- EXPLAIN $\frac{1}{r}$ DROP-OFF IN AMPLITUDE OF SPHERICAL WAVE (INTENSITY GOES AS AMPLITUDE SQUARED $\Rightarrow I = pv = \frac{p^2}{z} \Rightarrow$ DROPS OFF AS $\frac{1}{r^2}$ AS WE WOULD EXPECT)
- PROBLEM 1 OF HW 7
- ADVANCED LECTURE $\Rightarrow$ FRIDAY 4-5 pm
- FIELD TRIP TUESDAY 6pm - 9pm $\leftarrow$ MEET AT PARKING LOT BEHIND CLYDE BY 5:55 pm (EAST SIDE OF)
- SCHEDULES POSTED ON WEB

ULTRASOUND CONTINUED:

TRANSDUCER CAN TYPICALLY ONLY GENERATE AND RECEIVE A LIMITED BAND OF FREQUENCIES $\Rightarrow$ BANDWIDTH OF TRANSDUCER.

QUICK EXAMPLE:

IF WE WANT A TRANSDUCER AT A FREQUENCY OF 10MHz MADE OUT OF PZT, HOW THICK SHOULD IT BE?

$C_T = 8000$ m/s IN PZT

SO:

$$d_T = \frac{1}{2}\lambda_T = \frac{1}{2}\frac{C_T}{f_T} = \frac{1}{2}\frac{8000 \text{ m/s}}{10\times10^6 \text{ 1/s}} = 0.4 \text{ mm}$$

- TRANSDUCERS ARE TYPICALLY "SHOCK EXCITED" (i.e., HIT WITH AN ELECTRICAL SIGNAL THAT RESEMBLES AN IMPULSE).
- BACKING IS TYPICALLY AN EPOXY MATERIAL W/ IMPEDANCE CLOSE TO PZT (OR PVDF), TO MINIMIZE REFLECTION AND ABSORB WAVES SO DAMPING OCCURS QUICKLY.
- TYPICAL TRANSMIT PULSE DAMPS AFTER 3-5 CYCLES!

SINGLE ELEMENT PROBES:

- SINGLE TRANSDUCER ELEMENT, WITH A LENS OR CURVED CRYSTAL FOR FOCUSING.
- NEED TO SWEEP ACROSS A PLANE TO FORM A 2D IMAGE
  - EARLY SYSTEMS WERE MANUALLY SCANNED!
  - MODERN SYSTEMS USE MECHANICAL OR ELECTRICAL MEANS

MECHANICAL SCANNERS

ELECTRONIC SCANNERS
- LINEAR ARRAY PROBES $\leftarrow$ ELEMENT WIDTHS ~ 1 WAVELENGTH
- PHASED ARRAY PROBES $\leftarrow$ ELEMENT WIDTHS ON ORDER OF A QUARTER WAVELENGTH

DATA ACQUISITION MODES IN ULTRASOUND:

A-MODE: (FOR AMPLITUDE MODE)

- BASED ON THE "PULSE-ECHO" PRINCIPLE
- IMMEDIATELY AFTER TRANSMISSION OF THE PULSE, THE TRANSDUCER IS USED AS A RECEIVER
- BOTH SPECULAR AND SCATTERED REFLECTIONS ARE RECORDED
- REPETITION TIME BETWEEN PULSES (TR) IS CHOSEN SUCH THAT TIME THAT AN ECHO IS RECEIVED MAPS UNAMBIGUOUSLY TO POSITION
- DETECTED SIGNAL IS OFTEN CALLED THE RF SIGNAL BECAUSE FREQUENCY IS IN MHz, CORRESPONDING TO FREQUENCIES OF RADIO WAVES. ODD, BUT TRUE. ☺
- PRODUCES A 1-D SIGNAL (IMAGE)! CAN REPEAT IN TIME, DISPLAY ON OSCILLOSCOPE.

[FIGURE 7.6 FROM SUETENS]

M-MODE:

- REPEAT A-MODE ACQUISITIONS IN TIME, BUT PLOT IN 2D —
  - HORIZONTAL AXIS IS TIME
  - VERTICAL AXIS IS DISTANCE

[SHOW FIGURES 7.10 AND 7.11 FROM SUETENS]

B-MODE: (FOR BRIGHTNESS MODE) ← BRIGHTNESS MODULATING A CRT ALONG A COLUMN USING THE CORRESPONDING A-MODE SIGNAL.

- TRANSLATE, ROTATE, OR STEER THE BEAM BETWEEN A-MODE ACQUISITIONS TO FORM A 2D IMAGE

[SHOW FIGURE 7.12 FROM SUETENS]

- BONE HAS A HIGH ATTENUATION COEFFICIENT. FOR IMAGING HEART, THERE IS ONLY A SMALL "ACOUSTIC WINDOW" BETWEEN RIBS.

SECOND HARMONIC IMAGING:

- COMPLETE TRANSDUCER BANDWIDTH IS NOT USED DURING TRANSMISSION ⇒ ONLY A LOW-FREQUENCY PART.
- THIS IS ACCOMPLISHED BY MODIFYING THE ELECTRIC PULSES USED FOR TRANSDUCER EXCITATION
- HIGHER HARMONICS GENERATED DURING WAVE PROPAGATION ARE DETECTED WITH THE HIGH-FREQUENCY PART OF THE SENSITIVE BANDWIDTH OF THE TRANSDUCER.

FROM NONLINEAR WAVE PROPAGATION

SHOW FIGURE 7.14 IN SUETENS

- SECOND HARMONIC IMAGING YIELDS BETTER IMAGE QUALITY IN CORPULENT PATIENTS. ☺

IMAGE RECONSTRUCTION:

INVOLVES FOLLOWING STEPS:

1. FILTERING
2. ENVELOPE DETECTION
3. ATTENUATION CORRECTION
4. LOG-COMPRESSION
5. SCAN CONVERSION

FILTERING:

- REMOVE HIGH-FREQUENCY NOISE
- IN 2ND HARMONIC IMAGING, TRANSMITTED BAND IS FILTERED OUT

ENVELOPE DETECTION:

- VERY FAST FLUCTUATIONS IN THE RF SIGNAL ARE NOT TYPICALLY RELEVANT

FIGURE 7.15 IN SUETENS

- TYPICALLY DONE BY MEANS OF A QUADRATURE FILTER OR A HILBERT TRANSFORMATION.

ATTENUATION CORRECTION:

- ALSO CALLED "TIME GAIN COMPENSATION"
- STRUCTURES THAT ARE SIMILAR SHOULD HAVE SIMILAR GRAY LEVELS ⇒ NEED TO COMPENSATE FOR ATTENUATION
- SIMPLE EXPONENTIAL MODEL ASSUMING AN AVERAGE ATTENUATION IS USED
- MOST SCANNERS ALSO ALLOW OPERATOR TO CHANGE GAIN MANUALLY AT DIFFERENT DEPTHS.

LOG COMPRESSION:

- SPECULAR REFLECTIONS ARE TYPICALLY MUCH LARGER THAN SCATTER REFLECTIONS ⇒ DYNAMIC RANGE IS TOO BIG TO COMFORTABLY VIEW BOTH
- LOGARITHMIC GRAY-SCALE TRANSFORMATION TYPICALLY APPLIED

SCAN CONVERSION:

- CONVERT POLAR SAMPLES ONTO A RECTANGULAR GRID VIA INTERPOLATION.
- ALSO CALLED "SECTOR RECONSTRUCTION"

DOPPLER:

JOHN PAULY'S PRESENTATION (POSTED ONLINE)