# LECTURE 17



## ULTRASOUND SYSTEMS (CH 11, CH 10.5)

TIME-GAIN CONTROL

SCAN MODES

TRANSDUCERS

ARRAYS

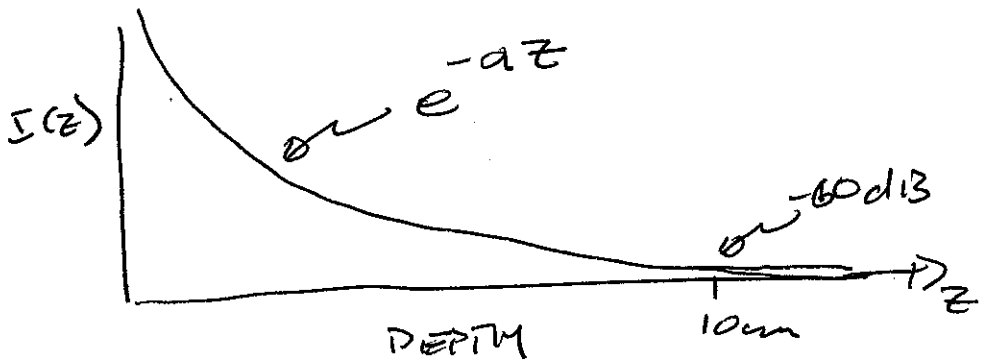
## TIME-GAIN CONTROL (TGC)

ULTRASOUND SIGNAL ATTENUATES RAPIDLY

LAST TIME

10 cm DEPTH IN LIVER, AT 3MHz

PRODUCES ~60dB ATTENUATION

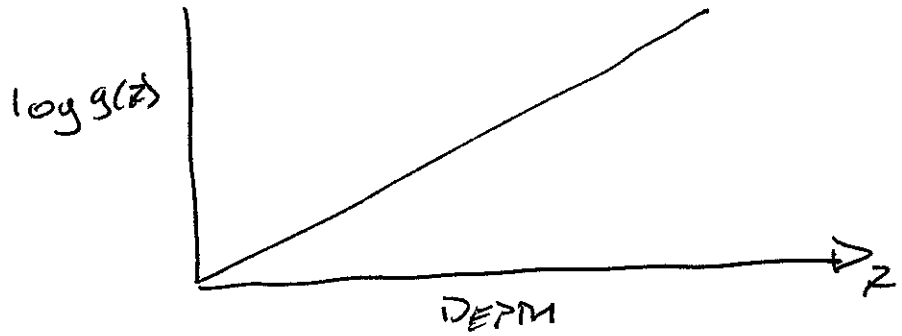



$z = ct$

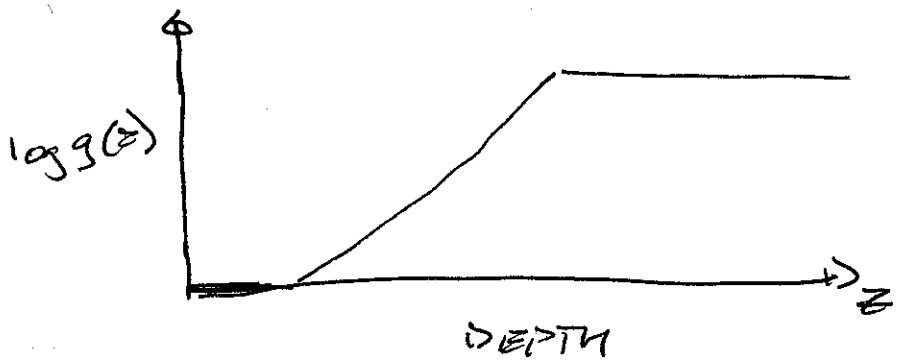
SIGNAL RAPIDLY LOST IN DYNAMIC RANGE OF DISPLAY!

SOLUTION: TIME VARYING GAIN AMPLIFIER

$$g(z) = e^{+kz}$$




IN PRACTICE, DIFFERENT GAINS FOR DIFFERENT REGIONS

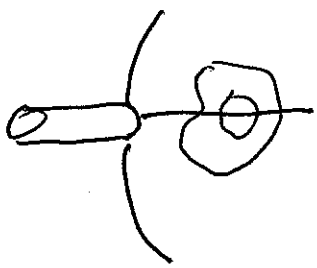


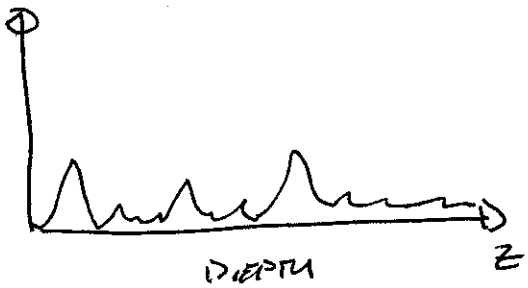

ABDOMINAL TGC

OPERATOR SETS BREAK POINTS AND SLOPES. CARDIAC SYSTEMS HAVE MORE BREAK POINTS

## SCAN MODES

### A-MODE



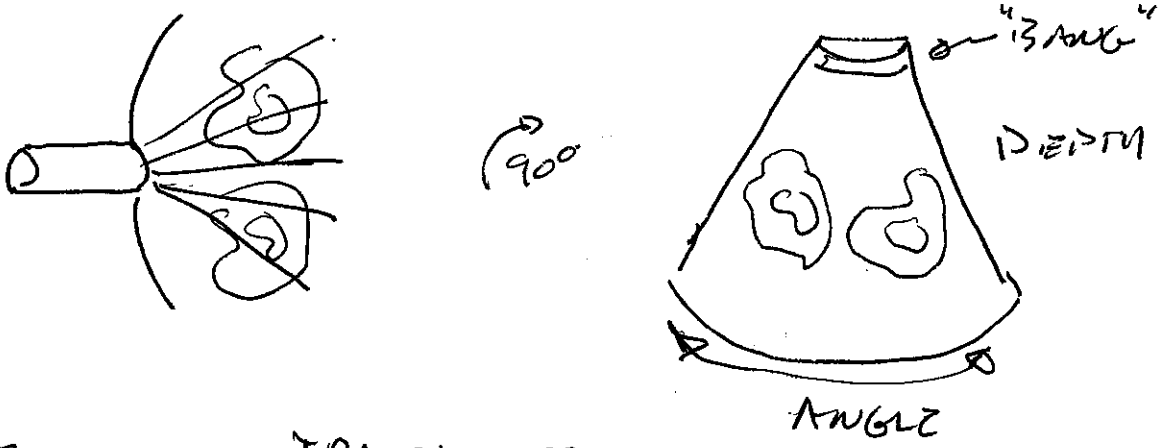



SINGLE LINE REPEATED RAPIDLY, PLOTTED (SCOPE!)

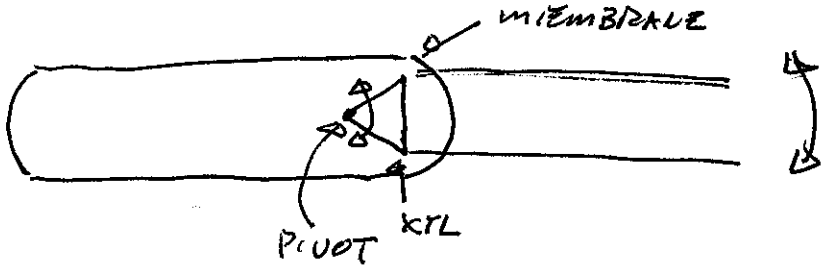
NO LONGER USED

A SINGLE ULTRASOUND ACQUISITION IS STILL CALLED AN "A-LINE"

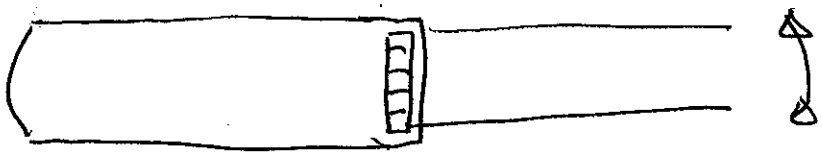
# B-MODE (SECTOR SCAN)




MECHANICAL TRANSDUCERS

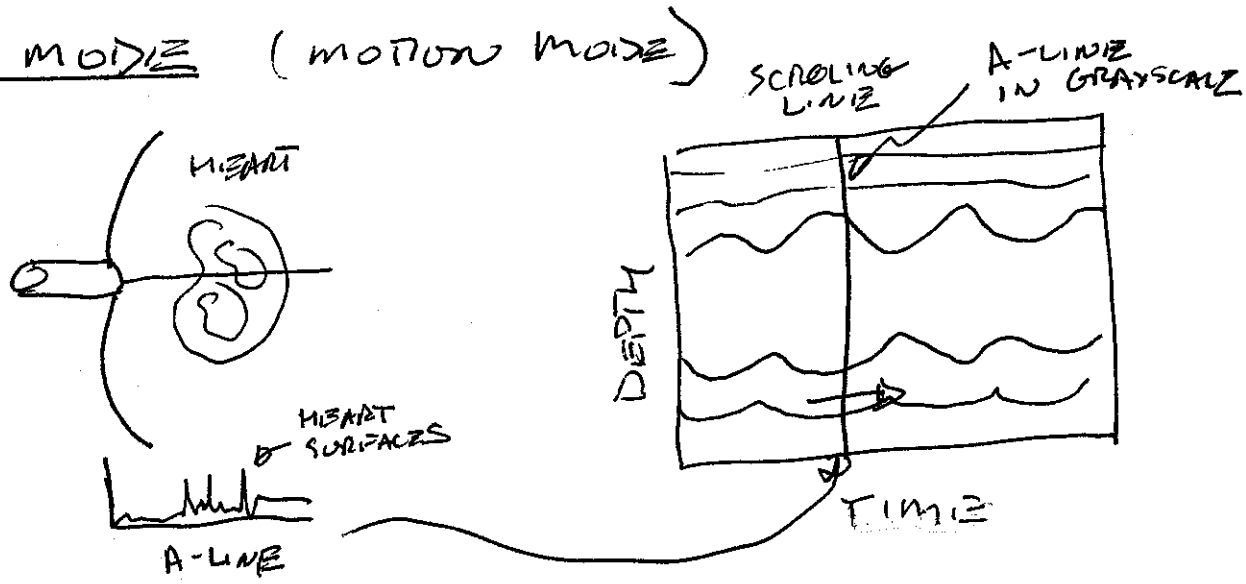



ELECTRICAL ARRAYS



WE WILL RETURN TO THIS SHORTLY.

# M-MODE (MOTION MODE)



M-MODE IS USED FOR VERY RAPIDLY MOVING STRUCTURES, LIKE HEART VALVES

NOT TOO IMPORTANT NOW.

## C-MODE

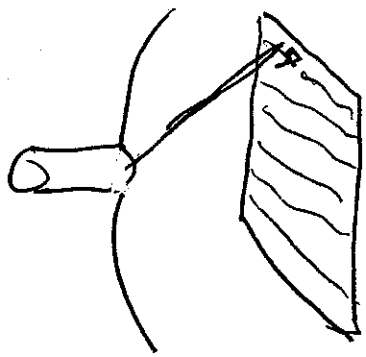


IMAGE AT A FIXED DEPTH PERPENDICULAR PLANE TO TRANSDUCER

NEED ARRAY TRANSDUCER

## MANY OTHER MODES

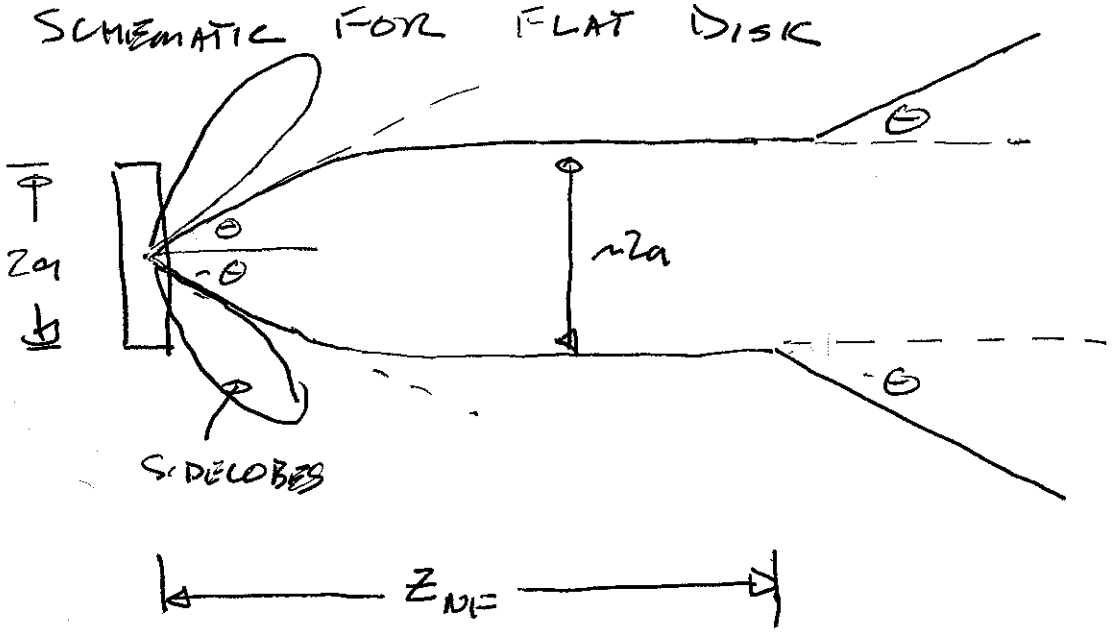
DOPPLER
COLOR FLOW
POWER DOPPLER
} MOTION

HARMONIC

# TRANSDUCER BEAM SHAPE

SCHEMATIC FOR FLAT DISK

$\Theta = \sin^{-1}\left(\frac{0.61\lambda}{a}\right)$







FRESNEL ZONE

FRAUNHOFER ZONE

NEAR FIELD DEPTH

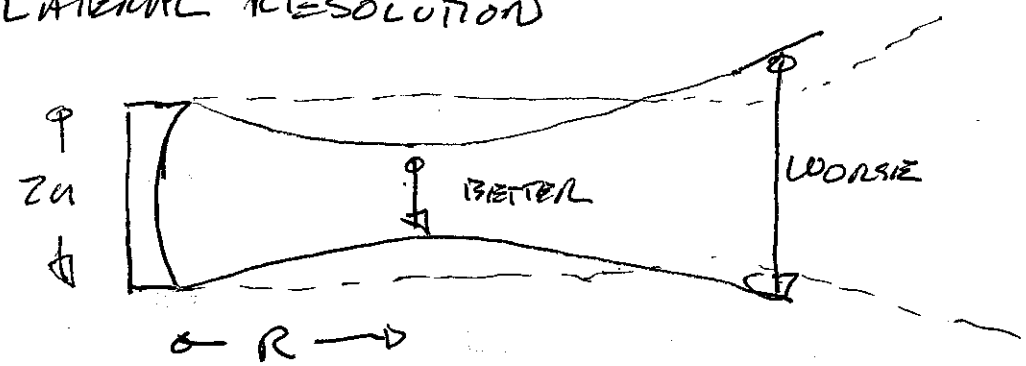
$$z_{NF} \simeq \frac{a^2}{\lambda}$$

FOR 2 cm TRANSDUCER AT 3 MHz

$$z_{NF} = \frac{1\text{ cm}}{0.5\text{ mm}} \simeq 20\text{ cm}$$

WE ARE ALWAYS IN NEAR FIELD

IN PRACTICE, YOU WANT TO FOCUS TO IMPROVE LATERAL RESOLUTION




R - RADIUS OF CURVATURE

BETTER RESOLUTION AT FOCAL DEPTH

WORSE RESOLUTION AWAY FROM FOCAL DEPTH

LIMITED DEPTH OF FOCUS

LIKE OPENING THE APERTURE ON YOUR CAMERA

BEAM WIDTH

$$FWHM \cong \frac{1.1\lambda R}{2a}$$

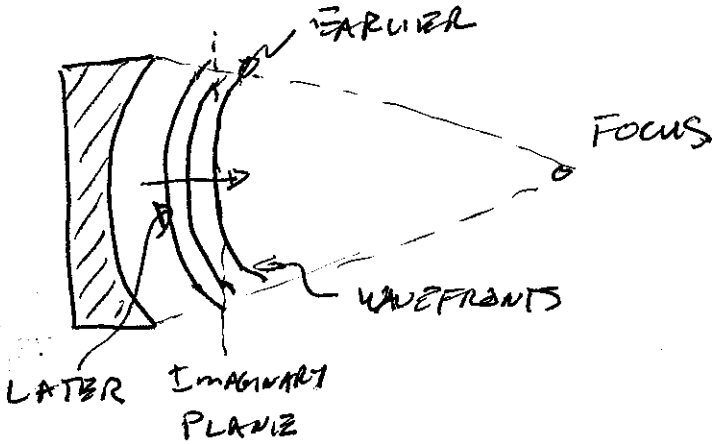
MAJOR LIMITATION

FOCUS SET IN TRANSDUCER CONSTRUCTION

NEED A WHOLE SET OF TRANSDUCERS!

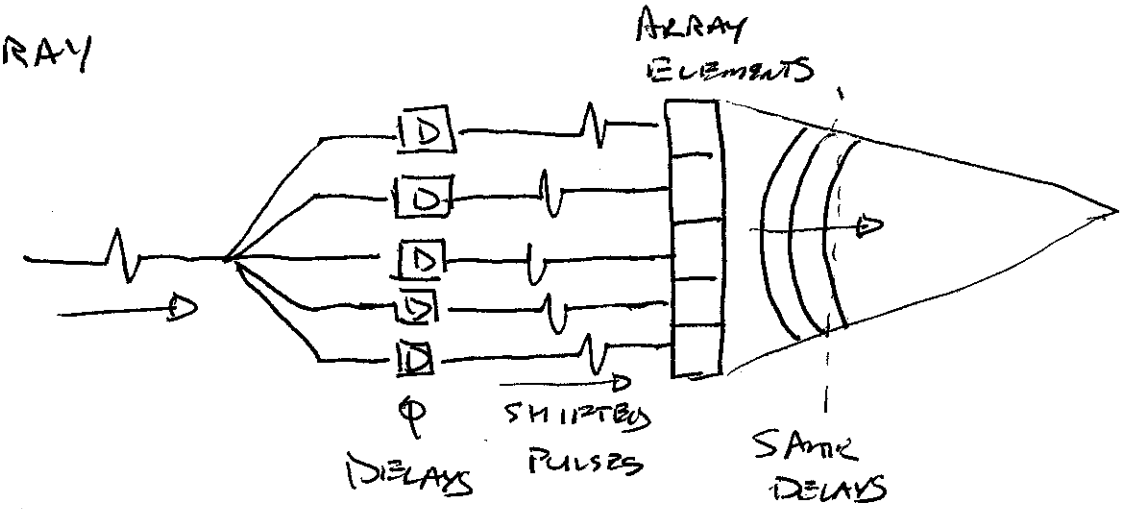
ARRAY TRANSDUCERS

FIXED TRANSDUCER




IF WE CAN CREATE THE SAME DELAYS, WE CREATE THE SAME WAVEFRONT

ARRAY

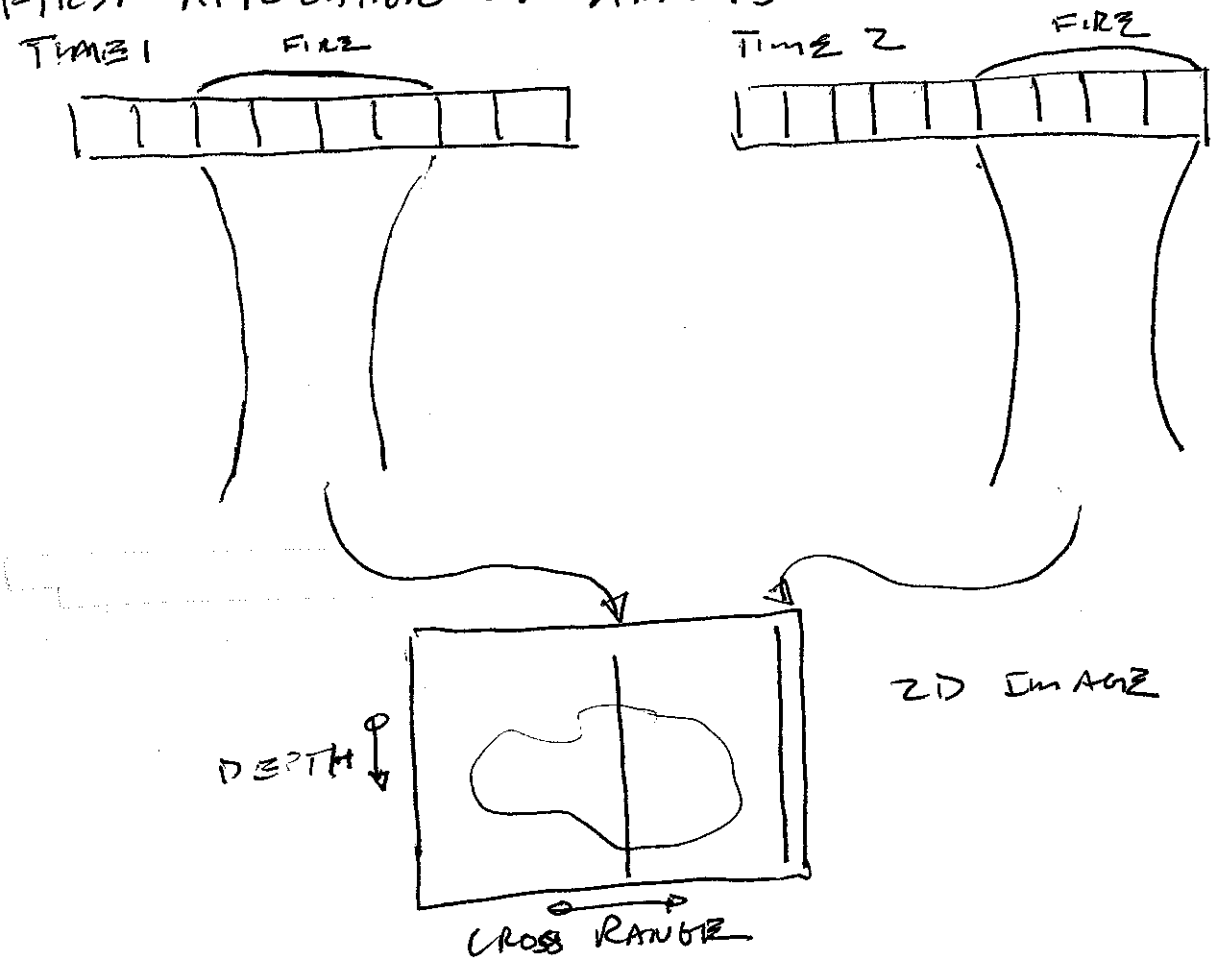



WE RECREATE THE SAME WAVEFRONTS.

NOW WE CAN SET ANY FOCAL DEPTH WE WANT!

## LINEAR ARRAY

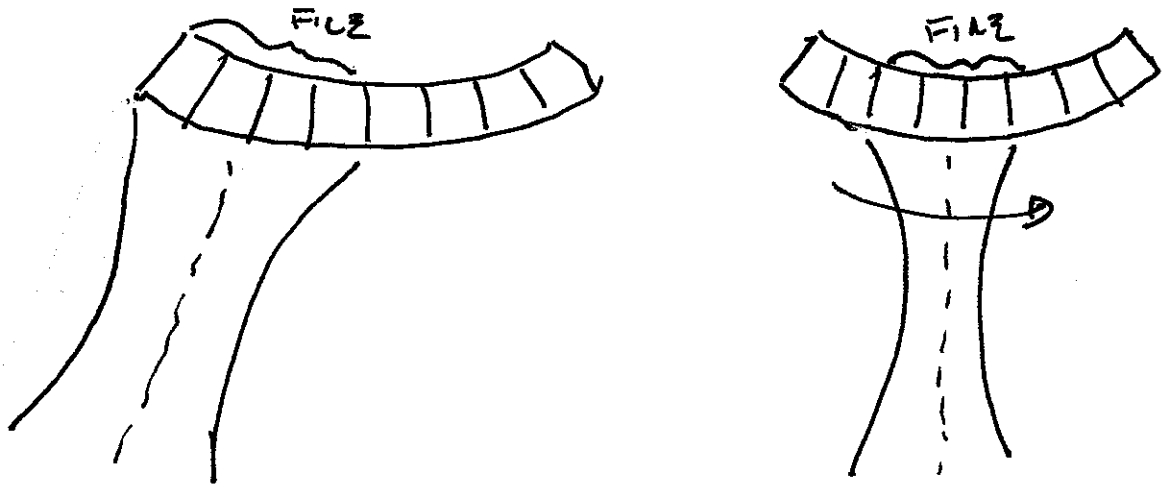
FIRST APPLICATION OF ARRAYS




FIRE SUBSET OF LONG ARRAY TO COLLECT LINE

SHIFT SUBSET TO COLLECT NEXT LINE

# CURVED LINEAR ARRAY




PROVIDES A SECTOR SCAN

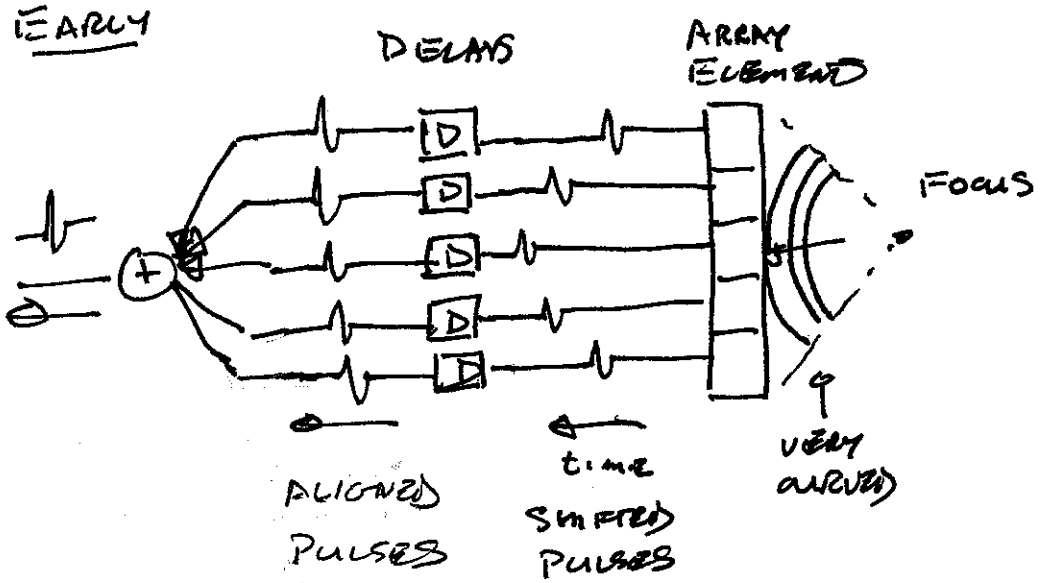
LINEAR ARRAYS ARE
- SIMPLE TO IMPLEMENT
- DELAYS ARE SMALL
- SAME SET OF DELAYS FOR EACH BEAM

## DYNAMIC FOCUS

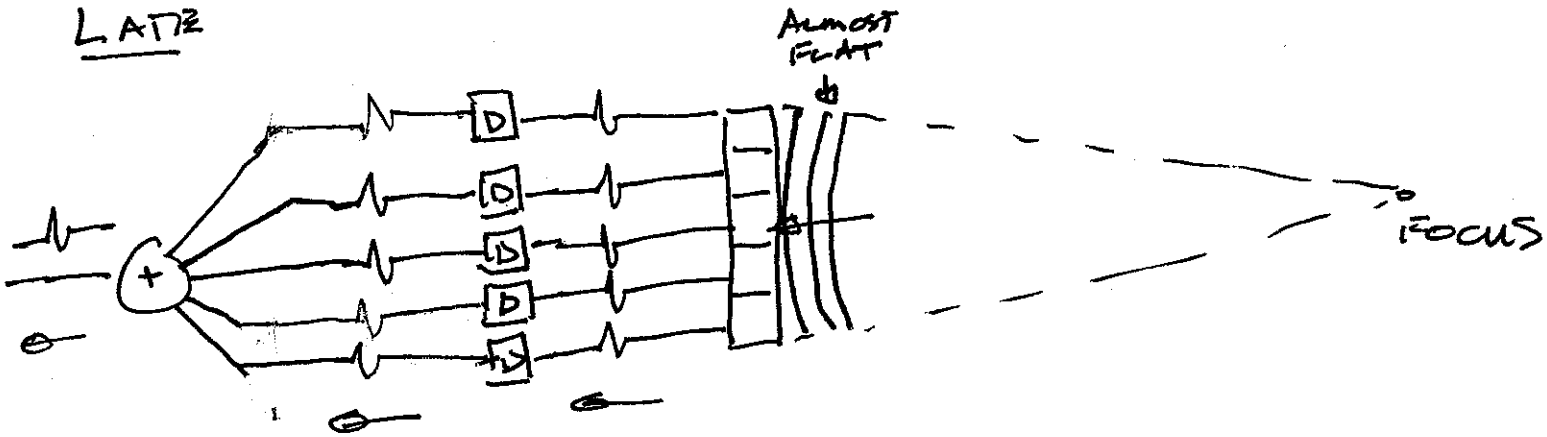
ON TRANSMIT, FOCUS IS FIXED

ON RECEIVE, FOCUS IS DETERMINED BY DELAYS, WHICH WE CAN CHANGE!

EARLY




LATE

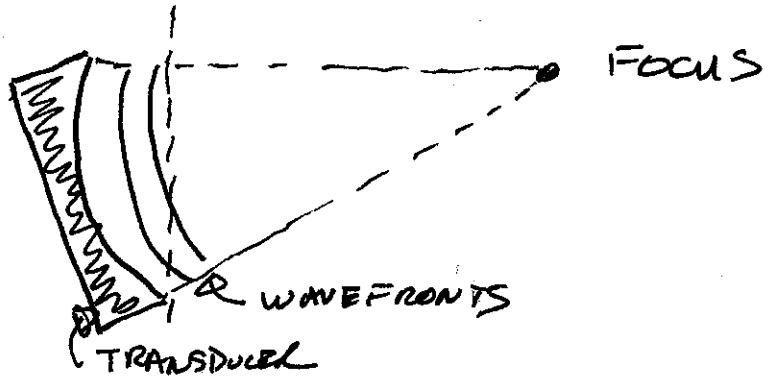



CHANGE DELAYS CONTINUOUSLY AS SIGNAL IS ACQUIRED

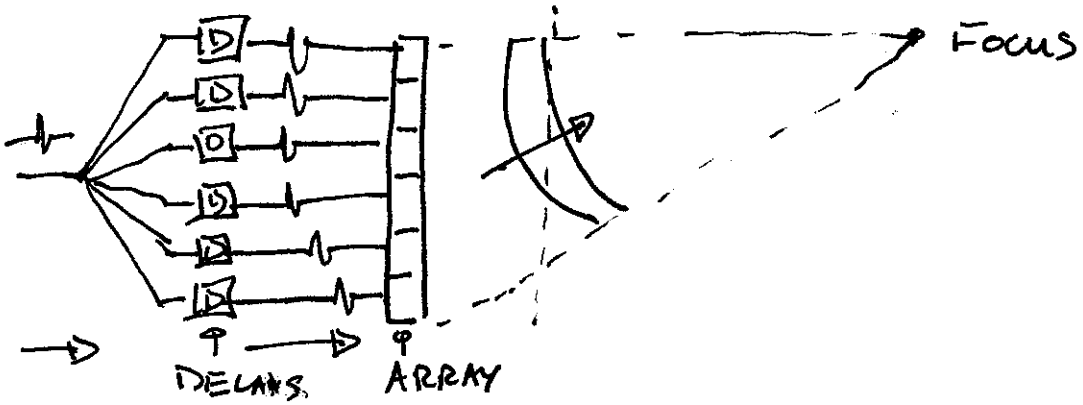
RECEIVE FOCUS ALWAYS OPTIMAL

# BEAM STEERING

FIXED FOCUS




ARRAY: SAME DELAYS




PHASED ARRAY

- MUCH GREATER DELAYS
- MUST BE MORE ACCURATE
- NEED FINER ELEMENT SPACING

VERY COMMON NOW

- 2 1/2 D TRANSDUCERS (MULTIPLE PLANES)
- 3 D TRANSDUCERS (C-MODE)