Frequency Hopping Spread Spectrum Transmitter

Transmitter Certification

FCC ID: JEH7730GA2

ACS Report Number: 04-0209-15C

Manufacturer: NCR Corporation
Models: 7730-2011, 7730-2012, 7730-2014 and 7730-2015

Theory of Operation

Document Number: **497-0437563** **Revision:** B

Title: 7730 Principles of Operation

Prepared by : Albert Claessen

Document Number: 497-0421268

Revision	Date	Description of Change	Change Reason
A	08/18/04	Original	
B	09/02/04	Editorial updates, correction antenna gain	Certification review

Table of Contents

1 SCOPE

1.1 Release 3.4

RealPrice™ release 3.4 functionality is identical to previously released 7730. Several design changes have been made that will have a major impact on the performance:
- 4 individual receivers rather than four antennas combined into one receiver
- Reducing the frequency channel spacing , which doubles the number of available frequency channels
- Diagnostic hardware improving the serviceability
- Using an Ethernet switch for networking , reducing networking problems.

The system consists of System and Application software running on the store's ISP (In-Store Processor), the infrastructure, and the display devices on the shelves (ESL).

The RealPrice™ infrastructure is usually installed in the back office and ceiling of the store. The infrastructure components are:

- CBS,
- CAT 5 communications cable,
- Two wire power cable,
- Ethernet Hub,
- AC-DC remote power supply,
- Transmit and Receive Antennae,

One CBS in the system is configured to provide timing to synchronize all CBS's in the store. Otherwise, all CBS's communicate directly with the ISP.

2 ENVIRONMENT

2.1 Location

Typically the CBS and antennae is installed on the roof support structure above a suspended /dropped ceiling or in an open ceiling environment. The other components of the infrastructure are typically installed in the back office or in a wiring closet. The CBS and antennae are provided with hardware for mounting on the roof support structure.

2.2 Temperature, Humidity and Barometric Pressure

Temperature Range (dry bulb)	5°C to 45°C (40°F to 113°F)
Relative Humidity	10% to 90% (No condensation)
Barometric Pressure	105 to 70 kPa

The internal temperature rise of the CBS is estimated to be 15 °C during normal operation and with 4 receive antennae connected.

2.3 Voltage & Frequencies

2.3.1 AC/DC power supply

The AC/DC power supply shall operate on the following voltages and frequencies:

Nominal Voltage	Voltage Range	Nominal Frequency	Phase
100, 120, 127 Vac	90 to 136 Vac	50/60 Hz	1
220, 230, 240 Vac	198 to 257 Vac	50/60 Hz	1

The 50/60 Hz line frequencies are allowed to range as follows:

Nominal Frequency	Range
50 Hz	49.0 to 50.5 Hz
60 Hz	59.0 to 60.6 Hz

2.3.2 CBS

The CBS operates on 12 to 48 Vdc.

2.3.3 Communications/Power Cables

The maximum lengths of the various interconnect cables in the system shall not exceed the following lengths:

Function	Type	Maximum length
central power supply to any CBS (power)	Two wire AWG 14	200 m. (656 ft.)
Ethernet Hub to CBS	CAT5 wire	100 m. (328 ft.)
CBS to CBS	CAT5 wire	100 m. (328 ft.)

2.3.4 Antenna Cables

The transmit antenna cable is permanently attached to the transmit antenna and terminated with a TNC connector at the CBS end. The receive antennae have a 10” short cable and are terminated with an in-line BNC jack. The receive antenna connect cables have a fixed length and are provided as an assembly with a BNC connector at both ends..

Function	Type	Length
Receiver cable	RG 58 Plenum rated	18.3 m. (60 ft.)

3 System Components

A large retail store typically requires 20 CBSs to cover an area of over 10,000 m^2 (110,000 ft^2). The CBS Ethernet communications architecture allows for a maximum of 85 CBSs in one installation, covering approximately 42,500 m^2 (470 ,000 ft^2). Figure 1 shows a typical configuration of such a system.

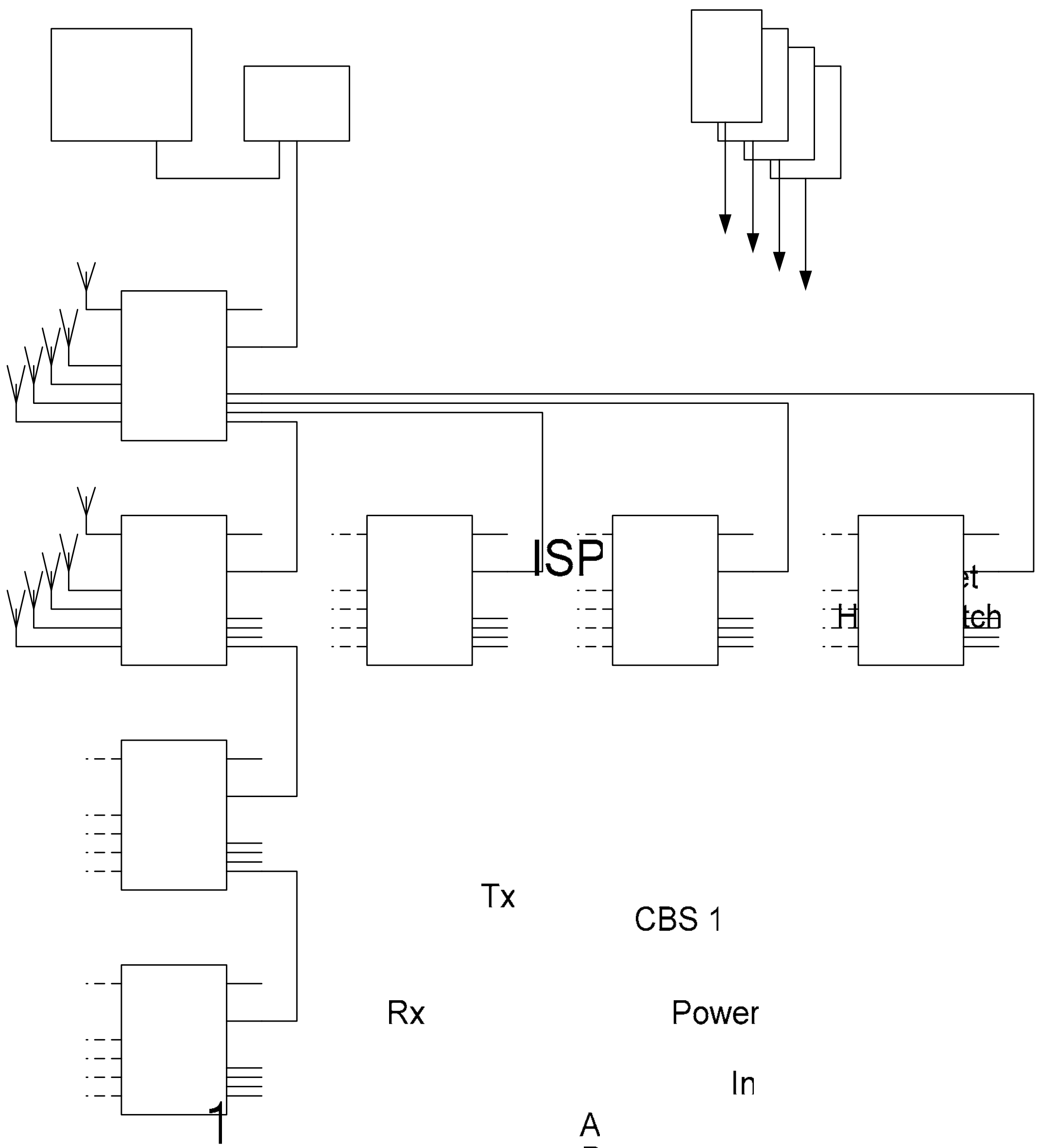

Fig. 1, Release 3.4 system configuration.

3.1 In-store Processor (ISP)

Typically the ISP in the back office is used for store management functions and to control the POS terminals. The store's price information for the POS terminal price look-up and the ESLs is stored in a database on the ISP. The Realprice™ system software will be linked with the ISP database.

3.2 Communication Base Station (CBS)

The CBS functions as a bridge between the ISP and the ESL. The CBS translates IEEE 802.3 10/100 BaseT (Ethernet) communications from the ISP into RF communications to the ESL and vice versa.

The CBS consists of a digital controller board and a radio board. The digital controller board also houses the DC to DC converter that powers the control logic and the RF board. The CBS control logic is based on a TMS3206411 DSP and a Net Silicon ARM RISC processor with integrated IEEE 802.3 10/100BaseT LAN communications. The digital control board and RF board are described in more detail in section 4.

3.3 Electronic Shelf Label (ESL)

The ESL is an electronic module that displays the item price and/or the unit price for a shelf location. The CBS communicates with the ESL via a Radio Frequency communications. Once the data is received correctly, the ESL responds with an acknowledgement back to the CBS.

3.4 Wired Communications

The Realprice System interfaces with the ISP through off the shelf IEEE 802.3 (10baseT) communications hardware. The topology for the V3 system is a star configuration (Figure 1). The communications from the 10BaseT HUB to the first CBS in the system is a standard Ethernet connection. Every CBS has an integrated HUB and can communicate to up to four CBSs downstream. The cable between the first CBS in the system (CBS1 in figure 1) and subsequent CBSs in the system carries standard Ethernet communications and CBS timing synchronization signals. The distance (cable length) between two CBSs in the system and the first CBS and the 10BaseT HUB is limited to the standard 10BaseT maximum of 100 meters (328 ft).

3.5 Wireless (RF) Communications

An overview of the RF communications protocol is given in section 6.

3.5.1 Transmit Antenna

The CBS has one transmit antenna connected with a 1.83 meter (6ft) coax cable. The antenna has a maximum gain of 4.5 dBi (dB relative to an isotropic radiator). The cable has a loss of 2.0 dB at 2.4 GHz, resulting in a total antenna gain of 2.5 dBi (maximum) for the antenna assembly.
The antenna and mounting hardware are available as a kit.

3.5.2 Receive Antenna

The CBS uses a maximum of 4 receive antennae connected with 18.3 m (60 ft.) of coax cable. Each receive antenna has an integrated Low Noise Amplifier (LNA). The receive antenna LNA is powered with a 5 Vdc supply from the CBS through the receive antenna BNC connector and cable. The supply current per receive antenna is 45 mA typical.

3.6 Power Supply

The CBS is remotely powered from an AC/DC converter. The nominal DC supply voltage is 48 V with a maximum power of 100 W. The remote supply is connected to the CBS with a two-wire power cable.
The CBS consumes 13 W of power maximum with all 4 receive antennae connected.
Including cable losses, a maximum of 5 CBSs can be powered from one central power supply.

4 HARDWARE DESCRIPTION

4.1 CBS Block Diagram

The figure below shows the block diagram of the CBS.

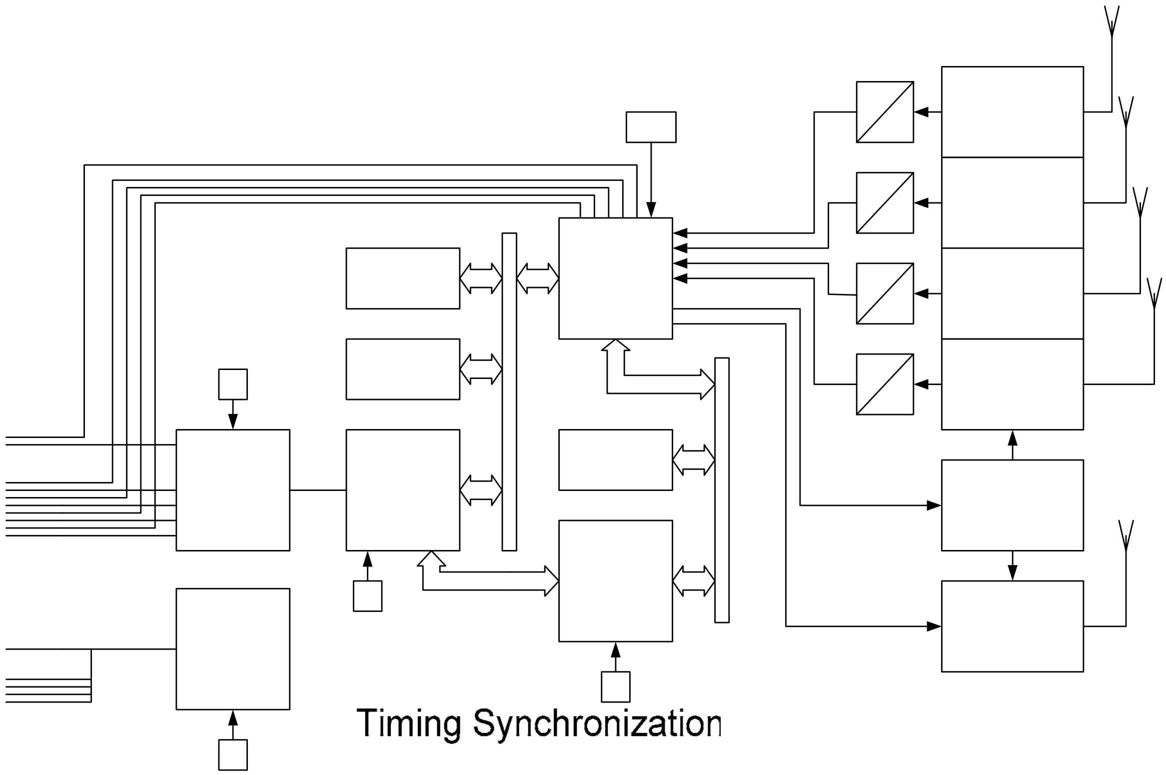

Fig. 2, CBS block diagram.

4.2 Major Modules and Functions

The CBS consists of 2 major modules:

1. Controller Board
   - Microcomputer
   - RAM and Flash Memory
   - A/D converters
   - Digital Signal Processor (DSP)
   - 802.3 10/100BaseT communications
   - Power regulators

2. RF board
- Transmitter
   - 2400-2483.5 MHz Frequency Synthesizer
   - 25.165824 MHz reference oscillator
   - Amplifier
   - Modulator

- PA driver amplifier
    - Directional coupler for receiver Local Oscillator
    - Power Amplifier
    - Forward/Reverse Power detector
- Receiver
    - Four receive antennae with integrated LNA and 60 ft of cable
    - Four receiver inputs with LNA and bandpass filters
    - 4 Homodyne receivers based on an I and Q demodulator
    - Receiver LO obtained from the transmitter Synthesizer output
    - LO amplifier
    - 4 way power splitter for individual receiver LO
    - I and Q baseband amplifiers with 24-40KHz bandpass filters
    - Receiver antenna power supply and current limiting
    - Receiver antenna status monitoring.

4.2.1 Controller Board

Microcomputer

The microcomputer controls the data communication with the ISP. The microcomputer also provides the higher layer functions of the communications with the ESL (data frame formatting, synchronization information and CRC generation). The microcomputer also provides diagnostic information to the ISP such that the ISP can maintain information on the communications quality.

Firmware and configuration information for both the microcomputer and DSP are stored in flash memory. At power up the microcomputer transfers the program information from the Flash memory to the DSP program memory. The DSP then continues to operate from its program memory. The RAM memory in the CBS is not protected when the CBS power is turned off. After power is turned on or the CBS receives a reset command, the CBS resets RAM and reinitializes the DSP program memory.

DSP

The main functions of the DSP are transmit data modulation, receiver signal processing (ACK/NACK detection) and controlling the transmit frequency.

The DSP receives the data for the ESL from the microcomputer, generates the Manchester coded data and drives the transmitter modulating circuit. The DSP also controls the operation of the Phase Locked Loop in the transmitter synthesizer and therefore the transmitter frequency.

The receiver baseband signals are fed through two 16 bit A/D converters to the DSP. The DSP performs a series of mathematical operations on the received signal to detect the ESLs ACK or NACK response. Also the signal level information is provided to the microcomputer.

The transmit power is sensed with a diode detector at the transmitter output. The resulting DC level is measured with an analog to digital converter by the DSP. This measurement is used to adjust the R-F level going into the output amplifier and adjust the transmitter output level at the start of every transmission. The DSP controls the power levels for all the country configurations.

Transmit power is turned off while the synthesizer is changing frequency to avoid out of band and out of spec emissions and also when the Synthesizer indicates that the synthesizer PLL is unlocked (malfunction).

Communications

The communications uses the Ethernet MAC controller integrated in the microcomputer. The MAC is interfaced through an industry standard MII interface to an on board repeater. One port of the repeater is used as the regular input to the CBS.
A second port is used for connection to a downstream CBS. The transmit and receive pair connections of the second port are crossed to provide a standard repeater compatible output.

Power Regulators

The control module contains a switching regulator module that converts the 48 Vdc input voltage down to 5.5 Vdc. A number of switching and linear regulators regulate the 5.5Vdc down to the various voltages required.

4.2.2 RF Board

Transmitter

The transmitter provides the RF power to drive the transmit antenna.
The transmitter also contains the on-off data modulator and filtering for the suppression of harmonic and out-of band emissions.
In addition the transmitter provides the RF drive signal for the demodulator and power level detection signal for diagnostics.

Receiver

The receiver has a low noise amplifier (LNA) and bandpass filter for every input.. After filtering and amplification, the four input signals are converted from RF to baseband signals in four quadrature diode mixers using the transmitter CW signal as demodulating LO signal. The resulting quadrature baseband signals are bandpass filtered and amplified and transferred to the controller board for further processing in the DSP.

The receiver circuit also provides the power for the LNAs in the receive antenna. The voltage and current of the four individual antennas is measured. This information is, through a multiplexer, transferred to the controller for AD conversion and diagnostics.

Synthesizer

The frequency synthesizer is based on a single 1200 MHz PLL circuit. The output frequency is doubled and amplified to generate the 2400 to 2483.5 MHz carrier signal.

5 Specifications

5.1 Transmitter

All specifications apply to the frequency band of 2400 MHz to 2483.5 MHz.

Output Power at transmitter output connector (into a 50 Ohm load)	
US (1W EIRP)	26 dBm +/- 1.5 dB
Europe (500mW EIRP)	23. dBm +/- 1.5 dB
France, Italy, Denmark, Norway (100mW EIRP)	16. dBm +/- 1.5 dB
Available frequencies	565 (channel 0-564)
Channel Spacing	146.312 KHz
Modulation (Manchester code)	16.384 kHz
Frequency Hopping Dwell time	362.5 msec.
Frequency Accuracy (CW) (reference oscillator)	+/- 3 ppm initial +/- 5 ppm lifetime
Output power low indicator threshold relative to nominal output level	-6 dBc +/- 1dB
Modulation depth	Better than 25 dB
Phase Noise (CW)	Better than -80dBc/Hz at 20kHz offset.
Frequency accuracy at CW on after frequency hop	+/- 50 kHz or better
Transmitter open (disconnected) without performance impact	Minimum 30 Minutes
Transmitter short circuit without performance impact	Minimum 30 Minutes
Out of band emissions	
< 2400MHz	< -50dBm
> 2483.5 MHz	< -50dBm
Harmonics	< -50dBm

5.2 Transmit Frequencies

The CBS selects at power up a subset of 83 of the available frequencies in its transmission band in a pseudo random order. The random sequence is stored in the CBS and used as the hopping sequence during operation.

5.3 Receiver

Receiver Noise Factor	Better than 17 dB
Receiver Sensitivity (at 50% error rate in a noise free communications channel)	Better than -130 dBm.
Input return loss	Better than 10 dB
Antenna LNA supply voltage (4 ports loaded at 45 mA per port)	5.0 to 5.5 Vdc
Antenna LNA supply current	100 mA minimum
Receiver short circuit without performance impact	30 Minutes minimum
Max. continuous RF input power (no damage)	10 dBm

6 Description of operation

6.1 System timing

The CBS has a transceiver with two modes of operation, a downlink to the display modules and an uplink for acknowledgments returning from the display modules. These two modes alternate every transmission. The downlink to the ESL is immediately followed by an uplink for responding to the system (CBS).

The System timing is defined by timeframes of 1.45 seconds. Each timeframe of 1.45 second is divided into 24 timeslots. Every CBS is assigned at least one timeslot and usually two timeslots separated by 11 timeslots, for instance one CBS can use timeslots 1 and 13 .

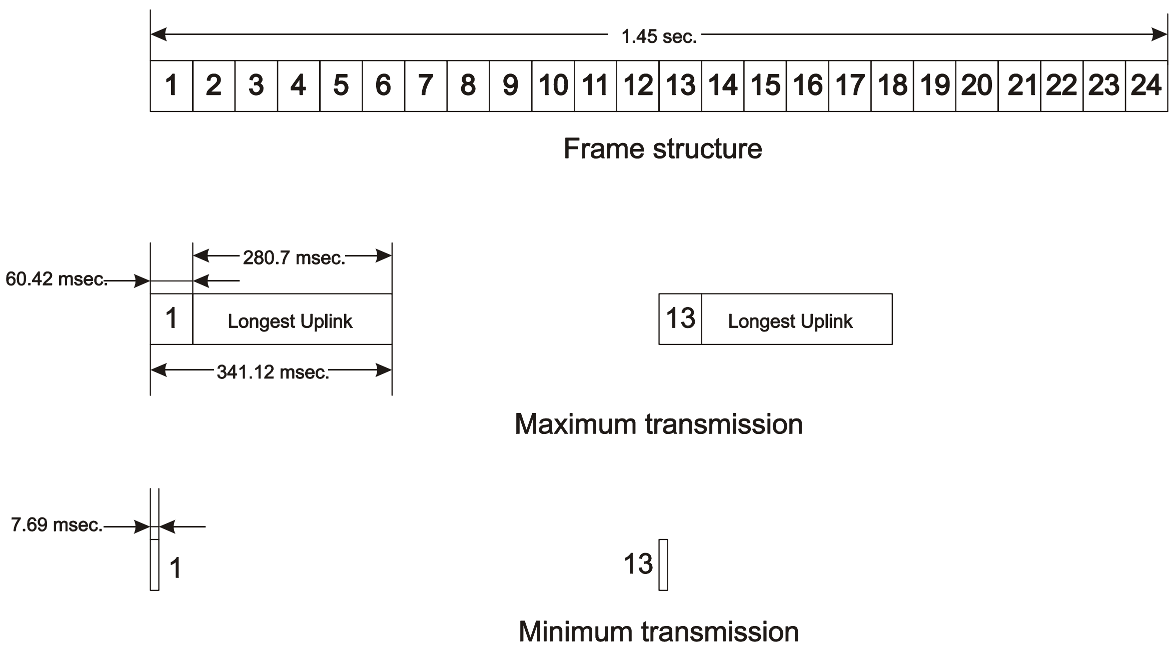

Fig. 3, System timing

At the beginning of the timeslot the CBS sends synchronization information. If no data needs to be sent, the CBS stops transmitting at the end of the synchronization phase (Minimum transmission). Otherwise, the CBS may continue transmitting data up to the maximum time limit.
If the CBS expects a response from and ESL, the CBS continues transmitting an unmodulated carrier after completing the downlink data transmission. Immediately after receiving the downlink data, the ESL starts sending up to 8 consecutive ACKs or NACKs.
The minimum is one NACK, indicating that the downlink communications failed due to a CRC error. The minimum after a successful downlink transmission will be two ACKs, one for the CRC, the next one to indicate successful command execution.

6.1.1 Downlink Operation

The Communications Base Station transmits data to the ESL as amplitude modulated Manchester coded data with a data rate of 16.384 KBps. The downlink includes CBS and timeslot identification information, start of frame delimiter, 32 bit address, command and data fields, a 16 bit CRC check, synchronization bits, and end of frame delimiter. The 32 bit address and the command and data fields are also protected with a 4+3, 8 block interleaved Hamming code that is designed to correct 8 bit burst errors. The detailed format of the data is described in ref. 2.3.

6.1.2 Uplink Operation

The uplink works similar to a field disturbance sensor or doppler radar system. The CBS transmits an unmodulated carrier wave at the same frequency as the downlink transmission. This fixed frequency carrier is left on for the duration of the uplink transmission that the CBS expects.

The ESL module receives the downlink information and after processing the downlink information returns an acknowledgment (ACK) or negative acknowledgement (NACK) by modulating the loading impedance of it's antenna. The CW energy that is transmitted by the CBS after the completion of the downlink is reflected in phase or inverted depending on whether the load is an open circuit or a short circuit. The modulation consist of a 511 bit pseudo random sequence (Spread Spectrum Gold Code) modulated on a 32 kHz carrier signal.
The receiver in the CBS can detect this modulation and, depending on the code, detects an ACK or NACK. If the modulation is not present or is not sufficiently strong (ambiguous), then the CBS will retry the communication with the ESL in question.

The CBSs four receivers use a homodyne architecture. The transmitter output signal is used as the frequency source for demodulator. This eliminates most of phase-noise in the frequency source and results in a lower receiver noise level than would have been achieved with other receiver architectures.
The demodulator in the receiver is followed by a 24 to 40 kHz bandpass filter and amplifier. The output of the amplifier feeds the signal into an A/D converter and into the DSP for further processing.
The DSP compares the received signal with the ACK and NACK sequences that it expects (correlation) to determine whether an ACK or NACK sequence was sent. The ratio between the two correlations determines the reliability of the sequence detection.

6.1.3 Frequency Hopping Sequence

The CBS uses a sequence of 83 frequencies. These frequencies are selected at random out of the 565 frequency channels that are available in the US ISM band of 2400 MHz to 2483.5 MHz. The frequency channels are spaced 146 kHz apart and are occupied for approximately 362.5 milliseconds, whether the CBS transmits or not. The table is stored in the CBS and used until the table is regenerated by a system command .
(the maximum dwell time allowed under CFR 15.247 is 400 ms). A frequency channel is not used again until the sequence repeats in 83*0.3625 = 30.1 s.

6.1.4 Engineering Modes

The CBS supports a number of special operating modes intended for engineering and certification testing.

- Lock the CBS in continuous CW transmission.
- Lock the CBS on any frequency in the legal transmission band in CW mode
- Lock the CBS on any frequency in the legal transmission band while continuing normal transmission operation.

6.2 Communication between ISP, CBS and ESL

The CBS functions as a bridge for communications between ISP and ESL. The CBS receives the data for the ESL from the ISP, converts it to the message format required for transmission and transmits the message over the RF subsystem. The CBS receives the remodulated backscatter signal (ACK or NACK) and transfers the measured uplink signal levels from the receiver to the ISP. The ISP then decides to accept the ACK (or NACK) based on the correlation ratios and retries the transmission if required. The CBS does not initiate error recovery. The ISP determines whether a transmission has failed and data needs to be retransmitted.

The CBS/ISP communications are based on IEEE 802.3 10Base T communications. An off-the-shelf TCP/IP protocol manager will support a connection-oriented TCP streams socket interface for normal communications and a connectionless UDP datagram sockets interface for reverse address resolution and exception reporting. The Socket interface provides APIs for opening a connection with a server, sending data, receiving data, and closing the connection with the server. The lower layers will make CBS Reverse Address Resolution, CBS Addressing, Error Detection, and Flow Control transparent to the upper layer. The top layer, the Application Layer, will support a CBS Messaging Protocol. This protocol will enforce a CBS Messaging Format and CBS Command Format.

6.3 CBS Initialization

The CBS retains all configuration information in its flash memory. After a power cycle the CBS retrieves its TCP-IP address from a DHCP server in the system. The CBS manager uses that address to communicate with the CBS and identify the device based on its MAC address. The CBS manager will then verify (or re-load) the configuration in configuration information.
When replacing a CBS, the MAC address of the new CBS needs to be entered in the DHCP servers database and needs to be related to the configuration information for the CBS manager software.
The CBS manager needs to be set up with this configuration information prior to powering up the Realprice infrastructure or the configuration information need to be changed/loaded interactively.

The CBS firmware resides in flash memory. The flash memory is first loaded when the CBS is configured for shipment. When configured on the production line all information, including country specific RF communications and the CBS MAC address are loaded into the flash memory.
The radio configuration information and MAC address are protected after the initial load and can only be reconfigured by an NCR authorized facility.
The CBS operating firmware can be reloaded in the field with a software flash memory load utility.

6.4 Data Recovery

The CBS performs an initial reset operation each time it is powered up or reset. The contents of all the RAM memories are cleared by the initial reset operation. Data is not stored in the CBS and no protection against power failures or brownouts exists.