Report: TR 14-1007

MEASUREMENT OF FUNDAMENTAL EMISSIONS OF FMCW LEVEL PROBING RADARS (LPR) UNDER PART 15, SECTION 15.256

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Measurement of Fundamental Emissions of
FMCW Level Probing Radars (LPR)
Under Part 15, Section 15.256

Section 15.256 of Part 15 provides for level probing radars. There are two basic types of LPRs – pulsed and swept frequency. The rules specify limits on the fundamental emission measured with an average detector in a 1 MHz RBW and with a peak detector in a 50 MHz RBW. Procedures for the determination of the 1 MHz average and the 50 MHz peak value for pulsed LPRs are well established. However, Section 15.31(c) specifies that unless otherwise indicated in Section 15.256, for swept frequency equipment, measurements shall be made with the frequency sweep stopped at those frequencies chosen for the measurements to be reported. This presents no problem for measuring the peak value of the signal, but is problematic for determining an average value.

Figures 1 through 4 show simulated FMCW LPR signals with sweep times of 10 msecs to 10 seconds and a retrace time of 80 msecs. During the on times the frequency is sweeping through a 1 GHz span for all sweep times. Therefore, the average in a 1 MHz RBW is not the duty cycle obtained by dividing the on time by the total cycle time (the on time plus the retrace time). Determining the average in 1 MHz for a complete cycle requires a different approach.

For example, if the frequency sweep time is 10 ms and the sweep span is 1000 MHz, then the sweep time per megahertz is 10 µsec/MHz (10 ms/1000MHz). With a retrace time of 80 ms, the total cycle time is 90 ms (10 ms sweep plus 80 ms retrace time), so the average signal time in any given 1 MHz for one cycle is 10µsec/90 ms which is 0.00011 = -39.5 dB. Therefore, the average in one cycle is 39.5 dB below the peak level. For another example, if the frequency sweep time is 10 ms and the sweep span is 100 MHz, then the signal time in any given MHz is 100 µsec (10 ms/100 MHz) and the average for one cycle is 100 µsec/90 ms or 0.0011 which is 29.5 dB below the peak level. In general, the average power in 1 MHz per cycle is less than the peak power by the factor

Average factor = (sweep freq. time/sweep span in MHz)/cycle time

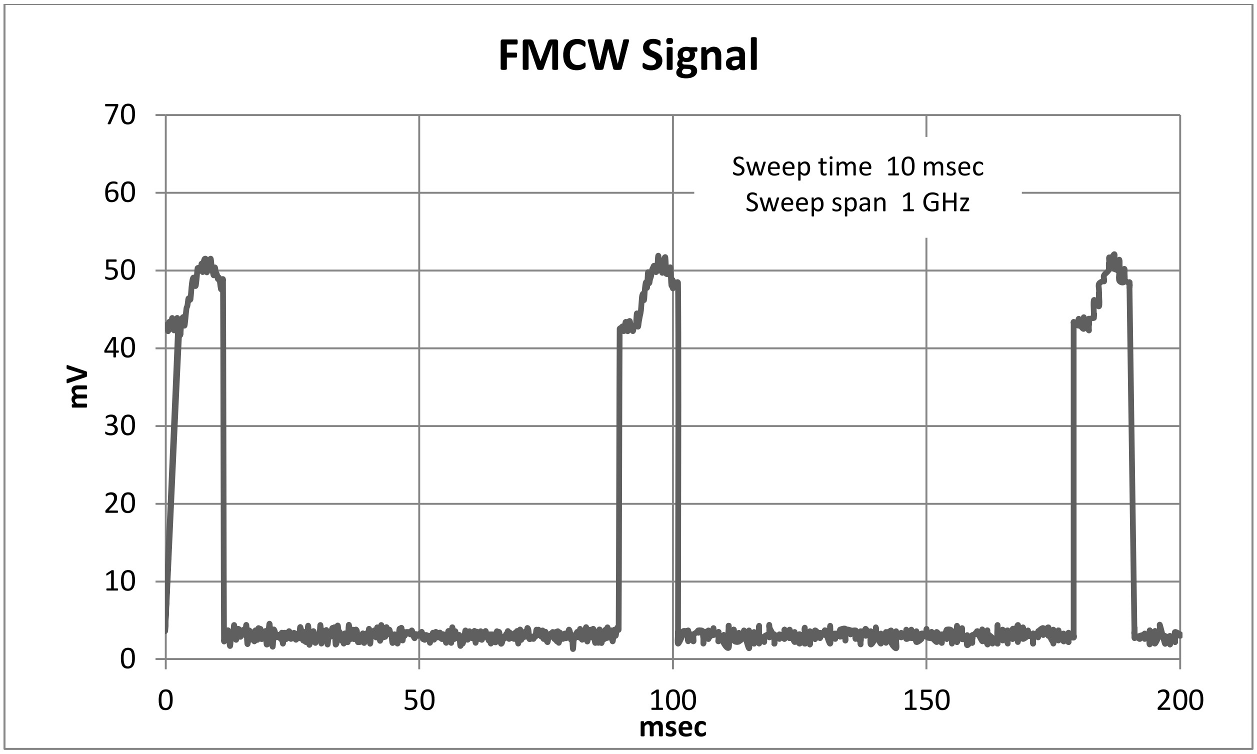

Figure 1

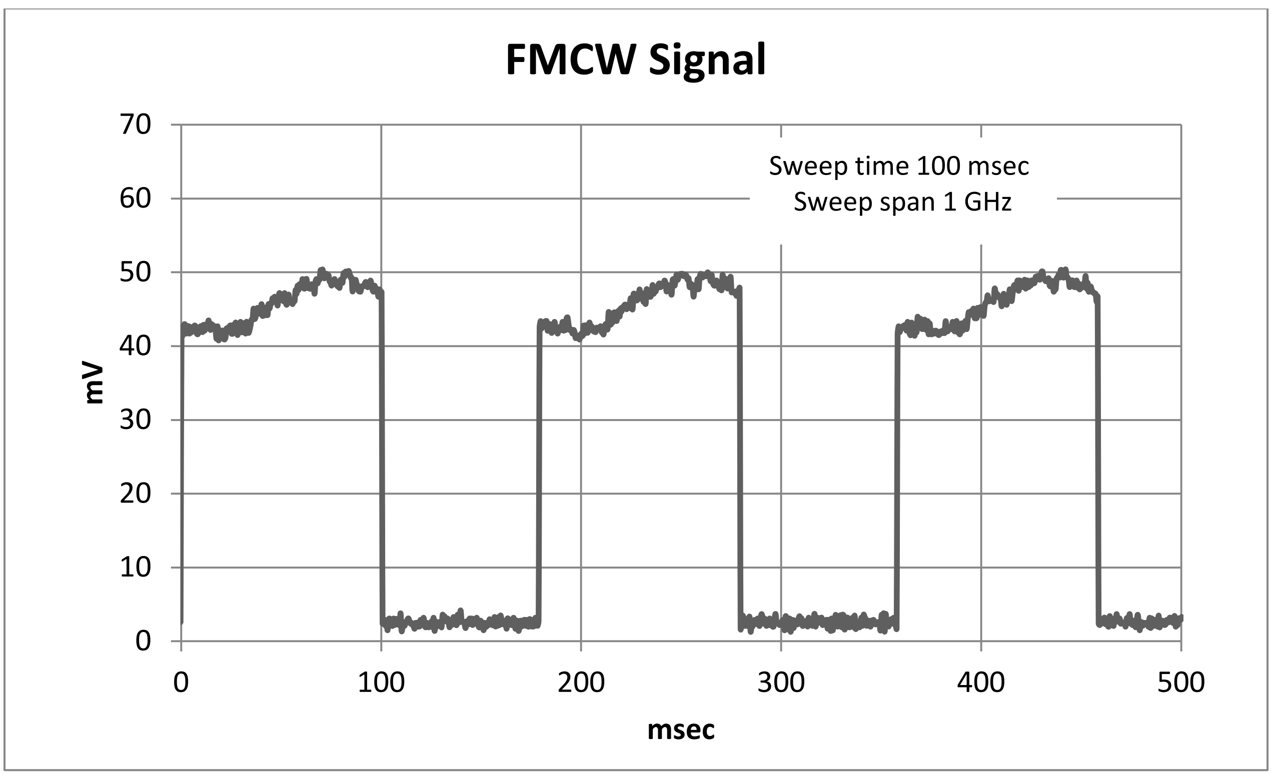

Figure 2

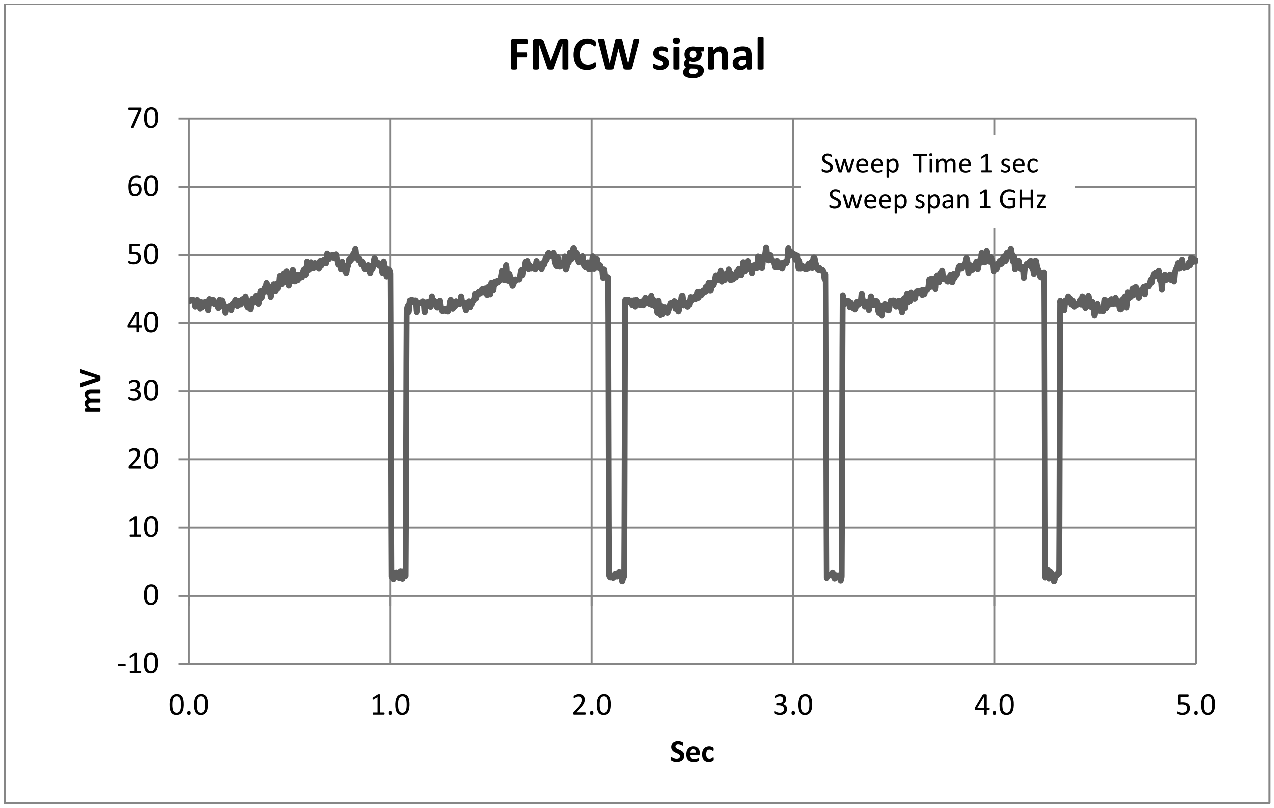

Figure 3

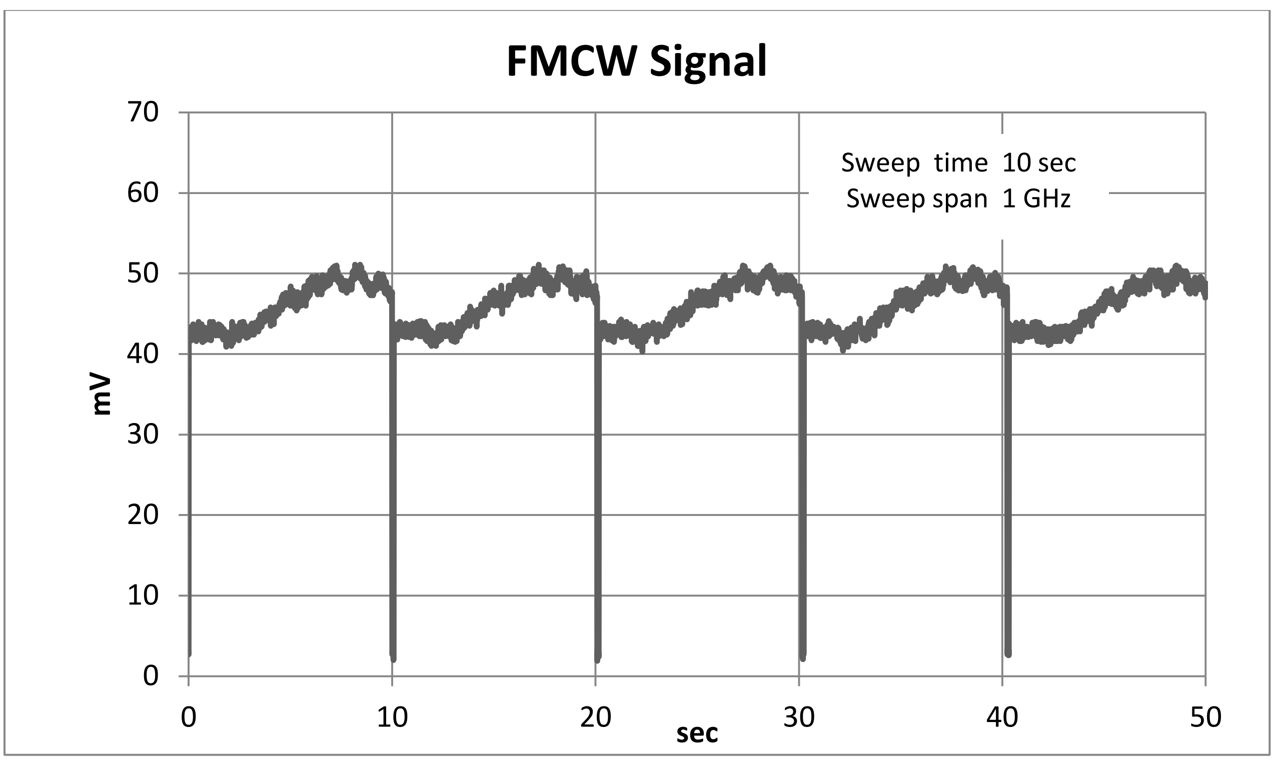

Figure 4

The theoretical calculation can be verified by actual measurement with a sweep frequency generator to simulate a sweep frequency LPR and a spectrum analyzer. The results for the first example are shown in Fig. 5. A word of explanation is required here. The plot is for multiple analyzer scans with an average detector and a 1 MHz RBW in Max Hold for scan times from 1 to 1000 sec. For an analyzer scan time of 1 sec over 1000 points, the dwell time at each point is 1 ms. If the signal sweep time is 10 ms over 1000 MHz, then the time per MHz is 10 µsec (10 ms/1000) so the averaging of a 10 µsec signal time for a dwell time of 1 ms will periodically produce a display point with an amplitude 20 dB (10 µsec/1 ms) below the peak amplitude when the signal sweep frequency is coincident with the analyzer scan frequency. At all other times the amplitude is zero. When the analyzer scan time is increased to 100 sec, the averaging occurs for 100 ms at each point (100 sec/1000) which is slightly more than the cycle time of 90 ms and the trace shows an average of about 40 dB below the peak with periodic spikes of 3 dB. The spikes are caused by the averaging time of 100 ms periodically including more than one 90 ms cycle time. When the analyzer scan time is increased to 1000 sec, 11 or 12 cycles are averaged to produce a plot at about 40 dB below the peak with smaller spikes. As the analyzer scan time is increased above 1000 sec, the average remains at about 40 dB below the peak with decreasing spike amplitude but with amplitude variation caused by the sweep signal variation with frequency. Fig. 6 shows the results of capturing the signal for a single scan for each scan time at the frequency where the sweep signal frequency is coincident with the analyzer scan frequency. As the analyzer scan time increases, the sweep frequency is equal to the scan frequency for a greater time, so the averaging time increases with respect to the cycle time which produces a lower average until the scan time increases to the point where the time at each scan frequency is equal to the cycle time. As the scan time increases, the average no long decreases but the amplitude of the spikes decreases.

Figures 7 to 12 show additional results for various combinations of the sweep signal parameters and the spectrum analyzer settings in Max Hold for multiple scans and for a single scan. Figure 13 shows the spectrum for a single scan time slightly below the cycle time, approximately at the cycle time, slightly above the cycle time and about 10 times the cycle time. Each scan time has been offset 10 dB above the next shorter scan time for better viewing but the actual power level is given to the left of each trace.

The measurements may also be performed at a given analyzer scan frequency in the zero scan mode. Figure 14 shows the results which are in agreement with Figure 8 which shows the spectrum for a 200 MHz analyzer scan width.

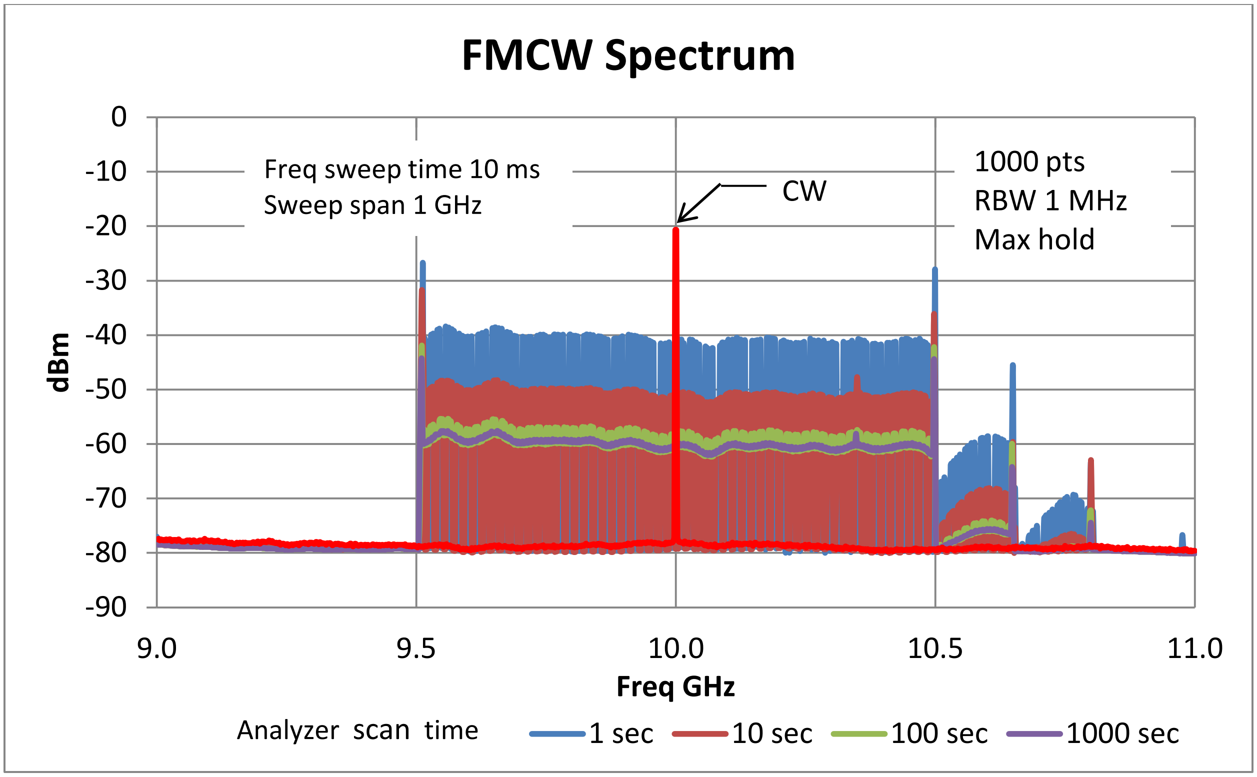

Figure 5

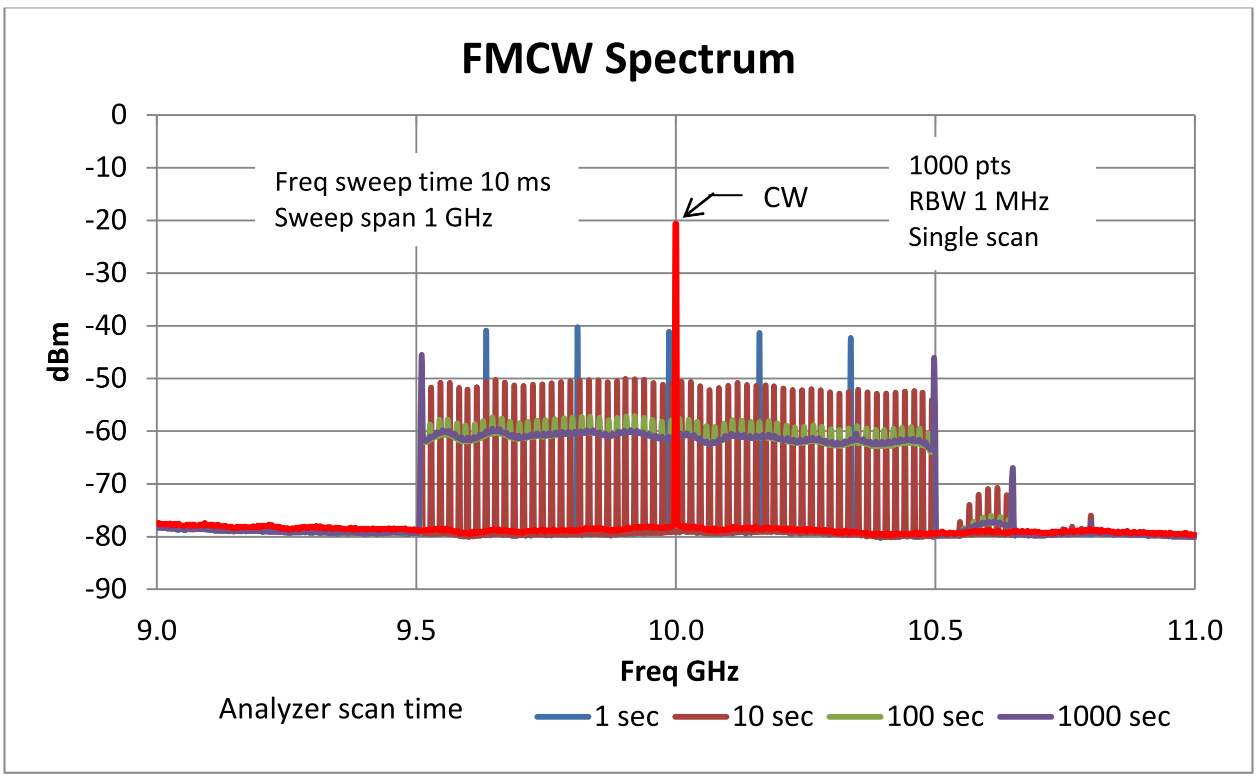

Figure 6

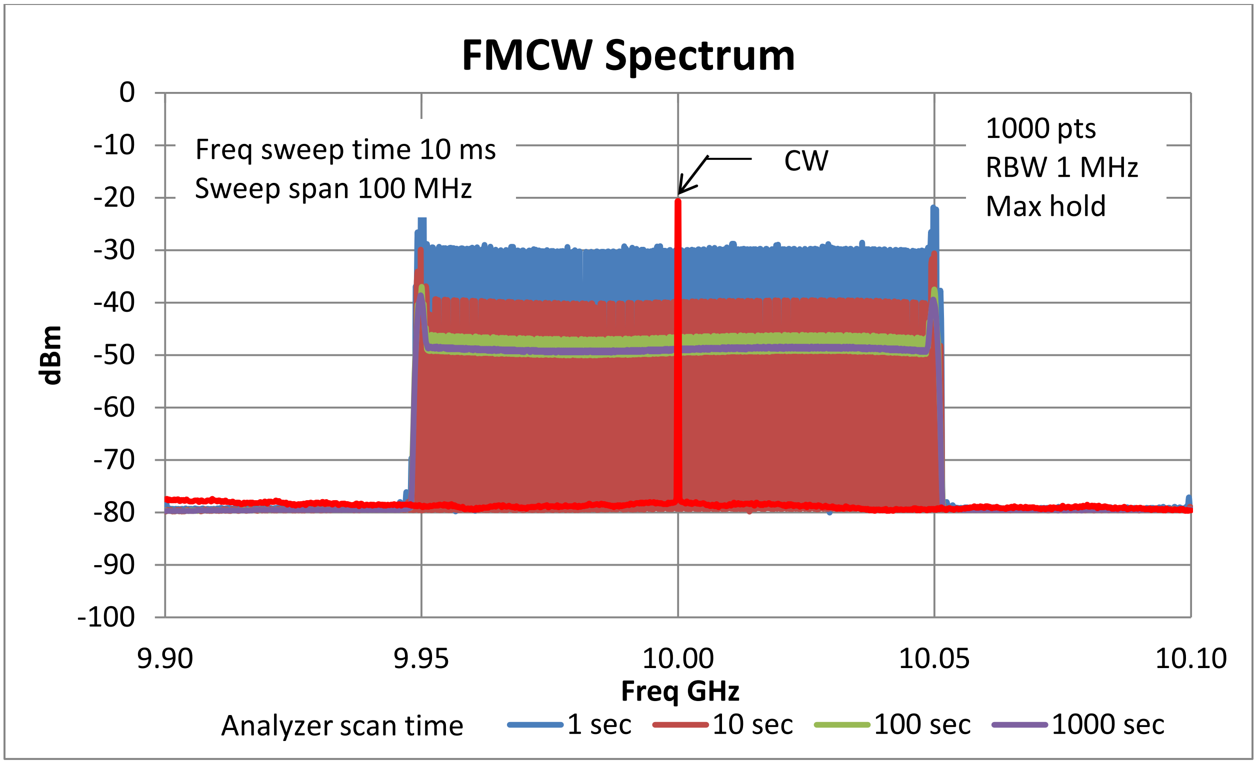

Figure 7

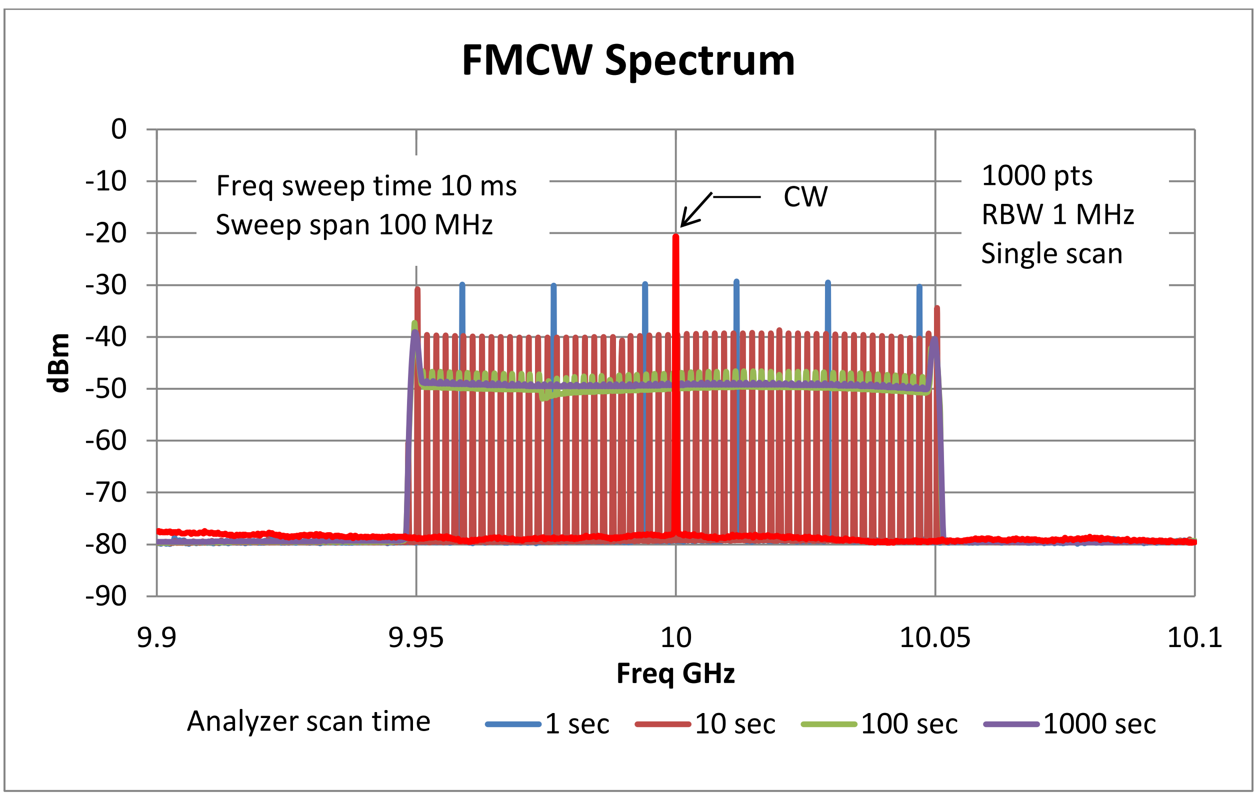

Figure 8

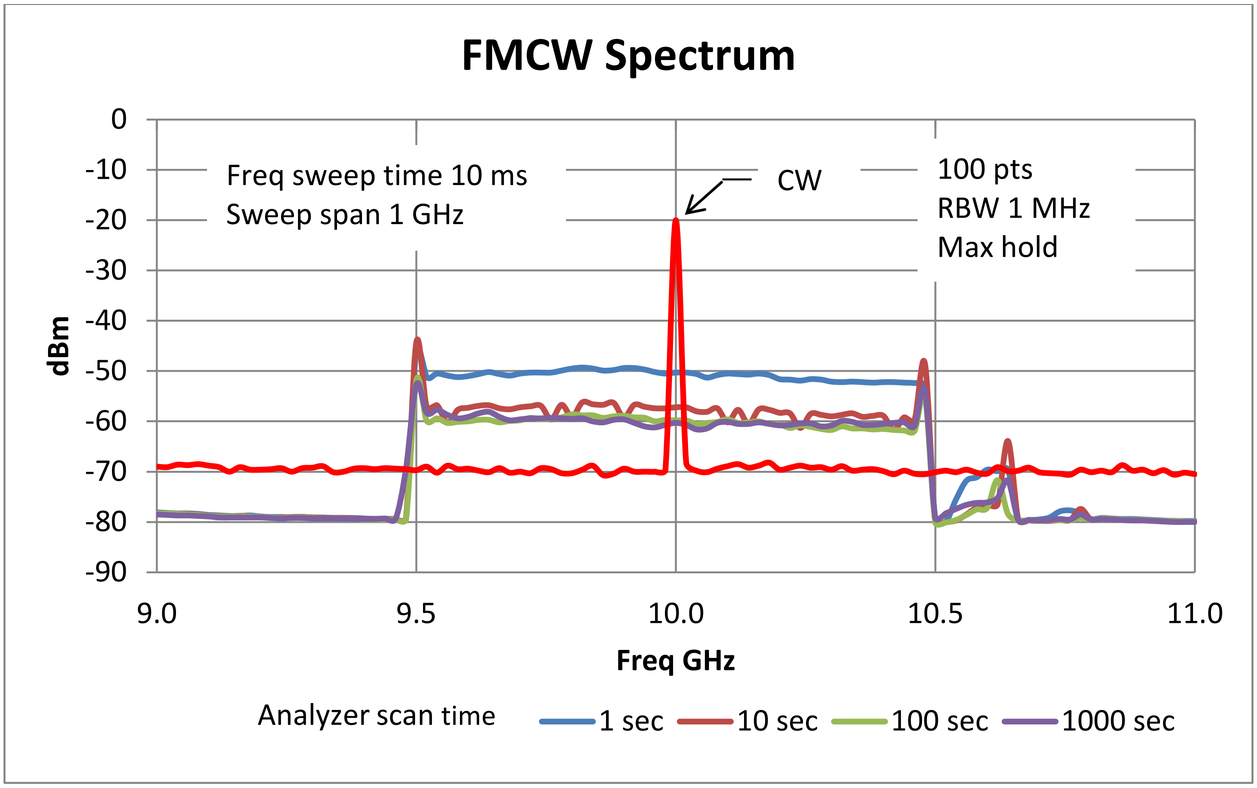

Figure 9

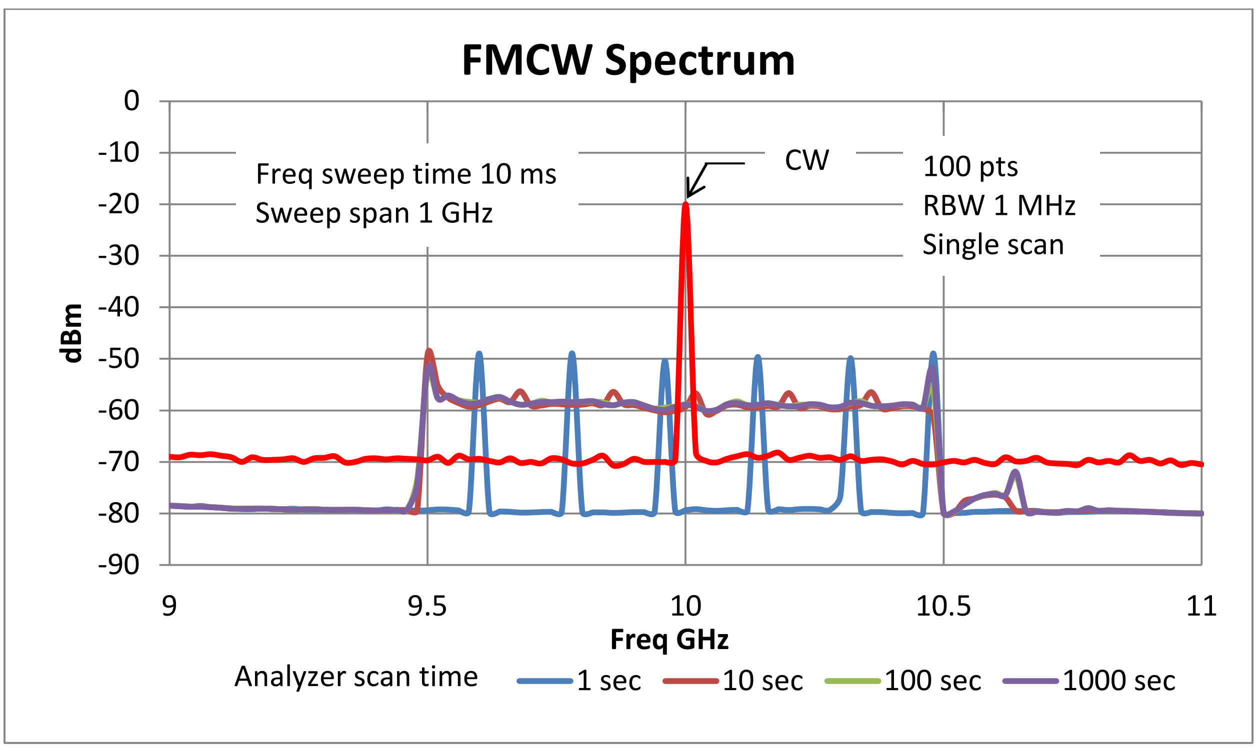

Figure 10

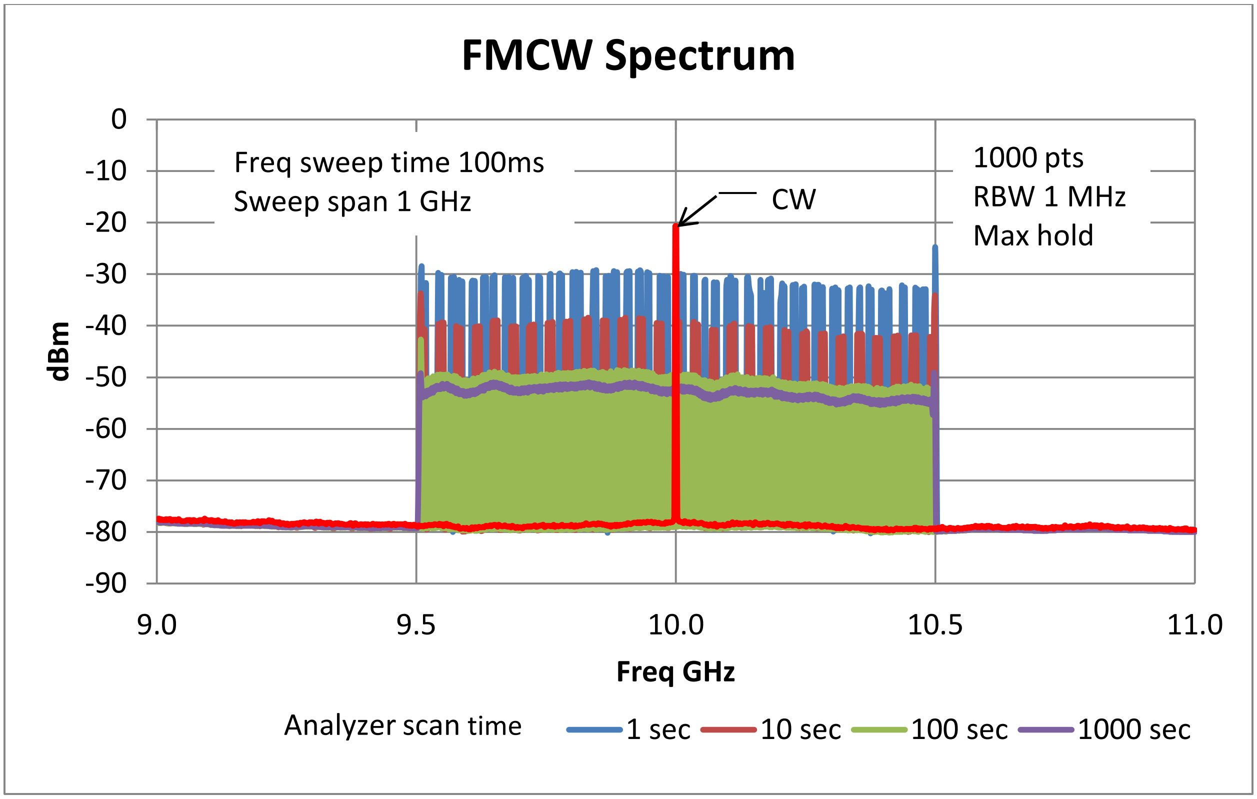

Figure 11

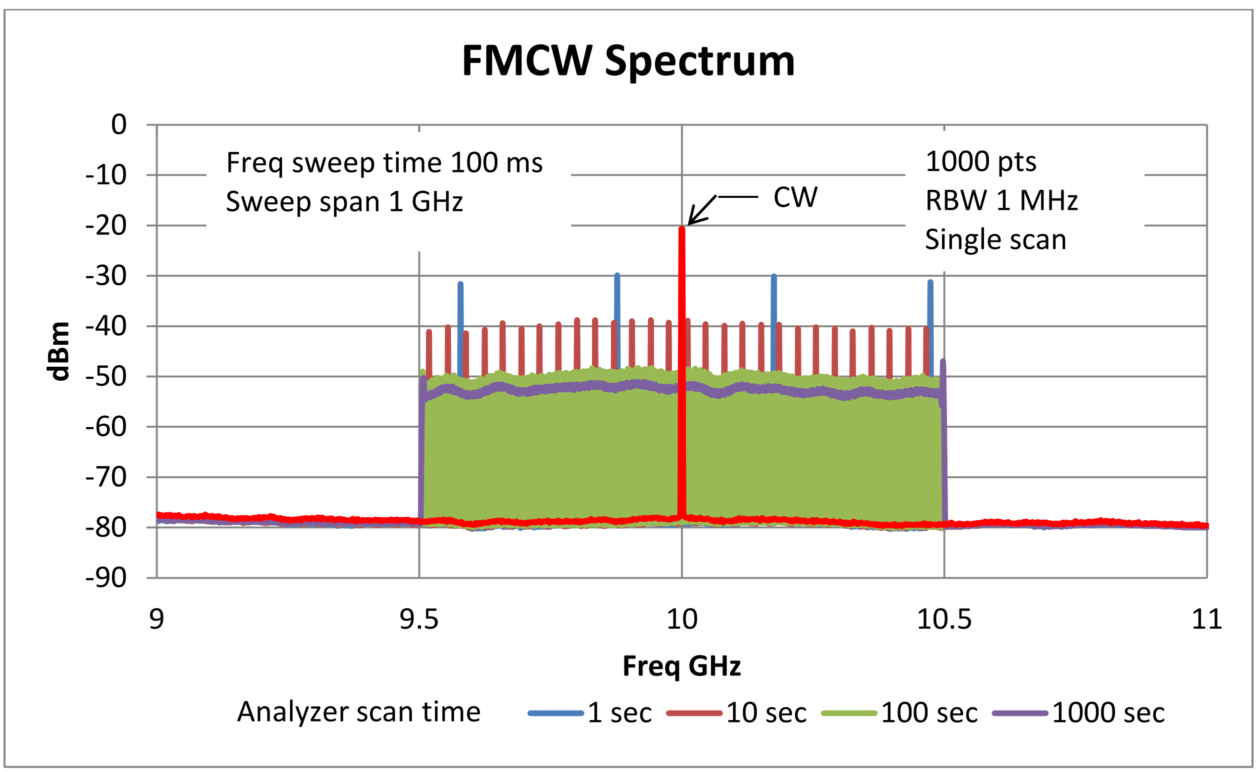

Figure 12

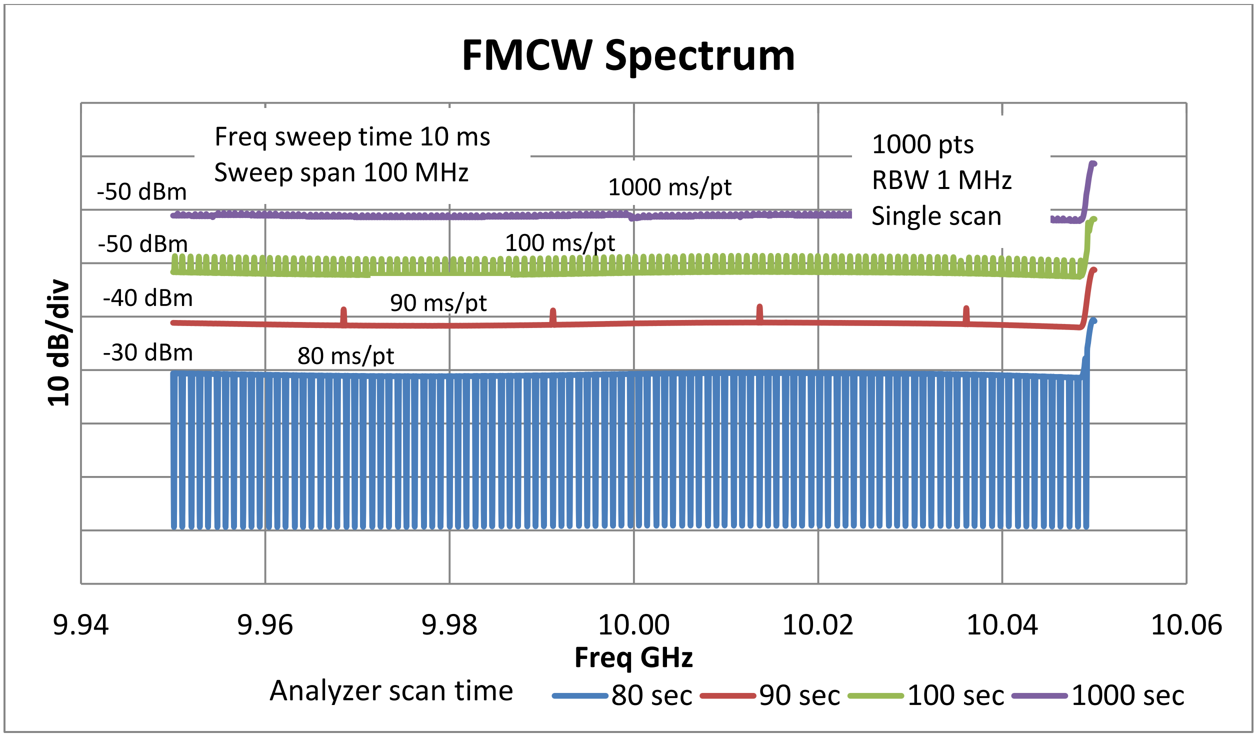

Figure 13

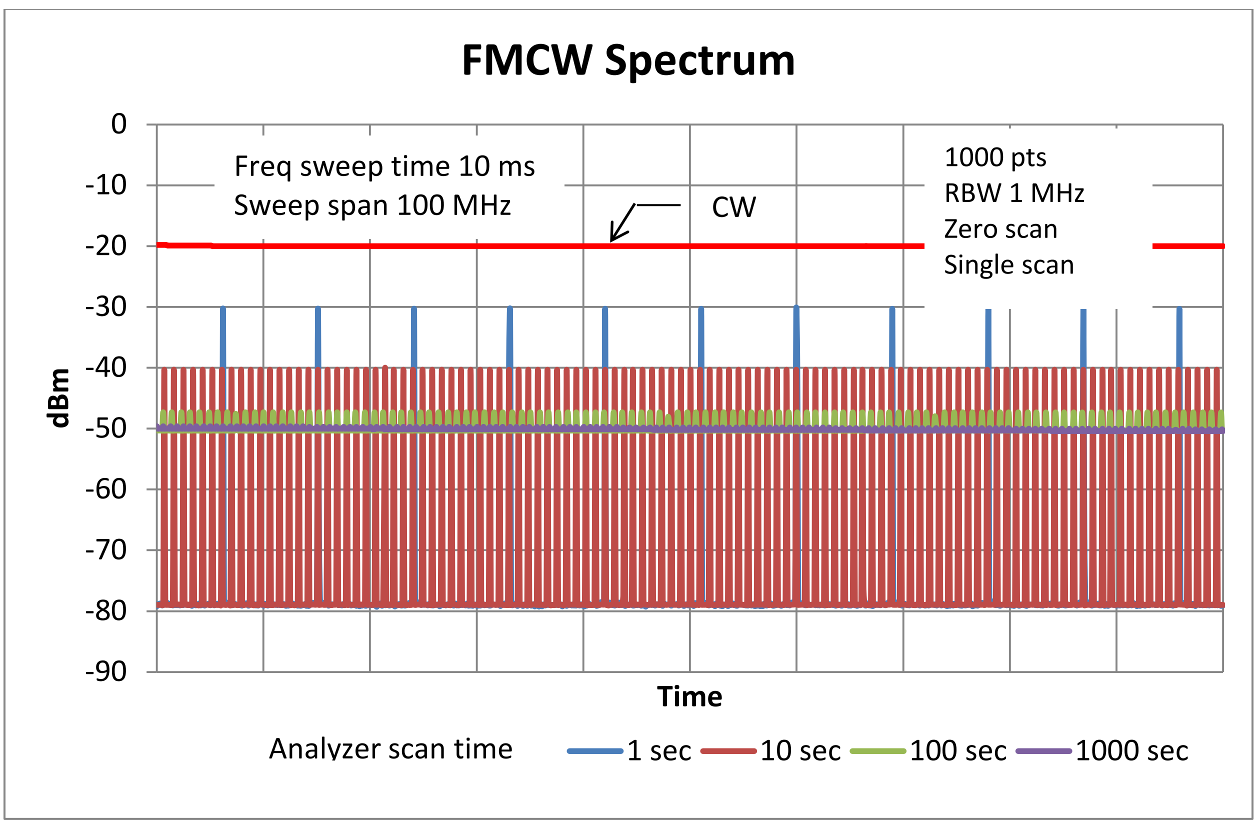

Figure 14