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# Improved Satellite Receiver Reflector Antenna for Digital Satellite Television using Parabolic Method

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**ABSTRACT**

**Parabolic antennas are used in a variety of communication systems including satellite communication. Signal loss due to distance and misalignment is a significant problem facing the satellite industry today. The research work is aimed at improving the parabolic reflector antenna in terms of gain and signal quality and is undertaken using CST simulation. This consists of employing the use of double sub reflectors on the main parabolic reflectors, which keeps the EM wave within the enclosure of the feed antenna and the main reflector.Thiswill then aid the antenna to accumulate more signals as well improve the gain of the antenna. The results of this research show that the antenna performance has a radiation efficiency of 85% at an antenna power of 0.5 watts, with a VSWR of less than 2 and a maximum radiation directivity of 8.94 dB.The double sub-reflector gain is found to be 40 dB. In conclusion, the research work considered the diameter of the parabolic reflector, the focal length, the diameter and lend length of the sub reflectors and the width and length of the feed horn antenna. For further research, it is recommended thatother advanced techniques be used for theimprovement of the gain of the parabolic antenna.**

Keywords –**Antenna, Gain, Satellite, Signal loss,VSWR.**

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## I. INTRODUCTION

An artificial satellite called communication satellite transmits and amplifies radio telecommunication signals between a source transmitter and a receiver located at various locations on Earth using a transponder. Military applications, internet, radio, television, and telephone all make use of communications satellites. There are 2,134 communications satellites that are used by both commercial and governmental organizations in orbit around the Earth [1]. Its limitless reception has given signal transmission and signal receiver new dimensions. The satellite is unaffected by geographical and political boundaries. Regardless of the user's location, satellite communication has evolved into a versatile and affordable option for both domestic and worldwide networks. Using satellite technology, cities across a vast area are now connected, solving some of the most difficult access issues [1].

A parabolic antenna is also defined as an antenna that makes use of a parabolic reflector. It has a curved surface with a parabola-shaped cross-section, which is mostly used to guide radio waves. Its most popular design is fashioned like a dish and is known as a parabolic dish or dish antenna. The concave lens, which reflects all signals parallel to it to the focus, and the operation of a parabolic dish is identical. Generally speaking, a satellite dish serves two key purposes in satellite communication [1]. It functions as both a transmitter and a receiver, making it a transceiver. The feed horn antenna functions as a transmitter, coupling radio frequency current from the satellite provider or service provider through a transmission line to the transducer that transforms electrical signals into radio waves appropriate for space travel. The feed emits radio waves back toward the dish, which the dish then reflects. Additionally, the satellite dish serves as a concave lens with a specific point of "focus" where all of the reflected signals converge when acting as a receiver. The incoming electromagnetic waves will be intercepted by a dish of the proper size, which will then reflect them onto the focus point's low-noise block converter (LNB). The LNB converts the radio waves into a signal that is transmitted by a cable to the receiver within the structure [2].

The most frequent problem related to satellite receivers is due tothe diameter and position of the antenna. Improper selection of these two variables can lead to signal loss and poor gain. Another key factor that results in signal loss is the material used as some materials are known to absorb over 40% of the received signal.

[3] stated that they explored many issues related to parabolic reflectors, their causes, and solutions in their research effort. The issues include cross-polarization, feed spillover, feed illumination taper, pointing error, surface error, and phase error. They also include side lobe radiations, edge diffraction, aperture obstruction, and edge

diffraction. These issues have a negative impact on the antenna's overall gain, efficiency, and directivity, impeding effective communication. Phase inaccuracy is typically the most challenging of the issues, according to the survey's findings, because it might be difficult to locate the phase center at the reflector's focus. Because the issue can be resolved by switching from a center feed to an offset feed, the aperture obstruction appears to have the least number of potential solutions. Since parabolic reflectors are one of the most popular antennas with a wide range of applications, a thorough analysis of these issues and the appropriate solutions is required.

[4] reduced the impact of edge diffraction caused by compact range reflectors by using serrated edge treatment. [4] emphasized that when taking measurements in CATR, there are several approaches to reduce ripples, both in terms of phase and magnitude (Compact Antenna Test Range). Folding and serration of the edge were taken into consideration to lessen edge diffracted fields at the reflector's edge.

With centre or front-fed antenna at the focus, aperture blockage is a common issue with parabolic reflectors. The feed horn creates a shadow that deflects the parabolic antenna reflector's beam and causes interference. The feed horn prevents the reflector's light from passing through it. By using an offset feed, [5] was able to resolve this issue.

In terms of communication, one of the cheapest and best means of communication is satellite communication, this method makes it easier for those in remote areas to also gain access to the same information, places where telecommunication mast hasn't gotten to. The most important factor of this research work is that the antenna improvement will give rise to high frequency gain, good reflection system, good voltage standing wave ratio for those in the urban and rural areas to enjoy quality signals.

## II. MATERIALS AND METHOD

The materials used for this study include PEC, feeder, parabolic reflector, and CST software. The method adopted is the CST parabolic reflector method. The parabolic reflector, as its name suggests, is made of a shape called a paraboloid. This form creates the antenna's reflective surface, which maintains the phase connection of the waves it reflects, allowing for the achievement of maximum gain.

Electromagnetic waves carrying RF energy will be reflected by the reflector and remain in phase at the focal point if they are moving in a plane wave front and headed in the direction of the antenna. This method avoids cancellation and maintains the phase of the full signal. The maximum signal is therefore maintained. The parabolic reflector, on the other hand, will bounce back signals that are emitted at the focal point, forming an in-phase parallel wave front that moves away from the antenna. The parabolic reflector shape enables the wave fronts to remain in phase:

$$A_1 + A_2 = B_1 + B_2 \quad (1)$$

The phase integrity of the system is maintained because the total length of A1 + A2 is the same as B1 + B2, etc. At the focal point, incoming waves combine with outgoing waves to form a single wave front that is flowing away from the reflector in parallel [6].

The properties of the reflector are determined by the parabolic reflector theory. All the power is reflected in a beam with wave traces that are parallel to one another thanks to the reflector's parabolic form. Because the travel length from the source to the reflector and then outwards is the same wherever it is reflected on the parabola's surface, all the reflected power is also in the same phase. [6].

The parabolic curve follows the equation:

$$Y^2 = 4\,S\,X$$

(2)The apex distance of the main reflector to the phase center Lm and Ls is the distance to the sub-reflectors to the phase center of the feed, which plays a crucial role in the reflector system for the double sub-reflector parabolic reflector antenna system for positioning the main reflector, sub-reflector, and feed at the appropriate position. This can be mathematically represented as [6]:

$$Lm = \frac{1}{16}\frac{y3}{pmsin(\theta_e)F(\sigma pm+4_{y1})} \quad (3)$$

$$Ls = \frac{\sigma pm(Lm-F)}{\sigma Dm-4Ftan\left(\frac{\theta_e}{2}\right)} \quad (4)$$

$$f = \frac{ps^2 y_2(\sigma pm-4y_1)}{32\sin(\theta_e)F(\sigma pm+4_{y1})pm} \quad (5)$$

$$a = \frac{ps^2 y_2}{32\sin(\theta_e)pm} \quad (6)$$

Where σ=-1 for a Gregory system, pm is the diameter of the main reflector and $ps^2$are the two sub reflectors while y1, y2 and y3 are variables which can be calculated using

$$\theta_e = 2tan^{-1}\left(\frac{1}{4\frac{eff}{D}}\right) \quad (7)$$

And for a small size antenna (D<100) for the Gregorian system, which is more attractive since it provides low blockades and avoids diffraction losses.

The focal length is a crucial component of the parabolic reflector antenna theory. The radiating element must be positioned at the focal point for the antenna to function properly. Knowing the focal length is important to make this determination[6].

$$f = \frac{D^2}{16C} \quad (8)$$

Where:

f is the focal length
D is the diameter of the reflector
c is the depth of the reflector

The f/D ratio is crucial in addition to that. The focal length can be easily determined by multiplying the f/D ratio by the provided diameter D because the f/D ratio is frequently specified together with the diameter. Additionally, as indicated, we can ascertain the reflector's depth [6]:

$$c = \frac{(D/2)^2}{4f} \quad (9)$$

In the overall gain formula for the antenna, an efficiency factor is included. Typically, this may be between 50 and 70% dependent upon the actual antenna.

The parabolic reflector antenna gain efficiency is dependent upon a variety of factors. These are all multiplied together to give overall efficiency.

$$k = k_r k_t k_s k_m \quad (10)$$

Radiation effectiveness, abbreviated as kr: The radiation effectiveness is indicated above. The resistive or Ohmic losses inside the antenna control it. It is governed by the antenna element's RF energy radiating component's

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radiation efficiency. This is high and very close to unity for most antennas. As a result, the radiation efficiency has little impact on the gain of the parabolic reflector antenna and is typically disregarded.

Spillover Efficiency ks: In the example above, ks stands for spillover efficiency. The efficiency and, consequently, the gain of the parabolic reflector antenna will be reduced by any energy that leaks over the edge of the reflector surface. The reflector surface should be fully and evenly lighted in the ideal situation, with no light spilling over the edge.

Aperture Taper Efficiency kt: In (10), kt stands for the aperture taper efficiency. Because the entire parabolic reflector must be adequately lighted to get the best gain, it has an impact on the antenna's gain. The gain of the parabolic reflector will be lessened if some areas of the surface are not sufficiently lit by the radiator's radiation. The centre should be illuminated slightly more than the periphery to work at its best.

Surface Error: The surface must closely match the parabolic contour to deliver the maximum potential levels of parabolic reflector antenna gain. Poor reflection accuracy will occur from deviations from this. However, if the holes in the gauze or mesh are small in relation to a wavelength, it is possible to utilize gauze for the reflector to reduce weight and wind resistance. The reflective metal mesh's slots and holes must be no wider than 1/10.

Aperture Blockage: A portion of the reflector is frequently hidden by the physical design of the feed and other antenna components. Naturally, this lowers efficiency and, as a result, antenna gain. The antenna gain calculation must take this element into account.

Cross Polarization: As with any other antenna, the sent and received signals' polarizations must coincide for there to be no loss more than the sine of the angle between the polarizations, providing that the polarizations are linear.

Non-Single Point Feed: The reflector has a single focal point. The antenna will, however, extend beyond the reflector's focal point because all antennas have a fixed size. This becomes a bigger issue and has a bigger effect on antenna gain the larger the radiating element is in relation to the reflecting surface.

The numerous auxiliary efficiency components, which are frequently harder to evaluate, are referred to as km. Aperture obstruction, cross-polarization, surface effort, and the non-single point feed are a few of these.

The beam width narrows as the gain of the parabolic antenna, or any antenna increases. The locations on a radiation pattern polar where the power drops to half of the maximum or the -3dB points, are typically used to define the beam width.

The following formula can be used to reliably calculate the beam width [6] and [9].

$$Beamwidth\,\psi = \frac{70\lambda}{D} \quad (11)$$

Where:

G is the gain over an isotropic source in dB

D is the diameter of the parabolic reflector

λ is the wavelength of the signal

All dimensions must be in the same units for the calculation to be correct, e.g., both diameter and wavelength in meters, or both in feet, etc.

Knowing the diameter of the reflecting surface, the signal's wavelength, and an estimate of the efficiency of the antenna will allow one to compute the parabolic antenna gain with ease. The gain over an isotropic source, or relative to a source that radiates evenly in all directions, is used to compute the parabolic reflector antenna gain. Most antennas are compared to this theoretical source, which serves as the standard. This form of quotation denotes the gain as dBi.

The standard formula for the parabolic reflector antenna gain is [6]:

$$G = 10log_{10}k(\frac{\pi D}{\lambda})^2 \quad (12)$$

Where:

G is the gain over an isotropic source in dB

k is the efficiency factor which is generally around 50% to 60%, i.e. 0.5 to 0.6

D is the diameter of the parabolic reflector in metres

λ is the wavelength of the signal in metres

This demonstrates that if sufficiently big reflectors are used, very high gains can be obtained. The beamwidth is likewise very tiny when the antenna has a very big gain, and thus necessitates extremely careful positioning of the antenna. Electrical servo systems are utilized in professional systems to give incredibly precise positioning.

As can be observed, for antennas with reflector diameters of 100 wavelengths or greater, the parabolic reflector gain can be of the order of 50 dB. While many antenna designs, like the Yagi and many others, would not be practical for antennas of this size, the parabolic reflector can be engineered to be quite large in proportion to the wavelength, allowing it to achieve these tremendous gain values. These antennas are typically a few wavelengths in size, but they can still deliver extremely high levels of gain.

It is vital to position the radiating element at the reflector's focal point when feeding a parabolic reflector antenna. The focal point of a parabolic reflector is where all reflected waves are concentrated. If the antenna's radiating element is positioned in this location, antenna reflection will work to maximize gain and preserve proper operation. The following equation is used to compute the focal length f (distance of the focal point from the reflector's centre) [6-8]:

$$f = \frac{D^2}{16C} \quad (13)$$

Where:

f is the focal length of the reflector

D is the reflector diameter in the same units as the wavelength

c is the depth of the reflector

The conductive reflector surface conducts current in response to the feed element's radiation, which then reradiates in the desired direction perpendicular to the paraboloid's directrix plane. Any of the many different types of antennas can serve as the feed element. Whichever type is employed, it must have the proper polarization for the application and must have a directivity that effectively illuminates the reflector. The polarization of the feed determines the polarization of the overall antenna system. At lower frequencies, a half-wave dipole is the most basic feed and is frequently employed, occasionally in conjunction with a strongly connected parasitic reflector or "splash plate." A horn-type becomes more practical and effective at higher frequencies. A section of waveguide is utilized to make the transition from the horn to a coaxial antenna cable.

The parabolic antenna has two dimensions that are very significant. These are the diameter, D, and the focal length, f. The f/D ratio is typically one of the characteristics used to identify parabolic antennas. The focal length can be easily determined by multiplying the f/D ratio by the provided diameter D because the f/D ratio is frequently specified together with the diameter.

The design parameters used are summarized in Table 1 to Table 4.

Table 1 Design parameters of the main parabolic reflector

| Diameter (cm) | Dish Thickness (mm) | Focus(mm) | Tapper Angle (mm) |
|---|---|---|---|
| 60 | 2 | 0.5 times 60 | 10 |

Table 2 Design parameters of the double sub reflectors of the parabolic reflector antenna

| Diameter (mm) | Length (mm) | Height (mm) | Thickness (mm) |
|---|---|---|---|
| 8 | 6 | 4 | 2 |

Table 3 Focus length of the main reflector and the sub reflectors

| Focus Length of the main Reflector (mm) | Focus Length of the Sub Reflector 1(mm) | Focus Length of the Sub Reflector 2(mm) |
|---|---|---|
| 0.5 times 60 | 0.5 times 58 | 0.5 times 58 |

Table 4 Feed horn receiver antenna design characteristics

| Feed Horn Length (mm) | Wall thickness (mm) | Waveguide Width (mm) | Waveguide Height(mm) |
|---|---|---|---|
| 10 | 2 | 5 | 4 |

## III. RESULTS

The farfield radiation pattern of the antenna has maximum radiation at the theta z with over 40 dB. This implies that the radiation on this part of the antenna is highly intense. The frequency is at 32 GHz with a very strong output directivity influenced by the double sub-reflectors. So the antenna at farfield also has a higher radiation efficiency of 40 dB as shown in Fig. 1 and Fig.2.

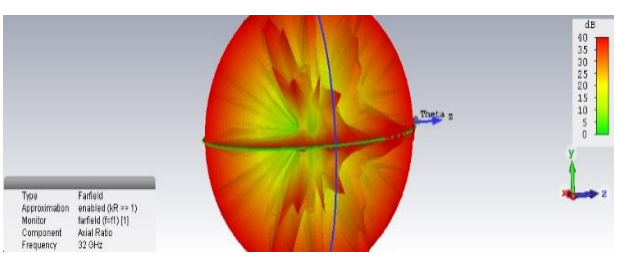
Figure 1: Farfield Radiation on the right-hand side of the reflector antenna

The directivity of the antenna in Fig.2 describes the maximum radiation of the antenna; this implies that the antenna is radiating fully. The results show that the antenna radiation efficiency is 77.10 dB with an 8.94 dBi directivity. From the theta axis of the antenna, it can be shown in Fig.2 that the antenna has rapid radiation due to the sub reflectors placed on the parabolic reflectors.

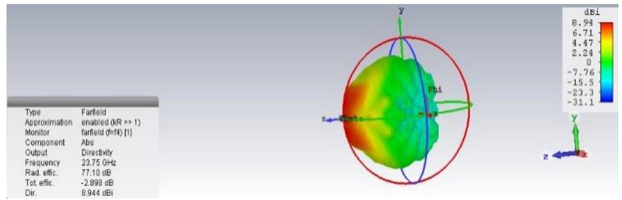
Figure 2 farfield radiation of the focal point

From the result in Fig.3, it is shown that the stimulated power is 0.5 watts, for antenna to be activated to receive or transmit signal, the antenna needs a stimulating power to stimulate the antennas electromagnetic fields. This stimulated power is so small but due to the material used in designing the parabolic reflector, makes it a low power consumption antenna. The antenna as stipulated has a stimulated power of 0.5 watts.

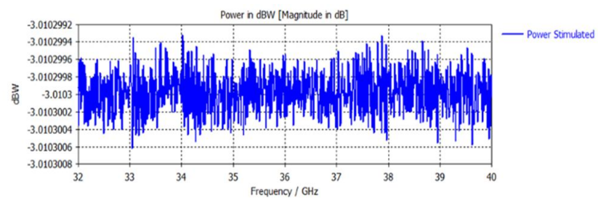

Figure 3 Stimulated power

From the results, it is also shown in Fig.4, that the accepted power to run the antenna is 0.49 watts acceptable power to run the antenna. That's to say that not all the stimulated power was accepted but recorded a very low loss due to the design and efficiency of the antenna.

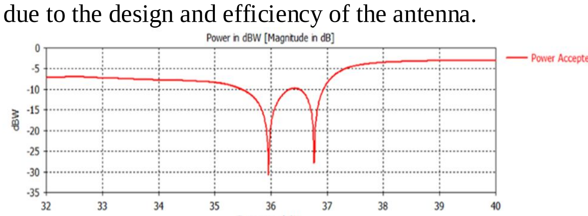

Figure 4 Accepted Power of the Antenna

The outgoing power of the parabolic reflector antenna is 0.45 watts which is 0.2 watts lesser than the stimulated power. This indicates that the strength of the signal strength that leaving to the receiver module. The outgoing power has a lesser loss due to wave dispersions and scatterings on the reflectors as shown in Fig.5.

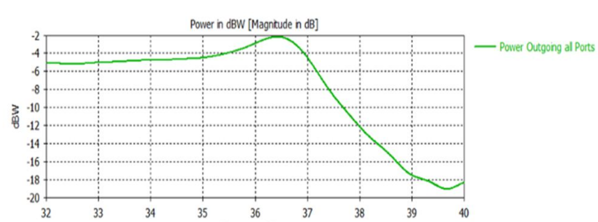

Figure 5 Outgoing Power

The radiated power of the antenna spiked to 1 watt at 38GHz. The radiated power became twice as strong as the

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stimulated power. Indicating that the double sub-reflectors were able to trap more of the signals within the parabolic reflectors. This method increased the radiation power and as well the radiation efficiency as seen in Fig. 6 and 7.

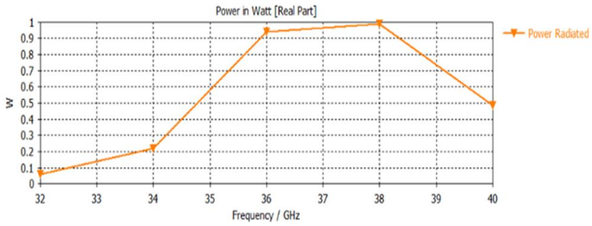

Figure 6 Radiated Power

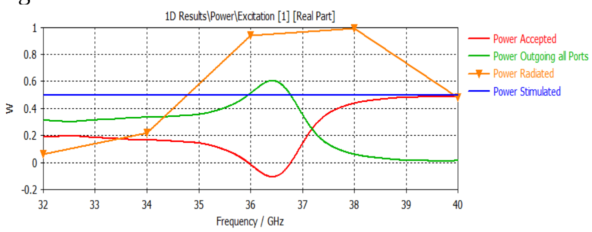

Figure 7 Results of the Radiated power and Accepted power

## IV. DISCUSSION

The conventional parabolic reflector antenna is shown in Fig. 8. This type of antenna has or experiences more losses because not all reflected signals from the satellite are trapped by the horn antenna. This is because when signals hit the reflectors, some of these signals are reflectedin free space while some are trapped by the horn or feed antenna. This method creates more losses in the channel because the gain of the antenna will be reduced since it doesn't get enough signals. This method of reflector antennas records more losses as shown in Fig.8.

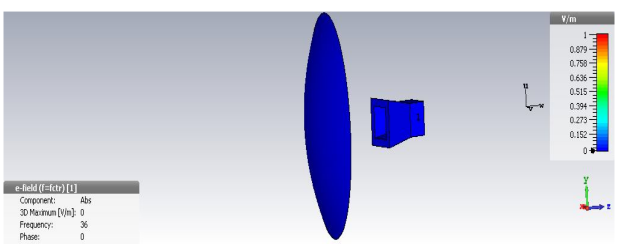

Figure 8 Conventional Parabolic Receiver

The improved Gregorian double sub-reflectorsare shown in the figure. This method of reflection antenna has more gains. The increment in directivity gain is dependent on the double sub-reflectors. This is because when signals from the satellite strike the parabolic reflector the dispersed signals are being trapped by the sub reflectors on both sides. These sub reflectors cause the signals to reflect again and bounce to the feed antenna or horn antenna of the receiver. This effect tends to make the antenna trap more signals. With this, the gain of the antenna is improved, the radiation efficiency is improved the directivity of the antenna is also improved. By this process, signal losses are reduced when compared to the conventional parabolic reflectors as shown in Fig. 9 and Fig.10.

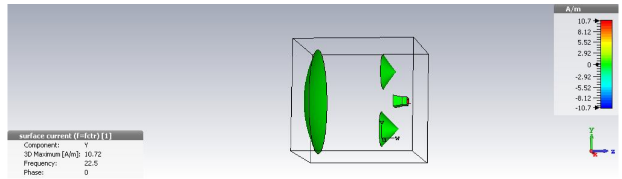

Figure 9 Side View of the Sub-Parabolic Reflector

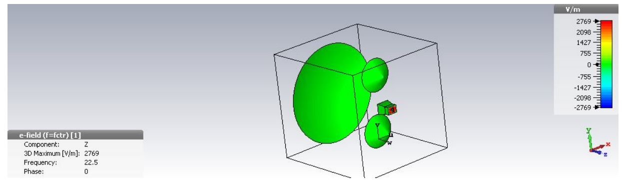

Figure 10 Full view of the Sub Parabolic Reflector Antenna

The voltage standing wave ratio is the most important thing in antenna design. The standing wave ratio of an antenna determines the efficiency of the antenna, the radiation efficiency of the antenna and the material used in designing the antenna. The voltage standing wave ratio of these antenna determines the return losses of the signal due to reflections. From the VSWR we can conclude whether the reflections are negative or positive reflections. However, Fig.11 shows that the reflection of this antenna is positive based on the VSWR which is lesser than too according to the ITU standard, once a VSWR is less than two but equals to one or greater than one. Such VSWR is ideal to be used for radiative purpose and as such has a lower signal loss.

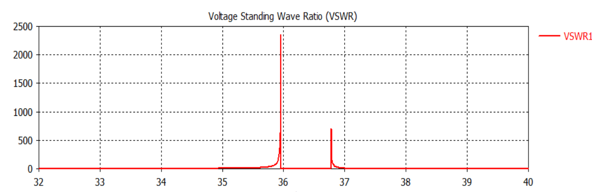

Figure 11 Antenna VSWR

The radiation efficiency of this reflector antenna is 85% as seen in Fig.12. The efficiency of the antenna system is said to be improve because of the double sub reflectors; the double sub reflectors are in conical shapes. This helps to trap in the signals within the enclosure in the parabolic reflectors, thereby giving room to the feed or horn antenna to take advantage of the presence of the so much signal in that environment. So, this makes the radiation efficiency of the antenna spike up with quality signals. And the total radiation efficiency of the antenna 2.2 dB as shown in the Fig.13

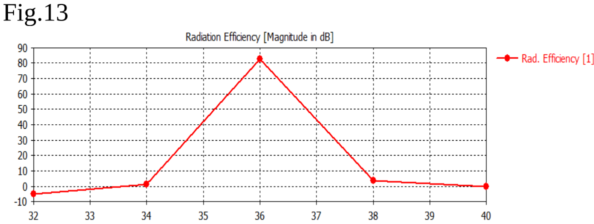

Figure 12 Radiation Efficiency

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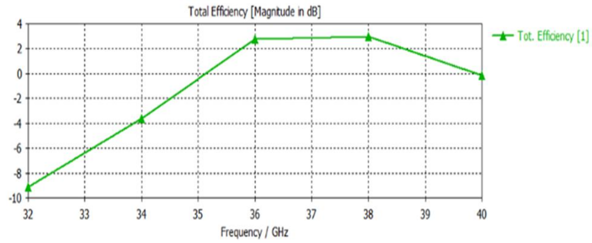


Figure 13 Total Radiation Efficiency in decibels.

The time signal of electromagnetic reflections within the reflector and the sub-reflectors is within the range of 0.4ns and 0.6 ns. The result in Fig.14 shows that the reflection process takes a very short time to get to the feed or horn antenna.

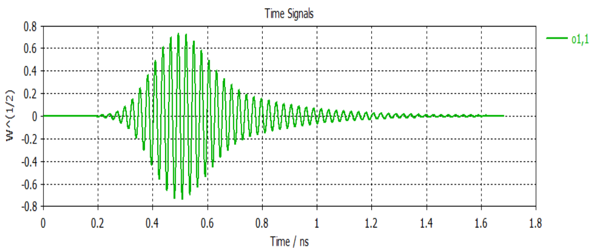


Figure 14 Time Signal

The result in Fig.15, shows the comparative behaviour of the double sub-reflector and the conventional reflector. It can be shown that the double sub-reflector has an improved gain ahead of the conventional reflector. The result shows that the improved reflector has a gain of 40dB while that of the conventional reflector has a gain of 25 dB. This result shows that the improved reflector canimprove gain in the receiver of the dish by trapping more of the reflected signals on the dish when compared to the conventional dish reflectors.

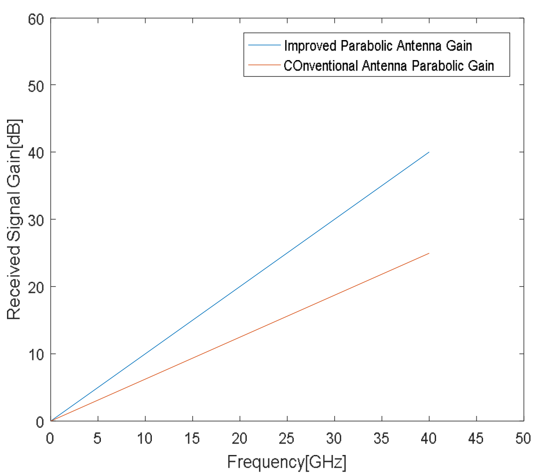


Figure 15 Comparative results of conventional and improved reflectors

## V. Conclusion

In this research work, the design of the parabolic reflector was considered. The diameter, focus length, and thickness of the antenna were considered when designing the parabolic reflector. The diameter of the antenna is 80mm, the thickness of the parabolic reflector is 2mm the focus length is the diameter multiplied by 60.The shape or curve of the reflector was also considered because the diameter of the reflector plays a major role inthe sustainable gain of the antenna. As it is known, the broader the reflector the higher the gain of the parabolic antenna. The shape of the reflector was analyzed and considered in this research work. The sub reflectors of the antenna play a major role in sustaining gain power for the receiver antenna. It is known that during signal reflections on the parabolic reflectors, the receiver of the antenna loses a lot of signals due to reflections back to free space. These signals that are reflected to free space are signals that couldn’t be trapped by the receiving antenna thereby resulting in losses. However, the good thing about the sub reflectors is to trap the escaping signals and reflect them to the antenna. This method improves the signal quality and as well the radiation efficiency of the parabolic reflector.The focal length of the antenna was also considered in this research work. The feed antenna is placed on the focus point of the reflector, this point is where the reflected signals are easily trapped by the antenna during the radiation process. The feed antenna receives signals from this point whether low or strong signals. But with the aid of the double sub reflectors signals are being trapped and improved. So, the radiation efficiency becomes high and at low power consumption. The beam width of the antenna and the antenna feed length were also analyzed. Ts noted that the reflector antenna has a higher radiation gain due to the double sub-reflectors introduced to reduce losses or reduce the signals from reflecting to free space.

From the results, it is clearly shown that the radiation efficiency is 85% and the total radiation efficiency of the antenna is 2.5 dB with a stimulated power of 0.5 watts and a maximum radiation directivity of 40 dB at farfield from 32 - 40 GHz.

This research work has contributed to the area of signal improvement in satellite receivers based on the reflectors of the antenna as the reflector antennas have served a great purpose in the communication and satellite industries. Specifically, the major achievements can be categorized as follows:

i. Introducing double sub reflectors for controlling the reflective process of EM waves on the parabolic antenna.
ii. Improved Radiation efficiency.
iii. Low-power parabolic reflector antenna

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