Fiber Optics Enhance Wireless Broadband System Deployment

Wireless broadband systems are a perfect solution to today's multimedia network requirements. Broadband channels provide multiple video channel delivery, high speed Internet access, and voice and computer network extensions, including multichannel multipoint distribution systems (MMDS) and local multipoint distribution or communication systems (LMDS/LMCS). These new systems provide most of the properties and performance needed for today's expanding information transfers.

"One solution to [the] RF headache can be found in a product technology that has grown to be a mainstay in telephony and community antenna television (CATV) communication networks — fiber optics."

Few problems exist with the basic technology — except at the installation site. One of the complexities involved in installing such high frequency systems is the location of the equipment since it impacts high frequency signal distribution. MMDS operates at 2.1 to 2.5 GHz; LMDS/LMCS operates at intermediate frequencies of 100 MHz to 2.5 GHz (depending on the design). With such high frequencies, RF loss through the coaxial cable is a potentially big problem. High RF cable losses, signal egress and interference hamper system configuration and affect equipment location choices.

One solution to this RF headache can be found in a product technology that has grown to be a mainstay in telephony and community antenna television (CATV) communication networks — fiber optics. Fiber is used exclusively in telecommunications systems for long-haul transmission and is working its way into local loop applications. CATV now uses fiber optics for super-trunk and distribution networks. Telecommunications uses digital fiber systems, while CATV operators use analog fiber-optic systems. Both technologies take advantage of fiber's low signal loss characteristics and enhanced system reliability.

Just as telecommunications and CATV have capitalized on the inherent positive characteristics of fiber optics, so can broadband wireless systems. In addition, while wireless fiber-optic subsystems are more closely related to the CATV implementation (in that they use direct analog modulation), these new module designs incorporate the particular features demanded by wireless broadband systems: high frequency bandwidth (up to 2.5 GHz); a highly linear, third-order response; easy integration into wireless designs; a wide operating temperature range; and compact packaging.

One of the issues of MMDS and LMDS system implementation is where to place the RF modulation equipment. One approach is to place the modulators near the antennas. This configuration is good in theory but, in practice, issues of maintenance and reliability exist. The antennas may be located on a roof or, quite often, on top of a tower; not an easy place to be for long-term reliability or access due to the harsh environment encountered.

The general philosophy of deploying such RF-intensive broadband antenna systems

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▲ *Fig. 1 DC-powered fiber-optic transmit and receive modules.*

Fig. 2 FC/APC and SC/APC fiber-optic connectors. ▼

must involve placing little equipment at the antenna (outdoors where nature and the elements can abuse it or where maintenance people must struggle to reach it). However, this configuration entails transporting the RF signal over a distance and, in some cases, thousands of feet or even kilometers.

FIBER-OPTIC TECHNOLOGY

A basic RF/fiber-optic subsystem comprises a fiber-optic transmitter, fiber-optic cable and connectors, and a fiber-optic receiver.

The Fiber-optic Transmitter

The fiber-optic transmitter has a 50 Ω RF input port (SMA-type connector, for example) and a fiber-optic output port. It functions as an RF-to-fiber converter, as shown in ***Figure 1***. A semiconductor laser diode is used as the optical source in the conversion. This laser has very high frequency response and is highly linear. Broadband matching circuitry is used to interface the RF system's 50 Ω impedance to the laser diode's 5 Ω impedance. Direct modulation is used as the conversion process, that is, the input signal level directly modulates the laser's drive current. Therefore, the transmitter's optical output intensity is directly proportional to the voltage input.

This modulation technique is also referred to as intensity modulation. The most common lasers used have an optical output at a wavelength of 1310 nm using proven laser technology developed for telecommunications and CATV. The wavelength of these lasers is beyond human eye capability, thus the light is invisible. (Human eyes can detect from 400 (blue) to 750 nm (red).) The 1310 nm wavelength is selected to match the wavelength of minimum loss in optical fiber.

The transmitter incorporates the laser diode in a control circuit, which maintains the proper operating condition for the laser — actively compensating its performance characteristics over a wide operating temperature range. A bias supply circuit sets the operating point of the laser. The transmitter uses an internal optical detector to monitor the optical output of the laser and constantly and instantaneously adjust the bias point. These adjustments are made to assure optimal linearity and maximum lifetime of the transmitter. For instance, as the ambient temperature increases, the laser's efficiency drops. If a fixed bias drive was used, the optical operating point would be set too low at elevated temperatures and the transmitter's linearity would degrade. The more advanced automatic optical feedback circuit recognizes the drop in efficiency, increases the bias operating current and assures the transmitter is operating in its optimal linear region.

Fiber Cable and Connectors

The fiber-optic cable of choice is single-mode fiber. Single mode is the same fiber used in high performance telecommunications systems and CATV networks. Only single-mode fiber has the high bandwidth so often touted when fiber optics are discussed. In contrast, multimode fiber is typically used in low speed digital local area networks. It has neither the bandwidth nor the low signal loss characteristics of single-mode fiber. Single-mode fiber provides a waveguide of 9 μm (dia) that contains the optical light injected into it by the laser transmitter and allows for transmission at extremely low loss for long distances. The typical RF loss of fiber cable is 1 dB/km compared with the 80+ dB/km for coaxial cable.

The most common fiber connectors are FC/APC or SC/APC, as shown in ***Figure 2***. The FC and SC designations refer to the basic design of the connector (similar to SMA and N types). FC is a screw-on connector while SC is a push-and-click design. Both designs provide a means to mate two 9 μm cores of fiber with low loss and high stability over time and temperature. The APC suffix refers to an angle-polished connector. The tip of the connector is polished at an 8° angle, the optimal angle that reduces optical reflections at the connector interface back into the laser transmitter to below –60 dB. Optical reflections returned to the laser diode cause disturbances in the lasing region of the semiconductor chip, which manifest themselves as an increase in the noise floor and increased distortion.

The Fiber-optic Receiver

The fiber-optic receiver performs the reverse function to the transmitter: It accepts an optical input and reconverts it back to an RF signal. A high linearity, low noise photodetector is used to detect the optical signal and convert it into an RF signal. Matching circuitry and RF gain stages boost the signal to the desired levels.

Both the transmitter and receiver provide monitors and alarms for enhanced system features. The transmitter has a laser monitor that confirms proper operating conditions for the laser diode. If an internal set point is exceeded, a visible light-emitting diode is toggled on the module itself. In addition, an open collector output is switched for remote monitoring. Some transmitters have an internal thermo-electric cooler/heater (Peltier type), which maintains the temperature of the laser chip constant. This temperature control guarantees consistent linear performance over a wide operating temperature range. Alarms are provided to assure that the temperature is in the desired range. The receiver provides a received optical monitor, a convenient way to confirm that the proper amount of light is reaching the optical detector.

SYSTEM PERFORMANCE

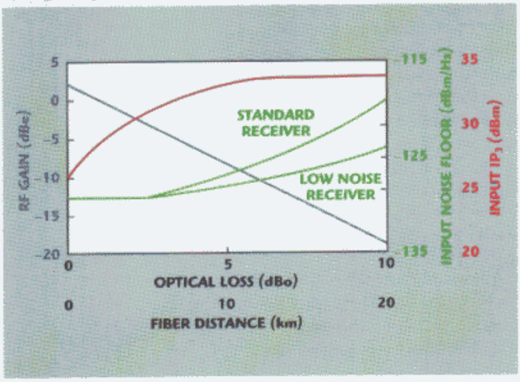
The main goal of an RF/fiber-optic link is to be as transparent as possible in the network. For instance, the typical fiber-optic link is designed such that the RF-to-RF gain (RF input at the transmitter to RF output at the receiver) is 0 dB for short-distance links. (Short in fiber speak means less than a

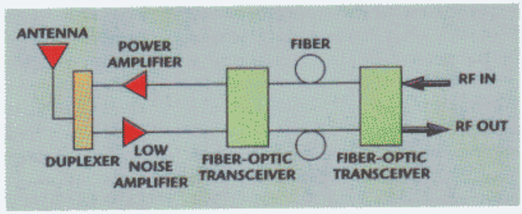
TABLE I

RF/FIBER-OPTIC LINK SPECIFICATIONS

Frequency (MHz)	100 to 2500
RF gain (dB) (typ)	0
Input IP3 (dBm)	+30
Input noise floor (dBm)	-130
Operating temperature range (°C)	-20 to +65

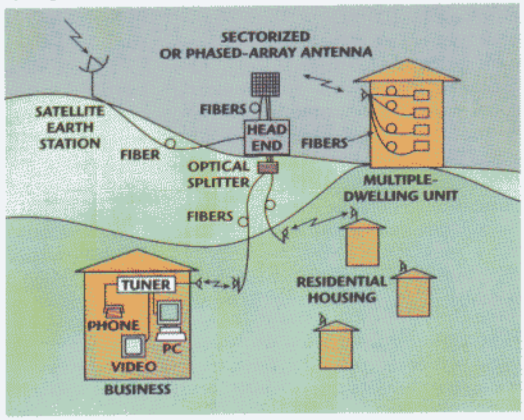
▼ *Fig. 3 A fiber-optic link's performance vs. fiber distance.*





▲ *Fig. 4 A basic antenna and bidirectional fiber-optic transceiver system.*

▼ *Fig. 5 A broadband fiber and wireless system.*



kilometer.) Therefore, whatever is input to the transmitter will be delivered out of the receiver. This mode of operation makes system implementation very convenient.

More important than the unity gain performance, noise and linearity also impact transparency. ***Table 1*** shows the performance of a typical fiber-optic transceiver. An RF/fiber-optic link can be modeled as an RF gain stage. It has RF gain, input noise and linearity as defined by a third-order intercept point (IP3). ***Figure 3*** shows how these three RF parameters of a fiber-optic link change with fiber distance. Once these specifications are known, conventional RF design techniques are used to configure a broadband wireless fiber-optic system.

SYSTEM CONFIGURATION

Figure 4 shows the basic setup of a bidirectional RF/fiber-optic system. In a single antenna system, a duplexer is used to filter the upstreams (U/S) and downstreams (D/S). The U/S path utilizes a low noise amplifier, which drives the laser transmitter; the D/S requires a high power amplifier, which drives the antenna. These added components are selected as usual to set the noise figure of the receiver (U/S) and for the required transmitted signal power level (D/S). If dual transmit and receive antennas are used, the duplexer is omitted.

The main point that is often missed when considering fiber optics is that fiber does not transmit power, it can only transmit the signal. The required power level must be re-established at the antenna by power amplifiers. Remember, the fiber-optic link will output the same RF level that was input at the headend. This level will only be significantly impacted by optical splitters used in the fiber path or very long fiber transmission distances. Additional gain in the fiber-optic receiver can compensate for the loss.

A good point to make at this time is that RF/fiber-optic subsystems operate independent of the baseband modulation format. Whether analog FM or a variety of digital formats is used (such as quadrature phase-shift keying, 64-quadrature amplitude modulation (QAM) or 256-QAM), the fiber link can handle any scenario because it directly transmits the RF carrier. There is no RF manipulation of the signal or RF conversion of any kind that would impact the baseband modulation. Therefore, if several different modulation techniques are employed — or as the system evolves and improved modulation techniques are incorporated — the same basic link can be used.

Once fiber is incorporated into the wireless system, a slew of options (not available previously) may be considered. These options include ground station remoting and electromagnetic interference isolation, fiber feeding a sectorized or cellularized antenna system, fiber remote antennas for RF fill-in, optical signal splitting for driving multiple antennas or feeding a single headend from multiple antennas, and in-building distributed antennas. As a tool to present all the potential system configurations possible in a broadband fiber-based system, ***Figure 5*** shows a multipoint distribution system that incorporates fiber optics in a number of techniques.

CAPACITY

Fiber optics play a big role in capacity extension. Sectorization and cellularization are two common techniques used in extending capacity. Sectorization is the technique whereby the central antenna transmitter is divided into several narrow beams for RF channel re-use. The same RF channel can be used in nonadjacent antenna sectors. These antennas may have 6, 12, 18 or more sectors. In a conventional system configuration, the modem for each sector is integrated into the hub housing. This configuration makes for an unwieldy, overheated and crammed hub. The more elegant approach is to use a fiber transceiver at the hub to remote each sector and locate the modems at the headend where access is more convenient. The fiber transceiver can be made small, which minimizes RF signal blockage at the antenna.

Cellularization, as the name implies, is the technique whereby multiple antenna hubs are located throughout a geographical area. Capacity is increased by re-using RF channels in nonadjacent cells. Fiber-optic transceivers help by allowing the system provider to centrally locate the base station and fiber feed the antenna farm from one site. This configuration saves on climate-controlled rent space and makes maintenance and system upgrades a snap.

CONCLUSION

RF/fiber-optic transmission offers many advantages in broadband wireless systems. RF/fiber-optic subsystems have proven their field reliability in high end communication systems such as telecommunications and CATV. RF/fiber-optic transmission has low RF loss for remoting modulation equipment from the antenna, and is independent of a modulation format for carefree integration. The fiber-optic modules are compact and offer a conventional RF interface. Fiber transmission is inherently immune to RF interference. Fiber-optic transceivers designed for wireless applications deliver bandwidth and RF performance such that they can provide transparent operation in existing or new system installations. Fiber may not replace more conventional transmission means such as copper coax, but in a growing number of applications and system installations when factors such as future system upgrades and system maintenance are considered, fiber is the most practical and efficient way to transport broadband wireless signals. ■

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