THE SPOrt MISSION ON ISSA

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Abstract. In the framework of the International Space Station (ISSA) utilisation a project to measure the sky diffuse polarised emission at microwave frequencies has been presented to the ESA AO. After its selection by ESA the Sky Polarisation Observatory (SPOrt) has been slightly modified, within ISSA constrains, to meet better its scientific goal. In this paper the current design of SPOrt is presented with emphasis on changes which have a major impact on the overall performances and that were imposed by the ISSA environment.

INTRODUCTION

The SPOrt project, an experiment selected by ESA for the Early Opportunity phase onboard the ISSA, is devoted to the construction of multifrequency (20-90 GHz) polarisation maps of the Galactic emission and the Cosmic Background Radiation (CMB) on angular scale ≅ 7°.

At present, maps of multifrequency observations of Galactic emission in the frequency range 10-90 GHz are lacking. On the other hand, this information is essential for the understanding of the structure and dynamics of our Galaxy. Observations of spectral changes as a function of direction will allow a study of the main characteristic of the Galactic magnetic field (its intensity and direction), the scales of its irregularities and the temperature and density of interstellar clouds. A detailed knowledge of the foreground features is also essential for the separation of the CMB cosmological signal from the Galactic signal.

During its 18 month lifetime and with more than 80% sky coverage, the SPOrt experiment will possibly reach a pixel sensitivity to linear polarization of few μK sufficient to obtain a detection or stringent upper limits to the polarisation of the CMB (at the same angular scale of COBE/DMR). As the temperature anisotropy and polarisation depend on the primordial power spectrum of the fluctuations and the ionization history of the Universe in different ways, a polarisation detection will provide significant additional information that will help to constrain cosmological parameters like: the total density of the Universe, the baryon content of the Universe, the duration of the recombination and the epoch of reionization. Measurements of the polarisation of the CMB are important for understanding the thermal history of the Universe, the properties of cosmic matter at intermediate z (range 10-100), and the nature of perturbations.

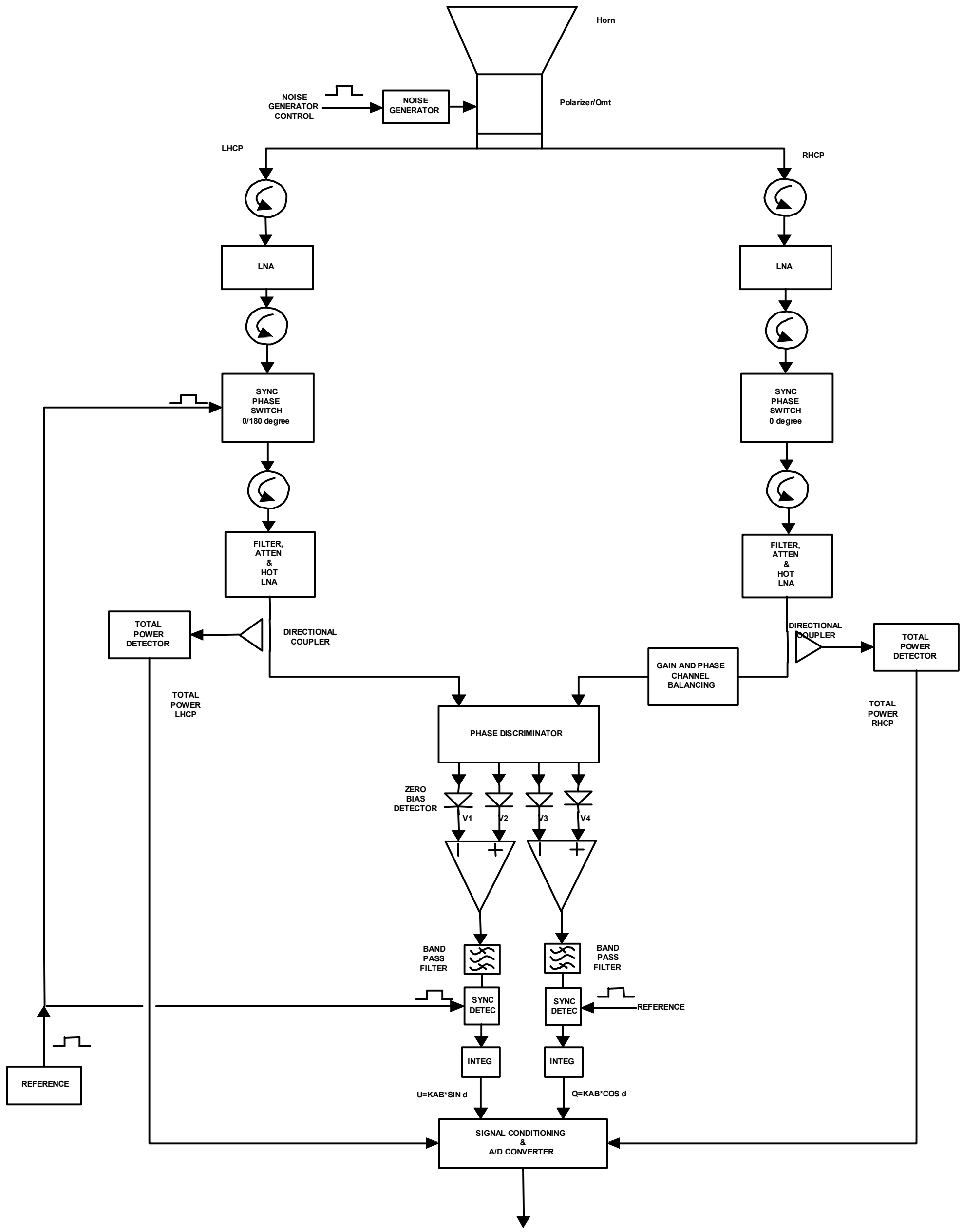

FIGURE 1. Block diagram of SPOrt correlation radio polarimeters.

EXPERIMENTAL DESIGN

The expected polarized signal from the sky (Galaxy + CMB) is few tens of μK at $\nu \approx 20$ GHz and of the order of a few μK at frequencies > 70GHz, then it may be measured only using dedicated strategies and techniques. Much care must be taken in the instrument design in order to minimize spurious effects which may be difficult to remove from data. In the light of this, main requirements are:

- good foreground spectral shape determination
- μK sensitivity and large sky coverage; previous ground based experiments have covered limited portions of the sky and only upper limits were obtained (Nanos, 1979; Lubin and Smoot, 1979, 1981; Partridge, 1988; Wollack *et al.*, 1993; Netterfield *et al.*, 1995)

- spurious (instrumental) polarizations must be taken as low as possible; contributions can come from poor isolation between channels (crosspolarization), so that part of the unpolarized component of the signal can be seen as polarized, and from experimental design of the optics, so that additional polarization can be generated by parts of the receiver system (e.g. reflectors).

The instrument design proposed for SPOrt is based on (see Figure 1):

- four frequency channels at 22, 32, 60, 90 GHz; the four frequency channels guarantee the maximum capability to disentangle among different foreground emission also in case of polarisation of the Bremmstrahlung emission (Thomson scattering in giant HII clouds)
- four corrugated feed horns with identical HPBW (7°); in this way no additional normalization is required for the comparison of results at different frequencies
- two-channels Correlation Radio-Polarimeters (CRP); correlation techniques are preferable because uncorrelated signals (e.g. those generated by gain fluctuations) do not produce any change in the receiver output
- switching techniques (to reduce 1/f noise and offsets)

The SPOrt CRPs are essentially the same proposed before (Cortiglioni et al., 1997) except for the phase modulation (0°-180°) technique which has been adopted to limit the effects of the 1/f noise in the post detection section and reduce the undesired effects of instabilities and offsets. In this configuration the two circular polarisations (LHC and RHC) provided by an antenna system (corrugated feed horn, polariser and Orthomode Transducer) are separately amplified by low noise chains. These provide the two signals which are correlated in the Hybrid Phase Discriminators (HPD). The 4 HPD outputs are then square detected and composed to get two signals proportional to U and Q Stokes parameters.

The proposed CRP technique is based on HPDs, which are not available up to now at frequencies higher than 18 GHz. So it is necessary to realize them within the SPOrt collaboration where the industry will provide HPD at the state of the art with the support of the scientific staff of SPOrt. Two different techniques, microstrips and waveguides, will be used at frequency lower than or higher than 35 GHz respectively.

The SPOrt antenna system is also a critical part of the experiment and shall require dedicated design to reach the goal particularly in terms of cross-polarisation and sidelobes. Since reflective optics cause unwanted cross-polarisation which is hard to control, corrugated feed horns have been adopted. In order to keep lower the instrumental polarisation, which in any case must be characterized, a preliminary value of ≈ –65 dB has been set for the product (Pn x Cn), where Pn and Cn indicate the polar and cross-polar antenna pattern respectively. Another important characteristic is the side-lobes rejection. In this case the optimal antenna pattern should be a "smoothed pattern", that is no lobes higher than –60 dB within –45 and +45 degrees from the axis.

TABLE 1.Technical Characteristics

Frequency channels (GHz)	22, 32, 60, 90
Bandwidth , $\Delta\nu/\nu$ (%)	10
Antennas	corrugated feed horns + polarizer +OMT smoothed beam shape
Xpolarized beam (dB)	< -45
Pn x Cn (dB)	< -65
Total LNA gain at 80K (dB)	≈ 70
T_{HORN} (K)	< 250 ± 5
T_{HEMT} (K)	≤ 80 ± 0.1
Sky coverage (%)	≈ 80
Dimensions (m)	0.5 x 0.5 x 1.2
Max. Weight (kg)	52
Max. Power (W)	120

Since the Express Pallet Adapter (EXPA) does not provide for active thermal cooling of the payloads, the required thermal conditions for SPOrt will be achieved by a dedicated cooling system. Short realization times as well as the power dissipation budget do not allow the use of state of the art cooling system for space. The adopted solution is

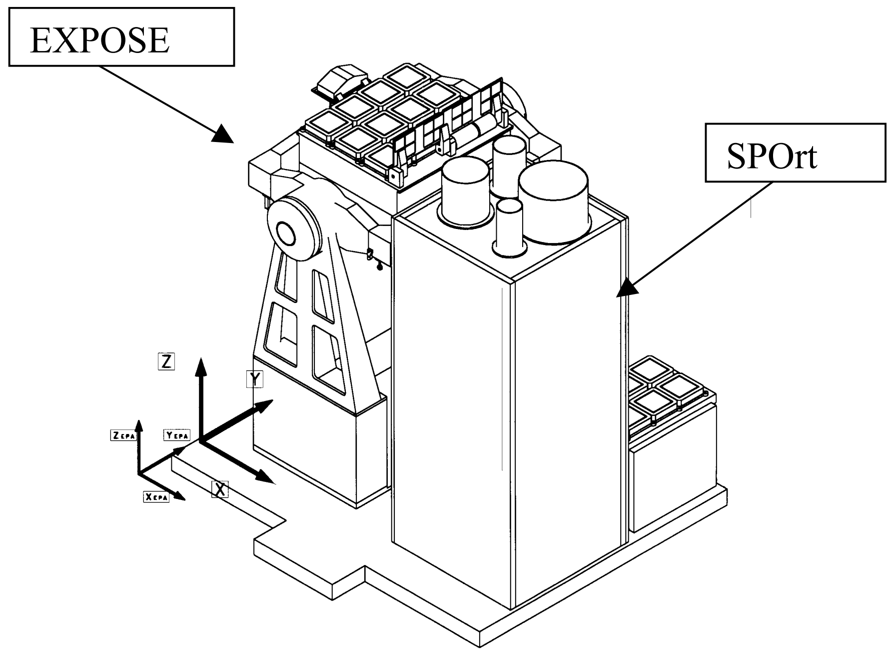

FIGURE 2. The SPOrt payload accommodation on the EXPA together with EXPOSE

based on commercial integrated cryo-coolers (RICOR K543) which can provide 1 W at 80 K. This is enough to cool down low noise front-end, but not the feed horns which will be kept at $\approx 250 \pm 5$ K by active thermal control. This temperature is slightly higher than the "natural" temperature they would have onboard the ISSA.

Table 1 summarizes the technical characteristics of SPOrt instrument and depicts the actual situation, independently on future developments. Taking into account these figures and an observation efficiency of 50%, the SPOrt capabilities are reported in Table 2.

In summary the SPOrt experiment has been improved with respect to its preliminary design (Cortiglioni et al., 1997) and will permit a wide range of scientific investigations.

TABLE 2. SPOrt capabilities

ν (GHz)	**T_{sys} (K)**	**ΔT_{rms} (mK $s^{1/2}$)**	**Pixel sensitivity (μK)**	**Full sky sensitivity (μK)**
22	65	2	13	0.5
32	82	2	14	0.5
60	119	2.2	15	0.6
90	167	2.5	17	0.7

The current design of SPOrt payload takes into account the sharing of a single Express Pallet Adapter (EXPA) with another experiment, EXPOSE (all together a package named EXPORT) as shown in Figure 2. The orbital motion of the ISSA will allow the 4 antennas pointing to the zenith to cover >80% of the sky many times during the 1.5 year flight duration (sky scanning mode).

CONCLUSIONS

SPOrt must be realized following the ISSA schedule, which is very tight, to be flown in 2002 (UF-4, UF-5 Flights). Then its design/realization will follow very precise guidelines resulting in a compressed schedule. With the maps provided by SPOrt it will be possible:

- to fill the gap in the experimental data about the polarization of the galactic emission at frequencies of interest for CMB measurements
- to make a new attempt in investigating the polarization of both the foregrounds and the CMB. Even if only upper limits will be consistently determined on large-scales, this result will have great impact on cosmological theories.

Therefore SPOrt observations would provide complementary information with respect to present and future CMB space mission (MAP, PLANCK,..). Moreover polarisation measurements can help in the interpretation of "total intensity" anisotropy measurements of the CMB, particularly those detected by COBE/DMR.

In addition to scientific (both theoretical and experimental) motivations we remark the importance of developing technological activities in the field of microwave instruments (up to ~100 GHz) both for space and ground applications. In fact a consistent technological fall out is expected as resulting from both scientific and industrial activities needed for the SPOrt project realization. Several components that will be designed and realized would be used also in back end facilities of ground based instrumentation. This will contribute to open new scientific perspectives in Radioastronomy.

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