Department of Systems and Biomedical Engineering

SBE 405 Medical Instrumentation IV: Ultrasound Imaging (4)

Ahmed M. Ehab Mahmoud, PhD

Department of Systems and Biomedical Engineering, Cairo University, Giza, Egypt.

Office: Room of Department Faculty, left wing (computer laboratory section), 2nd floor, Architecture building, Faculty of Engineering.

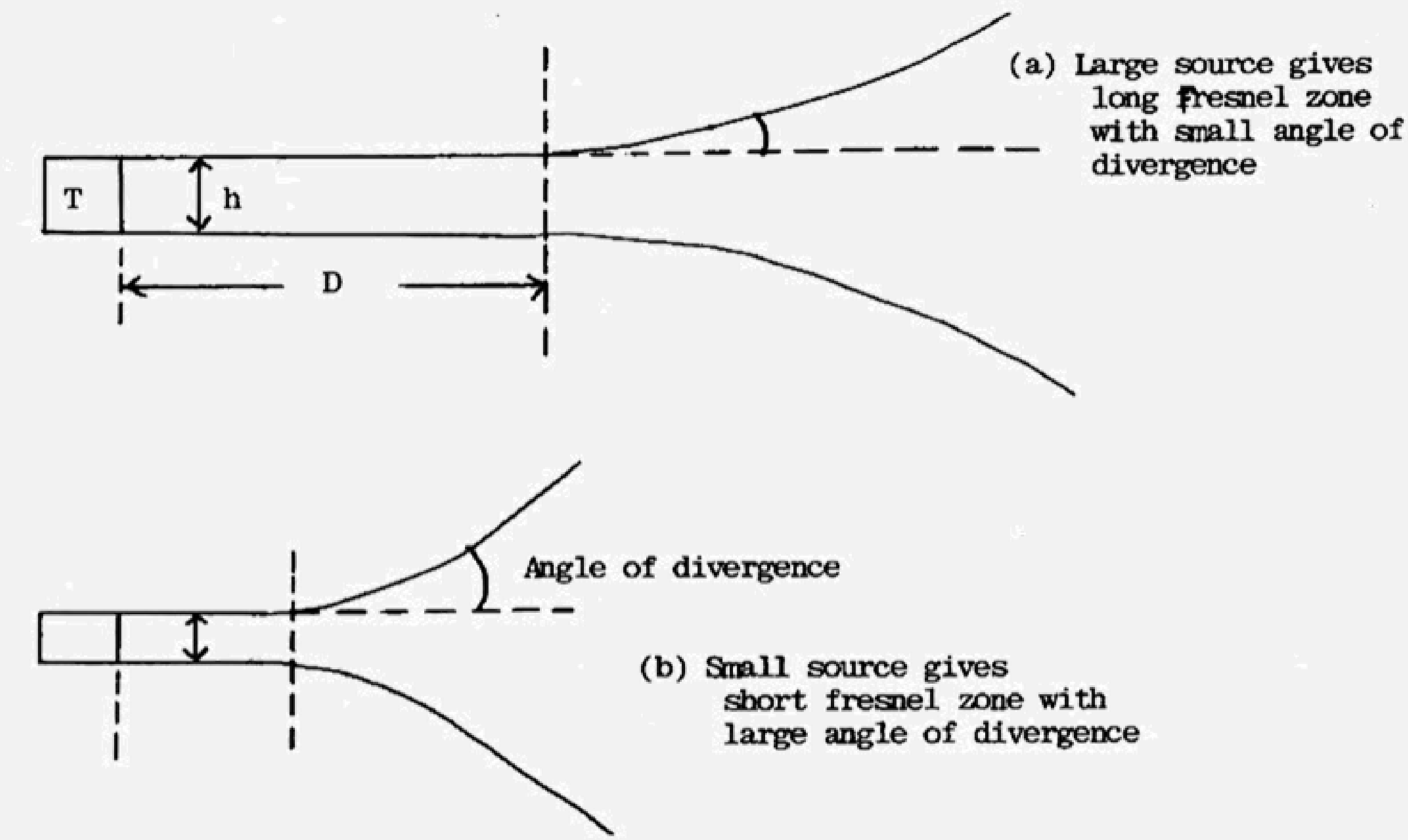
Email: a.ehab.mahmoud@eng1.cu.edu.eg

a.ehab.Mahmoud@gmail.com

Diffraction of Ultrasound

- If the aperture, the width of the source is smaller than the wavelength, the wave spreads out as it travels (diverges), an effect known as diffraction.
- If the width of the source is much greater than the wavelength of the wave, the waves are relatively flat (plane) rather than curved and lie parallel to the surface of the source.
- Such waves travel in a direction perpendicular to the surface of the source with relatively little sideways spread, i.e. in the form of a parallel-sided beam.

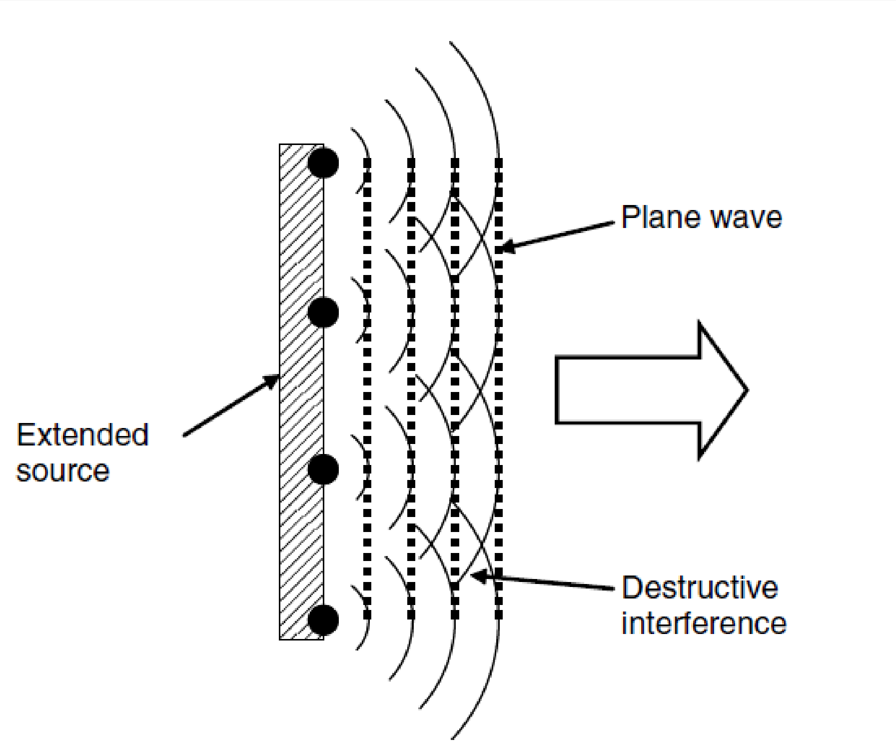
Diffraction of Ultrasound



Diffraction of Ultrasound

1- Each of the small sources generates a sound wave of the same frequency and amplitude and all are in phase.

2- The curved waves propagate outwards and the parts of the curve which are parallel to the surface of the source align to form plane waves. The other, non-parallel parts of the curved waves tend to interfere destructively and cancel out.



Ultrasound Beam: Plane Disk

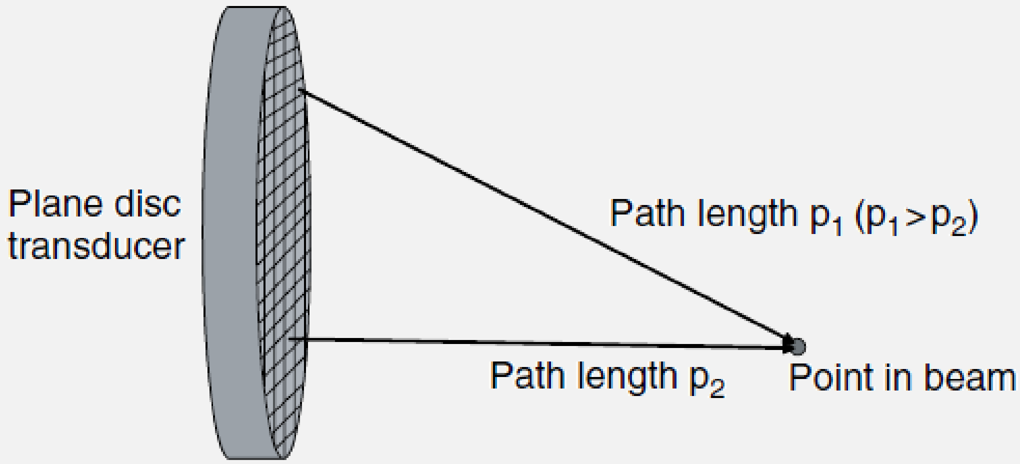


Fig. 2.14 The surface of the disc source can be considered to be made up of many small elements, each of which emits a spherical wave. The pressure amplitude at each point in the beam is determined by the sum of the spherical waves from all of the elements. The different path lengths, from the various elements to the summing point, mean that each of the spherical waves has a different phase when it arrives.

Ultrasound Beam: Plane Disk

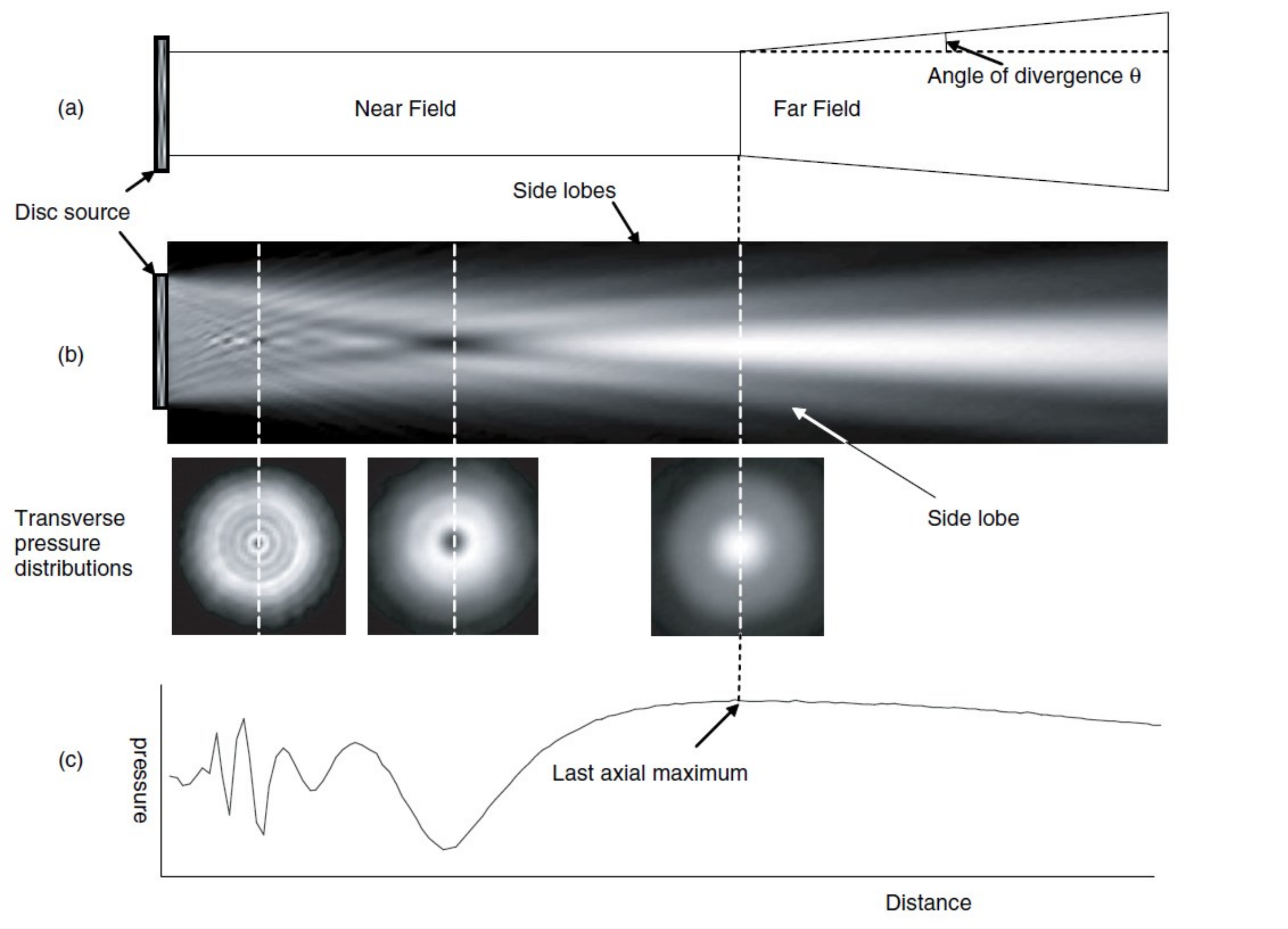
- Different path lengths from various elements means that each spherical wave has different phase when it arrives.

- At some points, this results in overall constructive interference, giving rise to an amplitude maximum.

- At other points, the overall effect is destructive and a minimum is formed.

- At points close to the source, the path lengths can be different by several wavelengths.

Ultrasound Beam: Plane Disk



Ultrasound Beam: Plane Disk

The basic shape of the ultrasound beam produced by a plane disc transducer can be divided into two parts.

These are:
(1) The near field, which is roughly cylindrical in shape and has approximately the same diameter as the source and
(2) The far field, which diverges gradually.

- Within the near field, the pressure amplitude of the wave is not constant everywhere but shows many peaks and troughs.

Ultrasound Beam: Plane Disk

- In the far field, destructive interference does not occur in the central lobe of the beam, as the path length differences are all less than $\lambda /2$.

- The resulting beam structure shows a maximum value on the beam axis, which falls away uniformly with radial distance from the axis.

- The intensity along the beam axis in the far field falls approximately as the inverse square law, i.e. proportional to $1/ z^2$, where z is the distance from the transducer.

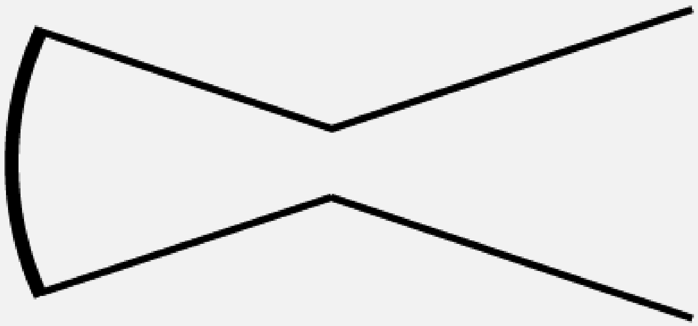
Ultrasound Beam: Plane Disk

- The beam diverges in the far field at an angle given by $\sin\theta = 0.61\ (\lambda/a)$, where θ is the angle between the beam axis and the edges of the central lobe of the beam.

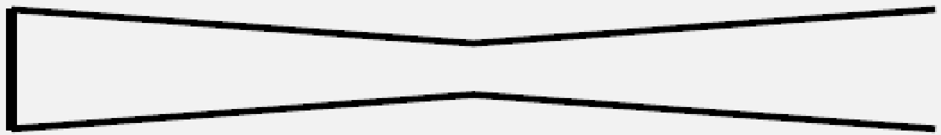
- The optimum beam shape is achieved when the aperture is 20 to 30 wavelengths in diameter.

- For imaging purposes, a narrow ultrasound beam is desirable as it allows closely spaced targets to be shown separately in the image.

Focusing



(b)



(c)

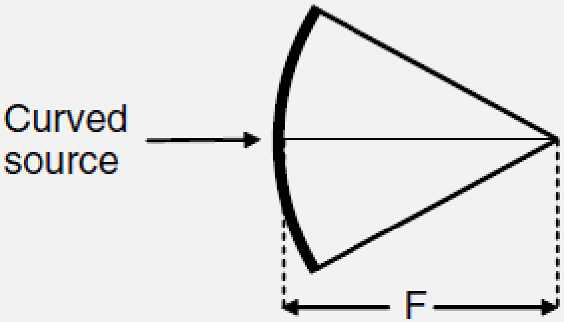
The beam width W at the focus for strong focusing is given approximately by the equation $W = F\lambda / a$. W is the beam width, a is radius and F focal length.

Focusing

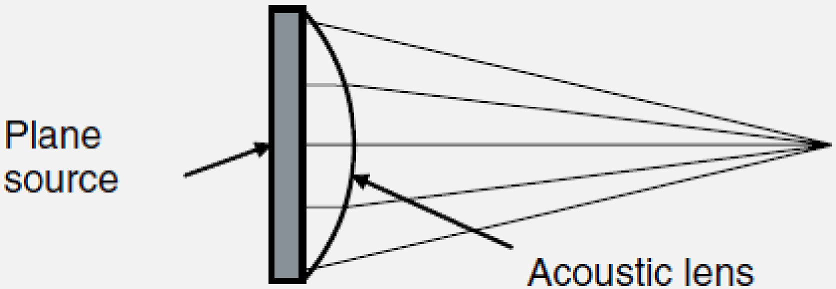
Lateral resolution is proportional to W and for circular transducer:

Lateral Resolution ≈ 2.44 $F\lambda/D$,

where D is the aperture diameter



(a)



(b)