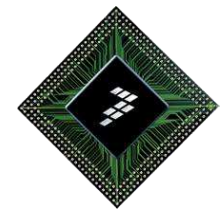


August, 2010

RF Amplifiers and RF Heating for Medical Applications

IND-F0690



Tiefeng Shi

- ▶ RF Power for Medical Applications
 - RF Welding of Plastic Materials
 - Non-Surgical Tumor Ablation
 - CO2 Laser Scalpels
 - Fractional Photothermolysis Skin Resurfacing
 - Magnetic Resonance Imaging
- ▶ Market Size and Growth Rates
- ▶ Market Leaders
- ▶ Freescale Device Solutions for Each Application
- ▶ Conclusions

RF Welding of Plastic Materials

- ▶ Radio frequency welding is the process of fusing materials together by applying RF energy to the material in the area to be joined
- ▶ The RF dynamic electric field causes the molecules in polar thermoplastics to oscillate
- ▶ The molecules translate this oscillatory motion into thermal energy and cause localized heating of the material



RF Welding of Plastic Materials

- ▶ The resulting weld is stronger than the original materials
- ▶ By incorporating a cutting edge adjacent to the welding surface, the process can simultaneously weld and cut a welded material. This process is often referred to as tear-seal welding



Common RF Plastic Welding Examples

- ▶ Stationery - Book covers, stationery wallets, zip bags, binders
- ▶ Inflatable items - Beach balls, air/water beds, rafts, life jackets
- ▶ Large items - Tarpaulins, tents, pool liners, outdoor covers
- ▶ Medical items - Blood bags, air bladders, colostomy bags
- ▶ Automotive - Air bags, dashboard covers, sun-visors
- ▶ Blister packs – Almost everything you buy

RF Welding of Plastic Materials

- ▶ RF plastic welding is a very mature technology that has been around since the 1940s. There are only a few manufacturers in the business
- ▶ Typical RF power requirements are at 27.12 MHz and at power levels ranging from 100W to 40KW



Current Market Leaders

▶ TWI Technology Engineering LTD



▶ Mark Peri International



▶ Alloy Brands/Tegant Corporation



▶ Northwest RF Corporation



▶ Cosmos Kabar Corporation

Cosmos Electronic Machine Corporation



▶ Hall Dielectric Machinery



RF Power Solutions for Plastic Welding Applications

MRF6V2010N



10W Rated Driver

Performance

Peak Power : 10W
Gain: 24 dB
PAE: 62%

Key Features

*Lowest cost plastic TO package
High gain two-stage device
Dual path configuration*

MRFE6VP6300H



300W Rated Power

Performance

Peak Power: 300W
Gain: 25 dB
Drain Efficiency 70%

Key Features

*High-performance VHV6 technology
50V operation for improved power density
Highest level of ruggedness*

MRF6VP11KH



1000W Rated Power

Performance

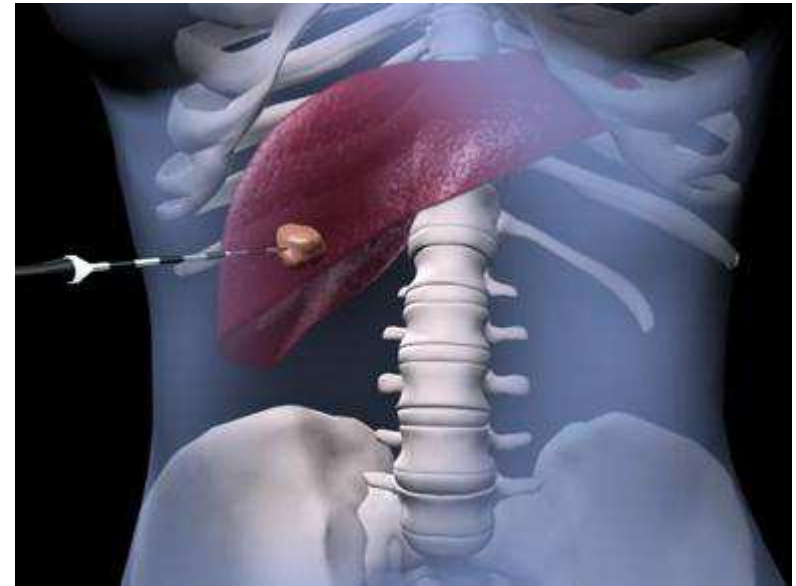
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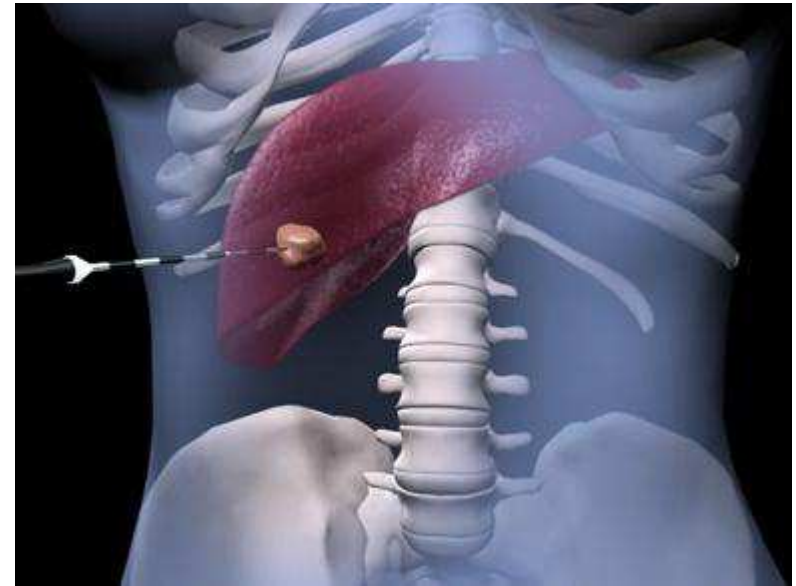
Non-Surgical RF Tumor Ablation

- ▶ RF energy is used to create heat, in a specific location, at a specific temperature, for a specific period of time, and ultimately results in the death of unwanted tissue
- ▶ An ablation probe is placed directly into the target tissue. An array of several small, curved electrodes are deployed from the end of the probe into the unwanted tissue

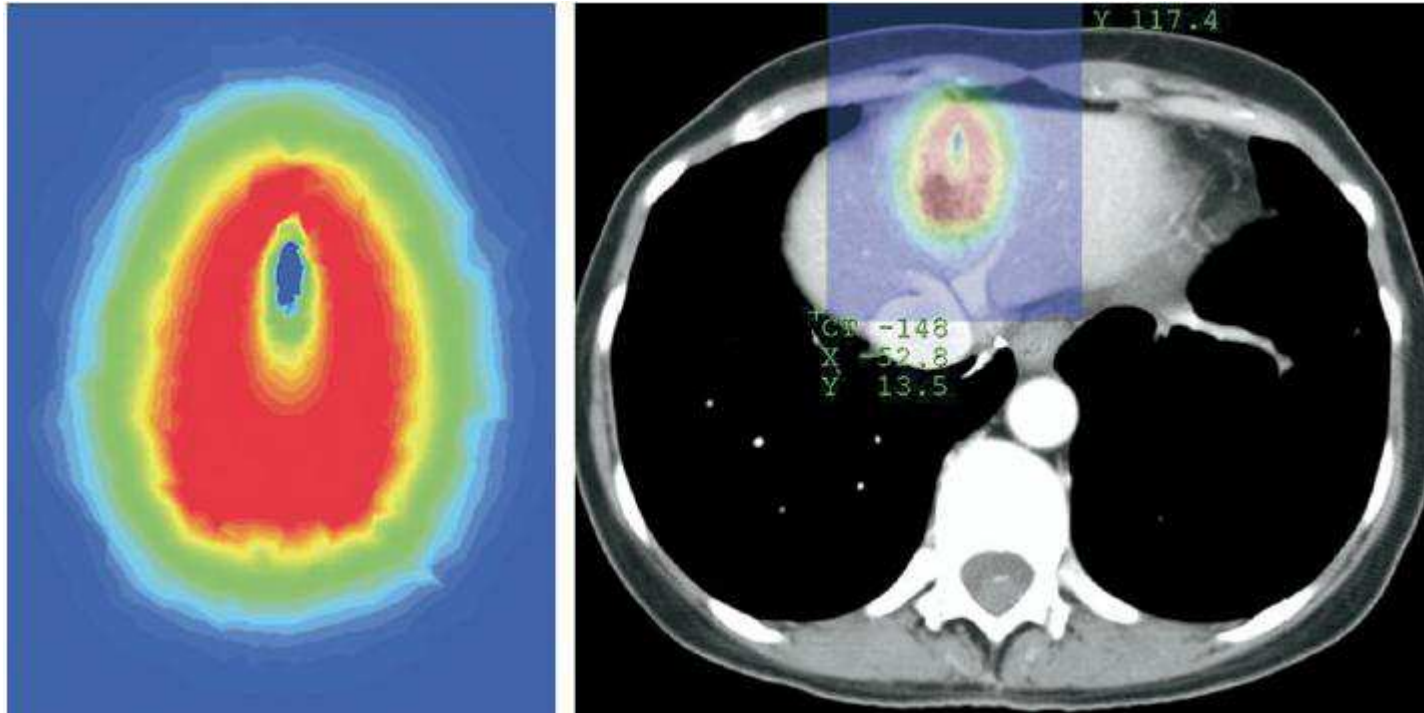


Non-Surgical RF Tumor Ablation

- ▶ RF energy flows through the electrodes, causing ionic agitation and therefore friction and heat in the target tissue
- ▶ Thermocouples in the tips of the electrodes monitor tissue temperatures. Power is adjusted until the target temperature is achieved and all target tissue is destroyed



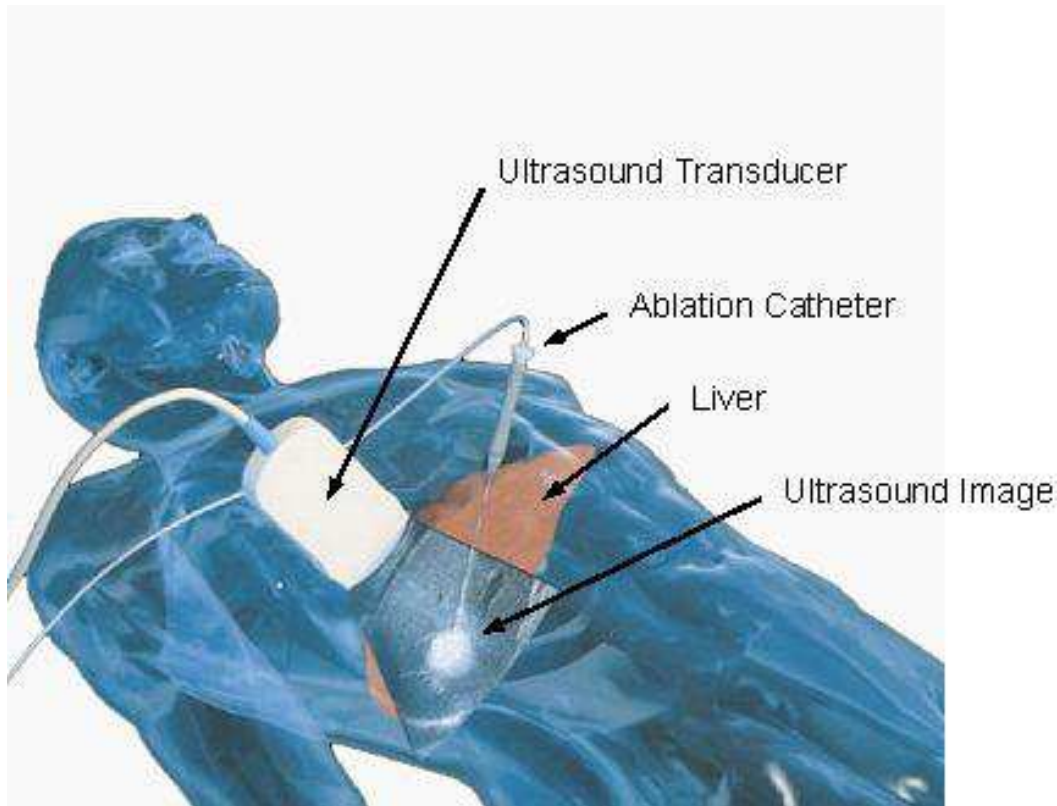
Computer Aided RF Tumor Ablation



- Computer models (left) are used for treatment planning, and are superimposed on the medical images (right) to estimate tissue temperature during treatment, RF power requirements and application duration

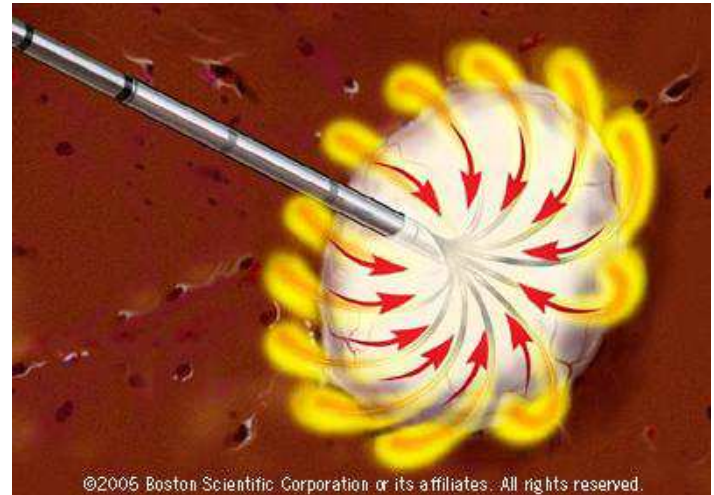
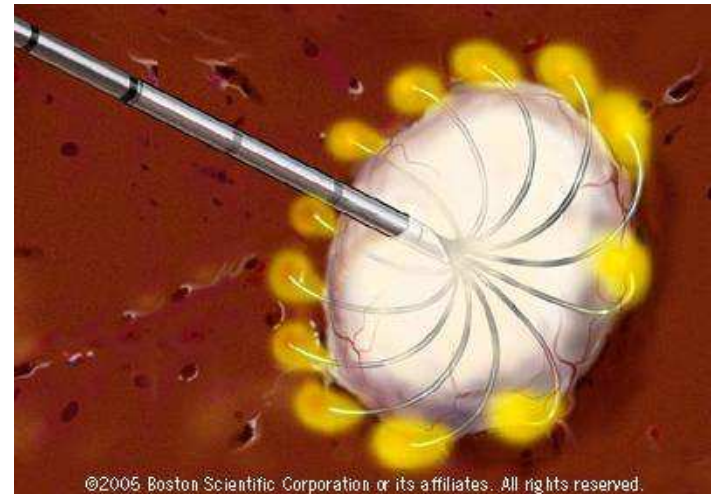
Patient Set-up for Liver Tumor Ablation

- ▶ The ablation catheter is inserted into the liver tumor through a small incision in the skin. Ultrasound imaging is used to guide the electrode into the tumor and monitor the ablation.



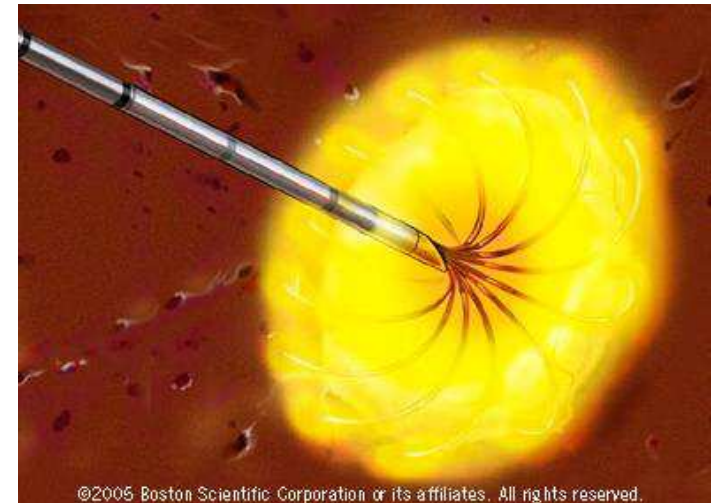
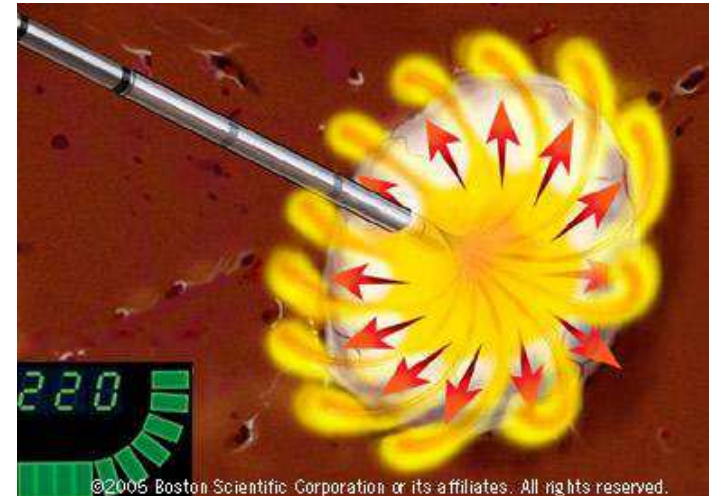
How RF Ablation Works

- ▶ Creation of a thermal lesion
 - Tissue desiccation begins at the tips of the array tines
- ▶ Ablation zone travels along tines
 - As the tissue near the tips of the tines desiccates, the zone of ablation travels back along the tines toward the center of the array



How RF Ablation Works

- ▶ Nearing completion, impedance rises
 - The thermal lesion then moves outward and begins to fill in the gaps between the tines. As lesion ablation nears completion, impedance rises exponentially
- ▶ Complete thermal lesion
 - A complete thermal lesion is achieved once tissue desiccation has occurred throughout the target tissue. Once the desired temperature is achieved, the generator is designed to automatically reduce power, signaling completion of the ablation process



Current Market Leaders

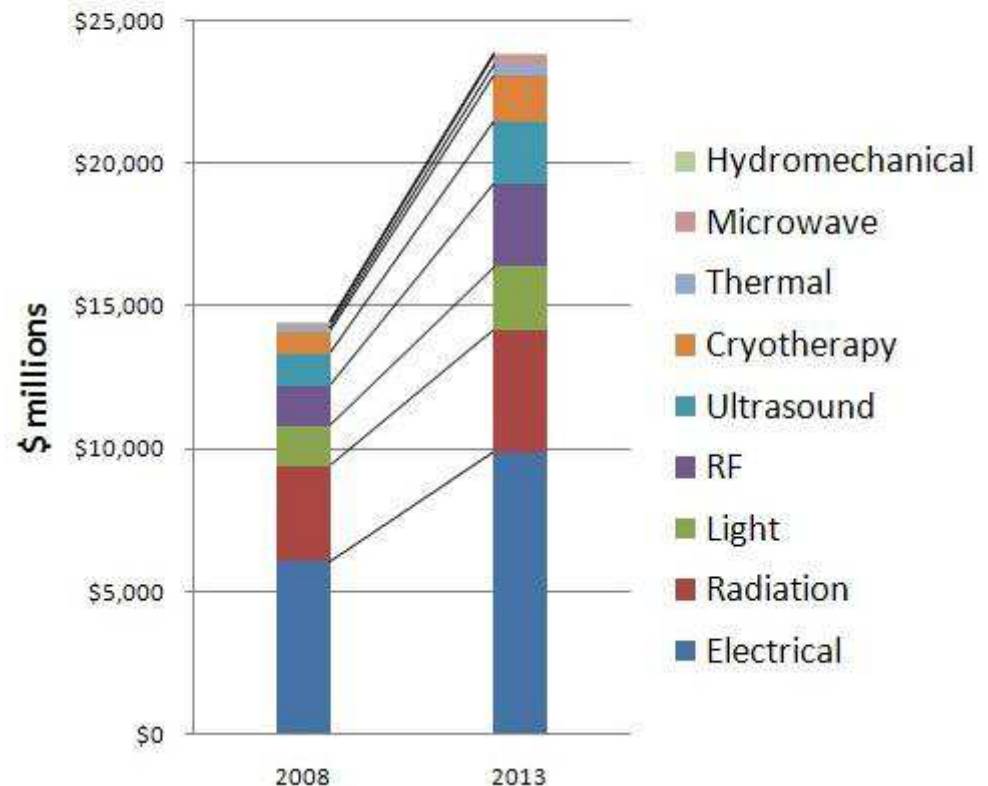
Radiofrequency Ablation Manufacturers

Manufacturer	Product	Indication
ACMI (Olympus)	Coag	Soft tissue coagulation
AngioDynamics	Starburst XL	Lung cancer
ArthroCare	ACD 50 Coblation	Arthroscopy
ArthroCare	SpineWand	Nucleoplasty
Atricure	Coolrail Pen	Atrial arrhythmias
Bard EP	Stinger catheters	Atrial arrhythmias
Bard EP	HD Mesh Ablation System	Atrial fibrillation
Boston Scientific	Blazer ablation catheters	Atrial arrhythmias
Cardima	Revelation catheters	Atrial arrhythmias
ConMed	Trident	Soft tissue coagulation
ConMed	Ultrablator	Arthroscopy
Cytoc/Hologic	NovaSure	Menorrhagia
Direx	Tempo	BPH
Gyrus (Olympus)	Tissue Management System	Gynaecological
Gyrus (Olympus)	Somnus	ENT
Irvine Biomedical (St Jude)	CoolPath ablation catheter	Atrial arrhythmias
J&J Biosense Webster	Thermocool	Atrial arrhythmias
J&J Mitek	VAPR II	Arthroscopy
Maquet Critical Care (Getinge)	RF 3000	Hepatic cancer
ProSurg	RF GEL	BPH
Radionics	Cool-Tip	Soft tissue ablation
Radiotherapeutics	RF 3000	Soft tissue ablation ?
RFA	InCircle	Liver tumours
SenoRx	Shape Select	Breast cancer
Smith & Nephew	Vulcan	Capsular shrinkage
Stryker	Neuro N50	Chronic pain
TissueLink	DS 3.0	Hepatectomy
Valleylab (Covidien)	Ligasure	Soft tissue coagulation
VNUS Medical Technologies	ClosureFast	Saphenous vein closure

Market Size and Growth Rate

- ▶ RF ablations will see significant growth in the next few years
- ▶ Other ablation methods include hydromechanical, microwave, thermal, cryotherapy, ultrasound, light, radiation and electrical
- ▶ The RF section is a \$4 billion dollar business

Ablation Market Revenues, U.S., by Product Segment, 2008 & 2013



RF Power Solutions For RF Ablation Applications

MRF6V2010N



10W Rated Driver

Performance

Peak Power : 10W
Gain: 24 dB
PAE: 62%

Key Features

Lowest cost plastic TO package
High gain two-stage device
Dual path configuration

MRFE6VP6300H



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Lasers Used in Medical Applications

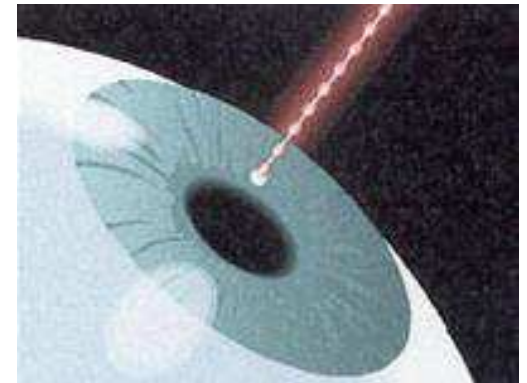
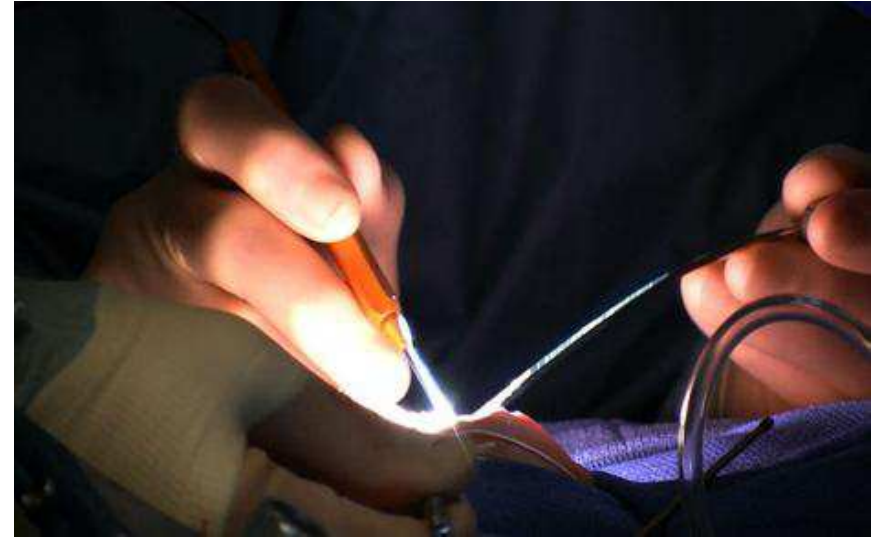
► There are many applications for lasers in medicine, including:

- Laser scalpels
- Fractional photothermolysis
- Lasik eye surgery



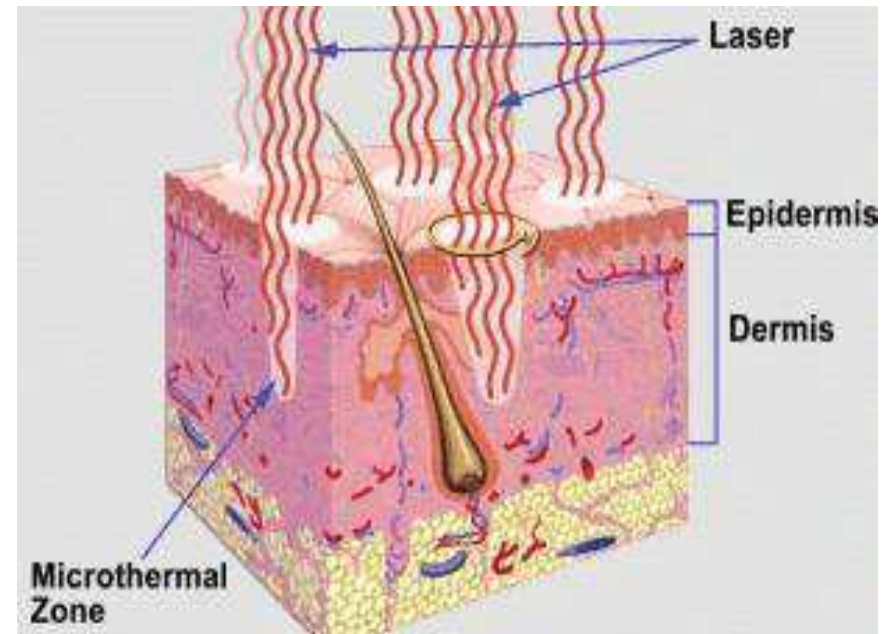
Benefits of Laser Scalpels

- ▶ Laser scalpels ablate living tissue with the energy of laser light
- ▶ The laser vaporizes all soft tissue with a high water content
 - i.e. skin, fat and muscles
- ▶ Can be computer-controlled for exact tissue molding, i.e. shaping the cornea in LASIK and LASEK surgery



Laser Skin Resurfacing

- ▶ Photo rejuvenation induces controlled wounds on the skin to prompt the creation of new skin cells
- ▶ Laser ablation creates microscopic thermal impact sites surrounded by unaffected healthy tissue
- ▶ Only 20% of the area is affected at any one time. This speeds healing.



Before and After Examples of Laser Skin Resurfacing

- ▶ Turns back the clock on aging and rejuvenates sun-damaged skin
- ▶ Here are the results of three to six treatments spaced about one to four weeks apart, with a four-week healing period



Current Market Leaders

► Fraxel



► Matrix Skin



► Palomar Medical



► DEKA Research and Development



RF Power Solutions For CO2 Laser Applications

MRF6V2010N



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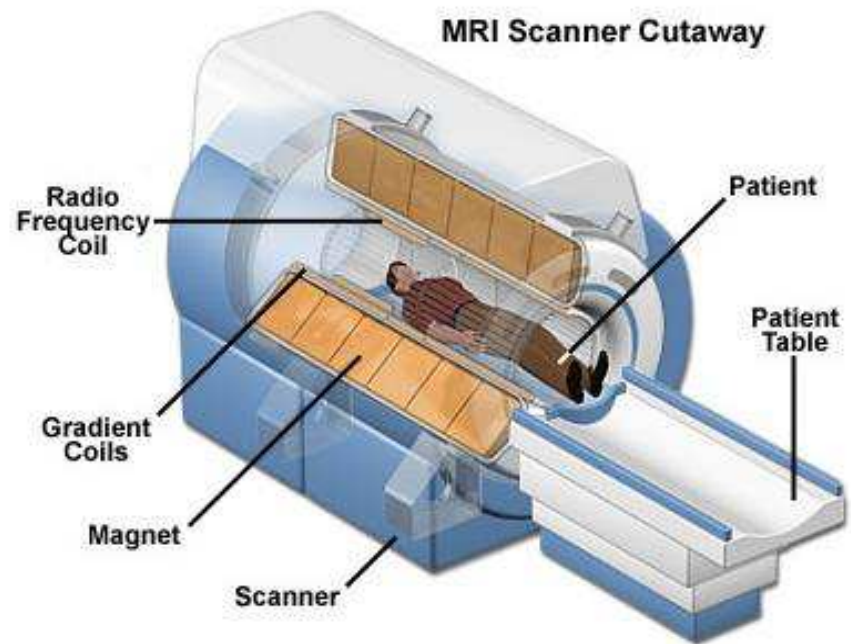
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History of Magnetic Resonance Imaging

- ▶ Developed in 1977 as a non-invasive cancer detection tool
- ▶ ASP for a 3Tor system is \$3M
- ▶ TAM is \$5.5B in 2010
- ▶ CARG of 11.6%
- ▶ Japan has highest ratio of MRI scanners per person



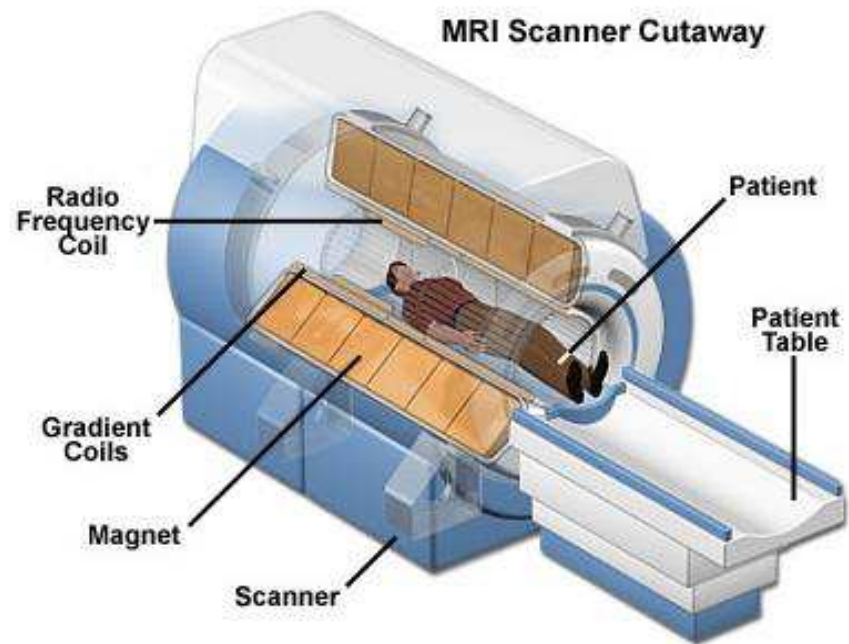
Amplifier Details for MRI

- ▶ RF amplifier is typically located in the equipment room adjacent to the coil location
- ▶ Low-loss coaxial cable or Heliax feeds the RF power from the PA to the radio frequency coil (transmit antenna)
- ▶ Frequencies typically range from 8 MHz to 130 MHz, but are operated band-specific: less than 1% bandwidth
- ▶ Blanking times are less than 1 μ S (rise and fall times less than 500nS); emissions have to be close to thermal noise

- ▶ Power levels are from 2 KW to 35 KW
- ▶ Duty cycle up to 10% and pulse widths to 10 mS (3% and 3 mS typical).
- ▶ High linearity and phase noise requirements, linearization techniques are usually used in the PA
- ▶ Device reliability is an important parameter. Mean time to failure (MTTF) for the system has to be more than 30,000 hours

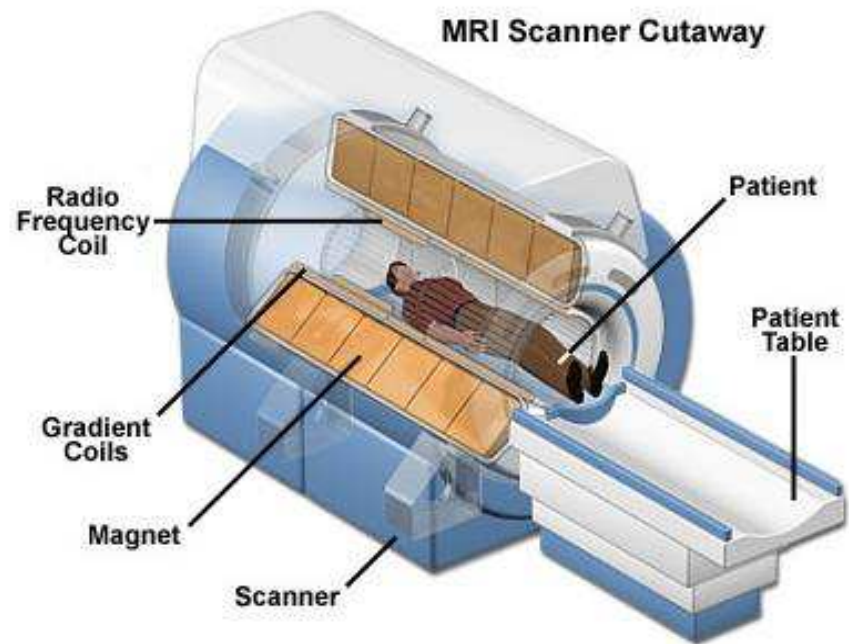
Major Components of the MRI Scanner

- ▶ Super-conducting magnet, cooled with liquid nitrogen -196C
- ▶ Gradient coils, X, Y, Z
- ▶ Radio frequency coil
- ▶ Patient transport bed
- ▶ RF power amplifier



Major Components of the MRI Scanner

- ▶ Software for Fourier transforms, signal processing, image reconstruction, cataloging and patient's electronic file storage
- ▶ Frequency conversion and DSP controller board
- ▶ Film printer
- ▶ High-resolution display
- ▶ Head and surface coils



MRI Sequence of Events

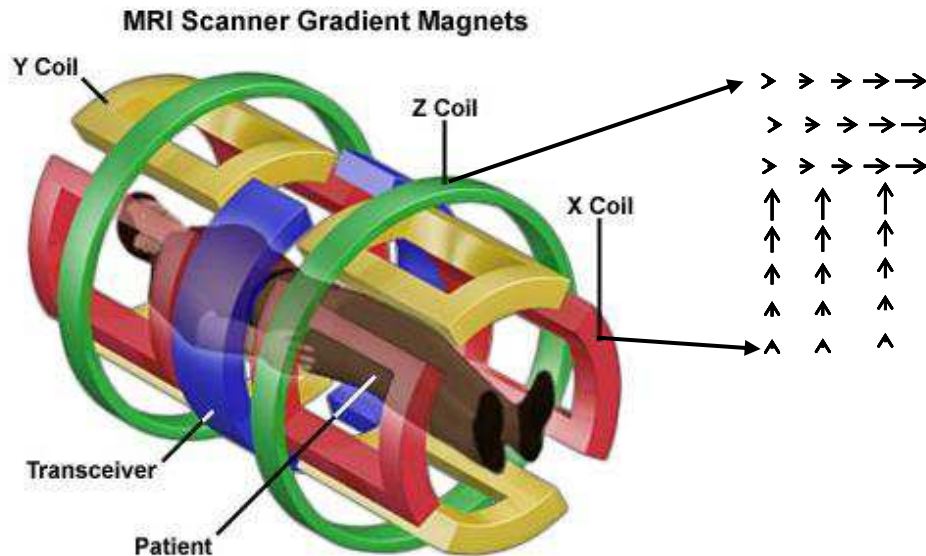
- ▶ Magnetic resonance imaging uses the spin of the hydrogen atom
- ▶ Half the atoms line up with the magnetic field (N-N and S-S), and the other half line up against the magnetic field
- ▶ Upon removal of the RF excitation, the atoms that have switched their orientation go back to their original alignment, giving off oscillating currents (free induction decay)
- ▶ Slices of the subject are generated by using gradient coils to modify the magnetic field strength locally around the imaging area

MRI Sequence of Events

- ▶ Gradient coils are used to get frequency separation in the X, Y and Z orientation
- ▶ Coils (head, body or surface) are used to pick up the currents and convert to a time-varying voltage (microvolts)
- ▶ To reduce heating in human tissue, duty cycle is typically only 3%. Pulse width is 3 milliseconds. It can take up to 47 μ S to flip the orientation of the H atom.
- ▶ A low noise amplifier will boost the signal strength (typically 0.5 to 1.5 dB NF).

MRI Sequence of Events

- ▶ Gradient fields can form a slice of tissue in any direction within the scanned subject



Current Market Leaders

- ▶ GE Healthcare
- ▶ Philips Medical Systems
- ▶ Siemens Medical Solutions
- ▶ Hitachi Medical Corp
- ▶ Toshiba medical Systems
- ▶ Medtronic



GE Healthcare

PHILIPS

SIEMENS
medical

HITACHI

TOSHIBA



RF Power Solutions For MRI Applications

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10W Rated Driver

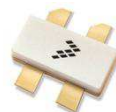
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- ▶ There are plenty of interesting uses of high power RF energy in a wide variety of medical applications
- ▶ Each require a slightly different spin on RF power device needs
- ▶ Freescale's RF division is actively pursuing new device designs and technologies to participate in this growing field

