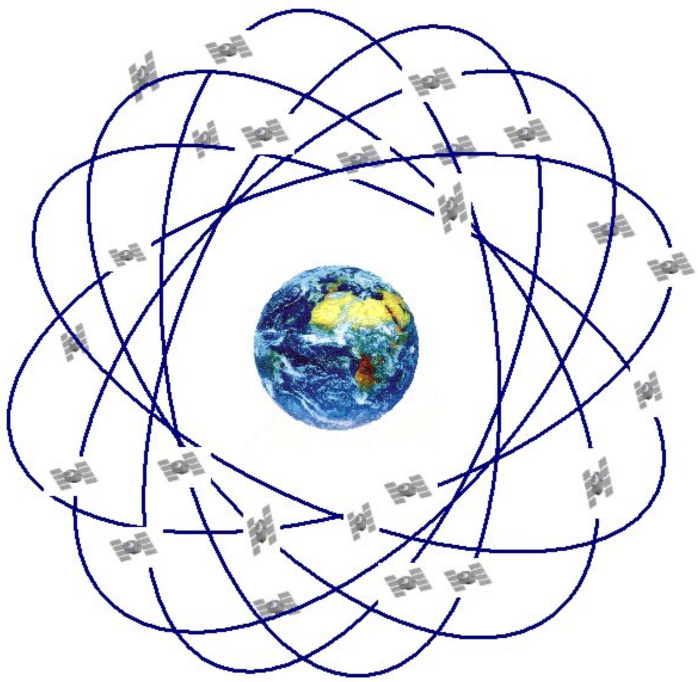
Application Note

GPS over Fiber Optics

Provided by

OPTICAL ZONU CORPORATION



Application Note

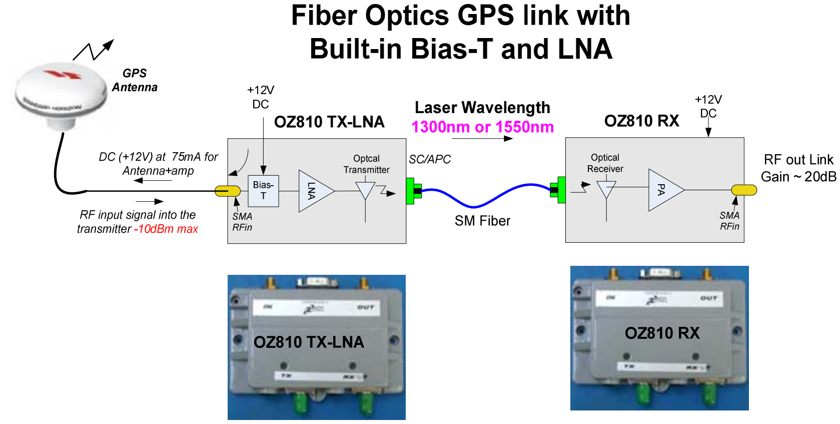
GENERAL DESCRIPTION

Optical fiber provides a ***cost-effective solution*** for long cable runs in GPS systems. The Optical Zonu GPS over Fiber Optics System allows signals to be carried from an antenna to a GPS receiver with minimal signal degradation over a non-conducting dielectric glass media. This system provides a completely transparent cross-site connection between an antenna and receiver. As is the case in many types of in-building environments, networks require accurate clock synchronization. By utilizing broadband RF over Fiber Optics (RFoF) Technology, Optical Zonu GPS over Fiber Optics Links provide easy to operate, low cost and reliable solutions that enable GPS signal distribution using fiber optic cable.

The broad bandwidth (47 MHz to 2.7 GHz) of the OZ800/600 series modules used in our GPS over Fiber Optics Link allows transmission of the two main signals in the GPS band, L1 and L2, at 1575.42 MHz and 1227.6 MHz respectively. These RFoF Links are designed to offer low noise figure by integrating a built-in LNA with Lasers featuring low Relative intensity Noise (RIN) and low loss broadband matching, in order to optimize the Link performance. Optical Zonu's GPS RFoF Link consists of stand-alone transmitter and receiver units. Each module is housed in compact (3 x 5 x 1.5 inches) metal ruggedized boxes which allow convenient installation in small spaces. Both units are powered via a DB-9 plug using +12 Volts DC (optional power supplies are available upon request).

Optical Zonu's GPS RFoF Link is an ideal solution for providing GPS timing and reference signals over fiber optic cable. It acts as a low loss extender between the GPS antenna and GPS receiver in places where GPS signals are otherwise unavailable, or where running long coaxial lines is impractical.

Fiber Optics GPS link with Built-in Bias-T and LNA



Note: Link Gain of approximately 20dB with 1 meter of fiber. Bandwidth 20Mhz to 2.7 Ghz

Application Note

FIBER versus COAX for GPS APPLICATIONS

Traditionally GPS systems have utilized coaxial cable to transfer signals between antenna and receiver. However, coax has a number of disadvantages, particularly over longer cable distances. It has a significant amount of signal loss over longer cable runs limiting its application for long distance links. Unfortunately, high quality low-loss coax is very bulky and expensive. Coax cable often has a large diameter, making it very inflexible and difficult to manipulate. There is also a direct electrical connection between the antenna and expensive receiver equipment. This direct electrical connection may conduct destructive electrical surges from environmental sources such as such as lightning.

Optical fiber supports very long cable distances, up to 10 Km or more, with minimal signal loss and degradation. Optical fiber operates by transmitting light along a dielectric glass fiber, rather than electrical signals over copper wires. This provides a highly secure tamper-proof medium for signal transfer, minimizing security risks and unauthorized signal interception concerns. Light is also unaffected by electro-magnetic interference, allowing signals to be transmitted unaffected through electrically noisy environments.

Often measuring less than 3 mm in diameter, optical fiber has a much smaller bend-radius than low-loss coax. Since it is much lighter, long reels of cable can be easily transported. Also, unlike coax, which has a larger minimum bend radius, optical fiber is very flexible and can be easily installed. Fiber also provides complete electrical isolation between an antenna and expensive receiving equipment, such as NTP (Network Time Protocol) servers and other network timing equipment. This means that an optical fiber system is immune to electrical surges such as lightning strikes that can easily damage or destroy expensive electronic equipment. Coax cable conducts electrical surges and often requires expensive surge suppressors that often need replacing in the event of activation by an electrical power surge.

Low-loss coax has a very high cost per meter ratio. Long cable runs can be very expensive to install. Optical fiber offers a relatively low cost per meter which is ideal for reducing installation costs when long cable distances are required. Additionally, GPS over optical fiber systems can often utilize legacy fiber that is part of a building's existing structured cabling. Pre-installed spare fiber cables can be utilized to save on expensive cabling costs. Optical fiber cable supports the transfer multiple signals over a single cable. Often GPS and LF radio time and frequency signals may be combined and transmitted over a single fiber optic cable. Coax installations would require separate cables for each particular signal type.

BASICS OF GPS

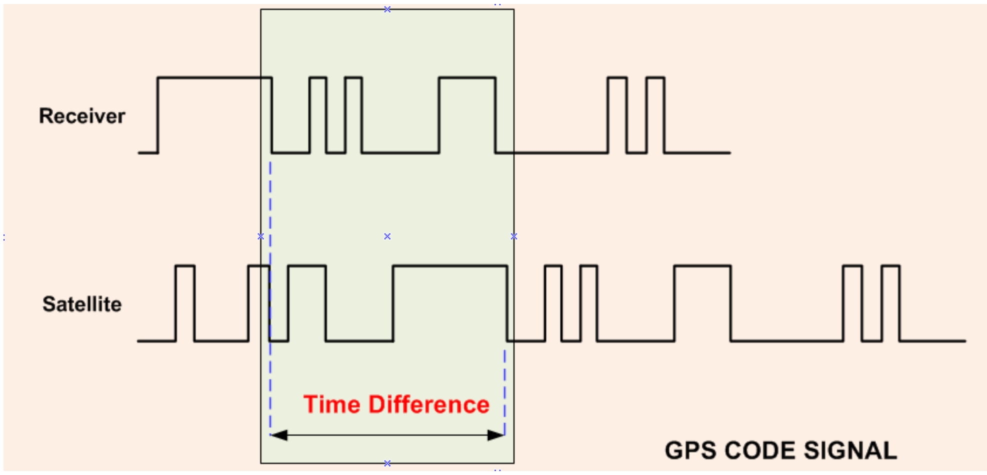
GPS, or the Global Positioning System, is a satellite navigation system which provides positioning and clock time to the terrestrial user. The system consists of more than just satellites, because while the satellites make up the space segment, the system also includes a control segment that monitors and maintains the satellites, as well as the user segment that ends up in users' hands. When most people think of GPS, they think of the United States NAVSTAR (Navigational System Time and Ranging) constellation. However, there are also the GLONASS system created by the former Soviet Union and the Galileo system recently approved for funding by the European Union.

Each of the 28 NAVSTAR Space Vehicles (SVs) is equipped with two channels: L1 and L2. The L1 channel produces a Carrier Phase signal at 1575.42 MHz as well as a C/A and P(Y) code. The L2 channel produces a Carrier Phase signal of 1227.6 MHz, but only P(Y) Code. Currently, there are plans in progress to implement an additional civilian code on the L2 band as well as the creation of a brand new L5, which is being implemented throughout the 2005 to 2015 time frame. The new L5 signal which is being added during this upgrade is a new civilian channel, which was designed to function in the 1176.45 MHz frequency range, with a 24 MHz bandwidth. Considering Optical Zonu's excess bandwidth design approach, implementing GPS over optical fiber is a robust, "future-proofed" endeavor.

C/A and the P(Y) Code: Binary data that is modulated or "superimposed" on the carrier signal is referred to as Code. Two main forms of code are used with NAVSTAR GPS: C/A or Coarse/Acquisition Code (also known as the civilian code), which is modulated and repeated on the L1 wave every millisecond; the P-Code, or Precise Code, is modulated on both the L1 and L2 waves and is repeated every seven days. The (Y) code is a special form of P code used to protect against false transmissions. Special hardware, available only to the U.S. government, must be used to decrypt the P(Y) code.

While the GPS receiver is listening to the satellites, it is also downloading information about the satellites' orbit and trajectory. An almanac is transmitted every 12.5 minutes and contains approximate orbits for the constellation, as well as atmospheric modeling. The ephemeris is transmitted every 30 seconds and contains shorter, more precise trajectory data for a given satellite.

Each satellite produces a unique digital code sequence of ones and zeroes. By matching the time difference of the code generated by the satellite's atomic clock and the user's clock (not necessarily very precise), the GPS receiver is able to match the code and calculate a time difference. Based upon the calculated time difference and known value of the speed of light, the distance between the SV and the receiver can be determined (speed of light multiplied by time). Because of the clocks' discrepancy, the slowing of light through the atmosphere and slight inaccuracy of the transmitted almanac, we call this distance a pseudo-range. The receiver position can then be calculated by intersecting distances from multiple satellites. Three (3) satellites are required to determine a 2-dimensional position and four (4), or more, are necessary for 3D.



The signals from the GPS satellites which operate in the L1 and L2 band are very weak signals with RF levels as low as -135.0 dBm in an open area facing the sky (like the roof top of a building). Thus, in many cases the antenna is far away from the GPS receiver. This poses a big problem for the GPS receiver's ability to acquire the signal. Typically, a high gain, low noise figure amplifier is constructed next to the antenna to boost the signal strength in order to drive potentially long coaxial cable, and more importantly, to reduce the Noise Figure of the link between the Antenna and the GPS receiver.

Unfortunately, as explained earlier, the use of coaxial cables is problematic because of the very high insertion losses of the coaxial cables and the GPS receiver's limited sensitivity which allows it to detect the signal properly. Consequently, the GPS over Fiber Optics Link, with built in Low Noise amplifier, not only drops the Noise Figure for the Link into the single digits (including the GPS antenna LNA), but also provides the much needed additional gain, necessary to enhance the GPS receiver's ability to detect the signal properly.

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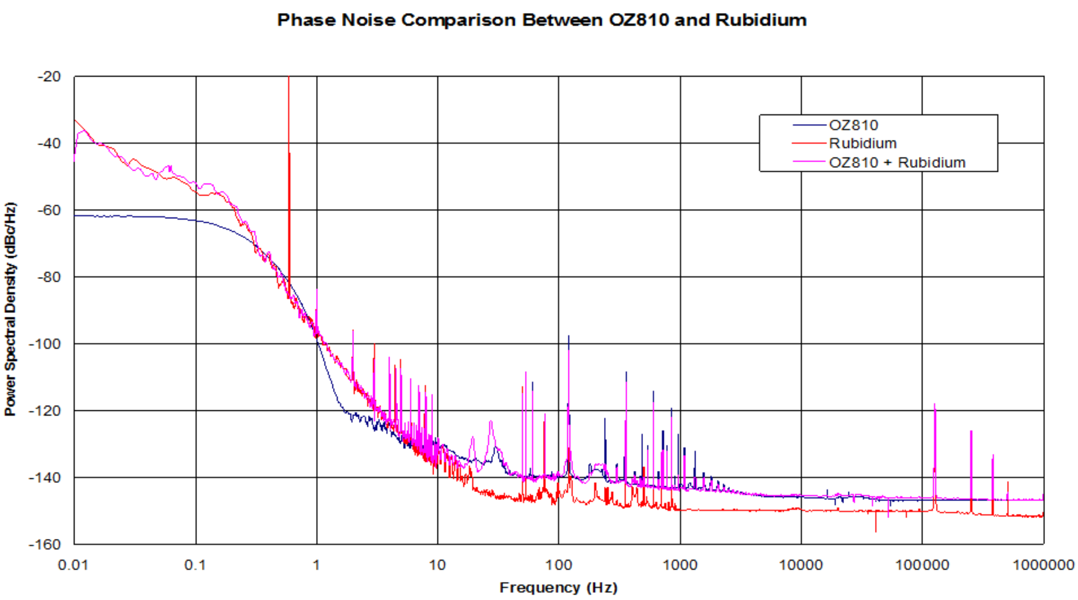
Application Note

GPS over FIBER + 10 MHz REFERENCE SIGNAL

Many GPS applications require distribution of 10 MHz (or other rates) reference signals. This is necessary for applications where maintaining precise synchronization is a must. To accomplish this effectively, maintaining low phase noise is extremely critical. Optical Zonu's OZ800 series and OZ1600 series Low Phase Noise RFoF Links provide highly reliable, cost-effective GPS timing distribution.

The plot below of the OZ810 Power Spectral Density versus Offset of Rubidium Clock, illustrates the performance of the low phase noise OZ810 module configuration for broad range frequency offsets from 0.01 Hz to 1.0 MHz. The OZ810 achieves better than -146 dBc/Hz at 1 MHz.



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OPTICAL LINK FUNCTIONALITY and HOW IT WORKS

Incoming GPS signals from the antenna are fed into the Transmitter module via the 50 Ohms RF connector. The Transmitter module contains RF signal conditioning, provides complex impedance matching between the 50 Ohms input impedance and the Laser, Laser Bias Control, APC, Monitoring and Alarm electronics. The Transmitter module utilizes an Intensity Modulation scheme to convert RF signals into light. This modulated light is then transported through an optical fiber to the optical Receiver module. The Receiver module converts the modulated light back into an RF signal. The recovered RF signal is again complex impedance matched and amplified before it becomes available at the output of the Receiver module, where it connects to the GPS receiver.

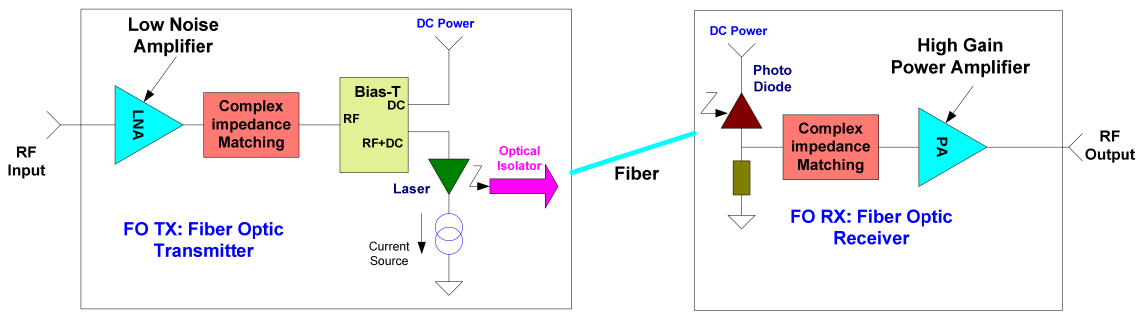


Figure 1

The distance between Transmitter and Receiver modules can range from 1 meter to over 20 Km, depending upon the system specification required by the user. Optimal performance of the GPS link requires single mode fiber terminated with angle polished (APC) optical connectors. However, we also have multimode fiber compatible GPS over Fiber Optic Links available upon request.

The Transmitter module has a built-in Bias-T to provide electrical power to the GPS Antenna. Specifications for this must be provided to the Factory, for Engineering to determine the correct configuration.

TECHNICAL SPECIFICATIONS

Parameter	Symbol	Min	Typical	Max	Units	Notes
Power Supply Voltage	VCC		12		Volts	
Power Supply Current	ICC		320	380	mA	
Laser Optical Output Power		1.25	1.6	4	mW	
Transmitter Operating Wavelength A/B			1310		nm	
Receiver Operating Wavelength B/A			1310		nm	
High Frequency Cutoff	HFC		2700	3300	MHz	1
Low Frequency Cutoff	LFC		28		MHz	2
Frequency Response (28 – 2700 MHz)			+/- 1.5		dB	
Input/Output Impedance	Z		50		Ohms	
Input/Output VSWR (28-2700 MHz)			1.6:1	1.8:1		
Spur Free Dynamic Range	SFDR		109		$(dB/Hz)^{2/3}$	3
RF Link Gain			20		dB	3
Input Noise Floor @ 1Ghz	EIN	-149	-153		dBm-Hz	3
Input Third Order Intercept @ 1Ghz	IIP3		12		dBm	4
Isolation		50	60		dB	5
Group Delay Over 4MHz (28-2700 MHz)			1		ns	

1. Typical High frequency cutoff (HFC) is 3000MHz. For higher HFC, contact Factory.
2. Typical Low frequency cutoff (LFC) is 28MHz, For lower LFC contact Factory.
3. Measured and Specified with Optical loss budget of 0 dB, and 1 meter of SMF28 optical fiber
4. Equivalent to IMD 60dB@0 dBm total output power (2 tone measurement).
5. Measured at 1 GHz.

Alarm Setting

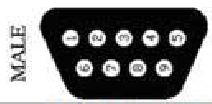
The Optical Transmitter and Optical Receiver modules have dual-color LED indicators onboard. The Transmitter LED monitors Laser Bias current and the Receiver LED monitors PD/RX receive optical power. The table below describes the topology.

LED Indicators	**Green**	**Red**
Transmitter	Laser Bias Current Normal <110 mA	Laser Bias Current Fault
Receiver	Input Optical Power Normal > -10 dBm	Input Power Fault

Note: The Transmitter LED will only turn **RED** when the Laser draws excessive current. Otherwise it will stay **GREEN**, even if the laser is disabled.

DB-9 Configuration

+12 Volts DC is provided to Optical Zonu's GPS over Fiber Optics Link via the DB-9 (male) connector with the pin-out configuration shown in this figure.



DB-9 CONFIGURATION

PIN	FUNCTION
1	Laser Enable (+12 v = Laser ON)
2	Data INPUT (Tx RS232)/ OR NC
3	Data OUTPUT (Rx RS232)/ OR NC
4	+12 volts (400 mA max)
5	Ground
6	Laser Bias Monitor (0.1 V = 10 mA)
7	Laser Bias Alarm (open collector, 25 mA)
8	Received Power Monitor (1V = 1mW)
9	Received Power Alarm (open collector, 25 mA)

ORDERING INFORMATION

PART NO: A03- GPS – F31 – AX – X L X

- **B** – Built-In Bias-T
- **0** – No Bias-T

- **S** – Single Mode Fiber Compatible
- **M** – Multimode Fiber Compatible

- **S** – SC/APC
- **F** – FC/APC

Optional Power Supply Part No. 350-1212-02

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