Theory of Operation

The vehicle tracking electronics assembly (08-0100-0100) provides communications as required by the PROTRAK, vehicle tracking system. This electronics assembly is installed as a "one per vehicle" type system and enables vehicle locations within a metropolitan area. Contained in each electronics assembly is an RF sub-assembly (08-0100-0130) that includes two VHF receivers operating from 88-108 MHz and one UHF transmitter operating from 450-470 MHz.

Reference will be made to the block diagram for the 08-0100-0130 assembly. Dual receivers are employed to provide space diversity during fading conditions. Simultaneous reception of telemetry data from a commercial broadcast station operating in the 88-108 MHz band re-assembles a transmitted message at a reduced bit error rate (BER). Both receivers are identical in circuit design and schematic presentation. The PWB design configuration offers the only differences in application of the two receivers. Receiver A is duplexed with the UHF transmitter while receiver B is a "stand alone" entity. The receiving systems are intended to recover telemetry data that is modulated on standard sub-carriers operating at 67 KHz and 92 KHz. This is an FM-FM system and in essence, requires demodulation twice in succession. These receivers provide this function.

Referring to the block diagram and receiver B, a received signal is amplified by the RF Preamp and the RF Amplifier. Both of these amplifiers are under AGC control to maintain a fixed input RF level to the mixer that is integral to the integrated circuit, SA626. The local oscillator is input to this mixer and is shared between the two receivers to provide phase coherency. The local oscillator consists of a Mini Circuits VCO and an LMX2301 PLL manufactured by National. Programming of this PLL is provided by the CPU card. This phase locked source operates at a frequency above the RF input frequency and provides a standard 10.7 MHz IF frequency that is filtered by ceramic filters, amplified, and finally limited in level. Initial FM demodulation is provided by a quadrature detector and is then buffered. A sub-carrier filter (band-pass) rejects the 10.7 MHz signal in addition to the base-band audio information, retaining only the sub-carriers.

Sub-carriers are input to the second IF integrated circuit (SA606) and are applied to a second mixer. It is at this point that the selection of the appropriate sub-carrier is made by the use of offset oscillators. The selected sub-carrier is translated up to a narrowband, 455 KHz IF system. It is then filtered, amplified, and limited in level to provide the input to a second quadrature detector. The demodulated output from the SA606 is applied to a 6^{th} order low-pass filter to remove the 455 KHz IF signal and retain the desired analog telemetry data. Through the use of a digital comparator, analog data is converted to digital data. The data is further conditioned by an 8 bit micro-controller and is output to the CPU card.

Operation of receiver A is identical to that of receiver B with exception of a shared antenna input. As required for system operation, this antenna is duplexed with the transmitter. The antenna that is attached to this port is of a "dual band" type and will perform equally as well on 450-470 MHz as 88-108 MHz. A functional part of this duplexer is to provide isolation between the UHF transmitter and receiver A as to avoid interference of operation .

The transmitter employs a phase locked VCO that operates directly at the desired output frequency. A VARIL VCO in conjunction with a NATIONAL PLL (LMX2325) provides the RF carrier source. Frequency programming of this PLL is performed by the CPU card. This VCO is modulated directly with telemetry data that is obtained from a digital filter. An 8 bit micro-controller receives telemetry data from the CPU card and provides a digital to analog conversion as part of a pre-modulation filter function. The analog data that is supplied as modulation to the carrier VCO undergoes a "cosine" low pass filter function that eliminates virtually all harmonic content related to the data input bit stream. This limits the final occupied RF bandwidth to that used for transmission in a 12.5 KHz channel. After the digital to analog conversion and prior to modulation of the carrier VCO, additional low-pass filtering is provided to eliminate any transient waveforms that may have been generated.

The phase locked carrier with modulation is amplified by means of class A pre-driver and driver gain stages. These amplifiers not only provide gain to an appropriate power level for input to the final power amp, but serve as a stage with minimum reverse transmission gain to isolate any RF load transients placed on the carrier VCO. The RF power amp raises the carrier to a 2 watt power level and is part of an output power leveling loop that includes an output coupler and power leveling logic. Output power can be set via a potentiometer setting. Use of this technique results in power stabilization over temperature and frequency. Finally, before transmission, a harmonic filter is employed to reduce all output harmonics of the carrier.

Description of Circuits Determining Frequency

The vehicle tracking electronics assembly (08-0100-0100) provides communications as required by the PROTRAK, vehicle tracking system. This electronics assembly is installed as a "one per vehicle" type system and enables vehicle locations within a metropolitan area. Each electronics assembly contains two VHF receivers operating from 88-108 MHz and one UHF transmitter operating from 450-470 MHz. Specific frequency assignments are made at the factory and are dependent upon the application locality.

Each electronics assembly contains circuit sub-assemblies that are dependent on coherent time and frequency information. As a result of this requirement, all electronics are slaved to a 10.000000 MHz Temperature Controlled Crystal Oscillator (TCXO) for generation of any subsequent sources. This TCXO is manufactured by Oscillatek , part number OSC-1A0, and has a stability of +/- 1.5PPM over the temperature range that exceeds FCC requirements.

Circuit sub-assemblies that are used in frequency generation and are dependent upon this TCXO consist of NATIONAL , phase locked loops U19(LMX2301TM) and U25(LMX2325TM). U19 is used as the primary LO for both VHF receivers and provides phase coherency to the data present at their outputs. This phase locked oscillator employs a Mini-Circuits VCO (pn# JTOS-200P) and operates from 98.7-118.7 MHz. U19 is used in generation of the UHF, transmitted carrier source. This phase locked oscillator uses a VARIL VCO (pn# VCO190_435MT) and is locked at UHF output frequencies spanning from 450-470 MHz. Both phase locked oscillators exhibit similar temperature stabilities as the factory calibrated TCXO.

Description of Circuits Suppressing Spurious and Harmonic Emissions

The vehicle tracking electronics assembly (08-0100-0100) provides communications as required by the PROTRAK, vehicle tracking system. This electronics assembly is installed as a "one per vehicle" type system and enables vehicle locations within a metropolitan area. Each electronics assembly contains two VHF receivers operating from 88-108 MHz and one UHF transmitter operating from 450-470 MHz. Specific frequency assignments are made at the factory and are dependent upon the application locality.

Sources of radiated, spurious emissions from the two receivers are suppressed by strategies employed in the design of a multilayer, printed wiring circuit board. Signal lines, including the single local oscillator used in conversion to a final IF of 10.7 MHz for both receivers, are contained on inner layers of the PWB and are shielded by alternating ground plane layers. This multilayer structure exhibits excellent suppression of spurious emissions. Additionally, shielded enclosures are provided for both receivers and the transmitter to aid in further reducing radiated emissions.

Transmitter frequency synthesis is generated by phase locking a carrier VCO directly at the output frequency. This eliminates all mixing spurs that would be representative of an up-conversion process. Further elimination of spurious components is provided by power limiting and leveling of the carrier output frequency. A leveling loop consisting of a wire-line coupler (U63), diode detector (D12), and error amplifier (U56B) maintains the output power at a constant level of 2 watts over temperature and frequency thus avoiding saturation. Finally, suppression of carrier output harmonics is provided by lumped component, 8 element low-pass filter.

Description of Digital Modulation, Filter Response, and Wavetrains

The vehicle tracking electronics assembly (08-0100-0100) provides communications as required by the PROTRAK, vehicle tracking system. This electronics assembly is installed as a "one per vehicle" type system and enables vehicle locations within a metropolitan area. Each electronics assembly contains a UHF transmitter operating from 450-470 MHz.

Digital data is provided for direct modulation of the UHF carrier in a Miller encoded data format at up to 9600 baud. Miller encoded data provides a transition on every bit, and unlike Manchester encoded data, provides a baud rate that is equivalent to the bit rate.

Data is received by a micro-controller (U58) which is programmed to provide a digital-to-analog conversion. In this process, the analog output data is wave-shaped to a half-cosine waveform and provides digital filtering. Modulation of the carrier VCO contains fundamental sine wave components of the data stream with no harmonic content. As a result of digital filtering, bit timing is synchronized, intersymbol interference is minimized, and group delay is flattened.

This technique minimizes the occupied bandwidth of the output RF spectrum. The continuous transitions contained in the data wavetrain allow for AC coupling and direct modulation of the carrier VCO resulting in a low distortion, symmetrical RF spectrum.