Telemetry quality & efficiency improvement by multi-location ground stations centrally controlled

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ABSTRACT

Expanding the area where telemetry can be received on a range is the expectation of any range operator. Adding receiving ground station (receiver & antennas) in different locations not only allows to expand the area but also improve the quality and efficiency of data reception by having visibility of the flying target from multiple angles, resulting into less masking effects when the target is maneuvering. Unfortunately, having multiple antennas usually adds complexity to operations, as the different antennas need to be controlled individually.

This paper explains how it is possible to have multiple ground station operated centrally thanks to a dedicated control system, including the control of the different range assets (receivers, recorders…), while the tracking is realized automatically using GPS through the telemetry stream or ADS-B reception, and whereas the best signal received from the different antennas is continuously selected using a Best Source Selector.

A concrete used case of new TMoIP AIRBUS HELICOPTERS (France) Telemetry range is detailed.

KEYWORDS

Telemetry, Flight test, Tracking Antenna, Telemetry receiver, Best Source Selector, Data Quality Encapsulation; Data Quality Metric, IRIG 106, TMoIP, IRIG 218-20, TM Maestro, ADS-B.

INTRODUCTION

Designing a flight test range is always a matter of compromises to be made, as multiple dimensions come into the discussion. Beyond pure technical requirement and cost of equipment purchase, many more parameters need to be considered, amongst others: cost of ownership, training of the operators, ease of use, and efficiency of the setup.

From a cost standpoint, the ideal situation would maybe consist of a single antenna providing enough area coverage to capture the signal transmitted by the test article and to feed this signal after demodulation and bit synchronizer to a decommutator unit.
The reality is that in many cases this ideal situation is not sufficient from a quality-of-service point of view. It becomes then necessary to have multiple antennas located at different places, with multiple receivers, that require more people to operate, and multiple streams from which it is required to choose, that is not an obvious selection to be done along the flight.

1) LIMITATIONS OF USING A SINGLE RECEPTION ANTENNA

Using a single antenna to receive the telemetry signal transmitted by a test article can be seen as a simple and cost effective solution, as there is only one receiving path with single implementation of an antenna and a receiver to feed the transmitted data to the decommutator unit, to give the flight test engineers all the data they are looking for in real time during the flight. Furthermore, all the equipment part of the system can be located on the same physical location, with no need for long cables and/or the need to go through extended network systems.

This single antenna has, however, some limitations in various cases.

A. Finding the right location

Having a single antenna means that this antenna needs to be located on a high elevation spot where the maximum visibility to the test article can be achieved during the flight. Finding such a place is not always easy and often results in some blind spots where the transmission is not going through because of hangars or buildings as depicted in figure 1. This is the typical case of receiving the signal from an aircraft while parking or taxiing.

![Figure 1 schematic view of masked area behind a hangar next to the tarmac](image1)

B. Low elevation flight and terrain flatness

Even though we can expect a line of sight up to more than 300 km for an aircraft flying at 30.000 feet or higher, quite often some tests must be done at rather low altitude for the test article, that reduce the distance that can be achieved between the test article and the receiving antenna. Adding to this the fact the terrain is usually not completely flat around the test range, this creates strong limitations on the areas that can be used for these tests as can be seen on figure 2

![Figure 2 schematic view of masked area behind a mountain (low altitude flight)](image2)

C. Test article maneuvering

During the tests, the test articles have to maneuver that possibly makes the transmitting antenna not to be in direct view of the receiving location as illustrated in figure 3.
Some techniques exist to address this limitation through the usage of multiple transmission antennas on the test article, but these have some limitations: Using frequency diversity requires the availability of two times more RF spectrum availability, that is harder and harder to reach, and using STC modulation introduces very long acquisition and reacquisition time in case of loss of the signal.

Figure 3 schematic view of area where the reception is masked during test article maneuver (single transmission antenna on the helicopter tail)

2) MULTIPLE RECEPTION ANTENNA BENEFITS AND CHALLENGES

Implementing multiple reception antennas bring a major improvement as the various masking areas as highlighted above when using one reception antenna will mostly be compensated from the other antennas if they are located at different places, with sufficient distance from each other. In addition to solving the masked areas created by the single reception antenna solution, having multiple antennas will certainly also expand the area that can be used for the flight test and where reception is possible.

The implementation of multiple antennas comes however with multiple new challenges to address.

A. Carry the received signals to a central location

As the benefit of using multiple antennas is valuable only when these antennas are far from each other, the signals that are received in these locations must be carried to the main station in real time.

Carrying a high frequency signal is really challenging therefore it makes sense to implement a telemetry receiver as close as possible to the antenna and transport only the baseband signal – the PCM content of the RF transmission.

As analog baseband signals or PCM signals’ transportation can be quite difficult on long distances and would require dedicated hardware implementation resulting into high costs, the easiest way is to use an Ethernet infrastructure, or possible Ethernet on RF link when there is no ground infrastructure available. In the past it was popular to use conversion boxes to convert PCM or analog baseband signals into Ethernet at one end of the link, and to do the opposite conversion at the other end.

Currently the state-of-the-art receivers have the Ethernet interface embedded, enabling a direct connection between the receiver and the Ethernet infrastructure, using standardized protocols as described in IRIG 106 ch10 or IRIG218-20. An example of such an implementation is displayed in figure 4.
B. Select the best stream

Having multiple streams received from multiple locations, we need to select the one that will be supplied to the decommutation. In order to have a good system performance, this selection needs to be done continuously as the quality of the reception from the different antennas can change rapidly, and the selection needs to be done based on the actual quality of the reception at each antenna.

IRIG106 has introduced the DQE/DQM specification that enables the BSS to have access to the quality information coming from each receiver and that is transmitted on a regular basis through the PCM interface, and possibly through Ethernet afterwards, without having the need for the implementation of a dedicated hardware or infrastructure.

DQE/DQM feature is available on the state-of-the-art receivers to provide the relevant reception quality at each receiving site, so that the BSS can make the best decision.

In addition to selecting the best stream based on the best-received quality, the BSS also needs to align in time the different incoming streams, as when switching from one stream to another one, the two streams have to be synchronized on the same moment as otherwise the BSS would introduce glitches that would degrade the system performance. There are two reasons for the signals reaching the BSS not to be in full sync, related to different latency on Ethernet infrastructure as well as related to the actual distance the signals must travel, these distances being different for the different antenna locations as well as depending on the actual test article position against the antenna positions.
C. Controlling the antennas

Telemetry tracking antennas can have multiple means of tracking, from manual – the operator is controlling the position of the antenna, slaving – the antenna position is following a position that is supplied through a radar or directly from the GNSS position of the test article that is transmitted in the telemetry data, and auto track – where the antenna follows the highest transmitted power direction.

It is popular to have one operator assigned to the antenna control system of each antenna all through the flight. Multiplying the number of antennas would then mean multiplying the number of operators, resulting in additional cost, but also organizational difficulties as all the operators ought to be present at the same time for each flight.

When having multiple antennas, it makes sense to automate the control of the antennas, with a system where all the antennas can be controlled from a single place and a single interface screen. While having such a system, only one operator can control all the antennas, and decide the slaving scheme based on the position of the test article.

While having a single control system in place, and as this system communicates with the antennas through the Ethernet infrastructure, it becomes easy to include also the different equipment part of the system. This is the typical use case of TM Maestro that has been developed as a flexible software solution to control multiple antennas, as well as associated receivers, recorders, as well as basically any type of equipment that has an Ethernet interface.

D. Multiple sources to acquire the test article position

When it comes to slaving telemetry tracking antennas, it is popular to use radars to provide the actual location of the test article. Such a system was used already in the early days of telemetry, however, proves to be very costly.

Recently it became popular to use the GNSS position of the test article, being transmitted into the telemetry stream. The data acquisition unit on-board the test article is then equipped with a GNSS receiver, and the actual position is continuously transmitted on the ground. In the test range one needs to create a UDP transmission link from the decommutation unit to the antenna control system to get the position of the test article. Knowing the position of the test article and the position of the antenna itself, it becomes straightforward to calculate the direction the antenna must track. But in case of bad telemetry signal reception the GNSS data is lost, and the tracking is not possible anymore.

In order to solve this limitation, another mean to define the tracking direction has been developed using the ADS-B system used by commercial aircrafts and can be applied to any test article adopting this system. ADS-B is a system that has been developed for air traffic control, by which the aircraft is equipped with a GNSS receiver and the actual position is transmitted to the ground through a dedicated radio system in a dedicated radio band.
Having a centralized and automated control system to address multiple antennas, it is rather easy to add an ADS-B receiver to the system, and this way adding another source of information on the position of the test article, using a different data path than the telemetry reception and therefore being a very good backup solution for the tracking. Using this scheme, even if the telemetry link is no more available for whatever reason, the various antennas are still positioned in the direction of the test article provided by the ADS-B system, therefore the telemetry stations can provide a reception of the telemetry to the longest distance, when the signal can be demodulated.

3) Concrete use case: AIRBUS HELICOPTERS FRANCE Test range

A. Background:
Airbus Helicopters France (AH) has a test range operating since the 80’s in MARIGNANE, within South of France. This range is about 100 Km wide around AH facilities and since the beginning 2 sites of reception are needed due to geographical configuration and masking effect:
- 1 site within MARIGNANE facility
- 1 remote site on VITROLLES hills

Both sites were manually monitored from MARIGNANE facilities and even if this “initial” architecture allows to insure the due safety of Flight Test, it has been decided to still improve the tests range coverage having in mind 3 strategies:

1. Create a full network architecture:
To be compliant with AIRBUS IT rules, including all TLM equipment and fully integrated within the AH IT network.

2. Create a third new remote station on MARTIGUES hills:
To improve the range coverage performance considering geographical environment but also existing installation.

3. Create a fully integrated and homogeneous architecture:
To improve the TM reliability by selecting and using best in class hardware and software based on last IRIG TLM standard version (106/218-20 & Chapter 7 implementation for data transfer) and including a full automation of the monitoring and control of all TLM hardware’s supported by ETHERNET Best Source Selector.

Consequently, the TLM AIRBUS HELICOPTER FRANCE range has been renovated and enlarged using the different techniques described above and using Safran Data Systems hardware and software suite.
In practice, the range is now made of:

- 3 Comtrack tracking antennas, located on 3 different locations around the test area:
  - One is located in Marignane, France, on the roof of the Flight Test facility
  - One is located on a high spot in Vitrolles, France
  - One is located on a high spot in Martigues, France
- 3 RX-1 telemetry receivers, each being associated to each Comtrack
- 2 Omni antennas located close to the parking area, each associated to Cortex RTR receiver already used in previous installation and upgraded for MAESTRO compliance.
- 1 Cortex BSS Best Source Selector
- 1 GMDR used as TLM session recorder as well as IRIG 106 chapter 7 demux and also time sync generator for the receivers and the BSS.
- All the telemetry equipment are centrally controlled using TM Maestro software suite.

Note: In addition, an AH mobile station (mostly installed in a van) is also fitted with Comtrack & RX1.
Also to be noticed, all data transmitted in Telemetry are processed through AIRBUS HELICOPTERS proprietary software suite “SANDRA” (decommutation and display software solution).

**B. Station location and area coverage**

The AH telemetry range is now fitted with 3 ground stations.

The following Figure (fig:5) highlights the locations around Airbus Helicopters Marignane, as well as the areas where most of the trials are carried out, specifically in “Istres/Camargue” where most of the flights are preformed and “La Fare les Oliviers” location, where low altitude dedicated flights are performed.

This new configuration provides different tracking angles on these areas and also different angle of visibility on test articles whatever the flying conditions (altitude up to the ground, pitch & roll attitude…). In addition, three independent stations also provide redundancy in case of failure of one site for whatever reason.

![Figure 5: Location 3 tracking antennas, as well as the specifics areas trials](image)
C. ETHERNET architecture

The main station is located in the flight test building in MARIGNANE, and the 2 other stations are remotely connected to the main station using the Airbus Ethernet infrastructure.

The AIRBUS HELICOPTERS ETH architecture is based on VRF CISCO switches (figure 6) and the due dedicated VLAN. The Telemetry network is fully monitored 24/7. As the VITROLLES and MARTIGUES stations are unmanned, they can be switched ON/OFF through IP power devices. In addition of antenna & receiver, both stations are also equipped with GNSS IRIG time generator for receiver sync and TMoIP timestamping.

Within MARIGNANE facility, in addition of TLM receiving system (antennas & receivers) there are also the setup of the CORTEX BSS, GMDR6 recorder, and the MAESTRO server & monitoring.

![Figure 6: Airbus Helicopters France Telemetry ground station Ethernet architecture](image)

Antenna tracking mode:
The 3 COMTRACK antennas are controlled through the MAESTRO system and can have 3 tracking modes: AUTO tracking, GNSS or ADS-B data position.

The ADS-B receiver is also located within MARIGNANE facility and benefits from a sufficient coverage for the whole area where trials are done. It is connected to the AIRBUS network too. Thanks to the Ethernet connection the 3 antennas receive the exact position of the test article and as soon as one TLM station receives a valid data flow with GNSS (from TLM data stream and/or ADS-B), all other antennas are automatically oriented on test article even if they do not receive a valid signal.
Best Source Selector (BSS): Automatic data stream selection
As showed in figure 7, the key element of this ETH installation is the BSS which is, through the
AIRBUS network, connected to all TLM data streams transmitted by the receivers and “live”
selects the best signal to be used for flight monitoring.

The function of this Best Source Selector is:
• Acquire and track data streams. (Baseband / PCM /Ethernet IRIG106-CH10 or IRIG218-20)
• Verify that all streams are locked in real time.
• Select best strategies for decision –making

The Selection of the best TLM signal received by the different sites is based on the choice of 4
strategies available and to be selected:

1) Best: output data stream with the best signal quality DQE/DQM or $E_b/N_0$
2) Frame synchronization: output data stream with the best F/S state
3) Majority vote: output combining of the data streams based on voting bit on bit.
4) Weighted Majority vote: output combining of the data streams based on voting bit on bit,
weighted by signal quality (DQE/DQM).

The output data stream selected is delivered through one dedicated PCM output (IRIG106 CH7
on Data & Clock) to a specific board of the GMDR recorder.

The BSS allows automatic selection of the best TLM data stream. It performs the selection
dynamically during flight and switches from one reception source to another within milliseconds.
Selection strategies are implemented by software and can also be done via the MAESTRO suite.

Figure 7: BSS interconnection with overall hardware
**D. Central operation of the range**

Automated monitoring of the 3 stations by a centralized unique system was an important requirement in order to ease the job and the efficiency of the operator.

Dedicated TM Maestro software has been developed to adapt to all the equipment (16) installed in all the sites of the AH stations. This TM Maestro station is made of a PC server connected to the telemetry VLAN network and it can exchange with all the telemetry equipment.

The GUI is made of 4 displays (figure 8) allowing control of ALL the monitoring data useful for analyzing and controlling the 3 ground sites in real time during the flight test.

- Display1 is dedicated to TLM “System Health status”, providing Go/NoGo of each site and power management control (IP Power), as well as the status of the GMDR and associated modules, the BSS inputs and outputs, and the alarms log book.

- Display 2 displays the operations map, showing the position of the test article based on coordinates reported by the GNSS over telemetry data and ADS-B.

- Display3 is dedicated to the Monitoring & Control of the Martigues and Vitrolles located antennas and receivers, the 2 remote sites.

Display4 is dedicated to the Monitoring & Control of the Marignane site antenna and receivers, therefore the COMTRACK antenna & RX1 receiver but also 2 omni antennas & CORTEX receivers already used in the past for local reception.

![Airbus Helicopters France TM Maestro display](image-url)
E. User experience

The implementation of this new station improves definitively the quality reception of the data used to monitor the flight tests with quite no data lost due to mask effect and multipath issue.

For the telemetry operators this new station definitely eases the efficiency and the quality of work to be done with a lower level of stress due to the automation of the process. Actually, the usage of the station is much simplified and the fact that all the controls are located at the same place really helps in daily life, both to control the operations and also to troubleshoot in case some signals differ from the expected ones.

The dissemination of the signals from the remote stations to the central location using TMoIP is completely transparent to the users, so that the system can really benefit from having 3 different reception locations without constraints coming from the data transfer and thanks to the high-quality level of the AIRBUS network technologies employed.

Thanks to the AH full Ethernet architecture, the BSS strategy for selection of the best source is “Weighted Majority vote” which includes DQE/DQM feature. The BSS performance provides a fantastic capability to use all the time the best available signal coming from the different antennas of the system. The BSS is switching more or less continuously (millisecond) between the different streams based on the location of the test article and the way the telemetry signal is received on the different sites. There is no glitch when switching from one site to another so that the unit is working in autonomy.

The full coverage of the AH range area by the 3 sites of reception associated with the ETHERNET network and automation of the TLM data stream selection provide now an unprecedented quality of data delivered for flight monitoring and the due s safety of flight test.
CONCLUSION

This paper explained the benefits of having multiple antennas located on different well selected locations around a test range, and provided solutions to address efficiently the challenges coming with these multiple antennas, being the signal distributions between the different locations, the selection of the best stream in real time, as well as the automation of the control of the different antennas and associated equipment.

A real-world use case of this kind of implementation at Airbus Helicopters France has been explained thoroughly, with an extremely positive return on experience.

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