Towards Integrated Communication and Ranging system using 1.5um wavelength fiber technology

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Table of Contents

• Why we move to synergy with laser comm. ?
  – Background and requirement
  – Wavelength/Modulation scheme
• How we designing system now.
  – Key elements
• Experiment plan using a pilot satellite
• Summary
Background (1): Global Fiber Network

Submarine Cable MAP 2013

EDFA: Er Doped Fiber Amplifier
WDM: Wavelength division multiplexing

232 cables between continents as of Jan. 2013, and growing, 10G-40Gbps/wavelength, <0.8nm spacing
Background(2): Demanding Space Communication Bandwidth

Communication Rate for Earth Observation Satellite

Downlink is more demanding than that of Uplink

Demanding Comm. Bandwidth
RF system: Matured and Robust against weather, however,
Up to 1Gbps per ch. (e.g. Ka band)
Limitation of Bandwidth
Subject to Radio license regulation

OPTICAL “SPACE” Communication

High bandwidth,
Small, Light weight
No license needed
But,
High Pointing accuracy
Subject to weather

M. Toyoshima, “Trends in satellite communications and the role of optical free-space communications”
Requirement(1) :
Global Optical Site Diversity

J. Degnan, IWLR, SanFernando, Spain, 2004

Synergy of two applications SLR and Comm

Figure 4: Candidate SLR2000C site locations relative to global MCI fiberoptic net.
Requirement(2): Eye safety
Consideration on Wavelength

Science Experiment had been less care about safety will be eventually over,
Consider about hundreds or more application to comm. expanding to infrastructure

2011.2. 10  YouTube
Consideration on Modulation

What is Pulse Position Modulation (PPM) among others

M-ary

PPM

M=4

One pulse per Symbol with High PeakPower ➔ Benefit when lossy channel.

Other Modulation
Consideration on Modulation:
Theoretical Transmission rate v.s. power for various modulation in comparison to PPM at distance of 1AU.

How we are designing(1) -WDM wavelength allocation-

<table>
<thead>
<tr>
<th></th>
<th>Wavelength</th>
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</thead>
<tbody>
<tr>
<td>PPM Comm.</td>
<td>(\lambda_{\text{comm}}=1550.12\text{nm})</td>
</tr>
<tr>
<td>Ranging (Beacon)</td>
<td>(\lambda_{\text{range}}=1558.17\text{nm})</td>
</tr>
<tr>
<td>Ref. Clock (Freq. Standard)</td>
<td>(\lambda_{\text{clock}}=1540.56\text{nm})</td>
</tr>
</tbody>
</table>

Use C-Band EDFA amplifier in which separation of wavelength must care.

To avoid contamination due to Non linear effect between WDM channel.
Block diagram of Whole System

PPM Transmitter and Ranging station

- **PD**
- **WDM Coppler**
- **EDFA Main-AMP**
- **T/R Switch**
- **Space Optics**
- **Telescope Interface**
- **Ranging Laser**
- **Start Disc.**
- **RGG/ET PRN Hz**
- **LNA Disc.**
- **SSPD1**
- **Cryostat1**
- **1.5um Ranging/Beacon**

**PPM Transmitter**
- **UTC-NICT Ref signal**
- **CLK (fo/N)**
- **DATA**
- **To TIA**

**PPM Comm.**

**Online Ranging data**
PPM Parameters:
Slot rate, M,N,T_{interval}

M=16, N=2 PPM Format

1 symbol WORD

M: M-ary PPMのM 1 Symbol=\log_2M \text{ bits}
T_{slot}: Baseslot width (N=1)
N: Natural number to slow effective slot rate by 1/N
T_{interval}: Dead Time for the next PPM symbol
EF_{coding}: Channel Coding Efficiency

Base Slot rate: 10GHz (width:100ps)
PPM Comm. Rate v.s. M
N=1, Tinterval(10ns)
PPM Comm. Rate vs. $T_{\text{interval}}$
\[ (N=1, \ M=16) \]
Experiment Plan: Evaluation of 1.5um Comm.&Range system using targets

Beacon and/or Ranging/Comm Beams

UAV (1-4km)

Optical Ground Station

Fixed station (0.5-4km) *

MicroSat. (600-1000km)
SOTA/VSOTA: TX1,TX4
SOTA TX2/TX3

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SOTA/VSOTA: TX1,TX4
SOTA TX2/TX3
HOST Satellite: RISESAT
Rapid International Scientific Experiment Satellite
One of “HODOYOSHI” Small Satellite Series
Under development by Tohoku University
VSOTA Component look-out

Alignment Cube

VSOTA-COL
(Collimator unit)

1550nm  980nm

Optical Fiber

VSOTA-E (Electric unit)
Summary

• New Optical Comm. Integrated SLR system using PPM is under development.
• The data rate (1Mbps) expansion to ranging engine as well as up to Multi 100Mbps data rate.
• Evaluation in this fiscal year through next FY.
  – Fiber only
  – 10~100m on ground
  – LEO(Ajisai) ranging and comm.
  – Small satellite downlink experiment