Whitepaper

Digital GPS Repeaters for Wireless Network Timing

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Abstract

Modern wireless telecommunications networks rely on accurate frequency and precise timing to synchronize base stations and mobile devices throughout the network. Unlike older 2G/3G wireless technologies which required only an accurate frequency reference, GPS timing signals are used today to ensure optimal signal quality & coverage, high speed data service with high capacity, spectral efficiency and advanced features.

In areas where no sky view exists, GPS signals are transmitted to remote devices using a GPS repeater system. Current solutions are based on analog signal transmission that limits network performance and reliability. Microlab has developed a digital GPS repeater system based on Digital SkyTiming Technology™ that provides the best network performance and cost, while also enabling future 5G network features.

Digital GPS Repeaters for Wireless Network Timing

One common approach to provide network timing is to use the Coordinated Universal Time (UTC) sent through Global Positioning System (GPS) satellite signals to align the network clock phase and frequency. In the US, GPS systems receive signals from up to 24 satellites, depending on the view of the sky and time of day. These signals are readily available at macro cell sites and towers with a clear sky view and are then decoded by a GPS receiver on-site into precise timing for use in network equipment.

Many Distributed Antenna Systems (DAS) and Centralized Radio Access Networks (C-RAN) also use GPS timing but these systems in buildings, stadiums and other venues may only have GPS access far from the base stations (BTS) or hub, requiring clock signal re-transmission using a GPS repeater. GPS repeaters that transmit RF signals over fiber were initially developed to solve this problem. They enable longer transmission distances and provide the additional benefit of immunity from EMI/RFI. Figure 1 illustrates a fiber optic GPS timing distribution network from the antenna to the GPS receiver. As network architectures have evolved and more advanced data services are offered, RF transmission of GPS signals over fiber (RFoF) can also limit the network performance, design flexibility and increase system costs. Signal impairments such as noise and distortion, which are important in analog communication systems, are important in RFoF systems as well. These impairments tend to limit the Noise Figure and Dynamic Range of the RFoF links. In advanced networks the amount and accuracy of the signal delay in RFoF signals have a significant impact on network performance.

Fiber optic links that transmit the GPS signals in digital format have been developed to overcome these limitations. Microlab employs commercial transceivers to improve system performance and provide several additional benefits, including:

- Smart (automatic) antenna switch over
- Reducing temperature sensitivity
- Timing correction using measured round-trip signal delay
- Remote monitoring and control
- Detection of interference or signal jamming
- Reducing noise and signal distortion

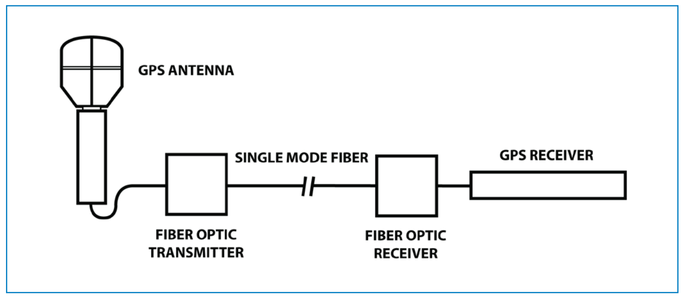


Fig. 1: Fiber optic GPS repeater

Microlab's new digital GPS repeater systems incorporates patent-pending Digital SkyTiming Technology™ to provide the most capable network timing solution available.

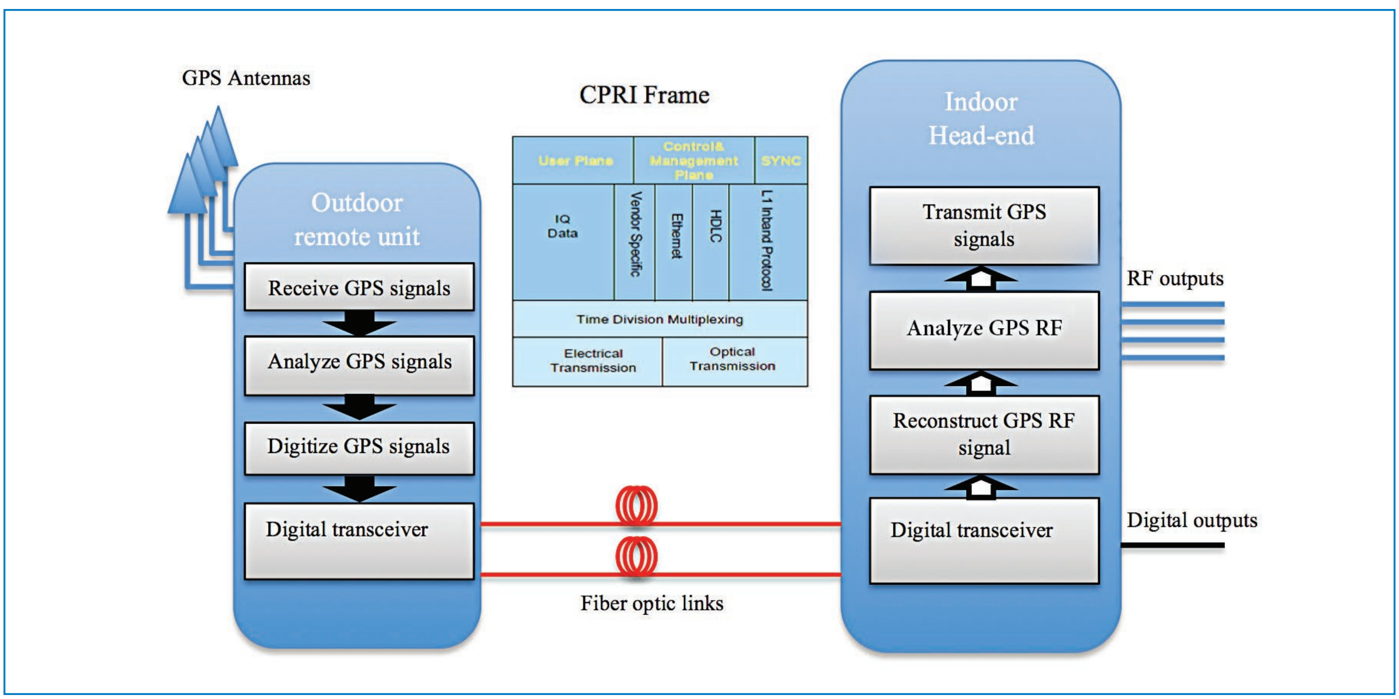


Fig. 2: Digital SkyTiming Technology(TM) system architecture

Digital SkyTiming Technology™

Digital SkyTiming Technology™ is a patent-pending technique to transmit GPS signals digitally over fiber for cellular network timing applications. It is used in wireless systems where GPS signals are not readily available close to the base station (where no sky view exists) or where remote monitoring and advanced alarms are required in the NOC. *Digital SkyTiming Technology™* is the only way to transmit digitized GPS signals using the CPRI protocol over fiber.

Figure 2 describes the Digital SkyTiming Technology™ approach. After GPS signals are received, the system digitizes the RF GPS signal, transmits the digital data over fiber using a CPRI protocol, then re-constructs the data back to original GPS RF signal. The RF data is output to the wireless system base stations and digital outputs are available for advanced system functions. Digitizing the RF GPS signal allows the data to be transmitted using commercial fiber optic links over a distance of up to 10km.

Figure 2 also illustrates the CPRI frame structure used to transport the GPS signal. The GPS signal is encoded as the I/Q data packet and the SYNC packet provides time synchronization. Delay measurements are transmitted between the head-end and remote unit in the Vendor Specific segment. This delay information is then provided to the user to align the base station. The CPRI protocol used is also the standard transmission protocol for Radio Access Network (RAN) fronthaul.

This digital capability allows functions that are not supported in analog systems such as end-to-end delay measurement for timing corrections, automatic antenna switchover, and two-way communication between the remote unit and head-end. The digital signals can be analyzed to determine the signal quality and availability of the several satellites that are typically required for system operation. Multiple antenna redundancy and smart features such as interference detection and automatic GPS source switch-over at adjustable signal levels ensure the best GPS signal available. Two-way fiber link communications facilitates remote monitoring and control that allows the entire GPS repeater system to be accessed over Ethernet from anywhere on the network using a web interface or SNMP.

One of the key benefits of the *Digital SkyTiming Technology™* is the ability to accurately determine the timing offset that is used to synchronize the base station with the wireless network. The timing offset can be affected by cable length, cable loss and temperature variations and can only be estimated in analog GPS systems leading to service limitations. *Digital SkyTiming Technology™* solves those problems by continuously and accurately measuring the data packet delays in order to align clock signals within 100 nsec. Advanced LTE video features and future networks will require timing within 1 µsec as summarized in Table 1. Higher data rates of mobile connected computing applications such as IoT, M2M and V2V communications in 5G wireless networks require the 100 nsec timing accuracy enabled by Digital SkyTiming Technology™

Standard	Application	Accuracy	Usage	Implications
LTE	4G wireless Broadband internet	±1.5µsec	Time slot allocation	Reduced signal quality Reduced bandwidth
LTE MBSFN	Mobile video	±500nsec	Time alignment of video signals from multiple towers	Video broadcast interruptions
LTE-A	8x8 MIMO Multipoint Transmission	±500nsec	Higher data speeds Increased capacity	Lower data rates Poor signal quality Location-based services accuracy
5G	Mobile Connected Computing IoT, M2M, V2V	±50nsec	Higher data speeds Increased capacity	E911 OTDOA

Table 1: Technology Timing Requirements

Wireless Communications System Applications

C-RAN Hub & DAS

Figures 3 & 4 illustrate how GPS repeater systems are used in the C-RAN hub and DAS systems, respectively. The C-RAN hub distributes cellular signals through a centralized transmitter to remote radio heads and antennas, while the DAS can be deployed in a building, outdoors, or in a stadium or venue. In both applications, there can be up to four GPS antennas connected on the rooftop of a building to optimize the sky view. These antenna feeds need to be transmitted to the basestation. The Microlab digital GPS signal repeater system transmits the GPS signals from an outdoor-rated receiver unit to a rack mounted head-end system. The outdoor receiver unit is placed near the GPS antennas and processes all available GPS satellite signals, transmitting them over redundant fiber optic cables to the indoor unit, which then reconstructs the GPS signals. The head-end system also splits the signals into 16 identical signals to be distributed to multiple C-RAN base stations cost effectively. Additional low-cost GPS signal splitters can be added to support additional hubs, frequency bands, or carriers. The GPS repeater system connects over Ethernet to the wireless network and can be accessed from any web-based system through standard internet protocols. System monitoring can be done with a local Ethernet connection or remotely,providing the ability to send SNMP traps and system alarms.This offers insight into system status and performance directly at the NOC and can alleviate costly truck rolls and service calls.

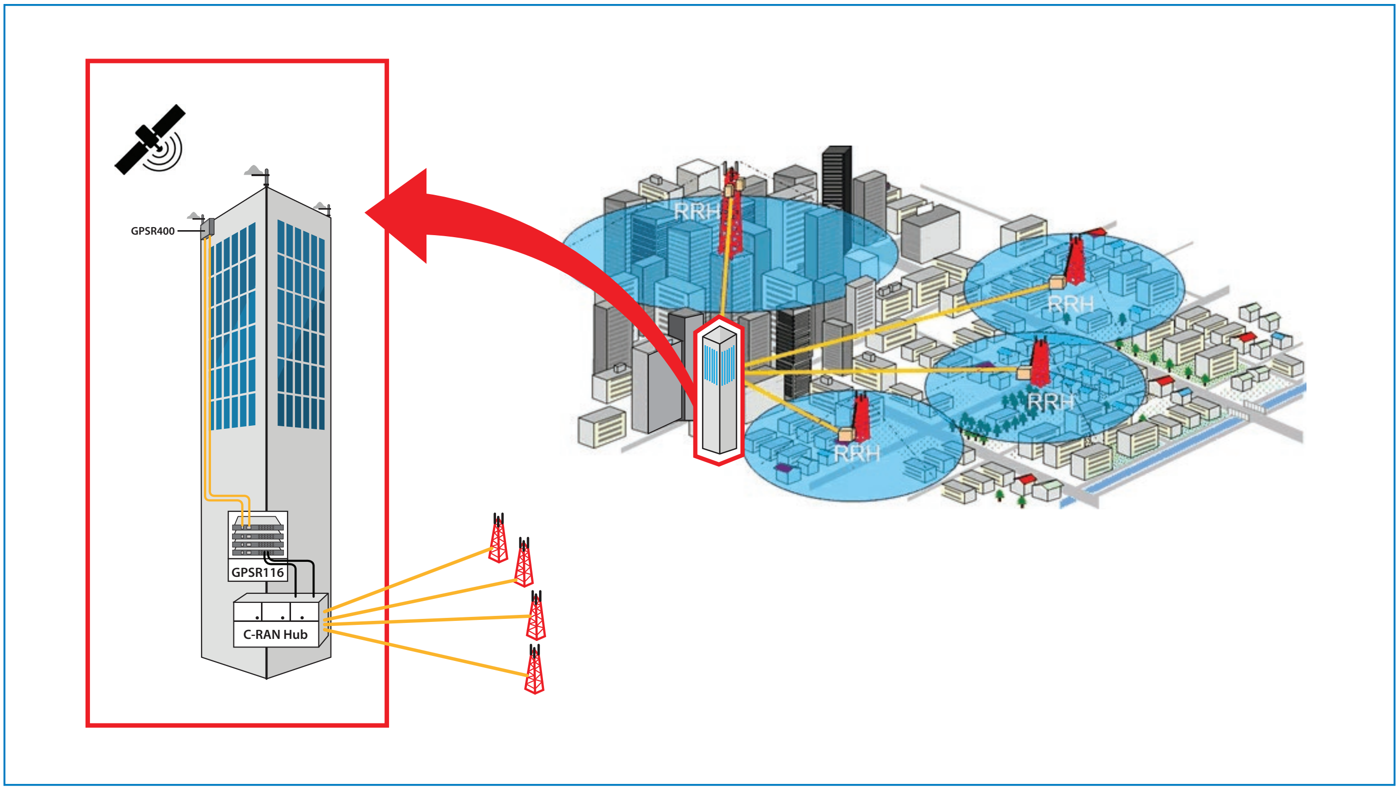


Fig. 3: C-RAN hub network timing application

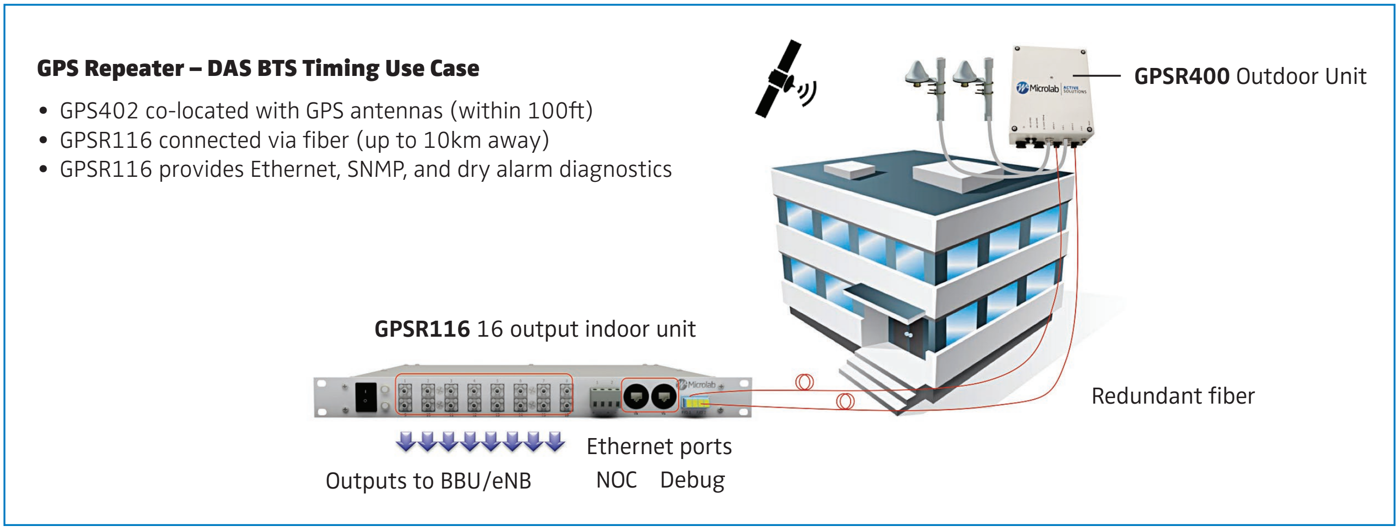


Fig. 4: DAS BTS timing solution

Microlab Digital GPS Repeater Systems

Microlab has introduced a complete line of GPS signal repeater systems using *Digital SkyTiming Technology™* for wireless network timing applications. The product line includes configurations that support up to 4 GPS antenna inputs with as many as 16 GPS output signals, along with GPS RF signal splitters that expand the output. These systems are configurable to provide antenna redundancy, the highest output signal density and most value in a 1RU chassis. These systems are managed through a web interface that can be accessed directly through Ethernet at either unit, or remotely over the network.

Digital SkyTiming Technology™ provides a smart GPS system implemented with an advanced web-based software interface for system administration and monitoring using the digital signal transport. The Microlab Digital GPS Repeater Systems provide the following unique features and benefits:

- Built-in antenna redundancy provides fault-tolerance and minimize system downtime
- Network Monitoring System (NMS) reports broken or degraded antenna and fiber optic signals
- GPS timing offset within 100ns accuracy
- Supports redundant single mode fiber with LC/UPC connectors
- Allows user to monitor GPS signal health, adjust to optimize system performance
- Allows automatic GPS antenna switch over
- Solves the challenges of analog RFoF signal transmission
- Allows longer fiber distances without signal degradation
- Provides accurate delay measurements for advanced system features
- Alarms provided locally (dry contact) and over Ethernet (SNMP traps)

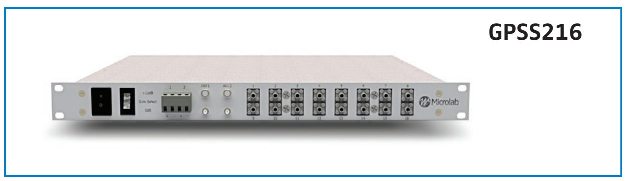
Microlab GPS Repeater software platform

Each Microlab Digital GPS Repeater system can be remotely controlled and monitored over Ethernet using a custom, web-based platform. The software allows configuration of both hardware and software, along with alarms. The system monitors antenna operation, satellite signal levels, fiber optic link status and system condition. The timing offset is also indicated and alarm levels can be customized. All of this diagnostic information is available to be transmitted to the NOC or system monitor.

Fig. 5: Microlab digital GPS system web interface

Microlab Digital GPS Repeater Product Line

Model	Description
GPSR116	Indoor head-end receiver, 16 RF outputs, 1 RU
GPSR400	Outdoor GPS signal transmitter, 4 antenna inputs, US version
GPSS216	Lossless GPS signal splitter, 2 RF inputs, 16 RF outputs, 1 RU
GPSS232	Lossless GPS signal splitter, 2 RF inputs, 32 RF outputs, 2 RU



The GPSS216 and GPSS232 lossless GPS signal splitters are configured to provide scalable output as shown in Figure 6. The splitters can be connected directly to GPS antennas that do not require digital transport over fiber optic cables and provide up to 10dB of selectable gain.

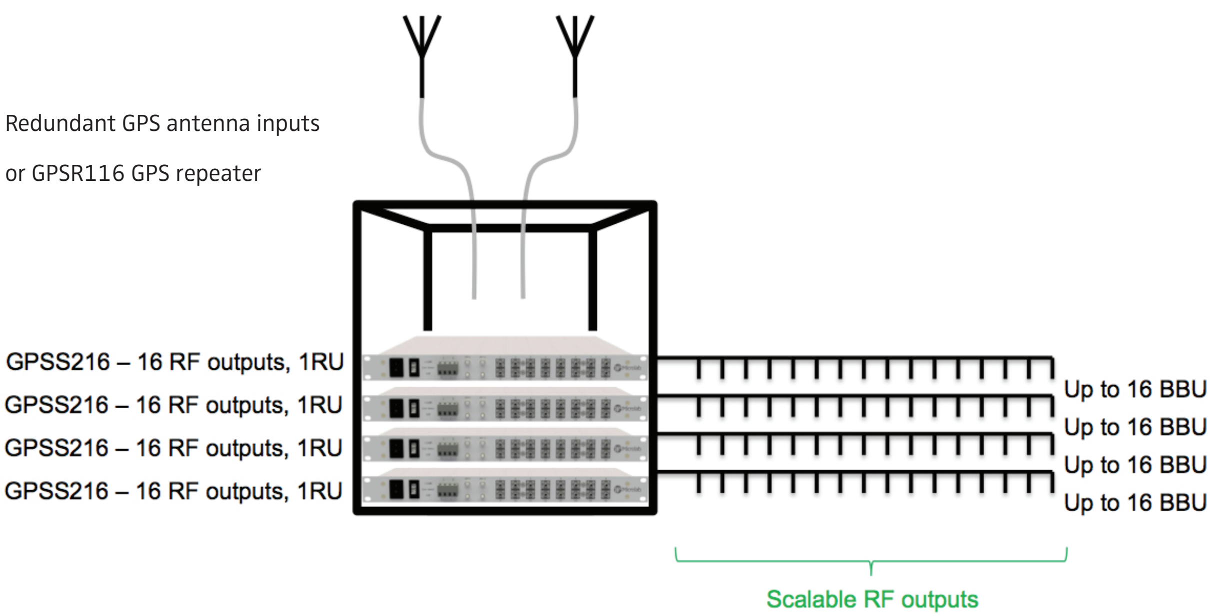


Fig. 6: Lossless GPS splitter provides scalable outputs

Summary

Microlab has developed Digital SkyTiming Technology™ to provide advanced GPS signal repeaters for wireless network timing applications. The technology uses a patent-pending approach to transport GPS signals digitally using a CPRI protocol.

The Microlab GPS Repeater systems support redundant inputs and outputs, with the ability to detect faults and switch over automatically, which can improve reliability, performance and uptime of C-RAN and DAS systems. The Microlab GPS Repeater systems include web-based software for remote monitoring and maintenance.

For more information, contact Microlab at www.microlabtech.com

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