RF over Fiber Architectures and EW applications

Military Electronics Show 2003 Booth 105

Ronald L. Fulton Director of Global Marketing and Sales

Fiber-Span Piscataway, NJ

© 2003 Fiber-Span
Topics

- Fiber Optic Technology
- Architectures and Topologies
- Applications
  - Battlefield Operations
  - Airborne/Shipboard Systems
  - Antenna Remoting
  - Satellite Communications (SATCOM)
  - Phased Array and DF Antenna Systems
  - Delay Lines
  - Wireless Technologies and DBS
  - Decoys, Jamming and Countermeasures
- Conclusion
Why Fiber? - Advantages

- Range, bandwidth and RF performance
- Low noise figure, high dynamic range
- No signal egress (security)
- EMI/RFI Immunity (interference)
- Isolation from lightning strikes
- Transports signals in native RF format, complex circuitry at remote location
- Thin cable size, very low cable weight
- High frequency, low signal loss
- Flexible system configurations
Figure 1.

**Laser Transmitter**
- RF Input
- RF Amplifier
- Laser Diode
- Z Match
- DC
- Electrical to Optical Conversion (E-O)
- Single-mode optical fiber

**Optical Receiver**
- RF Output
- Z Match
- Photodiode
- DC
- Optical to Electrical Conversion (O-E)

**RF frequencies:**
- VLF, LF, MF
- HF, VHF, UHF
- Microwave
- Satellite bands:
  - IFL, L/S/C//X/Ku

© 2003 Fiber-Span
RF frequencies:
VLF, LF, MF
HF, VHF, UHF
Microwave
Satellite bands:
IFL, L/S/C/X/Ku

Figure 1.
### Typical Insertion Loss – Coaxial Cable

<table>
<thead>
<tr>
<th>Model No.</th>
<th>912</th>
<th>916</th>
<th>919</th>
<th>930</th>
<th>945</th>
<th>950</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jacketed Outer Diam.</td>
<td>0.126 inches, nominal</td>
<td>0.160 inches, nominal</td>
<td>0.190 inches, nominal</td>
<td>0.305 inches, nominal</td>
<td>0.450 inches, nominal</td>
<td>0.500 inches, nominal</td>
</tr>
<tr>
<td>Max. Attenuation vs. Frequency (GHz)</td>
<td>912 dB/ft</td>
<td>916 dB/ft</td>
<td>919 dB/ft</td>
<td>930 dB/ft</td>
<td>945 dB/ft</td>
<td>950 dB/ft</td>
</tr>
<tr>
<td>0.450 VHF</td>
<td>0.10</td>
<td>0.08</td>
<td>0.05</td>
<td>0.03</td>
<td>0.02</td>
<td>0.02</td>
</tr>
<tr>
<td>0.900 UHF</td>
<td>0.15</td>
<td>0.11</td>
<td>0.07</td>
<td>0.05</td>
<td>0.03</td>
<td>0.03</td>
</tr>
<tr>
<td>1.000 L</td>
<td>0.16</td>
<td>0.12</td>
<td>0.08</td>
<td>0.06</td>
<td>0.04</td>
<td>0.04</td>
</tr>
<tr>
<td>2.000 S</td>
<td>0.23</td>
<td>0.17</td>
<td>0.11</td>
<td>0.08</td>
<td>0.06</td>
<td>0.05</td>
</tr>
<tr>
<td>3.000</td>
<td>0.28</td>
<td>0.21</td>
<td>0.14</td>
<td>0.09</td>
<td>0.07</td>
<td>0.06</td>
</tr>
<tr>
<td>6.000 C</td>
<td>0.41</td>
<td>0.31</td>
<td>0.21</td>
<td>0.14</td>
<td>0.11</td>
<td>0.10</td>
</tr>
<tr>
<td>12.000 Ku</td>
<td>0.60</td>
<td>0.45</td>
<td>0.30</td>
<td>0.21</td>
<td>0.16</td>
<td>0.08</td>
</tr>
<tr>
<td>18.000 Ku</td>
<td>0.75</td>
<td>0.56</td>
<td>0.38</td>
<td>0.27</td>
<td>0.0</td>
<td>0.11</td>
</tr>
</tbody>
</table>

Source: MegaPhase® LLC.
## RF Cable Loss

### LMR® Cable –

<table>
<thead>
<tr>
<th>Dia/Wgt (ft)</th>
<th>30MHz</th>
<th>146MHz</th>
<th>440MHz</th>
<th>2.4GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>.865&quot; / .27 lbs</td>
<td>.29</td>
<td>.65</td>
<td>1.2</td>
<td>2.9</td>
</tr>
<tr>
<td>.59” / .14 lbs</td>
<td>.42</td>
<td>.95</td>
<td>1.7</td>
<td>4.3</td>
</tr>
</tbody>
</table>
dB_o and dB_e

dB_o = dB optical loss

dB_e = dB electrical (RF) loss

Typical Fiber Loss vs. RF Loss – Singlemode Cable

dB_e Loss = dB_o Loss x 2

<table>
<thead>
<tr>
<th>Typical Loss at Wavelength on singlemode fiber</th>
<th>dB_o/m</th>
<th>dB_o/Km</th>
<th>dB_e/Km</th>
</tr>
</thead>
<tbody>
<tr>
<td>1310nm</td>
<td>0.0004</td>
<td>0.4</td>
<td>0.8dB_e</td>
</tr>
<tr>
<td>1550nm</td>
<td>0.00025</td>
<td>0.25</td>
<td>0.5dB_e</td>
</tr>
</tbody>
</table>
RF over FIBER Performance Specifications*

Wavelengths:  
1310nm (1.3µm)  
1550nm (1.5µm)  
ITU grid compliant

Input and Output VSWR:  
1.5:1

Spur Free Dynamic Range: >105 dB/Hz^{2/3}

Link Gain: 0 dB

Output Noise Floor:  
−137 dBm/Hz

Input 3rd Order Intercept (IIP3): 30 dBm

*Typical performance 50-2200MHz
Typical System Block Diagram

Laser Transmitter
- Low Noise Amplifier (LNA)

Optical Receiver
- Post RF Amplifier

RF Input
- DC

Single-mode optical fiber

RF Output
- DC

Temperature Control
- Optical Power Control
- Alarms and Monitoring

Receive Power Monitor
- Alarms and Monitoring

Figure 2.
Architectures
Fiber Optic Distributed Antenna System
Broadcast Architecture

- Low-cost Uplink or Downlink Solution
- Flexible Configurations

Fiber Optic Transmitter

RF interface from Base-Station or off-air

Fiber Optic Receiver

Multiple Fiber Cable 1 x 4 optical splitter

Low-cost Uplink or Downlink Solution

Flexible Configurations

Fiber Optic Receiver

TxRx = Transceiver
1310/1550nm Multi-fiber WDM or single fiber Architecture

RF interface from Base-Station or off-air
Single or multi-fiber D/WDM Star Architecture

WDM Fiber Optic TxRx

WDM Fiber Optic TxRx

WDM Fiber Optic TxRx

DWDM Fiber Optic TxRx

WDM Fiber Optic TxRx

One fiber to each remote unit

TxRx = Transceiver

© 2003 Fiber-Span
Optical Multiplexing/Demultiplexing Trunk Architecture

- ITU Grid DWDM or CWDM configurations

RF inputs/outputs from Base-Stations or Radios

TxRx = Transceiver

© 2003 Fiber-Span
High Dynamic Range Trunking System with DWDM or CWDM

Base-Stations

NODE
A
Fiber Optic Transmitter
B
Fiber Optic Transmitter
C
Fiber Optic Transmitter
D
Fiber Optic Transmitter

Optical MUX I

Optical Amplifier (optional)

Optical MUX II

Optical MUX III

Node A
Fiber Optic Module

Node B
Fiber Optic Module

Node C
Fiber Optic Module

Node n...
Fiber Optic Module
Trunk System using Broadcast Techniques

RF Interface or Base-Stations A

Remote B
Fiber Optic TxRx

Remote C
Fiber Optic TxRx

Remote D
Fiber Optic TxRx

Remote G
Fiber Optic TxRx

Remote F
Fiber Optic TxRx

Remote E
Fiber Optic TxRx

TxRx = Transceiver
Applications
Battlefield Operations and Airborne/Shipboard

GPS, Radar and Comms

C4I

SIGINT / COMINT

microwave

COMSEC

JTRS-JTIDS

Tracking-Telemetry

ECM

© 2003 Fiber-Span
Remote Antenna or TVRO Application

Distance/Functionality

< 1Km

Remote Antenna Site

Fiber Optic TxRx

Transmit and/or Receive Site

Fiber Optic TxRx

Performance/Features

TtxRx = Transceiver or Transmitter-Receiver link

> 65 Km

© 2003 Fiber-Span
SATCOM Links

Transmission Room

Remote Antenna Site

Optional Monitoring and Control (M&C) Link

Upconverter and/or HPA

Uplink

Tx - LHCP

Tx - RHCP

Downlink

Rx - LHCP

Rx - RHCP

Downconverter and/or LNA/LNB
Phased Array and DF Antenna Systems
Delay Lines
10MHz to >18GHz

- Programmable configurations
- Cellular, PCS, CDMA, GSM and 802.11a/b/g (WiFi)
Direct Broadcast Satellite (DBS) - Distributed

Weatherproof DBS optical transmitter solution with:
- AC or DC powering
- DC powering of the LNB
- Up to 4 optical outputs
- Optional LNA
- 10 to 20dB Optical Budget
Decoys, Jamming and Countermeasures

Fiber Optic Towed Decoy

Electronic Countermeasures (ECM)

Jamming or Deception

- Ground-based
- Airborne

Courtesy of BAE Systems
Decoys, Jamming and Countermeasures

**Figure 1.** Self Protection and Escort Jamming

**Figure 2.** Support Jamming
RF over FIBER Systems Today and Tomorrow

• What’s Emerging?
  – E-O/O-E Phased arrayed systems
  – Dynamic re-configurable Add/Drop networks
  – Wavelength routing for SDR systems
  – Hybrid Integration and Tunability
  – Implementation with existing digital fiber-based networks
Mixed Signals Architecture

PARTIAL LAYOUT OF MULTI-BAND ADD/DROP ARCHITECTURE
Dynamic Routing

RF ON FIBER® Applications Diagram
Wavelength Routing

RF Signal 1

RF to Fiber Transmitter 1310 nm

RF Signal 2

CW Laser Source 1550 nm tunable

Wavelength Converter

Coupler or switch

Optical Spectrum Analyzer

Fiber to RF Receiver 1.3 and 1.5um

RF Signal Output
Conclusions
- Large base of systems deployed
- Strong potential for further integration of photonics in RF systems
- Module through Subsystem designs, intelligent system-level product
- Scalable deployment capability
- No Cost disparity: fiber vs. coax
Thanks for your attention!
Ronald L. Fulton
Director of Marketing and Sales
Phone: 1.732.564.9000 x203
www.fiber-span.com
email: rfulton@fiber-span.com