Low cost amateur rotators for student's satellites and high altitude balloons application

Grzegorz Woźniak, Marcin Stolarski
Nicolaus Copernicus Astronomical Center, Space Research Center, Polish Academy of Sciences,
Bartycka 18/18a, 00-716 Warszawa, Poland

ABSTRACT

The student activity related to aviation and space systems requires utilization of appropriate antenna systems and suitable tracking devices which are responsible for pointing the antennas in the required direction. There are employed various solutions from manual tracking (antenna in hand) to sophisticated computer systems. In this article are presented experiences which are the result of projects – building devices mentioned above – realized by students from Warsaw University of Technology. There are presented professional constructions and their equivalents built by students in order to reduce cost. The latter ones were used in ground stations for high altitude balloon missions, utilized for communication with amateur satellites as well as the essential part of ground communication systems for PW-Sat and YES2 satellite missions.

Keywords: antenna, rotators, antenna positioning, satellites

1. INTRODUCTION

For building an academic ground station there are usually used ordinary rotators which can be bought as equipment for radio amateurs. This is the simplest way to success but rather expensive. The price of such rotator oscillates around the amount of 1500€. There are even more expensive professional solutions. Typical rotators which are most commonly used are YAESU G5500, SPID Electronic RAS [Fig. 1] and set of two rotators produced by M2 company: OR2800P and MT3000 [Fig. 2] [1, 2, 3].

Figure 1. YAESU G5500 rotator (left) and Spid Electronic RAS rotator (right)

Figure 2. Set of two M2 rotators: OR2800P used for azimuth positioning and MT3000 used for elevation positioning

The common feature of these rotators is the ability of tracking objects both in azimuth and elevation planes. These devices can be connected to the PC computer (sometimes additional hardware driver is needed) in order to automate the satellite tracking process utilizing appropriate software like ORBITRON [4]. The budget of student's projects is often very tight. Additionally, sometimes the installation is needed only once in specific localization and the simplifications are to be found in order to lower the costs. An example of such simplification is employment of manual tracking.

2. MANUAL ROTATORS

The simplest model of manual rotator is the person holding the antenna in hand [Fig. 3, left] (this configuration is sometimes referred to as the "intelligent rotator").

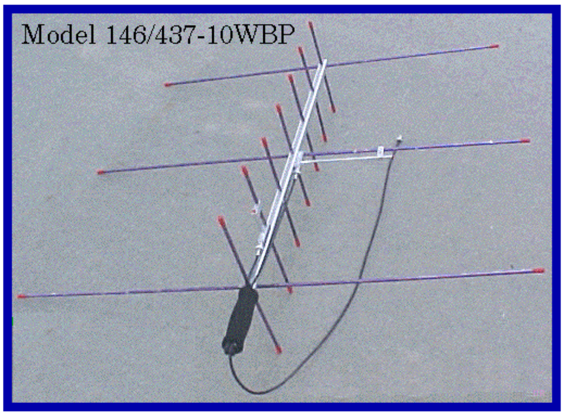

Figure 3. Left: manual satellite tracking, right: "Arrow" lightweight handheld antenna

The primary advantage of this solution is the minimal cost and small dimensions of the construction, which is easy to transport. The drawbacks appear as insufficient stability of the direction and quick fatigue of the operator. The dimensions and weight of antenna system are also limited by the physical abilities of "intelligent rotator" (that is why rather robust persons should fulfill this function – as it can be seen in [Fig. 3]). This solution is perfect during short demonstrations of satellite communication or in rough terrains. However, during several hours of receiving the telemetry from high altitude balloon requires frequent changes of antenna operator and causes that signals are periodically fading. There is even a lightweight antenna [5] specially constructed for operation while holding it in hand. It has YAGI elements for 145MHz and 435MHz bands mounted onto one boom [Fig. 3, right].

The improvement of this construction relies on adding the T-shape tripod onto which antennas are mounted [Fig. 4, left].

Figure 4. Left: stand "T" for manual satellite tracking, right: stand for manual tracking for YES2 mission

Thanks to this simple improvement there is no need to hold heavy antennas in hands. This significantly extend the time of the work of a single operator. During the BOBAS balloon mission [6] persons operating the antennas were being changed about every single hour (those changes were caused more by the fact that operators were bored rather than their fatigue). The solution with support tripod assures enough stability of direction and allows for employment of several antennas at the same moment. The elements of tripod don't take to much place when folded which makes it easy to transport. However, the constructions still cannot be much larger.

Requirements for the YES2 mission [7] forced authors to build more sophisticated construction. According to requirements the antenna system is composed of five CROSS-YAGI antennas, each 2 meters long. Additionally, the construction should be maximally mobile and its assembly – easy and fast. Operation of such device should be convenient for the sake of inaccurate track profile of Fotino lander [7]. The effect of work is the rotator presented in the [Fig.4, right].

As the base of the rotator the loudspeaker tripod is used. On its top the T-shape support element is mounted. Then, there are two CONRAD bearings mounted to this element, in which the boom is placed. Rotation of this boom causes change of elevation. On the boom is placed rectangular frame and handles for convenient operation. This construction allows for building the antenna systems consisting up to 9 single antennas for the 433MHz frequency. Bearings used in the construction allows for changing the elevation angle without any troubles. The azimuth change is possible thanks to the ability of rotating the main element of the tripod. During the tests with five 1,5m antennas system was very stable and very easy to operate. However, if there occurs the case when antennas are heavy enough to overbalance the construction it is possible to attach the counterbalance to the handles. The whole construction seems to be big, however, it has been designed to be foldable into elements not longer than 2 meters, which can be cached into snowboard-like casing.

3. AUTOMATIC ROTATOR RC_FNQ

Communication with amateur satellites, which in majority are placed in low earth orbits, requires constant tracking of their position on the hemisphere. While the manual rotators are simple to construct and easy to operate, they actually involves at least one hand and part of operator's attention. This situation is not very convenient, especially when digital connection is carried out which requires constant computer operation.

The solution is the employment of automatic rotator which can be positioned with use of remote controller. The situation is even better when the rotator position can be automatically updated by computer software. The rotators systems described earlier are good for this task but are expensive ones and thus not affordable for average users.

However, the automatic positioning of antennas can be achieved with the simple device that can be built at home at the cost even eight times lower than the off-the-shelf product.

RC_FNQ is the rotator system built by one of the authors, Marcin Stolarski SQ5FNQ [9]. It is composed of two low cost TV antenna rotators (from Conrad Electronics) and remote controller which can be connected to the PC computer in order to be controlled by appropriate software. Finished controller box is shown on the picture below. It is placed on the Yaesu FT-847 transceiver used by Marcin SQ5FNQ for satellite communication [Fig. 5].

Figure 5. FNQ_RC rotator controller on top of the Yaesu FT-847 satellite transceiver

The application diagram is shown in [Fig. 6].

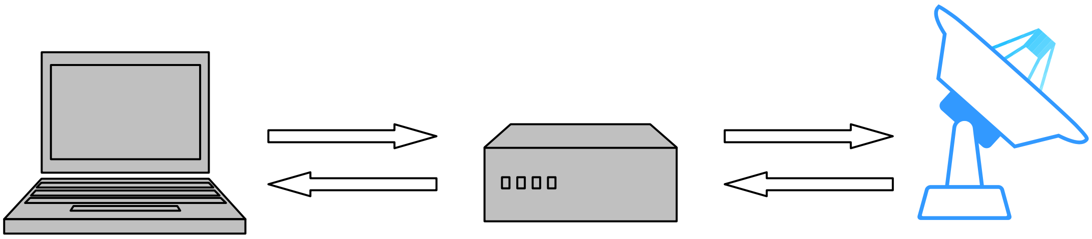

Figure 6. Application diagram of the RC_FNQ-FG rotor controller

The proposed rotator system can be divided into three main blocks: digital block (where the microcontroller with operation program and the circuitry for communication with PC computer are implemented), execution and feedback block (relays controlling the current for rotator's engines and feedback circuitry for position estimation are here) and the mechanics block (remote engines which position the antennas).

The mechanical structure of the rotator is simple. It is shown in [Fig. 7]:

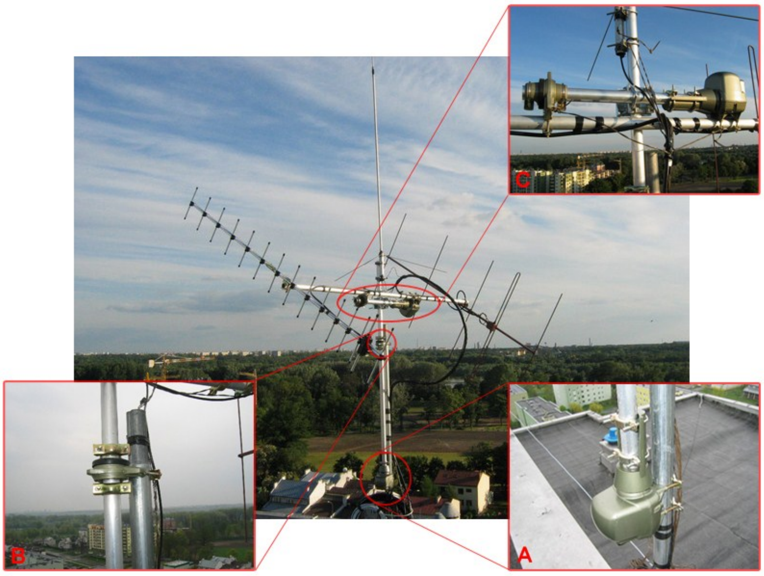

Figure 7. RC_FNQ rotor (A – azimuth rotator, B – azimuth support bearing, C – elevation rotator with support bearing)

The one Conrad rotator is responsible for azimuth motion and the other – for elevation motion. The only problem is obtaining support bearings the production of which has been stopped. They were being sold as complementary accessory for CONRAD rotators [8]. The support bearings are needed because these rotators can hold the support mast only at its end. However, there exists a homebrew solution which is the bearing constructed by radioamateur SP7DPT [Fig. 8]:

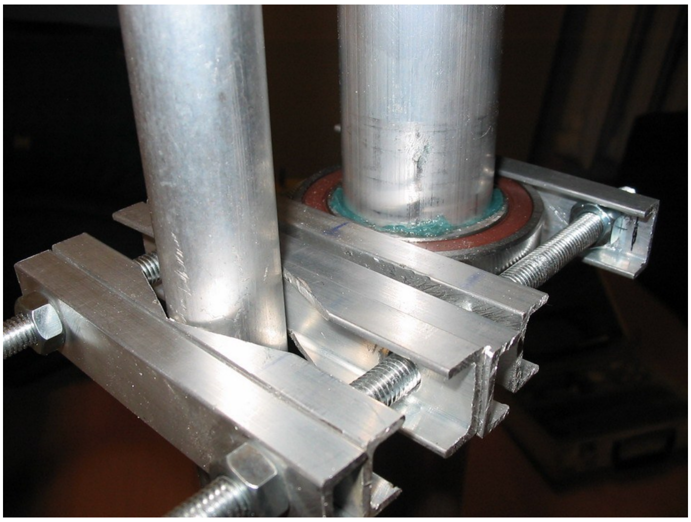

Figure 8. The support bearing for the rotator constructed by SP7DPT

The details of its construction are available at the SP7DPT homepage [10].

The Conrad rotators are not the only choice for the construction. There are also available Stolle rotators [Fig. 9].

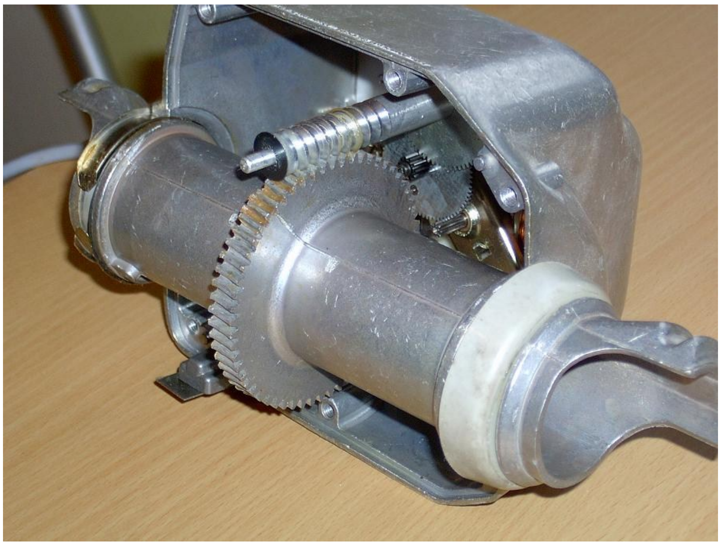

Figure 9. STOLLE rotator

Their advantage over Conrad rotators is the fact that they can hold the support mast anywhere along its length because they have the hole to put the mast through. This is particularly useful for elevation use because rotator can be placed in the middle of support boom thus giving more balanced structure.

Both types of rotators can be bought on internet auctions. The Conrad rotators are also still available brand new from Conrad Electronics at very affordable price.

The important issue in the matter of automatic antenna positioning is the problem of obtaining reliable and accurate position indication. In the stationary usage scheme, the rotator mechanics is often mounted in the remote location (i.e.

roof) so it is impossible to observe the motion of antennas from the position of operator. In the proposed device the feedback system is based on the rotary encoder placed inside the mechanical part of the rotator. This encoder produces impulses which are then counted by the microcontroller inside the controller box. The encoder is constructed as it is shown in [Fig. 10]:

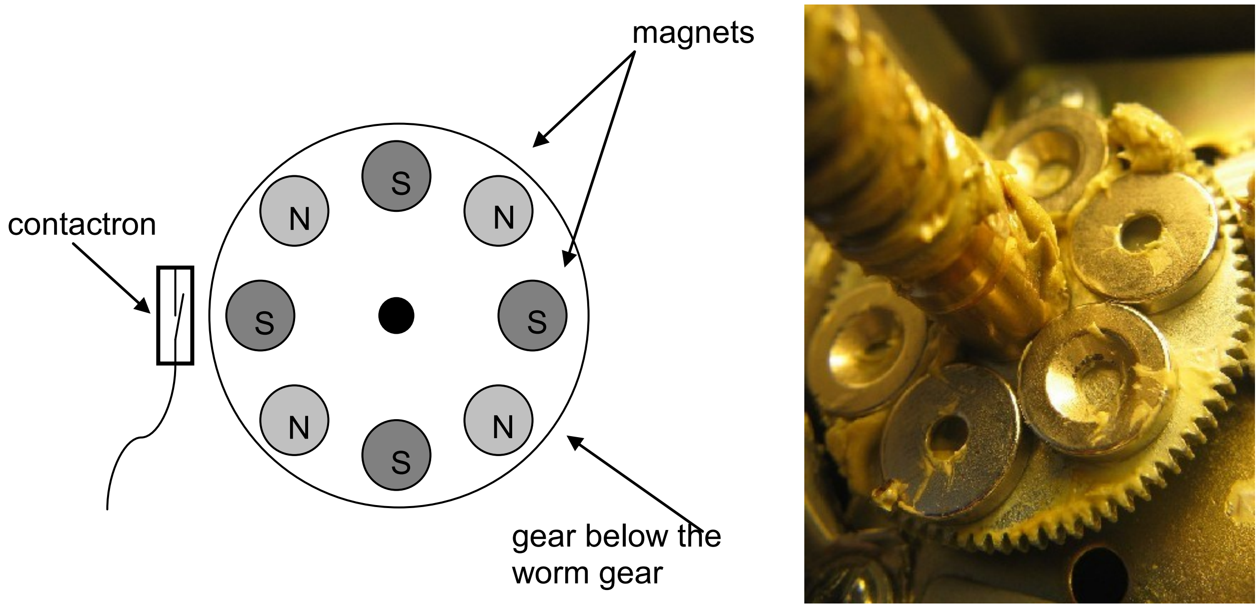

Figure 10. Rotation encoder for rotator

Mounting of the magnets at opposite polarization is important. When magnets pass near the contactron (small glass pipe with switch inside) it alternately opens and closes the circuit thus producing short impulses. The contactron is connected to alternating current power source, the same which supplies the rotator's engine. This solution is straight because this power source is already available in remote rotator box. It would be inconvenient to deliver DC power using additional cables. Moreover direct current is not suitable for supplying devices over longer distances. The signal in such form cannot be connected to the microcontroller inside the controller's box directly. That is why the additional circuits are needed: the rectifier which converts the alternating pulses to the direct current ones and the optocoupler which isolates high voltage circuitry form the digital circuit of the microcontroller. The path of the feedback signal is shown in [Fig. 11]:

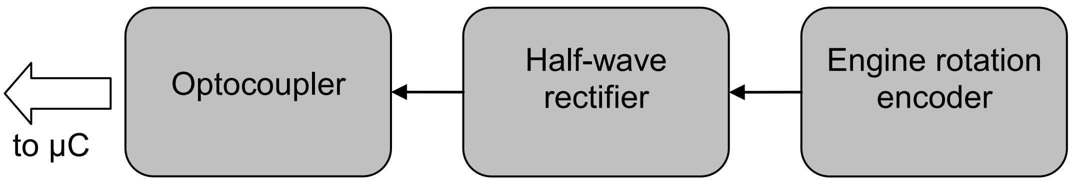

Figure 11. Block diagram of rotation encoder circuitry

The motion of the rotator's engines is controlled by execution unit. Because the microcontroller itself cannot generate currents which would drive the engines there are relays used. There are two pairs of relays: one for azimuth rotator and the other for elevation rotator [Fig. 12].

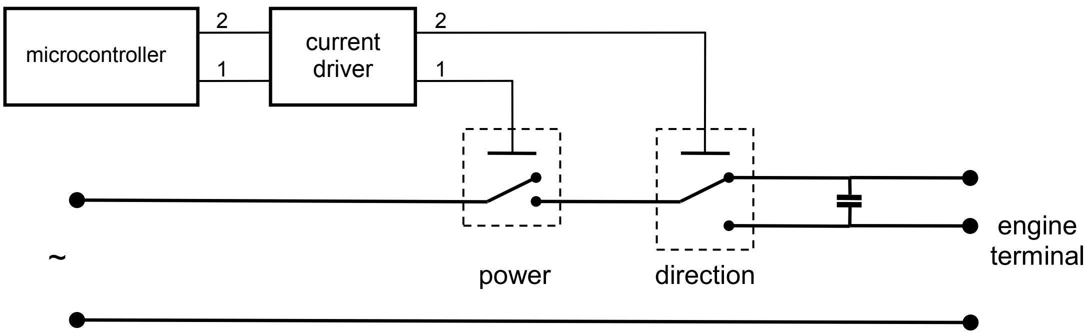

Figure 11. The interconnection scheme for execution unit

It can be seen that one relay is responsible for switching the current on and off and the other one – for changing the direction of the engine's rotation. This configuration of relays assures that if something goes wrong with the microcontroller's program the engine is secured against eventual damage.

The rotator's engines need 24V AC to operate properly. Thus, the power supply unit for the system is built by utilizing the standard 220V/24V transformer. There is made an additional winding producing about 8V AC. This current is rectified and stabilized by appropriate circuit (using the Graetz bridge and standard 7805 voltage stabilizer) for supplying the digital part of the controller.

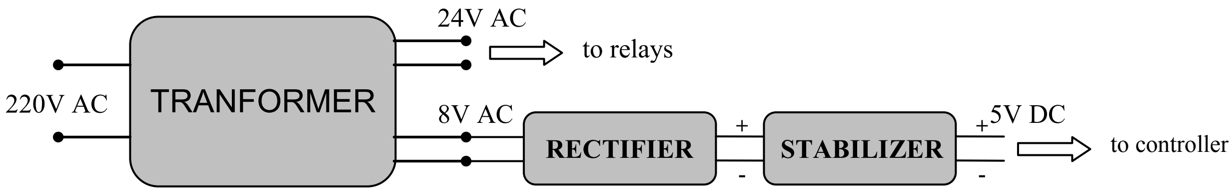

Figure 12. Block diagram of power supply

The digital part of the controller is based on the microcontroller. The version build by Marcin SQ5FNQ utilizes the AT89C51 microcontroller. The construction is simple enough to use another type of microcontroller and only a few changes in the circuit are needed.

The firmware of microcontroller allows for basic rotator operation (moving the antennas in two orthogonal planes) using the direction buttons in the front panel, acquiring the data about the actual rotator position and displaying it on the LCD display in the front panel of the controller. The most interesting function is that the controller can be connected to PC computer in order to fully automate the tracking process. The implemented communication protocol is compatible with the GS232A rotator controller protocol, so most programs that work with the original Yaesu controller will work with the proposed controller too.

The example of the software which can control the rotator is the worldwide known program called ORBITRON [4]. It is a Polish software developed by Sebastian Stoff as a freeware so it can be used fully functional one without any restrictions. The main screen at the moment when International Space Station (ISS) is flying over Warsaw is shown in [Fig. 13].

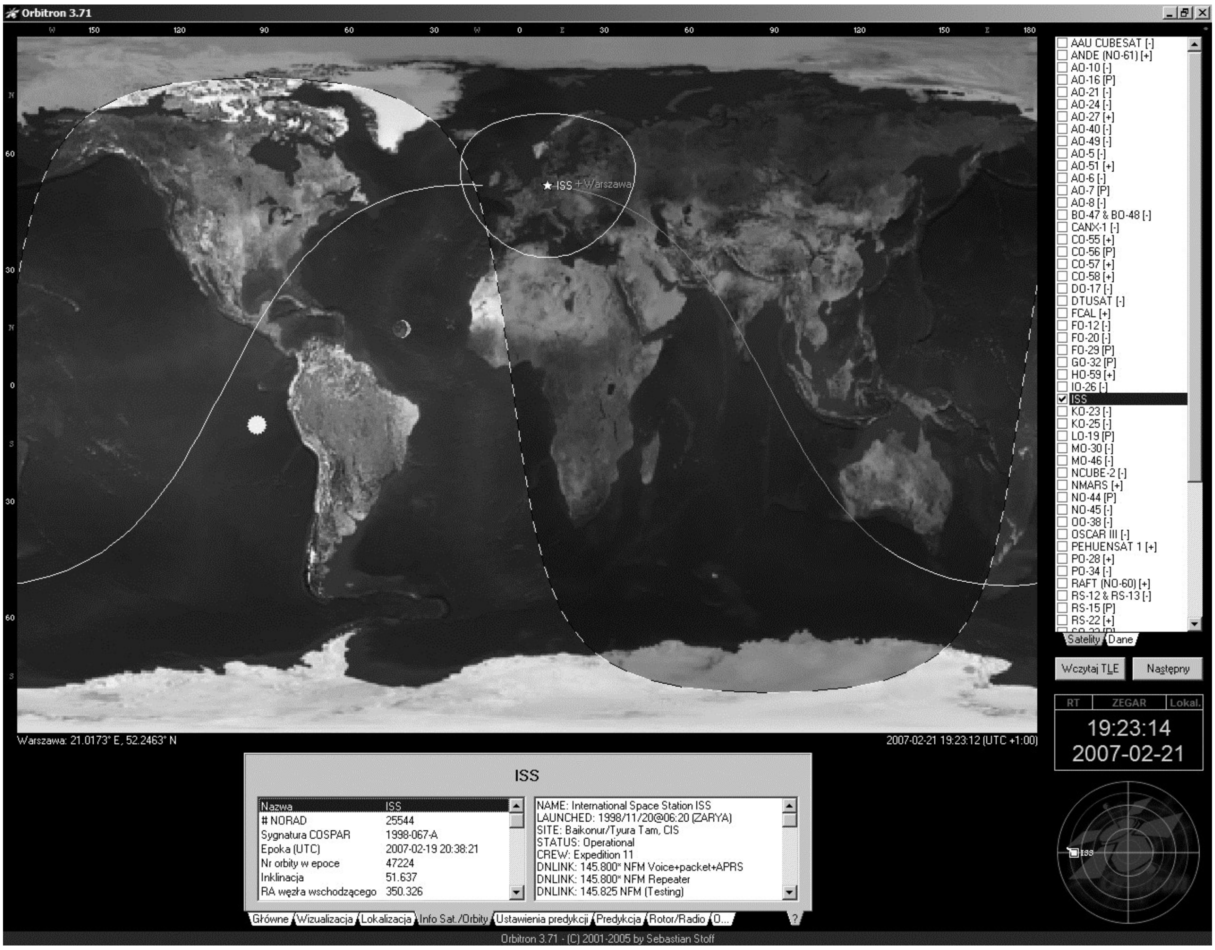

Figure 13. ORBITRON application main interface

The advantage of Orbitron is simple user interface, clear display of satellite path over the World's map and existence of many useful features. However, the most important function is the support for antenna rotator control.

Orbitron works as DDE (Dynamic Data Exchange) server delivering all necessary information about the satellite position to the special software driver. The driver works as a software interface between Orbitron and the rotator controller box. It directly feeds the controller box with appropriate position data over serial interface using special communication protocol. The data flow order in the antenna rotation system is shown in [Fig. 14].

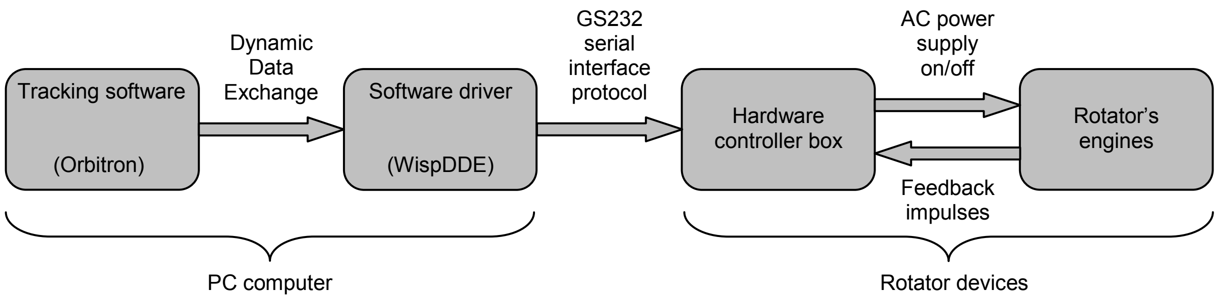

Figure 14. Data flow order in the antenna positioning system

The software driver which is used is the WiSPDDE [12]. This is a small program which is used to link the tracking software with external devices such as rotator controllers or radio transceivers. The main screen of WiSPDDE is shown in [Fig. 15].

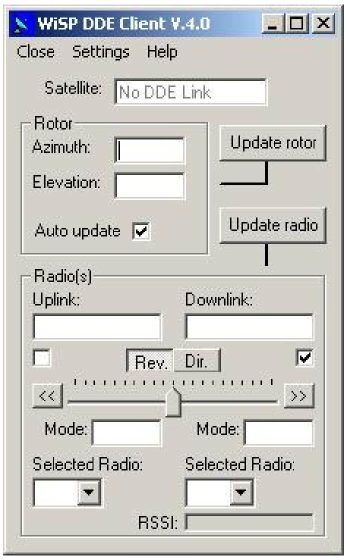

Figure 15. WiSP DDE Client software main interface

Currently there is being designed another version of the controller (ver. 3.0). In the initial version the AT89C51 microcontroller was being used but its limitations didn't allow for development and improvements. Grzegorz Woźniak SQ5FG has designed a new version of the controller based on the ATmega32 microcontroller. This allows for adding new functions such as ability to define number of impulses for the full revolution and storing it in the memory of the microcontroller.

4. SUMMARY

The article has presented several propositions of simple antenna rotation systems for tracking aviating and space objects. There has been presented examples of off-the-shelf products for radio amateur use. Later, simple manual rotators were described from simplest portable ones through sophisticated stationary constructions and their pros and cons were discussed. In the last part of the article was presented a prototype of cheap satellite rotator built by students from Warsaw University of Technology. The details of its mechanical structure and its electronic controller which allows for automatic operation with the PC computer was shown in order to convince the reader about the simplicity of the whole project.

The constructions described above were used to rotate antennas during various high altitude balloon missions. They are also used to communicate with radio amateur satellites. Presented solutions are very useful for such applications, however their development is still in progress. There are several modifications of those devices (i.e. RC-FNQ rotator) built by other radio amateurs which are satisfied with those constructions. At the home university some efforts are being made to improve the construction. There are also projects of new, more sophisticated tracking systems in progress. Currently there are performed operational tests of special version of BigRAS rotator from SPID Electronic. A special control protocol and positioning algorithm is being developed to ensure smooth movement of antennas while tracking. Such system is used to service such missions as PW-Sat [13] or BRITE-PL [14]. Beside those constructions there are researches in progress about new satellite communication methods such as network of academic ground stations GENSO [15] or the network of radio amateurs ground stations named Distributed Ground Station System (DGSS) [16, 17].

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