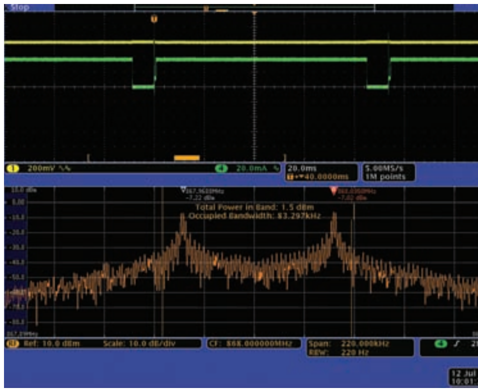

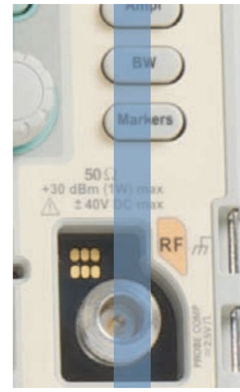

Hunting Noise Sources in Wireless Embedded Systems

Application Note

When integrating a radio chip or module into a typical embedded system, a common task designers must face is tracking down and eliminating noise and spurious signals. Potential noise sources include switching power supplies, digital noise from other parts of the system, and external sources. Noise considerations also include any possible interference generated by the radio; an important consideration to avoid interfering with other radios as well as to meet radio agency requirements. In this application note, tips and techniques for hunting noise sources with the MDO4000 Series Mixed Domain Oscilloscope Series will be explored.

Tektronix®

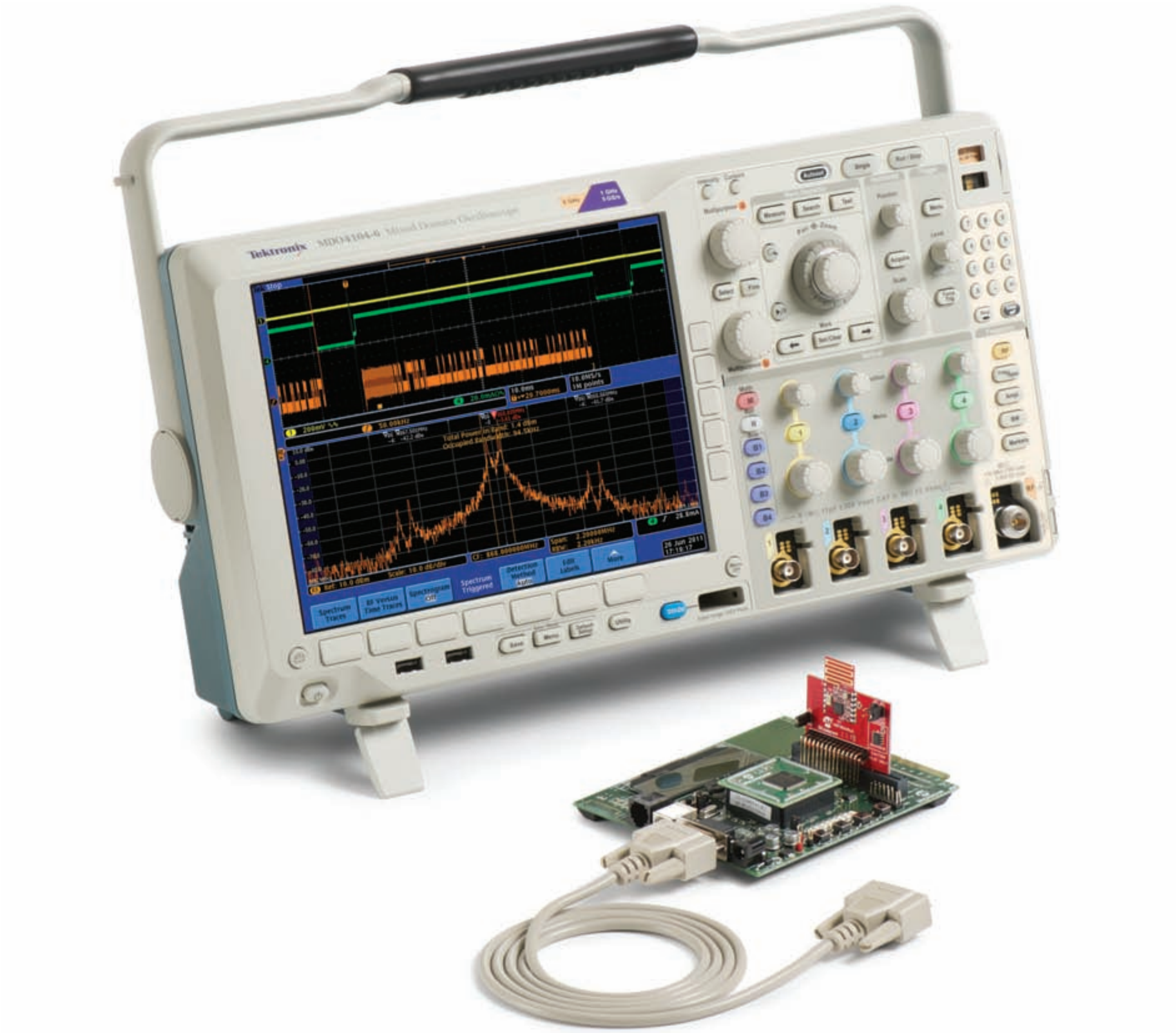

Figure 1. Tektronix MDO4000 Series Mixed Domain Oscilloscope and Microchip Radio Test Board Module.

Integrating Wireless Capability into Embedded Systems

In adding wireless capability to embedded systems, there are a number of issues typically encountered in the integration.

For battery powered systems, a switching regulator is typically used to have the highest practical efficiency at the lowest cost. The size of the power supply is also often an issue. This can lead to the use of high switching frequencies to minimize the size and requirements of output filtering. These power supplies often have ripple on the output voltage which can show up on the RF transmitter output, especially when under load or under low battery conditions. To avoid this, additional power supply filtering may be needed to avoid unwanted impairment of the radio signal, even though the cost or size is undesirable.

The hardware circuits and the software configuration of the radio chip or module can affect the quality of the transmitted signal. If not properly set up and filtered, the radio can cause interference to other radio systems and/ or fail to conform to applicable agency regulations. Some radio systems will need channel filters, RF Surface Acoustic Wave, or other relatively expensive filters to meet agency regulations for out-of-channel and out-of-band emissions.

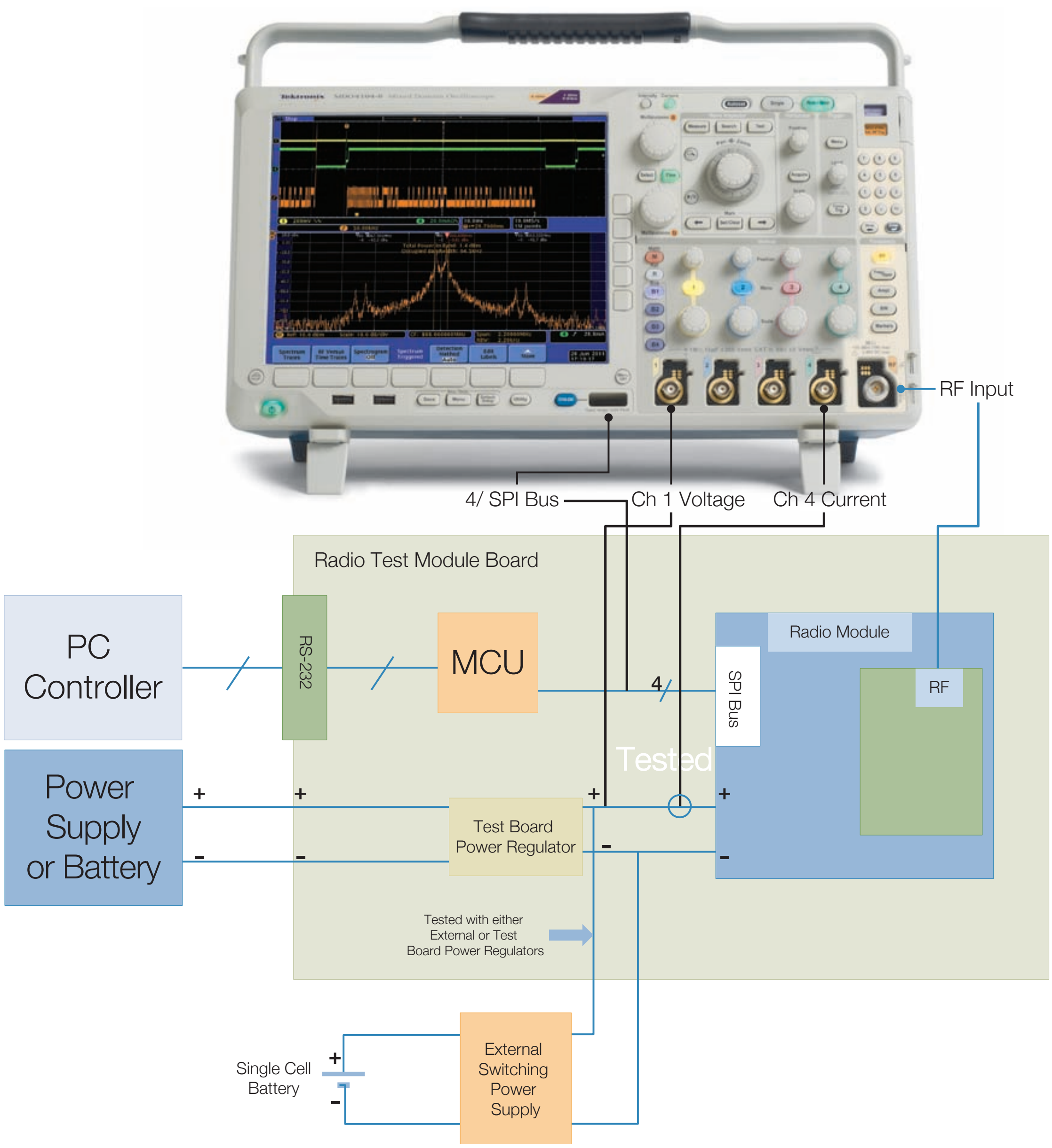

Figure 2. Test connection between the device under test (Microchip Technologies MRF89XA 868 MHz radio) and the MDO4000 Series Mixed Domain Oscilloscope.

Application Example: Wireless-enabled Embedded System with a Switching Power Supply

For the following discussion, the device under test will use a flexible radio integrated circuit already integrated into a module for radio test, the Microchip Technologies MRF89XM8A. This module incorporates the MRF89XA integrated circuit radio along with filtering and antenna matching. For demonstration, this module is mounted to a Microchip Explorer 16 board and is used with a PC to program the setup of the radio.

To illustrate the effects of powering the radio with a switching power supply, a boost converter IC, the Microchip MCP1640, incorporated into an MCP1640EV evaluation board, is used.

This converter switches at about 500 kHz which is common for switching regulators. It can provide the 3.3 Volt output voltage needed by the radio module with an input voltage down to 0.8 Volts. This means the radio can be powered from a single cell, reducing the size of the battery for the product.

To troubleshoot this device, the Tektronix MDO4000 Series Mixed Domain Oscilloscope is used. The MDO4000 Series has the unique ability to simultaneously display four analog signals, 16 digital waveforms, up to 4 decoded serial and/or parallel buses, and one RF signal. All of these signals are time correlated to show the effects of control signals on the analog and RF domains. Figure 2 shows the setup for the following tests.

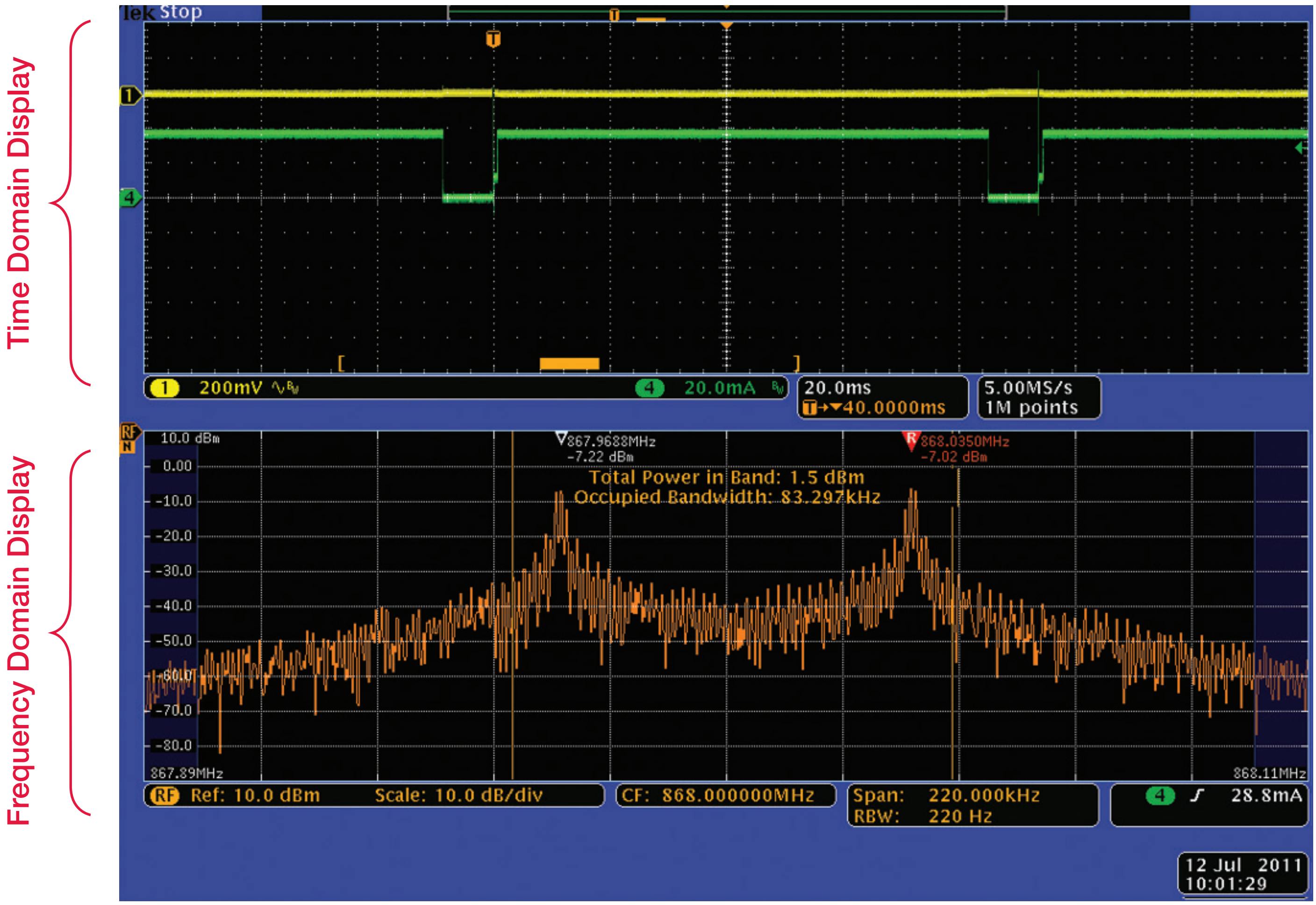

Figure 3. Viewing the time and frequency domains.

Identifying Noise Sources

For reference, measurements of the radio spectrum centered at 868 MHz with a fairly low data rate of 2 kbps of FSK modulation are taken. Figure 3 shows the reference spectrum. Notice that the MDO4000 Series displays both the time and frequency domain views, and all signals are time correlated.

The lower half of the display shows the frequency domain view of the RF signal, in this case the radio transmitter output, while the upper half of the display is a traditional oscilloscope view of the time domain. The spectrum shown in the frequency domain view is taken from the period of time indicated by the short orange bar in the time domain view – known as the Spectrum Time.

Since the Horizontal Scale of the Time Domain Display is independent of the amount of time required to process a Fourier Transform (FFT) for the Frequency Domain Display, it is important to represent the actual time period that correlates to the RF acquisition. The unique architecture of the MDO4000 Series Oscilloscope enables separate time-correlated acquisitions of all inputs (digital, analog, and RF). Each input has separate memory, and depending on the horizontal acquisition time of the Time Domain Display, the RF signal acquired in memory allows the Spectrum Time and be move within the Analog Time shown in Figure 4.

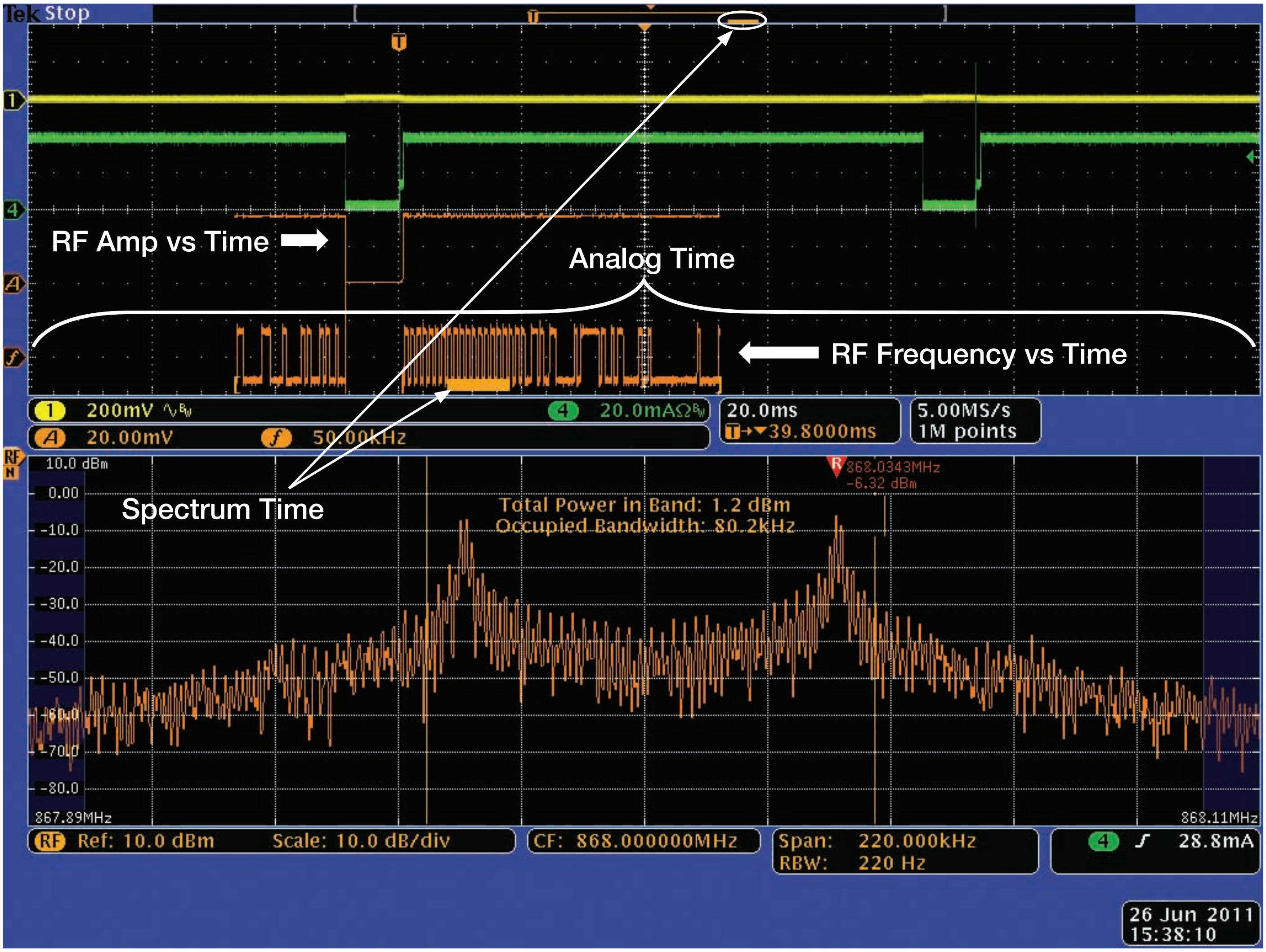

Figure 4. Occupied Power measurement shown during several symbols of the packet preamble using a clean laboratory power supply.

With the MDO4000 Series, Spectrum Time can be moved through the acquisition to investigate how the RF spectrum changes over time. In Figure 4, Spectrum Time is placed to show the spectrum of the transmitted signal during the several symbols of the preamble of the packet.

Spectrum Time is the amount of time required to support the desired resolution bandwidth (RBW) of the spectrum display. It is equivalent to the Window Shaping factor divided by the RBW. The default Kaiser Window has a shaping factor of 2.23, so the spectrum time is 2.23/220 Hz or approximately 10 ms in this example.

While FSK modulation has only one frequency of the RF signal on at a time, a longer acquisition time of the preamble is used for the spectrum to enable measurements of the occupied bandwidth and the total power.

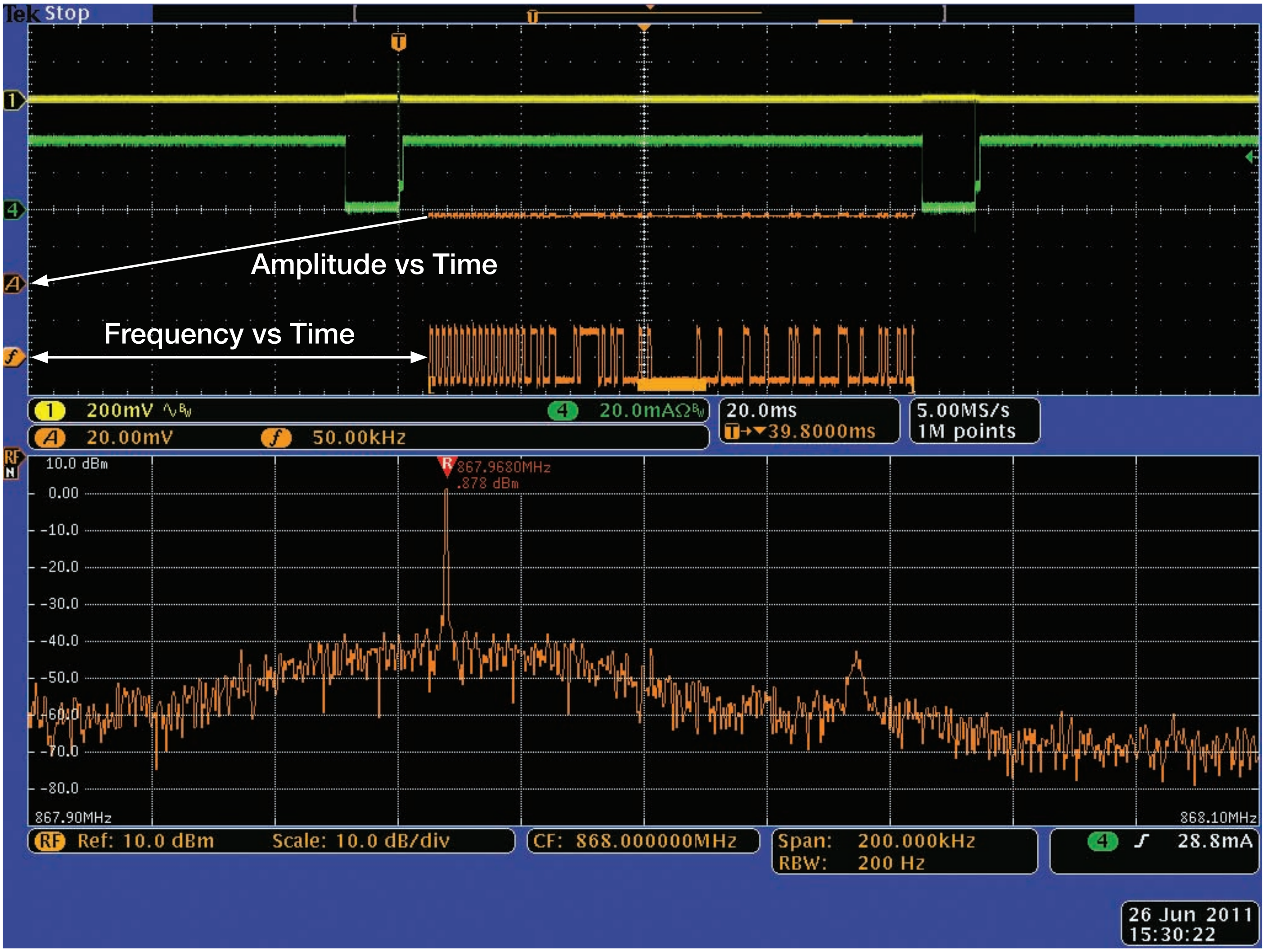

Figure 5. Spectrum during packet data. The Frequency vs. Time trace shows the Spectrum Time acquired primarily during the lower frequency Tx ON time.

To easily see the packet transmission from the radio, RF vs. Time traces have been added to the time domain view of the MDO4000 Series. The orange trace marked with "*A*" shows the instantaneous RF amplitude vs. time. While the orange trace marked with "*f*" shows the instantaneous RF frequency vs. time, relative to the center frequency of the display.

The green trace (Channel 4) shows the current into the module. As can be seen, the current rises from close to 0 between packets, to about 40 mA during transmission. The yellow trace (Channel 1) shows the AC ripple on the power supply voltage at the module. Note that there is only a small dip in the voltage during transmission.

Figure 5 shows the same signal taken during the data portion of the packet. Note that most of the energy is in the lower frequency. Both Figure 4 and Figure 5 are taken with the module powered by a clean laboratory power supply.

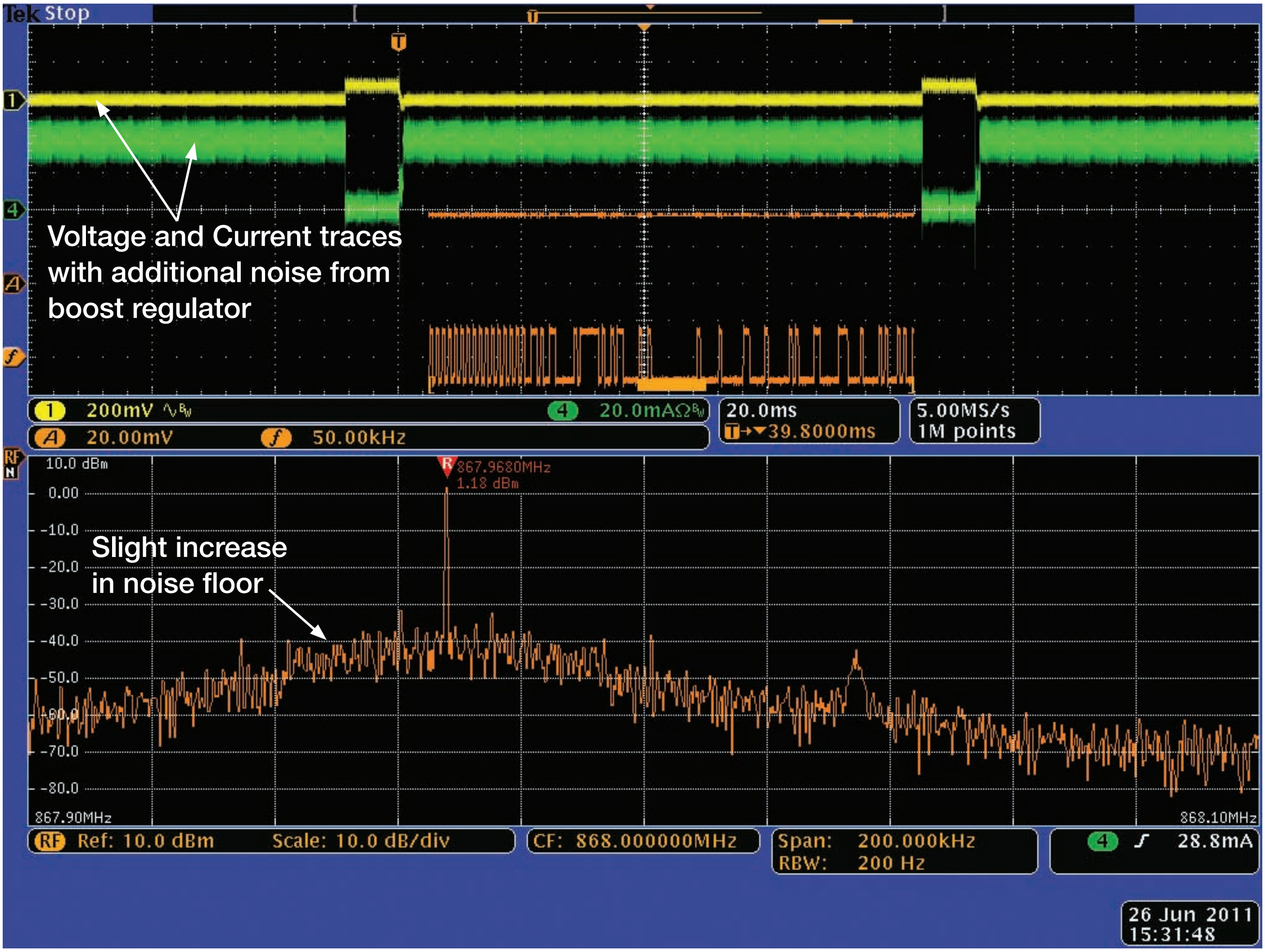

Figure 6. Spectrum and power supply measurements with a switching power supply.

In Figure 6, the same RF signal is shown but with a boost type switching supply powering the radio module. Boost regulators are notorious for generating noise, but are valuable to allow the use of a battery with one or two alkaline or NiCad cells and relatively few components, lowering the cost. Note the increase in noise at the base of the modulated signal. Near the transmitted signal, there is noise at least 5 dB higher than with the clean power supply. The noise is also readily apparent in the current and voltage waveforms. The additional noise would also degrade the signal-to-noise ratio of the signal at the receiver used to gather the data from this transmitter, reducing the effective range of the radio system.

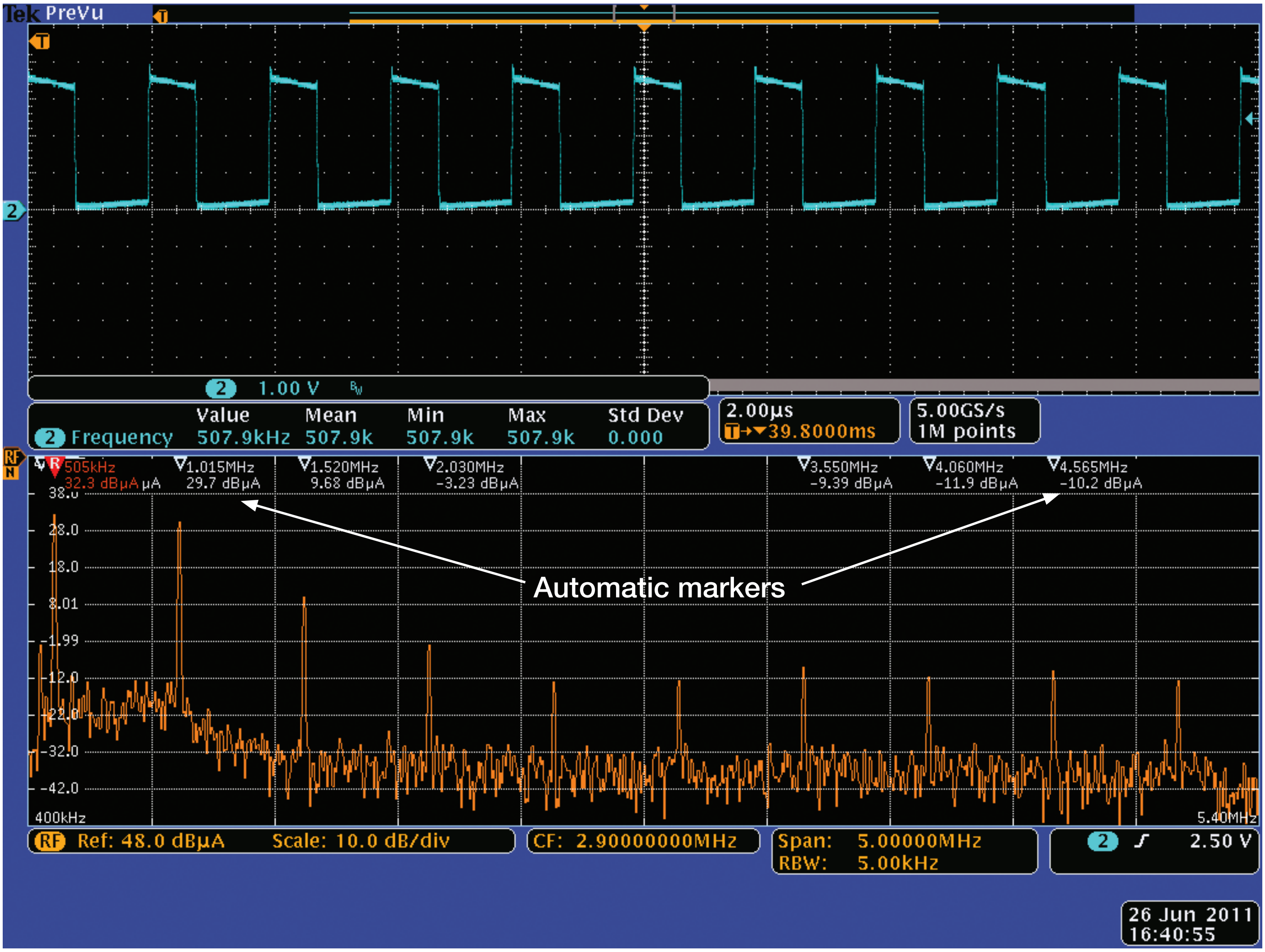

Figure 7. Power supply switching noise into dummy load.

The noise from the power supply can be measured with a commercially available EMI current probe used to observe the noise from the switcher in Figure 7. For this example, the switcher is being loaded by a resistor and small capacitor.

The automated marker function of the MDO4000 Series is used to show the frequency and amplitude of the most prominent seven signals radiating from the supply. The MDO4000 Series can provide up to 11 automated markers and display the results in absolute values, or referenced to the largest signal as delta values. The highest value is always represented as the Red Reference marker. Note that the fundamental frequency and the second harmonic are about the same level at around 30 dBuA. The upper half of the screen shows the waveform at the switching transistor in the MCP1640 IC. The measurement function is used to show the switching frequency to confirm the RF marker measurement.

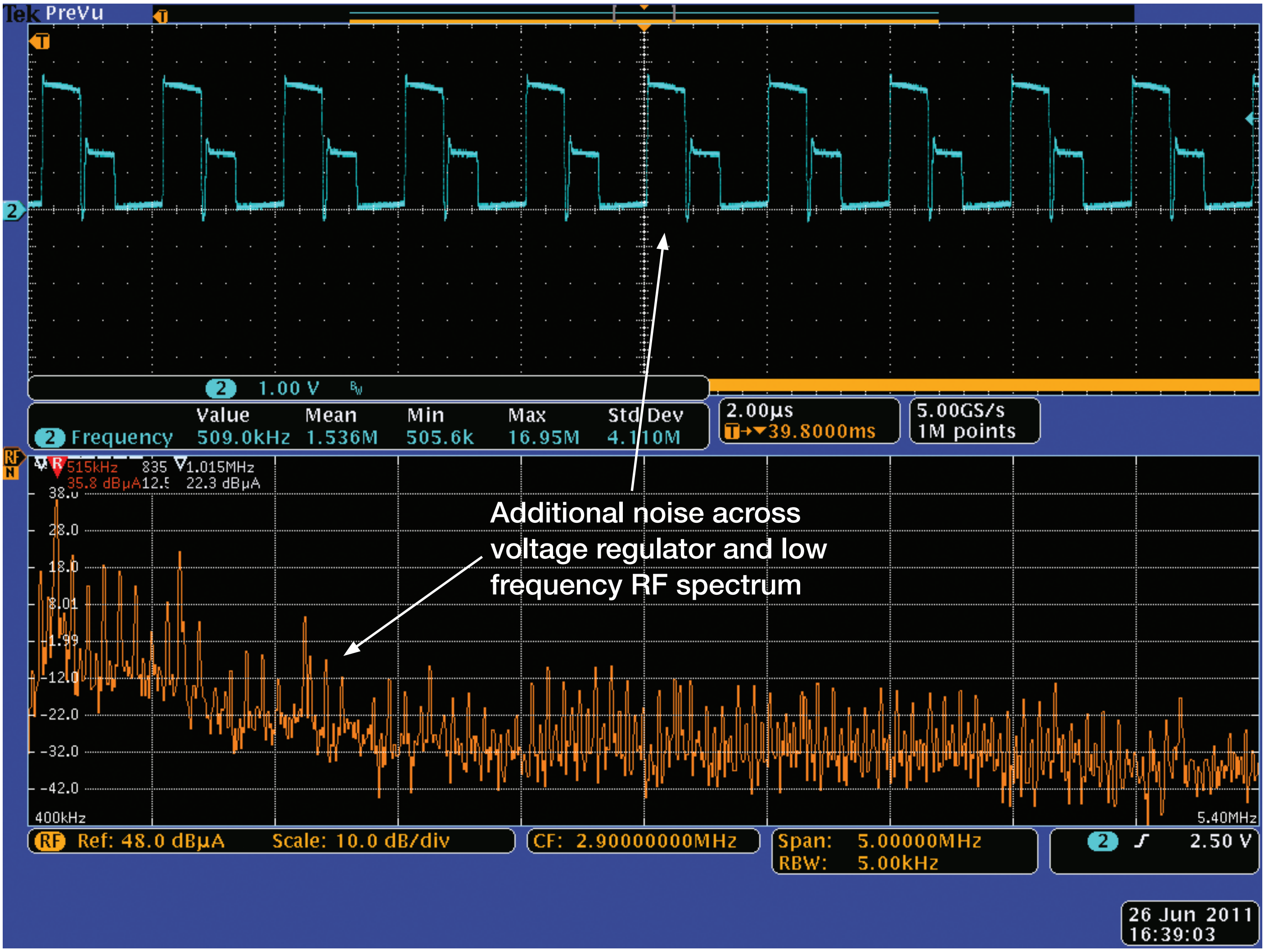

Figure 8. Power supply and board noise using boost converter.

When the power supply drives the RF board, the time and frequency domain displays of the noise power are changed. Figure 8 shows the same power supply noise plus additional signals. Note that the second harmonic is reduced, but there is a lot of other low level noise. Some of this noise may well interfere with the operation of the radio receiver and needs to be carefully evaluated.

The digital board can generate noise as seen in Figure 9. A simple wire probe can be used to look for the source, amplitude and frequencies of such noise. The MDO4000 Series can cover a wide range of frequencies in one sweep with good response time.

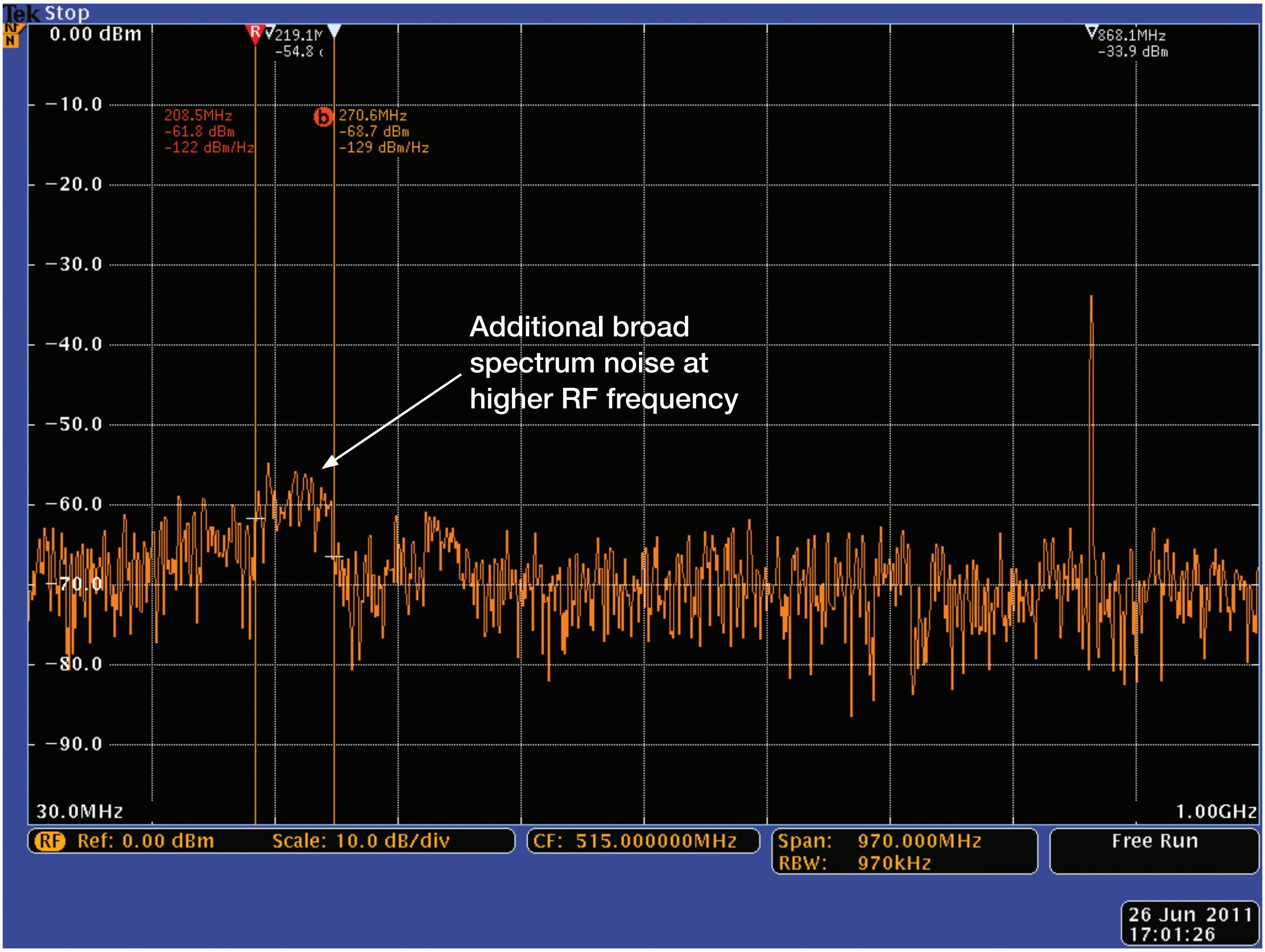

Figure 9. Broad spectrum noise from digital board when using boost converter.

Figure 9 shows significant noise in the range of 220 MHz. The automated markers show the 868 MHz transmitted signal as well as the highest level of unwanted signal. The manual markers are used to measure the frequency range of the highest level of noise. The displayed measurement in the manual markers also includes the noise density of the signal of interest. Understanding this type of noise power can be important because, depending on the radio receiver architecture, the receiver sensitivity can be impaired by noise at various frequencies.

Figure 10. Out of Channel Spectrum around fundamental signal.

Noise Generated by the Radio

In adding a radio system to an embedded system, there is also the potential problem of the radio generating noise and either interfering with other parts of the system, or of failing to meet regulatory limits on radio signals. The measurements offered by the MDO4000 Series such as occupied bandwidth and total power transmitted can also help evaluate regulatory compliance.

Figure 10 shows the spectrum of the desired signal as well as the spurious transmissions in neighboring frequencies. It shows some spurious signals around 500 kHz either side of the fundamental, but they are about 40 dB below the fundamental so they would be acceptable under most regulations. This figure also shows the measured signal power of 1.4 dBm and occupied bandwidth of 94.5 kHz which fits within a typical 100 kHz acceptable bandwidth.

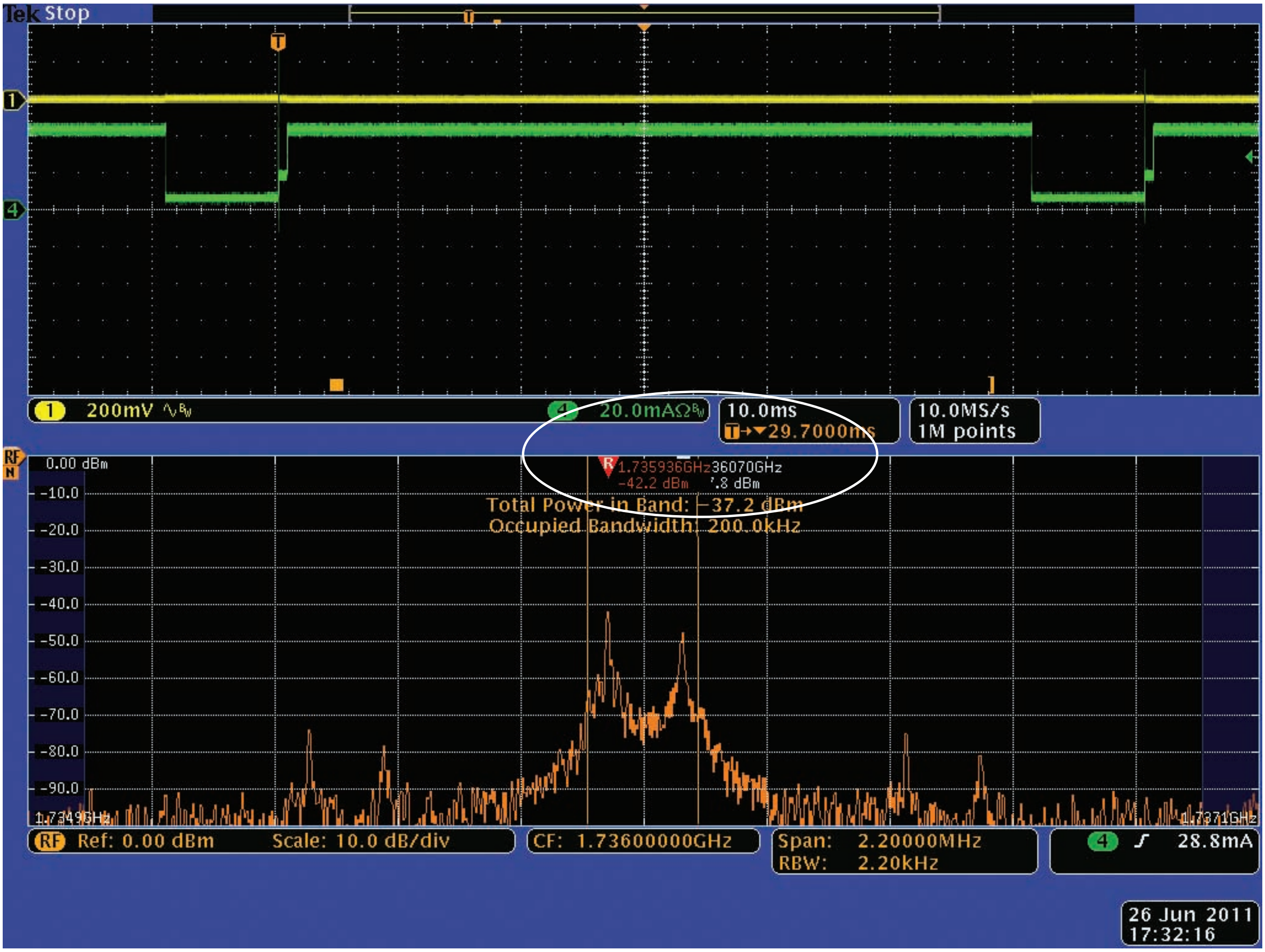

Figure 11. Spectrum at the second harmonic.

Figure 11 shows the second harmonic with the same measurements as at the fundamental frequency in Figure 10. Note that the power level at the second harmonic is slightly less than 40 dB down from the fundamental and the Occupied Bandwidth is twice the bandwidth of the spectrum of the fundamental.

Figure 12. Spectrum at the third harmonic.

Figure 12 shows the third harmonic which is often the most troublesome in radio systems. However, at this frequency the signal is down to a very low level of noise power relative to the carrier (~ -60dBc).

Figure 13. Spectrum at the sixth harmonic. Peak values of markers show signals down -80 dBm.

The MDO4000 Series allows for measurements in this band up to the sixth harmonic. By this frequency, this radio has almost insignificant emissions at less than -80 dBm as seen in Figure 13 (note the values at the two markers).

Summary

There are a number of key issues to watch for when including wireless communications in an embedded system. These include the effects of power supply switching noise, correctly setting up the operating parameters of the radio integrated circuit, and assuring that the transmitted output conforms to applicable radio regulations.

The Tektronix MDO4000 Mixed Domain Oscilloscope Series provides the capabilities to diagnose and test for power supply and other noise effects. It has the ability to confirm that the data commands to the radio are being set correctly, and the ability to check for spurious emissions from the transmitter and other circuits. It can be used to measure RF signals up to 6 GHz, but is also valuable to look at lower frequency noise from switching power supplies and from digital circuits with time-correlated acquisitions.

Contact Tektronix:

ASEAN / Australasia (65) 6356 3900
Austria* 00800 2255 4835
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium* 00800 2255 4835
Brazil +55 (11) 3759 7627
Canada 1 (800) 833-9200
Central East Europe and the Baltics +41 52 675 3777
Central Europe & Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
France* 00800 2255 4835
Germany* 00800 2255 4835
Hong Kong 400-820-5835
India 000-800-650-1835
Italy* 00800 2255 4835
Japan 81 (3) 6714-3010
Luxembourg +41 52 675 3777
Mexico, Central/South America & Caribbean 52 (55) 56 04 50 90
Middle East, Asia and North Africa +41 52 675 3777
The Netherlands* 00800 2255 4835
Norway 800 16098
People's Republic of China 400-820-5835
Poland +41 52 675 3777
Portugal 80 08 12370
Republic of Korea 001-800-8255-2835
Russia & CIS +7 (495) 7484900
South Africa +27 11 206 8360
Spain* 00800 2255 4835
Sweden* 00800 2255 4835
Switzerland* 00800 2255 4835
Taiwan 886 (2) 2722-9622
United Kingdom & Ireland* 00800 2255 4835
USA 1 (800) 833-9200

*** If the European phone number above is not accessible, please call +41 52 675 3777**

Contact List Updated 10 February 2011

For Further Information
Tektronix maintains a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit **www.tektronix.com**

Copyright © 2011, Tektronix. All rights reserved. Tektronix products are covered by U.S. and foreign patents, issued and pending. Information in this publication supersedes that in all previously published material. Specification and price change privileges reserved. TEKTRONIX and TEK are registered trademarks of Tektronix, Inc. All other trade names referenced are the service marks, trademarks or registered trademarks of their respective companies.

08/11 EA/FCA-POD 48W-26920-0

Tektronix®