HAMTV RECEPTION WITH A LOW GAIN ANTENNA

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In these notes we describe the reception tests performed with a helical antenna to receive signals from the HAMTV transmitter on board the ISS during the period in which it has been on (blank transmission) after the commissioning of 8 and 9 March 2014. The tests were performed with fixed pointing.

Throughout the period in which the HAMTV transmitter remained in operation after commissioning (see AMSAT-I news, vol.21 n.5 p.4), many amateur radio operators, equipped with high-gain antennas and with tracking systems, put in place their reception systems with the goal of maximizing the duration and quality of the video connection (to reach at the end over six minutes of uninterrupted video reception per station). But I wanted to test the ability to receive signals using a minimum configuration, using a low-gain antenna and operating in marginal conditions, without tracking. Purpose of these tests was also the evaluation of the intensity, and the quality of the received signal.

A brief aside. The ALSEP (Apollo Lunar Surface Experiments Package) was a small automatic laboratory, equipped with a set of "peripherals" such as a seismometer, a mortar, a solar wind measuring equipment etc. a control unit for the transmission of data to Earth, and a nuclear generator. What has always fascinated me was the small antenna that allowed the equipment, with a few watts of power in S-band to transmit information to Earth. It seemed incredible that so little was enough! (in reality, given the distance, and to ensure a given bit-rate, for the ground receiving antennas were used even the 70 meters dish such as that of Goldstone, CA).

The choice fell on the helix antenna. To check if with an antenna of such a low gain (about 12 dBi), it was possible to receive the signal from the ISS HAMTV, I used the link budget analysis that I0KPT Piero and Fabio ex IW8QKU have developed for the program HAMTV. The first tests were promising, at least for passes with a distance between the ISS and the receiving station less than 600 Km. Instead, to have an estimate of the duration of the connection, I used another tool, developed by Piero IK0KPT. This is a simulation that runs under Matlab© and allows you to accurately determine the duration of the connection, once the margins of the link were established.

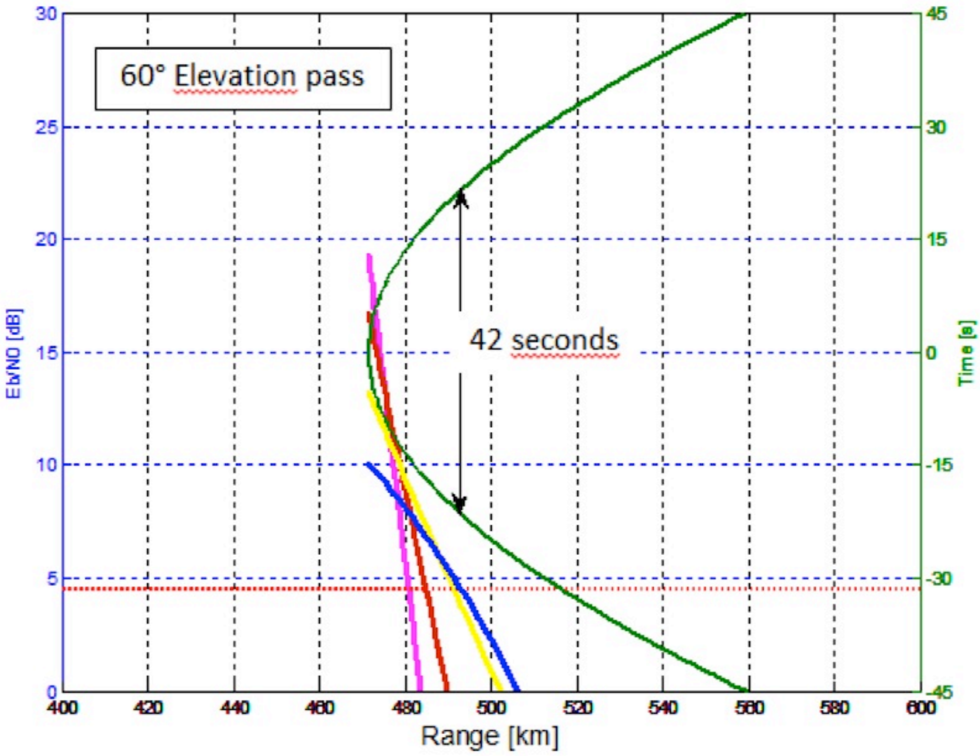

Fig. 1 - Simulation of a passage. The blue curve indicates the ratio Eb / No (left scale) as a function of the slant-range for an helical antenna of 16 turns (the other curves refer to parabolic reflector antennas 40, 60, and 80 cm without tracking). The duration of the pass is shown in green (right scale). The QEF (Quasi Error-Free) is marked by a dotted line, just below 5 dB. To be noted that for the helix antenna the maximum length of the received signal is 42 seconds, value which is obtained by measuring the green trace amplitude at the intersection of the blue curve with the QEF.

The program (see figure 1) generates a double graph on which are plotted both the duration of the pass (visibility) in function of the slant range, that the trend of the Eb/No (index of the amount of available energy per bit, the equivalent of the classic signal/noise ratio), which is also a function of the slant range, the antenna gain of the ground station, as well as the angles with which the antennas are "watching". The program has in fact stored inside the pattern of the ARISS antenna aboard the ISS. In this way, it is able to determine at each instant of the trajectory the antenna gain as a function of the reciprocal position between the ISS and the ground station.

The measurements carried out during the commissioning with the big antenna of 20 meters of the Matera VLBI have allowed us to verify how accurate was the estimate of the link budget, estimates on which was based the success of the entire project HAMTV, therefore validating the tool itself. It was then confirmed that it was possible to receive signals for nearly a minute using a small antenna, under appropriate conditions (maximum elevation of the pass, minimum distance between the ISS and the ground station). It only remained to gear up the equipment and get ready to receive the signals.

We have already said about the choice of the antenna. It is an helix antenna, TECOM© model 401022 (www.tecom-ind.com), operating in the band 2000-2400 MHz with right circular polarization (RHCP). The width of the lobe is 40° in the lower part of the band, and 30° in the upper part. With an average of 35°, the gain is 12 dBi (see fig.2).

Fig.2 - TECOM helix antenna and ECRIEE LNA/LNB used for the reception tests.

For the LNA/LNB I used a Chinese product, made by ECRIEE (East China Research Institute of Electronic Engineering, now also available from Bowei), normally used to receive S-band broadcast transmissions. The model used, kindly made available for experiments from "Rino" IZ6BMP, works in the band 2.3 - 2.7 GHz, and makes use of an LO at 3650 MHz stabilized with a DRO. I wanted to perform a series of measures to characterize and verify its electrical characteristics.

First of all I measured its gain, which I found to be equal to 51.5 dB. Then I measured the noise figure, as shown in the application note AN-150-9 (HP). The measure, despite its uncertainties (± 0.5 dB) was close enough to what is specified on the name plate of the LNA (NF <0.4 dB). In anticipation of the strong interferences present in the S-band, mainly coming from WiFi systems, I wanted also to measure the IP3 of the LNA, getting the good result, in my opinion, of an IP3 greater than +20 dBm (see graph, fig.3).

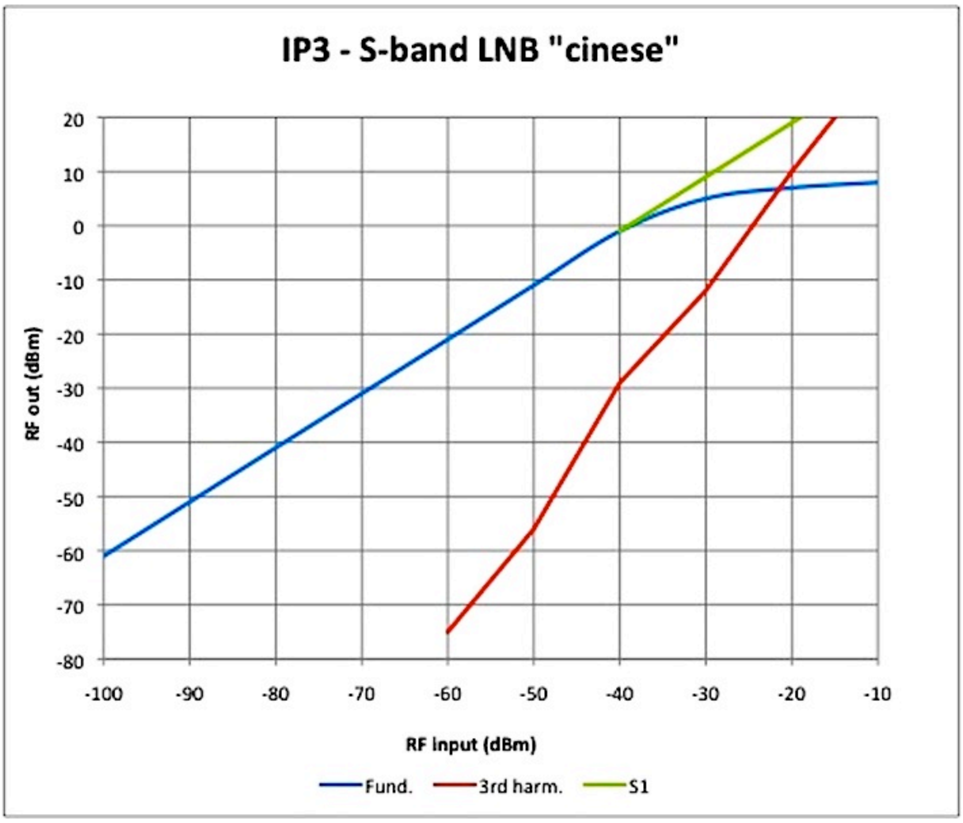

Fig.3 - Measurement of IP3 of the "Chinese" LNA/LNB. The measure was obtained by the use of a vector signal generator HP8780A, instrumented to generate two separate S-band carriers spaced 500 KHz.

For the receiver, there was no choice: I used a TechnoTrend, model S2-3200 (www.technotrend.eu) PCI card designed for satellite TV reception according to the DVB-S standard.

The card is based on a chipset made by ST Microelectronics© (NIM tuner chip STB6100, QPSK demodulator STB0899) and is therefore compatible with "Tutioune" (www.vivadatv.org), the magnificent program written by Jean Pierre F6DZP allowing you to have complete control of all the resources of the card, and to perform accurate measurements of MER (Modulation Error Ratio), VBER (bit-Error Rate after Viterbi correction), number of corrected bits from the Viterbi and Reed-Solomon (fig.4).

In addition, the software allows you to record both the measurement data on the received signal, and the received video (Transport Stream, TS format, according to the standard MPEG).

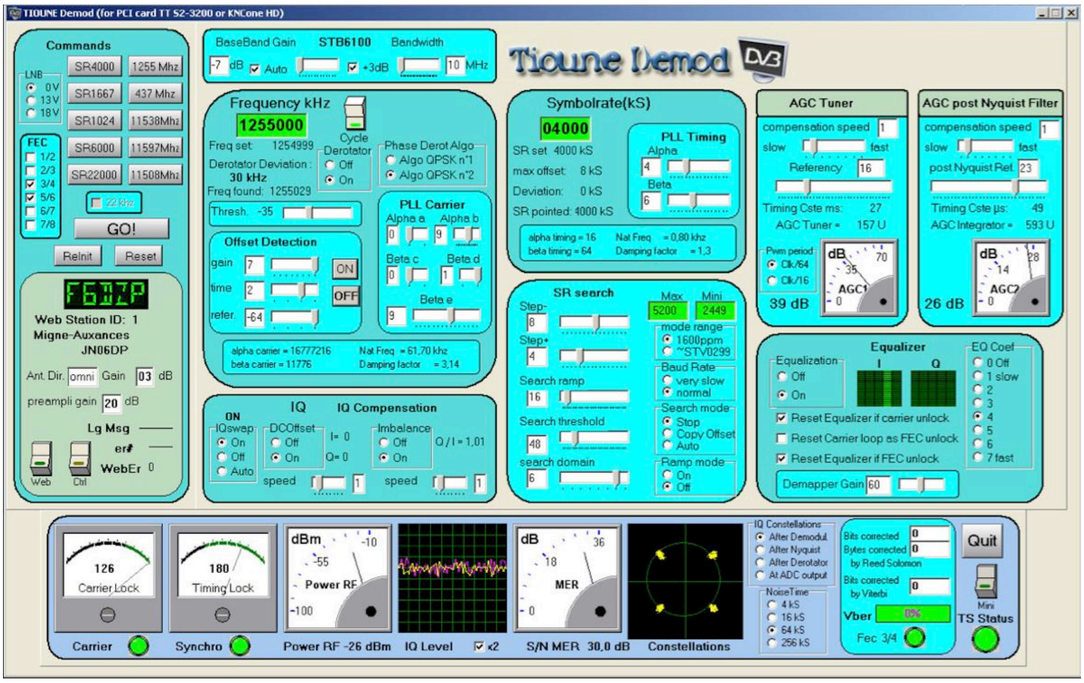

Fig.4 - Tutioune in expert mode. Visible in the middle, at the bottom, the constellation indicator with the 4 phases of the QPSK signal, and next to the left the MER meter, an IQ oscilloscope, an RF power meter, timing and carrier lock meters. In the upper left section are the controls of the NIM tuner. At the center are the parameters and controls of the QPSK demodulator (derotater), and the symbol rate (SR) search loop. In the upper right zone are present the AGC parameters.

Also the receiver, as a whole (card, computer and software) has been characterized by a series of measures to verify the accuracy of its various indicators on the control panel (visible in expert mode, see fig.4). For these measurements I used, as a source of QPSK modulated signals, one of the modulators of the series "Minimod" produced by SR Systems (www.maintech.de).

This is the same module mounted inside the transmitter HAMTV. By changing the attenuation between TX and RX, and checking the S/N ratio with the spectrum analyzer, I verified that the information provided by the MER indicator was in good agreement with the S/N ratio measured at the receiver input, as well as visible on the screen of the spectrum analyzer.

Unfortunately, interference from WiFi systems occasionally caused frequent carrier unlocks, despite the good level of the signal. I then had to put in line before the receiver a tunable filter in L-band, and a DC-block to restore the power supply upstream of the filter, so that we can continue to feed the LNB (see fig.6). This allowed me to mitigate part of the interference, meanwhile reducing the noise level at the input of the NIM tuner (fig.5).

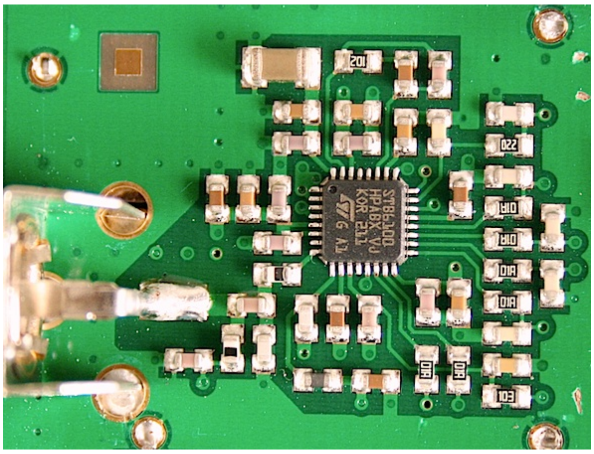

Fig.5 – RF front-end of the TechnoTrend S2-3200 tuner card. Visible the NIM tuner chip STB6100.

To complete the set-up, downstream of the filter I inserted in line also a directional coupler NARDA 3002-10, in order to withdraw part of the signal to be sent to the spectrum analyzer. The signal was then suitably amplified by means of a low noise amplifier type LPA 3-15 (www.rfbayinc.com), required to recover the insertion loss due to the directional coupler. We must in fact take into account that the noise figure of an analyzer is quite high, being the input signal applied directly to the mixer.

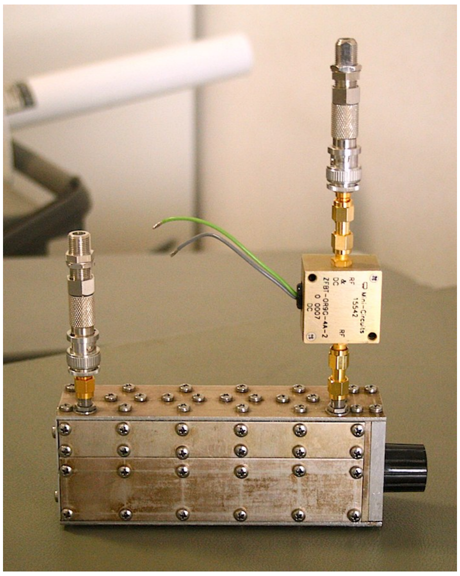

Fig.6 - L-band tunable filter and DC-block (Minicircuits© ZFBT series) for the reinsertion of the LNB DC-supply.

At this point, having characterized two of the three elements that contribute to the reception (for the first, the antenna, I trusted on the datasheet, even though I run a precautionary measure of VSWR, getting a return loss of more than 20 dB at 2400 MHz), I have prepared everything for the reception of the first useful pass, scheduled for March 20 at 08:30 UTC, with maximum elevation of 70° and a minimum distance of 445 Km (fig.7). Antenna was then oriented towards the point of minimum distance.

Fig.7 - Anticipation of the passage of March 20, performed with STSPLUS. The QTH is Rome.

The AOS was scheduled for 08:28:52 UTC (taking into account a minimum elevation of 30° and a distance of 770 Km). The first signal appeared on the spectrum analyzer shortly after, when the ISS was now at a distance of about 460 km and with an elevation of more than 66°. At this point, the receiver locked the carrier (as indicated by the timing-lock indicator), and maintained the sync for about 30 seconds. The measured data recorded by Tutioune and the recorded signal on the spectrum analyzer can be seen in the following images (fig. 8, 9).

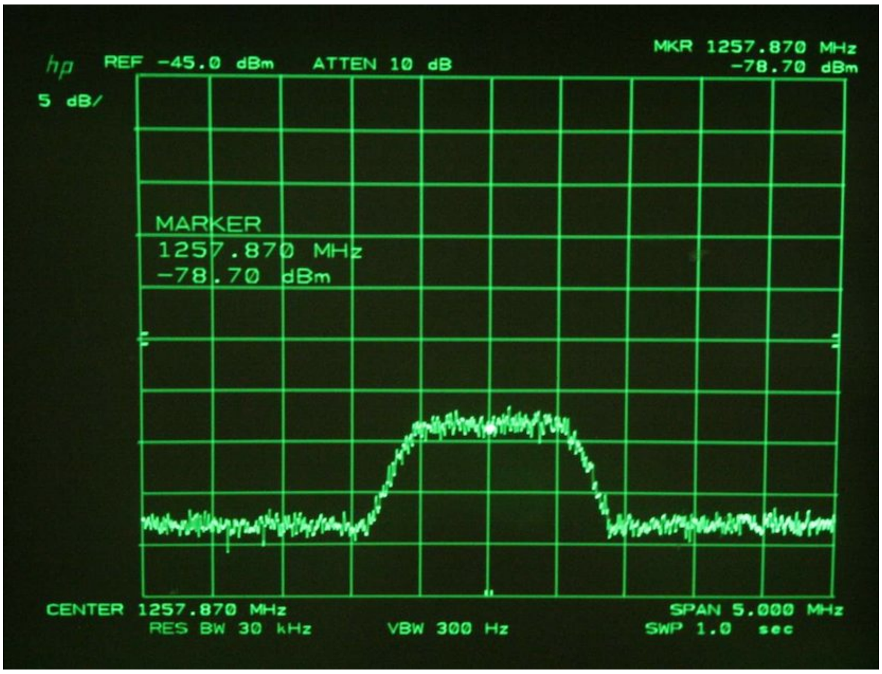

Fig.8 - HAMTV signal at 2395 MHz seen on the spectrum analyzer, downstream of the LNA/LNB (nominal LNB LO: 3650 MHz).

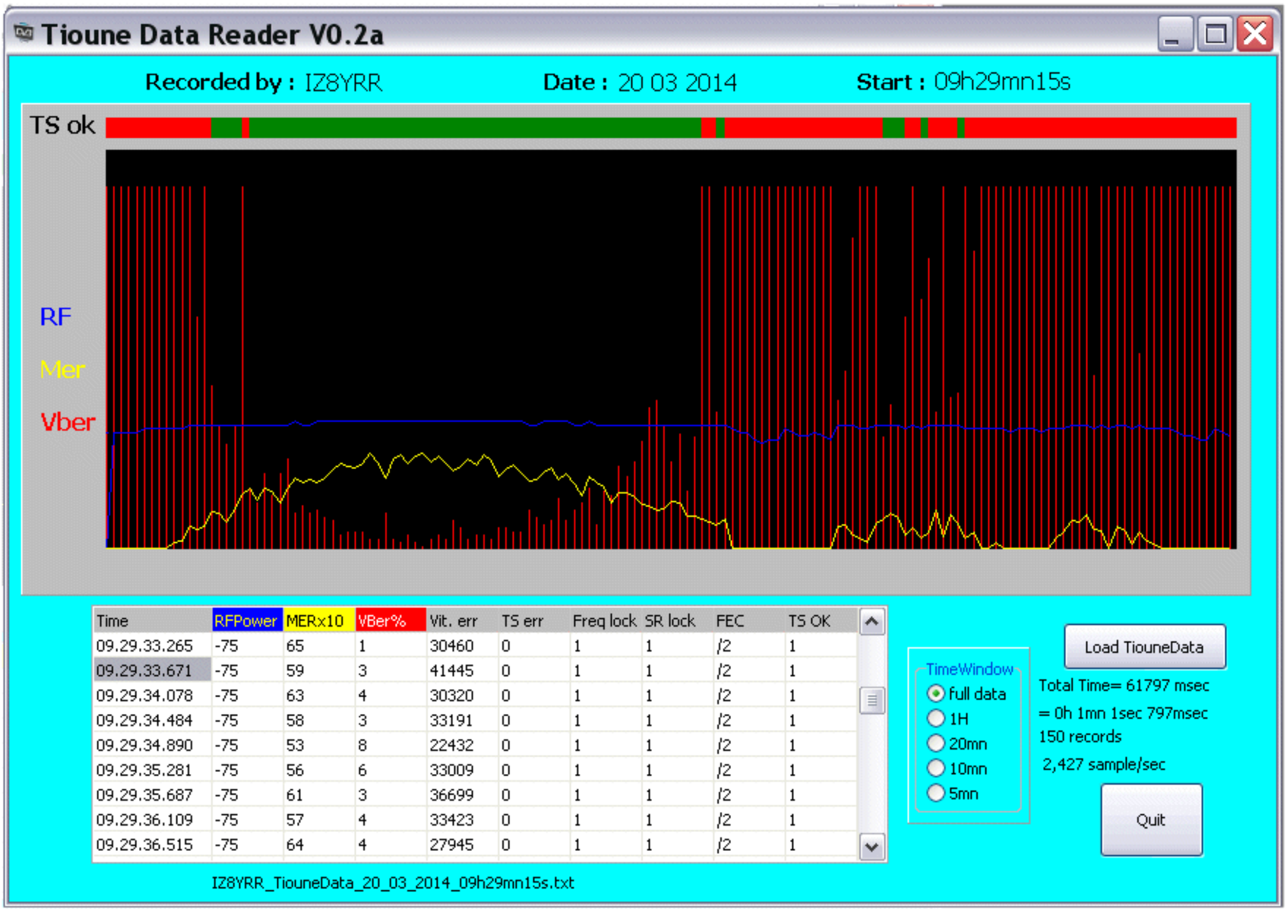

Fig.9 – Measured data recorded by Tutioune. Frequency: 2395 MHz. Minimum distance 450 Km. Green TS OK indicates video signal received without errors for about 30"

Data recorded by Tutioune can be viewed with the Tioune Data Reader (see fig.9). The data is organized in the following way. The red bars are the VBER, expressed in %, while the yellow line indicates the MER, in dB. Of minor interest is the indicator of RF Power (blue), since we are receiving a signal that is in fact comparable to the noise, when analyzed with filters whose bandwidth is narrower than the modulation envelope (in our case 1.2 Msymbols/sec, FEC ½).

It can be noted from the registration that the maximum of the received signal had a signal/noise ratio (MER) of 65, equal to 6.5 dB. The VBER remained below 10%, while obviously the Viterbi corrector worked at full capacity. The important thing to note is the solid green line at the top: this indicates that the video signal (TS, Transport Stream) has been successfully received without interruptions.

The next step was to receive the pass of April 8, scheduled at 01:00:53 UTC. Maximum elevation: 82°, minimum distance 430 Km. Practically an overhead pass. To try to maximize the duration of the reception, I pointed the antenna with an elevation of only 52° (fig. 10, 11).

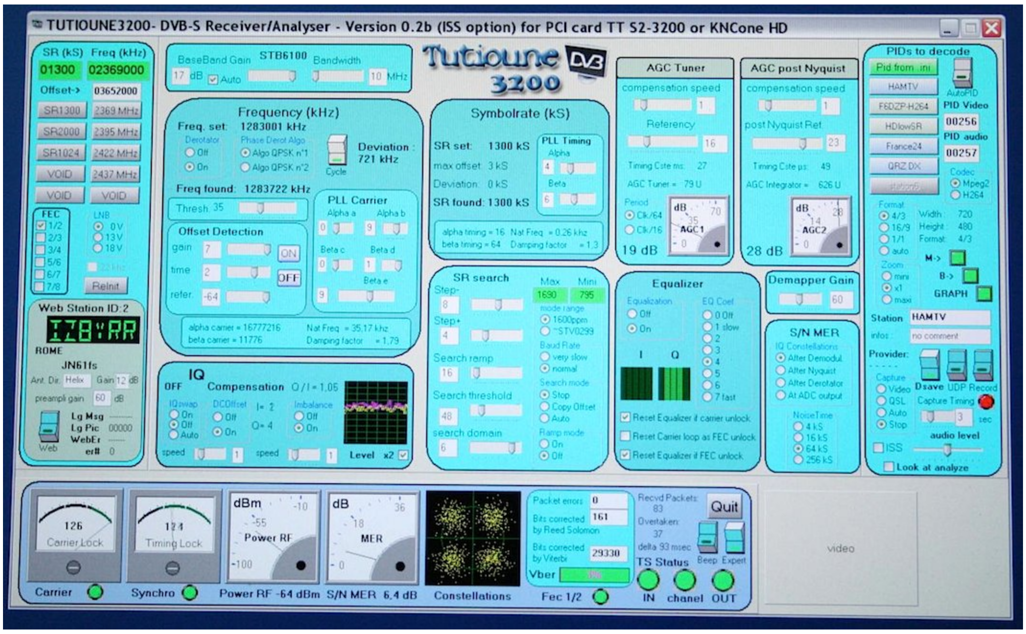

Fig.10 - HAMTV signal at 2369 MHz, received with Tutioune. Quality of the received signal: MER 6.4 dB. Bit corrected by Viterbi: 29330, bits corrected by Reed-Solomon: 161. The video section (lower left) has not been enabled, since we were receiving only blank transmissions.

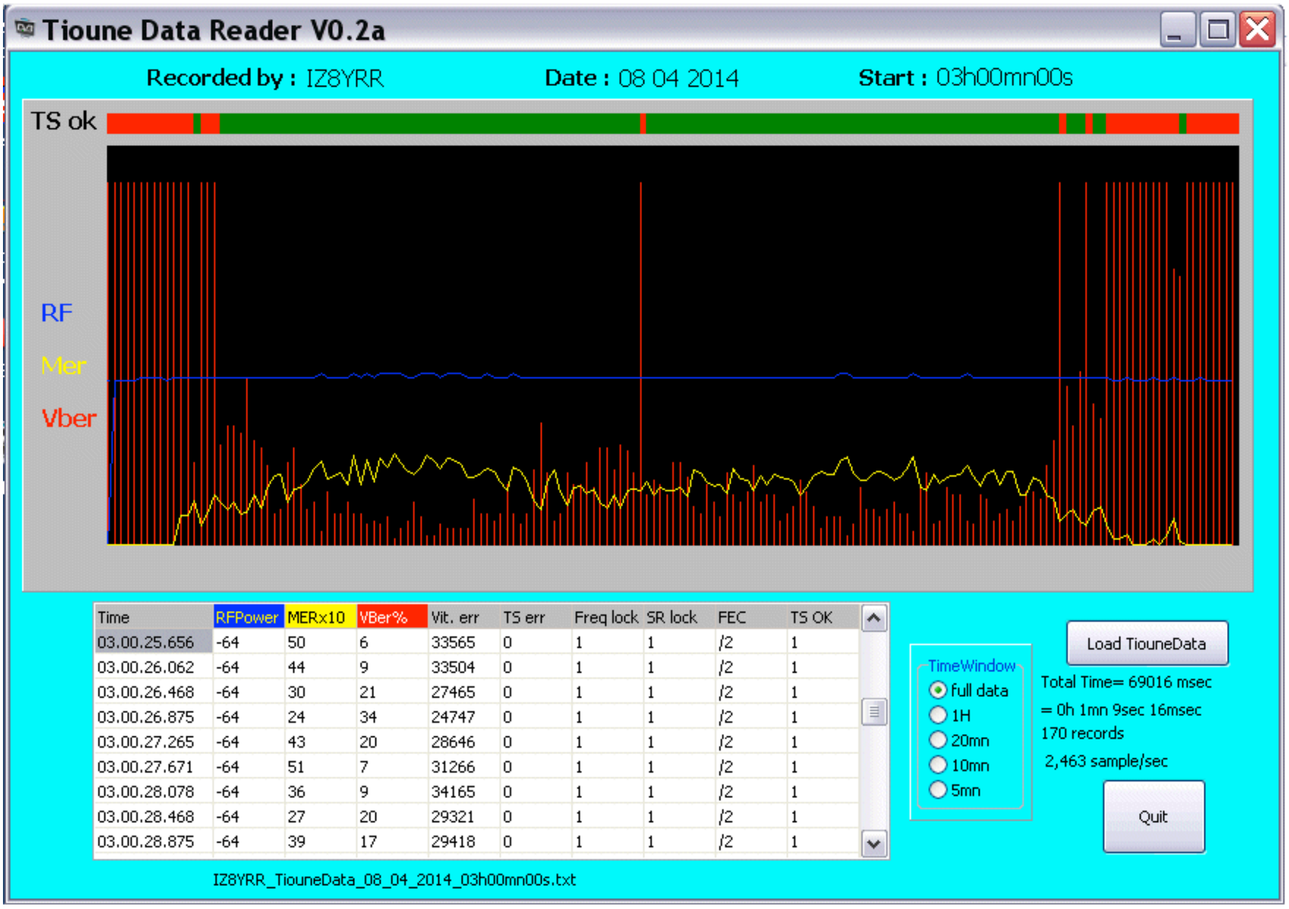

Fig.11 - Measured data recorded by Tutioune. Frequency: 2369 MHz. Minimum distance 430 Km. Visible a short break of the signal at the height of the pass. Duration of TS ok: about 60".

The recorded data, as well as being displayed by Tioune Data Reader, can be easily imported into Excel, because they are simple ASCII strings. I then plotted the data of MER and those slant-range provided by STSPLUS, related to each other according to UTC time (see Figure 12).

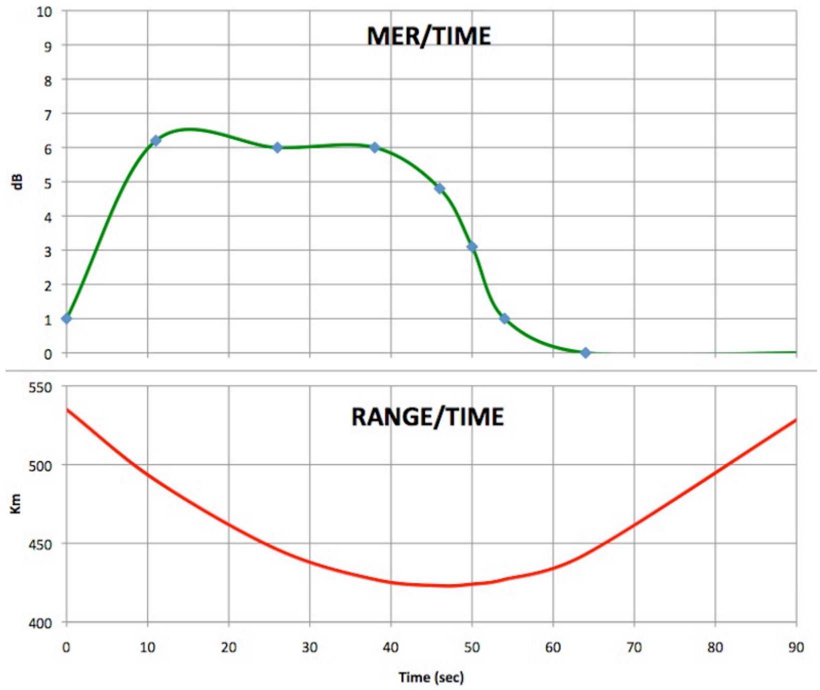

Fig.12 - Data analysis of the passage of April 8. The graph displays the MER (green) and the slant-range (red), correlated in time. Note the asymmetry of the reception. Among the possible causes: a) synchronization error between Tutioune and STSPLUS, b) orientation of the antenna on board the ISS ARISS, c) obstacles in my QTH looking south.

It is interesting to note that the reception was apparently made only during the first part of the pass (to be noted that this was a descending orbit, from NW to SE). Probably there was a small temporal misalignment between the timestamp of Tutioune data and the targeting data provided by STSPLUS. In addition, other causes may be due to the fact that the 2 ARISS antennas used for testing of HAMTV are not pointing toward the nadir of the ISS, but are slightly offset. The structures of the ISS (solar panels, other modules) behave as a screen. Then, at the rising of the ISS antennas are in sight, while at the set the same antennas are partially masked by the structures of the station itself.

This phenomenon has been verified when the ISS was temporarily redirected to facilitate the docking with a cargo module. In this case, the ARISS antenna #41 was partially masked in the ascending part of the orbit, and was instead perfectly "visible" in the descending part, phenomenon measurable by the different time required for the AOS, and for the LOS.

Instead, to find an explanation for the brief interruption of the signal, account must be taken of the existence of null reception that the helical antenna has compared its main lobe, a phenomenon to be taken into account if you do not use tracking. The antenna was in fact properly aligned in azimuth, but with an elevation of only 52° while the ISS has reached an elevation of 82°.

In a future article I will describe the tracking system used in the rest of the tests, and analysis of the data obtained.