Report

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Observation of SMART-1 beacon in S-band 2235.1MHz

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Abstract. The ESO spacecraft SMART-1 in its final destination in the moon orbit is an ideal transmitter (telemetry beacon) to check the quality and sensitivity of a small radio telescope. We wanted to take the opportunity to check our instrumentation before 3rd of September 2006 when SMART-1 will be destroyed by a controlled crash landing on the moon’s surface through ESA mission control. All measurements were successfully completed with audible sound and a high SNR of more than 40dB.

Key words. S-band, beacon, doppler.

1. Introduction

Observing space vehicles (Oslender, 1966) with small radio telescopes is rather challenging since many system parameters have to be optimized in parallel. In some cases it’s very difficult to get these data ready at the right time. One has to know the exact position at a certain time in space as well transmission frequency, transmission power, antenna gain, doppler shift and at least an assumption about the bandwidth of the signal. On August 23rd 2006 our 5m telescope was completed with a cylindrical horn feed for S-band built by our mechanic. The calibration unit was bypassed for minimal noise figure of the focal plane unit. A critical issue was the fact that the moon was rather near to the sun, just a few degrees away. There was a real risk that during the moon observation unknown sidelobes of the antenna may point to the sun. Different acronyms used in labels and text are described in table 1.

2. Sensitivity estimation

As a first test we measured the quiet sun to get an idea about system temperature $T_{sys}$ of the telescope. The result was promising since the signal to noise ratio or in this case the so called Y-factor was in the order of 11dB.

$$Y = \frac{V_{hot} - V_{cold}}{g} = 11dB \pm 0.5dB$$

Where $V_{hot} = 1055mV...1073mV$ is the measured voltage while pointing to the sun, $V_{cold} = 788mV$ the voltage while pointing to cold sky. Variable $g$ is the detector gradient of nominally $g = 25mV/dB$. Taking into account the interpolated quiet solar flux of $S = 60sfu$ (NOAA) on...
August 23th at 2235.1MHz we can estimate the system temperature \( T_{sys} \) to

\[
T_{sys} = \frac{SA_{eff}}{2k(Y-1)} = 183\text{Kelvin} \pm 16\text{Kelvin}
\] (2)

Where \( A_{eff} \) is the effective receiving area of the parabola antenna of

\[
A_{eff} = \pi r^2 \eta = 9.8m^2
\] (3)

where \( r = D/2 = 2.5m \) and \( \eta = 0.5 \) the efficiency factor (Kraus, 1965) as a first order assumption.

### 3. Station description

A 5m radio telescope, see figure 1, was pointed to the moon in two different tracking modes a) continuous tracking and b) on-/off source. The incoming signals were amplified by a high gain low noise preamplifier of MITEQ company and fed via a low ohmic loss coaxial cable to our communication receiver AR5000, see figure 2. The receiver AR5000 was set to 2235.1MHz with a small offset to compensate for actual doppler shift of 6.5KHz. The CW signal could be heard very clearly in the attached loudspeaker. The audio output was feed to a sound card of a standard PC and analyzed on line with the freeware spectrum analyzer SpectrumLab.

### 4. SNR estimation

We wanted to have a rough value of the expected SNR. Given the transmission power \( P_T \) of 5W on an isotropic helical antenna with a gain of \( G > -3 \text{dB}i \), \( G_{typ} = 0 \text{dB}i \) at a distance between moon and earth of about \( r = 384'000 \text{km} \), we can calculate the power flux density \( P_{FD} \) at Bleien to

\[
P_{FD} = \frac{P_T (G_{...G_{typ}})}{4\pi r^2} = (1.3...2.7) \times 10^{-16} \text{W/m}^2
\] (4)

And from that we may evaluate antenna power \( P_{SMART} \) of space vehicle SMART-1 to

\[
P_{SMART} = P_{FD} A_{eff} p \eta = 6.4 \times 10^{-16}...1.3 \times 10^{-15} \text{W}
\] (5)
where \( p = 0.5 \) denotes to polarization loss due to linear reception of a circularly polarized wave. To get the internal system power \( P_{sys} \) we need to know the signal bandwidth \( \Delta \nu \) which was measured using SpectrumLab to 12Hz ... 15Hz according to figures 3 and 4.

\[
P_{sys} = k T_{sys} \Delta \nu = 3.8 \times 10^{-20} \text{ W} \tag{6}
\]

Now we are in a position to evaluate the expected SNR for SMART-1 from equations 5 and 6.

\[
SNR = \frac{P_{SMART}}{P_{sys}} = 16'482...34'211 = 43.8 \pm 0.15 dB \tag{7}
\]

5. Results

Received signals were very loud and clear despite of polarization loss due to linear reception of circular waves. We got similar results expressed in SNR with our 7m dish whereas we could select both polarizations LHCP or RHCP separately. The 7m dish has a higher system temperature due to internal calibration hardware components in the FPU. Unfortunately it was not possible to observe SMART-1 with our new spectrometer ARGOS because reception bandwidth (12.2KHz ... 60KHz) is too large compared to the signal bandwidth of just a few hertz. Using the analysis function of SpectrumLab under best conditions we got a measured signal to noise ratio of \( SNR_{measured} > 40\text{dB} \) which perfectly fits with the theoretical estimation \( SNR_{val} = 43.8 \pm 0.15 dB \).

6. Conclusions

6.1. Conclusions in view of space vehicles

With our present hardware configuration it is quite easy to observe spacecrafts as long as all observation parameters are known. Gain, system temperature and pointing accuracy are sufficient to observe satellites in L- and S-band. The present setup is ideal for further observations for students exercises because a success can almost be guaranteed. Observations of Mars-Express at 8.419926GHz, Mars Global Surveyor at 8.422744GHz, NASA’s Spitzer at 8.4136188GHz and other planetary probes in X-band shall be part of another test together with people of University Zurich using a dual polarization septum feed horn on our 5m telescope.

6.2. Conclusions in view of Phoenix-3

In view of Phoenix-3 we have shown that the 5m dish has sufficient effective area and acceptable pointing accuracy above 2GHz to clearly observe the quiet sun (11dB Y-factor) unless the feed is out of the focal point. We should therefore think about moving spectral reception above 2GHz to the 5m dish because of less critical pointing uncertainty compared to our 7m dish.

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References

M. -Dieter Oslender, *Satelliten selbst beobachten*, TOPP Buchreihe Nr. 36, Frech Verlag Stuttgart-Botnang, 1966