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REVISION HISTORY

REVISION	DESCRIPTION	DATE
1.0	Original Version	June 99
1.1	Sections on design parameters, and design examples added	Aug 99
1.2	Changed Insertion Loss parameter on 7705MS to 9 dB	Jan 00
1.3	Changed Input power, and sensitivity values in Table 2 Changed part number of 7705EO15-HD-I to conform to new naming convention	July 00
1.4	Updated Input power, and sensitivity values in Table 2 Added CWDM and DS-4 and DS-8 passive devices to Table 3 Added OO devices to Table1 and 2	Feb 01

1. FIBER OPTICS FUNDAMENTALS

Fiber optics is best known for its applications in the telephone industry, even though it is widely used in video and television systems. In television systems they typically send signals between two locations or distribute the same signal to many destinations.

Traditional video distribution systems have used coaxial copper cabling. Fiber optic cable provides many advantages over traditional copper wire:

- Lower cable losses allow longer distances without distribution amplifiers
- Ability to carry higher data rate signals
- Improved signal quality
- Immunity from electro-magnetic radiation and Lightning
- Light Weight

The crucial difference between fiber optic distribution systems and coaxial cable systems is that signals are transmitted as light. The two key elements of optical fiber are its core and its cladding. The core is the inner part of the fiber, through which the light is guided. The cladding surrounds the core completely. The refractive property of the cladding is higher than that of the core, so light in the core that strikes the boundary with the cladding at a glancing angle, is totally reflected back into the core. The boundary of the core and cladding acts like a “cylindrical mirror”, causing the core to act as a light pipe.

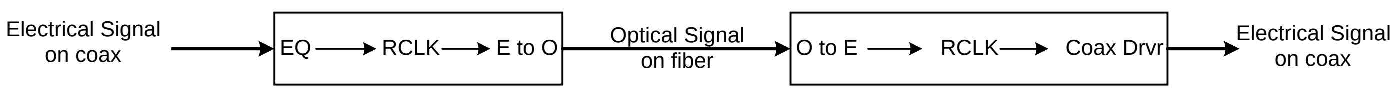


Figure 1: Components of a Fiber Optic Transmission System

The role of an optical transmitter is to convert an electrical data signal into an equivalent optical power waveform and couple it into an optical fiber. The role of the optical fiber is to convey the light from the source to the destination with the minimal amount of signal loss. The role of the optical receiver is to convert the optical power waveform back into an equivalent electrical data signal.

1.1. SYSTEM DESIGN PARAMETERS

1.1.1. Electrical to Optical Parameters

In optical output devices, the main design parameters that are important are the launched output power, the wavelength and the linewidth. Launch power and wavelength are always important in system designs. Line width is usually important only in high definition applications.

1.1.1.1. Transmitter Output Launch Power

The launched output power tells up the maximum power available at the optical transmitter. The following table indicates the launched output power available on current Evertz EO modules.

Module	Minimum Launch Power	Wavelength	Spectral width of Optical Signal
7705EO13	-7.5 dBm	1310 nm	5 nm
7705EO13-HD	-7.5 dBm	1310 nm	5 nm
7705EO13-HD-L	0 dBm	1310 nm	0.8 nm
7705EO15	0 dBm	1550 nm	0.8 nm
7705EO15-HD-L	0 dBm	1550 nm	0.8 nm
7705EOxx	0 dBm	1470 to 1610 nm *	0.8 nm
7705EOxx-HD-L	0 dBm	1470 to 1610 nm *	0.8 nm

* xx= 47 (1470 nm), 49 (1490 nm), 51 (1510 nm), 53 (1530 nm), 55 (1550 nm), 57 (1570 nm), 59 (1590 nm), 61 (1610 nm)

Table 1: Launch Power

1.1.1.2. Wavelength

The wavelength of the optical signal determines the cable loss window within which the system will operate.

The Loss versus wavelength graph in Figure 2 shows that at 1310nm the cable loss is 0.40dB/km and at 1550nm the loss is 0.30dB/km.

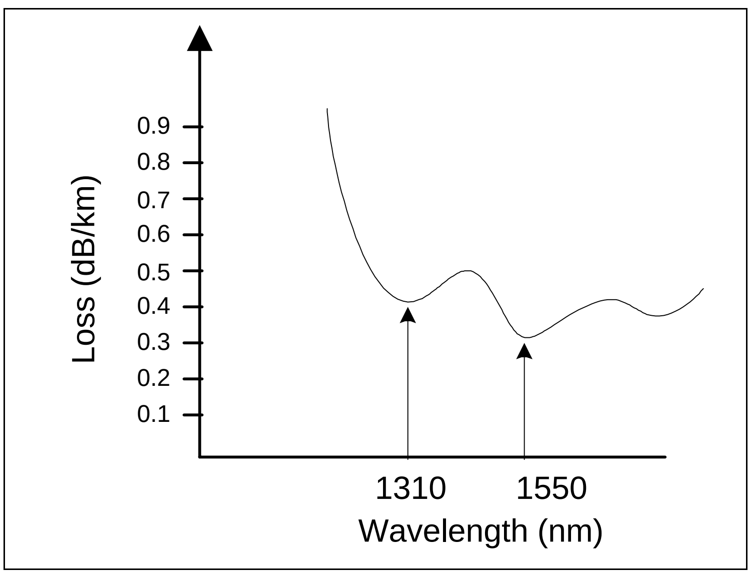


Figure 2: Cables Losses at Various Wavelengths

1.1.1.3. Linewidth

The linewidth is a measure of the laser's spectral purity, and determines the jitter penalty (how much jitter gets added to the signal). Linewidth is important in HD applications because the additional jitter penalty is significant compared to the bit period. In standard definition video applications linewidth is usually not a problem because the signal will lose too much power before it can go far enough for jitter to be a problem.

At 1310nm the jitter penalty is approximately 2.5psec/km of fiber /nm of linewidth. At 1550nm the jitter penalty is approximately 17ps/km of fiber/nm of linewidth.

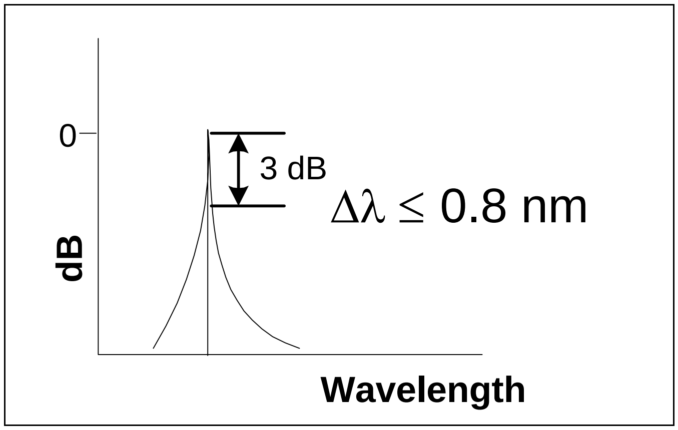


Figure 3: Spectrum of DFB Laser used in EO13-HD-L, EO15-HD-L and EOxx-HD

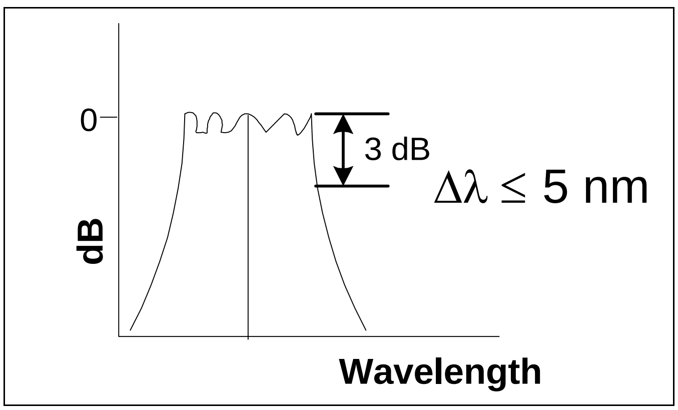


Figure 4: Spectrum of FP Laser used in EO13 and EO13-HD

1.1.2. Optical to Electrical Parameters

In Optical input devices, the main design parameters that are important are the maximum power before overload and the minimum power before errors (Sensitivity). The following table indicates the maximum power and sensitivity on current Evertz OE modules.

Module	Maximum Input Power	Sensitivity
7705OE	0 dBm	-30 dBm
7705OE-HD	-3 dBm	-17 dBm
7705OE-HD-L	-3 dBm	-20 dBm
7705OO	0 dBm	-30 dBm
7705OO-HD	0 dBm	-17 dBm

Table 2: Optical Receiver Power Parameters

1.1.3. Passive Optical Module Parameters

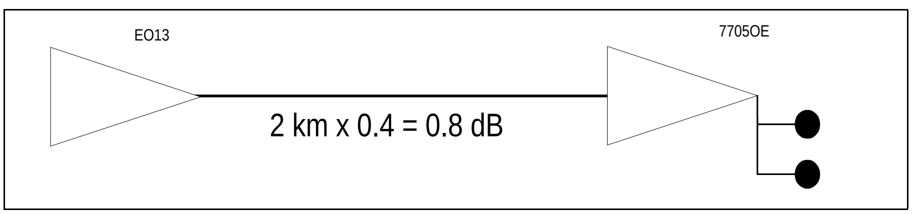
In passive optical modules, the main design parameter that is important is the loss through the passive device. The following table indicates the power loss on current Evertz passive fiber modules.

Module	Port	Insertion Loss
7705WDM		2 dB
7705CWDM-M4		< 3 dB
7705CWDM-D4		< 3 dB
7705CWDM-M8		< 6 dB
7705CWDM-M8		< 6 dB
7705DS		4 dB
7705DS-4		< 11 dB
7705DS-8		< 11 dB
7705MS	80 %	2 dB
	20 %	9 dB

Table 3: Passive Module Insertion Loss

1.2. DESIGN EXAMPLES

1.2.1. Standard Definition 2 km Link



Using the 7705EO13 as the transmitter.

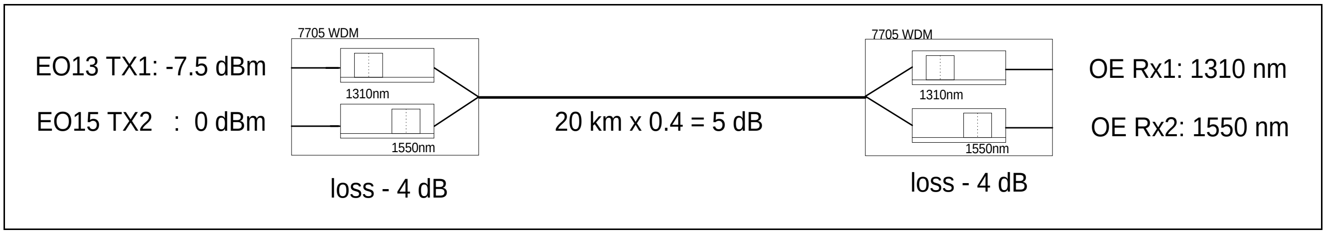
Launch Power =	-7.5 dBm
Connector Loss = 2 x 1	-2.0 dB
Fiber Loss = 2 x 0.4	-0.8 dB
Safety Margin =	-2.0 dB
Power at receiver	–12.3 dBm

The 7705OE has a listed sensitivity of –30 dBm which is lower than –12.3 dBm so we can implement the system with no problems, at least with respect to power availability.

Next we need to check the jitter penalty. The system jitter-penalty = 2.5 ps/ x 2 km x 5 nm = 25 ps. So by going through 2km of fiber, we add 25ps of jitter under the worst conditions (under the best conditions we would add 2ps total). The standard definition video bit period is 3.7 ns; so if the maximum jitter penalty is 20% or 740 ps., then the added jitter for this system is insignificant.

When would jitter-penalty be a problem? For 1310 nm wavelengths, the cable length where the jitter penalty becomes significant is calculated as: 740 ps divided by 2.5 ps/km/nm divided by 5 nm = 60 Km (worst case), or 600 Km (normal condition) At 60 Km cable length the cable loss is 60 x 0.4 = 24 dB. So the power into the receiver would be: – 6 dBm – 24 dB = – 30 dBm. This is equal to the published specification of -30 dBm but leaves no margin for connecotr or other losses. The jitter penalty at 1550 nm for standard definition video is calculated as: 740 divided by 17 divided by 0.8 = 54 Km (worst case). At 54 Km cable length the cable loss is 54 x 0.3 = 16.2 dB. So the power into the receiver would be: - 0 dBm – 16.2 dB = - 16.2 dBm. This is above the published specification of -30 dBm, so added jitter may become significant on cable lengths approaching 54 Km at 1550 nm.

1.2.2. 20 Km Link With 2 Standard Definition Signals On 1 Fiber



For Tx1 < Rx1:

Launch Power =	-7.5 dBm
Connector Loss = 4 x 1	-4.0 dB
Fiber Loss = 20 x 0.4	-8.0 dB
Safety Margin =	-2.0 dB
WDM Loss = 2 x 4	-8.0 dB
Power at receiver	–29.5 dBm

For the 1310 nm path the power available at the receiver is very close to the receiver input sensitivity of -30 dBm. This calculation assumes the worst case connector losses, and a safety margin of 2 dB. In practice, the actual system may be viable, but we should assemble the system including the connectors and actually measure the available power at the receiver to determine the viability for sure. For the 1550 nm path the transmitter launch power is greater and the cable loss is less, so the resulting system design is OK for power loss.

2. CALCULATING THE OPTICAL SYSTEM POWER BUDGET

Given a specific optical transmitter and receiver pair, the most important question concerning a system designer or integrator is the maximum possible link length. Here is a worksheet that simplifies this calculation. The specific receiver/transmitter parameters used in the worksheet vary depending on the specific module being used. Consult the specifications in the respective chapters for the modules to get the correct values for the worksheet.

Transmitter Launch Power.. ______ dBm

Receiver Sensitivity.. - _______dBm

Maximum Allowable Loss: .... **=** ________dB

Fiber Loss: † ____km X Attenuation: _______dB/km.......................... ________dB

Connector Loss: ‡ _____Connectors X Loss/Connector _______ dB ...... **+** ________dB

Passive Device Attenuation .... **+** ________ dB

Safety Margin.. **+** ________ dB

Total System Loss: .... **=** ________ dB

If the Total System Loss < Maximum Allowable loss, then the system is viable. A conservative industry standard for the safety margin is 2dB, and 1 dB per connector. However, these may vary and are usually determined by the system integrator/system engineer.

† Attenuation over Corning SMF 28 Single Mode Fiber: 0.3 dB/km @ 1550 nm, 0.4 dB/km @ 1310 nm

‡ If 62.5μm multimode fiber is used then 2dB must be added to the connector loss to account for receiver and cable fiber diameter mismatch.

3. CARE AND HANDLING OF OPTICAL FIBER

3.1. SAFETY

Never look directly into an optical fiber. Non-reversible damage to the eye can occur in a matter of milliseconds. The laser modules used in Evertz fiber optic products are all CLASS I, with a maximum output power of 2mW, and wavelengths of either 1310 nm or 14750 nm to 1610 nm.

3.2. HANDLING AND CONNECTING FIBERS

Never touch the end face of an optical fiber.

The transmission characteristics of the fiber are dependent on the shape of the optical core and therefore care must be taken to prevent fiber damage due to heavy objects or abrupt fiber bending. Evertz recommends that you maintain a minimum bending radius of 3 cm to avoid fiber bending loss that will decrease the maximum attainable distance of the fiber cable. Evertz fiber modules come with cable lockout devices, to prevent the user from damaging the fiber by installing a module into a slot in the frame that does not have a suitable I/O module.

Dust particles on the ends of the optical fiber greatly increase the signal loss at interconnections, and large dust particles can even obscure light transmission altogether. To minimize the effects of dust contamination at the interconnections, the fiber should be cleaned each time it is mated or unmated. When using interconnection housings to mate two optical fibers it is good practice to remove dust particles from the housing assembly with a blast of dry air. Whenever a fiber is unmated it must be covered immediately. Most fiber manufacturers provide a plastic boot that fits over the ferrule body for this purpose.

Fiber interconnections must be made securely. The Evertz fiber optical transmitters and receivers come with SC interconnection housings built into the module. With this style of connector, the fiber assembly and the housing assembly can only be connected in one way and with very good repeatability. The rear fiber interconnect panel that is provided with each module can be ordered with optional Sc/PC. ST/PC or FC/PC connectors. The customer is required to provide the optical fiber with the correct connectors to connect the modules together. SC/PC, ST/PC and FC/PC interconnection housing and connectors as well as adapters are industry standards with many available sources.

3.3. MAKING SURE THE OPTICAL FIBERS ARE CLEAN

It is very important to ensure that optical fibers are clean before mating and after unmating. You should have received a pre-moistened tissue with the optical module. Remove this tissue from its package and wipe the end of the fiber connector before mating it to the module.

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