Technology Trends on Broadband Optical Wireless Communication

(Y.I. Jun)
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(K.C. Park)   IT   ,

.

,

.

I.   .

,

IT   800MHz~ 30GHz   RF/MW

,

(ubiquitous)   ,   ,

. IT   ,   /

,   (security)

,   ,

,   .

,   FTTH

(carrier)

,

.   ,

,

.   .   ,

1972

3   2   ,   ,

124

[2004.1.28.].   ,

,   (Personal

(cordless)   ,   ,   Area Network; PAN)

. UV

(Free- Space　　　　　　　[1]. UV

Optical communication: FSO),　unguided　UVA, UVB　UVC　　　　　　　, UVB

optical communication

,　　　"　　　　(optical wireless　(InfraRed: IR)　　　,　　　　(Near- IR: NIR),

communication)"　　　　　　.　　　　(MIR),　　　(FIR)　　　　. NIR

　　　　　　　　　　　　　400~ 100

.　THz　　　　　　　,

PDA　　　PC　　　IrDA　　　,

　　　　　　　　850nm, 1300nm, 1550nm

.　　　　　. (　1)

155Mbps　　　　.

,　　　　　　　　　　　　　0.3~

750THz　　　,

km

.

/　, MP3 player

X-(1~ 10A)	(10A~ 400nm)	(400~ 750nm)
30EHz~ 30PHz	30PHz~ 0.75PHz	750THz~ 400THz

,

peripheral in-

terface　USB　IEEE 1394

(750nm- 3μm)	(3~ 30μm)	(30~ 1000μm)
400THz~ 100THz	100THz~ 10THz	10THz~ 0.3THz

.　　　m　　　Gb/s

1)　　　　　　　　　: 750THz~ 0.3THz
2)　　　　　　　　　: 400THz~ 100THz
3) EHz: 10^{18}Hz, PHz: 10^{15}Hz, THz: 10^{12}Hz

(　1)

,

PAN

.

II.

,

.　　　　(visible light)

750THz　　400THz,　　　　　400~　　　　　　　　.

750nm　　　　.　　　　　　　　　　　(O_2)　　　　,　　　(OH)

(Ultra Violet: UV)　　,　　　　　,

X-　　　,　　　　　　　　　　　. (　2)

14

Atmospheric Attenuation
Attenuation(dB/km)
20
10
5
2
1
.5
.2
.1
.05
.02
.01
.005
5   10   20   50   100   200
Frequency(GHz)
OH
Peak

——— Oxygen Absorption
------- Water Vapor 7.5g/m³
·-··-··- Sea Level

(2)

OH
(peak)   [2].
(NIR)

.   NIR

,

.

.

.
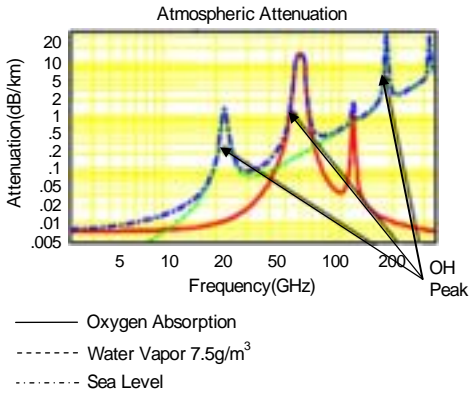
.   (cornea),
(lens),
(vitreous),   (retina)   NIR

.   ,   ,
.   ,   ,

NIR   400~1400nm
.   ,   NIR

. MIR, FIR   UVB
.

,   ,

NIR

.

MIR   FIR

.

UVB

, GaN

DARPA   . UVA
,   .
UVA
,
UVA
.

UV   .

MIR, FIR
(quantum dot)

.

NIR

,

,

NIR   .

LED/LD

.

IEC/ISO   "IEC
60825-1:2001 General laser safety"   "IEC
60825-2:2000 Optical Fiber Communications
Systems"   [3].

(hazard)   class- 1/2/3/4   , class- 1   ,   ,

,   ,

class- 2   (irradiance)   (MPE)

, class- 3   [3],[4].

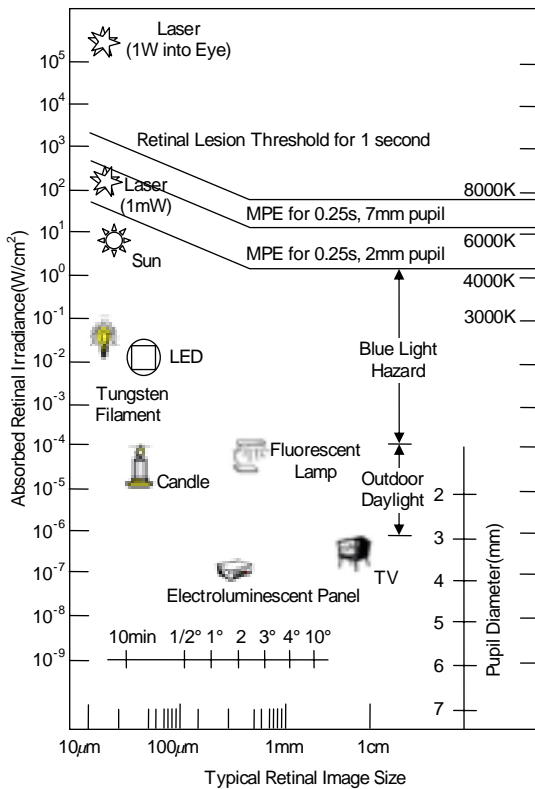class- 2   5

UV   IR   class- 1   ### Ⅲ.

5

, class- 4   ### 1.   (   )

,   10μm~1000nm   30~300THz

.   .   ,

.   802.11a/b, 802.15.3a   .

,   ,

(pupil)   ,   ,

.   (   )

(3)   .

LED/LD   ,   ,

(direct detection)

(photo detector)   .

(short dipole antenna)   .

(boresight)

,

LED/LD   (aperture)

.   ,   (horn)

,

.

.

(coverage)

,

.

.

<   >: David H. Sliney, "Laser and LED Eye Hazards,"
    Optics & Photonics News, Sep. 1997.

(3)   (effective

aperture) .

500nm, 1000nm

. 802.11b/a ,

2.4GHz, 5.3GHz .

~18cm² ~4cm²

. .

( ) ~1cm²

. . < 1>

" " [6]

6~12dB .

2.4μW [5]

2.

PD ,

, , .

. < 1>

(AC)

(irradiance) 1Watt ,

35dB [5],[6]. (colored noise) .

10dBm , 120, 240,

55dB 360Hz , 2kHz

. < 1> , 2 8 60dB

. PD

. 8.7 . < 1>

, 5×6m² 16~18

8 36Watt .

2.2m , 60

Watt 1m ( )

.

800nm , (PD)

0.85cm² Si PD

. < 1>

.

.

PD

(shot-noise)

.

<表 1> PD

	PD				(dB)	
	5100μA	1000μA	5.1	35	28
	740μA	190μA	3.9	27	21
	84μA	56μA	1.5	18	16
	40μA	2nA	20	14	1.4

LED/LD

20kHz   , 100

5kHz   ,   LED/LD

50dB   .   (EAM)

.

11~20   ,   4.7~8.9

.   .

,   IM/DD

$p(t)$ RMS $n(t)$

.   (   )

20~40kHz   , $h(t)$.   (   )

$y(t)$ $h(t)$ $p(t)$

1.0MHz   , $n(t)$.

. $p(t)$ Watt   , $n(t)$ Am-

pere, $h(t)$ Ampere/Watt   .

3~4

.   .

.

,   .

$$y(t) = h(t) \otimes p(t) + n(t) \qquad (1)$$

95%   (1)   Y(w)

.   H(w),   PSD P(w),

3.   N(w)   1   . IM/DD

(co-   .

herent)   .

(optical Inten-   ,

sity Modulation: IM)

(Photodiode: PD)   .

(Direct Detection: DD)   ,

. IM/DD   IM/DD

, IM/DD   .   ,

,   ,   ,

, IM/DD

.   ,   4

IM/DD   .

,

.   .

(path loss)

,   10

                    .

                              20

.   DC   H(0)

    PD   .

                              NRZ(Non

Return to Zero)   RZ(Return to Zero)

    "1"   , "0"

              (On-Off Keying: OOK), n

         2n

                    (Pulse Position Modulation:

PPM), n   2n

                                          (Pulse

Interval Modulation: PIM), PIM

          DHPIM(Dual Head PIM),

                    (PSK),   (ASK)

              (Sub-Carrier Modulation: SCM)

((4)   )[7].   ,

    SCM   IM/DD

                              .

                         PPM

        IrDA

              ,   ISI

                    ,

(4)

(Trellis Coded Modulation: TCM)

                                          (Maximal

Likehood Sequence Detection: MLSD)

    [8],[9].   TCM-

PPM   PPM

         6.3dB

         .

    OOK

    (Minimum Mean Squared Error: MMSE)

                                     zero forcing,

MMSE   DFE(Decision Feedback Equalizer)

    50Mbps

                    [10]. OOK   50Mbps

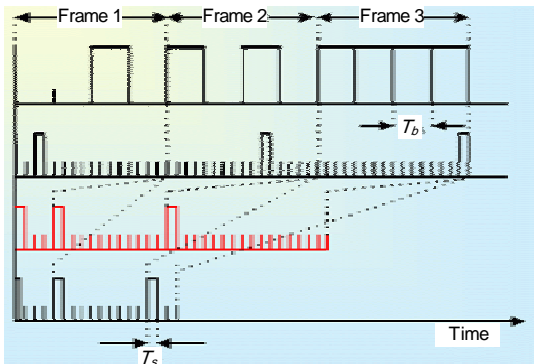   DFE   7dB

                                     ,

    10Mbps   ISI

                              [11].

OOK

         166Mbps

         [12],[13]. OOK

              CDMA

    . PIM   PPM

                                          (

)

(Sheffield Hallam)

         ,

                              [12],[14].

    OFDM   Open

Lab   CATV   SCM

                         ,

                    , CATV

                                          "

              "

    2003

                    .

SCM

LED/LD

,

[15].

(compact)

.

.

4. IrDA

IrDA

. IrDA 850~900nm

,

"Point and Shoot"

. IrDA ,

PDA, , PC

(IrFM/IrMC), (vNamecard),

(vCalendar)

. IrDA

1993 HP, IBM 150

.

2002 UFIR 100

Mbps 500Mbps

UFIR , 2004 6

.

UFIR

,

2005

[16]. UFIR

IrBurst

(peer to peer)

. 2003 12

, 2004 6 [17].

IrDA

IrLAP(Link Access Proto-
col), IrLAP

IrLMP(Link Management Pro-
tocol), IrDA

IAS(Informa-
tion Access Service),

Tiny TP(Transport Protocol),

IrOBEX(Object Ex-
change Protocol),

IR IrCOMM,
802.3 IrLAN

. IrFM, IrBurst, vCalen-
dar, vNamecard

.

.

PHY IrPHY SIR, FIR, VFIR, AIR
115.2kbps, 575kbps~4Mbps,
16Mbps , SIR~VFIR
, AIR ,
[18].

1m,
0.3m .

(FOV) 30 , 15
.

100~500mW , IEC/
ISO class-1

. IrPHY 115.2
kbps 3/16
RZI , 0.576~1.152Mbps
1/4 RZI , 4Mbps 4-PPM ,
16Mbps ,
13 1
RLL(Run-Length Limited) HHH
(1, 13) . PHY
LED , /
. PHY

, CRC   .

CRC   ,

4   "1"   "0"   (DAV- DS1000)   .

,   "DIAT(Digital Infrared Audio Transmission)"

.

SIP(Serial infrared Interaction Pulse)

500ms   1.6μs .   JVC   1.25 Gbps, 1.5Gbps   HDTV   HDTV

[19].   IrDA PHY   2003   2004   CES   .

PHY   JVC   HDTV

.   IrDA

(OBEX, IrMC, IrLAP, LM- MUX, IrLMP- IAS, Tiny TP and IrComm)

IV.

25,000   ,   Clarinet

SKT, KTF   LG   Systems   IrDA   PDA

IrFM   "Patient-

2005   30   Keeper"   . JVC, IBM,

.   2003   Spectrix   1990   1~ 10Mbps

1,800   ,

(ETCS)   (KS)

(IR)   .   .

,

. LG   ## V.

IrDA

.   (K- JIST)   1978

2003   (OKI)   .

. 2002   IrDA

FSO(Free- Space Optics)   , PDA

"FC-   "   .

2km,   155Mbps   . 2003   ,   ,

(KISTI)

Gbps   FSO   .   ,   ,

2002   ,   ,

.   3D   , e- learning, virtual- reality

,

, IP

IT   .   .

,   ,   ,   ,

                                                                    .

                                                          1,000

,   ,   ,

                              .   .   ,

,

                              .

                              .

~ 700THz

                    .

[1] whyfiles.org/173skin_cancer/2.html

[2] www.nepss.org/presentations/ETLlaser.ppt

[3] www.iec.ch

[4] freespaceotic.com/WhitePapers/WP_laser_eye_sa-
     fety.pdf

[5] Adriano J.C. Moreira et al., "Characterisation and
     Modeling of Artificial Light Interference in Optical
     Wireless Communication Systems," *IEEE Wireless
     Networks,* 1995.

[6] J.R. Barry, J.M. Kahn, W.J. Krause, E.A. Lee, and
     D.G. Messerschmitt, "Simulation of Multipath Im-
     pulse Response for Wireless Optical Channels,"
     IEEE J. Select. Areas in Comm, Vol.11, No.3, Apr.
     1993, pp.367-379.

[7] Z. Ghassemlooy, A.R. Hayes and N.L. Seed, "The
     Effect of Multipath Propagation on the Perform-
     ance of DPIM on Diffuse Optical Wireless Commu-
     nications," *Proc. of the IASTED Intern. Conf.
     Wireless and Optical Comm,* June 2001.

[8] M.D. Audeh, J.M. Kahn, and J.R. Barry, "Perform-
     ance of Pulse-position Modulation on Measured
     Non-directed Indoor Infrared Channels," *IEEE
     Trans. Comm,* Vol.44, June 1996.

[9] D.C. Lee, J.M. Kahn, and M.D. Audeh, "Trellis-
     coded Pulse-position Modulation for Indoor Wire-
     less Infrared Communications," *in Proc. 7th IEEE
     Int. Symp. on Personal, Indoor, and Mobile Radio
     Comm,* Taipei, Taiwan, Oct. 1996.

[10] Gene W. Marsh and Joseph M. Kahn, "Performance
     Evaluation of Experimental 50-Mb/s Diffuse Infra-
     red Wireless Link Using On-Off Keying with Deci-

                    .   ,

                                          ,

                              .

(   ) Gbps

                              .

                    .   ,

            ,

                                    .   ,

                              ,

                                    ,   ,

                              ,

sion- Feedback Equalization," *IEEE Tran. of Comm* Vol.44, No.11, Nov. 1996.

[11] M.D. Audeh, J.M. Kahn, and J.R. Barry, "Decision-feedback Equalization of Pulse- position Modulation on Measured Nondirected Indoor Infrared Channels," *IEEE Trans. Communications*, June 1996.

[12] R.J. Dickenson and Z. Ghassemlooy, "Bit Error Rate Performance of 166Mb/s OOK Diffuse Indoor IR Link Employing Wavelets and Neural Networks," http://soe.unn.ac.uk/ocr/publications.html

[13] R.J. Dickenson and Z. Ghassemlooy, "A Feature Extraction and Pattern Recognition Receiver Employing Wavelet Analysis and Aartificial Intelligence for Sgnal Detection in Difuse Pptical Wireless Communications," *IEEE Wireless Communications*, Vol.10, No.2, Apr. 2003.

[14] S. Jivkova and M. Kavehrad, "Holographic Optical Receiver Front End for Wireless Infrared Indoor Communications," *APPLIED OPTICS*, Vol.40, No. 17, June 2001.

[15] Walter Hirt, Martin Hassner, and Nyles Heise, "IrDA-VFIr(16Mb/s): Modulation Code and System Design," *IEEE Personal Communications*, Feb. 2001.

[16] http://www.irda.org/associations/2494/files/Publications/IrBurst_MRD.doc, Sep. 2003.

[17] Stuart Williams, "IrDA: Past, Present and Future," *IEEE Personal Communications*, Feb. 2000.

[18] IrDA, "Infrared Data Association Serial Infrared Physical Layer Specification Version 1.4," May 2001.

[19] http://www.irda.org/associations/2494/files/Publications/UFIR_MRD.doc, Oct. 2002.