Low-cost Switched Array-wide Band Antenna for Search and Rescue Disaster Management

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***Abstract*—The activity of SAR (Search and Rescue) is an activity that requires speed in finding the location point. Successfully search for victims can save many lives. Direction finder is proposing to accelerating search survivors. Direction finder can detect the direction and track the radio transmitter using Doppler function. The design, measuring, testing and integrating wideband switched parasitic antenna for direction finder application are conducted in the research. In this paper direction finder antenna made with simple devices and the materials can be found in Indonesia. The proposed architecture has advantages for cost-effective, easy to design and to integrate. The antenna design successfully reaches maximum gain by simulation and field test. The antenna success passes S_{11} measurement, in accord with international standards of antenna manufacturing. The antenna successfully tracks the transmitter using zero cross detector software.**

Keywords—Disaster management; direction finder; doppler; antenna; SAR; Tracking;victims; S_{11}; V_{SWR}

I. Introduction

The two main process of SAR (Search and Rescue), are tracking and evacuation [1]. Emergencies often occur when the sailing boat, flying plane, mountain climbing, and any other situations. The worst situation happens if the victim does not know the location where they are. If the victim has a radio communication tool, its can help by contact the SAR team through a public repeater or frequency channels owned by the government. The SAR team respond by doing a search process [1].The localization area, for searching, should be done. Localization of the victim search area to make it easier to find and expedite searches[1]. The ability of the radio direction finder is to find the direction of the transmitter. The victim search area can be localized by knowing the direction of the victim radio transmitter.

The Doppler Direction Finder detects the victims signal radio using the Doppler Effect [2]. The working principle of the Doppler Effect is the frequency will shift close or away when the transmitter was moving[2]. Many advannce method have been found to search the survivor, but they have problem to implemented in the field.

The use of Doppler method because this method is the easiest to implemented [2]. This system also has the lowest cost to build [2]. The device is integrated with the open software so easy to apply [3]. The direction finder tools on the market are very expensive. The existing system is also very complex operated by BPBD (Badan Penanggulangan Bencana Daerah).

Most of the victims using frequency VHF and UHF for their radio communication. The local SAR team Badan Penanggulangan Bencana Daerah (BPBD) also already familiar with this frequency band. In this paper, we build direction finder antenna for VHF and UHF frequency band. This direction finder antenna system is easy made with the parts available in Indonesia. In this research we do design, simulate, and do the test to find the best dimension for the direction finder antenna that working in UHF and VHF frequency. The dimension is smaller and lighter to adapt the environment and field situation. The dimension should pass the quality test for S_{11} and V_{SWR}. The antenna should be test using software zero cross detection to pass the field test.

II. Antenna Design

An antenna is required to rotate at high speed to meet the doppler effect. To get the desired speed we use 4 active antennas interchangeably. The four antennas rotate electrically at desired speed.

A. Antenna Swiched Array Design

Antenna system use monopole antenna installed in a ground plane. The ground plane avoids the antenna received the reflected signal from the ground. Therefore, antenna just gets the direct wave from the transmitter so that it is easier to analyze [4]. The monopole antenna called antenna element. This element antenna is only for receiving the signal from transmitter. The element antenna uses aluminum pipe with diameter 3 mm. Antenna element heights it's 0.25 λ. In this paper, we use VHF frequency center at 150 MHz and UHF frequency at 450 MHz.

Calculation of the round antenna can be determined by the following equation [2],[3][4].

$$dF = \frac{Vf_c}{C} = \frac{\omega f_c}{C} \quad (1)$$

$$= \frac{2\pi * f_r * r * fc}{C} \quad (2)$$

dF= Shift doppler (Hertz)
ω= Angular speed
ω= 2πfc
fc= Frequency transmission(Hertz)
fr= rotation frequency
C= Speed of light

r= radius antena from center ground plane.

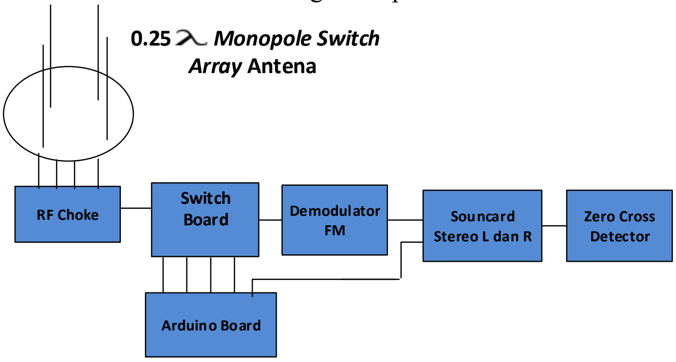

Fig. 1. System Blok Diagram

Figure 1 shows the block diagram, the antenna controlled by switchboard and Arduino. The output forwards the signal to demodulator and stereo soundcard, the audio signal recorded to Wav file. If we set the desired frequency doppler shift at 500 Hz, the Doppler effect 500 Hz and radius circle r = 0.1 meters and a working frequency of 430 MHz can we find the frequency value in the second round as follows [2],[3][4]:

$$fr = \frac{500 * 3x10^8}{430000000 * 2\pi * 0.1}$$

$$fr = 555$$

Ground plane integrated with Arduino ground system. The ground system from Arduino also connects with the computer ground. If the element antenna not working, then the element antenna short to the ground. This is to avoid the antenna resonate. The space between the element antenna (Re) to the center ground plane is 0,25 λ [5],[6],[7]. In the previous research, the radius of the ground plane (Rg) was 1.2λ[5],[6],[7].

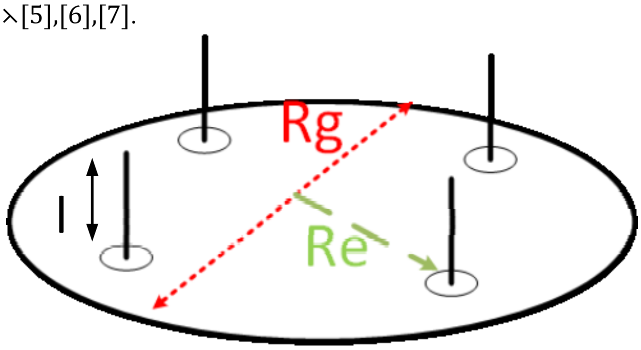

Fig. 2. Antenna Dimension

We propose new dimension of Rg 0,90 λ. The proposed dimension simulate using software simulation. The prototype fabrication measures the parameter quality such as VSWR, S11, and antenna gain. At the bottom, the antenna mounted RF switch circuit using semiconductor and inductor as RF choke[4]. The function of the inductor and the diode as a barrier . Thus barrier rejects the external signal frequency when the antenna off [9]. When the antenna is connected to ground the antenna functionality such as the main antenna reflector[10].

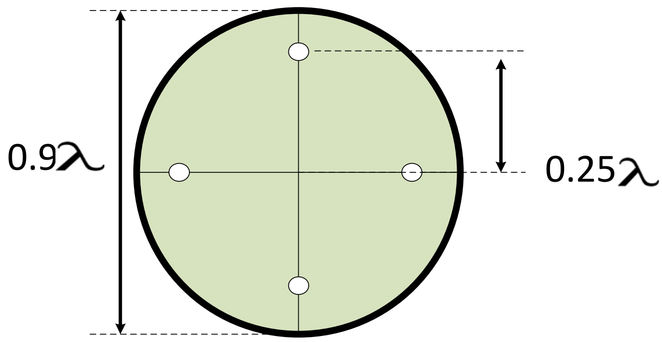

Fig. 3. Antenna Dimension layout from above

To activate the antenna turns with the desired Doppler frequency antenna circuit switch required. The circuit consists components diode, resistor, inductor[3].

B. Simulation And Prototipe Fabrication

The simulation in UHF use 450 MHz frequency for the antenna element size. Monopole antenna material builds from aluminum pipe diameter of 3 mm. The length of each element antenna is l [10].

$$l = 0.25\lambda. \qquad (3)$$

where lambda (λ) is the wavelength that can be obtained with equations [11]:

$$\lambda = \frac{c}{f} \qquad (4)$$

From equation (3), the element antenna is height 16,6 cm. The space between the antenna to the center ground plane Re is 16,3 cm, and the diameter ground plane Rg is 60, cm. The ground plane material is an aluminum plate with 2 mm thick. Before the antenna fabricates, the antenna should simulate the dimension design to get the maximum result. The simulation dimensions listed in Table 2. Simulation dimensions use for fabrication prototype. The antenna quality should be acceptable. The simulation conduct to get standard reflection coefficient (S_{11}) and desired voltage standing wave ratio (V_{SWR}). V_{SWR} defined as the ratio between the incident wave and the reflected wave [11].

$$VSWR = \frac{|Vmax|}{|Vmin|} = \frac{1+|\Gamma|}{1-|\Gamma|} \qquad (5)$$

Antenna V_{SWR} and S_{11} are measured and matching with the impedance. This measurement conduct to avoid the system not working in maximum condition. The simulation dimension after optimation show at table 2.

TABLE 2. DIMENSION SIMULATION IN HFSS 13

No	Antena Peripherals	Dimension at 150 Mhz Frequency	Dimension at 430 Frequency
1.	Monopole Diameter	3 mm	3mm
2.	Monopole Element Height (l)	52 cm	16.3 cm
3.	Ground Plane Diameter (Rg)	180 cm	60 cm
4.	Monopole radius from center grounplane(Re)	120 cm	20 cm

Table 2 shows the result simulation, this simulation result is importan to get the first dimension for design the protitipe antenna.

III. Measurement Field Test and Analisys

The initial dimensions of the manufacturing antenna use the sizes in table 2. The antenna fabrication results are optimized using a network analyzer, power meter and spectrum analyzer. The optimization result can be seen in table 3. Comparison of frequency of simulation work frequency with optimization result of manufacturing can be seen in table 4.

A. Antena Fabrication And Optimation

The Fabrication of antenna parameters using simulation design in Table 2. Maximize optimal design the antenna measured using a network analyzer, power meter, and spectrum analyzer.

Fig. 4. Diameter Prototipe Antena at UHF Band

Figure 4 shows the prototype antenna, the diameter of the ground plane is 60 cm. It is same with the simulation result. The 60 cm result is 0,9 ⅄, same with the proposed design. The radius element from the central ground plane is 20 cm or 0.3 ⅄ after adjusted, optimized and measured.

Fig.5. Element Height Prototipe at UHF Band

Figure 5 shows the height of the element antenna (l). The height is 14 cm after optimation during measurement. This 2.3 cm shorter than the simulation result in Table 2.

TABLE 3. AJUSTED MEASUREMENT DIMENSION

No	Antena Peripherals	Dimension at 150 Mhz Frequency	Dimension at 430 Frequency
1.	Monopole Diameter	3 mm	3mm
2.	Monopole Element Height	50 cm	14 cm
3.	Ground Plane Diameter	110 cm	60 cm
4.	Monopole radius from center grounplane	43 cm	25 cm

Table 3 shows the adjusted and optimized dimension when its measured using Netowrk Analizer. This result is final for the protitipe antenna dimension.

TABLE 4. WORKING FREQUENCY

No	Compared Frequency	VHF		UHF	
		Simulation	Prototype	Simulation	Prototype
1.	Low Frequency	135 MHz	125 MHz	430 MHz	315 MHz
2.	High Frequency	165 MHz	185 MHz	520 MHz	580 MHz
3.	Bandwidth	30 MHz	60 MHz	90 MHz	265 MHz

Table 4 shows the bandwith antenna simulation and optimation from measurement, this bandwidth show the performance antenna to works at the desired frequency. The result from the prototipe show the antenna can work in UHF and VHF frequency.

B. Reflection Coefision (S_{11})

The reflected wave measurement is done to find the maximum dimension of the ground plane and element, so the receiver not blocked because it does not match the impedance.

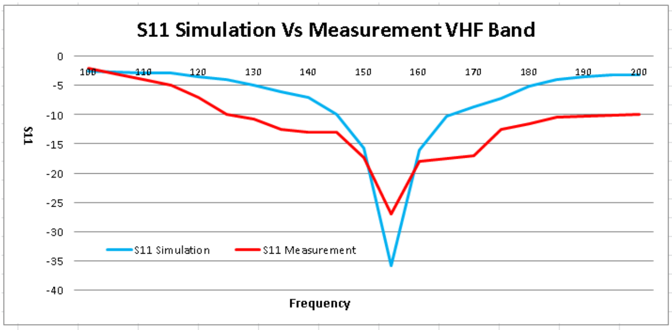

Fig.6. S_{11} VHF Frequency

Figure 6 shows the comparison simulation versus measurement, the measurement result is better significant in VHF frequency. The bandwidth antenna result is 60 MHz. The S11 for UHF graph shows in figure 7. We can see that the antenna works well from 315 MHz to 580 MHz. Antenna still working in 300 MHz and 600 MHz with the poor quality for transmitting and receiving signal.

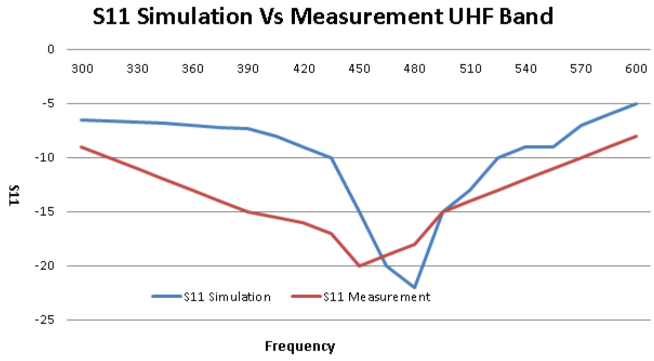

Fig.7. S_{11} UHF Frequency

C. *Beam Measurement*

Beam measurement was conducted to determine the radiation pattern. From the pattern of this radiation beam that is known to the maximum. Thus it can be seen toward the maximum antenna. In single antenna measurement antenna is supplied with a 3.8 volt circuit with the battery so that there is only one active antenna. The 3 dB gain antenna are reached at 330 to 30 degree, this antenna has single beam at 60 degrees.

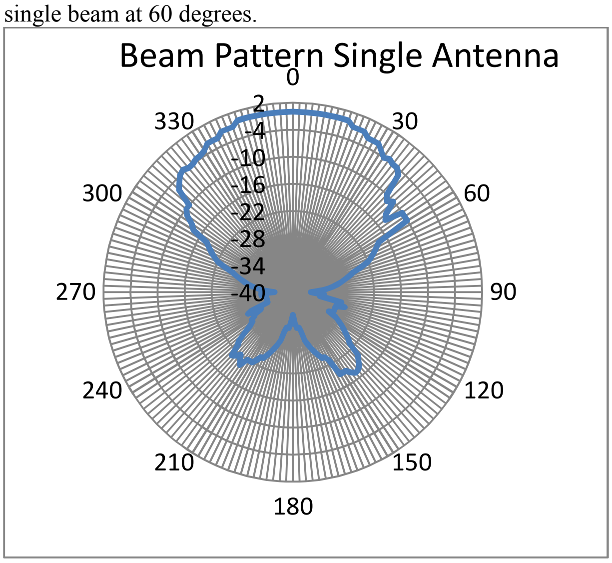

Fig. 8. Beam Measurement Single Antenna

Test all antenna done by 4 Antenna works alternately with the delay of 2 ms. with rapid delay has no effect on the quality of the sound received at the receiver. With alternate antenna beam measurements, to obtain the beam pattern. From the measurement results obtained beam -3dB antenna start at 330 degree to 30 degree.

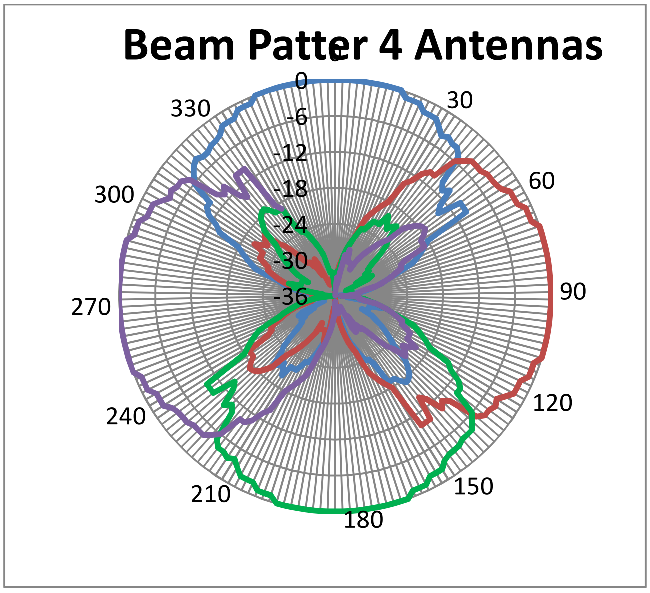

Fig. 9. Beam 4 Antenna

D. *Gain Analisys*

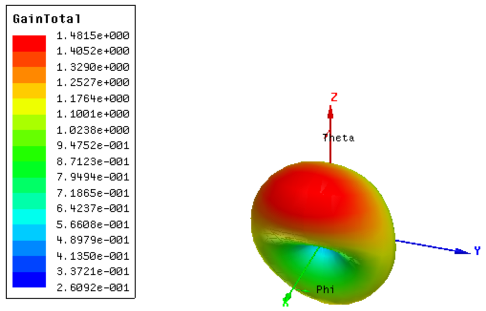

Fig. 10. 3D Beam Antena

The gain analysis is needed to determine the antenna's ability to amplify the electromagnetic wave signal. The higher gain, the greater range of the signal received by the receiving antenna with the same transmit power and environmental conditions[9]. HFSS software simulation gets antenna gain value near 2 dBi. Measurement of beamwidth field is used as initial data to calculate actual antenna gain.

The antenna gain equation is as follows[11]:

$$G(\theta,\emptyset) = \frac{U\,(\theta,\emptyset)}{W1/4\pi} \qquad (6)$$

Where :

$U\,(\theta,\emptyset)$ =Radiation Intensity As Functions θ and ∅

W_1 = Total power goes into the antenna

The equation (6) above is an equation which does not take losses input power. While the losses of power need to be inserted to the calculation considering the effectiveness of the antenna [10].

The antenna effectiveness is obtained by the equation:

$$W_t = \eta W_i \qquad (7)$$

$$\Omega_M = \text{Wt} = BW_E\ BW_H \qquad (8)$$

Ω_M=Wt= Main beam solid angle (Total Beam)

BW_E= Beamwidth plane E (Vertikal)

BW_H= Beamwidth plane H (Horizontal)

The gain equation is obtained from the efficiency [11] :

$$G(\theta,\emptyset) = \eta D(\theta,\emptyset) \quad (9)$$

The efficiency of antenna that we use in this research is η = 63%, so the gain value is obtained [11]:

$$G = \frac{25989}{\mathrm{BW}_E \mathrm{BW}_H} \quad (10)$$

$$G = \frac{25989}{60 \quad 60}$$

$$G = \frac{25989}{3600} = 7.23$$

The gain value above is still in numerical form, to facilitate the calculation then done in decibels. To get the gain value in decibels then 10 log 7.23 = 8.5 dB.

E. Direction Tracking

Direction tracking is done to test the antenna with zero cross detector software. This test requires demodulator and soundcard. Audio output and clock signals are stored in the form of wav files. This signal is then analyzed using a zero cross detector software. We can use free software soundoppler from Ludwig Baars.

F. Field Test

Tests conducted in the field on condition NonLOS. Tests carried out at the International Ground Station Pare-pare South Sulawesi Indonesia. Site selection is done because it is located on a hill surrounded by forest. Around the place of testing is also a protected forest and beach so similar to the real situation. Antenna arrays placed on the ground. As a source of transmitters, we used radio transmitter with power 5 Watt with 2 dBi antenna gain. The air distance between the transmitter to the antenna is 500 meter.

TABLE 5. FIELD TEST 500 METER AIR DISTANCE

No	True Direction (Degree)	Detected Direction (Degree)	Insident Angle (Degree)
1	38.2	44.5	6.3
2.	98.4	107.9	9.5
3.	201.8	185.2	16.6
4.	265.1	274.2	9.1

Table 5 show the measurement on 500-meter air distance. The result is the insistence angle is 6.3 degree to 9.1 degrees. The high of the incidence angle mostly because of the multipath and the reflected signal from the wood and hill. This result is better than the measurement from previous research [8] that the incidence angle is 10 to 30 degree.

IV. CONCLUSION

From the optimization results of antenna work on the frequency VHF and UHF band. The frequency range is 125-185 MHz with 60 MHz bandwidth in VHF Band. In the UHF frequency band, the antenna works on the frequency 315-580 MHz with bandwidth 265 MHz. The prototipe antenna gain is 8.5 dB. Test results indicate this antenna is able to search the direction transmitter. This antenna devices affordable price cost.

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