RFD900/868x and ux Peer-to-peer V3.X Firmware User Manual

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1 Introduction

The x series radio modem can be loaded with three official firmware releases to achieve different communication architectures and node topologies .Available firmware types are:

- Peer-to-peer (P2P) (SiK)
- Asynchronous mesh
- Multipoint network

This document describes the configuration of the peer-to-peer releases V3 and up. x series sold after April 2019 come with a 3.xx version loaded by default. The firmware has a set of default settings that allow it to work out of the box in most cases. If using a mixture of new and old modems there can be issues when using different firmware versions so it is recommended to update all modems to the same latest release.

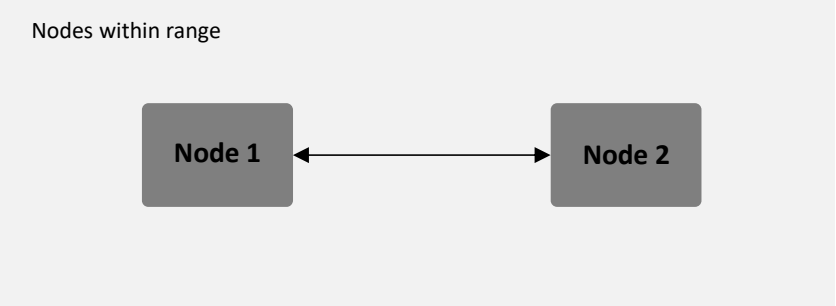

Figure 1- 1: Peer-to-peer network architecture

2 Peer-to-peer Network

The peer-to-peer firmware offers straight forward data communication between two nodes. Figure 4-2 depicts this very simple communication topology. Whenever two nodes have compatible parameters and are within range, communication will be established after the units synchronise. A solid green LED state indicates synchronisation has been successful.

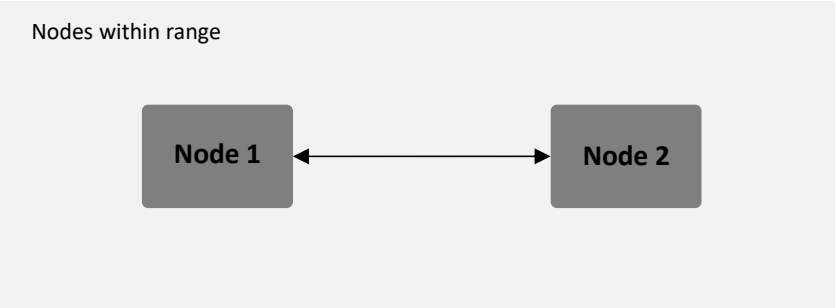

Figure 4-2: Simple pair mode

If operating with other RFD modems on the same band, you will need to set different network ID's to each pair to distinguish the networks from each other. It is also advisable when possible to set the different pairs on different frequencies. This prevents packet collision, communication instability and other interference that may reduce the effectiveness of the links.

3 Software/GCS Support

This firmware is a development of the open source project called “SiK” that was created by Mike Smith and further developed and modified by Andrew Tridgell and RFDesign.

The modems feature a boot loader to facilitate field upgrade of the modem firmware via the serial port. This is most easily performed by using the latest version RFD Modem tools (see “Useful links”)

Parameters such as power levels, air data rates, serial speeds, GPIO pins etc can all be custom set by using the AT Command set, the RFD Modem Tools and APM Planner.

Default serial port settings are as follows:

- 57600 baud rate
- No parity
- 8 data bits
- 1 stop bit

The x series Radio Modem has many software features including:

- Frequency Hopping Spread Spectrum
- Transparent Serial Link
- Configuration by AT commands for local radio, RT commands for remote radio
- User configurable serial data rates and air data rates
- 128-bit AES hardware encryption with user settable key
- MAVLink protocol framing (user selectable)
- MAVLink radio status reporting (Local RSSI, Remote RSSI, Local Noise, Remote Noise)
- Automatic antenna diversity switching on a packet basis in real-time
- Automatic duty cycle throttling based on radio temperature to avoid overheating
- PPM or SBUS (R/C signal) pass through (Control vehicle across radio).
- GIPO pin mirroring

4 Configuration of Settings

The RFD x series modems can be configured in two main ways. The use of a GUI tool and using AT modem commands by serial terminal.

4.1 GUI

There are a number of graphical ways to modify the settings of x series modems using the peer to peer firmware including the SiK Radio tab under Optional Hardware in Mission Planner and the RFD900 Tools available from the RFD website (see useful links). This section will provide a very brief outline of the use of the RFD900 Tools for more information please read the user manual (see useful links).

Figure 3-1 RFD900 Tools main screen

The COM or network port that the modem is connected to along with the connection rate can be set in the top right of the screen.

Pressing connect opens the port.

Pressing load settings will connect to the modem and populate the screen with the current settings of the modem/s.

Settings can be changed using the check and drop down boxes.

Save settings saves changes made to the modem/s.

Reset to default will apply default settings to the modem/s.

Upload firmware provides a way for the user to update firmware or load an alternative firmware type.

4.2 AT Commands

The AT command mode can be entered by using the '+++', without quotes, sequence in a serial terminal connected to the radio.

You should allow at least one second after the sending of data before entering the sequence to ensure that the modem will correctly enter command mode.

If successful, an 'OK' prompt will be displayed on the screen and the x series modem will stop displaying incoming data from the remote modem. In command mode, you can use the AT commands to control the local x series modem or the RT commands to control the remote modem.

To set certain registers to a value, follow these steps:

1. Use the command ATSn=X where *n* is the register number and *X* is the value to assign.
2. Use the command AT&W to save the new values to the x series modem.
3. Use the command ATZ to reboot the x series modem for changes to take effect.

By replacing A with R the settings of the remote modem can be changed. It is recommended that changes to remote settings be made first as some of the changes can unlink the modems after being applied.

Table 3-1 shows a gives a list of AT commands and their description.

AT Command	Description
ATI	Shows the firmware version and country code
ATI1	Shows the firmware version number
ATI2	Shows the board type
ATI3	Shows board frequency
ATI4	Shows board version
ATI5	Shows all user settable EEPROM parameters and their values
ATI5?	Shows all user settable EEPROM parameters and their possible range
ATI6	Displays TDM timing report
ATI7	Displays RSSI signal report
ATI8	Display Device 64-bit unique ID
ATI9	Calibration validation test
ATO	Exits AT command mode
ATSn?	Displays radio 'S' parameter number 'n'
ATSn=X	Sets radio 'S' parameter number 'n' to 'X'
ATRn?	Displays radio 'R' parameter number 'n'
ATRn=X	Sets radio 'R' parameter number 'n' to 'X'
ATZ	Reboots the radio
AT&F	Resets all parameters to factory defaults
AT&W	Writes current parameters to EEPROM
AT&UPDATE	Reset and enter boot mode
AT&P	Change TDM phase (debug only)
AT&R	Record default PPM stream for PPM output (vehicle side)
AT&T	Disables debugging report
AT&T=RSSI	Enables RSSI debugging report

AT&T=TDM	Enables TDM debugging report
AT Command	**Description**
AT&E=X	Set new encryption key (128-bit AES in 32 hex characters 5A02D5BB...)
AT&E?	Shows current encryption key
ATPP	Shows GPIO configuration and state
ATPO=X	Sets GPIO X to output
ATPI=X	Sets GPIO X to input
ATPM=X	Sets input GPIO pin to mirror on remote radio (local GPIO must be set to input and remote GPIO pin must be set to output)
ATPR=X	Shows GPIO input state
ATPC=X,S	Sets output GPIO X to state S

Table 3-1: AT Commands and their description

An example that command will return the local modem's firmware version string.

```
ATI

Response

RFD SiK 3.00 on RFD900X R1.3-AU   # On a region locked modem

RFD SiK 3.00 on RFD900X R1.3      # On an unlocked modem
```

Note the letters after the -, AU in the above example, designate the region of the modem. AU Australia, NZ New Zealand, USA United States of America (also applies to Canada), EU European Union and IN India. No –XX format in the response string indicates that the modem is not region locked.

Issuing a AT command will take affect only in the local node. A reset ATZ may be required before the changes will take effect even after a writing the parameters with AT&W.

RT commands are terminal commands that take effect on a remote node. They allow the user to set or get a remote node's parameter, for instance, as if they were being set locally. Table 3-2 lists the RT commands and their respective descriptions.

RT Command	Description
RTI	Shows the firmware version and country code
RTI1	Shows the firmware version number
RTI2	Shows the board type
RTI3	Shows board frequency
RTI4	Shows board version
RTI5	Shows all user settable EEPROM parameters and their values
RTI5?	Shows all user settable EEPROM parameters and their possible range
RTI6	Displays TDM timing report
RTI7	Displays RSSI signal report
RTI8	Display Device 64-bit unique ID
RTI9	Calibration validation test
RTO	Exits AT command mode
RTSn?	Displays radio 'S' parameter number 'n'
RTSn=X	Sets radio 'S' parameter number 'n' to 'X'

RTRn?	Displays radio 'R' parameter number ‘n’
RTRn=X	Sets radio 'R' parameter number ‘n’ to ‘X’
RT Command	**Description**
RTZ	Reboots the radio
RT&F	Resets all parameters to factory defaults
RT&W	Writes current parameters to EEPROM
RT&UPDATE	Reset and enter boot mode
RT&P	Change TDM phase (debug only)
RT&R	Record default PPM stream for PPM output (vehicle side)
RT&T	Disables debugging report
RT&T=RSSI	Enables RSSI debugging report
RT&T=TDM	Enables TDM debugging report
RT&E=X	Set new encryption key (128-bit AES in 16 hex bytes e.g. 5A02D5BB...)
RT&E?	Shows current encryption key
RTPP	Shows GPIO configuration and state
RTPO=X	Sets GPIO X to output
RTPI=X	Sets GPIO X to input
RTPM=X	Sets input GPIO pin to mirror on remote radio (local GPIO must be set to input and remote GPIO pin must be set to output)
RTPR=X	Shows GPIO input state
RTPC=X,S	Sets output GPIO X to state S

Figure 3-2: RT Commands and their description

Issuing a RT command will take affect only in the remote node. A reset RTZ may be required before the changes will take effect even after a writing the parameters with RT&W. Link may be lost due to mismatch in parameter until local settings match the remote node.

Table 3-3 detailing the S-register parameters settings on the RFD x series modem.

Reg #	S Register Description	Default Value	Maximum Value	Minimum Value	Must be the same at both ends of the link?
S0	**FORMAT** This is for EEPROM version, it should not be changed. It is set by the firmware	Firmware dependant	N/A	N/A	No
S1	**SERIAL_SPEED** Serial speed in ‘one-byte form’. Accepted values are 1, 2, 4, 9, 19, 38, 57, 115, 230, 460 and 1000 corresponding to 1200bps, 2400bps, 4800bps, 9600bps, 19200bps, 38400bps, 57600bps, 115200bps, 230400bps, 460800bps and 1000000bps respectively.	57	1000	1	No
S2	**AIR_SPEED**[1] Air data rate in ‘one-byte form’. Accepted values are 12, 56, 64, 100, 125, 200, 224, 500 and 750 corresponding to 12000bps, 56000bps 64000bps, 100000bps, 125000bps, 200000bps, 250000bps, 224000bps, 500000bps and 750000bps respectively.	64/200[4,8]	750	12	Yes

Reg #	S Register Description	Default Value	Maximum Value	Minimum Value	Must be the same at both ends of the link?
S3	**NETID** Network ID.	25	255	0	Yes
S4	**TXPOWER**[1] Transmit power in dBm.	30	30	0	No
S5	**ECC**[2] Enables or disables the Golay error correcting code.	0	1	0	Yes
S6	**MAVLINK**[3] Enables or disables the MAVLink framing and reporting	1	1	0	No
S7	**OP_RESEND** Opportunistic resend allows the node to resend packets if it has spare bandwidth	0	1	0	No
S8	**MIN_FREQ**[1] Min frequency in KHz	915000 /868000[4,8]	927000 /870000[4]	902000 /865000[4,8]	Yes
S9	**MAX_FREQ**[1] Max frequency in KHz	928000 /870000[4]	928000 /870000[4]	903000 /865000[4,8]	Yes
S10	**NUM_CHANNELS**[1] Number of frequency hopping channels	20/1[4,8]	51[8]/8[4,8]	1	Yes
S11	**DUTY_CYCLE**[1] The percentage of time to allow transmit	100	100	10	No
S12	**LBT_RSSI**[1] Listen before talk threshold	0	220	25	Yes
S13	**RTSCTS** Ready-to-send and Clear-to-send flow control.	0	1	0	No
S14	**Max Window** Max transit window size used to limit max time/latency if required otherwise will be set automatically	131	400	20	Yes
S15	**Encryption Level** Encryption level 0=off, 1=128bit AES	0	1	0	Yes
S16	**GPIO1.1 R/C input** Set GPIO 1.1 (pin 15) as R/C(PPM) input	0	1	0	No
S17	**GPIO1.1 R/C output** Set GPIO 1.1 (pin 15) as R/C(PPM) output	0	1	0	No
S18	**GPIO1.1 SBUS input**[7] Set GPIO 1.1 (pin 15) as R/C(PPM) input	0	1	0	No
S19	**GPIO1.1 SBUS output**[7] Set GPIO 1.1 (pin 15) as R/C(PPM) output	0	1	0	No
S20	**ANT_MODE** 0= Diversity, 1= Antenna 1 only, 2= Antenna 2 only, 3= Antenna 1 TX and antenna 2 RX	0	3	0	No

Reg #	S Register Description	Default Value	Maximum Value	Minimum Value	Must be the same at both ends of the link?
S21	**GPIO1.3 Status LED output** Set GPIO 1.3 (pin 12) as output with state that mirrors the status LED on the modem	0	1	0	No
S22	**GPIO1.0 485 TX control output[6]** Set GPIO 1.0 (pin 13) as control signal on DINIO and RS485 interface boards.	0	1	0	No
S23	**Rate and Frequency Band** Switches between valid settings for the frequencies, channels and airspeeds that can be set on compliant modems ensuring compliance is maintained. See section 3.4 for FCC-related information.	0	3	0	Yes
R0	**TARGET_RSSI** Optimal RSSI value to try to sustain (255/0[8] disables the feature) V3.09 and earlier this is based on RSSI figures. After v3.12 this changes to being based on receiver dBm	255/110[8]	50/0[8]	255/0[8]	No
R1	**HYSTERESIS_RSSI** Amount of change before power levels altered. V3.09 and earlier this is based on RSSI figures. After v3.12 this changes to being based on receiver dBm	50/15[8]	20/2[8]	50/5[8]	No

Table 3-3: x series parameters

Notes:

[1] The listed values are the full range of options available on unrestricted modems. The range of settings available may be altered on compliant systems to maintain compliance to the appropriate standards

[2] ECC - Software Detection and correction, extra packet information, twice the packet length, is sent to allow the recovery of corrupted packets. Disabled in version 3.15 and up. Error detection is handled by CRC since at least version 3.01

[3] Injects RSSI packet when MAVLink protocol used and heartbeat packet detected.

[4] 868 modems

[5] Experimental feature settings not currently available

[6] This setting controls modem functionality linked with 485 interface and DINIO products it is not intended for use outside of this application.

[7] Version 3.09 the SBUS function is mapped to GPIO1.3

[8] Version 3.15 and up

AT commands examples

Encryption

The 128-bit AES data encryption may be set, enabled and disabled using the AT commands (see Table 3.1). The encryption key can be any 32-character hexadecimal string.

To encrypt a device, the encryption mode must first be enabled by typing ‘ATS15=1’ in the command terminal. Once the encryption mode is active, an encryption key may be set after typing ‘AT&E’ into

the command terminal. The encryption key may be of any 32-character hexadecimal string of the users choosing. Any devices with different encryption settings will not communicate.

After entering command mode, send the following commands to set encryption on using an arbitrary 32 hexadecimal character key. For example:

```
ATS15=1
AT&E=5AEEF103125C0AA233678909160111CA
AT&W
ATZ
```

Airdata rate

An air speed of 64kps will give a maximum range of about 40km in open space depending on antenna configurations, terrain and weather. Reducing the air speed can help to increase the range and link quality limits the data throughput.

Considerations for the air speed setting:

- The desired range
- The amount of data across the link
- Whether you send data in one direction or both
- Whether you have enabled ECC or not
- Whether you have adaptive flow control

It is important to note that the air rate should be set to a higher value then the baud rate to prevent bottlenecking and data loss.

Example of changing air data rate:

```
ATS2=224
AT&W
ATZ
```

PPM

To enable PPM control signal passthrough on a modem link it is necessary to set the ground station modem to PPM input and the receiver modem to PPM output. This is enabled using the S registers 16 or 17. The PPM stream can then be injected/retrieved from GPIO1 (aka P1.1 or pin 15) the right most pin on the bottom row of the header.

On the input side, you must issue:

```
ATPI=1
ATS16=1
AT&W
ATZ
```

And on the output side:

```
ATPO=1
ATS17=1
AT&W
ATZ
```

To record a failsafe PPM stream first connect the PPM generator to the ground station modem. Then power up the receiving modem. Connect the ground station modem using the FTDI cable. After the modems have established a link set the desired PPM failsafe stream using the generator and connect to the ground station modem. Then send the following command to set the failsafe on the receiver modem.

```
RT&R
RT&W
RTZ
```

This could alternatively be done by powering up the ground station and sending the PPM while connected to the receive modem via the FTDI cable in which case the command would be.

```
AT&R
AT&W
ATZ
```

Please note that it is the modem that receiver modem that must record the failsafe mode.

5 Region Certified Modems

A modem restricted to regional certified settings will be set at the factory. The country setting cannot be modified or removed after the modem release. By the same token an unlocked modem cannot be set with country compliance after the modem release. Modems with country settings cannot be regressed to firmware versions prior to the SiK version they released with or other firmware types like asynchronous firmware. Unlocked modems can be loaded with other firmware version. Any 900x modems sold before the release of certified modems can be updated with the v3 and later firmware and will operate as an unlocked modem.

5.1 Frequency band example

FCC-compliant radios, designated as RFD900x-US, are allowed to operate in two different frequency bands. The user might operate two pairs of radio simultaneously without them interfering with each other – given a minimal physical distance between the radios are respected – while remaining FCC-compliant by setting each pair to a different frequency band. This can be achieved by setting the S23 parameter according to the table below.

S23 value	Description	Minimum frequency	Maximum Frequency	Number of channels
0	Lower frequency band	902.125 MHz	914.875 MHz	51
1	Upper frequency band	915.125 MHz	927.875 MHz	51

Given the spectral proximity between the upper and lower bands, enough physical separation is required to operate radios communicating in separate bands without interference. Users must ensure the power output setting and antenna configuration are suitable for their application prior to deployment.

Airspeed on FCC-compliant radios are limited to 12, 64, 125 and 224kbps as to meet FCC requirements. The airspeed is set using the S1 parameter.

6 Certifications

Compliance
AS/NZS 4268:2012
FCC 47CFR 15.247
FCC 47CFR Part 1.1307
FCC 47CFR 1.1310
IC RSS247
EN 300200
EN62311
EN301489

7 Frequently asked questions (FAQ)

7.1 How many antennas do I need to use?

One is the minimum. Two is recommended.

7.2 How do I connect the FTDI cable to the modem?

The black cable of the FTDI (pin 1) should connect to pin 1 on the modem as shown in Figure 6-2.

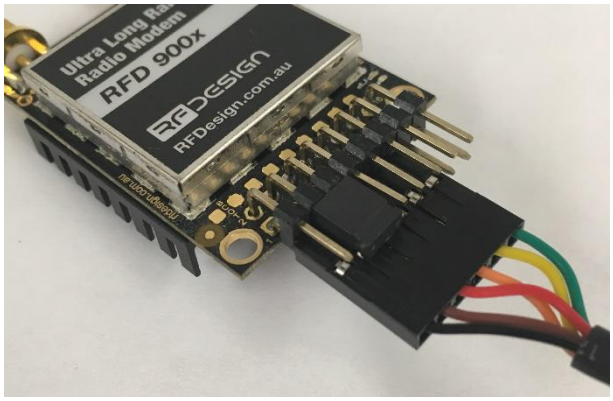

Figure 6- 2: An FTDI cable connected to the RFD900x modem

7.3 What do I need to upload the firmware or to change the modem configuration?

Download the latest firmware (see “Useful Links”). Download the RFD900 Tools (see “Useful Links”). Connect the FTDI cable to the modem and to a computer. Use the RFD900 Tools to upload the latest firmware or to change the modem configuration (see “RFD900 Tools User Manual”).

8 Useful links

x series Firmware

http://rfdesign.com.au/firmware/

RFD900 Tools

http://rfdesign.com.au/downloads/

http://files.rfdesign.com.au/Files/documents/RFD%20Modem%20Tools%20Manual%20V1.1.pdf

FTDI Cable documentation

http://www.ftdichip.com/Support/Documents/DataSheets/Cables/DS_TTL-232R_CABLES.pdf

9 Document revision history

Version	Date	Changes
1.0	19/03/19	Release document
1.1	24/09/19	
1.2	16/03/20	Added section 3.4
1.3	03/04/20	Updated for changes in v3.15 firmware