Electromagnetics Research Group
Department of Physics
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Charles V Sammut

Electromagnetics Research Group

- Charles V Sammut (Group Leader & Head, Dept of Physics)
- Louis Zammit Mangion (Dept of Physics)
- Pierre Schembri Wismayer (Head, Dept of Anatomy)
- Postgraduate research students:
  - Lourdes Farrugia
  - Eman O Farhat
  - Stephen Vella
  - Julian Bonello
  - Ruth Grech Marguerat
  - Giuseppe Gauci

Electromagnetics Laboratory

Main T&M equipment

- VNA R&S ZVA-50 10MHz-50GHz (with extension to 90 GHz)
- Dielctric measurement kit (85070E Agilent Dielectric Probe kit) plus additional probes and WGs to cover 10MHz-90GHz
- Speag Time domain **E** and **H** measurement system with miniature optic fibre coupled sensors, 10MHz-6GHz
- Spectrum analyser R&S 50Hz-50GHz
- Hand-held instruments:
  - Anritsu Spectrum analyser (9 kHz-18 GHz)
  - Narda SRM-3006
  - Narda NBM-550
  - Narda EFA 300
  - Additional before end 2014:
    - Interference & direction analyser
    - VNA 85MHz-14GHz
    - Frequency selective personal radiation monitor 80MHz-6GHz
    - Selective frequency broadband ELF analyser 5Hz-100kHz
- Frequency counter (400 MHz – 40 GHz)
- Power meter, power sensors (10MHz-20GHz)
- EMC/EMI capabilities to pre-compliance standard

Electromagnetics Laboratory

Other facilities

- Anechoic chamber 700MHz-18GHz (soon)
- A range of antennas covering RF & MW frequencies to 90GHz
- Sweep oscillators, function/signal generators (<50Hz – 90GHz)
- Power amplifiers 100kHz-3GHz, 100W
- Multichannel temperature sensor
- Constant temperature bath: 0 – 99 ± 0.02ºC
- Software: ANSYS, HFSS, FEKO, Maxwell, CST, SEMCAD X (including full suite of computational phantoms), Narda EFC-400
- Supercomputing cluster (7 T Flop)

Ongoing Research

- Complex permittivity measurements
  - Liquids as a function of frequency and temperature
  - Biological tissues:
    - Rat and canine healthy & tumour
    - Bovine and porcine liver and muscle
    - Cortical bone
- Design and development of wideband fractal antenna arrays for radio astronomy (in collaboration with the Astrophysics Group) – part of the SKA project
- Measurement and simulation of RF & MW emissions from mobile phone base stations, broadcast stations, radar
- Measurement and simulation of occupational exposure to ELF magnetic fields
- Measurement and modelling of near fields of mobile phone base station antennas
- Measurement and modelling of occupational exposure to MRI static and gradient magnetic fields

Dielectric properties of biological tissues for medical applications

RF & MW diagnostics:

- Tomography & radiometry (TD1301)
- MW imaging (breast tumours) (TD1301)
- Terahertz imaging (skin lesions) (BM1205 & MP1204)

RF & MW therapeutics: (BM1309)

- RF fields are being used in a range of new medical treatments (e.g.: Conductive Keratoplasty to correct hyperopia; RF ablation – liver tumours, enlarged prostate, Wolff-Parkinson-White syndrome, sleep apnea, snoring, physiotherapy,…)
- Tissue ablation by MW hyperthermia (e.g.: MW endometrial ablation; liver, kidney and lung tumours)
- Potential for bone tumours

Complex permittivity of biological tissues

- Accurate knowledge of the permittivity of body tissues is crucial for both diagnostic and therapeutic procedures
  - Diagnosis relies on detecting a difference in permittivity between healthy and diseased tissue
  - Design of RF and MW applicators for tissue ablation requires extensive simulation, which requires detailed knowledge of permittivity at the treatment frequency and over a range of temperatures

Measurement of permittivity

- Motivation - to address gaps in knowledge:
  - Most published values are in the frequency range 100 MHz-20 GHz
    - Scarce experimental data at higher and lower frequencies; current models require experimental validation outside this frequeny range and at higher temperatures
  - Permittivity values used for dosimetric studies derived from the 1996 database - mostly human, bovine and ovine at 37ºC
    - Values at higher temperatures are required for hyperthermia modelling
  - Almost all accepted values were measured using ex-vivo samples
    - In-vivo permittivity values are higher than ex-vivo for the same tissue type at RF and lower frequencies

Measurement of permittivity

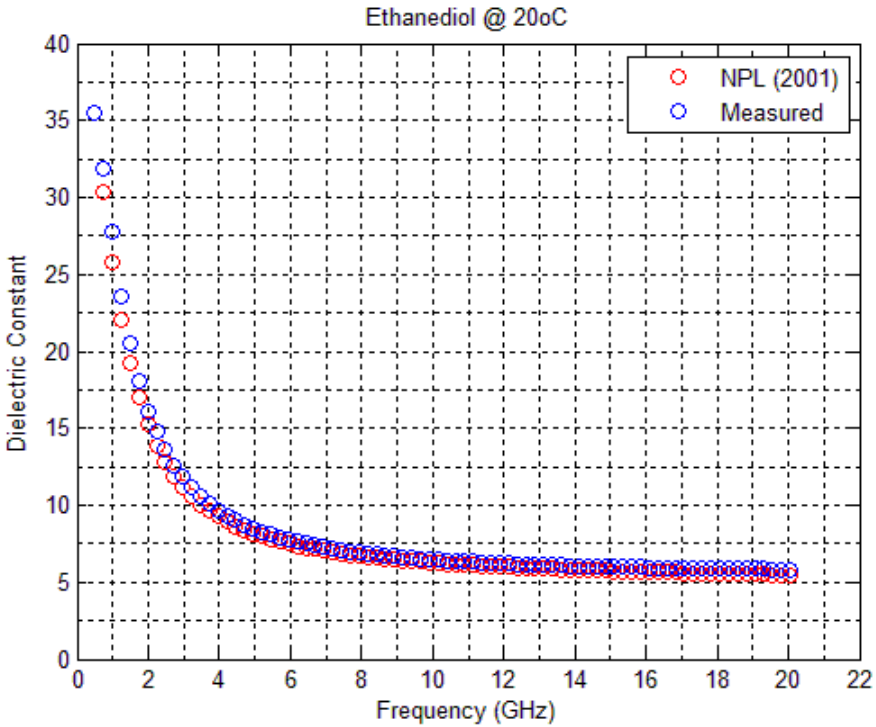
The permittivity of biological tissues can be modelled

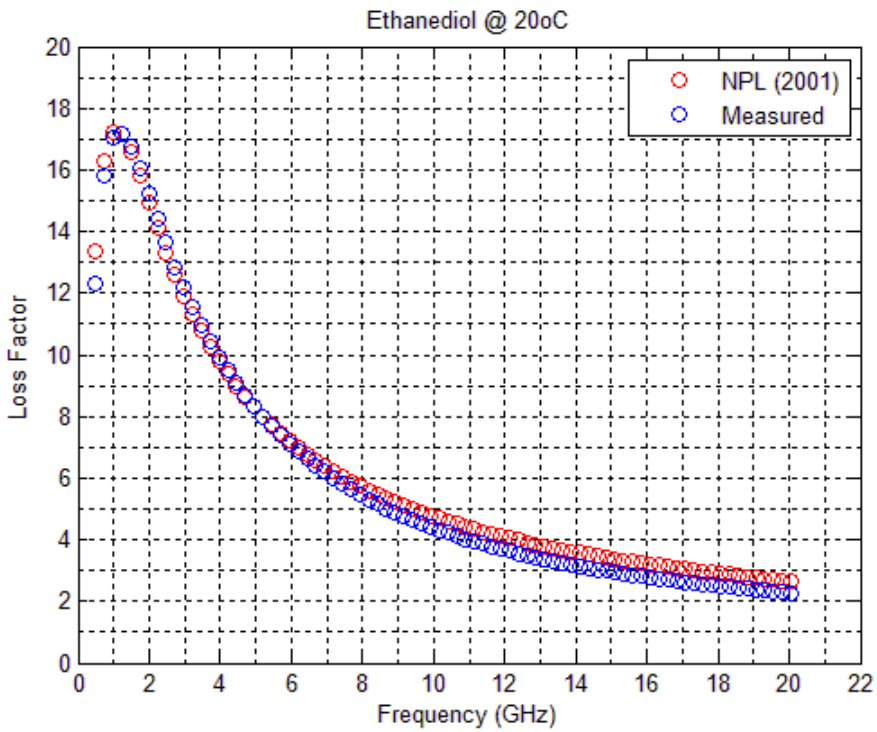
- Cole-Cole equation

$$\hat{\varepsilon}(\omega) = \varepsilon_\infty + \sum_n \frac{\Delta\varepsilon_n}{1 + (\mathrm{j}\omega\tau_n)^{(1-\alpha_n)}} + \frac{\sigma_i}{\mathrm{j}\omega\varepsilon_0}$$

- We use open-ended coaxial probes and obtain reflection measurements, from which the parameters of the Cole-Cole equation are obtained
- We also use an X-band rectangular waveguide kit to carry out transmission and reflected measurements on solid samples (bone)

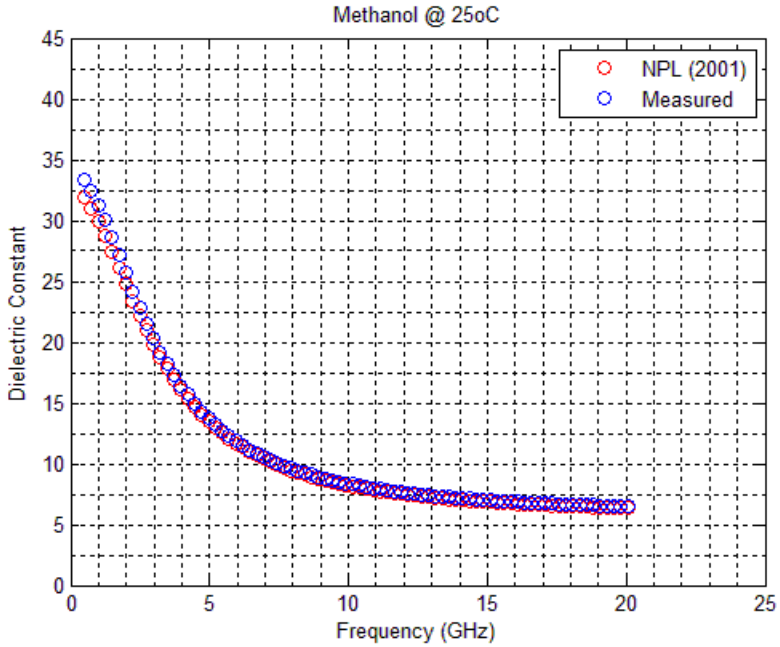
System validation with standard liquids

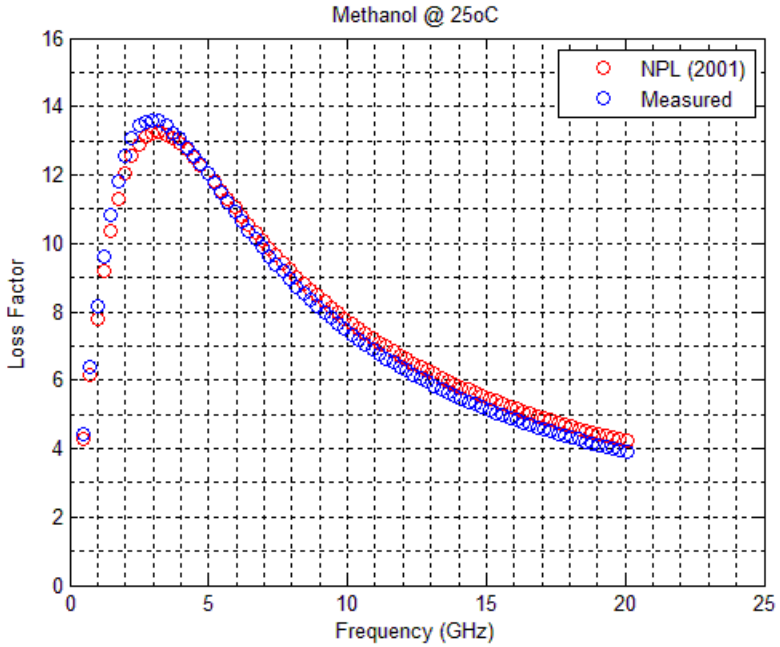




System validation with standard liquids

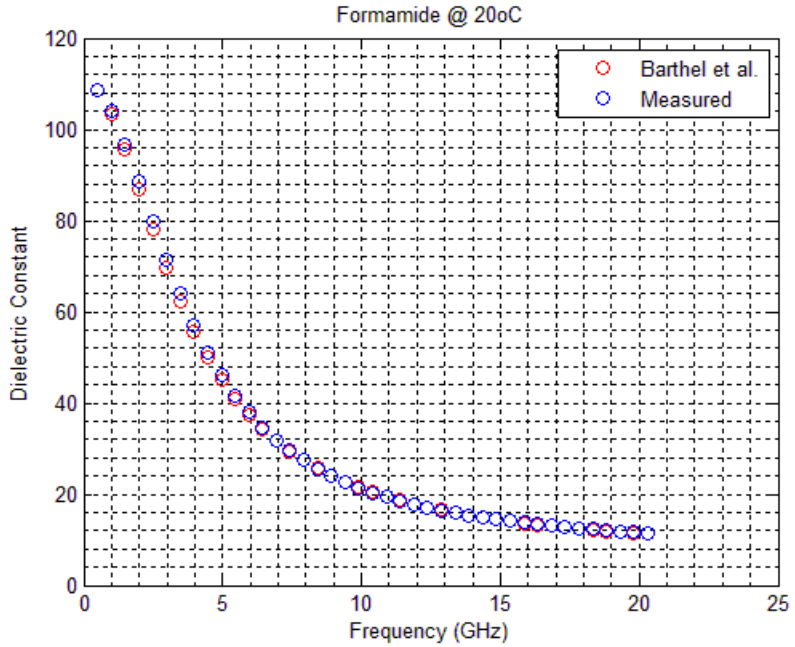
Methanol

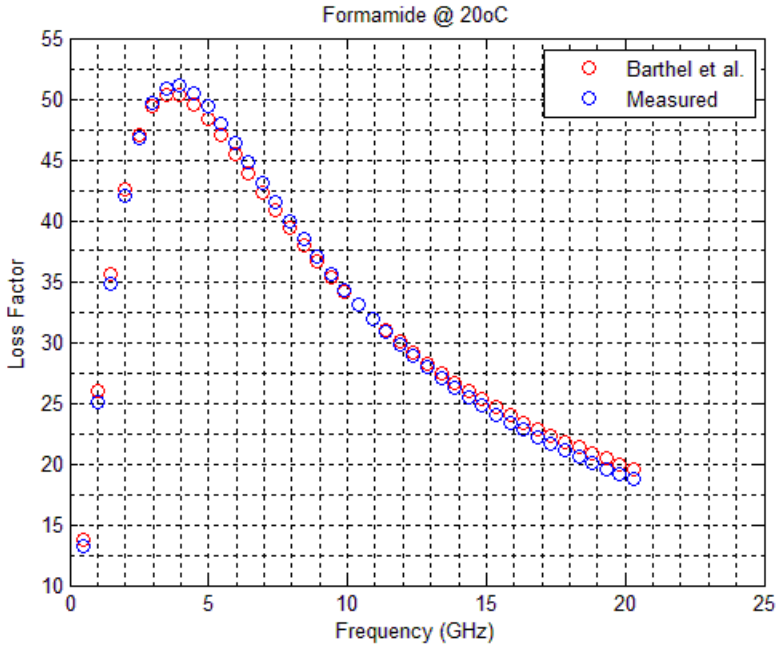




System validation with standard liquids

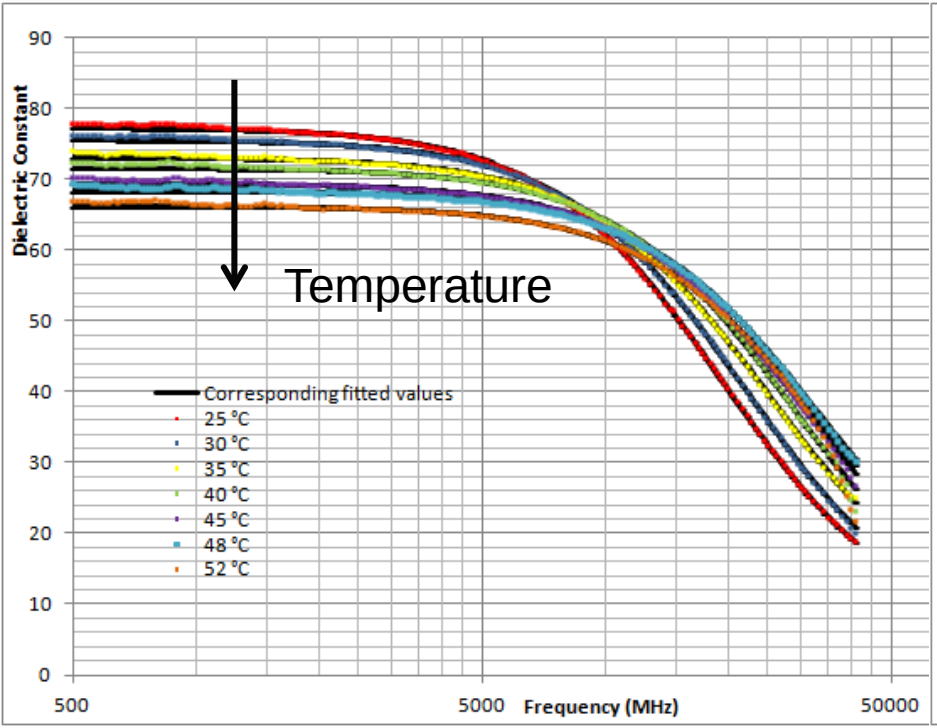
Formamide

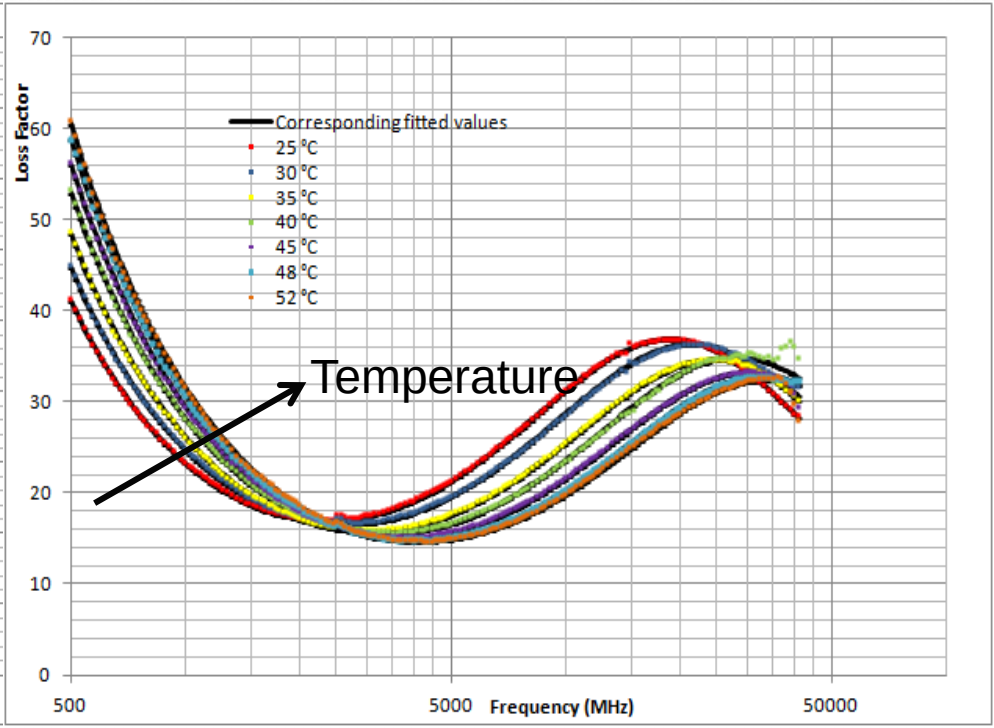




Preliminary results

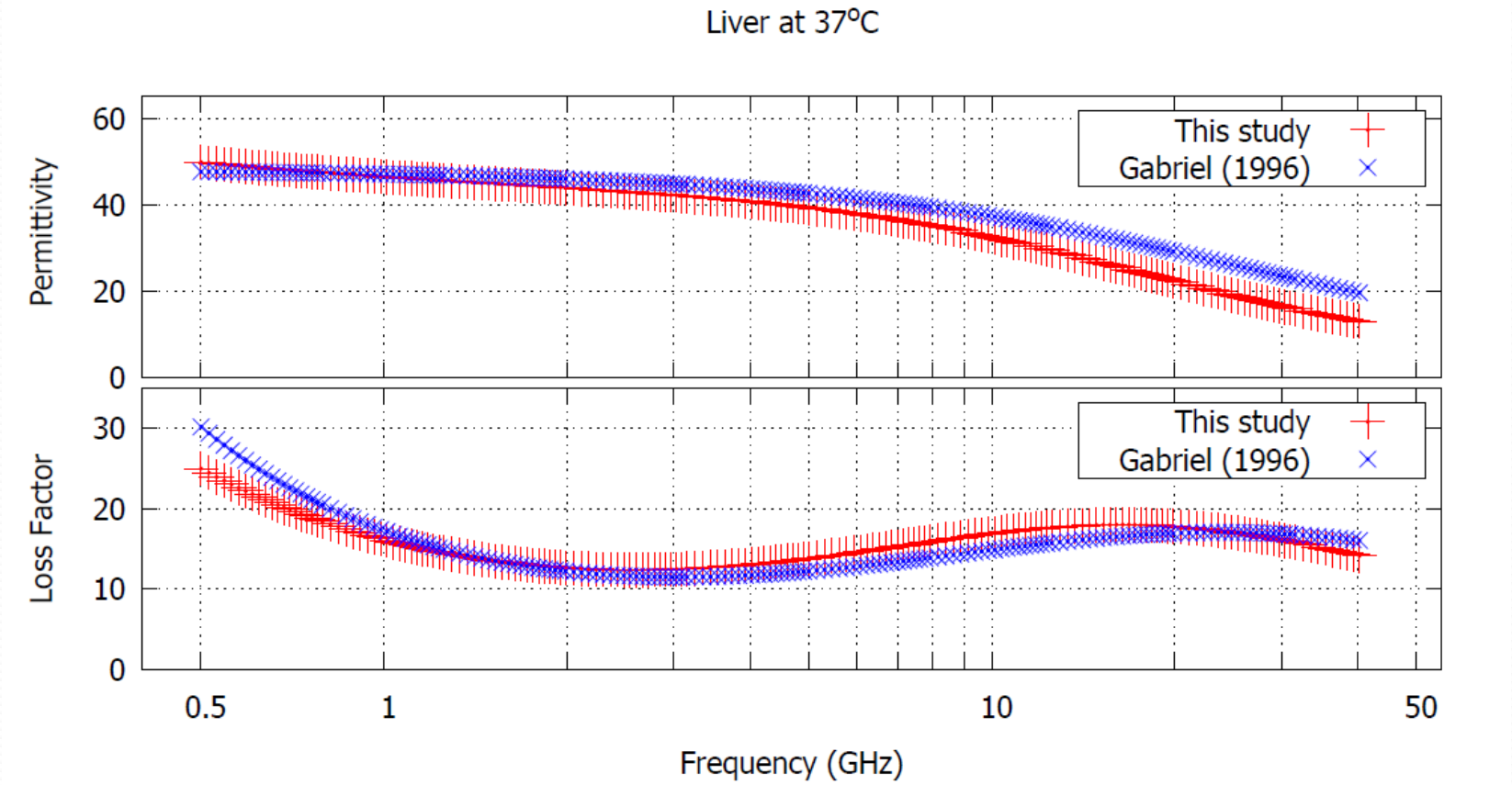
0.1 mol/l NaCl solution





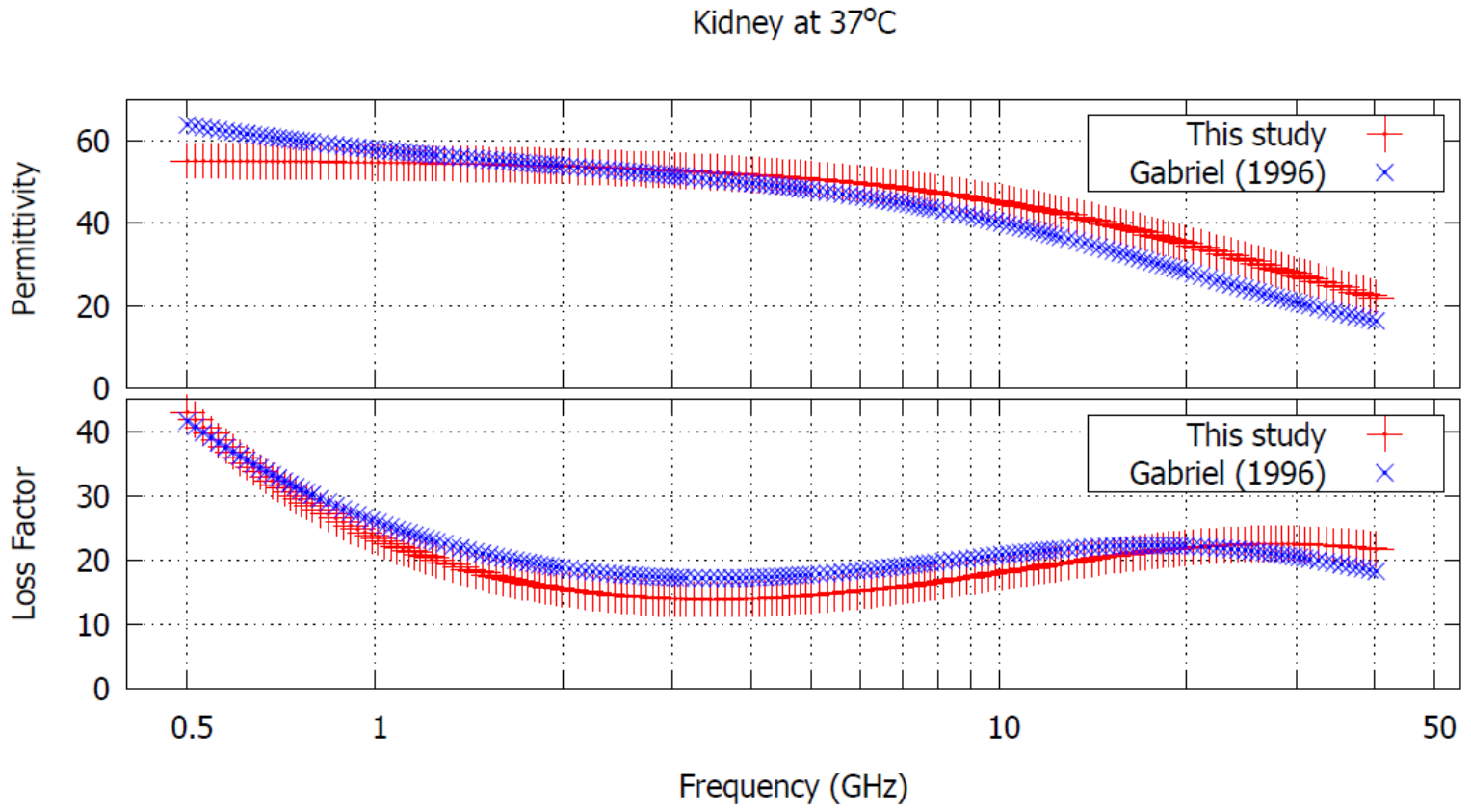
Preliminary results

Normal liver tissue at 37ºC



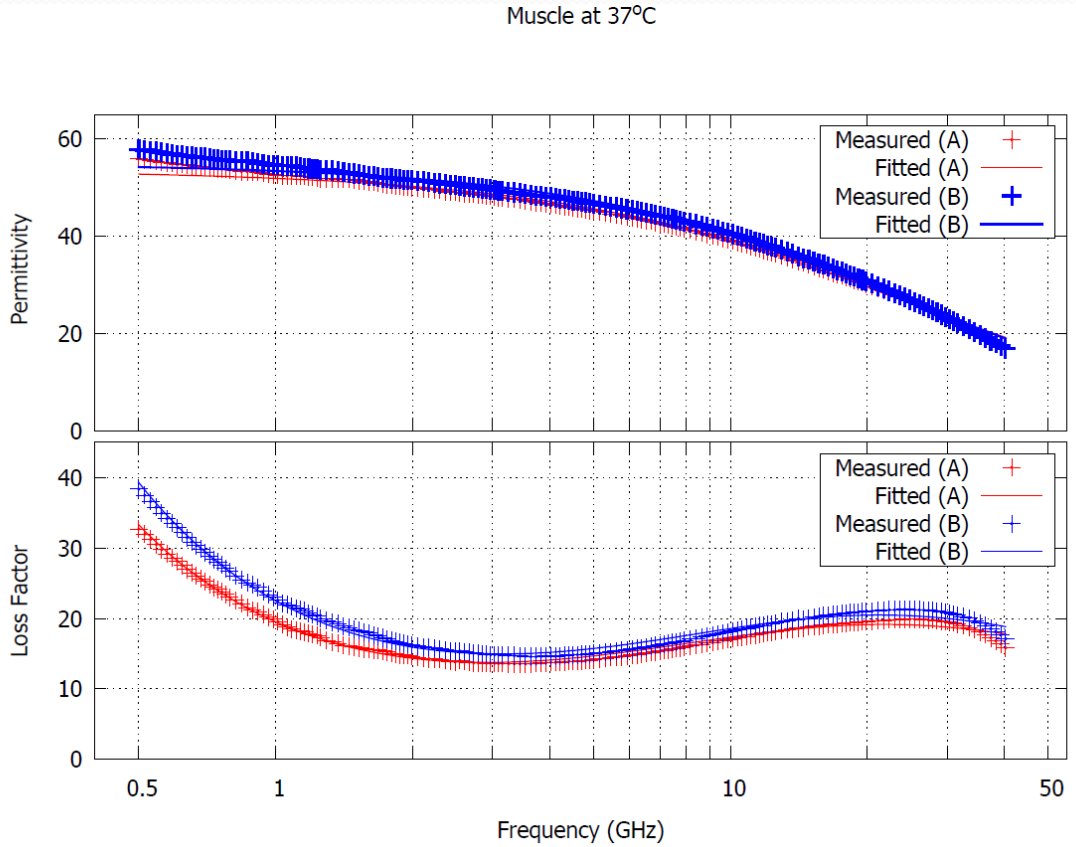
Preliminary results

Normal kidney tissue at 37ºC



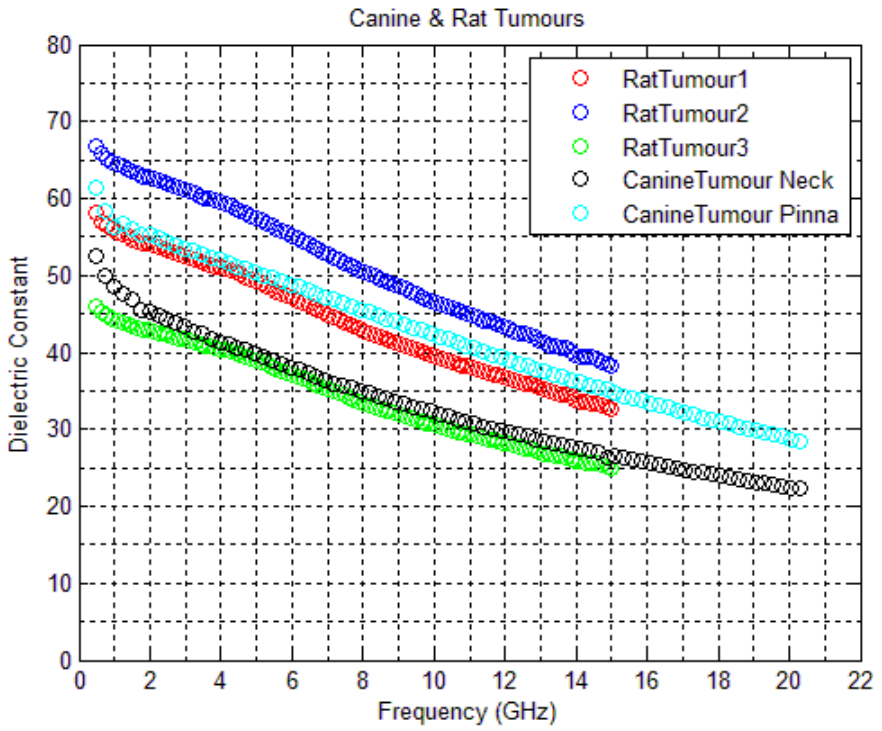
Preliminary results

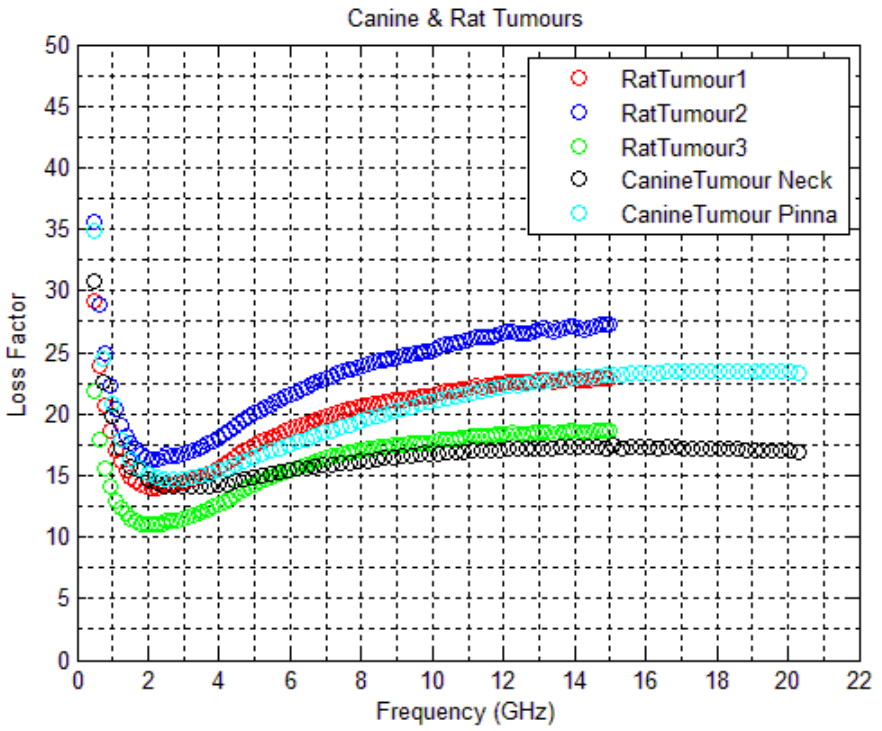
Normal muscle tissue at 37ºC



Preliminary results

Canine and rat tumours





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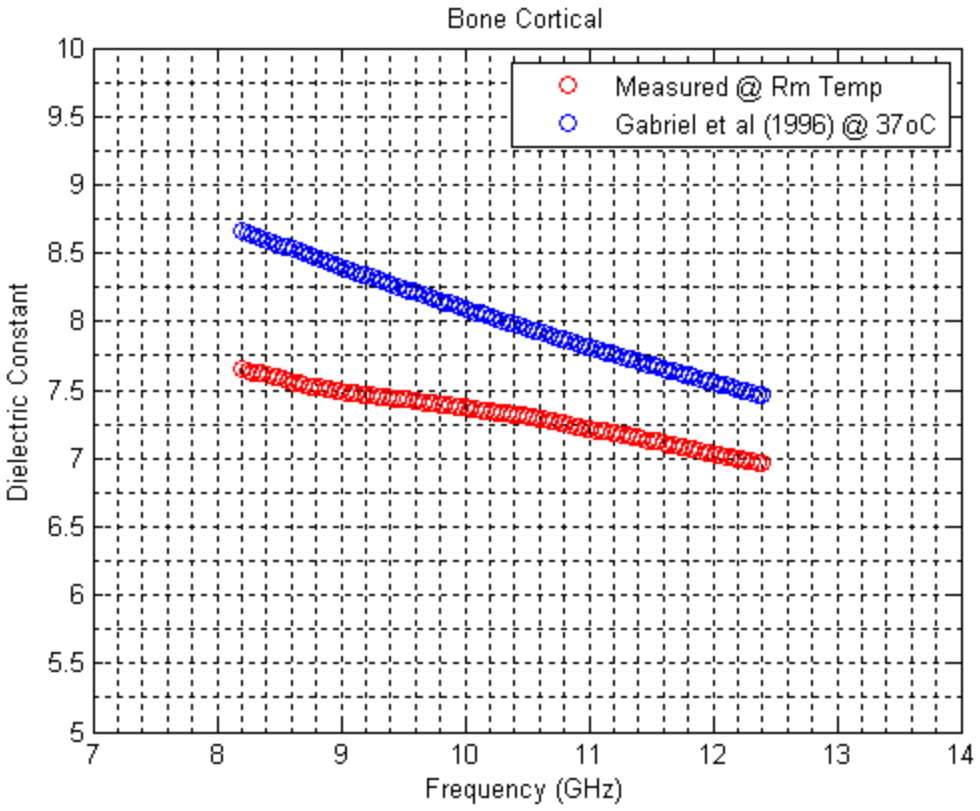
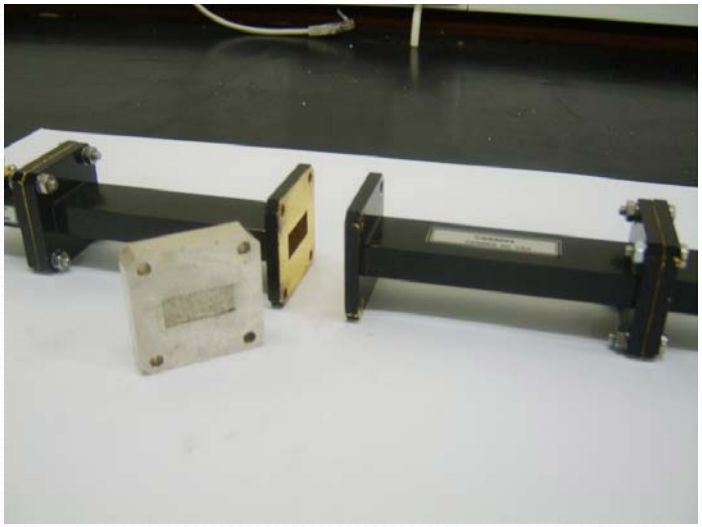
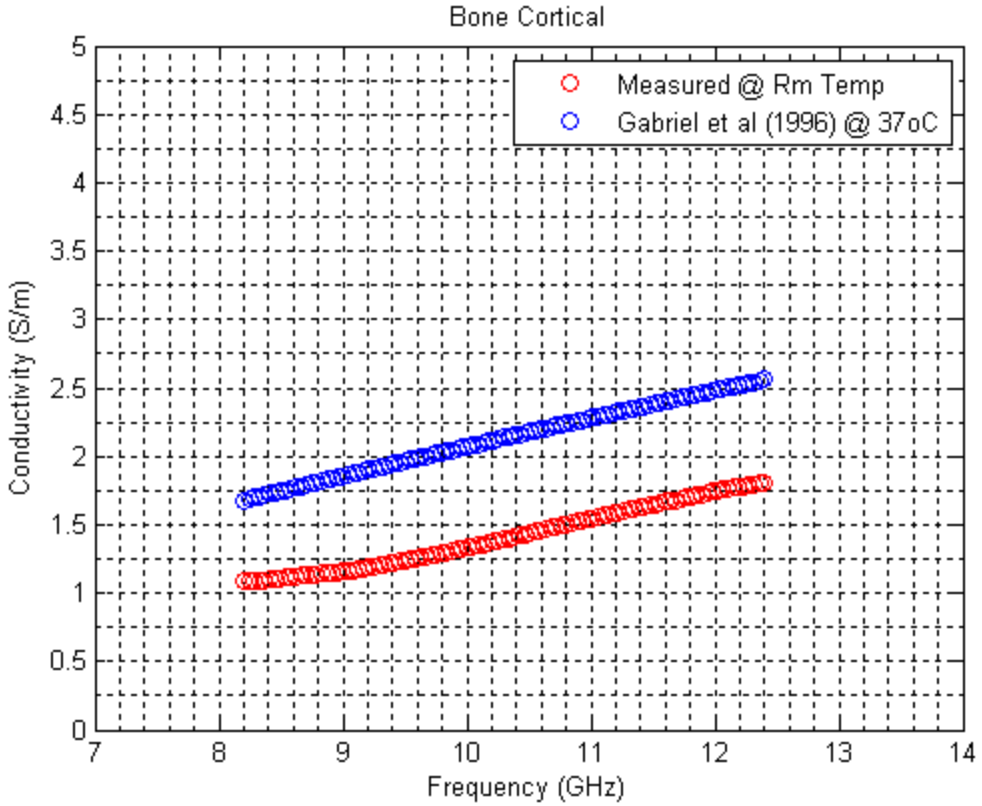


Bone (cortical)

Preliminary results

Bone (cortical)





Thank you