A new approach to remote control of aids to navigation

Rolf Bäckström,
Finnish National Board of Navigation

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The article describes the design philosophy and reasoning behind a new remote control system for aids to navigation. The salient features of the new system is extremely low power consumption, exceptionally high reliability, extensive integration, low cost and no need for interface circuits. The author works as a senior engineer at the research and development facility of the Finnish National Board of Navigation.

Background

Finnish law says, that everybody, who detects a fault in the promulgated operation of an aid to navigation, is obliged to report it to the authorities. Since the last Finnish light was automated in 1986, and even long before, Finnish lights are regularly serviced but have largely been monitored only by pilots and navigators in passing. Surely everybody must agree that there is a gross inconsistency in this approach. The user is very dependent on and is supposed to put a high reliance on, aids to navigation (AoN), but the system itself relies on, to a large extent, that the user detects and reports the malfunctions himself. This is bound to have a detrimental effect on the safety of navigation.

Every lighthouse service, conscious of cost, targets on saving money by keeping the AoN service frequency as low as possible. The cost of the actual work on the light is not expensive, but when the cost of actually taking men out there and time spent on travelling is added, the ultimate cost is rising to astronomic figures. Raising the service frequency infinitely does not make all faults going away anyway, so a reasonable compromise between cost and navigational safety must be found. A good way of keeping down cost, but still improving safety, is to monitor AoN's by using remote control. Faults and, in particular, slowly emerging faults can be detected, possibly before the AoN goes into a navigational fault condition.

The Finnish National Board of Navigation (FNBoN) has studied, and indeed used, remote control of Aids to Navigation at a small scale for almost three decades. The system was built to support a major lighthouse installation, including a high power light, radio beacon and fog signal. The energy was provided by four dieselgenerator sets, two small and two large ones. The electronics also included radio beacon and fog signalling keying characters and timing, also monitoring of all essential characteristics. These systems were installed on four remote lighthouses. Everything was designed and manufactured at the workshops of FNBoN. At the beginning of the 80's we looked with envy at the Swedes who had installed a comprehensive remote control network to cover more than 70 lighthouses and DECCA-stations, all monitored and controlled from one point. Consequently, a comprehensive study was made on the benefits of such an approach. In spite of the obvious benefits, several major problems were identified that were difficult or even impossible to address in our specific conditions with a remote control system of 1980 vintage. Following design criteria for any new remote control system were expressed:

1. A remote control system must cover a major part of all aids to navigation installed. If all AoN's cannot be monitored, even to be able to monitor all AoN's on a specific fairway would be acceptable, rather than some AoN's here and there. Consequently, to be able to fit remote control systems on a large number of AoN's, it must also be inexpensive.

2. The interface between the remote control equipment and the equipment to be monitored must be simple and standardised.
3. The energy consumption of the remote control may be only a small fraction of what the equipment to be monitored uses.
4. The reliability of the remote control equipment must be better than the equipment to be monitored. If the remote control system is more complex than the AoN itself, the reliability of the remote control equipment is bound to be inferior to the equipment to be monitored.
5. The remote control system must be simple to install, to use and to service.

We had only a few major electric lights then, other electric lights were rather small and of a simple construction. Most of the lights were on acethylene. Finnish buoys are rather special, as they have to withstand drifting ice and frequent and extended periods of submersion. All lighted buoys are only using electric light and primary batteries. The lights had equipments of different times and makes and it seemed impossible to build interface circuits to all 2400 lights. In 1982 FNBoN, however, started a comprehensive program to convert all fixed lights to renewable energy sources or the mains were it is readily available. Most of the lights are located far away from power lines. To this date, some 1400 lights are converted to solar power, with about 534 remaining. We have acknowledged the fact that the importance of major lighthouses has declined significantly with the advent of numerous other AoN's and, in particular, radionavigation systems. Hence all Finnish major lighthouses have been downgraded in range (changed from 20 - 25M to a maximum of 12M) and consequently the required energy to achieve the new range was reduced to a fraction of what it was before. In 1984 all fog horns and in 1992 all radiobeacons were closed down.

As a consequence of the facts listed in the above paragraph, there was suddenly no use for a remote control of the conventional type, as it could not fulfil any of the requirements listed above in the new circumstances. We searched the market and the remote control equipment, for the least energy consumption, which was about 50 mA at 12 V at that time, corresponding to 1.2 Ah per day and that was without the radio receiver. Our lateral buoy light uses about 1.2 Ah/day, which would have meant that battery replenishment times had to be halved as there is no spare room for more batteries in the battery compartment. The development of a remote control system now came to a hold. What happened after this is more a matter of three or four converging lines of evolution (components development) and an emerging insight, rather than strict advance planning. A short description on what happened with the different components:

The new flasher

A new type of flasher was developed in 1987 and further refined 1993, to correct the many flaws of flashers on the market then. Problems or desires to be addressed were:

- *output voltage control problems, particularly with high current lamps and long wires,*
- *lack of adjustable output voltage for e.g. 6, 12, 24 V in addition to 10.3 V,*
- *allow for 200 W, 28 V sealed beam lamps*
- *flasher shall shut down when a certain preset adjustable voltage is reached,*
- *quiescent current is to be reduced to an absolute minimum,*
- *improve reliability and efficiency,*
- *improve synchronisation capabilities,*
- *enable use of lamp changers w/o external components*
- *integrate flasher with solar panel regulator,*
- *add integral Ah-meter for both the load and the energy source*
- *add extensive user programming capabilities* (e.g.. Lamp voltage, light characters, photocell adjustment).

All the wishes were met at least partly. The Ah-measurement of the load was found to be not impossible, but difficult to realise as it would have required an energyconsuming high resolution AD-converter. This feature was replaced by an accumulating filament ON-time calculation, from which at least a rather accurate relative

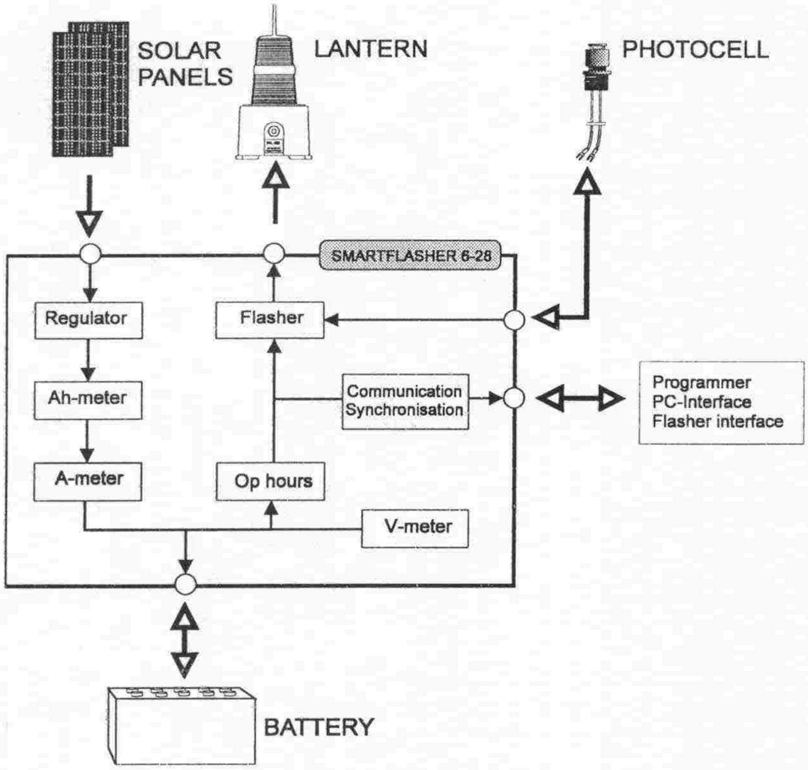

Figure 1. Functional block diagram of the new flasher.

or more synchronised range light pairs and synchronisation of channel markings ("running light effects" etc.), even with buoys. The "running light effect" has particular interest as the user or the AoN provider can detect a missing AoN in the sequence, by a glance. A number of approaches were studied, including radio, optical and international time standard synchronisation. Radio communication was found to be best, in particular when it could be used for other purposes as well.

A new photovoltaic charge regulator device

FNBoN has always used charge regulators with photovoltaic panels, contrary to some other major and prominent solar power users. Without a regulator, photovoltaic panel and the battery voltage curves have to be accurately matched to each other, i.e. the system is self-regulating. Finland is a small country and cannot afford to buy custom-made basic components, as solar panels and secondary batteries, in large batches, neither to keep large storage of these. Thus, using a charge regulator gives latitude to change to whatever photovoltaic panel or battery type is wanted, whenever replacement is required.

Introducing a solar panel regulator introduces a new additional component in the AoN system, with a failure rate grossly exceeding that of the other components, as experience has shown. Also, the regulator has it's own quiescent current, 5 - 15 mA, depending on make. Even if this figure appears rather low, it is there all the time and becomes ultimately a major energy consumer in a small solar panel system and as a consequence the system has to be enlarged by some 5 - 30%. Finland is geographically located between 60° and 67° in latitude, which gives 3 - 4 months with virtually no sun energy production, while the energy consumption peaks. Finally, checking and setting the precise charging

energy consumption may be calculated. The feature, that filament voltage is always measured at the lamp terminals, no matter how long the wires are, was particularly appreciated. This maintains the desired lamp terminal voltage always at ±2%, no matter how long the lines are. We use bifilament lamps extensively but lamp changers for other lamp types are easily adapted. A functional diagram of the new flasher can be seen in *figure 1*. A hand-held programming device was also developed. The project was realised with the aid of microprocessors and software, of course...

A new synchronisation transmitter/receive

Another line of development was to find systems and ideas whereby the energy consumption of AoN's could be reduced. Energy could e.g. be saved by using synchronisation of range light pairs, whereby one can build the energy source of both lights identical (otherwise the rear light always has a slightly larger energy consumption). As a further bonus, navigational safety can be increased. FNBoN also wanted to implement other synchronisation schemes, such as maintaining non-synchronisation between two voltage in field conditions is an intricate and major problem, in particular as the required charging voltage has to follow the ambient temperature at all state of charge's (S.O.C.). A number of considerable advantages follow, if the regulator could be incorporated with the flasher, still maintaining the flasher's high reliability and low quiescent current and using the flasher voltage control. A functional diagram of the final realisation is seen in *figure 1*.

The final remote control system

Finally FNBoN sponsored a large study in 1991 to find out whether a remote control system could be developed, incorporating all the building blocks described above, adhering to the initial design criteria also described above. Some additional design criteria (or clarifications) were incorporated at this stage:

1. The system shall contain neither external interface circuits nor external sensors. Everything is to be integrated in the flasher. During the design process, however, it was decided that external sensors could be added as a part of one single 8-bit dataword. This was considered adequate for most purposes.
2. The basic system is short range, 10M maximum, with the type of radios and frequency band (230.7 MHz) used. Range extensions are provided by larger data collection stations that are located at stations with mains electricity available, see *figure 2*. These stations could collect the compiled data from a number of data collecting nodes. Data collection can also be performed by any mobile unit, with fully automatic polling and without human intervention, for later processing.
3. Slaves are required to respond only as a result of a poll. The receiver is the main energy consumer of the system. Therefore listening periods are programmable and the slave could programmed to be dormant for e.g. 10 s and listening for 1 s.
4. Equipment shall be small enough to fit within present equipment compartments and boxes.

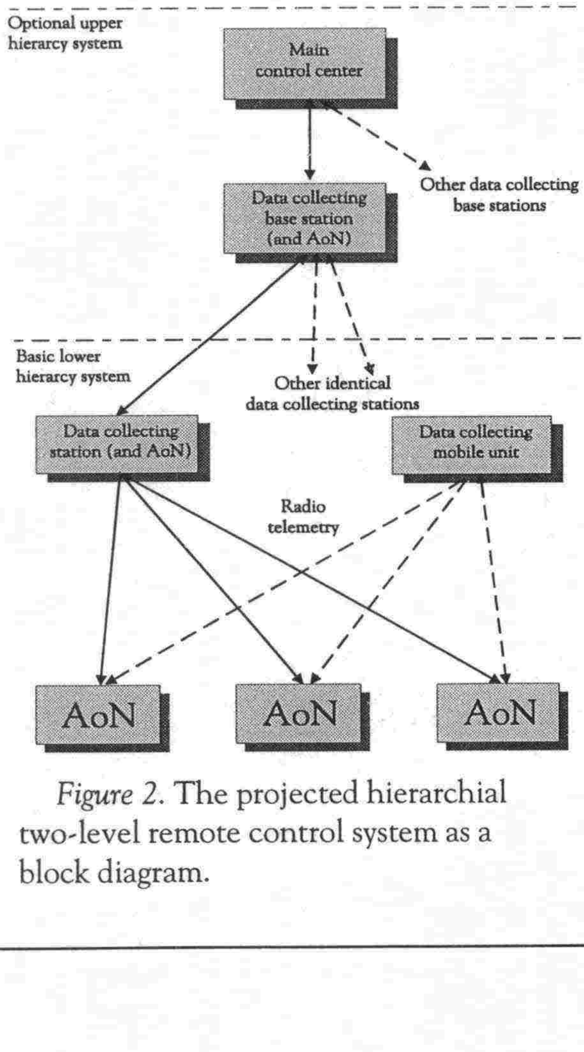

Figure 2. The projected hierarchial two-level remote control system as a block diagram.

A working prototype was produced and tested. The idea proved to be feasible. The concept allows the AoN provider to build an as small remote control network as he wants, still remaining fully featured. The keywords are: *total control, extremely low energy consumption, high level of integration, high reliability, simplicity* and *low cost.* Any provider of AoN's, familiar with remote control systems, should be able to grasp the significance of these features.

Projected, but not yet realised, is providing at least the interface to higher hierarcy system, see *figure 2.* Before realising upper hierarcy structure we will study how does the use of this product affects AoN logistics.

Equipment description

In the next the whole system is briefly described, not in detail, merely a few highlights.

AoN remote substation

The remote control substation contains a *transmitter* and a *receiver* with a common antenna and a *8-bit micro processor*. The unit is connected to the flasher with two wires. No additional wire terminals are required on the flasher. The AoN

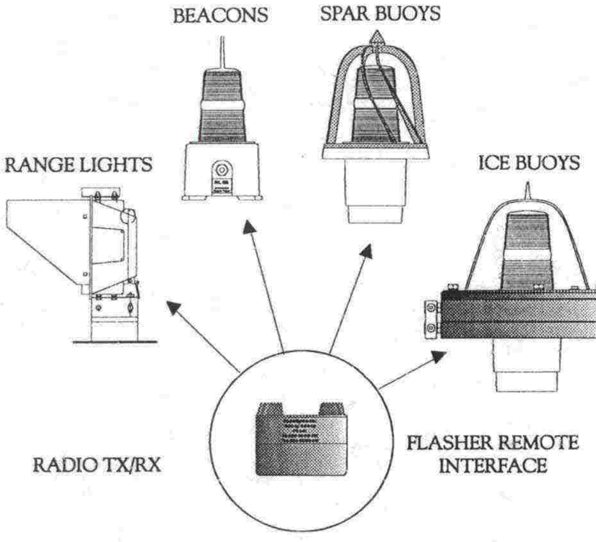

Figure 3. The remote control sub station may control a wide range of different lanterns.

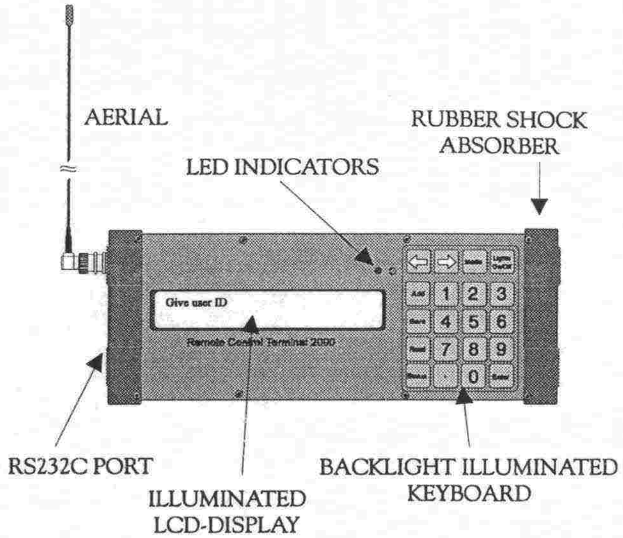

Figure 4. The hand held remote control terminal.

remote control substation is contained in a tubular housing, the diameter, of which, is the same as the flasher, see *figure 3*. They can be mounted on top of each other for easy installation. Every AoN unit has a *user programmable identification code*. When a unit is remotely polled by the operator, following parameters are transmitted:

- supply voltage, with load and w/o load, readings
- operating hours for filament1 & filament2 (bifilament lamp), readings
- voltage loss in the wires and connections between lamp and flasher, reading
- voltage loss within the flasher regulator circuit, reading
- filament nr. or lamp in lamp changer nr. in use , reading
- light character in use, setting
- photocell sensitivity, setting
- low voltage treshold, setting
- lamp voltage, setting
- synchronisation delay, setting
- charge cut-off voltage, cut-in voltage hysteresis, temperature compensation (-mV/°C), boost charge voltage hysteresis
- radio receiver ON- and OFF-times

Remote control terminal

The remote control looks different than the sub station unit but the content is partly the same, see *figure 4*. It contains a *transmitter* and a *receiver* with a common antenna and a *8-bit micro processor*. The terminal operates with a chargeable secondary battery to enable mobile operation. The terminal can call up any substation by ID number or transmit a *broadcast call*, requesting all substations hearing the call to respond. By the aid of a PC the terminal may call a prepared list of ID's and then starts calling every substation in turn. When a contact is established, the photocell is bypassed to briefly fire up the substation AoN, even if it is daytime, to get the correct readings and a visual impression that the AoN works. All the data listed under the previous paragraph can now be received. Also the following commands and settings can be transmitted, if so wished:

- light character to be used
- photocell sensitivity, setting
- low voltage treshold, setting
- lamp voltage, setting
- synchronisation delay, setting

The system can even command the light even to shut down for any length of time until the operator switches the light on again. This is a useful feature in areas where there is no traffic in wintertime because of the ice and the light is promulgated to be closed. This may give possibilities to design the solar system smaller than otherwise.

Conclusion

Already from the outset it was clear that FNBoN is not an equipment manufacturer and thus the idea and plans were sold to SABIK, a domestic supplier of lighthouse components. SABIK put the unit in production. The first units came out from the production line in April 1994 as a part of the order for twenty systems, which are going to be installed in a test area, once the ice has melted away in Finnish waters. Thus the experience on how well the system operates is still to be gained. FNBoN is very optimistic regarding the prospects and possibilities of this new system.