MODE S TRANSPONDER DESIGNED WITH A SOFTWARE DEFINED RADIO
(Transponder Mode S Basic Functionality Implemented)

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RESEARCH PROBLEM
For some years now, aerospace and aviation industries have been demanding for a new approach using a single generic system, which could be reprogrammable and universal, replacing multiple radios and antennas present on aircraft.

The Mode S technology was first developed by MIT Lincoln Laboratory as a modernization for previous Air Traffic Control Radar Beacon System (ATCRBS). It has already proved its benefits in comparison to ATCRBS (modes A and C), as shown in Table 1. The most significant ones are the possibility of selective interrogation for aircraft, drastically reducing response garbling (see Figure 1), and the increase of data types transmitted so that more information can be acquired from the aircraft.

Table 1: Comparison of Mode S technology with ATCRBS system

<table>
<thead>
<tr>
<th>ATCRBS system</th>
<th>Mode S system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Addresses available</td>
<td>• 406</td>
</tr>
<tr>
<td>Jam encountered</td>
<td>• FRAF, jamming, etc.</td>
</tr>
<tr>
<td>Selective interrogation</td>
<td>• Only based on radar beam direction</td>
</tr>
<tr>
<td>Information exchanged</td>
<td>• Altitude, aircraft’s GENT</td>
</tr>
</tbody>
</table>

To build a system like this, the Laboratory of Specialized Embedded Systems, Navigation and Avionics (LASSEN'A) of the École de technologie Supérieure has chosen to take a relatively new approach in the field. This approach, Software Defined Radio (SDR), is mainly used in various communication systems for its flexibility and high performance, thus will be implemented for our system in SDRs NZ10 manufactured by Ettus Research.

MODE S

Mode S or mode “selective,” is a new way to interrogate an aircraft by using a distinctive address so that only a particular aircraft will respond. Many years ago, mode A and C were developed for airframe identification and altitude reporting. This was and still is an important component of air traffic control and air space management [1].

METHODS

To deal with Mode S technology implementation within a SDR, a first objective of our project is to create a part of program that recognizes and treats a Mode S interrogation, to respond only if it contains the specific prototype’s ICAO address.

A second task is to implement all Downlink Format (DF) messages corresponding to a Level 2 Mode S transponder shown in Table 2, to be able to respond when we detect an interrogation.

Table 2: Contained fields in DF messages of Level 2 transponder

<table>
<thead>
<tr>
<th>DF</th>
<th>Fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>DF21</td>
<td>Level 2 Mode S Message</td>
</tr>
</tbody>
</table>

MODE S TRANSPONDER DESIGN

The architecture of our transponder is shown in Figure 2. The first path of our prototype (the receiving one in the top), concerns detection of interrogations, the most critical task.

To manage transition from detection to transmission, we have created exceptions (one by UF type) that allow interrupting the detection routine, to swiftly our Mode S transponder program to transmission mode. These exceptions enable the transmission path (composed of some basic GNU Radio blocks, shown in Figure 4) with the generated message we want to transmit as the source of the flow-graph.

Figure 2: Receiver and transmitter section of the Mode S transponder based on GNU Radio blocks

At this stage, we have demonstrated that it is possible to implement Mode S technology in an SDR. One of the most significant benefits of SDRs is the ability to reconfigure by software the parameters required (reducing costs).

After the implementation of the SDR Mode S prototype on USRP B100, our next step is to implement our prototype on an embedded SDR, such as USRB E110. This type of SDR can run standalone operations for embedded applications, thanks to its Real-Time Operating System (RTOS), Embedded Linux. Work on our Mode S transponder with a SDR is continuing, with initial results already very promising.

REFERENCES


CONCLUSION

At the stage of this, we have demonstrated that it is possible to implement Mode S technology in an SDR. One of the most significant benefits of SDRs is the ability to reconfigure by software the parameters required (reducing costs).

The GR-AIR-MODES program [3], designed by Nick Foster, was used as a ground receiver simulator to verify that our messages have been transmitted without being corrupted by the transmission channel (in our case, the UHF channel). It’s a real-time program very useful to make tests. In order to recognize easily our replies, all DF messages generated by the prototype contain the ICAO address ABC123. We see in Figure 6 below some type of our DF messages decoded by the GR-AIR-MODES program.

Figure 6: Decoding of Mode S messages sent from the transmitter section

In Figure 6, we can observe messages received and decoded by GR-AIR-MODES. Therefore we can conclude that the “Replies generation logic” block and the whole transmitting path works correctly.

Figure 7: Configuration of Transmitter/Receiver for tests in LASSENA’s labs

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