Appendix D.

Justification for exlusion from SAR testing (Supplied by Manufacturer).

Network Params					
Num Nodes	100				
Absolute Worst Case					
Packet Type	**Size (bytes)**	**Packets/Sec Average**	**Bits/Sec**		**Note**
Status - Own	38	0.03	10.13		Our own status message generated and sent to a neighboring device
Status - Routed (for all of Num Nodes)	48	3.33	1280.00		Worst case size. Accounts for all 100 devices routing through this one.
Ack	16	105.42	13493.33		All unicasts have an Ack, so all packet rates of unicasts messages are included.
M2ORR	48	3	1152.00		Worst case size. Broadcast, max 3 times in one second.
Evac Individual (30 addresses)	120	3.00	2880.00		This is a MAX, and is extremely rarely if ever used. Broadcast, max 3 times in one second.
Withdrawl Ack - Routed Only (for all of Num Nodes)	32	1	256.00		Forced limit from gateway
Alarm Ack - Routed Only (for all of Num Nodes)	32	1	256.00		Forced limit from gateway
Leave Gateway - Own	40	0.05	16.00		This normally done once per incident
Leave Gateway - Routed (for all of Num Nodes)	40	100	32000.00		This normally done once per incident. Would be pretty much impossible to get all 100 leaves at the same node in the same second. The ember radio can only send up to 60 packets per second.
Totals			51343.47		Bits Per Second Transmitted MAX
802.15.4 BPS MAX			250000		
TX Duty Cycle			20.54%	<- THIS IS WITH ALL 100 PEOPLE MANUALLY LEAVING THE NETWORK SIMULTANEOUSLY. WILL NEVER OCCUR IN REAL WORLD SITUATIONS.	
	Size	**Raw Packets >> >>>>>**	>>>>>>>>>>	>>>>>>>>>>	This INCLUDES the Ack, so this is a data/ack combo
Packet Rate/Sec	64	100.2802083			The size here is the average of all the sizes using the size and frequency/period of the packet
Normal Operation					
Packet Type	**Size (bytes)**	**Packets/Sec Average**	**Bits/Sec**		**Note**
Status - Own	38	0.033	10.13		Our own status message generated and sent to a neighboring device
Status - Routed (for all of Num Nodes)	48	3.333	1280.00		Worst case size. Accounts for all 100 devices routing through this one.
Ack	16	3.367	430.93		All unicasts have an Ack, so all packet rates of unicasts messages are included.
M2ORR	48	3	1152.00		Worst case size. Broadcast, max 3 times in one second.
Totals			2873.067		Bits Per Second Transmitted MAX
802.15.4 BPS MAX			250000		
TX Duty Cycle			1.15%	<- NORMAL NETWORK TRAFFIC WITH PERIODIC STATUS CHECKS	
	Size	**Raw Packets >> >>>>>**	>>>>>>>>>>	>>>>>>>>>>	This INCLUDES the Ack
Packet Rate/Sec	64	5.611458333			The size here is the average of all the sizes using the size and frequency/period of the packet

Explanation of SAR Duty Cycle Calculations

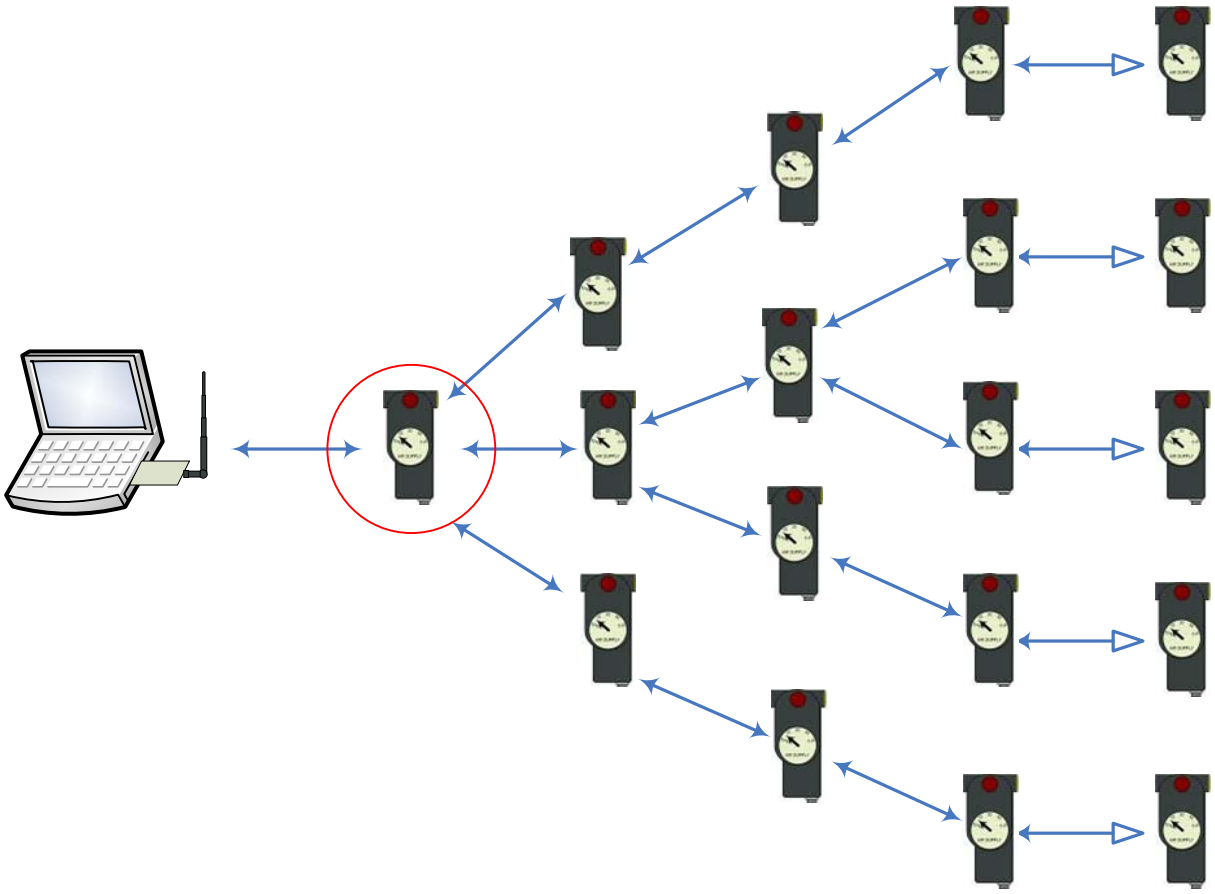
Summary

This spreadsheet and explanation of said spreadsheet shows what the absolute peak possible rate of transmit that can come out of a node during any second. This is a theoretical max rate for a 1 second period, and thus the average rate over several seconds would be MUCH lower. This rate is a worst cast average such that it is the worst rate possible in the network at any once second. In addition, this theoretical second is extremely unlikely to ever occur in the first place. The goal is to show we are WELL below any required TX duty cycle for the system to pass SAR testing by at least an order of magnitude.

Configurable Parameter:

Num Nodes: this is the maximum number of devices in the network. This value was originally specified as 200, however it has been reduced to 100. This number determines linearly how much traffic is pumped into the gateway, and thus how much traffic (equal) could be run through a routing device in the worst case scenario, which is all traffic to the gateway.

Worst Case System Definition



This picture illustrates how the worst case network forms. The laptop is the Gateway, and the black devices are the Pack Units worn by firefighters. All devices in this diagram MUST route all data to and from the Gateway/Coordinator through the device with the red circle around it. The hollow arrows represent paths to nodes not in the drawing, but assumed to be there. This worst case would have a total of 100 nodes. All worst case numbers and explanations are based on this diagram and this network scenario.

Two Sets of Calculations

There are two sets of calculations run. The first is a theoretical worst case that would be for the worst second possible in this system; however this would only be for a single second in which this worst case would occur, then the system would return to the normal/average case quickly after this worst case peak.

The second is the normal/average case, which is the transmit rates you get after averaging all transmissions over a period of time.

Explanation of Columns in the Calculations

All packets listed here are being "generated or forwarded" by the node that is considered the busiest in the system in terms of Transmit in the worst case scenario. What is transmitted is summed in bits per second to determine what the duty cycle is.

1. Packet Type: This is the type of mess that a node can transmit

2. Size (Bytes): This is the number of bytes in this type of packet. If variable length packets are possible, then the worst case number is used.
3. Packets/Sec Average: This number is the frequency of this type of packet in the system shown as an average. This is a worst case packet rate that any one node could see.
4. Bits/Sec: This is simply bytes that a node can send in a single second = bytes * 8 * packets/sec.
5. Note: This gives some information about the numbers in that row.

Explanation of Packet Types and Sizes

The following tables contain additional information about the packet types listed in the calculations that may need to be known, or may help understand the calculations better. The first table is a definition of the message and how it occurs. The second table provides additions information on each message. Unicast means it is only addressed to one device, and only one device will process it, and only one device will respond to it with an Ack to acknowledge the receipt of the message. The Broadcast message is not specifically addressed, and thus is processed by every node. There are no Acks with a broadcast. Broadcasts are forwarded (in most cases) by each node 3 times. Nodes only forward the same message 1 set of three times even if they hear the same message from many nodes. Thus, each node in the network forwards a single broadcast 3 times. Therefore if there are 10 nodes in a network, and 1 of those nodes sends a broadcast, it sends it 3 times, then each node hearing that sends it 3 times, repeating until all nodes have sent it 3 times for a total of 30 individual transmissions.

Packet Type	**Definition**
Status - Own	This message is the periodic status message for each node in the network. It is sent on a periodic basis. It is a unicast message.
Status - Routed	This is the same as that above, however these are status messages being routed for other nodes, from other nodes, to the gateway. It is a unicast message. Routed status information can occasionally contain route information for up to 6 hops out which adds an extra 10 bytes to the message max.
Ack	This is a message that is sent in response to the successful receipt of a unicast message. It is only sent on a link from one neighboring device to another and is not propagated over multiple hops.
M2ORR	This is a Many-to-One-Route-Request. It is a broadcast sent from the gateway to all devices. It is sent to generate a route to all devices in the network. Each hearing device adds its address to the broadcast (two extra bytes) before sending it on. It also chooses the best of all received messages which is the shortest list, and best receive strength on hearing. As this propagates out in broadcast style, it allows all devices to know the route to the gateway.
Evac Individual	This is a message with a list from 1 up to 30 2-byte addresses. It is a broadcast sent from the gateway to all devices.
Withdrawal Ack	This is a unicast message sent in response to a value in the status message being sent. It is sent from the gateway to an individual device.
Alarm Ack	This is a unicast message sent in response to a value in the status message being sent. It is sent from the gateway to an individual device.
Leave Gateway - Own	This is sent from a device to the gateway when a user presses a button to

	turn its unit off. It is a unicast.
Leave Gateway - Routed	This is the same as that above, however these are leave gateway messages being routed for other nodes, from other nodes, to the gateway. It is a unicast message.

N = Number of Nodes up to 100 MAX.
GW = Gateway

Packet Type	**Bytes Min**	**Bytes Max**	**Rate of Transmit**
Status - Own	38	38	1 every 30 seconds
Status - Routed	38	48	1 * N every 30 seconds
Ack	32	32	1 for every unicast sent
M2ORR	32	42	1 broadcast every 20 seconds
Evac Individual	34	92	When a user pushes an Evac button at the GW. Forced to 10 second spacing.
Withdrawal Ack	32	32	1 per second MAX
Alarm Ack	32	32	1 per second MAX
Leave Gateway - Own	40	40	1 per incident
Leave Gateway - Routed	40	40	Up to 100 in a single incident, but in theory could occur in the same second, which is essentially impossible.

Summations

The column of Bits/Sec is summed. This becomes all of the worst case rates of all types of packets that can be transmitted from any one node in the system. That number is then divided by the raw bit rate of the radio to arrive at the TX Duty Cycle.

Results

This number is a result of summing all worst case scenarios, which individually are extremely unlikely to ever occur in any one second, and this the summation of all worse case scenarios is astronomically unlikely to ever occur in a single second.
In the terms of this system, the largest effects are:

1. All devices send status at a time such that all of the status messages arrive at a single point in the system in the same second. Since status messages are sent every 30 seconds, and are completely random, it is essentially impossible for this to occur.
2. All devices send status at a time such that all of the leave gateway messages arrive at a single point in the system in the same second. Since this requires a button push when logging off when done with an incident, it would require users to be synchronized in their pushing of the button, which is essentially not going to ever occur in the real world.

Last, it is critical to note that if running averages exceeding 1 second where done, we could show that the duty cycle is even less.
So, with our number coming in at just over 20% for the peak rate, and the normal/average rate of 1.2%, the results are acceptable for SAR.

Screen Captures

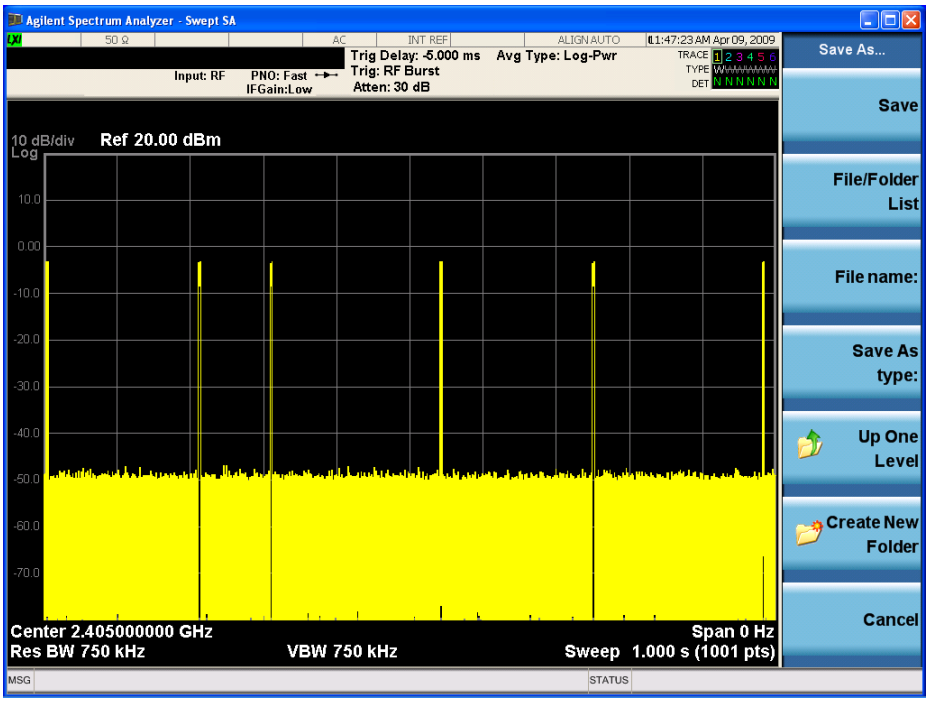


Figure 1. Normal message traffic in a 1 second period.

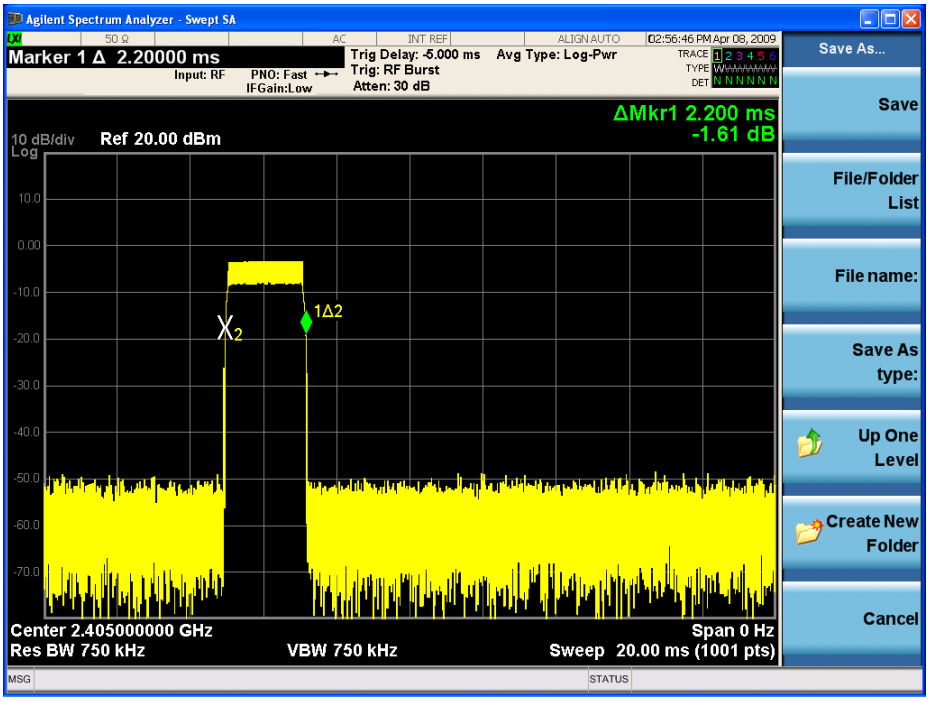


Figure 2. Status message.

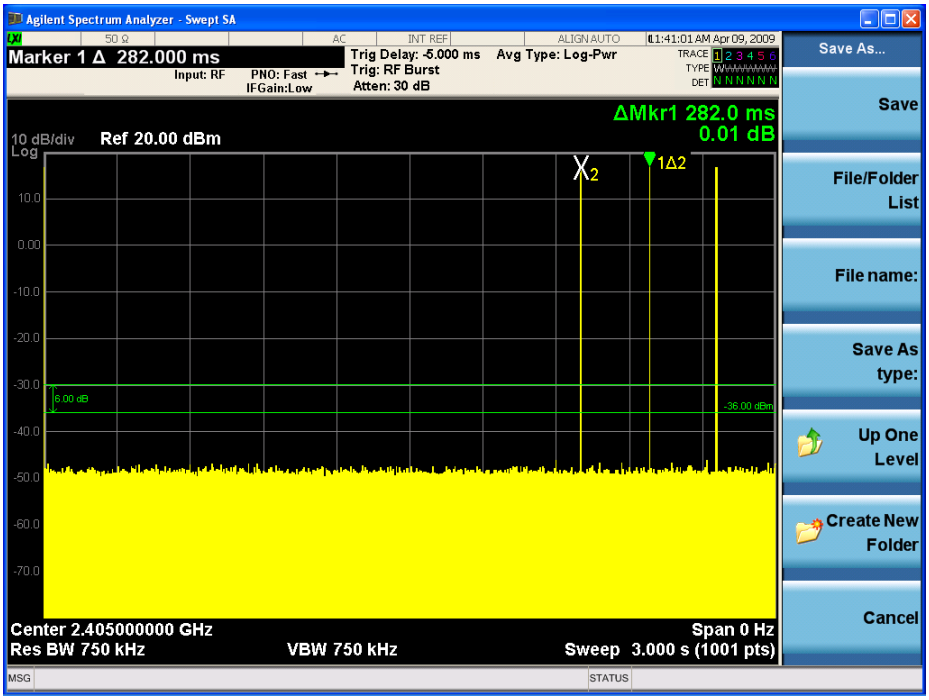


Figure 3. Route Request (M2ORR).

1. Power threshold for SAR exclusion.

F(GHz) Low	F(GHz) High	Center of Tunable Band (GHz)	FCC Limitation based on center of band (mW)
2405.0	2405.0	2405.0	24.95

2. Maximum measured transmitter power.

   Pout (Conducted) = 19.0 dBm = 79.43 mW
   Source Based Time Average Power (Worst case) = 0.2054 X 79.43 = 16.31 mW

Source Based Time Averaged power (mW)	Maximum Antenna Gain (dBi)	Pout EIRP (mW)
16.31	1.80	**24.69**

3. Conclusion.

The threshold for exclusion from SAR evaluation is 24.95mW for FCC and since the SEMS II has a maximum transmitted power of **24.69** mW no SAR evaluation is required.

4. MPE calculation

The following MPE calculations are based on an internal PCB dipole antenna with a measured ERP of 113.4 dBuV/m (at 3 meters) and conducted RF power of +19.0 dBm. The source based time averaged conducted RF power as presented to the antenna is 16.31 mW or 12.12 dBm (worst case). The maximum gain of this antenna, based on the data sheet is +1.8 dBi.

Prediction of MPE limit at a given distance

Equation from page 18 of OET Bulletin 65, Edition 97-01

$$S = \frac{PG}{4\pi R^2}$$

where: S = power density
P = power input to the antenna
G = power gain of the antenna in the direction of interest relative to an isotropic radiator
R = distance to the center of radiation of the antenna

Maximum peak output power at antenna input terminal:	12.12	(dBm)
Maximum peak output power at antenna input terminal:	16.293	(mW)
Antenna gain(typical):	1.8	(dBi)
Maximum antenna gain:	1.514	(numeric)
Prediction distance:	20	(cm)
Prediction frequency:	2405	(MHz)
MPE limit for uncontrolled exposure at prediction frequency:	1	(mW/cm^2)
Power density at prediction frequency:	0.004906	(mW/cm^2)
Maximum allowable antenna gain:	24.9	(dBi)
Margin of Compliance at 20 cm =	23.1	dB