Everything you never knew you wanted to know about SAR and B1+RMS, and were too busy to ask.

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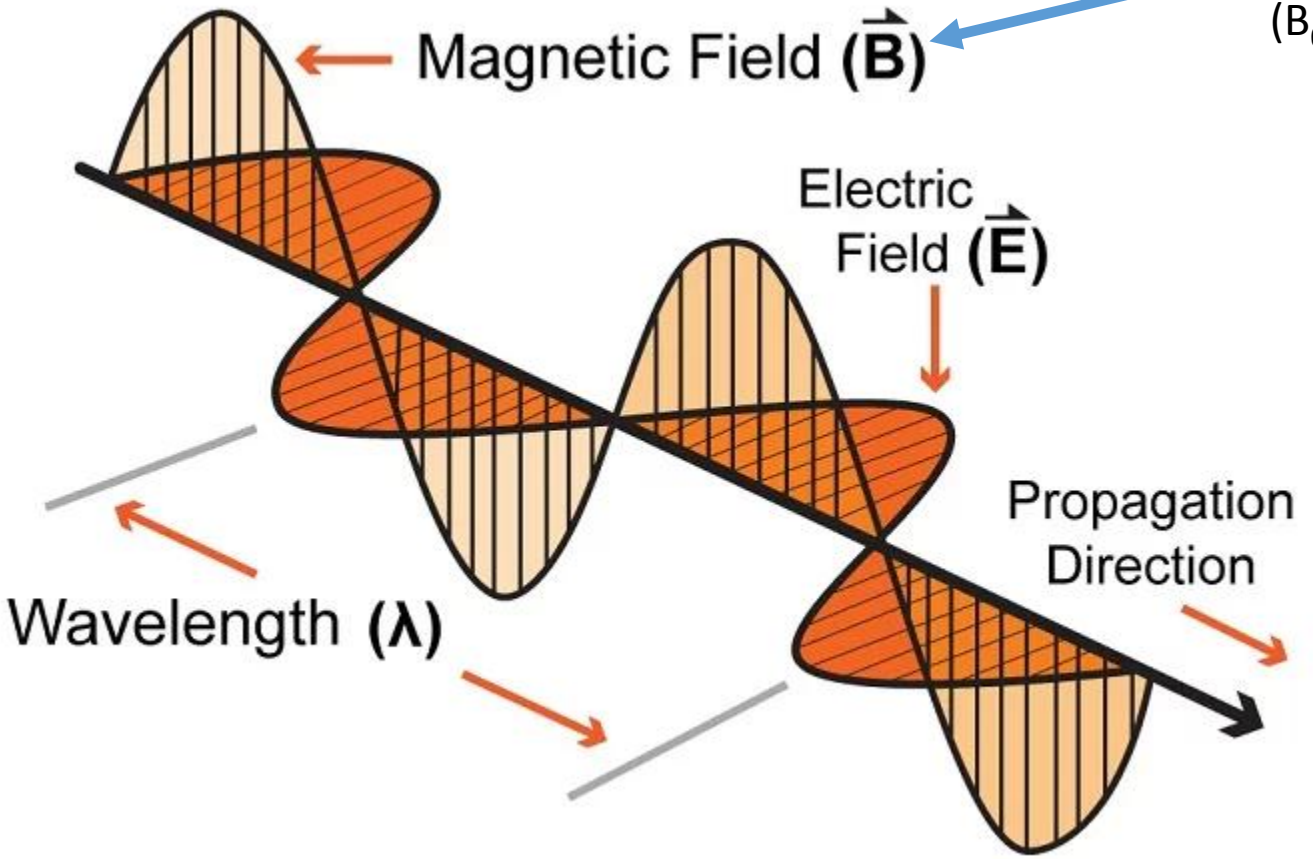
Remember when physics was fun?

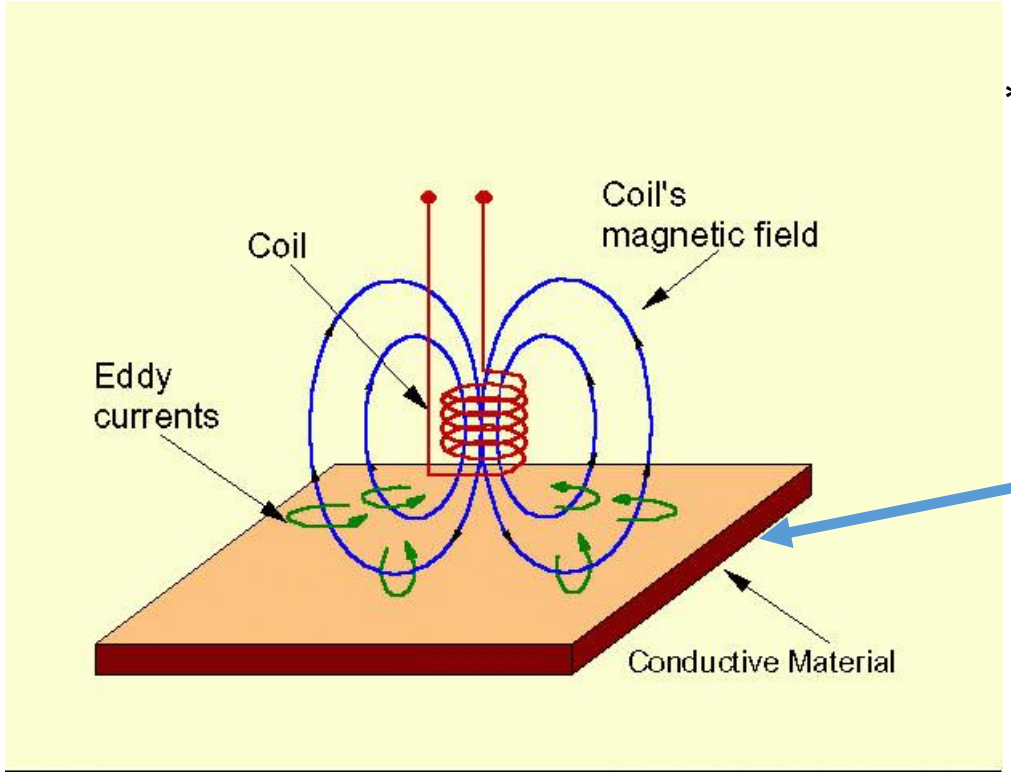
In an MRI scanner with a big field (B_0) this is called B_1



https://www.allaboutcircuits.com/textbook/radio-frequency-analysis-design/rf-principles-components/what-is-rf-and-why-do-we-use-it/

The fun never ends…

A calloused, dry hand may have more than 100,000 Ω because of a thick outer layer of dead cells (usually lower, but still significant). The internal body resistance is about 300 Ω, being related to the wet, relatively salty tissues beneath the skin.*



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Patient's body

*R.M. Fish & L.A. Geddes, Eplasty. 2009 Oct 12;9:e44

**https://www.nde-ed.org/EducationResources/CommunityCollege/EddyCurrents/Physics/PopUps/picpopup2.htm

Oh Wait, the fun is ending…

A 1200W heater.

Fortunately we don’t pump in 1200W, but even small wattages can heat tissue up.

Specific Absorption Rate (SAR)

- The amount of power deposited in a patient per unit weight
  - Power – Watts (W)
  - Weight- Kilogram (Kg)
  - SAR = W/Kg
- MRI
  - Normal Mode – Whole body SAR of 2 W/Kg (head SAR 3.2 W/Kg)
  - First Level Mode – Whole Body SAR of 4 W/Kg (head SAR 3.2 W/kg)
- Not Just MRI!
  - Mobile Phones
  - 1.6 W/Kg in the US
  - 2 W/Kg in the EU (Head and trunk)
  - UK after Brexit – Who knows?!

Is it really that simple?

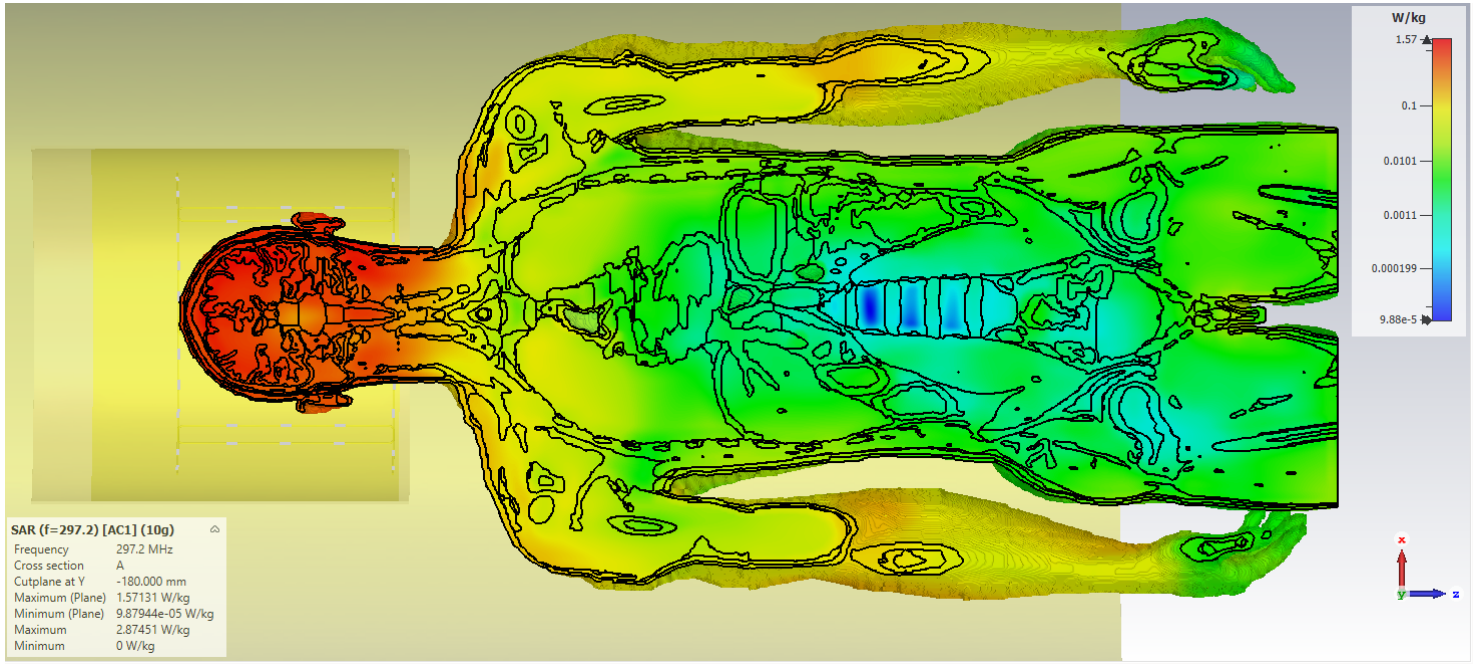
	Whole body	Partial body			Local	
		Head	Not head [a]	Head [b]	Trunk	Extremities
NORMAL MODE	2	3.2	2–10	10	10	20
CONTROLLED MODE	4	3.2	4–10	20	20	40
RESEARCH / EXPERIMENTAL MODE	>4	>3.2	>(4–10)	>20	>20	>40

a Partial-body SAR scales dynamically with the ratio r between the patient mass exposed and the total patient mass:
– normal operating mode: SAR = (10-8×r) Wkg^{-1}
– controlled operating mode: SAR = (10-6×r) Wkg^{-1}

b In cases where the eye is in the field of a small local coil used for RF transmission, care should be taken to ensure that the temperature rise is limited to 1°C.
Averaging time = 6 min.

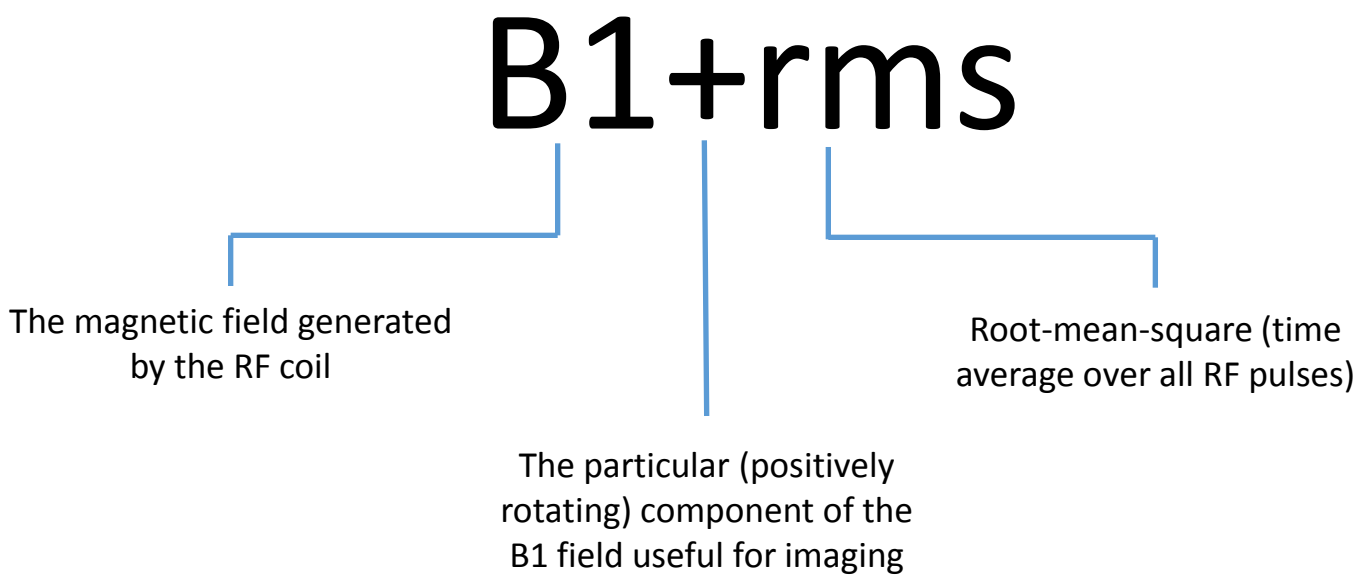
Safety Guidelines for Magnetic Resonance Imaging Equipment in Clinical Use, MHRA 2014

Is it really that simple?



RF penetration and absorption are complex and need to be modelled for different body shapes and sizes.

What's this B1+rms gobbledygook?



What's this B1+rms gobbledygook?

B1+rms

A measure of the RF power going into the patient averaged over 10 seconds

What's the point?

- B1+rms is independent of patient characteristics
  - Not dependant on patient's weight or height
  - Is dependant in imaging parameters i.e. TR, number & type of RF pules, flip angle etc
- Useful in situations where there is an implant
  - Manufacturers can work out how much RF power an implant can safely tolerate
  - Less conservative than setting SAR which needs to take into account potentially large variations in patient weight

Goodbye SAR? Long live B1+rms!?

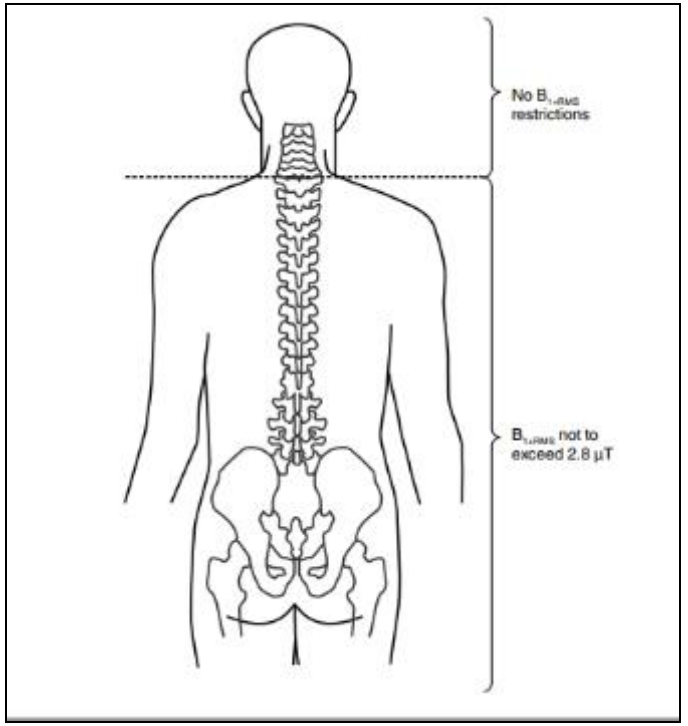
- SAR is and will remain important in determining patient TISSUE heating
  - Patients who have temperature autoregulation dysfunction
  - Patients with fever
  - Infants and children
- B1+rms provides better, less conservative information in patients with IMPLANTS

Enough with the theory!!

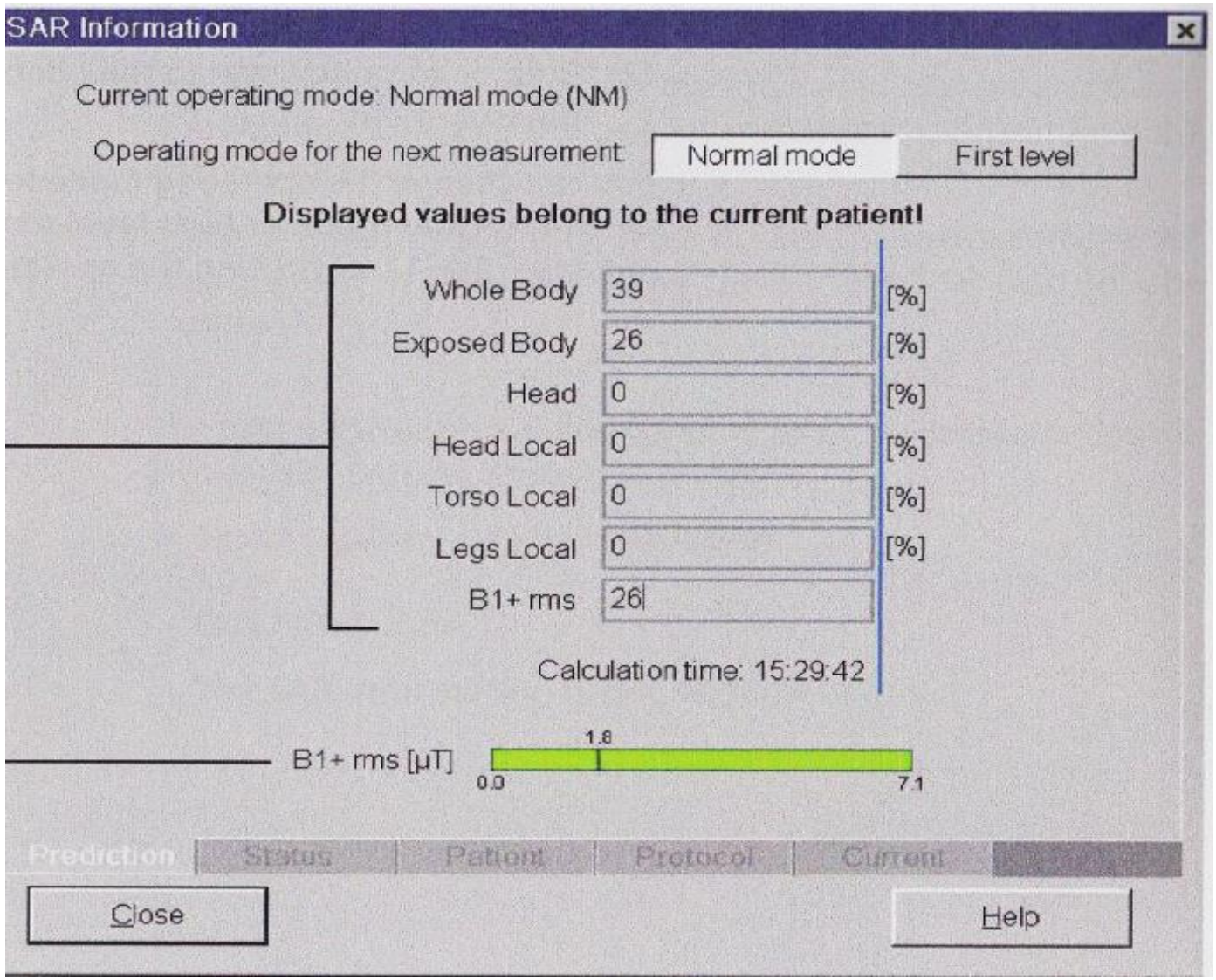
- What is it really good for?
- Likely to increase in use in the future, especially in active implants
- Increased awareness with MRI scanner manufacturers
  - More options to monitor B1+rms and limit it.
- Deep Brain Stimulators, Spinal Cord Stimulators, and some Pacemakers

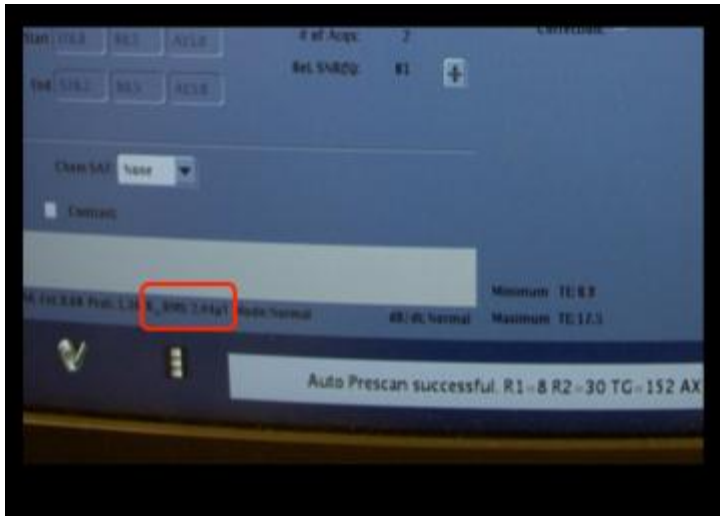
Medtronic Advisa and Endura MRI Pacemakers

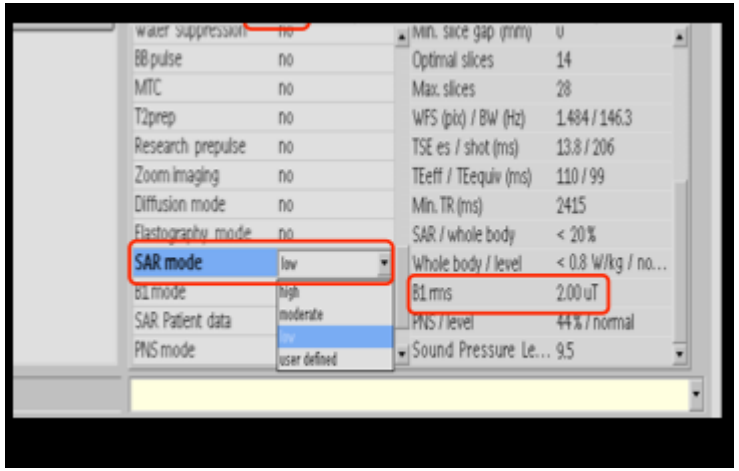
Scanner type	Horizontal field, cylindrical bore, clinical system for hydrogen proton imaging
Scanner characteristics	• Static magnetic field of one of the following strengths: – 1.5 T – 3 T • Maximum spatial gradient of ≤ 20 T/m (2000 gauss/cm) • Gradient systems with maximum gradient slew rate performance per axis of ≤ 200 T/m/s
Scanner operation	**1.5T –** MRI radio frequency (RF) power – Normal Operating Mode. • The whole body averaged specific absorption rate (SAR) must be ≤ 2.0 W/kg. • The head SAR must be ≤ 3.2 W/kg.
	3T – MRI radio frequency (RF) power – First Level Controlled Operating Mode or Normal Operating Mode: • B_{1+RMS} must be ≤ 2.8 µT when the isocenter (center of the MRI bore) is inferior to the C7 vertebra. • Scans can be performed without restriction when the isocenter is at or superior to the C7 vertebra (see Figure 1).



On the Scanner?







What does the future hold?

- Implant modes
  - All manufacturers looking to implement
  - Set limit for SAR or B1+rms
- Further in the future….
  - Implant databases
  - How, or would these deal with multiple implants and potential interactions?
  - Who would assume risk?