

INTERNAL REPORT

**An alternative method for accelerating integration of
digital backends in the control software of
Italian radiotelescopes**

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Abstract

Digital backend integration represents one of the most complicated task in the context of a radiotelescope's control software.

As a final stage in the receiving chain, data produced by every backend must include overall informations concerning antenna and observation, moreover each backend has its own special features we must bear in mind.

In this report we will discuss the big breakthrough guaranteed by an alternative approach regards digital backends integration in the control software of the telescope than the usual one. By adopting such a method we are able to dramatically batter down the time necessary to their testing and implementations, as well as making them quicker exploitable.

1 Introduction

The development of new digital backends, albeit extremely quickly, is far too often unexploited. This occurs because they take too long to fit them with the entire software controlling the telescope. Regardless man-power and time required, another major obstacle is the necessity to get the whole control of the telescope during the testing on field, needful so as to be sure that the overall system is working properly; a waste of time is thus unavoidable.

As well as these points, new wide-band digital spectrometers produce a very huge quantity of data, therefore the traditional software thought for the actual FITS writer is quite unsuitable.

In order to overcome these problems, an alternative method has been thought. Basically the FITS file produced by the “main” backend (Total Power in our case) is filled up with the data from the backend we are interested; this is done with respect to synchronization, i. e. in such a way that every dump has a time-stamp as close as possible to the one of the foremost backend.

In this report the strategy details adopted and the software implemented will be discussed, then some results we achieved in some tests will be reported.

2 Traditional control software backend's integration

The control software at Italian radiotelescopes either is (SRT, Medicina) or will be soon (Noto) based on the framework ALMA Common Software (ACS) [1]. Even if a single-dish telescope is fully different, the versatility of ACS lead to use it at any case.

One of the major control software's task is the *FitsWriter*, i. e. the component that retrieves informations from the other ones (in order to generate the header file) and uses the *Bulk Data Transfer* [2] (BDT) to get the data from each backend and then insert them in the FITS file. However, the main BDT's criticism is the limitation concerning the data rate (80 Mbit/sec); this is not an

issue for backends like the *Total Power* and *XARCOS* [3] whereas is absolutely unsuitable in case of the new digital platforms capable to provide up to 80 Gbit/sec (ROACH2 for instance).

Experience has now taught us that the way forward a digital backend fully integrated in the control software ACS-based takes a very long time.

The reason for its slowness is intrinsically due to the complexity of the control software but even more is just caused by the final files produced. These files must contain a lot of informations from different components software as we mentioned, therefore a notable effort is needful so as to ascertain that the final FITS file is exactly what it should and contains what is expected.

Moreover, with the advent of 10 GbE links a single backend can produce an unmanageable flood of data for the actual infrastructure software; this force us to change the approach we have taken up until now by trying, at the same time, to make this job easier and quicker than in the past.

In the next chapter we will explain what has been done in detail.

3 Strategy adopted

In essence, we tried to understand how we can taken advantage of what already exists and what the control software produces conventionally.

There are essentially two courses of action: either exploiting FITS file produced by Total Power or interrogating the control software so as to retrieves all the necessary parameters as frequently as possible. They are both described in the next paragraphs.

3.1 Total Power FITS file mode

Within a short time, all the three Italian radio-telescopes (Medicina, Noto, SRT) will have the same control software and the same “main” Total Power backend, also acting as focus selector platform.

It is the best known and time-tested system as well as the most reliable, therefore it will not come as a surprise we thought to use it as a point of reference.

The minimum dump time permitted is roughly 1 ms, i. e. up to a thousand of different acquisitions in a second can be registered and stored into a FITS file.

As far as we know, 100 dump/sec represents the worst case at the moment at SRT (in particular for the K-band), this means that the maximum timing error is of the order of 0.5 ms in case of “parallel” acquisition made up by another back-end; such a tiny value is perfectly reasonable.

And so this opens up the whole idea of exploiting this opportunity. Essentially the “secondary” digital backend works entirely independently, retrieving of the data is performed on a PC synchronized with the control software and time-stamp is written just before taking data. An example of spectra from the ROACH backend is the following:

1#23-09-14-15-01-24-909

0 195368832

1 828160

2 1101568

3 997632

4 1407744

5 1203712

6 1476480

7 1461632

8 1554048

9 1515904

10 1551616

.....

.....

4093 619392

4094 657792

4095 664832

2#23-09-14-15-01-25-325

0 195627136

1 822144

2 1070208

3 1049088

.....

Each spectrum has corresponding number, data and hours until third decimal digit. The detail concerning software implementation is described in chapter 4, we just wish to pointing out that whatever informations bound with telescope is fully contained in the FITS produced by Total Power.

3.2 External Client mode

We have already mentioned about this mode in a previous report [3]. Basically the control software of the telescope makes available a server called *“External Client”* with which we can get all the parameters regarding antenna status.

The goal is in this case retrieving as many status as possible in order to minimize the difference between time-stamp of the backend and corresponding antenna's parameters. This is very important in case of high frequency on-the-fly mapping: an excessive timing difference would impact on the relative beam sky-position.

Fortunately, up to a hundred *“antennaParameters”* command is accepted by external client, which is consistent with dump time from ROACH/ROACH2 data rate.

In the following an example of what the external client provides:

antennaParameters\2014-266-

13:15:03.275,OK,Tsys,355.4081,013.9263,+02:41:02.245,+64:03:23.161,+134
:34:16.060,+03:41:23.166,-0.016701,-0.000220,-
0.038485,0.001204,0.001307,0.000000,0.000000,0.044680,0.022689,0.00000
0,0.000000,LLP,0.000000,SLEWING

antennaParameters\2014-266-

13:15:03.279,OK,Tsys,355.4078,013.9263,+02:41:02.438,+64:03:22.985,+134
:34:17.289,+03:41:23.522,-0.016701,-0.000220,-
0.038485,0.001204,0.001307,0.000000,0.000000,0.044680,0.022689,0.00000
0,0.000000,LLP,0.000000,SLEWING

antennaParameters\2014-266-

13:15:03.283,OK,Tsys,355.4074,013.9263,+02:41:02.641,+64:03:22.799,+134
:34:18.585,+03:41:23.899,-0.016701,-0.000220,-
0.038485,0.001204,0.001307,0.000000,0.000000,0.044680,0.022689,0.00000
0,0.000000,LLP,0.000000,TRACKING

antennaParameters\2014-266-

13:15:03.290,OK,Tsys,355.4191,013.9264,+02:40:56.473,+64:03:28.724,+134
:33:39.141,+03:41:12.808,-0.016701,-0.000220,-
0.038485,0.001204,0.001307,0.000000,0.000000,0.044680,0.022689,0.00000
0,0.000000,LLP,0.000000,TRACKING

4 Software description

As we said earlier, if we wish to make an observation, we just launch a Total Power schedule.

The pipeline is composed by several softwares written in C/C++; logically, it consists essentially by two major steps.

The first one step is to create a FITS file containing the spectrum provided by the digital backend and the time acquisition for that spectrum. Indeed, the digital backend produces a single binary file for each dump, therefore an enormous quantity of files are generated during an observation. So that, is needful to “compact” them in a single huge file within which data are put in columns in a proper way (see fig. 1).

<input type="checkbox"/> TIME <input type="checkbox"/> DATA		
Select	1D	2048D
<input type="checkbox"/> All	mjd	
Invert	Modify	Modify
1	5.698889338373E+04	Plot
2	5.698889338385E+04	Plot
3	5.698889338398E+04	Plot
4	5.698889338411E+04	Plot
5	5.698889338424E+04	Plot
6	5.698889338436E+04	Plot
7	5.698889338449E+04	Plot
8	5.698889338462E+04	Plot
9	5.698889338475E+04	Plot
10	5.698889338487E+04	Plot

Figure 1: Spectral data and corresponding time-stamp

At the end of the schedule, the next step is to “convolve” the FITS file from the Total Power and the “fictitious” one, i. e. replacing the data from Total Power with the data from digital backend. The latter one operation must be consistent with the timestamps, making the correct association between timing reference of the two FITS. Basically, times are compared and an algorithm calculates the minimum difference in order to reduce timing errors as much as possible. The output format (see fig.2) will be the same produced by XARCOS (traditional FITS produced by FitsWriter). Moreover, in order to provide an output format compatible with the standard tools (*psr archive*, *single dish imager*, *class*, etc.) the pipeline will provide several output formats (selected at the beginning of the observation or when the data are retrieved).

File Edit Tools								Help	
<input type="checkbox"/> time		<input type="checkbox"/> raj2000		<input type="checkbox"/> decj2000		<input type="checkbox"/> az		<input type="checkbox"/> el	
D		D		D		D		8192D	
Select		radians		radians		radians		radians	
<input type="checkbox"/> All		MJD		radians		radians		8192D	
Invert		Modify		Modify		Modify		Modify	
1	5.689855103303E+04	4.490438114436E-01	1.148069539823E+00	6.131556519914E+00	2.890320844305E-01	Plot	Plot		
2	5.689855116358E+04	4.490406550321E-01	1.148066766718E+00	6.131893549804E+00	2.889332895867E-01	Plot	Plot		
3	5.689855129389E+04	4.490048342049E-01	1.148013753316E+00	6.132228658118E+00	2.887829041851E-01	Plot	Plot		
4	5.689855142336E+04	4.489658612141E-01	1.147958737828E+00	6.132562442650E+00	2.886310551092E-01	Plot	Plot		
5	5.689855155341E+04	4.489272199535E-01	1.147900897723E+00	6.132896909090E+00	2.884763147171E-01	Plot	Plot		
6	5.689855168318E+04	4.488903453672E-01	1.147846614828E+00	6.133231126532E+00	2.883255977031E-01	Plot	Plot		

Figure 2: FITS file produced

As far as the external client method, the unique difference is that the main FITS must be created. The concept is very similar: getting the timestamps from string retrieved via the external client, the temporal merging between timestamps can be achieved with the identical principle.

However, the external client method is no longer used both because is used for RFI purposes [4] and above all else because is less convenient.

5 Results

In this chapter a few first results will be shown. All the tests were held by ROACH and ROACH2 boards observing some well known celestial sources. The first one (figure 3) is the supernovae remnants W44 observed in C-band with the ROACH2 board, 2048 MHz bandwidth, 2048 channels, 9 dump/sec:

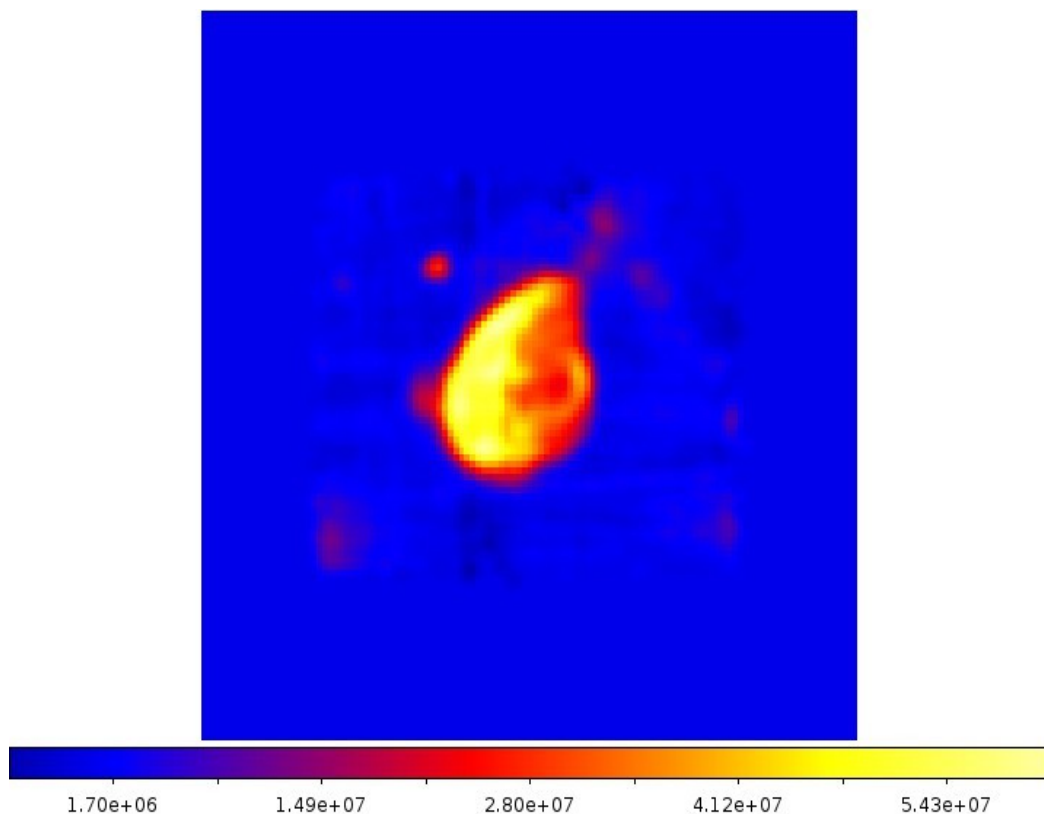


Figure 3: Supernovae W44 observed with the ROACH2 board

The same one map, contemporaneously observed by both Total Power and ROACH2 with 100 dump/sec, is shown in fig. 4:

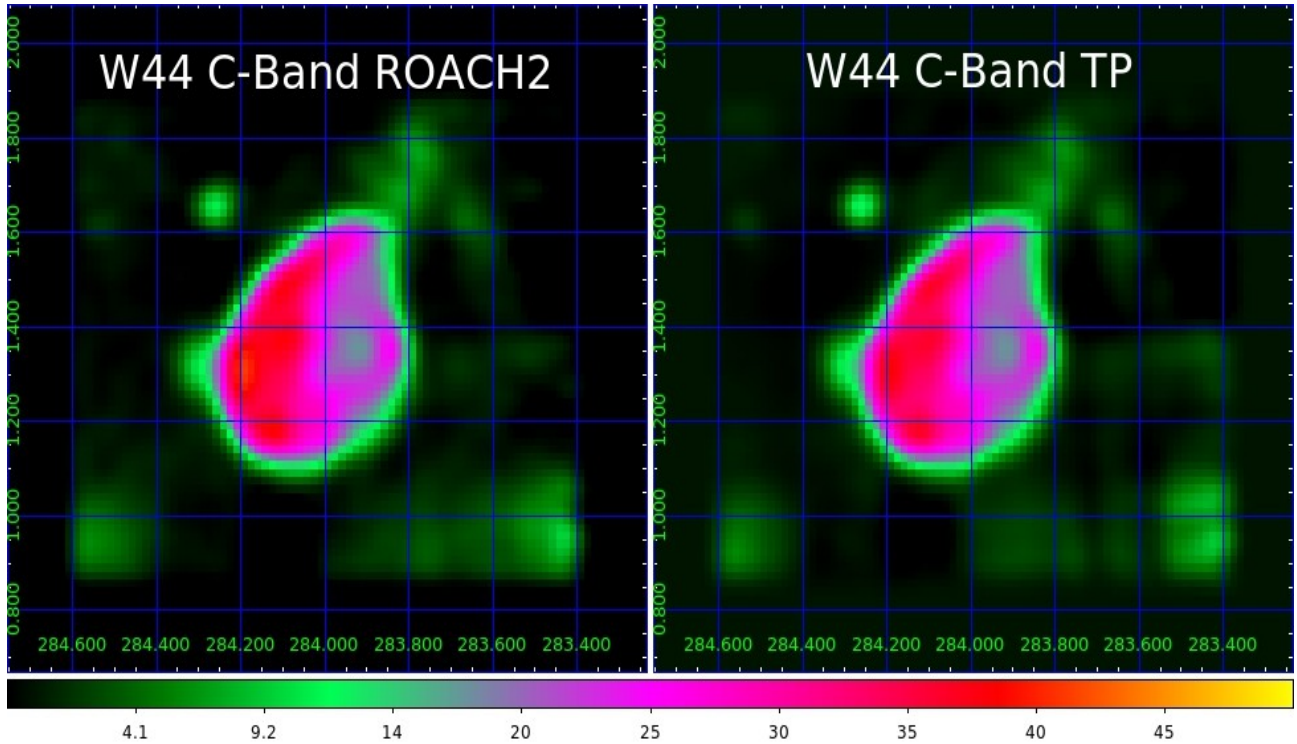


Figure 4: Supernovae W44 observed both with the ROACH2 board and with the Total Power

Another one supernovae observed in C-band was 3C157 (figure 5), using 1500 MHz bandwidth, 1024 channels, 100 dump/sec.

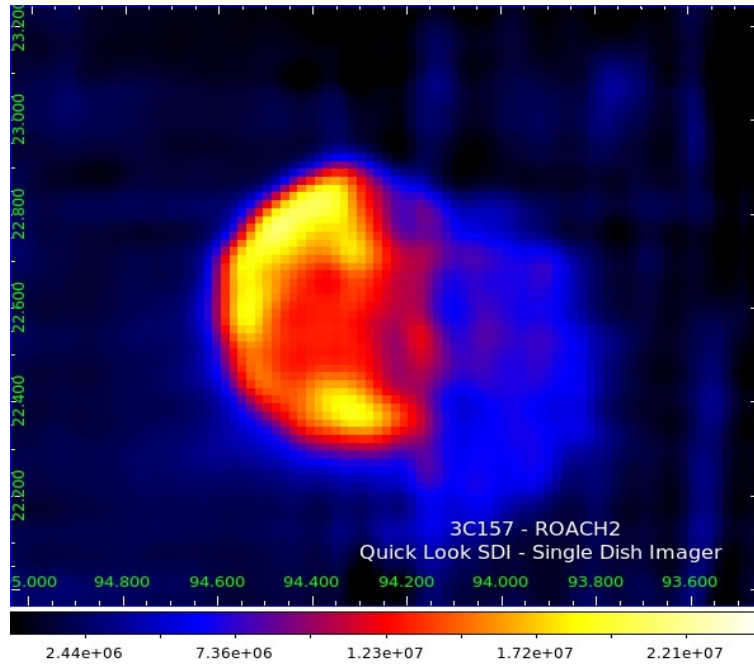


Figure 5: supernovae 3C157 with the ROACH2 board

The MASER of W3OH observed in C-band is shown in figure 6, the backend is the ROACH1 board, 512 MHz bandwidth, 8192 channels, 1.5 dump/sec.

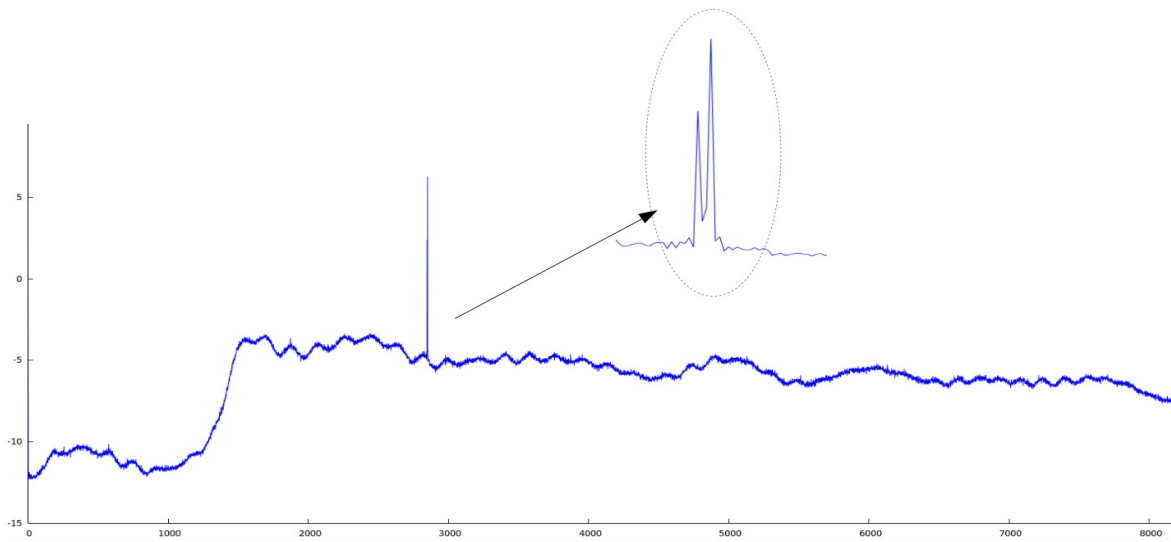


Figure 6: MASER of W3OH with the ROACH1 board

Finally, a pulsar B2021 was observed in C-band with the ROACH2 by using 1500 MHz, 1024 channels, 200 dump/sec; the profile is shown in figure 7.

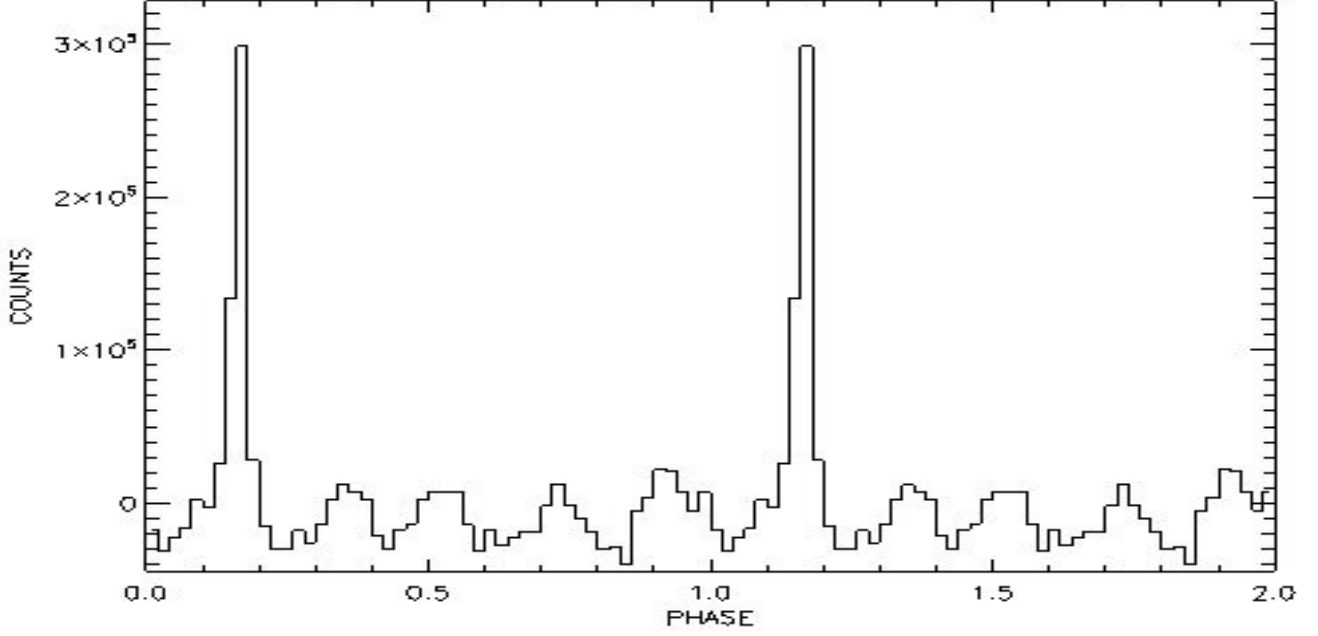


Figure 7: Pulsar B2021 observed in C-band with the ROACH2 board

6 Conclusions and future works

In this report we discussed how the existing control software features can be exploited to avoid backend's integration in the control software becoming just a matter too long and heavyweight.

The results we achieved confirm the forcefulness of this solution, nevertheless it is just an intermediate step which allows any developer to test each backend configuration without waste of telescope time.

Obviously the entire integration of each backend in the control software remains absolutely necessary, however it is very important that meanwhile the astronomers can immediately exploit the ongoing development providing, among other things, useful feedbacks to the developers.

7 References

- [1] <http://www.eso.org/~almamgr/AlmaAcs/>
- [2] R. Cirami, P. Di Marcantonio, G. Chiozzi, B. Jeram :*" Bulk data transfer distributer: a high performance multicast model in ALMA ACS"*, SPIE 2006
- [3] A. Melis, C. Migoni, R. Concu, G. Comoretto, P. Castangia, P. Marongiu, A. Poddighe, A. Tarchi, G. Valente : *"Installation, cabling and testing of the XARCOS spectropolarimeter on the Sardinia Radio Telescope"*, OAC Internal Report n.29, 2013
- [4] A. Melis, R. Concu, A. Trois, C. Migoni, R. Ricci, M. Bartolini et al: *"An RFI monitoring system based on a wide- band digital back-end for the Sardinia Radio Telescope"*, OAC Internal Report n.36, 2014.

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