COP89F

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

IN THE MATTER OF:	)	
	)	File Nos:
Reply Comments to	)	49/50-DSS-P/LA-90
the Application of	)	58/59-DSS-AMEND-90
Satellite CD Radio, Inc.,	)	
to provide Digital	)	
Audio Radio Services	)	

COMMENTS OF STANFORD TELECOM

These comments address the suitability of frequencies above 2000 Mhz for digital audio with regard to interference from microwave ovens. Evidence from measurements indicates that oven emissions can seriously compromise CD Radio system performance. Given that one of the primary service benefits of CD Radio is audio quality, this potential threat cannot be ignored.

The operating frequency of microwave ovens is at 2454 Mhz, but there is substantial splatter throughout the 2400-2500 Mhz region. In addition, if the measurements performed by Stanford Telecom are typical, there are significant out-of-band peaks even down below 2100 Mhz. Whether such emissions are representative and would, thus, lead to chronic degradation of CD radio reception cannot be established with certainty without undertaking a major study. However, the following conclusions can be made:

- Measurement data indicates that ovens do not comply with standards, particularly for out-of-band emissions. This is not surprising since the standards require roughly 50 to 60 Db emissions reduction of out-of-band relative to in-band, a figure difficult to achieve and maintain over product lifetime. Data taken by Stel on one oven shows only 30-40 Db reduction in out-of-band emissions. If this data is representative, then such emissions would seriously degrade CD radio performance at frequencies down to and below 2100 Mhz.

- However, if all microwave ovens operate in compliance with established emission standards, only ovens very near the radio receiver (< 100 meters) could have any impact under worst case assumptions. Thus, if ovens obeyed the standards, we do not believe that they would present a problem for mobile receivers. The impact on indoor radios would still be catastrophic.

The attached technical appendix summarizes the supporting work and is organized as follows:

1. Standards
2. Data
3. Interference Criteria
4. Interference Analysis

TECHNICAL APPENDIX

Assessment of S-Band Interference from Microwave Ovens

1. Standards and Resulting Interference EIRPs

There are two applicable standards:

- In-Band Standard: Emissions in the 2400-2500 Mhz band must be less than
  - 1 Mw/cm^2 at 5 cm at factory
  - 5 Mw/cm^2 at 5 cm over lifetime

- Out-of-Band Standard: Emissions outside the 2400-2500 Mhz band must result in electric field strengths of less than
  - 300 μV/m at 30 meters (present)
  - 25 μV/m at 300 meters (before 1980)

These standards result in the following EIRPs:

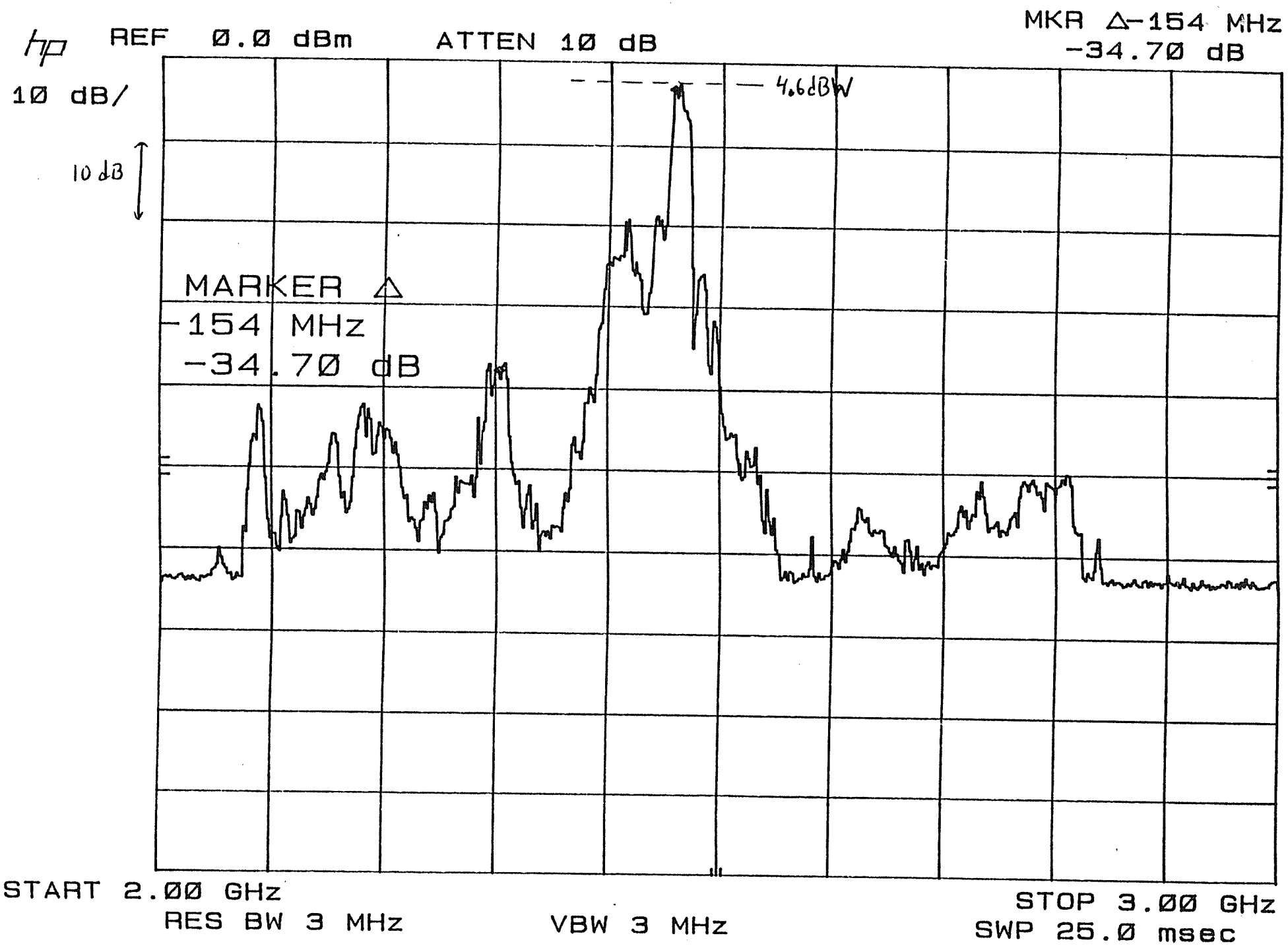
- In-Band EIRP:
  - $EIRP = S\,(4\pi r^2) \approx 1.6$ w ≈ 2 dBw
  - $S = 5$ Mw/cm^2 } lifetime standard
  - $r = 5$ cm }
- Out-of-Band EIRP:
  - $EIRP = S(4\pi r^2) \approx 2.7 \mu W/m^2 \approx -55.7$ dBw
  - $S = \frac{1}{\mu_0 c} E^2 \approx 2.4 \times 10^{-10}$ W/m^2
  - $\mu_0 C = 377$ V^2/W
  - $E = 300$ μV/m } present standard
  - $r = 30$ meters }
  - EIRP prior to 1980 is 9.2 Db higher or ≈ -46.5 DBW
  - Note that these values are some 50-60 Db below the in-band standard

2. Measurement Data of Oven EIRPs

Measurement data is available from a number of sources:

- Stel: A single oven was monitored over the entire frequency range from 2 Ghz to 3 Ghz. Figure 1 shows a plot of the emissions over a 3 Mhz sliding bandwidth. Although this data is limited to a single oven, it is the best documented data we have found.

Figure 1


REF 0.0 dBm
ATTEN 10 dB
MKR Δ-154 MHz
-34.70 dB
10 dB/
10 dB
4.6dBW
MARKER Δ
-154 MHz
-34.70 dB
START 2.00 GHz
RES BW 3 MHz
VBW 3 MHz
STOP 3.00 GHz
SWP 25.0 msec

- In-Band EIRP: This is dominated by a peak of magnitude ≈ 4.6 DBW over roughly 10 Mhz. The total EIRP will be approximately 3 times this value since the 10 Mhz width is about 3 times the bandwidth. Thus, the total in-band EIRP ≈ 9.4 DBW. Note that this is somewhat over the standard.

- Out-of-Band EIRP: This is dominated by a peak at 2300 Mhz with about a 10 Mhz bandwidth. This peak is 34 Db less than the in-band peak. Thus, the out-of-band EIRP ≈ -24.6 DBW. Note that this is more than 30 Db above the current standard, and more then 20 Db above even the "prior to 1980" standard.

- Systematics General Corp: Four oven EIRPs were measured over 2450-2500 Mhz thus providing data for only in-band emissions. The peak EIRPs measured in a 5 Mhz sliding bandwidths were as follows:

  + 15 DBW with a bandwidth ≈ 5 Mhz
  - 3 DBW with a bandwidth ≈ 20 Mhz
  - 8 DBW with a bandwidth ≈ 40 Mhz
  + 5 DBW with a bandwidth ≈ 20 Mhz

  Taking into account the bandwidths involved, the peak EIRPs should be adjusted upward by 6 Db for the 20 Mhz Bandwidth and 9 Db for the 40 Mhz bandwidth. Thus, the peak total EIRPs of the four measurements are:

  + 15 DBW
  + 3 DBW
  + 1 DBW
  + 11 DBW

  Note that two of these measurements are much above the standard of 2 DBW.

- Data from CCIR 854-1: Data was taken on 4 ovens at frequencies from 1 Ghz to 6 Ghz. The measurement bandwidth was 100 Khz. Peak field strengths in-band between 3×10^5 and 10^6 μV/m were measured at 30 meters. This translates to an EIRP of between 1.5 DBW and 15 DBW. Note that the upper value is well above the 2 DBW limit which corresponds to the in-band standard. This report indicates however that the mean values are more than 10 Db less than the peak values, but supporting data is not included. It is also important to recall that the measurements were taken over a 100 Khz bandwidth. Thus, for emissions with a wide spectrum the total output over 10 Mhz will be much greater. Regarding out-of-band emissions, peak electric field values up to 1200 μV/m were measured at around 2300 Mhz. This is above the current out-of-band standard, but below the pre-1980 standard. As before, for wide band emissions over 10 Mhz, this value could be up to 20 Db larger because the measurement was limited to 100 Khz. Thus, if the peak measured value were uniform over a 10 Mhz band, the resulting out-of-band emissions would be comparable to that measured by Stel.

3. Interference Criteria

The interference criteria for the CD Radio System are as follows:

- -147 DBW = insignificant system impact
- -139 DBW = 2 Db erosion of system margin
- -132 DBW = catastrophic impact

The information and analysis supporting these levels are described below.

According to the current CD Radio link budget, the radio receiver requires a minimum signal per stereo program of -144 DBW, and operates with a margin of 6 Db to counteract excess path loss and interference. Assuming that 30 programs are multiplexed in a 10 Mhz bandwidth, the total signal strength in a 10 Mhz band will be between - 129 DBW and -123 DBW representing a 0 Db and 6 Db margin assumption respectively. In order to avoid a serious impact on the system performance, interference should be at least 10 Db below this range, or less than -139 DBW. Another benchmark to judge interference by is to compare it to the power implied by the system noise temperature. The current CD Radio link budget projects a noise temperature of roughly 150°K. The noise power in a 10 Mhz band is given by $k_BTB \approx$ -136.8 DBW. An interference level of -139 DBW would produce a small rise in the total system equivalent noise ($\approx$ 2 Db): thus, an interference at that level would absorb 2 Db of the 6 Db allocated margin, leaving only 4 Db for other losses. An interference level of -147 DBW would absorb less than 0.5 Db of allocated margin so is considered an insignificant impact. Finally, an interference level of -132 DBW would result in a catastrophic degradation.

4. Estimation of Interference from Ovens

The interference emissions from a microwave oven may be expressed as follows:

$I = EIRP \cdot \Delta_F \cdot L_p \cdot G \cdot L_{other}$
where:

- EIRP = peak EIRP of the oven within 10 Mhz of the center frequency
- Δ_F = the fraction of the peak EIRP in a 10 Mhz band at an offset frequency out-of-band
- L_p = path loss = $(\lambda/4\pi r)^2$
- r = oven range
- λ = wavelength
- G = receiver gain
- L_{other} = other losses such as building attenuation

Consider the EIRP with the following assumptions:

- EIRP = 2 DBW (the standard)
- 2300 Mhz frequency

- G = 5 Db
- 1 mile range

Under these assumptions,

$I = 2\ DBW - 10\log \Delta_F - 104\ Db + 5\ Db - 10 \log L_{other}$
$I = -97\ DBW - 10\log \Delta_F - 10\log L_{other}$

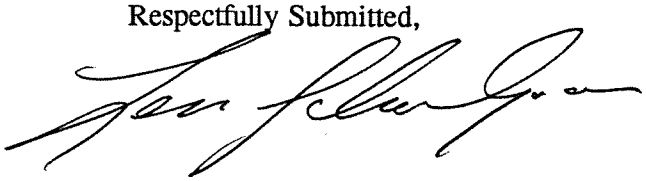
The Δ_F and L_{other} together must decrease the interference as follows to avoid the consequent degradations:

- -50 Db = no system impact
- -42 Db = 2 Db degradation
- -35 Db = catastrophic degradation

If the out-of-bound standards accurately describe microwave emissions, Δ_F alone will result in more than 50 Db attenuation so that an oven within 1 mile will have no system impact. Alternatively, if the Stel data is typical, Δ_F will account for only 34 Db of attenuation. Thus, without assuming additional building loss, this would result in catastrophic degradation. Even with an assumption of a 10 Db building attenuation, the oven would result in a roughly 1.5 Db degradation in margin. Thus, the combined effect of multiple ovens within a 1 mile range could therefore cause catastrophic degradation.

For an oven at 100 m range, 20 Db additional interference attenuation is required from Δ_F and L_{other} to make up the decrease in range. Clearly, if the oven measured by Stel is typical, at a 100 m range, radio reception would be impossible even allowing for building attenuation. However, if all microwave ovens comply with the present out-of-band standard, then about 60 Db will be provided by Δ_F. With 10 Db additional from building attenuation, the degradation would be insignificant. Without the building attenuation, the system degradation would be significant, but within the 6 Db system margin. Given the short range of 100 m, and the built-in conservativeness of this analysis in assuming that the out-of-band emissions of the oven is dominant in the CD Radio receiver band, we would therefore conclude that ovens which meet emission standards do not pose a significant threat to the CD Radio System performance.

Respectfully Submitted,



Len Schuchman
Sr. Vice President
Stanford Telecom