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Exploitation of Radio Direction Finder in the design of a UHF Transmitter Locator System

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Abstract

This paper outlines how the direction finder technology was exploited in the design of a device; capable of locating the where about of a UHF transmitter. The value of amplitude and frequency of the signal were employed in the determination of the signal source direction. The study emphasized on the utilization of low cost components. The assembled prototype offers 22.5° bearing coverage. The determination of the direction was achieved by differentiating the received frequency signal involving multiple antenna arrays. Direction of transmitter was determined by making the receiver antenna arrays emulating condition of motion with the use of antenna switcher. Received signals were converted into tones where larger signal amplitude translates to louder tone. Antenna arrays were arranged in specific manner where the tone volumes were compared and the direction within 360° position was determined. The result suggests that the system can provide the detection coverages up to 22.5 degree which is better than the existing solutions in terms of equipment selection, cost, and coverage.

Keywords: Antenna Switcher, Direction Finder Technology, Pseudo Doppler Technique, RDF

1. Introduction

Finding a direction or location is one of the important components in communication. By knowing the location of wanted parties, the communication can become more reliable. Nowadays through Global System for Mobile Communication (GSM) signal, we are able to know the location of our friends as well as family member. By submitting their phone number to the subscribed telecommunication service provider, they are able to be tracked from their phone signal communication with the base station even without Global Positioning System (GPS).

Figure 1 display the example of a base station which accommodate multiple antennas in different angle. Base station transmit GSM downlink signal and receive GSM uplink signal while the mobile phone works vice versa. By manipulating the signal received from each antenna, transmitting signal direction can be determined[6].

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2. Radio Direction Finder Techniques

One of the techniques on determining the direction of source signal is by determining its Angle Of Arrival (AOA). This kind of method usually used in radar system in order to determine the location of aircraft heading towards the airport. Based on paper Guerin, Jackson and Kelly, Passive Direction Finding, 2012, AOA technique is used and discussed to develop a device which may determine the direction of signal source and display it[4]. Figure 2 shows the AOA technique model.

Pseudo Doppler technique is another common technique used in resolving direction finder of signal source. This technique is based on the Doppler shift principle. Doppler shift is a type of frequency modulation. Relative motion of objects towards each other causes the observed frequency to increase. Relative motion away from each other causes a decrease in frequency. This shift can be

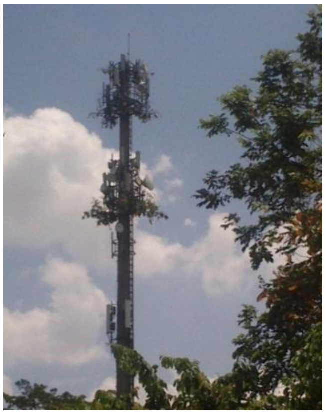

Figure 1. Base Station Tower.

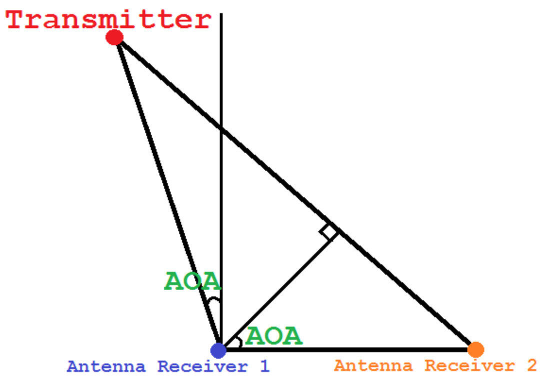

Figure 2. Angle Arrival(AOA) Model.

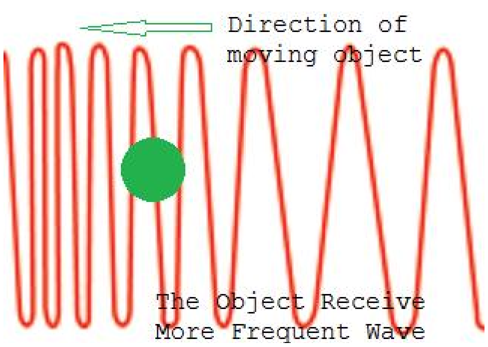

Figure 3. Frequency shift illustration.

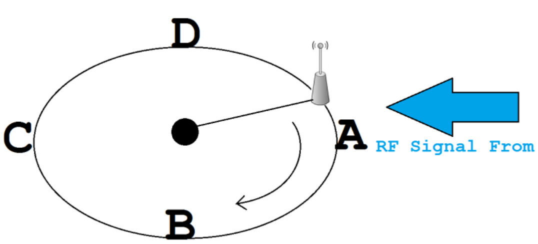

Figure 4. Rotating Antenna.

detected and used if the transmitter or the receiver moving in the right direction. Then we would know whether we are closer to subject or in reverse[1]. Figure 3 illustrates the frequency shift phenomenon.

This technique detects the frequency shift by the implementation of rotating the antenna. As the antenna is rotated, the antenna will move closer to and then further away from the transmitter. By collecting frequency shift measurements as we go around the wheel, we can acquire a Doppler sine wave with two zero crossings at A and C, i.e. where there is no Doppler shift.

As the antenna moves from point C to point D and from point D back to point A, the frequency of the received signal increases. Maximum frequency deviation occurs again as the antenna passes through point D. The frequency changes result vice versa as the antenna moves from point A to point C through point B[5]. This is illustrated in Figure 4. The Doppler shift can be calculated through equation 1[2].

$$dF = \frac{Vf_c}{C} = \frac{\omega r f_c}{C} = \frac{2\pi \, x \, f_r \, x \, r \, x \, f_c}{C} \qquad (1)$$

Where

dF = Peak change in frequency (Doppler shift in Hertz)

ω = Angular velocity of rotation in Radian per second (2 x ð x frequency of rotation)

r = Radius of antenna rotation (meters)

f_c = Frequency of transmittal signal (Hertz)

f_r = Rotational frequency

C = speed of light

Equation 1 can be simplified in order to identify the rotational frequency of the antenna. In the study, 500Hz sound tones function to be plot with 462.12MHz Frequency carrier and radius 10.6cm.

$$fr = \frac{dF \, x \, 1879.8}{R \, x \, f_c} = \frac{500 \, x \, 4774.65}{462.17 \, x \, 10.6} \approx 487 \text{ Hertz} \qquad (2)$$

where, f_r = Rotational frequency in Hertz

dF = Doppler shift in Hertz

R = Radius of antenna rotation (Centimetres)

f_c = Carrier Frequency of receive signal (MegaHertz)

A rotational frequency is about 487Hertz. It means, 487 complete rotations should be done within 1 second.

3. Assembly of Direction Finder Operation

Direction of a transmitter finder can be uncovered by exploiting the Doppler shift theorem. Rather than using mechanically rotating antenna which is impractical, antenna switcher can be employed. The antenna is to be rotated electronically. This is a rational alternative compare to the option of having to physically rotating the antenna. Figure 5 shows the circuit of antenna switcher. When 5volt is applied to J1-1, antenna 1 is activated. When the supply voltage is provided, current then flows through L5 which acts as a Radio Frequency (RF) choke and only allow Direct Current (DC) to flow through D11, D7 and L1. L1 again acts as RF choke thus flow the DC to ground. Current flows through D11 and D7 set these diodes in forward bias condition, hence increasing their junction capacitance then allows presented RF signal from the antenna to pass to the receiver through C49. The presence of C49 in the circuitry acts as the blocking capacitor which blocks the DC.

Without the presence of 5volt, the RF signal cannot pass through the D7 due to its non-forward bias condition. Antenna switching application occurs when 5volt supplied to J1-1, J1-2, J1-3 and J1-4 one after another. These are shown in figure 5.

We incorporated a 555Timer IC which operates as an oscillator that drives the binary counter. As the result from the use of the counter, 4 antennas were activated consecutively. The counter also drives the LED display as well as running the digital filter. The antennas were spanned 500 times per second sequentially in order of antenna A, B, C, and D. In the same time, it also drives the LED display through 1 of 16 multiplexers which sync with the spinning antenna. The receiver is connected to the spinning antenna which imposes 500 Hz frequency deviation on the received signal. The receiver then connected to a demodulator which demodulates the 500 Hz frequency deviation into 500 Hz tone with loudness set by the frequency deviation. The high pass band and low pass band rejects other tone and result an extraction of 500 Hz Doppler tone[3].

The Doppler signal then passes through the digital filter in order to recognize the frequency shift of the tone. The tone shift frequency is illustrated in Figure 7. The figure is patterned base on the source of the signal which is directly toward the antenna A and opposite to antenna C. The adjustable delay responsible to calibrate the LED direction indicator to the right direction after zero crossing signals detected. Figure 6 shows the full set up of the Radio Direction Finder unit. The cost of components involved in the study was only around 200USD.

4. Experimental Result

The signals which activate the antennas sequentially can be detected from the output of data selector shown in the block diagram Figure 8. The LED display is connected to 1-4 antenna switcher board and the outputs are illustrated in Figure 9. From the result, each input antenna switcher receives 5volt pulses for every 2ms sequentially. Every shown pulse is the results of connection between the antenna and the receiver. This means, by proper arrangement, the antennas act as one antenna which is rotate completely in 2ms. For one second, it rotates 500 times.

The amplitude of receive signal result from each antenna shown in Table 1. The transmitted signal is

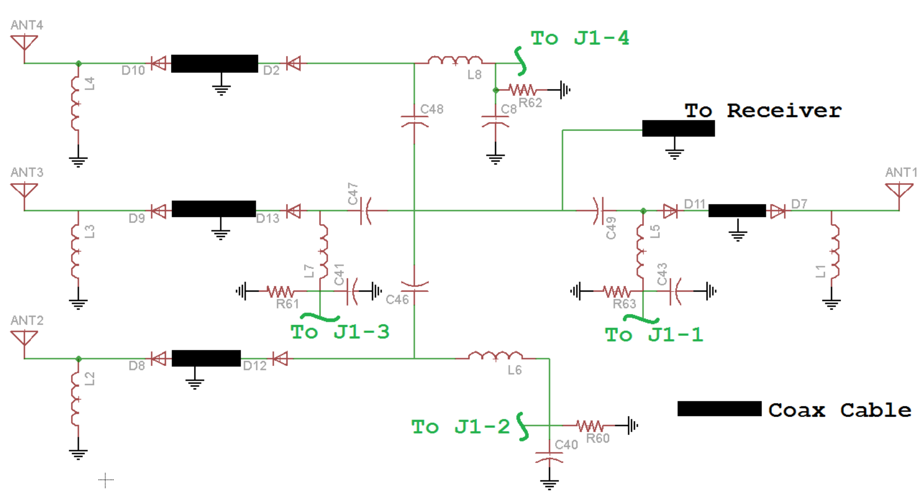

Figure 5. Antenna Switcher.

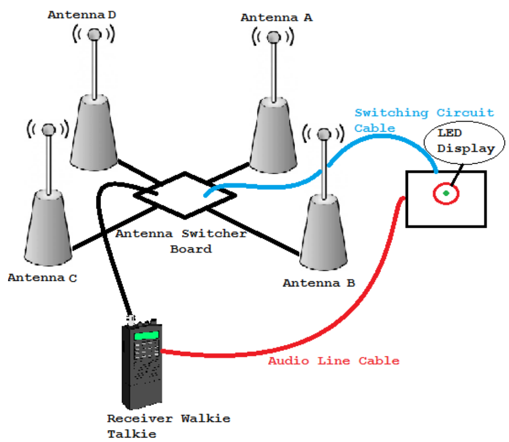

Figure 6. Direction Finder Unit.

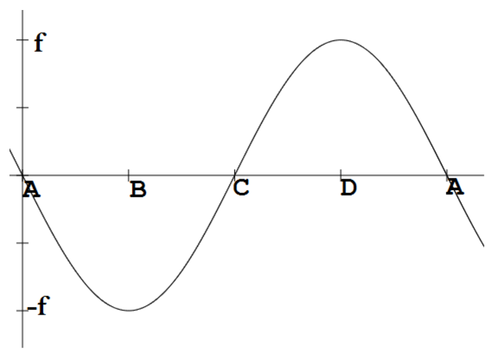

Figure 7. Doppler Shift Tone.

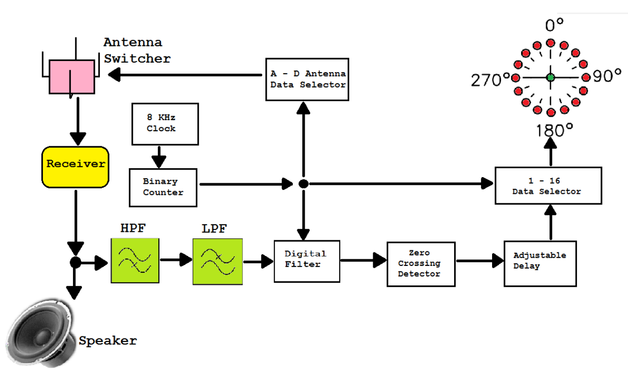

Figure 8. Direction Finder Block Diagram.

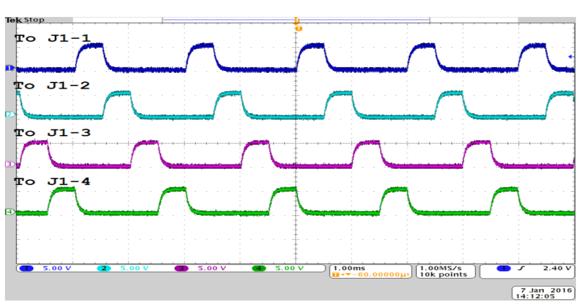

Figure 9. Voltage supply to each Antenna.

Table 1. Signal Receives Power Results

Antenna	Received Power Signal
A	-43.45dBm
B	-46.89dBm
C	-51.64dBm
D	-45.46dBm

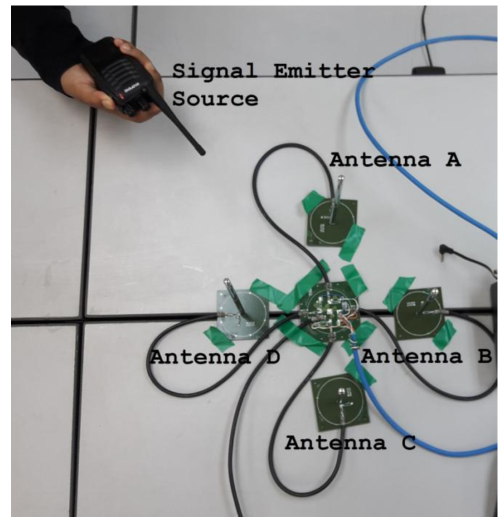

Figure 10. Example of Position of Transmitter and Antenna Receiver.

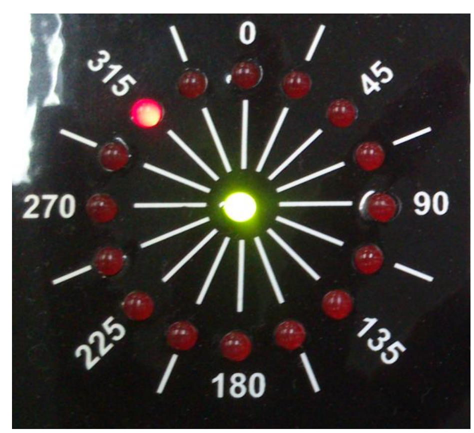

Figure 11. Direction Finder Result.

462.17 MHz and the transmitter was placed in between antenna A and antenna D as shown in Figure 10. From the received signal frequency, the tone was produced, thus enable the circuit to trigger the LED which are in line with the direction of transmitter location. The result of the Radio Direction Finder unit is shown in Figure 11.

5. Conclusions

In conclusion, the parameter such as voltage, current and power characteristic which received by the antenna may lead to reveal the information of direction source. In our study, instead of using 4 different antennas with 4 receivers the system can be simplified by only using one receiver which sequentially selects 4 different antennas at 4 different locations. The device also does not dig, store and analyze the imaginary characteristic such as the phase of the signal but through the difference of the amplitude from the antenna, the tone itself is created.

A UHF transmitter locator system was assembled by exploiting of radio direction finder technology.

For our assemble system, the device components may accept and process received signals between 100 MHz to 1000 MHz. The system is able to detect devices with transmit power signal above 1 Watt for more than 5Km base on the receiver sensitivity. Works are currently in progress in designing a locator device capable of uncovering the position of a GSM transmitter.

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