IEEE 802.4L Submission on Microwave Oven Interference Measurement

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Synopsis:

Measurements were made on the radiation characteristics of microwave ovens. The interpretation of the results obtained in these measurements led to the belief that the radiation had basically a random and piece-meal contiguous frequency content over approximately 100 Mhz bandwidth with specific amplitude envelope distributions.

The results obtained in time domain power measurements showed abrupt amplitude variations over time. It was hypothesized that the abruptness of the amplitude behaviour contributed significantly to the frequency spectra observed.

The results and the observations during the measurement process led to the assertion that there was no evidence that the interference potential from the microwave ovens resembles an unique frequency line interferer, within the observation time and frequency constraints.

The absence of a clearly observable fundamental frequency from the magnetron output indicates that this may have been an intentional design feature for an oven. The measurement results suggested that the magnetron was operating in a spurious moding condition with abrupt amplitude variations. This operating mode may present a severe channel interference problem.
Measurement Set Up:

The measurement was conducted using a HP 8566 spectrum analyzer calibrated using its internal automatic calibration procedure. A test antenna was designed to provide an overall return loss performance of about 10 dB over the measurement frequency range. The test antenna was calibrated by a HP8753A network analyzer coupled with a HP 85046A S parameter test set.

Figure 1 shows the calibration result and a picture of the test antenna. The test antenna will not exert significant frequency response of its own onto the intended test results. The reason for the use of a special test antenna rather than a 900 Mhz flexible normal mode helical antenna which was used in previous tests, was that these antennas have unacceptable frequency response characteristics within the measurement band of interest centered at 2.45 Ghz.

The measurements were conducted within the near field region at the bore-sight of the front of the oven door. The following near field assumptions were made:-

1) The radiation near field region of the radiation is determined by the smallest dimension D of the oven using the following relationship:-

\[
d \leq \frac{2d^2}{\lambda}
\]

where d is the distance perpendicular to the oven door at bore-sight from the test antenna.

D is the smallest dimension of the oven cooking chamber.

\(\lambda\) is the operating wavelength. In this case, the operating frequency was taken to be 2.45 Ghz.

2) The radiating antenna area effect can be estimated by the dimension D of the oven cooking chamber.

3) The radiation propagation is directed towards the antenna from the oven door.

The reason for conducting the measurement within the near field region of the oven under test is to eliminate any possible radiation antenna effect that may be present from the oven. Antenna effect in the far field may have a significant specific frequency response that may bias the test measurements.

Precautions was also taken to select an appropriate load for the microwave oven. It was determined that a measured 12 oz water load at an initial measured temperature of 25 degree C allowed an optimum result in regards to a 10 minutes test and the maximum radiation power extracted. The same load condition was used for every measurement to ensure the uniformity of the test environment.

All frequency domain measurements were made over a 10 seconds cooking time with the spectrum analyzer in
max-hold mode. The measurement time for the time domain is one single sweep.

The detail measurement results appended in the Appendices are indexed in the following table:

<table>
<thead>
<tr>
<th>Microwave Oven Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oven name</td>
</tr>
<tr>
<td>Kenmore 1400 W</td>
</tr>
<tr>
<td>Magic Chef 1400 W</td>
</tr>
<tr>
<td>Kenmore 1400 W</td>
</tr>
</tbody>
</table>

Observations

1. The interference power measured was log-linear proportional to the measurement resolution bandwidth. This relationship held true from 30 Hz to 3 MHz bandwidth.

2. There were very rapid amplitude bursting characteristics which may have had a rise time much shorter than 300 nsecs.

3. There was no evidence of a detectable single frequency spectrum line during the measurements. The rapid and abrupt amplitude variation behaviour precluded this possibility.

Analysis

A few of the interesting measurement results are highlighted here to illustrate the perception of the interference characteristics.

a. Wide frequency span measurement results:

In the wide frequency span measurement, it can be seen that the detected signal levels in the measurement results are not exactly reduced by the same amount of the resolution bandwidth reduction. This phenomenon implies that the spectra measured was not really white noise. The small amount of additional reduction in the measured signal power indicates an impulsive signal origin where the effective impulsive resolution bandwidth is actually related to the nature of the amplitude response $V(t)$ of the impulse:

$$B_{impulse} = \frac{V_{pk}}{\left(\int_{-\infty}^{\infty} V(t)dt \right)^{-1}}$$

Actual measurement of the impulse bandwidth of the Spectrum Analyzer to validate this hypothesis was not carried out.
b. Narrow frequency span measurement results:

A typical plot for the narrow frequency span measurements such as Figure 2 shows signs of carrier frequency drifts. It is relevant to point out that this plot is the result of a "max-hold" function, and thus that the frequency lines do not appear in a single scan. So it should not be assumed that the frequency offset between the frequency lines is the repetitive frequency of the pulse train. A more plausible scenario is that of the interference source carrier frequency drifting during the measurement.

The need to limit the resolution bandwidth to 1 KHz in this case is governed by the resolution bandwidth filter shape factor. This is represented by a constant $k$ in the following relationship:

$$T_{sweep \ time} \geq \frac{k f_{\text{span}}}{B_{\text{res \ bw}}}$$

As it can be seen from the plots, the Spectrum Analyzer resolution filter has an extremely good performance.

c. Wide resolution bandwidth time domain measurement

Figure 3 shows the fine grain structure of the impulse characteristics. The power level point, during each period $\Delta t$ can be viewed as:

$$\int_{t}^{t+\Delta t} |S(t)|^2 \, dt$$

where $S(t)$ is the Fourier Series of the impulse train after the resolution filter.

Then, from Figure 3, it can be argued that interference power can in fact exist for, within a given frequency interval, up to 8 milliseconds at any given frequency.

The fine oscillatory power variations is most likely caused by a power impulse that approaches a Delta Function with respect to the filter bandwidth. In this case, $S(t)$ can be simply written as:

$$S(t) = \frac{2A}{\pi(t-t_0)} \sin(\pi(f_2-f_1)(t-t_0)) \cos(\pi(f_2+f_1)(t-t_0))$$

where $f_1$ and $f_2$ are the lower and Upper frequencies of the resolution filter.

The derived impulse response suggests an almost sinusoidal oscillation similar to the power wave shape depicted in Figure 3 when $|S(t)|^2$ is computed with incremental time. This observation is consistent with the isolated discrete sub-micro second frequency bursts observed previously with a 22 Mhz bandwidth filter.
d. Narrow resolution bandwidth time domain measurement

Figure 4 shows a typical result obtained using a 10 Hz resolution bandwidth filter where the average impulses from the interfering source would have produced a near perfect impulse response of the filter.

Conclusion

It is the author's opinion that the interference characteristics of the microwave ovens to the proposed Radio Lan system cannot be taken as a possible line interferer as previously assumed, although it is impulsive in nature. Because of the perceived carrier frequency drifts from the interference source, it is also claimed that the interference energy existed over a broad frequency spectrum with rapidly varying amplitudes, and the resultant effect is a seemingly random and piece-meal contiguous frequency spectrum in time.
APPENDIX A

Kenmore
1400W
14 3/4" x 10 1/4"
February 3rd

4500 MHz
1400W
Power

10 minutes

10% of the equivalent 18% of moisture
Figure 3-5

humane

1 hour

humane

1/2 cup of Jews 1/2 cup of 10 minutes

deco 7/8 chp of juv 7/8 cups of stock
<table>
<thead>
<tr>
<th>START 2.435 GHz</th>
<th>RES BW 800 Hz</th>
<th>NBW 3 MHz</th>
<th>STOP 2.440 GHz</th>
<th>SWP 150 sec</th>
<th>REF 0.0 dBm</th>
<th>ATTEN 10 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>MARKER</td>
<td>2.437500 GHz</td>
<td>-75.30 dBm</td>
<td>MARKER</td>
<td>2.437500 GHz</td>
<td>-75.30 dBm</td>
<td></td>
</tr>
</tbody>
</table>
Heat a little over 1/3 cup of the original 1 1/2 cups water

10 minutes

Wmnoac 1100 W

450 ml Hz

Figure 3-8
Figure 3–13

4450 MHz
1400m
Humidity
10 minutes
Good 30% of the year and 10% of winter

Page 3–13
Figure 3-14

9
100W
9450 MHz

about 3 1/2 Gy of the original 18 Gy of x-rays

10 minutes
Figure 3.30

1100 W

2450 MHz

Kenmore

10 minutes

Least 3/4 of the original 12% of water
Figure 1-16

Magic Chef

9480 mHz

Lost 3 oz. of the original 12 oz. of water

10 minutes
Pyridine
1400°C
2450 MHz

Figure 3-3 A

10 minutes

Least 4 1/2 oz of the original 12oz of water
Lost 3 oz of the original 12 oz of water

10 minutes

Kenmore
1400 W
2450 MHz

Figure 3-25
Phenamidine
1400 W
2-150 mHz

Figure 3-28

10 minutes
about 11.2 oz of the original 9 oz of water
Железо Fe,
1400°C,
3450 мин,
APPENDIX B
Magic Chef
14 1/2" x 9 1/2"
FIGURE B.0
Figure 4-5

3.50 nm Hz

Magnum Chief

10 minutes

1/4 cup of the equivalent 1/4 cup water
at least 1/2 cup of the original 1/2 cup water

10 minutes

Magic Chef
2450 MHz
Lost ½ cup of the original 1 ½ cups water
10 minutes

Magic Chef
2450 MHz

Figure 4-9
Lost 1/2 cup of the original 1/2 cups water
10 minutes

Magic Chef
2450 MHz

Figure 4-10
February 9-13

Average Chart

250 MHz

10 minutes

Check 3/11 at the operation 12048507
Figure 4-17

A150 MHz Magic Chef

Heat 1/4 cup of the england 1/2 cup water

10 minutes
Figure 4-19

Michael Choy

4/50 MHz

10 minutes

Dead end of the output of water
Feb 4-31

Average Chef

10 minutes

Pour 1 cup of the evaporated milk into

Start 1/4 cup of the original 1/4 cup water
March 1-31

3450 MHz

Mike Chaffee

10 minutes

Pour 1/4 cup of the sugar and 1/3 cup water

Dissolve 1/4 cup of the sugar and 1/3 cup water
Figure 4-30

Magic Chef

3450 mHz

At least 1/2 cup of the original 11/2 cups water

10 minutes
February 14-31
A 10-minute
On average, daily 10 minutes

Most see at the end of 10 minutes
February 4-33
ASMDMAE
amalef Deal
10 minuets

dead 7 years of age. She employed 14 years wirelo
Tuesday 1-33
8:30 M HZ
Mommy O
10 minutes

Check 3a split 1a experimental with...
3450Mhz

Figure 4-34

Chains ofchef

10 minutes

Beat 1/4 cup of olive oil and 1/2 cup water
Figure 4-36
3150 MHz
Charger Chip
10 minutes
Data: 1% of the observed 95% of median
Figure 4-37

3.50 MHz

Magic Chef

10 minutes

1 cup of the original 11/2 cups water
Magic Chef
2.50 MHz

Figure 4-44
APPENDIX C
Kenmore #2
14 3/4" x 10 1/4"
Figure S-3

Model ± 56.8868510

1400 mL

8450 mHz

phenomenon

13 minuters

does 1/4 cup of salt and 1/2 cup water.
Figure S-3

ATMOSPHERE

1. Room

2. Chamber

10 minutes

10 minutes

Park S-3 of the experiment 100% of water
Figures 5-7
8:30 AM
11:00 AM
Problem 2
Good 1/2 cup of sugar and 1/4 cup of water
10 min
Figure 5-10

Kamehameha II
1400 W
3450 MPH

10 minutes

3/4 cup of the original 1/3 cup water
February 5-11
3450 MHz
1000 m
10 minutes
10 minutes

1/4 cup of oil, 1/2 cup water
Figure 5-13

2450 MHz

1400 W

10 minutes