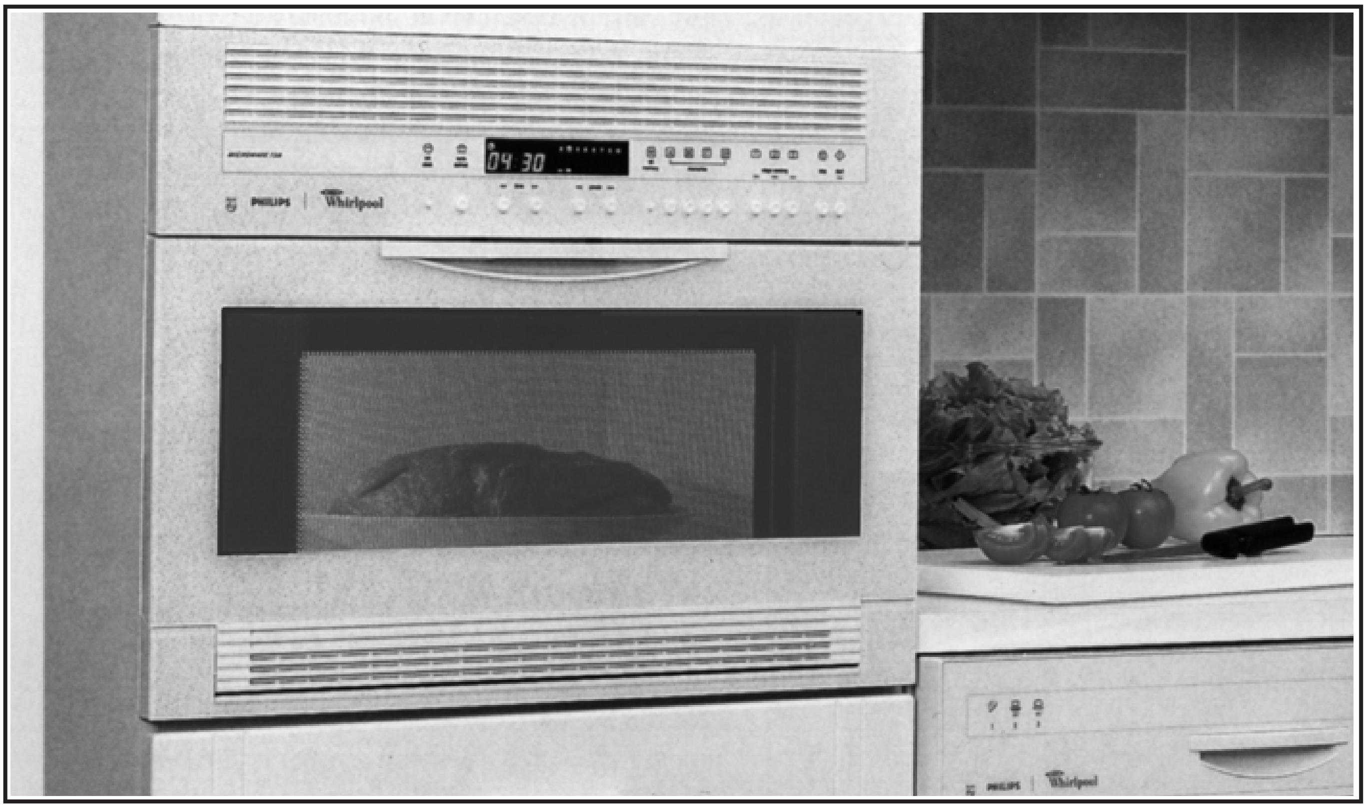
Monitoring magnetron on/off switching in microwave ovens



Background

One of the world's largest manufacturers of microwave ovens is the Whirlpool factory in Norrköping, Sweden. The microvawe radiation in the oven is generated by magnetrons, operating at approx 2.45 GHz. To control the radiated power, the magnetron is switched on and off at regular intervals. A sort of pulse width modulation is applied, using the 50Hz mains voltage, that is the magnetron's switching frequency is 50 Hz.

The measurement problem at Whirlpool was to view the settling of the magnetron frequency at switch-on. That is to sample the frequency very fast and show the *frequency vs time*.

Model CNT-81 and TimeView forms together a 2.7 GHz Modulation Domain Anayzer, and is a very easy-to-use and cost-effective solution to the measurement problem.

Measurement set-up

A CNT-81, incl. a 2.7 GHz HF-input, plus a portable PC with TimeView installed was used. The radiation from the microwave oven was picked up using a receiving antenna from R&S, whose output was directly fed to HF-input of the counter.

TimeView was easily configured. The measuring function was set to "Frequency on input C (HF)". That's all. All other TimeView settings were default settings.

Frequency vs time graph shows HF-burst

Figure 1 shows the magnetron's emitted frequency vs time. At regular intervals of 20 ms (50 Hz) the magnetron is switched off and then on again. The OFF-time is somewhat longer than the ON-time.

The magnetron can best be described as a 2.5 GHz burst frequency source. Five measurement values out of 512 are extremely low (MHz). The reason is that the counter may start to measure the

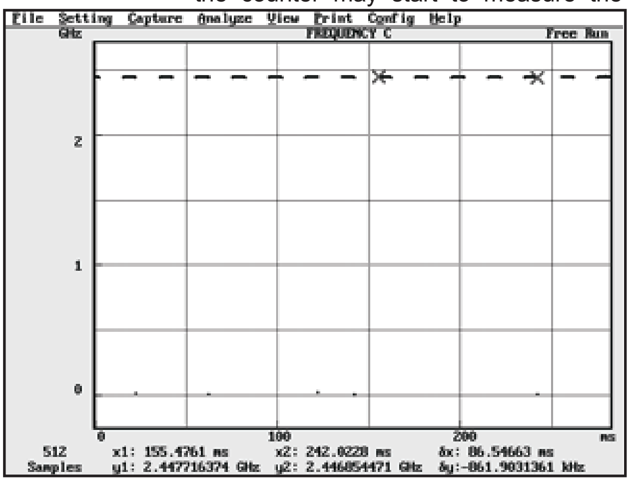


Figure 1 *The frequency vs time graph of a few on/off cycles*

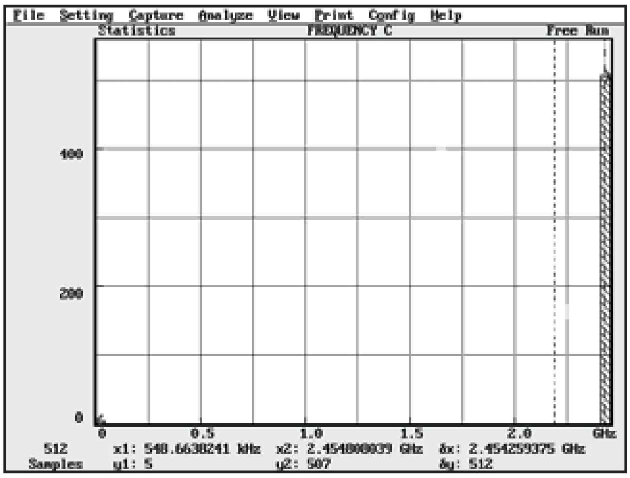


Figure 2 *The distribution of the measured frequency samples*

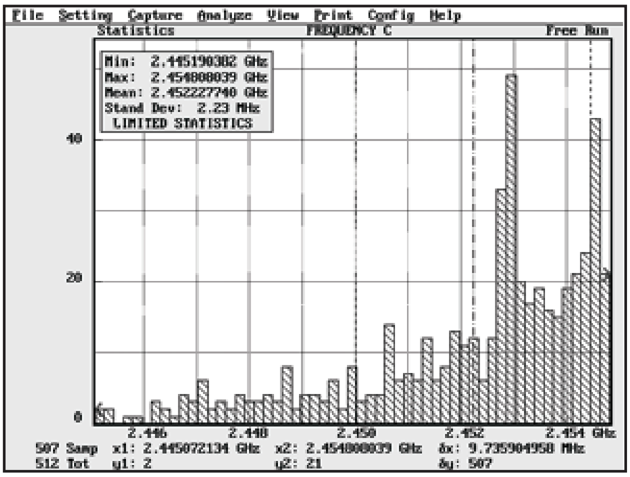


Figure 3 *Zoom-in on the frequency samples obtained during the "on-time" only*

frequency at the very end of one "burst" and (due to the reciprocal measurement principle) then stop at the first cycle of the following "burst". These frequency values thus include the OFF-time, and are not relevant.

Statistical distribution of the frequency samples

The histogram in figure 2 shows the distribution of the 512 frequency samples. 507 are real frequency values close to 2.45 GHz (inside each burst-ON-time) and 5 are non-relevant (include burst-OFF-time).

Zooming in on the "real" values in the histogram gives the distribution of the 507 frequency samples, relevant for the burst-ON-time. See figure 3. Note that higher frequency values are more frequent than lower.

Zooming-in on "real" frequencies

Let's go back to picture 1 and zoom in on the longest part of the graph with only real values (between the cursors at t=160 ms and t=240 ms in figure 1). Now 5 cycles (burst-ON) are visible, with 35 frequency samples in each cycle. See figure 4.

Each frequency sample has a resolution of 7 digits. Here the frequency settling is clearly visualized. The magnetrons frequency shift is approx 8 MHz during the ON-time. The actual switch-ON time can easlily be measured using the graph cursors.

Quantifying the on/off switching frequency

The actual switching frequency from figure 4 can be directly read in an FFT-diagram. Note that the graph cursors in figure 4 are set to cover four integer switching cycles to avoid broadening of the modulation peaks in the FFT-diagram.

The resulting FFT-diagram is shown in figure 5. Here the "carrier" is the long bar at x=0 Hz (look at cursor reading "y1=2.448.. GHz") and the dominant switching (modulation) frequency is 50Hz (cursor reading "x2=49.9.. Hz"). Since the switching (modulation) source is not a perfect sine wave, various harmonics of 50 Hz are also present, see figure 5.

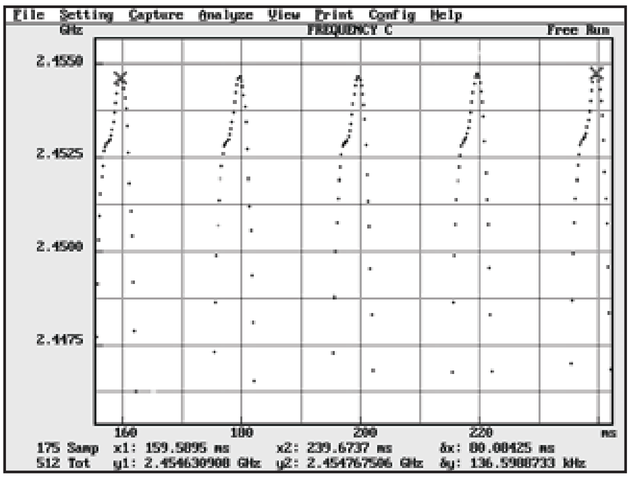


Figure 4 *Zoom-in on a part of the frequency vs time graph in figure 1*

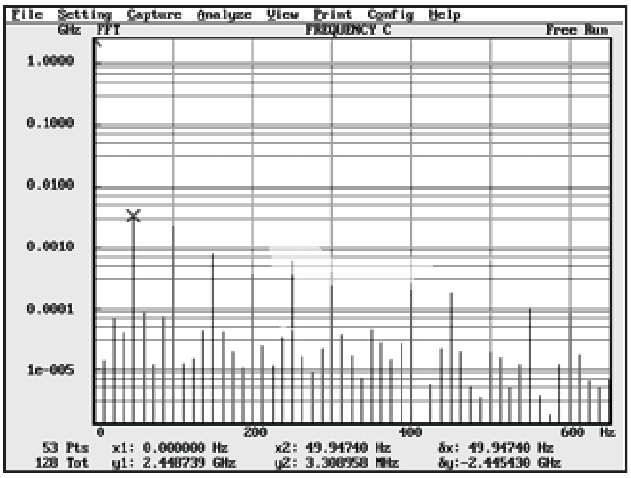


Figure 5 *The FFT-diagram quantifies the actual modulation frequency. Cursor 2 is moved to first modulation frequency peak (x2=50Hz)*

pendulum