DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

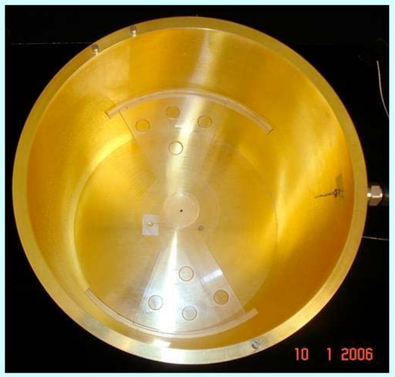
BIOLOGICAL CELLS ARE NOT NONLINEAR: THEY DO NOT DEMODULATE RF SIGNALS WITH LOWER FREQUENCY SIDEBANDS — YOUR CELL PHONE IS NOT FRYING YOUR BRAIN!

Quirino Balzano, Vildana Hodzic, *Robert W. Gammon, **Christine Kowalczuk, Christopher C. Davis
* IPST, ** Health Protection Agency, Chilton, UK

INTRODUCTION

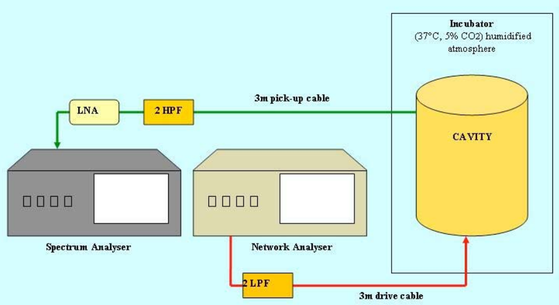
It has been hypothesized that cell phones present a health hazard because biological cells can demodulate an RF carrier and thereby expose tissue to low frequency signals. We have shown definitively that this does not occur.

Doubly Resonant Cavity



- Cavity made at University of Maryland for HPA.
- Radius = 12.35 cm
- Length = 27.22 cm
- Unloaded Q ≈ 1250
- Dominant modes $TE_{111} \approx 883$MHz, $TE_{113} \approx 1766$ MHz

Equipment Setup



NA: Agilent Tecnologies E8357A; SA: Agilent Technologies E4407B
LNA: Kuhne LNA172A Gain 35dB NF 0.7dB @1.8GHz
HPF: Mini-Circuits VHF-1320+; LPF: Mini-Circuits NLP-1000
SA set for 30 integrations and effective noise bandwidth of 30 Hz

Research supported by MTHR

Cavity Quality Factor and SAR

DEFINITION of Q: Energy stored/ Energy dissipated per signal cycle

$$Q_o = \omega_o |V_o|^2 E \Big/ \left(|V_o|^2 / R_o\right) = \omega_o E/(1/R_o)$$

Unloaded Cavity: Empty Petri dish. R_o is the effective resistance of The empty Petri dish and its support structure

$$Q_L = \omega_L |V_L|^2 E \Big/ \left(|V_L|^2 / R_L\right) = \omega_L E/(1/R_L)$$

Loaded Cavity: biosample in Petri dish, effective resistance R_B. R_L is the effective resistance of the sample, Petri dish, and its support structure.

$$1/R_L = 1/R_o + 1/R_B$$

Load Factor of Test Cavity

$$LF = (1/Q_L - 1/Q_o)/(1/Q_o) = (Q_o/Q_L - 1)$$

$$= (\omega_o/\omega_L)(R_o/R_B + 1) - 1 \approx R_o/R_B$$

$(\omega_o/\omega_L) \approx 1$ **PI**= Power input, m =mass of sample

$$SAR = (LF)PI/m \text{ [W/kg]}$$

Range of Measured SAR 0.5-15 W/kg

Measurement of Load Factor

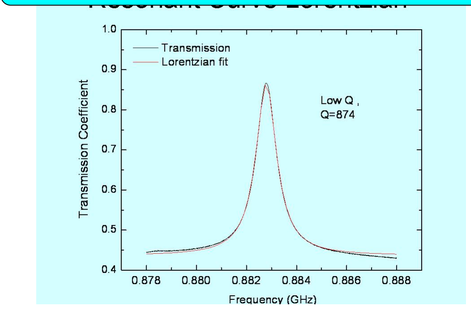
- Measure Input Power vs. Frequency (Resonance Curve) with Network Analyzer and Input Power at f_0 (Resonance)
- Lorentzian Fit to Resonance Curve Provides the Cavity Q

$$Q = f_0/\Delta f$$

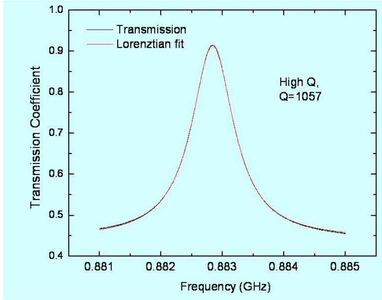
f_0 = Frequency of Minimum Reflection

Δf = Band of Return Loss < 3 dB

Resonance Curve Lorentzian



Resonance Curve Lorentzian

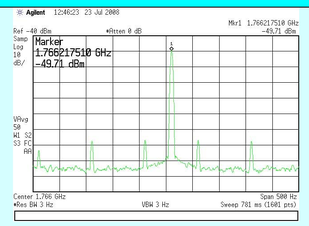


Evaluation of Nonlinear Response of Cell Samples

- Measure Power Level of Second Harmonic ($2f_1$) of Incident RF Signal (f_1) with Spectrum Analyzer
- Measured Levels < -155 dBm with 1mW Input (30dB RF amplifier at $2f_1$)
- Measure Cavity Q and RF Power Dissipated (P_d) at $2f_1$
- Energy of Second Harmonic $E = QP_d/4\pi f_1$
  $Q \approx 1000$ at $2f_1$ $P_d \approx 185$ dBw
- Second Harmonic Generation Coefficient $\chi^{(2)}$

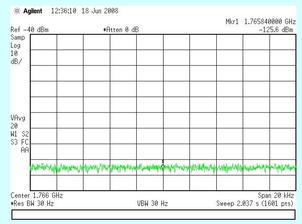
$$P(2\omega) = \varepsilon_0 \chi^{(2)} E^2(\omega)$$

Diode Response

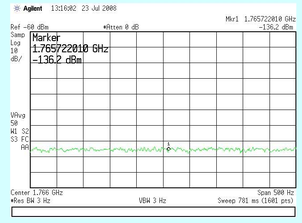


Schottky Diode MZB 600 MonoMetrics, Inc Londonderry, N.H.

Cell Response (1 mW)



Cell Response (0.1 mW)



Conclusions

Cell nonlinear response not above noise floor = -185 dBw for 1mW and -195 dBw for 0.1 mW input power

- **Nonlinearity coefficient** $\chi^{(2)} < 10\, pm/V$
- **Coherent rectification of RF CW carriers by individual cells not found.**
- **No cooperative rectification by cells**
- **Second harmonic probably detectable with strong pulses**