INFRARED WIRELESS NETWORKS

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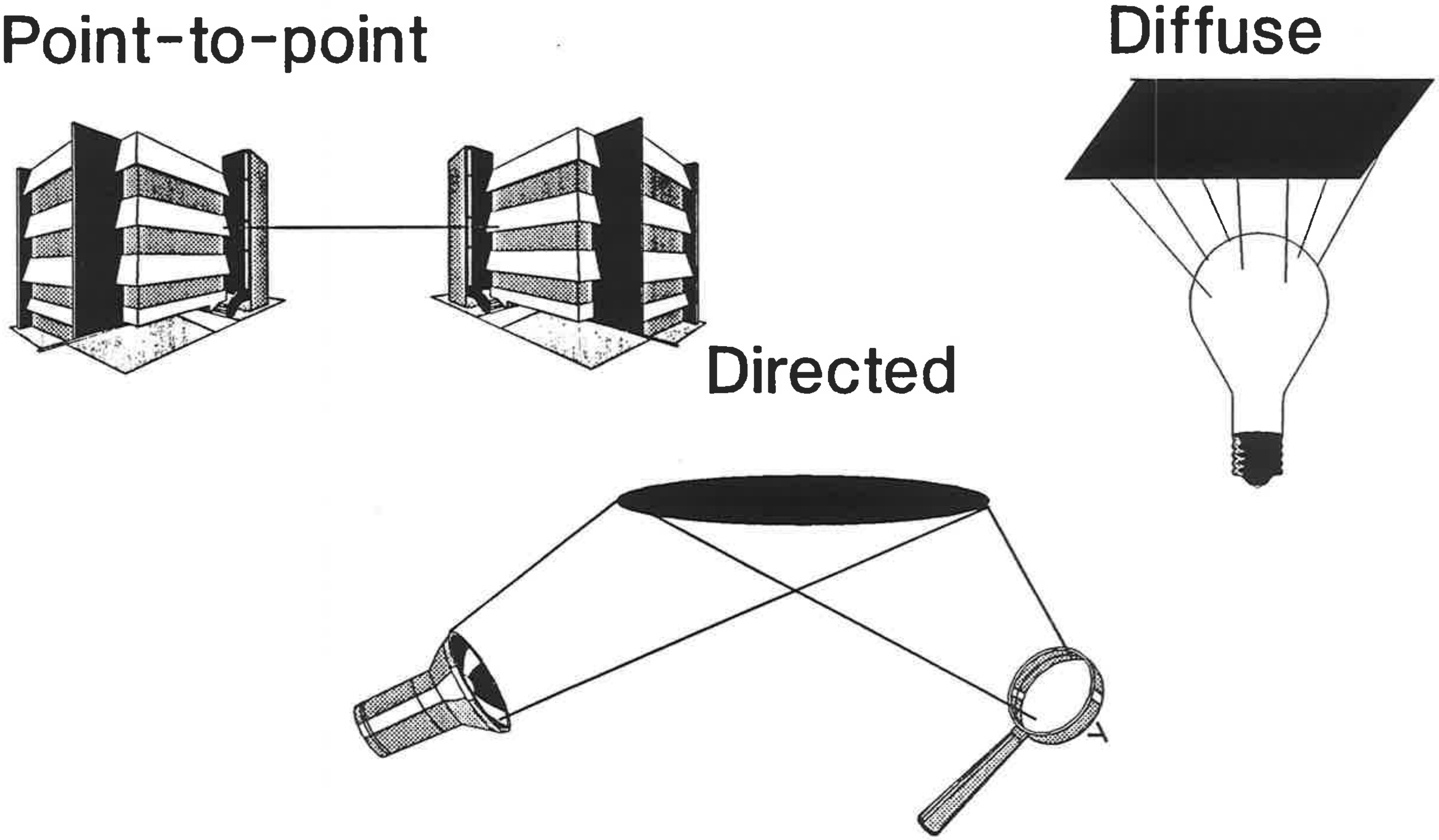
Infrared Types
Description



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Infrared Types
Characteristics

	Point-to-Point	Directed	Diffuse
Range:	600ft+	70 ft	30 ft
Speed:	>10 Mb/s	10 Mb/s	1-10 Mb/s
Alignment:	Precision	Simple	None
SNR/BER:	>20 dB;<10^-8	>20 dB ; < 10^-8	>20 dB ; <10^-8
Safety:	Safe(LED)	Safe	Safe
Power:	35 W (1)	35 W (1)	50 mW (2) 20 mW/kB (2)

(1) AC Line Power

(2) DC Power

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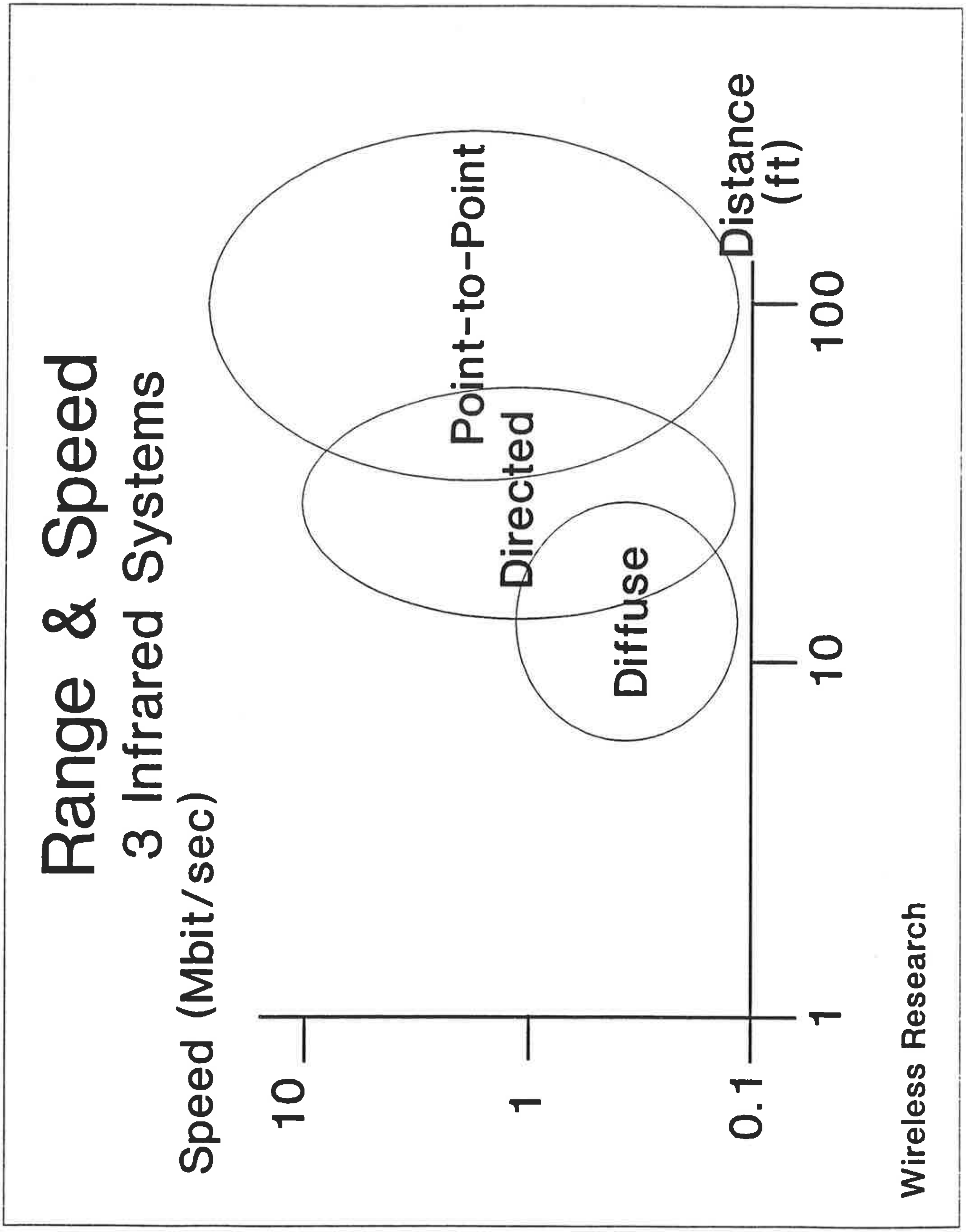
Range & Speed
3 Infrared Systems
Speed (Mbit/sec)
10
1
0.1
Point-to-Point
Directed
Diffuse
1
10
100
Distance (ft)
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Infrared Types
Advantages

Point-to-Point

Maximum distance
Excludes interference
Power efficient
Secure indoors
Simple alignment

Directed

Efficient vs Diffuse
Many channels
Excludes interference
Minimizes shot noise
Secure indoors
Simple alignment
Line-of-sight not required

Diffuse

No aiming required

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Infrared Types
Disadvantages

Point-to-Point

Stopped by walls
Stray reflections
  can self-interfere
Requires
  line-of-sight

Directed

Stopped by walls

Limited range
Not well matched to
  ring architecture

Diffuse

Stopped by walls

Very limited range

Limited speed
Single channel

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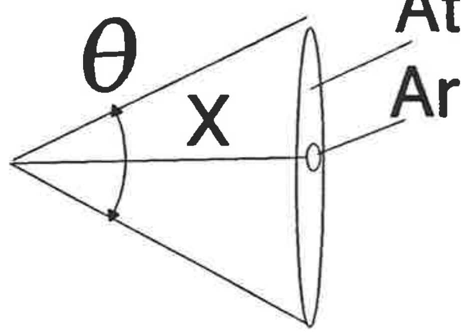
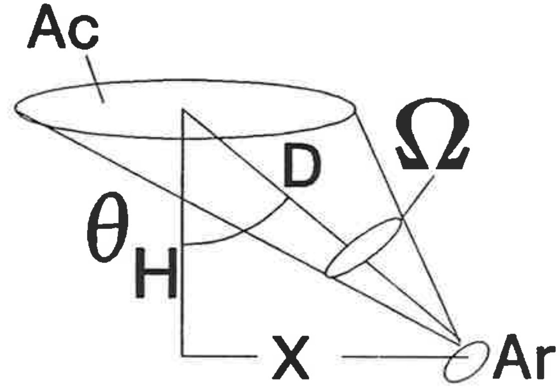
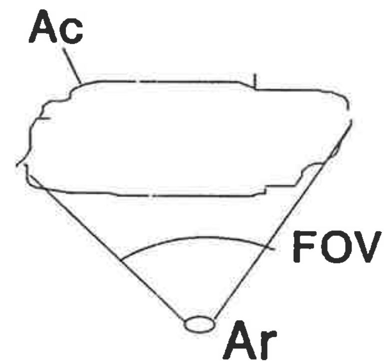
Signal Strength & SNR
Comparison of 3 types

Point-to-point	*Directed*	*Diffuse*







Pr:

Point-to-point	Directed	Diffuse
Pt Ar/ π[X tan(θ/2)]^2	Pt H Ar/π X^3	Pt Ar [Sin(FOV/2)]^2/Ac

SNR vs Pt & X:

Point-to-point	Directed	Diffuse
Pt^2 * X^-4	Pt^2 * X^-6	Pt^2 (Independent of X)

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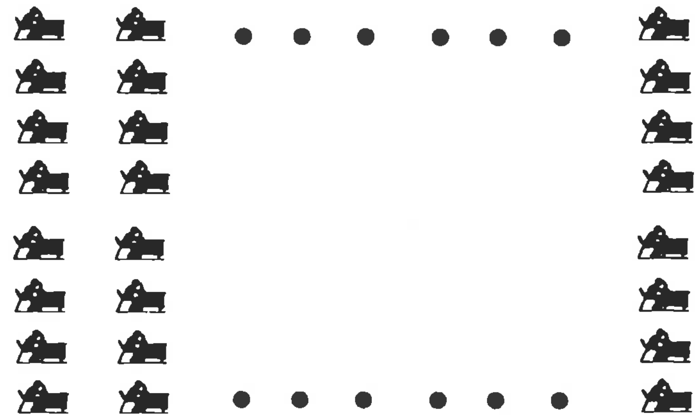
In Wireless -- Small is Beautiful

Shorter Range is Better



600 ft (183 M) Range

› 1400 Workers
on a SINGLE network

TOO MANY!

70 ft (21 M) Range

20 - 40 Workers

on a SINGLE network

JUST RIGHT!

Link zones together
for full connectivity

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Small is Beautiful (Cont.)
Shorter Range is Better

- Smaller network zones improve performance
  - Reduced contention
  - More parallelism
- Smaller network zones improve dependability
  - Less subject to system-wide outages
  - Easier fault isolation and repair
- Smaller network zones increase efficiency
  - Greater "frequency" reuse
  - Less interference between networks

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Infrared Doesn't Penetrate Walls

... but that's not all bad

- 2/3 of office workers are in open offices
- Confining IR signals improves security
  - Can't be intercepted by outsiders
- Minimizes interference between network zones
- Other through-the-wall solutions allow links
  - Short range radio
  - Cable

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Directed Multipoint Infrared

- First introduced by Photonics in 1989
- Uses small portion of office ceiling as passive reflector
- Physical layer device
  - Connects like cabling
  - Combines with cabling
  - Standard interfaces
  - Suitable for open offices

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Directed Infrared
Characteristics

- Economic < $300 per node ($1195 for a 4 port unit)
- User installable
  - No software required
  - No plug-in cards required
  - Simple alignment
- Permits multiple networks to coexist
- Speeds to 10 Mb/s (Ethernet interface)
- Secure
- Safe
- Immune to RF or self-interference

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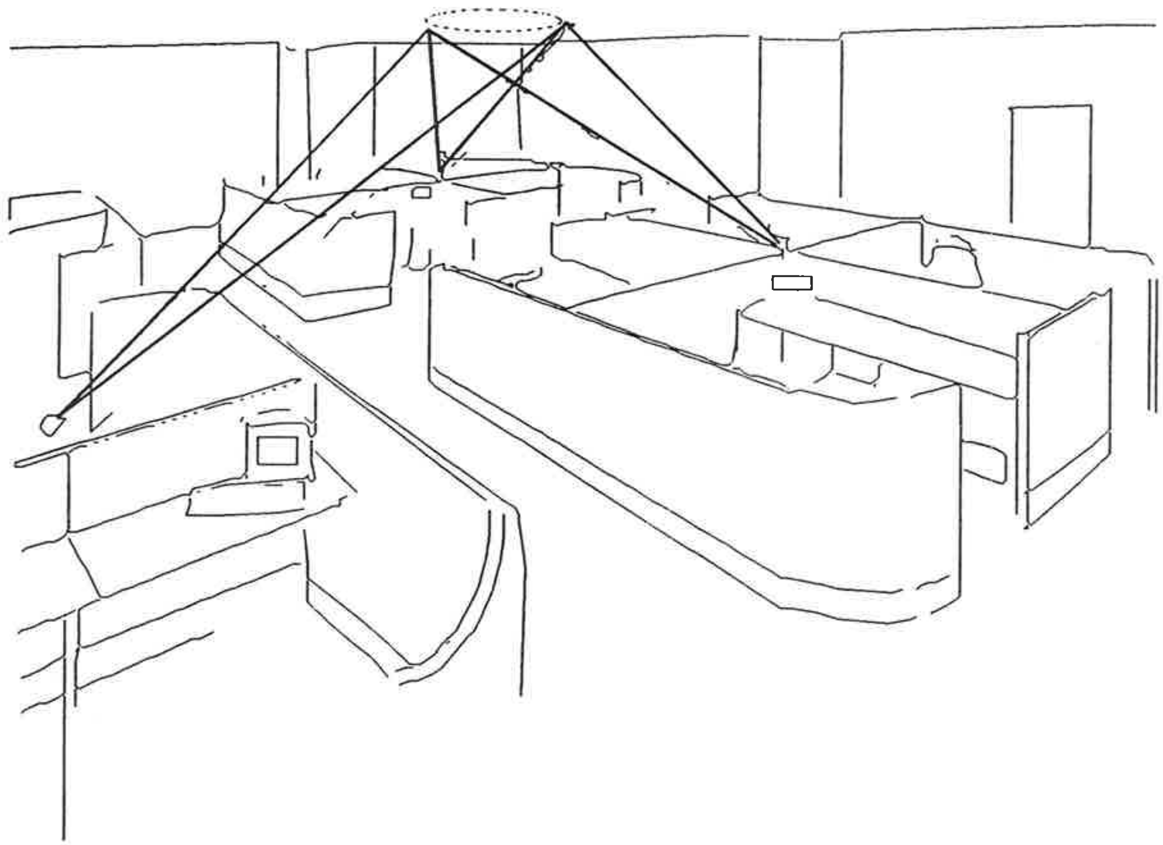
Open-Office Infrared Installation

Nothing on Ceiling 8 - 10 ft Spot



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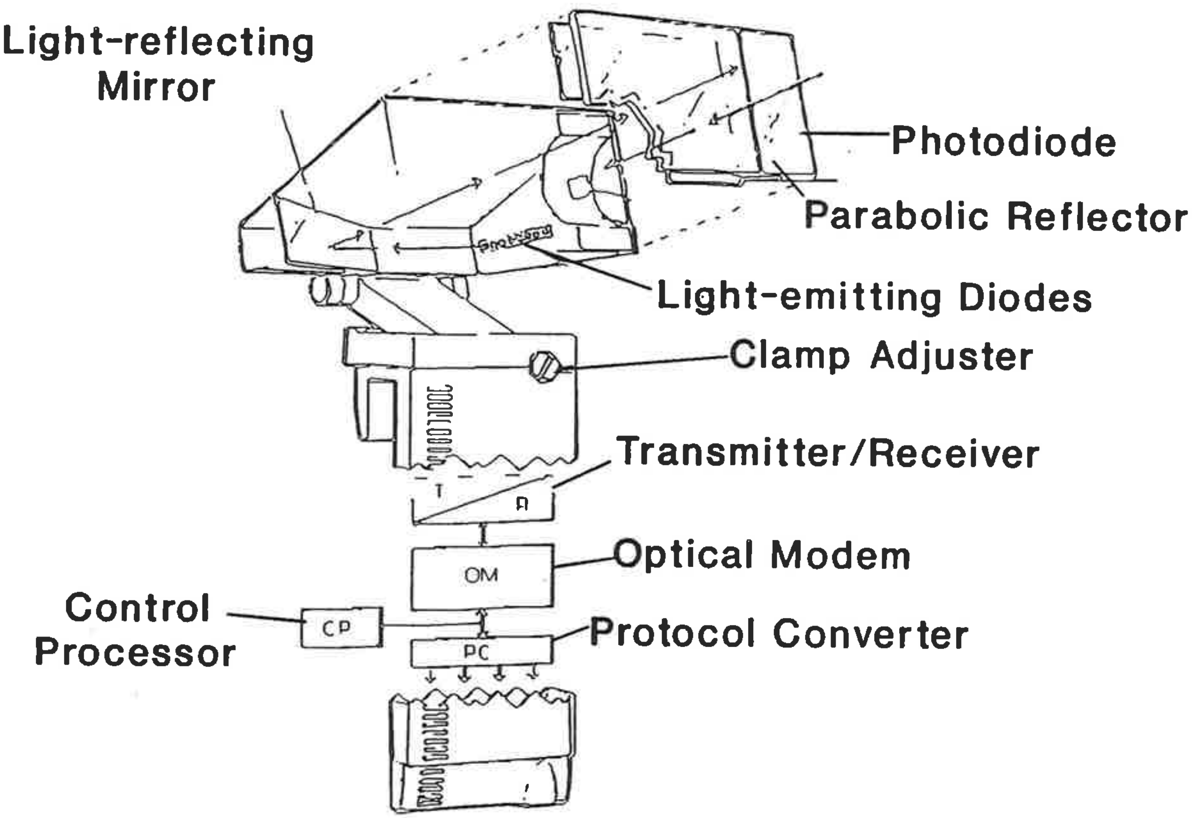
Inside an Infrared Transceiver



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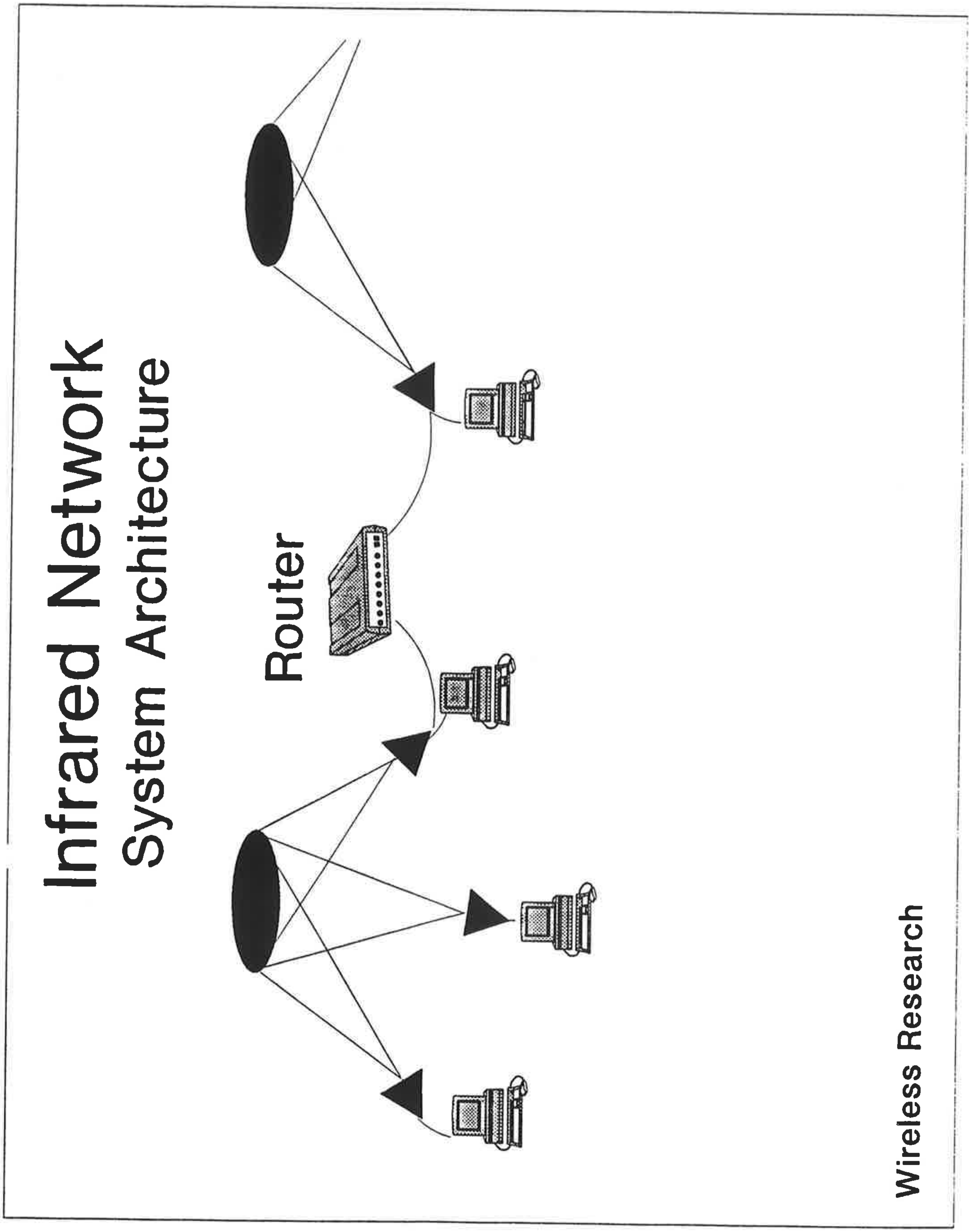
Infrared Network
System Architecture
Router
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Directed Infrared Dependability

How do you make it more dependable than cable?

- Resist blockage
  - Fan-shaped beams
  - Directed overhead
- Built-in error correction
- Indicator lights to aid troubleshooting

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Directed Infrared Applications
Where should I use it?

- Local Area Networks
  - Open offices and manufacturing environments
  - Bus or star architectures (Ethernet or Appletalk)
  - High "churn" environments (project teams, auditors)
  - Temporary installations (leased facilities)
  - Security requirements
  - Disaster recovery
  - Repair of broken cabling
- Terminal-to-Host Connections
  - Open offices
  - 16 - 32 terminal clusters @ 9600 b/s
- Building-to-Building Links
  - Distances to 600 feet

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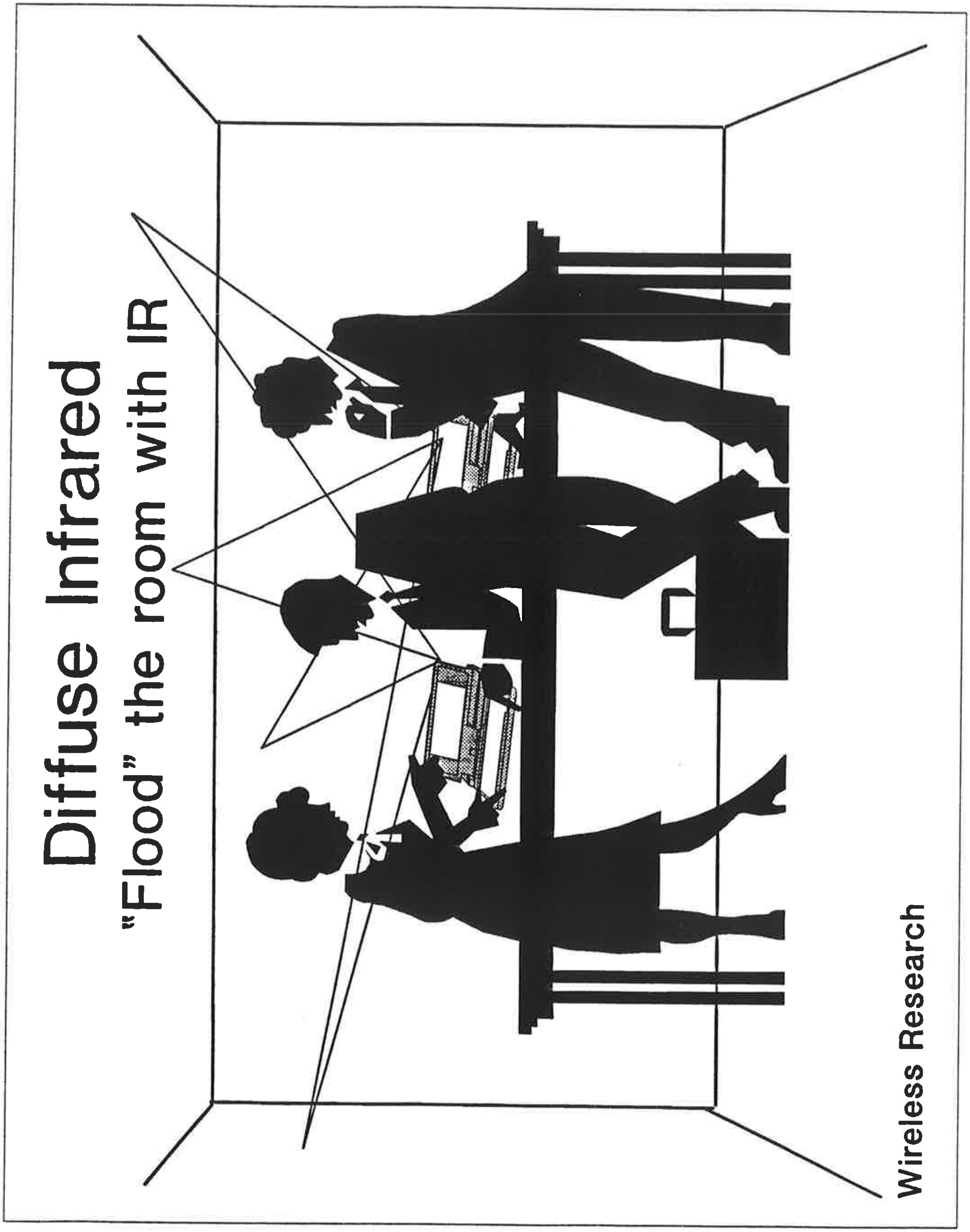
Diffuse Infrared
"Flood" the room with IR
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Diffuse Infrared
Characteristics

- Short range (< 30 ft)
- Low power (50 mW listening)
- Low cost ($20 in OEM quantities)
- Moderate Speed (1 Mb/s)

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Diffuse Infrared Applications

- "Docking Station"
- Classroom training
- Conference room "Collaborative Computing"
- Cover larger areas using repeaters

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Alignment Methods

Permit easy installation

- Signal strength indicators
- Roll-call of infrared transceivers
  - Transparent to data traffic
  - Utilizes very little bandwidth
  - Assures network integrity (no hidden nodes)
- Diffuse systems require no alignment

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Infrared Access Methods

- CSMA
  - Point-to-Point, Directed or Diffuse systems
  - Collision detection possible with PPM
- Token Ring
  - Point-to-Point systems
- Token Passing Bus
  - Point-to-Point, Directed or Diffuse systems

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Power Requirements

- Typical directed or diffuse transceiver
  - 10 LEDs of average (<5%) efficiency
  - Pulse Position Modulation
  - 1 Mbit/sec data rate
  - 20 mW-sec/kilobyte
- Energy per data unit sent is the proper measure
  - Transmit duty cycles can vary among applications
  - Indicates battery drain for portable units
- "Listen" power can be as low as 50 mW
  - Rises during data reception
- Varies with level of circuit integration

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Infrared Noise Sources

- External noise sources
  - RF energy (eliminated by shielding)
  - External light sources (minimize by optical filtering)
    - + Produce shot noise
    - + Sunlight
    - + Incandescent lights
    - + Fluorescent lights

- Internal noise sources
  - Preamplifier noise
    - + Noise power rises as 3.0 power of bandwidth
  - Shot noise from Photodiode dark current (negligible)
  - Thermal noise from feedback resistance
    - + Shot & thermal noise power rises as 1.0 power of bandwidth

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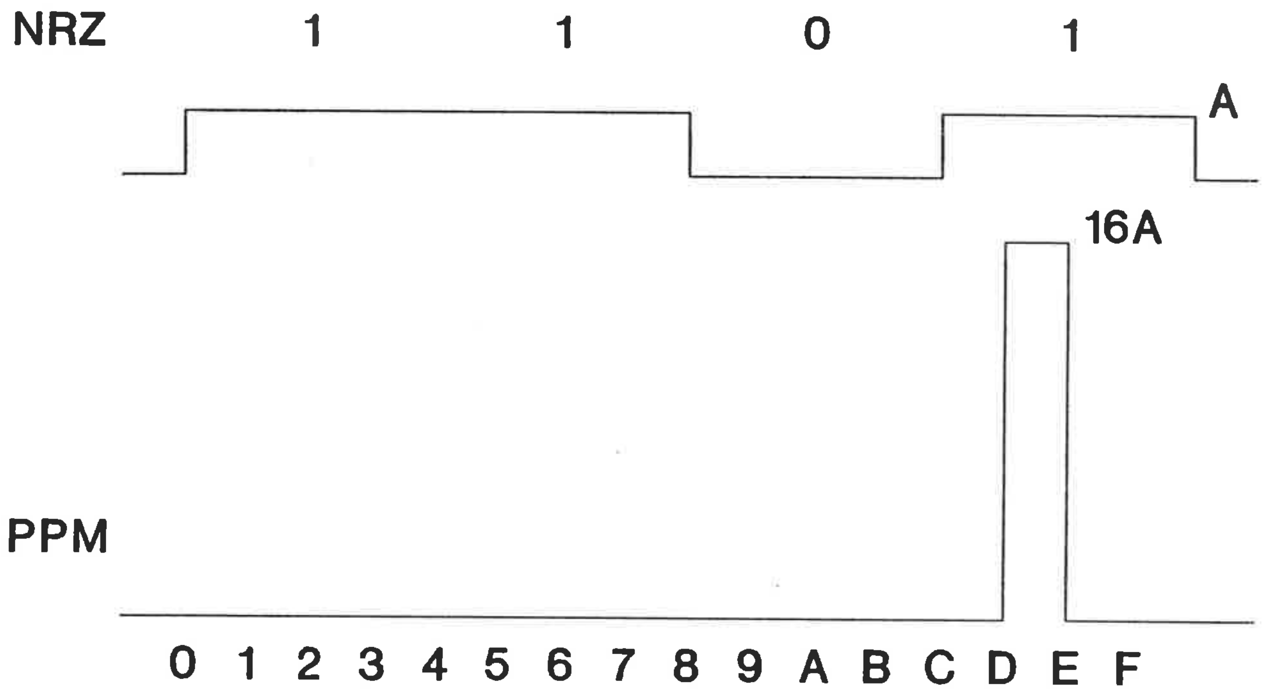
IR Modulation Methods

Pulse Position Modulation is Optimum



Permits erasure detection
Permits collision detection
Maximizes SNR

Pppm/Pnrz = 16

SIGNALppm/SIGNALnrz = 256

BWppm/BWnrz = 4

SNRppm/SNRnrz = 64 (+18 dB)

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Infrared Suppliers

Supplier	IR Type	Customer Type
Photonics	Directed Diffuse	End-user OEM
BICC	Point-to-point	End-user
Texas Instruments	Diffuse	OEM/Custom
Spectrix	Diffuse	OEM/Custom

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Why Wireless Infrared?

- Ideal for portable applications
  - Low cost
  - High speed
  - Low power
- Completely eliminates wiring
- Links to other devices/networks
  - Desktop PCs
  - Wired or wireless networks
  - Nationwide packet radio nets
  - Cellular modems
  - Peripherals

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Infrared
Summary

- Fast
- Economical
- Interference-Free
- Easily Installed
- Dependable
- Unregulated

-- *For the open environment.*

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Diffuse IR suitability for Portable

Power

e.g., Laptop w/ 7.2V, 1700 mA-hr = 12,240 mJ

Typical Batterylife 2-3 hr

Average Power 4.1-6.1 W

Diffuse IR modem impact on life:

≈1% listening

~2%-10% mix of Send/Rcv.

Price/Cost

e.g. Laptop List Price	$2000
Wireless modem %	10%-20%
Wireless List	$200-$400
Dist. Channel Discount	40%-50%
Mfg Sell Price	$100-$240
Mfg. Gross Margin	40%-50%
Mfg. Cost	$60-$120

Diffuse IR can be built-in for $20-$30

DIFFUSE IR vs MICROWAVE Radio

SIMILARITIES & DIFFERENCES & SO WHAT?

SIMILARITIES

- BROADCAST Media
- Limited Range
- PROTOCOLS can be the same

SO WHAT? IT SHOULD BE EASY TO DESIGN a MAC FOR BOTH

DIFFERENCES

- INCOHERENT IR
- LOSSY Reflections compared to microwave (diffuse vs specular) (dielectric)
- Signal Power varies as 2nd Power of Optical Signal Power
- Less "OPEN" PHY

No phase cancell

Higher attenuati vs DISTANCE

Reduced effects of delay spread

Fewer "Secondary" Users (more easily excluded)

More easily Secured

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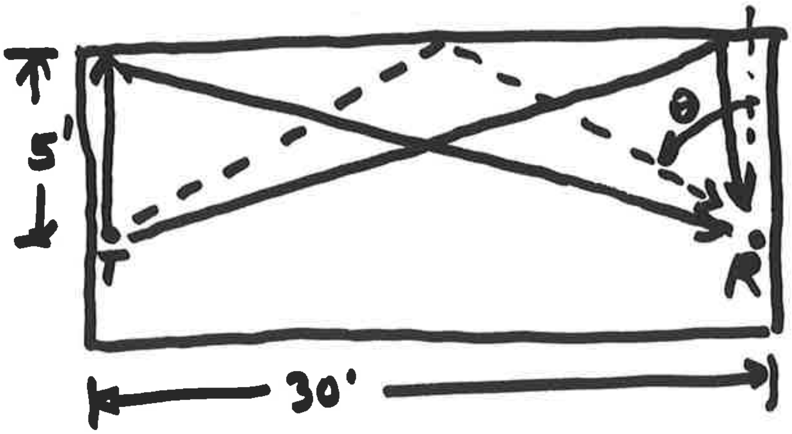
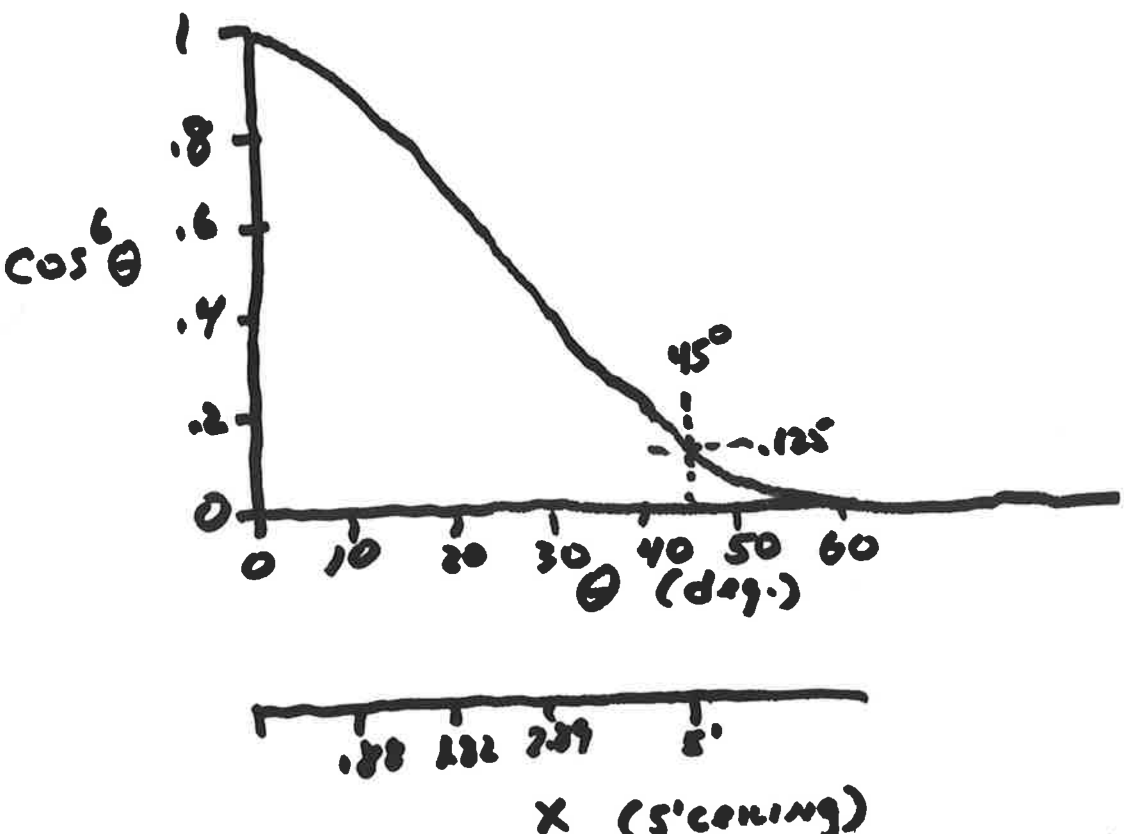
DIFFUSE INFRARED MULTIPATH



SIMPLE MODEL

Note: Incoherent source
No phase cancellation



$X = 5 \tan \theta$

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OPTICAL VS ELECTRICAL SIGNAL POWER

$$i_R = k P_{OPT}$$

$$P_{R_{elec}} = (k P_{OPT})^2 R$$

SINCE $P_{OPT} \propto \cos^3\theta \propto \frac{1}{x^3}$

$$P_{R_{elec}} \propto \cos^6\theta$$

$$P_{R_{elec.}} \propto \frac{1}{x^6}$$

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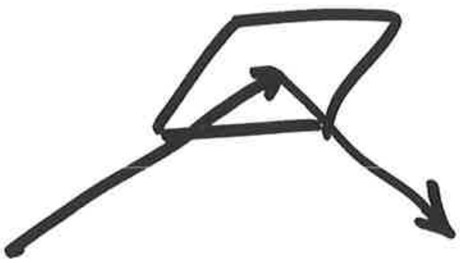
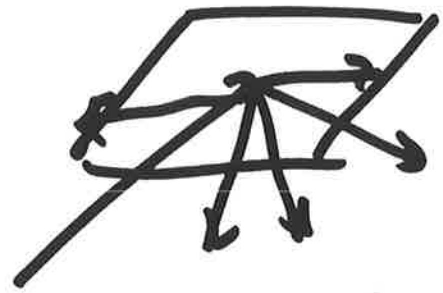
Diffuse vs Specular Reflection



Specular

$\theta_{in} = \theta_R$



Diffuse

Lambertian (cos

Distribution

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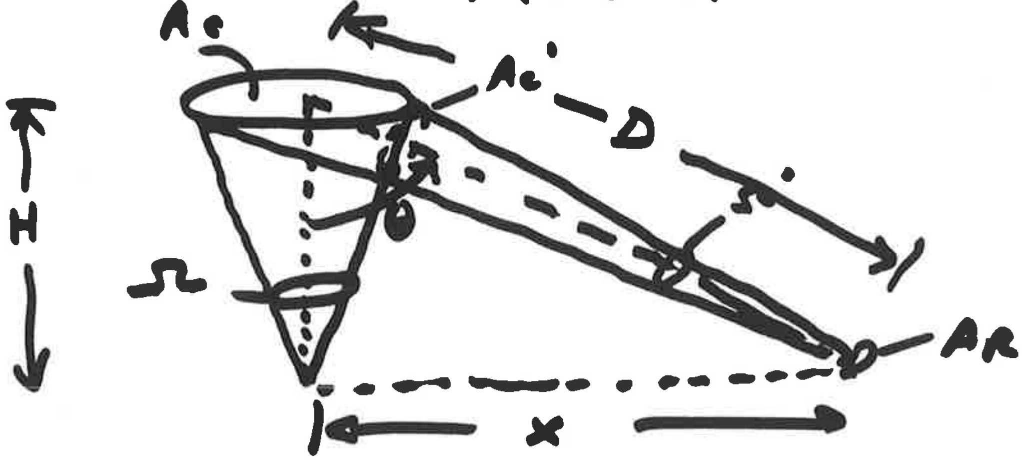
Diffuse Reflection Attenuation



$D = H/\cos\theta$

$A_c' = A_c \cos\theta$

$\Omega' = \frac{A_c}{H^2} \cos^3\theta$

$P_{R\,OPT} = \frac{P_T}{\pi H^2} \cos^3\theta \, A_R$ (IF $H \ll X$: $P_{R\,OPT} \approx \frac{P_T}{\pi} \frac{H}{X^3} A_R$)

(IF FOV @ AR includes all Ac)

<u>NOTE:</u> IF Room interior is uniformly illuminated

$P_{R\,OPT} = w \, A_R \sin^2\left(\frac{FOV}{2}\right)$.

where w is ceiling optical power density

This is independent of position

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