Geophysical Imaging

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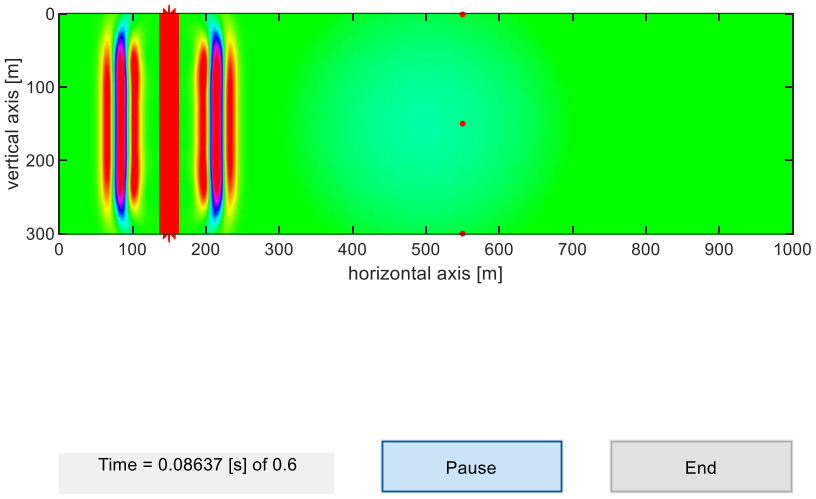
Beam forming and guiding a wave

In this exercise we are asked to build a model that "focuses" the wave field in one direction and/or against one target, there are some ways to accomplish this aim three of which are as

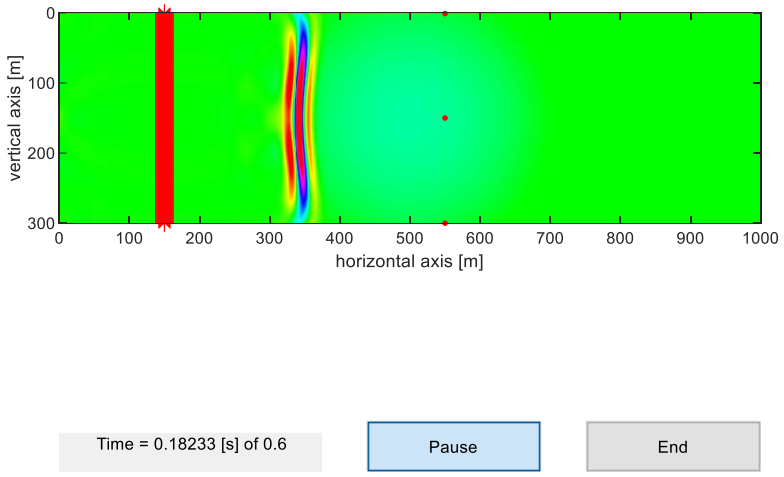
1st Solution:

The magnifying glass is a tool with which you are very familiar. On a sunny summer day, if you have a magnifying glass with medium zoom quality, you can use it to light a piece of paper or ignite a fire. In fact, the sun acts as a distant point source that emits electromagnetic waves towards the Earth, and since the Earth is relatively far away(we are in the far field of the sun), the wavefront reaching us becomes nearly planar. This planar wavefront can be converged to a focal point upon encountering a converging lens. By utilizing this natural phenomenon, our first method can be executed as follows:

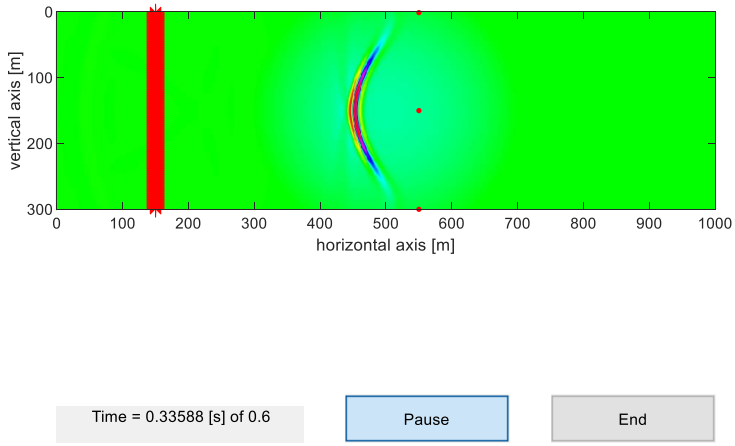
To achieve this, we simply need to fabricate a medium with a lens shape that possesses varying refractive indices or velocities. As you may already know, convex lenses come in various types and shapes, each with distinct focal points determined by their material composition and thickness.



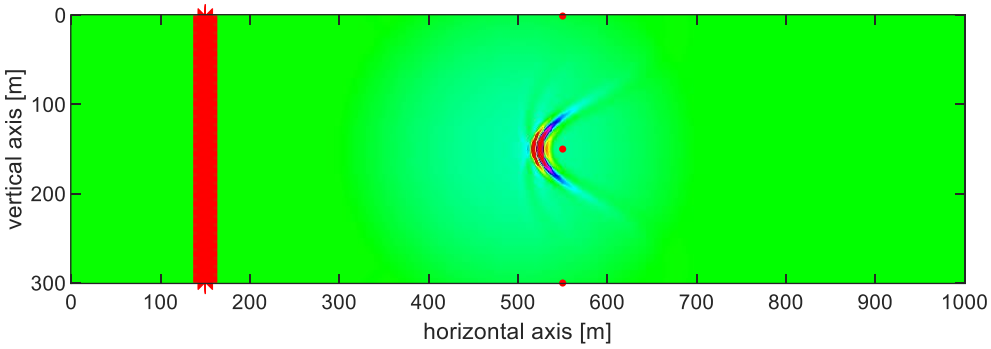
In this figure, we observe a scenario where a plane wave originates from a linear arrangement of point sources aligned vertically. These sources initiate transmission simultaneously, resulting in wavespropagating with synchronized starting times.



When the plane wave encounters the lens, it undergoes bending due to the variation in velocity across different media, as depicted in the plot above



And then, it progresses towards the designated receiver. It's evident that we can direct the beam towards any desired receiver simply by adjusting the angles of the aligned sources.



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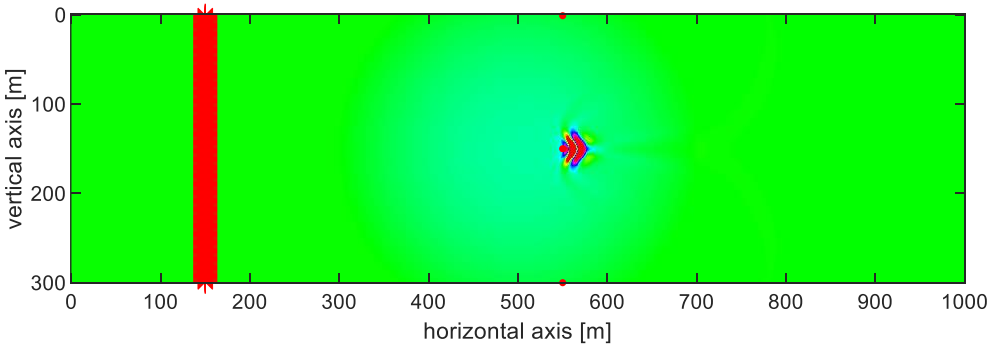

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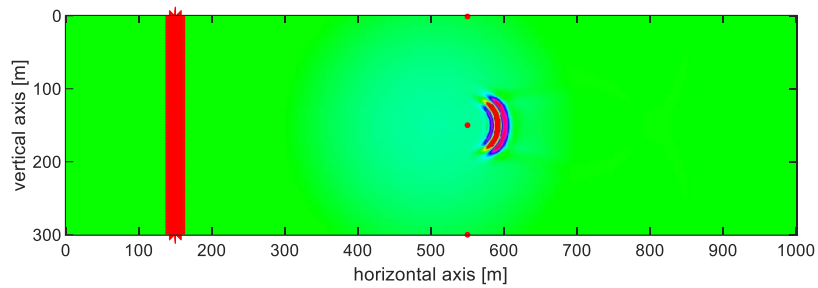
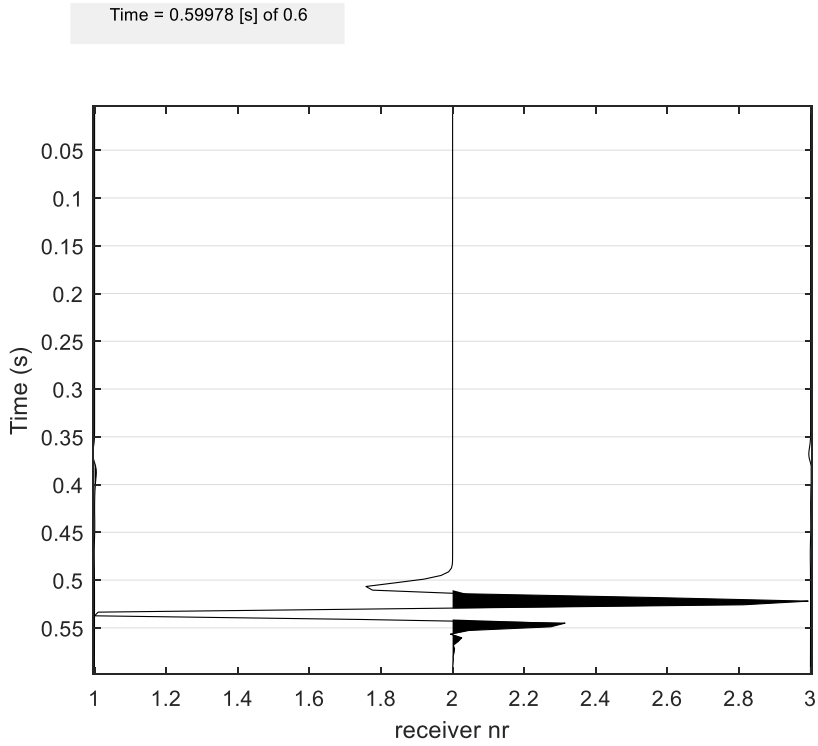
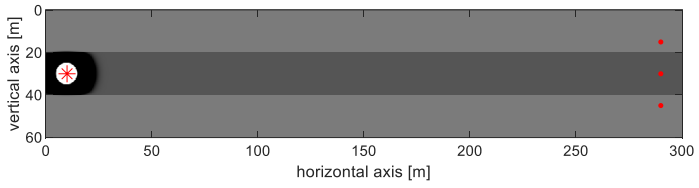


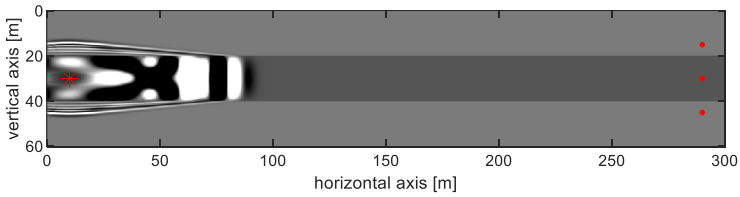


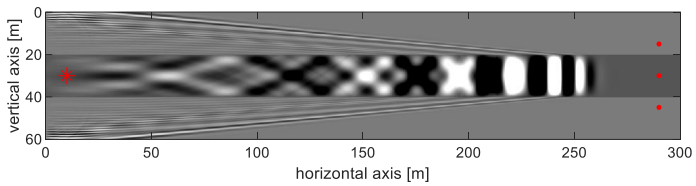
In the figure above, it's clear that the majority of the energy is captured by the second receiver, indicating that we have achieved our objective.

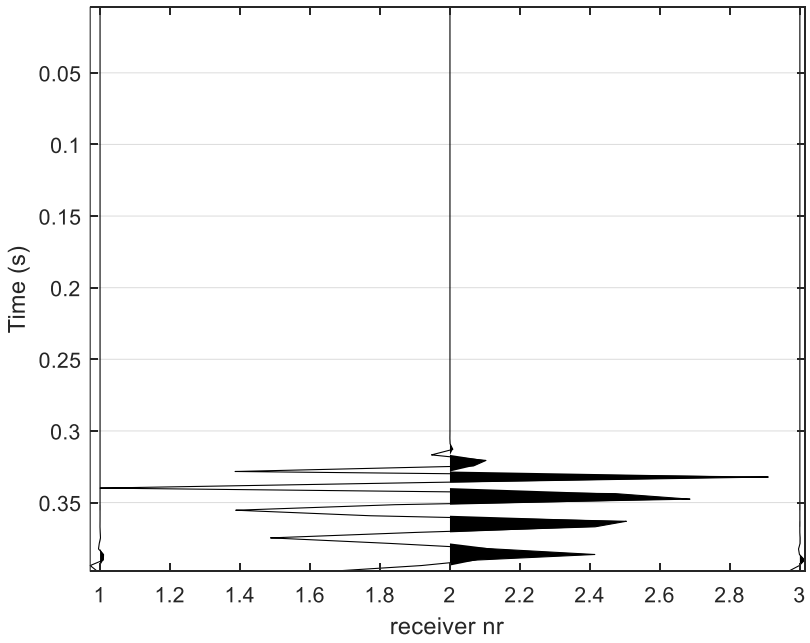
2nd Solution:

Another strategy involves creating a medium akin to a fiber optic to channel the energy of a source point wavelet towards a specific receiver. While the second receiver is targeted in this illustration, it's crucial to emphasize that we possess the capability to guide this energy towards any chosen receiver by constructing a channel leading to the intended destination.





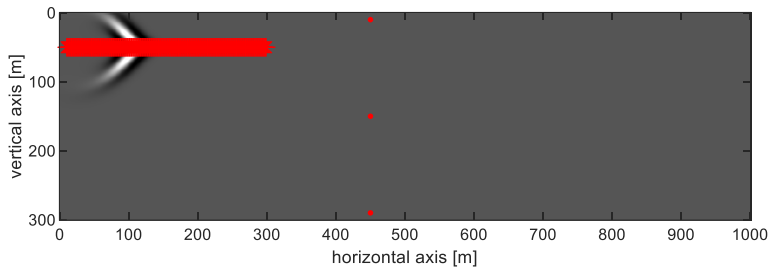


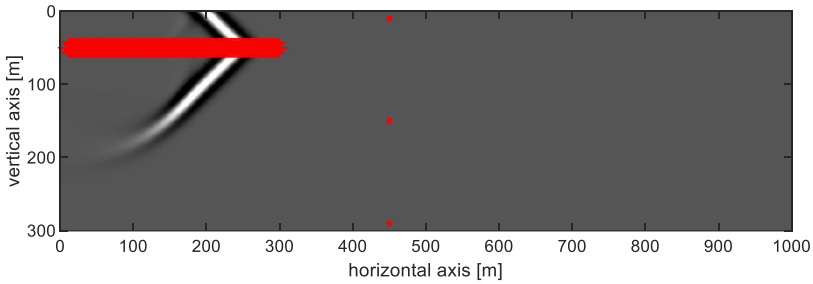


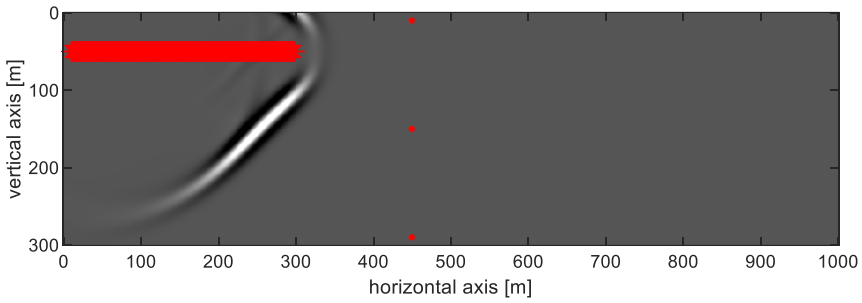
In the image above, a significant portion of the source point energy is effectively captured by the desired receiver.

3rd Solution:

The final solution involves arranging an array of points to form a pencil beam shape. Achieving this configuration requires positioning the array of point sources at specific locations with varying amplitudes and starting times.







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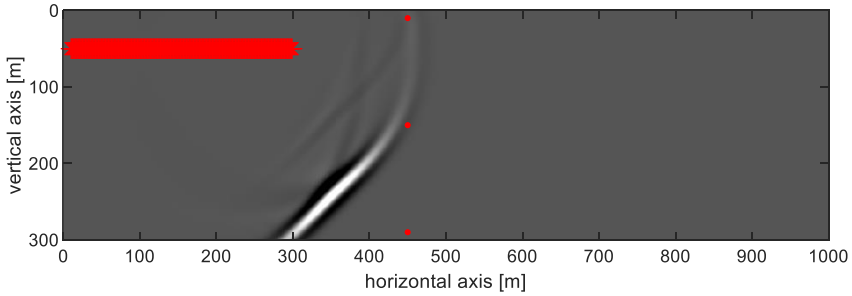

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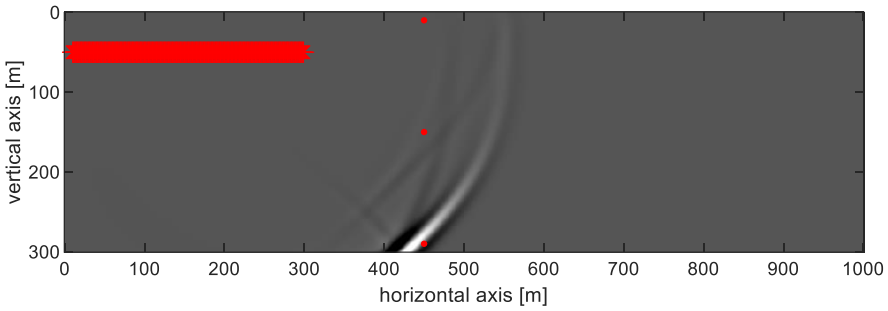
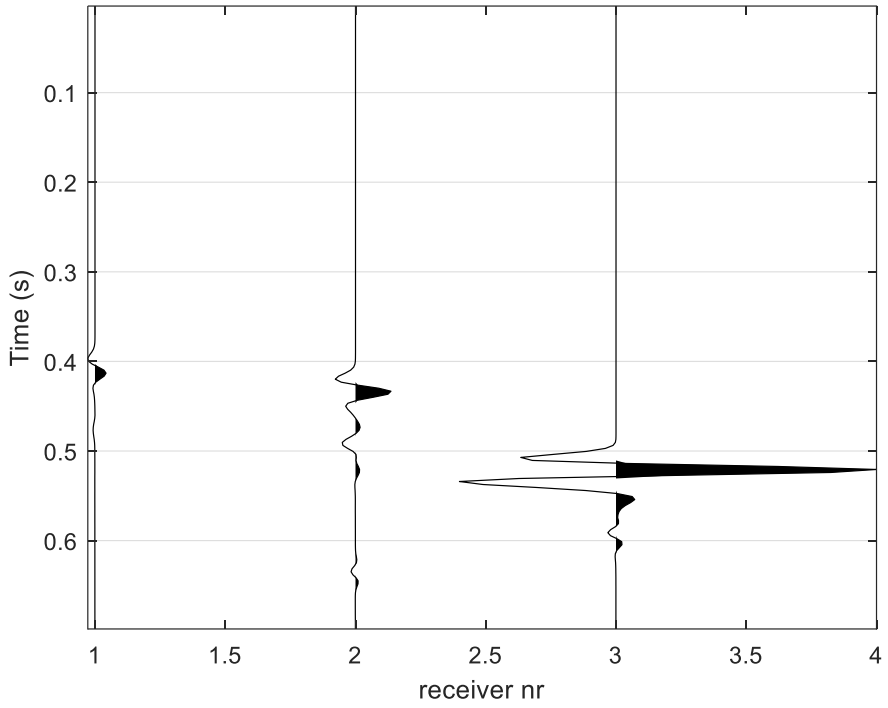


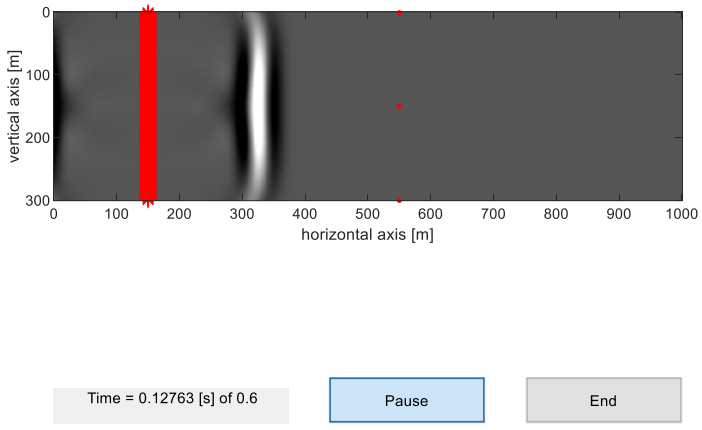


As illustrated, there are numerous potential solutions to address this problem, several of which have been presented here. However, there are likely many other creative and innovative approaches yet to be explored.

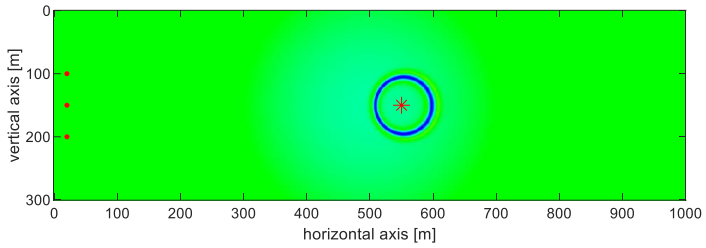
Generating a Plane Wave

Generating a plane wave can be achieved through various methods, three of which are outlined below:

1. **Arranging a line of point sources:** By organizing a series of point sources in a line, we can have a plane wave, and also we can manipulate the angle of the plane wave by:
    - Adjusting the starting propagation time for each source.
    - Changing the alignment angle of the sources.
    - Modifying the velocity of the medium.



2. **By a convex lens:** Placing a point source at the focal point of a convex lens results in the generation of a plane wave



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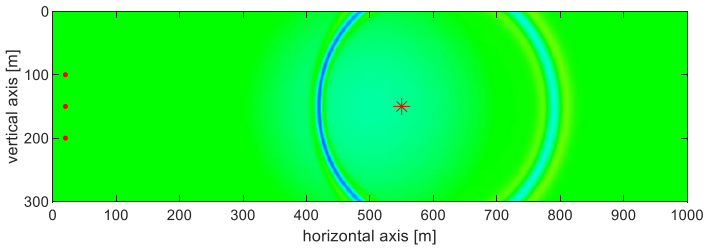

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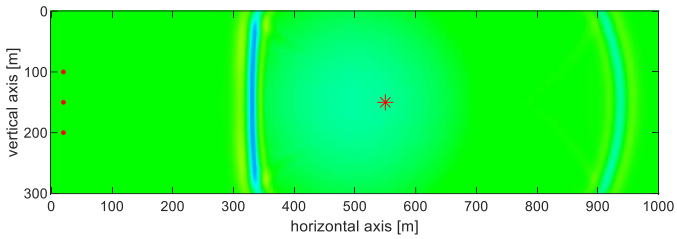

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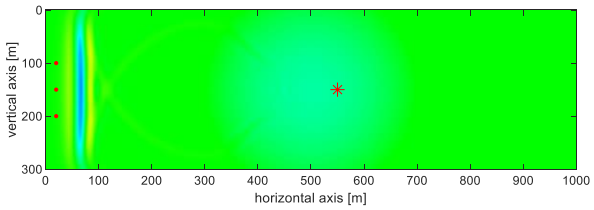

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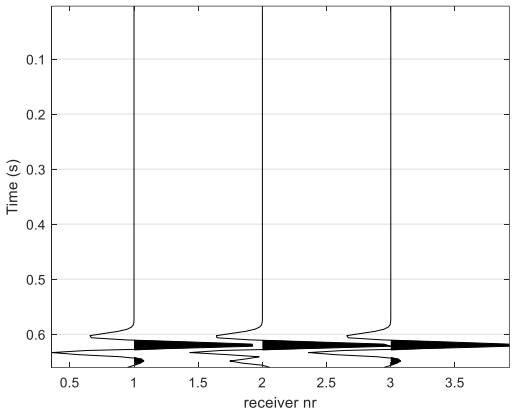
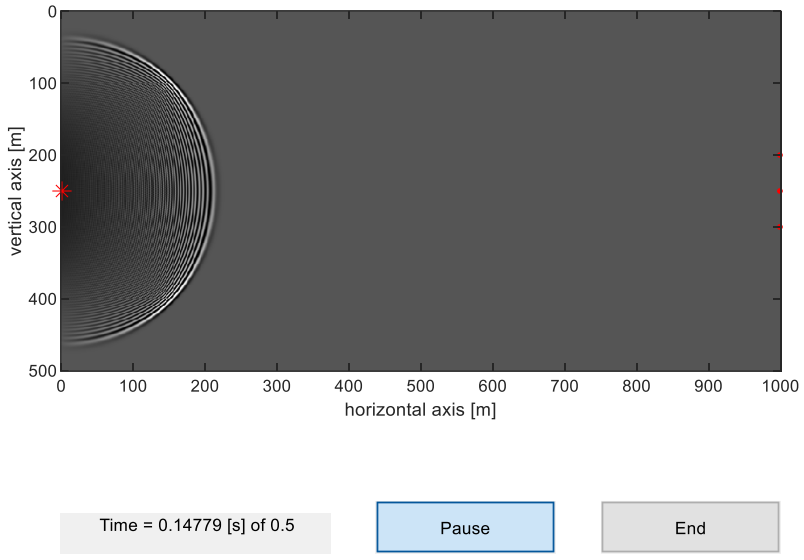
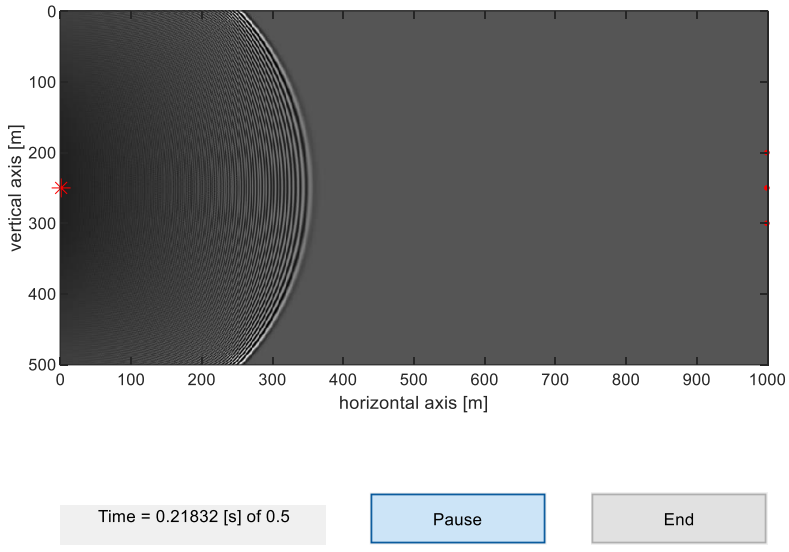
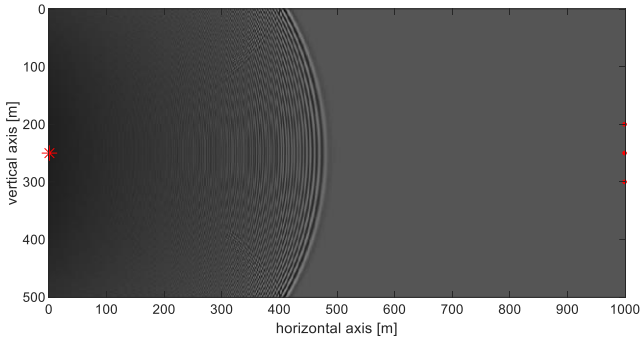


3. **Far-field of a point source:** It can be mathematically illustrated that when observing from a sufficient distance away from a point source, known as the far field, the wave reaching a receiver exhibits characteristics akin to a plane wave.







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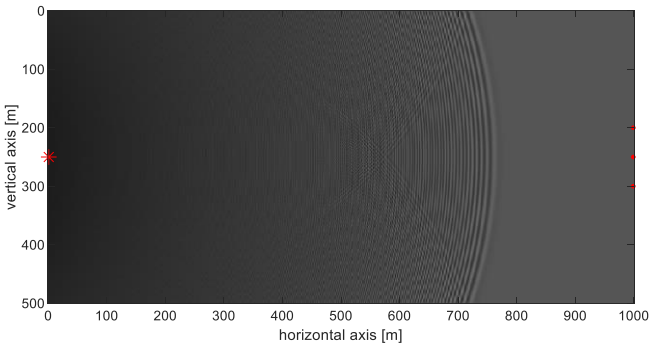

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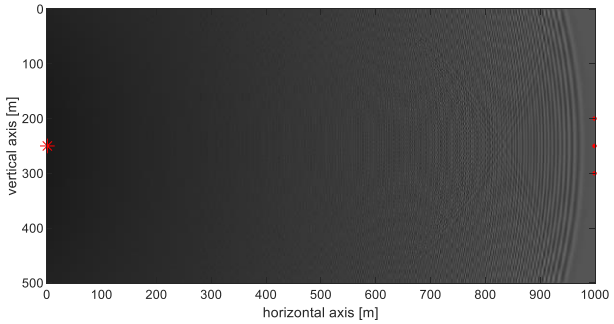

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Here, we have introduced several approaches that offer control over the direction and characteristics of the resulting plane wave. While three methods have been outlined here, it's important to note that there are likely other ways to generate the same wave, and the methods presented are not exhaustive.