

Pub. RLR-465 MRM  
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# RLR-465NX

BY RITRON

## PROGRAMMABLE NXDN 10W REPEATER



**MAINTENANCE/REPAIR/OPERATING MANUAL**  
*FOR USE BY AUTHORIZED SERVICE/MAINTENANCE PERSONNEL ONLY*

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# 1. SPECIFICATIONS

## 1.1 GENERAL

Modulation format	NXDN Super Narrowband
Frequency Range	450-470 MHz
FCC ID	AIERIT44-465
IC ID	1084A-RIT44465
RX/TX Separation:	5 MHz
Operational Bandwidth	
Duplexer	50 kHz
Receiver and Transmitter	20 MHz
Synthesizer Step Size	6.25 kHz
Channels	1
Power Requirements	
Receive	130mA at 13.8 VDC
Transmit:	
5 watt maximum output	10 VDC nominal @ 2.0A
8 watt maximum output	12 VDC regulated @ 2.4A
10 watt maximum output	13.8 VDC regulated @ 2.8A
TX Timeout Timer	0-34 min, programmable by PC
Analog CW Morse Code Interval Timer	0-34 min, programmable by PC
Front Panel I/O Connector	RJ-12
Programming port	Mini USB
RF Connector	Type N
Front Panel Indicators	1 Power Green LED 1 RX Amber LED 1 TX Red LED
Antenna Impedance	50 ohms resistive, VSWR 1.5:1 or less
Dimensions	8”L x 5.75”W x 2.125” H
Weight	3.5 lbs.
Operating Temperature Range	-30°C to +50°C

## 1.2 RECEIVER (At antenna connector)

Sensitivity	0.3 uV
Adjacent Channel Selectivity	40 dB (6.25 kHz offset with 1.3 kHz jammer deviation)
Spurious Response Rejection	75 dB
Image Rejection	90 dB
Intermodulation Rejection	73 dB
Frequency Stability	1.0 ppm

## 1.3 TRANSMITTER (At antenna connector)

Output Power	2 to 10 watts programmable
Duty Cycle	100% up to +30°C (degraded linearly to 10% at +50°C)
Frequency Stability	1.0 ppm
Spurious and Harmonics	-25 dBm

## **2. INTRODUCTION**

### **2.1 GENERAL**

The RITRON RLR-465NX NXDN repeater is a synthesized table-top UHF repeater that operates in the 450 to 470 MHz FM communications band. This repeater is designed to handle super narrow band 6.25 kHz NXDN signals only. Its maximum output power level is 10 watts. Depending upon the type of power supply which is available to power the unit it can be programmed for power output from 2 to 10 Watts. The unit receives signals originating from handheld, mobile, or fixed stations on one frequency and simultaneously retransmits the signals on a second frequency. This type of operation is described as full duplex. The unit contains an integral duplexer which allows a single antenna to be used for simultaneous transmission and reception. Full duplex operation with a repeater enables mobile and handheld units to communicate over much greater distance than is possible without a repeater. The Repeater is designed to be powered from an external DC power source. It draws about 140 mA in RX mode making it ideal for use with a 12 volt lead acid battery.

The received NXDN signal is demodulated and is error corrected. The retransmitted signal is thus cleaned up and received noise is not repeated as in a conventional analog repeater. All NXDN signals received can be repeated. However, if the operator chooses, only specific received RAN codes are allowed to repeat. A table of up to 10 RAN codes allows filtering of what can be repeated.

### **2.2 INSPECTION**

Inspect the unit immediately after delivery and report any damages to the shipping company. The repeater package should contain:

- RLR-465NX repeater
- RPS-3000 3Amp 13.8 VDC power supply
- DC power supply cable
- RLR-PCPS programing software

### **2.3 MODEL IDENTIFICATION**

The Repeater's model, serial number, and FCC identification number appear on a label attached to the rear panel.

### **2.4 FCC REGULATIONS**

The Federal Communications Commission (FCC) requires that the radio owner obtain a station license before using the equipment to transmit. The user is not required to obtain an operating license. The station licensee is responsible for proper operation and maintenance of his radio equipment and for ensuring that transmitter power, frequency, and occupied bandwidth are within the limits specified by the station license. This is effected by aligning the unit per the instructions in the Alignment section of this manual as well as periodically checking that transmitter and deviation. Because the RLR-465NX contains a transmitter, **THE REPEATER MUST BE LICENSED BEFORE USE.** A RITRON dealer can help with obtaining an FCC license. There are no user adjustments available inside this product. All alignment steps and adjustments including programming frequency, trimming frequency, setting modulation and power must be performed by a qualified two-way radio technician. The programming software and hardware is available only to RITRON authorized radio dealers and must not be made available to the end user.

### **2.5 RF SAFETY ISSUES**

On August 25, 1997, the FCC adopted the second of two Orders finalizing its rules regarding compliance with safety limits for human exposure to radio frequency (RF) emissions. All transmitting facilities, operations and devices regulated by the FCC, including this product, must be in compliance with the RF exposure limits contained in Code of Federal Regulations (CFR) 47 parts 1.1307(b)(1)-(b)(3). It is the responsibility of the licensee or grantee to either take action to bring the facility, operation or device into

compliance or file an Environmental Assessment with the FCC. The following precautions should be taken with regard to the use of this equipment:

**PLEASE NOTE THE FOLLOWING WITH REGARD TO RF EXPOSURE FOR THIS PRODUCT, EXPOSURE TO RADIO FREQUENCY ENERGY:**

This product generates radio frequency (RF) energy when transmitting. This product has been evaluated for compliance with the maximum permissible exposure limits for RF energy at the maximum power rating of the unit. To meet the minimum separation distance and keep the maximum RF exposure at or below the General Population/Uncontrolled limits in the country of use the table below to determine the minimum distances. This product is not to be used by the general public in an uncontrolled environment unless compliance with the Uncontrolled/General Population limits for RF exposure can be assured.

The receiver section of this device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

This radio transmitter (RLR-465) has been approved by Industry Canada to operate with the antenna types listed below with the maximum permissible gain and required antenna impedance for each antenna type indicated. Antenna types not included in this list, having a gain greater than the maximum gain indicated for that type, are strictly prohibited for use with this device.

The following 50 ohm antenna types can be used with the RLR-465:

<b>Antenna Type</b>	<b>Antenna Gain(dBi)</b>	<b>Canadian Minimum Distance (m)</b>	<b>USA Minimum Distance (m)</b>
Yagi	12	2.72	2.05
High gain Omni	10	2.16	1.63
5/8 wavelength	3	0.97	0.73
Quarter wave	2	0.86	0.65

**Veillez NOTER CE QUI SUIT À L'ÉGARD DE L'exposition aux RF SUR CE PRODUIT :**

Ce produit génère de l'énergie radiofréquence (RF) lors de la transmission. Ce produit a été évalué pour la conformité aux limites d'exposition maximales admissibles pour l'énergie RF à la puissance nominale maximale de l'unité. Pour respecter la distance de séparation minimale et maintenir l'exposition maximale aux fréquences radioélectriques égale ou inférieure aux limites de la population générale / non contrôlée du pays d'utilisation, le tableau ci-dessous permet de déterminer les distances minimales. Ce produit ne doit pas être utilisé par le grand public dans un environnement non contrôlé, sauf si les limites de la population générale / non contrôlée pour l'exposition aux radiofréquences peuvent être respectées. Des gains plus élevés que les antennes avec un dipôle sont capables de générer des champs dans la partie la plus solide de leur domaine et, par conséquent, exigent une plus grande séparation de l'antenne. Ils peuvent être montés plus haut que l'unité de répétition qui feront augmenter la séparation de l'opérateur de l'antenne. Ce produit n'est pas d'être utilisées par le grand public dans un environnement non contrôlé à moins que le respect de la population générale/incontrôlée des limites pour l'exposition aux RF peuvent être assurés.

Le récepteur de ce présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage, et (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Le présent émetteur radio (RLR-465) a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés ci-dessous et ayant un gain admissible maximal et l'impédance requise pour chaque

type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur.

Les types d'antenne de 50 ohms peut être utilisé avec le RLR-465 :

<b>Antenna Type</b>	<b>Antenna Gain(dBi)</b>	<b>Canadian Minimum Distance (m)</b>	<b>USA Minimum Distance (m)</b>
Yagi	12	2.72	2.05
High gain Omni	10	2.16	1.63
5/8 wavelength	3	0.97	0.73
Quarter wave	2	0.86	0.65

To limit exposure to RF energy to levels below the limit, please observe the following:

- DO NOT OPERATE THIS EQUIPMENT unless all RF connectors are secure and any open connectors are properly terminated.
- GROUND ALL RADIO EQUIPMENT.
- ALLOW ONLY QUALIFIED SERVICE PERSONNEL to service this product.
- DO NOT ALLOW THIS EQUIPMENT to be set to power levels above its design limit or the licensed maximum.

When used as directed, this series of radios is designed to comply with the FCC's and Industry Canada's RF exposure limits for "Uncontrolled/General Population". In addition, they are designed to comply with the following Standards and Guidelines:

- United States Federal Communications Commission, Code of Federal Regulations; 47 CFR §§ 2 sub-part J.
- American National Standards Institute (ANSI) / Institute of Electrical and Electronic Engineers (IEEE) C95. 1-1992.
- Institute of Electrical and Electronic Engineers (IEEE) C95.1-1999 Edition.  
Copyright Telecommunications Industry Association

**2.6 RITRON, INC. LIMITED WARRANTY**

RITRON, INC. ("RITRON") provides the following warranty against defects in materials and/or workmanship in this RITRON Liberty Repeater and its Accessories under normal use and service during the applicable warranty period (as stated below). "Accessories" means original power supply, antennas, cables and items contained in the programming and programming/service kits.

<b>WHAT IS COVERED</b>	<b>FOR HOW LONG</b>	<b>WHAT RITRON WILL DO</b>
RLR-456 Digital Repeater	1 year	During the first year after date of purchase, RITRON® will repair or replace the defective product, at RITRON's option, parts and labor included at no charge.
Accessories	90 days	after date of purchase

**WHAT THIS WARRANTY DOES NOT COVER:**

- Any technical information provided with the covered product or any other RITRON products;
- Installation, maintenance or service of the product, unless this is covered by a separate written agreement with RITRON;
- Any products not furnished by RITRON which are attached or used with the covered product, or defects or damage from the use of the covered product with equipment that is not covered (such as defects or damage from the charging or use of batteries other than with covered product);
- Defects or damage, including broken antennas, resulting from:
  - misuse, abuse, improper maintenance, alteration, modification, neglect, accident or act of God,
  - the use of covered products other than in normal and customary manner or,
  - improper testing or installation;
- Defects or damages from unauthorized disassembly, repair or modification, or where unauthorized disassembly, repair or modification prevents inspection and testing necessary to validate warranty claims;
- Defects or damages in which the serial number has been removed, altered or defaced.
- Batteries if any of the seals are not intact.

**IMPORTANT:** This warranty sets forth the full extent of RITRON’s express responsibilities regarding the covered products, and is given in lieu of all other express warranties. What RITRON has agreed to do above is your sole and exclusive remedy. No person is authorized to make any other warranty to you on behalf of RITRON. Warranties implied by state law, such as implied warranties of merchantability and fitness for a particular purpose, are limited to the duration of this limited warranty as it applies to the covered product. Incidental and consequential damages are not re-coverable under this warranty (this includes loss of use or time, inconvenience, business interruption, commercial loss, lost profits or savings). Some states do not allow the exclusion or limitation of incidental or consequential damages, or limitation on how long an implied warranty lasts, so the above limitations or exclusions may not apply to you. Because each covered product system is unique, RITRON disclaims liability for range, coverage, or operation of the system as a whole under this warranty

**WHO IS COVERED BY THIS WARRANTY:** This warranty is given only to the purchaser or lessee of covered products when acquired for use, not resale. This warranty is not assignable or transferable.

**HOW TO GET WARRANTY SERVICE:** To receive warranty service, you must deliver or send the defective product, delivery costs and insurance prepaid, within the applicable warranty period, to RITRON, INC., 505 West Carmel Drive, Carmel, Indiana 46032, Attention: Warranty Department. Please point out the nature of the defect in as much detail as you can. You must retain your sales or lease receipt (or other written evidence of the date of purchase) and deliver it along with the product. If RITRON chooses to repair or replace a defective product, RITRON may replace the product or any part or component with reconditioned product, parts or components. Replacements are covered for the balance of the original applicable warranty period. All replaced covered products, parts or components become RITRON’s property.

**RIGHTS TO SOFTWARE RETAINED:** Title and all rights or licenses to patents, copyrights, trademarks and trade secrets in any RITRON software contained in covered products are and shall remain in RITRON. RITRON nevertheless grants you a limited non-exclusive, transferable right to use the RITRON software only in conjunction with covered products. No other license or right to the RITRON software is granted or permitted.

**YOUR RIGHTS UNDER STATE LAW:** This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

**WHERE THIS WARRANTY IS VALID:** This warranty is valid only within the United States, the District of Columbia and Puerto Rico.



### **3. OPERATION**

#### **3.1 GENERAL OPERATION**

Test the Repeater for proper operation as the unit is received before attempting to reprogram and/or retune it. There is no On/Off switch on the unit; it is powered up when a power supply is connected. Standard factory programming is a receive frequency of 469.500 MHz and a transmit frequency of 464.500 MHz. Custom set up can be requested from the factory.

Retune the internal duplexer if either the receive or transmit frequency are to be changed by more than 50 kHz. Note that the nominal transmit/receive spacing is 5 MHz for this product. Larger spacing may be accommodated, but not smaller. See the Alignment section.

The Repeater is setup to accept a 13.8 volt/3amp RITRON RS-4A regulated source of power and can provide up to 10 watts of output power at the antenna connector. See the duty cycle/temperature limits below. The transmitter power output at the antenna connector can be programmed to vary from 2 watts to the 10 watts. Ten Watts can only be realized by using at least a 13.8 volt source. If operating from a nominal 12 volt lead acid battery the power will be somewhat lower depending on the voltage.

The RLR-465NX has a standard frequency separation of 5 MHz between transmit and receive. The normal configuration is for the receive frequency to be above the transmit frequency. “Inverted” systems are reversed with the transmit frequency higher than the receive frequency. The cables on the duplexer are long enough to allow them to be swapped. Normally, the duplexer cables are tie-wrapped in a loop. The tie-wraps can be cut to allow swapping the connections.

Unlike an analog repeater there is no transmitter “hang time”. This allows lower duty cycle operation keeping the unit cooler since the transmitter turns off when there is no speech. The analog “hang time” kept the repeater transmitter up for a number of seconds after speech to eliminate squelch tails and allow only certain people repeater access. There is no squelch tails in digital communications.

#### **3.2 DUTY CYCLE/TEMPERATURE LIMITS**

Due to internal heating of the RF transmitter components, there is a limit on the maximum duty cycle of the repeater depending upon temperature and output power. The repeater is designed for 100% duty cycle at 25 °C or below. It should be linearly de-rated to 10% at 50 °C. Lower power settings will improve this slightly. Also adjusting the final FET output matching cap for minimum current drain while transmitting will reduce heat generation. Once the PCB reaches 55 °C the repeater will power down to 2 Watts. Full power operation will resume when the temperature falls to 52 °C. If the repeater temperature reaches 60 °C the repeater will shut down.

Usage data is available on the “Usage” tab. Amongst other data it logs the six warmest repeater “events”. An “event” or conversation starts when at least 2 minutes of no transmission has occurred on the repeater. This data informs the operator of start and stop temperatures as well as conversation durations and transmitter duty cycle usage.



### 3.3 INDICATORS

There are three LED indicators, green, amber and red, on the front panel. Their operation is detailed below:

<u>Indicator</u>	<u>Function</u>	<u>Status</u>
Green	Power-On	Off: Unit not powered-up Blinking: Receiver Synthesizer Out-of-Lock Steady On: Normal Operation
Amber	Receiver status	Blinking: carrier is on channel as set by RSSI squelch Steady On: NXDN signal detected
Red	Transmit	Off: Unit not transmitting Blinking: Transmitter Synthesizer Out-of-Lock Steady On: Unit Transmitting

Note: If the receiver is out-of-lock (Green LED blinking), the unit will NOT transmit. See the Alignment Section for details on tuning the VCO's. Both the receiver and transmitter VCO are tuned at the factory for operation over the 20 MHz band and should not need retuning.

### 3.4 CONNECTORS

There are four connectors on the Repeater: an antenna connector on the rear panel, a DC power connector, RJ interface connector and USB port on the front panel. Their operation is detailed below:

#### 3.4.1 Antenna Connector

On the rear panel is a type N Antenna Connector. An antenna, tuned to a 50 ohm match at the transmit frequency, should be connected to this connector. Although it is permissible to connect a whip antenna directly to the connector, best results are usually obtained by using a quarter-wave ground-plane antenna mounted in an optimum location and connected to the Repeater via a length of low-loss, high quality coaxial cable. The performance of the duplexer is somewhat dependent on the tuning of the antenna. Whip antennas are very sensitive to proximity to metal and other surfaces which can make their operation, when directly connected to the repeater, less than optimum. Also, a good quality coaxial cable should be used to avoid de-sensing the repeater. Also, older cables have been known to cause problems.

### 3.4.2 DC Power Connector

On the right side of the front panel is the DC Power Connector. This connector is a male P-5 type with a 2.11 mm (0.083 in.) inside diameter, 5.51 mm (0.217 in.) outside diameter and a 9.5 mm (0.374 in.) internal length. The positive terminal is on the inside.

### 3.4.3 Interface Connector

Near the middle of the front panel is the Interface Connector. This connector is a female telephone RJ-12 modular connector:

Pin No.	Name	Description
1	GND	Circuit ground and common point for other pins.
2	AS2_RX	0 to 3.3 volt asynchronous RX interface to microcontroller
3	PTT	Bringing low will cause unit to transmit. Can also transmit via Ritron programmer.
4	RSSI	Voltage increases with larger signals
5	Data Out/AS2_TX	Jumper J308 determines mode. Normally set to inverted discriminator output. Can view 4FSK eye pattern.
6	De-emphasized audio	De-emphasized inverted discriminator output. Can be used to measure SINAD.

Note: There is no vocoder in the repeater so voice output is not available. Likewise, no voice can be transmitted from the repeater interface connector.

### 3.4.4 Mini USB programming port

Connect cable between this port and the PC USB port for use with the Ritron RLR-PCPS programming software.



## 4. REPEATER FEATURES

The RLR-465NX repeater may be programmed with a transmit frequency, receive frequency, and a number of other features:

Transmit time-out timer	This feature determines how long the unit may transmit continuously before the transmitter automatically shuts off. It is delivered from the factory as “0” meaning no time out.
Morse code identifier	The repeater can be programmed to transmit a Morse code identifier at a specified time interval as required by the FCC
RAN	The repeater can be set up to repeat all NXDN traffic. It can also be set up to allow up to only 10 unique RAN codes. This helps eliminate an inadvertent NXDN on channel signal from triggering the repeater.
Low Voltage voice alert	When the input voltage to the repeater falls below 11 volts the repeater will transmit an NXDN voice message alerting users to a low battery condition. This alert will repeat every 30 minutes until the voltage recovers. A custom voice message can be written using a portable radio by clicking “Record Low voltage Voice” and then PTTing the portable while speaking the message. This alert voice message can have a RAN code and/or source and destination ID so as to target a specific radio such as the system operator.
High temperature operation	The RLR-465NX has sufficient heatsinking to allow the repeater to work continuously at temperatures of 25 degrees Celsius or below. At higher temperatures with prolonged usage the thermal sensor on the PCB will sense an excessive temperature at 55 C and reduce power output to 2 Watts. A power of 10 Watts will resume when the temperature falls below 52 C. A temperature of 60 C will shut the transmitter down until temperature cools to 59 C and resume 2 Watts.

### 4.1 PROGRAMMING SETUP

RITRON programming kit RLR-PCPK supports programming the RLR-465NX repeater using a PC compatible computer. To use the programming software, connect the Repeater to the computer USB port of the PC. The software includes on-screen instructions and Help files.

### 4.2 COMPUTER SOFTWARE COPYRIGHTS

The RITRON, Inc. products described in this manual include copyrighted RITRON, Inc. computer programs. Laws in the United States and other countries grant to RITRON, Inc. certain exclusive rights in its copyrighted computer programs, including the exclusive right to distribute copies of the programs, make reproductions of the programs, and prepare derivative works based on the programs. Accordingly, any computer programs contained in RITRON, Inc. products may not be copied or reproduced in any manner without the express written permission of RITRON. The purchase of RITRON, Inc. products does not grant any license or rights under the copyrights or other intellectual property of RITRON, Inc., except for the non-exclusive, royalty-free license to use that arises in the sale of a product, or as addressed in a written agreement between RITRON, Inc. and the purchaser of RITRON, Inc. products.

## 5. THEORY OF OPERATION

This repeater is designed to handle super narrow band 6.25 kHz NXDN. It will receive on one frequency and transmit on another a nominal 5 MHz offset. It has no voice vocoder so it cannot receive voice on a

speaker or transmit voice from a microphone. It is designed to operate at 13.8 VDC to yield 10 Watts output. The repeater can be set up to repeat all super narrowband signals on the receive frequencies or be set up via a table to repeat only certain RAN codes. For further explanation see the RITRON programmer and help file. The unit draws about 140 mA in receive mode and about 3 Amps in transmit mode. This allows it to be battery operated or battery backed up.

## **5.1 DUPLEXER**

The duplexer allows for simultaneous transmission and reception of RF signals. There is a receive path and a transmit path which connect to the RF input and output of the main PCB and a common point at the antenna connector.

In the receive path is a two-cavity notch filter. This filter allows the receive signal from the antenna connector to pass through with about 1.5 dB loss, but notches the transmitter RF output signal by 70 dB or more to prevent overloading the receiver. The transmit path also contains a two-cavity notch filter, this one tuned to the receive frequency. This filter removes transmitter noise which exists at the receive frequency and which would interfere with the desired receive signal, if not removed. This filter has about 1.75 dB loss. Because the notches are very narrow, the duplexer must be re-tuned if the frequency of operation is changed by more than 50 kHz. If the repeater receive frequency is lower than the transmit frequency then these two notch filters are physically reversed. The coaxial connectors will cross if this is the case. The low pass filter, which is physically next to the transmitter connector, will be routed to the receive connector and the high pass filter, next to the receive connector, will be routed to the transmit connector.

## **5.2 RECEIVER**

### **5.2.1 Front-End**

The receiver front-end comprises the RF amplifier stages with associated filters and the first mixer. The input signal from the J101 (RX IN) passes through a two resonator bandpass filter formed around L101 and L102. This filter is narrow enough at 10 MHz to protect the receive RF amplifier, but wide enough to keep its insertion loss low at 2 dB. This filter stage is followed by the RF amplifier. The RF amplifier stage has a gain of about 12 dB and a noise figure of 1.5 dB. This stage, along with the first filter, are largely responsible for the sensitivity of the Repeater. The RF amplifier is followed by a two resonator bandpass filter formed around L103 and L104. This filter is somewhat narrower than the two-pole filter and thus has a higher insertion loss at 7 dB. The total filtering action is to limit the number of off-channel interfering signals that the receiver might be exposed to and to remove signals at the spurious response frequencies of the mixer which follows. More amplification through Q102 is needed to overcome this second filter section insertion loss.

The job of the 1<sup>st</sup> mixer, U101 is to convert signals at the receive frequency to that of the 1<sup>st</sup> IF at 43.65 MHz. It does this by mixing the 1<sup>st</sup> local oscillator signal at a frequency 43.65 MHz below that of the desired receive frequency to the IF frequency of 43.65 MHz. The 43.65 MHz output of U101 exits through T102 and is routed to the 1<sup>st</sup> IF filter. U101 has a conversion gain of 2 dB and a noise figure of 10 dB. This performance in combination with the front-end RF amplifier stages determines the sensitivity of the receiver.

### **5.2.2 1<sup>st</sup> IF**

The 1<sup>st</sup> IF stage consists of two two-pole monolithic crystal filters separated by an amplifier. The two filters are FL101 and FL102. These filters are bandpass in response with a bandwidth of 4 kHz and an insertion loss of 1.5 dB. To overcome the losses of the filters and to prevent interaction between them, they are separated by an amplifier formed around Q109.

### **5.2.3 2<sup>nd</sup> IF Sub-System**

IC U102 is responsible for converting signals at the 1<sup>st</sup> IF to the 2<sup>nd</sup> IF where additional filtering and amplification take place. The 43.65 MHz signals enters U102 at pin 16. It is then mixed with the 2<sup>nd</sup> local oscillator signal at pin 1 to produce a signal at the 2<sup>nd</sup> IF of 450 kHz at pin 3. The 2<sup>nd</sup> IF signal at pin 3 is filtered by the FL103, the 2<sup>nd</sup> IF filter. This filter is a bandpass filter with a bandwidth of 4 kHz and an insertion loss of 5 dB. The output of the filter re-enters U102 at pin 5 where it is amplified and then limited to remove amplitude modulation components. The limited signal is then mixed against a 90° phase shifted version of itself and filtered by Y101. This acts as an FM demodulator. The demodulated output exits U102 at pin 9.

#### **5.2.4 1<sup>ST</sup> Local Oscillator/Receive Synthesizer**

The local oscillator signal for the 1<sup>st</sup> mixer is generated by the receive synthesizer. The receive synthesizer is based around a voltage controlled oscillator (VCO) and a synthesizer sub-system IC which handles the digital portion of the synthesizer. The voltage controlled oscillator is an oscillator whose frequency can be controlled by a voltage. The receive voltage controlled oscillator is formed around Q107 with varactor diode D101 and D102 electronically controlling the frequency. A sample of the oscillator frequency is sampled by R124 and C160 and sent to U104, an integrated monolithic Phase-Locked Loop (PLL) synthesizer IC. Inside U104, the VCO frequency is divided by programmable digital dividers to a frequency in the 50 kHz range. FL104, the 36.4 MHz receive reference oscillator's frequency is also divided down to the 50 kHz range. A phase/frequency detector compares the two divided down frequencies and generates an error signal at U104, pin 2 which is filtered and used to pull the VCO on frequency. By controlling the VCO divider number, the locked frequency can be changed. The divider numbers are loaded into U104 by the microprocessor. The 20 MHz tuning range of the VCO is set by C150. Because the VCO is locked to the receive reference oscillator, FL104, the frequency stability of FL104 determines the frequency stability of the VCO and thus the 1<sup>st</sup> local oscillator.

The output of the VCO is amplified by Q104 and Q106 to about 5 dBm to drive the 1<sup>st</sup> mixer. For alignment purposes, a sample of the 1<sup>st</sup> local oscillator is available at TP101. For proper mixing operation, the VCO is made to oscillate at a frequency 43.65 MHz below the receive frequency.

#### **5.2.5 2<sup>ND</sup> Local Oscillator**

To convert the 1<sup>st</sup> IF signals at 43.65 MHz to the 2<sup>nd</sup> IF frequency of 450 kHz, requires a 2<sup>nd</sup> local oscillator frequency of 43.2 MHz (43.65 – 0.450). This is created by multiplying the 14.4 MHz output frequency of FL105 by three in Q103.

#### **5.2.6 Base band data**

Discriminator audio from U102 passes to U103-C and it is amplified and through U103-D where is equalized. It is then sent to the NXDN decoder IC U302 for demodulation. The main controller U301 reads the data and performs needed tasks such as error correction, RAN and ID decoding.

### **5.3 TRANSMITTER**

#### **5.3.1 Transmit Synthesizer**

The transmit synthesizer operates similar to the receive synthesizer except that the oscillator is locked to the transmit frequency rather than offset by the 1<sup>st</sup> IF frequency. The transmit VCO is formed around Q207 and electronically tuned by D202 and D203. The oscillator frequency is sampled by R227 and C226 and routed to U201, the transmit synthesizer IC. The oscillator frequency is divided down around 50 kHz and compared in phase and frequency to the divided transmit reference oscillator signal. The error signal is filtered and sent to the varactor diode D202 and D203 to lock the VCO on frequency. The reference is created by dividing down the transmit reference oscillator frequency of 36.4 MHz from FL201. To modulate the transmitter, the VCO must allow for frequency modulation other than what is required to put it on frequency. This is effected by D204. The 20 MHz tuning range of the VCO is set by

C296. Q212 is an electronic switch which keeps the transmit VCO turned off when the unit is not transmitting.

### **5.3.2 RF Power Amplifier Stages**

The output of the VCO buffer stage, Q205 is at a level of about 5 dBm. This is amplified to the 2 to 10 watt level by Q201, Q202, Q203, and Q204. Q210 allows the first two amplifier stages to be turned on after the transmit VCO is locked and on frequency. After this the RF power output is ramped up by increasing the bias voltage on the last two FETs. The output power can be adjusted by programmer and the voltage appears at pin 9 of U203-C, which sets the bias voltage on the current control loop. This current control loop formed by current sensor Q211 and op-amp U202 maintain the FET final (Q201) current. As the gain of the driver stages change due to temperature the current loop keeps the power steady. It does this by changing the FET bias on the final two FETs Q202 and Q201. Q201 is followed by an impedance matching network and a low-pass filter to remove transmitter frequency harmonics. This amplifier can output about 15 Watts into the duplexer which dissipates 4 to 5 Watts when a full 10 Watts is needed.

### **5.3.3 Transmitter signaling**

Once a transmit NXDN packet is ready the main microcontroller U301 will send it to the transmitter NXDN modulator IC U303. It sends the NXDN 4FSK signal out pin 23 via the TX\_MOD line. The TX\_MOD line is sent to a summing amplifier U205-C. Also summed into the amp is the Morse code ID signal CWID from the microcontroller. The CWID is fed through a 5-pole low-pass filter which removes audio harmonics and keeps the signal within FCC occupied bandwidth limits. After the summing amplifier the NXDN signal is sent through a deviation pot U204-C and then through a summing amplifier which trims the reference oscillator bias voltage to bring the RF carrier on frequency. The last pot to go through is the balance pot U203-B which adjusts the VCO modulating signal level to form a nice “eye” pattern.

## **5.4 POWER DISTRIBUTION**

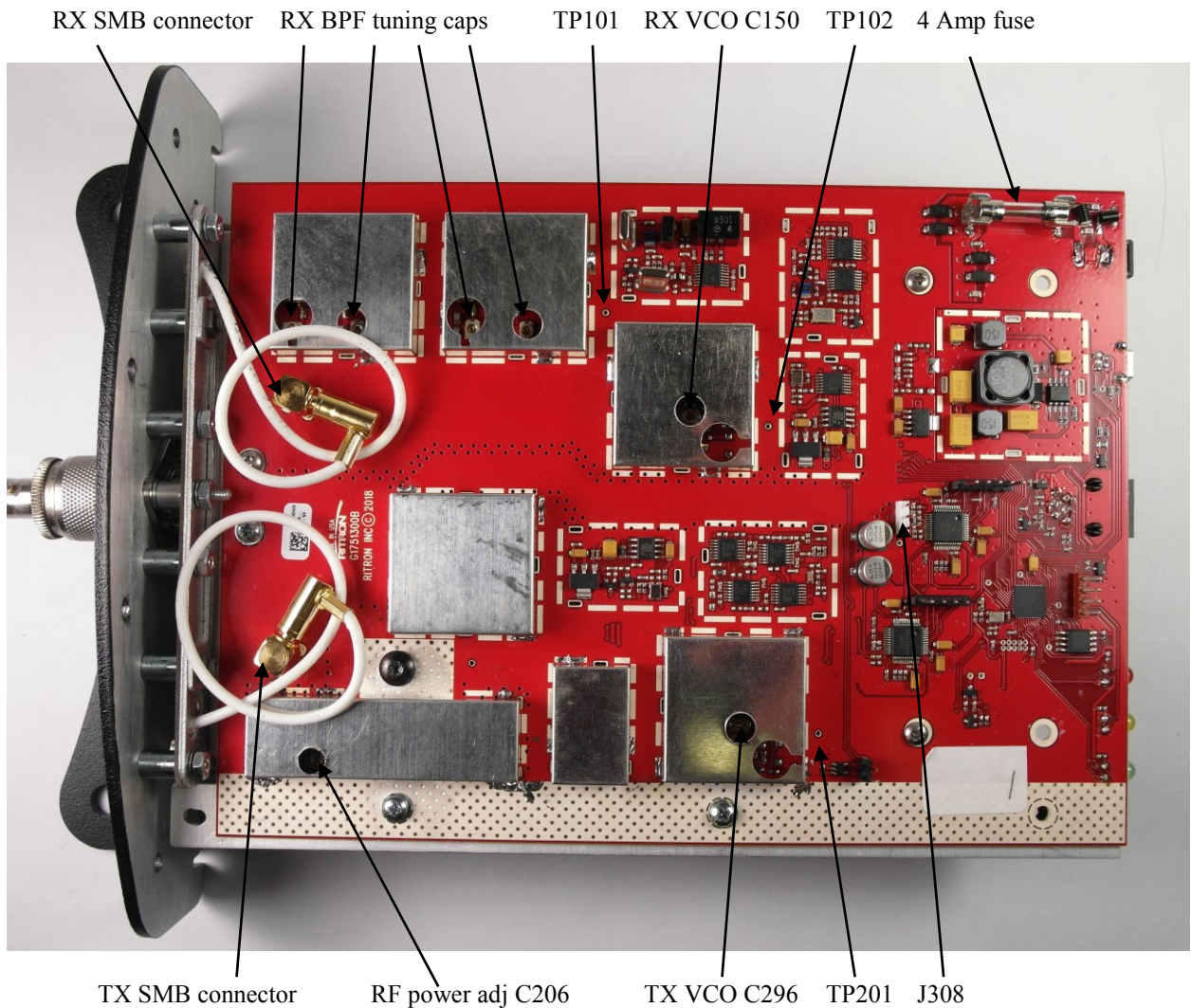
Power enters the unit through J601 and is protected from reverse voltage by D601 through D604 diodes. The 4 Amp fuse will blow if either a short or reverse polarity on the supply exists. A 6 volt switching power supply exists to reduce current consumption both in receive mode and in transmit mode. This keeps the unit cooler by eliminating excess power dissipation in voltage regulators.

## **5.5 MICROCONTROLLER**

U301 controls the following radio functions:

- 1) USB programming of the radio via J302.
- 2) NXDN packet handling and FEC error correction through U302 and U303.
- 3) Radio status indicators via RED, AMBER and GREEN LEDs.
- 4) PCB temperature monitoring via U609. Causes “overheat” shut back when too hot.
- 5) Power supply under voltage monitoring via U103-B. Useful when a battery only supply is used.
- 6) Low voltage voice message and can be programmed via RITRON programmer and portable radio.
- 7) Sends CW ID periodically. Programmable 1 to 34 minutes.
- 8) Loads RX and TX frequency synthesizers as well as deviation, balance and frequency trim pots.





## 6. FACTORY ALIGNMENT

### 6.1 DUPLEXER

Tuning the duplexer requires either a network analyzer or an accurate RF signal generator and low level RF detector. If the customer uses a repeater transmit frequency that is lower than the receive frequency the coaxial cable connections are direct. That is to say, the transmit duplexer cavities are directly below the transmitter and the receive duplexer cavities are below the receiver section. Otherwise the cables will cross each other when connected to the RF board.

- 1) Disconnect power from the repeater. Disconnect SMB coaxial connectors from the RF board. Inserting a flat screw drive between the connector parts and twisting will aid in releasing the cable. *Do not pull on the cable base* as this could damage the cable. Connect SMB adapters and coaxial cables to test instrument. If desired test equipment can go through both duplexers at once. This will produce notches at two frequencies 5 MHz apart.
- 2) To adjust transmit duplexer to notch receive frequency where TX frequency is below RX frequency, set or look at response at receive frequency. Adjust screws under transmitter to minimize response at RX frequency.



- 3) To adjust transmit duplexer to notch TX frequency where TX frequency is below RX frequency, set or look at response at transmit frequency. Adjust screws under receiver to minimize response at TX frequency.
- 4) Tighten nuts when finished.

## **6.2 RECEIVER**

### **6.2.1 RX VCO Band adjustment and reference Oscillator tuning**

- 1) Go to the “Alignment” tab and click “Frequency/Power” then “Center Frequency Adjustment”. This will load a 425 MHz local oscillator frequency into the RX synthesizer.
- 2) Adjust the C150 band shifting cap to yield a 3.8 +/- 0.2 VDC tuning voltage on TP102. The RX band will now operate anywhere in the 20 MHz RX band after being programmed to that frequency by the RITRON programmer. The VCO tuning voltage will range from about 1 volt at 450 MHz to 4 volts at 470 MHz.
- 3) Connect probe to the receiver local oscillator test point TP101 and measure the 425 MHz frequency. Perform next three steps if more than +/- 200 Hz off.
- 4) “Center Frequency Adjustment”: adjust “RX Freq Trim” to yield 425 MHz +/- 50 Hz
- 5) “Frequency Positive Correction Factor”: adjust “RX Freq Trim” to yield 425 MHz +/- 50 Hz
- 6) “Frequency Negative Correction Factor”: adjust “RX Freq Trim” to yield 425 MHz +/- 50 Hz. The 36.4 MHz RX reference crystal is now calibrated. Click “Program Repeater” to save.
- 7) Click the “Main” tab to return to the repeater’s programmed RX frequency. The VCO tuning voltage will change to correspond to that frequency.

### **6.2.2 RX filter alignment and Sensitivity**

- 1) Connect receive duplexer cable to RX port (J101). Set signal generator to -118 dBm with 1.5 kHz deviation on a 1 kHz tone and connect to duplexer antenna port.
- 2) Connect oscilloscope and SINAD meter to pin 6 of RJ-12 connector. This is the de-emphasized output.
- 3) Adjust C102, C108, C115 and C121 to maximize SINAD. Signal generator can be temporarily set higher if need be to see 1 kHz sine wave. Unit should obtain at least -118 dBm sensitivity for a 12 dB SINAD when tuned up.

### **6.2.3 2<sup>nd</sup> IF local oscillator trimming for minimum filter distortion**

- 8) Modulate RX carrier frequency with square wave of 400 Hz. Raise the amplitude to about -110 dBm.
- 9) Click the “Miscellaneous” tab and then the “IF Trim” radio button. Connect scope probe to the flat output port (pin 5) of the RJ-12 connector. Jumper J308 should be connecting pins 2 and 3 to get the RX signal. These are the lower two pins as seen on the picture above. This is the factory default.
- 10) Adjust the “IF Trim” for symmetrical ringing on the demodulated and band pass limited square wave. This adjusts the 43.2 MHz 2<sup>nd</sup> local oscillator frequency to center the signal in the 450 kHz pass band. The DC discriminator output level will also vary as this is adjusted. The adjacent channel rejection is also affected by this tuning.

### **6.2.4 Squelch**

- 11) Although squelch levels are not used in NXDN communications the carrier detect amber LED can be set to serve as a diagnostic of channel activity. Recall the amber LED will flash when RSSI detection level is exceeded and be a solid color when and NXDN signal is detected.
- 12) Click the “Alignment” tab then “CD calibration” and follow the instructions on that tab. Here you will calibrate at two predefined RF levels and once done set the squelch on and off levels in two other boxes. This is done by typing in your desired “Carrier Detect ON” and “Carrier Detect OFF” levels in the boxes. The yellow RX LED will blink when a carrier is detected in this range.

## 6.3 TRANSMITTER

- 1) Connect the TX RF port J201 of the PCB to the service monitor. Do not go through the Duplexer since we will need to tune at various frequencies across the 450 to 470 MHz range.

### 6.3.1 TX frequency adjustment

- 2) Click the “Alignment” tab and “Frequency/Power” then click “Center Frequency Adjustment”. By clicking the “Transmit” button at the top of the form you can now adjust the TX reference oscillator center frequency to 469.000000 MHz +/- 50 Hz. Next, do the same with “Positive Correction factor” and “Negative Correction Factor” both to be set to 469.000000 Mhz. These three will calibrate the TX crystal tuning curve. When this is performed the green box next to the scroll bar will indicate the present setting. Click either “Transmit” again or “Receive” to return to receive mode.

### 6.3.2 TX VCO Band, Modulation Balance and Deviation adjustment

- 3) To set up the modulation of the transmitter we will start by balancing the top and bottom of the operating band. We will next set the deviation at the top and bottom of the band to 1350 Hz. This way any frequency programmed in the unit will interpolate between these settings. To get best performance we will align balance using the internally generated 1031 Hz 4FSK NXDN signal using a test set capable of decoding and displaying NXDN 4FSK signaling parameters.
- 4) Click the “Alignment” tab and “Deviation/Balance”. Now click “Analog” to toggle into “NXDN 1031” mode. Click “Auto alignment- Upper Edge Balance”. Now click the “Transmit”. Now adjust the transmitter VCO range pot C296 so that the VCO tuning voltage at TP201 measures 4.0 +/- 0.2 volts. Now adjust the “Auto alignment- Upper Edge Balance” slider bar to yield the best “eye” pattern on the NXDN test set. Stop transmitting. Repeat this for the lower frequency edge. Once balance is set click “NXDN 1031” button to toggle back to “Analog” mode. Click “Auto alignment- Upper Edge Deviation” and “Transmit”. Adjust the slider to yield 1350 +/- 50 Hz peak deviation. Here, an internal 600 Hz sine wave is generated. Repeat the above procedure for the “Auto alignment- Lower edge”. The VCO tuning voltage should read about 1 volt.
- 5) **Alternate analog method-** If an NXDN test set is not available the following can be performed. Click the “Alignment” tab and “Deviation/Balance”. Now in “Analog” mode click “Auto alignment- Upper Edge Balance”. Click the “Transmit”. Now adjust the transmitter VCO range pot C296 so that the VCO tuning voltage at TP201 measures 4.0 +/- 0.2 volts. Now adjust the “Auto alignment- Upper Edge Balance” slider bar to yield flattest square wave on the transmitter recovered audio. Stop transmitting. Repeat this for the lower frequency edge. Once balance is set click “Auto alignment- Upper Edge Deviation” and “Transmit”. Adjust the slider to yield 1350 +/- 50 Hz peak deviation. Here, an internal 600 Hz sine wave is generated. Repeat the above procedure for the “Auto alignment- Lower edge”. The VCO tuning voltage should read about 1 volt.

### 6.3.3 Alternate TX Modulation Balance and Deviation adjustment

- 6) The “Alignment” tab allows for calibration over the entire 20 MHz band by calibrating at the edges and interpolating across the frequency band to find the right pot settings. If the user wants to “tweak” the settings on his frequency he can go to the “Alignment” tab and “Deviation/Balance” and adjust these same parameters. However, if adjustments are made in this section the processor’s interpolation capability and settings will be overwritten.

### 6.3.4 TX power adjustment

- 7) Reconnect the TX SMB cable to J201 so that the duplexer is now used.

- 8) For power, click “Alignment” tab and “Frequency/Power”. Click “High Power” and “Transmit”. Set slider bar to desired power between 2 and 10 W. Confirm that while transmitting power input voltage on the input fuse is 13.8 +/- 0.2 VDC. Lower voltages can be used but will result in lower power output.
- 9) While transmitting adjust FET output cap C206 for maximum power. Look at current consumed and adjust a bit to minimize current if possible. A non-metal tuning tool must be used to avoid incorrect tuning.
- 10) On “Alignment” tab adjust low power to 2 Watts. This will be the reduced power output should the repeater PCB temperature ever exceed 55 degrees C. This power output will persist until the temperature reaches 52 degrees C. Click “Program Repeater” to save settings.