AUTOMATIC SATELLITE TRACKING SYSTEM ON A MOVABLE PLATFORM

BY

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ABSTRACT

Satellite dish antennas have become popular in recent years primarily for use in-vehicle communication systems. Accordingly, the satellite dish antenna further comprises a roof mount to install the dish on the roof of the vehicle, such as maritime vessel, truck, or caravan. However, such a mobile satellite dish has several drawbacks. As it is mentioned above, since the satellite dish antenna is a highly directional antenna, the dish must be manually adjusted its orientation when the vehicle travels from place to place. The tuning process requires the user to manually elevate, lower, and position the dish to the direction of the satellite, where the alignment of the dish is somewhat difficult to be fixed due to the manual adjustment and usually resulted in low-quality signal reception and possible satellite interference. Furthermore, the dish may be unintentionally shifted its orientation misalign with the direction satellite in a high wind operating environment. An automated satellite TV tracking system can rather be very expensive depending on system complexity. The mobile satellite dish antennas are costly to manufacture, install, and maintain in order to perform as the mentioned condition. Accordingly, the manufacture of the receiving dish itself is somewhat inexpensive. However, the installation of the satellite dish antenna is time-consuming and requires an experienced technician to install and maintain the whole electrical wiring for the user's requirements and the system's safety. This project is aimed to produce a reliable and cheaper prototype of satellite TV tracker system. The output of this project is intended to be mounted on a maritime vessel. The tracking of the satellite TV signal is difficult to achieve as the vessel is always in motion on the sea surface. Thus, this research presents the study, design and development of positioning control for the satellite tracking system on a maritime vessel. A stable satellite tracking controller by the module of combining Arduino microcontroller and accelerometer is designed to cope with the sensor imprecision and sea environment. DC motors are then used to move the satellite television dish according to the input of azimuth and elevation angles. The determination of where the motor should stop was achieved with the integration of a control system operated by Arduino programming and accelerometer sensor. The desired television signal can be brought to the TVRO on the mobile vessel through the antenna with the inputs orientation and the tracking controller. This information will depend on the latitude and longitude of the vessel's current position. The designed prototype is capable to track MEASAT 3B signal automatically using the programmable language. Hence, the signal gain is validated using a spectrum analyzer at any specific location to confirm and measure the signal strength of the TVRO which is more than the allowable minimum performance of the received satellite signal (≥ -31.987dBm). The accuracy of the tracker is measured within the allowable performance.

Keywords: Satellite Tracker, DC Motors, Automatic Controller

خلاصة البحث

أصبحت الهوائيات طبق الأقمار الصناعية شعبية في السنوات الأخيرة في المقام الأول لاستخدامها في أنظمة الاتصالات السيارة. وفقًا لذلك ، يشتمل هوائي طبق الأقمار الصناعية أيضًا على حامل سقف لتثبيت الطبق على سطح السيارة ، مثل السفينة البحرية أو الشاحنة أو القافلة. ومع ذلك ، فإن طبق الأقمار الصناعية المحمول لديه العديد من العيوب. كما هو مذكور أعلاه ، نظرًا لأن هوائي طبق الأقمار الصناعية هو هوائي اتجاهي للغاية ، يجب ضبط الطبق للاتجاه يدويًا عندما تنتقل المركبة من مكان إلى آخر. تتطلب عملية الضبط من المستخدم رفع الطبق يدويًا وخفضه ووضعه في اتجاه القمر الصناعي ، حيث يصعب تثبيت محاذاة الطبق إلى حد ما بسبب الضبط اليدوي وعادة ما يؤدي إلى استقبال إشارة منخفضة الجودة وإمكانية تدخل الاشارات مع بعض. علاوة على ذلك ، قد يتم تغيير الطبق عن غير قصد في اختلال اتجاهه مع اتجاه القمر الصناعي في بيئة تشغيل الرياح عالية. كذلك قد يكون نظام التتبع الفضائي الآلي مكلفًا جدًا وفقًا لتعقيد النظام. إن هوائيات طبق الأقمار الصناعية المتنقلة مكلفة في التصنيع والتركيب والصيانة من أجل الأداء حسب الحالة المذكورة. تبعا لذلك ، فإن تصنيع طبق الاستقبال نفسه غير مكلف إلى حد ما. ومع ذلك ، فإن تركيب هوائي طبق الأقمار الصناعية يستغرق وقتًا طويلاً ويتطلب فني متمرس لتثبيت وصيانة الأسلاك الكهربائية بالكامل كاتلبية احتياجات المستخدم وسلامة النظام. يهدف هذا المشروع إلى إنتاج نموذج أولي موثوق وأرخص لنظام تعقب القنوات الفضائية. كذلك يهدف المشروع إلى تركيبه على متن سفينة بحرية. يصعب تحقيق تتبع إشارة القنوات الفضائية لأن السفينة تعمل دائمًا على سطح البحر. وبالتالي ، يقدم هذا البحث دراسة وتصميم وتطوير نظام تحديد المواقع لنظام التتبع عبر الأقمار الصناعية على متن سفينة بحرية. تم تصميم وحدة التحكم في تتبع الأقمار الصناعية المستقرة للتعامل مع دقة أجهزة الاستشعار والبيئة البحرية. ثم تستخدم محركات التيار المستمر لتحريك طبق تلفزيون الأقمار الصناعية وفقا لمدخلات السمت وزوايا الارتفاع. تحديد مكان المحرك يجب أن يتحقق وقف مع دمج نظام التحكم التي تديرها اردوينو استشعار البرمجة والتسارع. إشارة التلفزيون المطلوبة يمكن إحضارها إلى TVRO على متن السفينة عبر الهوائي مع اتجاه المدخلات والتتبع مراقب. تعتمد هذه المعلومات على خطوط الطول والعرض الحالية للسفينة موضع. النموذج الأولي المصمم قادر على تتبع إشارة MEASAT 3B تلقائيًا باستخدام لغة قابلة للبرمجة. وبالتالي ، يتم التحقق من صحة كسب إشارة باستخدام محلل الطيف في أي موقع محدد لتأكيد وقياس قوة إشارة TVRO وهو أكثر من الحد الأدنى المسموح به من أداء إشارة القمر الصناعي المستقبلة (31.987dBm- 9.) الدقة من تعقب يقاس ضمن الأداء المسموح به.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion; it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science (Electronics Engineering)

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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Firstly, it is my utmost pleasure to dedicate this work to my dear parents and my family, who granted me the gift of their unwavering belief in my ability to accomplish this goal: thank you for your support and patience.

I wish to express my appreciation and thanks to those who provided their time, effort and support for this project. To the members of my dissertation committee, thank you for sticking with me.

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LIST OF ABBREVIATIONS

GPS	Global Positioning System
TV	Television
TVRO	Television Reception Only
MPEG	Moving Picture Expert Group
DTH	direct-to-home
RISC	Reduced Instruction Set Computer
I/O	Input Output
DC	Direct Current
AGC	Automatic Gain Control
PID	Proportional Integral Derivation
PI	Proportional Integral
PD	Proportional Derivation
A/D	Analog to Digital
NIMC	Nonlinear Internal Model Control
STA	Satellite Tracking Antenna
FDI	Fault Detection and Isolation
PCB	Printed Circuit Board
LNB	Low Noise Block
LNA	Low Noise Amplifier
LNC	Low Noise Converter
VHF	Very High Frequency
UHF	Ultra High Frequency
IF	Intermediate Frequency
IIUM	International Islamic University Malaysia
MCMC	Malaysian Communications and Multimedia Commission
MTFSB	Malaysian Technical Standards Forum Bhd

LIST OF SYMBOLS

E°	Degree East
N°	Degree North
r_s	Distance of The Satellite from Center of The Earth
r_e	Distance of The Earth Station from The Center of The Earth
d	Distance of the Satellite from The Earth Station
l_s	Longitude of The Satellite
l_e	Longitude of The Earth Station
L_e	Latitude of The Earth Station
γ	Central angle

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Satellite television receivers which cognize satellite broadcast television signals for display by a television monitor are well known in the art. These receivers are commonly used in earth stations by users in connection with an antenna in order to directly receive satellite broadcast television signals. Satellite broadcasting is the distribution of multimedia content or broadcast signals via a satellite network (Oppurtunities, November 2006). The broadcast signals usually originate from television (TV) or radio station and then are sent via a satellite uplink to a geostationary artificial satellite for redistribution or retransmission to other predetermined geographic locations through an open or a secure channel. Downlinks are then received by base stations such as small home satellite dishes or by base stations owned by the local cable network for redistribution to their customers. Figure 1.1 shows the satellite transmission from and to the Earth.

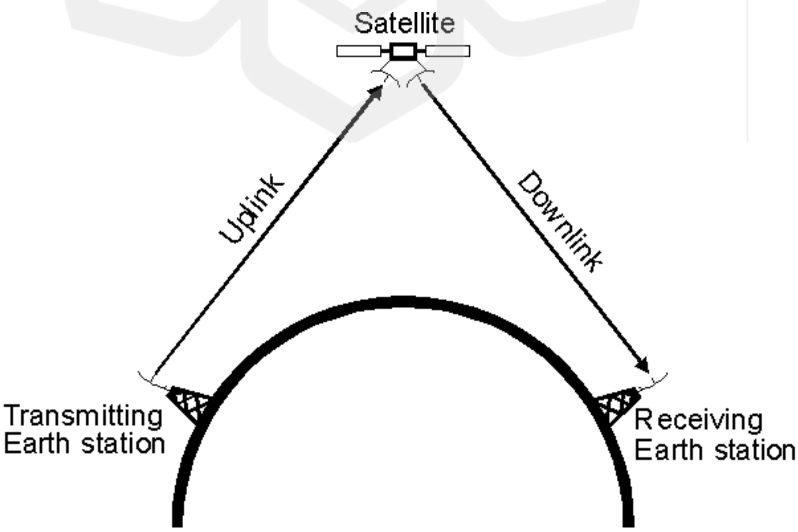

Figure 1.1: Satellite Transmission from and to the Earth

Satellite broadcasting is a system of content distribution using broadcast signals relayed to and from communication satellites, which are then received by parabolic receiving satellite dishes. The signals are then passed through a low-noise block converter for conditioning.

A satellite receiver cognizes the incoming signals and transfers them to the user through television or satellite radio. In the case of satellite television, the signals coming in are encoded and digitally compressed so as to minimize the size that enables the provider can bundle more channels into the signal. The user can then select which channel to decode and view. The compression used for satellite digital TV is often moving picture expert group (MPEG) compression so that quality can be retained.

Television satellite television reception only (TVRO) systems are very popular in rural areas where the conventional broadcast program is unavailable, and even in those areas where a cable is not yet available as it provides an incredibly broad range of channels to choose from. These satellite receivers are generally coupled with an associated actuator which is controllable by the operator to change the positioning of the antenna from one satellite to another. Figure 1.2 shows the transmit-receive broadcasting satellite service.

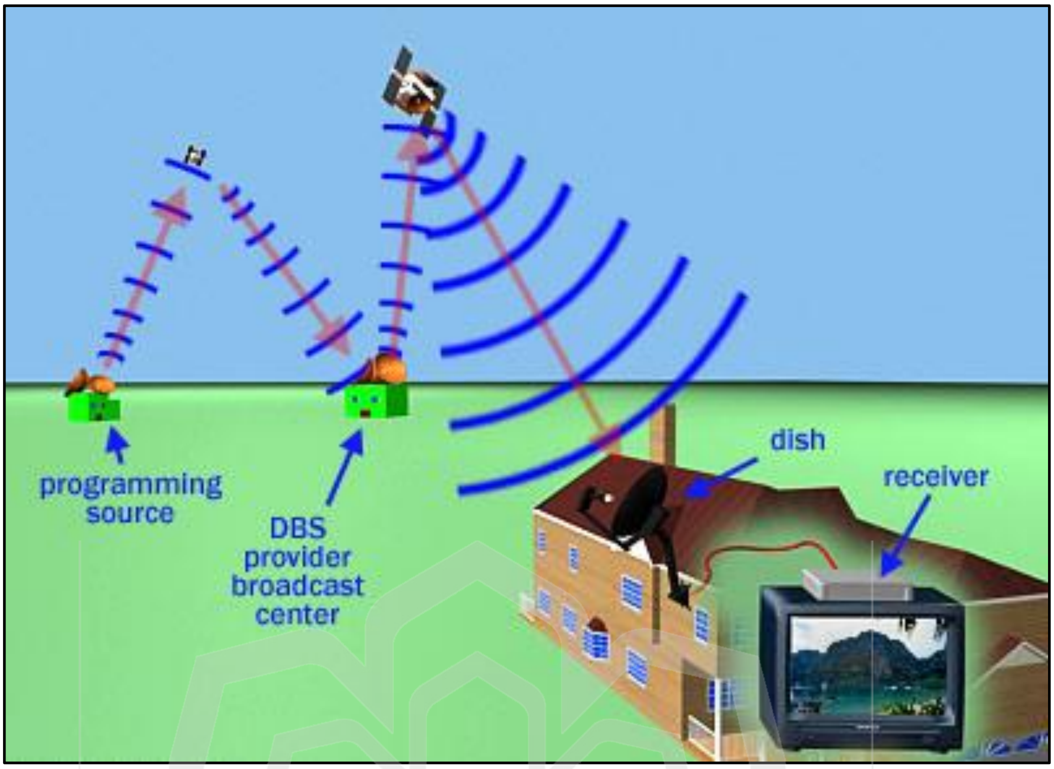

Figure 1.2: Satellite Transmission from and to the Earth

(Rashedul Huq, December 2016)

In this research, the satellite signal that needs to be recognized by the automatic satellite tracker is MEASAT; which is a premium supplier of services that leading broadcasters, Direct-To-Home (DTH) platforms and telecom operators. The MEASAT fleet includes MEASAT-3, MEASAT-3A and MEASAT-3B satellites co-located at 91.5°E (Oppurtunities, November 2006). Leveraging facilities at the MEASAT Teleport and Broadcast Centre, and working with a select group of world-class partners, MEASAT also provides a complete range of broadcast and telecommunications solutions. Services include ultra-high definition, high definition and standard definition video playout, video turnaround, co-location, uplinking, broadband and IP termination services.

1.2 PROBLEM STATEMENTS

In order to position the satellite dish automatically, the angle and elevation of the dish have to be correctly positioned. This is to ensure a clear receiving signal received by users. That is why for home installation, a broadcast satellite dish is always in fix mounted position in order to maintain constant signal coverage for users. However, this situation differs with mobile platforms such as maritime vessel, air and land mobile transportation. Identifying the bearing and azimuth for the dish on a mobile platform can certainly take hours especially during the rough condition. Watching TV while the vessel is in motion using a fixed pointing satellite dish would be impossible since the direction towards the satellite keeps changing as the vessel moves about.

The ability to get clear television reception on a mobile platform has always been an important issue. Tracking satellite signal is a must for a marine vessel in order to connect with local channels. Movements of a ship, partly generated by waves, will force the antenna to point away from the satellite and this could cause the interruption of the satellite signal. Another problem arises when the signal is blocked due to change in atmosphere, or a physical hurdle between the antenna and satellite. This results in feeding the faulty data to the control loop and hence leading to the loss of tracking functionality. Figure 1.3 shows the real application of broadcast satellite antenna on a mobile maritime vessel.

Figure 1.3: Broadcast Satellite Antenna on a Maritime Vessel (Soltani, January 2011)

Land-based satellite tracking antenna requires adjusting the orientation to align with the current location of the ship. Since the satellite is typically synchronized with the Earth motion, no further adjustment is required once the antenna is locked to the truly desired orientation in static condition. The ship mounted antenna tracking control is more challenging since the ship is constantly plying. Motors and driver that need to move the satellite dish on the mobile platform also is part of the problem that needs to be looked into the kinematics and tracking control of the system. Hence, a suitable type of motors is one of the important aspects as well in the designing process. Due to the load weight of the whole system of the satellite tracker, an electronics motor is suitable to sustain the load.

There are certain details we will require in order to successfully align the satellite dish accurately to the correct satellite for our requirements. There are two details need to detected for satellite tracking system. The orientation of azimuth will be the heading required for the dish. The satellite that is broadcasting the signal will have a point of reference which the dish needs to be aligned to. As for example, satellite A, B or D is set at 28.2° East of True South of the ship current location. The other orientation is the elevation angle which is the angle required for the dish that is above the reference heading for the satellite that we have aligned the heading towards. As the Earth curves, we need to find the correct elevation for the area where the dish will be situated (Pooja, 2013).

An Arduino microcontroller is as important as the computer control system. The main benefit of the microcontroller is also to control the position of the antenna. A microcontroller can be the command to move satellite pointing dish exactly to a specific position pointing Measat 3B satellite. Satellite dish requires accuracy. In this research, Arduino microcontroller has been selected to control the satellite dish for the system. The correct positioning of the satellite dish can be achieved by comparing its current position and the position inputs from accelerometers. Moreover, Arduino microcontroller is selected as it is a low-cost high-performance RISC (Reduced Instruction Set Computer) system that has many input-output (I/O) ports, memory and communication ports.

So it is suitable for controlling the actual position of the systems. The system can locate the satellite receiver dish at different positions. The most common issue anyone will come across when aligning the dish is aiming at the correct satellite for the broadcasts they require. Satellite receivers do have certain details on them regarding the satellites, but they cannot determine whether you are aligned to the correct satellite (Soltani, January 2011). They rely on the user to align the dish in the correct direction.

The control system of the satellite tracker is fundamental in moving the antenna. In this research, the controller is focused on controlling direct (DC) motors to adjust the antenna dish according to the required orientation. It is consists of a few hardware connected before the dish. However, due to time limitation, this system is controlled in an open loop.

This hardware configuration is built within the dish to control the dish movement. This system consists of hardware components which accelerometer as the positioning sensor, Arduino microcontroller, a driver for DC motor and DC motors. The inputs of the controller will be the orientation of azimuth and elevation angle detected by the detection by Global Positioning System (GPS). This input will be the command for the controller to initiate the DC motors operation. This is only for the movement of the motors.

1.3 PURPOSE OF THE STUDY

This research aimed to investigate how to automatically position the satellite receiver dish by means of automatic control. The pointing of a satellite TV dish can be automatically controlled by an accelerometer that controls the desired azimuth and elevation angle respectively at a different location. These magnetic compasses act as the positioning sensors that allow DC motors to rotate the receiver antenna's platform. This system is aimed to be operated on a maritime vessel and land vehicle to enable users to receive satellite television channel on-the-go. There are many existing systems that have been using this system for the same purpose. This research aimed to produce a working prototype built with minimal cost and complexity compared to most of the existed system in the market.

1.4 RESEARCH OBJECTIVES

The problem is addressed by developing a dedicated system mechanism that uses the received signals from the satellite. These objectives of this research are:

1. To design a reliable automatic satellite tracker system for maritime vessel application.
2. To develop an automatic satellite tracker for Measat 3B broadcasting.
3. To validate the signal output of the television channel's frequency based on the defined azimuth and elevation.

1.5 RESEARCH SCOPE

This research will only cover the experimental of prototyping design of positioning controller of a satellite TV dish for maritime vessel by DC motors. By using the azimuth and elevation angle read by the GPS, the antenna dish will move according to the movement of DC motors. The system only covers the configuration and designing of the positioning controller.

1.6 RESEARCH METHODOLOGY

The following activities have been carried out during the research period:

1. A thorough preliminary investigation has been done through a literature review on the design of satellite tracking controller prototype from existing systems and researches as well as potential tools and software. This step has been done throughout the research until the final stage is successfully achieved. The most suitable tools, software and equipment were determined.
2. The compatibility of DC motors controller design and its proper dimensions were determined based on a three-axis positioning system technique. All components of the satellite tracking system are assembled and integrated with the defined program of the microcontroller.

3. An electronics controller was built to control DC motors movement to stop satellite dish platform to the correct position of azimuth and elevation angle.
4. The development and validation of satellite tracking system controller were performed after proper testing.

   The whole project research and study are analyzed and reported for future reference.

1.7 SIGNIFICANCE OF THE STUDY

This research aspires to assemble a low-cost prototype that can be comparable to many existed products in the market. Users can operate this prototype easily as it applies user-friendly components that enable them to watch television channel on-the-go.

1.8 LIMITATIONS OF THE STUDY

This research will only cover the tracking of MEASAT-3b signal only. The on-field test for this research' output will be operated a portable platform. This platform is the indication of a maritime vessel as the test is aimed to be installed on a mobile maritime vessel. In order for the satellite tracker to work, azimuth and elevation angle inputs are calculated based on the latitude and longitude of the specific location. Thus, it will not consider the alteration of the polarization of the satellite dish. The production of this system prototype will be done through the process of the designing and development of a satellite tracker prototype that use DC motors to operate the whole system. There are also other electronics geared motors such as hydraulic, stepper and other servo motors that can be applied into the operation of this system. However, due to the load of the receiver antenna, DC motor is the most suitable motor that can sustain the load.

1.9 CONCLUSION

This chapter has presented and discussed the background of the study. It explained the overview and the motivations that triggered the research. The study area of this research also was discussed. Other than that, the statement of the problem was discussed as this study is to design a compatible controller for satellite tracking system. This controller system has to be able to move a satellite television dish automatically according to the detected angle of both azimuth and elevation. It will follow the current location reading. The realization of this system is fulfilled by the operation of DC motors and its driver to point the satellite dish as per required. Every working step of this design and development can be achieved by following the research objectives and research scope. The research methodology followed which highlighting the activities taken to fulfil the aims of this research. Finally, the outcomes of this dissertation were presented.