Operational Description of FCC ID: H9PLA3021 Spectrum 24® 2.4 MHz Wireless LAN PCMCIA Card

TABLE OF CONTENTS

1. Introduction

The LA3021 PCMCIA PC Card can be used in hand held and notebook computers to provide a Wireless Local Area Network (WLAN) called Spectrum24. Spectrum24 is based on the IEEE 802.11 WLAN specification. The LA3021 PC Card is the latest in a family of Spectrum24 WLAN devices including: PCMCIA PC Card LA3020 (FCC ID:H9PLA3020), ISA Card LA2470 (FCC ID: H9PLA247O5AZK), hand held computers LRT 3840, PDT 3140 (FCC ID: H9P3840, H9P3 140), and several other devices. The LA3021 PC Card includes all of the functions including the digital circuits and software to implement the protocol for the communication with other devices on the network. The Spectrum24 WLAN operates from 2,4 to 2~5 GHz at 1 Mbps using binary GFSK modulation or at 2 Mbps using 4 level GFSK. The LA3021 PC Card device uses frequency hopping technology to provide robust communication, mitigating the effects of interference and multipath fading and providing for sharing of multiple wireless devices in the same area.

2. System Overview

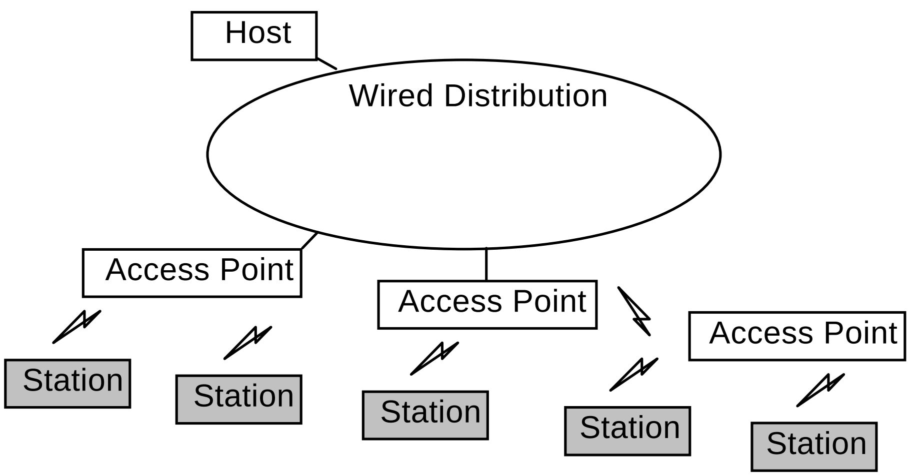


Figure 1. Typical Spectrum24 WLAN Topology

The Spectrum 24 network is a cellular infrastructure network using multiple access points (AP). Each AP controls a Basic Service Area (BSA) or cell consisting of a number of terminals that communicate entirely through the AP. Handoff is performed by the terminals and AP's when the terminal moves from one BSA to another within an Extended Service Area (ESA).

Spectrum 24 uses a Frequency Hopped Spread Spectrum (FHSS) method of wireless communication. All AP's are asynchronous to each other in frequency hop timing as mandated by the FCC. A terminal entering the network must first scan for the hop frequency being used by all APs within range and select the strongest AP.

The radio portion of the LA3021 PC Card provides a Received Signal Strength Indicator (RSSI) which facilitates initial AP selection, AP handoff, and antenna diversity. The data is processed through a data whitening algorithm prior to transmission to minimize long strings of zeroes or ones and to suppress the DC offset of the data. The LA3021 PC Card uses a physical modulation method called binary Gaussian Frequency Shift Keyed (GFSK) modulation to be compatible with the IEEE 802.11 standard in development.

Wireless networks sharing common frequencies inherently produce co-channel interference. The amount of interference is minimized by using Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), random backoff in retries, and carrier sense deferrals. This protocol also allows ad hoc networks to share the same frequencies with infrastructure or other ad hoc networks in overlapping geographical areas. RTS/CTS is optionally used to provide carrier sense range extension for transmission of long packets. This minimizes collisions due to the hidden terminal problem.

The impact of interference, when it does occur, is minimized with CRC error detection, MAC level acknowledgement of correctly received packets, and retransmit if no acknowledge received.

Some amount of multipath is always present in Spectrum 24's operating environment. FHSS improves performance in multipath environments by allowing the radios to hop out of frequencies affected by a multipath null. The LA3021 PC Card dual antenna diversity also significantly improves performance in multipath by constantly testing and using the best of two nearly independent propagation paths.

A key feature of the Spectrum24 network is its multi-mode power conservation to maximize battery life in portable devices. The power conservation feature uses buffering in AP's and TIM message flags to alert devices periodically waking up from "sleep" mode that messages are waiting. While "awake", the LA3021 PC Card turns on only sections of the radio needed and turns off sections as soon as possible to minimize battery drain at all times.

2.1 WLAN Adapter Architecture

2.1.1 Overview

The LA3021 PC Card is composed of a digital and an RF section. The digital section handles all of the MAC processing, the control processing of the radio, packet formatting, and the bit clock recovery and carrier sense functions. The radio section converts the digital bits to a modulated waveform, transmits and receives the RF signal, and converts the received waveform back to a binary signal. The LA3021 PC Card conserves power by powering up/down various radio sections as needed.

2.1.2 Digital Section

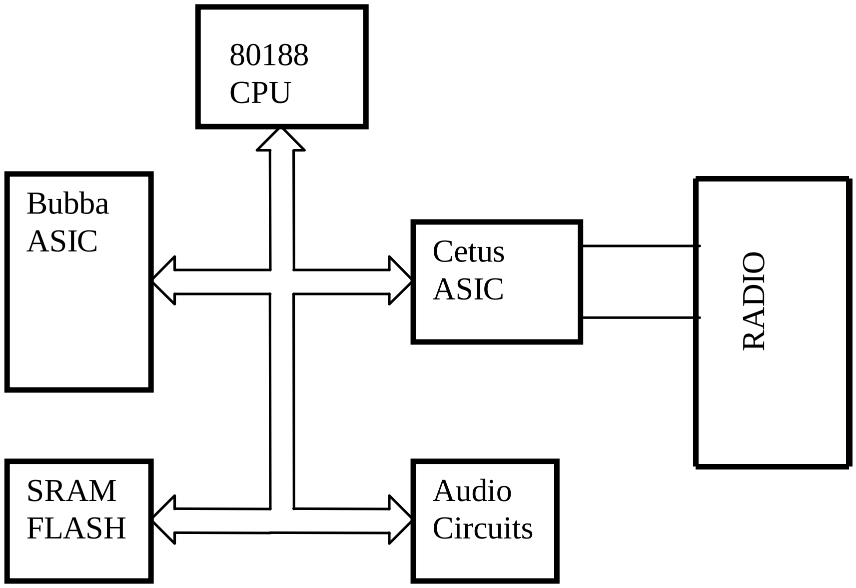


Figure 2.1.2. Digital Section Block Diagram

The Bubba ASIC performs some functions including

- Power conservation state control (sleep, idle)
- Firmware change downloading from the host PC

The microprocessor uses firmware stored in the Flash ROM to perform overall management, most of the MAC protocol functions, and some of the PHY functions including:

- Firmware execution directly from ROM
- Command/data interface
  - Terminal mode
  - Access Point mode
- Diagnostics support
- CSMA/CA protocol
  - Defer on carrier sense with random backoff (collision avoidance)
  - RTS/CTS on long packets
  - Message length indicator
  - Acknowledge
- Data scrambling/descrambling for randomization
- FH PHY layer management
  - Frequency scanning/active polling
  - Time/hop frequency synchronization
  - AP scanning and handoff
- PHY packet formatting (preamble, frame sync, and length indicator)
- Power conservation state control
- Antenna diversity selection

Cetus performs time critical sections of the MAC protocol, some PHY processing functions, and all interface functions between the microprocessor and the radio section.

MAC protocol functions performed by Cetus include:

- CRC generation
- CRC error detection

PHY functions performed by Cetus include:

- Stuffing/destuffing for data DC offset minimization
- Carrier sense detection using a combination of RSSI and 1 Mbaud detector
- Bit clock recovery

2.1.3 Radio Section

The radio portion uses a frequency hopping spread spectrum method over an extended range of 2.4 to 2.5 GHz, with actual operating frequency bands depending on various countries' regulations. The FH channels are 1 MHz wide, with nominal channel centers at the 1 MHz increments starting at 2401 MHz, and hop dwell times up to a maximum of 400 msec. The radio transmits and receives at 1 Mbps using a binary GFSK modulation with BT=0.5 and minimum deviation of 160 KHz (h=0.32) or at 2 Mbps using 4 level GFSK. The data rate is chosen to be 2 Mbps and will back down to 1 Mbps when out of range or service of 2 Mbps.

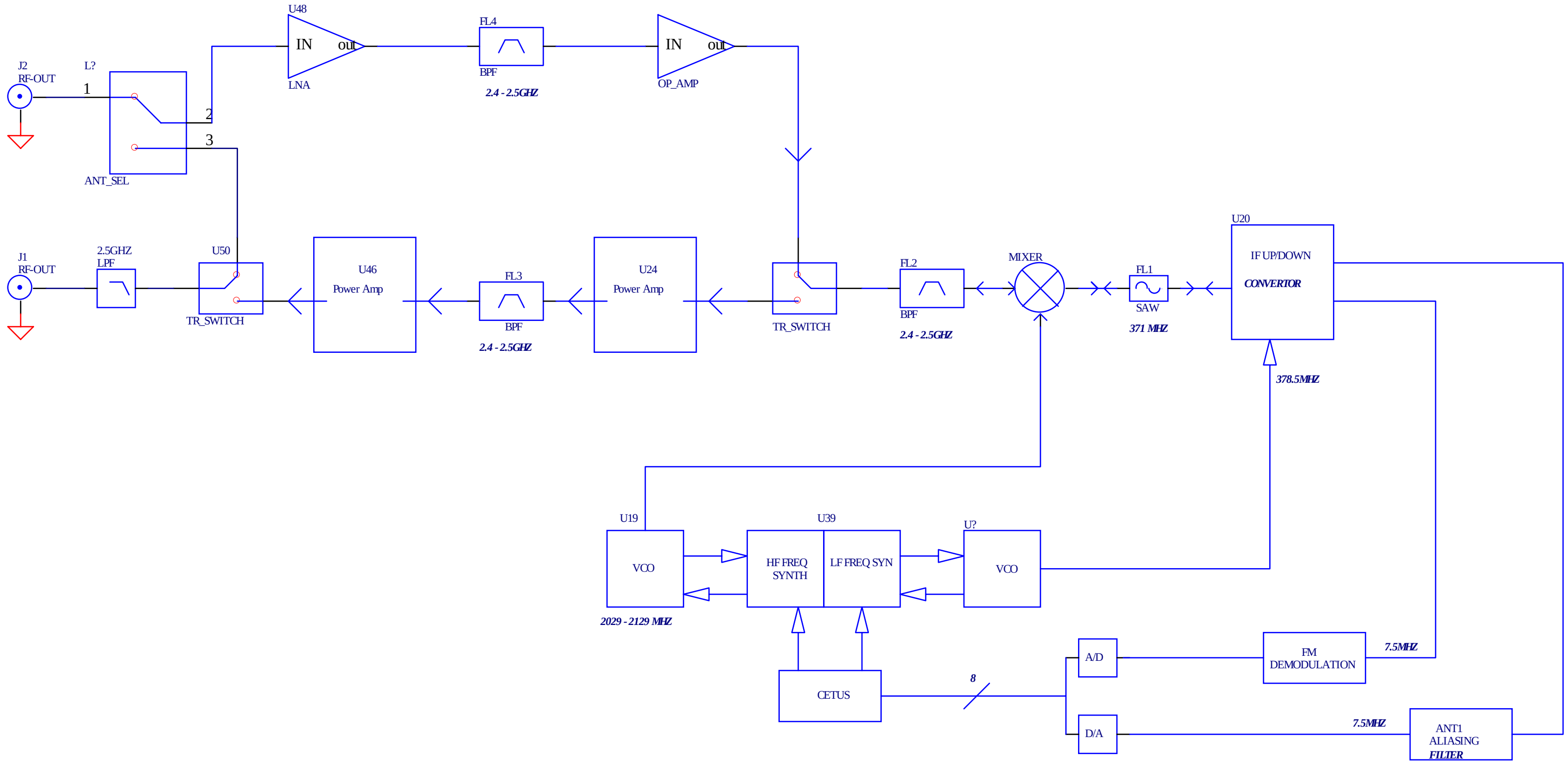
The radio card in manufactured in two different versions. The LA3021-100 is a 100 mW transmitter while the LA3021-500 is a 331 mW one. The only difference between these two versions is the output power amp stage and associated components.

Antenna diversity is included. Antenna diversity improves performance in multipath environments by constantly testing and using the best of two nearly independent propagation paths. Diversity is only used for receiving; the transmit path is hardwired to a single antenna.

The radio is designed with two synthesizers in a single IC, a frequency hopped and a fixed frequency synthesizer. The output of the fixed frequency synthesizer is divided down with two different modulus values to provide different frequencies for transmit IF and receiver second LO. The receiver uses a 5.888 MHz second IF for FM demodulation.

In transmit mode, transmit data is filtered by a 3-pole Bessel low pass filter with 3 dB bandwidth of 0.5 MHz and summed with the fixed frequency synthesizer loop error at the input of the VCO. Compensation is used to reduce data bias tracking within the loop.

In receive mode, the received signal is input into an FM demodulator which has two output signals. The RSSI output of the FM demodulator is routed to an A/D with a parallel interface to Cetus. DC offset at the baseband output of the demodulator is removed with a switchable time constant RC filter. The bias compensated signal is then sliced into a bi-level signal and input into Cetus. Cetus performs a carrier sense algorithm, recovers the symbol timing, and converts the signal into bits. Upon detection of the start frame delimiter, Cetus sends a signal back to the radio to switch the RC time constant 0from fast to slow.



Notes: (Unless Otherwise Specified)

1. All Resistors are 5% in Ohms.
2. All Caps >= 1 are 5% in pF.
3. All Caps < 1 are 5% in uF.
4. All Inductors are 10% in nH.
5. Footprint for Res, and Caps are 0603
6. Footprint for Ind. are 0603

Title: **LA3021-X00 Block Diagram**			*Symbol Technologies, Inc.* *2145 Hamilton Avenue* *San Jose, CA 95125* *Phone: (408) 369-2600* *Fax: (408) 369-2740*
Size: B	Number:	Revision: 1	EIC: .author
Date: 10-Jul-1999 Time: 16:04:56	Sheet 0 of 0	File: V:\PROTEL\PROJ\NORM\PROJ_C_1.SCH	

FCC ID: H9PLA3021

Confidential

3. Hopping Method and Hopping Patterns

The hopping pattern for USA FCC 15.247 and Europe ETSI 300-328 is a pseudo-random sequence which selects one of 79, 1 MHz channels centered from 2402 to 2480 MHz.

Each channel is evenly utilized by selecting each channel once and only once in each cycle, and using identical dwells at each channel.

Each channel is evenly utilized by selecting each channel once and only once in each cycle, and using identical dwells at each channel. The hop pattern does not reset (recycle) until the hop pattern has been completed.

The radios always follow the hop patterns. There is never any attempt to avoid a frequency in the pattern.

The Spectrum24 network which the LA3021 PC Card is a part of communicates by half duplex. A transmitter and receiver must and do follow the same hop pattern in synchronization. In this way a unit which wishes to transmit to a receiver which is part of the same association will find on any hop that the potential receivers are also on the same hop at the same time and are following the same sequence.

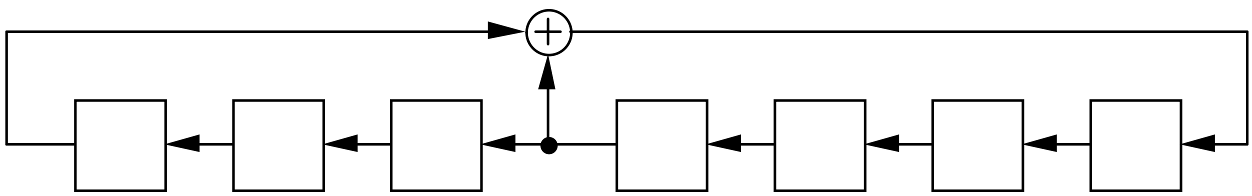
In order to coordinate mobile units an Access Point sends out periodic beacons at a rate of typically 100 msec near the beginning of each hop. The time between beacons is used for the transmission of data to and from the Access Point and the mobile units. The mobiles and Access Point compete for using this time to transmit with a listen before talk protocol. There can be multiple Access Points within radio range of one another but they do not in any way coordinate their hop patterns for any purpose including for the purpose of avoiding the simultaneous occupancy of individual hopping frequencies by multiple transmitters.

The beacon transmission occurs when the LA3021 PC Card is used in an access point. The access point sends out a beacon sometime close to the beginning of each hop. The purpose of the beacon is to provide information to other units listening to the beacon on things such as packets which may be in the AP which are waiting for a unit to call in for and time sync to help keep hops in syncs.

The radios always follow the hop patterns as described in the technical report. There is never any attempt to avoid a frequency in the pattern. The statement "FHSS improves performance in multipath environments by allowing the radios to hop out of frequencies affected by a multipath null." does not mean the radios will avoid frequencies in a null (they actually have no way of knowing). What this statement means is if communication is being adversely affected at a particular time and hop frequency that since the radio is hopping and the next hop will be at a different frequency the communication will with some probability hop out of the null in the next or some subsequent hop. In this way FHSS mitigate multipath just by the nature of hopping but they do not avoid it.

The hopping pattern is a pseudo-random sequence which selects one of 79, 1 MHz channels centered from 2402 to 2480 MHz. Each channel is evenly utilized by selecting each channel once and only once in each cycle, and using identical dwells at each channel. Each channel is equally used by the hop pattern and dwell time operation and each unit is a transceiver with receiver and transmitter following the hop pattern together. The data presented to the transceiver is random and on average evenly distributed in time. The evenly distributed data presented to the transmitter together with the equally distributed channel utilization by the hop pattern and dwell time produce on the average each frequency equally used by the transmitter. The hop pattern does not reset (recycle) until the hop pattern has been completed.

The hopping pattern is based on a pseudo-random sequence generated by a linear shift register with taps corresponding to the irreducible polynomial $x^7 + x^4 + 1$ as shown in the figure below.



The contents of the registers form 7-bit words with values from 1 to 127. The irreducible polynomial produces a maximal length sequence which means that each value from 1 to 127 occurs once and only once in each cycle. Values less than 2 and greater than 80 are eliminated, leaving 79 values from 2 through 80 which corresponds to the frequencies 2402 through 2480.

A set of 78 hopping patterns are derived by permutations of the basic pseudo-random sequence. The permutations are derived by a sequential incrementing with modulo wrap-around through the basic pseudo-random sequence with an incremental delta from 1 to 78. Because the number of channels (79) in the hopping set is a prime number, a sequential incrementing through the base pseudo-random sequence using a delta from 1 to 78 will produce a unique sequence that is equally pseudo-random and evenly utilized as the basic pseudo-random sequence.

The basic pseudo-random sequence and the first 8 permutations with deltas of 2 to 9 are shown in the tables below. A delta of 1 reproduces the basic pseudo-random sequence. The values in all columns including the index are between 2 and 80 for a total of 79 channels, and each sequence begins at the same channel as a point of reference.

Index	Basic PRN Sequence	Delta= 2	Delta= 3	Delta= 4	Delta= 5	Delta= 6	Delta= 7	Delta= 8	Delta= 9
2	67	67	67	67	67	67	67	67	67
3	7	14	29	59	60	75	22	44	50
4	14	59	75	44	73	36	16	64	4
5	29	75	50	36	32	4	34	19	24
6	59	44	36	64	17	19	49	46	48
7	60	73	32	17	38	11	54	12	53
8	75	36	4	19	11	48	51	78	52
9	22	16	34	49	54	51	28	33	47
10	44	64	19	46	12	78	33	62	27
11	50	4	24	48	53	52	47	27	14
12	73	17	11	12	57	21	70	7	18
13	18	68	58	26	80	74	31	50	17
14	36	19	48	78	21	27	60	2	69
15	72	76	6	30	37	63	36	38	3
16	16	49	51	33	70	60	8	58	39
17	32	11	53	21	71	18	76	25	33
18	64	46	78	62	7	2	58	28	37
19	2	45	79	40	75	9	12	66	56
20	4	48	52	27	18	69	39	37	59
21	8	3	66	15	64	54	52	55	72
22	17	12	21	7	34	25	42	14	68
23	34	51	47	60	76	39	40	73	23
24	68	26	74	50	23	61	71	4	12
25	9	41	35	72	48	10	29	76	28
26	19	78	27	2	25	37	73	45	5
27	38	57	71	34	41	13	2	51	20
28	76	30	63	38	79	31	19	57	15
29	24	52	14	69	33	59	23	5	75
30	49	33	60	58	42	73	3	74	32
31	69	5	44	65	74	64	53	56	19
32	11	21	18	25	13	68	30	29	58
33	23	43	16	53	15	49	10	18	51
34	46	62	2	28	14	45	74	8	79
35	58	74	17	61	22	12	55	24	21
36	45	40	9	66	36	41	7	54	35
37	54	70	76	42	2	30	44	77	63
38	48	27	69	37	68	5	32	79	44
39	65	56	46	35	24	62	68	10	2
40	3	15	54	55	46	70	69	20	76
41	6	63	3	31	65	15	48	71	54
42	12	7	25	14	51	29	77	59	26
43	25	29	26	75	39	50	57	36	61
44	51	60	39	73	30	32	66	17	43
45	77	22	57	16	66	34	62	49	13
46	26	50	61	4	43	24	13	48	7
47	53	18	33	68	20	58	63	26	73
48	41	72	10	76	27	6	75	30	8
49	39	32	43	11	31	53	72	21	49
50	78	2	37	45	29	79	17	40	65
51	28	8	40	3	44	66	24	15	41

Index	Basic PRN Sequence	Delta= 2	Delta= 3	Delta= 4	Delta= 5	Delta= 6	Delta= 7	Delta= 8	Delta= 9
52	57	34	13	51	72	47	45	60	80
53	79	9	56	41	4	35	25	72	62
54	30	38	31	57	9	71	78	34	55
55	61	24	7	52	49	14	80	69	29
56	52	69	59	5	58	44	43	65	36
57	80	23	22	43	3	16	35	53	34
58	33	58	73	74	77	17	15	61	11
59	66	54	72	70	78	76	59	42	6
60	5	65	64	56	61	46	18	35	78
61	10	6	8	63	5	3	4	31	66
62	21	25	68	29	47	26	38	75	74
63	42	77	38	22	40	57	46	16	71
64	43	53	49	18	55	33	6	68	60
65	47	39	23	32	63	43	41	11	16
66	62	28	45	8	59	40	61	3	9
67	37	79	65	9	50	56	21	41	46
68	74	61	12	24	16	7	20	52	25
69	20	80	77	23	8	22	56	43	57
70	40	66	41	54	19	72	14	70	10
71	35	10	28	6	69	8	50	63	40
72	70	42	30	77	45	38	64	22	31
73	13	47	80	39	6	23	9	32	22
74	27	37	5	79	26	65	11	9	64
75	55	20	42	80	28	77	65	23	38
76	56	35	62	10	52	28	26	6	45
77	71	13	20	47	10	80	79	39	77
78	15	55	70	20	62	42	5	80	30
79	31	71	55	13	35	20	37	47	42
80	63	31	15	71	56	55	27	13	70

The hopping patterns have been selected to create a list for US (FCC 15.247) and Europe (ETSI 300-328) of 22 hopping patterns which can be selected for use in an Access Point. Some countries have unique regulatory requirements which require special hopping patterns including: France (2448 - 2482) with 11 patterns, Japan (2471 - 2497) with 6 patterns, Korea (2454 - 2476) with 6 patterns, and Spain (2447 - 2473) with 9 patterns.
Access Point hopping patterns should be selected such that Access Points within geographic radio range should use different hopping patterns in order to maxmize network throughput.

4. Performance Requirements and Objectives

4.1 General

Frequency range:	2400 to 2500 MHz programmable for different country regulations
Number of channels:	100 programmable in 1 MHz steps for different country regulations
Minimum hopping rate:	2.5 hops/sec (per FCC part 15.247)
Hopping sequence:	Per IEEE 802.11

4.2 Transmit Performance

Transmit power level:	
Low power version:	100 mW
High power version:	331 mW
Maximum radiated EIRP	FCC regulations part 15.247 in the USA
	ETSI 300-328 in Europe
	RCR STD-33 in Japan
Center frequency tolerance:	± 25 ppm
Modulation:	Binary GFSK, or 4 Level GFSK
Occupied 20 dB bandwidth:	1 MHz
Out-of-band emissions	FCC regulations part 15.247, 15.205, 15.209 in US
	ETSI RES 02-09 in Europe

4.3 Receive Performance

Sensitivity:	10^{-5} BER @ -85 dBm (min signal level)
Maximum useable input level:	10^{-5} BER @ -10 dBm (1 W @ 1 meter)
Center frequency acceptance range:	+/- 25 ppm

4.4 Timing Requirements

State Transition Times	
Off to Idle	1 ms
Idle to Standby	8 ms
Transmit to Receive	<20 µs
Receive to Transmit	<20 µs

4.5 Interface Specification

The RF connector used for antenna attachment is an MMCX style connector which is not readily available to users through retail distribution but is available from manufacturers including Amphenol and Radial.