# OPERATION OF THE LARUS MODEL 9000, 5.7 GHz DIRECT SEQUENCE SPREAD SPECTRUM RADIO TRANSMITTER.

1. Summary. This transmitting system (hereafter referred to as Atransmitter≅) provides point-to-point transmission of IF/RF carriers, modulated with a serial bit stream designed to process either four E1 or four T1 multiplexed carriers or digital baseband signals. The unit under test is designated for E1 carrier traffic. This is not a Apulsed≅ type transmitting system; the type of carrier modulation is 16QAM.

The IF transmit frequency is at 140 MHz, where the modulated transmit carrier is spread and translated up to the radio transmit center frequencies of 5752.5 MHz (TX Low) or 5822.5 MHz (TX Hi). The IF receive frequency is 70 MHz.

The transmit-receive operating mode is full duplex, single channel within the ISM band, occupying the bandwidths of 5752.5 ∀ 22.5 MHz and 5852.5 ∀ 22.5 MHz. For the frequency plan of this transmitter, see Figure 1.

The Model 9000 system consists of two separate rack-mountable modules: the RF and Control modules. The **RF Module** contains the transmitter IF/spread circuits (to be described in detail below.The **Control Module** is utilized for the status, control functions and baseband/IF modulation/signal processing of the transmitter. It contains the E1/DS1 mux , modulator/demodulator circuits and receive AGC.

The antenna that connects to the bulkhead is not part of the transmitter. It is provided and installed by the customer in compliance with FCC regulations, as stated in the Operating and Installation Manual.

## 2. List of transmitter main functions.

1. 16QAM modulator to modulate the 140 MHz IF carrier with the incoming serial bit stream of the four multiplexed E1 carriers coming from the E1/DS1 Mux.
2. Spreading circuits that include the Code Multiplier containing the access code, the chip filter to attenuate unwanted products and to define the spectral shape of the modulated carrier.
3. IF chain to provide amplification, equalization and gain control/stabilization of the IF carrier before translating up to the 5.7 Ghz band. The RF drive level to the output power amplifier is set here as required, consistent with antenna size, or EIRP.
4. RF chain provides frequency translation of the 140 MHz IF, bandpass filtering and final amplification of the translated carrier at the 5.7 Ghz band.
5. The transmit power amplifier provides rated power to the antenna through th diplexer which in turn feeds the receiver at the LNA input.

## 3. Transmitter functional description.

16QAM Modulator. The purpose of this circuit (located in the Control Module) is to quadrature-amplitude modulate the 140 MHz carrier with the serial bit stream, that contains the information of the four multiplexed E1 carriers. Each E1 baseband carrier is 2.048 MHz, thus the baseband width of the multiplexed serial bit stream entering the I-Q modulator is 8.192 MHz (+ some additional BW for overhead bits due to coding and control purposes). The bit stream is converted to symbols here so that one symbol corresponds to four bits of information. The baseband bandwidth is 2.048 MHz + 0.213 = 2.2613 MHz. The 140 MHz IF bandwidth of the modulated carrier is 2x2.2613 = 4.522 MHz. This IF signal at 140 MHz is fed to the Spread Spectrum Code Multiplier.

Spread Spectrum Code Multiplier. The function of this circuit (located in the RF module) is to spread the spectrum to achieve a processing gain of at least 10 dB. Spreading is accomplished by multiplying the modulated IF carrier with a pseudo-random (PN) pulse sequence. Because of the randomness of baseband data stream and the spreading PN pulse sequence, the spectrum is noise-like with *no distinct spectral lines*. The system is designed to achieve a theoretical processing gain of about 10.45dB, which is obtained as follows. The null-to-null IF bandwidth (or main lobe bandwidth) before spreading is 4.522 MHz. The chip width, Tc of the spreading pulse is 44.19 nsec, thus the null-to-null chip bandwidth of the
spreading spectrum at IF is 2/Tc = 45.25 MHz. These two timing waveforms are multiplied, hence, considering convolution in the frequency domain, the theoretical spectral null-to-null bandwidth is the sum of the individual bandwidths:

$$Bw_{(convolved)} = Bw_{(modulation)} + Bw_{(chip)} = 49.77 \text{ MHz} = Bw_{(spread)}$$

In practice, the spread bandwidth is narrower because of the sharp filtering in subsequent stages. The sidelobes and nulls and band edges are effectively filtered out, and based on measured data, the nominal bandwidth is taken here as 45 MHz.

The theoretical processing gain, Gp is the ratio of signal bandwidth after spreading to the bandwidth before spreading. Hence,

$$Gp = 49.77/4.522 = 11 \text{ or } 10.41 \text{ dB}$$

The measured typical transmit output spread spectra of a TX low unit is shown in Figure 2.

De-spreading is also taking place in the RF module. The de-spread 70 MHz receive signal is then fed to the Control Module for the receiver demodulator functions through a coaxial cable. In addition, this cable also carries the following signals:

a. 4.5/10.7 MHz modulated telemetry/control signals to carry information: terminal diagnostics and local/remote faults (transmit power level set).

b. –24/–48 VDC, 2A battery power supply line to the transmitter.
c. 140 MHz IF from the 140 MHz I/Q modulator/VCO from the Control Module to the transmitter.

IF Amplifier Chain. Amplification, equalization, gain/level control and gain setting takes place in the 140 MHz transmit IF amplifier chain. Equalization helps to reduce inter-symbol interference thereby improving BER performance. The gain control helps to stabilize the drive power at the 5.7 Ghz power amplifier input over the operating environment. The gain setting is entered manually by the operator via keyboard. The accuracy of this attenuator is about ∀ 0.4 dB.

RF Amplifier Chain. This contains the 140 MHz to RF mixer/upconverter stage, waveguide bandpass filter, transmit RF amplifier and diplexer. The upconversion is low side LO injection. The RF amplifier provides linear gain and power level of nominal +23 dBm for undistorted transmission at the output frequency. The waveguide filters provide the out-of-band attenuation needed to suppress unwanted spurious: local oscillator leakage and all other mixing/intermodulation products.

Diplexer. Additional filtering of the transmit signal and the required transmit-receive isolation is provided by the waveguide diplexer according to the frequency plan shown in Figure 1. The transmit spectrum at the diplexer port is shown in Figure 2.

Setting transmit power. The transmit power at the diplexer port is set with the keyboard of the display terminal according to the desired EIRP. Nominal power at the bulkhead is +23 dBm at –7 dB attenuator setting. As an example, for a 28 dBi antenna and interconnecting cable loss of 1 dB, the EIRP is +23 -1 +28 = 50 dBm or 20 dBw (100 W).

The +23 dBm can be attenuated in 1 db steps. The value of attenuation can be observed on a monitor display intended for remote reporting, status and control.

Setting the EIRP is the responsibility of customer, who installs the antenna and owns and operates the system.

## 4. Receiver functional description.

Diplexer/RF filter. The received frequency is filtered and fed to the down converter, contained in the RF module. The received RF spectrum at the diplexer output is as shown in Figure 1. The purpose of the RF filters is to:

a. Filter out unwanted spurious products and responses (image response).
b. To provide the necessary transmit-receive isolation.

Up/Down Converter. This function is contained in the RF module. It provides LNA preamplification and the translation from RF to the 70 MHz receive IF.

The downconverted IF spread-spectrum signal is then applied to the de-spreader. The receiver control circuits generate early, timely and late codes to correlate the receive signal plus an uncorrelated signal utilized for AGC control.
The de-spread 70 MHz signal is fed to the Control Module through the multiplexer cable, where processed further.

<u>Receive IF signal processing</u>. At the controller interface, the extracted 70 MHz signal is passed through a SAW filter. This filtered signal is the downconverted to 6 MHz through a mixer/AGC circuit. The downconverted signal is then applied to the demodulator chip.

The demod chip performs the A/D conversion function. The demodulated digital signal is then converted to four E1 digital streams by the E1 multiplexer.

## 5. Controller/Telemetry functions.

The controller circuits provide the data interfaces and microcontroller functions for local control and housekeeping chores.

The signal transmission between the RF and Control module is via a coaxial interface cable that carries the telemetry signals with the monitoring/control information. The telemetry signals frequencies within the system are:

| | |
|---|---|
| RF Module to Control Module: | Transmit: 4.43 MHz, Receive: 10.7 MHz |
| Control Module to RF Module: | Transmit: 10.7 MHz, Receive: 4.43 MHz |

These telemetry channels are processed in transceivers at each end (e.g., in each the RF and Control module). They contain information of system operational parameters: transmit level, spreading code, etc.

This scheme allows the separation of RF and Control unit as much, as 30 feet via the coaxial interface cable. Extensive filtering of telemetry channels is provided in the transceivers to eliminate any interference between the IF channels and the telemetry channels that are simultaneously present in the same cable.

**REFERENCE**. MODEL 9000 E1/DS1 Spread Spectrum 5.78 GHz Digital Microwave Radio System, Volume 1, System Description.

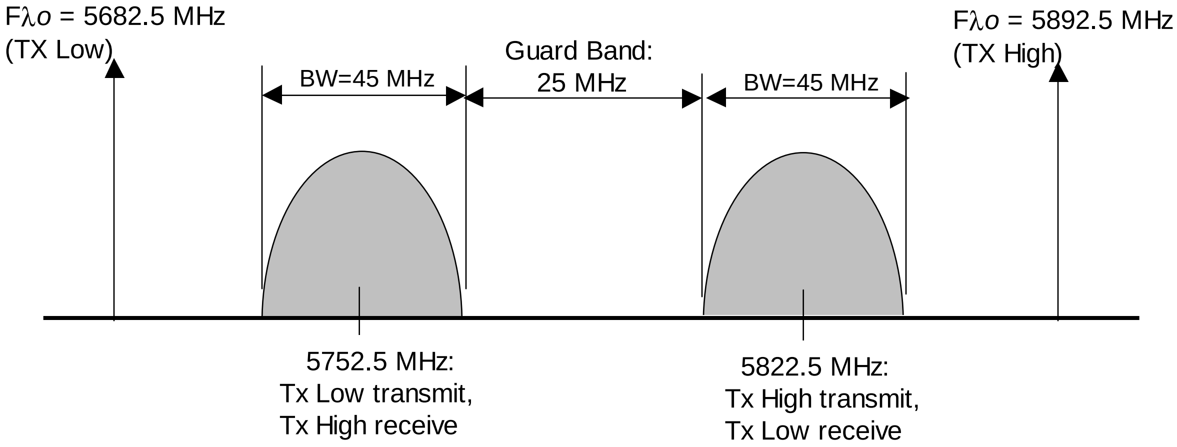

Figure 1. Frequency plan and spectrum of the MODEL 9000 digital spread spectrum radio.

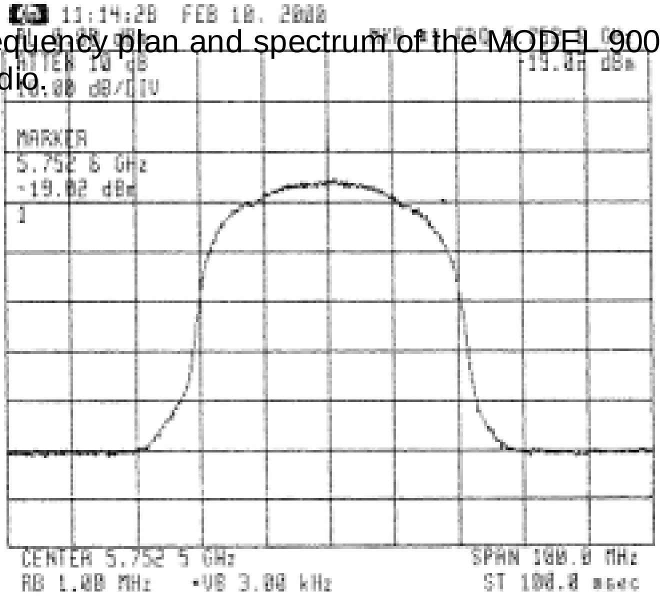

Figure 2. Typical spectrum of the Model 9000 system. The TX Low spectrum is shown here.