Measurement of the Sun's Angular Width

Purpose: To measure the angular width of the Sun using a VSRT system as a radio wave interferometer with an adjustable baseline of approximately 5-10 feet.

Student Info:

1) Designed for Physics (11/12)
2) Prior Knowledge: Graphing and Right Angle Trigonometry
3) Suggested Website(s)
   http://www.walter-fendt.de/ph14e/singleslit.htm

Teacher Info:

1) Prior Knowledge: VSRT Operation, Solar Width ~ 0.5° ~ 30 minutes
2) Vocabulary: Single Slit Diffraction, Airy Pattern & Bessel Function
3) Suggested Website(s)
   http://en.wikipedia.org/wiki/Single_slit_diffraction

Time Required:

1) Setup ≈ 30 min
2) Experiment ≈ 60 min
3) Data Analysis ≈ 20 min
4) Discussion / Wrap Up ≈ 30 min

Materials Needed:

1) VSRT System (See Appendix I)
2) Dual LNBFs with 6 feet BNC Cables (Same Length for Interferometer)
3) Two (2) DirecTV Parabolic Dishes with Alignment Mirrors, and a Sunny Day!
4) Tape Measure (at least 12feet long), 2 Long Level Tables or flat ground/sidewalk

Procedure:

1) Starting with a baseline (separation) of 6 feet between the parabolic dishes, point each dish by aligning the reflection of the mirror on the leftmost LNBF.

**Note: For best results, the imaginary line connecting the two LNBFs should be perpendicular to the Sun, so the setup may need to be rotated to "track" the Sun.

2) Measure the system power [K] from 6 feet to roughly 2 or 3 feet beyond the minimum reading in 6 inch increments and record in the data table below.

Data Table:

	Power [K]			
Baseline [ft]	**Trial #1**	**Trial #2**	**Trial #3**	**Avg Power [K]**
6				
6.5				
7				
7.5				
8				
8.5				
9				
9.5				
10				
10.5				
11				
11.5				
12				
12.5				
13				
13.5				
14				

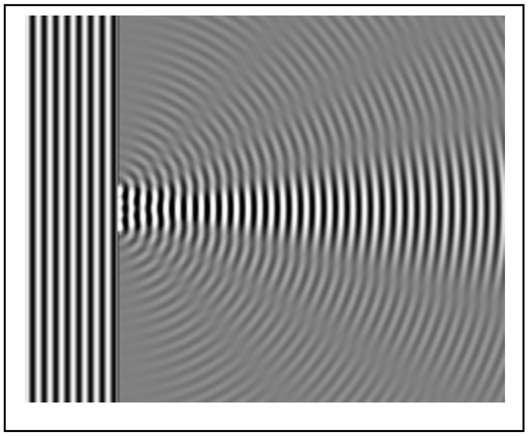
Graphing:

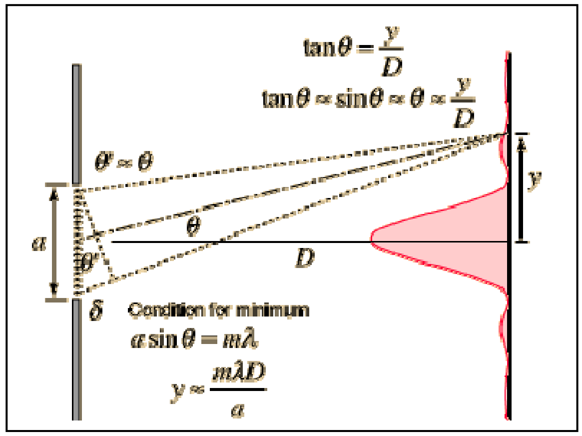
1) Make a graph of Average Power [K] vs. baseline [ft].

2) Sketch a curve of best fit through the data with careful detail near the minimum point (near 10 feet).

Simulated Wave Pattern and Diagram for Single Slit Diffraction:

The computer simulation on the left shows a plane wave encountering a single slit whose width is approximately 4 times the wavelength ($a \approx 4\lambda$). The diagram on the right shows the geometrical derivation for determining the relationship between the slit width (a), the distance between the slit and viewing screen (D), the location of the minima (y) and the angle (θ) connecting them.





Calculations:

Recall the wavelength of the radio waves as measured in the previous experiment.

1) From the destructive wave condition for the minima (m=1), the equation $a \sin\theta = m\lambda$ can be arranged for $\sin\theta = \lambda / a$, where a = baseline.
2) For small angles (<5°) , the $\sin\theta \approx \theta$, so the above equation simplifies to $\theta = \lambda / a$. Calculate this result: θ = 1” / 126” = 0.0079 rad = 0.45°

Questions:

1) Estimate the Sun’s angular diameter by recalling that when your fingers are held an arm’s length away (~100cm), the diameter of your fingernail (~1cm) blocks the Sun ($\theta \approx$ 1cm / 100cm = 0.01rad = 0.57°). ***Note***: The 12GHz radio width should be larger than the visible light width – See VSRT Memo#030.
2) Compare your results from the calculation section to the result from question #1. Which is larger/smaller and what is the % difference between them?

Additional Activities:

1) Measurement of Sun’s Visible Angular Width using small aperture hole projected onto a viewing surface. For example, at a distance of 1m (~3ft) the spot size is roughly 9mm (~3/8”) and will scale linearly for longer distances.
2) A better approximation for this measurement is to treat the Sun as a circular aperture, so the aperture has fringe minima which satisfy the Airy condition, $\theta = 1.22\,\lambda / a$, which is a 22% increase in the apparent solar diameter.
3) The shape of the power vs. baseline curve is found by calculating the visibility integral which results in a first order Bessel Function. While this is beyond the scope of this project, interested teachers and students can work with the EXCEL file attached at the end of the unit.

Sample Data:

baseline [inch]	Power [K]	Bessel Fit
22.5	281	263.69
36	215	239.52
48	205	210.82
60	158	177.25
72	123	140.91
84	93	104.01
96	61	68.65
108	24.5	36.71
120	8	9.67
132	8.5	11.46
144	17.5	26.19
156	21	34.54
168	24	37.04
180	19	34.58
192	17.5	28.37