Notes for Teachers on:

The Davis MFSA Radar as a demonstration of the two slit experiment

Introduction:

This document seeks to illustrate the phenomena of two-slit interference through a description of its practical application in an atmospheric radar. It is hoped that the fact that the example is set in Antarctica will add to the interest generated by the illustration.

Required prior knowledge:

The illustration is aimed at students of upper level high-school physics. They will need to understand wave parameters such as frequency and wavelength, and the results of wave superposition - nodes and antinodes.

Intended use:

The document is designed to be easily printed and distributed to students as an illustration of the two-slit experiment. It is not intended as a first source of instruction on the experiment.

Associated websites:

The following websites can be used to obtain more information about the experiment described in the following document and about the physical principles it describes.

http://www.aad.gov.au/default.asp?casid=3565 ; The Davis MFSA Radar

Background

The Medium Frequency Spaced Antenna (MFSA) radar at Davis in Antarctica uses atmospheric radar technology to measure the wind speed at heights in the range 60-100km.

Radars of this kind send pulses of radio waves into the atmosphere and measure the characteristics of the signal that are reflected back. Reflections from a thin layer of the atmosphere can be isolated by sampling the returned signal shortly after the radio pulse has been transmitted. The delay between the pulse and the sample is set equal to the time it takes for the pulse to get to (for example) 80 km and back at the speed of light.

The problem

How does the radar designer ensure that the radio wave pulses that are detected have come from a layer overhead and not from along the ground?

The radar at Davis operates at a frequency (f) of 2 MHz. The wavelength (λ) can be obtained using the equation $c=f\lambda$ with $c=3\times10^8$ m/sec. So the pulses it transmits have a wavelength of 150m. (Each pulse contains a large number of wavelengths and so is quite like a continuous wave source.)

A very simple form of radio antenna is called a half-wave dipole antenna. It consists of two pieces of wire that are half a wavelength long (for the frequency at which the radio equipment operates) and that are placed end to end. However, the radio pulse radiates out in all directions that are in the plane perpendicular to the wires (*Figure 1*).

Radio waves are another form of electromagnetic radiation: like visible light but with a different wavelength and frequency. Therefore the mechanisms that cause the bright and dark bands (antinodes and nodes) to appear on a screen in the two-slit experiment could be used with radio waves and the remote reflecting layer.

If it were possible to put a radio wave antinode overhead and a node on the horizon, then the radar designer could be sure that most of the pulses were being reflected from overhead (as none of them would be going horizontally).

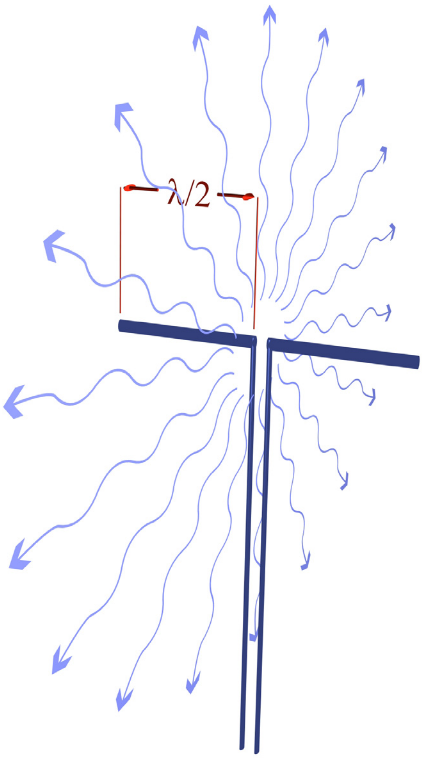

Figure 1. Diagram showing half wave dipole and its radiation pattern.

Stage one of the solution

Build two half-wave dipole antennas for transmitting the radio pulses and position them parallel to each other and in a horizontal plane. But how far apart should they be?

The radar pulse wavelength of 150m means that it is practical to place the two dipole antennas less than a wavelength apart. (This is usually not possible with visible light because of its short wavelength.)

If the dipole antennas were one wavelength apart, an observer or screen that was on the horizon and perpendicular to the antennas would receive the pulse emanating from the nearest antenna in-phase with the pulse emanating from the furthest one. (See Figure 2a.) This would mean the pulses would add up and form an antinode or maximum in intensity: not what we want. The same would be true of an observer overhead, so that part of the design is OK.

If the dipole antennas were half a wavelength apart, (Figure 2b) the observer on the horizon would receive the two pulses out of phase by half a wavelength and they would cancel each other out and form a node or minimum in intensity. For an

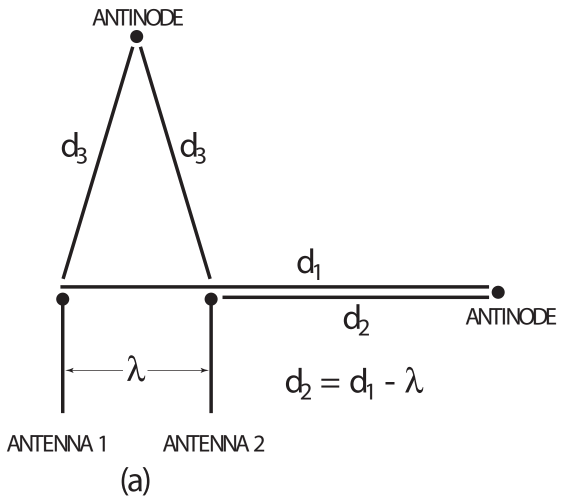

Figure 2. Dipole antennas at different spacings.

observer overhead the pulses would have travelled about the same distance and so would be in-phase. The result would be a maximum in the pulse intensity overhead (an antinode).

The final solution

Build two transmitter antennas that are half a wavelength apart. This is exactly the design used in the MFSA radar transmitter at Davis! The picture below shows the masts that support the half wave dipole antennas. The parallel rows of masts that are half a wavelength apart are visible. The white building houses the radar electronics.

Getting a wind speed

The MFSA radar transmitting antennas at Davis station in Antarctica.

The radar is used to measure wind speed in the atmosphere and this is done by observing the pattern created by reflectors in the sampled layer. These reflectors, associated with patches of turbulence in the atmosphere, move with the wind. By observing the speed and direction of the pattern, the radar can calculate the speed and direction of the wind that caused it. The antennas that receive the radio pulses are arranged in an equilateral triangle and are able to measure how long it takes for parts of the pattern to travel from one antenna to another.

Wind speeds are a fundamental parameter in the development of our understanding the nature of the atmosphere. But direct measurements of the wind between 60 and 100 km from the earth's surface are very difficult to make. Atmospheric radars like the one at Davis help to overcome this difficulty and to understand what drives this remote part of the atmosphere.

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