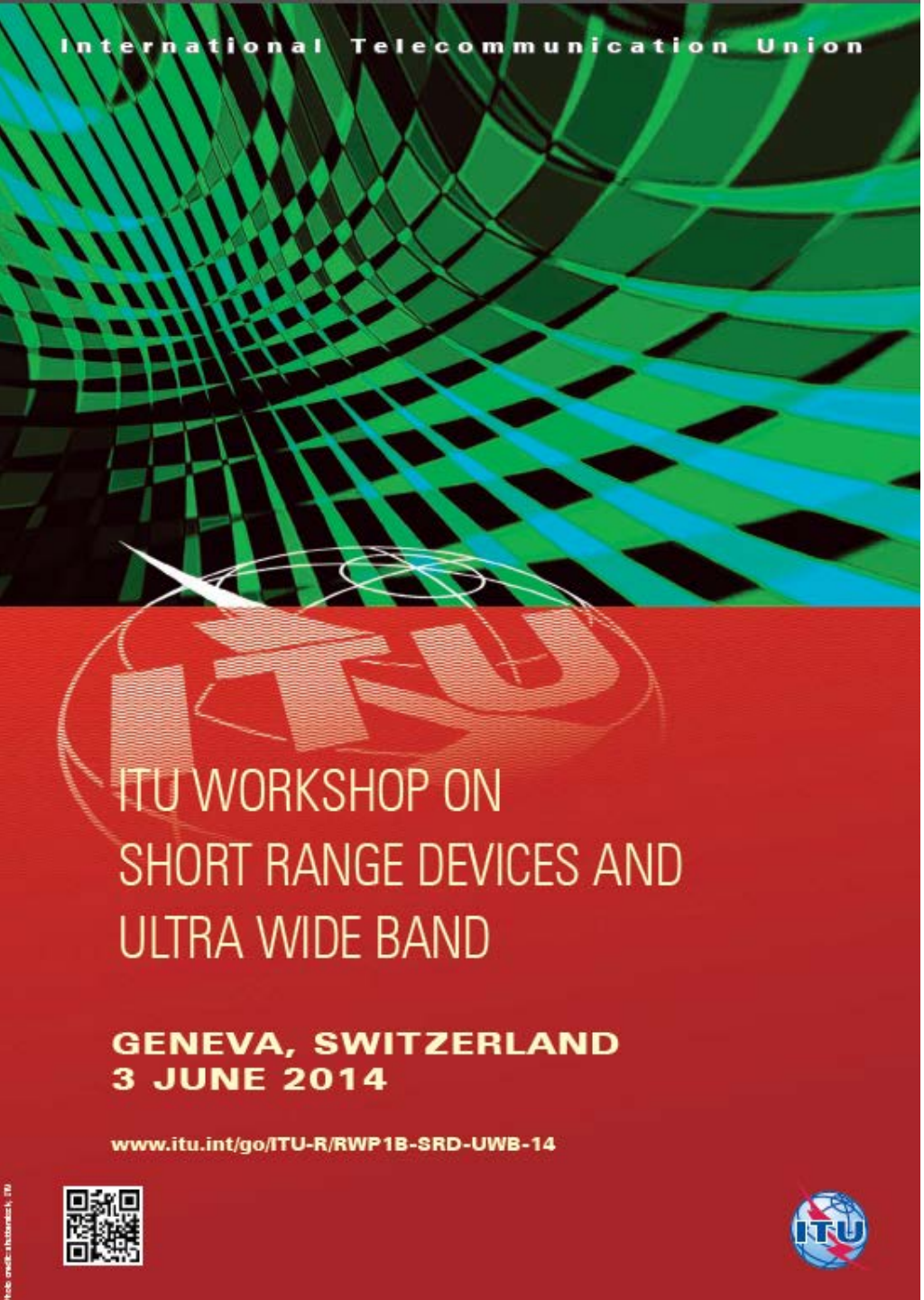

ITU WORKSHOP on
SHORT RANGE DEVICES (SRDs)
AND ULTRA WIDE BAND (UWB)
(Geneva, 3 June 2014*)

UWB Radar in Health Monitoring Products

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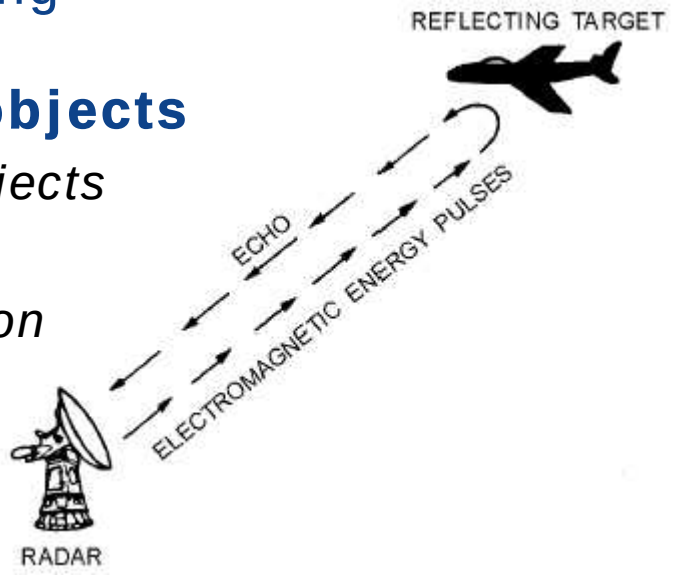
** in conjunction with the June 2014 block of meetings of ITU-R Study Group 1*

Review of Radar Concepts

- **RADAR – RA**dio **D**etection **A**nd **R**anging
- **Actively detect remote or hidden objects**
  - *Transmit electromagnetic energy at objects*
  - *Receive reflections from objects*
  - *Process reflections to extract information*



- **Common examples:**
  - *Aircraft radar, maritime radar, police radar, weather radar*
- **UWB health monitoring radar:**
  - *Applications under development since 2002*
  - *Historical challenges with commercial deployments*
    - Development costs, regulatory hurdles, recognition by health care system as reimbursable device

Comparison of Radar Systems

- **Traditional radar application: marine and airspace surveillance**
  - *Typical operational characteristics:*
    - Large targets with high media contrast
      - Boats, ships, aircraft (10-100m)
    - Long range: 10^3 to $>10^5$ meters (far field)
    - Fast speeds: 10^0 to 10^3 meters/second
    - Transmitted power: 2.1kW average
  - *Example: ASR-11 Airport Surveillance Radar*

Photo obtained from: www.faa.gov

- **UWB radar application: health monitoring**
  - *Typical operational characteristics:*
    - Small targets with low media contrast
      - Carotid artery, anterior heart wall
    - Close range: 10^{-2} to 10^{-1} meters (near field)
      - Necessitates short pulse (~150 picoseconds)
    - Slow speeds: 10^{-3} to 10^{-1} meters/second
      - Adult heart: moves 2cm at 60BPM = 0.02mps
    - Transmitted power: 1mW average

Why UWB Radar for Health Monitoring?

- **Need for non-invasive monitoring system of key cardio-pulmonary functions and other internal structures**
  - *Traditional technology limitations (ECG, ultrasound, pulse Ox, bio-impedance, etc.)*
    - Require direct skin contact: gels, clips, patches, bands, or wires
    - Limited to short duration studies with compliant patients
    - Challenged by intervening anatomical structures (air and bone)
  - *Patient behavior and environmental conditions dramatically affect accuracy and reliability*
  - *Difficulties compounded outside clinical environments*
    - Or when patients are uncooperative and/or are ambulatory

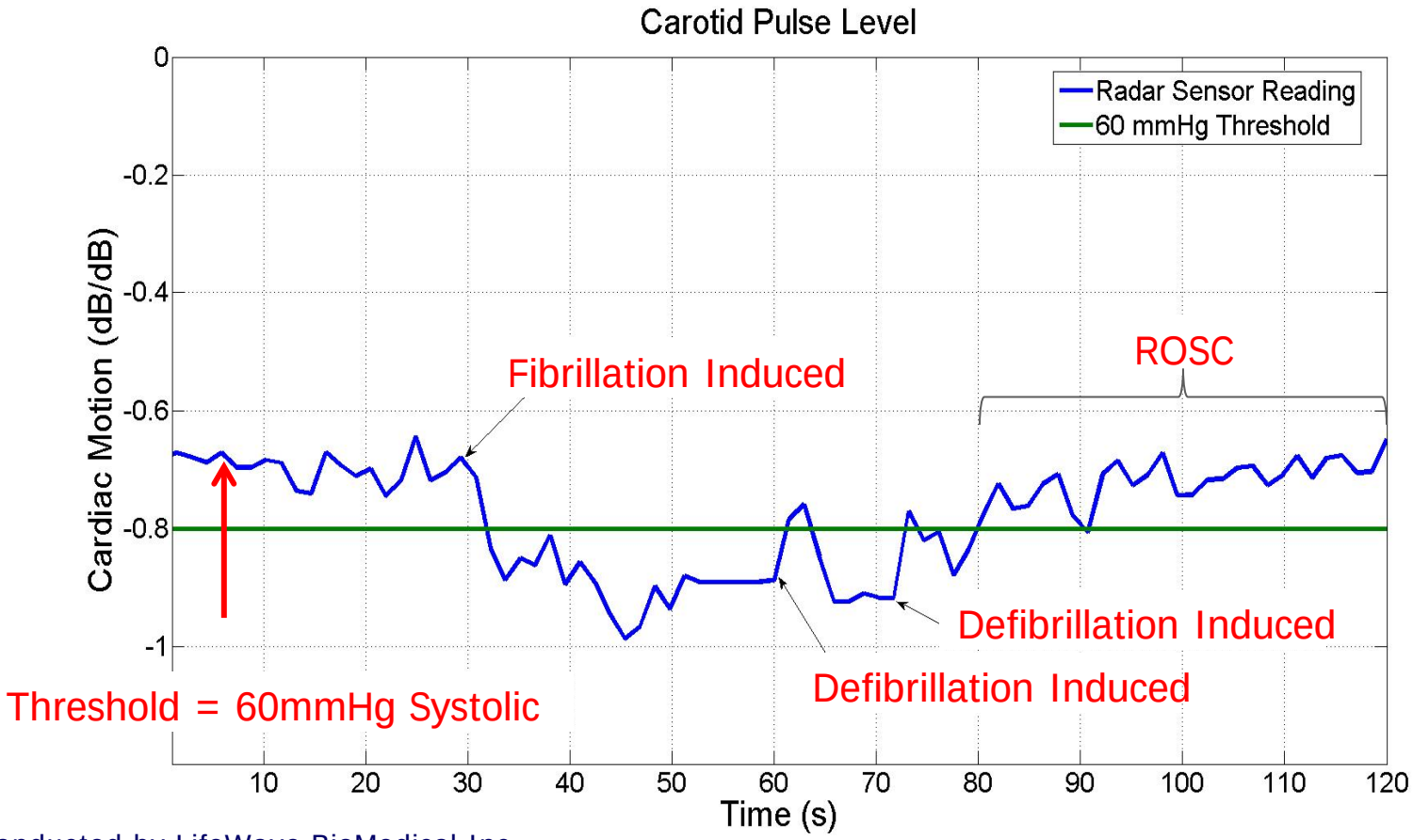
- **Advantages of UWB radar for health monitoring applications**
  - *Skin contact not required*
    - Works through clothing, hair, fur and thick fat layers
  - *Able to detect sub-mm movement of internal structures*
  - *Can be sealed in a hard plastic case*
    - Insensitive to environmental conditions
  - *Low-power transceivers are relatively inexpensive and easily miniaturized*
  - *Enables a new class of wearable/wireless health monitoring products*

UWB Radar Health Monitoring Applications

- **Basic cardiopulmonary monitoring**
  - *Cardiac and pulmonary rates*
    - LifeWave BioMedical Inc., i4C Innovations Inc., Sensiotech
- **Advanced cardiopulmonary monitoring**
  - *Relative cardiac stroke volume and cardiac output*
    - U.S. Army Institute of Surgical Research, LifeWave BioMedical Inc.
  - *Cardiac resuscitation and return of spontaneous circulation*
    - U.S. National Institute of Health, NHLBI, LifeWave BioMedical Inc.
  - *Changes in blood pressure*
    - U.S. National Institute of Health, NHLBI, LifeWave BioMedical Inc.
- **Other health monitoring applications**
  - *Detection of breast tumors*
    - University of Michigan (Ann Arbor)
  - *Detection of cranial hematomas*
    - U.S. Army Institute of Surgical Research
  - *Detection of hemothorax and pneumothorax*
    - U.S. Army Institute of Surgical Research
  - *Measurement of fetal heart rate and uterine contractions*
    - LifeWave BioMedical Inc., University of California (Davis and Irvine)

Example: Resuscitation Monitoring

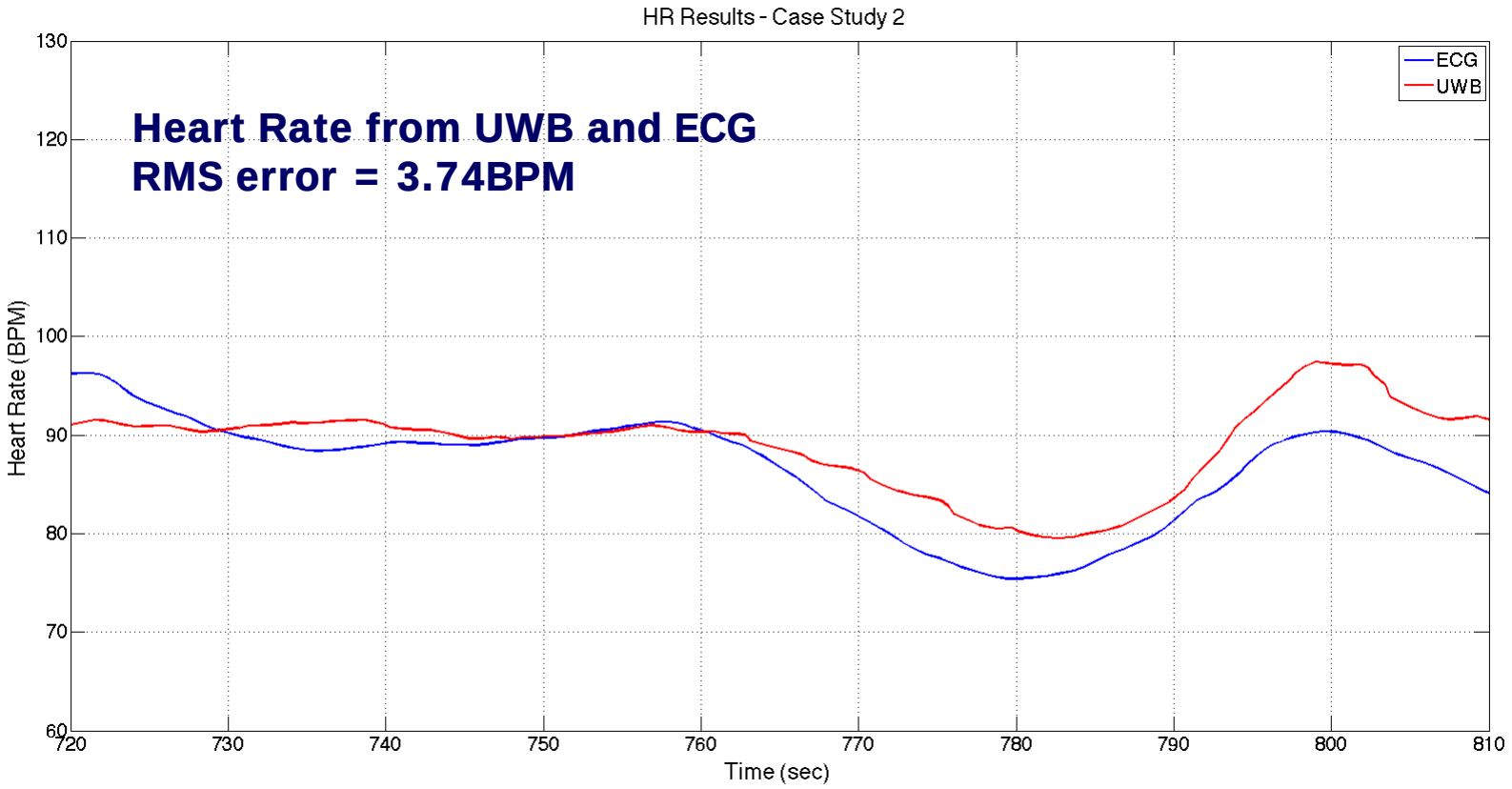
- **UWB radar advantages for cardiac resuscitation***
  - *Measures mechanical motion, not electrical activity*
    - Better for assessing blood flow and discriminating against PEA
  - *Enables readings in non-clinical environments (mobile, EMT, etc.)*



*Study conducted by LifeWave BioMedical Inc.

Example: Canine Cardiopulmonary Reading

- **UWB radar advantages for canine heart and respiratory readings**
  - *Traditional monitoring technologies require immobility and direct skin contact*
  - *Enables monitoring from secondary anatomical sites (neck vs. heart)*



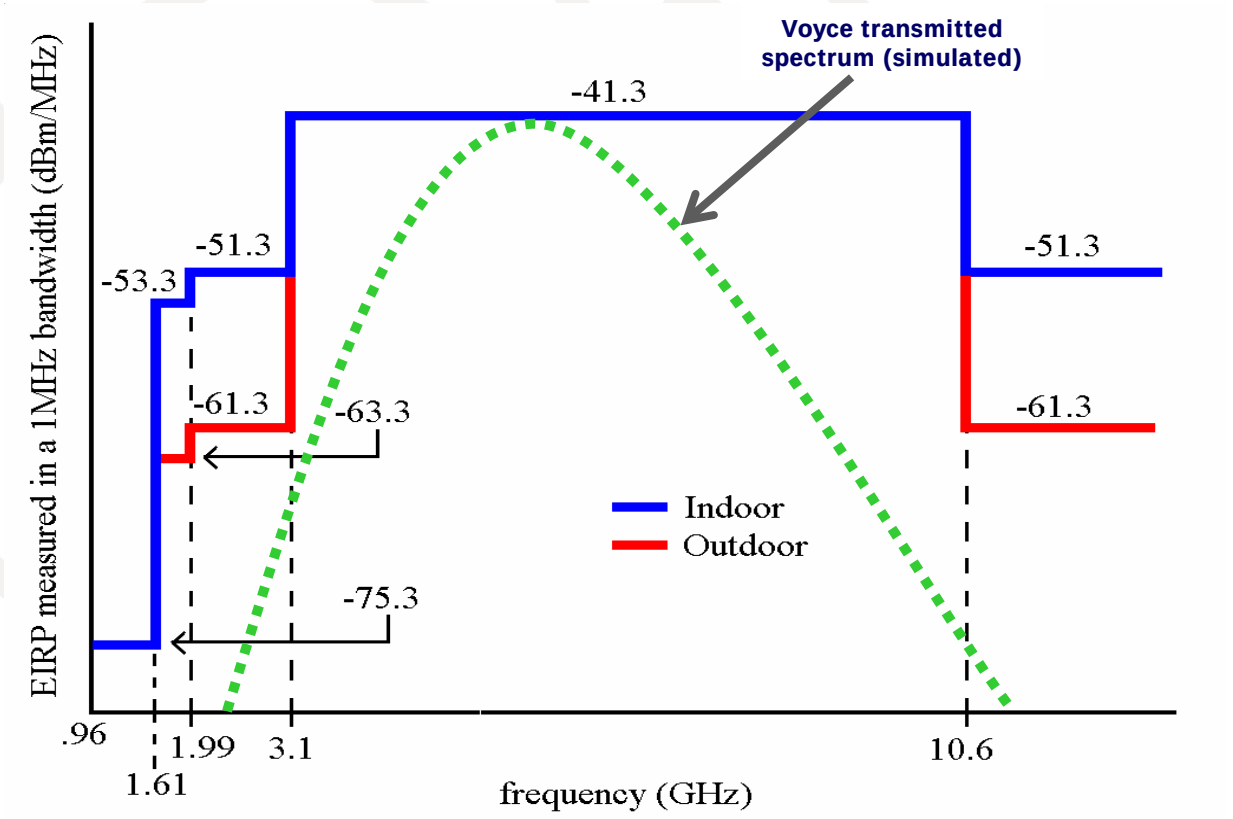
UWB Radar Product: VOYCE™ Health Band

- **VOYCE™ is a "health band" designed for animals**
  - *Measures temperature, activity/motion, and cardiopulmonary functions*
  - *Similar to other wearable sports monitor devices (Fitbit, Nike Fuel, etc.)*
- **Sensor platform**
  - *Temperature sensor – environmental conditions*
  - *Light sensor – time spent indoor/outdoor*
  - *Triple axis accelerometer – activity, distance, calories*
  - *UWB radar – resting cardiopulmonary rates*
- **On-board data analysis and wireless links to the "cloud"**
  - *Dual 32b processors*
  - *Dual radios - 802.11 b/g/n and Bluetooth 4.0 LE*
- **Not a UWB medical imaging system**
  - *No images, diagnosis or treatment*
  - *Designed to be used by consumers in and around home*
  - *Veterinary clinic version under development*

U.S. Equipment Certification for VOYCE™

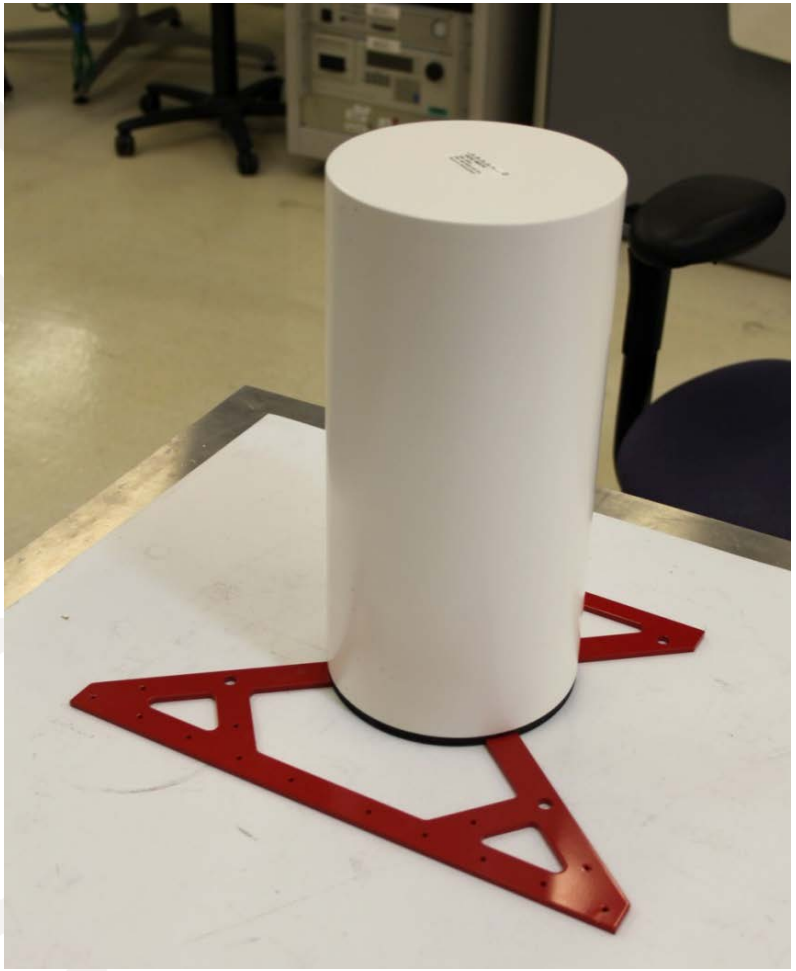
- **FCC equipment certification in progress**
  - *Extensive conversations with FCC staff resulted in decision to demonstrate compliance with Rule Part 15.519 (portable UWB devices allowed outdoors)*
  - *Currently conducting field tests under FCC experimental license*
  - *VOYCE operational bandwidth: 3.1-8.0 GHz (subset of U.S. 3.1-10.6 GHz UWB band)*

FCC Masks for Indoor (Part 15.517) and Portable+Outdoor (Part 15.519) UWB Devices

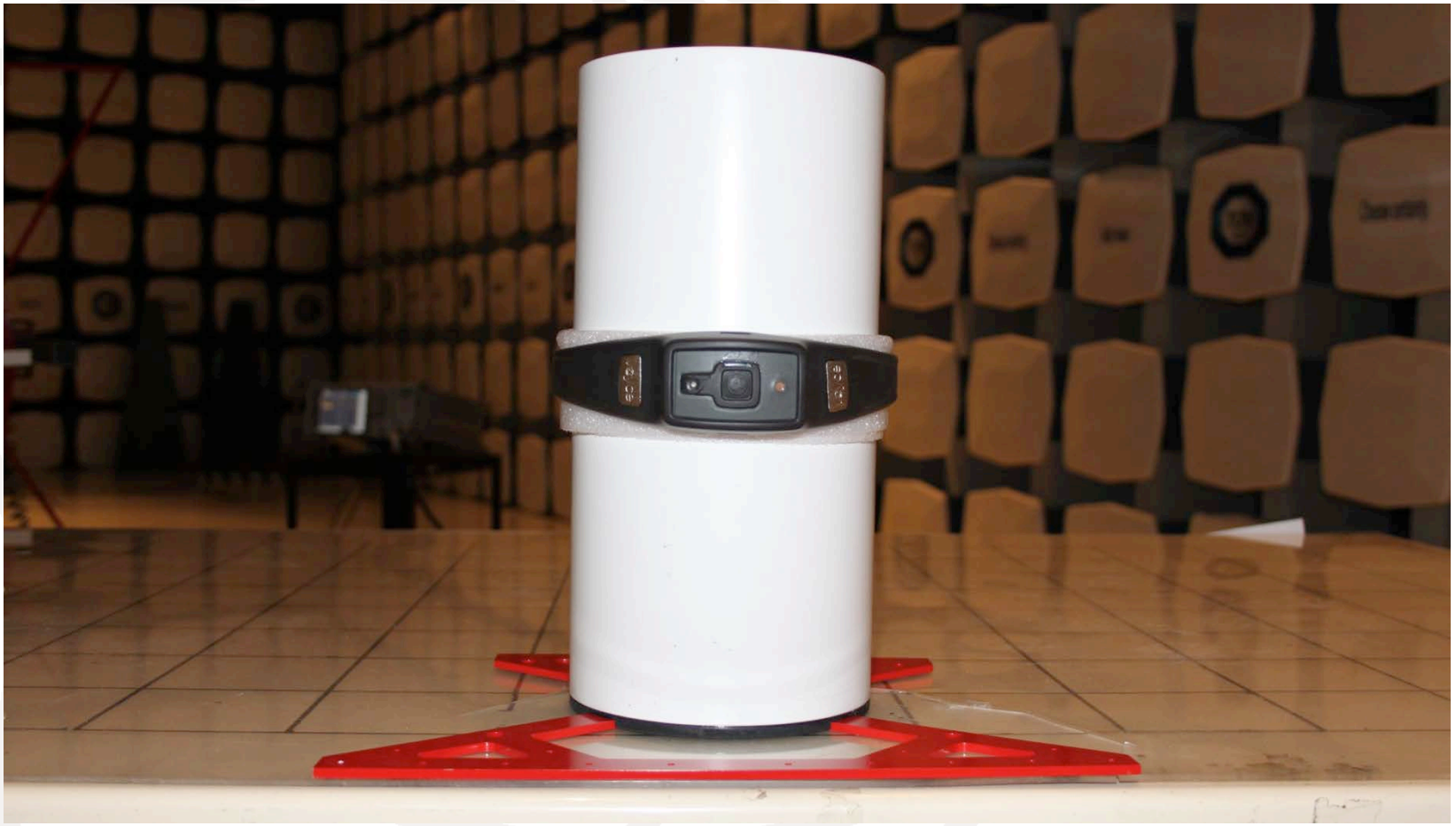


FCC VOYCE™ Certification Test Set-up

- **"Phantom" dog neck developed by SPEAG (photo on right)**
  - *Simulates realistic operating conditions of device (against a dog's neck)*
  - *Without dielectric load of animal body, the UWB antenna behaves like a Hi-Q resonator with a large return loss*
  - *Free-space measurements are impractical*
- **Cylinder**
  - *Length = 30 cm; Diameter = 15 cm*
- **Gel**
  - *SPEAG dielectric "Head Gel" deemed closest match to neck tissue*
- **1cm spacing between VOYCE™ band and cylinder**
  - *Represents 2-finger fit test between collar and dog neck*

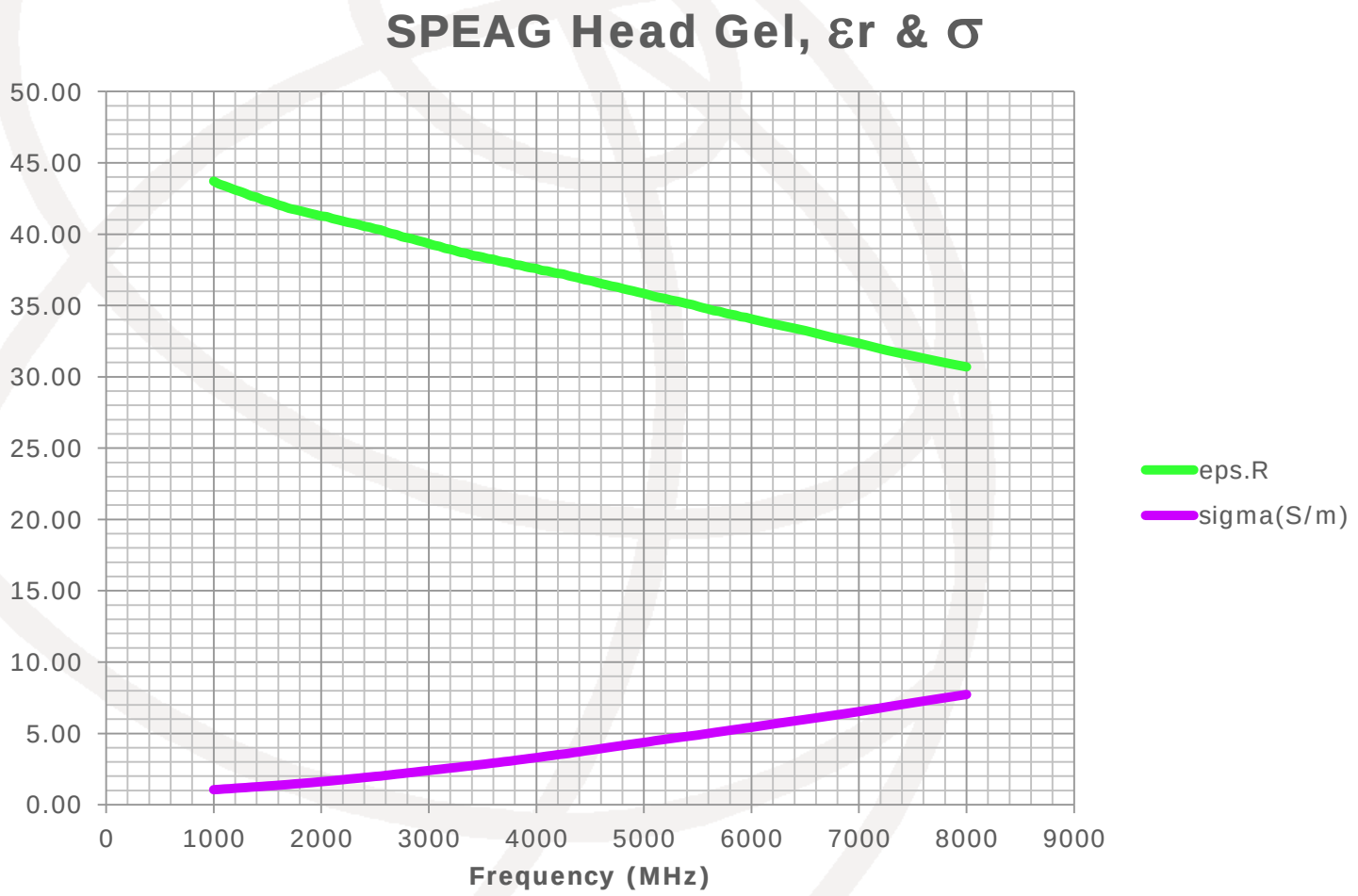


VOYCE™ Band On SPEAG Neck Phantom



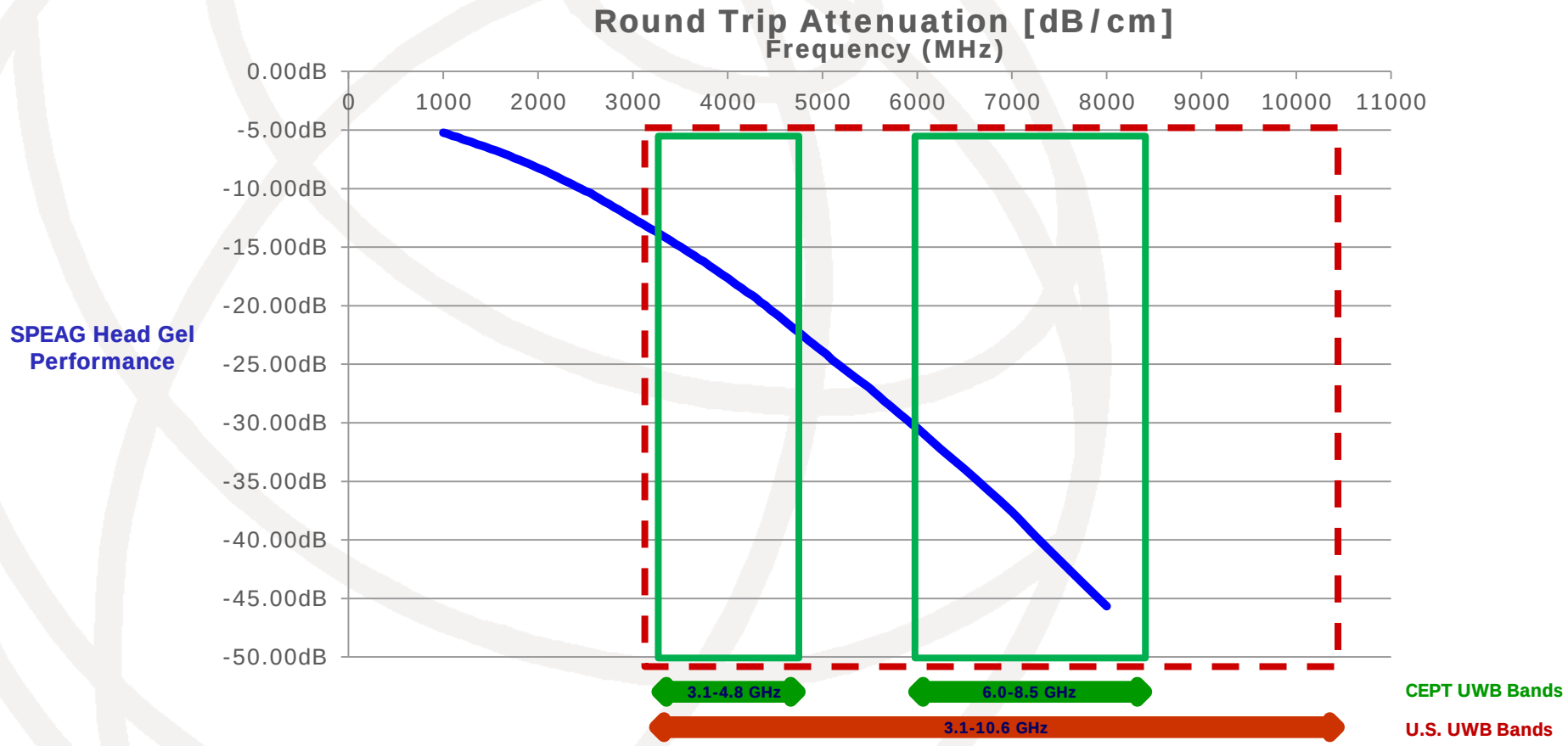
SPEAG Gel: Dielectric Properties

- **SPEAG "Head Gel" provided the most acceptable properties**
  - *FCC staff proposed Head Gel due to SAR performance*
  - *Good match to measured porcine grey matter (good proxy for dogs)*



UWB Signal Loss vs. Frequency

- **Attenuation of UWB radar signal in living tissue increases significantly as frequency increases**
  - *Empirical tests show UWB radar operation above 6 GHz produces little (if any) useable physiological data in animals or humans*
  - *UWB health monitoring applications need access to bands below 6 GHz*



UWB Radar Bandwidth Requirements

- **UWB radar range performance driven by:**
  - *Velocity of propagation (up), pulse width (t), and pulse repetition interval (PRI)*
    - Minimum range = Receiver Dead Zone: $R_d = \upsilon_p \tau/2$
    - Maximum range = Unambiguous Range: $R_u = \upsilon_p (PRI-\tau)/2$
    - Minimum separation = Range Resolution: $\delta R = R_d = \upsilon_p \tau/2$
- **Narrow UWB pulse = wide bandwidth**
  - *Wide bandwidth results in higher resolution and ability to measure near-field objects*
    - Critical for health monitoring applications and wearable devices
  - *Optimal bandwidth for UWB radar health monitoring is >2 GHz*
    - 2 GHz wide = 12 mm resolution and range
    - 5 GHz wide = 5 mm resolution and range

UWB Radar RF Exposure and Safety

- **Tissue heating from RF exposure is main biological phenomenon and health concern**
  - *FCC/FDA limits on human exposure*
    - Exposure defined in terms of SAR (specific absorption rate)
    - 0.08mW/gm for whole body exposure
    - 1.6mW/gm for spatial peak exposure (localized average)
  - *Tests conducted on small mammals used to derive human limits*
    - RF exposure of 4mW/gm caused 1^{o}C rise in core temperature and an observed degradation in behavior
    - Human whole body SAR limits set 50x lower than 4mW/gm
- **No RF exposure limits in FCC rules for animals**
- **UWB medical radar below FCC human SAR limits**
  - *UWB energy is non-ionizing*
  - *Average UWB transmitter power < 1mW at 32MHz PRF*
    - Less than 1.6mW/gm human exposure limit
  - *Actual exposure levels reduced by antenna aperture*

Summary

- **UWB radar for health monitoring applications has been studied in depth since 2002**
  - *Numerous research institutes and companies looking at a wide variety of applications*
  - *From cardiopulmonary to fetal monitoring to detection of breast tumors…*
- **Several UWB health monitoring products are in development and/or ready for commercial introduction**
- **Key regulatory requirements for UWB health monitoring deployments to be successful:**
  - *Classification of UWB health monitoring devices as "consumer" products*
    - Not limited to use in hospitals or under supervision of a physician
    - Convergence of wearable personal technology and health monitoring
  - *Authorization to use UWB health monitoring devices outdoors*
  - *Spectrum allocations for UWB health monitoring*
    - Below 6 GHz
    - Wide bandwidths >2 GHz (preferably 3-4 GHz)
  - *Global spectrum harmonization*

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