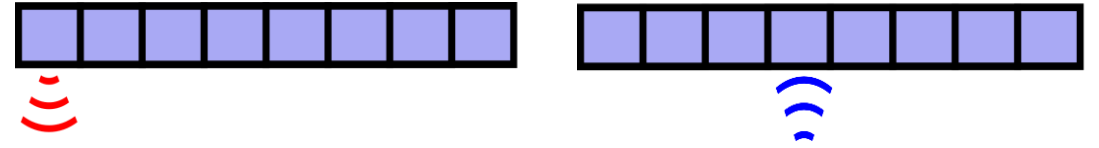




Virtual Source Aperture Imaging with Auto Focussing of Unknown Complex Geometry Through Dual Layered Media

Ewan Hoyle

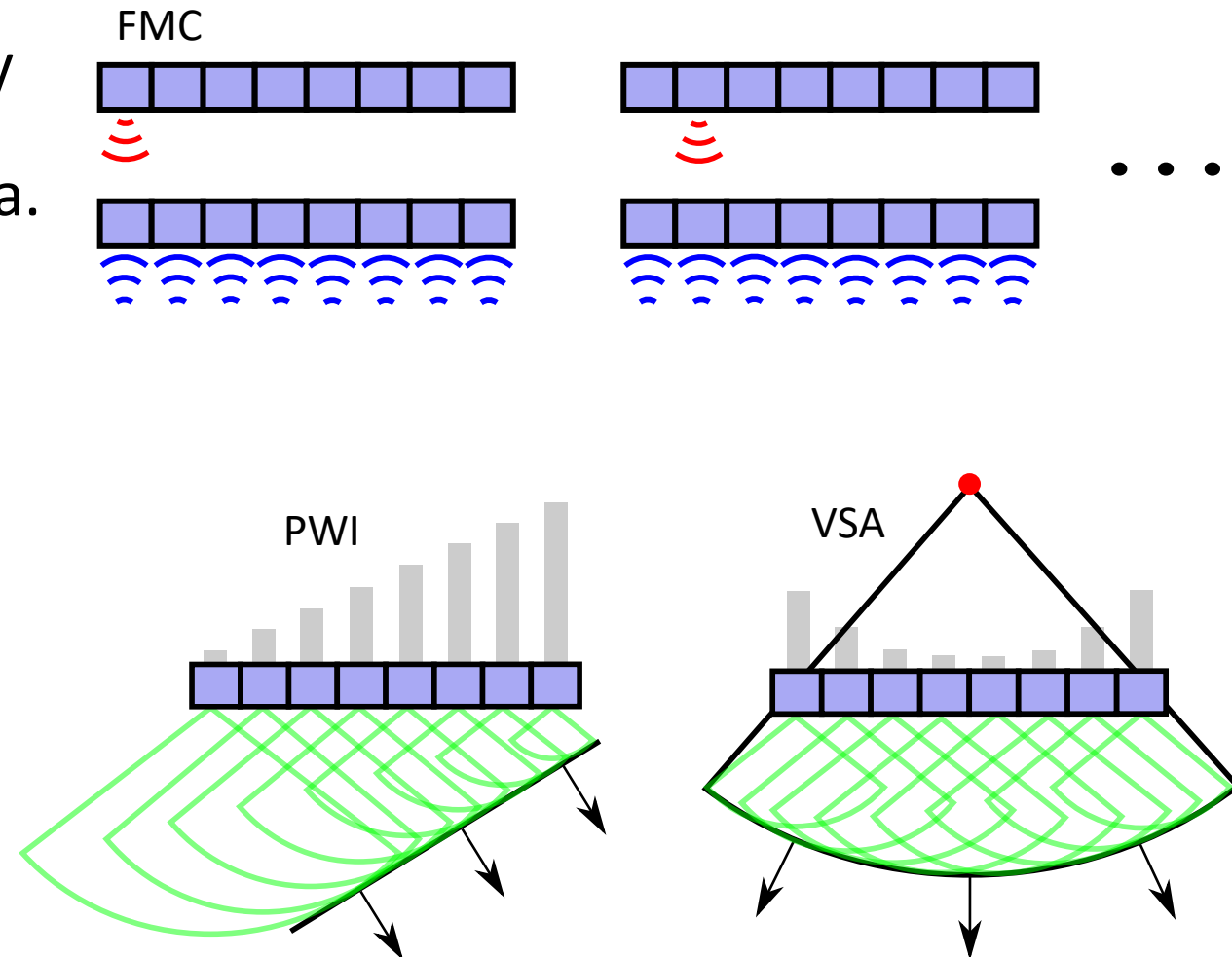
Ultrasonic Arrays



- Linear array of elements that can transmit and receive ultrasound.
- Pulse is transmitted into material, listen for any echos.
- Use known velocity of sound in the material to calculate the distance travelled.
- Developed originally for Phased Array (PA).
- Since been used to develop for Full Matrix Capture (FMC), Plane Wave Imaging (PWI) and Virtual Source Aperture (VSA).

Ultrasonic Imaging Techniques

- FMC – each element is fired individually while receiving on all. This captures what is known as the Full Matrix of Data.
- PWI – flat delay law used to generate a planar beam front travelling in a given direction depending on the delays applied.
- VSA – delay laws applied in order to simulate a virtual source placed behind the aperture.
- For these techniques a fully focussed image is generated using the Total Focussing Method (TFM).

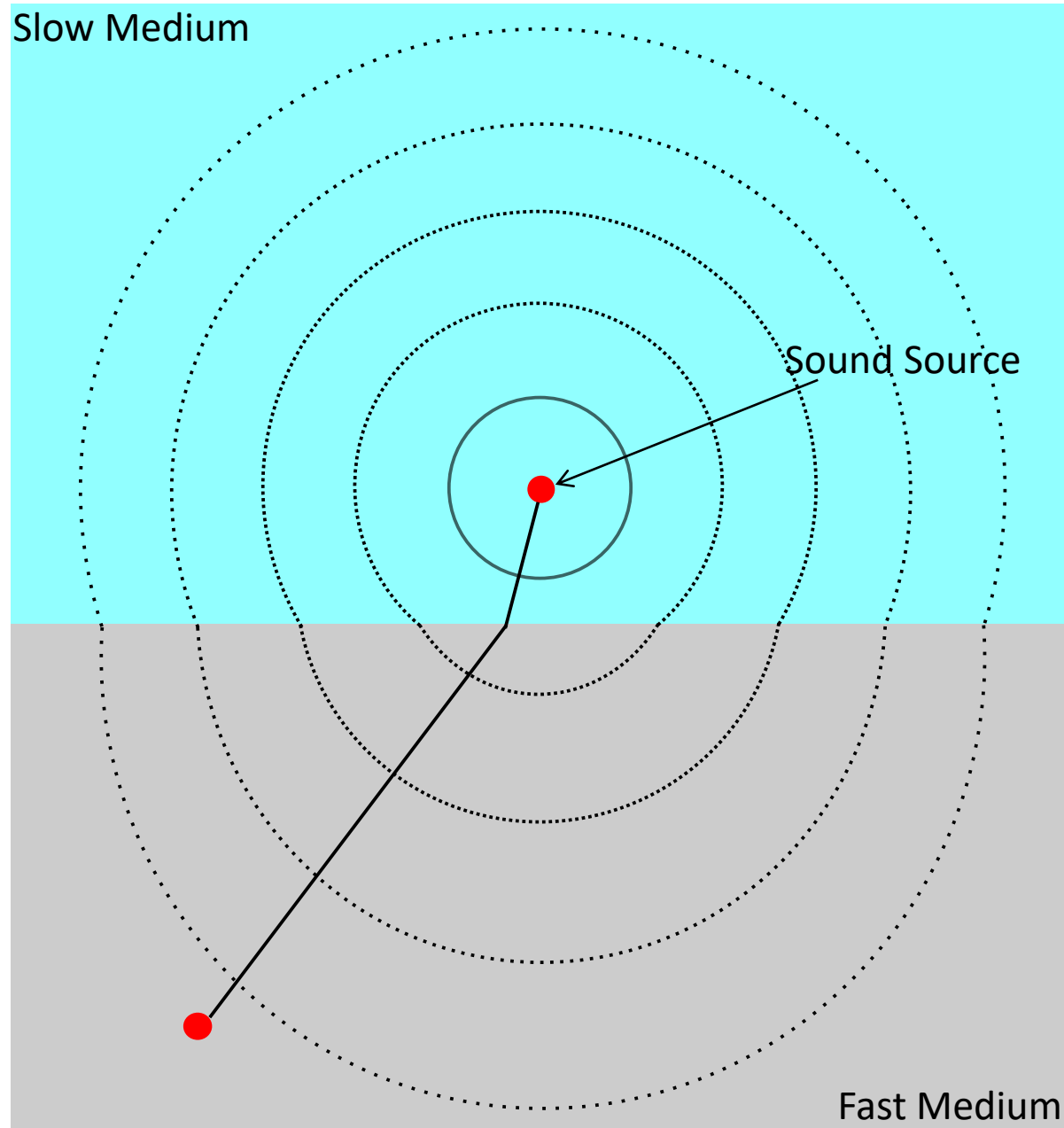


Total Focussing Method (Imaging Algorithm)

- Used for FMC, PWI and VSA.
- Theoretical time of flight calculated from the sound source to a region of interest and back to the receiving element.
- Amplitudes of the corresponding Ascans at the calculated time are summed.
- Indications produced when coherent summation of the signals give a high intensity.

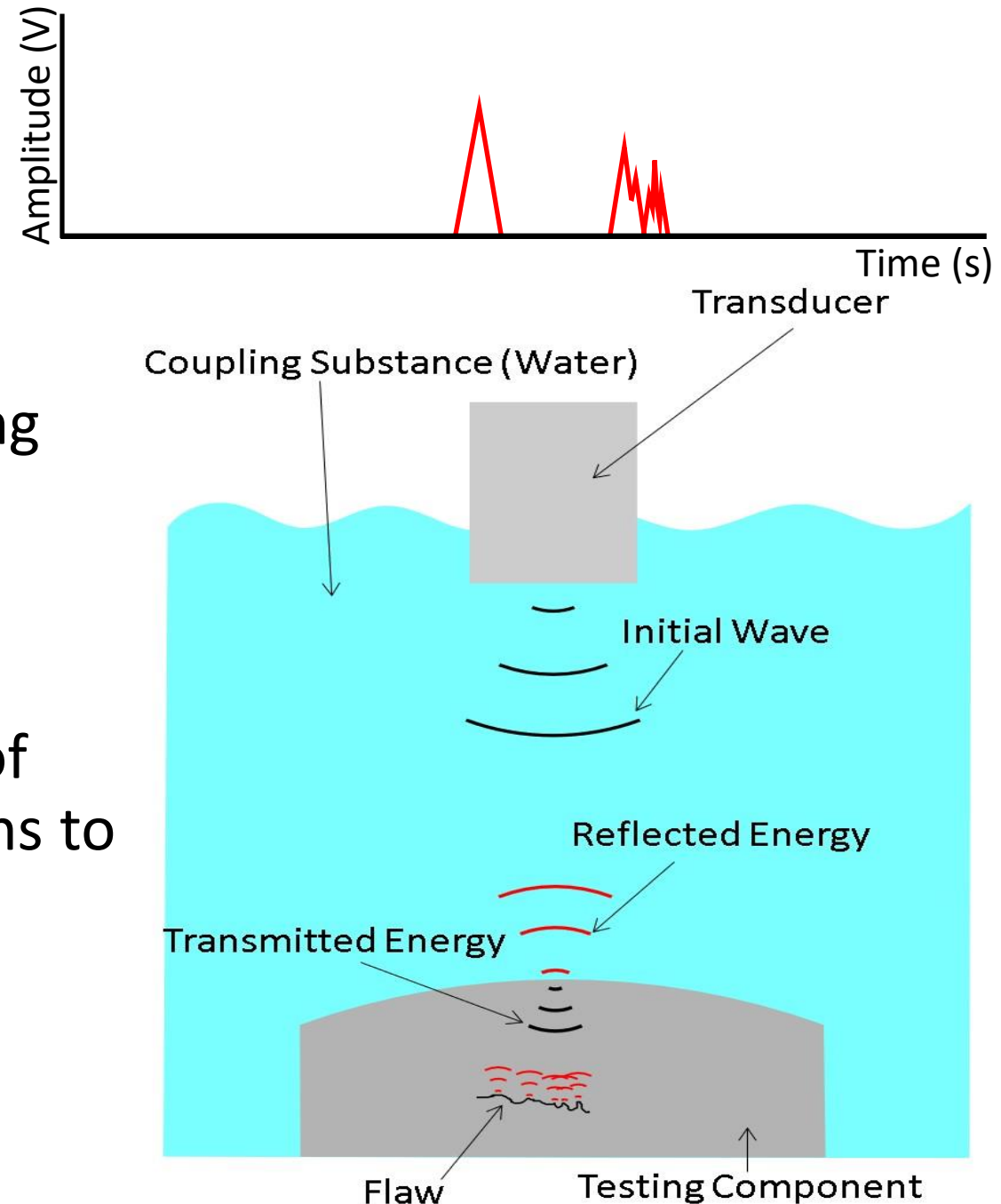
$$I(x, z) = \sum_{t=1}^{N_t} \sum_{r=1}^{N_r} A_{t,r} (\tau'_{x,y} + \tau''_{x,y})$$

- Fermat's principle used when considering a refractive boundary.



Immersion Testing

- Transducer is coupled to inspected component by submersion in a coupling fluid such as water.
- Ultrasound is transmitted into the component.
- Echos reflected and known velocities of sound in each material allow indications to be detected, characterised and sized.
- Usually surface profile relative to the transducer must be known or found.

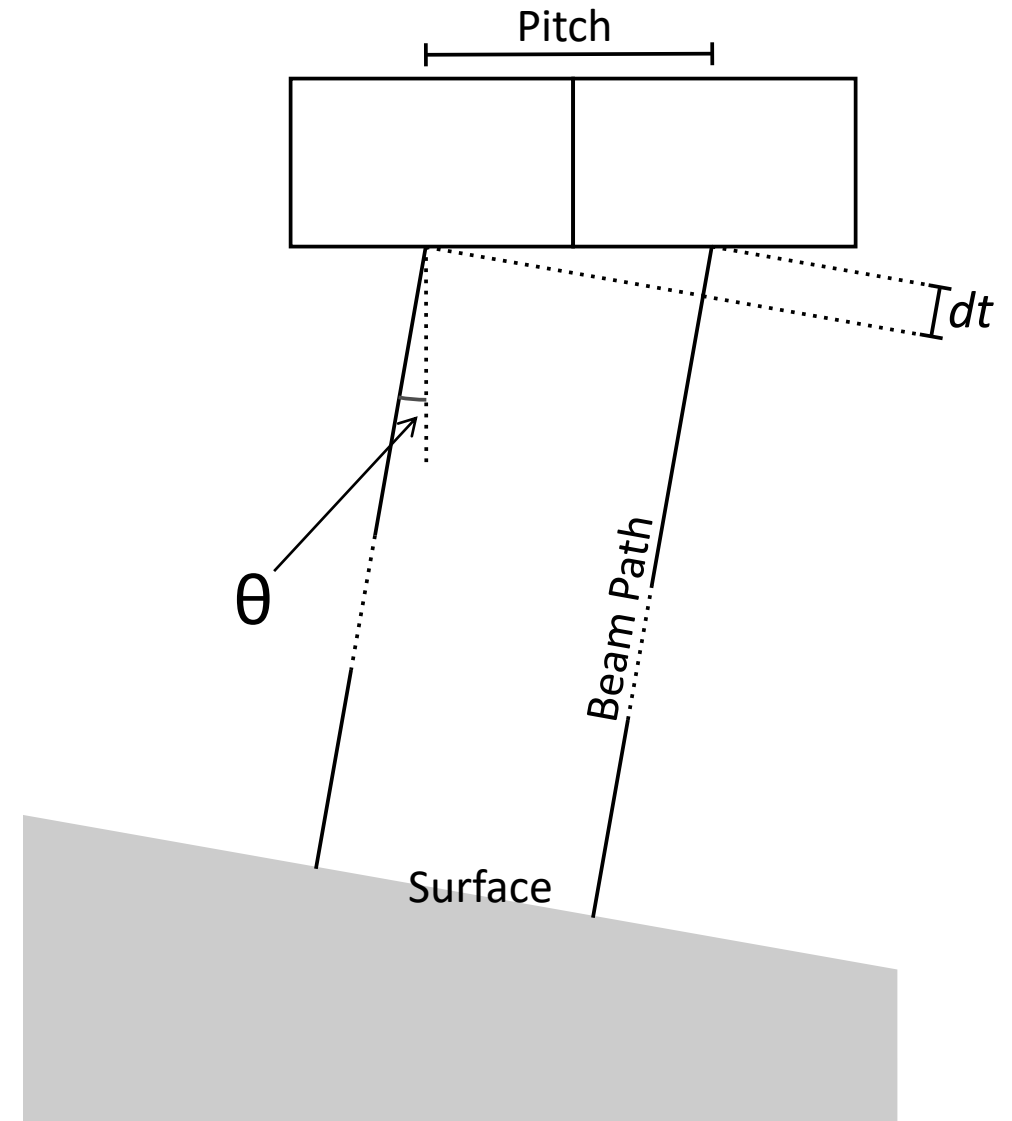


Other Surface Mapping Methods

- Several other surface mapping techniques exist.
- First responses from the surface and trigonometry used to map the surface.
- Commonly used methods include:
 - Dipping Reflector Method
 - Plane Wave Method
 - Total Focussing Method in coupling substance

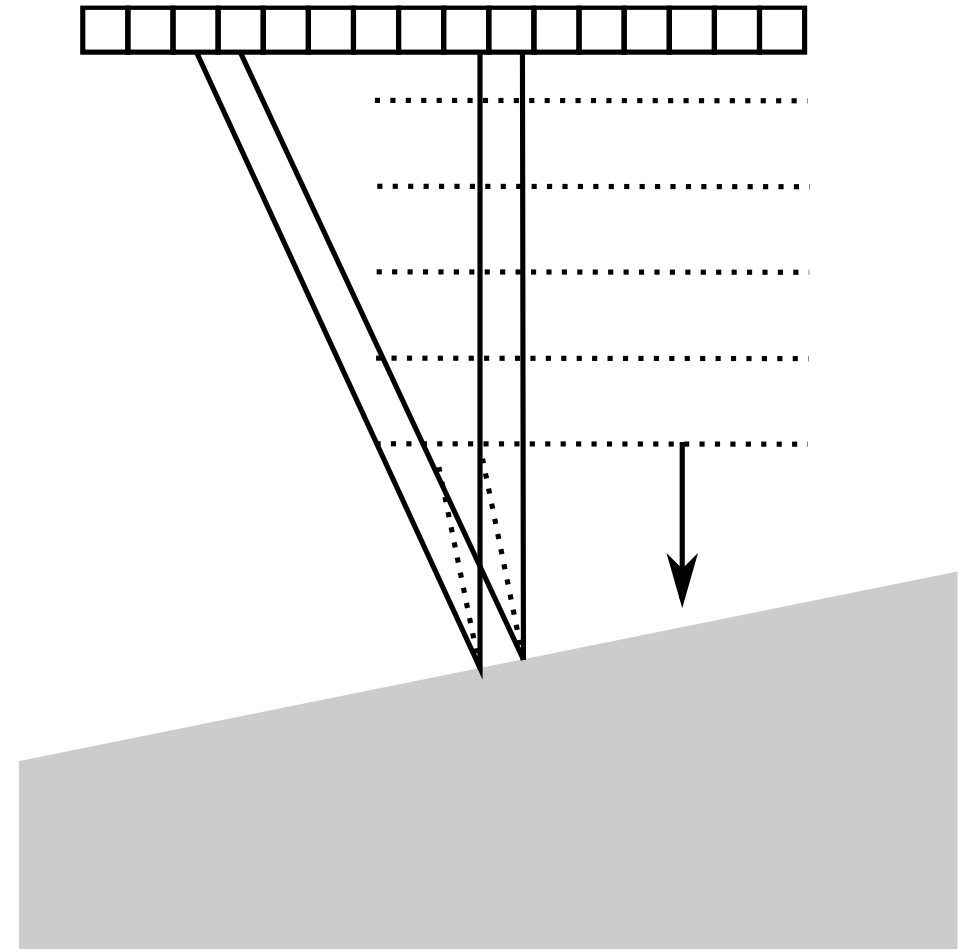
Dipping Reflector Algorithm

- Each Element Transmits and Receives Individually – First echos recorded.
- Assumed that the surface gradient off which the echo received from two adjacent elements is equal.
- Using difference in the time of flights the position of the surface can be found.
- Multiple emissions needed – however quick to process.
- Useful when inspecting with Full Matrix Capture.



Plane Wave Method

- Incident Plane Wave, individual receivers.
- Assumed that the surface gradient off which the echo received from two adjacent elements is equal.
- Difference in time of flight for two receivers and trigonometry used to map the surface.
- Advantage of a single emission – faster than Dipping Reflector.

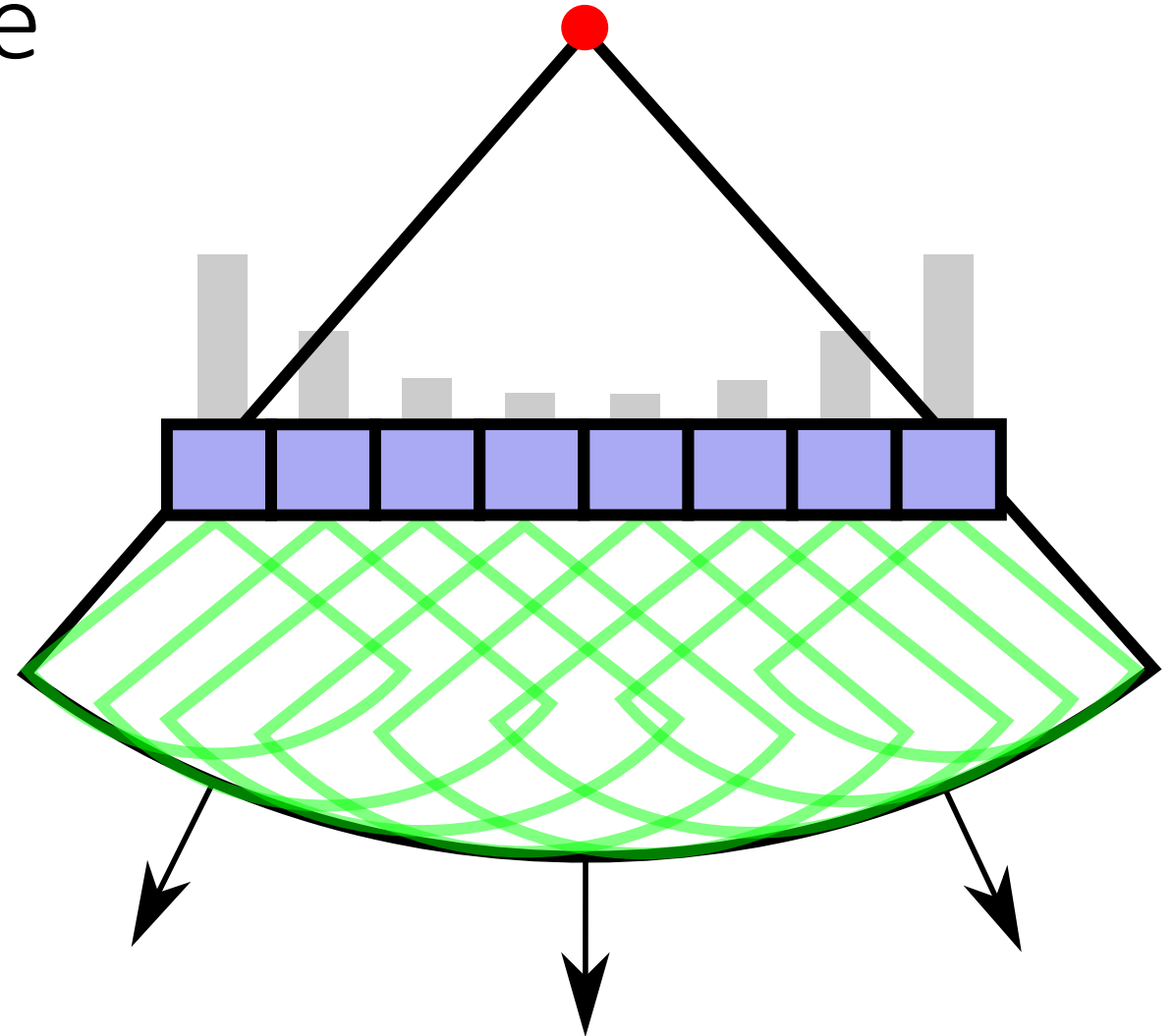


Total Focussing Method (TFM)

- TFM is the algorithm used for imaging beneath the surface.
- TFM can also be used to generate an image of the surface in the coupling substance.
- Requires a lot of post processing – creating two images increases the processing time.

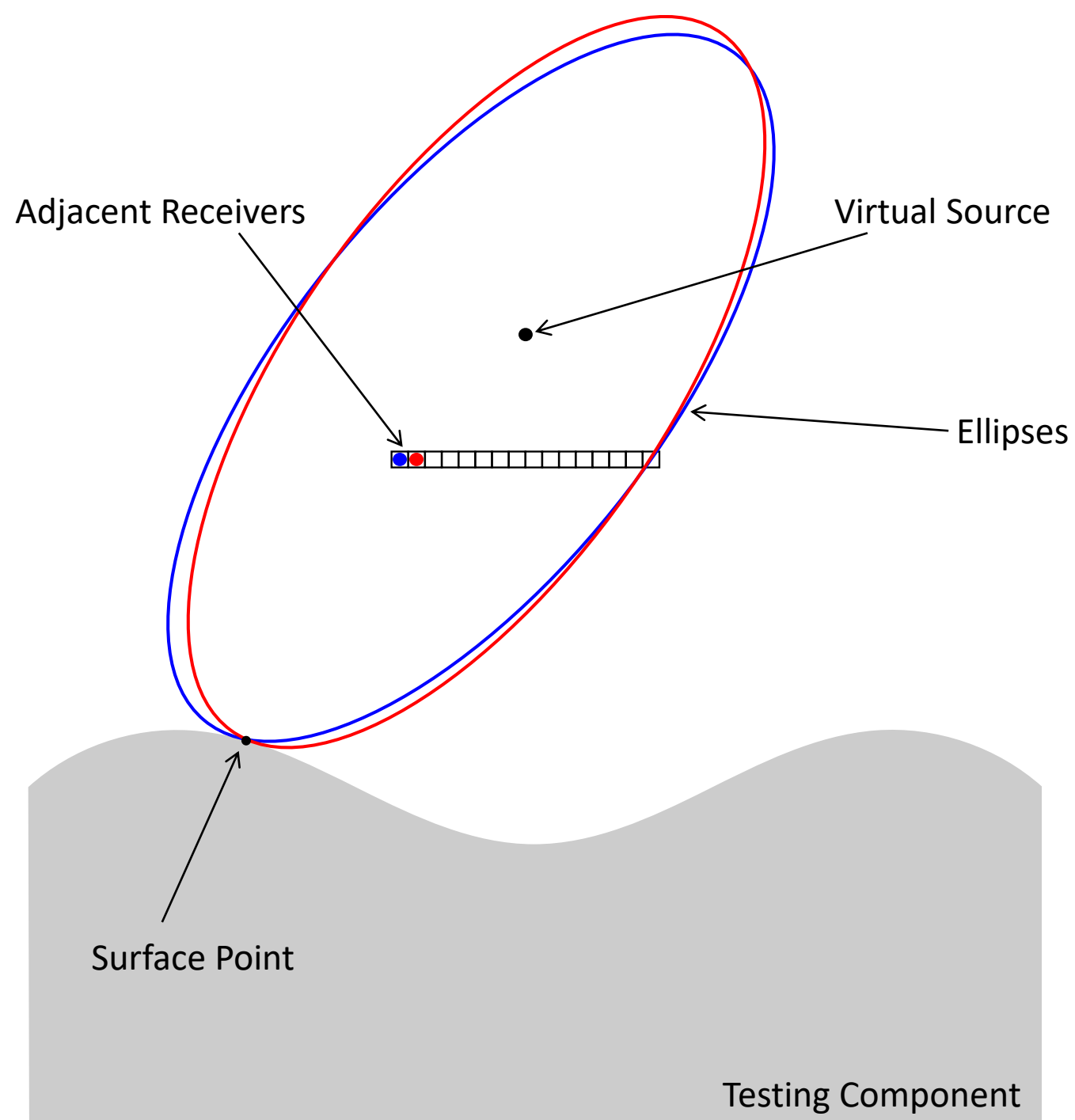
Virtual Source Aperture

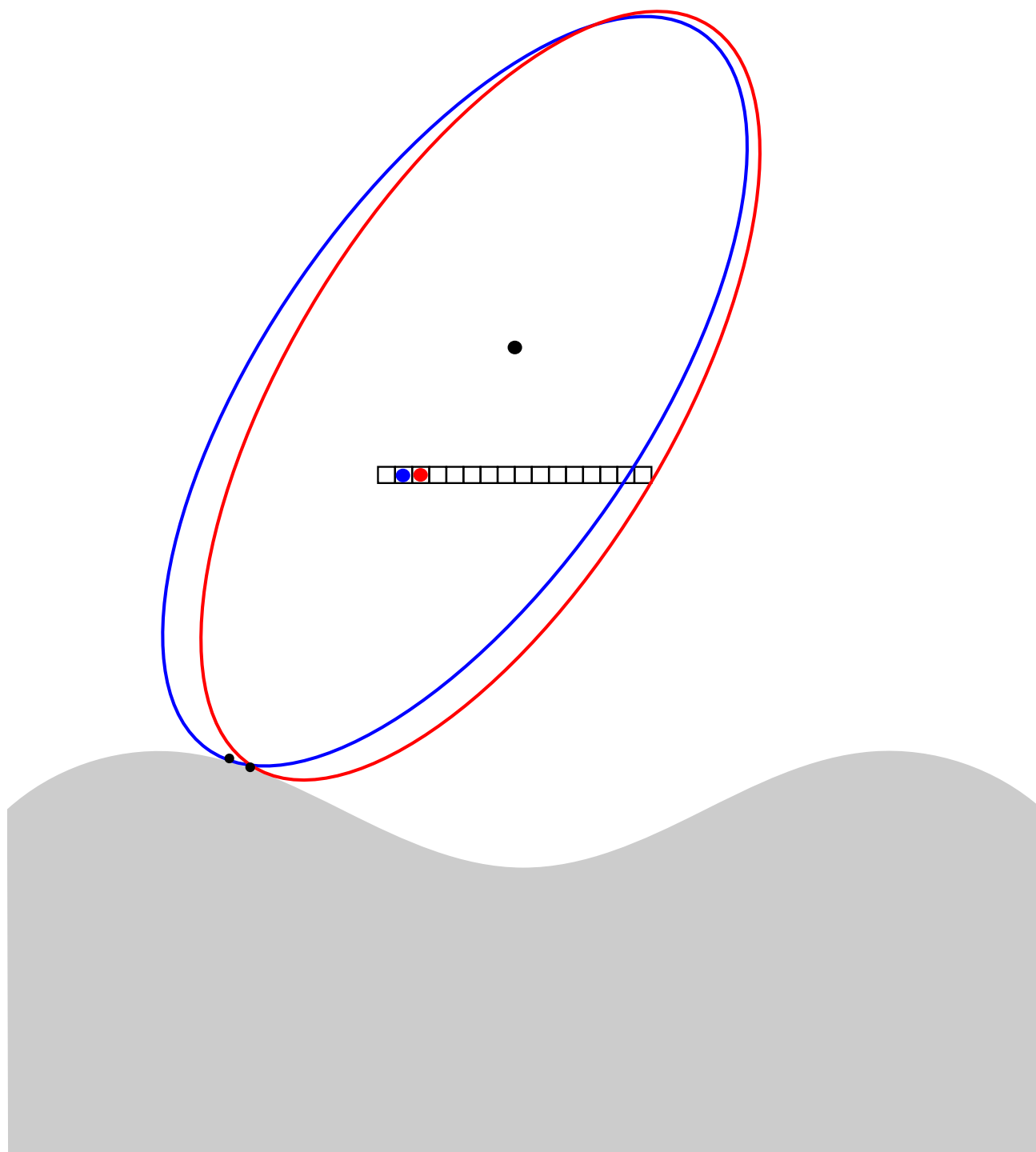
- Use Virtual Sources.
- Increases the SNR of returned A-scans – less transmissions required.
- Rapid inspection Speed.
- Ellipse method developed for surface mapping using virtual sources.

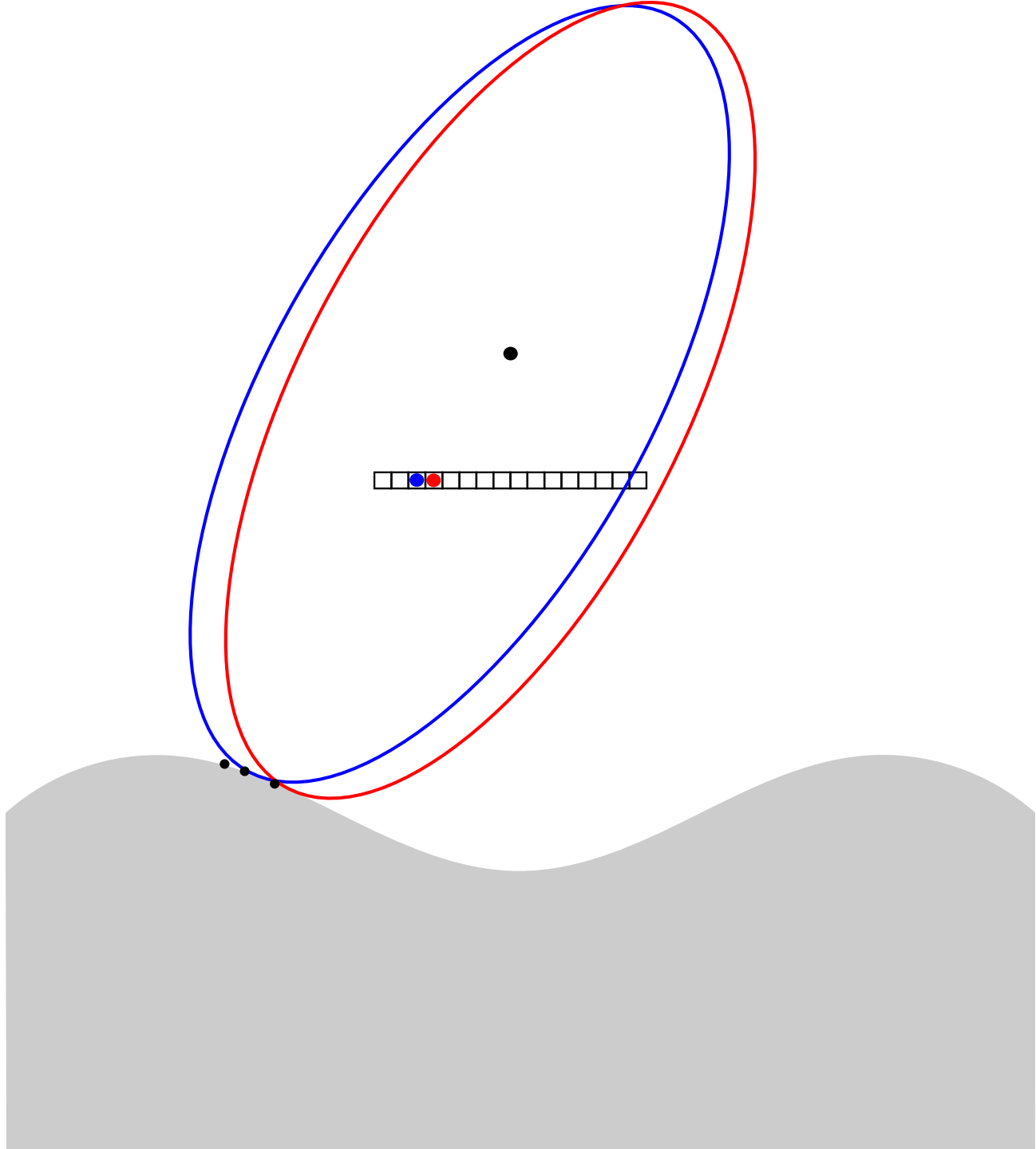


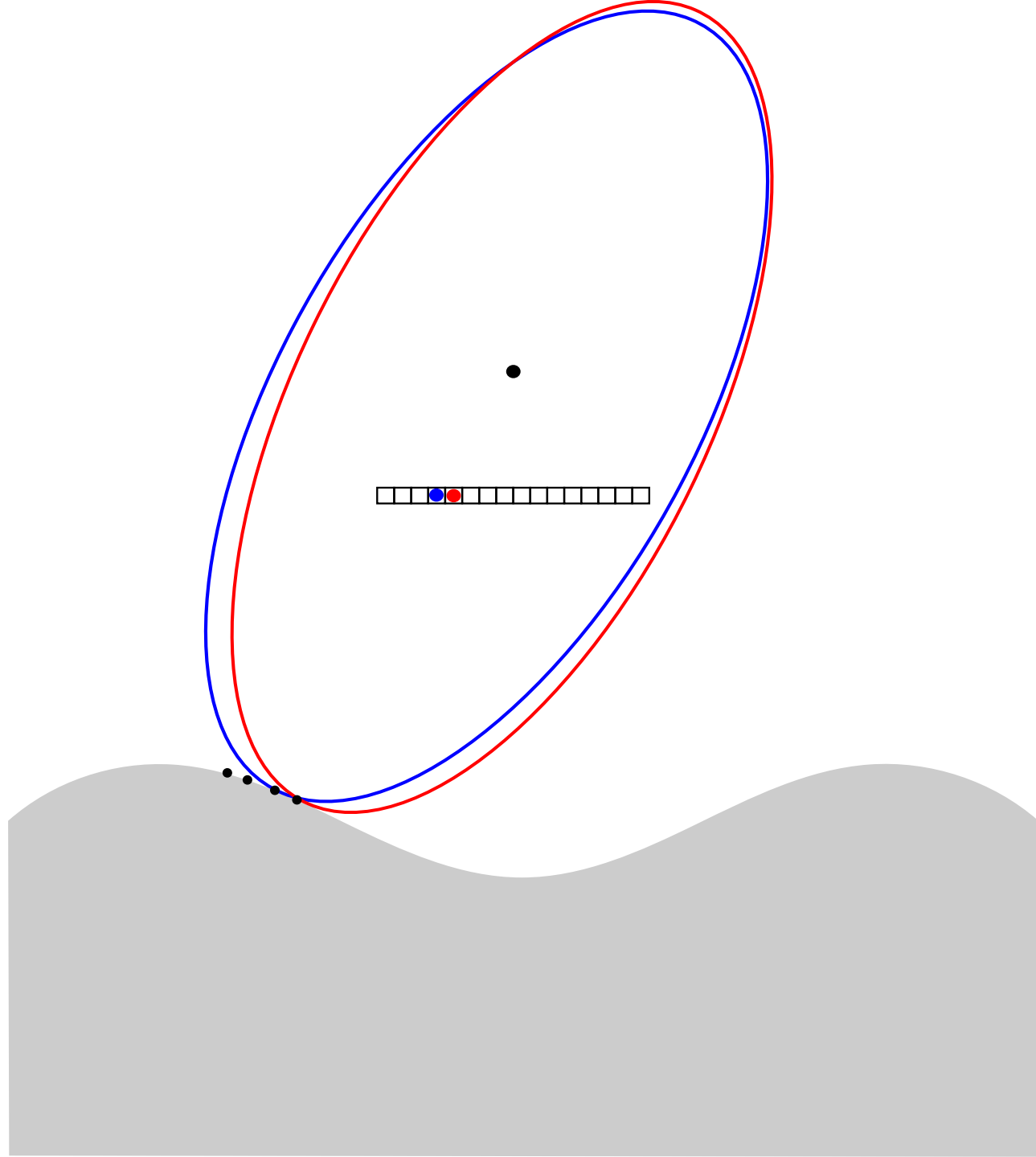
Ellipse Method for VSA

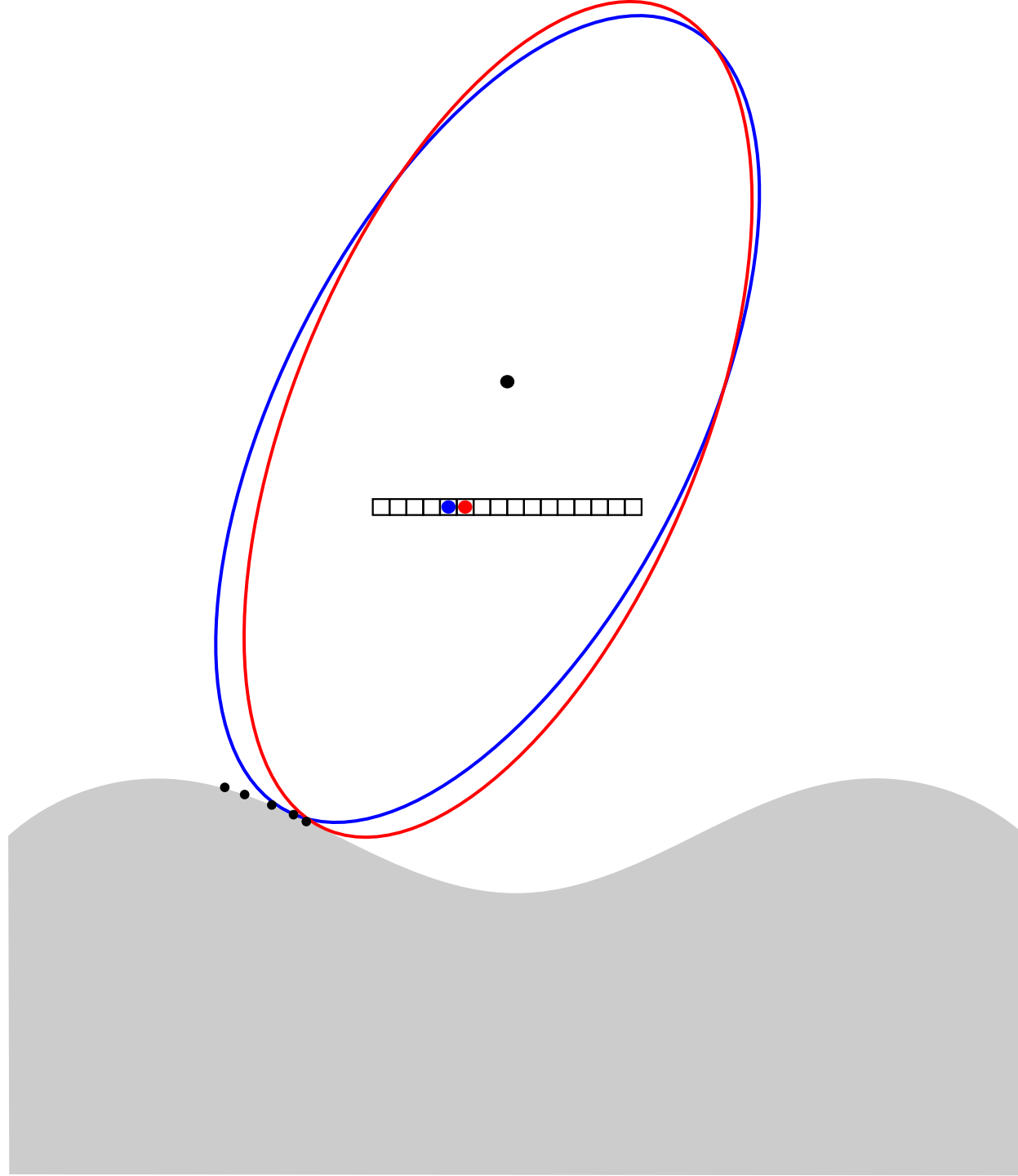
- Ellipse is drawn using the source and receiver position and the focal points.
- Distance from first focal point to the circumference and back to the second is equal to the first response distance.
- Some assumptions made:
 - Assumed that the surface gradient off which the echo received from two adjacent elements is equal.
 - Surface Continuity.
- Want two points on each ellipse with equal gradient and whose tangent intercept the other point.

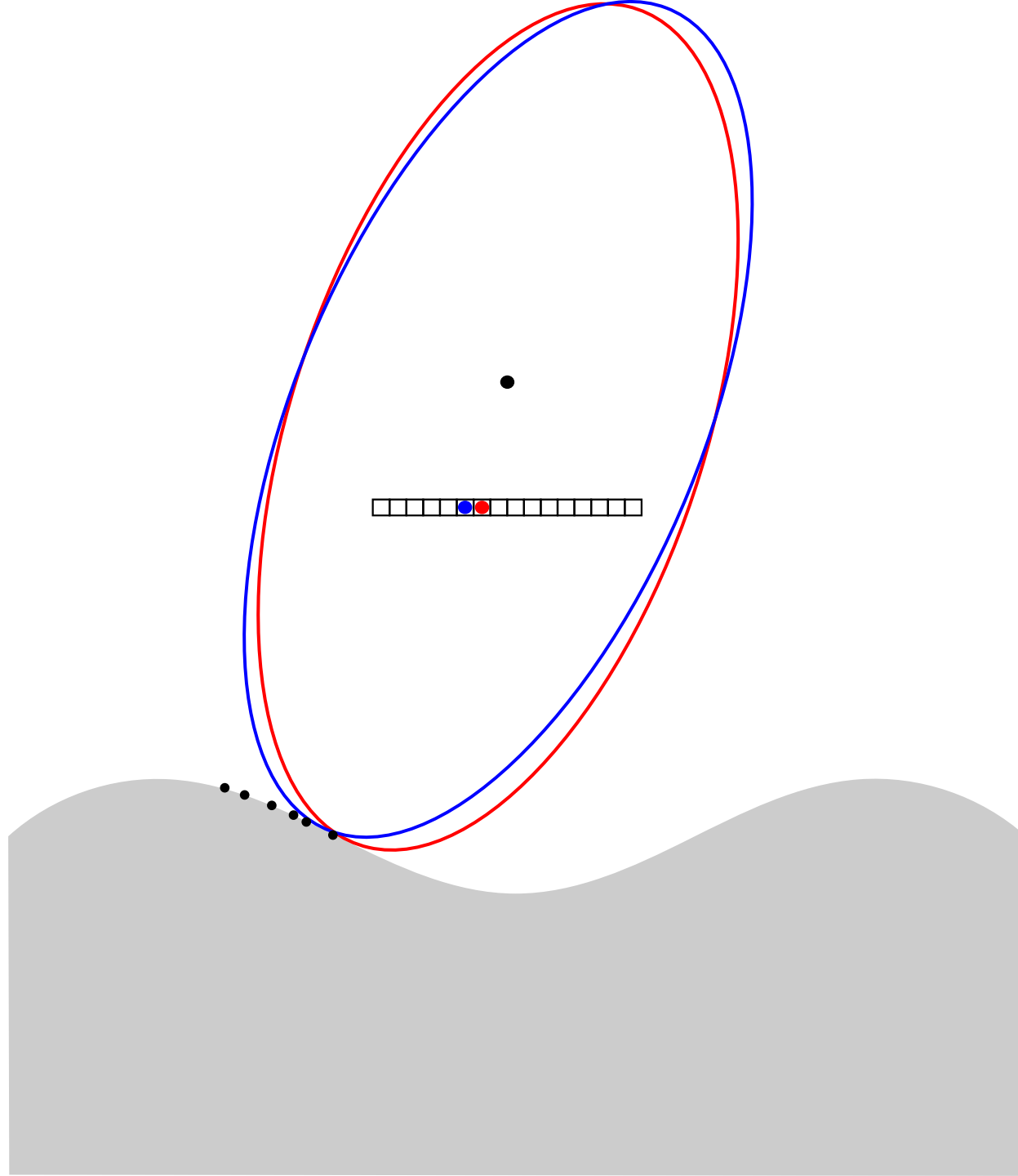


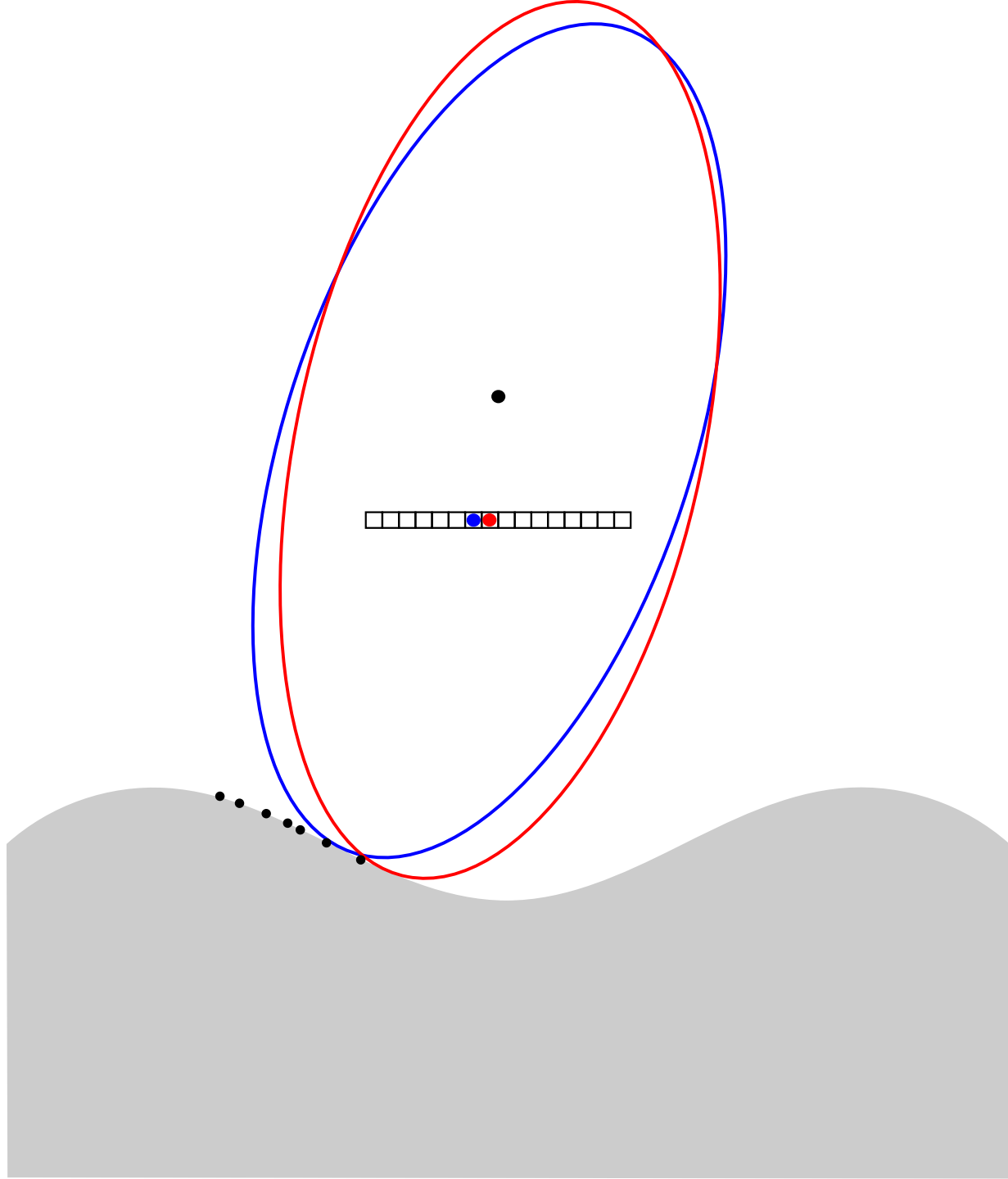


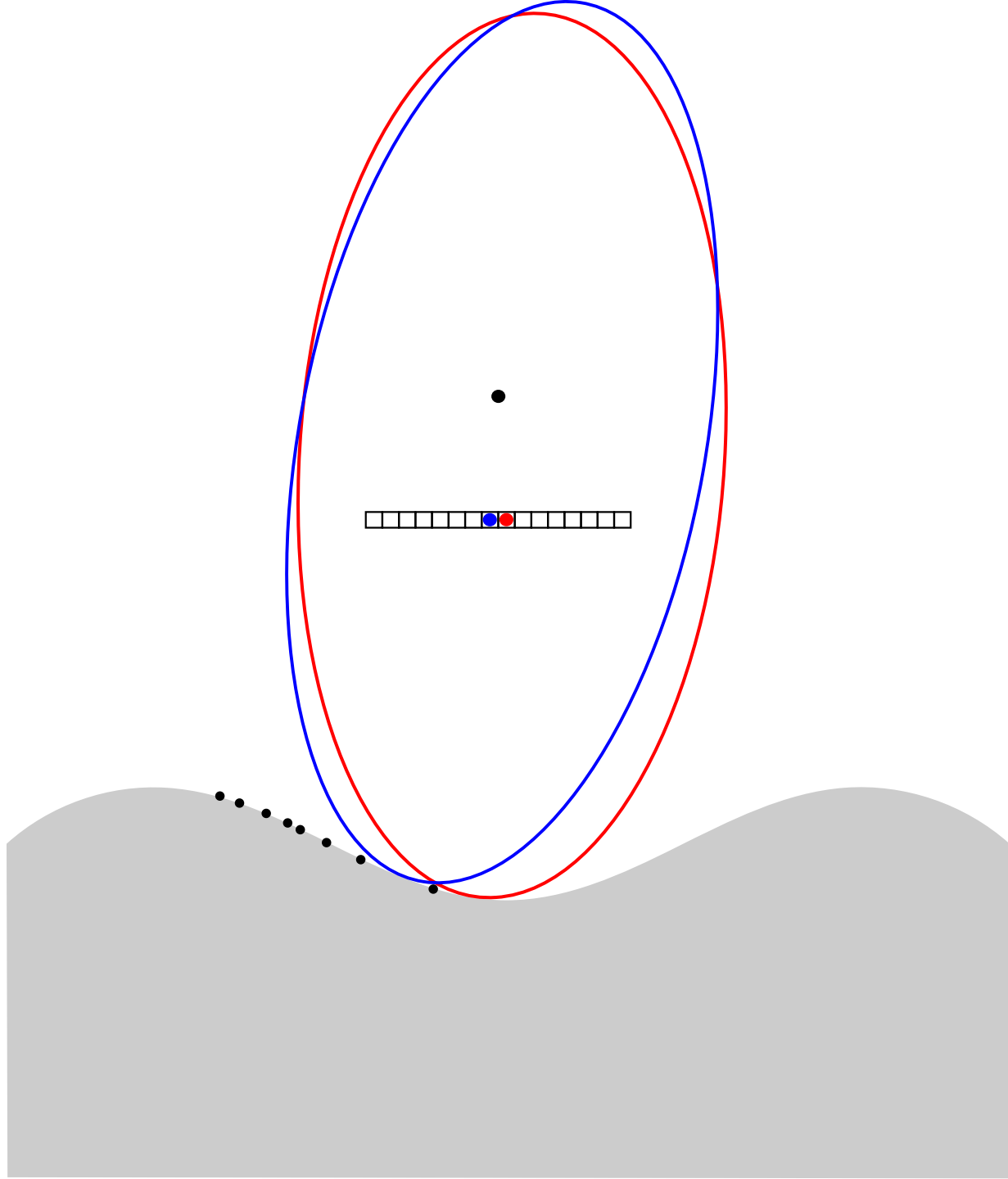


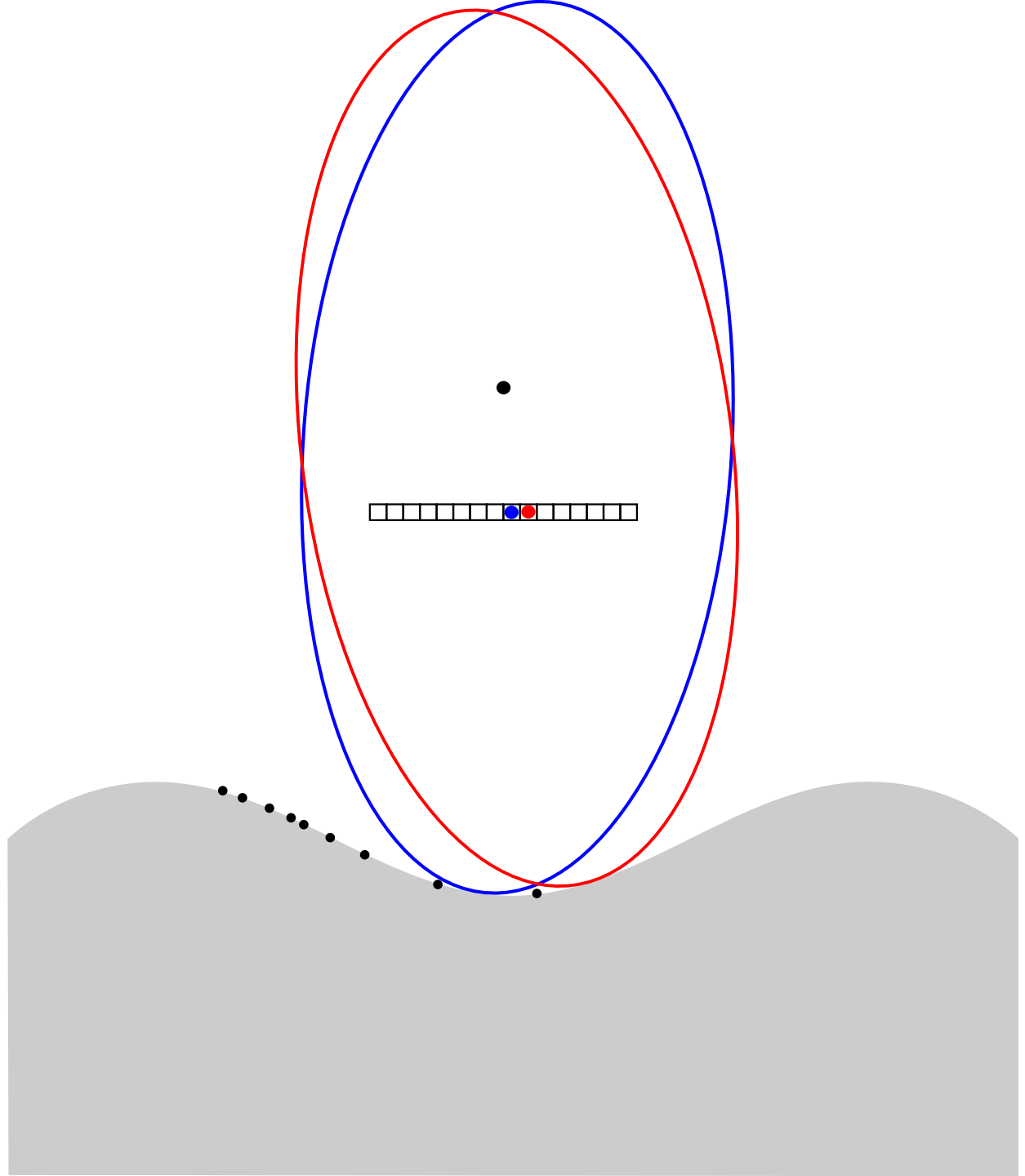


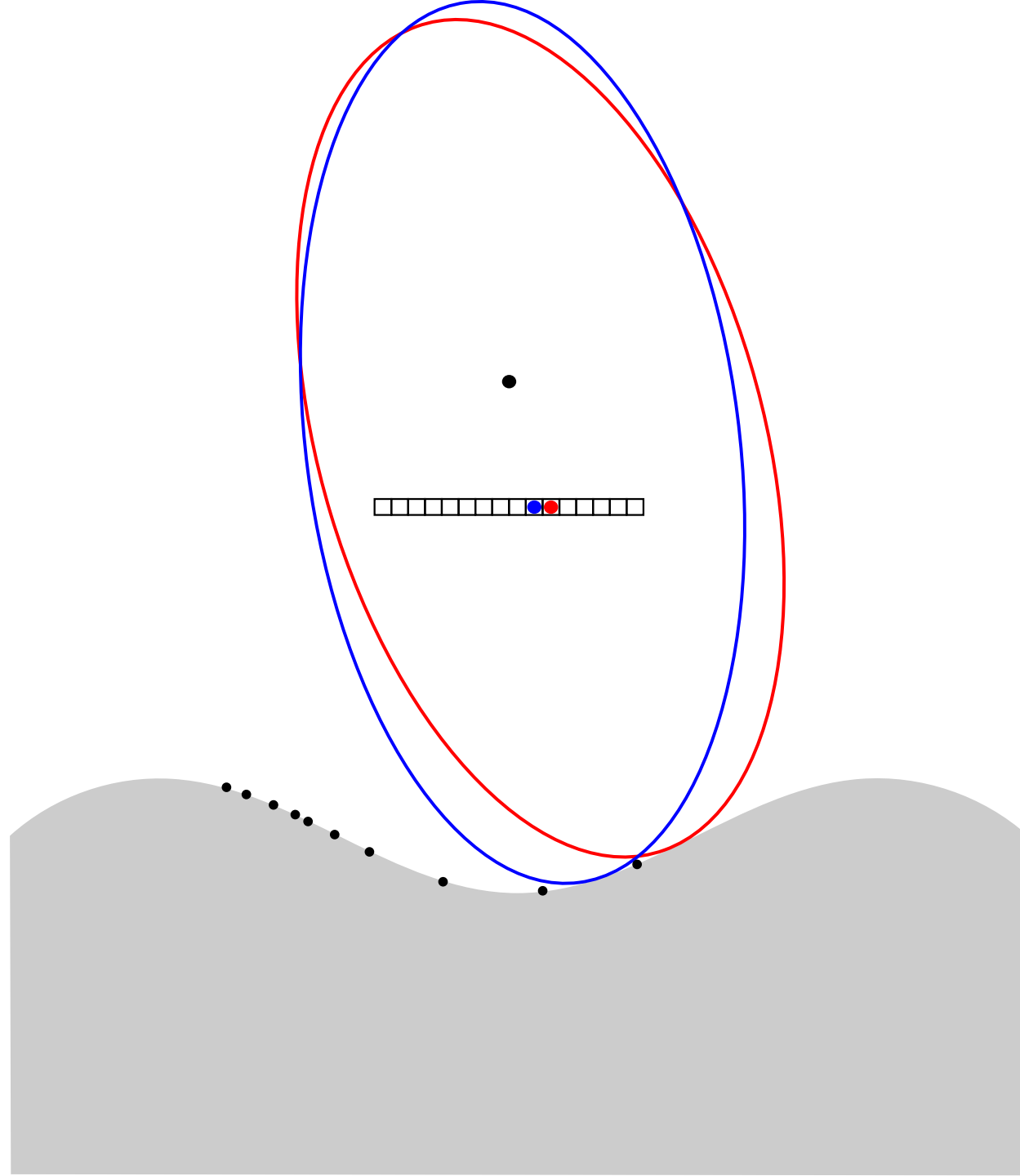


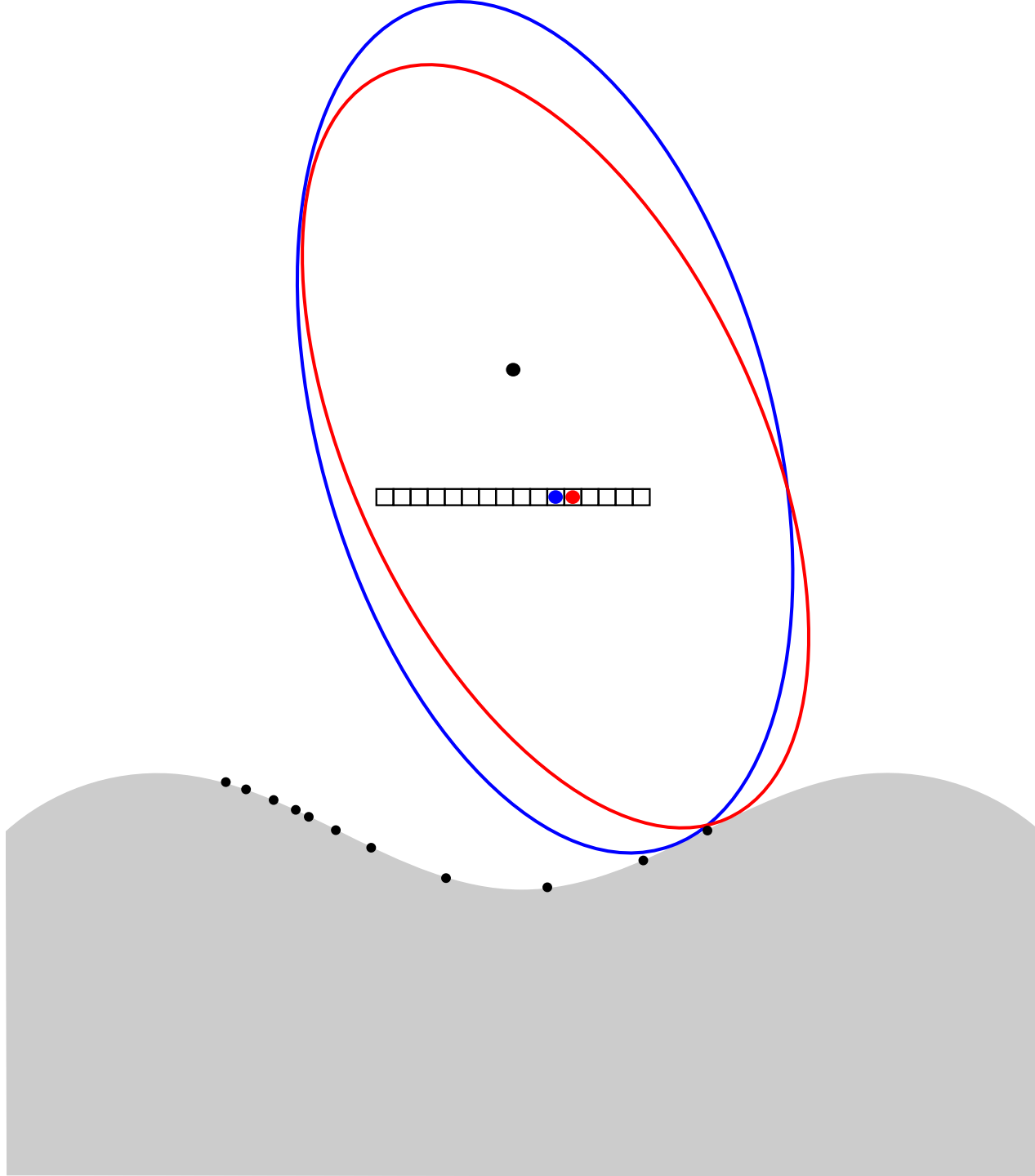


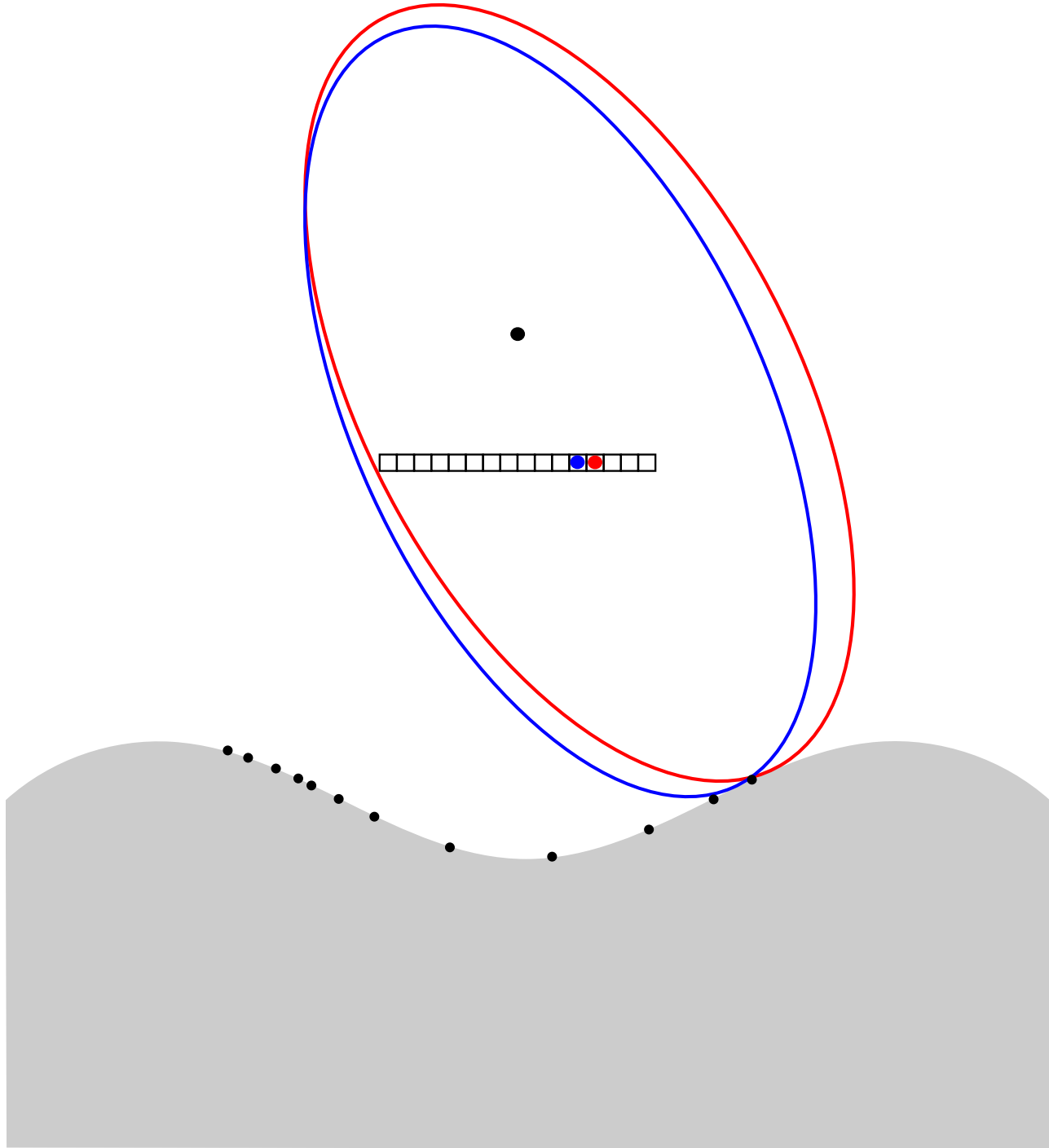


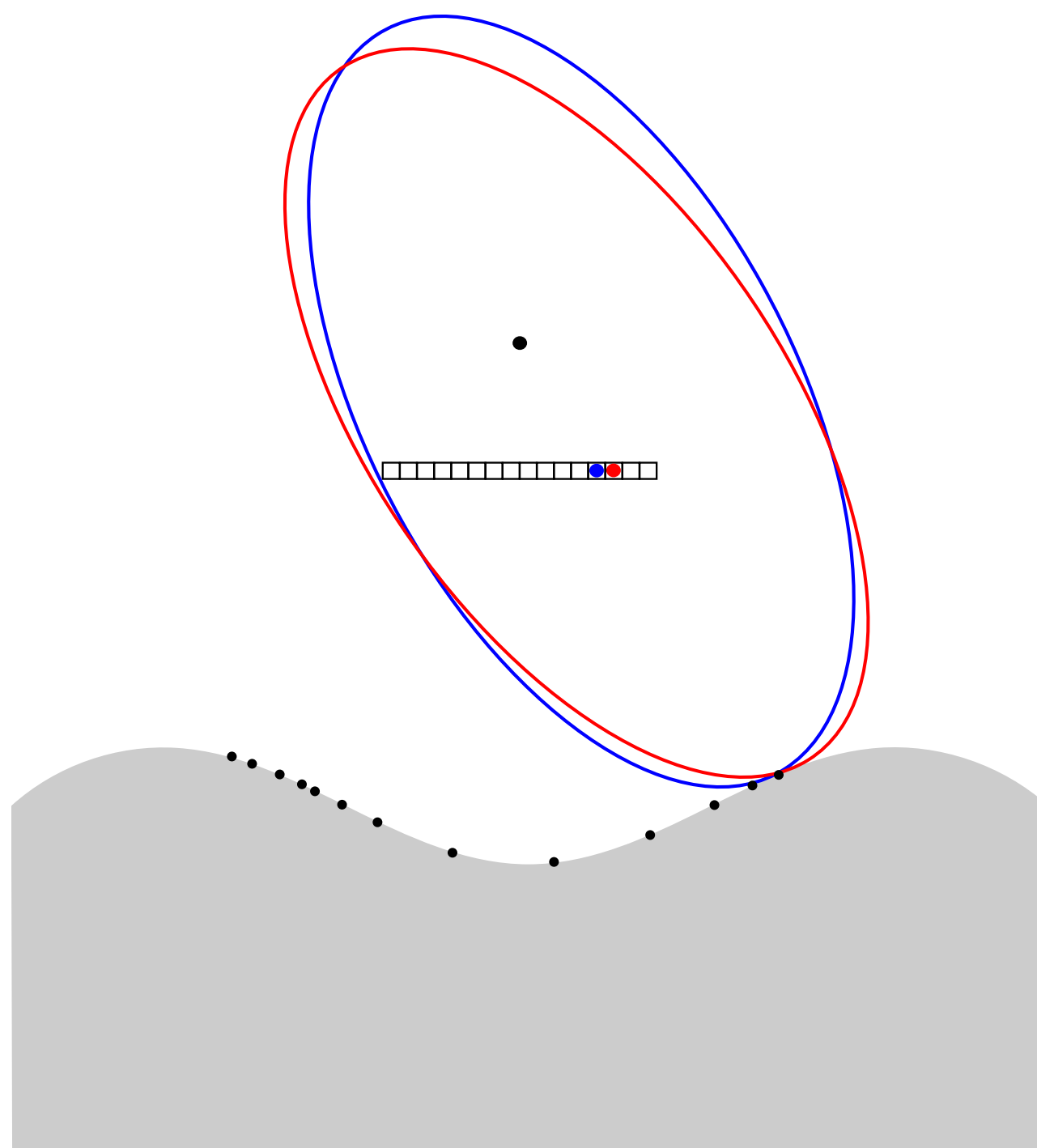


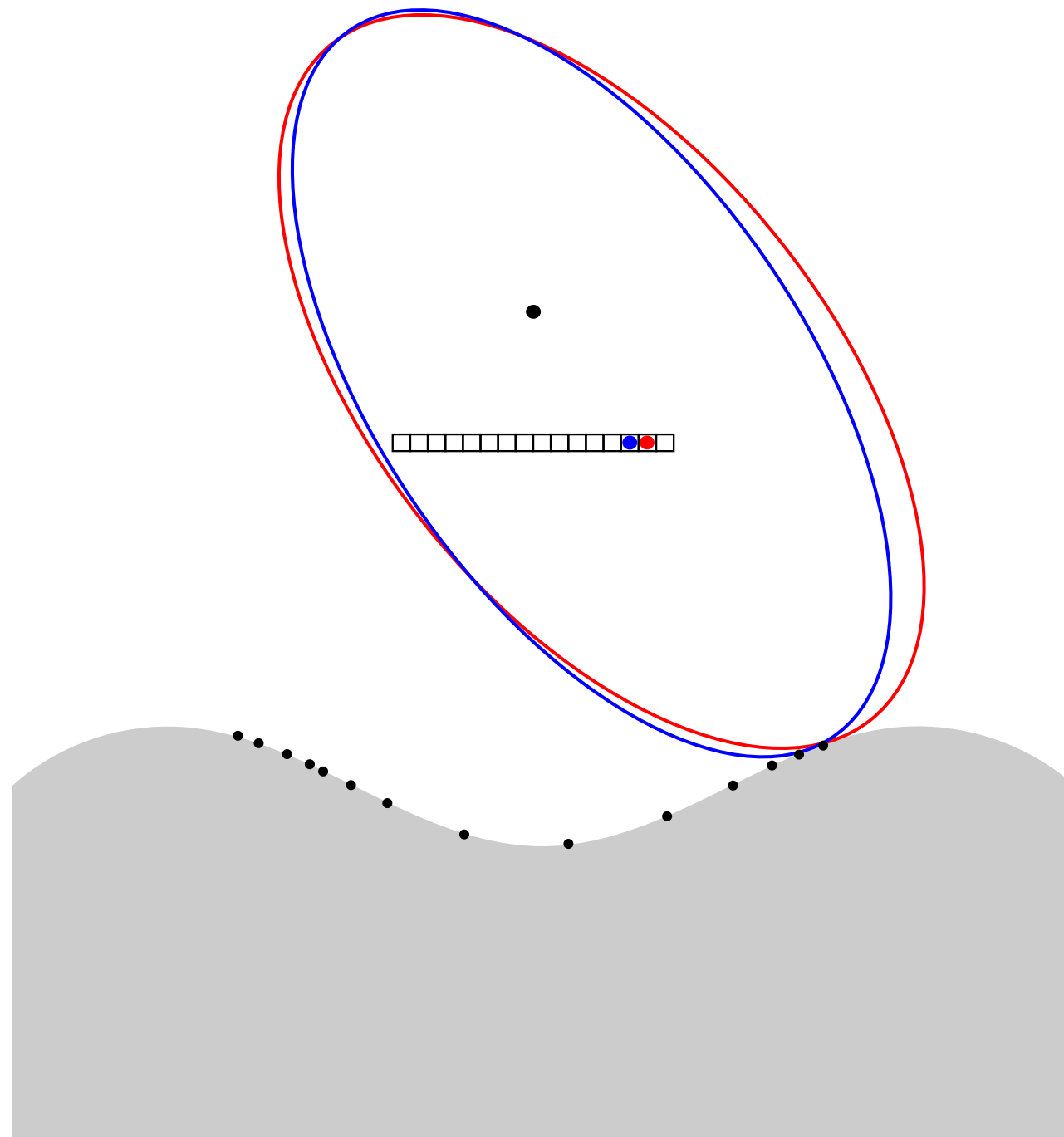


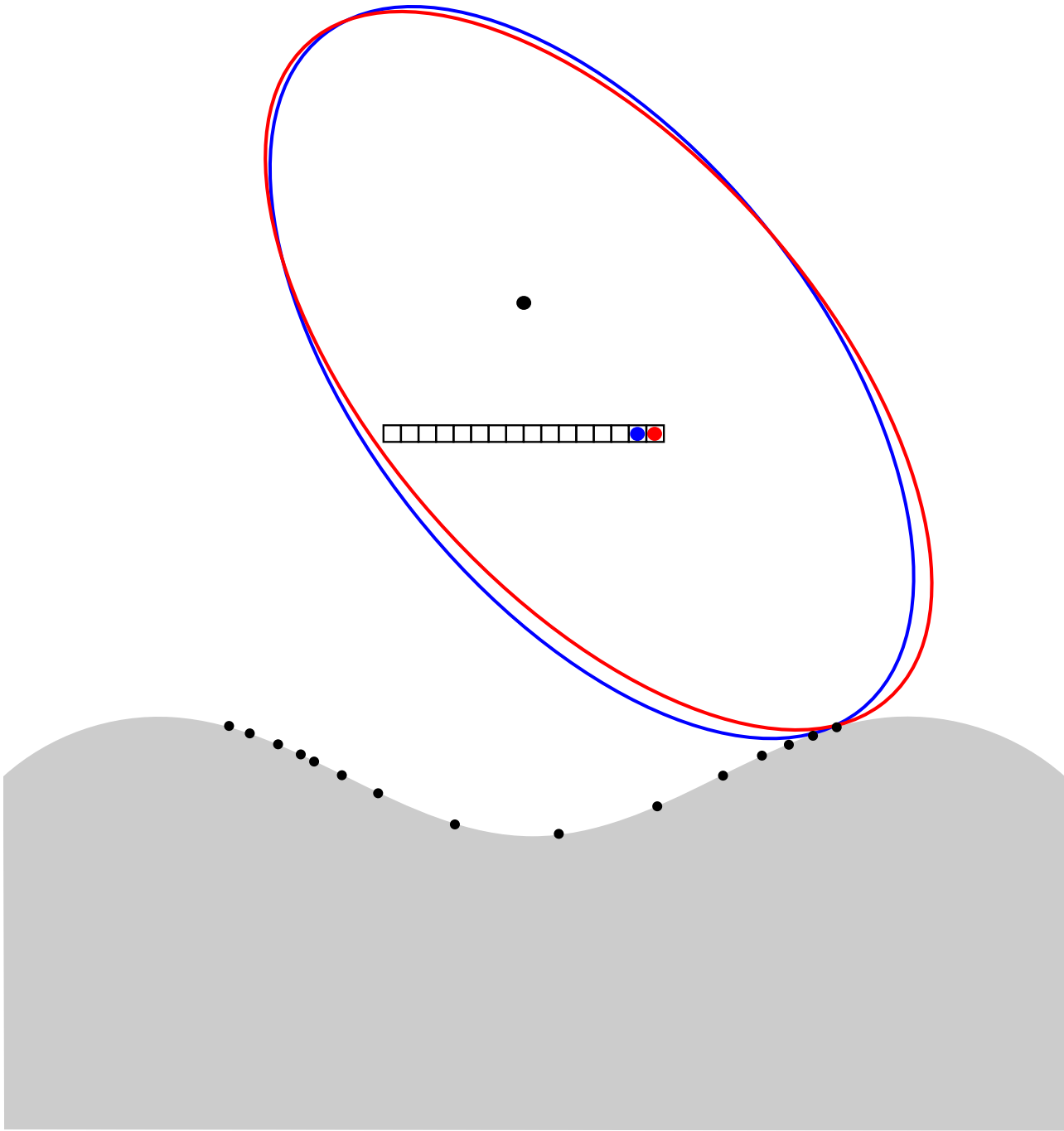


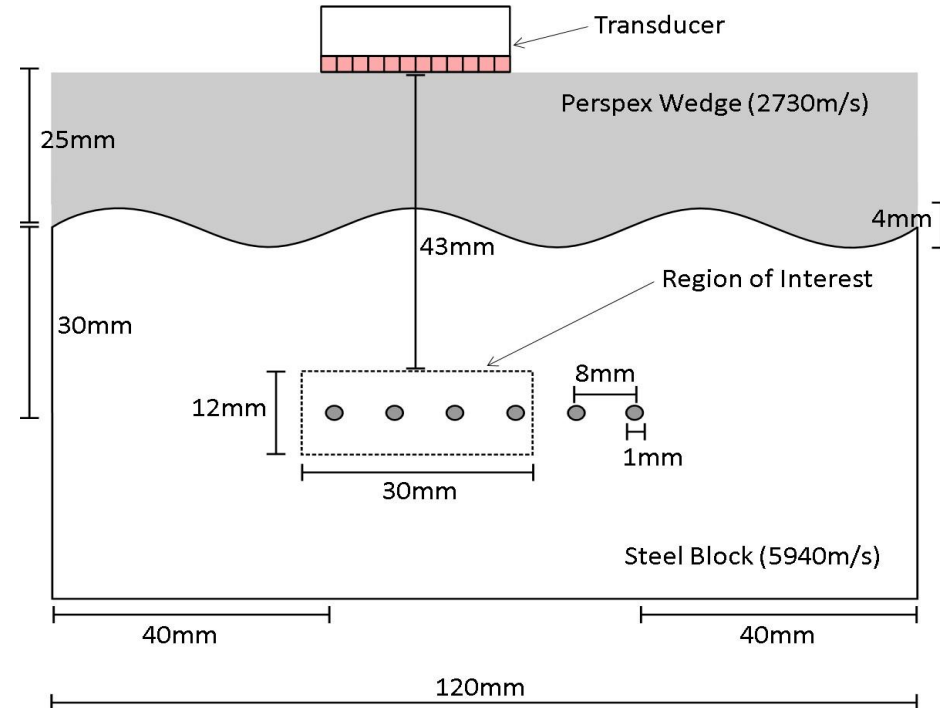
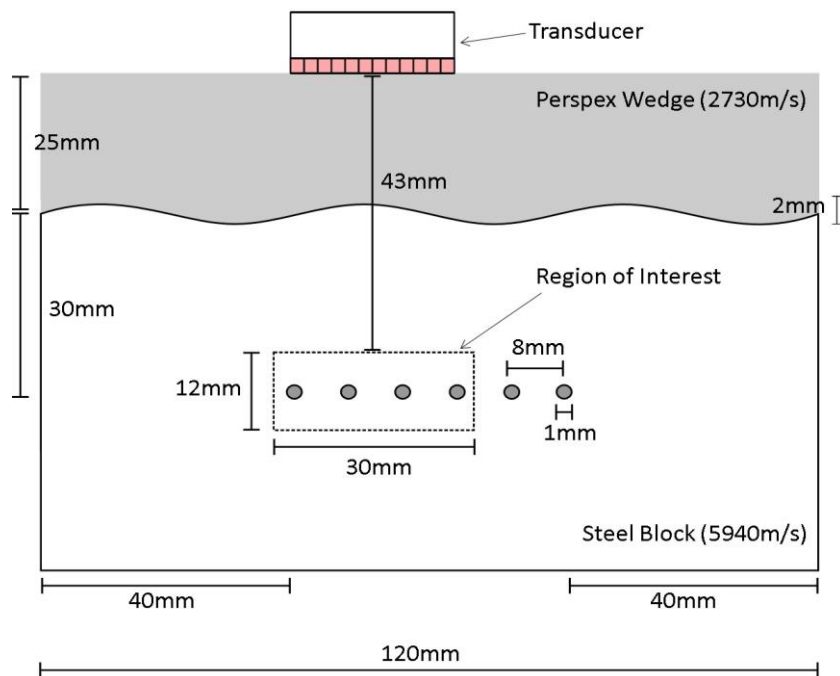
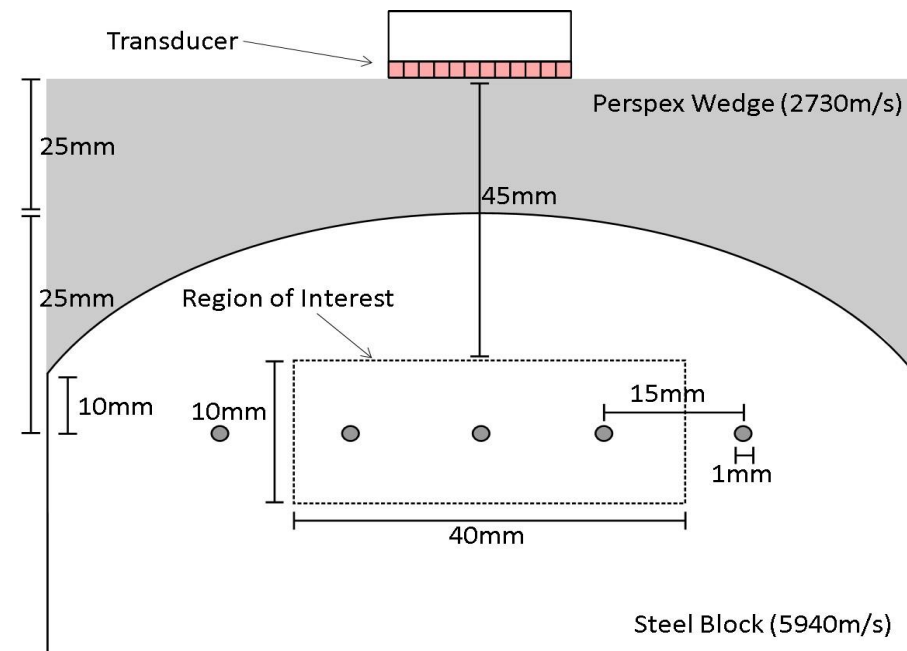
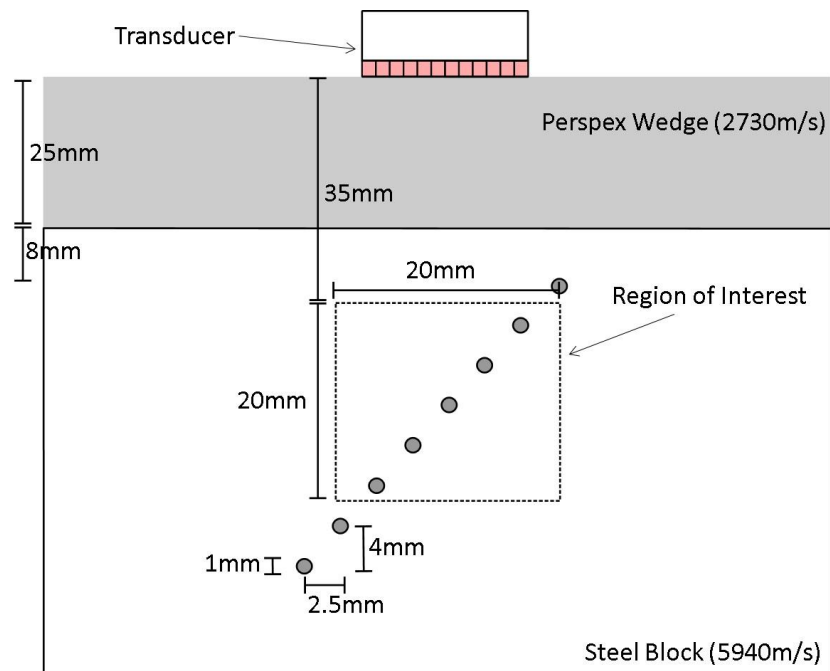




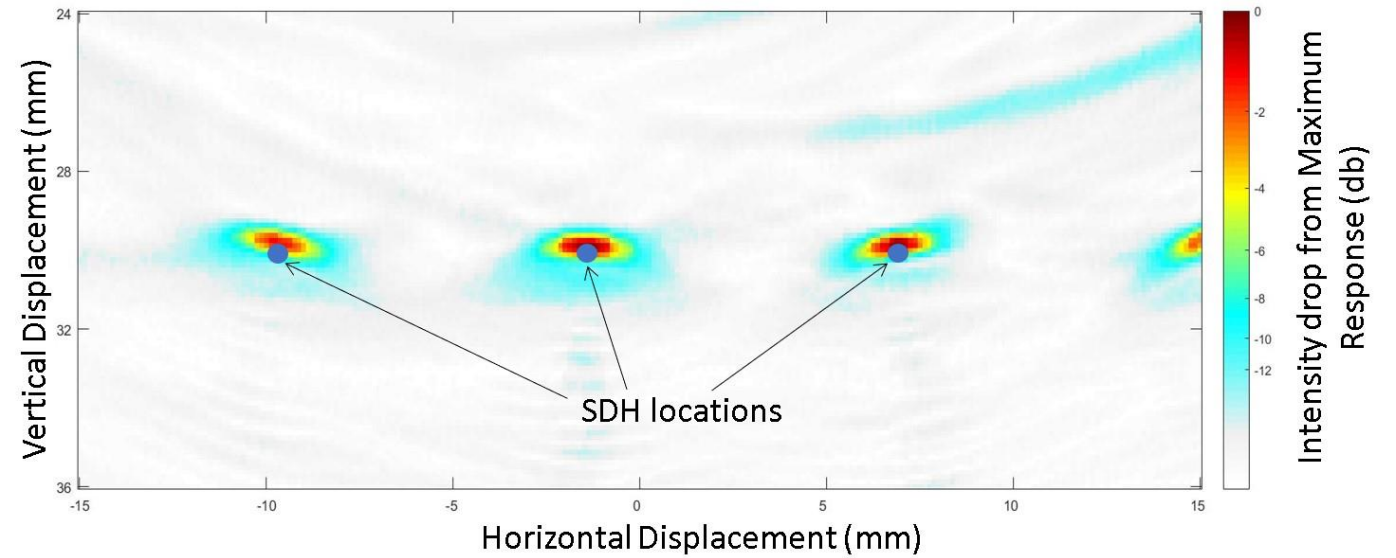
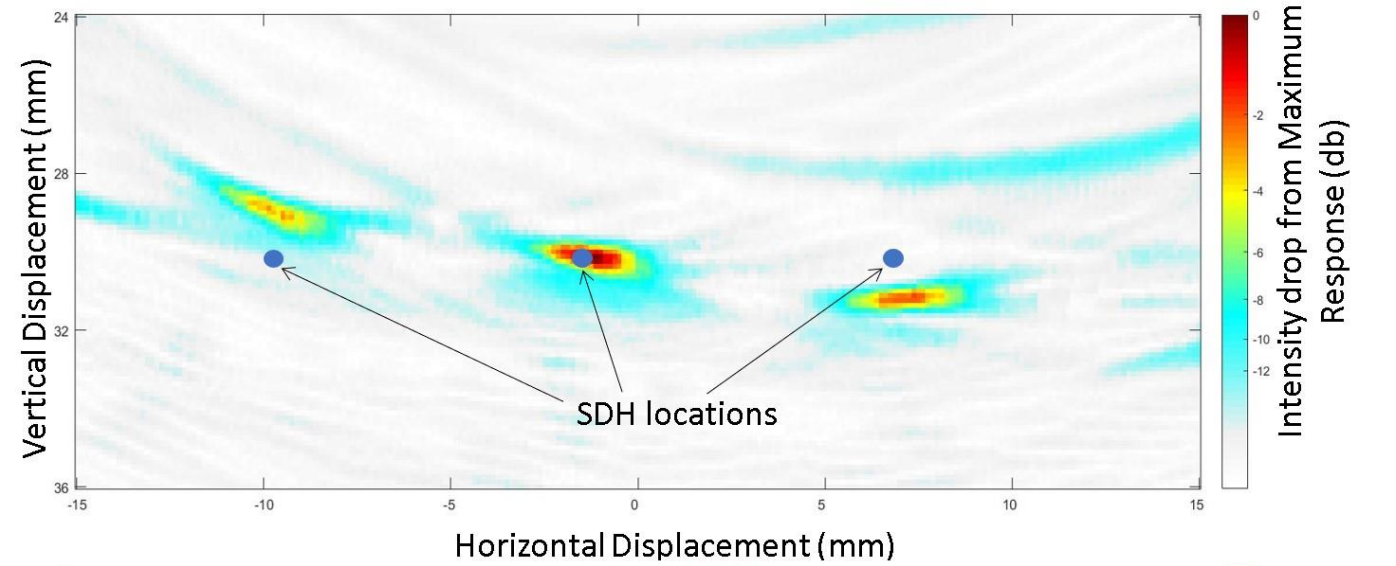
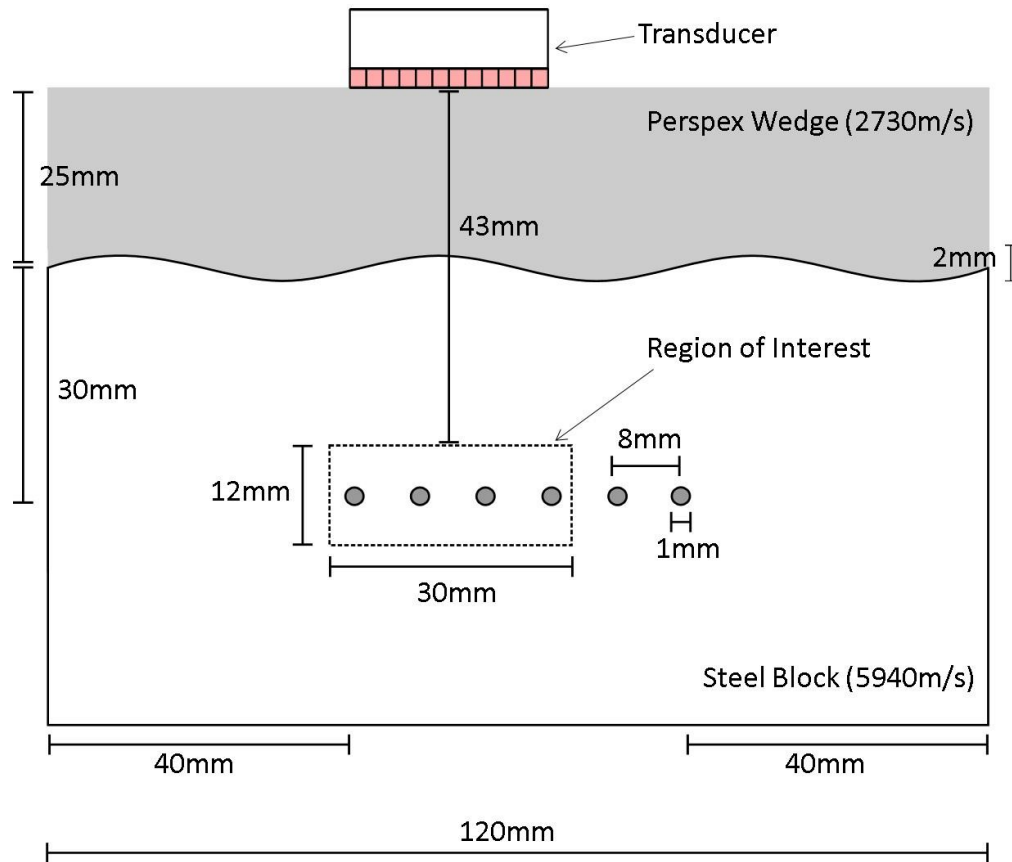








Results



Advantages of VSA Ellipse Method over Existing

- For an array of N elements, $N-1$ surface points are found – same.
- Surface information can be obtained with a single transmission.
- Imaging can be done with the same data set – only method where surface mapping and imaging can be done using a single transmission.
- Providing $N_e^2 < N_x N_z$, which is usually the case, less post processing is required than performing TFM in the first material to map the surface.
- Fast inspection possible.

Future Work

- Evaluation and comparison of VSA method with other existing methods.
- Investigate how many points is needed in order to generate an accurate surface estimation. More points = more processing = slower inspection rate.
- Reduce computation by developing a mathematical solution – tricky.

Summary

- New surface mapping method using virtual sources.
- Surface mapping and imaging can be done with a single transmission from the array.
- Fast inspection – potential applications for NDT.

Questions?