Application Note

#5412 **July 27, 2002**

Synchronizing Collocated Masters
(Multi-Master Sync Mode)

Note: This document contains outdated and offensive "master-slave" terminology. Within UNAVCO and in our in-house materials, we have replaced this with "Access point (AP) – Station/Endpoint (STA)", but in manufacturer documentation and configuration software, the original usage will still remain when implemented.

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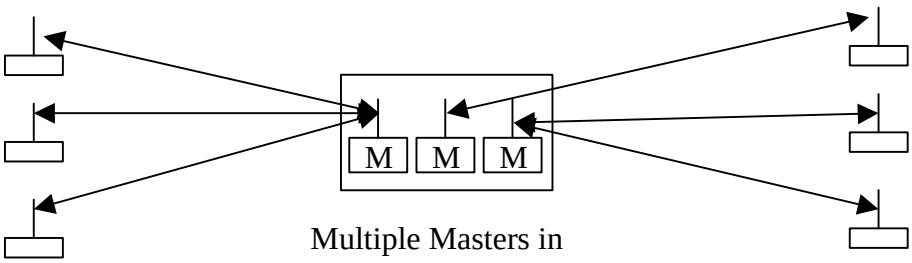
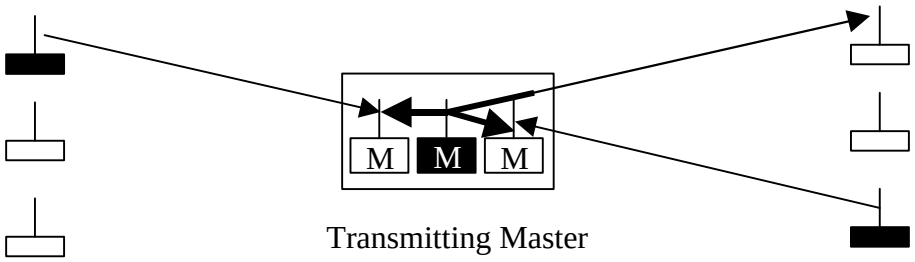
Introduction

Multiple networks of FreeWave modems may be deployed in the same geographical area. In particular, multiple networks may have all of their masters collocated, in which case, their antennas are mounted in close proximity (such as on the same mast).



Multiple Masters in
the same location

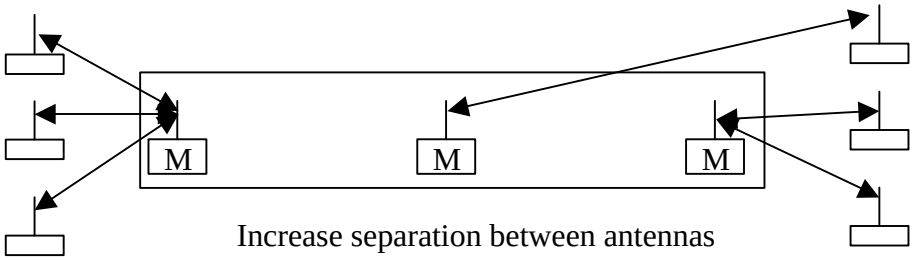
It's possible that a Master is trying to receive a faint signal, but it can't, because it is overwhelmed by a collocated Master that is transmitting at the same time. Even though each Master may be operating on a different channel (that is, a different frequency), the signal from the transmitting Master could be strong enough to saturate the input stage of the receiving Masters, and block-out the desired signal. In spread spectrum radios, the input stage must be open to the entire band, so sharp filtering (such as using a cavity tuned filter) cannot be used.



Transmitting Master
overpowers
Receiving Masters

There are two things that you must do to keep collocated Masters form interfering with each other.

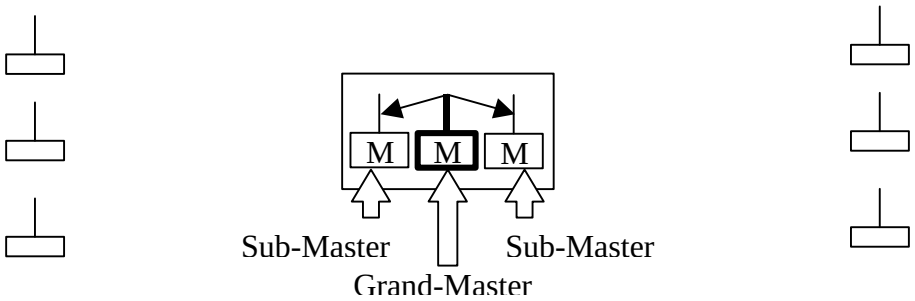
1) You must reduce the coupling between the various Masters, by mounting their antennas with some distance between each other.



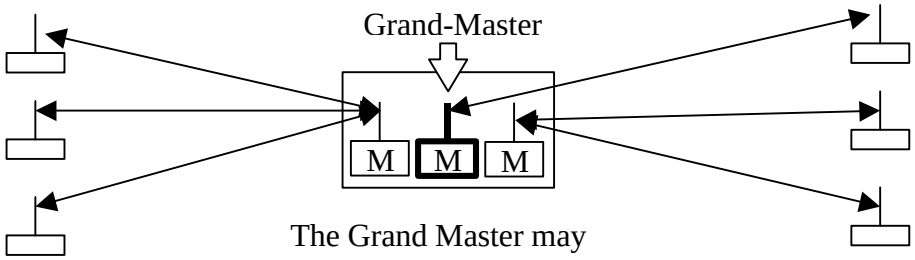
Increase separation between antennas

2) You must synchronize the Masters, with the Multi-Master Sync Mode. This ensures that none of the collocated Masters transmits while one of them is trying to receive.

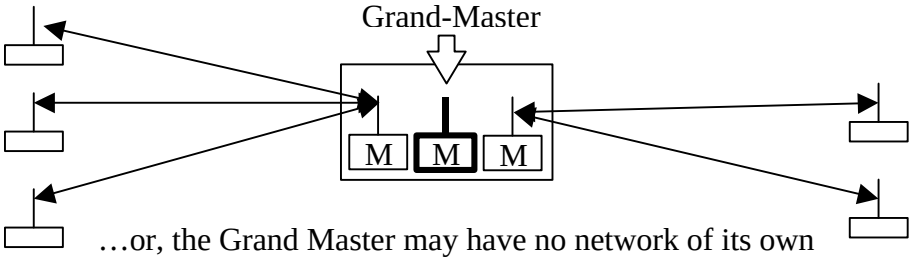
In the Multi-Master Sync Mode, one of the Masters (the Grand Master) operates normally, while the others (the Sub Masters) monitor the Grand Master's transmissions to know when its OK for them to transmit as well.



The Grand Master may or may not have its own network.



The Grand Master may
have its own network…



…or, the Grand Master may have no network of its own
(it may be used just to synchronize the Sub Masters)

The Grand Master's network and all the Sub Masters' networks are Synchronized Networks. (The Synchronized Networks form a Synchronized System.)

This Mode works with Point-to-point and with Multi-Point networks. It works with networks that use Call-Books and with those that use Network IDs. As a matter of fact, it works with any combination of these networks.

If you want a more detailed description, please see the "Principles of Operation" section.

Terminology used

Term	Its meaning
Dwell time	In this document, it is frequency channel occupancy time. For the FreeWave radios dwell time is always equal to slot duration.
Asynchronous system	Two or more systems that do not use a common clock/synch source. For example, two independent wireless communication networks will be asynchronous if each one of them uses its own master's transmissions for synchronization within the network.
Balanced Data Load	If all synchronized Masters typically transmit much more data than they receive back, the system's Data Load is balanced. Similarly, if all synchronized Masters transmit much less data than they receive back, the system's Data Load is balanced. Conversely, if some Masters transmit much more than they receive, and some transmit much less than they receive, the system's Data Load is Unbalanced.
BER	Stands for "Bit Error Rate". Commonly used abbreviation meaning the rate of erroneously received bits within the data stream. BER usually used to measure a quality of communication channel. The higher BER - the worst the channel.
Frequency Channel	It is a portion of a frequency band used by the radio modems. For example, FreeWave Technologies' 900 Mhz radio transceivers use 902-928 MHz frequency band, which consists 112 frequency channels separated from each other by 230 kHz.
Collision	It is an event which occurs when more than one radio transceiver sends its data packet on a given frequency channel at a given moment. As a result of collision, this data packet usually will not be received on the receiving end of the communication link. Collision is relatively rare even for frequency hopping radio transceivers, yet normal and inherent in asynchronous packet communications. FreeWave modems overcome it by requesting a retransmission.
Collocated Masters	For the purposes of this application note, this means Master modems whose antennas are installed near each other, such as on the same antenna mast.
Data Port Rate	The number of characters per second that the modems transfer to the equipment that generates or uses the data. Data Port Rate is measured in kbit/sec. This is NOT the rate at which modems communicate to each other over the air.
Hex, Hexadecimal number	A base-16 number: 0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F.
Transceiver's Hopping Pattern	It is a sequence of frequency channels used by a radio network. This sequence determined by Frequency Key, Hop Table Version and Hop Table Size settings on the radio. Please refer to the User Manual for more details.
Grand Master	A Master that is a source of synchronization to collocated Sub Masters.

Sub Master	Master modem that start transmitting at the same time as the Grand Master modem does.
Packet Size	The number of bytes in a data packet.
Slot	The time during which two modems exchange a packet.
Terminal	A computer or any other device, which allows receive, display and transmit RS232 characters.

Multi-Master Synch Mode Limitations

The Multi-Master Sync Mode works in a system with up to 15 independent networks (that is, for up to 15 collocated Masters). Of course, the Grand Master's network counts as one of these 15 networks.

The Call-Book has ten slots. With the Multi-Master Sync Mode, one of these slots in the Sub Master is taken by the Serial Number of the Grand Master, leaving only nine slots available. The other modems are not affected. Of course, Multi-Point Sub Masters using Network IDs instead of a Call Book, are not limited by this fact.

Because the Sub Masters require the Grand Master for synchronization, their networks won't work unless the Grand Master is up and running. (Actually, the Sub Masters' networks do keep on running for a while after they no longer receive a signal from the Grand Master.)

The Multi-Master Sync Mode is designed only to synchronize collocated Masters. Using this Mode to synchronize Masters that are not collocated may actually result in reduced performance.

For timing purposes,

- either there must be no Repeaters in any of the Synchronized Networks,
- or all the synchronized Point-to-point networks must have Repeaters, and the synchronized Multi-Point networks must be told they have Repeaters (whether or not they actually do)

The Synchronized Networks can include Slave / Master Switchable modems. However, you can't designate a Slave / Master Switchable modem as the Grand Master; that's because, when the Slave / Master Switchable modem isn't operating as a Master, the Sub Masters won't have a source of synchronization.

All Synchronized Networks must use the same Min and Max Packet Size, and the same RF Data Rate.

Point-to-Point set-up summary

Preview of the set-up

What we are going to do is:

- tell the Sub Masters the Serial Number of the Grand Master
- tell the Grand Master to transmit during every slot
- tell the Sub Masters to synchronize themselves to the Grand Master
- assign a different Hopping Pattern to each network
- match the packet size and RF data rate of all the Synchronized Networks

Summary of settings

The following table lists the parameters that need to be set in a particular way in a Point-to-point network that is part of a Synchronized System. No other setting needs to be set in a particular way for the Multi-Master Sync Mode.

Setting	Menu #, Sub-menu #	Grand Master	Sub Master	All others
Call-book	2	same as for normal set-up	append the Serial Number of the Grand Master (no Repeaters) to the normal list	same as for normal set-up
Freq Key	3,0	0	1-14*	-
Max Packet Size††	3,1	8††	-	-
Min Packet Size††	3,2	9††	-	-
Xmit Rate	3,3	0	1	-
RF Data Rate	3,4	x†	x†	-
Multi-Master Sync	5,8	0	1	-

NOTES:

-: Doesn't matter.

*: Assign a unique number to each Master; Note: 'A' = 10, 'B' = 11… 'E' = 14

8††: Default value. Regardless, the values in all the Synchronized Masters must be identical. See later description for appropriate values.

9††: Default value. Regardless, the values in all the Synchronized Masters must be identical. See later description for appropriate values.

x†: Doesn't matter (2 or 3) but all the Masters must have the same value.

Point-to-Point step-by-step instructions

The following step-by-step instructions assume that

- you have already set-up the networks per the Main Manual,
- a terminal is connected to the modem,
- the modem's set-up mode is invoked,
- the modem is in the Main Menu.

These step-by-step instructions are quite succinct; if you want more detail about what each menu does, see the Menu Description section later on.

Point-to-point Grand Master

- Press '3', '0', then '0' (to set the "Freq Key" to 0).
- Press '1', then the Maximum Packet size (typically '8').
- Press '2', then the Minimum Packet size (typically '9').
- Press '3', then '0' (for the Transmit Rate).
- Press '4', then '3' (this is the default RF Data Rate).
- Press 'Esc' to return to the Main Menu
- Press '5', '8'', then '0' (Multi-Master Sync should already be '0').
- Press 'Esc' to return to the Main Menu

Point-to-point Sub Master (including Slave/Master Switchable)

- Press '2', enter the Serial Number of the Grand Master right after the list of Slaves (there must be no "000-0000" entry above the Grand Master's Serial Number).
- Press 'Esc' to return to the Main Menu
- Press '3', '0', then the "Freq Key" (a unique number, 1 to 14).
- Press '1', then the Maximum Packet size (typically '8').
- Press '2', then the Minimum Packet size (typically '9').
- Press '3', then '1' (for the Xmit Rate) (it should already be '1').
- Press '4', then '3' (this is the default RF Data Rate).
- Press 'Esc' to return to the Main Menu
- Press '5', '8'', then '1' (for the Multi-Master Sync mode).
- Press 'Esc' to return to the Main Menu

All other Point-to-point modems

These are:

- Point-to-point Slave/Master switchable (remotely located).
- Point-to-point Slave.
- Point-to-point Repeater.
- Point-to-point Slave/Repeater.

These modems require no special settings to work with the Multi-Master Sync Mode.

Multi-Point set-up

Preview of the set-up

What we are going to do is:

- tell the Sub Masters the Serial Number of the Grand Master
- tell the Sub Masters to synchronize themselves to the Grand Master
- assign a different Hopping Pattern to each network
- match the packet size and RF data rate of all the Synchronized Networks
- specify if there are Repeaters

Summary of settings

The following table lists the parameters that need to be set in a particular way in a Multi-Point network that is part of a Synchronized System. No other setting needs to be set in a particular way for the Multi-Master Sync Mode.

Setting	Menu #, Sub-menu #	Grand Master	Sub Master	All others
Call-book	2	same as for normal set-up	append the Serial Number of the Grand Master (no Repeaters) to the normal list	same as for normal set-up
Freq Key	3,0	0	1-14*	z†
Max Packet Size	3,1	8†	8†	8†
Min Packet Size	3,2	9†	9†	9†
RF Data Rate	3,4	x†	x†	x†
Number of Repeaters	5,0	y†	y†	-
Multi-Master Sync	5,8	0	1	-

NOTES:

-: Doesn't matter

*: Assign a unique number to each Master; Note: 'A' = 10, 'B' = 11… 'E' = 14

8†: Default value. Regardless, the values in all the Synchronized Networks must be identical. See later description for appropriate values.

9†: Default value. Regardless, the values in all the Synchronized Networks must be identical. See later description for appropriate values.

x†: Doesn't matter (2 or 3) but all the modems must have the same value.

y†: Doesn't matter (0 or 1) but all the Masters must have the same value. Note: either a) there must be no Repeaters in any of the Synchronized Networks, or b) all the synchronized Point-to-point networks must have Repeaters, and the synchronized Multi-Point networks must be told they have Repeaters (whether or not they actually do)

z†: Same as the modem's Master

Multi-Point step-by-step instructions

The following step-by-step instructions assume that

- you have already set-up the networks per the Main Manual,
- a terminal is connected to the modem,
- the modem's set-up mode is invoked,
- the modem is in the Main Menu.

These step-by-step instructions are quite succinct; if you want more detail about what each menu does, see the Menu Description section later on.

Multi-Point Grand Master

- Press '3', '0', then '0' (to set the "Freq Key" to 0).
- Press '1', then the Maximum Packet size (typically '8').
- Press '2', then the Minimum Packet size (typically '9').
- Press '4', then '3' (this is the default RF Data Rate).
- Press 'Esc' to return to the Main Menu
- Press '5', '0', then the number of Repeaters (0 if none, 1 if any).
- Press '8', then '0' (Multi-Master Sync should already be '0').
- Press 'Esc' to return to the Main Menu

Multi-Point Sub Master

- Press '2', '0', enter the Serial Number of the Grand Master, press "Esc".
- Press 'Esc' to return to the Main Menu
- Press '3', '0', then the "Freq Key" (a unique number, 1 to 14).
- Press '1', then the Maximum Packet size (typically '8').
- Press '2', then the Minimum Packet size (typically '9').
- Press '4', then '3' (this is the default RF Data Rate).
- Press 'Esc' to return to the Main Menu
- Press '5', '0', then the number of Repeaters (0 if none, 1 if any).
- Press '8', then '1' (for the Multi-Master Sync mode).
- Press 'Esc' to return to the Main Menu

All other Multi-Point modems

These are:

- Multi-Point Slave.
- Multi-Point Repeater.

- Press '3', '0', then the "Freq Key" (same number as the Master).
- Press '1', then the Maximum Packet size (typically '8').
- Press '2', then enter the Minimum Packet size (same as the Master's).
- Press '4', then the same number as the Master.
- Press 'Esc' to return to the Main Menu

Details about menus

Invoking the Set-up mode

Connect a terminal to a modem that you need to program (see the Main Manual for more information on this). Invoke the set-up mode (in most cases, you do this by pressing the "Set-up" button; else, see the Main Manual for details on how to do this with your particular modem).

The terminal will show the Main Menu.

```
                                MAIN MENU
                          Version 5.77 10-26-2001
                            Standard Hop Table
                         Modem Serial Number 906-4439

(0)   Set Operation Mode
(1)   Set Baud Rate
(2)   Edit Call Book
(3)   Edit Radio Transmission Characteristics
(4)   Show Radio Statistics
(5)   Edit MultiPoint Parameters
(6)   TDMA Menu
(8)   Chg Password
(Esc) Exit Setup
```

Edit Call Book

This menu lets you edit the Serial Numbers of the modems with which this modem will communicate. Please see the Main Manual for more information.

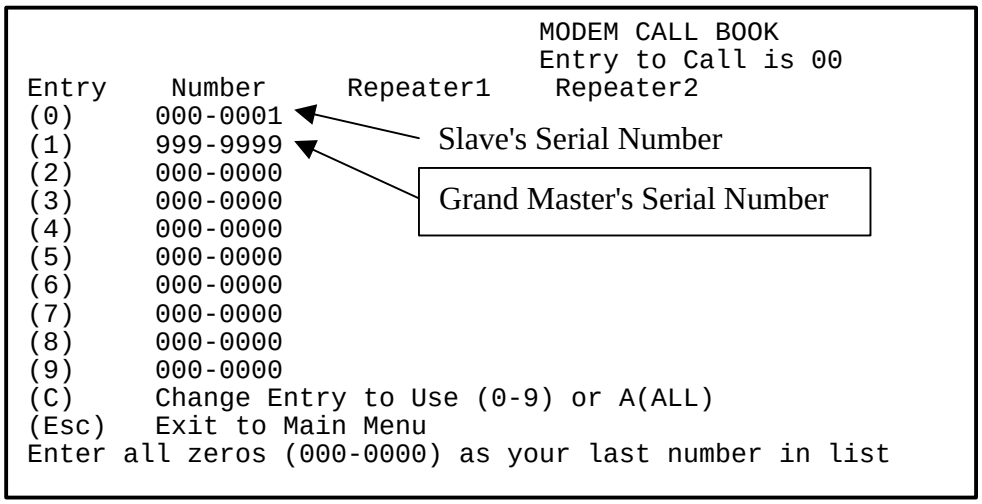
In the MultiMaster Sync Mode, you must include the Serial Number of the Grand Master as the last non-zero item in the Call Books of the Sub Masters.

These examples of Sub Masters' Call Books assume that the Grand Master's Serial Number is 999-9999.

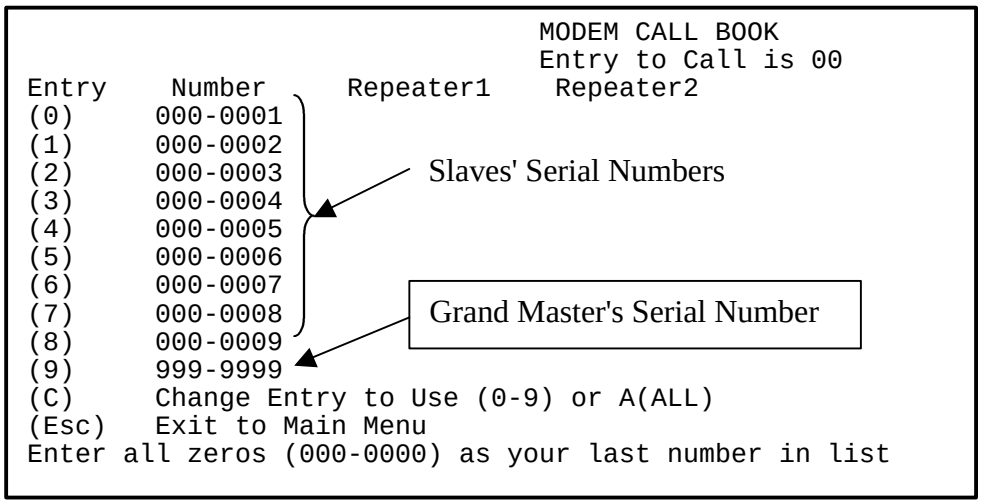
Multi-Point Sub Master (not using its Call Book):

```
                                MODEM CALL BOOK
                                Entry to Call is 00
Entry    Number     Repeater1    Repeater2
(0)     999-9999
(1)     000-0000
(2)     000-0000
(3)     000-0000
(4)     000-0000
(5)     000-0000
(6)     000-0000
(7)     000-0000
(8)     000-0000
(9)     000-0000
(C)     Change Entry to Use (0-9) or A(ALL)
(Esc)   Exit to Main Menu
Enter all zeros (000-0000) as your last number in list
```

Point-to-Point Sub Master with only 1 slave in its Call Book:



Point-to-Point Sub Master with 9 slaves in its Call Book:



Note that, as one of the slots is filled with the Serial Number of the Grand Master, the Sub Master's Call Book has only 9 slots left to list its Slaves. All other modems have all 10 slots available in their Call Books. Of course, this is not an issue for modems that don't use their Call Book (Multi-Point Masters, and modems using Network IDs.)

Frequency Key

The frequency band used by these modems is divided into many channels (112 in 900 MHz modems). When communicating, the modems hop from channel to channel, in a pseudo-random fashion (called the “Hop Pattern”).

You can use this setting to minimize the interference between FreeWave networks in the same geographical area. For instance, if there were 10 different networks in operation within a factory, assigning a different Hop Pattern to each network will ensure that they would not continuously jump onto the same channels at the same time.

In the Multi-Master Sync Mode, if all the Synchronized Masters also used the same Hop Pattern, they would all always use the same channel at the same time, so they would collide continuously. Therefore, we must assign a different Hop Pattern to each network, with the Frequency Key setting. Specifically, the Grand

Master must have a Frequency Key of 0, while each Sub Master must have a unique Frequency Key other than 0 (1 trough 14).

You select the Hop Pattern of a network by selecting a Frequency Key in that network's Master. The Master will then tell the rest of its network to use that same Frequency Key (this overrides the Frequency Key setting of the other modems in that network).

For example:

	Frequency Key
Grand Master	0
Other modems in the Grand Master's network (if any)	(use 0)
Sub Master A	2
Other modems in Sub Master A's network	(use 2)
Sub Master B	7
Other modems in Sub Master B's network	(use 7)
Sub Master C	3
Other modems in Sub Master C's network	(use 3)

To set the Frequency Key, from the Main Menu, press '3' on the terminal ("Edit Radio Characteristics").

The terminal will show the "Radio Parameters" menu.

```
                                RADIO PARAMETERS

WARNING: Do not change parameters without reading manual

(0)   FreqKey          5
(1)   Max Packet Size  8
(2)   Min Packet Size  9
(3)   Xmit Rate        1
(4)   RF Data Rate     2
(5)   RF Xmit Power    9
(6)   Slave Security   0
(7)   RTS to CTS       0
(8)   Retry Time Out 255
(9)   Lowpower Mode    0
(Esc) Exit to Main Menu
```

Press '0' on the terminal ("FreqKey").

The terminal will show the "FreqKey" menu.

```
Enter New Frequency Key (0-E) (F for more)
```

Enter a hex number ('0' to '9' or 'A' to 'E') to select the Frequency Key.
Note the decimal equivalent of hex numbers:

Hex digit	Decimal equivalent
A	10
B	11
C	12
D	13
E	14

Set the Frequency Key to '0' on the Grand Master, and to a unique number in each Sub Master. Set this parameters in all other modems to the same value as in their masters.

Max and Min Packet Size

The modems transmit data in packets. These menus let you adjust the range in size of the packets.

While the default values will work in most situations, you may improve the performance of a network by tweaking the packet size. Changing these settings may be of particular value when using modems with different communications software packages: you may find that you can optimize the overall network throughput when the modem restricts packet sizes. In Point-to-point networks, you may see these setting have an effect only when at least one of the modems has a Data Port rate of 115.2 KBaud.

In the Multi-Master Sync Mode, these settings are particularly important to ensure that a Master won't start receiving while another Master is still transmitting. (The "Principles of Operation" section explains why.)

In the Multi-Master Sync Mode, use the following considerations:

- The Min and Max Packet setting must be the same in all the Synchronized Networks.
- If the data loads of the various networks are balanced (see the "Definitions" section), the default settings (Max = 8, Min = 9) should work fine. If the data loads are heavily unbalanced, use a setting of Max = 0. This will force all transmitted packed to be a certain size, so that all the synchronized Masters will start receiving at the same time.

> ***TIP**: Remember that, to run the diagnostics mode, the settings must be such that the packet can be at least 32 bytes*

The actual size of the packets transmitted in the radio link is limited by these two menus, and by the “RF Data Rate” menu.

The following tables list the Minimum and Maximum packet sizes for a given set of settings. The "Principles of Operation" section explains how that works.

This table shows the minimum size of a packet (in bytes), depending on the "Min Packet Size" and the "RF Data Rate" menus. Note that the minimum size varies from 8 to 64 bytes per packet.

Min Packet size setting	RF Data Rate = 2	RF Data Rate = 3
0	16	8
1	21	12
2	26	16
3	32	20
4	37	24
5	42	28
6	48	32
7	53	36
8	58	40
9	64	**44***

*Default minimum packet size (in bytes).

These tables show the maximum size of a packet (in bytes), depending on the "Min Packet Size", the "Max Packet Size" and the "RF Data Rate" menus. Note that the maximum size varies from 8 to 256 bytes per packet.

This table is for an RF Data Rate of 2.

	RF Data Rate = 2									
Min	**Max Setting**									
Setting	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	16	37	58	80	101	122	144	165	186	208
1	21	42	64	85	106	128	149	170	192	213
2	26	48	69	90	112	133	154	176	197	218
3	32	53	74	96	117	138	160	181	202	224
4	37	58	80	101	122	144	165	186	208	229
5	42	64	85	106	128	149	170	192	213	234
6	48	69	90	112	133	154	176	197	218	240
7	53	74	96	117	138	160	181	202	224	245
8	58	80	101	122	144	165	186	208	229	250
9	64	85	106	128	149	170	192	213	234	256

This table is for an RF Data Rate of 3 (this is the default).

	RF Data Rate = 3									
Min	**Max Setting**									
Setting	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	8	24	40	56	72	88	104	120	136	152
1	12	28	44	60	76	92	108	124	140	156
2	16	32	48	64	80	96	112	128	144	160
3	20	36	52	68	84	100	116	132	148	164
4	24	40	56	72	88	104	120	136	152	168
5	28	44	60	76	92	108	124	140	156	172
6	32	48	64	80	96	112	128	144	160	176
7	36	52	68	84	100	116	132	148	164	180
8	40	56	72	88	104	120	136	152	168	184
9	44	60	76	92	108	124	140	156	**172***	188

* Default maximum packet size (in bytes)

In Point-to-point networks, you set these two items just in the Master, and the Master will tell the other modems in its network to use those same values. (Changing these values in the other Point-to-point modems has no effect.)
In a Multi-Point network, you must set these items identically in all modems in the network.

To set the Maximum Packet Size, from the Main Menu, press '3' on the terminal ("Edit Radio Characteristics").

The terminal will show the "Radio Parameters" menu.

Press '1' on the terminal ("Max Packet Size").

The terminal will show the "Max Packet" menu.

```
Enter Max Packet (0-9)
```

The factory default is “8”.

Enter a value (0 to 9) or press "Escape".

Press '2' on the terminal ("Min Packet Size").

The terminal will show the "Min Packet" menu.

```
Enter Min Packet (0-9)
```

The factory default is “9”.

Enter a value (0 to 9) or press "Escape".

RF Data Rate

This menu lets you select the over-the-air data rate of the radio link (this is not the Baud rate of the Data Ports).
In a Point-to-Point network you set this item in the Master (it has no effect in a Slave), and it will be applied to any modem that the Master calls. In a Multi-Point network you must set this to be the same in all the modems.

There are two settings:

Code	Function
2	Optimized for highest radio link rate
3	Optimized for longest distance

Use code 2 when the modems are close together and you want to maximize the throughput of the radio link, especially if you need a continuous 115.2 KBaud rate for the Data Ports.
Use code 3 when the modems are farther away and you prefer a solid data link over a high data throughput.
In a Synchronized System, use the same setting in all the Synchronized Networks.

To set the RF Data Rate, from the Main Menu, press '3' on the terminal ("Edit Radio Characteristics").

The terminal will show the "Radio Parameters" menu.

Press '4' on the terminal (" RF Data Rate ").

The terminal will show the " RF Data Rate " menu.

```
Enter New RF Data Rate (2-3)
```

The factory default is “3” (Optimized for longest distance).

Transmit Rate

This menu lets you enable a mode in which a Point-to-point Master transmits during every slot. You must turn on this mode in a Point-to-point Grand Master to ensure that it transmits every slot. That way, during any slot, any Sub Master that needs to synchronize itself to the Grand Master can do so. You don't need to do this with Multi-Point Masters, as they transmit every slot regardless of this setting.

> ***TIP**: This mode is also a useful tool to analyze a radio Point-to-point link, because the CTS LED average brightness will be inversely proportional to the radio link's BER. A solid red CTS LED will indicate a strong signal; as the signal becomes weaker, the LED will be On less and less time.*

To set the Transmit Rate, from the Main Menu, press '3' on the terminal ("Edit Radio Transmission Characteristics ").

The " RADIO PARAMETERS " menu will appear.

Press '3' on the terminal ("Xmit Rate ").

The terminal will show the " Xmit Rate " menu.

```
Enter New Xmit Rate (0-1)
```

Code	Function
0	Transmits during every slot
1	Normal: transmits only when needed

The factory default is “1” (normal operation).

Set this parameter to '0' in the Point-to-point Grand Master, and leave it at '1' in the Point-to-point Sub Masters. This parameters has no effect in any other modem.

Number of Repeaters

Use this menu to tell a Multi-Point Master whether or not there are Repeaters in the network.

For the purposes of the MultiMaster Sync Mode, it doesn't matter how this menu is set. However, it does matter that all the synchronized Masters have the same timing, and therefore this menu should be set the same on all the Masters.
However, in systems that include both Point-to-Point and Multi-Point networks,

- either there must be no Repeaters at all in the Synchronized System,
- or each of the Point-to-point networks' links must have one or more Repeaters, and the Multi-Point networks must be told they have Repeaters (whether or not they actually do)

The "Principles of Operation" section explains what this setting does.

To set the Number of Repeaters, from the Main Menu, press '5' on the terminal ("Edit Multi-Point Parameters")

The "Multi-Point Parameters" menu will appear.

```
                                MULTIPOINT PARAMETERS


(0)   Number Repeaters      1
(1)   Master Packet Repeat  2
(2)   Max Slave Retry       9
(3)   Retry Odds            9
(4)   DTR Connect           0
(5)   Repeater Frequency    0
(6)   NetWork ID         0255
(7)   Reserved
(8)   MultiMasterSync       0
(9)   1 PPS Enable/Delay  255
(A)   Slave/Repeater        0
(B)   Diagnostics           0
(C)   SubNet ID          Disabled
(D)   Radio ID           Not Set
(Esc) Exit to Main Menu
```

Press '0' to select the " `Number Repeaters`" menu.

```
Enter Number of Parallel Repeaters in Network(0-9)
```

Code	Function
0	There are no Repeaters in this network
1	There is at least 1 Repeater in the network

Even though the menu asks you to enter a number up to 9, the Master will interpret any number between “1” and “9” as “there is at least 1 Repeater in the system”.
The factory default is “1” (there are Repeaters).

Multi-Master Sync

This menu tells a Sub Master if it should synchronize itself to a Grand Master. Note that you turn on this Mode only in the Sub Masters.

To set the Multi-Master Sync, from the Main Menu, press '5' on the terminal ("Edit Multi-Point Parameters")

The "Multi-Point Parameters" menu will appear.

Press '8' to select the "MultiMaster Sync" menu.

```
Enter 1 for Master Sync, 0 Otherwise
```

Code	Function
0	Operate asynchronously
1	Synchronize with a Grand Master

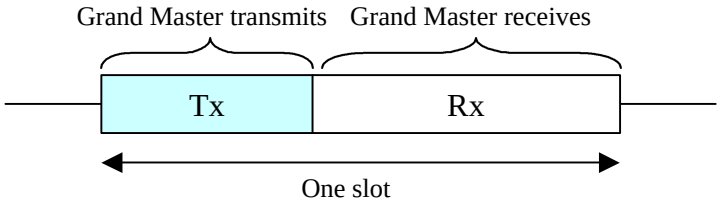
The factory default is “0” (Operate asynchronously).

Enter '1' to tell a Sub Master to use the Grand Master (whose serial number is stored in this modem's Call Book) as a source of synchronization. Leave this at '0' in the Grand Master. This setting has no effect in any other modem.

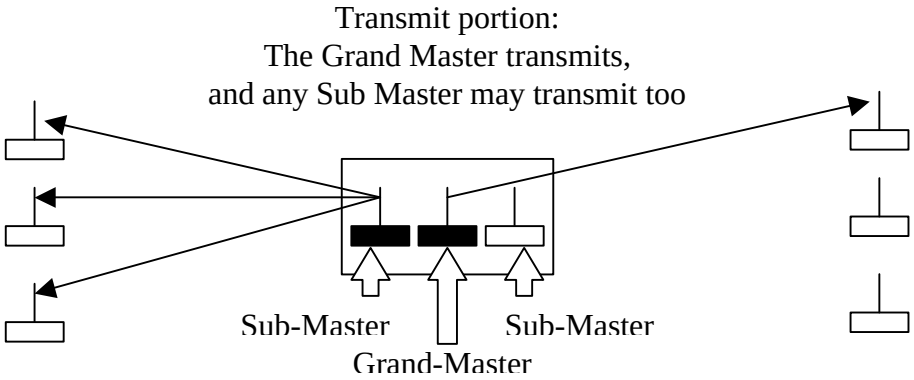
Principles of operation

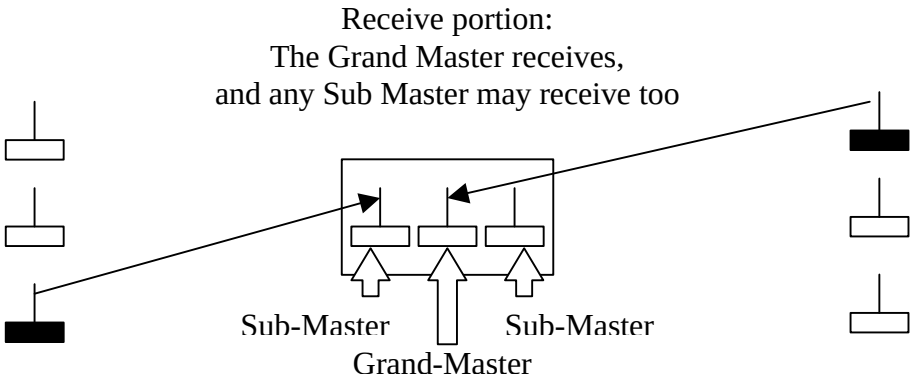
Multi-Master Sync

The Multi-Master Sync Mode works by synchronizing the collocated Masters so none of them will transmit while another one needs to be receiving. The idea is to keep a Masters' input stage from being overpowered from a Master next to it that is transmitting.
The Grand Master slots are divided in 2 parts: one in which it transmits, and one in which it receives.



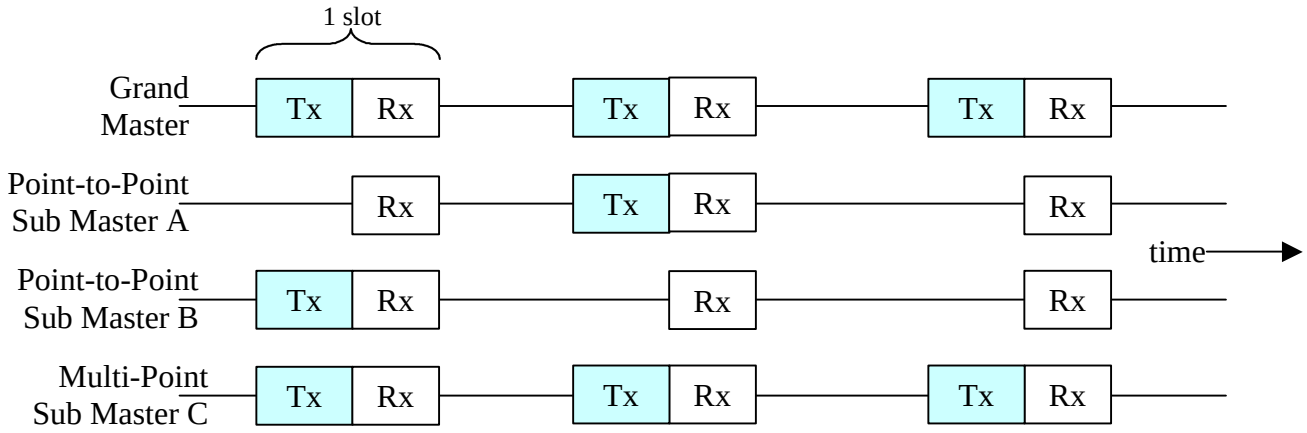
All the Sub Masters may transmit (if they need to) in that same transmit portion, and receive in that same receive portion.





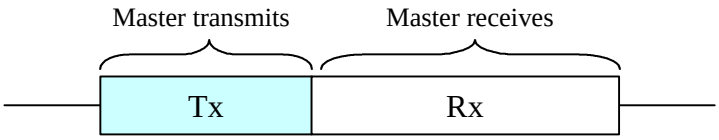
***TIP**: Multi-Point Masters will transmit on every slot; while, Point-to-point Masters will transmit only when they need to communicate. Therefore, normally, a Point-to-point Master will be more efficient of air time than a Multi-Point Master. But a Point-to-point Master used as a Grand Master will use as much air time as a Multi-Point Master (Grand or not).*

The Grand Master will transmit on each slot, because during any slot there may be a Sub Master that needs to transmit, so it needs a Grand Master's transmission for synchronization.

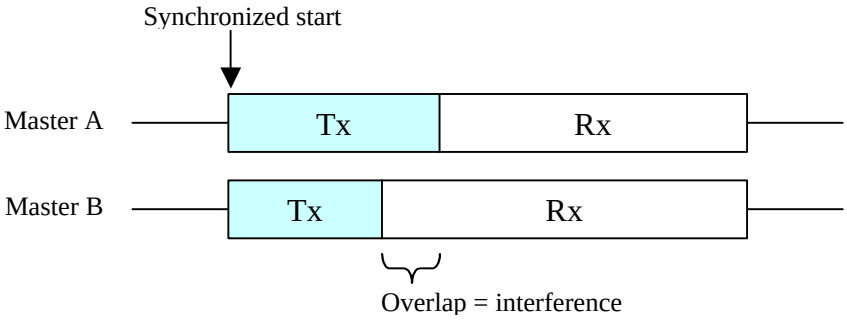


Packet size

Each slot consists of 2 parts: Transmit and Receive (from the point of view of the Master).

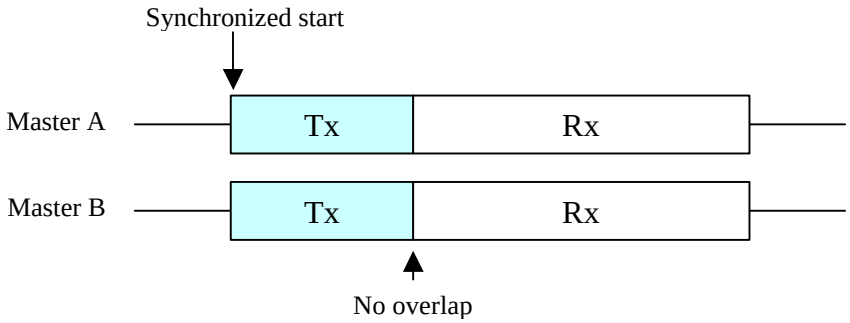


The Multi-Master Sync Mode will ensure that all the Masters' transmissions will start at the same time.



However, the length of each Master's transmission (and the point when it starts receiving) depends on how long its transmission lasts. This could result is an overlap between when one Master starts receiving and a collocated master is still transmitting; during this time, the Master that is trying to receive will be overwhelmed by the one that is still transmitting.

Therefore, not only must you synchronize collocated Masters, but you must also ensure that their transmission lengths are equal.



Partially, you do so by setting all the Synchronized Networks to use the same range of packet sizes, with the Max Packet Size and Min Packet Size menus.

Note that these menus do not set the size limits directly in number of bytes. Instead, the modems calculate the Minimum Limit and the Maximum Limit (in number of bytes) as a function of these settings.

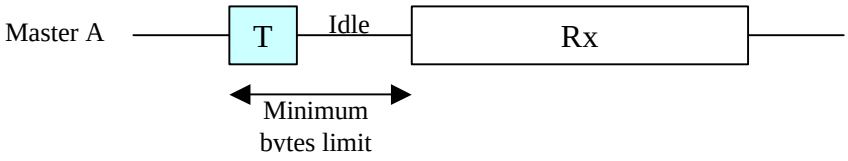
For the moment let's assume the modems are set for the default RF Data Rate of '3'.

For a given set of values of the Minimum and Maximum Packet Size settings, the duration of every slot is exactly equal. In that slot, the total number of bytes transferred (transmitted and received) is also exactly equal, and is:

Total bytes transferred = Minimum Bytes Limit + Maximum Bytes Limit

For example, with the default settings (Max ='8', Min = '9'), the Minimum number of bytes is 44 and the Maximum is 172. So, the total number of bytes transferred is always = 44 + 172 = 216.

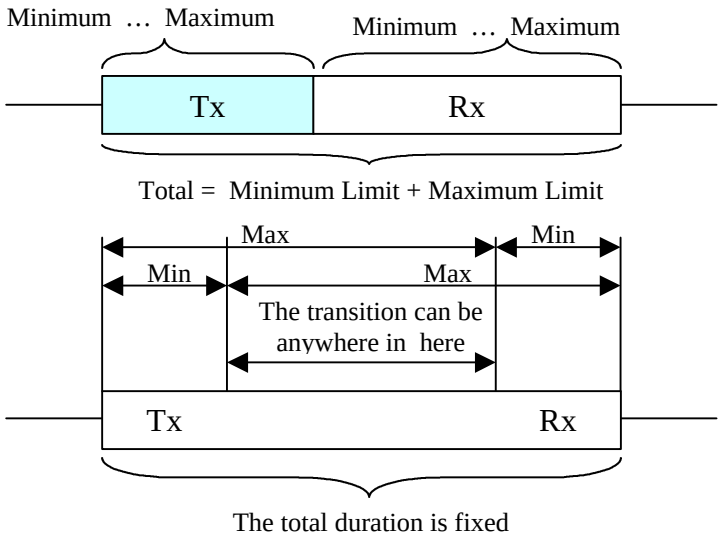
Now, the actual number of bytes the Master transmits can be anywhere between the Minimum Limit and the Maximum Limit. Even if there is not enough user's data to fill the Minimum Bytes Limit, when the Master is done transmitting them, it goes idle for the remainder of the reserved time, before it starts receiving.



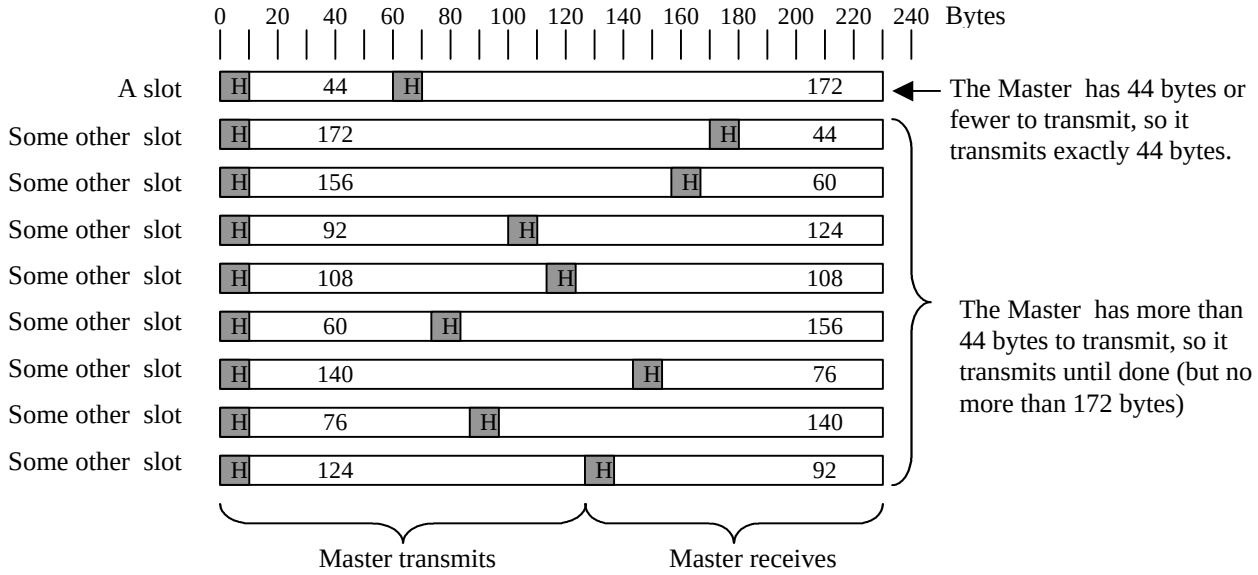
As the total number of bytes transferred is fixed, the Master will receive however many bytes are left:

Bytes received = Total bytes transferred – Bytes transmitted

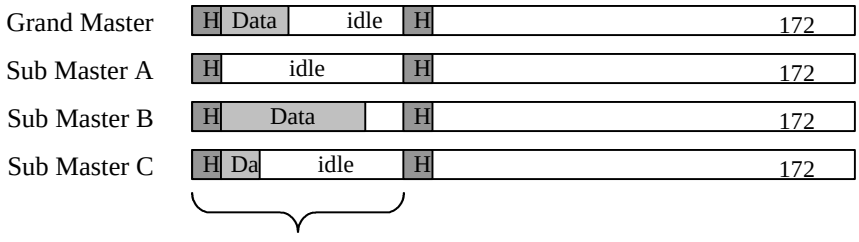
So, for the default settings, if the Master happens to transmit 100 bytes, it will then have to receive 216 - 100 = 116 bytes.



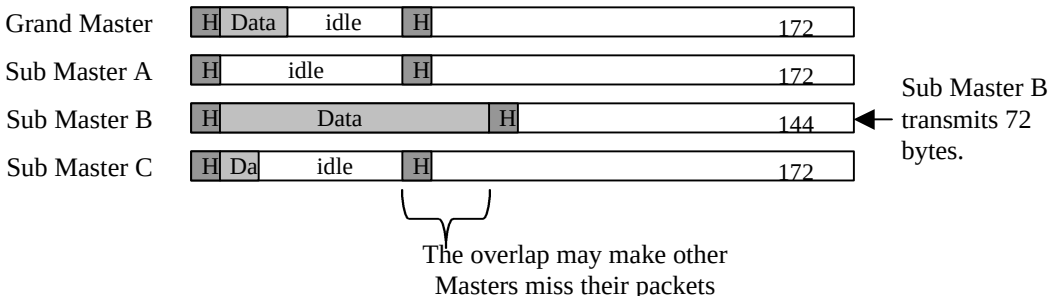
This graph shows a set of slots from a given Master at different times. This shows some of many possible combinations of bytes transmitted and received in the default settings. Note that, in addition to the bytes of data, the modems send 2 headers (H) .



Normally you may leave these settings to their defaults. As long as no synchronized Master needs to transmit more than 44 bytes, all the Masters will transmit for exactly the same duration.

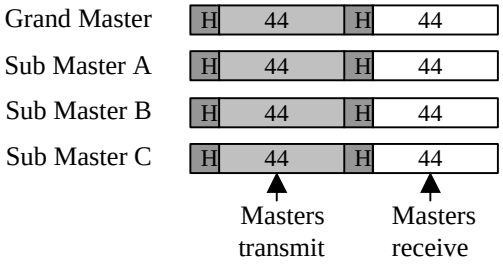


If one of the Masters sends more than 44 bytes, it will transmit longer than the Minimum Limit. The resulting overlap while other Masters are trying to receive may make the other Masters miss their packets.



If this occurs only occasionally, that's OK, because the FreeWave system can easily recuperate those lost packets, so no harm is done. On the other side, if this is likely to happen often, the number of packets lost due to the overlap may be prohibitive.

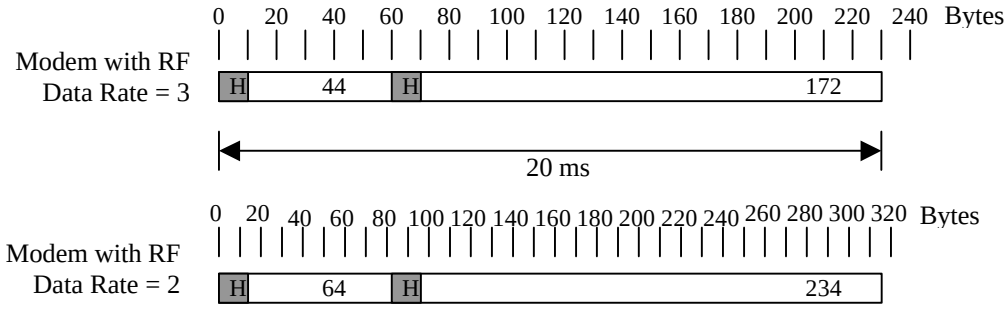
In that case, you must force all the synchronized Masters to transmit the same number of bytes (so no Master's transmission will overlap any other Master's reception). You do that by setting the Max Packet Size to '0' in all the synchronized Masters. This will force all the Masters to always transmit and receive exactly the number of bytes per packet specified with the Min Packet Size setting. For example, if the Min Packet Size is 9 (the default), all the packets will have exactly 44 bytes.



RF Data Rate.

So far, we assumed that the RF Data Rate setting was '3' (the default). If the Data Rate is '2', the modems transmit more bytes per second. For a given set of values of the Min and Max Packet Size settings, the slot duration doesn't change with the RF Data Rate.

For example, with the default Min Max Packet Size settings:

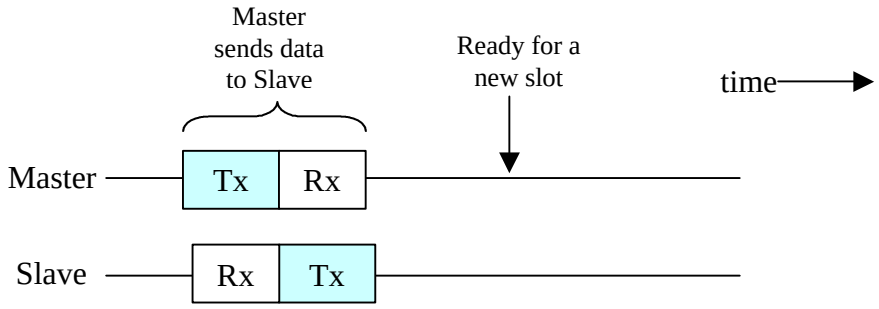


Therefore, even if some Synchronized Masters have their RF Data Rate set at '2' and some at '3', as long as they all have the same Min and Max Packet Size settings, all of them will transmit for the same duration. This would imply that networks with different RF Data Rates may be synchronized.

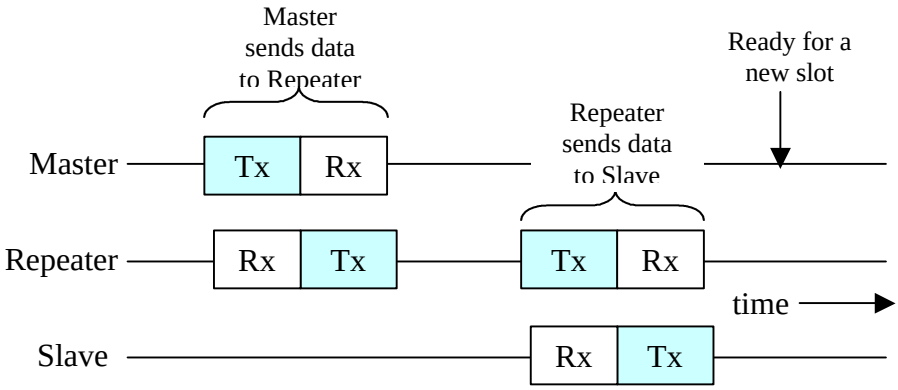
However, if a Sub Master has a different Data Rate than the Grand Master, it won't be able to receive its transmission, and therefore it won't be able to synchronize to it. Therefore, all the Masters in a Synchronized System must have the same value for the RF Data Rate setting.

Repeaters

The timing of a network's transmission is quite different if it has Repeaters. That's because a Repeater needs 2 slots: one to receive a packet, and one to retransmit it (because it can't receive and transmit simultaneously).



With no Repeaters, it takes one slot to send a packet.



With one or more Repeaters, it takes two slots to send a packet.

Therefore, the throughput of a network with Repeaters is halved.

A Point-to-point network knows if it has a Repeater in a given link because the Serial Number of the Repeater is listed in the Call Book entry for that link. On the other side, a Multi-Point Master doesn't use a Call Book, so, you must tell it if it has Repeaters with the "Number Repeaters" menu.

In order to keep the timing identical in the whole system, all of the Synchronized Networks must either behave like they have no Repeaters, or they must all behave as they do. Therefore, you must:

- either use no Repeaters at all in the whole Synchronized Network(and tell all the Multi-Point Masters that they have no Repeaters with the "Number Repeaters" menu);
- or, you must place at least one Repeater in each Point-to-point link (that is, each entry in the Call Book must include at least one repeater) and tell each Multi-Point Master that it has a Repeater (whether it really does or not).