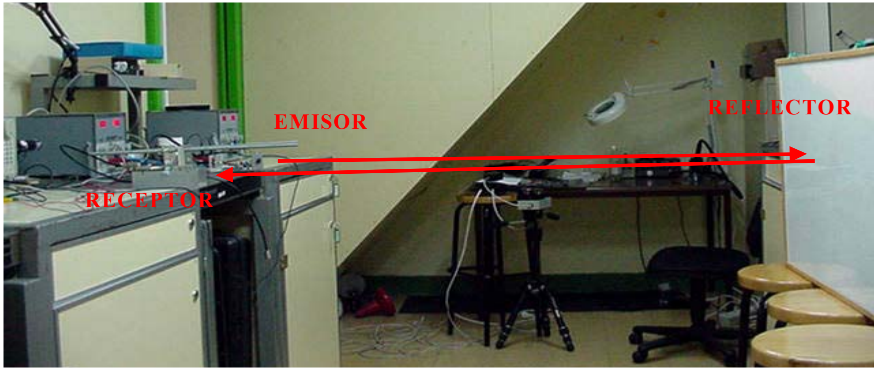
Eye diagram (APD output)



Indoor and outdoor wireless optical systems

WIRELESS OPTICAL-DSSS: RESULTS



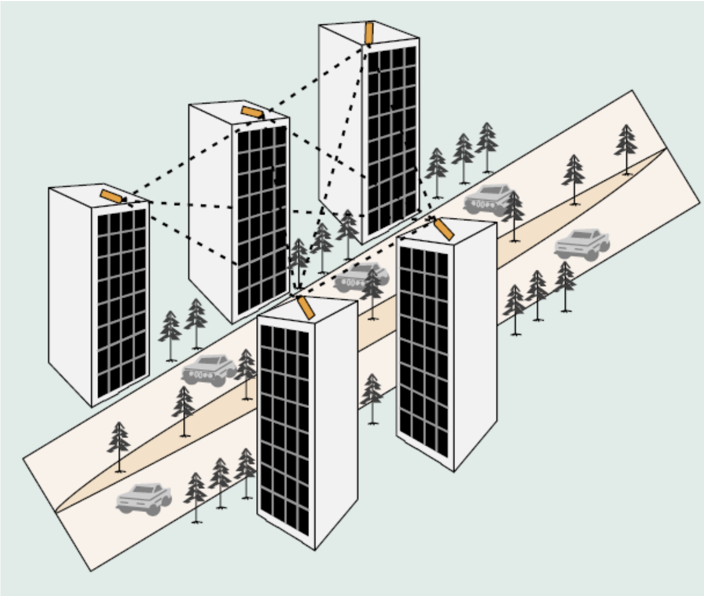


Indoor and outdoor wireless optical systems

FREE SPACE OPTICAL LINKS

Includes all outdoor optical communications systems

Urban optical wireless communication (UOWC) is rapidly gaining popularity as an effective means of transferring data at high rates over short distances.



A MAN optical wireless communication network

The UOWC terminal includes an optical transmitter and a receiver positioned, separated by several hundred meters.

UOWC boasts many advantages over its rivals:
- Rapid deployment
- Lightweight
- High-capacity communication without licensing fees and tariffs.

Its main drawback is their dependence with weather conditions and atmospherical phaenomena

Indoor and outdoor wireless optical systems

FREE SPACE OPTICAL: COMMERCIAL LINKS

There are about 20 worldwide distributors

Optical transmitter: LD (class 1,2,3A y 3B)
Wavelength: 700-900 nm
Output power: up to 80 mW
Max. Range: 2-4 km
Data rate: from 2 to 622 Mb/s (and even 1.25 Gb/s)
Interface: fiber
Protocol: transparent (IM/DD)

LightPointe FlightStrata:
Up to 1.25 Gbps, 800 nm,
700 m

LightPointe FlightApex:
Multi-Beam Array Tracking (MBAT)
Up to 2.5 Gbps
Rated at 1,000 meters
1550 nm

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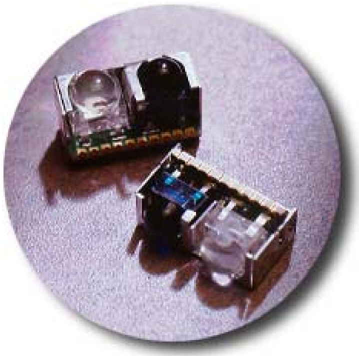
Application Scenarios

IrDA STANDARDS FAMILY

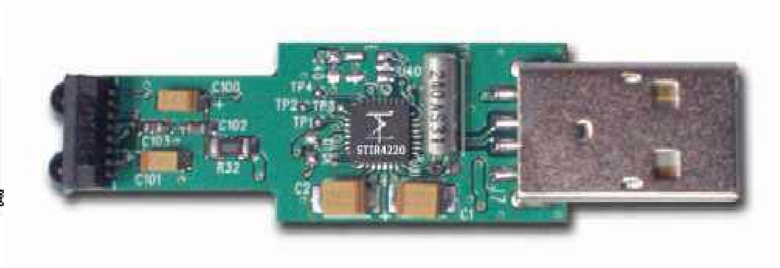
IrDA defines standards for both the physical devices and the protocols they use to communicate with each other.
The standards include: IrDA Data (SIR, FIR, VFIR), IrDA Control, and AIR. Ports built to the above standards can be found in products such as PDAs, Palm devices, printers, desktop adapters, notebooks, and digital cameras.



IrDA devices communicate using infrared LED's.
Wavelength used is 875 nm
(with a tolerance around 30 nm).

Receivers utilize PIN photodiodes

Infrared Data Association®



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Application Scenarios

IEEE 1073: WHY INFRARED FOR MEDICAL APPLICATIONS?

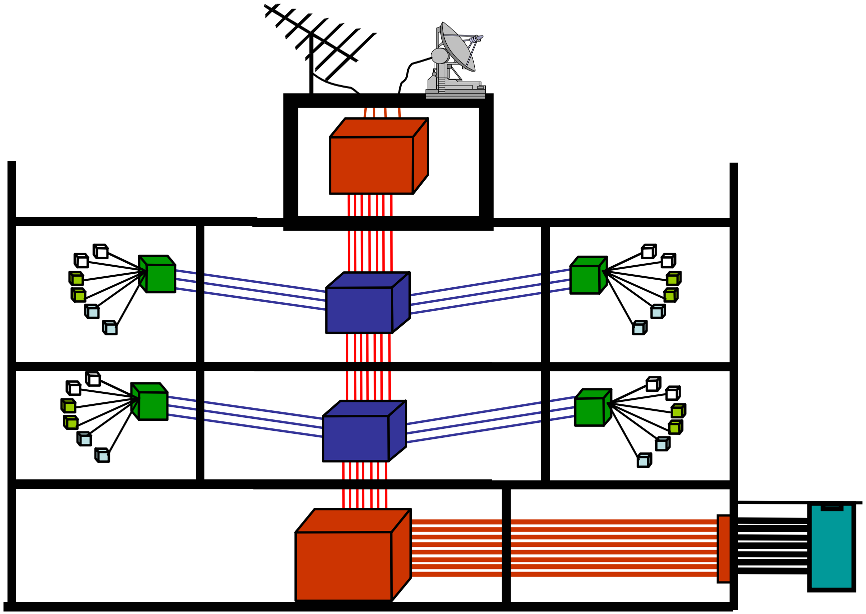
- The standardization of communication processes that has led to the explosion of telecommunications products in the consumer area has yet to take hold in the world of clinical medicine

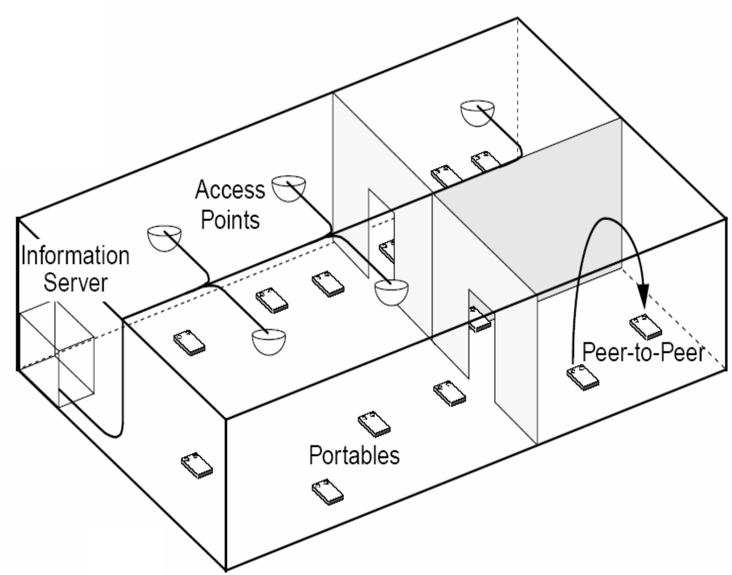
- Information technology (IT) standards within the commercial application domain (e.g., IEEE 802.x standards) are inadequate to fully address the needs of the clinical IT domain, particularly at the patient bedside

- RF systems have security and operation problems that not affect IR systems (e.g. with legacy equipment using ISM bands or privacy of medical data)

Application Scenarios

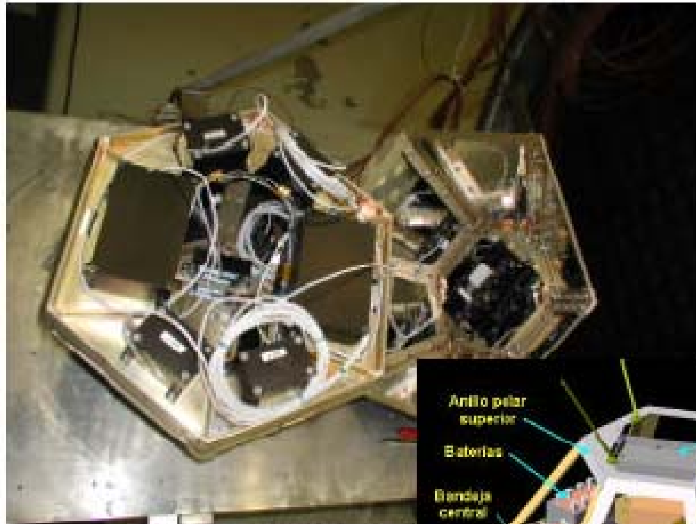
IN-HOUSE (DOMOTICS) APPLICATIONS

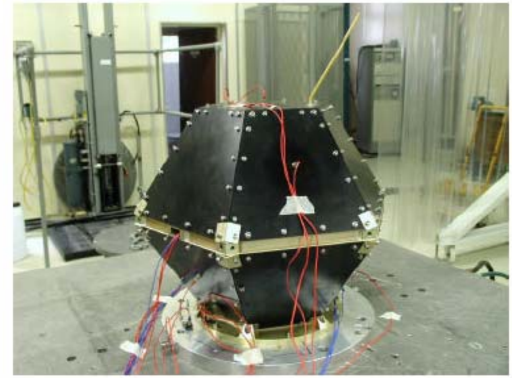


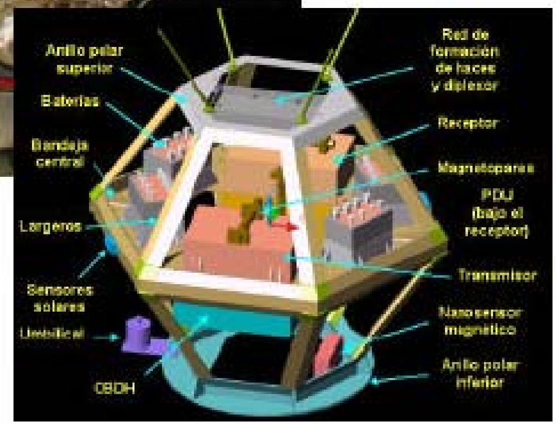


- Sensor interconnections and networking
- Audio systems control (even by visible light)

Application Scenarios

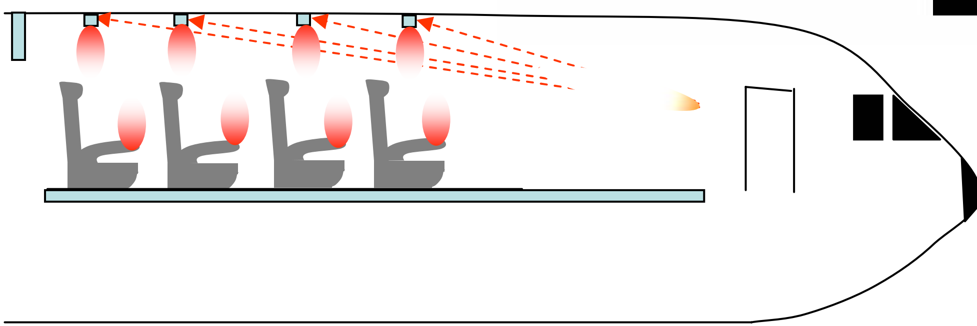






ON-BOARD SYSTEMS

On board systems for cable replacement on satellites
- Weight considerations
- Robustness on rocket launching



EADS proporsal for on-board wireless infrared system, to provide internet and entertainment during the flight

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Wireless optical and IR-UWB systems

Wireless optical communications and impulse-radio Ultra Wide Band systems share many characteristics (but UWB overcomes many of their main drawbacks!!!)

•Large bandwidth available (when regulated!!!)

•Carrierless modulation schemes (need MAC protocols without carrier sensing)

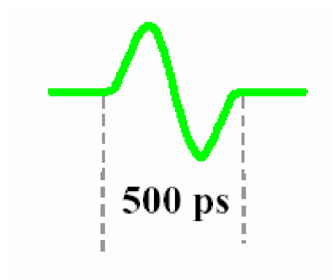
•Interferences over existing RF systems can be neglected: suitable for "special" applications (hospitals, airplanes….)

•Power looses on infrared transmission are substancially reduced on IR-UWB

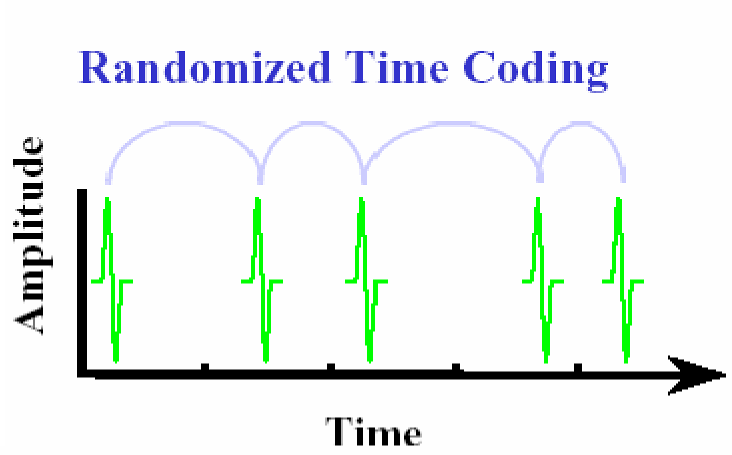
•Infrared systems have been extensively tested with spread spectrum systems and some experiences over receiver design, access control can be used for UWB systems

Wireless optical and IR-UWB systems

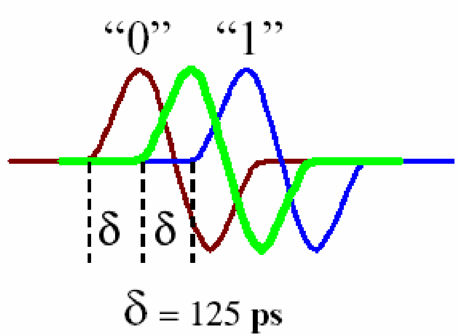
• Not a sinewave, but millions of pulses per second



• Time coded to make noise-like



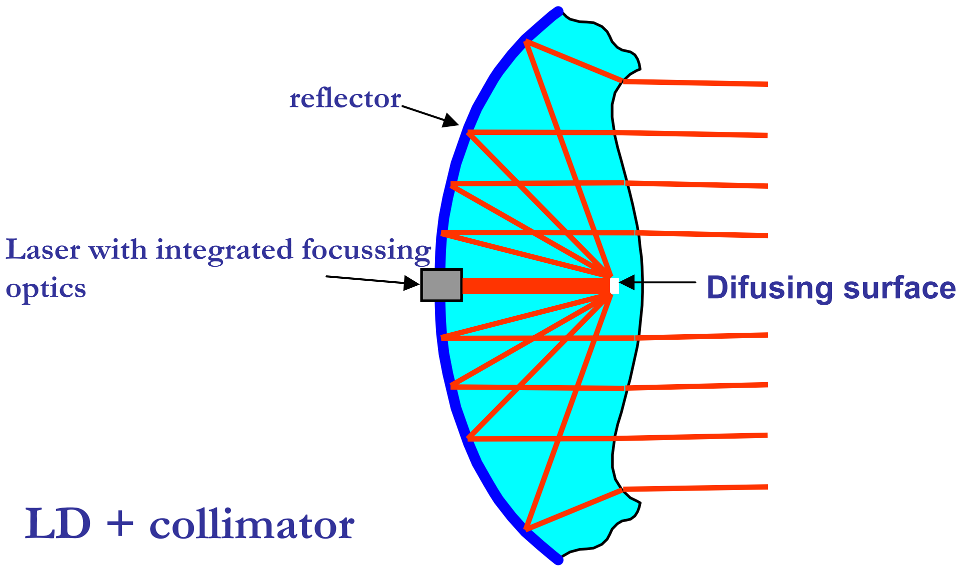
• Pulse position modulation



Wireless optical and IR-UWB systems

How to combine optical broadband transmission with omnidirectional transmission and safety?

Difussed laser beams



LD + collimator

Integrated Laser
+ collimator

Wireless optical and IR-UWB systems

CSMA/CA protocols on wireless optical systems

First proppposed by IBM for diffuse infrared *ad-hoc* LANs.

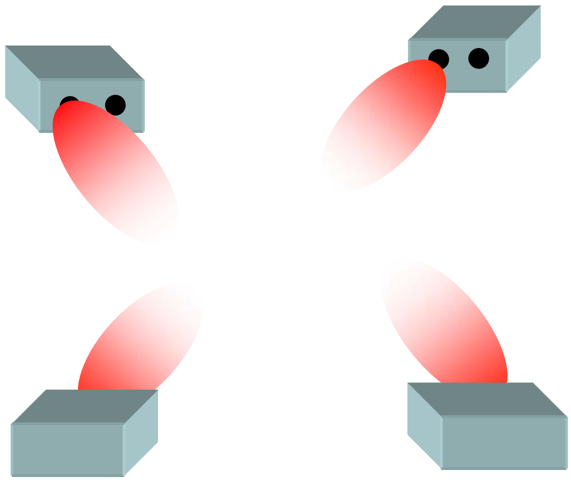
Optical transceivers are not able to receive with high sensitivity while transmitting, so they cannot perform collision detection: CSMA/CA protocol.

In order to perform collision avoidance, prior to initiating transmission, a transceiver listens to the shared channel. If the channel is free, it transmits a jam signal to reserve the channel, waits a time sufficient for all the stations to receive the jam signal, then transmits the payload packet. If acknowledgments indicate that a packet has been lost (usually due to a collision), the lost packet is retransmitted.

When hidden nodes are present, collision avoidance can fail, causing the CSMA/CA protocol to crash. In this case, the protocol can change to a deterministic, bandwidth-reservation scheme, which is stable, although it achieves lower throughput than CSMA/CA would in the absence of hidden nodes.

Wireless optical and IR-UWB systems

Work proposal on the way: implementing a short-range wireless optical network for testing UWB MAC protocols



- Based on CSMA/CA protocols
- Using low cost emitters
- Baud rate up to 100 Mb/s
- Easy to implement
- Allow testing until european regulations are OK and until cheap transceivers are available

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Conclussions

Infrared represents an attractive choice for many cheap short-range applications.

Its advantages include the:

- Availability of a wide bandwidth that is unregulated worldwide and that can be reused in a very dense fashion
- Security
- Low signal-processing complexity, and potentially very low cost.

The most difficult challenges in infrared link design are:

- Achieving a high SNR.
- Multipath propagation causes significant ISI in nondirected links at bit rates above 10 Mb/s, but can be mitigated through proper modulation and detection techniques.
- Advanced components, such as quasi-diffuse transmitters and angle-diversity receivers, produce significant increases in link efficiency and bit rate, at the price of increased complexity.

Conclussions

UWB is to asume much of the nowadays application scenarios of wireless optical systems

Many of the scenarios are held by very "conservative" organizations (hospitals, ESA, nuclear administrations….) and changes are delayed to the "state of the art" in communications.

UWB still to deal with the frequency holders in europe….Optical systems have an oportunity on cheap in-house ad-hoc sensor internetworking.

THANK YOU FOR YOUR ATTENTION

QUESTIONS ARE WELCOME!!

You can also contact me at:
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