EXHIBIT F

(Support Information, PROCESSING GAIN)

PROX-100 Theory of Operation

ProNet Tracking Systems

Proximity Transceivers

Model PROX-100C

And

Model PROX-100W

Theory of Operation

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Introduction

ProNet Tracking Systems' Campus-Trac System is a Wireless Personal Security System developed for operation in a campus environment. The system operates in the 902 to 928 MHz frequency band, and employs frequency-hopping to obtain diversity. Proximity Transceivers are installed inside buildings or in small open areas to continuously scan for test and alarm signals from Personal Alarm Devices (PAD's). The PROX-100C is designed to be mounted horizontally on ceilings, while the PROX-100W is designed to be mounted vertically on walls. The only differences between the units are the antennas and plastic housings.

2. General Theory Of Operation

2.1 Scanning Receive Function

In normal operation, the PROX-100C continuously scans one of four interleaved sets of 50 frequencies between 904.800 and 914.750 MHz for activity. If activity is detected on a given channel, an attempt is made to synchronize to the 15625 bit per second FSK signal that is generated by all ProNet Campus-Trac radios. If synchronization is achieved, the data is extracted from the signal and a report is generated and passed on to a Group Concentrator by a twisted pair wired connection. Scanning is resumed immediately after the data has been extracted or the synchronization has failed.

2.2 Transmit Function

Upon command from the Network Control Computer (NCC), the PROX-100C transmits acknowledgement signals to Personal Alarm Devices in response to test or alarm messages. The PROX-100C may also be commanded by the NCC to transmit a calibration signal that is heard by all other receivers in the system within range. This process allows the proper operation of all system components to be regularly verified, and provides a means for estimating the expected path losses between different locations in the system.

2.3 Digital Control Function

The PROX-100C contains a microprocessor responsible for the control of the radio receiver and transmitter and communication with the Group Concentrator. Communication with the Concentrator is via a twisted pair cable using a commercially available Echelon LonWorks Neuron processor and twisted pair transceiver.

3. Top Level Block Diagram and Physical Configuration

Figure 1 is the block diagram of the PROX-100 units. Figure 2 shows the physical configuration of the PROX-100C. Note that the "C" in the model number indicates that this version of the Proximity Transceiver is to be mounted horizontally in ceilings. The physical configuration of the PROX-100W, for mounting to walls, is shown in Figure 3.

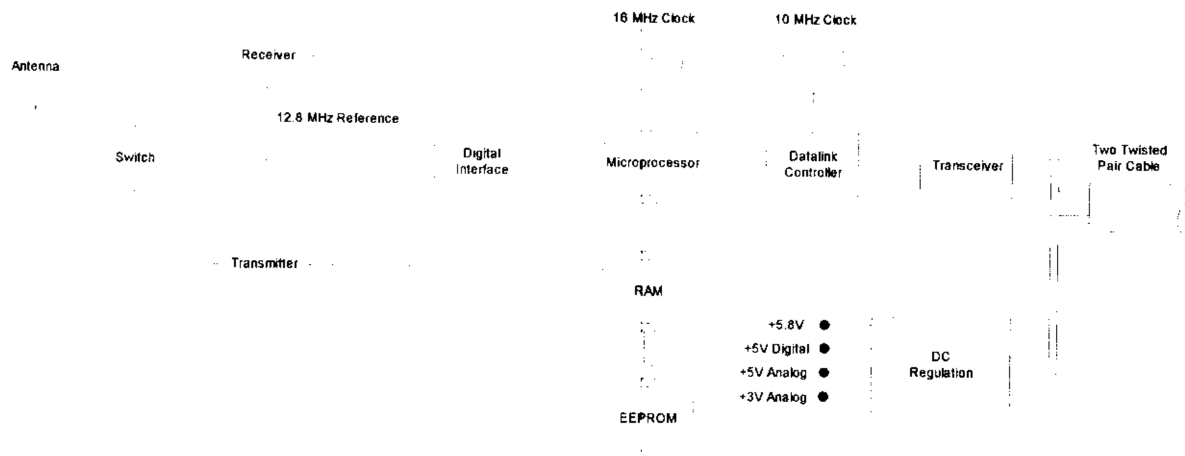

Figure 1. PROX-100 Block Diagram

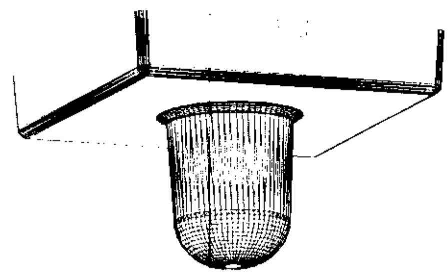

Figure 2. PROX-100C Physical Configuration

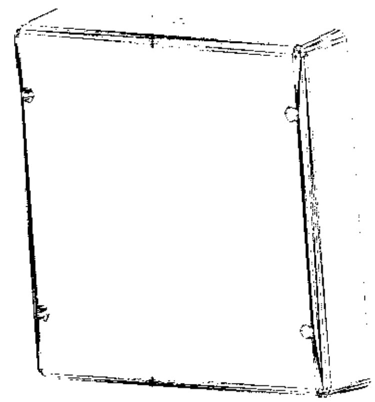

Figure 3. PROX-100W Physical Configuration

4. Detailed Block Diagram and Functional Description

4.1 Radio Section

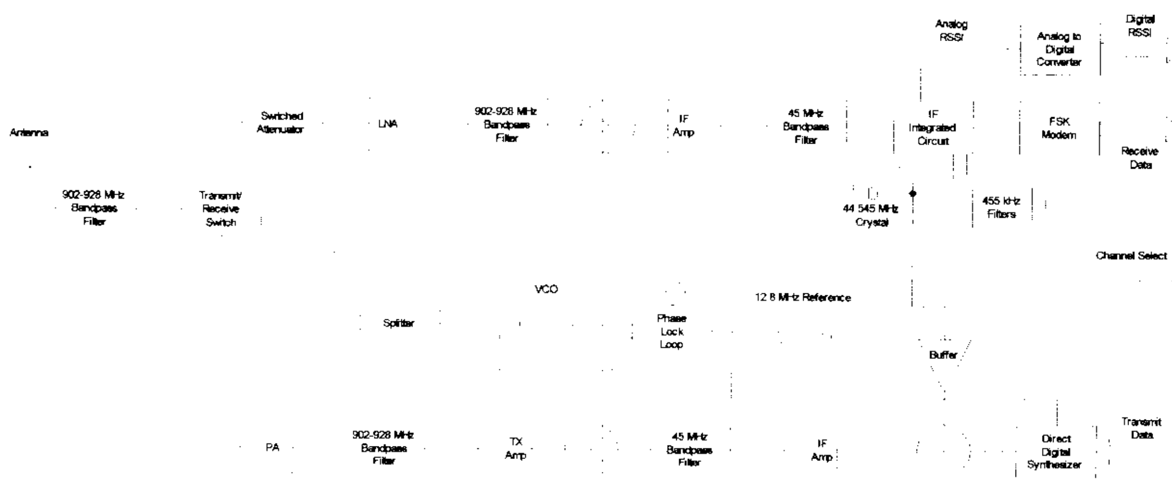

Figure 4. Block Diagram of PROX-100 Radio Section

Figure 4 shows the detailed block diagram of the PROX-100 radio section. The radio uses FSK modulation at 15625 bits per second, and utilizes channels of 25 kHz bandwidth. The primary function of the PROX radio is to continuously scan all 50 of the channels for test or alarm activity generated by other Campus-Trac radios. It is, however, occasionally called upon to transmit for acknowledgment or system test and calibration purposes. All transmissions are hopped over 50 channels chosen from a pseudo-random table, with equal transmission time on all channels. Transmissions are typically of 40 to 90 ms duration on a given channel, and never exceed 400 ms duration. The radio is half-duplex; meaning it is either receiving or transmitting at any given time.

4.1.1 Antenna

The only differences between the PROX-100C and PROX-100W radios is that the antennas and plastic housings are different. In both cases, the antennas are completely covered by the housings, and are not accessible by the user.

4.1.1.1 Ceiling-Mounted PROX-100C Antenna

In the PROX-100C ceiling-mounted unit, the antenna is a small "rubber-duck" vertical antenna that protrudes down from a ground plane parallel to the ceiling. The gain of this antenna configuration is 2 dBi.

4.1.1.2 Wall-Mounted PROX-100W Antenna

In the PROX-100W wall-mounted unit, the antenna is a microstrip patch mounted parallel to the wall. The gain of this antenna is 4 dBi.

4.1.2 Tunable Local Oscillator

4.1.2.1 12.8 MHz TCXO

A temperature compensated crystal oscillator (TCXO) at 12.8 MHz is used as the reference frequency for the phase-lock loop and direct digital synthesizer. This reference oscillator is specified to be accurate to within ± 2.5 PPM over the temperature range of –30 to +75 C.

4.1.2.2 Voltage Controlled Oscillator

The local oscillator signal originates in the voltage controlled oscillator, which is tuned between 859.800 and 869.750 MHz at a constant 45 MHz offset from the receive or transmit frequencies in the 904.800 to 914.750 MHz range.

4.1.2.3 Phase Lock Loop

The phase-lock loop integrated circuit tunes the voltage-controlled oscillator to a given channel based on the control words received from the microprocessor. Tuning is achieved in 600 μs.

4.1.3 Receiver

The receiver architecture is dual-downconversion, with intermediate frequencies of 45 MHz and 455 kHz. The first conversion is performed in a diode mixer, the second conversion is performed in the IF integrated circuit, which generates its own LO signal using a 44.545 MHz crystal oscillator.

4.1.3.1 902-928 MHz Bandpass Filter

A three-section ceramic bandpass filter has been used at two different points in the radio receiver front-end. Note that the filter that appears before transmit/receive switch also appears in the transmit signal path.

The selected filter has excellent out-of-band rejection to eliminate undesired signals received at the antenna and reduce emissions other than the desired RF output during transmission.

4.1.3.2 Transmit/Receive Switch

An integrated circuit GaAs MESFET switch is used to switch the antenna between transmit and receive functions. The unit does not transmit and receive simultaneously.

4.1.3.3 Switched Attenuator

A switched attenuator is included in the front-end of the receive chain to increase the dynamic range of the receiver. If the receiver detects high level signals present at the antenna, the attenuator is activated to allow the accurate measurement of the received signal strength.

4.1.3.4 First Downconversion Mixer

A diode mixer has been selected at this stage in the receive chain to preserve a high third-order-intercept at the input of the receiver. The mixer converts the incoming RF signals to a fixed 45 MHz first intermediate frequency using the tunable local oscillator signal.

4.1.3.5 IF Amplifier

Following the mixer, a single-transistor amplifier is used to boost the IF signal level 20 dB prior to bandpass filtering.

4.1.3.6 45 MHz Bandpass Filter

At the 45 MHz intermediate frequency, a monolithic crystal filter with is used to limit the bandwidth of the signal to 30 kHz prior to passing it to the intermediate frequency integrated circuit.

4.1.3.7 Intermediate Frequency Integrated Circuit

The intermediate frequency integrated circuit (IFIC) performs several functions. Using an external crystal, the IFIC generates the second local oscillator signal at 44.545 MHz. This LO is used to convert the first IF of 45 MHz into the second IF of 455 kHz. Several stages of limiting gain and two stages of 25 kHz wide filters prepare the signal for FM demodulation. This demodulation is performed in the IFIC using an external quadrature coil. The received modulation signal is then passed on the FSK modem. Additionally, a received signal strength indicator (RSSI) signal is produced in the IFIC and passed to an analog-to-digital converter.

4.1.3.8 FSK Modem

The FSK modem integrated circuit converts the received modulating signal into a data bit stream that is passed along to the microprocessor. The conversion involves synchronization based upon zero-crossings in the modulation, which allows bit decisions to be made at optimum times.

4.1.3.9 RSSI Analog-to-Digital Converter

An eight-bit analog-to-digital converter is used to convert the RSSI signal generated by the IFIC into a digital form which can be read as desired by the microprocessor. To facilitate fast channel scanning, a converter with 2.5 μs conversion time and parallel read has been selected.

4.1.4 Transmitter

In a manner quite analogous to the receiver, the transmitter uses a dual-upconversion architecture. The signal originates in a direct digital synthesizer centered about 455 kHz, and is then converted to 45 MHz and finally to the desired RF frequency in the 904.800 to 914.750 MHz range. Transmit power never exceeds one watt, and neither of the two antennas used in the PROX-100 units has gain in excess of 6 dBi.

4.1.4.1 Direct Digital Synthesizer

The FSK signal is originally generated in the direct digital synthesizer (DDS) integrated circuit. The microprocessor directs the DDS to generate either one or the other of two tones on either side of the center frequency of 455 kHz. The 12.8 MHz TCXO signal is used as the clock, and this signal is responsible for the frequency accuracy of the two tones.

4.1.4.2 First Upconversion Mixer

In the first upconversion mixer, the output of the DDS is mixed with the crystal oscillator signal at 44.545 MHz that is produced by the IFIC. The result is an FSK modulated signal centered at 45 MHz.

4.1.4.3 IF Amplifier

Prior to filtering, the transmit IF signal is boosted 20 dB in amplitude by the IF amplifier.

4.1.4.4 45 MHz Bandpass Filter

A monolithic crystal bandpass filter is used to reduce the bandwidth of the transmit signal to 25 kHz, and to remove the image signal at 44.090 MHz and local oscillator signal at 44.545 MHz.

4.1.4.5 Second Upconversion Mixer

A second mixer is used to convert the transmit signal to the final RF frequency in the 904.800 to 914.750 MHz range. The tunable LO signal is used to select the exact channel that is used for any transmission.

4.1.4.6 Power Amplifier

Two stages of amplification boost the transmit signal level to a nominal 28 dBm at the radio output port. The transmit power level will never exceed 30 dBm (one Watt).

4.1.4.7 902-928 MHz Bandpass Filter

A three-section ceramic bandpass filter has been used at two different points in the transmitter signal chain. As mentioned above in the receiver section, one of the filters is shared between the receiver and transmitter. The selected filter has excellent out-of-band rejection to reduce undesired emissions.

4.2 Digital Section

4.2.1 Microprocessor

The microprocessor portion of the digital section is composed of a 16-bit digital signal processor, a 32k x 8 EEPROM for code storage and two 32k x 8 RAM's. The DSP operates from a 16 MHz clock at a 16 MHz instruction rate. The functions performed include control of the radio section (frequency tuning, transmit/receive control, and attenuator control), receive data decoding, and transmit data generation. The DSP communicates with the datalink processor via a half-duplex, 4800-bits/sec serial port.

A field-programmable gate array (FPGA) is used as the digital interface between the digital section and the radio section. Its primary function is address decoding and latching of commands.

4.2.2 Datalink Processor

The datalink processor is a Neuron microcontroller running at 10 MHz. It communicates with the DSP via a 4800-baud, half-duplex serial port. Communications with the concentrator is via a free topology, 78-kbits/sec Manchester encoded serial link using the LonWorks protocol.

4.2.3 Datalink Transceiver

The datalink transceiver is an isolated, differential 78-kbits/sec twisted pair line interface.

5. Precautions Taken to Avoid Interference

5.1 RF Filtering

The transmit signal passes through two three-section ceramic filters before reaching the output port. These filters greatly reduce spurious signals, harmonics, and out-of-band transmitter phase noise.

5.2 Shielding

Critical components on the printed circuit board are enclosed in board-mounted shielding cans. The entire board is then contained in a shielded enclosure formed by the coated plastic housing and the antenna ground plane.