t.a.c

May 12, 2006

Mike Buchholz
Curtis – Strauss LLC
527 Great Road
Littleton, MA 01460

UPDATED TECHNICAL DESCRIPTION:

The Wireless Adapter operates in conjunction with other Wireless Adapters to form a wireless "mesh network" of our HVAC controller products.   This wireless mesh network will replace our wired RS-485 hard wired network for customers who do not wish to install network wiring.   The Wireless Adapter connects to the HVAC controller's RS-485 port for obtaining power and communicating to the HVAC controller. The Wireless Adapter provides wireless communication between HVAC controllers allowing the formation of a wireless mesh network.

The mesh network is so named since there is RF transmission overlap of several, but not all, nearby nodes (Wireless Adapters) in a mesh network. During system installation a"cost" table are determined and stored in each Wireless Adapter that lists the "cost" of transmission to nearby nodes. If node A needs to communicate data to node Z that is beyond its RF range the data packet must make several "hops", via nearby nodes, in order to reach node Z. Cost is described in more detail in the "Repeater/Router Operation" section below and basically is a value of the likelihood a transmission from a routing node will reach a respective nearby node.

The block diagram on Page 3 of the schematic diagram illustrates the Wireless Adapter design. Power and RS-485 communication are provided by the host controller over a 4 conductor cable. An LDO regulates the 3.3V input voltage down to the 3.0V system voltage. The 3.0V supply voltage powers the MCU, external SRAM, RF transceiver and RF power amplifier.

An RS-485 transceiver converts the half duplex communication to/from RS-485 levels to CMOS/TTL signals for communication to/from the onboard Atmega128L MCU.   An external SRAM is connected to the address and data bus of the MCU.

TAC
One High Street
North Andover, MA 01845 USA

Phone +1 978-470-0555
Fax +1 978-470-0946
Web www.tac.com

Communication from the MCU to the 802.15.4 compliant EM2420 RF transceiver is achieved via an SPI bus. Also additional communication signals (interrupt signals, etc.) complete the communication between the MCU and RF transceiver.

The output signal of the EM2420 RF transceiver is amplified by an external RF power amplifier. Two RF switches provide steering of the transmit and receive signals to/from the EM2420. An integral PCB mounted antenna completes the RF signal path.

TCB Questions with answers :

1. Paper label is unacceptable. See Label exhibit. "60# matte white thermal transfer paper."

The FCC ID label material has been changed from a paper label to THERMLfilm SELECT 31800 from FLEXcon. It is a printable hard white polypropylene material, coated with a permanent pressure sensitive acrylic adhesive. See the Product Information sheet from FLEXcon for detailed information.

2. Duty cycle calculation is unacceptable. The description provided is anecdotal and does not contain a technical description of the transmitter on off cycles when imbedded in a worst case mesh. Please provide an analysis of the worst case 100 mS interval considering transmitter on-off times when working in a worst case repeat situation with a worst case routing repeat table. We note that the transmitter is only 0.4 dB below the anecdotal duty cycle. There is not much margin for error here.

The theoretical worst case transmit duty cycle analysis is shown below. The analysis is for a worst case scenario based on the software stack from Ember Corporation utilized on the Wireless Adapter. The theoretical worst case duty cycle is independent of whether or not the node is in "repeater/router" operation or transmitting host controller packets and is independent of the size of the routing or "cost" table. This worst case transmit duty cycle calculation, shown below, can never be achieved strictly from host generated packets due to the latency of the RS-485 communication bus operating at 50kbaud between the wireless adapter and host controller. This theoretical worst case transmit duty cycle can only be achieved, if ever, during "repeater/router" operation.

The result is that the theoretical maximum transmit duty cycle of the Wireless Adapter, which for all intents and purposes will never be achieved, is 27% in a 100msec interval. Worst case measured transmit duty cycle of a mesh network node in the TAC building in North Andover, MA is 12% to 13%. Listed below is a calculation from Ember Corporation of the theoretical worst case transmit duty cycle that their software stack is capable of generating. Please reference new measurement data based on the theoretical 27% worst case duty cycle.

IEEE 802.15.4 2.4 GHz
PHY

Data Rate	250000	bits / sec	
	31250	bytes / sec	
Symbols/byte	2	sym / bytes	
Symbol Timing	62500	sym / sec	
	0.000016	sec / sym	
Byte Timing	0.000032	sec / byte	
PHY PSDU	6	bytes	4 Preamble, SPD, Length
Max Length	127	bytes	
Total Packet Length	133	bytes	
Maximum Time TX PKT	0.004256	sec	

Long Frame Scenario:

1) TX Frame — Assume Frame is Data Frame
2) Wait for ACK
3) Wait for LIFS
4) Repeat

Long InterFrame Spacing (Slotted w/ ACK)			
Long Frame	127	bytes	
Data Frame Payload	102	bytes	
ACK Frame	5	bytes	
tack	12	sym	
LIFS	40	sym	
ACK Frame	11	bytes	
Backoff Period	20	sym	
Maximum Backoff	7		Random between 0 and 7
Backoff Required	2		
Backoff Time	60	sym	

Network Based Calculation

Long InterFrame Spacing (Slotted w/ ACK)			
Long Frame	127	bytes	
Data Frame Payload	102	bytes	
ACK Frame	5	bytes	
tack	12	sym	
LIFS	625	sym	Single hop data indicates 10 ms inte
ACK Frame	11	bytes	
Backoff Period	20	sym	
Maximum Backoff	7		Random between 0 and 7
Backoff Required	2		
Backoff Time	60	sym	

Transmit Time	
TX Time (Packet)	0.004256
TX Time (ACK)	0.000352
Total TX Time (sec)	0.004608

Off Time	
Backoff Time	0.00192
tack(minimum)	0.000192
LIFS	0.01
Total Off Time	0.012112

Duty Cycle (On /total) 27% Calculated Network Performance

3. Please provide an acknowledgment from the applicant that they will "reduce the power level at channel 15 by -5" in all production units. Please describe how this will be accomplished (modification to firmware, or other).

Based on re-testing using the 27% theoretical worst case transmit duty cycle correction factor the output power is limited as follows for channels 0 through 15.

Based on the new 27% worst case transmit duty cycle measurements power levels of all channels are now affected and lowered as described below. TAC, Inc. acknowledges that the power output of all Wireless Adapter production units will be limited in software as follows:

Channels 1 through 14 output power limits:

Channels 1 through 14 will transmit at a maximum setting of –6 in order to achieve the tested margins. This setting will be a hard coded setting in firmware. Upon selection of channels 1 through 14 the firmware will restrict the transmit power to a maximum –6 setting.

Channel 0 adherence to Lower Band Edge Limits:

Channel 0 will transmit 5dBm lower (-11 setting) than channels 1 through 14 to achieve the margin for the lower band edge measurement. This lower setting will be a hard coded setting in firmware. Upon selection of channel 0 the firmware will restrict the transmit power to a maximum –11 setting.

Channel 15 adherence to Upper Band Edge Limits:

Channel 15 will transmit 8dBm lower (-14 setting) than channels 1 through 14 to achieve the margin for the upper band edge measurement. This lower setting will be a hard coded setting in firmware. Upon selection of channel 15 the firmware will restrict the transmit power to a maximum –14 setting.

4) *The transmitter is described as a "repeater". Please list all other FCC IDs of transmitters that operate with this transmitter. Please describe how the output signal level varies based on the input signal that is repeated.*

The Wireless Adapter operating as a repeater/router is communicating with other Wireless Adapters only. Thus there are no other transmitting devices with other FCC IDs involved. The worst case transmit duty cycle of a Wireless Adapter in "routing" mode adheres to the theoretical worst case transmit duty cycle calculation shown above. Transmit power level remains the same whether or not Wireless Adapter is transmitting a host packet or "routing" a packet from another Wireless Adapter.

The term "repeater" is a misnomer and the node should be referred to as a router that will retransmit another node's packet if the "cost" to the destination node is low. The term repeater is more of a marketing name that is easier for a customer to understand and was chosen for this reason.

All nodes are routers and when connected to a host, may also originate messages on the mesh. The Wireless Adapter operates as a transmitter when transmitting host packets or when routing a packet from another node as part of the mesh network. The routing table described in a previous document is not a completely correct way of describing the table. It is actually a cost table that lists the likelihood a transmitted packet from a particular Wireless Adapter will reach another node in the multi-hop path to the destination node.

If a node receives a packet destined for another node it will determine whether or not to re-transmit the packet based on the “cost” to the destination node. If the cost is too high it assumes another node in the mesh network will retransmit that packet and will not re-transmit. If the cost is low, meaning the destination node is closest to it, it will retransmit. Only one node (the one with the lowest cost) will route (repeat/retransmit) a packet, for each hop. Nodes that have higher costs will not route the packet.

5. *The technical description of the transmitter does not address the 15.247 types of transmitters. Hopping, digital modulation, etc. Please update the technical description to justify the classification of the device as using "digital modulation" techniques.*

The EM2420 transceiver digitally modulates the carrier and adheres to the following specifications and therefore is a 15.247 type of transmitter. It is an 802.15.4 compliant transceiver and has the specifications listed below.

Frequency Range: 2.400GHz to 2.483.5GHz; 16 software selectable channels with 5MHz channel spacing beginning at 2.405GHz per IEEE 802.15.4 standard.
Modulation Type: O-QPSK Direct Sequence Spread Spectrum (DSSS) digital modulation per IEEE 802.15.4 standard.
Transmit Bit Rate: 250Kbps
Transmit Chip Rate: 2000kChips/sec
Native Transmit Power: Programmable –32dBm to 0dBm in 1dBm increments