Installation and Operation Manual for the SBIII Digital Signal Booster Model 6138X

**Manual Part Number
7-9485**

WARNING: This is **NOT** a consumer device. It is designed for installation by **FCC Licensees** and **Qualified Installers**. You must have an **FCC license** or express consent of an FCC Licensee to operate this device. This booster can be configured as either a Class A or Class B signal booster. If configured as a Class B signal booster (as defined in 47 CFR 90.219), you MUST register this signal booster online at www.fcc.gov/signal-booster/registration. Unauthorized use may result in significant forfeiture penalties, including penalties in excess of $100,000 for each continuing violation.

WARNING: This is NOT a CONSUMER device. It is designed for installation by an installer approved by an ISED licensee. You MUST have an ISED LICENCE or the express consent of an ISED licensee to operate this device.

AVERTISSEMENT: Ce n'est PAS un appareil CONSOMMATEUR. Il est conçu pour être installé par un installateur agréé par un détenteur de licence ISED. Vous DEVEZ avoir une LICENCE ISED ou le consentement exprès d'un détenteur de licence ISED pour utiliser cet appareil.

Warranty

This warranty applies for one year from shipping date.

TX RX Systems Inc. warrants its products to be free from defect in material and workmanship at the time of shipment. Our obligation under warranty is limited to replacement or repair, at our option, of any such products that shall have been defective at the time of manufacture. **TX RX Systems Inc.** reserves the right to replace with merchandise of equal performance although not identical in every way to that originally sold. **TX RX Systems Inc.** is not liable for damage caused by lightning or other natural disasters. No product will be accepted for repair or replacement without our prior written approval. The purchaser must prepay all shipping charges on returned products. **TX RX Systems Inc.** shall in no event be liable for consequential damages, installation costs or expense of any nature resulting from the purchase or use of products, whether or not they are used in accordance with instructions. This warranty is in lieu of all other warranties, either expressed or implied, including any implied warranty or merchantability of fitness. No representative is authorized to assume for **TX RX Systems Inc.** any other liability or warranty than set forth above in connection with our products or services.

TERMS AND CONDITIONS OF SALE

PRICES AND TERMS:
Prices are FOB seller's plant in Angola, NY domestic packaging only, and are subject to change without notice. Federal, State and local sales or excise taxes are not included in prices. When Net 30 terms are applicable, payment is due within 30 days of invoice date. All orders are subject to a $100.00 net minimum.

QUOTATIONS:
Only written quotations are valid.

ACCEPTANCE OF ORDERS:
Acceptance of orders is valid only when so acknowledged in writing by the seller.

SHIPPING:
Unless otherwise agreed at the time the order is placed, seller reserves the right to make partial shipments for which payment shall be made in accordance with seller's stated terms. Shipments are made with transportation charges collect unless otherwise specified by the buyer. Seller's best judgement will be used in routing, except that buyer's routing is used where practicable. The seller is not responsible for selection of most economical or timeliest routing.

CLAIMS:
All claims for damage or loss in transit must be made promptly by the buyer against the carrier. All claims for shortages must be made within 30 days after date of shipment of material from the seller's plant.

SPECIFICATION CHANGES OR MODIFICATIONS:
All designs and specifications of seller's products are subject to change without notice provided the changes or modifications do not affect performance.

RETURN MATERIAL:
Product or material may be returned for credit only after written authorization from the seller, as to which seller shall have sole discretion. In the event of such authorization, credit given shall not exceed 80 percent of the original purchase. In no case will Seller authorize return of material more than 90 days after shipment from Seller's plant. Credit for returned material is issued by the Seller only to the original purchaser.

ORDER CANCELLATION OR ALTERATION:
Cancellation or alteration of acknowledged orders by the buyer will be accepted only on terms that protect the seller against loss.

NON WARRANTY REPAIRS AND RETURN WORK:
Consult seller's plant for pricing. Buyer must prepay all transportation charges to seller's plant. Standard shipping policy set forth above shall apply with respect to return shipment from TX RX Systems Inc. to buyer.

DISCLAIMER

Product part numbering in photographs and drawings is accurate at time of printing. Part number labels on TX RX products supersede part numbers given within this manual. Information is subject to change without notice.

Bird Technologies Group   **TX RX Systems Inc.**

Symbols Commonly Used

WARNING

ESD Electrostatic Discharge

CAUTION or ATTENTION

Hot Surface

High Voltage

Electrical Shock Hazard

Heavy Lifting

NOTE — Important Information

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Table of Contents

Figures and Tables

Appendixes

For Class A Unintentional Radiators

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to Part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which the user will be required to correct the interference at his own expense.

Pour Classe-A Radiateurs Involontaires

Cet équipement a été testé et jugé conforme avec les limites de la Classe-A des appareils numériques, suivants à la Partie 15 des règlements de la FCC. Ces limites sont conçues pour fournir une protection raisonnable contre les interférences dangereuses lorsque l'équipement est utilisé dans un environnement commercial. Cet équipement génère, utilise et peut émettre des fréquences radio et, s'il n'est pas installé et utilisé conformément aux instructions du manuel, ceci peut causer des interférences dangereuses aux communications radio. Le fonctionnement de cet équipement dans une zone résidentielle est susceptible de causer des interférences mauvaises dans lequel l'utilisateur sera tenu pour responsable de corriger l'interférence à sa propre discrétion.

WARNING: **Changes or modifications which are not expressly approved by TXRX Systems Inc. could void the user's authority to operate the equipment.**

AVERTISSEMENT: **Les changements ou modifications qui ne sont pas approuvés par TXRX Systems Inc. pourrait annuler l'autorité de l'utilisateur de faire fonctionner l'équipement.**

ATTENTION: This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference and (2) this device must accept any interference received, including interference that may cause undesired operation.

ATTENTION : Cet appareil est conforme à la Partie 15 des règlements de la FCC. L'opération doit se conformer aux deux conditions suivantes: (1) cet appareil ne peut causer d'interférences nuisibles et (2) cet appareil doit accepter toute interférence reçue, y compris les interférences qui peuvent provoquer un fonctionnement indésirable.

OVERVIEW

Signal boosters extend radio coverage into areas where abrupt propagation losses prevent reliable communication. The system receives an RF signal, raises its power level, and couples it to an antenna so that it can be re-radiated. The TXRX model 6138X family of channelized signal boosters is designed to operate in either the 700 or 800 MHz range. Dual band models are available that include both 700 and 800 MHz systems in the same enclosure box. The system is based on a module design with each module capable of handling 14 or 30 carriers in the uplink and downlink direction. The signal booster is available in a variety of configurations as shown in **Table 1**. The product model number is used to describe each configuration available. Model number nomenclature is described in table 1.

The size of the system can be tailored to the customers needs by increasing or decreasing the number of carriers used. Each module is bi-directional with one downlink and one uplink signal branch. Each of the two branches in a module are independently tunable to their required pass frequencies via software interface. System specifica-

6138X-XX-YY-UD-Z-Options (nomenclature breakdown)	
6138X	Designates product as 700 - 800 MHz channelized signal booster
XX	Designates operating frequency band 9A = 806 - 869 MHz 3B = 763 - 805 MHz 3G = 763 - 869 MHz
YY	Designates how many modules used and number of filters available A = 1 module with 14 filters B = 1 module with 30 filters AA = 2 modules with 14 filters each BB = 2 modules with 30 filters each AB = 1 module (700 MHz) with 14 filters and 1 module (800 MHz) with 30 filters BA = 1 module (700 MHz) with 30 filters and 1 module (800 MHz) with 14 filters
UD	Designates the type of output for the uplink and downlink HH = high power uplink and downlink HL = high power uplink and low power downlink LH = low power uplink and high power downlink LL = low power for both uplink and downlink FH = fiber output uplink and high power downlink FL = fiber output uplink and low power downlink HF = high power uplink and fiber output downlink LF = low power uplink and fiber output downlink FF = fiber uplink and fiber downlink
Z	Designates mounting style RM = 19" rack mount G1 = Painted enclosure G2 = Stainless steel enclosure
Options	Designates the options that have been added Blank = no options added N = NFPA compliant (National Fire Protection Association) P = 10 MHz high precision reference D = -48 VDC Q = Fiber input downlink only R = Fiber input uplink only S = Fiber input downlink and uplink
Table 1: Model number nomenclature.	

Frequency Range (MHz)	763 - 775 and 793 - 805 (units sold in USA) 806 - 824 and 851 - 869 (units sold in USA) 764 - 776 and 794 - 806 (units sold in Canada) 806 - 824 and 851 - 869 (units sold in Canada)
Number of Carriers per Module Low Density Model High Density Model	14 uplink and downlink 30 uplink and downlink
Gain Low Power Version High Power Version	80 dB (min) 95 dB (min)
Maximum RF Bandwidth 700 MHz module 800 MHz module	12 MHz 15 MHz
Output Level Low Power High Power	-30 to 10 dBm composite -15 to 32 dBm composite
Maximum Continuous Input Level	Operational: -20 dBm Static w/o damage: -10dBm
RF In/Out Impedance	50 Ohms
Alarms	Form-C Contacts
Power	90 - 250 VAC, 50/60 Hz or - 48 VDC
Operating Temperature Range	-30°C to +60°C 95% RH (non-condensing)
Table 2: Specifications.	

tions for the 6138X family of channelized signal boosters are listed in **Table 2**.

Down / Up Conversion

A channelized signal booster has much in common with a superheterodyne (superhet) receiver. The incoming signal is converted to a lower frequency so that single channel selectivity can be obtained. It is then filtered. Unlike the superhet receiver however, the signal is not demodulated. Instead, it is up-converted back to its original frequency where it is further amplified to reach a useful power level.

Figure 1 shows a simplified block diagram that illustrates the down/up conversion principle. An incoming signal at (Freq IN) is amplified and applied to the first mixer along with a signal from a local oscillator (Freq LO). A third signal at an intermediate frequency (Freq IF) is produced as a result of the mixing. The intermediate frequency is given by the following relationship:

(1)   Freq IF = Freq IN - Freq LO

The IF signal from the mixer then passes through digital filtering with single channel bandwidth before being amplified and passed on to the second mixer. The second mixer also receives the same local oscillator signal (Freq LO). The result is a mixing product frequency at the output of mixer 2. The output frequency (Freq OUT) is given by the following relationship:

(2)   Freq OUT = Freq IF + Freq LO

Substituting equation (1) for the "Freq IF" term in equation (2) allows the "Freq LO" terms to be canceled yielding:

(3)   Freq Out = Freq IN
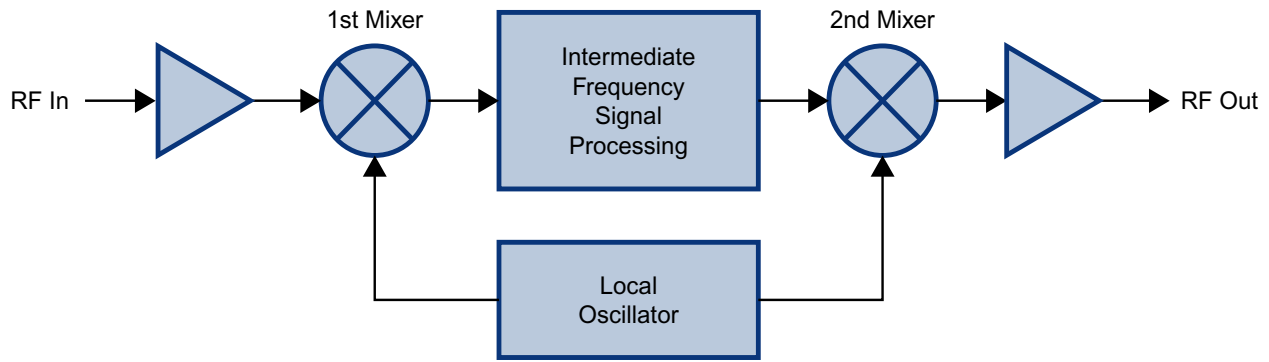
Figure 1: The down converter / up converter process.

The implication of equation (3) is that the frequency stability of the signal that is processed by this type of signal booster is not affected by the frequency stability of the signal booster itself. Frequency stability depends only on the stability of the signal source producing the signal to be boosted. A shift in the LO frequency will cause the center of the filter bandwidth to move with respect to the signal. For very narrow filter widths, the channel modules LO may be locked to a high stability 10 MHz reference.

UNPACKING

It is important to report any visible damage to the shipping company immediately. It is the customers responsibility to file damage claims with the shipping company within a short period of time (1 to 5 days). Care should be taken when removing the unit from the packing box to avoid damage to the unit.

INSTALLATION

The following sub-sections of the manual discuss general considerations for installing the booster. All work should be performed by qualified personnel and in accordance with local codes.

Location

The layout of the signal distribution system will be the prime factor in determining the mounting location of this unit. However, safety and serviceability are also key considerations. The unit should be located where it can not be tampered with by the general public, yet is easily accessible to service personnel. Also, consider the weight of the unit and the possibility for injury if it should become detached from its mounting for any reason.

The booster needs to be installed such that there can be unobstructed air flow around the equipment. Insure that the heat sink fins are unobstructed. The various subassemblies within the equipment cabinet will stay warm during normal operation so in the interest of equipment longevity, avoid installation locations that carry hot exhaust air or are continually hot.

Mounting

Figure 2 shows the mounting hole dimensions and layout for the cabinet. Mount the cabinet using 3/8" (10 MM) diameter steel bolts (not supplied). We recommend flat washers on both ends and a lock washer under the nut. Nut and bolt mounting is preferred to the use of lag bolts. Use backer blocks where necessary to spread the force over a larger area. In areas of known seismic activity, additional devices such as tether lines may be necessary.

Because Bird Technologies cannot anticipate all of the possible mounting locations and the structure types where these devices will be located, we recommend consulting local building inspectors, engineering consultants or architects for advice on how to properly mount objects of this type, size and weight in your particular situation. It is the customers responsibility to make sure that these devices are mounted safely and in compliance with building codes.

Connections

All RF cabling connections to the booster should be made and checked for correctness prior to powering up the system. N(f) bulkhead connectors are available at the top of the booster enclosure box for connection to the system antennas. Make sure the
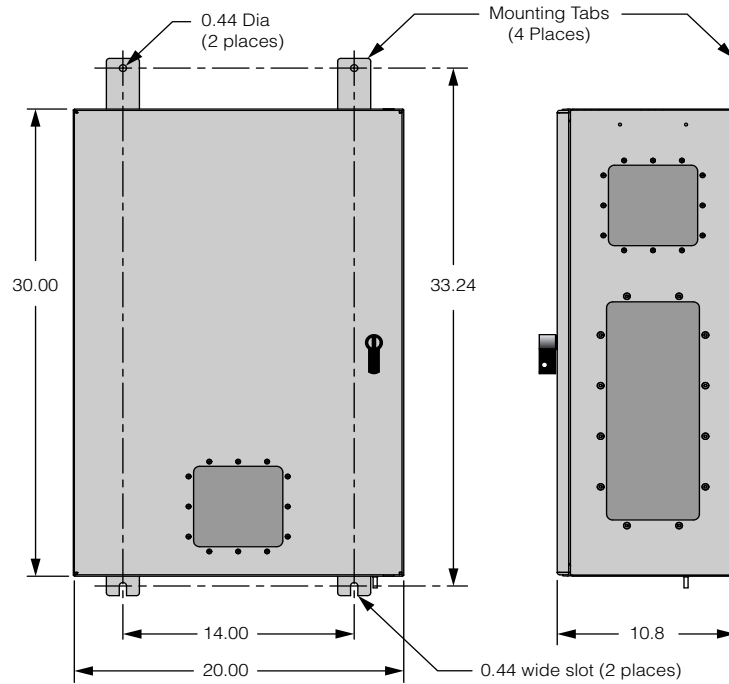
Figure 2: Cabinet mounting hole layout.

correct branch of the antenna system is connected to its corresponding uplink/downlink connector or the system will not work properly. Using high quality connectors with gold center pins is advised. Flexible jumper cables made of high quality coax are also acceptable for connecting to rigid cable sections.

Caution: The ERP (effective radiated power) from the booster system must not exceed +37 dBm (5 Watts) in order to remain compliant with FCC regulations.

Caution: The maximum continuous input power level for this booster is -20 dBm. Stronger input signals will cause the unit to exceed it's IM specifications. Static input signals greater than -10 dBm may damage the unit.

Models of the booster are available for either AC or DC operation. Based on the model number (see table 1) the booster is designed to be plugged into either a single phase AC line (110 VAC at 50/60 Hz) or a - 48 Volt DC source. A connector is avail-

able at the top of the equipment box for connecting the AC or DC source voltage.

Antenna Isolation

Antenna isolation between uplink and downlink should be measured before connecting the signal booster to the antenna system. This step is necessary to insure that no conditions exist that could possibly damage the signal booster and should not be skipped for even the most thoroughly designed system.

Just like the feedback squeal that can occur when the microphone and speaker get too close together in a public address system, a signal booster can start to self oscillate. This can occur when the isolation between the Uplink and Downlink antennas does not exceed the signal boosters gain by at least 15 dB. Oscillation will reduce the effectiveness of the system and may possibly damage amplifier stages. Isolation values are relatively easy to measure with a spectrum analyzer and signal generator.

REQUIRED EQUIPMENT
The following equipment is required in order to perform the antenna isolation measurements.

1) Signal generator for the frequencies of interest capable of a 0 dBm output level. Modulation is not necessary.

2) Bird Technologies "Signal Hawk" spectrum analyzer which will cover the frequencies of interest and is capable of observing signal levels down to -100 dBm or better.

3) Double shielded coaxial test cables made from RG142, RG55 or RG223 coaxial cable.

MEASUREMENT PROCEDURE
To measure the antenna isolation perform the following in a step-by-step fashion.

1) Set the signal generator for a 0 dBm output level at the center frequency of the boosters passband.

2) Set the spectrum analyzer for the same center frequency and a sweep width equal to or just slightly greater than the passband chosen earlier in step 1.

3) Temporarily connect the test leads of the signal generator and spectrum analyzer together using a female barrel connector, see **Figure 3**. Observe the signal on the analyzer and adjust the input attenuator of the spectrum analyzer for a signal level that just reaches the 0 dBm level at the top of the graticule.

4) Referring to figure 3, connect the generator test lead to one side of the antenna system and the spectrum analyzer to the other then observe the signal level. The difference between the observed level and 0 dBm is the isolation between the sections. If the signal is too weak to observe, the spectrum analyzer's bandwidth may have to be narrowed and it's input attenuation reduced. The isolation value measured
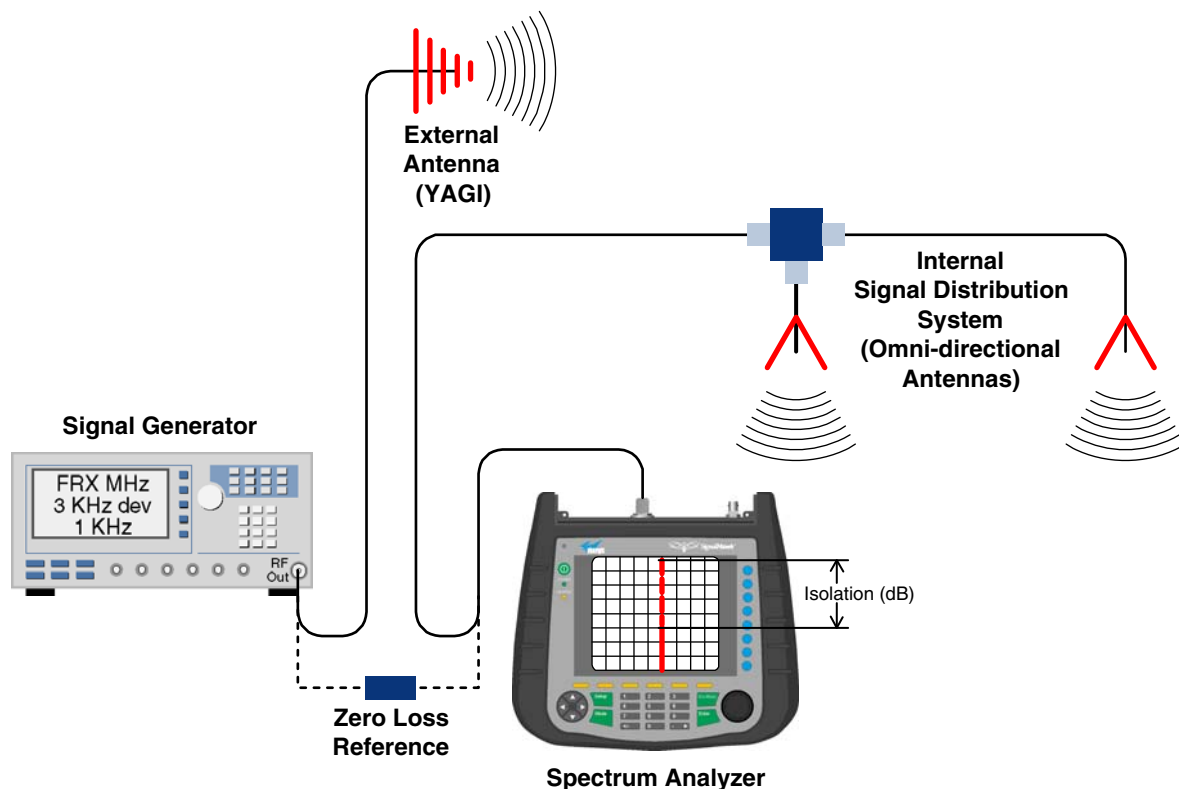
Figure 3: Typical test equipment interconnection for measuring antenna isolation.

should exceed the signal booster's gain figure by at least 15 dB.

5) Repeat step 4 again with the signal generator set at the passband edges in order to see if the isolation is remaining relatively constant over the complete width of the passband.

6) Repeat the isolation measurements if necessary at other system passbands to determine the overall minimum isolation value for the system. Physical modification of the antenna system maybe required in order to reach an acceptable minimum value.

RF EXPOSURE

To comply with FCC RF exposure compliance requirements, a separation distance of at least 69 cm must be maintained between the antennas of this device and all persons. To comply with IC RF exposure compliance requirements, a separation distance of at least 100 cm must be maintained between the antennas of this device and all persons. This device must not be co-located or operating in conjunction with any other antenna or transmitter.

EXPOSITION RF

Pour conformer aux exigences d'exposition de FCC RF, une distance de séparation d'au moins 69 cm doit être maintenue entre les antennes de cet appareil et toutes les personnes. Pour conformer aux exigences d'exposition de IC RF, une distance de séparation d'au moins 100 cm doit être maintenue entre les antennes de cet appareil et toutes les personnes. Cet appareil ne doit pas être co-localisé ou exploités en conjonction avec toute autre antenne ou transmetteur.

SIGNAL FLOW BLOCK DIAGRAM

Figure 4 is the signal flow block diagram of the standard channelized signal booster model 6138X. **Figure 5** shows the front view of the booster cabinet. The channel modules are bi-directional with each module containing one downlink branch and one uplink branch. The branches are functionally identical because the same circuit board designs are used in each branch. The uplink and downlink branches may be programmed to any frequency in the appropriate band.

Uplink and Downlink Input Signals

Uplink input signals (794 - 806 and 806 - 824) are picked up by the DAS antenna and applied to the triplexer. The uplink input signals pass through the triplexer and are fed into a directional coupler
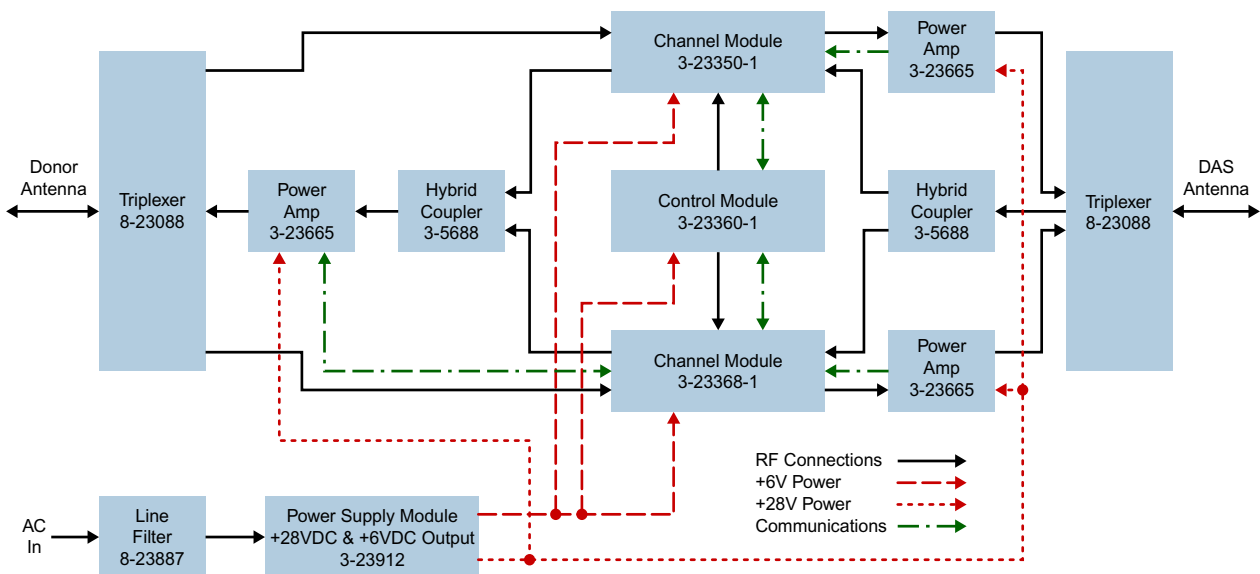
Figure 4: Signal flow block diagram of the channelized signal booster.
Dual band high power model shown as an example.

Line
Filter

Power
Supply

Power
Amplifier

Control
Board

Power
Amplifier

Power
Amplifier

Directional
Coupler

Channel
Module
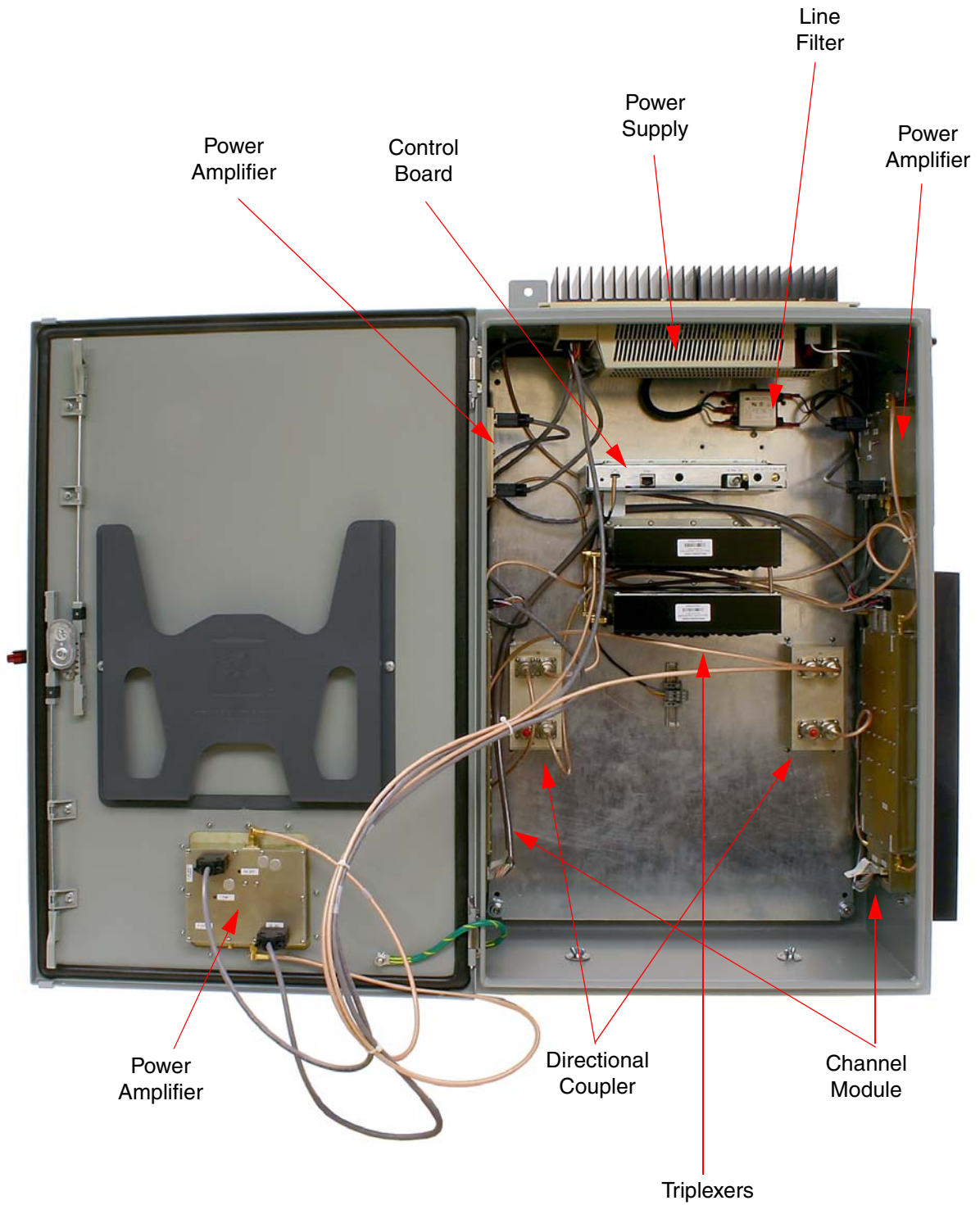
Triplexers

Figure 5: Front view of the booster.

where they are distributed to the uplink input port of both the 700 and 800 MHz channel modules.

Downlink input signals (764 - 776 and 851 - 869) are picked up by the Donor antenna and applied to the triplexer. The downlink input signals pass through the triplexer and exit at either the 700 or 800 MHz output port. The 700 and 800 MHz downlink inputs signals are then applied to the downlink inputs of the respective 700 and 800 MHz channel modules.

Channel Module

The uplink input signals and the downlink input signals are applied to a down-converter board when they enter the channel module. Within the channel module input signals are down converted, digitized, and DSP filtering is performed. There are two

Location	Label	Possible States	Causes	Action to take
Bottom of channel module	DL/UL PWR	Green solid	FPGA successfully loaded	None
Bottom of channel module	DL/UL PWR	Off	Issue with board	Return to factory
Bottom of channel module	DL/UL COM	Red flashes	Exchanging data with control board	None
Bottom of channel module	DL/UL COM	Red solid	Exchanging data with control board	None
Bottom of channel module	DL/UL COM	Off	No data exchanging	None
Bottom of channel module	DL/UL COM	Always Off and it is expected to flash	No data exchanging	Check cabling; return control board to factory
Bottom of channel module	DL/UL DAC	Red solid	DAC overflow	Lower output power setting
Bottom of channel module	DL/UL DAC	Off	DAC normal operation	None
Bottom of channel module	DL/UL ADC	Red solid	ADC overflow	Increase down converter attenuation
Bottom of channel module	DL/UL ADC	Off	ADC normal operation	None
Control board	Ctrl LED	Off	no power, no bootloader, no program	Return to factory
Control board	Ctrl LED	Orange	bootloader installed, no program	return to factory or perform field update
Control board	Ctrl LED	Red	Control board detected a fault	Address fault condition. Contact factory
Control board	Ctrl LED	Green solid	Control board normal operation	None
Power Amplifier	PWR	Green solid	6 VDC supply to Amplifier is OK	None
Power Amplifier	PWR	Off	No supply voltage	check power supply and cabling
Power Amplifier	PA OFF	Off	Power Amp normal operation	None
Power Amplifier	PA OFF	Red solid	Over current, over temp	Amp shut down, contact factory
Table 3: Subassembly LED descriptions.				

styles of Channel modules available, a 14 channel version and a 30 channel version. After DSP filtering the analog signal is recreated and up converted with an up-converter board to the original frequency before being output from the channel module at the downlink and uplink output ports.

Up converter boards are available in two different styles including low level and high level. If the signal booster is a high-power model then a low level up converter board is used in the channel module. If the booster is a low power model then high level up converter boards are used. Signal booster models that have the fiber-optic option installed in them have enhanced down-converter boards that are capable of dealing with the low level signals from the optical conversion.

Uplink and Downlink Output Signals
Uplink and Downlink output signals leave the channel module at the UL OUT and DL OUT connectors respectively. The 700 and 800 MHz uplink output signals are combined with a directional coupler then passed on to a power amplifier stage. The output of the power amplifier is passed through a triplexer then radiated from the donor antenna. *Note: When the booster is operated at the maximum uplink output power level the gain of the donor antenna should be limited to +10 dBi.*

Downlink output signals leave the channel module and are applied to a power amplifier stage. The output of the power amplifier is passed through a triplexer then radiated from the DAS antenna. *Note: When the booster is operated at the maximum downlink output power level the gain of the DAS antenna should be limited to -4 dBi.*

OPERATION
Power is applied to the channelized booster by plugging in the AC or DC power cord (depending on how the system was configured for input power).

Subassembly LED's
LED's are located on several of the subassemblies within the Booster cabinet. The function of each of these indicator LED's are listed in **Table 3**.

COMMUNICATING WITH THE BOOSTER
The booster provides Ethernet connectivity that allows access to a web-based user interface for communicating with the control board, programming the individual channels, checking system status, etc. Communications will require connecting your laptop computer to the Enet connector on the control board. **Figure 6** shows the connector. A standard Ethernet crossover cable is used to make the connection between your laptop computer and the booster cabinet. Refer to **Appendix A** at the back of this manual for detailed instructions on how to properly connect your laptop computer to the Enet port of the booster.

System Summary Submenu
Once your laptop computer is properly connected to the signal booster the web-based user interface screen will appear as shown in **Figure 7.** This is the System Summary page which shows the IP and MAC address of the control module. On the

Summed Alarm
Green = Normal
Red = Alarm

Enet
Connector

Fiber Optic Module
connects here
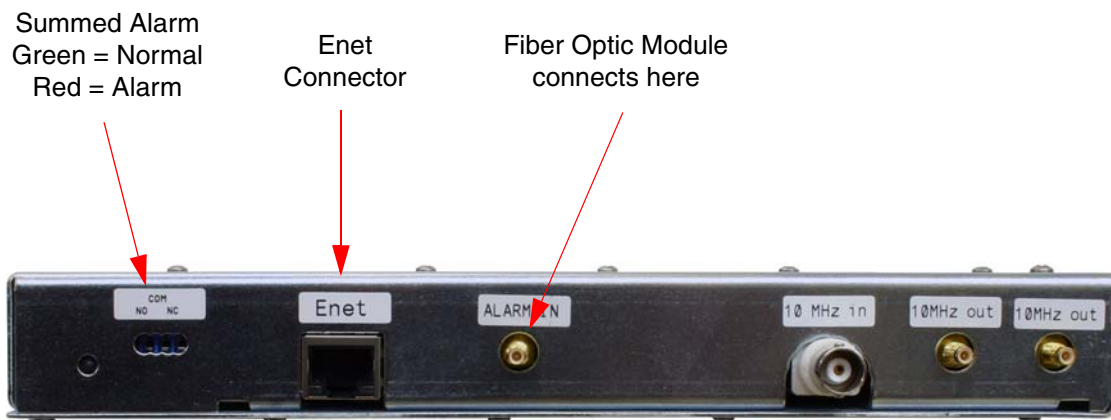
Figure 6: Enet connector on the control board.
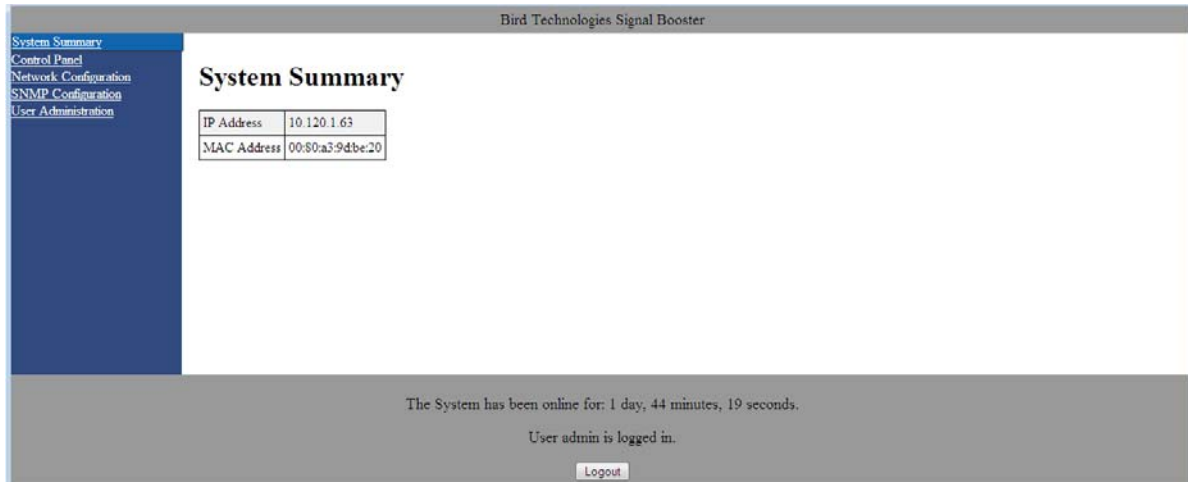
Figure 7: System Summary Submenu.

left-hand side of the page are a list of the major submenus available to the user including System Summary, Control Panel (see note below), Network Configuration, SNMP Configuration, and User Administration.

NOTE When the web-based user interface first comes up, the Control Panel submenu choice will not be displayed. The user needs to go to the User Administration submenu and type in the default user name (**admin**) and default user password (**admin**). After the login function is performed the Control Panel submenu choice will appear.

Place your cursor over a particular submenu heading and left click to make a selection. Each major submenu page contains a group of related functions. Without entering your user password the user will only be allowed to view the pages however and will not be able to make changes without entering a password. After entering a valid password via the Admin submenu the pages will switch from read only to fully interactive and the user can begin making selections and changes if desired.

Control Panel Submenu
The Control Panel submenu gives the user the ability to interface with and adjust the RF parameters of the booster. Four tabs are available on the Control Panel Page including FILTERS, FILTER DETAIL, LINK, and SYSTEM. When selected each

tab presents a new screen and each screen contains groups of related functions. Selection is made by placing your cursor over the tab and performing a left click.

FILTERS TAB
The Filters page gives an overview of all the filters associated with each branch in the booster system. Refer to **Figure 8.** The link drop-down box allows you to select which branch you want to overview. Press the down arrow button and highlight the desired branch. Each filter is accorded one row in the display. The first row of displayed data is used to provide a summation of the input and output power for the branch. The parameters displayed for each filter include; Center Frequency, Bandwidth, Channel Enabled, Test Signal, Squelch, the Input Signal Level as both a numeric value and a bar graph, Maximum Allowed Output Level, and Output Signal Level as both a numeric value and a bar graph. Changes to the filters are made from the Filter Detail page.

The enable, test signal, and squelch boxes are interactive on this display. Place a check mark in the box when you want the function selected. Place your mouse cursor over the box and left click. A check mark placed in the box for enable, test signal, or squelch indicates that function is turned on while no check mark indicates the function is turned off. The All Filters area at the top of the page allows the user to adjust the Maximum Output Level of all the filters in a branch simulta-
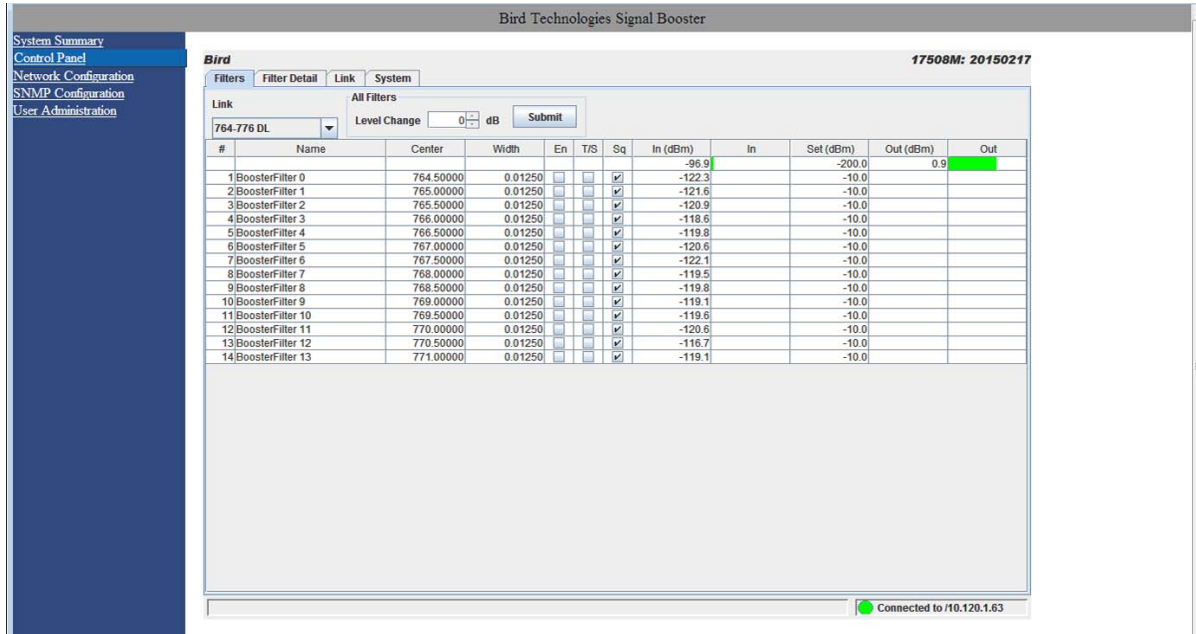
Figure 8: The Filter Summary Tab.

neously. Use the up or down arrow to set the level change amount then press the submit button.

NOTE On start-up, the booster validates the widths of programmed filters. If any are configured wider than 75 KHz and the booster is set to Class A mode an error message as shown in **Figure 9** will appear. The offending filter or filters must be corrected or the booster must be switched to Class B mode. Refer to the System tab discussion later in this manual for instructions on switching from Class A to Class B mode of operation.
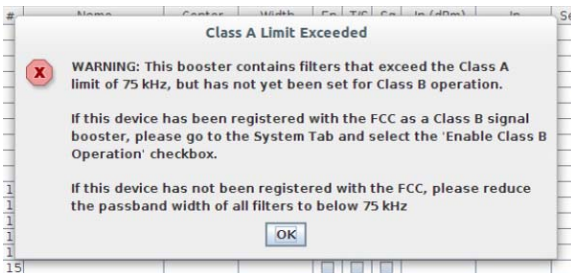

Figure 9: Class A limit exceeded warning message.

FILTER DETAIL TAB

The Filter Detail page is divided into three functional areas. The first area includes a pair of drop down boxes along with a row of command buttons running down the left side of the screen. The second area is a filter details area in the middle of the screen. The third is a status area on the right side of the screen as shown in **Figure 10**. Once you have interactive access to the Filter Detail page you can begin programming the individual filters that you want the booster to pass in the uplink and downlink direction.

The Filter Detail page is designed to interact with one filter at a time. To program individual filters you must select the branch and the filter of interest using the Link and Filter boxes on the left side of the screen. Once the filter has been selected for interaction a label can be assigned to the filter by typing into the name box. Three groups of characteristics need to be defined including frequency band, OLC, and filter specifics. Frequency band is selected from a drop down list. Center Frequency and Desired Output Power level must be entered by the user by clicking in the box and typing in the desired value. Likewise OLC style is determined with a drop down box. The two choices are Custom and APCO 25 Phase 2. OLC Hold time and OLC Decay time must be entered by the user.
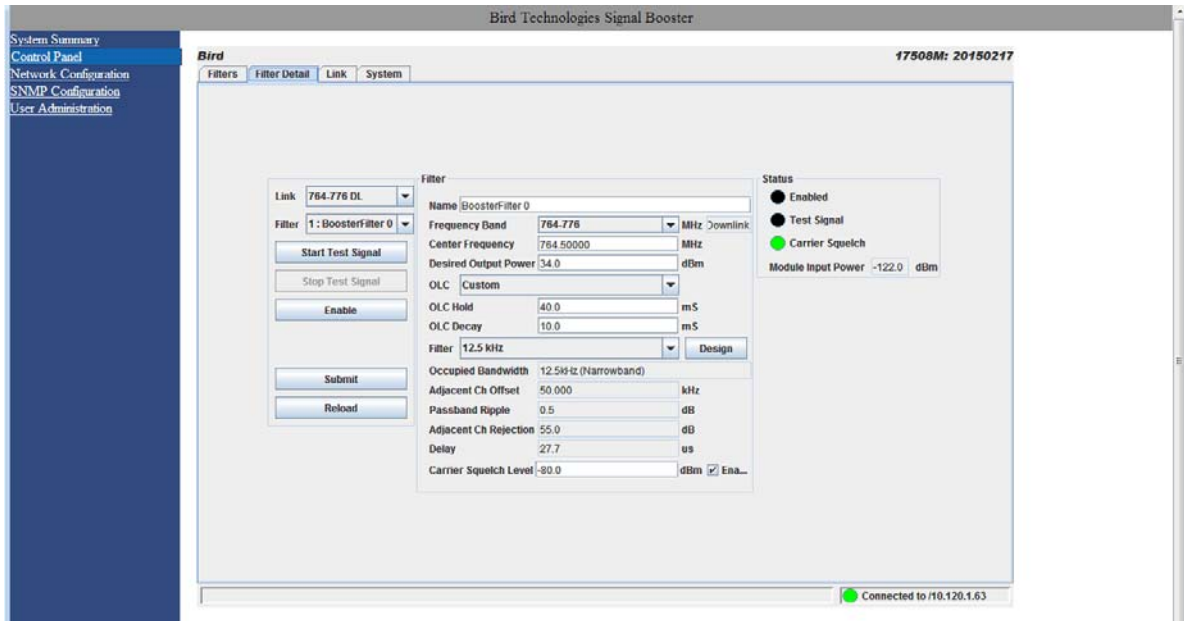
Figure 10: Filter Detail Tab.

Filter specifics are selected from a drop down list that includes Custom, 12.5 KHz, 25 KHz, 12.5 KHz Low Delay, and XML File. Four parameters are customer adjustable including Occupied Bandwidth, Adjacent Channel Offset, Passband Ripple, and Adjacent Channel Rejection. Delay time is calculated by the software. The four adjustable parameters are setup using the Design Filter tool, see the following section of this manual for details.
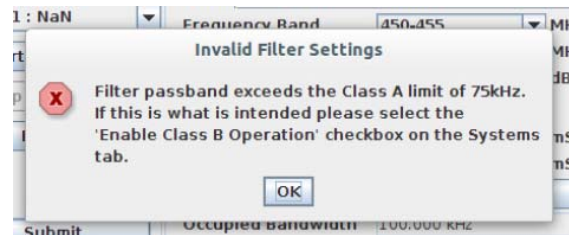

Figure 11: Invalid filter settings warning message.

> **NOTE**
> If a filter passband is selected that exceeds the Class A limit of 75 KHz and Class B operation is not selected (see discussion in System tab section of this manual) then a warning message will appear as shown in **Figure 11.** You must set the booster to the Class B mode of operation if you have any filter with a passband greater than 75 KHz.

Design Button

When the Design Filter button is pressed a custom design template will be displayed as shown in **Figure 12**. Boxes for the four required filter parameters mentioned earlier are shown along with a graphical representation of the filter's response curve. Enter into the four boxes the parameters you want. Click on the Estimate button at the bottom of the screen

and the software will calculate the Delay time for you. Press the Design button to design the filter. The rejection scale of the display can be changed by making a selection from the "maximum plot rejection" drop down list. Choices include -10, -50, and -100 dB scale. When the display is to your satisfaction and does not violate any parameter ranges press the Save and Close button to exit back to the filter detail screen then load the design into the selected filter by pressing the Submit button on the filter detail page.

Status Area

The status area of the Filter Detail page uses status indicators to let the user know whether the channel is enabled, if the test signal is on, and if the carrier squelch is on. When the status indicator
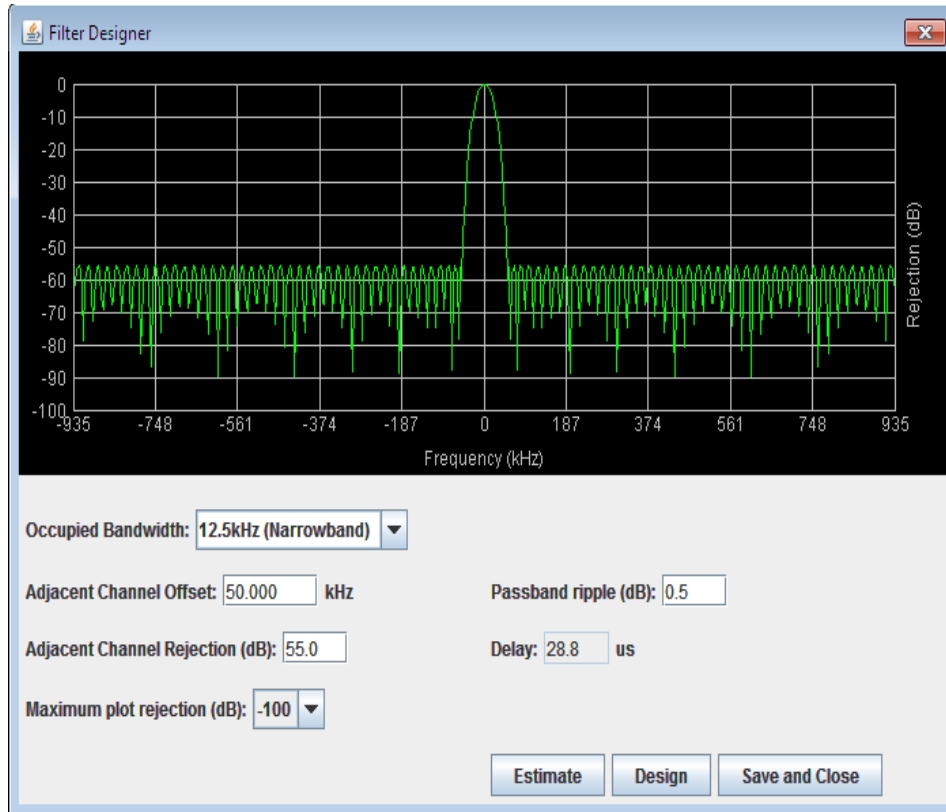
Figure 12: The design filter interactive display screen.

is illuminated the feature is on and when it is dark the feature is off. The Carrier Squelch status indicator will be green if the channel is squelched. The Carrier Squelch status indicator will stay dark if there is no squelching even if the Carrier Squelch radio button is set to enabled. A test signal can be generated for any channel within the system or every channel simultaneously.

The output power box displays the output power for the channel module. This value should be close but not necessarily exactly the same as the "Desired Output Level" discussed earlier. The box showing output power is only displayed if the filter is giving an output power. If the filter is not enabled or there is no signal present then there would be no value to display.
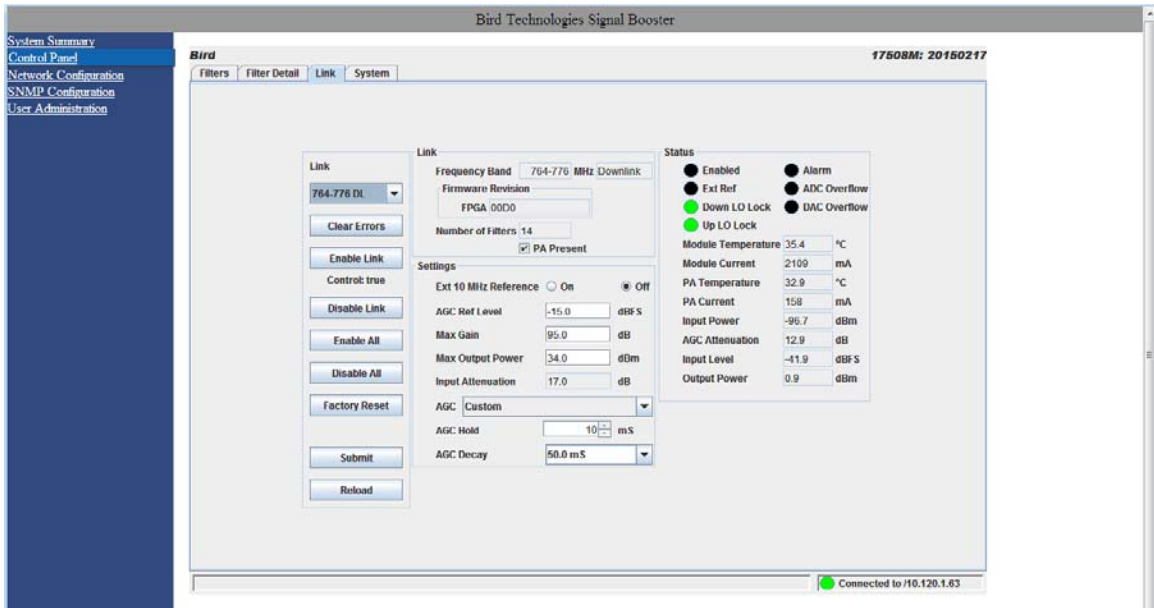
LINK TAB

The link page is divided into three functional areas including a row of command buttons running down the left side of the screen, a link and a settings

area in the middle of the screen, and finally a status area on the right side of the screen as shown in **Figure 13.** The link page is designed to interact with one branch of a module at a time. The branch that is selected for interaction is determined by the Link box on the upper left of the screen. To change the branch that you are going to interact with click on the arrow to display the full drop down box. Scroll down the list until the desired branch is highlighted and click on it. The data displayed in the link area of the display screen will now be for the selected branch.

Command Buttons

Clicking on a command button (located on the extreme left-hand side of the page) performs the associated task immediately. The Submit and Reload buttons in the bottom left corner allow any changes you make to the display/interface boxes to be downloaded to the booster. The Submit and Reload buttons act like a trigger sending any changes you made in the interface boxes to the

Figure 13: The Link Tab.

channel module as well as updating any displayed data from the module, but only after the button is pressed. Individual branches or all branches can be enabled or disabled using the enable/disable buttons. After an alarm condition is corrected the alarm can be cleared by selecting the clear errors button. Selecting the factory reset button will return the system to the factory default settings.

Link and Settings Area

The link portion of the area displays status information for the branch. The Settings area is a user interactive area where the field engineer can program the operating characteristics of the selected branch. Each parameter in the settings area can be changed by clicking in the box and typing in the new values or by pointing at an arrow to display a drop down box. Most of the adjustable parameters have adjustment limitations as applicable.

The parameters include turning on/off the use of an external 10 MHz reference signal when an external reference is available. If an external reference is not available then leave this feature off and the system will operate from the internal 10 MHz signal. The AGC Reference Level should be set to the calibration value which is -15 dBFS. The ADC reference level can be adjusted when excessively strong input signals are present. The Maximum

Output Power is the desired output power level from the booster for the selected branch. The Max Gain allows the user to determine the maximum operating gain of the booster. This can be adjusted based on your antenna isolation.

The changes you make in the Settings area are only applicable to the selected branch. After you have made changes to the various parameters press the Submit command interface button (lower left corner of the screen) in order to copy the changes into the channel module itself.

Status Area

The status area of the link page lets the user know the status of the channel module and power amplifier if a power amplifier is used in the system design. The status for seven parameters are conveyed by the status indicator next to the parameter name. When the status indicator is green it indicates that the parameter is on and when it is black it indicates the parameter is off. In the case of the Alarm (Summed Alarm), ADC Overflow, and DAC Overflow, the status indicator will turn red during a fault condition.

NOTE When the Summed Alarm indicator is red, if the cursor is placed over the indicator, a message tab will appear briefly describing the reason for the alarm condition.

NOTE If a fault occurs, press the clear errors button on the left side of the page. If the error reappears right away then trouble shooting will need to take place.

Seven additional parameters are displayed with numerical values. The first group of parameters include; Enabled which indicates whether the branch is on or off, Ext Ref which indicates whether the system is running on an external or internal 10 MHz clock signal, and Down and Up LO Lock which indicate if the down converter and up converter local oscillators are synchronized to their respective RF signals. The second group of parameters using a status indicator will be black under normal conditions and will turn red to indicate a fault. The Alarm indicator is a summed alarm and will activate when either the module or power amplifier temperature/current exceeds their normal range. Also, the Form-C contacts inside the cabinet will change states. ADC or DAC Overflow indicator shows that the input power to the branch is too high.

The first four numerical parameters are real-time indications of the module and power amplifier temperature/current values. AGC Attenuation updates in real-time and provides an indication of what the AGC is doing. Input Power is a summation of all the input signals to the branch. Output power also updates in real-time and indicates the composite power output for the branch.

SYSTEM TAB

The system tab lists the control board software versions. A customer-designated location name can be recorded and is useful in situations where multiple boosters are used in the overall system design. There is also a system logbook available on the bottom of this page for use by field engineers when working on the system. Refer to **Figure 14**.
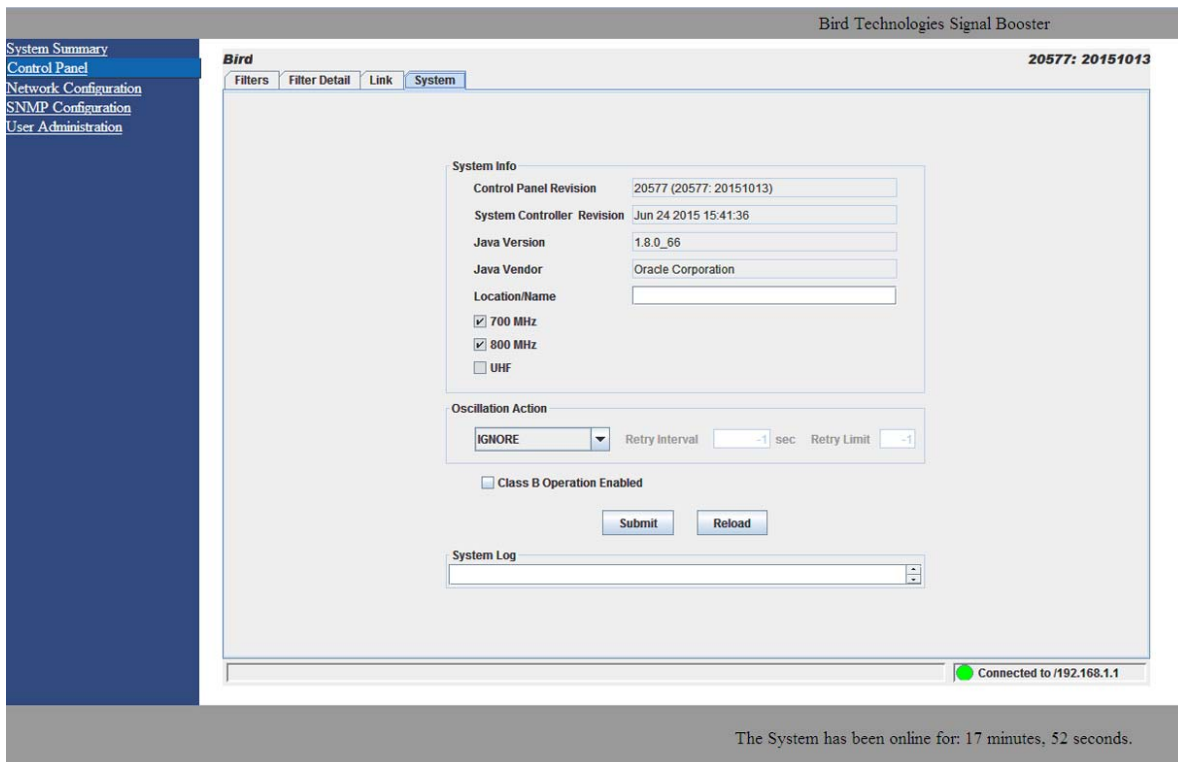

Figure 14: The System Tab.

Oscillation Detection

This feature shuts off the output signals from the booster for both the uplink and downlink whenever an oscillation condition is detected. Oscillation detection occurs whenever port to port isolation falls down to 25 dB or less. For normal operation the port to port isolation needs to be at least 10 dB greater than the gain of the booster. There are four modes of operation for the Oscillation Detection feature including Ignore, Alarm, Shutdown, and Shutdown/Retry.

In the Ignore mode the booster will ignore oscillation events. In the Alarm mode the booster will generate an alarm notification by illuminating (RED) the alarm button on the Link Tab and illuminating (RED) an LED indicator on the control module. The Shutdown mode is the same as Alarm mode except the booster shuts off the output signals in both the uplink and downlink direction. The shutdown continues until the filters are re-enabled and the alarm is reset. The Shutdown/Retry mode is the same as the Shutdown mode except the booster will retry operation the number of times specified by the user. This is called the retry limit which is entered into the associated box on the System Page. How long the booster waits between each retry attempt is determined by the retry interval. After the retry limit is reached, if the booster is still experiencing an oscillation condition, the booster will enter the regular shutdown mode. The Shutdown/ Retry mode is useful in situations where brief transient overdrive signals are occurring.

Class B Enable

In order to operate the booster with a filter passband greater than 75 KHz the booster MUST be configured as a Class B booster and the customer must register the booster online with the FCC. Class B operation is enabled by checking the box labeled "Enable Class B Operation". When the box is checked a warning message will be displayed as shown in **Figure 15** reminding the user to register the booster with the FCC.
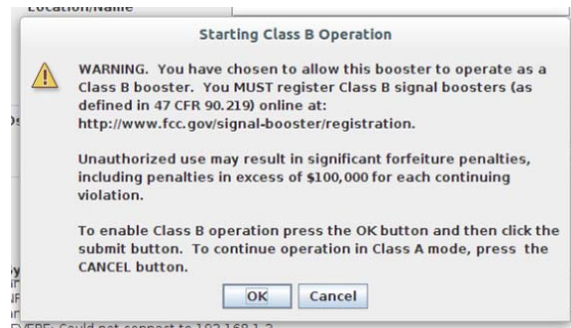
Figure 15: Starting Class B operation message.

Network Configuration Submenu

Values for IP Address, Netmask, the Gateway and MAC Address are displayed on the network configuration page. Refer to **Figure 16**.

The network configuration page allows the user to enable or disable DCHP. The Dynamic Host Control Protocol (DHCP) is a standardized networking protocol used on IP networks for dynamically dis-
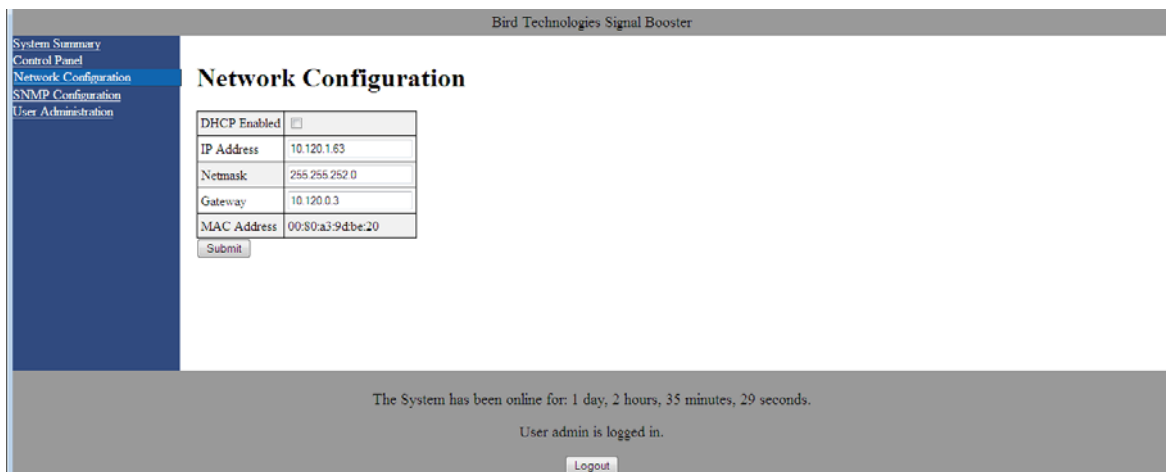
Figure 16: Network Configuration Submenu.

tributing network configuration parameters, such as IP addresses for interfaces and services. With DHCP, computers request IP addresses and networking parameters automatically from a DHCP server, reducing the need for a network administrator or a user to configure these settings manually.

The DCHP (Dynamic Host Configuration Protocol) is either active or inactive. When DCHP is active the values for IP address, netmask, and gateway are set to zero. When the DCHP is inactive (default setting from the factory) the IP address, netmask, and gateway values can be modified by the user by typing the desired values into the associated box and pressing the submit button. The customer should consult with their IT department to determine whether DCHP should be active or inactive.
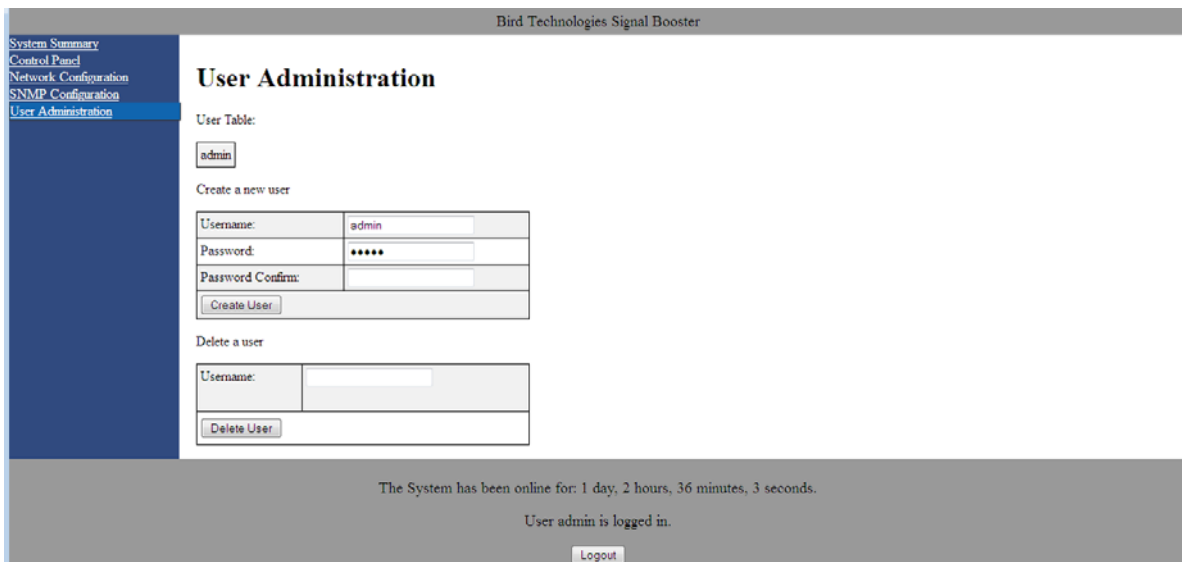
User Administration Submenu

The User Administration submenu allows password protected access to the booster. The boxes on this page are interactive. To make changes click inside the box and a cursor will appear. Refer to **Figure 17**. The user is queried for a User Name and User Password. The default user name is **"admin"** and the default password is **"admin"**. It is recommended that once the booster system is installed approved users with unique passwords are loaded into the system and the default admin user/password is deleted.

Once the correct user name and password are entered then a menu box for creating a new user will be presented. To create a new user enter the new user name and associated password. Confirm the new password by entering it again and then press the Create User button. Make sure you write down the new user name and password for safe keeping. A menu box for deleting a user is also presented. To delete a user enter their user name in the box and click on the Delete User button.
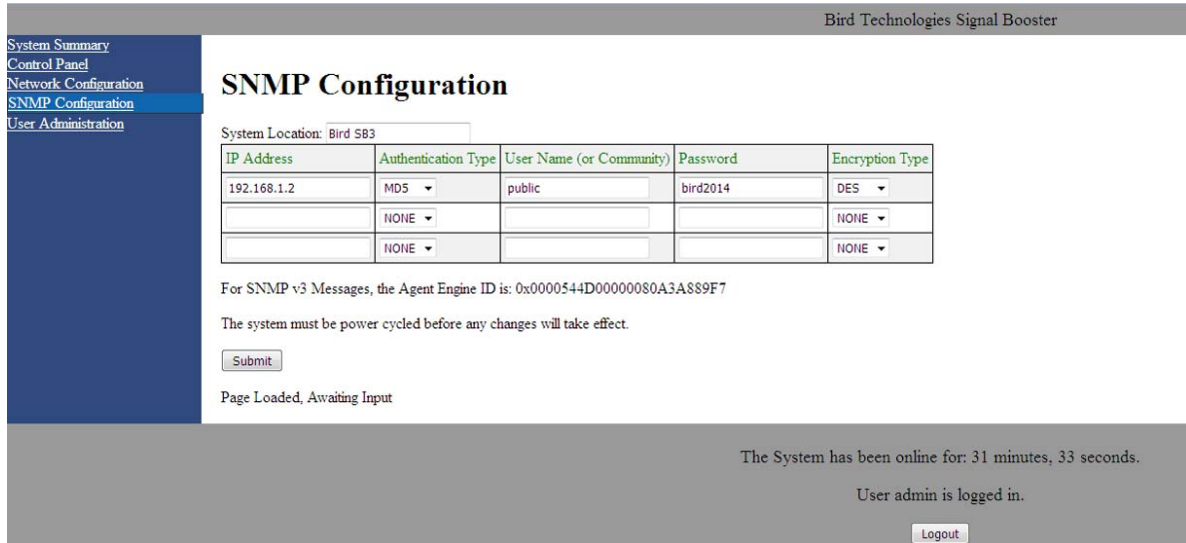
SNMP Configuration Submenu

Simple Network Management Protocol (SNMP) is an Internet-standard protocol for managing devices on IP networks. The SNMP feature is designed to provide reliable internet notification of an alarm occurrence or a change in operational status in the booster. In order to configure the booster to send SNMP messages (called traps) to a destination device, such as your computer, the following values need to be entered into the booster; System location, the IP address of the destination computer, Authentication type, User name, Password, and Encryption type, and the Encryption passphrase. **Figure 18** shows the SNMP Configuration display.

The System location is a user defined string which will be returned with every trap that is generated and can assist the user in identifying which unit is sending the trap message. The three destination IP addresses that are entered into the table should be

Figure 17: User Administration Submenu.

Figure 18: SNMP Configuration Submenu.

the IP addresses of the computers that you want the traps to be sent to. These destination computers must have SNMP manager software installed and running in order to receive the messages. SNMP manager software installation into the destination computers is the customers responsibility. Consult with your IT specialist for assistance.

Authentication type is used to verify that the person receiving the trap is the person the trap is intended for. Authentication type choices are NONE, MD5, or SHA, with SHA being the strongest encryption type. When using authentication and/or encryption the User Name is the name of the person to receive the trap. If not, this is the community name of the trap receiver. The Password is a string used to encrypt and authenticate the user. It is only used when authentication and/or encryption types are enabled. The Encryption type is used to protect the contents of the message from unauthorized receivers. Encryption type choices are NONE, DES, or AES, with AES being the strongest supported encryption type.

The Agent ID is a value that uniquely identifies the agent sending the traps. The agent is software which runs on the device being monitored and in this case is the signal booster. The SNMP manager software receives the traps and can be run on your computer or another server on your network. For traps that use encryption and/or authentication

the manager needs to be configured to receive traps from the specified agent ID. This number is shown on the SNMP submenu page underneath the table, refer to figure 18.

Whenever values in the SNMP Configuration screen are changed you must click on the submit button to save the changes.

INITIAL SNMP SETUP
When the booster is installed the SNMP feature should be setup for proper communications. There are several steps required for proper setup of the SNMP feature as discussed below.

1) Connect a laptop directly to the booster. Refer to **Appendix A** for detailed instructions on how to make a direct connection. The booster is shipped from the factory setup for static IP addressing and with a default IP address of "**192.168.1.1**". The factory default subnet mask is "**255.255.255.0**". Change the factory default IP address of the booster to one provided by your IT department.

2) Use the Network Configuration to setup the DHCP as either active or inactive. When DHCP is inactive the deck will be using a static IP and the user must enter values for IP address, netmask, and gateway. Make sure you consult with

your IT department regarding setting DCHP active or inactive.

3) Use the SNMP Configuration submenu page to enter up to three destination device addresses. These are addresses where the SNMP feature will send trap messages whenever a qualifying event takes place. Qualifying events include the following;

   A) Down Converter LO Lock Fail

   B) UP Converter LO Lock Fail

   C) ADC Overflow

   D) DAC Overflow

   E) General Alarm - over current, over temp, and oscillation.

4) Setup the SNMP format using the SNMP Configuration submenu page. Items that need to be configured include Authentication Type, User Name, Password, and Encryption Type. Consult with your IT specialist for assistance.

5) Load the SNMP manager software into the destination computer and configure the manager so that it will be able to receive the SNMP traps.

6) Download MIB files from the Bird Technologies website (www.birdrf.com) and load the MIB files into your SNMP manager software. The MIB files allow the SNMP manager software to sort out the trap messages into an understandable message format.

The signal booster supports several SNMP Configuration validation checks which help ensure the configuration is setup in a logical format. The validation checks include;

A) If encryption is enabled but authentication is not enabled a popup window will appear stating that you must enable authentication when encryption is enabled.

B) If Authentication and/or Encryption is enabled and a password is entered which is < 8 characters long an error message will be displayed.

C) If an IP address is entered but a User Name is not entered a popup warning will appear but the changes will be submitted.

D) If a User name is entered but an IP address is not entered a popup warning will appear but the changes will be submitted.

SNMP MANAGER EXAMPLE

SNMP manager software is designed to provide a GUI style interface for the user so that traps sent from the booster can be received and displayed for viewing. The SNMP manager software chosen and used by the customer is up to the customers discretion and as such may not exactly match the example shown in this discussion. SNMP manager software packages will need to be properly configured in order to successfully receive messages from the booster. Refer to the SNMP configuration setup discussed earlier in this manual and ask your IT specialists for assistance.

When a qualifying event occurs in the booster a trap is formulated and sent to the destination computer. A typical trap is shown in **Figure 19**. In the example shown the trap messages are shown at the top of the screen display. Three trap messages have been received by this manager from a signal booster. In this particular SNMP manager software package if a trap message is selected the details of that message are displayed in the lower portion of the screen. The details show the raw message as it was received by the manager while the upper box shows the message after it has been interpreted by the MIB files.

Creating an Alarm for Testing Purposes

In the example shown in figure 19 an alarm condition was generated in the booster in order to create the trap messages shown. The booster was told to generate its oscillator clock signals using an external reference source but no external source was connected to the booster. This is a quick and easy way to create a temporary alarm for testing purposes. This is accomplished via the Link Page discussed earlier in the manual. Select the ON radio button labeled EXT 10 MHz Reference then click the Submit button. Do not connect a signal source to the external osc port on the control module. This will cause the downlink and uplink oscillators in the channel to shutdown and the booster will enter an alarm condition. Please note that on-air signals will be interrupted during this time. To clear the alarm select the OFF radio button then click the Submit

button and finally the Clear Errors button. This will take the booster out of the alarm condition and return it to normal operation.

NOTE

IMPORTANT: The SNMP feature may not send traps when the web page is operational. It may hold the trap messages until the web page interface is closed at which point it will then send the traps to the destination computers.

Figure 19: SNMP manager example.

APPENDIX A
Front Panel Ethernet Connectivity

ETHERNET CONNECTIVITY

The front panel User Interface connector on the booster provides for 10/100 BASE-T Ethernet connection using the TCP-IP protocol. This product feature allows access to a web-based interface for programming the individual modules within the booster. The web based interface requires a JAVA runtime environment (version 1.6.0 or later) to be installed on your laptop. The JAVA software can be downloaded free of charge from the Sun Microsystems website found at "http://java.com/en/download/index.jsp". The channelized booster is shipped from the factory with a default IP address of "**192.168.1.1**".

Two connection schemes are discussed including a direct connection from your laptop computer to the booster front panel as well as connecting the booster to a networked environment. A direct connection (at the installation site) should be established the first time you interface to the booster using the fixed IP mentioned above. Once the initial communications are established the IP address in the booster can be changed to permit a networked connection (from a remote site such as your office).

Direct Connection

Your initial connection to the booster system should be a direct connection to the front panel using an Ethernet crossover cable. **Figure A1** shows the proper way to interconnect the equipment as well as the pinout for a CAT-5 crossover cable.

REQUIRED EQUIPMENT

Cat-5 Crossover Cable
Laptop Computer with a network interface card installed. In addition, the JAVA run-time environment version 1.6.0 or later, and a web browser such as Internet Explorer must also be installed on the laptop.

PROCEDURE

To connect your laptop computer to the front panel LAN port and access the web page interface, perform the following steps;

1) Insure the JAVA runtime environment software is installed on your laptop.

2) Connect your laptop network port to the LAN connector on the booster front panel using a standard CAT-5 Crossover cable.
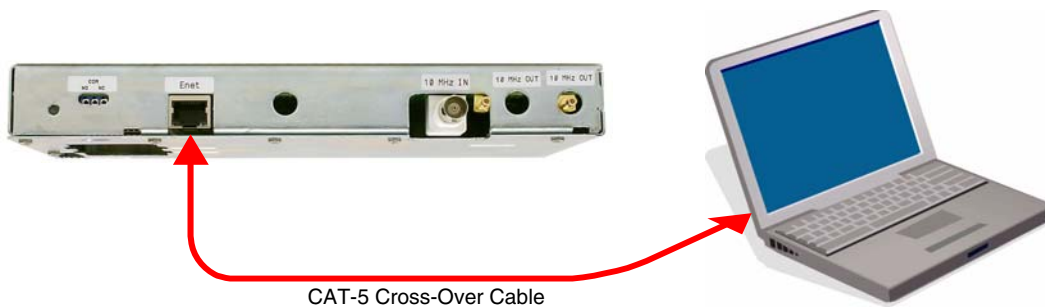
> **NOTE**
> The front panel LAN connector has two built-in bi-color status LED's which will aid you in establishing communications. The meaning of each LED is shown in **Table A1**.

LINK LED (left side)		ACTIVITY LED (right side)	
Color	Meaning	Color	Meaning
Off	No Link	Off	No Activity
Amber	10 Mbps	Amber	Half-Duplex
Green	100 Mbps	Green	Full-Duplex
Table A1: LAN port status LED's			

3) The left-most (LINK) status LED built-in to the LAN port connector should illuminate amber or green indicating that a good physical connection is established between your computer and the booster.

4) Insure that your laptop's IP address is compatible with the default address of the signal booster system. This may require changes be made to the Ethernet adaptor address on your laptop (refer to **Appendix B**). Your laptop's IP address will need to be set to **"192.168.1.2"** along with a subnet mask of **"255.255.255.0"**. The right-most (ACTIVITY) status LED built-in to the LAN port connector will turn amber or green indicating good TCP-IP communications are established between the laptop and the booster.

5) Launch your web browser software on the laptop.

	Pin			Pin		
Transmit (1 & 2)	**Orange/White**	**1**		**1**	**Green/White**	Receive (1& 2)
	Orange	**2**		**2**	**Green**	
Receive (3 & 6)	**Green/White**	**3**		**3**	**Orange/White**	Transmit (3 & 6)
	Blue	**4**		**4**	Blue	
	Blue/White	**5**		**5**	Blue/White	
	Green	**6**		**6**	**Orange**	
	Brown/White	**7**		**7**	Brown/White	
	Brown	**8**		**8**	Brown	

Pins 4, 5, 7 and 8 are not used

CAT-5 Cross-Over Cable
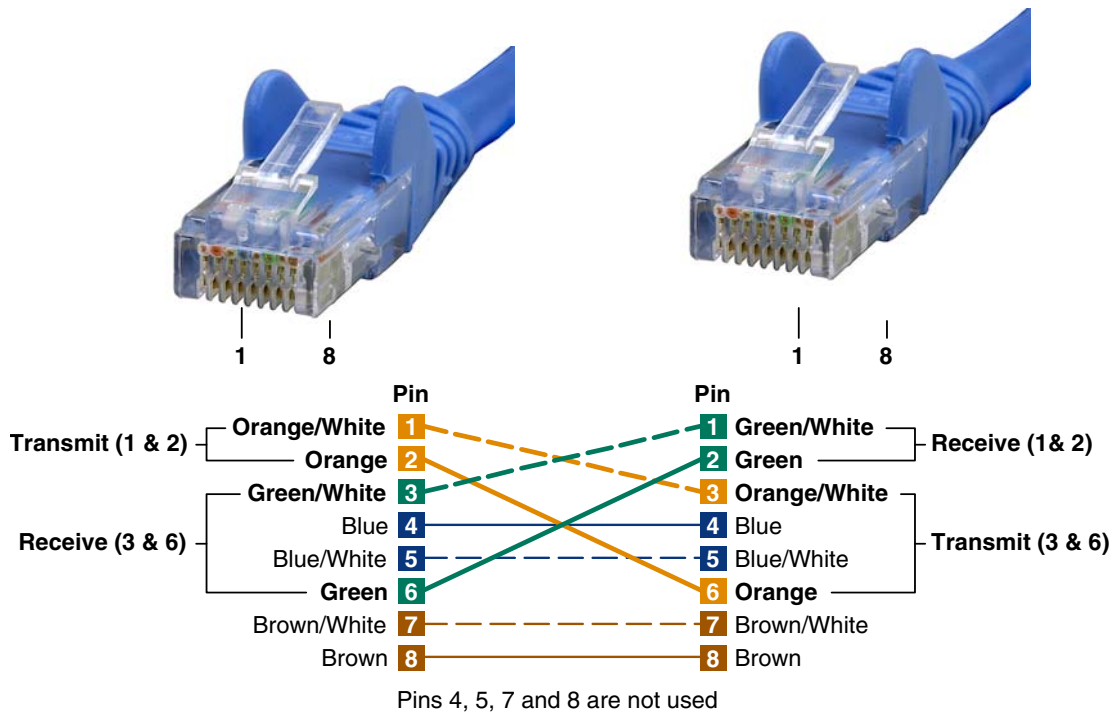
Figure A1: Direct connection to the booster using crossover cable.

6) In your web browsers address box type-in the address of the booster "http://192.168.1.1" and press the ENTER key. The web page interface to the booster should appear in your laptop's browser window. When you launch the web page you may notice that the JAVA applet will load first.

Networked Connection

Before attempting a networked connection to the signal booster system consult with your IT support personnel for information concerning the correct IP address to use and any additional connectivity issues such as firewalls. Once you have the correct IP address you will need to direct connect to the booster system as discussed in the earlier section of this appendix and reconfigure the booster LAN port with this new address. You can then connect the signal booster system using a straight-through CAT-5 cable to the networked environment and interface to it from a remote computer. **Figure A2** shows the proper way to interconnect the equipment for a networked connection as well as the pinout for a straight-thru CAT-5 cable.

REQUIRED EQUIPMENT

Cat-5 Straight-thru Cable
Laptop Computer with a network interface card installed. In addition, the JAVA run-time environment version 1.6.0 or later, and a web browser such as Internet Explorer must also be installed on the laptop.
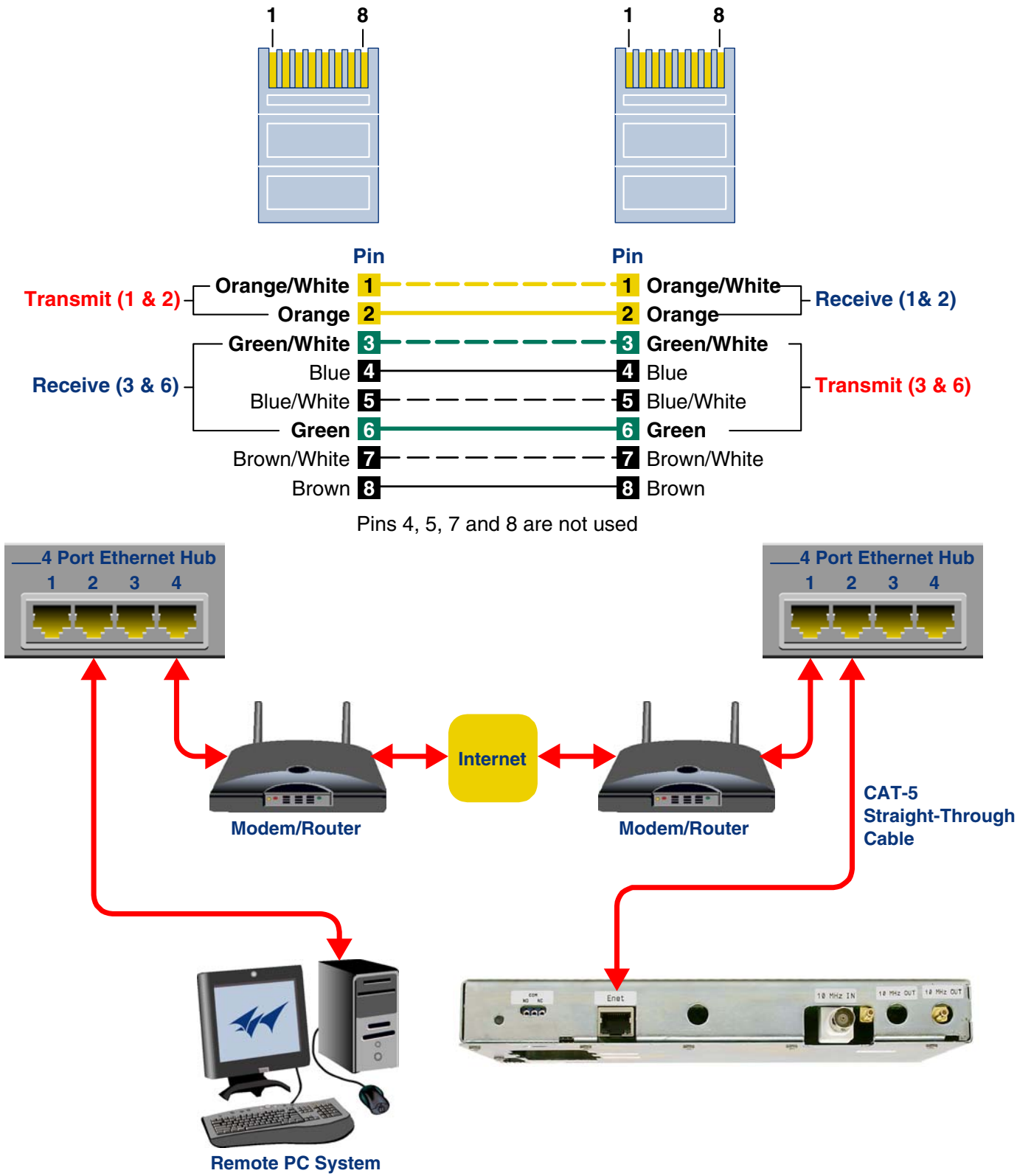
Pin   **Pin**

Transmit (1 & 2) — **Orange/White** `1` – – – – – – – `1` **Orange/White** — **Receive (1& 2)**
                         Orange `2` ──────────── `2` **Orange**

Receive (3 & 6) — **Green/White** `3` – – – – – – – `3` **Green/White** — **Transmit (3 & 6)**
                       Blue `4` ──────────── `4` Blue
                       Blue/White `5` – – – – – – – `5` Blue/White
                       Green `6` ──────────── `6` **Green**
                       Brown/White `7` – – – – – – – `7` Brown/White
                       Brown `8` ──────────── `8` Brown

Pins 4, 5, 7 and 8 are not used

___4 Port Ethernet Hub   **___4 Port Ethernet Hub**
1   2   3   4   **1   2   3   4**

Internet

Modem/Router   **Modem/Router**

**CAT-5
Straight-Through
Cable**

Remote PC System

Figure A2: WAN connection to the booster using straight-through cable.

PROCEDURE

Before a networked connection can be established, the booster LAN Port must be changed to an IP address that's compatible with your network. If you are unsure how to determine this address check with your IT support personnel. To connect the booster LAN port to a networked environment and access the web page interface, perform the following steps;

1) Change the boosters LAN port IP address. To do this, direct connect your laptop to the booster as discussed in the earlier section of this appendix titled "Direct Connection" and follow steps 1 through 4.

2) Launch the configuration Applet in your web browser.

3) Click the "Admin" tab at the top of the interface display screen.

4) To be safe, take note of the settings currently displayed.

5) Select the "User Static IP" radio button.

6) Enter the following settings provided by your network administrator;

   A) IP Address

   B) Subnet Mask

   C) Gateway Address

7) Click the "Submit" button to apply the changes.

8) Once the changes have been successfully applied close your web browser.

9) Launch the configuration Applet in your web browser using the newly entered IP address.

APPENDIX B
Changing Your Service Computers IP Address

When you initially direct connect your laptop service computer to the booster it will be necessary to change the computers IP address. The procedure for doing this varies depending upon your operating system. As an example, this appendix illustrates how to make the change using the Microsoft XP operating system. The procedure for other operating systems will vary slightly from this example. Consult with your IT support personnel if needed. To change the IP address (assuming the Microsoft XP operating system is being used) perform the following in a step-by-step fashion;

1) Select "Start" from the status menu.

2) Single click the "Control Panel" choice from the "Start" pop-up menu as shown in **Figure B1**.

3) From the "Control Panel" icon selections double click on the "Network Connections" icon. Refer to **Figure B2**.

4) When the "Network Connections" folder opens double click on the "Local Area Connection" icon. See **Figure B3**.

5) The "Local Area Connection Status" box will open. Single click the "Properties" tab as shown in **Figure B4**. **Note:** If you do not have the cable connected between the service computer and the booster front panel the "Local Area Connection Status" box will not open. Instead proceed to step 6.

6) The "Local Area Connection Properties" box will open. Use the arrow buttons to scroll down the list until the "Internet Protocol (TCP/IP)" choice is highlighted as shown in **Figure B5**. Click the "Properties" tab at the right-center of the box.

7) Select the "Use the following IP address" bubble. Make sure the circle is filled-in. Refer to **Figure B6**.

8) Enter the new IP address and subnet mask values as shown in **Figure B7**. To interface your computer to the signal booster use an IP address of "**192.168.1.2**" and a subnet mask of "**255.255.255.0**".

9) Click on the "OK" tab to initiate the changes. This completes the procedure. Close any open boxes.
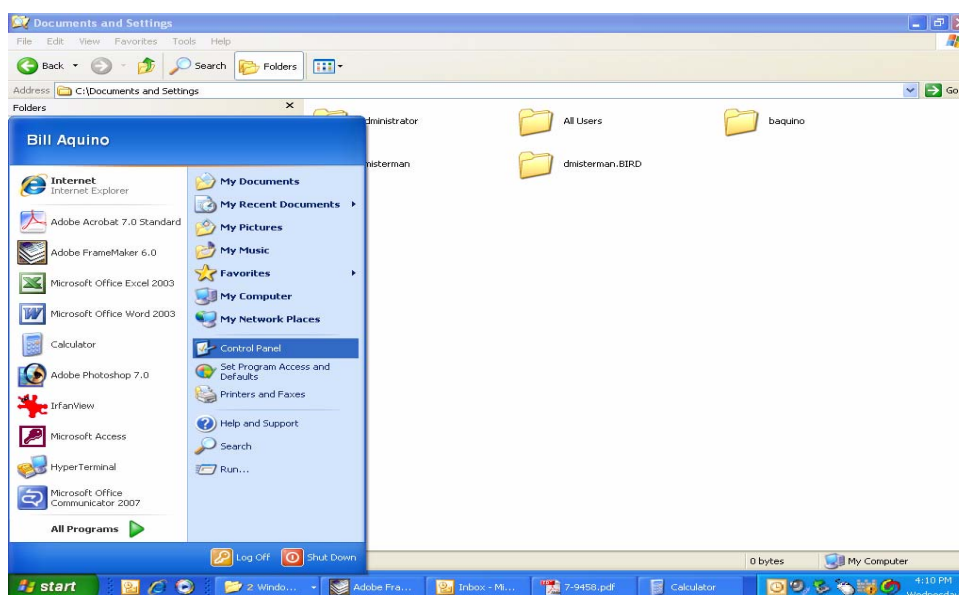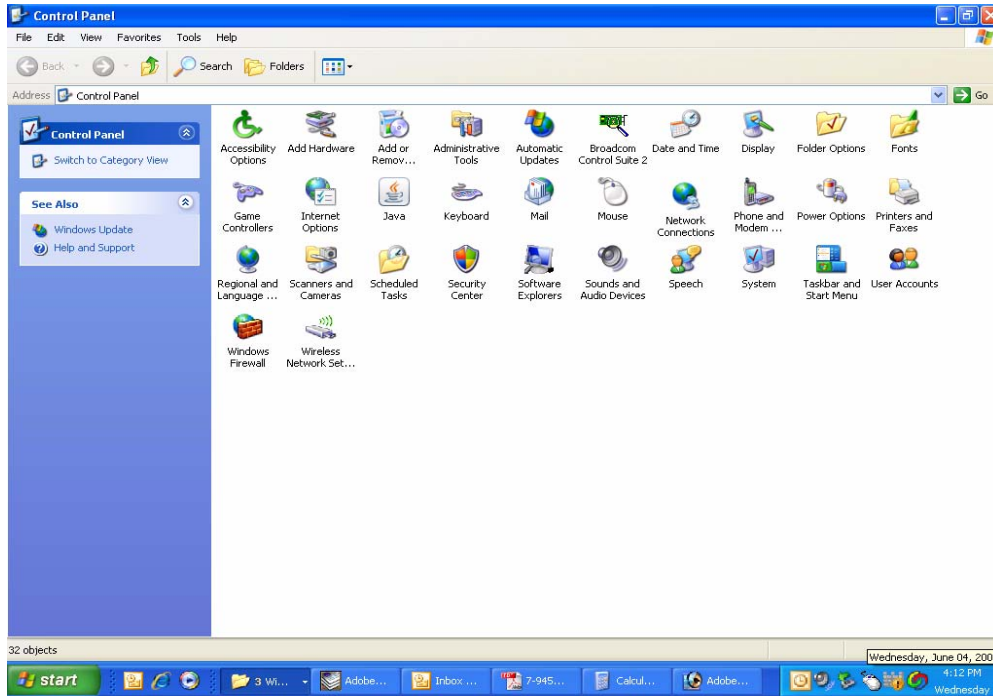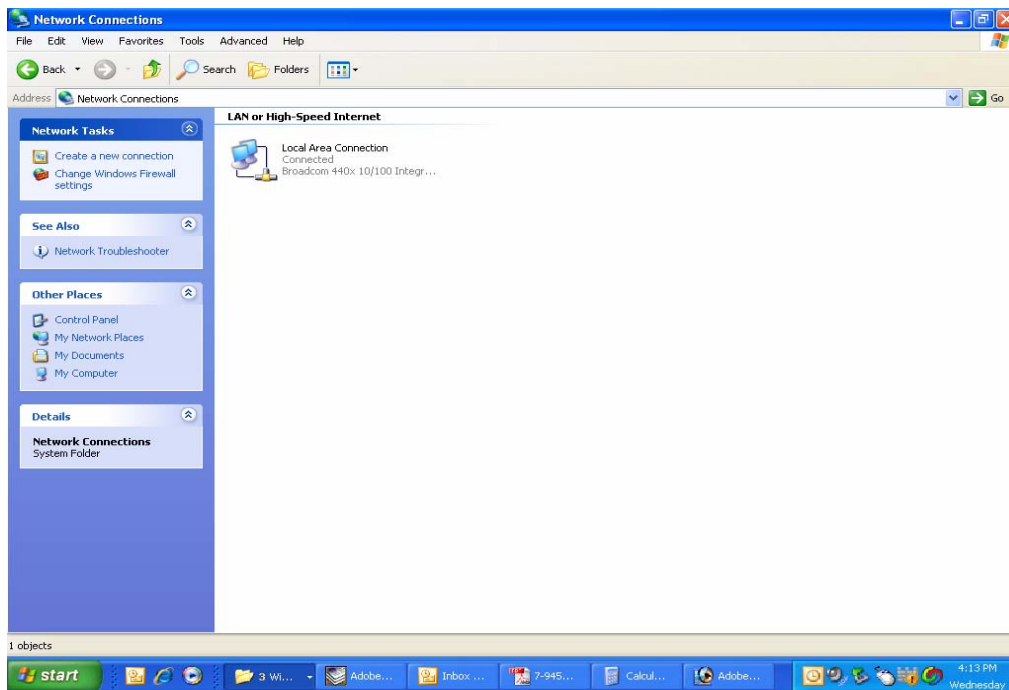

Figure B1: Choose the "Control panel" icon.

Figure B2: Select the "Network Connections" icon.

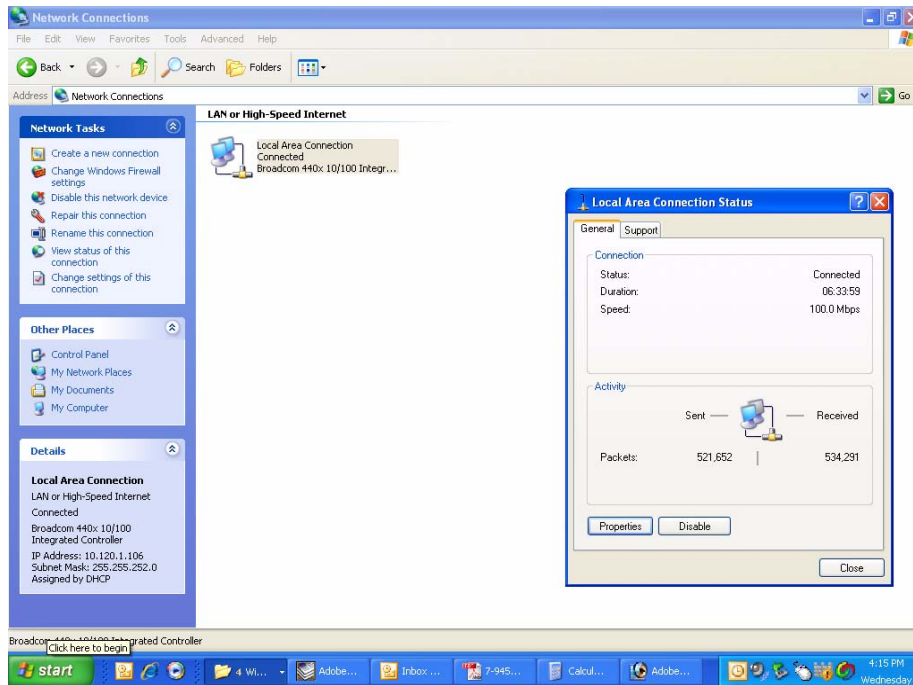**Figure B3:** Select the "Local Area Connection" icon.
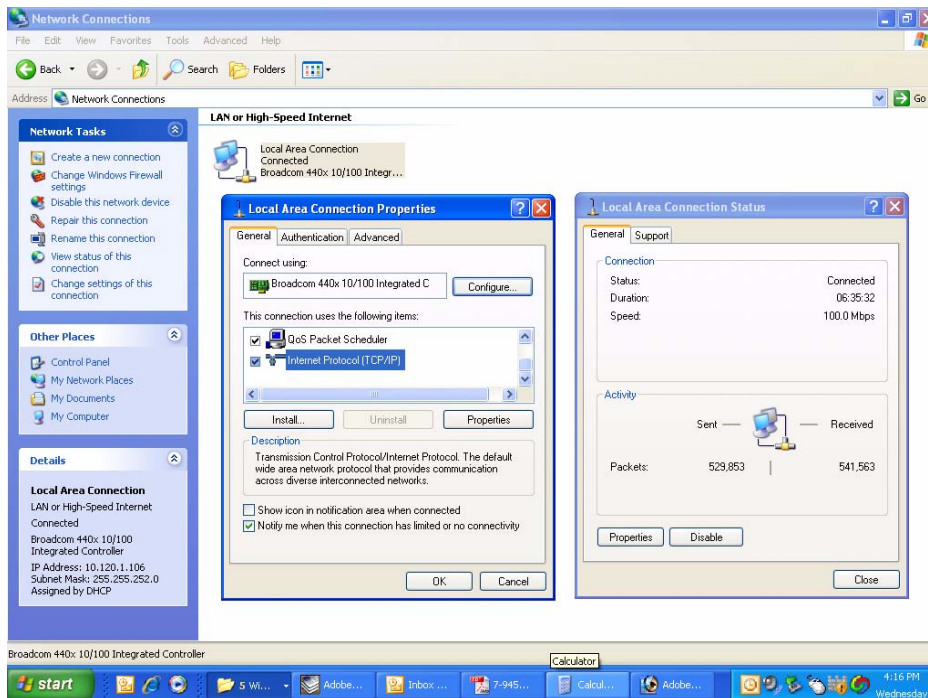
Figure B4: Select the "Properties" tab.

Figure B5: Make sure the "Internet Protocol (TCP/IP)" choice is highlighted. Then select "OK".
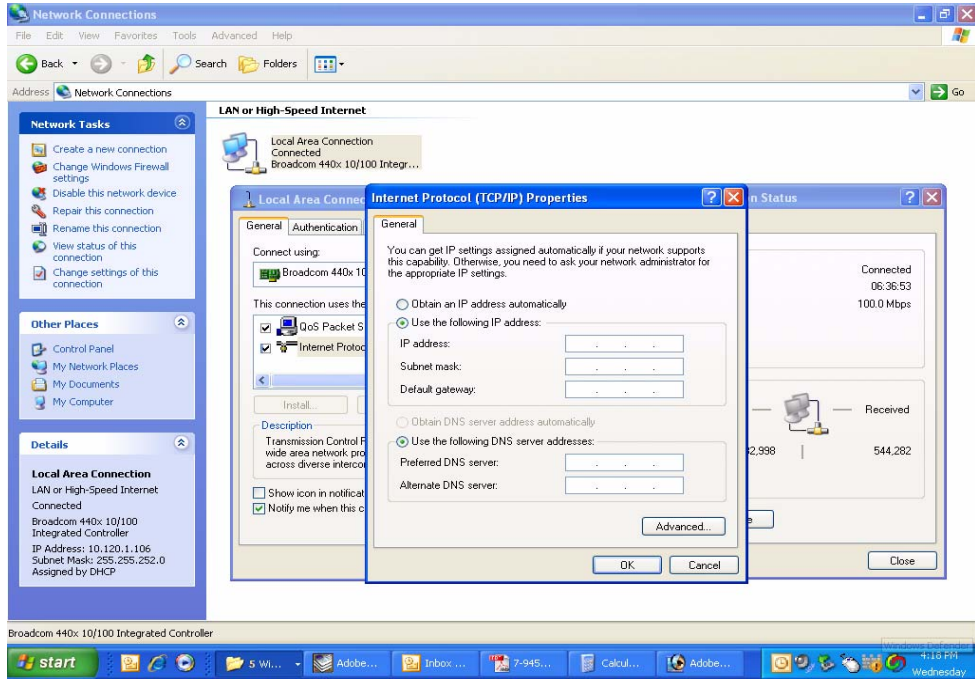
Figure B6: Select "Use the Following IP Address".
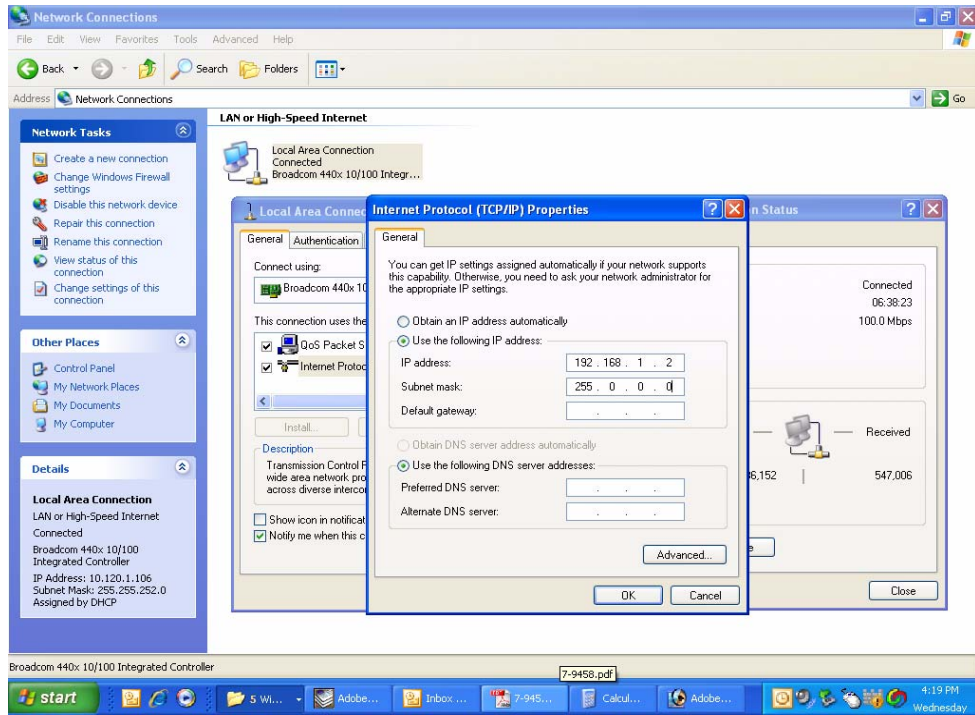

Figure B7: Enter the new IP Address and Subnet mask Values.

Return Loss vs. VSWR

Return Loss	VSWR
30	1.06
25	1.11
20	1.20
19	1.25
18	1.28
17	1.33
16	1.37
15	1.43
14	1.50
13	1.57
12	1.67
11	1.78
10	1.92
9	2.10

Watts to dBm

Watts	dBm
300	54.8
250	54.0
200	53.0
150	51.8
100	50.0
75	48.8
50	47.0
25	44.0
20	43.0
15	41.8
10	40.0
5	37.0
4	36.0
3	34.8
2	33.0
1	30.0

$$dBm = 10\log P/1mW$$
Where P = power (Watt)

Insertion Loss
Input Power (Watts)

Insertion Loss	50	75	100	125	150	200	250	300
3	25	38	50	63	75	100	125	150
2.5	28	42	56	70	84	112	141	169
2	32	47	63	79	95	126	158	189
1.5	35	53	71	88	106	142	177	212
1	40	60	79	99	119	159	199	238
.5	45	67	89	111	134	178	223	267

Output Power (Watts)

Free Space Loss
Distance (miles)

Frequency (MHz)	.25	.50	.75	1	2	5	10	15
150	68	74	78	80	86	94	100	104
220	71	77	81	83	89	97	103	107
460	78	84	87	90	96	104	110	113
860	83	89	93	95	101	109	115	119
940	84	90	94	96	102	110	116	120
1920	90	96	100	102	108	116	122	126

Free Space Loss (dB)
$$\text{Free space loss} = 36.6 + 20\log D + 20\log F$$
Where D = distance in miles and F = frequency in MHz