1. GPS Transmitter System Functional Description

1.1. GPS Transmitter System Block Diagram

A block diagram of the GPS synchronized transmitter system is provided as a separate document and is referred to below.

1.2. GPS Timing Receiver and Antenna Subsystem

At the upper left of the block diagram is the GPS timing receiver and antenna subsystem. These units differ from the usual hand-held GPS receiver used for position location in that they have a precision ovenized oscillator that is phase locked to GPS standard time.

1.2.1. GPS Antenna

The GPS timing receiver picks up the transmissions from the GPS satellites using the GPS antenna connected to the receiver through a 75 Ω coaxial cable. For convenience in connecting the system, a front-panel connector is provided

1.2.2. GPS Timing Receiver

The GPS timing receiver is mounted inside the GPS-1 Synchronizer module and it draws its power from the BlackMax Rack.

The outputs from the GPS timing receiver are a 10 MHz sine wave and a 1 PPS (pulse per second) digital pulse both locked to GPS standard time within 50 nano seconds (0.000 000 050 seconds) or less. The green front-panel LED indicators for "GPS 10 MHz" and "GPS 1 PPS" indicate the presence of these signals.

Note, however, that these signals will be produced whenever the GPS timing receiver is operating, whether or not it is locked to absolute GPS time. Thus, the presence of these signals as indicated by the front-panel LEDs does not assure that the system is locked to GPS time. This can only be determined by monitoring the serial output of the GPS timing receiver, as described below in Section 3.2.3.

1.2.3. GPS Receiver Monitor Program Running on a PC

In the upper left of the block diagram is a desktop or laptop personal computer (PC) running a program that monitors and reports the status of the GPS timing receiver inside the GPS-1 Synchronizer module. As shown in the figure, the computer is connected through a standard serial cable to the front panel connector on the GPS-1 labeled "RS-232C."

1.3. GPS-1 Local Oscillator and Divider Chain

1.3.1. GPS-1 Local Oscillator

At the upper right of the block diagram is the GPS-1 local oscillator. This oscillator is a voltage-controlled crystal oscillator (VCXO), whose frequency and phase can be fine tuned by the application of a control voltage.

1.3.2. GPS-1 Local Oscillator Operating Modes

In normal operation, the synchronization circuitry (to be described below) keeps the GPS-1 local oscillator precisely phase locked with the 10 MHz and 1 PPS signals from the GPS timing receiver. If the GPS 10 MHz signal is not present, the synchronization circuit automatically switches the GPS-1 oscillator over to GPS-1 manual control mode. In GPS-1 manual control mode the oscillator no longer has the precision of a GPS oscillator, but rather, has the precision typical of a standard HAR transmitter. Note that the various frequency control modes mentioned throughout this chapter are summarized at the end of the chapter.

1.3.3. RF Divider Chain

The RF divider chain shown below the GPS-1 local oscillator divides the oscillator frequency down to the RF frequency of the transmitter. This signal is fed to the transmitter via the front-panel circular connector labeled "Output to Transmitter" and then travels through the circular cable through the rear of the transmitter cabinet to the Transmitter GPS interface adapter board inside the transmitter.

1.4. GPS to Local Oscillator Synchronization Circuitry

1.4.1. Synchronization Circuitry

The synchronization circuitry block shown near the top center of the diagram synchronizes the GPS-1 local oscillator to the GPS timing signals. This is accomplished by dividing both the 10 MHz GPS timing signal and the GPS-1 local oscillator signal down to the greatest common divisor, namely 10 kHz (10,000 Hz). The synchronization circuitry then uses a phase-locked-loop circuit to precisely control the phase and frequency of the local oscillator so that it is always precisely synchronized with the GPS timing signals.

1.4.2. RF Phase Degrees Control

The front-panel "RF Phase Degrees Control" connects to the synchronization circuitry and precisely changes the phase of the local oscillator relative to the GPS timing signals so that the phase of the RF output from the transmitter can be adjusted through the full 360 degrees. In fact, the range of the adjustment is 000 to 999 degrees, but use of values greater than 360 is both unnecessary and not recommended.

1.5. Transmitter GPS Interface

1.5.1. Transmitter GPS Interface Adapter Board

Shown in the lower right of the block diagram is a dotted line corresponding to the DRTXM3 Transmitter. Located in the transmitter is the Transmitter GPS Interface Adapter Board which processes the frequency control signals from the GPS-1 Synchronizer module to make them suitable for controlling the transmitter RF.

1.5.2. Transmitter Local Oscillator Switching Function

The transmitter GPS interface adapter board incorporates a switching function such that if the frequency control signals from the GPS-1 are present, the transmitter will be under GPS control, but if these signals are not present, the transmitter will automatically switch over to operate from its own local oscillator.

1.5.3. Transmitter Lock LED

The transmitter GPS interface adapter board also generates the "Transmitter Lock" signal which is fed to the front panel LED on the GPS-1 Synchronizer. When this LED is lit it indicates that the transmitter is operating properly from the signal being provided from the GPS-1 synchronizer. Note that it does not necessarily indicate that the system is locked to the GPS time signal, which can only be determined using the GPS receiver monitor program running on a PC.

1.6. Transmitter Module Functions

1.6.1. Audio Input, Limiter, and Low-Pass Filter

As shown in the left middle part of the block diagram, the audio signal from an external source (such as a digital recorder player) is input to the audio interface circuit which provides switching and amplification functions. The audio signal is then fed to an audio limiter, which prevents over modulation. This is followed by a three-pole low-pass audio filter which conforms to the FCC specification that between 3 kHz and 20 kHz the attenuation be 60 $\log_{10}(f/3)$, where f is the audio frequency in kHz.

1.6.2. Transmitter Local Oscillator and Divider

As shown in the lower right part of the block diagram, the transmitter local oscillator is used to generate a stable frequency at a multiple of the transmitters output frequency for use when the GPS module is not providing the control frequency, i.e., when the transmitter is operating in the stand-alone mode. The output of the oscillator is passed through a frequency divider circuit. For example as shown in the diagram, a 15.900 MHz crystal oscillator is used in conjunction with a ÷30 logic circuit to produce a stable and symmetric RF frequency of 530 kHz.

1.6.3. Modulator and Driver Stage

The audio signal from the limiter and low pass filter are fed to the modulator stage which is then fed to the class D driver stage along with the RF signal from the transmitter-GPS interface adapter board.

1.6.4. RF Output Filter

The modulated output of the driver stage passes through a seven-element low-pass RF output filter to attenuate harmonics to the FCC specification of better than 53 dB below 10 Watts. The filtered signal is terminated at the UHF-type antenna output connector.

1.6.5. Meter

A built in front-panel meter is provided to allow measurements of forward power, reflected power, and VSWR. This meter uses a 20 LED bar-graph display and a front-panel switch to select the function.

1.7. Summary of Frequency Control Operating Modes

The GPS synchronization system has several frequency control modes to ensure continuous operation of the system even when the mode of being fully locked to GPS time is not available. The following subsections describe these modes starting with the system operating in the fully-locked mode and continuing sequentially to the transmitter operating in stand-alone mode.

1.7.1. Fully-Locked Mode (Test Mode #1)

In the fully-locked mode, the precision oscillator in the GPS receiver is phase locked to timing signals coming from the GPS satellites. Both the GPS 10 MHz and GPS 1 PPS signals from the internal oscillator are processed by the synchronizer circuit so that the GPS local oscillator is phase locked to GPS time. The RF timing signals derived from the local oscillator are fed to the transmitter and control the RF driver so that the RF power output is phase locked to the GPS time, as desired.

1.7.2. Operating Mode Without GPS-1 Synchronizer Signal to Transmitter (Test Mode #2)

If the frequency control signals from the GPS-1 synchronizer are not present at the transmitter, the GPS interface adapter board automatically switches over to the transmitter's local oscillator. Operation in this mode is indicated by the front-panel "Transmitter Lock" LED being off. In this mode the phase of the system will drift so that there may be a waffling sound depending on the frequency error of the DRTXM3 local oscillator.

1.7.3. Operating Mode Without 1 PPS Timing Signal (Test Mode #3)

If the 1 PPS timing signals is not present, the system continues to operate at a *frequency* that is exactly locked to GPS time, but it may not be operating at a *phase* exactly locked to GPS time. Operation in this mode is indicated by the front-panel "GPS 1 PPS" LED being off. Operating in this mode will produce only a slight change in overall system operation. This change will be that the exact geographical locations of the nodes in the overlap region between two transmitters will be different from the positions when the phase is exactly locked. In general the positions of these nodes will remain fixed until the power to the GPS-1 is turned off and then back on again.

1.7.4. Operating Mode Without 10 MHz Timing Signal (Test Mode #4)

If the 10 MHz timing signal from the GPS timing receiver is not present, the system automatically switches over to the local oscillator in the GPS-1 Synchronizer. Operation in this mode is indicated by the front-panel "GPS 10 MHz" LED being off. The frequency error in this mode will be on the order of 10^{-6} or less. In this mode the phase of the system will drift so that there may be a waffling sound depending on the frequency error of the GPS-1 local oscillator.

1.7.5. Operating Mode Without Satellite Reception (Test Mode #5)

If there is no satellite reception, the system will continue to operate with the frequency and phase controlled by the ovenized oscillator in the GPS receiver. Operation in this mode can be detected by running the Trimble monitor program through the front panel RS-232C port. The frequency error in this mode will be on the order of 10^{-8} or less. Depending on the frequency error, the phase of the system will drift slightly so that, for example, two transmitters might be in phase one minute and out of phase a few minutes later. This change will mean that the exact geographical locations of the nodes in the overlap region between two transmitters will move slowly, or alternatively, with an AM receiver fixed in place, the signal will drift slowing in and out of phase. In general, this will produce little audible difference except for the short period of time when the signals are exactly out of phase, at which point there may be some slight fuzziness to the audio signal.