## OPERATIONAL DESCRIPTION

Signal booster systems typically work into a distributed antenna system (DAS) or leaky-feeder system. Individual antennas used in a DAS in this frequency range exhibit a gain of 0 dBi or less and, with only 2 antennas and a splitter and cable, the antenna system gain would be -6 dBi. In a leaky-feeder system, coupling loss from the cable ranges from 50 to 80 or more dB which would provide an effective antenna system gain of -50 to -80 dBi. Licensees are aware of the 37 dBm ERP limitations and we will work with them on system designs.

Signal boosters extend radio coverage into areas where abrupt propagation losses prevent reliable communication. The system receives an RF signal, raises its power level, and couples it to an antenna so that it can be re-radiated. The TXRX model 611-70 channelized signal booster is designed to operate in the 450 to 470 MHz range. The emission designators and modulations the system is designed to accommodate are listed in **Table 1**. The system is based on a module design with each module capable of handling one uplink and one downlink channel simultaneously. The size of the system can be tailored to the customers needs by increasing or decreasing the number of modules used. Each module is bi-directional with one downlink and one uplink signal branch. Each of the two branches in a module are independently tunable to their required pass frequency via software interface. Signal flow through the system is illustrated with the signal flow block diagram.

### Downlink / Uplink Input Signals

Downlink and Uplink input signals are applied to a distribution amplifier 3-22340. This is an ultra-low noise high linearity amplifier with a gain of 18.9 dB. Refer to schematic 3-22341. Following the distribution amp is a 6-way power divider which is used to distribute the signal to individual channel modules. Downlink signals are applied to the down converter board of a downlink branch while uplink signals are applied to the down converter board of an uplink branch. Any unused output ports of the 6-Way should be terminated with a 50 ohm load. Signal processing within the channel module is discussed in the Channel module section below.

### Channel Module 3-22322

The channel modules are bi-directional with each module containing one downlink branch and one uplink branch. The branches are functionally identical because the same set of circuit boards are used in each branch. The uplink and downlink branches can work on different frequencies within the modules passband (450 to 470 MHz) but for either branch the input and output signals will be the same frequency.

Each branch consists of four boards; Digital, Local Oscillator, Down Converter, and Up Converter. RF signals enter the branch at the down converter board where they are filtered, amplified, and converted into a 70 MHz intermediate frequency. The digital board digitizes the IF signal with an ADC. The digitized samples are applied to a programmable gated array for digital filtering. The filtered signals from the array are converted back into analog by a DAC and output to the up converter board. The up converter board converts the IF back into the original UHF signal and outputs it from the module. The Local Oscillator board generates the reference signals for mixing and sampling. The mixing frequency can range from 380 to 400 MHz and is determined by the user via interface with the micro controller on the digital board. Signal flow through a module branch is discussed in detail below.

#### DOWN CONVERTER BOARD

A single UHF signal in the 450 to 470 MHz range is applied to the channel branch at the down converter board at J2. This input signal is first passed through the digital attenuator UI which is a broadband 6-bit GaAs IC Digital Attenuator. RF is input to the device at pin 6 and output at pin 13. Attenuation is controlled with a serial interface at pin 3. The attenuation range for this device is from 0.0 db to 31.5 dB in 0.5 dB increments. The first amplification stage is U3 which is a high performance, ultra low noise figure, high linearity amplifier stage. The gain of this stage is 24 db. A second 6-bit digital attenuator follows the amplifier which provides an additional range of 0.0 dB to 31.5 dB of signal attenuation. The attenuation control input (serial) for both attenuators are tied together and sourced from the Channel Module Micro controller U6 located on the digital board. This arrangement allows the attenuation value of both attenuators to always be set to the same value. Following the second attenuator is another low noise amplifier stage U4. The gain of this stage is 31 dB.

The output of the amplifier stage U4 is applied to the RF input of the active mixer U7 for down-conversion to a fixed IF frequency of 70 MHz. RF is input to the mixer at pin 3 and the LO signal is input at pin 15. The source of the LO signal is the Local Oscillator Board at J3 (see schematic 6-22312). The IF signal is output by the mixer at pins 10 and 11 and is the difference between the RF signal and the LO signal. The differential output of the mixer is matched to the next stage by T1.

The IF signal is coupled into the shielded portion of the circuit board by T1 and is applied to amplifier U9. The gain of this stage is 15.5 dB. After amplification the IF signal is passed through a SAW-type bandpass filter FLI which has a 70 MHz center frequency and a 2 MHz bandwidth.

The next stage U8, is an AGC amplifier with built in detector. The AGC amplifier detects its output level and adjusts its internal attenuation to keep the output level at +5 dBm; a level suitable for digitizing by the following ADC. The built-in detector monitors the AGC gain control and sends a voltage to comparators U11A and U11B where it is monitored by the Channel Module Micro controller U6 located on the digital board. The interface to the Micro controller consists of two digital signals (*SIGNAL low and *SIGNAL high) which indicate if the AGC amplifier is out of its limits. The limits are set to keep the AGC amplifier in its most linear region by applying digital attenuation in the RF front end as needed. Input signals of approximately -70dBm will just reach the AGC level. Signals significantly above -70dBm will be attenuated by the IF AGC and front-end RF attenuators. Signals below -70dBm will not be at the maximum level into the digitizer and may result in less than maximum final output power from the module.

The output of the AGC amplifier at pin 10 is coupled through T3 to the low-pass filter FL2. After filtering the IF signal (ADCin+ / ADCin-) is coupled through T2 to the digital board via connector J2.

DIGITAL BOARD

The IF signal output from the down converter board arrives at the digital board at connector J3. The signal is applied to an analog to digital converter U1 where it is converted to a digital signal. U1 is a 14 bit A/D converter.

The digital signal is passed into a Field Programmable Gate Array (FPGA) U5A/B/C/D where it is digitally mixed with another signal to move the digital intermediate frequency (IF) signal down to baseband and separate it into in-phase and quadrature components. The in-phase and quadrature components are both low pass filtered by a programmable set of filters to achieve the desired pass bandwidth and stopband rejection. The power of the resulting signal is measured and digitally adjusted to the desired level. The In-phase and quadrature components of the signal are then digitally mixed again with a signal to up convert the signal to a digital IF that can then be turned into an analog signal.

The output of the FPGA continues on to a digital to analog converter U4 where the analog signal is re-created. The IF signal outputs from the DAC at pins 20 and 21 (DACout+ / DACout-). The IF signal exits the digital board at J2.

UP CONVERTER BOARD

The IF signal enters the Up Converter Board at J4 and is routed to the shielded area of the board where it is coupled by T1 to the first filter stage FL4. T1 provides impedance matching. FL4 is a low pass ceramic filter. The IF amplification stage is U1 which has a gain of 22 dB. The amplified analog signal is then filtered by a SAW-type bandpass filter FLI which has a 70 MHz center frequency and a 2 MHz bandwidth. The IF signal now leaves the shielded area of the circuit board and is coupled to the mixing stage by T2 which provides a differential input for the mixer.

The mixer is designated as U2 and is a high linearity type optimized for low distortion and low LO leakage. The IF is input to the mixer at pins 1 and 2 and the LO signal inputs at pin 15. The source of the LO signal is the Local Oscillator Board at J4 (see schematic 6-22312). This is the same Local Oscillator (LO) frequency, which was used in the down conversion process, so that the original UHF frequency is re-created. The RF signal is output from the mixer at pins 12 and 9 and is the sum of the IF signal and the LO signal. The differential output of the mixer is matched to the next stage by T3.

The next stage in the signal path is an amplifier U5 which has a gain of 21.4 dB. Following the amplifier is filter FL2 which is a ceramic filter with a 20 MHz wide passband to reduce LO “bleed-through”. After filtering the signal is amplified by U3 which has a gain of 21 dB. further filtering is provided by the ceramic low pass filter FL3. The final stage of amplification is U4 which has a gain of 18 dB. The RF signal leaves the up converter board (and the channel module) at connector J5.

| Emission Designator | Type of Transmission | Modulation |
|---|---|---|
| F1D | Data | RD-LAP [9.6,19.2] (4-L FSK)<br>Dataradio 50 KHz (16FSK)<br>P25 Phase 1 (C4FM) Control/Data |
| F1E | Voice | 4-L FSK (Voice)<br>P25 Phase 1 (C4FM)<br>Tyco-M/A-Com EDACS (GFSK)<br>Securenet (Encrypted Quantized Voice) |
| F3E | Voice Analog | |
| FXE | Voice | MotoTrbo, Kenwood, ICOM DMR |
| FXD | Data | ETSI DMR 2-slot TDMA |
| G1E | Voice | F4FM (Phase 2 P25 TDMA, Tetrapol) |
| G1D | Data | F4FM (Phase 2 P25 TDMA, Tetrapol) |
| D7W | | TETRA, P25 Phase 2 (pi/4 [W]CQPSK) |
| D7D | | Motorola HPD |
| D1E | | CQPSK |
| D1W | | LSM (Motorola Linear Simulcast) |
| F9W | | Tyco-M/A-Com OpenSky (F4FGSK) |
| D1E | Voice | WCQPSK (Simulcast) |

**Table 1:** Emission Designators, Type of Transmission, and Modulations for the Channelized Signal Booster.

### Downlink / Uplink Output Signals

Downlink signals leave the channel module at the DL OUT connector and are applied to a power amplifier 8-22290 which has a typical gain of 35 dB. After amplification, signals from multiple modules are combined by a Hybrid Combiner 3-18317-1 and fed into combline filtering before being applied to an antenna. Uplink output signals leave the channel module at the UL OUT connector and are applied to an active combiner 3-22319. The active combiner amplifies and combines signals from multiple modules. Following the active combiner is combline filtering.