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Design of Multipurpose Auto Alignment Mast Mounted on Portable Trolley

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Abstract:

This paper emphases on the design of a tower system that is to be multipurpose in in its application. Since telecommunication and surveillance are the inseparable part of the armed forces an uninterrupted communication in remote areas play very vital role. The tower system is of retractable form so that it can be mounted over a portable trolley, which is either autonomous or towed. The trolley has to be stable during multi-terrain operations. The tower is provided with manual drive to reach the estimated height. The second phase of the paper focuses on developing a multipurpose auto alignable mast. The adjustable mast will provide a platform for mounting multiple accessories such as 360 degree rotating antenna, optical sensor, etc. This complete setup is mobile and thus can be moved and fixed to the desired location.

Keywords: antenna,auto-alignment, mast, multi-terrain, tower, trolley

I. Introduction

Operational fitness of a defense system is mainly dependent on its communication efficiency. For the Air Force, telecommunication plays even more vital role [1]. To suffice this need towers are used to mount the antennas and optical sensor for communication, surveillance and other armed forces purposes. Particularly during various covert operations conducted by armed forces, an uninterrupted communication and surveillance are the inseparable parts. Since most of the telecommunication systems are of permanent type, in remote and uninhabited areas it is not possible to create a permanent network there. Different towers of varying heights are used for different applications. They can vary from 15 to 60 meters and sometimes more if required [2]. Telecommunication towers, such as the ones used for emergency response system require elevated antennas to effectively transmit and receive radio communications. In the absence of tall buildings that antennas can be mounted to, self-supporting and guyed towers tend to be most economical choice for mounting antennas.

For the height of 10 to 20 meters the lift can be used for lightweight applications.. Today scissor lifts are most popular lifts in industry are used for material handling and various other purposes such as firefighting, street lamp repairing, etc. Telescopic towers are also used for serving the purpose of portable antennas. These systems are a kind of maintenance-repair vehicle that can carry weight of two to three persons. The system is driven by electric motor, hydraulically or pneumatically. They can be guyed or unguyed depending upon the working height on the antenna. Articulated lifts are operated by hydraulic system and can move in x-y-z directions. They are safer than telescopic lifts and are mainly used for light weight applications. The Aerial Working Platform (AWP) is the top portion of the mechanism which serves as platform for performing various activities at given height.

Towers have been used since ages for surveillance till date for telecommunication purpose. There are different types of the telecommunication towers which are used i.e. monopole, self-supporting and guyed etc. Even portable scissor lifts acts as towers for material handling, street light repairing lift, lifts used in fire fighting vehicle are some the examples

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of advance lifts. Many of the towers being stationary are restricted for its application. Portable towers suffer from the restriction of height, the weathering effect, etc.

II. Literature Review

Author	Research Work	Remark/ Conclusion
Robert W. Lucky Jon Eisenberg (2006)	Renewing US Telecommunication system.	Development of temporary radar and network system to create a zone that receives strong network signals.
Georgy Olenin (2016)	Design of hydraulic scissors lifting platform.	Aerial Working Platform is designed for the purpose of heavy loads.
Amay Saxena (2015)	Generalized derivation for force output and velocity ratio of scissor lift.	The generalized equation for velocity ratio is not suitable for tapered scissor lift.
Gaffar G Momin (2014)	Design, Analysis, Manufacturing of Hydraulic Scissor Lift.	Uniform Scissor arm length is used. Motive drive is provided manually instead of electrical power.
Cao Hung Pham Gregory J. Hancock (2016)	Direct strength design of Cold-formed C-sections in combined bending and shear.	The paper discusses about the properties of material used for C sections.
Corrado Andrea, Polini Wilma (2017)	To design a belt drive scissor lifting table.	Dynamic motion analysis and structural analysis are conducted in order to satisfy the required conditions.
Sabde Abhijit Manoharrao, Prof. Jamgekar R.S. (2017)	Design and Analysis of Hydraulic Scissor Lift By Finite Element Analysis.	Vibrations were studied during the lifting of tower by using modal analysis.
Amit Pawar D U Patil (2015)	Design of linear motion guideways.	Paper discussed about the linear motion guideway and obtaining high accuracy and precision in motion.
Manjushree D. Sutar Bhagyesh B. Deshmukh (2013)	Linear Motion Guideways a recent technology for higher accuracy and precision motion of machine tool.	The study of linear motion guideways is done in CNC machine for precise and accurate outputs.

III. Objectives

The Project is aimed at:

- Designing a mobile lifting system that can be used for communication or surveillance purpose in remote locations.
- The lifting mechanism should achieve the height of nearly 40fts.
- The mechanism should be light in weight and should remain as stable as possible during operating conditions.
- To provide aerial working platform that will be used to mount the 360 degree rotatable mast.

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IV. Methodology

The method followed for the project is as follows:

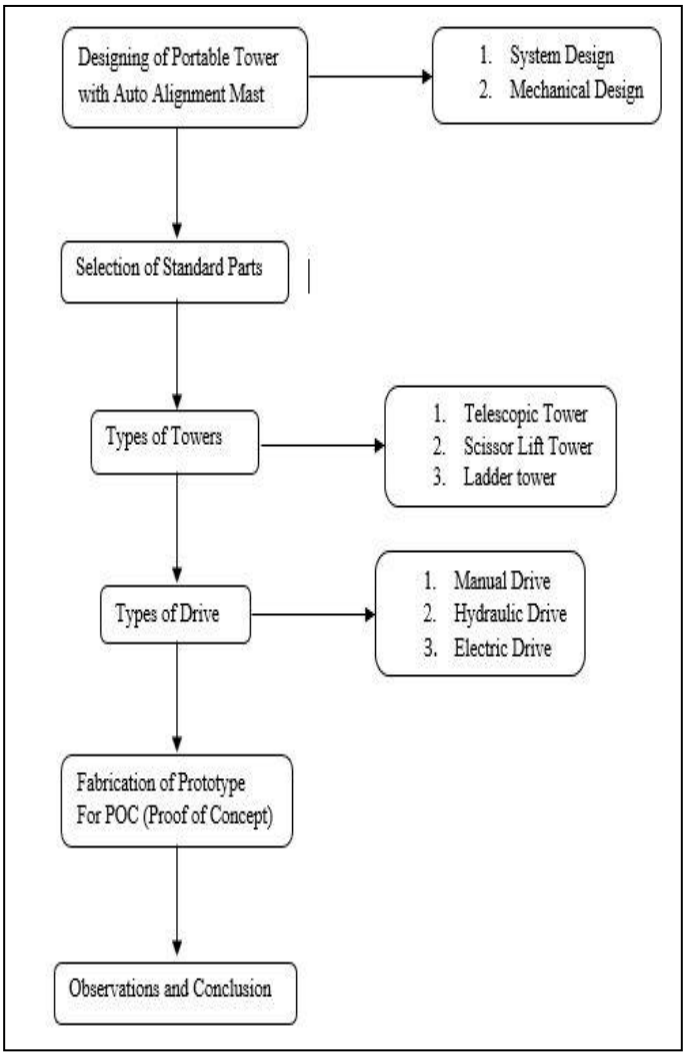

Fig-1: Methodology

In mechanical section a trolley/ buggy like structure needs to be designed that can be used for mounting the lifting tower setup as well as provide enough space for mounting electrical items.

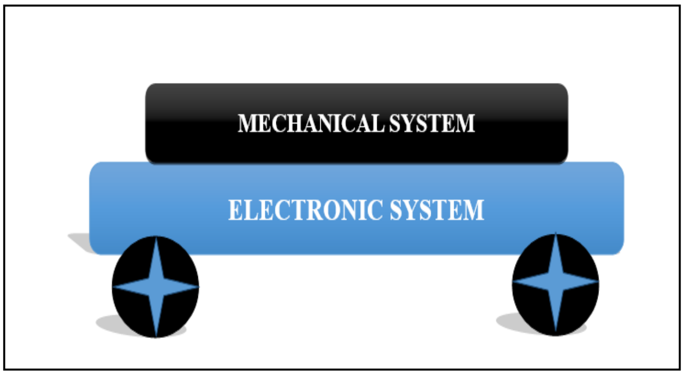

Fig-2: Trolley/Buggy

V. Selection of Lifting Mechanism

After studying various lifting mechanisms viz. telescopic tower, scissor lift, ladder lift; as per the system requirement, the system should be light in weight, should be stable during operation, easy extension and retraction of the system, the tower of 'C Lip Channel' that will be working on the principle of ladder lift used by fire fighting vehicle was decided to use. The advantages of this modified system over the other systems were as follows:

- System will occupy less area.
- System will be light in weight.
- The process of extension and retraction will be quick.
- Piercing on the back of channel will help the air to pass and thus the system will remain stable during operation.
- For the required load at the top of lift this type of mechanism is suitable.
- Collapsible height of the system is minimum.

For proving the concept we decided to make a prototype of the system with reduced scale of 1:10. The actual working height of the product will be nearly 40ft to 50ft, so the prototype is expected to achieve the height of 4 to 5ft. The C Lip Channel tower is prepared in such a way that each channel is of reduced with engaged with one another and while extension and retraction the gets locked due to the guideway provided from both the sides of the channel.

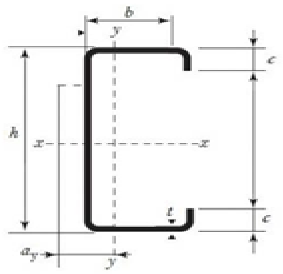

Fig-3: C Lip Channel

Four C Lip Channel are used for the prototype, each one with reduced width as follows,

1. Base Level [h=285 b=85 c=50]

2. Stage 3 [h=275 b=75 c=25]
3. Stage 2 [h=265 b=65 c=25]
4. Stage 1 [h=255 b=55 c=25]
   (All dimensions are in mm)

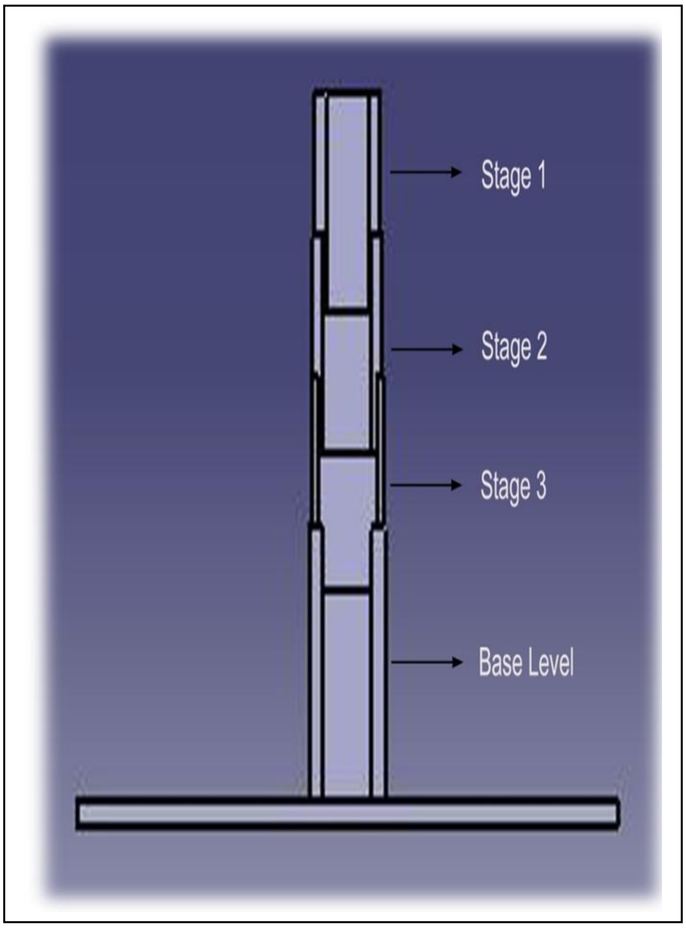

Fig-4: CAD model of all stages in extended position

Height of each level is 450mm and that of base level is 500mm.
Active height for base level = Total height of base – The guide length
= 500 – 50
= 450 mm
Similarly, Active height for Stage 3 = 450 – 50 – 50
= 350 mm
Active height for Stage 2 = 450 – 50 – 50 = 350mm
Active height for Stage 1 = 450 -50 = 400mm
Now,
Total Active Height = 450 + 350 + 350 + 400
= 1550 mm
= 5ft (approx.)

So the total height of the prototype will be around 5ft after complete erection.
Material Selection: For the C Lip channels the material to be selected needs to be light in weight as well as possess high strength. All the four channels slides into each other but due to the guideways provided there is negligible friction between them while extension as well as retraction. For the fabrication of prototype we have used all the four channels of MS. Since the base plate will undergo maximum loading effect it can be of high strength material such as hot dipped galvanized steel of 2.5mm thickness [11]. And for the remaining levels we can use lightweight materials such as aluminum.
For guideways we used the same material as that used for channels that is MS. The main purpose of the guides provided in each channel was to direct each channel while extension as well as retraction. Also these guides serve as locking mechanism for the channels so that do not leave the preceding channel.
Drive Mechanism: Manual drive mechanism is used to provide the lifting drive for the system. Use of rope and pulley arrangement makes the system to achieve the required height.

I. Shafts: Three shafts are used in the assembly and the gear is mounted on each shaft. The shaft attached with the central gear acts as driver shaft, it is rotated with the help of handle.
The remaining two shafts acts as spindle while winding and unwinding the rope. The one end of the GI wire rope is fixed into this spindle using grub screw.
Calculations:
Material: Carbon Steel (15C8)
S_{ut} = Ultimate Tensile Strength = 440 N/mm^2
S_{yt} = Yield Strength = 240 N/mm^2
According to ASME code permissible values of shear stress may be calculated from various relations.
$\tau_{(allowable)} = 0.18 \times S_{ut}$
$= 0.18 \times 440$
$= 79.2$ N/mm^2

OR

$\tau_{(allowable)} = 0.3 \times S_{yt}$
$= 0.3 \times 240$
$= 72$ N/mm²

Considering minimum of the above values

$\tau_{(allowable)} = 72$ N/mm²

This is allowable value of shear stress that can be induced in shaft material for safe operation.

Now,

Input Torque (T) = F x s
= 25 x 1
= 25 N-m

Taking Factor of Safety 2

T(design) = 2 x T
= 2 x 25
= 50 N-m

Now,

For torsional shear failure of shaft,

Assuming the diameter of shaft to be 32 mm

Now,

d = 32 mm, T – 50 N-m

$\tau_{(actaul)} = 16Td/\pi d^3$
$= 16 \times 50 \times 10^3 / 3.14 \times (32)^2$
$= 24.88$ N/mm^2

Since

$\tau_{(actaul)} < \tau_{(allowable)}$

The shaft of diameter 32mm is safe under torsional load.

The diameter of the driven shaft cum spindle is 32mm.

∴ D = 32mm

R = D/2 = 32/2 = 16mm

Now,

The circumference of the spindle,

$C = 2\pi R$
= 2 x 3.14 x 16
= 100mm

∴ with complete one rotation of spindle 100mm of GI wire will get winded by spindle.

i.e. With each rotation of spindle the mechanism will get lifted by 100mm.

II. Gears: Three gears in combination of which one is driver and other two are driven. The driver gear has 32 teeth and the driven gear has 20 teeth. The gears are mounted on the shaft cum spindle. The driver gear is rotated with the help of handle. Since these gears are mounted on the shafts in inner diameter of shaft is 32mm.

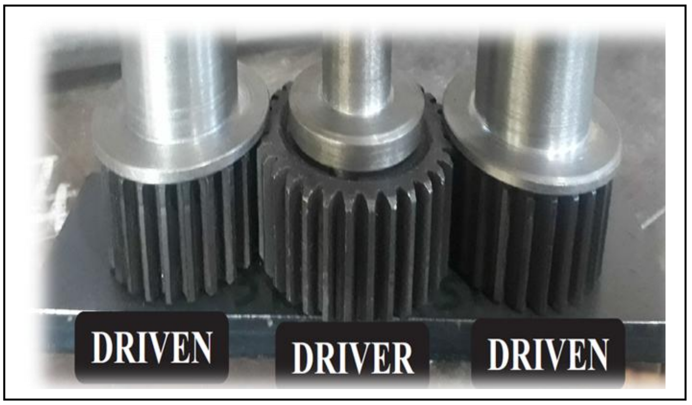

Fig-5: Gear Assembly

III. Pulley: A pulley is a wheel on an axle or shaft that is designed to support movement and change of direction of a taut cable or belt, or transfer of power between the shaft or belt. Total four numbers of pulley are used in the prototype. Two of them are mounted on the top portion of stage 1 from inner side, these pulley help in giving the rope a proper direction and avoid entangling of the ropes.The remaining two pulley are mounted on the top of 0.75inches pipe facing opposite to each other. These pulley acts as a fulcrum and the helps in pulling the mechanism in upward direction or even while retracting it.

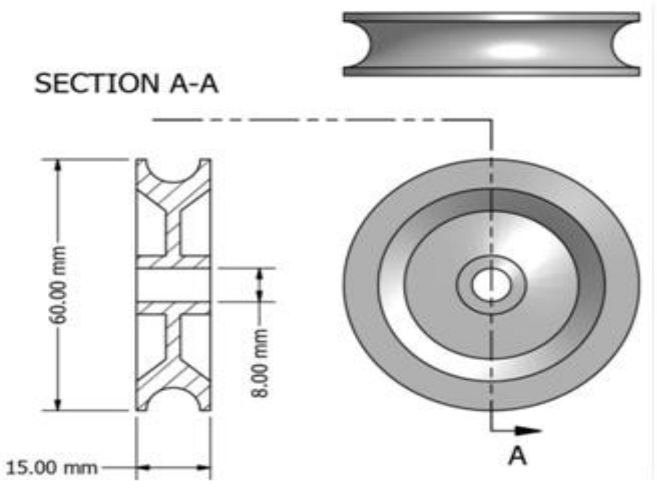

Fig-6: CAD Model and C/S of Pulley

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For prototype standard size pulley are selected having 60mm outer diameter and 15 mm groove.
Handle made of MS is used for rotating the shaft. GI wire is fixed on the fixer welded on Stage 1 and is passed through the pulley at top and moved till the spindle shaft.

VI. CAD ASSEMBLY

The 3D model of the prototype is prepared using CATIA V5 software. Firstly the all the parts were prepared and then assembled.

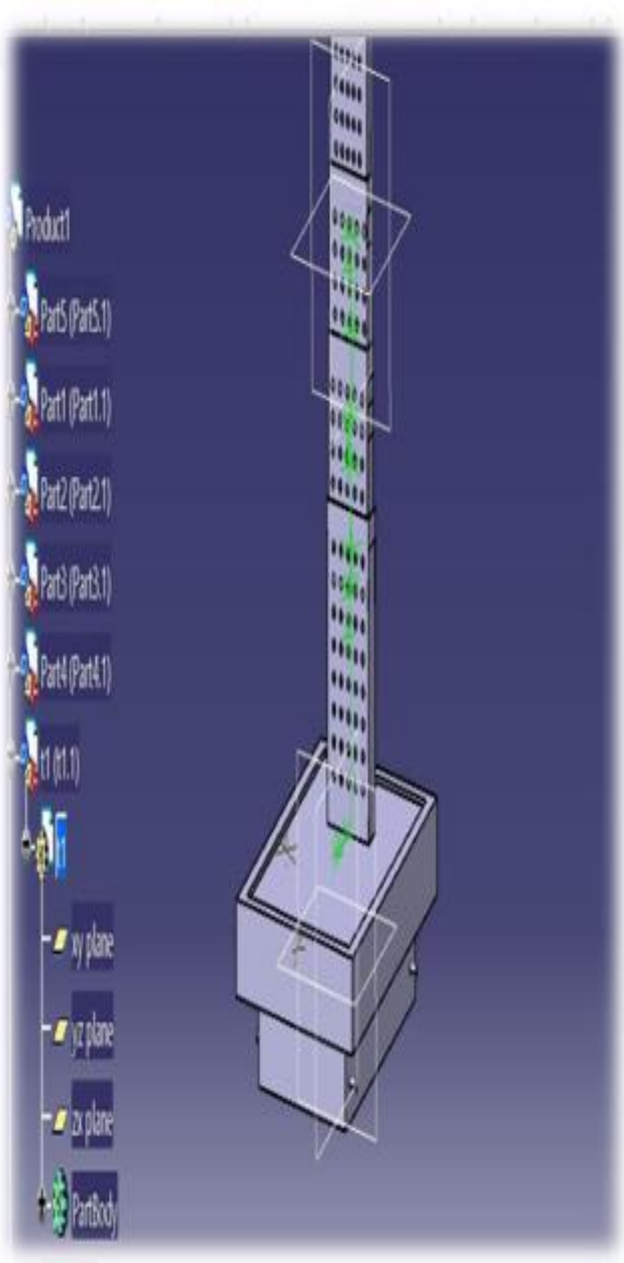

Fig-7: Basic CAD structure

Final structure of the buggy was designed. Auto alignment mast was prepared and mounted on the aerial working platform. Also antenna was mounted on the mast. The buggy prepared has been given the provision to be towed. All the parts prepared in part design were assemble in assembly as shown in the following figure:

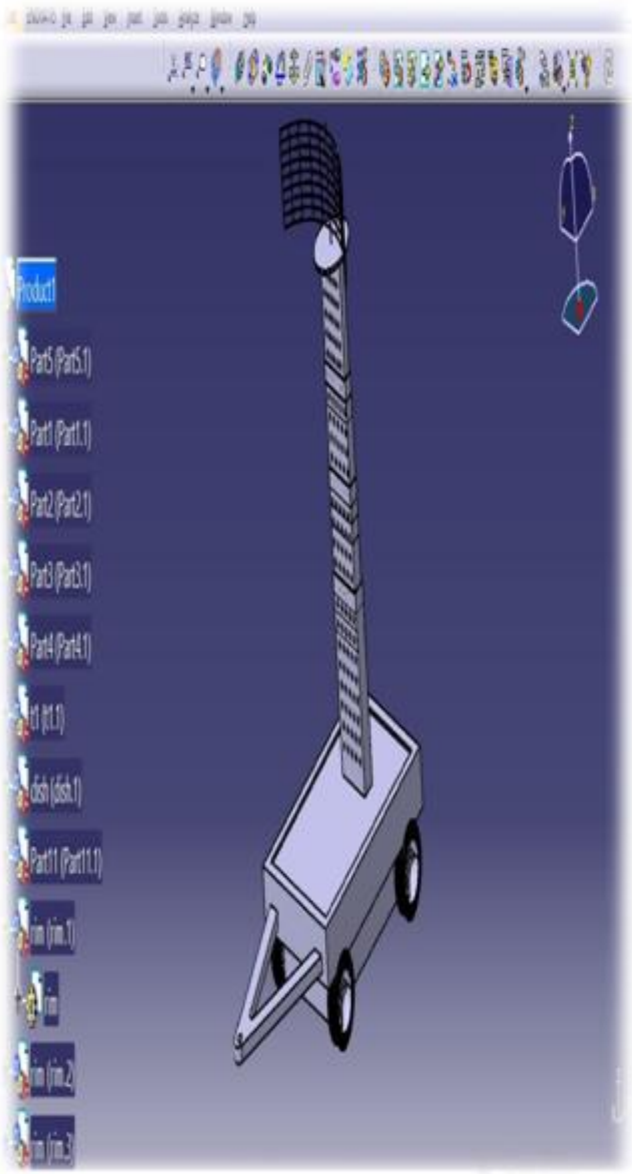

Fig-8: Final CAD structure

VII. FABRICATION & ASSEMBLY

Using all the components we started assembling the prototype. For proving the concept we decided to fabricate a prototype of 1:10 scale. We started with the bending of the C Lip Channel according to design. Then prepared guides for the channel interlocking system. These guides were welded on their positions on the channel by using TIG welding. Since the C Lip channels were machine bended and after welding the guides its thickness increased and we faced the problem that the channels were not sliding into each other. To overcome this problem we had to grind the channel surfaces as well the guides and applying some lubrication on it.

Fig-9: Actual Channel Position

Then it was the time to decide for the lifting system, so we decided to use pulley and rope arrangement giving it a manual drive. For this system we prepared three shafts of which one was driver shaft rotated using handle and other two were driven shafts cum spindle. Three gears were mounted on these shafts and this mechanism was fixed using plate and this plates is attached to the Base channel using nuts and bolt. Then the mounting of pulleys was done. Two pulleys were mounted on the top portion of Stage 1 from inner side. Other two pulleys were mounted on the top of small square pipe facing opposite to each other.

Now we needed the pulley to act as fulcrum so we need to mount it on the height of the maximum height that will be attained by the prototype. For this purpose we used to square pipes which can retract into each other and can get locked to required height. Then finally a GI wire rope was used, its one end was fixed on the fixer welded on Stage 1 then passing it through pulley on same stage the through the upper pulley on the pipe and finally fixing other end in the spindle.

Fig-10: First & Second stage erection

Fig-11: Complete Erected Front & Rear View

VIII. ADVANTAGES

a. The prototype is able to achieve the required height of 5ft.
b. The system is more stable.
c. The retracted height of system is compartively less.
d. There is enough space at the top portion that is Stage 1 for providing Aerial Working Platform.
e. The system can be driven maually as well as electrically.

IX. CONCLUSION

From the overall project we concluded that:

1. With the help of prototype fabricated, height of 5 ft was succvessfully achieved.
2. Manual drive using rope and pulley thus proved to be economical and efficient for driviing the lift to the required height.
3. The piercing done on the face of C Lip Channel helps the air to easily pass through the channel thus avoiding air resistance and helping in achieve greater stability.
4. The immediate retraction of the system helps in avoiding the damage of critical components such as antennas, optical sensors during rough weather condtions.

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