# A low-power cost-effective flexible solar panel powered device for wireless livestock tracking

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# A low-power cost-effective flexible solar panel powered device for wireless livestock tracking

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*Abstract* — **This paper presents a development of a low-power device for livestock tracking in an outdoor environment by using RF technologies. The animal tracking device (AnTrack) is self-sustainable with a watertight solar panel(s). The device records the exact location every 15 minutes and when the device is within the radio range of the base station, it automatically sends the data to be relayed to a server Over-the-Air. Analysis can then be done on the location points of each animal. We perform a detailed analysis of the power consumption and prove that our AnTrack is capable of generating enough supply power even when there is no sunshine for a week.**

*Keywords* — **Livestock tracking, RF signal, Wireless technology.**

## I. Introduction

Technology in the machining agricultural sector around the world has been advancing at a steady pace to increase productivity and efficiency of different farmland processes. But the technology advances with regards to cattle ranching did not follow the same path. The simple reason would be that stock theft is not that big problem in the USA or Australia and there was no need to develop more technology for this purpose. In South Africa however, it is certainly a huge problem for farmers with around 25000 cases reported in 2015 [1, 2]. From 2006 until 2010 around 377000 animals were stolen in South Africa, which adds to around R1 billion lost in 4 years [3].

One way to reduce stock theft is to keep account of all the cattle on a farm by constantly mustering them and counting the cattle [4]. This is a very labor intensive task but farmers have found that if they do not keep track of all their cattle on a frequent basis, the thieves steal more and more cattle from a herd.

A South African product called CelMax has been developed specifically for stock theft prevention of sheep. It works by placing a collar device around the neck of a single sheep in a herd of 500. Sheep usually follow the actions of the others; when one sheep behave abnormally, all of them will. When the collar devices detect running at night then it is assumed that someone is chasing them, which could be a thief trying to catch sheep. The device then sends an SMS to the farmer to let him know that the sheep are running and probably being chased. The battery life of this device ranges from 6 to 8 weeks and the whole device, in general, is very expensive [5].

Another product called the ProTagTor system has been launched in 2009 which works on the same principle as the CelMax system but uses base stations instead of onboard GSM module to send an SMS to a farmer. Their signals are forwarded to the base stations for analysis. Each of these tags has a battery life of 4 to 7 years and only costs 10% of the GSM collar.

In this paper, we propose AnTrack, a new device for livestock tracking in an outdoor environment based on RF technologies. We are to develop a more cost-effective solution to manage livestock by tracking all or most of the animals which behavioral analysis can be conducted on the live paths. AnTrack is self-sustainable with a watertight solar panel(s) capable of generating enough power to supply the device even when there is no sunshine for a week.

## II. Design and Architecture of AnTrack

The three key modules of AnTrack are: a locator based on GPS, a solar panel to recharge the battery and a transmitter. The complete system will be in the form of a collar as seen in Fig. 1. The collar's strap will house part of the flexible solar cells which will be wired to the device found underneath the animals' neck on the strap. The processor, as shown in Fig. 1, is an enclosure to house the electronics and battery in a watertight environment.

Fig. 2 shows the basic system diagram of the proposed device. The microcontroller unit (MCU) is responsible to control all other units connected to the system. The system contains two energy supply units: a battery and a solar panel. When the solar panel provides more power than the system needs, the power management subsystem charges the battery until it is fully charged. The system will rely exclusively on the battery if the solar panel is not providing enough power. The MCU controls the power supplied to the GPS module and RF transceiver. To keep power to a minimum the MCU uses its internal oscillators and should be in sleep mode when the system is not

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recording the position or transmitting. The GPS module has a constant supply to its V Backup pin to ensure that SRAM is always being powered; the voltage will be stepped down to the specified range. The MCU has an external storage connected where location data will be saved when the base station is not in range, with the nRF option or if there is not enough GSM signal to transmit a location point using this method.

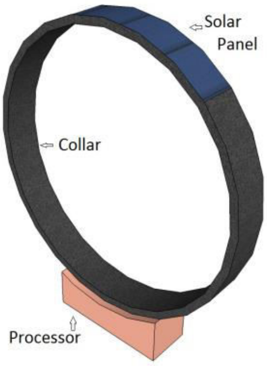


Fig. 1. Representation of collar device

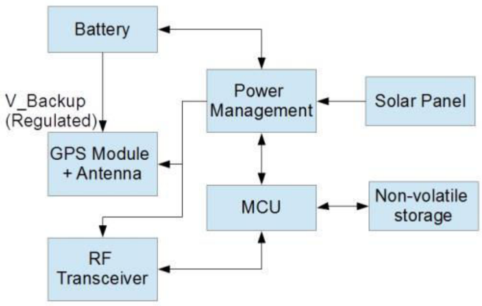


Fig. 2. AnTrack system diagram

## III. Wireless Technologies

In this section, the main modules of AnTrack are elaborated in detail. To complete this system, it is needed to use two different wireless technologies. One of them would be to find the location of the animal and the other wireless technology to use would be to transmit the data back to a server for analysis.

### A. *GPS based tracking module*

GPS or Global Positioning Satellite has a lot of different uses ranging from home to services.

Table 1: NMEA short description [6].

| NMEA Sentence | Description |
|---|---|
| GGA | Time, position and fix type data |
| GSA | GPS receiver operating mode, active satellites used in the position solution and DOP values |
| GSV | The number of GPS satellites in view satellite |
| ID numbers, elevation, azimuth, and SNR values | |
| RMC | Time, date, position, course and speed data. |

In AnTrack, the GPS module is used to track the animal in its habitat. The position is recorded by the microcontroller at an adjustable interval.

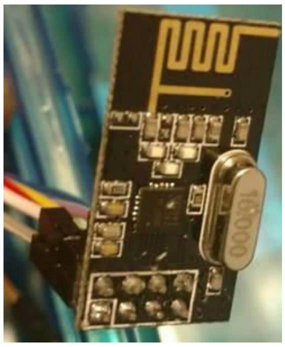

Fig. 3. AnTrack prototype

The GPTA010 GPS Module's datasheet [7] is used for additional information requirements. It runs with a voltage source from 3.0 V to 4.3 V, typically 3.3 V. At an update rate of 1 Hz, to get a lock onto the position, the typical current consumption of this device is around 25 mA, or power consumption at 82 mW. While tracking, it uses 20mA of current. Yet, for the purpose of this application, tracking is not necessary since we only need the location every 15 minutes.

This module uses Universal Asynchronous Receiver/Transmitter (UART) to communicate. The following is an example of how the GPS transmits data to a device connected via UART; it is called the NMEA protocol and is a universal protocol used by most GPS devices.

$GPGGA,064951.000,2307.1256,N,12016.4438,E,1,8,0.95,39.9,M,17.8,M,,*65

$GPGSA,A,3,29,21,26,15,18,09,06,10,,,,,2.32,0.95,2.11*00

$GPGSV,3,2,09,18,26,314,40,09,57,170,44,06,20,229,37,10,26,084,37*77

$GPRMC,064951.000,A,2307.1256,N,12016.4438,E,0.03,165.48,260406,3.05,W,A*2C

$GPVTG,165.48,T,,M,0.03,N,0.06,K,A*37

These NMEA sentences (see Table I), are sent at a rate of 1 Hz but can be adjustable. Each sentence displays different information about the location, speed, time and satellite statuses. Table II sums up these sentences, note that $GP is used as the header and not included in the table. We only require the GGA sentence because we only require the location.

### B. *Data transmission module*

AnTrack can rely on two different methods to transmit position data to the server, based on GSM and RF technology respectively.

**GSM based transmission:** The GSM Module is able to transmit an animal's paths constantly to a server using already available GSM network provided by cellular service providers. This method has its drawbacks. Each device needs a SIM card to operate and this SIM card needs to be loaded with data each time it nears its end of the data bundle. API's can be used for this process [8] which monitors each SIM and our server will be able to determine which SIM card needs recharging and adequately recharge the device with the correct data bundles. A quite important for these GSM modules related to power use is the fact that they can draw peak currents [6] of up to 2A, which requires that a sufficiently charged Lithium-ion battery be present to use when this module is to be used. To communicate, this module uses the UART protocol. It uses the AT command protocol to communicate with an external device and the complete setup will be done using these commands. The GPRS module will need to establish connectivity to its cellular network.

TABLE 2: GGA SENTENCE STRUCTURE [6].

| Type | Example | Description |
|---|---|---|
| Message ID | $GPGGA | GGA protocol header |
| UTC Time | 064951.000 | hhmmss.sss |
| Latitude | 2307.1256 | ddmm.mmmm |
| N/S Indicator | N | N=north or S=south |
| Longitude | 12016.4438 | dddmm.mmmm |
| E/W Indicator | E | E=east or W=west |
| Position Fix | | |
| Indicator | 1 | 0 |
| 1 | - GPS Fix | |
| 2 | - Differential GPS Fix | |
| Satellites Used | 8 | Range 0 to 14 |
| HDOP | 0.95 | Horizontal Dilution of Precision |
| MSL Altitude | 39.9 | Antenna Altitude above/below mean-sea-level |
| Units | M | Units of antenna altitude |
| Geoidal Separation | 17.8 | |
| Units | M | Units of geoids separation |

When the GPRS module is in use and transmitting, the current being drawn can range from 156 mA to 408 mA depending on the number of RX/TX channels in use. To accurately predict the current consumption beforehand will be quite impossible which is why the worst-case scenario should always be assumed, 1.63 W at 4 V of power being used. The amount of time the module may search for its network and connect to the server will also be within quite a large range of seconds depending on the environment. A true range could not be found and estimation will be made that the whole process may take around 1 minute to send a location to an HTTP server from personal experience.

**RF based transmission:** The nRF24L01L is an RF transceiver operating at the 2.4GHz frequency, with a range of around 1.1 km and data rate at a maximum of 2Mbps. This device is very feasible for this research project. The only downside of using this approach is that it requires a base station to receive the locations from the device. Its ultra-low current consumption of around 0.12mA when transmitting [9], allows being almost solely powered by the solar panels except when operating at night. The device uses the SPI protocol to communicate with an MCU.

### C. *Solar panel module*

Flexible solar panels are quite new in the industry but will be very useful in this application and in PowerFilm's product range; one can find a permanent outdoor unit [10]. The PT15-75 is 90 mm wide and 270 mm long, about the dimensions of the proposed collar strap. It is water protected and sealed for outdoor use. We now need to calculate if this solar panel will be adequate for this application. The expression (1) to calculate energy (E) has been adopted from [11] and [12]:

$$E = A * r * H * PR \qquad (1)$$

where E is Energy (kWh/year), A is a total solar panel area ($m^2$) which is 0.0243 $m^2$, r is solar panel yield (%) which is 3.16%, H is an annual average solar radiation on tilted panels (shadings not included) which is 2007kWh/$m^2$/year, PR is a performance ratio, coefficient for losses (range between 0.5 and 0.9, default value = 0.75).

As seen in Table III, the power needed per day is only calculated at 23.99 mWh (nRF24L01) [13, 14]. The solar panel which has been used to fit onto the collar will on average generate 2740 mWh a day. For reliable operation of the AnTrack, the amount of power needed will be estimated to power the device for 5 days. This is a rough estimate where low light is possible due to heavy rainfall days and will be around 120 mWh/day of power, backtracking this to the flexible solar panels [10]. Using the panel sizes and current specifications, related that a solar panel with an estimate area size of 0.001 $m^2$ is necessary or a solar panel of 1cm by 1cm.

When looking at the SIM800 as an option, the total power required each day is 2.75 Wh. The solar panel can supply an average of 2.74 Wh each day. This option is too close for comfort and the reliability of the system will not be good enough. To solve this, a large battery can be used but will drain over time; the next option is to use a larger solar panel which will increase the size of the device. The last option to consider is to extend the intervals when locations are being sent to the server. When looking at Table III, the MCU and GPS [16, 17] use are negligible and when increasing the locations sent to every hour, the device will have a power consumption of 4 times less, suitable enough for the solar panel used.

TABLE 3: POWER USAGE FOR DIFFERENT DEVICES

| **Device (State)** | **Power Usage** | **Runtime per position** | **Watt/hr each day** |
|---|---|---|---|
| GPS (Get Position) | 82.5mW [7] | 10 seconds | 22.917 mWh |
| nRF24L01 (Power Down Mode) | 0.0027mW [9] | 14.5 minutes | 0.065mWh |
| nRF24L01(TX) | 33.9mW [9] | 1 second (1Mb of data) | 0.942mWh |
| SIM800 (Power Down) | 0.52mW [6] | 14 minutes | 0.0225 mWh |
| SIM800 (Active) | 1.63W [6] | 1 minutes | 2.72Wh |
| PIC16F1508 (RTC) | 0.0009mW [15] | 15 minutes | 12.13mWh |
| PIC16F1508 (in Use) | 0.105mW [15] | 15seconds | 0.044mWh |
| | | **Total (nRF24L01)** | **23.99mWh** |
| | | **Total (SIM800)** | **2.75Wh** |

## IV. Discussions and Future Directions

This paper contains different power calculations when using two different transmitting devices which are around the same cost. These calculations have confirmed that the device can be self-sustainable by keeping its battery charged using small flexible solar panels. The biggest difference between the two communication methods is the fact that the GSM module can transmit from anywhere without any extra infrastructure and the nRF24L101 needs a base station which will only send the data to the server when within the 1 km specified range. However, the nRF24L101 uses a lot less power and it will almost be possible to manufacture the device in an ear tag form and not the proposed collar specified, the device is self-sustainable with a relatively small solar panel to keep its battery charged. The downfall of the GSM module is its large power consumption, it is so large that the other devices' consumption is negligible when transmitting at 15 minutes intervals, which means that the interval must be extended and then base station solution is comparable as the two approaches can be set to send all the backed-up location data only once every day. Because of the probability to decrease the size of the complete system when using the nRF, this will be the better solution.

The following tests have to be conducted with the collar, the solar cell, and GPS in a real-world scenario. Only the specified components and modules will be used for each test and after enough data has been captured to specify a plausible working system, the different modules will be combined. This method is preferred to determine any shortcomings the system might have in real-world scenarios as it will be quite hard to determine where problems have been found in the device malfunctions.

- For a week in summer and in winter, the flexible strip will be placed on the top of the strap to receive a rough estimate of how much energy is produced a day by this device.
- With a GPS Module with a mounted chip antenna, the signal must be tested. It is recommended that the GPS antenna is pointed to the sky, but we would prefer that the module is placed inside a watertight enclosure with the MCU and battery with only 1 external connection to the solar cell. This test will determine if it is required that the GPS antenna is mounted on the solar cell to point to the top.
- Real world GPS tests will determine the amount of current the GPS uses to lock onto its signal and how long the system should run to lock onto a signal. This should determine the interval's which positions can be determined.
- Real world RF transmitter test will determine the current used to transmit a single as well as multiple positions to the base station. Because the base station and RF transmitter will not always be in range, tests should be conducted to determine how much current the device will use to check if the base station is in range.

## V. Conclusion

In this paper, we propose AnTrack, a new device for livestock tracking in an outdoor environment based on RF technologies. AnTrack is a self-sustainable device with a watertight solar panel(s) and aims to be more cost-effective solution compared to traditional tracking devices. Through advanced calculations, we prove that AnTrack is capable of generating enough power to supply the device even when there is no sunshine for a week.

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