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# AEROSPACE STANDARD

SAE AS4075/1

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Submitted for recognition as an American National Standard

# OPTICAL IMPLEMENTATION RELATING TO THE HIGH SPEED RING BUS (HSRB) STANDARD



## 1. SCOPE:

This SAE Aerospace Standard (AS) has been prepared by the Ring Implementation Task Group of the SAE AS-2 Committee. It is intended as a companion document to the SAE AS4075 High Speed Ring Bus Standard. While the Standard is intended to provide as complete a description as possible of an HSRB implementation, certain parameters are system-dependent and evolutionary. This document contains those parameters. The text through Table 1 is intended to provide definitions and descriptions applicable to all applications. Table 2 contains specific parameter values for one or more implementations. This table will change as new systems are implemented or new HSRB speed options are defined.

### 1.1 System Characteristics:

The fiber optics characteristics germane to HSRB implementation are specified in five groups as follows:

a. Common system characteristics
b. Media characteristics
c. Bypass switch characteristics
d. Transmitter characteristics
e. Receiver characteristics

This slash sheet covers (a), (d), and (e); (b) and (c) are contained in the Handbook for the SAE AS4075 High Speed Ring Bus AIR4289.

### 1.2 Definitions and Requirements:

Detailed procurement-oriented parameter definitions and requirements for optical transmitters and receivers are contained in the following paragraphs of this document. Table 1 provides a summary of the parameter abbreviations, brief descriptions, and units of measurement for component characteristics.

TABLE 1 - Summary of Fiber Optic Parameters

| Parameter | Abbreviation | Unit of Measurement |
|---|---|---|
| Common System Characteristics | | |
| Operating temperature range | $T_{min}$, $T_{max}$ | degrees Celsius |
| Power supply tolerances | $\pm dV$ | percent |
| Signaling Baud rate | $BR_s \pm .009\%$ | MegaBaud |
| Signaling Baud width | $BT_s \pm .009\%$ | nanoseconds |
| Optical wavelength | | |
| nominal | $WO_{nom}$ | nanometers |
| maximum | $WO_{max}$ | nanometers |
| minimum | $WO_{min}$ | nanometers |
| Spectral bandwidth | SBW | nanometers |
| Fiber Optic Transmitter Characteristics | | |
| Risetime | $T_{or}$ | nanoseconds maximum |
| Falltime | $T_{of}$ | nanoseconds maximum |
| Signal overshoot and undershoot | OS, US | percent maximum |
| Distortion | $D_t$ | nanoseconds maximum |
| Distortion+ISI jitter | $D_t+J_t$ | nanoseconds maximum |
| Radiant power output, on | $RPO_{on}$ | dBm |
| Radiant power output, off | $RPO_{off}$ | dBm |
| Static extinction ratio | $R_{se}$ | dB minimum |
| Fiber Optic Receiver Characteristics | | |
| Allowed bit error rate | $BER_r$ | error probability/bit max |
| Radiant power input, min (sensitivity) | $RPI_{min}$ | dBm minimum |
| Radiant power input, max | $RPI_{max}$ | dBm maximum |
| Optical signal range | OSR | dB minimum |
| Radiant power input, absolute maximum | $RPI_{abmx}$ | dBm maximum |
| Acquisition time | $T_{acq}$ | microseconds maximum |

TABLE 2 - Slash Sheet Parameter Values

| Parameter | | Fiber Optic 100 MBd | Fiber Optic System 1[2] | Fiber Optic System 2[2] |
|---|---|---|---|---|
| Common System Characteristics | | | | |
| $T_{min}$ | degrees Celsius | [1] | | |
| $T_{max}$ | degrees Celsius | [1] | | |
| ±dV | percent | [1] | | |
| $BR_s$ ± .009% | MegaBaud | 100 | | |
| $BT_s$ ± .009% | nanoseconds | 10 | | |
| $WO_{nom}$ | nanometers | 840 | | |
| $WO_{max}$ | nanometers | 880 | | |
| $WO_{min}$ | nanometers | 800 | | |
| SBW | nanometers | 60 | | |
| BLT | nanoseconds | (127 x 6+40) x $BT_s$ + T where T is the delay of 3 km of fiber. See AS4075 paragraph 3.3.1 and 3.5.12.11.5. | | |
| LTC | nanoseconds | (127 x 6 x 2+40) x $BT_s$ + 2xT where T is the medium delay of the maximum length of fiber. See AS4075 paragraph 3.5.12.11.1 | | |
| $T_{or}$ | nanoseconds maximum | 4 | | |
| $T_{of}$ | nanoseconds maximum | 6 | | |
| OS, US | percent maximum | 5 | | |
| $D_t$ | nanoseconds maximum | 0.5 | | |
| $D_t+J_t$ | nanoseconds maximum | 1.0 | | |
| $RPO_{on}$<br>± tolerance | dBm | -3.5<br>±1.5 | | |
| $R_{se}$ | dB minimum | -16.5 | | |
| Fiber Optic Receiver Characteristics | | | | |
| $BER_r$ | error probability per bit max | 1E-10 | | |
| $RPI_{min}$ | dBm minimum | -32 | | |
| $RPI_{max}$ | dBm maximum | -10 | | |
| OSR | dB minimum | 22 | | |
| $RPI_{abmx}$ | dBm maximum | 0 | | |
| $T_{acq}$ | microseconds maximum | 1.0 | | |

[1] System dependent.
[2] Reserved for future implementations.

1.2 (Continued):

Specific numerical values for the parameters for specific implementations of the HSRB are given in Table 2.

The definitions provided herein are generally accepted by vendors of fiber optic components, as are the measurement techniques specified. The definitions are consistent with National Bureau of Standards Handbook 140 as the authority on usage.

The specific numerical values noted in Table 2 represent beginning-of-life values for the worst-case operating temperature range and power supply allowance noted. It is incumbent on the system design activity to account for excess loss due to other environmental factors and aging.



## 2. REFERENCES:

### 2.1 SAE Publications:

Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

AS4075
AIR4289

### 2.2 Other Publications:

National Bureau of Standards Handbook 140, "Optical Waveguide Communications Glossary"

### 2.3 Acronyms:

| | |
|---|---|
| $BER_r$ | FORX Bit Error Rate |
| BLT | Beacon Loop Timer |
| $BR_s$ | Signaling Baud Rate for continuous transmission on the medium |
| $BT_s$ | Nominal signaling Baud width |
| dV | Voltage tolerance |
| $D_t$ | Distortion |
| $D_t + J_t$ | Total Distortion and Jitter |
| FL | Fiber Length |
| FORX | Fiber Optic Receiver |
| FOTX | Fiber Optic Transmitter |
| FWHM | Full Width at Half Maximum |
| HSRB | High Speed Ring Bus |
| ISI | Inter-Symbol Interference |
| $J_t$ | Jitter |
| LTC | Loop Timer Counter |
| NRZI | Nonreturn to Zero Invert |
| OS | Optical Signal Overshoot |
| OSR | FORX Optical Signal Range |
| $P_{rx}$ | Receiver input Port |
| $P_{tx}$ | Transmitter output Port |
| PW | Pulse Width |
| $RPI_{abmx}$ | FORX absolute maximum Radiant Power Input |

2.3 (Continued):

| | |
|---|---|
| $RPI_{max}$ | FORX maximum Radiant Power Input |
| $RPI_{min}$ | FORX minimum Radiant Power Input |
| $RPO_{on}$ | FOTX Radiant Power Output on |
| $RPO_{off}$ | FOTX Radiant Power Output (off/steady state low) |
| $R_{se}$ | FOTX static extinction Ratio |
| SBW | Spectral Bandwidth |
| $T_{acq}$ | FORX acquisition time |
| $T_{min}$ | Minimum Temperature |
| $T_{max}$ | Maximum Temperature |
| $T_{of}$ | Optical falltime |
| $T_{or}$ | Optical risetime |
| US | Optical Signal Undershoot |
| WCP | Worst-Case test Pattern |
| WO | Wavelength of peak radiance |

## 3. COMMON SYSTEM CHARACTERISTICS:

The characteristics that are common to the transmitter, receiver, bypass switch, and media include:

a. System operating temperature range
b. System power supply tolerances
c. Fiber optic component input/output ports
d. Fiber optic bus signaling rate
e. Optical wavelength and spectral bandwidth
f. Precision test fiber and measurement tolerances
g. Worst-case test pattern - WCP

### 3.1 System Operating Temperature Range:

All components related to the HSRB implementation shall meet all functional performance and reliability requirements over the environmental temperature range of $T_{min}$ to $T_{max}$, with no auxiliary cooling provisions other than that provided by the host system.

### 3.2 System Power Supply Tolerances:

All components related to the fiber optic ring bus implementation shall meet all functional performance and reliability requirements with supply voltages provided by the host system with a $\pm$dV tolerance.

### 3.3 Fiber Optic Component Input/Output Ports:

For the purposes of this slash sheet, all optical power levels and insertion losses are defined as at or between the ports defined in the following paragraphs and shown in Figure 1. The connectors constituting the defined ports do not accrue a connector loss, as these losses are incorporated in the defined optical power levels. The losses of any other connectors used in the system and fiber media attenuation must fall between the limits of the optical power budget defined in respect to these ports and are the

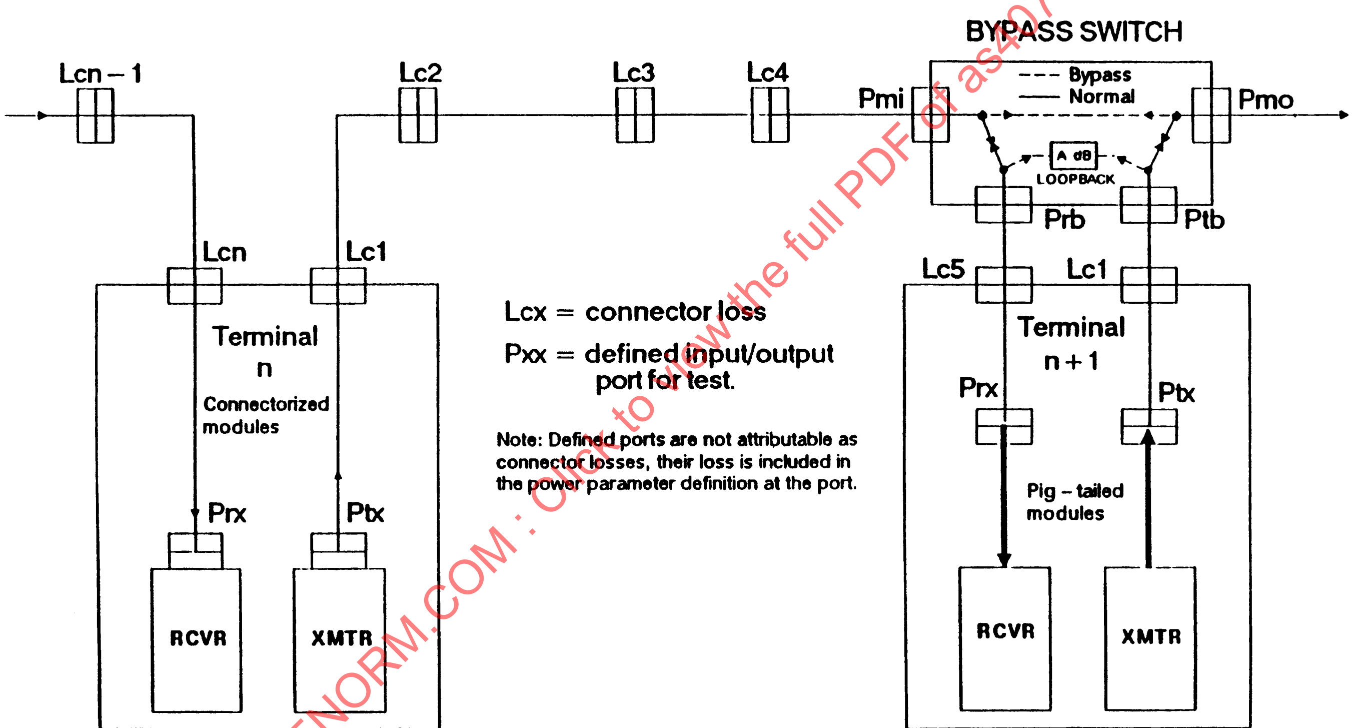



FIGURE 1 - Media Path and Test Port Description

3.3 (Continued):

responsibility of the system design activity to define. For access to the bus media, optical connections to these ports shall be accomplished with connector types and termini selected by the system design activity, utilizing the optical fiber defined in Section 4.

3.3.1 Terminal Hardware: Each station shall have a receiver input port, $P_{rx}$, and a transmitter output port, $P_{tx}$. These ports are defined as either:

a. The connector on the transmitter or receiver module, if they are equipped with connectors

b. The connector on the end of the integral "pigtail" fiber on a transmitter or receiver module, if so equipped

The optical losses between these points and the optical media external to the terminal enclosure (which will include any optical connector or fiber loss internal to the terminal enclosure and the loss accrued at the terminal enclosure bulkhead connector) must be included in the overall system power budget by the terminal design activity.

This method of specifying the transmit and receive ports is necessary to enable the specification and test of the transmitter and receiver functions as "components" for design or procurement purposes. The standard does not define or control the internal configuration of the terminal, so it cannot anticipate what losses may be incurred. It is therefore incumbent upon the terminal design activity to make these decisions.



3.4 Fiber Optic Bus Signaling Rate:

The signaling Baud rate for continuous transmission on the fiber optic medium shall be $BR_s$ Megabaud (with a tolerance including initial accuracy, temperature/voltage stability, and long term aging). The nominal signaling Baud width shall be $BT_s$ nanoseconds ($BT_s = 1000/BR_s$). The nominal duration between transitions, pulse width (PW, nanoseconds), can be any integer multiple value from 1 x $BT_s$ up to 4 x $BT_s$, as required for the NRZI modulated transmission of 4 bit/5 bit substitution code (which is run-length-limited to 4 bit periods). When the ring bus is in operation, there will always be a signal in the media with PWs within these limits.

3.5 Optical Wavelength and Spectral Bandwidth:

The wavelength of peak radiance (WO) of the emitted optical radiation shall be between the limits of $WO_{min}$ and $WO_{max}$ nanometers. The nominal value, $WO_{nom} = (WO_{min} + WO_{max})/2$. The spectral bandwidth (SBW, nanometers) shall be the measurement of the wavelength range of the source's output spectrum. The spectral bandwidth shall be the full width at half maximum (FWHM) of the peak level at its own WO.

3.6 Precision Test Fiber and Measurement Tolerances:

The precision test fiber is used for all measurements and is 'precision' in that it is as close as possible to nominal in all parameters. A 10% accuracy uncertainty results from this fiber, variations in coupling to test equipment, and the uncertainty of the test equipment itself.

Establishing whether a unit under test meets the requirements of this document requires defining the test fiber and test method in detail and accounting for the accuracy uncertainty. The appropriate test plan will provide the detail required.

3.7 Worst-Case Test Pattern - WCP:

A defined worst-case test pattern (WCP) is required for several of the parameter measurements specified for the transmitter and receiver. The WCP shall consist of a sequence of pulses encompassing the maximum duty cycle range exhibited by any combination of the valid 4B/5B code symbols that can be transmitted, in a sequence that generates the maximum possible amount of baseline shift.

The worst-case pattern is a stream of symbols whose DC imbalance is at its maximum. For example, a succession of 10010 symbols yields a signal whose digital representation is 01110011100 or 60% high, 40% low (or the inversion depending on the initial condition).

This pulse train followed by the shortest low pulse (one baud time) would create a condition where the low pulse is most distorted. Therefore, for this slash sheet the following constitutes a worst-case pattern:

a. 16 symbols of 10010 followed by 10011



4. FIBER OPTIC TRANSMITTER (FOTX) CHARACTERISTICS:

This section defines the characteristics that are applicable to the transmitter of each station. The characteristics shall be measured at the opposite end of a precision test fiber connected to port $P_{tx}$. All optical power levels in this section and the following receiver section, shall be stated as "PEAK values" and must either be measured as peak or measured as average with correction for the duty cycle applied to convert to peak. This method forces the activity, making the measurements apply the proper correction factor for duty cycle rather than leave a potential ambiguity for the later observer of the test data. Note that average measurements without a known duty cycle are meaningless.

4.1 FOTX Optical Output Waveform:

The transmitter shall produce a waveform within the limits shown in Figure 2 when the appropriate parameter values from Table 2 are supplied. There shall be no reversal of slope of the signal waveform during the 20 to 80% and 80 to 20% transition periods.

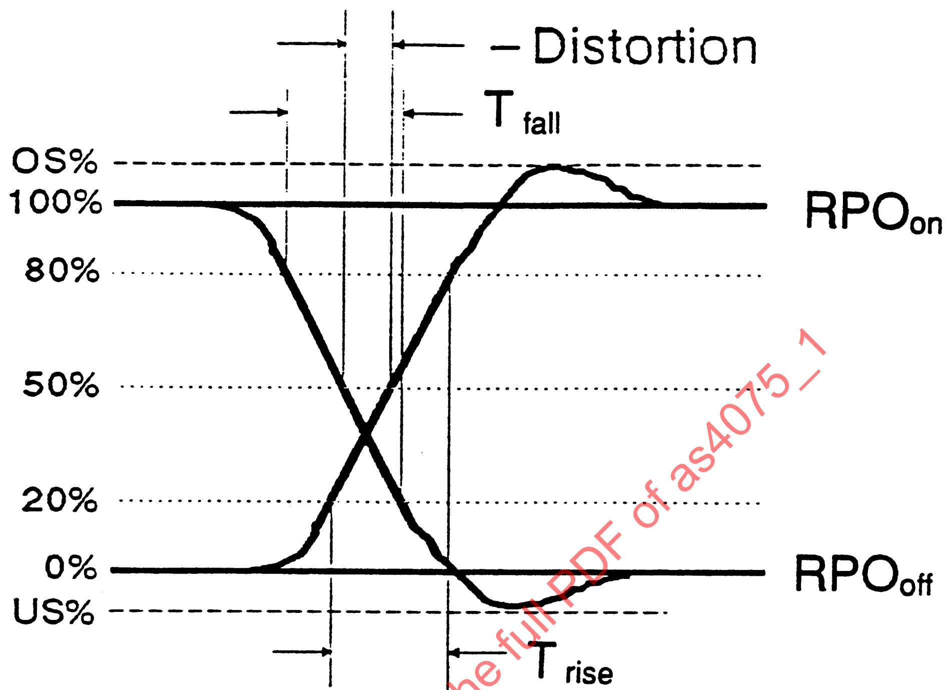


FIGURE 2A - Output With Square Wave Input

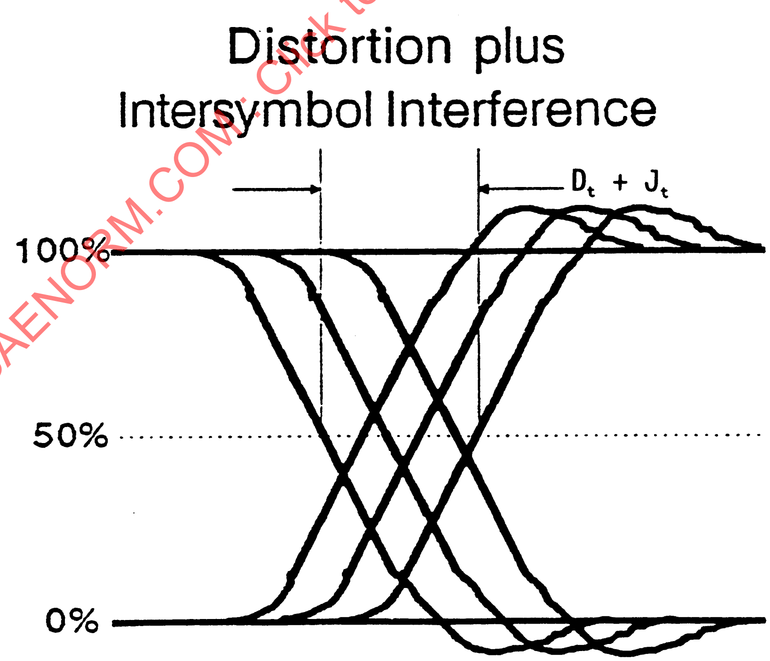


FIGURE 2B - Output With Worst-Case Pattern Input

FIGURE 2 - Transmitter Optical Waveform Parameters

4.1.1 Optical Signal Risetime, $T_{or}$ - nanoseconds: The optical risetime shall be $T_{or}$ nanoseconds maximum, as measured between the 20 and 80% points as shown in Figure 2A. This test shall be performed with a square wave input with a period of 2, 4, 6, or 8 $BT_s$, whichever gives the largest value.

4.1.2 Optical Signal Falltime, $T_{of}$ - nanoseconds: The optical falltime shall be $T_{of}$ nanoseconds maximum, as measured between the 80 and 20% points shown in Figure 2A. This test shall be performed with a square wave input with a period of 2, 4, 6, or 8 $BT_s$, whichever gives the largest value (the worst-cast pulse width for $T_{of}$ is not necessarily the same as that for $T_{or}$).

4.1.3 Optical Signal Overshoot, OS, and Undershoot, US - percent: The signal overshoot shall be OS% maximum and the undershoot shall be US% maximum, as shown in Figure 2A. This test shall be performed with a square wave input with a period of 2, 4, 6, or 8 $BT_s$, whichever gives the largest value.

$$OS\% = ([OS_{peak} - RPO_{on}] / [RPO_{on} - RPO_{off}]) \times 100\% \qquad \text{(Eq.1)}$$

$$US\% = ([RPO_{off} - US_{peak}] / [RPO_{on} - RPO_{off}]) \times 100\% \qquad \text{(Eq.2)}$$

where all power representation here are in milliwatts. See Figure 2A.

4.1.4 Optical Signal Distortion, $D_t$, and Jitter, $J_t$ - nanoseconds: Transmitter plane width distortion is defined as the broadening or shrinking of the width of either high or low level pulses, relative to the nominal width of the signaling Baud.

NOTE: The total observed distortion consists of two components, distortion ($D_t$) and inter-symbol interference, which produces jitter, $J_t$. $D_t$ is a long term (slowly varying) parameter produced by the effect of power supply and temperature variations on the operation of the circuit. This effect can be minimized over the required temperature and supply voltage range by careful design. The second component is $J_t$, produced by the upper and lower frequency cutoff (bandwidth) limitation of the circuitry, when successive pulses of different widths are transmitted. If the circuitry has a bandwidth from DC to $1/BT_s$ (Hertz) or greater, inter-symbol interference (ISI) jitter will be negligible.

The total distortion and jitter that can be allowed in the system is limited by the tolerance of the NRZI demodulator. Distortion and jitter generation is unavoidable in the receiver threshold detection and clock recovery functions. At signal levels near minimum, receiver self-noise adds additional jitter to the signal on top of the long term distortion and ISI effects that are produced similarly in the transmitter function. Controlling these factors at the receive function is much more difficult than at the transmitter. For example, it is not practical to use excess bandwidth for ISI reduction in the receiver, as this also increases total RMS self-

4.1.4 (Continued):

noise. It is, therefore, good design practice to specify the transmitter as tightly as possible and leave as much of the system distortion and jitter budget as possible for the receive function.

Transmitter distortion shall be $\pm D_t$ nanoseconds maximum, when measured by the method shown in Figure 2A, as the time between the rising and falling edges of the pulses in an "eye" diagram display at the 50% amplitude level. Positive distortion is defined as broadening of the width of the high level pulses (or the crossover of the rising edge and falling edge shown in the "eye" diagram in the figure occurs above the 50% amplitude level). Negative distortion results from broadening of the low level pulse (or the crossover occurring below the 50% level in the diagram). This test shall be performed with a square wave input with a period of 2, 4, 6, or 8 $BT_s$, whichever gives the largest value. The duty cycle of the logic input to the transmitter shall be adjusted to exactly 50%, as measured at the threshold level of the logic waveform, before the measurement is made on the optical output waveform.

The total algebraic sum of distortion plus inter-symbol interference jitter shall be $D_t + J_t$ nanoseconds maximum, defined as the time between when the earliest pulse edge crosses the 50% level until the latest pulse edge crosses the 50% level, as shown in the "eye" diagram of Figure 2B. This test shall be performed with worst-case test pattern, WCP, driving the transmitter.

4.2 FOTX Radiant Power Output, $RPO_{on}$ - dBm:

The transmitter radiant power output, $RPO_{on}$ $\pm$ tolerance, is defined as the optical power measured exiting a precision test fiber connected to port $P_{tx}$, over the entire operating supply voltage tolerance and temperature range, when the transmitter input signal is a square wave of period 2 $BT_s$ with the input duty cycle adjusted to give an optical output with exactly a 50% duty cycle, as measured at the 50% amplitude level. 3 dB is added to convert from average to peak value.

$$RPO_{on} = 10 \times Log\ [measured\ power\ (mw)/1\ mw] + 3\ dBm \qquad \text{(Eq.3)}$$

4.3 FOTX Static Extinction Ratio, $R_{se}$ - dB:

The transmitter static extinction ratio, $R_{se}$ minimum, is defined as the ratio of the transmitter $RPO_{on}$ value measured above to the radiant power output ($RPO_{off}$) in the precision test fiber, when the input is a steady state logical low. The ratio is expressed in dB.

$$R_{se} = RPO_{on} - RPO_{off}\ dB \qquad \text{(Eq.4)}$$

## 5. FIBER OPTIC RECEIVER (FORX) CHARACTERISTICS:

This section defines the characteristics that are applicable to the receiver of each station. The characteristics shall be measured based on an optical input signal conforming with parameters defined in Section 4, this section and Figure 2 with parameter limits specified in Table 2. The test signal shall be introduced to port $P_{rx}$ by a precision test fiber.

### 5.1 FORX Bit Error Rate, $BER_r$ - Error Probability per Bit:

The overall receiver bit error rate shall be less than/equal to $BER_r$ (error probability per bit). This $BER_r$ or better shall be sustained for the worst-case waveforms and over the entire operating environment range of the receiver. Receiver sensitivity and optical signal range shall be defined in relation to the signal amplitude range over which the error rate is less than/equal to the $BER_r$ parameter value from Table 2, when the receiver is combined with the clock recovery and NRZI demodulator used in the system.

### 5.2 FORX Minimum Radiant Power Input, $RPI_{min}$ (Sensitivity) - dBm:

Minimum radiant power input is defined as the lowest peak optical input power required to produce logic outputs, in conjunction with the system clock recovery and NRZI demodulator functions, with an error rate equal/less than $BER_r$ defined in 5.1. A bit error occurs when the total pulse width distortion + ISI jitter + noise induced jitter instantaneously moves a pulse transition away from the nominal time of occurrence by an amount greater than that which is tolerated by the combination of the clock recovery and NRZI demodulator used in the system. Therefore, in order for this measurement to be valid, it must be made utilizing the system clock recovery and NRZI demodulator circuitry for bit detection, or test equipment that can be adjusted to simulate their characteristics very closely.

The receiver input test signal shall be WCP, the worst-case test pattern allowed by the parameters of Section 4 and Table 2. The test input pulse risetimes and falltimes shall be further degraded to simulate the multimode and chromatic distortion possible in the longest length of the selected fiber that is allowed between terminals in the system, if that is significant. One method of generating this waveform is to use a transmitter of the type to be used in the system that has been trimmed to output the worst-case transmitter waveform and to connect the transmitter to the precision test fiber (connected to the receiver input) through a $FL_{max}$ length of system fiber. It shall be the responsibility of the system design activity to make a determination that post transmitter signal conditioning is required.

Minimum radiant power input shall be determined by reducing input power level until a very high error rate occurs and then slowly increasing RPI while measuring and recording the peak optical power level and exact bit error rates at bit error rates of approximately 1 x 10 exp-3, 1 x 10 exp-5, 1 x 10 exp-7, and 1 x 10 exp-9. Each point should be averaged for at least the period required to accumulate 40 errors. Changing input power by 10% will change the bit error rate by approximately two orders of magnitude.