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Implementation Satellite Interference Geolocation Using TDOA Algorithm In Indonesia

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Abstract: Indonesia, Country with many islands have at least four geostationary satellites for telecommunication services to connect all-region with high-speed internet, telephony backbone and other private data such as banking and government application. Using VSAT (very small aperture terminal) as an earth station is fast to deploy with minimum infrastructure and can reach some remote area easily. The other hand, VSAT makes the satellite become susceptible to interference and also very difficult to find the source of interference. Some satellite interference caused by VSAT mis-alignment, VSAT equipment failure and unauthorized VSAT operation. There are some methods and algorithm to find a signal source such as AOA (Angle of Arrival), FDOA (frequency difference of arrival), TOA (time of arrival) and TDOA (time difference of arrival). TDOA measure the difference of time signal arrival at multiple receivers and calculate the distance between the signal source and receiver to locate the signal source. This paper studied how to find satellite interference source using TDOA algorithm and also the experimental result.

Index Terms: Satellite, interference, geolocation, VSAT (very small aperture terminal), TOA (time of arrival), TDOA (time difference of arrival), FDOA (frequency difference of arrival), AOA (Angle of Arrival).

1 INTRODUCTION

The normal VSAT (very small aperture terminal) Telecommunication consist of VSAT antenna aligned to one satellite with center beam and certain transmit/receive frequency for both sites as shown in fig 1.

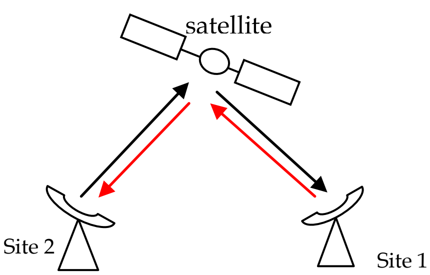

Fig 1. *Normal VSAT Telecommunication.*

In abnormal condition, some sites may be mis-aligned or mis-pointed as described in fig. 2 and cause interference to other satellite. Equipment failure can also be a cause of interference to other frequency at the same satellite, like spurious error or intermodulation error.

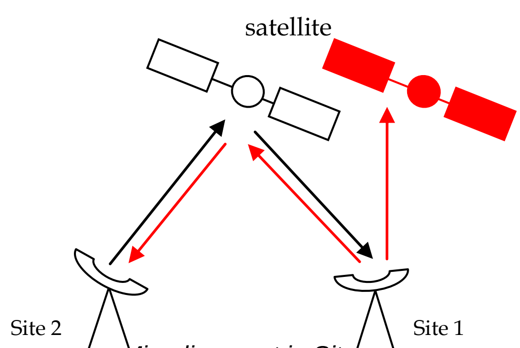

Fig 2. *Mis-alignment in Site 1.*

Interference can cause communication problems in the path itself and more severe interfere with other paths. Some satellite operators even give fines to anyone who causes interference. However, there is still a lot of satellite interference. Locating the satellite interference source is very important to eliminate the signal source that causes the communication problem. There are two methods to find the source of signal from the unknown node on the surface of the earth (geolocation): range-based and range-free [1]. The range-free method can be used by collecting the received signal strength indication (RSSI) data between the signal source and sensors to obtain the signal strength model and estimate the coordinate of the signal source. The range-free method widely used in the radio direction finding (RDF). The range-based method including AOA, FDOA, TOA and TDOA. AOA methods calculate the angle from which a signal from the source is propagating, that can be used to measure the position of the transmitter and usually using array antennas for measuring the angle. FDOA method is usually to find the moving signal source by measuring the frequency change because of the doppler effect. TOA method measure the time of the signal from the source arrive at the sensor and measure the distance between source and sensor. TOA require to measure the exact time that the signal was sent from the source and the exact time the signal arrives at the sensors. TDOA algorithm uses at least 3 sensors for receiving the signal from the source and only measure the different arrival time from each sensor, no need to measure the time that the signal was sent from the source. Base on this condition, the

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TDOA algorithm will measure the distance between source and sensors. Because of the geostationary satellite behaviour that has a place in 36,000 km from the earth, TDOA algorithm is the best algorithm to be applied for satellite interference finder.

2 METHOD

TDOA Algorithm is basically using at least 3 sensors for making the difference of time arrival. In satellite interference, the next adjacent satellite to the right and to the left becomes the sensor [2].

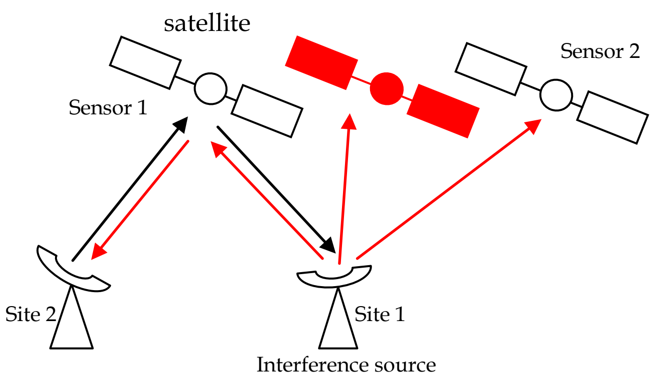

Fig 3. *Using satellite as sensor.*

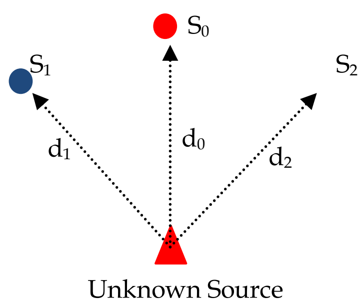

Fig 4. *TDOA with three sensors diagram.*

The distance d_i between the source and the sensor can be calculated as follow:

$$d_i = t_i c \qquad i = 1,2 \qquad (1)$$

where c is the speed of light, t is the time between when the signal leaves the unknown transmitter (source) and when it arrives the sensor. TDOA algorithm does not require the time that the signal from the source was sent, only the time the signal was received by each sensor and the speed that the signal travels. When the signal is received at each sensor points, the difference between each sensor in arrival time can be used to calculate the difference of the distances between the target and each sensor [3]. We can calculate TDOA between sensor 0 and the ith sensor by the following formula:

$$t_{i0} = t_0 - t_i = ({}^{1}/_{c})(d_0 - d_i) \qquad i=1,2 \qquad (2)$$

where t_0 is the time of the signal arrives at sensor 0 and t_i is the time the signal arrives at the ith sensor. With the formula (2), we can calculate the distance difference between sensor 0 and sensor ith.

$$d_{i0} = d_0 - d_i = (t_0 - t_1)c = t_{i0}c \qquad i=1,2 \qquad (3)$$

Now, the distance d_i between the signal source and the ith sensor can be written [1]:

$$d_i = \sqrt{(Xi-Xs)^2+(Yi-Ys)^2+(Zi-Zs)^2} \qquad i=1,2 \qquad (4)$$

Subtitution between equation (4) and (2) become:

$$t_{i0}c = d_0 - d_i = \sqrt{(X0-Xs)^2+(Y0-Ys)^2+(Z0-Zs)^2} - \sqrt{(Xi-Xs)^2+(Yi-Ys)^2+(Zi-Zs)^2} \qquad i=1,2 \qquad (5)$$

t_{i0} can be measured using digital storage oscilloscope [4].

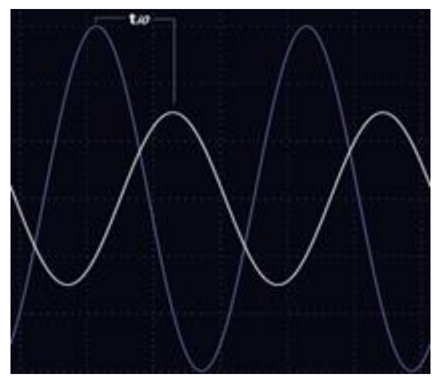

Fig 5. *TDOA measurement*

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The blue line at fig 5 is the signal received by S_0 and the white line is the signal received by S_i. Signal received by S_0 should have a higher amplitude than the signal received by S_i. x0,x0 and z0 is the known coordinate of sensor 0, xi,xi and zi is the known coordinate of sensor ith and xs,ys and zs is the coordinate of signal source that will be found using this equation.

3 EXPERIMENT RESULT

In this experiment, a continuous wave transmitter was setup as a signal source and three satellites as a sensor. Total 4 experiments were conducted with varied satellite location and transmitter source location.

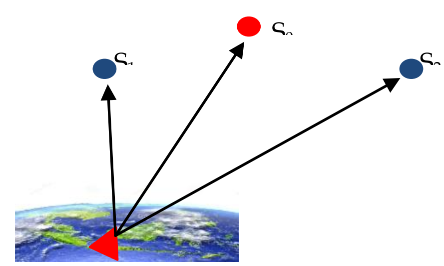

Fig 6. *Satellite illustration above the earth (earth picture source:https://www.dreamstime.com/stock-illustration-indonesia-realistic-model-earth-d-illustration-planet-surface-elements-image-furnished-nasa-image88735636).*

1st experiment put one VSAT transmitter in the Serpong City and transmitted to the Telkom 3S satellite 118°E (S0). Another two satellites are ABS-7 116.1°E (S1) and Thaicom 4 119.5°E (S2) as sensors as shown in Fig 5.

2nd experiment put one VSAT transmitter in the Ambon City and transmitted to the Telkom 3S satellite 118°E (S0). Another two satellites are ABS-7 116.1°E (S1) and Thaicom 4 119.5°E (S2) as sensors.

3rd experiment put one VSAT transmitter in the Serpong City and transmitted to the Palapa D satellite 113°E (S0). Another two satellites are ChinaSat 10/16 110.5°E (S1) and ChinaSat 6B 115.5°E (S2) as sensors.

4th experiment put one VSAT transmitter in the Ambon City and transmitted to the Palapa D satellite 113°E (S0). Another two satellites are ChinaSat 10/16 110.5°E (S1) and ChinaSat 6B 115.5°E (S2) as sensors.

To increase accuracy, the position of all sensors should be check realtime to the satellite operator or by online satellite tracking system.

Table 1 shows the experiment result t_{10}, t_{20} and calculation result by equation 5.

TABLE 1

Measurement of t_{i0} and Latitude,Longitude Calculation

No.of Experiment	t10	t20	Latitude,Longitude	
			Calculation	Real Location
1.	5.52ns	-4.31ns	-6.322, 106.613	-6.322, 106.614
2.	-6.13ns	4.52ns	-3.6955, 128.18	-3.6955, 128.179
3.	5.22ns	-6.39ns	-6.322, 106.613	-6.322, 106.614
4.	-8.12ns	8.05ns	-3.6955, 128.18	-3.6955, 128.179

Graphically we can see the calculation results from equation 5 by fig 7-10 for each experiment. The location of the signal source is shown by the intersection of equation 5 with i = 1 and i = 2. Red line for i = 1 and green line for i = 2. The location point is shown by longitude (which is indicated by the x-axis) and latitude (which is indicated by the y-axis). In this calculation, we ignore the z-axis as altitude, because geolocation only needs longitude and latitude.

***Fig 7. 1st** Experiment calculation result.*

***Fig 8. 2nd** Experiment calculation result.*

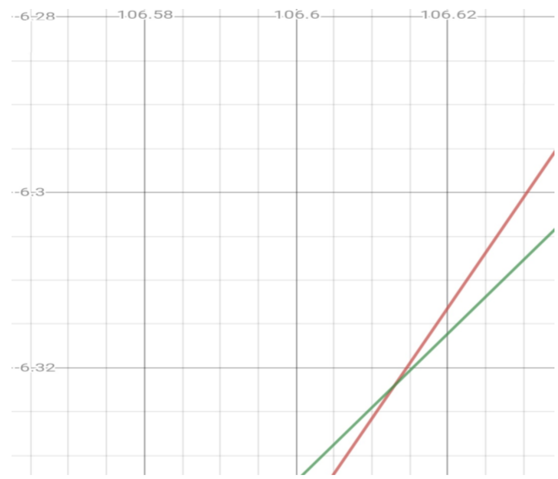

***Fig 9.** 3rd Experiment calculation result.*

***Fig 10. 4th** Experiment calculation result.*

4 CONCLUSION

The TDOA algorithm described above shows good results for determining the location of the source of satellite interference in two cities experiments with varied satellites in Indonesia. Accuracy and precision when measuring the time difference of arrival are very important in determining the result. This method is very effective and can be implemented by satellite operators in Indonesia to localize satellite interference source.

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