
AT05558: Wireless Manufacturing Test Kit

Atmel ATmega256RFR2

Description

Manufacturers need rapid test capability for mass production of wireless products. This Manufacturing Tool Kit (MTK) is designed to work with automated equipment or manual testing. CW and Modulated Carrier outputs are generated for use with RF Power Meters, VSAs, and Spectrum Analyzers. A one-shot test feature allows products to self-test with “Gold” units for scalable production. The manual interface can be used for advanced trouble shooting and verification of RF PHY performance.

Features

- Test Firmware for Mass Production
- Continuous Modulated Carrier Mode (PRBS)
- Continuous Carrier Wave Mode (CW)
- One-Shot Test
- Channel Selection
- Power Selection
- DUT Status
- Battery Test
- Serial Host Control Interface
- Manual Test Mode
- RF PHY Diagnostics
- Works with Automated Scripts
- Example Python Script

1 Background

High volume manufacturing requires efficient and scalable testing. For quick functional testing of RF assemblies; verification of TX power, carrier frequency and line power is sufficient. Low-cost RF test equipment can measure power and frequency of continuous CW or Modulated Carrier (PRBS) signals, however; these devices do not support IEEE® 802.15.4 packet generation or demodulation. The MTK provides a firmware tool that produces Continuous Carrier Wave (CW) and Pseudo-Random Binary Sequence Modulated Carrier (PRBS) signals for inspection with low-cost equipment. For trouble shooting and repairs the MTK can be used manually with a serial terminal. Additionally it provides a one-shot test that can be used with calibrated “Gold” units. This allows manufactures to self-test product and rapidly scale production test capacity.

A common setup for production testing uses conducted RF signals from batches of DUTs connected to a spectrum analyzer through an RF multiplexor. The multiplexor and test equipment are controlled using a computer network to manage the tests and log results. The MTK allows the same system to configure and control the PCBAs over wired serial connections. This system provides space-division multiplexing (SDMA), isolation of individual PCBAs, and stable measurements free from crosstalk and background interference.

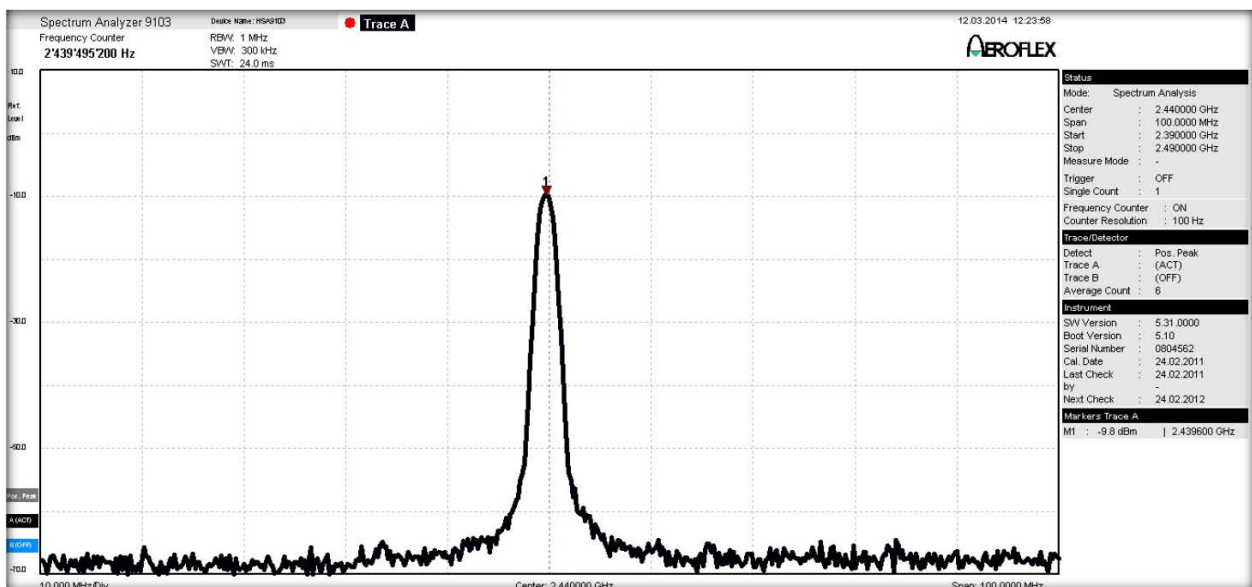
An alternative low-cost method uses radiated testing and a “Gold” unit to examine several DUTs in the same space, or mini-RF-chamber. Measurements from this method are empirical but sufficient for many users. Using a “Gold” unit allows manufacturers to self-test products which enables geometric expansion of test capacity for mass production.

2 Modulation Modes

2.1 CW Mode

The MTK supports continuous Carrier Wave (CW) transmission. This signal can be used to verify carrier center frequency, RF power output, and equalization across the spectrum. Normally IEEE 802.15.4 transmitters use DSSS and O-QPSK modulation with a 500kHz deviation. To create a CW waveform using the IEEE 802.15.4 transmitters the symbols are all sent in the lower sideband with a -500kHz offset. For example a setting of CH18, 2440.0MHz will have a peak at 2439.5MHz.

Figure 2-1. CW Mode CH18 -500kHz Offset



2.2 PRBS Mode

The MTK also supports continuous Modulated Carrier mode. A Pseudo-Random Binary Sequence (PRBS) is transmitted using O-QPSK modulation. This format is useful for Power Spectral Density measurements and verification of suppression in restricted bands.

Figure 2-2. PRBS Mode CH25 Restricted Band Test



Figure 2-3. PRBS Mode CH26 PLL_TX_FLT Enabled

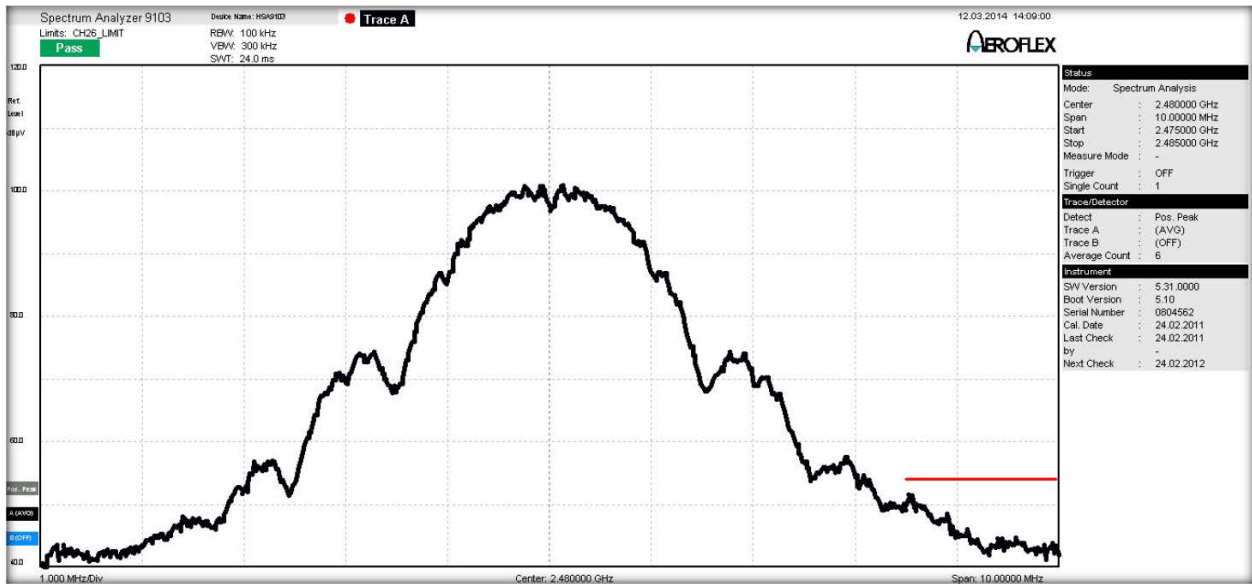
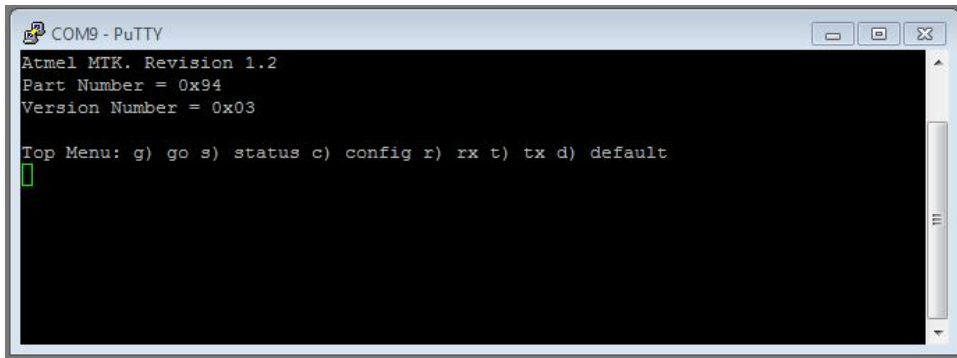


Figure 2-2 and Figure 2-3 show ATmega256RFR2 passing Restricted Band tests in the high channels. The horizontal red line on the right is the $-54\text{dB}\mu\text{V}$ @ 3m limit, in the 2483.5 to 2500MHz band, set by FCC regulations [3]. The Channel 25 example is the normal spectral profile for 256kbps O-QPSK. The Channel 26 example has the PLL_TX_FLT enabled with sharper band-edge roll-off.

3 User Interface

The MTK uses UART Channel 1 of the ATmega256RFR2. The default serial port settings are Baud=38400, DataBits=8, StopBits=1, Parity=None, FlowControl=None.

Figure 3-1. MTK Terminal Display



The MTK includes a menu driven interface that can be run using a serial terminal or automated script. The interface returns to the Top Menu when the system is idle. At the top level there are several choices:

Top Menu

g) go

This starts the CW or PRBS tests. Pressing any key will stop the test and turn the transmitter off.

s) status

This choice dumps the DUT settings to the terminal. The channel, power, modulation mode, and battery voltage are displayed. This choice is used to verify the DUT configuration before testing.

c) configure

This selection calls a sub-menu to configure the DUT.

Config Submenu

c) channel. Channels 11 through 26.

p) power. Tx power levels +3dBm to -17dBm.

m) modulation. CW and PRBS modes.

q) quit. Return to Top Menu.

r) rx

Enable receiver for one-shot test.

t) tx

Transmits one packet.

d) default

Reload default configuration to DUT.

4 DUT Default Settings

Settings are preserved as long as the DUT is active. Power cycling, resetting the device, or selecting the **d)** **default** choice will reload the DUT with the default settings:

TX Channel = CH18 2440MHz

TX Power = 0dBm

TX Modulation = CW

5 Submenus

The channel, power, and modulation submenus are straightforward. All submenus include a **q)** **quit** choice that aborts the selection process and take the user back to the Top Menu. When a menu choice sequence has been completed the MTK will cycle back to the Top Menu.

6 Error Messages

If the user makes an incorrect selection the warning “QRM Bad Key” is thrown, the choice sequence is aborted and the user is taken back to the Top Menu.

7 Interacting with automated scripts

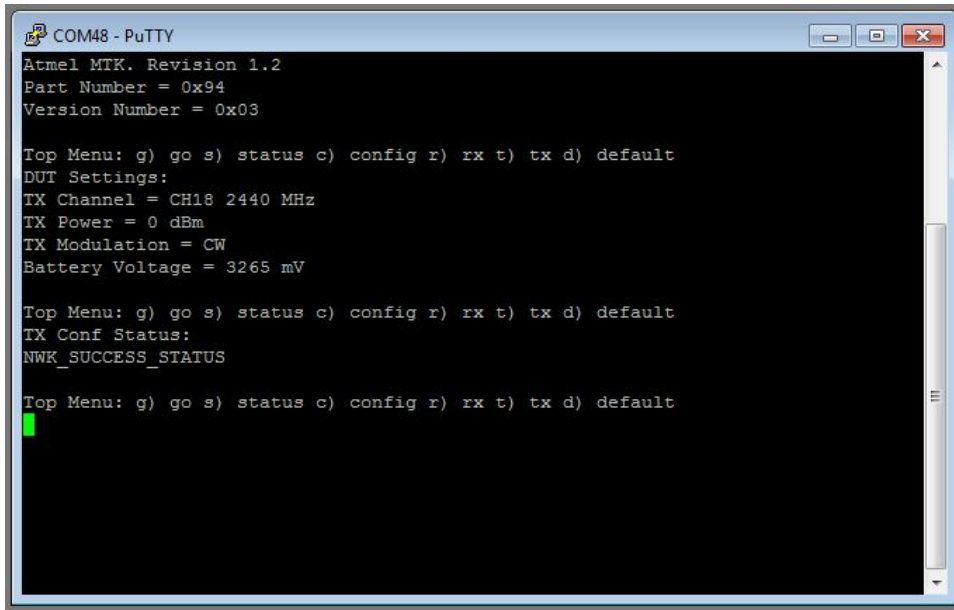
With high-speed automation routines the “Top Menu:” string can be used for flow control and verification that the MTK firmware is IDLE and ready for commands. For consistent message handling by automated scripts all responses from the MTK are strings terminated with `\r \n` and all menus and submenu choices take only one keystroke as input.

8 One-Shot Test

The One-Shot test is included for functional verification of the PHY. The One-Shot test uses the Atmel[®] LwMesh [1] to implement a simple point-to-point network between two devices running the MTK firmware. The PANID 0x5558 is used. The Transmitter is Address 1. The Receiver is Address 0. Normal 250kbps O-QPSK modulation is used. (CW and PRBS settings are ignored.) The test payload is “QRV ATMEL MTK”, 13 bytes. The NWK header used by the LwMesh is 7 bytes. This result in a 20 byte (octet) PDSU recommended for receiver sensitivity evaluation in Section 6.1.7 of the IEEE 802.15.4 spec [2].

To run the test make sure the channel settings on both devices match. Start the receiver first with the `r)` `rx` command. The Receiver will monitor the channel for the first packet it observes (including broadcast messages). Next send the packet by selecting the `t)` `tx` choice on the “Gold” unit. The Transmitter will display transmission status returned by `appDataConf()`. The Receiver will display the payload and RSSI returned by `appDataInd()` when a packet is received. On-air packet behavior can be observed using the Atmel Wireshark Packet Analyzer [4].

Figure 8-1. Successful One-shot Transmission



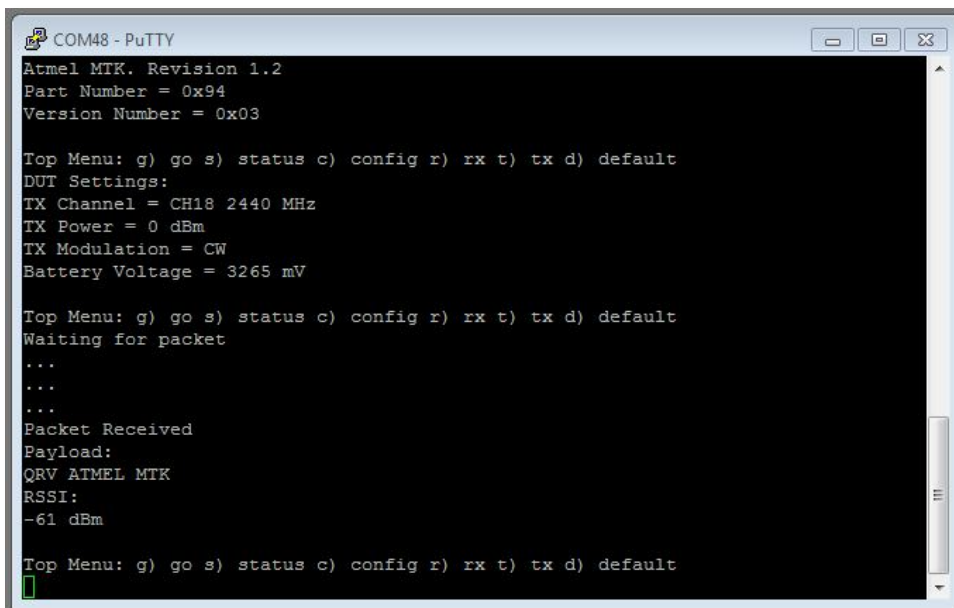
```
COM48 - PuTTY
Atmel MTK. Revision 1.2
Part Number = 0x94
Version Number = 0x03

Top Menu: g) go s) status c) config r) rx t) tx d) default
DUT Settings:
TX Channel = CH18 2440 MHz
TX Power = 0 dBm
TX Modulation = CW
Battery Voltage = 3265 mV

Top Menu: g) go s) status c) config r) rx t) tx d) default
TX Conf Status:
NWK_SUCCESS_STATUS

Top Menu: g) go s) status c) config r) rx t) tx d) default
```

Figure 8-2. Successful One-shot Reception



```
COM48 - PuTTY
Atmel MTK. Revision 1.2
Part Number = 0x94
Version Number = 0x03

Top Menu: g) go s) status c) config r) rx t) tx d) default
DUT Settings:
TX Channel = CH18 2440 MHz
TX Power = 0 dBm
TX Modulation = CW
Battery Voltage = 3265 mV

Top Menu: g) go s) status c) config r) rx t) tx d) default
Waiting for packet
...
...
...
Packet Received
Payload:
QRV ATMEL MTK
RSSI:
-61 dBm

Top Menu: g) go s) status c) config r) rx t) tx d) default
```

9 Know Issues

The one-shot test is a compromise; one-shot was chosen to avoid network configuration issues, code space consumption and feature creep on the DUT. Test protocols requiring larger sample populations, parametric variation and statistical analysis can be managed at higher levels using test scripts and post-processing.

The LwMesh uses CSMA and AACK. These may have odd side effects in point-to-multi-point networks. To avoid confusion it is recommended to use SDMA or just power one DUT at a time.

The MTK is released for the ATmega256RFR2 Xplained PRO platform. This is a low cost platform and is not calibrated. Power outputs can be several dBm lower than the datasheet specs. Test systems also add cable losses and other attenuating elements. Furthermore, power settings in the transmitter and the RF power detector (used to measure RSSI) are not precisely linear. Characterization of “Gold” units with calibrated instruments is strongly recommended.

10 Python Script

Mtk_driver.py is a short python script is included as a starting point for Test Engineers. This was written using python 2.7.

11 References

- [1] [AVR[®] 2130: Lightweight Mesh Developer Guide](#)
- [2] IEEE Std 802.15.4[™]-2006
- [3] FCC CFR-2009-title47-vol1-part15
- [4] [AT02597: ZigBee[®] PRO Packet Analysis with Sniffer](#)

12 Appendix

12.1 IEEE 802.15.4 Relevant Sections

6.1.7, 6.1.2.1, 6.5 6.9 and Appendix E and Appendix F

12.2 Minimum Product Performance Targets

6.5.3.1 Transmit power spectral density (PSD) mask (-20dBc and -30dBm $f > f_c \pm 3.5\text{MHz}$)

6.5.3.3 Receiver Sensitivity -85dBm or better (using 6.1.7 packets)

6.5.3.4 Anti-jam and ACPR

6.9.3 Error Vector Magnitude 35%

6.9.4 Transmit carrier center frequency tolerance $\pm 40\text{PPM}$ ($\sim \pm 100\text{kHz}$) Across temperature, voltage and aging

6.9.5 Transmit Power -3dBm

6.9.6 Receiver maximum input level -20dBm

Line power $\leq 5\text{mA}$ Active mode and 14.5mA in Tx

12.3 Regulatory Testing

15.35 definitions Quasi-peak 100k bw $< 1\text{G}$ and average 1MHz bw $> 1\text{G}$

15.205 restricted bands; 2483.5-2500 and 4.5-5.15GHz $500\mu\text{V/m}$ @ 3m (+54dB μV)

(-41dBm/MHz ERP average using 1MHz detector, absolute limit)

15.209 general rule spurious emissions -20dBc

15.247 wideband DSSS 1 Watt max. w/ +6dBi antenna

13 Revision History

| Doc Rev. | Date | Comments |
|----------|---------|---------------------------|
| 42286A | 04/2014 | Initial document release. |

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