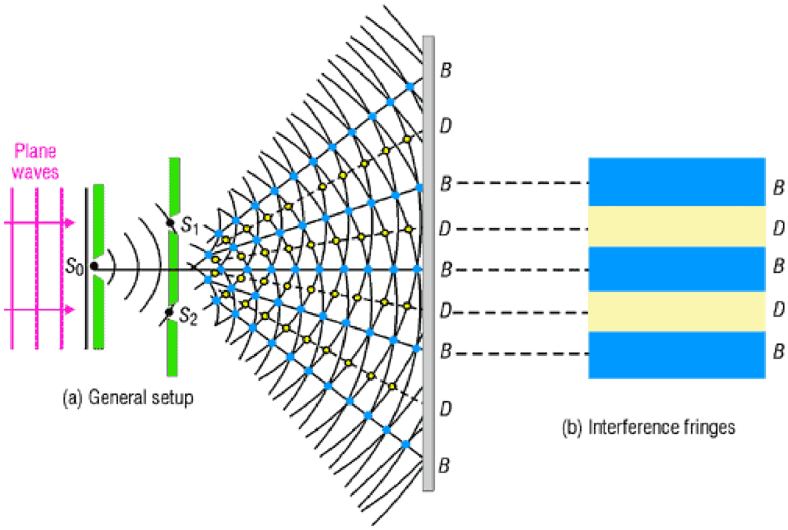
Interference Method to Measure

the Wavelength of Radio Waves



http://cord.org/step_online/st1-4/st14eiii2.htm

Purpose:

Measurement of the wavelength of DirecTV radio waves (f~12GHz) by examining the interference pattern from a double source (acting as a double slit).

Student Info:

1) Designed for Physics (11/12)
2) Prior Knowledge: Graphing, Functions, Trigonometry, Interference Equation, Wave Superposition, Young's Double Slit Measurement of Light's Wavelength
3) Suggested Websites:
   http://www.colorado.edu/physics/2000/schroedinger/two-slit2.html
   http://en.wikipedia.org/wiki/Double-slit_experiment

Teacher Info:

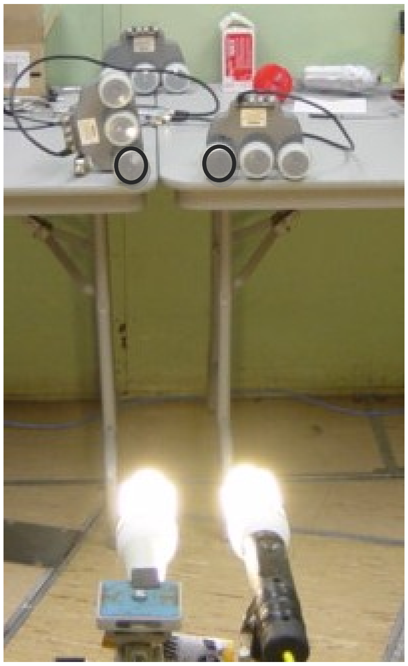
1) Prior Knowledge: VSRT Operation, Young Double-Slit Experiment
2) Vocabulary: Constructive and Destructive Interference, Baseline, Order Number
3) Suggested Website(s): Same as Above

Time Required:

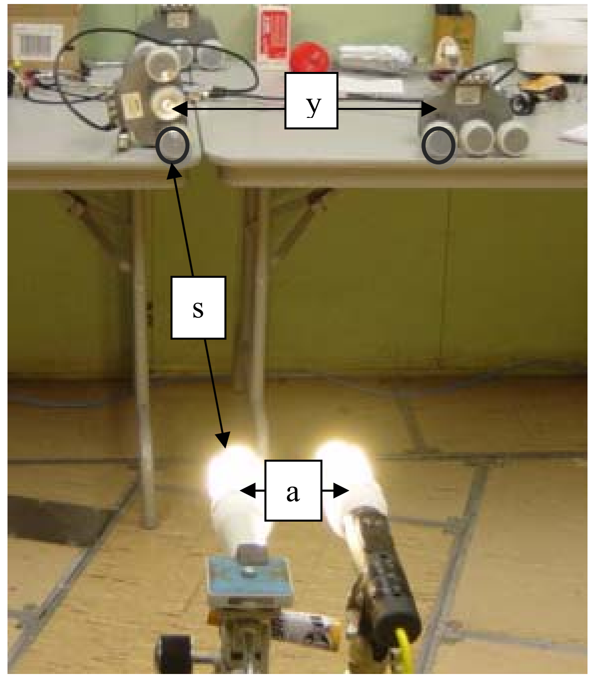
1) Setup ≈ 10 min
2) Activity/Lab ≈ 40 min
3) Data Analysis ≈ 40 min
4) Discussion/Wrap Up ≈ 20 min

Materials Needed:

1) VSRT System (See Appendix I)
2) 2 CFL Radio Wave Sources & a meterstick (100cm) or a ruler (30cm)



~ 6 inch LNBF separation



~ 24 inch LNBF separation

Procedure:

1) Place bulbs nearly 4 feet from the LNBF's, at the same height above the floor as the detectors. The distance from the CFLs to the LNBFs is (**s)** in the calculations.

2) Place bulbs as close to each other as possible (about 4.5 inches, depending on how they are secured). The separation distance is (**a**) in the calculations.

3) Place the detectors 4 inches from each other (4" measured from center-to-center of the LNBFs). The separation between the LNBFs is (**y**) in the calculations.

4) Record the average power (the unit is Kelvin).

5) Increase the distance between the LNBFs in ½ inch steps, collect data & record.

6) Repeat Step #5 until at least 4 readings (2 inches) beyond the minimum (1^{st} null).

7) It is possible to measure the 1^{st} order maxima (**y** ~ 12 inches), but measuring higher (2^{nd} or more) order minima and maxima become more difficult.

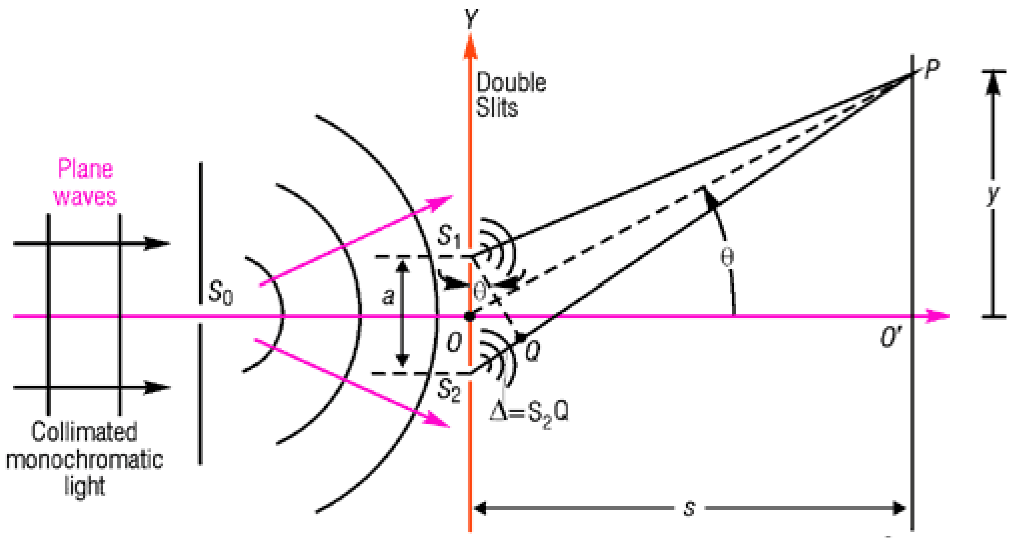
Data Table:

LNBF Separation "y" in [inches]	****Power [K]***	*LNBF Separation "y" in [inches]*	** Power [K]*
4			
4.5		12.5	
5		13	
5.5		13.5	
6		14	
6.5		14.5	
7		15	
7.5		15.5	
8		16	
8.5		16.5	
9		17	
9.5		17.5	
10		18	
10.5		18.5	
11		19	
11.5		19.5	
12		20	

* - See Basic VSRT Operation for discussion of Power [K]

Graphing: Graph the data (Power [K] vs. LNBF separation [inches].

Diagram for Calculations:



http://cord.org/step_online/st1-4/st14eiii2.htm

Calculations:

Due to the destructive interference condition, the 1st minimum occurs at

$\frac{1}{2} \lambda = a * \sin(\theta)$ => $\lambda = 2 a * \sin(\theta)$ where $\theta = \tan^{-1}(y / s)$

Example: For this setup, y = 6" and s = 48" so $\theta = \tan^{-1}$ (6" / 48") = 7.1°

$\lambda = 2 a * \sin(\theta) = 2 * 4" * \sin(7.1°) =$ ***0.99"***

(Using c ($3.0x10^8$ m/s) = λf => $\lambda = c/f = (3x10^8 m/s)/(12GHz)$=2.5cm~0.98")

Questions:

1) What is the wavelength of the radio wave detected by the LNBFs?

2) What is the theoretical distance to the first minima for this wavelength (2.5 cm) for this source separation and distance from the stationary LNBF?

3) What is the percent difference between the theoretical position of the null and the measured position?

4) What can you say, based on your measurements, regarding the validity of the interference equation $(m + \frac{1}{2}) \lambda = d \sin \theta$.

5) How many wave cycles does a wave go through from the CFLs to the stationary LNBF detector at the minima position? (Hint: measure the distance between)

6) How many wave cycles would a wave from the CFLs go through to arrive at the movable LNBF detector (same as #5)? (Hint: measure the distance between)

7) Are your results from #5 & #6 in agreement with the expected path-length difference ?

8) The LNBF is rated to have an uncertainty of 1GHz. What degree of uncertainty does this introduce into our wavelength and frequency assumptions?

9) Could you also perform the same experiment keeping the distance to the LNBFs fixed and changing the distance between the lamps? In this case, predict the lamp separation for the 1st and 2nd nulls when the detectors are placed 9 inches apart?

Example Data: