SKY POLARISATION OBSERVATORY (SPOrt): A PROJECT FOR THE INTERNATIONAL SPACE STATION

Cortiglioni, S. Cecchini, S. Orsini, M.
I.Te.S.R.E./CNR via P. Gobetti 101, 40129 Bologna, Italy

Boella, G. Gervasi, M. Sironi, G.
Dip. Fisica Univ. Milano, v. Celoria 16, 20133 Milano, Italy

Fabbri, R.
Univ. Firenze, P.zza S. Marco 4, 50121 Firenze, Italy

Monari, J. Orfei, A.
I.R.A./CNR VLBI Radioastronomical Station of Medicina, Bologna, Italy

Ng, K.-W.
Institute of Physics, Academia Sinica, Taipei, Taiwan 11529, R.O.C.

Nicastro, L.
I.F.C.A.I./CNR, via La Malfa 153, 90146 Palermo, Italy

Pisani, U.
Dip. Elettronica Politecnico di Torino, c.so Duca degli Abruzzi 24, 10129 Torino, Italy

Tascone, R.
CESPA/CNR c/o Dip. Elettronica Politecnico di Torino, c.so Duca degli Abruzzi 24, 10129 Torino, Italy

Popa, L.
Institute of Space Sciences, R-76900, Bucharest-Magurele, Romania

Strukov, I.A.
Space Research Institute (IKI), Profsojuznaja ul. 84/32, Moskow 117810, Russia

ABSTRACT

The SPOrt project, an experiment selected by ESA for the Early Opportunity phase onboard the ISSA, is devoted to the construction of multifrequency (20-90GHz) polarisation maps of the Galactic emission and the Cosmic Background Radiation. By using these maps it will be possible to study spectral index variation patterns of the polarised components of the various Galactic foregrounds (synchrotron, bremsstrahlung and dust emissions). The detailed knowledge of these features is essential for the understanding of Galaxy dynamics and magnetic field structure and has strong implications for the subtraction of foreground contributions to the CMB. The sensitivity achievable by SPOrt for the Stokes parameters will also allow the detection (or at least the determination of stringent upper limits) of the polarisation of the CMB itself.

1. INTRODUCTION

In the frequency range 1-100 GHz the diffuse emission from the sky is the sum of three contributions (see Fig. 1):

a) The Cosmic Microwave Background (CMB), a relic of the Big Bang. To a very high degree of accuracy the CMB has Planckian spectrum, isotropic distribution and is unpolarised. Small deviations (spectral distortions, anisotropic distribution, residual polarisation) are however expected to exist and their detection is very important for Cosmology. So far only very small anisotropies (few parts on 10^5) have been detected with good confidence. Such detections tell us that polarisation has to be searched at levels of few parts on 10^6 or less. Its actual magnitude and pattern features should be powerful tools for discriminating between different cosmological models in a manner complementary to anisotropy measurements.

b) Galactic diffuse Background (GB) a mixture of synchrotron emission (GS) with power law temperature spectrum (spectral index ~-2.8), bremsstrahlung emission from the disk (temperature spectral index ~-2.1), and dust radiation with a complex spectrum. The GB is expected to be anisotropically distributed with large degrees of linear polarisation (depending on frequency, direction of observation and angular resolution). Measurements of the GB polarisation can provide useful information on the properties of the galactic magnetic field (like strength and direction) as well as on the scale of its irregularities, constraining different models of the intergalactic medium.

c) Blend of extragalactic unresolved radiosources. It has a power spectrum similar to the one of the Galactic diffuse emission, is isotropically distributed and is weakly polarised or unpolarised at angular scales of a few degrees.

Thus the construction of observed maps of the polarised component of the diffuse radiation from extended regions of sky, at various frequencies, is essential for both Cosmology and Astrophysics. In the 20-90 GHz spectral range, practically unexplored, SPOrt in 18 months of observation is planned to reach a pixel sensitivity to linear polarisation of few μK, sufficient to obtain:

i) a substantial improvement of our knowledge of the polarisation of the galactic background, dominant at the lowest frequencies,

ii) positive detection or important upper limits on the polarisation of the CMB, which is expected to overcome the galactic signal at high frequencies (Ref. 1). In order to get a better discrimination among these components, the SPOrt experiment has the following characteristics:

1) Frequency channels at 22, 32, 60, 90 GHz.
2) Geometrically scaled antennas with identical beams (HPBW=7°) coupled to orthomode transducers. In this way no additional normalization is required for the comparison of results at different frequencies.
3) Two channels Correlation Radio-Polarimeters (CRP) with outputs proportional to the Stokes Parameters U and Q.
4) Sky coverage > 80% (Fig. 2).

2. EXPERIMENTAL DESIGN

The current design of SPOrt is substantially different from those presented before (Refs. 2,3); however main characteristics are very similar and can be summarized in Tab. 1. It was necessary, in fact, to re-design the experiment taking into account the accommodation onboard the Express Pallet Adapter (EXPA) together with another experiment (EXPOSE). The result of such a study is a package, named EXPORT, which permits to both experiments to be accommodated on the EXPA (Fig. 3). Also the operating frequencies have been changed from the previous ones in order to reduce the overall size and to have 4 channels instead of three.
In this way also in presence of a polarised component from galactic bremsstrahlung it should be possible to disentangle the different sources.
Thanks to the availability of low noise HEMT amplifiers from NRAO (the same of the NASA-MAP satellite) the new SPOrt design extends its maximum observing frequency up to 90 GHz, opening a new window on the study of the CMB polarisation.
The SPOrt CRP (Fig. 4) are essentially the same proposed before except for the modulation 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 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 of the observed radiation.

Frequency	*Sensitivity ($mK/s^{1/2}$)*	*T_{sys} (K)*
22	2	65.6
32	2.1	81.6
60	2.2	119.3
90	2.5	167.5

Table 1. Characteristics of the SPOrt radiometers. T_{sys} is the system noise temperature, calculated for a 300K working temperature of the electronics but for the HEMT (cooled to 80K).

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 status 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. A block diagram of HPDs is shown in Fig. 5 as well as the characteristics achievable by current design of antenna system are shown in Tab. 2.

Frequency band: [GHz] [%]	22 10	34 10	60 10	90 10
Return Loss [dB]: *complete feed (goal)	<-28 (-30)	<-28 (-30)	<-27 (-30)	<-27 (-30)
Isolation [dB]	<-40	<-40	<-40	<-40
Cross-polar [dB]: * on axis	<-40	<-40	<-40	<-40
Insertion loss [dB]:	TO BE MINIMIZED			

Table 2. Electrical specifications for the feed systems.

In summary the SPOrt experiment has been improved with respect to its preliminary design and will permit a larger range of scientific investigations taking into account ISSA constrains.

3. CONCLUSIONS

SPOrt must be realized following the ISSA schedule, which is very tight to be flown in 2002 (UF-5 Flight). Then the SPOrt design/realization will follow very precise guidelines resulting in a compressed experiment schedule (see Fig. 6).
During its 18 months lifetime, the SPOrt experiment will possibly reach the two main goals:

a)Detailed maps of the polarised component of the galactic background.
At present maps of multifrequency observations of Galactic emission in the high-frequency range 10-90GHz 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 function of direction will allow to study 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 foregrounds features is also essential for the separation of the CMB cosmological signal from the Galactic signal.
b)Detection or stringent upper limits to the polarisation of the CMB on angular scales of 7°.
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, in particular, 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 10^1-10^2), and the nature of perturbations, such as primordial gravitational waves.
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 (at the same angular scale).

Even if only upper limits will be consistently determined on large-scales (at levels of ~10 μK or less for the rms polarisation degree), this result will have great impact on cosmological theories.

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. A consistent ground-based experimental activity, even if potentially affected by the atmospheric foreground, is carried out by some groups participating to the SPOrt project (Ref. 4). Such an activity would greatly benefit from both experimental and theoretical efforts growing around the SPOrt project.

Moreover, 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 for SPOrt, like for example low cross polarisation and low sidelobe feed horns, Hybrid Phase Discriminator, polarimetric calibrators, would be used also in back end facilities of ground based instrumentation. This will contribute to open new scientific perspectives in Radioastronomy.

4. ACKNOWLEDGEMENTS

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5. REFERENCES

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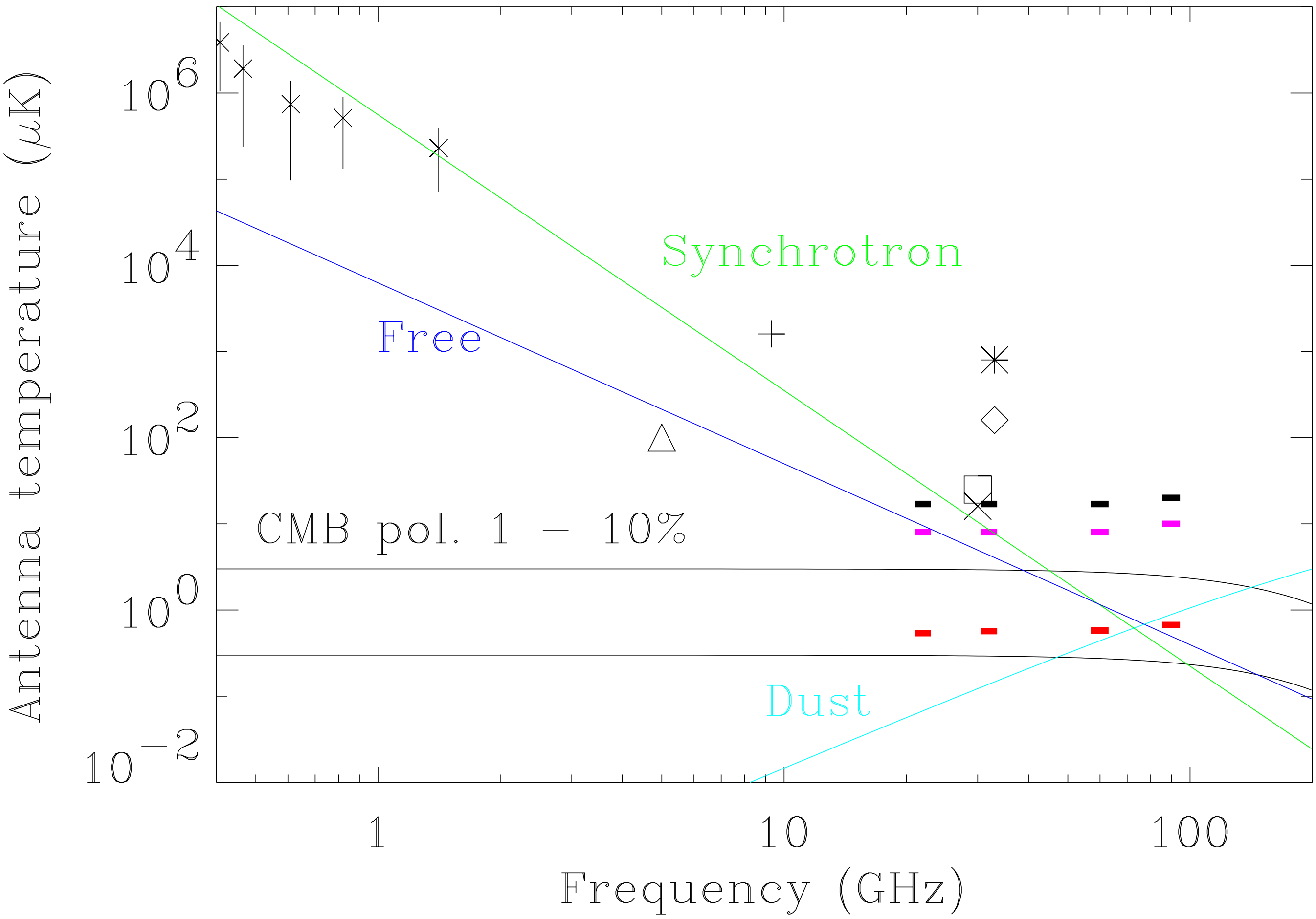

Figure 1. Predicted intensity levels of both the galactic polarised emissions and the CMB polarised component. Points with error bars comes from Ref. 5. Different symbols refer to upper limits on the CMB polarised component from previous experiments: Nanos, 1979 (cross, Ref. 6); Lubin & Smoot, 1979 and 1981 (asterisc and diamond respectively, Refs. 7, 8); Partridge et al., 1988 (triangle, Ref. 9); Wollack et al., 1993 (square, Ref. 10); Netterfield et al., 1995 ('X', Ref. 11). Color ticks at 22, 32, 60 and 90 GHz show the expected minimum (black), maximum (violet) sensitivity per pixel and full sky (red) sensitivity for the SPOrt experiment.

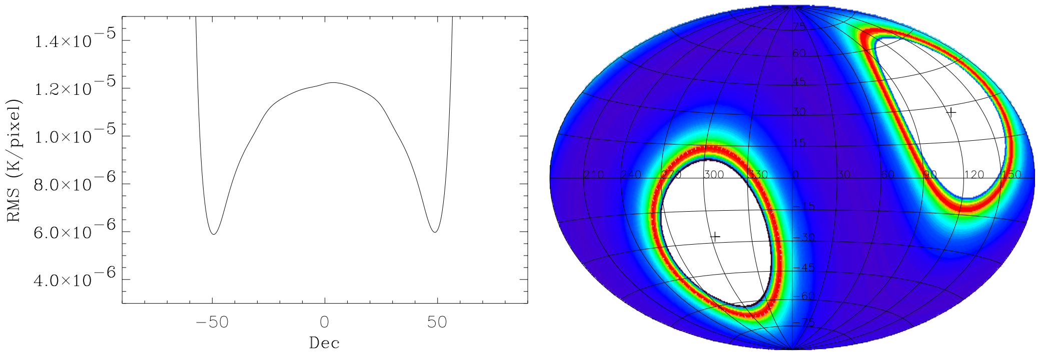

Figure 2. Expected sensitivity for 1.5 years SPOrt lifetime across the sky for the 90GHz channel (left panel) and the sky coverage in galactic coordinates (right panel). Colors refer to different integration time (from 30 to 120 Ksec).

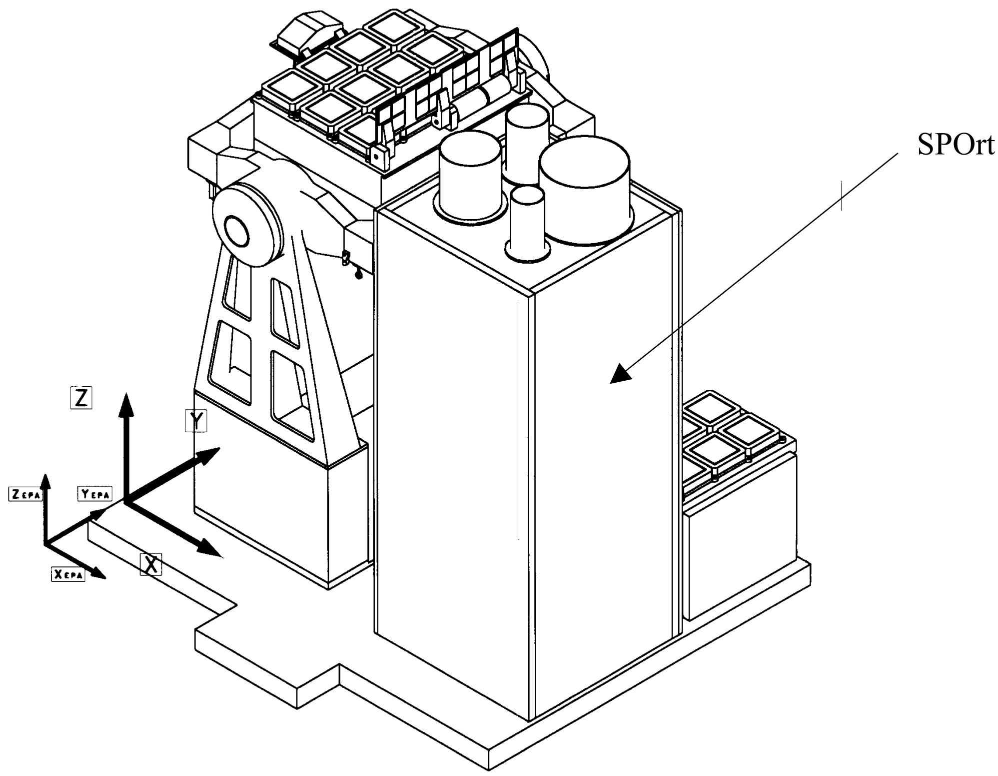

Figure 3. The SPOrt payload accomodation on the EXPA together with EXPOSE

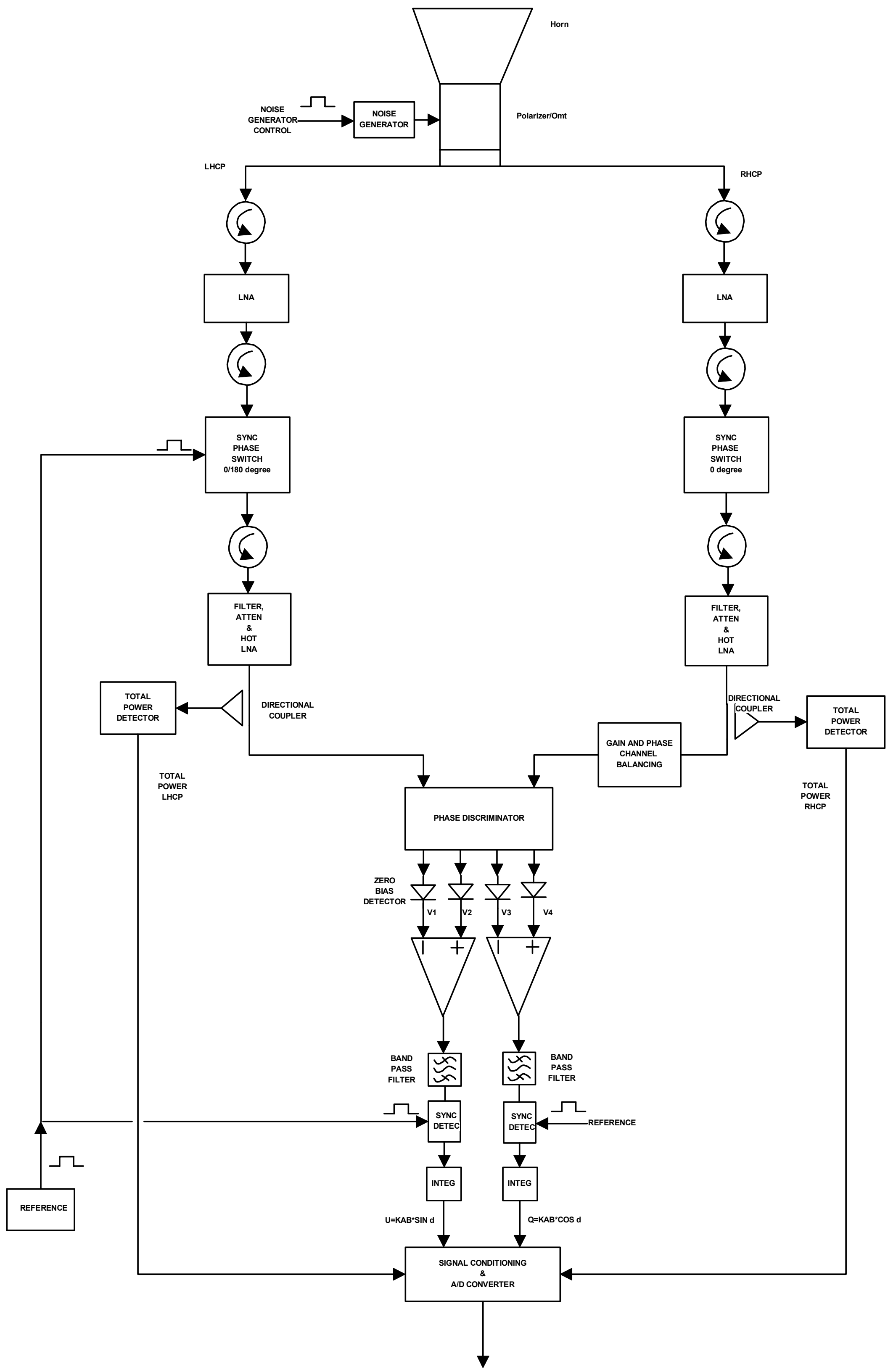

Figure 4. Block diagram of SPOrt correlation radio polarimeters.

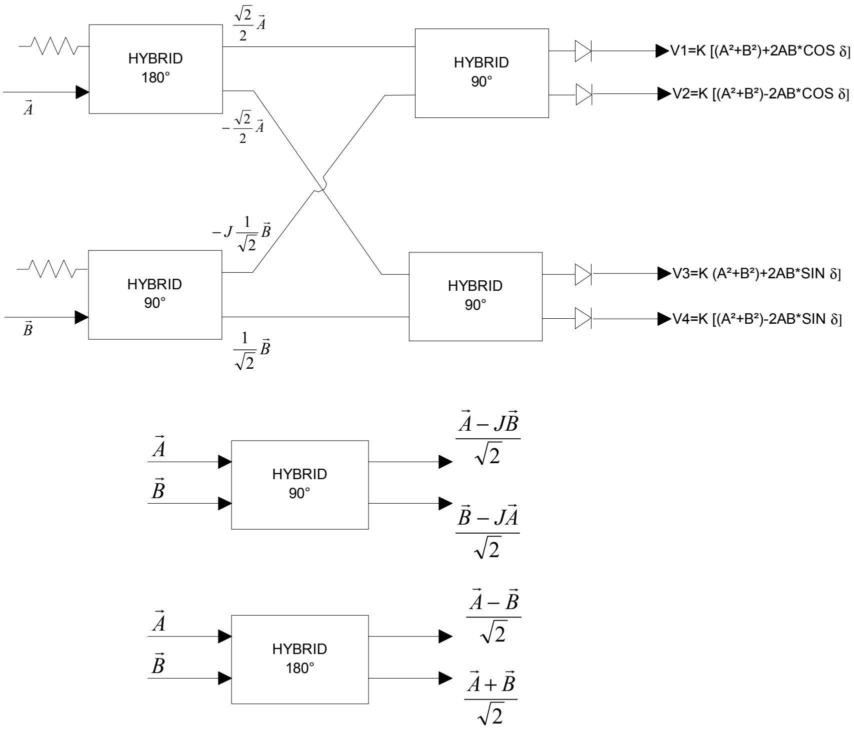

Figure 5. A tipical configuration of the SPOrt Hybrid Phase Discriminators (HPD).

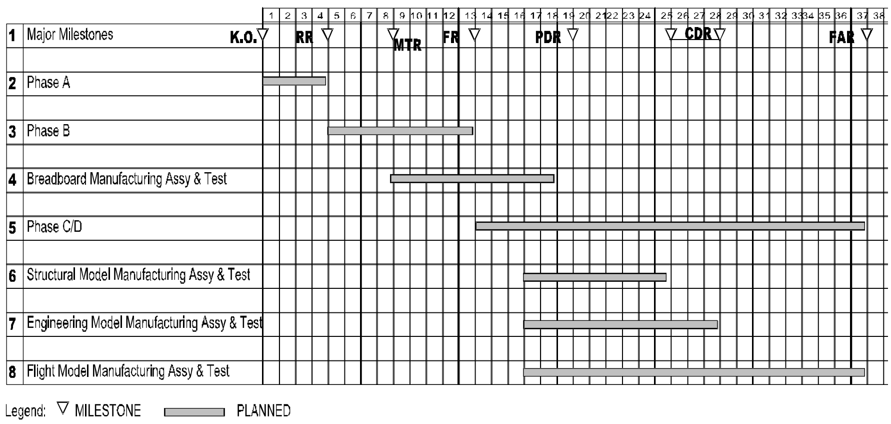

Figure 6. The SPOrt experiment schedule summary: flight model delivery is foreseen at the end of 2000.