EE169

"INTRODUCTION TO BIOIMAGING"

UPPER LEVEL UNDERGRAD COURSE

FOLLOWS:

102A,B	FOURIER TRANSFORMS, 1D
178	RANDOM VARIABLES (USEFUL, NONREQUIRED)

COVERS MATERIAL FROM

261	FOURIER TRANSFORMS
262	2D FOURIER TRANSFORMS
369A	X-RAY, CT, PET
369B	MRI, ULTRASOUND
369C	IMAGE RECONSTRUCTION

COURSE PERSPECTIVE

MANY IMAGING SYSTEMS, DIFFERENT PHYSICS

FEW FUNDAMENTAL IMAGING ALGORITHMS

COURSE ORGANIZED BY ALGORITHM

1) PROJECTION IMAGING	X-RAY	(MICROSCOPY...)
2) BACKPROJECTION	CT	(PET, SPECT, MRI, US...)
3) BEAM FORMING	US	(RF, OPTICS, ...)
4) FOURIER ENCODING	MRI	(OPTICS, SUPERRESOLUTION)

INTRODUCE ENOUGH PHYSICS TO FRAME PROBLEM

GOAL: RECOGNIZE THESE ALGORITHMS WHEN YOU SEE A NEW PROBLEM.

NOBEL PRISES COME FROM THIS!

WHY IS BIOIMAGING INTERESTING?

VISUALIZATION INSIDE LIVING ORGANISMS

HUGE CLINICAL IMPACT

NO EXPLORATORY SURGERY ANY MORE

HUGE IMPACT ON BIOLOGICAL AND MEDICAL RESEARCH.

FOLLOW DISEASE MODELS OVER TIME

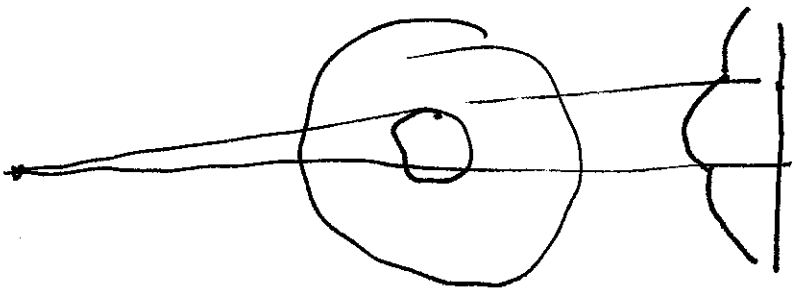
CUSTOM RATS ARE EXPENSIVE

3D VISUALIZATION IN VIVO

PROJECTION IMAGING

X-RAY

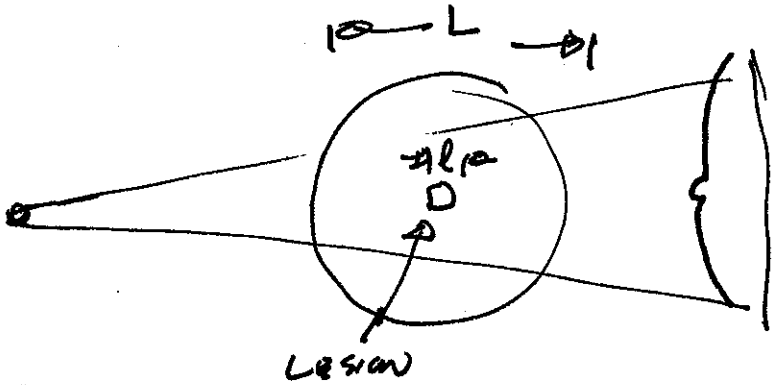
TOP VIEW



QUESTIONS

CAN I DETECT A SIGNAL? SNR

CAN I DETECT A CHANGE IN SIGNAL? CNR



CONTRAST IS $\frac{l}{L}$

THE BODY HAS TO ABSORB SOME RADIATION

NO ABSORBTION → NO INFORMATION

TOTAL ABSORBTION → NO INFORMATION

X-RAYS ARE A USEFUL WINDOW INTO BODY

L1, 2012

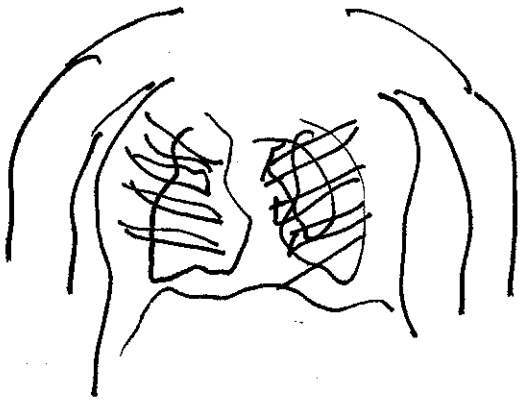
WHAT IS THE RESOLUTION OF THIS SYSTEM?

WHEN CAN I DETECT A LESION?

SENSITIVITY - DETECT DISEASE

SPECIFICITY - POSITIVE TEST IS ACTUALLY DISEASE

LIMITATIONS OF PROJECTION IMAGING

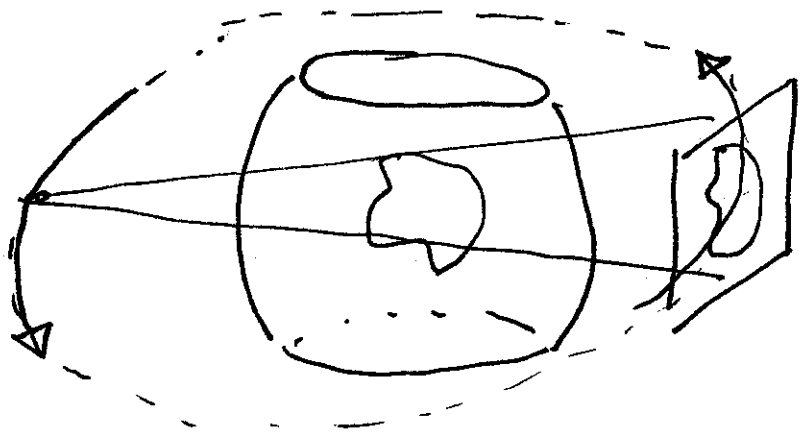


EVERYTHING OVERLAPS

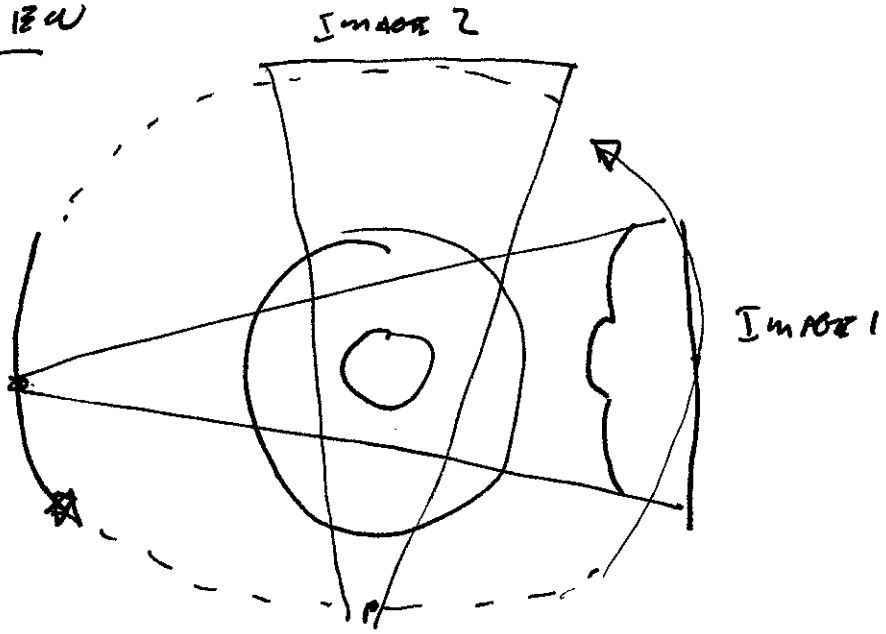
LESION CNR LIMITED

BACKPROJECTION SYSTEMS

IMPROVE OUR ABILITY TO FIND LESIONS BY LOOKING AT MANY ANGLES



TOP VIEW



WHAT CAN I DO WITH THIS?

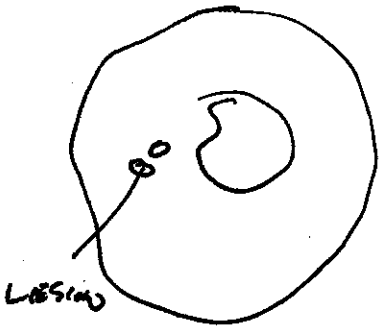
THINK OF WATCHING SOMETHING FLOAT IN A GLASS OF WATER

SPIN THE GLASS, AND YOU MENTALLY RECONSTRUCT THE 3D VOLUME

WE CAN DO THIS MATHEMATICALLY

L1, 2012 - PROJECTION RECONSTRUCTION CT

NOW WE HAVE CROSS SECTIONS OF THE BODY.



MUCH LOWER SNR THAN PROJECTION IMAGING

MUCH HIGHER CONTRAST, AND HOPEFULLY, CNR

QUESTIONS

HOW DO YOU DO THE RECONSTRUCTION?

HOW MANY VIEWS DO YOU NEED?

HOW DOES SNR, CNR CHANGE?

WHAT TYPE OF ATTENUATION ALONG THE PROJECTION WORKS?

MANY IMAGING MODALITIES HAVE BEEN FIT INTO THIS FORM.

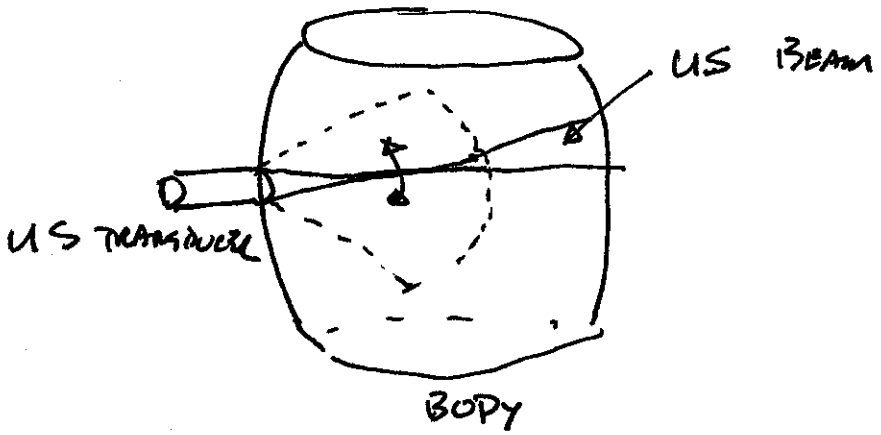
CT
SPECT
PET
US
MRI

BEAM FORMING SYSTEMS

SOME FORMS OF ENERGY CAN BE FOCUSED (LIGHT, RF, ULTRASOUND)

IF WE CAN FOCUS ENERGY INTO A BEAM, WE CAN MAKE AN IMAGE

ULTRASOUND



TOP VIEW

DEPTH ≡ TIME

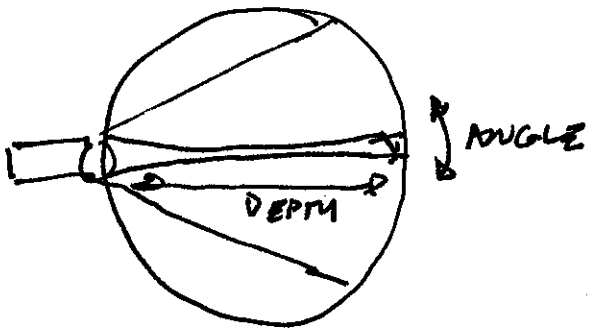


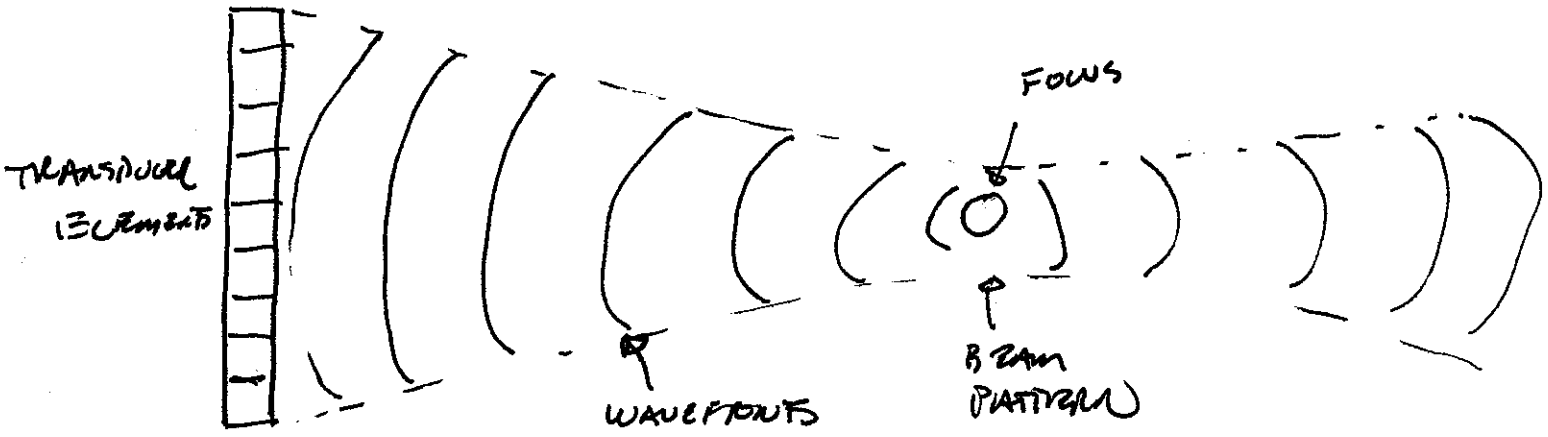
IMAGE IS ANGLE VS DEPTH

SHOWS REFLECTIVITY OF TISSUES

ORIGINALLY, TRANSDUCER ACTUALLY WOBBLED TO SCAN ANGLES

NOW, MOSTLY PHASED ARRAY TRANSDUCERS.

ARRAY TRANSDUCERS



EACH ELEMENT IS DRIVEN SEPERATELY

QUESTIONS

HOW DO I DRIVE THE ELEMENTS TO FOCUS AT A POINT?

HOW SMALL IS THAT POINT

HOW DO I FOCUS THE RECEIVED SIGNAL

CAN I (OR DO I NEED TO) FOCUS ON TRANSMIT AND RECEIVE

WHAT HAPPENS WHEN I MOVE THE FOCUS? WHERE CAN I OPERATE?

HOW MANY ELEMENTS DO I NEED? HOW FAR APART?

ALSO TURNS UP IN

RF ANTENNAS

OPTICS

PHOTO ACOUSTIC

HALL EFFECT

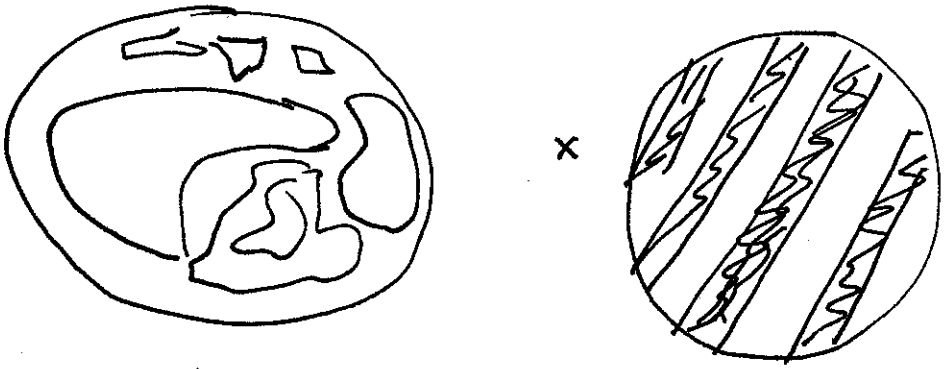
FOURIER ENCODING SYSTEMS (MODULATION SYSTEMS)

SO FAR, ALL OF THE SYSTEMS NEED TO BE ABLE TO DIRECTLY RESOLVE THE OBJECT (X-RAY DETECTOR, CT-DETECTOR, US ARRAY)

CAN WE IMAGE WITHOUT THIS? YES!

SUBJECT

MODULATION FUNCTION



$m(x,y)$ $\times$ $f_j(x,y)$

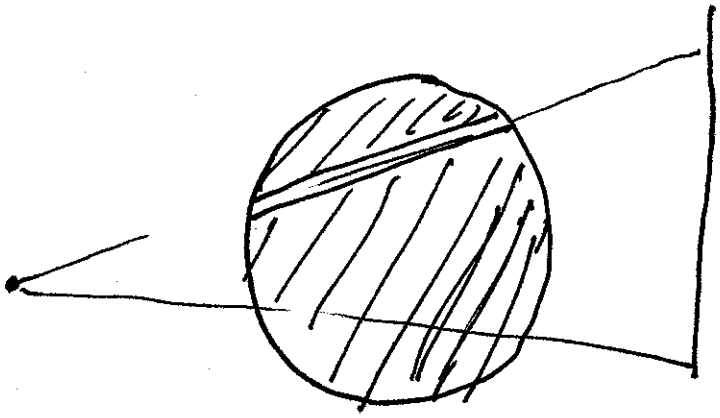
SIGNAL

$$s_j = \int_{\underline{X}} m(x,y)\, f_j(x,y)\, dx\,dy$$

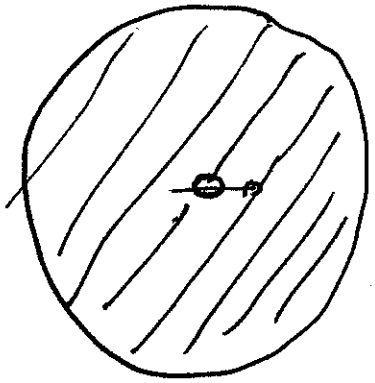
WE ONLY GET THE TOTAL SIGNAL.

CAN WE RECOVER $m(x,y)$ FROM $\{s_j\}$ MEASUREMENTS?

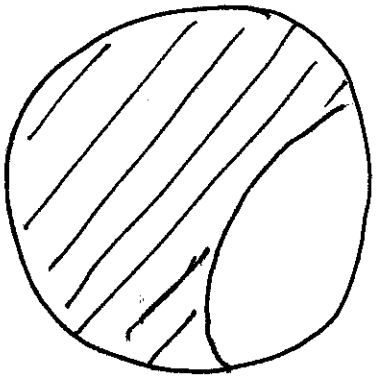
OTHER MODULATION FUNCTIONS



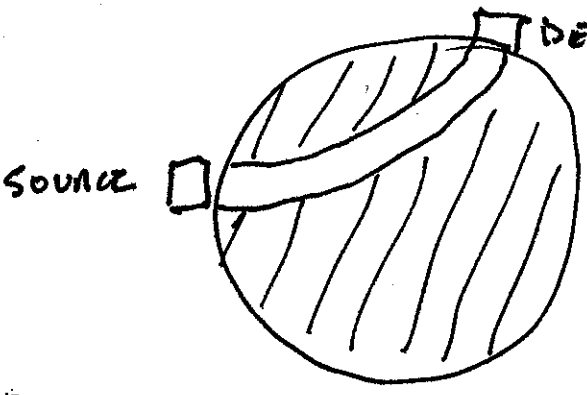
CT!



SCANNER



MR, PARALLEL IMAGING



OPTICAL TOMOGRAPHY
IMPEDANCE TOMOGRAPHY

MRI

$m(x,y)$ IS NUCLEAR SPIN OF PROTONS

$f(x,y) = e^{i 2\pi(k_x x + k_y y)}$ IS A PHASE MODULATION

$0 \leq m(x,y)$

$$s_j = \int_{\underline{x}} m(x,y)\, e^{i 2\pi(k_{x_j} x + k_{y_j} y)}\, dx\, dy$$

QUESTIONS

HOW MANY (AND WHICH) VALUES OF k_x AND k_y DO I NEED

DO OTHER $f(x,y)$ MODULATION FUNCTIONS WORK?

HOW DO I DO THE RECONSTRUCTION?

OTHER APPLICATIONS

INVERSE IMAGING SYSTEMS (SINGLE DETECTOR CAMERA)

SUPER-RESOLUTION

PARALLEL MRI