Deep Space Exploration Society

Science Update 9-26-16

Phased Array and Interferometer Basics

Author: Dr. Rich Russel, DrRichRussel@netscape.net

1.0 Introduction

The DSES Radio Jove telescope at the Plishner site is an example of a system that uses a phased array to increase the gain in the direction of Jupiter's path through the sky. The Very Large Array (VLA) in Socorro, N.M. utilizes antennas that make use of interferometry to increase the precision pointing angle of the beam toward a target.

This science update gives some basics on the Radio Jove phased array calculations and the calculations needed for a two antenna interferometer.

2.0 Background Story

One weekend Ray invited me to drive up to the top of Cheyenne Mountain with him. As he was hanging the passenger side of the truck over the side of thousand foot cliffs (from my perspective), he mentioned that the Radio Jove antenna was not really an interferometer as I have been touting all of this time. Well, I didn't debate him then as he was showing me the dangerous parts of the road that were named after people who didn't pay attention to their driving up the mountain. So, I researched the difference between a phased array and interferometer.

The next week, Michael Lowe lent me a great book, "Radio Astronomy Projects, 2nd ed." By William Lonc (1). This book gives a simple to understand approach to doing the calculations for a simple two antenna interferometer.

3.0 Radio Jove Phased Array

The Radio Jove antenna is a phased array. The current design uses two half wavelength dipoles with a phasing line that is directed South toward the ecliptic. The south wire has an extra cable that delays the signal to the combiner. This delay effectively makes the combiner signal better at a lower elevation, which is where Jupiter transits.

The theory for calculating the phase delay follows using figure 1:
When Jupiter is at an elevation of Ø from the horizon, the south antenna receives the signal first at A.

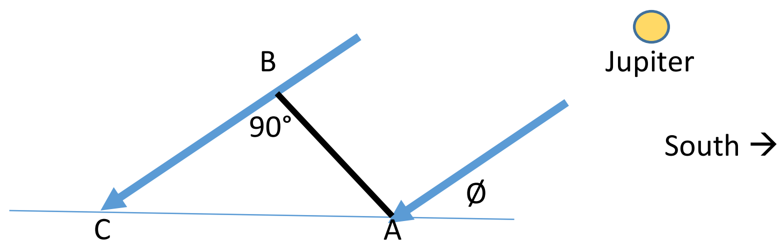

Figure 1: Radio Jove, 2 - Element Phased Array

The signal at the north antenna has to travel an extra distance B→ C.

Now since we know Ø and the distance between the antennas A→ C, and also that the angle at B is 90°, the distance between B and C is:

$$BC = AC\cos(\emptyset)$$

The signal between BC travels at the speed of light (c) (3 x10^8 m/s). Therefore, the actual time it takes for the signal to travel the distance BC is:

$$t_{BC} = \frac{BC(m)}{3x10^8(\frac{m}{s})}$$

To calculate the length of cable to add to the phase delay, realize that the speed of the signal in the cable is slower than the speed of light. The signal speed is specified by the cable type which is specified by the velocity factor (VF), which is the ratio of c. Velocity factors for different cables can be found at: (2)

The cable length would therefore be:

$$Phase\ Cable\ Length = BC\ (VF) = AC(VF)cos\emptyset$$

Example: The distance between the two dipoles of a phased array is 10 meters. The angle to the meridian is 45°. The cable used is RG-8 which has a VF of 0.84. What is the length of the phase cable?

$$Phase\ Cable\ Length = AC(VF)cos\emptyset = 10(0.84)\cos(45°) = 4.41\ meters$$

This phased array design will give a higher gain at 45° elevation but will not give any fringe patterns that are normally associated with interferometers.

4.0 Interferometer Design

William Lonc provides a basic design for a 2-element interferometer he used in his radio astronomy course (1). A two element interferometer is best designed so that the object being observed passes in front of the two antennas. As the source moves past the two antennas, the signals combine to form positive and negative interference patterns on the strip chart as shown in figures 2 to 4.

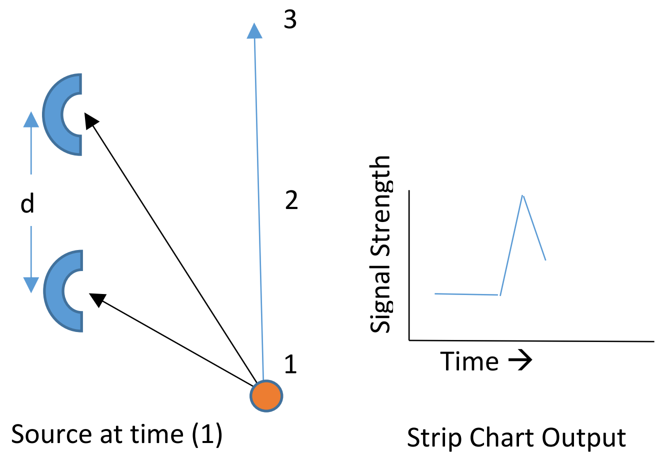

Figure 2: Interferometer Output at time 1

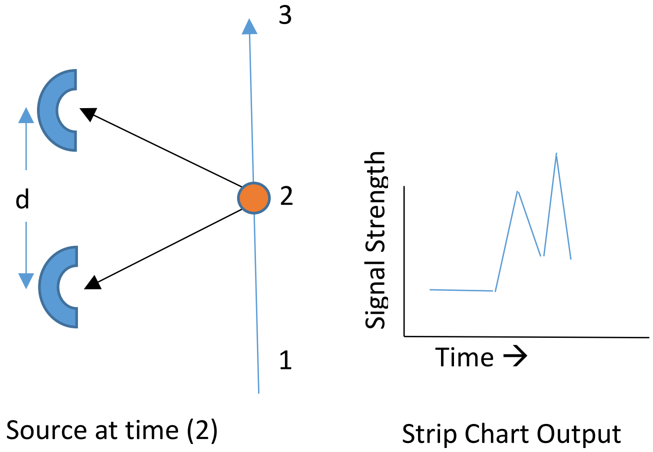

Figure 3: Interferometer Output at Time 2

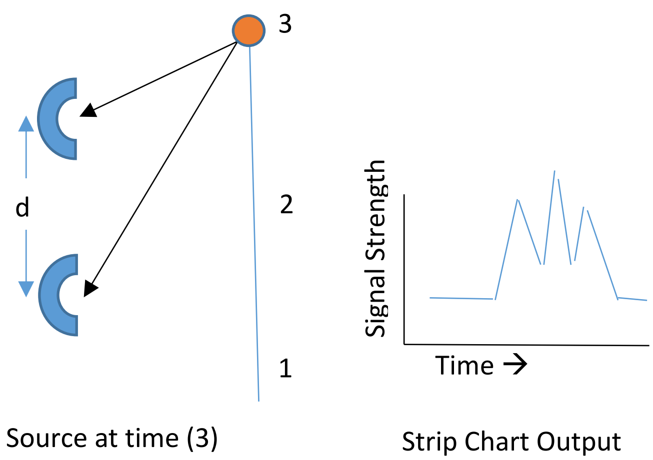

Figure 4: Interferometer Output at Time 3

The average angle (Δθ) between fringe peaks is defined by:

$$\Delta\theta = \frac{57.3\lambda}{(d)\cos(\delta)} \text{ degrees}$$

Where:

- λ is the wavelength in meters
- δ is the declination of the source
- d is the spacing between the antennas
- 57.3 is the conversion from radians to degrees (180/π)

Example: The distance between two Direct TV 1 meter dishes with outputs tied to a combiner is d= 4 meters. The wavelength being observed is λ = 0.15 m (2.0 GHz). The declination of the source, δ, = 40°. The average angle between maxima is:

$$\Delta\theta = \frac{57.3(0.15m)}{(4m)\cos(40°)} = 2.8\ degrees$$

The strip chart though shows peaks in time. To convert the expected Δθ to time we will take into account the rotation rate of the Earth: (24 hours) (60 minutes/hr)/(360°) = 4.0 Minutes/degree. This is the conversion factor to convert Δθ to minutes on the strip chart.

So, to continue the example, the average distance expected on the strip chart between maxima is:

$$2.8\ degrees\ x\ 4.0\frac{minutes}{degree} = 11.2\ minutes$$

Special note: The Low noise block (LNB) elements on the satellite dishes, destroy the original phase information when they mix the local oscillator with the signal as part of the down-converting process. Recommend that a simple interferometer mix the signals before down-converting.

5.0 Summary

The two element interferometer will allow for higher precision pointing than a standard beam width of a single dish of the same diameter. By combining the gain increases of the phased array with the pointing precision of the interferometer, it will be possible to utilize multiple small dish antennas to allow DSES to make a precise celestial map of radio sources.

Works Cited

1. **Lonc, William.** *Radio Astronomy Projects, 2nd Edition.* Ocean View, HI : Radio Sky Publishing, 2003. 1-889076-03-1.

2. **WWW.FEBO.COM. [Online] http://www.febo.com/reference/cable_data.html.**