Theory of Operation
For the
Model 0229HP

1. Introduction.

The Model 0229HP Radio is a low power, 2.4GHz Direct Sequence Spread Spectrum (DSSS) telemetry transceiver (or Telesensor) intended for monitoring of industrial battery systems. Intended operating frequencies are in the unlicensed Industrial Scientific and Medical (ISM) band. A Telesensor consists of a highly integrated RF ASIC and mixed signal System on a Chip (SOC) microcontroller. A typical installation consists of several Telesensors controlled by a single master or WAN gateway product as shown in Figure 1. In its simplest form one telesensor assumes the role of the master and is connected into a Personal Computer (PC) or similar monitoring device.

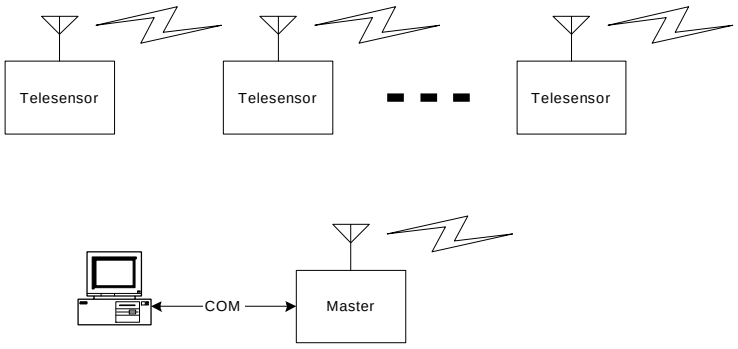

Figure 1 Typical System

2. Operation.

The block diagram is shown in Figure 2. Data gathered by the SOC via the analog input interface are stored. The SOC also controls the RF ASIC. A Phase Lock Loop (PLL) voltage controlled oscillator (VCO) internal to the RF ASIC accomplishes the frequency control. All of the frequencies are derived from a 24MHz crystal controlled reference oscillator. Since the receiver uses a direct conversion to base band, the VCO simply tunes to the center frequency.

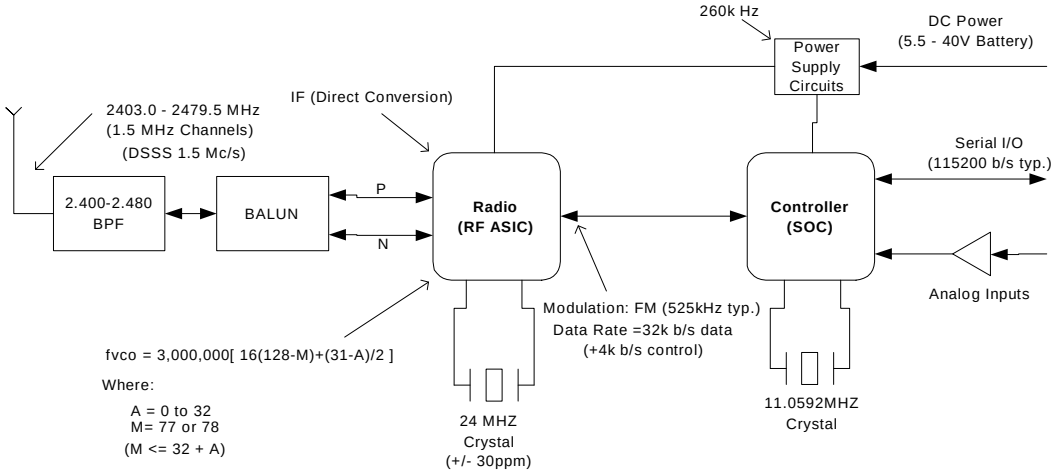

Figure 2 Block Diagram

The center frequency of operation is determined PLL reference, which is divided by two internal counters (A and M). Table 1 shows the valid range of operation of the VCO.

Table 1 PLL Programming

Channel	Freq (MHz)	Fref (MHz)	M count	A count
1	2403.00	24	78	29
2	2404.50	24	78	28
3	2406.00	24	78	27
4	2407.50	24	78	26
5	2409.00	24	78	25
6	2410.50	24	78	24
7	2412.00	24	78	23
8	2413.50	24	78	22
9	2415.00	24	78	21
10	2416.50	24	78	20
11	2418.00	24	78	19
12	2419.50	24	78	18
13	2421.00	24	78	17
14	2422.50	24	78	16
15	2424.00	24	78	15
16	2425.50	24	78	14
17	2427.00	24	78	13
18	2428.50	24	78	12
19	2430.00	24	78	11
20	2431.50	24	78	10
21	2433.00	24	78	9
22	2434.50	24	78	8
23	2436.00	24	78	7
24	2437.50	24	78	6
25	2439.00	24	78	5
26	2440.50	24	78	4
27	2442.00	24	78	3
28	2443.50	24	78	2

Channel	Freq (MHz)	Fref (MHz)	M count	A count
29	2445.00	24	78	1
30	2446.50	24	78	0
31	2448.00	24	77	31
32	2449.50	24	77	30
33	2451.00	24	77	29
34	2452.50	24	77	28
35	2454.00	24	77	27
36	2455.50	24	77	26
37	2457.00	24	77	25
38	2458.50	24	77	24
39	2460.00	24	77	23
40	2461.50	24	77	22
41	2463.00	24	77	21
42	2464.50	24	77	20
43	2466.00	24	77	19
44	2467.50	24	77	18
45	2469.00	24	77	17
46	2470.50	24	77	16
47	2472.00	24	77	15
48	2473.50	24	77	14
49	2475.00	24	77	13
50	2476.50	24	77	12
51	2478.00	24	77	11
52	2479.50	24	77	10

Actual data is transferred 8-bytes at a time at a 32k bits-per-second (bps) data rate. The receiver continues scanning the channel list until a master is detected. The transmitters spread the data using a Pseudorandom Numerical (PN) sequence with a chipping rate of 1.5Megachips per second. When the receiver locks to the PN sequence it can read the control channel and determine if the sampled data can be sent. The master only occupies any single channel for a predetermined number of milliseconds before switching to a new frequency. Data is transferred in a Time Division Duplex (TDD) format only transmitting 50% in any given frame. The frame consists of two data packets: a 12-bit preamble, an 8-bit sync byte, and an 8-bit control byte. The packet also includes a 4-bit CRC post amble. A data diagram is shown in Figure 3. Once in sync, the slave begins to transmit, the master locks to the slaves PN sequence, and master and slave alternately transmit for approximately 1 millisecond in the 2 milliseconds long frame. A total of 96 bits are transmitted and transferred in each packet.

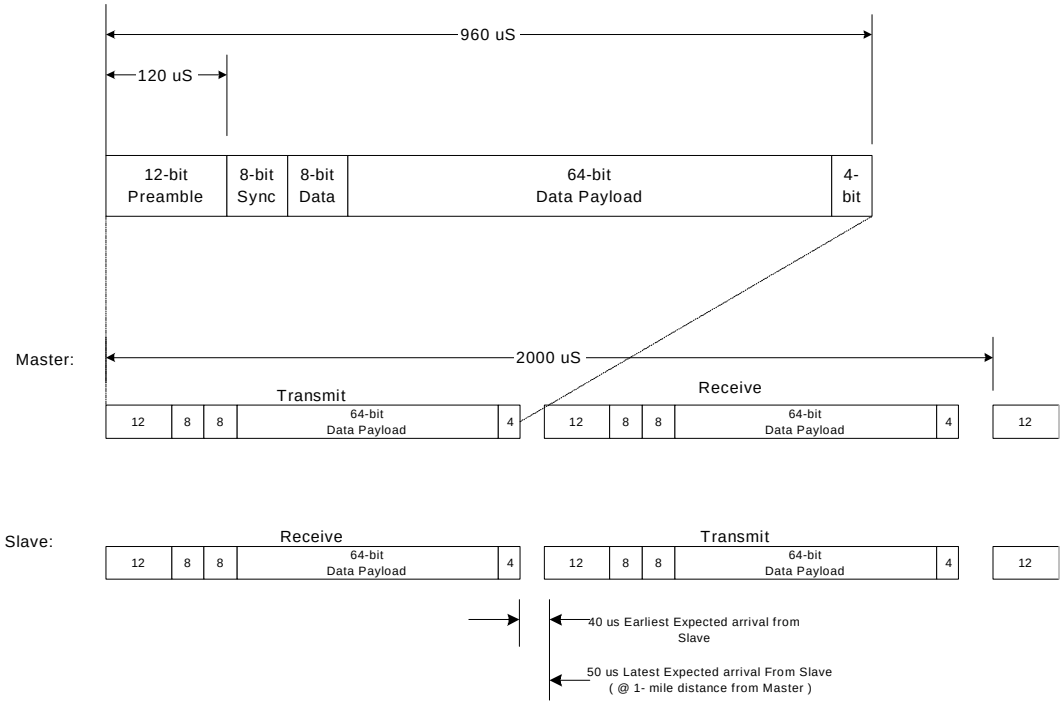

Figure 3 Data Frame Format

In actual operation, the system periodically (several minutes typically) the SOC wakes up and tunes the receiver to various channels in search of a master. The system is designed to allow only one master/telesensor pair to be transmitting at any given time. A controlling node (master) is periodically beaconing on each channel in the ISM band. The master transmitter either ready to accept a new telesensor on a channel or is currently communicating with one. The status is communicated in the 8-bit control channel. After the data is transferred the telesensor switches off its transmitter and goes back to sleep mode. The master also stops transmitting on this channel and retunes to another channel, this prevents any one channel from being used on a continuous basis, and if the channel is clear the master begins beaconing for the next telesensor. If no telesensors are found within a certain time interval, the master will again change its beaconing frequency.

3. Channels.

The Model 920 divides up the allotted ISM band into 51 channels each approximately 1.5 MHz wide. The actual channels of operation within the ISM band are shown in Table 2.

Table 2 Channels of Operation

Channel	Center Frequency (MHz)	Spread Frequency (MHz)	
1	2403.0	2402.25	2403.75
2	2404.5	2403.75	2405.25
3	2406.0	2405.25	2406.75
4	2407.5	2406.75	2408.25
5	2409.0	2408.25	2409.75
6	2410.5	2409.75	2411.25
7	2412.0	2411.25	2412.75
8	2413.5	2412.75	2414.25
9	2415.0	2414.25	2415.75
10	2416.5	2415.75	2417.25
11	2418.0	2417.25	2418.75
12	2419.5	2418.75	2420.25
13	2421.0	2420.25	2421.75
14	2422.5	2421.75	2423.25
15	2424.0	2423.25	2424.75
16	2425.5	2424.75	2426.25
17	2427.0	2426.25	2427.75
18	2428.5	2427.75	2429.25
19	2430.0	2429.25	2430.75
20	2431.5	2430.75	2432.25
21	2433.0	2432.25	2433.75
22	2434.5	2433.75	2435.25
23	2436.0	2435.25	2436.75
24	2437.5	2436.75	2438.25
25	2439.0	2438.25	2439.75
26	2440.5	2439.75	2441.25
27	2442.0	2441.25	2442.75
28	2443.5	2442.75	2444.25
29	2445.0	2444.25	2445.75
30	2446.5	2445.75	2447.25
31	2448.0	2447.25	2448.75
32	2449.5	2448.75	2450.25
33	2451.0	2450.25	2451.75
34	2452.5	2451.75	2453.25
35	2454.0	2453.25	2454.75
36	2455.5	2454.75	2456.25
37	2457.0	2456.25	2457.75
38	2458.5	2457.75	2459.25
39	2460.0	2459.25	2460.75
40	2461.5	2460.75	2462.25
41	2463.0	2462.25	2463.75
42	2464.5	2463.75	2465.25
43	2466.0	2465.25	2466.75
44	2467.5	2466.75	2468.25
45	2469.0	2468.25	2469.75
46	2470.5	2469.75	2471.25
47	2472.0	2471.25	2472.75
48	2473.5	2472.75	2474.25
49	2475.0	2474.25	2475.75
50	2476.5	2475.75	2477.25
51	2478.0	2477.25	2478.75