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SELECTION OF FIBEROPTIC COMPONENTS FOR RF COMMUNICATION

Part I

by Todd Olson.

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APPLICATIONS OF RF FIBER OPTICS

Since the late 1980's linear lasers and photodiodes have been used in a wide variety of RF applications. For Cable TV, Hybrid Fiber Coax (HFC) networks transmit broadband information from head-ends to neighborhood nodes and complement this with a lower bandwidth return path from the customers. Satellite antenna users transport IF, L, S, C, X & Ku-band signals hundreds of meters to tens of kilometers. Wireless networks send and receive the original GSM, CDMA and analog RF carriers to hard-to-reach areas like tunnels, subways and the insides of buildings. And most recently, Fiber To The Premise (FTTP) Passive Optical Networks (PON) have begun bringing RF video channels directly to customers homes without any intermediate copper or active components.

For all of these applications, because the signals remain in their original RF format, network design, installation and maintenance are much less complicated and less expensive than could be achieved with other approaches. Of course, the RF laser transmitters, photodiode receivers and other optical components found in these systems require unique attributes for each use. This article describes some of the primary issues and choices with respect to these devices for RF over fiber applications.

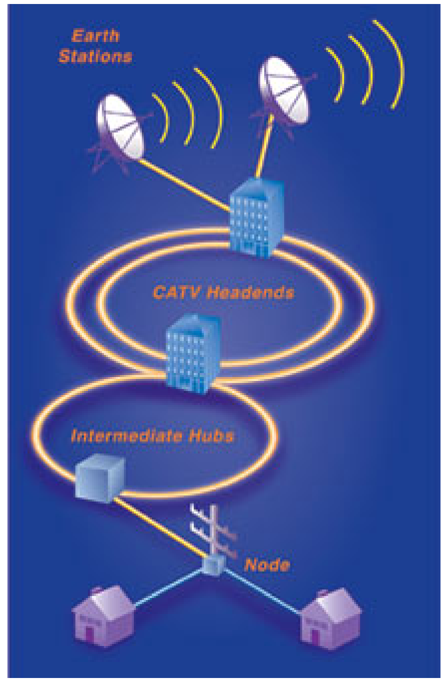

Figure 1: *RF fiber links transmit video all the way from the satellite antenna to the node.*

TRANSMITTER TYPES

As the start of the signal path, the laser type used in the optical transmitter represents the most significant choice when designing any RF fiber transmission system. The first laser that gained widespread use in digital fiber optics was the Fabry-Perot (FP) laser due to its low cost and simplicity. For RF signal transmission FP lasers provide moderate noise and linearity performance, therefore are found only in the less demanding applications such as some cases of CATV return path, satellite antenna remoting and wireless networks.

A more preferred choice of RF laser, even for the less demanding applications, is the Distributed Feedback (DFB) laser. DFBs produce light in only a single, narrow optical wavelength as compared with an FP, which lases in many wavelengths at once. This single wavelength of a DFB is very stable even for different drive currents, while an FP's output will jump around between these different wavelengths when it is modulated. Sending the light from an FP down an optical fiber magnifies the effect of this jumping around still further because each wavelength travels at slightly different speeds (by a process called dispersion) and smear together in a way that degrades the noise, distortion and RF gain, as shown in figure 3. In contrast, DFB lasers exhibit a much more linear and lower noise behavior, which is why they are used more than any other laser type in RF communications.

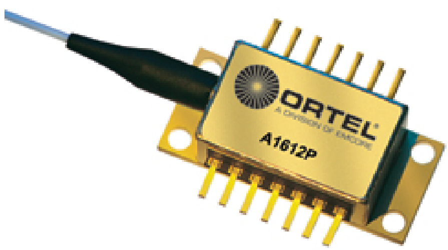

Figure 2: *Typical cooled, isolated DFB laser.*

DFB lasers also can be modulated in two distinct ways – directly and externally. In the more common directly modulated case, the RF signal being transmitted varies an electrical current into the laser thus resulting in an optical signal that varies just like the original RF one. In comparison, externally modulated transmitters drive the DFB at a constant current and then send the resulting CW light to a modulator that varies the optical power in proportion to the RF signal. While these "ex mod" transmitters are necessarily more complex than a direct mod one, because an ex mod laser remains at a constant level it's optical wavelength also remains more stable which further reduces the effects of fiber dispersion.

These ex mod transmitters are used in the more difficult applications covering extremely long distances or splitting to many different receivers. Various names are used for these transmitters, such as Lithium Niobate, LnBO3, and Mach-Zender, all of which describe the optical modulator.

Finally, several other types of optical transmitters have been explored for RF links, such as Vertical

Cavity Surface Emitting Lasers (VCSEL), Electo-absorption Externally Modulated Lasers (EML), and External Cavity Lasers (ECL). Each of these has unique properties that make them potentially lower cost or higher performance for certain classes of RF links. While VCSEL and EML transmitters have been used extensively in digital communication, as of yet VCSEL, EML and ECL lasers have not yet been deployed widely for RF over fiber applications.

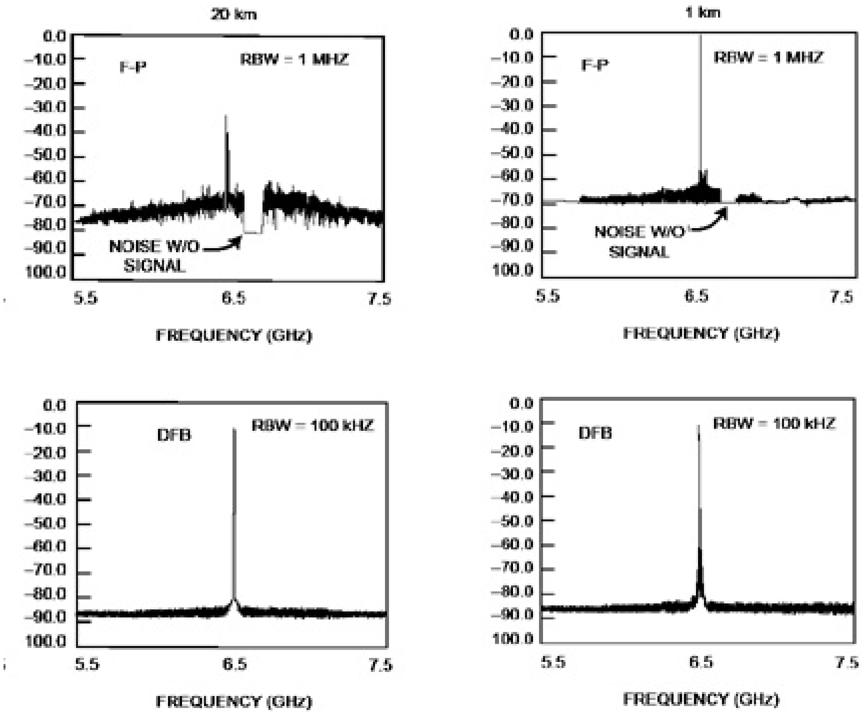

Figure 3: DFB lasers avoid the excess noise generated by FPs down long fibers.

OTHER TRANSMITTER ISSUES

While the basic choice of laser type plays the most obvious role in transmitter choice, several other transmitter features can contribute significantly to performance and cost, most notably optical isolators, laser coolers, pre-distorters, and wavelength.

The simplest of these, the optical isolator, is a small set of optical elements integrated into the laser component package that prevents light from reflecting back into the laser. This reflected light can degrade the link's noise and distortion. Lasers with isolators can be found in many satellite, wireless and CATV return path links and virtually all forward path CATV transmitters.

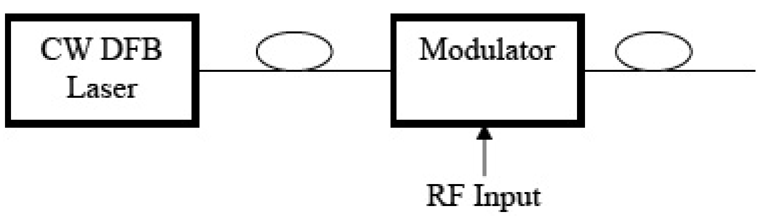

Figure 4: Externally Modulated Transmitter.

Similarly, "Peltier" or thermoelectric coolers (TEC) are employed in many satellite, wireless and CATV return path links and virtually all forward path CATV transmitters. In the majority of cases, these TECs are integrated into the laser package in order to keep the chip at a constant temperature. Not only does this constant temperature stabilize the distortion, gain and noise performance, it also improves the life of the laser. Of course few things come for free, which holds true for TECs as well. These coolers require extra control circuitry and as much as several watts of electrical power to operate.

Yet another way to improve performance is with predistortion circuitry. Such circuits compensate for non-idealities in the RF behavior of both directly and externally modulated transmitters. Usually they must be tuned in manufacturing to the unique characteristics of each laser or modulator, therefore add cost and complexity to the design. However, the distortion improvement that predistorters provide makes them very popular in HFC and PON transmitters.

The final transmitter feature, wavelength, affects overall system performance in a number of ways. RF links work best in single-mode fiber, which almost exclusively is used for RF applications. (The alternate multi-mode fiber used in many digital applications creates too much noise, distortion and instability.) Standard single-mode fibers operate well at the two infrared wavelengths 1310 nm and 1550 nm. At medium to short distances 1310 nm systems provide good noise and distortion with less complexity than 1550 nm ones because the dispersion of fiber is nearly zero at 1310 nm.

In contrast, 1550 nm lasers are preferred at long distances or when the optical power is split to many different fibers. Due to some subtleties of their physics, Erbium Doped Fiber Amplifiers (EDFA) work well at 1550 nm and extremely poorly at 1310 nm, resulting in 1550 nm being the only practical option when amplification is desired. Additionally, light at 1550 nm can go about 40-50% farther in fiber than can 1310 nm for the same amount of loss, which further improves the advantage of 1550 nm for long-distance applications.

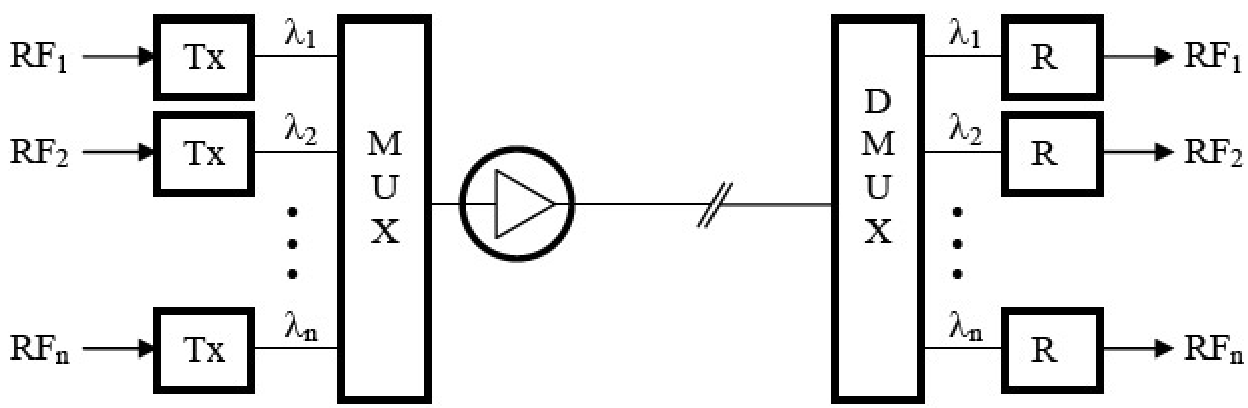

Figure 5: *Figure 5 : Typical Dense Wavelength Division Multiplexed System*

1550 nm also is popular for Dense Wavelength Division Multiplex (DWDM) systems in which the optical wavelength of the lasers is designed to fall on a discrete grid of values defined by the International Telecommunication Union (ITU). In these DWDM systems, 4, 8, 16 or more laser outputs can be combined into a single fiber, amplified with a single EDFA, and then at some distance away split into their individual wavelengths again thus saving significantly on amplifier and fiber costs and complexity. To take advantage of the benefits of 1550 nm, such 1550 nm systems typically accommodate the high dispersion of the fiber by using one or more of the following options – short fiber distance, low RF channel count, low chirp (narrow optical linewidth) transmitter such as an external modulator style, or extra fiber of opposite but equal magnitude dispersion. ■

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