IVS Technology Coordinator Report

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Abstract These last years have seen intense activity aimed at setting up new VGOS stations, such as the beginning of VGOS observing in both experimental and operational fashion from more stations. An important activity has been dedication to verifying the broadband performance of the equipment in the entire processing chain, so as to practice this new observing mode. The signal chains in the field have different methods and approaches to producing the VGOS data, and harmonization has to be taken into account. This is not only useful but mandatory for the main elements to guarantee compatibility. Additionally those elements that can make the process well-integrated in a unique vision system should be taken under consideration. Advanced automatic or remote-controlled observing and correlation could involve a large amount of effort in the future; then we will need to dedicate careful evaluation and monitoring of the activities involving such tasks. In this short report I want to recall the main elements we need to focalize now and in the coming years.

1 Currently Available Processing Chains

In the IVS network a variety of different solutions are consolidated or under investigation. In the previous years, on multiple occasions, the definitions for a VGOS signal chain have been discussed in some detail (IVS VLBI2010 Workshop on Technical Specifications, Bad Kötzting, 2012 and different previous IVS reports in 2005 and 2009). Under these indications, developments have been proposed and experimentally evaluated by the different Technology Development Centers. As a result, there are a number of different solutions that need to be harmonized, also taking into consideration new possibilities and technology solutions which in the mean time have appeared.

There are some elements which can be mentioned as basic points. To summarize:

1. The actual frequency broadband, which is determined mainly by the local RFI. The 'official' 2.2–14 GHz VGOS band could actually present some restrictions or limitations to be actually covered as a site dependent element. In a VGOS network, any limitation at a site involves the entire network.
2. The number of antennas per station and their types in terms of the speed of their mechanical structures. A number of sites are planning or have available more than one VGOS antenna, which will offer a great level of flexibility. Antenna types and speeds are different, going from the slow legacy ones to the fastest, fully VGOS-compliant ones.
3. The feed type. Feed types having linear polarization output, even with direct generated circular polarization at the feed stage, are under investigation. A number of solutions are being studied to consider circular polarization reconstructed at the digital level at the station or at the correlator.
4. The LNA. LNA projects and commercial products are available from different sources with good performance. These components must be further considered from the point of view of RFI and for possible cryogenic filter inclusion.

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5. The backend. Backend types at present developed by the IVS groups can be mainly distinguished as one of three types:

   - The broadband input within 2.2–14 GHz is flexibly tuned in pieces of 1 GHz afterwards sampled. Then a number of 32-MHz channels under 2-bit resampling are extracted at a maximum data rate of 16 Gbps, but the current common sustained data rate is 8 Gbps. The data representation can be either real or complex.
   - The input band is fully sampled in pieces of prefiltered 4-GHz chunks, then sampled and made available in digital format, from which narrow band channels (e.g., 64 or 32 MHz) can be extracted. A full data rate of 128 Gbps for the entire eight bands of 4 GHz is also possible.
   - The entire broadband is sampled with a sampling clock, to present aliased pieces of superimposed bands. The data are sampled with only three bits, which is a limitation in processing a potentially RFI-affected full wide band, and no narrow band channelization is available.

   Such different systems present different ancillary performances useful for phase, delay, and total power calibration.
6. Recording. For recording, we can distinguish again different types:

   - Mark 6, Octadisk2 types, which allow a maximum of 16 Gbps per unit, making use of removable disk packs that can be physically transferred from a station to a correlator and viceversa.
   - Flexbuffer-like types, in different fashions developed or under development, which can permit even larger sustained recording data rates (up to 32 Gbps), with a fixed pool of internally connected disks. Data transfer to the correlators is then performed asynchronously with respect to observing.

   Both types of recorders permit the transfer of observed data in real time, when the network connections between the stations and the correlator permit.
7. Correlation. The correlation process is currently software-based and is performed with different software versions. The standard approach is to move the entire set of data from all the stations involved in an experiment to the correlator appointed for processing it.

2 VGOS Technology Evolution and Efforts

At present we can envisage directions from which an evolution could come, bringing benefits for VGOS networks. Here are the main ones that I would like to report.

1. Direct full VGOS band sampling
   This method, performed in multi-bit representation, could be a quantum leap in the signal chain. The entire data set represents, indeed, a huge opportunity to handle the output data, having elements driving the entire band information. Such elements will greatly simplify the signal chain and offer support for additional tasks, such as the full band polarization conversion in FPGA.
2. System interoperability
   As reported above, different systems, as developed and available at different stations, are a reality in the VGOS scenario. Compatibility between those systems is an element involving not only the individual systems in their structures, but also the capability of the entire system of accommodating different solutions offered to the community. A normalization process in this respect has to deal with such a capability, too.
3. Broadband coverage / RFI status
   The actual use of the entire band is problematic due to the presence of RFI, which varies at different sites. On the other hand, for compatibility with the legacy S/X stations, it would be important to observe the lower part of the band. An effort is then to be dedicated to the handling and mitigation of RFI, in opposition to the trend of simply cutting out this portion and moving the lower observation edge of the band to higher frequencies.
4. 24 hour/day, continuous observing sessions require a reduced contribution from the operators, so the efforts to introduce automatic and remotely-controlled observing sessions cover a fundamental aspect.
5. The data rate has to be increased to move the network to the planned goals. A first limitation looks to be the recording capability, with other different lim-

itations following immediately after, such as data storage capability, data transfer speed, and correlation capability. All of those elements need to be considered and addressed.

6. Distributed correlation is a necessity that can mitigate and optimize the massive amount of required data handling when more stations will be operative and the actual data rate will be increased. A studied approach, maybe supported by simulations, is required. Cloud computing could play a role. Additionally, more architectures need to be evaluated: similarly to the automatic station control, an automatic/remote correlation approach has to be evaluated for reducing the human contribution in a 'routine' VGOS network.