Introduction to the OpenSky Digital Base Station

Base Station Overview

Within the OpenSky network, the base station functions as a link that provides voice and data connectivity between OpenSky wireless communication devices, such as mobile and portable radios, and the wireline infrastructure of the OpenSky network. Operating in the OpenSky network architecture, the base station provides a data rate of 19.2 kbps for all OpenSky protocols (OCP, OTP and FMP).

The OpenSky protocols, FMP (Federal Express Mobile Protocol), OCP (Opensky Communication Protocol), and OTP (Opensky Trunking Protocol) are fully digital, TDMA network protocols. For all modes, the OpenSky Base Station implements a complete seven-layer protocol stack.

Note that for all three protocols, the base station hardware operates identically. Only the software is different. Thus the accompanying detailed technical theory of operation is applicable for any operational mode.

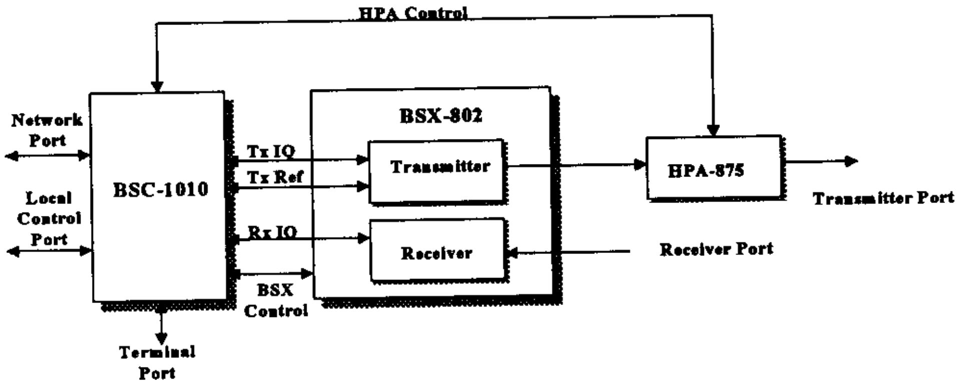
Although voice is supported in FMP, it is digital voice; all modulation is digital. The digital modulation technique used is 4-level Gaussian Minimum Shift Keying (GMSK), with a symbol rate of 9600 Hz (data rate of 19.2 kbps).

This high data rate is supported simultaneously on the transmit and receive channels. The base station provides this full duplex connectivity by transmitting over SMR channels with frequencies ranging from 851-869 MHz, with the corresponding receive channels utilizing the frequency range 806-824 MHz; the receive channel is 45 MHz below the selected transmitter frequency channel. The RF bandwidth utilized for both transmission and reception is 25 kHz.

The Base Station operates full duplex with a nominal maximum output power of 75 Watts. At this maximum output power, the base station can cover up to a thirty-mile radius—given normal terrain—and provide service for up to 200 users.

Physically, the standard base station consists of three chassis and all the associated interconnect cables. The three chassis are mounted in a rugged 19" standard equipment rack. Base stations may be augmented through the addition of specific options such as a duplexer.

The standard base station is comprised of three distinct functional units: the Base Station Controller (BSC-1010), Base Station Transceiver (BSX-802), and the High Power Amplifier (HPA-875.) An interconnection diagram for these chassis is shown below.



The base station's flexibility allows customers the freedom to implement site configurations that can range from a single base station to multiple base stations requiring additional RF and control networks.

Benefits of the OpenSky Base Station

The value inherent from owning an OpenSky Base Station is derived from three central benefits. These benefits are increased capacity, software upgrades and long hardware life.

The suite of current OpenSky protocols provide SMR channel utilization that exceeds that offered by any competitors' products. Through the use of digital voice compression and efficient modulation techniques, OpenSky protocols are able to provide true, "as advertised" high data rates. Given the increasingly high cost of RF spectrum, the ability to maximize channel capacity provides direct financial benefit.

To ensure that channel usage continues to outpace all other current technology, the OpenSky base station's performance can be continually improved through software upgrades. The unique architecture of the OpenSky Base Station is differentiated from its competitors as being software-based, rather than hardware-based. Since all signal processing functions are performed in software, it is a simply a matter of loading new software-based protocols as they are developed, to improve even the current high rate.

An additional benefit that stems from the ability to enhance performance through software-based upgrades is increased hardware life. With an eye toward the goal of extending the time until hardware obsolescence, the OpenSky Base Station is designed for maximum hardware flexibility. This hardware flexibility combined with software-based upgrades, increases the useful life of the OpenSky Base Station, leading directly to a very low cost of ownership.

Summary of Key Features

The OpenSky Base Station employs a modular design approach. All three functional elements—the BSC-1010, BSX-802 and HPA-875--are self-contained within their respective chassis. This modular approach offers customers the benefit of ease of service. Replacement of any of the three main functional components can be accomplished in minutes. All three functional elements of the base station are separately mounted within the 19" equipment rack, making chassis substitution a simple matter of a few mounting screws and a couple of cables.

This 19" 4U rack also includes the required integral cooling fans and AC power supply. The division of the three main functional elements and the power supply into separate metal enclosures minimizes spurious emissions and component interaction.

BSC-1010 - Base Station Controller: The BSC-1010 is the processing engine of the base station. Utilizing software exclusively, the BSC-1010 implements all base station network and digital signal-processing functions. These functions include the Physical Layer (PHY), Medium Access Control (MAC), Mobile Data Link Protocol (MDLP), Radio Resource Management (RRM), Network Management (NMS) and Secondary Registration.

BSX-802 - Base Station Transceiver: The BSX-802 consists of a transmitter and receiver section, each of which implements the corresponding analog transmit and receive functions.

As seen in the accompanying figure, during transmission, the BSC-1010 generates an In-Phase/Quadrature (IQ) baseband signal that is routed to the baseband input of the BSX-802 transmitter. The BSX-802 transmitter converts this baseband signal to a RF output signal, at the selected SMR channel frequency. The nominal output power of this output signal is 0 dBm when measured into a 50 Ω load.

The receiver section of the BSX-802 essentially reverses the transmit process. The antenna routes the desired receive signal to the RF input of the BSX-802. The receiver section converts the signal to a baseband I/Q signal that is routed to the BSC-1010 for further processing.

A DC reference signal is also provided by the BSC-1010 to the BSX-802 to provide a common reference for both the receive and transmit I/Q baseband signals.

HPA-875 - High Power Amplifier: The HPA-875 provides the high power transmit signal to the antenna. To generate this transmit signal, the HPA-875 amplifies the nominal 0 dBm RF input provided by the BSX-802, to generate a maximum output power of 75 Watts.

The HPA-875 also includes an RS-485 communications port that provides control, monitoring, and alarm generation. The HPA-875's output power is controllable via this RS-485 connection from the BSC-1010. Using this serial connection the BSC-1010 can adjust the output power of the HPA-875 from 15 to 75 Watts.

The HPA-875 generates alarms in the case of excessive reflected power or input power, low power output and over-temperature alarms. These alarms are reported to the BCS-1010 and subsequently relayed through the NMS interface across the network port.

Signal input power above 6 dBm causes the HPA to generate an input overdrive alarm and de-key the HPA-875 output. Input signal levels below –10 dBm may prevent the HPA-875 from generating full output power. This condition generates a power leveling control loop alarm, which de-keys the HPA-875.

As described previously, the HPA-875 provides a programmable 15 – 75 watt RF output signal into a 50Ω load. Output protection insures no damage to the HPA from any mismatch condition. However, a programmable threshold on reflected power would normally de-key the HPA under mismatch conditions.

AC Power Strip: The rack-mounted power strip provides all electrical power to the base station. This power strip provides a maximum power output of 1875 Watts and can accept line voltages from 95-135 AC.

The input to the power strip is through a standard three-prong AC plug, with the line length being ten feet.

Specifications

Transmitter Performance

Frequency Band:	851-869 MHz
Channel Step Size:	12.5 kHz
Channel Bandwidth:	25 kHz
Frequency Stability:	0.1 PPM
Output Power into a 50 Ω Load:	75 watts Maximum
Power Adjustment:	15-75 watts
Duty Cycle:	100%
Emission Designator:	20K0F1D
Spurious and Harmonic Emissions:	FCC Part 90

Receiver Performance

Frequency Band:	806-824 MHz
Channel Step Size:	12.5 kHz
Channel Bandwidth:	25 kHz
Frequency Stability:	0.1 PPM
Input VSWR with respect to 50 Ω:	2.0:1 Maximum
Sensitivity:	0.28 μV (-118 dBm) EIA 603 -110 dBm 5% Block Error Rate
Adjacent Channel Selectivity:	70 dB EIA 603
Intermodulation:	70 dB EIA 603

Physical Specifications

Electrical Power:	96-132 VAC, 47-63 Hz
Power Consumption:	400 watts nominal
Height:	27"
Width:	22"
Depth:	20"

Environmental Specifications

Operating Temperature:	-30 C to +60
Storage Temperature:	-40 C to +70

RF Cabling

FROM		TO			
CHASSIS	CONNECTOR	CHASSIS	CONNECTOR	CABLE	SIGNAL
BSX-802	RF Out	HPA-875	RF Input	24" Type N to SMA	RF Tx
BSC-1010	Rx I	BSX-802	Rx I	12" BNC to BNC	Rx I
BSC-1010	Rx Q	BSX-802	Rx Q	12" BNC to BNC	Rx Q
BSC-1010	Tx I	BSX-802	Tx I	12" BNC to BNC	Tx I
BSC-1010	Tx Q	BSX-802	Tx Q	12" BNC to BNC	Tx Q
BSC-1010	REF	BSX-802	REF	12" BNC to BNC	I/Q Ref.

Communication Cables

FROM		TO			
CHASSIS	CONNECTOR	CHASSIS	CONNECTOR	CABLE	SIGNAL
BSC-1010	RS-232	HPA-875	RS-485	24" DB9 to DB9	HPA Ctrl.
BSC-1010	COM 1	BSX-802	RS-485	12" DB9 to DB9	Rx I

Network Connection

The connection to the wireline network is made through the "Network Port" connector located on the rear of the BSC-1010. The port is a DTE RS-232 interface utilizing a Serial Line IP protocol (SLIP).

Electrical Power Connections

The three chassis draw their power from the rack-mounted power strip. The supplied chassis power cords can be plugged directly into any of the ten outlets on the rear of the power strip.

The power strip power cord can be plugged into any AC outlet capable of supplying a minimum of 15 Amps.

Transmitter Calibration

There are two calibrations specific to the transmitter required and they are both performed prior to shipment. To calibrate the base station for high fidelity transmit modulation, the DC offsets and relative phase of the transmit I/Q baseband signals from the BSC-1010 must be adjusted.

To ensure the frequency accuracy of the transmit signal, the ovenized crystal oscillator in the BSX-802 is adjusted at the factory to within ±0.5 PPM.

Transmitter Modulator Calibration:

Transmitter modulation calibration removes errors generated by offsets, amplitude imbalance and phase quadrature. These parameters are calibrated in the factory by generating a test signal. The test signal is a single tone, offset from the channel center by a few kHz. The factory automatic test equipment measures the spectral purity of this signal. Correction factors are computed and downloaded to the BSC-1010, where they are stored in nonvolatile memory.

Transmitter Frequency Accuracy

The transmitter frequency is measured with a frequency counter to verify accuracy. Adjustments as necessary are made to the BSX-802 OCXO to ensure it is accurate to ±0.5 PPM.

5	Segment C
6	Segment D
7	Segment E
8	Segment F
9	Segment G
10	Segment DP

3.6 Processor Section

3.6.1 External Reset Switch Input

The Processor Section contains a connector intended to be connected directly to an external reset switch. The connector is designated as J6. The pinout for this connector is shown in Table 27. The reset is effected by shorting the PBRESET* signal to ground for at least 1 microsecond. During this period the reset switch will carry less than 1 mA of current.

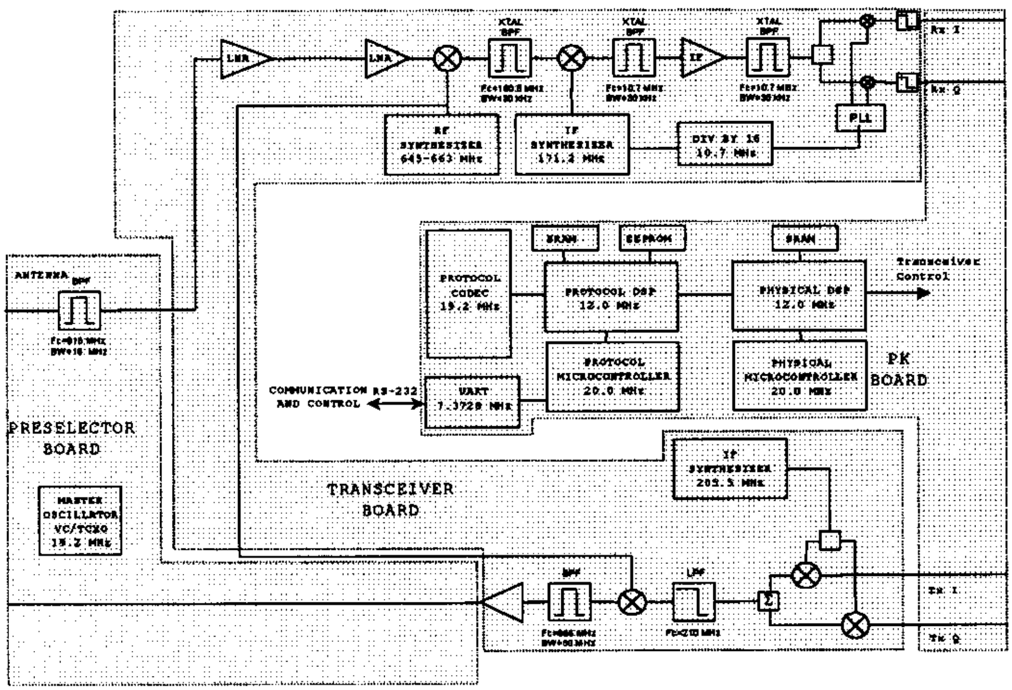
Table 27: External Reset Switch Connector Pinout

Pin Number	Signal Name
1	NC
2	PBRESET*
3	GND

Technical Overview

The BSX-802 performs all analog receiver and transmitter functions in the base station. The BSX-802 is comprised of five printed circuit boards. The five boards are the Front Panel board, the Processing Kernel Board, the Transceiver board, the High Performance Synthesizer board, and the Reference/ Preselector board.

Transceiver Sub-Assembly Block Diagram showing Circuit Board Functions



The latter four boards are mounted within a sub-housing to provide interconnectivity, prevent RF interaction and effect sufficient shielding to ensure compliance with all relevant spectral and spurious emission requirements. This sub-housing is henceforth referred to as the transceiver sub-assembly. The transceiver sub-assembly and the Front Panel board are then installed in the BSX-802 chassis. See the attached block diagram.

The Front Panel board, which is mounted to the front of the chassis, provides the power switch, audio volume control and an audio monitor button. A 50-pin cable assembly connects the Front Panel board with the Processing Kernel board.

The Processing Kernel board provides the control and communication functions for the transceiver. These functions are implemented using two DSPs and two PIC microcontrollers.

The DSPs handle the baseband and audio interfaces to the outside world, as well as the higher levels of the communications protocol stack. The Processing Kernel board also contains the two PIC16C74 microcontrollers. These microcontrollers are responsible for various interfacing and sequencing functions, such as front panel keyboard / LED management (in the "protocol" microcontroller) and transceiver management (in the "physical" microcontroller).

Each DSP has a dedicated AD1845 Σ/Δ CODEC for both A/D and D/A functions. These CODECs are very high performance converters, with built in digital filtering. Completing the DSP processing block is the associated memory. Each DSP has its own bank of static random access memory (SRAM). This memory is used for both program and data storage. Permanent (non-volatile) program memory is "flash" EEPROM, which may be reprogrammed at any time via the serial port.

The Transceiver board contains the complete receiver and transmitter (less the final amplifying stage contained in the HPA-875. The Transceiver board is divided into four sections: receiver, transmitter, local oscillators (LO), and control. The receiver section is a triple-downconversion superheterodyne receiver, which converts an 815 MHz (typical) RF received signal to an I/Q baseband signal. This I/Q baseband signal is then sent to the BSC-1010 for demodulation.

The transmitter section is a double-upconversion transmitter that takes an I/Q baseband signal from the BSC-1010 and creates an 860 MHz (typical) RF output signal. This nominal 0 dBm signal is sent to the HPA-875 for further amplification.

The LO section contains three RF synthesizers located on the Transceiver board and a master ovenized crystal oscillator resident on the Preselector/Reference board. The High Performance Synthesizer board, a 650 MHz (nominal) synthesizer, is mounted as a daughter board to the transceiver board. These phase-locked-loop synthesizers provide all of the local oscillator signals necessary for operation of the receiver and transmitter sections. The control section contains all of the circuitry necessary to control and interface the transceiver board with the Processing Kernel board.

Detailed Theory of Operation - Receive Mode

In receive mode, a signal from an external antenna enters the BSX-802 at the Type "N" connector located at the rear of the BSX-802. The receive signal is then routed to the "mini-UHF" connector on the Reference/Preselector board J5. This signal is routed through the preselector filter FL1, to the OSX connector J6. The preselector filter passes the entire SMR band, which is approximately 806-821 MHz. A semi-rigid coaxial cable carries the signal from the Reference/Preselector board to the transceiver board, where the cable is soldered directly to the board. The output of the cable passes to a low noise amplifier, U35. The output of this amplifier is then down-converted to the first IF of 160.5 MHz by a double-balanced mixer, U39, and amplified by an IF LNA, U41.

The first IF 160.5 MHz receive signal is routed through a three-pole crystal filter, FL3, before moving to the IF subsystem chip, U28. This subsystem chip provides downconversion to the second IF (10.7 MHz), using the second 171.2 MHz LO. The second IF 10.7 MHz signal goes through a four-pole crystal filter, FL4 and FL5, before entering a high gain IF strip. The output of the IF strip enters a two pole 10.7 MHz crystal filter, FL6. The resultant signal enters the I/Q demodulator. This demodulator performs the final downconversion to complex baseband, using the third LO of 10.7 MHz. Operational amplifiers U16 and U17, condition the I/Q output signals before they are sent differentially to the BSC-1010.

Detailed Theory of Operation - Transmit Mode

The I/Q transmit baseband signals are originated by the BSC-1010 and sent to the BSX-802. These baseband signals are then amplified and filtered by an operational amplifier, U12 on the Processing Kernel board, before being transferred to the transceiver board.

The received I/Q signals are conditioned and filtered by an operational amplifier, U16. The resulting I/Q signals are then applied to an I/Q modulator, U24. The I/Q modulator uses the second transmit LO to produce a 205.5 MHz bandpass output signal. This bandpass signal is then filtered, FL7, and amplified, U30, and subsequently up-converted to the output frequency by a double-balanced mixer, U32. This mixer uses the same first LO as the receive section. The resulting UHF signal is filtered, FL9, amplified, U1, and then output via an OSX connector, J4.

A semi-rigid cable carries the UHF signal from the OSX connector on the Transceiver board to an SSMA connector mounted on the rear panel of the transceiver sub-assembly. A semi-rigid cable routes the UHF to a SMA connector on the rear BSX-802.

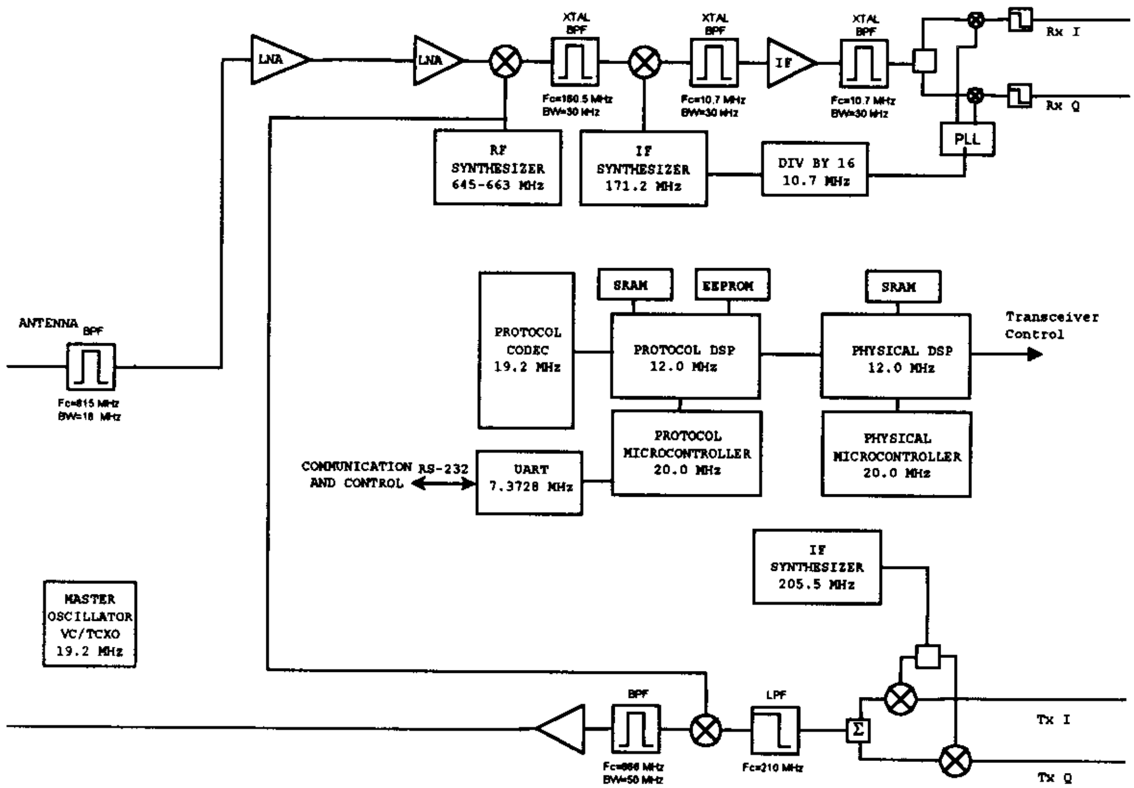
Detailed Theory of Operation – Frequency Distribution

The LO for the double-balanced mixer, U39, is low side, approximately 645-660 MHz, and originates from the High Performance Synthesizer daughter board. The first LO is shared between receive and transmit sections of the transceiver, with separate buffer amplifiers for each; U38 for receive and U37 for transmit. The receiver second LO is 171.2 MHz and comes from the second receiver synthesizer module, U11. A prescaler, U13, divides this 171.2 MHz LO signal by 16 to form the third receiver LO of 10.7 MHz.

The transmitter section second LO is 205.5 MHz and comes from synthesizer module, U10. The frequency reference for all of the synthesizers is a 19.2 MHz VC/TCXO, X1, which provides ±0.1 PPM frequency error over temperature. This 19.2 MHz reference is buffered by a transistor, Q4, and then sent to the Processing Kernel board as the CODEC master clock.

The lock status of all three synthesizers is continuously monitored. If any one of these synthesizers fails to remain locked, either the Processing Kernel board microcontroller or hardware controlled lock status monitor, U9 on the Transceiver board, prevents transmission. This prevents the radio from transmitting on the wrong channel.

Transceiver Sub-Assembly Block Diagram showing Clock Frequencies



Function of Each Active Device in the Transmitter

Chassis/Board	Reference Designator	Device Description	Function in Transmit Mode
BSX-802/PK	U12	Operational Amplifier	Buffer and filter the baseband I/Q transmit signals
BSX-802/XCVR	U16	Operational Amplifier	Buffer and filter the baseband I/Q transmit signals
BSX-802/XCVR	U24	I/Q Modulator	Generate a 205.5 MHz modulated bandpass signal
BSX-802/XCVR	U10	Synthesizer	Generate a 205.5 MHz Local Oscillator
BSX-802/XCVR	U2	Amplifier	Amplify the 205.5 MHz Local Oscillator
BSX-802/XCVR	X1	VC/TCXO	Generate a 19.2 MHz reference for PLL synthesizers
BSX-802/XCVR	FL7	Filter	Lowpass filter the 205.5 MHz transmit signal
BSX-802/XCVR	U30	Amplifier	Amplify the 205.5 MHz transmit signal
BSX-802/XCVR	U32	Mixer	Mix 205.5 MHz transmit signal to final UHF frequency
BSX-802/XCVR	U12	Synthesizer	Generate the first LO (1010-1050 MHz)
BSX-802/XCVR	U25	Splitter	Distribute the first LO
BSX-802/XCVR	U37	Amplifier	Amplify the first LO
BSX-802/XCVR	FL9	Filter	Filter the UHF transmit signal
BSX-802/XCVR	U1	Amplifier	Amplify the UHF transmit signal
HPA-875/RF	U1	3 dB Coupler	Couple Signal to the input power detector
HPA-875/RF	U3	RF Attenuator	Control the output power level
HPA-875/RF	Q3	Transistor	Amplify the UHF output signal
HPA-875/RF	FL9	Filter	Filter the UHF output signal
HPA-875/RF	U4	Amplifier	Amplify the UHF output signal
HPA-875/RF	U6	Isolator	Reflected Power Detection

HPA-875

Detailed Theory of Operation

The HPA-875 is a microcontroller-based high power amplifier that can produce a programmable 15-75 Watt output signal. As shown in the block diagram, the HPA-875 is comprised of five main functional blocks: the microcontroller, RS-485 communications, RF detectors, power supply and RF transmit chain.

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The microcontroller, U7, integrates and controls all the central features provided by the HPA-875. These features are output power control and leveling, reflected power detection, input power detection, alarm generation and serial communications.

The transmit chain architecture is designed to support all the aforementioned functionality. The UHF transmit signal from the BSX-802 first enters the HPA-875 through its RF input connector. This input is a SMA connector mounted on the rear of the HPA-875. As seen from the accompanying block diagram, the transmit signal is first routed through a 3dB coupler, U1. The output of the coupler is fed to a voltage-controlled attenuator, U3, while the coupled path is sent to the input power detector. The output of the voltage variable attenuator is then amplified by a transistor-based gain stage, Q3, bandpass filtered, FL9, and then amplified again, U4. This high power signal is then passed through a 30-dB coupler and an isolator, U6, before being sent to the type "N" output connector located on the rear of the HPA-875.

Output power control and leveling are achieved through the use of a diode-based, CR6, output power detector and the microcontroller to implement a control and leveling loop. The RF input for the output power detector is derived from the coupled output of the 30-dB coupler following the output amplifier stage. The output power detector converts the RF power level of this signal to an analog voltage signal, which is routed to an analog input on the microcontroller.

The microcontroller compares this analog input signal level to the signal level expected from the desired power output. The microcontroller then adjusts the voltage input to the attenuator to minimize the discrepancy detected and desired output levels.

The input power detector is used to identify both excessive and insufficient input signals. This detector is a diode-based, CR1, detector that converts the coupled RF signal to a corresponding analog voltage. This analog voltage is sent directly to the microcontroller. If the microcontroller detects a RF input signal in excess of 6 dBm, an input overdrive alarm is generated and the HPA-875 is de-keyed. Input signals less than –10 dBm cause the microcontroller to issue a power leveling control loop alarm and, again, the HPA-875 is de-keyed.

The reflected power detector ensures that the HPA-875 will not attempt to transmit a high power RF signal into a severe mismatch. This detector operates in a manner similar to the input and output detectors with the exception that the reflected power threshold level are programmable by the user. The reflected power level is detected from the isolator preceding the RF output connector. This RF signal is converted to an analog voltage by the reflected power detector. This analog voltage is sent to the microcontroller where it compared to the programmable threshold level. If the threshold level is exceeded, the HPA-875 is de-keyed.

It is important to note that all detectors are calibrated and tested at the factory prior to shipment, to ensure that the required accuracy has been achieved.

The RS-485 interface processes all communications between the HPA-875 and the BSC-1010. This serial communications interface is comprised of the receiver, U17, the transmitter, U18, and the microcontroller, U7. This communications interface processes all commands to the HPA-875—output levels, reflected power thresholds, etc.—and alarm outputs—input overdrive, power leveling, over temperature, etc.

The final function block in the HPA-875 is the power supply. The power supply accepts a nominal 125 vac input that is converted directly to 23 volts DC. The AC/DC converter used to produce this DC output is U10. The 23 volts DC output is applied to a linear regulator, U14, to produce 15 volts DC. This 15 volts DC output is then applied to another linear regulator, U13, to produce +5 volts DC. Applying the +5 volts DC to a switching regulator, U3, produces the final –5 volts DC.

Power Strip

The UL approved, rack-mounted power strip used by the base station provides ten switched 125 vac outlets on the back of the strip and two unswitched outlets on the front. The power strip can supply a total of 15 Amp to attached devices for a total power output of 1875 Watts. The power strip has a 15 Amp circuit breaker with reset, to protect against excessive current draw.

The power strip also features surge suppression and status monitors. These status monitors are LED's, which provide information on the state of the power switch, state of the surge suppression circuitry and the voltage range. 95-135 vac, of the incoming AC line.