TRAKUS

Transceiver Functional Description Document

Functional Descriptions

General

ISM Band Radio Link for ELAPS

The Tower Transceiver (TT) and Player Patch (PP) were developed as part of a microwave radio link operating in the Industrial, Scientific, & Medical (ISM) band for spread spectrum transmissions at 2.4 GHz to 2.485 GHz. The transceivers were developed for an Electronic Local Area Positioning System (ELAPS) which uses pairs of TT's as delta time of arrival (ΔTOA) sensors to determine exact locations of multiple PP's within a defined viewing area. Multiple PP locations are determined based on TOA correlation data called Digital Signal Processing Records (DSPR's). Location, Velocity, and Acceleration (LVA) calculations are made from DSPR's and then grouped for each PP and used as statistics for real-time display and amassed in a database. The Trakus system will be owned and operated by Trakus personnel and will not be for sale to the consumer market. However, the digital data that is collected by the Trakus system will be sold to interested consumer markets (i.e. Television/Sports networks, gaming and internet companies etc.).

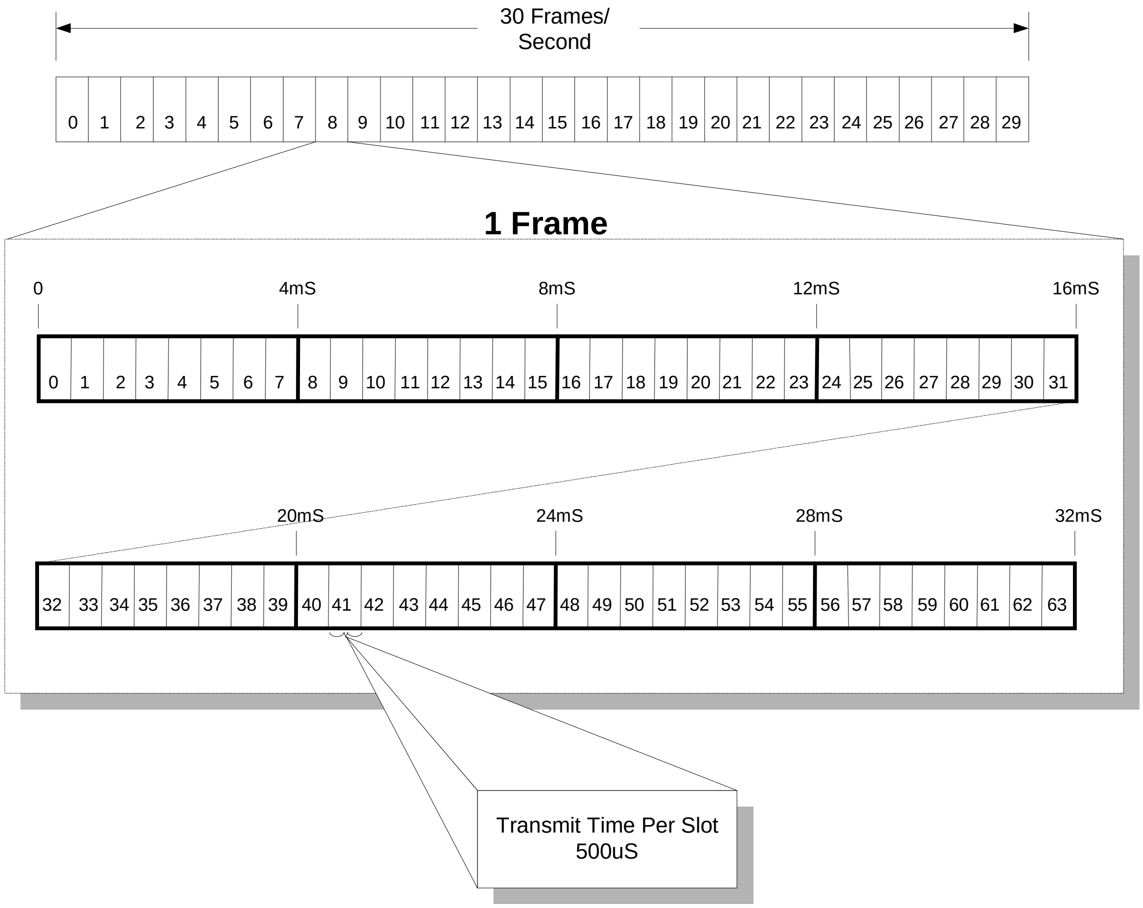
Current Applications

The immediate application is for the televised sports industry, starting in the National Hockey League. The Tower Transceivers are deployed around an ice rink to determine the LVA's of all athletes during an entire game. Eight to sixteen TT's are used to cover the area confined by the rink boards. TT's will be located as close to the boards as possible, positioned at a predetermined height above the ice. All skaters in the game will be equipped with a PP affixed in their helmets. PP's will be worn at all times by the athletes throughout the game and will periodically transmit signals back to the TT's so that TOA correlation data may be obtained. LVA's can then be produced by the Trakus system to determine the locations and speeds of the hockey players at all times during the game, total distances skated by hockey players, the force of a hit between two or more hockey players (such as in checking), as well as many other insightful statistics.

Other applications include football and soccer, both of which would utilize pairs of TT's around the playing field as ΔTOA sensors to determine the LVA's of all players involved in the game. Eight to sixteen TT's will be spaced evenly around the playing field, positioned at a predetermined height above the ground.

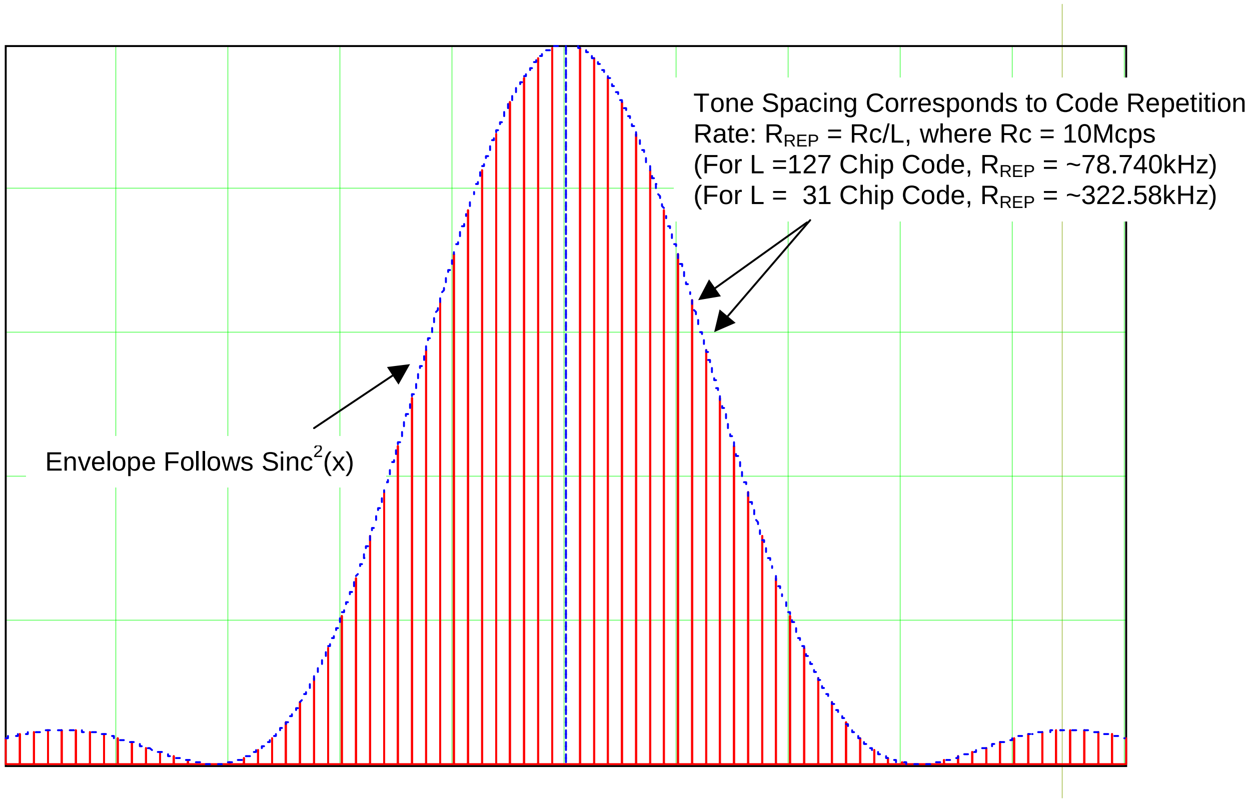
TDMA

ELAPS utilizes Time Division Multi-Access (TDMA) to track multiple objects in real-time. Each player on the field is given a time division SLOT in which to transmit. The players each transmit a Pseudo-Random Noise (PRN) code by phase modulating an ISM band carrier frequency (currently 2.450 GHz). This transmission is referred to as a Direct Sequence Spread Spectrum (DSSS), and complies with FCC regulations for transmission in the ISM band. The update rate, referred to as the frame rate, for TOA's from each player is approximately 1/30th of a second. 64 time divisions fit within one frame and are referred to as SLOTS. Currently the available transmission time per SLOT is ~500µs. SLOTs 1 through 63 are designated for TT DSSS signal reception (Refer to the TDMA timing diagram shown below). For the master TT in the Trakus system, SLOT 0 is designated for back channel transmission. The back channel transmission is performed to synchronize all PP clocks with the master TT timing schedule. If the back channel sync code is not received by the PP after 15 consecutive timing frames, the PP is designed to enter a SLEEP mode. The PP's and TT's are software configurable and can be programmed to operate in many different modes. For testing purposes the units can be operated in a constant transmit and/or receive test mode. While in the test mode the PP will not be allowed to enter the SLEEP mode and will remain in either constant mode to simplify the testing process. The programmed test mode also offers the flexibility of not having to form a communication link between the two transceivers and therefore they can be tested independently.



TDMA Timing Diagram

PRN codes are sample sequences that are represented by a series of “ones” and “zeros” arranged in a specific pattern (or code). Each sample of one or zero in a PRN code is referred to as a chip. The chip rate for the PRN codes used in the transceivers is 10MChip/s (0.1usec/chip). The chip rate is 1/4 the transceiver’s clock which is approximately 40 MHz. A single PRN code modulation of the carrier frequency is referred to as an epoch, and its length is based on the length of the PRN code, namely the number of chips in the sequence. Currently the TT’s and the PP’s use different length codes. For the back channel transmission the TT transmits in time SLOT 0 with an epoch length of 31 chips, with an epoch rate of 3.1µs (or ~322.6kHz). Therefore, 160 epochs will be transmitted in the allotted time (~500µs). For the remaining 63 time SLOTs each PP will transmit an epoch length of 127 chips. Each player will therefore transmit 39 epochs at an epoch rate of 12.7µs (or 78.740kHz) within their designated TDMA slot. The figure below shows the power spectral density of a typical spread spectrum waveform. As seen in the figure, the envelope of the waveform follows a $\mathrm{sinc}^2(x)$ function. The spectral lines, or tones that are seen are generate by the repetitive nature of the PRN code. When longer PRN codes are used the closer the spectral lines become. Likewise, when shorted codes are used the spectral lines spacing is increased.



Power Spectral Density of SS Signal

Processing Gain

The processing gain of a spread spectrum system is often determined by:

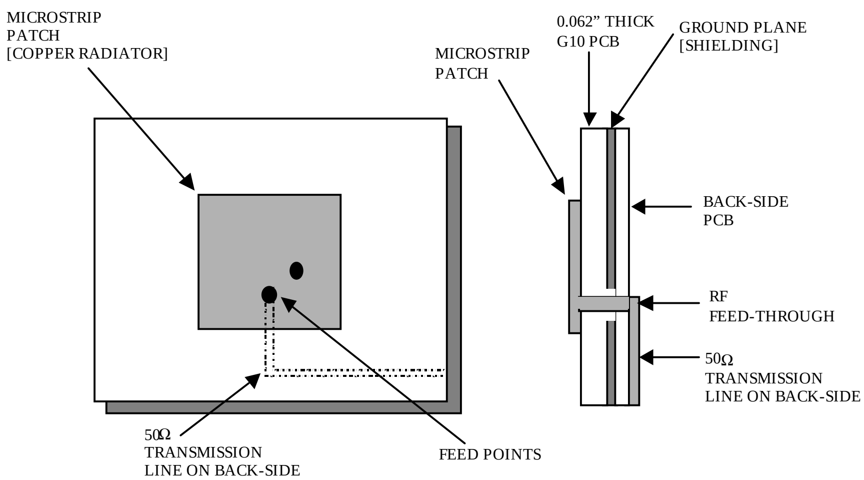
$$G_p := 10 \cdot \log\left(\frac{R_c}{R_b}\right)$$

Where Rc is the code rate and Rb is the desired data rate. The Trakus system was designed to use PRN code inversion as a method of determining what logic value was transmitted. An inverted code would correspond to a logic "1" and a logic "0" would correspond to a non-inverted code. Therefore, the maximum data rate of the system is determined by the length of the PRN code and the number of epochs transmitted per time slot. As mentioned previously, the PP and the TT's use different PRN code lengths. However, both systems use a maximum chip rate of 10Mcps. The table below shows the PRN code length, the number of epochs transmitted per time slot, the maximum allowable data rate per given slot, and the processing gain for each receiver.

System Type	RX Code Length	Epochs per Slot	Max Data Rate	Processing Gain
Player Patch	31	160	322kbps	14.92dB
Tower Transceiver	127	39	78kbps	21.07dB

Microwave Antenna

A microstrip patch design is utilized for the antenna radiator because of its low profile and ease of construction. A rectangular copper radiator is generated via printed circuit board artwork. Dual feed points are used in order to generate the circularly polarized (CP) electric fields that needed for transmission and reception. The feed points are centered on the patch and are fed by 50 Ω transmission lines. Refer to the Patch Antenna Diagram.



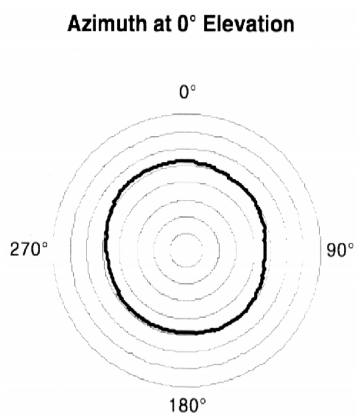
Patch Antenna Diagram

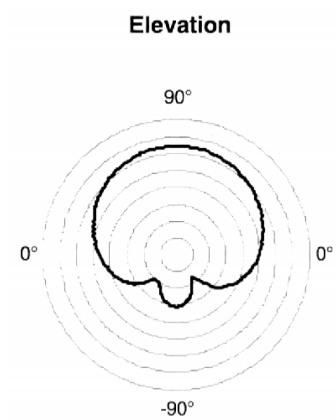
The antenna must be located 12' to 20' above the playing surface for current applications, and is therefore separate from the TT circuitry, being fed through a 50' low-loss coaxial cable. The cable has 8 dB of loss at 2.45 GHz, or 0.16 dB/ft. The antenna itself can handle power levels up to 1,000 dBm at full duty cycle but will actually radiate only 10-20 dBm for approximately 1/64th of the time.

The sense of the antenna's circular polarization is right-hand, designated RHCP. Circularly polarized electric fields have natural multi-path rejection qualities since transmitted signals that bounce once off the ground or surrounding objects will reverse their polarity sense. (i.e. RHCP electric fields transform to LHCP after bouncing once off the ground.) Cross-polarization isolation of the microwave antenna is better than 25 dB from RHCP to LHCP.

The patch antenna pattern demonstrates the antenna's ability to radiate or receive power in a given direction relative to its orientation. The RHCP microstrip patch antenna's power pattern is given below. The radiation pattern is nearly omni-directional in the antenna's radiated half-space (in azimuth). No radiated power is directed behind TT's (towards fans) or towards players' heads in helmets for PP configurations due to the ground plane shielding below the radiator on the backside of the PCB (elevation roll-off).

Patch Antenna Patterns

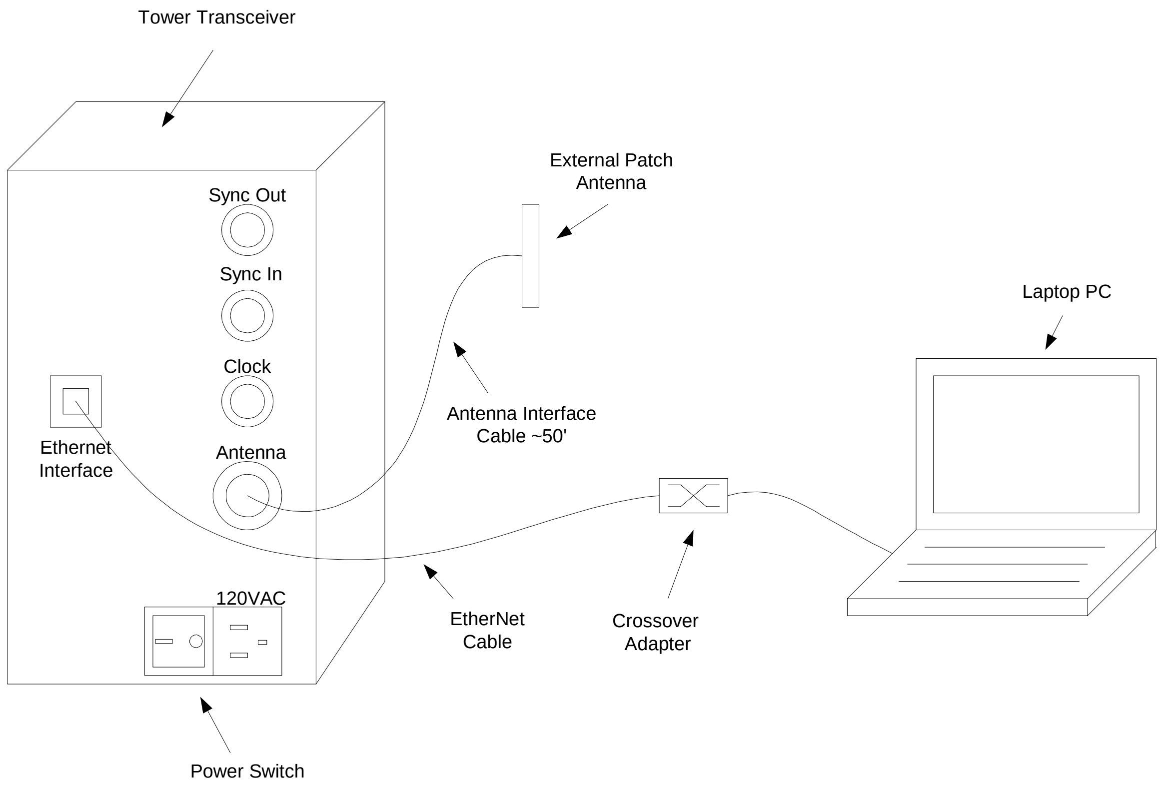




Operational Instructions

Tower Transceiver

Connect the antenna and power cables to the transceiver as shown in the TT connectivity figure. Push the power switch to the “ON” position and allow 2-3 minutes for the unit to boot-up. After the TT has successfully completed its boot-up cycle, the transceiver will wakeup and will immediately begin TDMA operation as stated above.

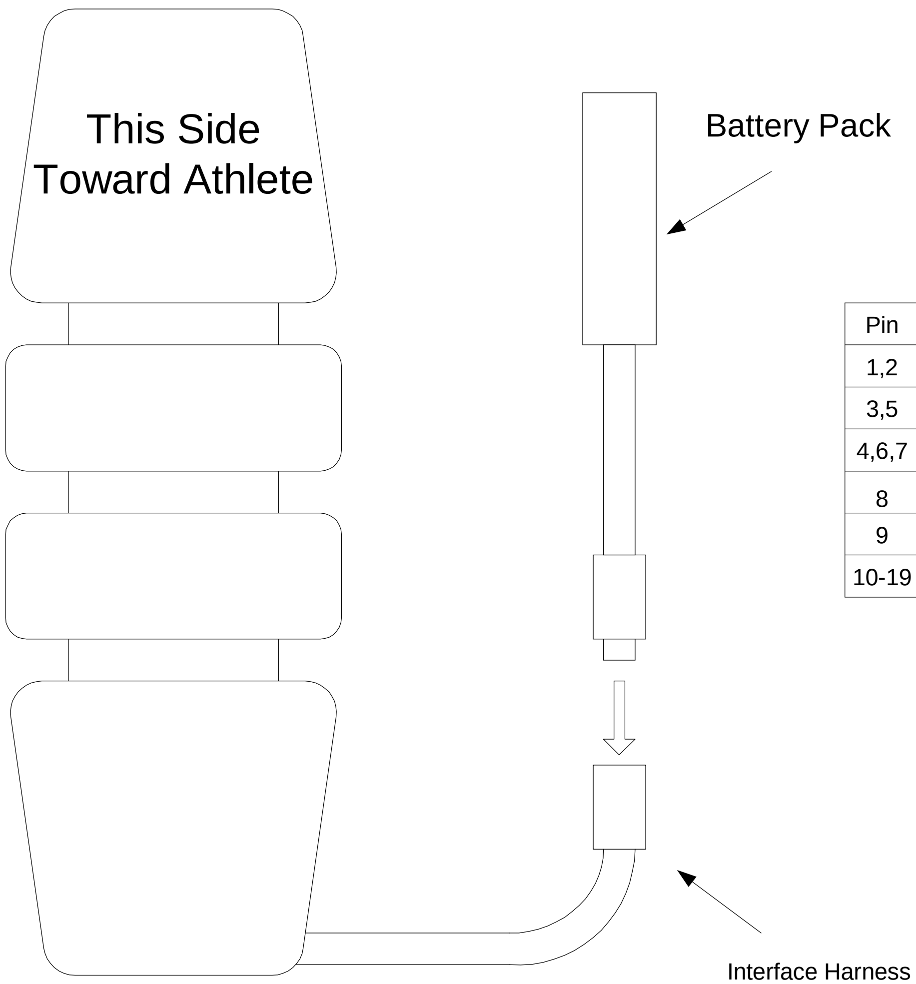


Tower Transceiver Connectivity Diagram

Player Patch

Be sure to start with a fully charged battery pack. Connect the battery harness to the PP interface harness as shown in the PP connectivity figure. When the battery connection is made the PP transceiver will wakeup and will immediately begin TDMA operation as stated above.

The marking on the tiles indicates the direction of the radiated RF energy. The RF energy is directed away from the label “This Side Toward Athlete” and should exhibit a far field radiation pattern that is consistent with the patch patterns shown above (note: Far Field Zone is ~2” from the radiator).



Harness Pin Out

Pin	Description
1,2	GND
3,5	3.3Vdc
4,6,7	Monitor ckt
8	Shield
9	Battery Charge
10-19	Firmware Download

Player Patch Connectivity Diagram