CHAPTER THREE

SYSTEM DESIGN

3.1 System Overview:

For receiving signals from any satellite the dish must be pointed perfectly so it can receive those signals. Perfect pointing depends on two factors the satellite position and the dish position which are used for calculating the azimuth and elevation angles. automatic satellite dish positioner uses android application for calculating the azimuth and elevation angles. Then these values are transmitted wirelessly to a controller responsible for moving two motors to adjust the dish into the correct position. Figure (3.1) illustrate the above procedure.

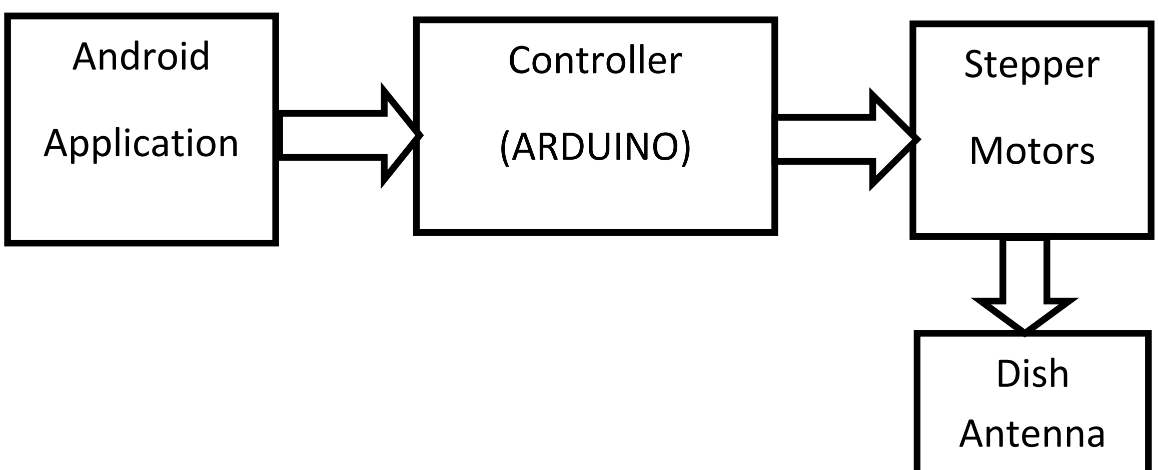

Figure (3.1): General block diagram of the system.

3.2 Calculation of the Angles using Android Application:

Pointing dish antenna to a satellite requires calculations of the antenna look angles. The look angles for the ground station antenna are Azimuth and Elevation angles. Elevation angle refers to the angle between the beam pointing direction, directly towards the satellite, and the local horizontal plane. It is the up-down angle. Azimuth angle refers to the rotation of the whole antenna around a vertical axis. It is the side to side angle. They are required at the antenna so that it points directly to the satellite. Look angles are calculated by considering the elliptical orbit. These angles change in order to track the satellite. For geostationary orbit, these angels values do not change as the satellites are stationary with respect to earth so the dish is pointed to a fixed point on the sky[2].

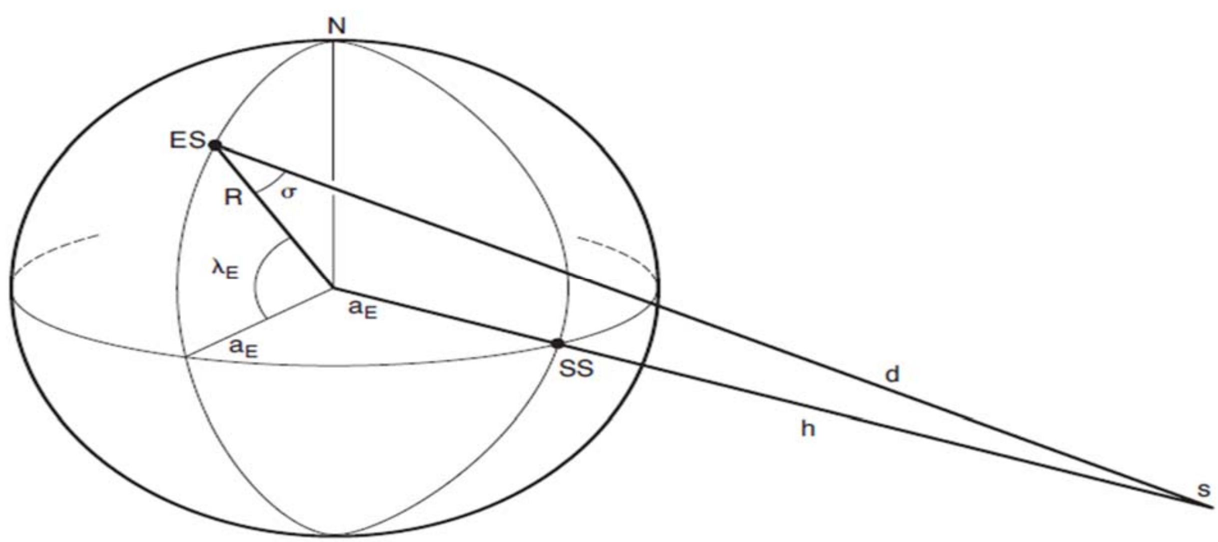

Figure (3.2): the geometric relation between the earth station (Dish) and the satellite position.

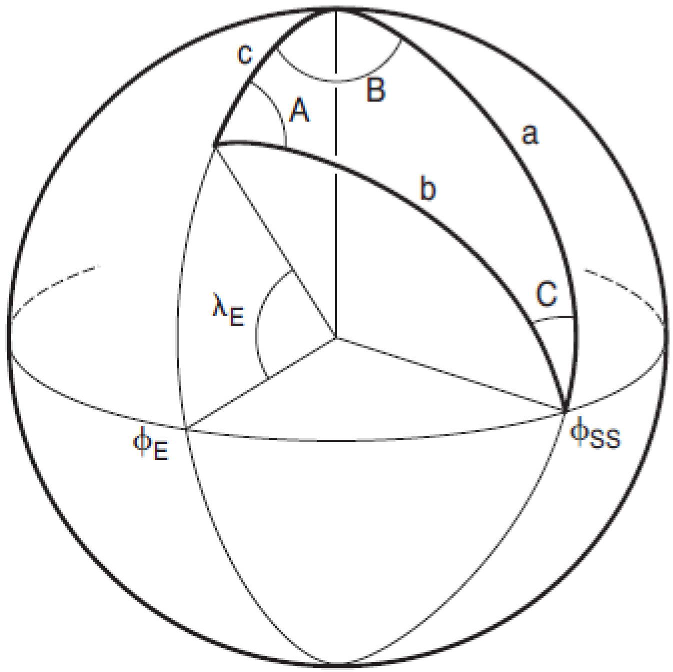

Figure (3.3): The spherical geometry related to figure (3.2).

With respect to the figure (3.2) and (3.3), the following information is needed to determine the look angles of geostationary orbit.

- Earth Station Latitude: λ_E
- Earth Station Longitude: Φ_E
- Sub-Satellite Point's Longitude: Φ_{SS}
- ES: Position of Earth Station
- SS: Sub-Satellite Point
- S: Satellite
- d: Range from ES to S
- σ: angle to be determined

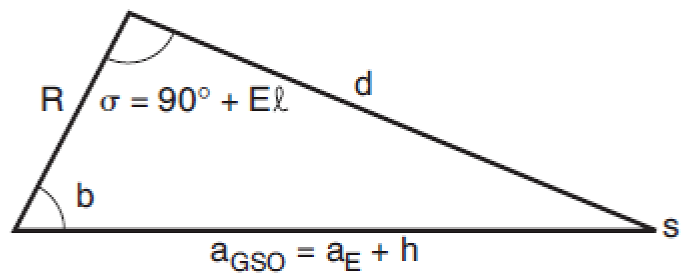

Figure (3.4): A plane triangle obtained from figure (3.2).

Considering figure (3.4), it's a spherical triangle. All sides are the arcs of a great circle. Three sides of this triangle are defined by the angles subtended by the center of the earth.

- Side a: angle between North Pole and radius of the sub-satellite point.
- Side b: angle between radius of Earth and radius of the sub-satellite point.
- Side c: angle between radius of Earth and the North Pole.

a = $90^0$and such a spherical triangle is called quadrantal triangle.

$$c = 90^0 - \lambda_E \tag{3.1}$$

Angle B is the angle between the plane containing c and the plane containing a.

$$B = \phi_E - \phi_{ss} \tag{3.2}$$

Angle A is the angle between the plane containing b and the plane containing c. Angle C is the angle between the plane containing a and the plane containing b. Thus, a = 90^0 so $c = 90^0 - \lambda_E$.

$$B = \phi_E - \phi_{ss} \tag{3.3}$$

Thus,

$$B = \cos^{-1}(\cos B \ \cos \lambda_E) \tag{3.4}$$

$$A = \sin^{-1}\left(\frac{\sin|B|}{\sin b}\right) \tag{3.5}$$

Table (3.1): azimuth angle related to angle A

Earth station Latitude	B	Azimuth angle AZ
<0	<0	A
<0	0>	360-A
0>	<0	180-A
0>	0>	180+A

$$d = \sqrt[2]{R^2 + a_{GSO}{}^2 - 2Ra_{GSO}cosb} \tag{3.6}$$

$$EL = \cos^{-1}\left(\frac{a_{GSO}}{d} \sin b\right) \tag{3.7}$$

Android is an operating system for mobiles. Android is the most spread OS ever. For selecting the intended satellite and current satellite, android will provide the easiest way. Android application had contained one activity that provided to menus, one for the current satellite that the user is currently receives it's signals and the other for the desired satellite that the user wishes to receive its signals, the application will also support the user with every informations and actions it will take[16].

Background processing will perform. First the application determines the position of the user using GPS feature (it will assume the position of Khartoum if GPS is not available). Second calculation of the elevation and azimuth angles based on the user position and the satellite position. Third calculation of number steps taken by each motor based on azimuth and elevation angles. Fourth sending of these values to the ARDUINO using BLUETOOTH feature of the mobile. After both of the azimuth and elevation angles are aligned the dish must be adjusted to the correct satellite.

3.3 Selection of Stepper Motors:

A stepper motor is an electromechanical device which converts electrical pulses into discrete mechanical movements. Stepper motors provide precise positioning. The basic operation of a stepper motor allows the shaft to move a precise number of degrees each time a pulse of electricity is sent to the motor. Since the shaft is designed to move a predetermined number of degrees for each electric pulse sent to the motor. So controlling the pulses, controlling the position of the dish. Stepper motor depend on magnets to turn the motor shaft to precise degrees (or fraction of the degree) when an electric pulse is received at the motor. Mechanical operation with precise moving system is required by the system. Stepper motor is the best choice for the movement of this system. The system will include two motors one for adjusting the elevation angle and the other for adjusting the azimuth angle thereby receiving the intended satellite signals. Each motor must have step angle equal or less than the satellite's beam width for maximum reception.

Pointing the antenna to the calculated elevation and azimuth angle means directed the antenna to the 0dB angle which is the center of the antenna beam-width (HPBW). So the limit of the directional antenna angle which lets the antenna point to the intended satellite and still within the HPBW of the antenna can be given by this equation:

$$limit = \left(Az \pm \frac{HPBW}{2}\right) \quad (3.8)$$

In this scenario, the parabolic antenna with a circular aperture, the HPBW in the azimuth and elevation are equal. So the equation will be done in one direction (azimuth). The stepping motor does not offer all calculated positions. It divides the looking radius in to discrete positions base on the step-angle β as mentioned. So the calculated angle maybe aligned with a discrete position or drooped between two discrete positions. To convert the calculated azimuth angle (Az) in to number of steps (n):

$$x = \frac{Az}{a} \quad (3.9)$$

$x \equiv number\ of\ steps$

$a \equiv step\ angle$

The result x will be one of these:

$$x = n\ (when\ x\ is\ an\ integer) \quad (3.10)$$

$$x = n(when\ xmod1 < 0.5) \quad (3.11)$$

$$x = n + 1(when\ xmod1 > 0.5) \quad (3.12)$$

Where n is the integer part of x .

The pointing azimuth (Az) must be one of these:

$$Az = na \tag{3.13}$$

Or

$$Az = (n+1)a \tag{3.14}$$

But at least one of them must be dropped within the antenna beam-width (HPBW) as shown in Figure (3.5)

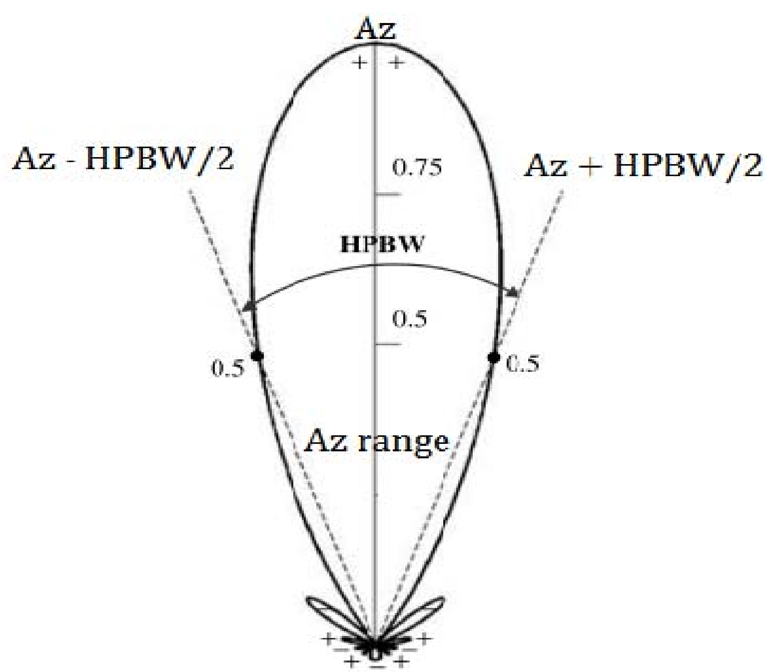

Figure (3.5) illustrates the limits of AZ

This means:

$$na \geq Az - \frac{HPBW}{2} \tag{3.15}$$

Or

$$(n+1)a \leq Az + \frac{HPBW}{2} \tag{3.16}$$

By Multiplying (3.15)* (-1) we find:

$$-na \leq -Az + \frac{HPBW}{2} \tag{3.17}$$

By adding (3.16) to (3.17) we find:

$$a \leq 2 * \frac{HPBW}{2} \tag{3.18}$$

Or

$$a \leq HPBW \tag{3.19}$$

That means the motor step-angle a must be less than or equal to the Half-Power Beam Width (HPBW) of the intended antenna. the diameter of the antenna is a function of motor steps-angle(a) :

$$a \leq 70\frac{\lambda}{D} \tag{3.20}$$

the step-angle of the stepper motor limits the diameter of the antenna that can be used when we connect them[17].

3.4 Steps Taken by Each Motor:

Azimuth and elevation angles are calculated using an android application running in a mobile, the mobile app will first determine the position of the mobile terminal using GPS facility if the GPS isn't turned on or the mobile has a certain damage in the GPS facility the application will choose the longitude and latitude of capital Khartoum as the default position of the users. then application will use the location of the mobile in addition to the positions of both of the current and desired satellites to calculate the values of the elevation and the azimuth angles, to determine the number of steps that the motor responsible for elevation angle adjusting need to take to be aligned to the desired elevation angle the application must compute five values. First the desired elevation angle using look angles equations, Second the number of steps to achieve the desired elevation angle using:

$$DEl_{steps} = \frac{DEl}{a} \tag{3.21}$$

DEl_{steps} : number of steps to reach the desired elevation angle.

DEl : the desired elevation angle.

Third the current elevation angle that the dish is currently pointed to it, Fourth the number of steps that the motor had moved until it reached the current elevation angle which is calculated from

$$CEl_{steps} = \frac{CEl}{a} \tag{3.22}$$

CEl_{steps}: the number of steps that the motor had moved until it reached the current elevation angle.

CEl : the current elevation angle.

Fifth the application calculates the number of steps that the motor will need to reach the intended elevation angle using

$$number\ of\ steps\ for\ elevation\ adjustment =$$

$$DEl_{steps} - CEl_{steps} \qquad (3.23)$$

after calculating the steps for the desired elevation angle the mobile will do the same steps for the desired azimuth angle. Then the mobile will send these values to a controller using BLUETOOTH after they are concatenated into a single string.

3.5 Interfacing between the ARDUINO and the Application:

The use of BLUETOOTH technology in a smart phone today is not just for the transfer of data and files only. BLUETOOTH technology operate over unlicensed, its available at 2.4GHz frequency, it also can link digital devices within a range of 10m to 100m at the speed of up to 3Mbps but it depending on the BLUETOOTH device class[18].

BLUETOOTH provide useful interfacing between the mobile and any others controllers because many manufactures' devices running Android nowadays coming with BLUETOOTH feature so using this existing feature will consume a lower cost because it's just require a slave BLUETOOTH shield in the controller site while master shield is available in the user's mobile, so as result the remote control units cost is reduced.

After the numbers of steps to align both of elevation and azimuth angles are calculated in the android app, it will send these values to the controller which will use BLUETOOTH module connected to the controller directly. The controller will generate two signals corresponding to the received values, one for the vertical motor and the other for the horizontal motor.

The motors' movements are controlled using ARDIUNO. ARDUINO is a microcontroller-based for building digital circuits that can sense and control physical sensors and devices. It provides a set of digital and analog inputs and outputs that provide interfacing to many types of equipment. ARDUINO has a programmable hardware and IDE used to write and upload computer code to the physical board.

ARDUINO has a BLUETOOTH shield that can be connected directly to it. A BLUTOOTH shield provide interface between the mobile terminal and the ARDUINO, once both of the desired and the current broadcasting satellites are selected the app immediately calculate the number of steps for each motor and send it using it's BLUETOOTH feature to the BLUTOOTH shield of the ARDUINO. ARDUINO receives the two values and then it generates two signals according to the values that are received by the BLUETOOTH module. Each signal has a sequence of electric pulses, each pulse enable its corresponding motor to move one step.

Stepper motors are connected to ARDUINO using digital input/output ports, each motor will be connected to four ports.

ARDUINO has a library that support stepper motors. It’s providing functions that can enable a stepper motor to move specific number of steps in specific direction. Stepper motors could be connected directly to ARDUINO if they have small sizes. Stepper motors with large sizes will need external circuits these circuits called stepper drivers. Stepper driver is a circuit that keep the power that drives the motor separate from the power that on the ARDUINO. L293D is stepper driver used to drive stepper motor it act as current amplifiers since they take a low-current control signal and provide a higher-current control signal. This higher current signal is used to drive the motors.

L293D is fed from 5v for its operation; L293D is connected for both of the power supply and ARDUINO. Since there are two motors there is one L293D for each motor. L293D has two enables for Stepper operation both of the two enables must be on.

ARDUINO will be fed from external battery at 9v level and BLUETOOTH shield will be fed from the ARDUINO board at 5v level. Adapter converts 220 AC voltage into 12 DC voltage that is required for the operation of the motor.

Figure (3.6) illustrates the connection of the ARDUINO to steeper motor using [L293D] driver circuit connected to DC power supply.

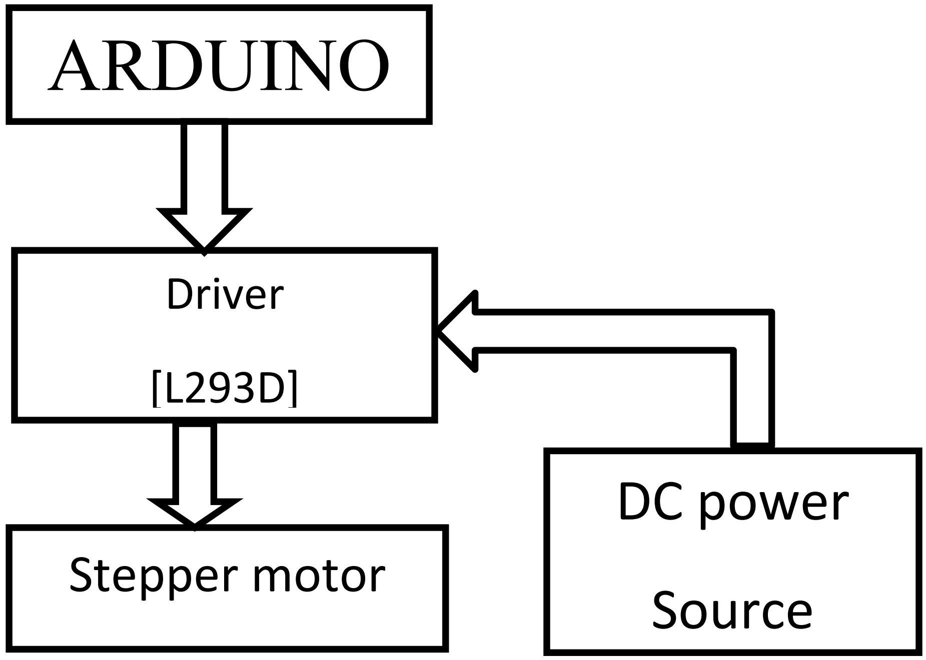

Figure (3.6): Connection of ARDUINO to stepper motor.

3.6 Flow Chart of Android Application:

Flow chart in figure (3.7) illustrates the algorithm of ANDROID application. First the user selects both of current satellite (satellite that the dish is already aligned to it) and the desired satellite (satellite that the user wants the dish to be aligned to it) depending on the user position determined by the GPS (default position is Khartoum), the current satellite position and the desired satellite position. Second the application will calculate the azimuth and elevation angles for both of current satellite and desired satellite using the look angles equations (described in section 3.2). Third the azimuth and elevation angles for both of current satellite and desired satellite values are used to calculate the number of steps for each motor. finally, the numbers of steps for the horizontal motor and the vertical motor are concatenated into a single string that will be transmitted using BLUETOOTH.

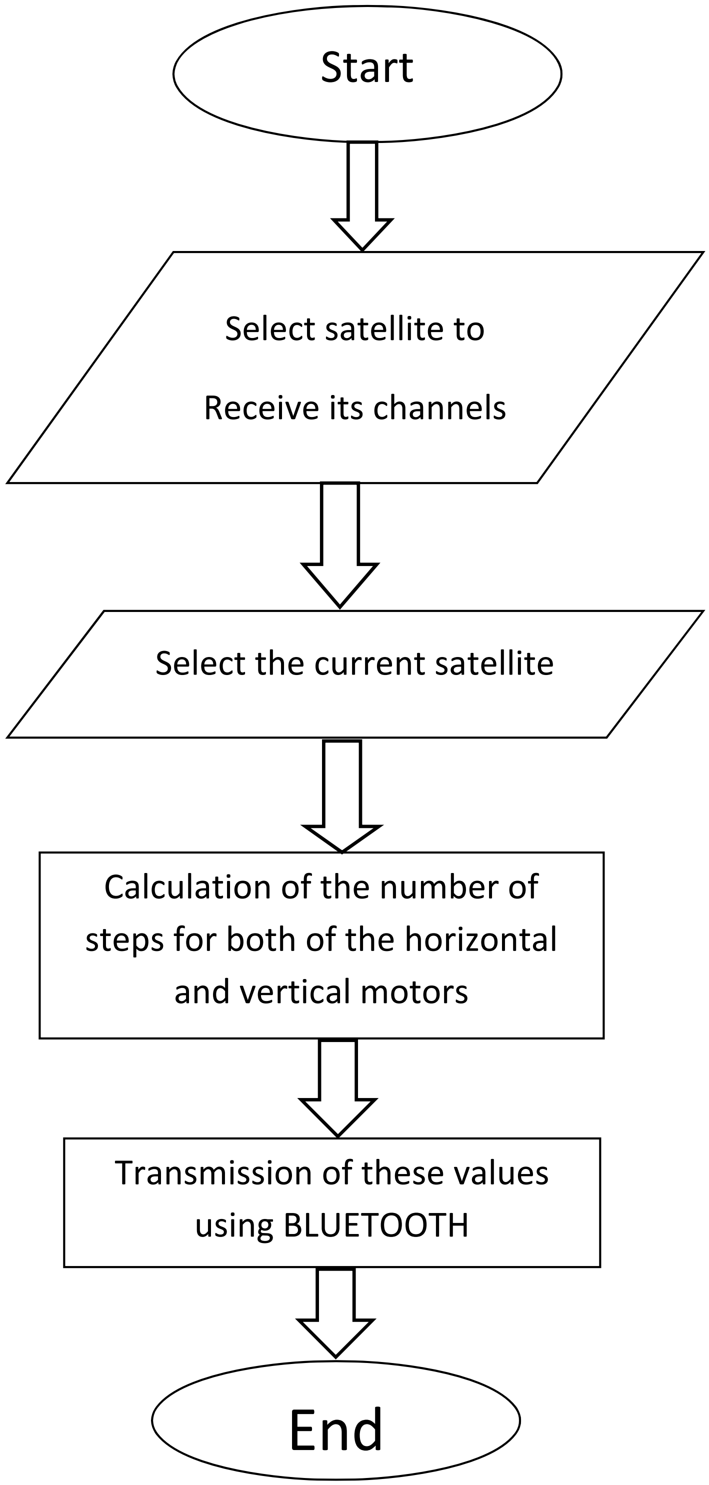

Figure (3.7): Flow chart of the android application

3.7 Flow Chart of ARDUINO Site:

Flow chart in figure (3.8) explains the algorithm of ARDUINO site. First ARDUINO will receive a string that contain the numbers of steps and the direction of moving for both of the horizontal and vertical motors via BLUETOOTH. Second ARDUINO will generate two signals each signal contain number of pulses that corresponded to the number of steps for intended motor. Third each received pulse has the effect of causing the motor to move the dish a single step. Fourth each motor will rotate to the specified angle that is composed from a number of an integer number of steps. Finally, the dish will be pointed to the desired satellite.

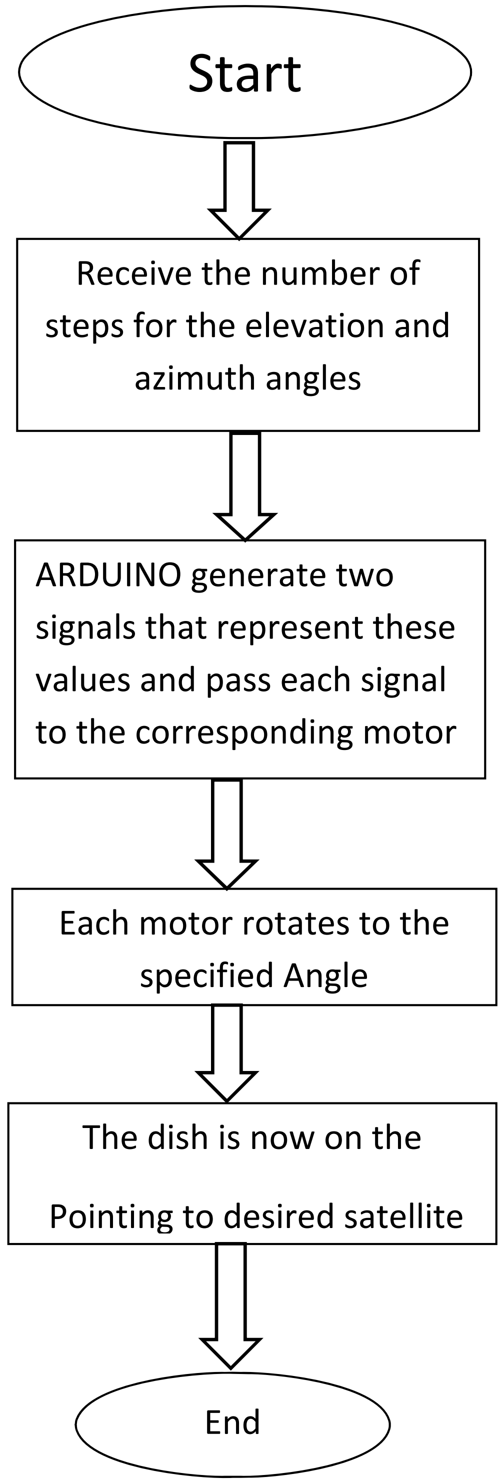

Figure (3.8): Flow chart of the ARDUINO site.