Operations Manual for RF Series Data Loggers

MadgeTech, Inc.
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INTRODUCTION

MadgeTech's RF series line of wireless-enabled data loggers provides a simple, low-cost wireless solution for short-range data collection applications. These products are powered by a user-replaceable internal battery and can be configured for up to ten years of battery life. They are designed for one-way, low data-rate applications, and transmit real-time data directly to a PC for monitoring. Like MadgeTech's standard series of data loggers, they are simple to use and their versatile configuration options allow for easy integration into a wide variety of applications. The product line includes models for all the most popular commercial and industrial measurements, as shown in this table:

PRODUCT	DESCRIPTION
RFTemp101A	Temperature Recorder and Wireless Transmitter
RFRHTemp101A	Humidity / Temperature Recorder and Wireless Transmitter
RFTC4000A	Thermocouple Temperature Recorder and Wireless Transmitter
RFRTDTemp101A	RTD Temperature Recorder and Wireless Transmitter
RFpHTemp101A	pH / Temperature Recorder and Wireless Transmitter
RFVolt101A	DC Voltage Recorder and Wireless Transmitter
RFProcess101A	DC Current Recorder and Wireless Transmitter
RFPulse101A	Pulse Recorder and Wireless Transmitter

These products have onboard memory in addition to the wireless transmitter, so they can completely replace existing data loggers and strip chart recorders while providing an added wireless data link. This memory can also serve as a failsafe backup, in the event of interference in the wireless channel or interruption of service to the monitoring computer.

TRANSMITTER CHARACTERISTICS

The transmitter used in the RF series products is a carrier present-carrier absent (CPCA) amplitude-modulated (AM) signal operating at a carrier frequency of 418 MHz. The data being transmitted is encoded similarly to standard RS232 serial data at a bit rate of 4,800 baud. This signal is detected by the RFC101A receiver module and converted to RS232 signals, which are passed to the COM port of the monitoring PC.

The transmitter type and encoding method permit the device to use the maximum allowable output power specified by the FCC, and also minimizes the amount of battery power required for the transmission. This gives the user the best possible range, and also ensures a long battery life.

To conform to FCC Part 15.231 rules, the data transmission takes less than one second and the minimum periodic transmission rate allowed by the device is 30 seconds. The low duty cycle permits several devices to use the same communication band and receiver without excessive interference caused by "talking over" each other.

TRANSMISSION DISTANCE

The transmission distance achievable with any wireless system is dependent on many factors. The only consistent measurement of transmission distance that can be used with these devices is called the "line-of-sight" transmission distance. The transmitter and receiver are set up in a large open area, free of obstacles and interference, and are aligned so their antennas are oriented in the same direction. Under these circumstances, the RF series products can achieve up to 120 feet (36 m) transmission range.

SYSTEM COMPONENTS AND SETUP

The following components are required to successfully set up and use the RF series products:

- A personal computer running the Windows operating system (Windows 95 or higher)
- One of the RF series wireless-enabled data loggers
- An RFC101A wireless receiver module and power supply, for receiving wireless transmissions from the data logger
- An IFC110 interface cable, for communicating with the wireless data logger
- MadgeTech Data Recorder software, included with the RFC101A or IFC110

To configure the data logger, and register it on the PC for data reception, connect it to the PC through the IFC110 serial interface cable as shown in Figure 1 below.

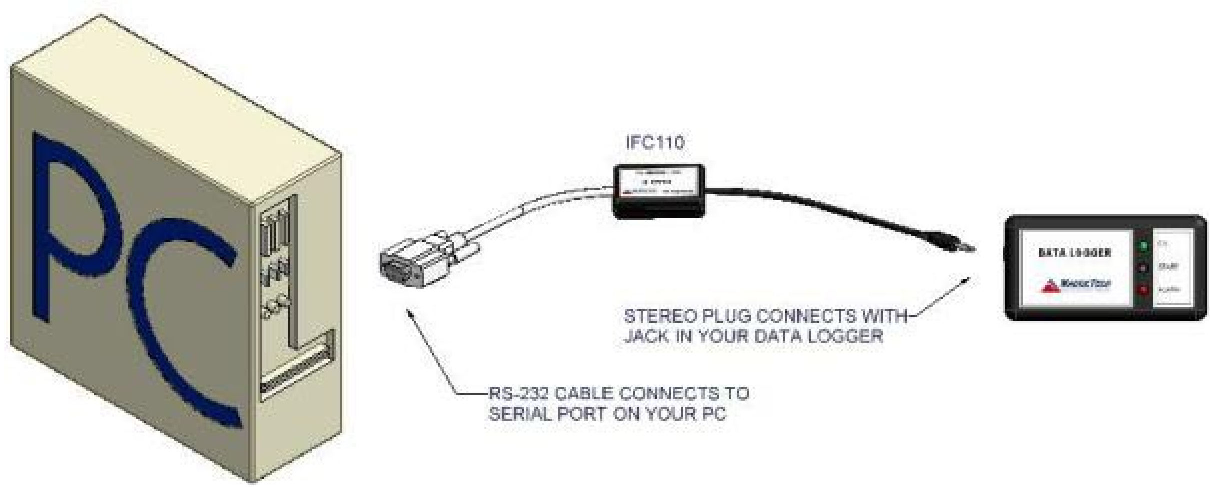

Figure 1. Connecting the IFC110 interface cable

To set up the system for receiving wireless data, connect the RFC101A to the PC and plug in the power supply to a 110VAC outlet (as shown in Figure 2). In most cases, the IFC110 will need to be removed from the PC to connect the RFC101A. If there are multiple COM ports available on the PC, the RFC101A may be connected to a different COM port than the IFC110, thus leaving IFC110 connected. To switch between using the IFC110 and RFC101A, simply change to the appropriate COM port under the "Communications" menu.

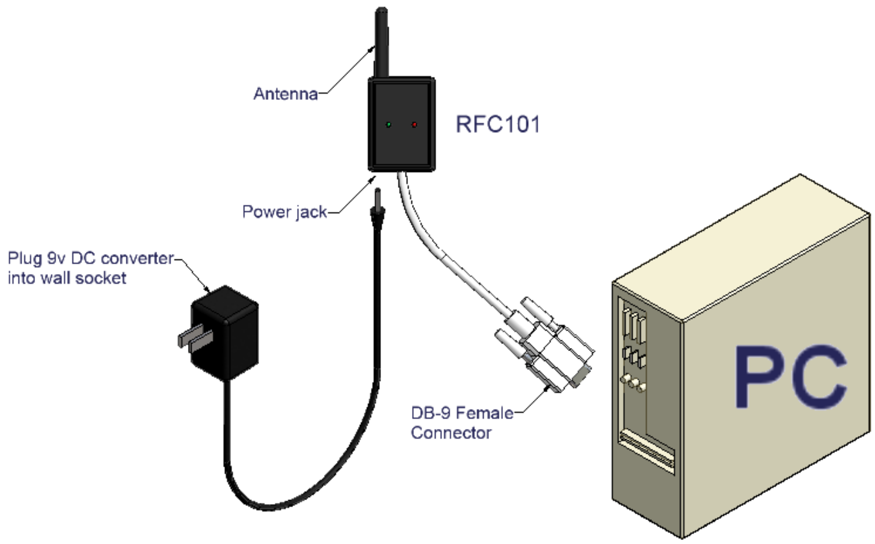

Figure 2. Connecting the RFC101A wireless receiver

WIRELESS CONFIGURATION DIALOG

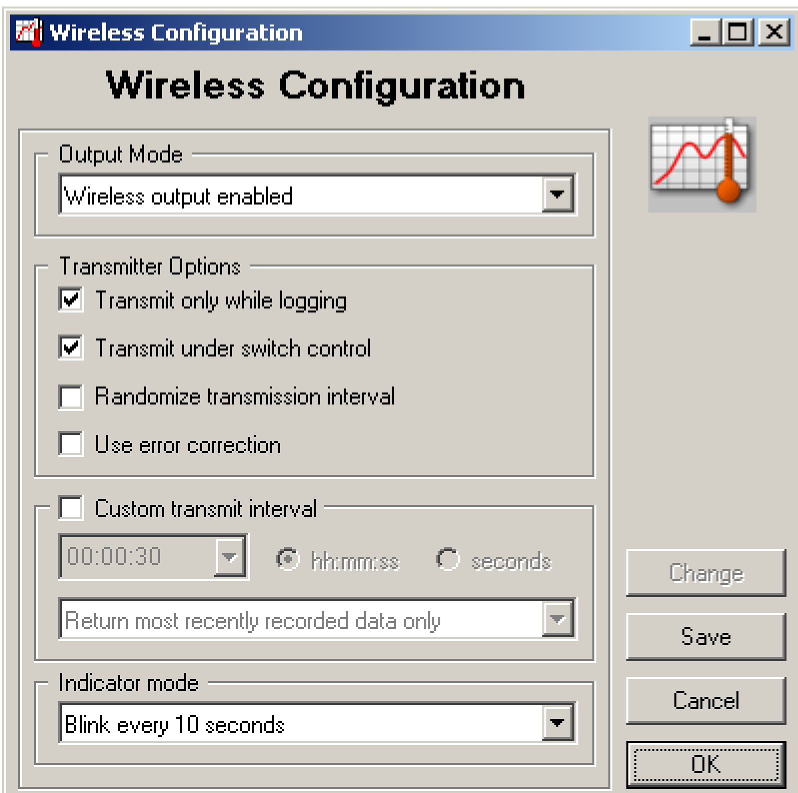

Figure 3. The Wireless Configuration dialog

The Wireless Configuration dialog (shown in Figure 3) allows the user to select from a variety of operating modes to meet the requirements of different monitoring systems. To access this dialog, identify the device using the Device -> Identify Device and Read Status menu item, switch to the "Device Detail" tab, and click the "Wireless Configuration" button. To edit the configuration, press the "Change" button in the dialog, make the appropriate changes, then press the "Save" button to commit the changes to the device. Note: Closing the dialog or exiting with the "OK" button will not store the changes in the device.

To comply with FCC regulations, saving a configuration change may cause the device to inhibit output from the transmitter while the internal timers synchronize to the new configuration (this may be the longer of the reading interval or custom transmit interval). To force synchronization of the timers and enable output before the aforementioned interval has passed, restart the device from the software.

Transmitter Output Modes

Real-time data transmissions may be sent through the RF antenna, the device's serial port, both or neither. If both the serial and RF transmitters are disabled, the device will function strictly as a standard data logger. The typical user will configure the device for wireless transmission only thus transmitting data from the device to the RFC101A receiver. However, serial transmission may be desirable for some systems where the built-in transmitter is not powerful enough to maintain a reliable link, the signal must be brought outside of an environment that blocks RF, or when a hardwired connection to an alternate transmitter is required. Additionally, both modes may be enabled for combined local and long-distance monitoring of the signal. See "Increasing Range with the RFExtender" later in this manual.

Transmitter Options

The transmitter module has four configuration options. Two of these options pertain to enabling and disabling the transmitter under different operating conditions and two pertain to the timing and format of the transmitted signal. These options are summarized below.

1. **Transmit only while logging** – If this option is selected, the transmitter will only output data when the logger is recording data to memory. When memory is filled and the device stops logging, the transmitter will stop as well to indicate the logger needs to be offloaded and restarted. If the memory wrap-around mode of the logger is enabled, the device will continue to overwrite the oldest internal data and continue transmitting data wirelessly. If this transmitter option is not selected, the transmitter will continue to operate regardless of whether the device is recording data.

2. **Transmit under switch control** – If this option is selected, the on/off switch may be used to inhibit the transmitter output. This allows the user to manually stop the transmitter without affecting the logger operation or transmission timing. This may be useful for transporting the device through an area where other devices are operating on the same frequency band, disabling the transmitter until the device is placed in-system, or disabling individual devices to evaluate system performance and troubleshoot interference or collisions. In systems where a manual override is not desirable, this option may be left unchecked, and the transmitter will not be affected by the position of the switch.

   Note: The above two transmitter options function as such: if either one of the modes would disable the transmitter under given conditions, the transmitter will be disabled. For the transmitter to be enabled, the required conditions must be met for both options to allow the transmission.

3. **Randomize transmit interval** – If this option is selected, the transmitter will wait a short random delay of up to 5 seconds before it transmits each data packet. This can decrease the chances of lost packets due to devices "talking over" each other because of long-term timer drift. Devices that are initially synchronized to transmit 10 seconds apart can drift in their timekeeping by up to 2 seconds per day, meaning that they could potentially interfere with each other after a few days of sustained operation. Because the transmission lasts less than a second, a random delay of up to 5 seconds can allow the majority of the transmissions to escape interference. If this transmitter option is not selected, the device will transmit at the interval set by its timer to within a few milliseconds. It is then up to the user to make any necessary accommodations for the timer drift. See "Using Multiple Devices" later in this manual.

4. **Use error correction** – If this option is selected, the transmitter output format will be modified to include a simple forward error correction scheme known as a Hamming code. This method of error correction allows the receiver in a one-way transmission to correct any single bit error in each block of eight data bits being received. This option may help to increase system reliability in some environments.

   Note: System reliability will most commonly be degraded by loss of signal or by burst noise longer than a single bit, thus this option may not substantially improve performance for the typical user. Additionally, if this option is not selected, the device may be able to transmit two complete copies of the data packet, increasing the likelihood that one of the copies will be received even when the other is lost due to interference. (Each packet always contains error detection, to ensure that invalid data is not displayed.)

Custom Transmit Interval

By default, the transmitter module will transmit a data packet with each internally recorded data point, or if it is not recording, at the reading rate specified for the data logger. This option allows the user to specify a custom transmit interval that will be used only by the transmitter. Like the data logger reading rate, this interval is limited to a minimum of 30 seconds and a maximum of 12 hours, but unlike the reading rate it may be set to any multiple of 10 seconds. Additionally, the device can be configured to return new data every interval, or to repeatedly send the data from the most recent internally recorded reading. This option can be useful for the following reasons:

1. **Real-time monitoring** – Some applications may require relatively quick feedback of trend data to the user, but only need to be recorded at longer intervals. With this option, for example, an operator could check the trend of a system every 10 minutes and make necessary adjustments to keep the system within specifications, but the official logger record of the data only needs to indicate the value on an hourly basis.

2. **Increasing system reliability** – In applications where the operating environment is unfriendly to RF, this option can be used to repeat the same data multiple times to increase the probability of successful reception. If the logger is recording every 5 minutes, the transmitter can be configured to send the data from the last reading every 30 seconds, allowing for 10 transmissions per logger reading. If the environment sees a burst of RF interference a few times per minute, it is highly probable that one or more transmissions will be received properly.

3. **Staggering transmissions from multiple devices** – If several devices need to record data at the same time while transmitting the output in real time, this option can be used to ensure that at least one transmission from each device is sent without interference from the other devices. This is similar to the randomization option provided above, but is better suited to some applications. See "Using Multiple Devices" later in this manual.

Indicator Mode

The device may be configured to blink the LED activity indicator every 10 seconds (the factory default setting) or only when a scheduled reading is taken. The green LED indicator will blink to indicate that the device is configured properly to allow a wireless transmission to occur. If the wireless transmitter is disabled by any of the available configuration options (by setting the transmitter output mode to disable the wireless output, or by selecting either of the related transmitter control options), the indicator will not blink. When a wireless transmission is about to be sent, both the green and the red LED indicators will blink.

The primary reason to turn off the 10-second indicator is to conserve battery capacity. See "Battery Life" later in this manual. The 10-second mode is forced "on" if the custom transmit interval discussed above is enabled.

REGISTERING THE DEVICE ON A SYSTEM

Before the MadgeTech software will receive data from an RF-series transmitter, the device must be properly registered on the system. When the device is identified or configured, the PC software will store an image of the device for future reference. This image is stored on the PC's hard disk so it is retained even when the software or PC is shut down. The software then refers to the device image when receiving a transmission to "fill in" the information that is not transmitted in the data packet. This information includes the device ID, calibration data, and measurement variables such as a thermocouple type or engineering units. The data packet contains a checksum of critical settings to ensure invalid data is not displayed. For this reason, the device must be re-registered if it is calibrated or the measurement data is changed on another PC.

STARTING THE DEVICE AND SYNCHRONIZING THE TRANSMITTER

Like other MadgeTech data loggers, the RF series devices must be configured through a PC. The wireless transmitter is primarily set up through the "Wireless Configuration" dialog discussed previously, but synchronization of the transmitter to the desired starting time is accomplished through the "Start Device" dialog when launching the data logger. When launching, choose the start time, and set the logger parameters (device ID and reading rate) for the run. When the device is started, both the logger and transmitter time base will be set for the selected start time. They will remain inactive until the selected time, and then begin to operate as configured in the "Start Device" and "Wireless Configuration" dialogs. When the delay-start time arrives, the logger will take readings (if enabled) at the programmed reading rate, and wireless transmissions (if enabled) will be made at the reading rate or custom interval, depending on how the device is configured.

If a delayed start is specified, the device will remain completely inactive during the start delay period. The indicators will not blink, no readings will be taken and no transmissions will be sent. It will continue to communicate normally, and may be queried, stopped, or restarted. If the application only requires the wireless transmitter without data logging capability, the device may be stopped immediately (when the "Transmit only while logging" option is not selected) after launching without affecting the scheduled start of the wireless transmissions. This will marginally improve the battery life when data logging capability is not required.

If immediate start is specified, the device will begin logging immediately, but it will inhibit transmitter output for the first reading to comply with FCC regulations. To ensure the first transmission is sent, use the delayed start mode with a 1-2 minute delay (minimum allowed by software).

USING MULTIPLE DEVICES

When using more than one RF transmitter, should transmissions overlap, it is certain that one or both of the transmissions will be lost. There are several methods, described below in order of complexity (least to most), to circumvent this issue:

1. **Rely on the logged data** - The RF transmitters can be configured to log all data to non-volatile memory. If a data point is lost, it may be fully recovered by a later off-load.

2. **Provide a direct connection** - If it is possible to have a PC always connected to the RF series logger (while monitoring via RF elsewhere), then using the serial output transmitter mode or the real-time chart recording feature of the software will avoid RF interference.

3. **Randomize the transmission interval** – This option is selected from the wireless configuration menu. Selecting this option will cause the transmitter to wait a short random delay of up to 5 seconds before it transmits each data packet. Should two transmitters drift to within 5 seconds of each other, this feature will reduce the dropped points by about 80% until the transmitter clocks drift apart again. This will also decrease the chances of sequential lost packets.

4. **Staggering of scheduled transmissions –** By starting the RF transmitters at different times, the transmissions will not overlap until the time drift between the transmitter clocks causes transmission collisions. At room temperature, the typical clock will drift no more than 1-2 seconds per day. Higher or lower temperatures will cause more drift. For example: if you use delay start to start one transmitter at 11:00:00 and a second transmitter at 11:00:30 (at 1 minute sample rates), then typically they would run for about 30 days (at similar temperatures) before there was a possibility of a collision. However, temperature fluctuations that deviate up or down from room temperature will generally cause the clock to run slower. Thus, potential collisions depend the time between samples, relative clock accuracy and relative ambient temperatures.

5. **Prime number scheduled transmissions** – This method utilizes prime numbers to help prevent transmission collisions. See the next section for further detail on this method.

PREVENTING COLLISIONS WITH PRIME NUMBERS

As mentioned in the previous section, prime numbers can be helpful in preventing collisions, allowing the maximum amount of data to be received from every transmitter. This section will outline the steps to follow to select the best transmission intervals, and provide a worked example.

Using prime numbers is advantageous because the common multiples of two prime numbers are farther apart than the multiples of two nearby non-primes. (For example, the numbers 8 and 12 have a common multiple at 24, 48, 72, etc., while 7 and 11 have their first common multiple at 77.) So, if two transmitters were set up to transmit at 8 and 12 minutes respectively, a collision (and a lost transmission) would occur every 24 minutes, much more often than if they were set up to transmit at 7 and 11 minutes. When expanding to 3 or more transmitters, this property is even more pronounced.

The size of the prime number matters as well. For larger prime numbers, fewer collisions will occur in a given amount of time.

Finally, to minimize the impact of the collisions that do occur, the transmitter should be configured to transmit the same data at least twice for every reading. This can be accomplished using the "Return most recently recorded data only" option in the Wireless Configuration dialog. For two transmitter systems, this ensures that every reading will have at least one clear slot for transmission. If two transmitters collide during the first transmission attempt, they cannot possibly collide during the second (they are scheduled to select different sots for the second attempt). For three or more transmitters, it is possible to collide with one transmitter on the first attempt and another on the second attempt, but the number of these "sequential collisions" is very small.

The general procedure for selecting transmission intervals follows below. It assumes that all the transmitters will be recording data at the same rate.

1. **Determine the number of transmitters** – Determine the number of points that need to be monitored, and select the transmitters that will cover those points most efficiently.

2. **Determine the reading interval** – The reading interval selected for the devices should be the longest interval that will provide the data needed for the application.

3. **Select the prime numbers** – The transmission intervals must always be a multiple of 10 seconds. So, divide the reading interval (in seconds) by 20, and pick the largest prime numbers that are less than this value. This ensures that there will always be at least two transmission slots per reading for each transmitter. Prime numbers in the necessary range are listed in Table 1.

4. **Assign the transmission intervals** – Multiply the prime numbers selected in step 3 by 10, and assign them to the transmitters. If some transmitters are monitoring more critical data than others, they may be assigned the smaller or larger numbers depending on the application. If the smallest numbers are substantially less than half the reading interval (e.g. 130 seconds for a 10 minute reading interval), assign them to the more critical transmitters to increase the number of transmissions per reading. If the smaller numbers are close to half the reading interval, assign the

larger numbers to the critical transmitters, as the larger numbers will experience slightly fewer collisions.

5. **Configure and launch the devices** – In the Wireless Configuration dialog, enable the custom transmit interval, and select the "Return most recently recorded data only" option for each device. Enter the proper transmission interval in seconds (be careful not to enter the number incorrectly as hours/minutes/seconds), and save the configuration before exiting the dialog. When launching the devices, use delayed start mode to begin the transmission schedules at the same time, and select the reading interval determined in step 2.

Table 1. Prime numbers from 3 to 2160

--	3	5	7	11	13	17	19	23	29
31	37	41	43	47	53	59	61	67	71
73	79	83	89	97	101	103	107	109	113
127	131	137	139	149	151	157	163	167	173
179	181	191	193	197	199	211	223	227	229
233	239	241	251	257	263	269	271	277	281
283	293	307	311	313	317	331	337	347	349
353	359	367	373	379	383	389	397	401	409
419	421	431	433	439	443	449	457	461	463
467	479	487	491	499	503	509	521	523	541
547	557	563	569	571	577	587	593	599	601
607	613	617	619	631	641	643	647	653	659
661	673	677	683	691	701	709	719	727	733
739	743	751	757	761	769	773	787	797	809
811	821	823	827	829	839	853	857	859	863
877	881	883	887	907	911	919	929	937	941
947	953	967	971	977	983	991	997	1009	1013
1019	1021	1031	1033	1039	1049	1051	1061	1063	1069
1087	1091	1093	1097	1103	1109	1117	1123	1129	1151
1153	1163	1171	1181	1187	1193	1201	1213	1217	1223
1229	1231	1237	1249	1259	1277	1279	1283	1289	1291
1297	1301	1303	1307	1319	1321	1327	1361	1367	1373
1381	1399	1409	1423	1427	1429	1433	1439	1447	1451
1453	1459	1471	1481	1483	1487	1489	1493	1499	1511
1523	1531	1543	1549	1553	1559	1567	1571	1579	1583
1597	1601	1607	1609	1613	1619	1621	1627	1637	1657
1663	1667	1669	1693	1697	1699	1709	1721	1723	1733
1741	1747	1753	1759	1777	1783	1787	1789	1801	1811
1823	1831	1847	1861	1867	1871	1873	1877	1879	1889
1901	1907	1913	1931	1933	1949	1951	1973	1979	1987
1993	1997	1999	2003	2011	2017	2027	2029	2039	2053
2063	2069	2081	2083	2087	2089	2099	2111	2113	2129
2131	2137	2141	2143	2153	--	--	--	--	--

Prime Number Examples

Two examples are provided in Table 2 below to illustrate the procedure. Notice that increasing the reading interval by a factor of 6 (1 hour instead of 10 minutes) results in an increase by a factor of 540 in the time before data is lost (45 days instead of 2 hours)!

Table 2. Prime number examples

	Example 1	**Example 2**
Number of Transmitters	5	5
Reading Interval	10 minutes (600 seconds)	1 hour (3600 seconds)
Max Transmission Interval	300 seconds (= 600/2)	1800 seconds (= 3600/2)
Max Prime Number	30 (= 300/10)	180 (= 1800/10)
Selected Prime Numbers	29, 23, 19, 17, 13	179, 173, 167, 163, 157
Transmission Intervals *** More critical devices**	290 seconds 230 seconds 190 seconds* 170 seconds* 130 seconds*	1790 seconds* 1730 seconds* 1670 seconds 1630 seconds 1570 seconds
First Lost Reading After	> 2 hours	> 45 days

INCREASING RANGE WITH THE RFEXTENDER

The RFExtender products can extend the transmission distance of MadgeTech's RF series products for up to 1 mile (1.6 km) under ideal conditions. Typical ranges are 1000 to 2000 feet (300 to 600 m) outdoors, and up to 300 feet (100 m) indoors. An RFExtender system requires a minimum of two RFExtender transceivers, one at each node of the wireless link. The RFExtender transceivers require AC power.

Simple RFExtender System

A basic set-up might be one of the two configurations below:

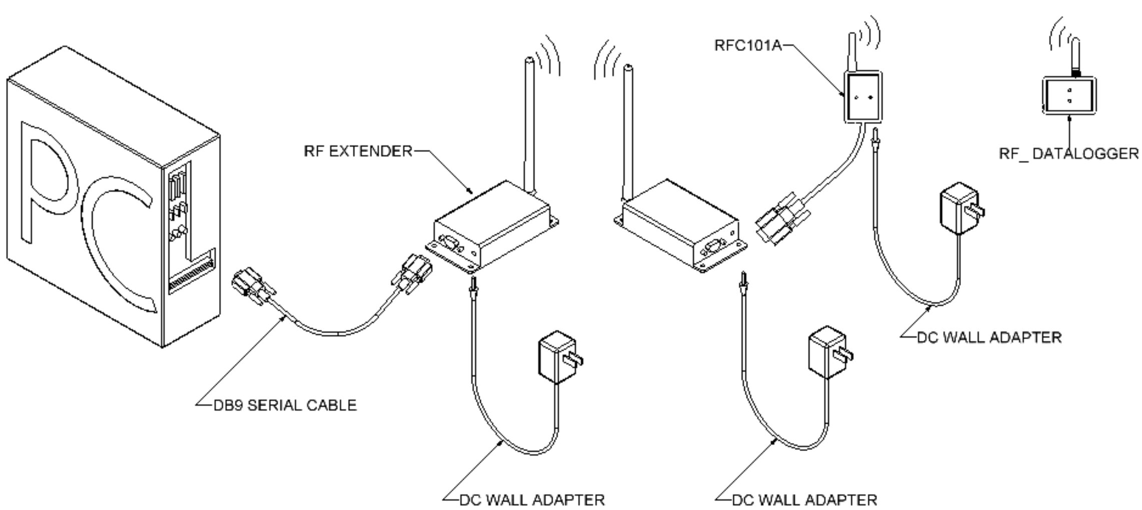

Figure 4. RFExtender as a wireless repeater

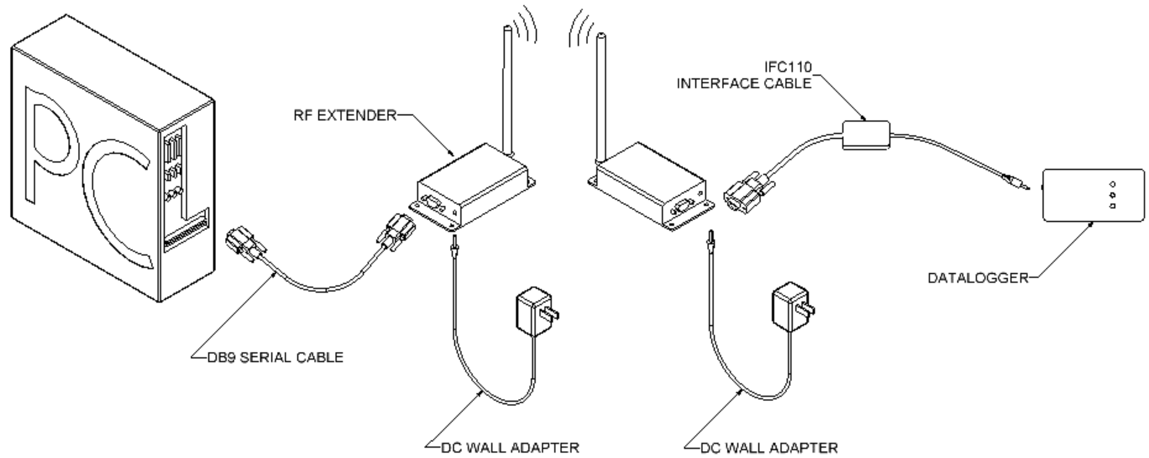

Figure 5. RFExtender as a wireless communication interface

In either configuration, the RFExtender functions like an extension cable between the logger interface and the PC. The primary difference between the two setups is the logger interface that is connected to the RFExtender. Figure 4 uses an RFC101A, and is therefore limited by the one-way communication between the RF data logger and the RFC101A. Just like using the RFC101A by itself, this setup requires that the logger be brought back to the PC and connected to an IFC110 interface cable to launch, download, or configure the logger. Figure 5 allows two-way communication through the IFC110 and thus can allow full use of the data logger features.

The setup in Figure 4 is necessary when several transmitters must send their data to the same RFExtender. The data is received by the RFC101A, and retransmitted or "repeated" to the PC. Figure 5 is appropriate when only one data logger needs to be used with a particular RFExtender. The data logger is configured to transmit data packets over the serial cable instead of through the wireless transmitter, and the RFExtender transmits the serial data back to the PC. This setup has two advantages: the logger can be launched, downloaded, and configured without bringing it back to the PC, and the IFC110 interface cable is less expensive than the RFC101A.

Complex RFExtender System

It is possible to use more than two RFExtenders in a system with more than two nodes. This type of setup will be an extension of the two simple setups demonstrated above. Refer to Figure 6 for an example of a complex system.

The setup in Figure 6 shows an RFExtender connected to a PC that can receive data from 8 other transceivers. Each of the remote transceivers can either communicate serially with one logger via an IFC110 or receive wireless data from multiple RF series transmitters through an RFC101A. For this system to function properly, each transceiver must be set up to receive data only from the proper location. This is accomplished by assigning each transceiver a unique module address to identify itself, and a receiver address mask to identify the module addresses from which it will receive data.

Module Address and Receiver Address Mask

The module address provides a unique identification of the individual transceivers. It consists of 4 hexadecimal digits, which can be divided between a "system number" and a node address within that system. Most applications will us a module address of the format XXYY, where XX is the system number and YY is the node address. A system is comprised of a PC connected to an RFExtender transceiver (the "Local Node") and several other transceivers ("Remote Nodes") set up within the transmission range. Using the system number is not strictly necessary, but it allows several groups of transceivers to be located within transmission distance of each other without allowing data from one group to be received by the other.

The receiver address mask is also 4 digits and will usually be configured in one of two ways: to receive data from all the modules within a system, or to receive data only from another module with the same module address. Only the local node at the PC will be configured to receive from multiple modules, as only the PC is capable of receiving and processing the data being transmitted by all the modules. The remote nodes will be assigned individual addresses, and configured only to accept transmissions from a module with the same address as their own. To allow two-way communication with a remote node, the local node module address and receiver address mask will be changed temporarily to match that of the remote node.

Assigning module addresses should begin with the determination of the system number. The system numbers used may be sequential, starting with one, as the zero address has special significance. The local node should be assigned node address zero, and the remote nodes may be sequential starting with one. Note that this is how the module addresses in Figure 6 were generated.

The receiver address mask instructs the transceiver which data to receive by indicating what part of the incoming module address should be compared to its own module address. The remote nodes should be assigned receiver address masks of "FFFF". In general terms, a hexadecimal digit "F" in the receiver address mask means "compare this digit". So a receiver address mask of "FFFF" means "compare all the digits", and if all the digits do not match, ignore the incoming data. In technical terms, the comparison is performed as a logical "AND" operation, which is a common function in computers and digital circuits.

The local node in Figure 6 is assigned an address mask of "FF00". This can be interpreted as "compare the system number, but not the node number". (Technically, the "AND" function will always result in a node address of "00".) This way, the PC will receive data from all the transceivers in its system.

Receiver Address Mask Example

The local node in Figure 6 has a module address of "0100" and a receiver address mask of "FF00". Suppose that it receives data from module address "0104". The incoming address is processed through the mask as "0104" AND "FF00" = "0100". The result matches the local node address of "0100", so the transceiver passes the data through.

Likewise, suppose that module address "0104" receives data from module address "0108". The incoming address is processed through the mask as "0108" AND "FFFF" = "0108". The result does not match the receiver's module address of "0104", so the receiver ignores the data.

For further information on uses of the module address and receiver address mask, contact MadgeTech Technical Support.

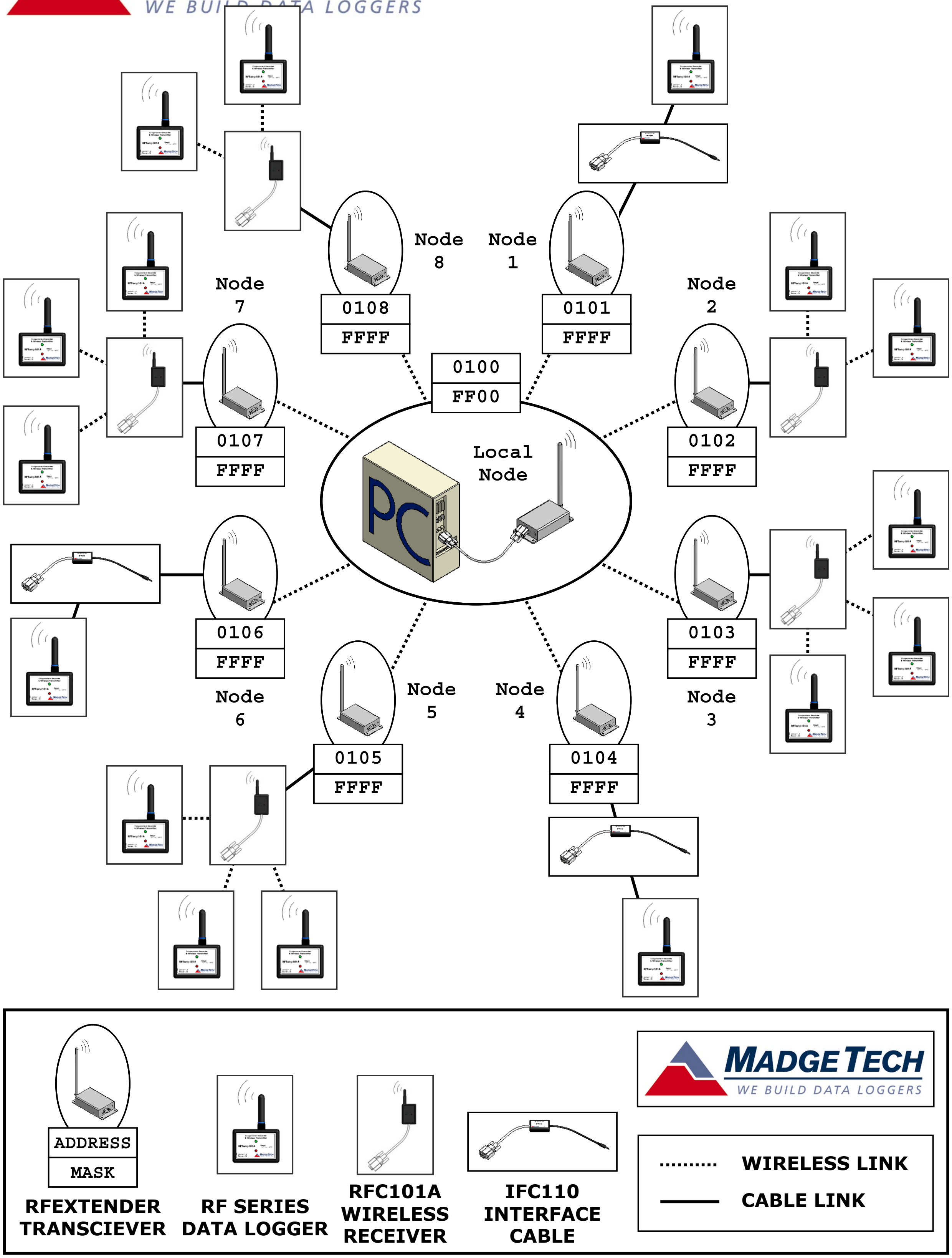

Figure 6. A complex RFExtender system

BATTERY LIFE

There are many variables that affect the battery lifetime. These variables include (but are not limited to) sample rate, transmit rate, LED settings, transmission settings, ambient temperature and battery self-discharge.

For the purposes of approximating battery life, please consult Tables 3 and 4 below. These numbers should not be used as an absolute guarantee, but as an approximate guide for deciding when the battery will need replacement. This table is useful because the lithium batteries used in the RF products do not show a strong correlation between voltage and remaining capacity, which makes it very difficult to measure their remaining life. In lithium batteries, the voltage stays very nearly constant for the entire life of the battery until it drops sharply and suddenly when depleted.

There are variables that it is not possible to account for in the tables. The table assumes a pattern of continuous use, in which both the logger and transmitter features are used such that both the transmitter and logger are active at approximately the indicated "activity rate" (for cases where the logger and transmitter operate at different rates, use the faster rate for estimation). The calculations assume that the device is configured and deployed, then downloaded and redeployed when the logger is nearly full.

Table 3. Estimated battery life

ACTIVITY RATE	WORST CASE	FACTORY DEFAULT	BEST CASE
30 seconds	3 months	6 months	6 months
1 minute	6 months	12 months	12 months
2 minutes	12 months	20 months	24 months
3 minutes	15 months	27 months	3 years
4 minutes	21 months	33 months	3.5 years
5 minutes	24 months	3 years	4 years
6 minutes	27 months	3.5 years	5 years
8 minutes	33 months	4 years	6 years
10 minutes	3 years	4.5 years	7 years
15 minutes	4 years	5 years	8.5 years
30 minutes	5 years	6 years	10+ years
1 hour	6 years	6.5 years	10+ years
2 hours	6.5 years	7 years	10+ years
4 hours	7 years	7+ years	10+ years

The transmitter settings used to calculate the best, worst and factory default cases are indicated in Table 4.

Table 4. Transmitter settings for battery life estimation

	WORST CASE	FACTORY DEFAULT	BEST CASE
Wireless Output	Enabled	Enabled	Enabled
Serial Output	Not Significant	Not Significant	Not Significant
Logging Option	Not Significant	Not Significant	Not Significant
Switch Option	Not Significant	Not Significant	Not Significant
Randomization	Enabled	Disabled	Disabled
Error Correction	Enabled	Disabled	Enabled

Custom Interval	Enabled	Disabled	Disabled
Sampling Option	Not Significant	Not Applicable	Not Applicable
Indicator Mode	10 seconds	10 seconds	Reading only

Even longer battery life can be achieved by disabling the wireless output in favor of serial-only or no transmission. Battery life is not calculated for these unusual cases.

OPERATING ENVIRONMENT

The RF series data loggers are rated for –30 to +70 °C and up to 95 %RH (non-condensing). Although the devices are fully functional over this range, the strength of the wireless output signal may vary with changes in environment. In particular, the signal strength may be reduced at the temperature extremes, in high humidity, or if humidity condenses inside the device.

SYSTEM PERFORMANCE AND RELIABILITY

To achieve maximum distance for the wireless transmission, there are a number of guidelines that should be followed. Consider these points when setting up the system:

Transmitter location – Keep the transmitter as close to the receiver as possible. If either the transmitter or receiver must be in an enclosed area, keep the other inside the same area. This is especially important if there would be metal walls, conduit, or wires between the units. In particular, attempting to transmit from inside of a freezer or refrigerator is not likely to be successful.

Line of sight – Try to keep the transmitting and receiving antennas along a direct line of sight from one to the other. Keep the number of corners or obstacles in between them to a minimum.

Nearby objects – Try to keep the transmitting and receiving antennas away from any foreign objects, especially those made of metal. Performance may be improved by moving the antenna away from the ground, ceiling, or nearby objects.

Antenna orientation – Keeping the transmitting and receiving antennae parallel with one another may improve performance.

Minimize interference – Keep external sources of radio frequency noise to a minimum. Locate the antenna and receiver as far from any other electrical or wireless devices as possible. If multiple transmitters are being used, set up the system to minimize interference between transmitters.

FCC COMPLIANCE AND REQUIREMENTS

MadgeTech's RF series products operate in an "unlicensed" operation band, meaning the end-user does not need to do anything special (such as obtain a license) to legally make use of the product. MadgeTech has performed all the required testing and certification to ensure that these products meet the requirements for unlicensed operation outlined in 47 CFR Part 15.231 of the FCC rules. However, the user must understand and adhere to the following notes and guidelines:

Any user changes or modifications that are not expressly approved by MadgeTech, Inc. may void the user's authority to operate the device per FCC code, section 15.231.

FEDERAL COMMUNICATIONS COMMISSION (FCC) NOTICE

The following FCC IDs are associated with the devices covered by this manual:

PRODUCT	FCC ID	TRADE NAME
RFTemp101A	**RUYBOARDRF**	**MadgeTech, Inc.**
RFRHTemp101A	**RUYBOARDRF**	**MadgeTech, Inc.**
RFTC4000A	**RUYBOARDRF**	**MadgeTech, Inc.**
RFRTDTemp101A	**RUYBOARDRF**	**MadgeTech, Inc.**
RFpHTemp101A	**RUYRFPHTEMP**	**MadgeTech, Inc.**
RFVolt101A	**RUYBOARDRF**	**MadgeTech, Inc.**
RFProcess101A	**RUYBOARDRF**	**MadgeTech, Inc.**
RFPulse101A	**RUYBOARDRF**	**MadgeTech, Inc.**

The following statement applies to all of the devices covered in this manual:

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.

NOTE: This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one of more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

INDUSTRY CANADA (IC) NOTICE

The following IC identification numbers are associated with the devices covered by this manual. These certifications/registrant numbers are displayed on the labels of the products. Removal or defacement of these numbers will void the IC certification.

PRODUCT	IC #	TRADE NAME
RFTemp101A	**4953A-BOARDRF**	**MadgeTech, Inc.**
RFRHTemp101A	**4953A-BOARDRF**	**MadgeTech, Inc.**
RFTC4000A	**4953A-BOARDRF**	**MadgeTech, Inc.**
RFRTDTemp101A	**4953A-BOARDRF**	**MadgeTech, Inc.**
RFpHTemp101A	**4953A-RFPHTEMP**	**MadgeTech, Inc.**
RFVolt101A	**4953A-BOARDRF**	**MadgeTech, Inc.**
RFProcess101A	**4953A-BOARDRF**	**MadgeTech, Inc.**
RFPulse101A	**4953A-BOARDRF**	**MadgeTech, Inc.**

CONTACT INFORMATION

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