Distributed Antenna Systems using RF over Fiber Technology

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ABSTRACT

The expected increase in space and terrestrial services that include two-way fixed, SATCOM, CATV and mobile wireless services require expanding the system capacity. This expansion has created an opportunity for the utilization of the demonstrated photonic transport systems in wireless networks. System demonstrations and architectural developments have been proposed for distribution of communication services over fiber. Termed Fiber Radio and Distributed Antenna Systems (DAS), these systems offer the potential to improve services and reduce base station costs through increased bandwidth and ease of installation.

We have developed and demonstrated DWDM broadband photonic transport systems able to meet the requirements for IS-95 Personal Communications Services operating at 1.9 GHz and Broadband Wireless Internet operating over the band of 2.5 to 2.7 GHz. Each DWDM channel operates from 1 to 3 GHz transporting services up to 80 Km [1].

Solutions are being sought for low cost transmitters to meet DWDM SATCOM system requirements include extending the transmission distance to over 100 Km with a bandwidth that exceeds multiple octaves. These new requirements put high performance demands on the optical components. We have developed high performance transmitters based on electro-absorption modulated lasers (EML) that can meet SATCOM requirements. We have shown that the EML is capable of providing the required CNR of 32 dB for satellite transmission in the band of 950 to 2150 MHz over a 100 Km distance.

1. INTRODUCTION

Fiber optic transmission of digital data for long haul and metro access is widely used in the telecommunications industry. As new services are being developed and offered, such as PCS, Broadband Wireless Internet, Digital Video, and Passive Optical Networks, new opportunities for analog fiber optic distribution are emerging including commercial and military applications that take advantage of DWDM. The question exists whether optical components are capable of meeting the stringent demands of the new analog distribution systems since most optical components have been designed specifically for digital applications; and, with the exception of CATV, there has been limited component development for analog high frequency RF and microwave systems. However, this is changing as more attention is being given to analog requirements and new optical transmitter, photoreceiver and passive optical component technologies are being developed. Additionally, new military applications are on the horizon that will take advantage of DWDM systems. We will demonstrate that analog fiber optic systems using DWDM components are now capable of meeting current and future applications for new services. These demonstrations include distribution of PCS, wireless internet and satellite signals that operate up to 3 GHz.

2. PHOTONIC TRANSPORT FOR BROADBAND WIRELESS ACCESS AND PERSONAL COMMUNICATIONS SERVICES

The expected high demand of two-way fixed and mobile wireless services, the consequent need for expanding the system capacity, and the urgency of reducing the costs, have created an opportunity for the utilization of the proposed photonic transport in wired and wireless networks. System demonstrations

(2,3,4) and architectural developments (5) have been proposed for distribution of communication services over fiber. Termed Fiber Radio and Hybrid Fiber Wireless, these systems offer the potential to improve services and reduce base station costs through increased bandwidth and ease of installation. We have developed and demonstrated a DWDM broadband photonic transport able to meet the requirements for both IS-95 Personal Communications Services (PCS) operating at 1.9 GHz and Broadband Wireless Access operating over the Multi-channel Multipoint Distribution System (MMDS) band of 2.5 to 2.7 GHz.

2.1 System Architecture

The architecture selected is based on adding /dropping of the requested wavelength to the cell site or base station as shown in Fig. 1. The Headend (a) consists of four laser transmitter modules, each operating on different ITU grid channels spaced 200 GHz, and 4 photoreceiver modules for the return traffic. The operating frequencies of the module are 1 GHz to 3 GHz. In the forward direction, these channels are multiplexed together and amplified with an optical amplifier. At the cell site, the desired wavelengths are dropped, detected, amplified and radiated. For this demonstration the same wavelength that is dropped at the cell is added back. The received signal from the antenna is amplified and used to modulate a laser transmitter module that returns the signal to the Headend.

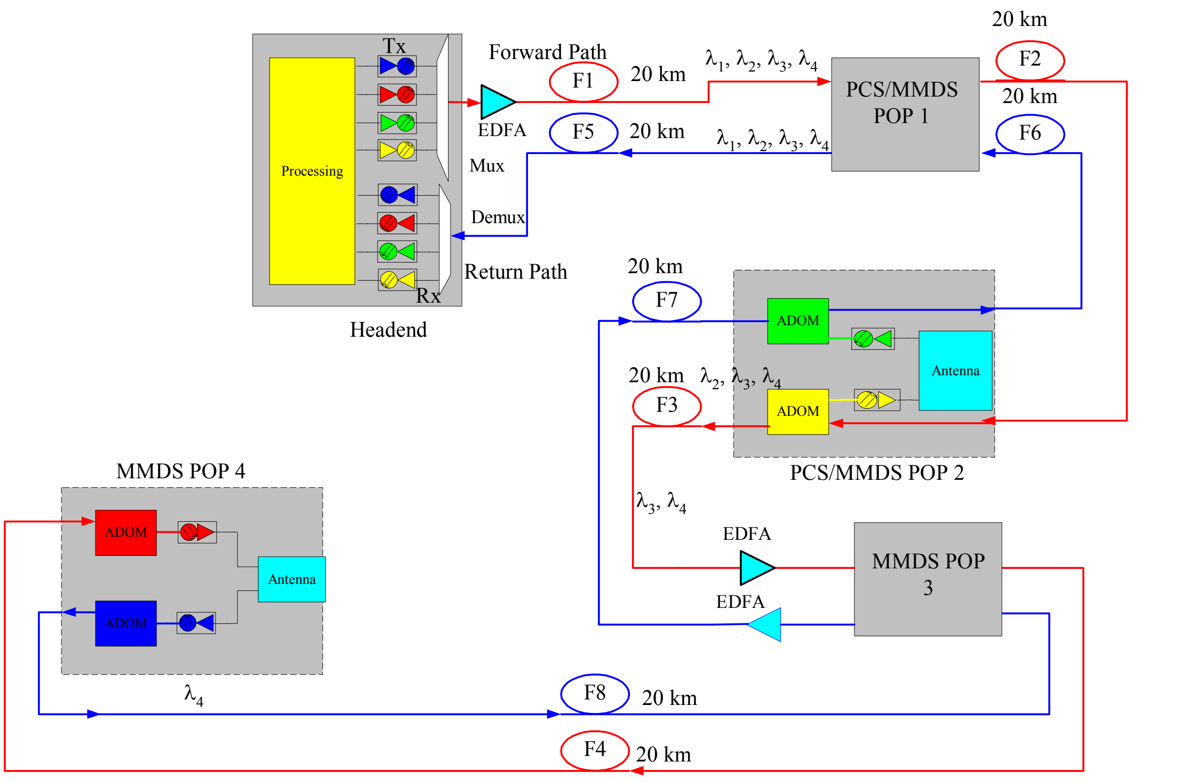

Fig. 1. Fiber optic transmission of multi-services over a DWDM Network. The headend carries the services on RF signals over fiber to cell sites. At the cell site a wavelength is dropped depending on which service is required. Return data is added back to the network.

The photonic transport system developed for this application was tested carrying simultaneous CDMA data for PCS at 1.9 GHz and 64 QAM for the BWA in the MMDS band from 2.5 to 2.7 GHz. The requirement of the photonic transport system is that it does not impact the performance of the PCS and BWA systems under simultaneous transmission.

2.2 Test Results

The experimental results for the 40 km fiber optic link were obtained by simultaneously transmitting PCS and BWA traffic. This traffic included eleven 1.3 MHz channels of PCS loading and one 64 QAM (5 MHz) channel, with the remaining channels stimulated by noise to fully load the 200 MHz spectrum.

The photonic transport consists of laser transmitters, photoreceivers, optical amplifiers, and passive optics to perform multiplexing, de-multiplexing and add/drop functions. The passive optics selected has high isolation and high adjacent channel rejection to limit the impact of cross-talk which has been shown to reduce performance.

The laser transmitter consists of a directly modulated laser with a maximum modulation frequency of approximately 6 GHz operating on an ITU channel. The transmitter is designed for operation over the 1 to 3 GHz frequency range. Supporting transmitter circuitry includes amplification to set the proper optical modulation index (OMI) for optimum performance and channel loading. Standard channel loading for

Test	Required	Measured
Code domain power	27 dBc	>27 dBc
Quality factor	0.91	0.96
SNR	27 dB	35 dB

Table 1. Summary of single channel CDMA specifications and measured results over a 40 Km fiber optic link.

laser transport requires maximizing the signal to noise performance while operating below the limit imposed by the laser due to its clipping effects. Directly modulated lasers begin to generate unacceptable levels of clipping distortion at approximately 25-27% total RMS OMI. For this demonstration, the channel loading consisted of 200 MHz of noise, one 5 MHz 64 QAM signal, and 15 MHz of PCS CDMA channels. While the cresting factors of the two channel types (PCS and BWA) are different, the fact that the PCS signals occupied such a small percentage of the total bandwidth, as well as fact that both had similar S/N targets, a power/per Hertz loading arrangement was used and an OMI of 25 % was implemented for an 8 dBm laser transmitter. The spurious free dynamic range is 108 dB $*Hz^{2/3}$.

To qualify the link for a single PCS channel, the following parameters were measured: code domain power ratio, waveform quality factor, and SNR. For these measurements a signal generator was used to generate an IS-95 CDMA signal capable of producing the pilot channel, code channel, and associated timing and synchronization signals. Table 1 summarizes the results which indicate that the use of a photonic transport system does not adversely impact the system performance. Figure 2 shows that the adjacent power requirement is met for the multi-channel CDMA system indicating again that the fiber optic transport is not adversely impacting system performance.

The BWA is based on multiple 64 QAM digital channels occupying the 2.5 to 2.7 GHz frequency band. To simulate a fully loaded system, a 5 MHz QAM channel in combination with noise was utilized. A QAM signal was generated and up-converted to an IF frequency of 705 MHz. It was then combined with a 600 to 800 MHz wide noise signal which had been filtered to provide a notch at the QAM channel frequency. The combined signals were then up-converted to the BWA band to simulate a fully loaded spectrum.

Once combined with the PCS it was transmitted over one of the fiber optic links. At the photoreceiver module the signals were detected and demodulated. Clock and data outputs from the demodulator were then fed to a Digital Analyzer, where bit error rate (BER) was measured. Fig. 3 shows the resulting BER of 10^{-6} which meets the requirements.

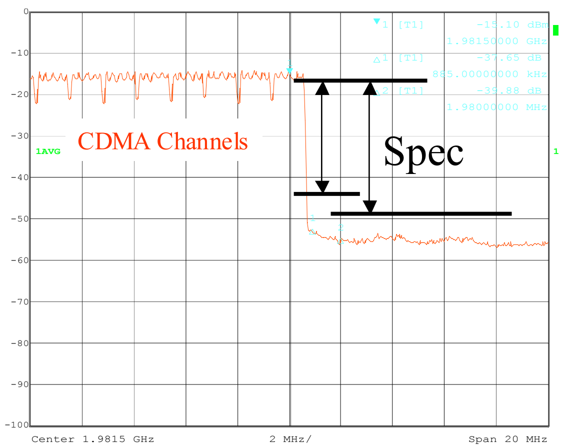

Figure 2. The power spectrum of the multi-channel CDMA transmission. The adjacent channel power specifications at 885 KHz and 1.98 MHz are exceeded 10 dB and 5 dB respectively

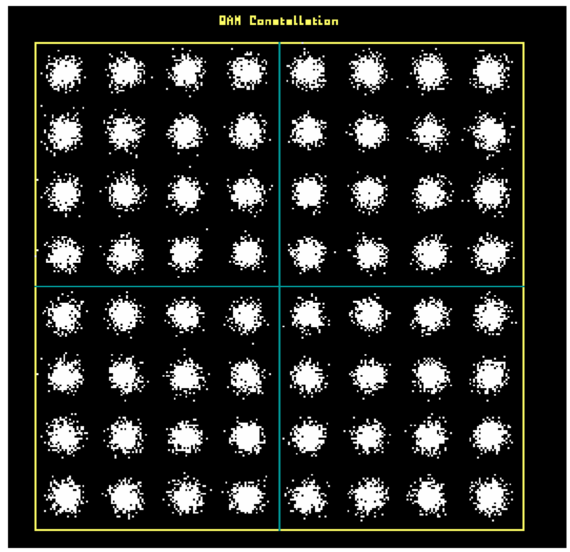

Figure 3. Constellation diagram of a 64 QAM signal through an 80 Km fiber optic link. The associated BER was 10^{-6} meeting the requirements.

3.0 Conclusions

Transporting PCS and BWA over a DWDM photonic transport system, as shown in Fig. 4., can meet system performance over the 40 km requirement. Both the PCS and BWA can be transported over longer distances, however the PCS is limited by system timing requirements. Transporting these services over fiber at the native frequencies will provide both BWA and PCS networks operators with benefits such as incremental increase in coverage; increased capacity by extensively re-using assigned spectrum; and centralization of expensive transmission and control equipment, making the deployment of the above services quicker and less expensive.

Figure 4. DWDM system hardware for PCS and BWA distribution that can be used in DAS

REFERENCES

1. Arthur Paolella, William Jemison, Javier Borlando, Jun Wang, "Dense Wavelength Division Multiplexing Photonic Transport for Radio Frequency and Microwave Wireless Services" SPIE, Philadelphia 2004.

2. W. D. Jemison, P. R. Herczfeld, A. Paolella, A. Vieira, A. Rosen, A. Joshi, Hybrid Fiber Wireless, *IEEE Microwave Magazine*, June 2000.

3. H. Ogawa, D. Polifiko, and S. Banba, *IEEE Trans. Microwave Theory* Tech., vol. 40 pp. 2285-2292, 1992.

4. Y. Ito, et. al., *Microwave Photonics 2000*, 11-13 September 2000, Oxford, England, pp. 35-38.

5. Y. Lin, W. I. Way, *IEEE Photonics Lett*., Vol. 11, No. 6, June 1999, pp736-738.