

# Doppler Circular Array Antenna Principle for Determining Azimuth Angle of Radio Transmitter

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**Abstract**—Radio tracking is widely used in communication technology because it can determine the coordinate position of radio transmitter and the distance of rocket to the ground station in a similar manner toradar system. this paper describes a method of azimuth angle detection of transmitter based on doppler circular array antenna. the difference of signal power when the antenna is switched rapidly, is used to calculate the horizontal/azimuth angle from the radio transmitter. The results of the calculation is quite accurate only when the wave source is settled, so further research is needed to more accurately both the state still or moving object. This instrument will support rocket tracking systems.

**Keywords**- Radio Tracking; Azimuth Angle; Dopple; Array Antenna; Radio Transmitter

## I. INTRODUCTION

Measurement of rocket telemetry radio signal is quite important in order to know the relation between quality of signal and received data. This powermeter can also be applied for detecting the azimuth and elevation angles of rocket trajectory using Yagi-Uda antenna, [1] The azimuth and elevation position of the rocket during flight is a very important parameter to be measured in real time.

In the present market there are many Radio- Telemetry techniques which are used to track fast moving objects. However, no radio tracking system has been designed that will work in every situation. [2]

From the obtained results it was observed that the array antenna performed better in terms of the receiving gain compared to the Horn and the Yagi-Uda antenna. [2]

This paper describes a method of azimuth angle detection of radio transmitter based on Doppler circular array antenna. Data changes of azimuth angle can be measured by detecting radio signals that are emitted by the radio transmitter or rocket payload. The detection method uses the differences of signal power from each receiving array antenna. The differences can be observed as the Doppler effect by choosing an antenna arranged in a circle and switched rapidly. This instrument will support rocket tracking systems.

The final goal of this research is making instrument for determining azimuth and elevation angles of rocket using the

doppler circular array principle. This instrument will be able to support long-range rocket tracking system.

## II. SWITCHING ANTENNA TECHNOLOGY

Radio wave signal emitted by the rocket payload can be detected by using several antenna in separated position. As shown in figure 1, each antenna will receive signal power depending on its position and distance to the transmitter. There will be differences in signal power among antenna A, B, C and D. This is caused by a signal at the fourth position of the antenna that looks different. When the direction of wave propagation sources angle is 0 degree, the power received at antenna A is high (1), antenna B and D is equals zero (0), whereas antenna C is low (-1). So if all four antenna are switched quickly and continuously, they can produce a sinusoidal wave which has a peak on point A.

If the position of the source wave is shifted 30 degree as shown in Figure 2, the power received by each antenna will also be shifted. The power received by antenna A is approximately 0.8, the power at the antenna B and D is 0.5, while the power at antenna C is approximately -0.8. Radio power shift ultimately produces a sinusoidal wave shifted as well.

If the source of radio waves is shifted in  $\alpha$  degrees, the sinusoidal wave will also be shifted in  $\alpha$  degrees. If the antenna is switched (rotated) continuously with a certain speed, then the frequency of a sinusoidal wave will follow the rotation speed of the antenna.

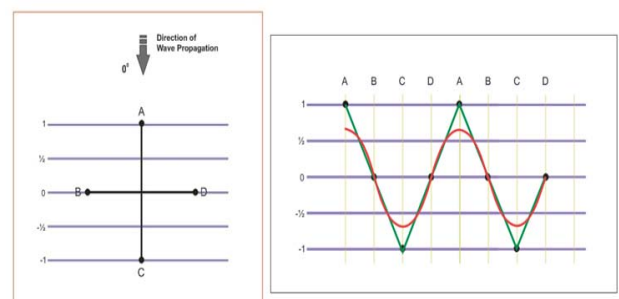


Figure 1. The principle of difference signal power with the wave propagation direction is 0 degrees.

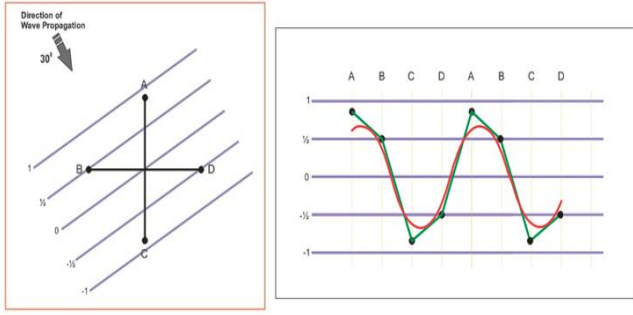


Figure 2. The principle of difference signal power with the wave propagation direction is 30 degrees

### III. SISTEM DESIGN

After learning basic theory of the receiving process of radio signal transmitter to determine the azimuth angle, it can be designed a device by making a block diagram of the system first. Block diagram is shown in Figure 3 as follows:

#### A. Switching Antenna 500 Hz

Circular array antenna consists of 4 dipole antenna which circular fitted with the distance between the antenna have been adjusted based on the long-wave radio signals are used ( $\lambda$ ). Optimal spacing is  $\frac{1}{4} \lambda$  or less so that the power obtained at each antenna is the wave peak. Because the frequency signals using 430 MHz, the distance between the antenna is 17 cm.

If using more than 4 pieces of the dipole antenna, to maintain the distance between the antenna in order to stay  $\frac{1}{4} \lambda$ , the radius of circular antenna needs to be calculated based on the following equation:

(1)

$r$  = radius of circular antenna  
 $\theta$  = central angel  
 $p$  = number of antenna

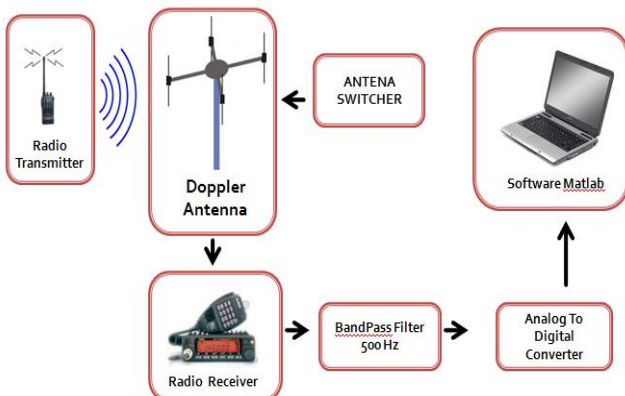


Figure 3. Block diagram of the instrumentation systems for measuring azimuth angle

Frequency used in switching antenna is 500 Hz. This frequency is selected because of some reason:

1. To eliminate noise from human voice.
2. Radio capability used in this project is only has output frequency 300 - 4000 Hz.
3. With respect to the speed of the ADC and the amount of data / frame that is sent to the computer. Ie 922 data with sampling rate is 116000 sampling per second. So that when using a frequency of 500 Hz, one frame can be seen as much as  $922 / (116000 / 500) \approx 4$  wave. Amount quite fitting to analyze the shape and shift of the signal.

In hardware, switching antenna applies a microcontroller and switch diode BAR 3606 to connect and disconnect the flow of signals from the antenna

#### B. Bandpass Filter 500 Hz

To improve the signal from the radio receiver, it's use analog bandpass filters. Frequency to be used in the switching antenna is 500 Hz. Bandpass filter will also be made narrower with a frequency of 450 Hz - 500 Hz. bandpass filter was designed using Sallen-Key circuit by connecting a lowpass filter and high pass filters in series.

Lowpass filter designed to pass frequencies below 500 Hz and using fourth order. By using the transfer function Sallen Key for lowpass filter, we can calculate the value of the active filter components that are designed. Transfer function for Sallen Key low pass filter shown in equation 2 follows:

$$H_{cL}(s) = \frac{K}{s^2 + \left[ \frac{1}{R_1 C_1} + \frac{1}{R_2 C_1} + \frac{(1-k)}{R_2 C_2} \right] s + \frac{1}{R_1 R_2 C_1 C_2}} \quad (2)$$

(3)

The capacitor value is determined

$$C_1 = C_2 = 0.01 \mu F \text{ dan}$$

The obtained value of the component as follows:

$$R_1 = R_2 = 31,8K \\ R_{b1} = 12,3K \text{ dan } R_{b2} = 1,5K$$

The final circuit for the 500 Hz sallenkey lowpass filter with fourth order shown in figure 4.

Highpass filter is designed to pass frequencies above 450 Hz and using fourth order. As in lowpass filter, calculate the value of the components are designed is using the transfer function for the Sallen Key for highpass filter, transfer function Sallen Key for highpass filter shown in equation 4 follows:

$$H_{cH}(s) = \frac{K \cdot s^2}{s^2 + \left[ \frac{1}{R_2 C_2} + \frac{1}{R_2 C_1} + \frac{(1-k)}{R_1 C_1} \right] s + \frac{1}{R_1 R_2 C_1 C_2}} \quad (4)$$

(5)

Value for the high pass component is

$$C_1 = C_2 = 0.01\mu F$$

$$R_a = 10K\Omega, R_1 = R_2 = 35,4K$$

$$R_{b1} = 12,35K \text{ dan } R_{b2} = 1,53K$$

The final circuit for the 450 Hz sallenkey highpass filter with fourth shown in figure 5.

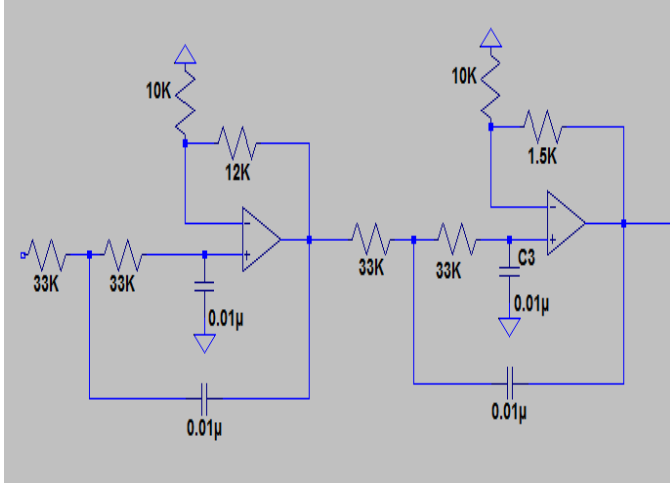


Figure 4. 500Hz Lowpass filter circuit.

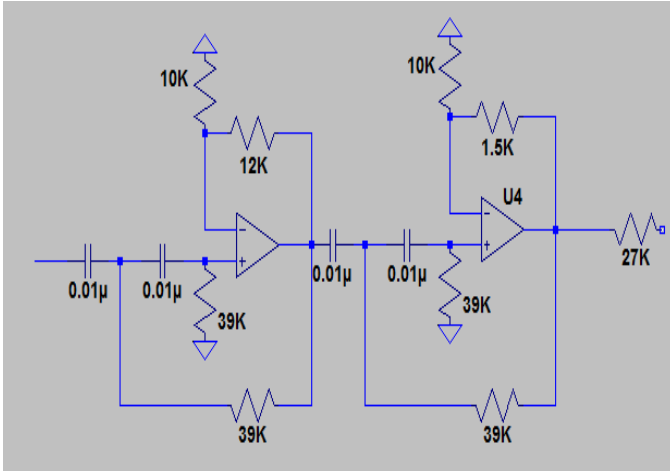


Figure 5. 450Hz Highpass filter circuit.

### C. Analog to Digital Converter

Analog to Digital Converter (ADC) applies hardware microcontroller ATmega 32 with sampling rate 116000 sampling per second (SPS). For 500 Hz frequency, data will be obtained 232 every wave. It is expected that the resolution of shift wave in this system is  $360/232 = 1.55 \approx 2$  degrees.

### D. Signal Processor

All processes in the signal processor are run by software on the computer. Signal processing consists of two important processes, namely Bandpass filters and cross-correlation.

Cross-correlation is widely used in signal and system analysis. Cross correlation function however measure the dependence of on signal on another signal. For two WSS (wide sense stationary) processes of signal X (t) and signal Y (t) is expressed in the following equation:

$$R_{xy}(\tau) = \lim_{T \rightarrow \infty} \frac{1}{T} \int_{-T}^T x(t) y(t+\tau) dt \quad (6)$$

or

$$R_{yx}(\tau) = \lim_{T \rightarrow \infty} \frac{1}{T} \int_{-T}^T y(t) x(t+\tau) dt \quad (7)$$

T is the observation time. For the sampled signal as used in this system of determining the azimuth angle, Cross correlation function is expressed in the following equation:

$$R_{yx}(m) = \frac{1}{N} \sum_{n=1}^{N-m+1} y(n)x(n+m) \quad (8)$$

$m = 1, 2, 3, \dots, N+1$

N is the length of sampling data. Before the Cross correlation process, there is need a reference signal to represent zero point degrees ( $0^\circ$ ). This signal is taken from the same source ie from the radio transmitter at a certain time and a certain direction. Reference signal will be auto-correlated to determine the zero point degrees. This reference signal will be always cross-correlated with the signal from the transmitter in real time.

## IV. RESULT AND ANALYSIS

The sistem is tested by placing a radio transmitter at a distance of approximately 1 km radius of the antenna array. At a certain point (eg north) signal from the radio transmitter will be recorded as a reference signal represent angle 0 degrees.

After getting a reference point, the first experiment is to shift a radio transmitter at an angle 30, 45, 90 degrees to the point of reference. The signal transmitted at an angle will be cross correlated with a reference signal to compare the azimuth angle radio transmitter through correlation calculation with the actual azimuth angle.

Based on several tests it was found that azimuth angle detection device is quite accurate if used on a stationary wave source.

Figure 6 shows the shifting signal between the reference signal and the transmission signal.

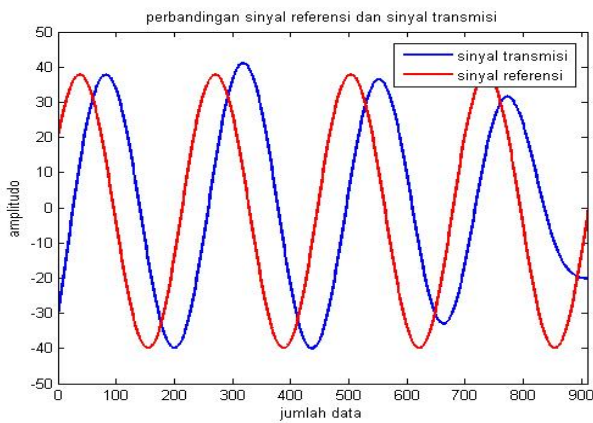


Figure 6. Shifting the reference signal and the signal transmission

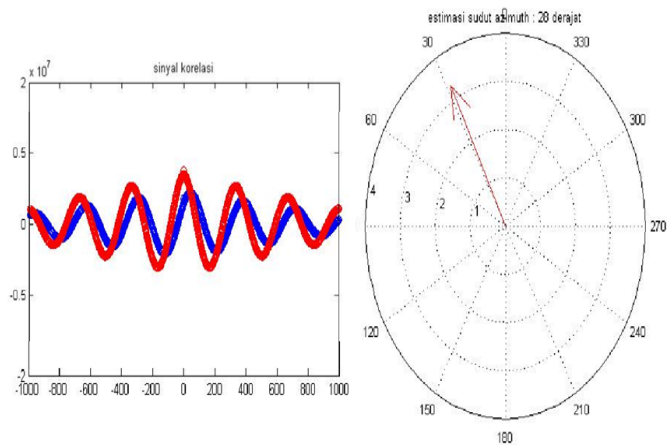


Figure 7. The results of cross-correlation between the reference signal and the signal transmission at angle of 30 degrees

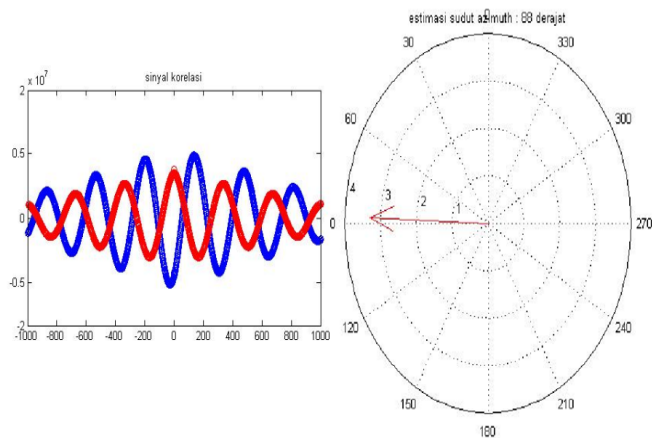


Figure 8. The results of cross-correlation between the reference signal and the signal transmission at angle of 90 degrees.

The results of cross-correlation between the reference signal and the signal transmission at angle of 30 degrees is shown in Figure 7. While The results of cross-correlation between the reference signal and the signal transmission at angle of 90 degrees is shown in Figure 8.

## V. CONCLUSION AND RECOMMENDATION

Azimuth angle measurement radio transmitter can be calculated by doppler principle of circular array antenna. With the addition of 450-500 Hz bandpass filter, the interference / noise can be minimized so that the signal can be directly used effectively in cross-correlation algorithm for determining the phase angle difference.

The results of the calculation is quite accurate only when the wave source is settled. Further research is needed to detect the direction of either moving or static wave source.

## REFERENCES

- [1] Zain S.G, A. Susanto , SriKliwati, Wahyu Widada, "Estimation Method of Azimuth and Elevation Angles for Rocket Trajectory Using Array Crossed Yagi Antenna", Proceeding of ICT International Conference on Rural Information and Communication Technology, ITB Bandung, 2007
- [2] Raheez Reppal Hector A. Ochoa, "Radio Telemetry Antenna Design System For Tracking Small And Slow Moving Objects" 42nd South Eastern Symposium on System Theory, pages: 213 - 216, Tyler, TX, April 2010.
- [3] Kuga, N.; Arai, H.A "four beam-switched planar array antenna for mobile terminals". Antennas and Propagation Society International Symposium, page: 1450 - 1454 vol.3, Newport Beach, CA , USA, August 2002
- [4] John D.Kraus, "Antennas", McGraw-Hill, Inc., Publication 1998.
- [5] Smith-Rose, R.L.; Hopkins, H.G, "Radio direction-finding on wavelengths between 6 and 10 metres" journal of The institute of Electrical Engineers, Vol: 83 , , page(s): 87 – 97, january 2010.