# Design of a Small-Sized VSAT Antenna

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***ABSTRACT***

*VSAT dish antenna is mainly of the size 5.5m to 15m for hub station and 1.2m to 3.5m for other uses such as mobile station, TV signal reception etc. There is need for this size to be reduced especially for the mobile station to allow easy mobility of the vehicle carrying it from one place to another. This is the aim of this work. From the design, which was carried out using analytical method, it was showed that smaller size of VSAT dish can be used for signal propagation with high gain and low beam width but at higher frequency. Reduced size or portable VSAT dish antenna can be used for signal propagation. This can be used for transmitting and/or receiving signals at higher frequencies with appreciable gain. Mobile stations like ships, security operation vehicle, satellite communication television or radio operators can transmit their signals using a very reduced size such as that of 0.3m diameter, 0.07m depth, 30GHz frequency, beam with of 2.33 and gain of 37.27dB seen in table 12 of this work.*

***KEYWORDS:*** *VSAT, Beamwidth, Gain, Frequency.*

## I. INTRODUCTION

A VSAT is a form of parabolic antenna which is used for signal transmission and/or reception at microwave frequency level. Parabolic dish are designed with different diameters which determines the focal length of it. Parabolic dish antenna can be used to receive signal like in the case of satellite television while some are used to send signals such as radio station. Some are also used for both reception and transmission of signals depending on the function which the station is made to perform. It has a feed, which after the dish has received the signal, the signal is then reflected to it which passes through different components, one of which is low noise block converter before it is delivered to the decoder that removes the signal from the carrier and allowed to be seen or heard as the case may be. This is the case of receiving station. In the case of transmitting station, the signal from the transmitter passes through various parts one of which is high power amplifier, from where the signal comes to the feed which then beams it on the dish and the dish now reflects the signal into space to be received by the satellite or other devices programmed to receive it. The feed of a dish is located at its focal point, which is where the signals tend to converge. The distance between the focal point and the inner centre of the dish is called the focal length. Figure 1 shows the schematic diagram of dish antenna.

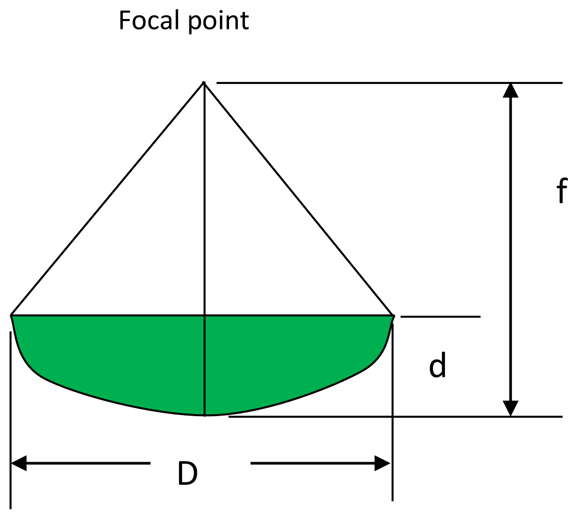


**Fig.: 1:** Shows the schematic diagram of dish antenna.

## II. LITERATURE REVIEW

Some of the works reviewed in the course of this work are as follows.

a. Design and Analysis of Parabolic Reflector Using MATLAB by Kirti and Satish, 2015. The work employed mathematical formula to determine the parameters of a dish antenna at frequencies from 2.79 - 3.75 GHz. The H- and E-plane radiation patterns were also done using matlab software.

b. Parabolic Antennas And Its Applications by Akshay et al., 2014. The design of a parabolic cylinder reflector antenna was done for high-power radar observations of signals scattered from the ionospheric plasma which will operate at a frequency of 224 MHz. Their paper describes the design considerations, the construction, and the testing of the performance of the completed antenna.

c. Design and Analysis of Parabolic Reflector with High Gain Pencil Beam and Low side lobes by Varying feed by Prabhakar et al., 2011. The work considers the radiation pattern of some antennas like dipole and horn antenna, and then compared with parabolic reflector.

d. Basic Antenna Theory and Application by Chuck Fung, 2011. It was a project report submitted to WORCESTER POLYTECHNIC INSTITUTE. The work looked at various antenna design including dish antenna

e. Antenna Theory, Analysis and Design by Balanis C.A., 1997

## III. METHODOLOGY

This paper makes use of mathematical (analytical) method using various formulas of parabolic dish design. In addition, Matlab softwarewill be used for the graphical relationship between some parameters of the designed VSAT dish.

At a particular frequency, the depth and diameter of the dish will be varied while the frequency will be kept constant. This trend was repeated for frequencies 3.0, 3.5, … 30.0 GHz. The gain and the beamwidth of the designed antenna were observed at various sizes (diameter and depths) with the view to obtain a reduced size with higher gain.

## IV. DESIGN PROCEDURE

The parameters of dish antenna and the way they can be gotten are explained briefly as follows.

The numerical or analytical method applies the mathematical processes to determine the values of the parameters of the dish antenna. The procedure involved in the mathematical method is shown below in a step-by-step form.

**i. Calculation of the focal length (f) of the dish:** The focal length of the dish is the distance between the centre of the dish and the point in which the reflected signals are focused or tend to converge. The focal length of the dish can be calculated using the values of the diameter, (D) and the depth, (d) of the dish. It is calculated using the formula given in equation 1.

$$f = \frac{D^2}{16d} \text{ ----------------------1}$$

Where $D$ = Diameter of the dish, $d$= Depth of the dish and $f$ = focal length of the antenna.
This is when the diameter and the depth are known or chosen for the design. In a situation where the diameter and the focal length are already selected, then the dish depth is to be determined. The depth of the dish is determined using the formula given in equation 2 as;

$$d = \frac{D^2}{16f} \text{ -------------------2}$$

**ii. Calculation of the ratio of the focal length (f) to the dish diameter (D), (f/D):** The ratio, (f/D) is a standard value used for installation of the dish. It is calculated using the formula given in equation3 as;

$$Focal\ lenght\ \ diameter\ ratio = \frac{f}{D} \text{ --- 3}$$

Where $f$ = focal length of the dish and D = diameter.
**iii. Calculation of the area (A) of the dish:** The area of the dish is calculated using the formula given in equation 4 as;

$$A = \frac{\pi D^2}{4} \text{ ------------------------- 4}$$

iv. Calculation of the gain, (G) of the antenna: The antenna gain is determined using the relation given in equations 5a and 5b as:

$$G = \frac{4\eta\pi \text{ A}}{\lambda^2} \text{ --------------------- 5a}$$

$$G = Log\left(\frac{4\eta\pi \text{ A}}{\lambda^2}\right) \text{ --------------- 5b}$$

Where A = Area of the dish, $\lambda$ = wavelength, $\eta$ = the efficiency of the antenna which is between 50% to 70% but 60% is used in this design.
Equation 5a is the gain in watt (W) and equation 5b is the gain is decibel, (dB).
**v. Calculation of the beam width:** Beam width is the angular diameter of the region adjoining an antenna through which the reception of the signal is best. It is the point at which the intensity of an antenna is at half of its maximum value.
The band width of the dish antenna is found using the formula given in equation 6 as;

$$Beam\ \text{width} = \frac{70\lambda}{D} \text{ ----------------- 6}$$

## V. RESULTS AND DISCUSSION

Summary of the result from Microsoft excel package.

**Table1:** At freq =2.5GHz, Efficiency = 0.6, and varying depth, d and diameter, D.

| D(m) | d (m) | Focal length (m) | f/D ratio | Beam Width($^0$) | Gain(dB) |
|---|---|---|---|---|---|
| **0.20** | 0.05 | 0.050 | 0.250 | 42.00 | 12.16 |
| 0.25 | **0.06** | 0.065 | 0.260 | 33.60 | 14.10 |
| **0.30** | 0.07 | 0.080 | 0.268 | 28.00 | 15.68 |
| **0.35** | 0.08 | 0.096 | 0.273 | 24.00 | 17.02 |
| **0.40** | 0.09 | 0.111 | 0.278 | 21.00 | 18.18 |
| **0.45** | 0.10 | 0.127 | 0.281 | 18.67 | 19.21 |
| **0.50** | 0.11 | 0.142 | 0.284 | 16.80 | 20.12 |
| **0.55** | 0.12 | 0.158 | 0.286 | 15.27 | 20.95 |

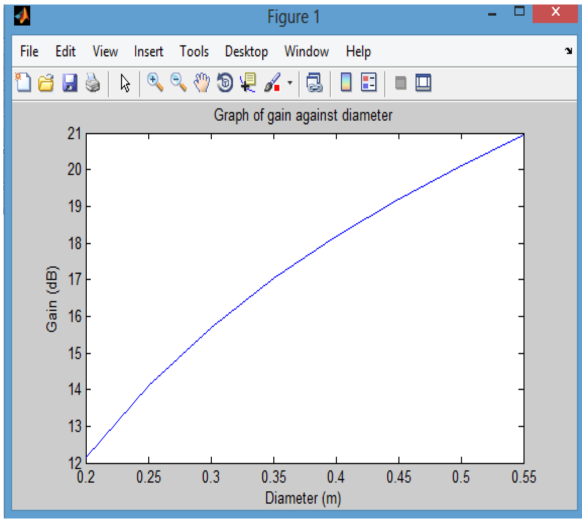


**Fig. 2:** Graph of antenna gain against diameter.

The gain of a dish antenna will decrease with increase in diameter when the frequency is constant, and will increase with increase in diameter. This is shown in figure 4.

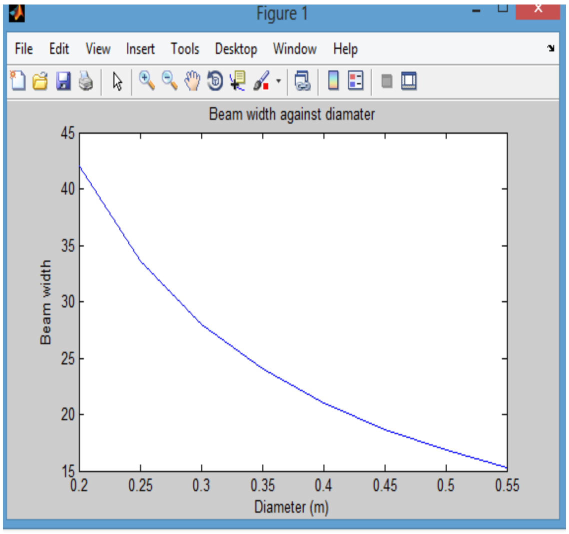


**Fig. 3:** Graph of beam width against diameter.

As the diameter is increasing, the beam width is decreasing. This shows the sloping down of the curve from left to the right.

**Table2:** At freq = 3GHz, Efficiency = 0.6, and varying depth, d and diameter, D.

| D (m) | d (m) | Focal length (m) | f/D ratio | Area $(m^2)$ | Beam Width $(^0)$ | Gain (dB) |
|---|---|---|---|---|---|---|
| **0.20** | 0.05 | 0.050 | 0.250 | 0.031 | 35.00 | 13.75 |
| 0.25 | **0.06** | 0.065 | 0.260 | 0.049 | 28.00 | 15.68 |
| **0.30** | 0.07 | 0.080 | 0.268 | 0.071 | 23.33 | 17.27 |
| **0.35** | 0.08 | 0.096 | 0.273 | 0.096 | 20.00 | 18.61 |
| **0.40** | 0.09 | 0.111 | 0.278 | 0.126 | 17.50 | 19.77 |
| **0.45** | 0.10 | 0.127 | 0.281 | 0.159 | 15.56 | 20.79 |
| **0.50** | 0.11 | 0.142 | 0.284 | 0.196 | 14.00 | 21.71 |
| **0.55** | 0.12 | 0.158 | 0.286 | 0.238 | 12.73 | 22.53 |

**Table3:** At freq =3.5GHz, Effi. = 0.6, and varying depth, d and diameter, D.

| D (m) | d (m) | Focal length (m) | f/D ratio | Area ($m^2$) | Beam Width ($^0$) | Gain(dB) |
|---|---|---|---|---|---|---|
| **0.20** | 0.05 | 0.050 | 0.250 | 0.031 | 30.00 | 15.09 |
| **0.25** | 0.06 | 0.065 | 0.260 | 0.049 | 24.00 | 17.02 |
| **0.30** | 0.07 | 0.080 | 0.268 | 0.071 | 20.00 | 18.61 |
| **0.35** | 0.08 | 0.096 | 0.273 | 0.096 | 17.14 | 19.95 |
| **0.40** | 0.09 | 0.111 | 0.278 | 0.126 | 15.00 | 21.11 |
| **0.45** | 0.10 | 0.127 | 0.281 | 0.159 | 13.33 | 22.13 |
| **0.50** | 0.11 | 0.142 | 0.284 | 0.196 | 12.00 | 23.04 |
| **0.55** | 0.12 | 0.158 | 0.286 | 0.238 | 10.91 | 23.87 |

**Table4:** At freq = 4GHz, Effi. = 0.6, and varying depth, d and diameter, D.

| D (m) | d (m) | Focal length (m) | f/D ratio | Area ($m^2$) | Beam Width ($^0$) | Gain (dB) |
|---|---|---|---|---|---|---|
| **0.20** | 0.05 | 0.050 | 0.250 | 0.031 | 26.25 | 16.25 |
| **0.25** | 0.06 | 0.065 | 0.260 | 0.049 | 21.00 | 18.18 |
| **0.30** | 0.07 | 0.080 | 0.268 | 0.071 | 17.50 | 19.77 |
| **0.35** | 0.08 | 0.096 | 0.273 | 0.096 | 15.00 | 21.11 |
| **0.40** | 0.09 | 0.111 | 0.278 | 0.126 | 13.13 | 22.27 |
| **0.45** | 0.10 | 0.127 | 0.281 | 0.159 | 11.67 | 23.29 |
| **0.50** | 0.11 | 0.142 | 0.284 | 0.196 | 10.50 | 24.20 |
| **0.55** | 0.12 | 0.158 | 0.286 | 0.238 | 9.55 | 25.03 |

**Table5:** At freq =4.5GHz, Efficiency = 0.6, and varying depth, d and diameter, D.

| D (m) | d (m) | Focal length (m) | f/D ratio | Area ($m^2$) | Beam Width ($^0$) | Gain (dB) |
|---|---|---|---|---|---|---|
| **0.20** | 0.05 | 0.050 | 0.250 | 0.031 | 23.33 | 17.27 |
| **0.25** | 0.06 | 0.065 | 0.260 | 0.049 | 18.67 | 19.21 |
| **0.30** | 0.07 | 0.080 | 0.268 | 0.071 | 15.56 | 20.79 |
| **0.35** | 0.08 | 0.096 | 0.273 | 0.096 | 13.33 | 22.13 |
| **0.40** | 0.09 | 0.111 | 0.278 | 0.126 | 11.67 | 23.29 |
| **0.45** | 0.10 | 0.127 | 0.281 | 0.159 | 10.37 | 24.31 |
| **0.50** | 0.11 | 0.142 | 0.284 | 0.196 | 9.33 | 25.23 |
| **0.55** | 0.12 | 0.158 | 0.286 | 0.238 | 8.48 | 26.05 |

**Table6:** At freq =5GHz, Efficiency = 0.6, and varying depth, d and diameter, D.

| D (m) | d (m) | Focal length (m) | f/D ratio | Area ($m^2$) | Beam Width ($^0$) | Gain (dB) |
|---|---|---|---|---|---|---|
| **0.20** | 0.05 | 0.050 | 0.250 | 0.031 | 21.00 | 18.18 |
| **0.25** | 0.06 | 0.065 | 0.260 | 0.049 | 16.80 | 20.12 |
| **0.30** | 0.07 | 0.080 | 0.268 | 0.071 | 14.00 | 21.71 |
| **0.35** | 0.08 | 0.096 | 0.273 | 0.096 | 12.00 | 23.04 |
| **0.40** | 0.09 | 0.111 | 0.278 | 0.126 | 10.50 | 24.20 |
| **0.45** | 0.10 | 0.127 | 0.281 | 0.159 | 9.33 | 25.23 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **0.50** | 0.11 | 0.142 | 0.284 | 0.196 | 8.40 | 26.14 |
| **0.55** | 0.12 | 0.158 | 0.286 | 0.238 | 7.64 | 26.97 |

**Table7:** At freq =10GHz, Efficiency= 0.6, and varying depth, d and diameter, D.

| D(m) | d (m) | Focal length (m) | f/D ratio | Area ($m^2$) | Beam Width($^0$) | Gain (dB) |
|---|---|---|---|---|---|---|
| **0.20** | 0.05 | 0.050 | 0.250 | 0.031 | 10.50 | 24.20 |
| **0.25** | 0.06 | 0.065 | 0.260 | 0.049 | 8.40 | 26.14 |
| **0.30** | 0.07 | 0.080 | 0.268 | 0.071 | 7.00 | 27.73 |
| **0.35** | 0.08 | 0.096 | 0.273 | 0.096 | 6.00 | 29.06 |
| **0.40** | 0.09 | 0.111 | 0.278 | 0.126 | 5.25 | 30.22 |
| **0.45** | 0.10 | 0.127 | 0.281 | 0.159 | 4.67 | 31.25 |
| **0.50** | 0.11 | 0.142 | 0.284 | 0.196 | 4.20 | 32.16 |
| **0.55** | 0.12 | 0.158 | 0.286 | 0.238 | 3.82 | 32.99 |

**Table8:** At freq =15GHz, Efficiency = 0.6, and varying depth, d and diameter, D.

| D (m) | d (m) | Focal length (m) | f/D ratio | Area ($m^2$) | Beam Width ($^0$) | Gain (dB) |
|---|---|---|---|---|---|---|
| **0.20** | 0.05 | 0.050 | 0.250 | 0.031 | 7.00 | 27.73 |
| **0.25** | 0.06 | 0.065 | 0.260 | 0.049 | 5.60 | 29.66 |
| **0.30** | 0.07 | 0.080 | 0.268 | 0.071 | 4.67 | 31.25 |
| **0.35** | 0.08 | 0.096 | 0.273 | 0.096 | 4.00 | 32.59 |
| **0.40** | 0.09 | 0.111 | 0.278 | 0.126 | 3.50 | 33.75 |
| **0.45** | 0.10 | 0.127 | 0.281 | 0.159 | 3.11 | 34.77 |
| **0.50** | 0.11 | 0.142 | 0.284 | 0.196 | 2.80 | 35.68 |
| **0.55** | 0.12 | 0.158 | 0.286 | 0.238 | 2.55 | 36.51 |

**Table 9:** At freq =20GHz, Efficiency = 0.6, and varying depth, d and diameter, D.

| D (m) | d (m) | Focal length (m) | f/D ratio | Area ($m^2$) | Beam Width ($^0$) | Gain (dB) |
|---|---|---|---|---|---|---|
| **0.20** | 0.05 | 0.050 | 0.250 | 0.031 | 5.25 | 30.22 |
| **0.25** | 0.06 | 0.065 | 0.260 | 0.049 | 4.20 | 32.16 |
| **0.30** | 0.07 | 0.080 | 0.268 | 0.071 | 3.50 | 33.75 |
| **0.35** | 0.08 | 0.096 | 0.273 | 0.096 | 3.00 | 35.09 |
| **0.40** | 0.09 | 0.111 | 0.278 | 0.126 | 2.63 | 36.25 |
| **0.45** | 0.10 | 0.127 | 0.281 | 0.159 | 2.33 | 37.27 |
| **0.50** | 0.11 | 0.142 | 0.284 | 0.196 | 2.10 | 38.18 |
| **0.55** | 0.12 | 0.158 | 0.286 | 0.238 | 1.91 | 39.01 |

**Table10:** At freq =25GHz, Efficiency = 0.6, and varying depth, d and diameter.

| D (m) | d (m) | Focal length (m) | f/D ratio | Area ($m^2$) | Beam Width ($^0$) | Gain (dB) |
|---|---|---|---|---|---|---|
| **0.20** | 0.05 | 0.050 | 0.250 | 0.031 | 4.20 | 32.16 |
| **0.25** | 0.06 | 0.065 | 0.260 | 0.049 | 3.36 | 34.10 |
| **0.30** | 0.07 | 0.080 | 0.268 | 0.071 | 2.80 | 35.68 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **0.35** | 0.08 | 0.096 | 0.273 | 0.096 | 2.40 | 37.02 |
| **0.40** | 0.09 | 0.111 | 0.278 | 0.126 | 2.10 | 38.18 |
| **0.45** | 0.10 | 0.127 | 0.281 | 0.159 | 1.87 | 39.21 |
| **0.50** | 0.11 | 0.142 | 0.284 | 0.196 | 1.68 | 40.12 |
| **0.55** | 0.12 | 0.158 | 0.286 | 0.238 | 1.53 | 40.95 |

**Table11:** At freq =30GHz, Efficiency = 0.6, and varying depth, d and diameter, D.

| D (m) | d (m) | Focal length (m) | f/D ratio | Area ($m^2$) | Beam Width ($^0$) | Gain (dB) |
|---|---|---|---|---|---|---|
| **0.20** | 0.05 | 0.050 | 0.250 | 0.031 | 3.50 | 33.75 |
| **0.25** | 0.06 | 0.065 | 0.260 | 0.049 | 2.80 | 35.68 |
| **0.30** | 0.07 | 0.080 | 0.268 | 0.071 | 2.33 | 37.27 |
| **0.35** | 0.08 | 0.096 | 0.273 | 0.096 | 2.00 | 38.61 |
| **0.40** | 0.09 | 0.111 | 0.278 | 0.126 | 1.75 | 39.77 |
| **0.45** | 0.10 | 0.127 | 0.281 | 0.159 | 1.56 | 40.79 |
| **0.50** | 0.11 | 0.142 | 0.284 | 0.196 | 1.40 | 41.71 |
| **0.55** | 0.12 | 0.158 | 0.286 | 0.238 | 1.27 | 42.53 |

**Table12:** Summary for diameter of 0.3m and depth 0.07m at efficiency of 0.6 and varying frequencies

| Freq (GHz) | λ (m) | Area ($m^2$) | Beam Width ($^0$) | Gain(dB) |
|---|---|---|---|---|
| **2.5** | 0.120 | 0.071 | 28.00 | 15.68 |
| **3.0** | 0.100 | 0.071 | 23.33 | 17.27 |
| **3.5** | 0.086 | 0.071 | 20.00 | 18.61 |
| **4.0** | 0.075 | 0.071 | 17.50 | 19.77 |
| **4.5** | 0.067 | 0.071 | 15.56 | 20.79 |
| **5.0** | 0.06 | 0.071 | 14.00 | 21.71 |
| **10.0** | 0.030 | 0.071 | 7.00 | 27.73 |
| **15.0** | 0.020 | 0.071 | 4.67 | 31.25 |
| **20.0** | 0.015 | 0.071 | 3.50 | 33.75 |
| **25.0** | 0.012 | 0.071 | 2.80 | 35.68 |
| **30.0** | 0.010 | 0.071 | 2.33 | 37.27 |

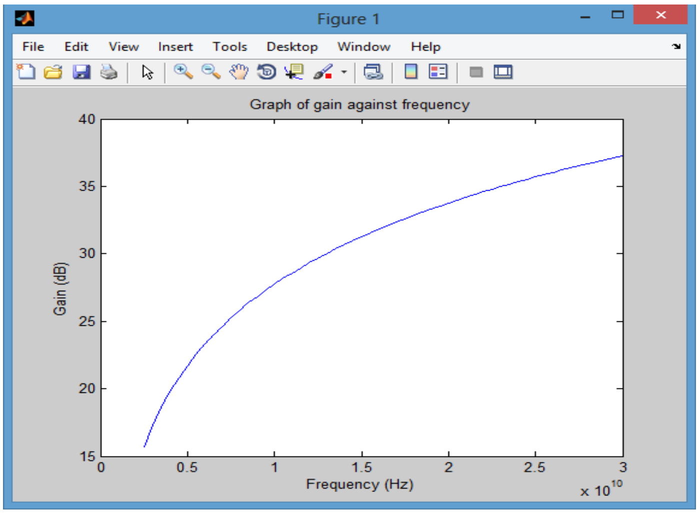

**Fig. 4:** Graph of gain against frequency.

At varying frequency and constant diameter, the antenna gain increases with increase in frequency.

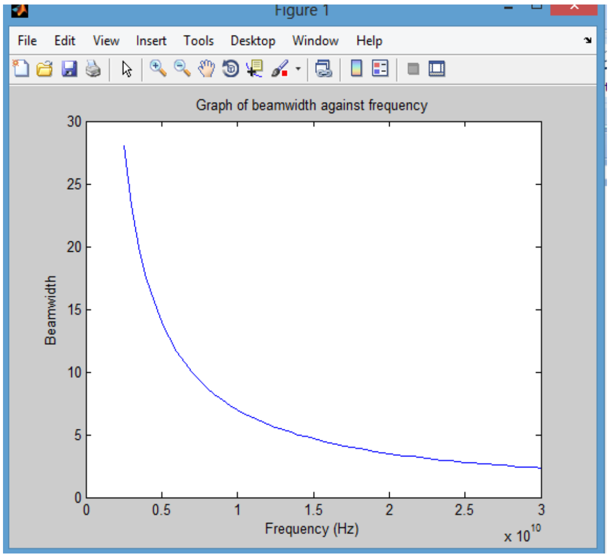


**Fig. 5:** Graph of beam width against frequency.

At varying frequency and constant diameter, the beam width decreases with increase in frequency.

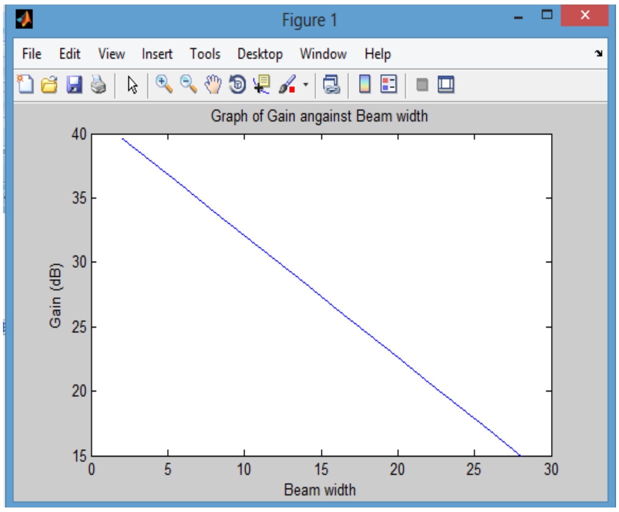


**Fig. 6:** Graph of antenna gain and beam width. The gain increases with decrease in beam width.

## VI. DISCUSSION

From tables 1 -11, it can be seen that the focal length increases with increase in the diameter of the dish and vice versa. Also, the result shows that at constant frequency, the beam width of the antenna decreases as the diameter is increasing. In antenna, narrow beam width enables the signals to have more precise targeting. This means that the signal will have narrow angle in which the signal will be radiated from the antenna. In the case of gain, at constant frequency, the gain of the antenna increases with increase in the diameter of the dish. It is also desirable to have higher gain in any antenna design as that will allow reception of clear signals. As the frequency was varied with the same values of diameter of the dish and its depth, it was seen that the gain continued to increase. These are shown in table 12. The table showed the various gains and beam widths at the constant diameter of 0.3m

(30cm) and depth of 0.07m (7cm). When the frequency was varied from 2.5GHz to 3GHz, the gain increased from 15.68dB to 17.27dB, while the beam width decreases from 28 to 23.33. As the frequency was varied from 3GHz to 3.5GHz, the gain increased from 17.27dB to 18.61dB, while the beam width decreases from 23.33 to 20. When frequency was varied from 3.5GHz to 4GHz, the gain increased from 18.61dBdB to 19.77dB, while the beam width decreases from 20 to 17.5. At the frequency of 15GHz, the antenna gain is 31.25dB, at 20GHz, the gain increased to 33.75dB, while at the frequency of 30GHz, the gain increased to 37.27dB. At these frequencies, i.e. 15GHz, 20GHz and 30GHz, the beam widths decreased from one value to the other. All these changes occur at constant diameter of the dish and constant depth. This indicates that, at higher frequency, portable dish antenna can be used to transmit or receive signals with desirable gain and beam width. This type of dish can be used by security operatives that require such equipment for signal transmission during emergency or when other forms of communication are not functioning. Ships and outside broadcasting vans that transmit via satellite will make of this type of VSAT dish antenna. The smaller the size of the VSAT dish on the vehicle, the faster it will move to the destination where it is needed as the wider one reduces its movement due to air resistance. At these higher frequencies in which the antenna can transmit and /or receive signal of higher gain, the signal will at the same time travels in narrow angular direction towards the target.

## VII. CONCLUSION

The major parameters of the dish antenna have been discussed briefly, and their values are calculated with some been varied. Basing the design of the VSAT dish on the efficiency of 60%, the beam width and gains determined from various values of diameters, depths and frequencies showed that at higher frequency, the size of the transmitting or receiving antenna will be reduced. Also, from the values gotten from the determination of the beam width of the antenna and its gains at varying frequencies and constant diameter and depth of the dish, it showed that at higher frequency, a reduced or portable type of VSAT dish antenna can be used for signal propagation.

## VIII. RECOMMENDATION

This design was carried out using analytical method with just little software applications. The simulation of the radiation patterns and other parameters using antenna design software for the same antenna should be further looked into.

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