IMPROVED MULTI-OCTAVE **3dB HYBRID** FOR RADIO ASTRONOMY **CRYOGENIC** RECEIVERS

ABSTRACT

Modern ultra low noise receivers used for radio astronomy have evolved to provide very wide instantaneous bandwidth. Some of the configurations used in present cryogenic front-ends, like sideband separating mixers and balanced amplifiers, need 90º hybrids at the IF, typically in the **4-12 GHz** band. There are commercially available devices covering this band with good ambient temperature characteristics, but their **cryogenic** performance drops to unacceptable levels.

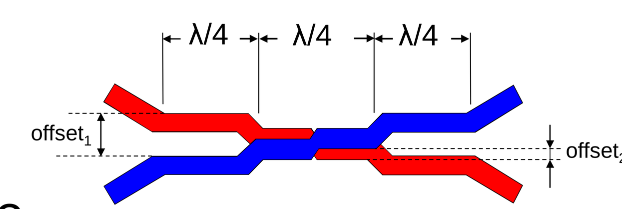
This poster describes the **design**, **construction** and **measurement** of a multioctave **stripline hybrid** for the 4 to 12 GHz band specially conceived to survive and fulfill accurate specifications when cooled to **15 K** (-258 ºC).

The materials and mechanical construction procedure have been specially selected and the result is a very compact, reliable and low thermal mass device, able to survive extreme thermal cycling. The coupling and reflection show very little temperature dependence.

Finally, the comparison of the results of a typical commercial unit with the new design presented clearly shows its advantages at cryogenic temperature.

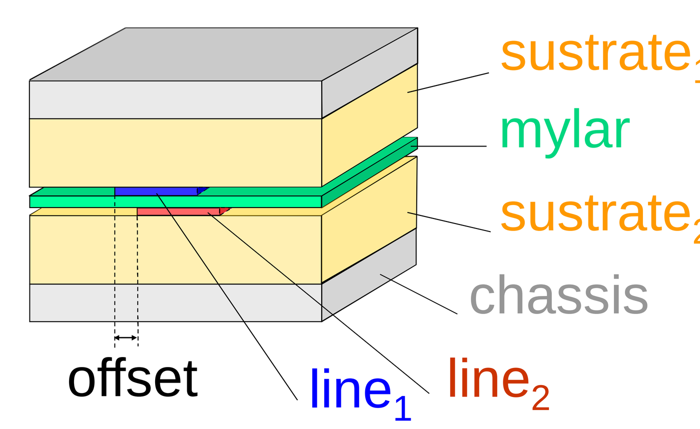
DESIGN

- Three sections of λ/4 coupled lines:
  - Maximum coupling for transmision lines of n λ/4 length (n: odd).
  - Three sections allows coupling ripple of 0.1dB in two octaves band.

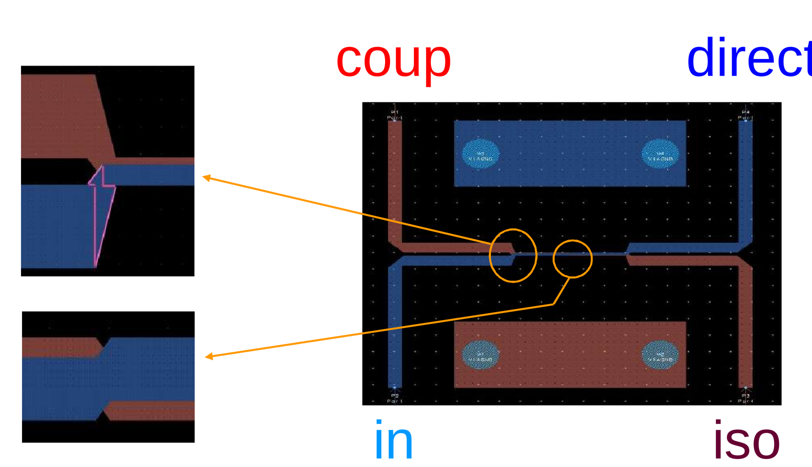


Schematic top view

- The coupled lines are "offset broadside coupled striplines":
  - Offset of central section is used to tune the coupling factor.
  - Perfect alignment of sustrates is critical to obtain the design specifications but is dificult to achieve in the fabrication process.
- Stripline technology in shielded chassis, with a mylar separation layer.

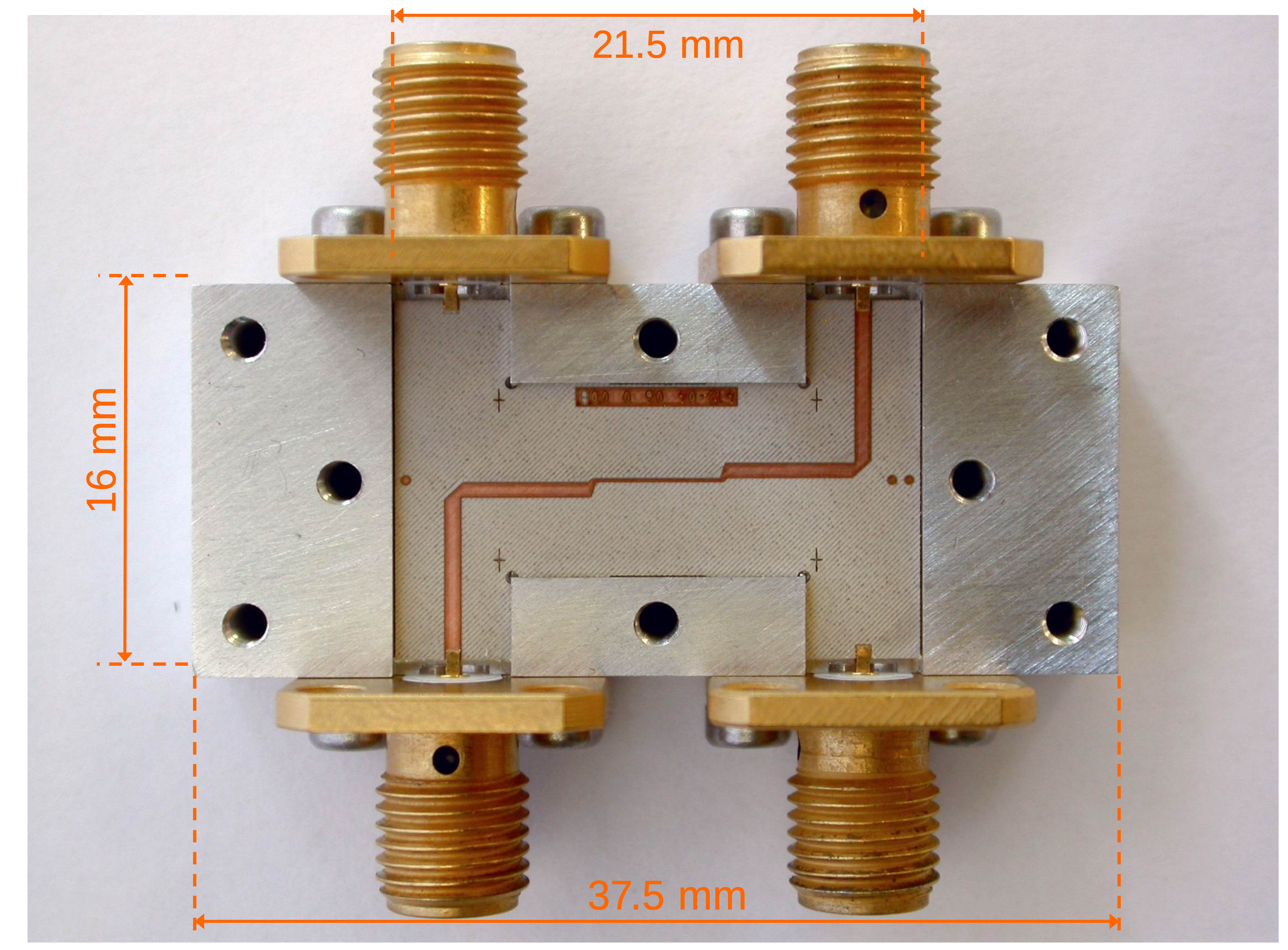


- Simulation:
  - J.P.Shelton model ("Impedances of offset parallel-coupled strip transmission lines". *IEEE Trans. Microw. Theory Tech., vol.14, Jan.1966*).
  - Coupling is very sensitive to the dimensions of the central λ/4 section geometry, the most critical parameter is the separation between sustrates.
  - First and third λ/4 sections are equal. They reduce the ripple of the coupling and influence on input reflection.



  - Carefull design of transitions between sections improves the input reflection.
  - Simulation tool: Momentum 2.5D tool from Agilent EESOF ADS software.

FABRICATION



One half of the coupler without the mylar film, in the Al chassis, with the sliding pin SMA connectors. Sustrate dimensions: 21.4 x 16 x 1,073mm.

- Chassis in Aluminium alloy.
- Substrates: RT/duroid ® 6002.
  - Thermal expansion coefficient matching Aluminum.
  - ε_r = 2.94. Thickness: 20mills. 17 µm of copper in one side only.
  - Machined with LPKF Proto Laser 200 (it engraves and cuts the sustrate in the same operation making the aligment between top and bottom sustrates very accurate).
- Dielectric separation layer: Mylar film (thickness 23µm).
  - ε_r similar to Duroid.
  - High rigidity and good thermal stability.
- Input/output connector: Sliding pin SMA.
  - Pin shifts absorbing mechanical contractions due to thermal cycling.
- Experimental optimization of the transition connector – line to allow good input matching.

Inmaculada Malo Gómez.
Juan Daniel Gallego Puyol, *IEEE, Member*.
Carmen Diez González.
Carlos Cortés.
César Briso Rodríguez.

CAY

Centro Astronómico de Yebes.
Observatorio Astronómico Nacional.
Apto. correos, 148. 19080 Guadalajara. Spain.

e-mail: **i.malo@oan.es**

EUIT Telecomunicación.
Departamento IAC
UPM. A-3, km 7. 28031 Madrid. Spain.

IMPROVED MULTI-OCTAVE **3dB HYBRID** FOR RADIO ASTRONOMY **CRYOGENIC** RECEIVERS

CAY

Inmaculada Malo Gómez
Juan Daniel Gallego Puyol
Carmen Diez González
Carlos Cortés
César Briso Rodríguez

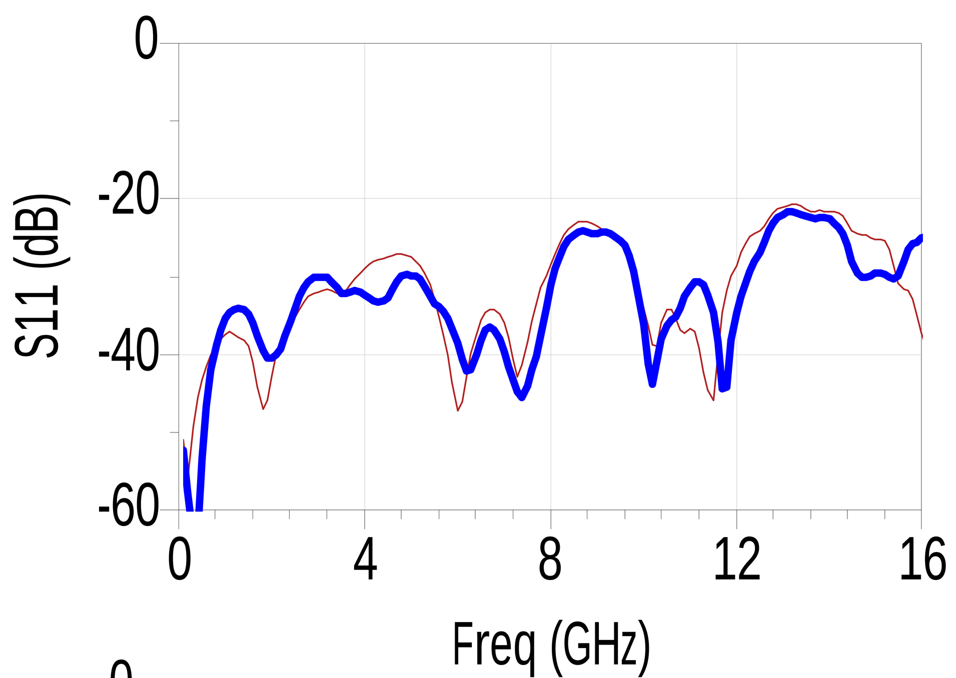
Centro Astronómico de Yebes. Observatorio Astronómico Nacional. Apto. correos, 148. 19080 Guadalajara. Spain.

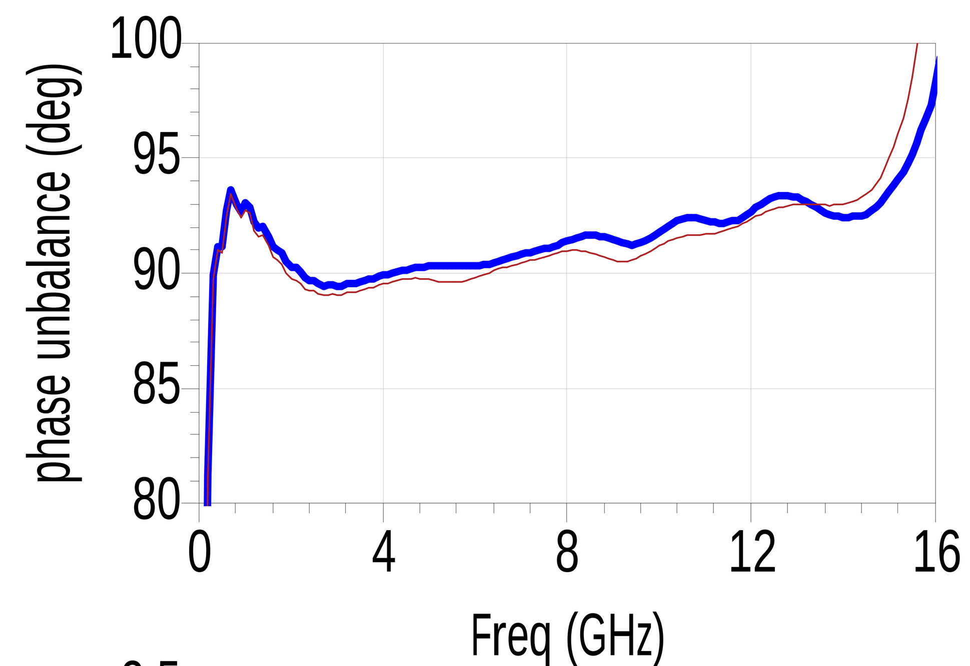
e-mail: **i.malo@oan.es**

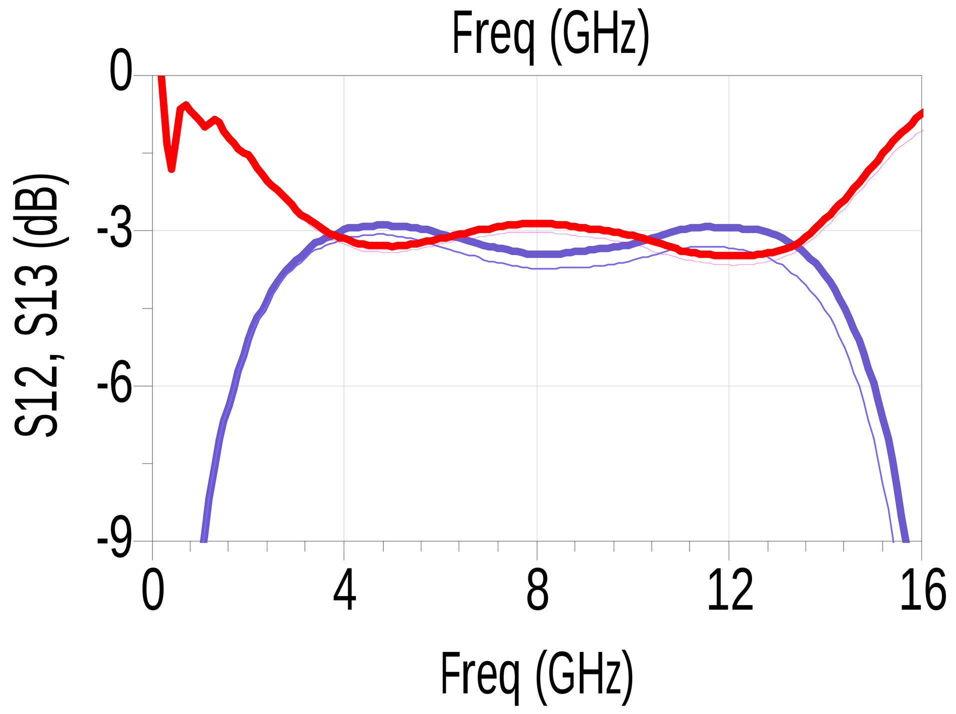
EUIT Telecomunicación. UPM. A-3, km 7. 28031 Madrid. Spain

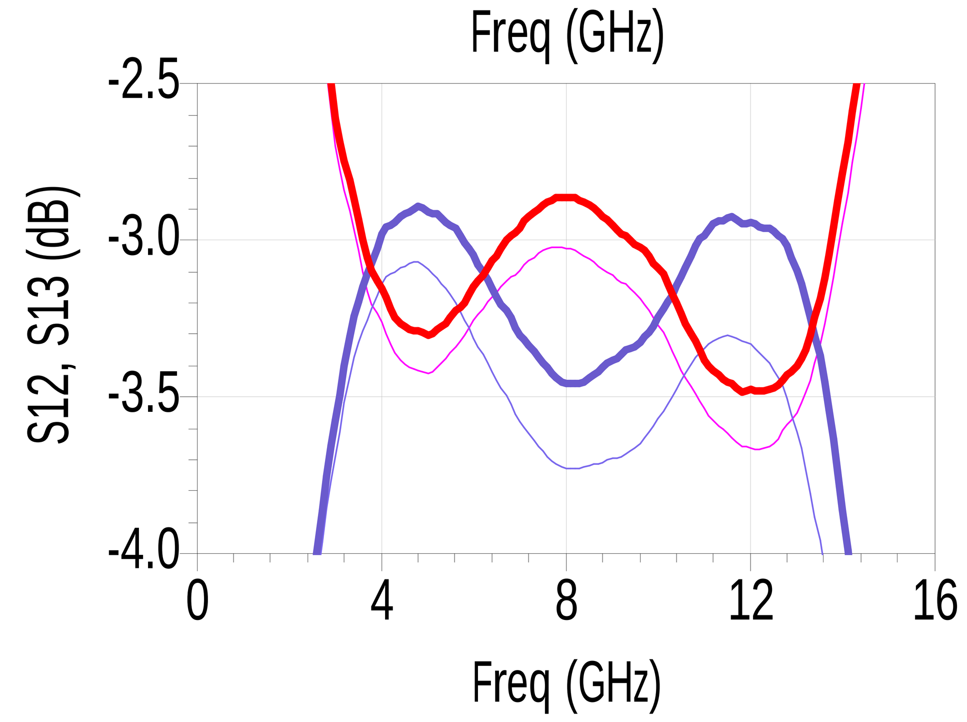
MEASUREMENTS

Good cryo performance, similar to room temperature







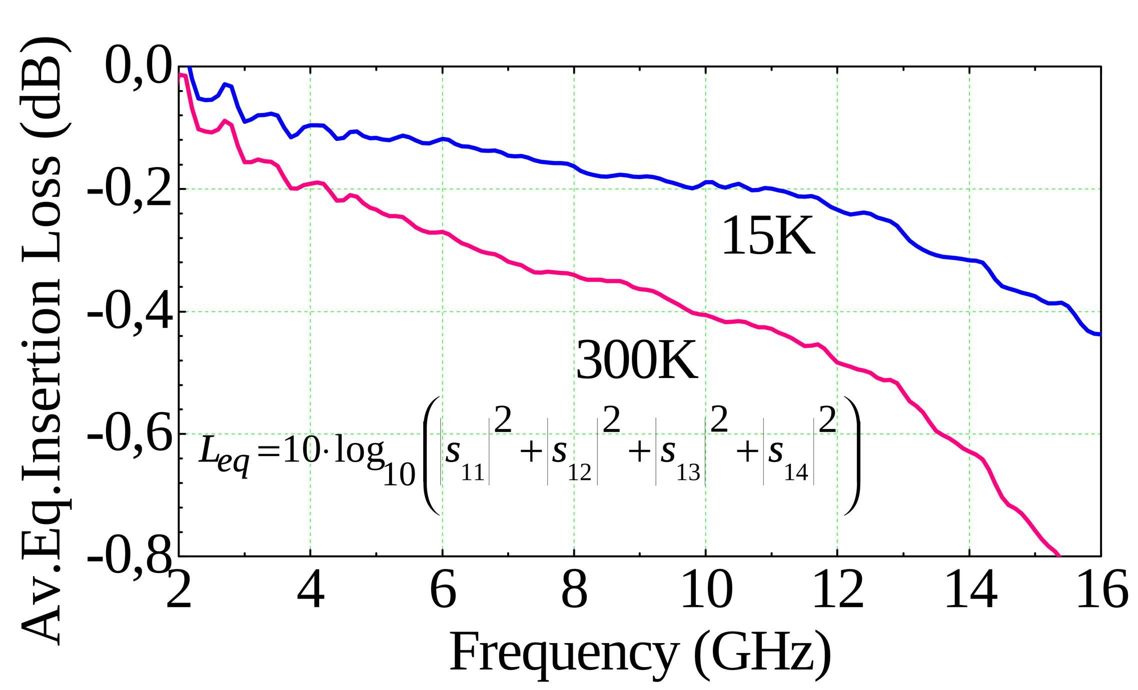


Measurements of the hybrid at 15 K (thick lines) and 300 K (thin lines). Note the almost invariant behavior with temperature due to the careful selection of materials and technologies.

CAY 3dB hybrid in the test dewar

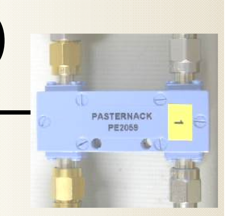
Very low Insertion loss

Average equivalent insertion loss 0.2 dB @ 15 K calculated from measured S parameters



Comparison with best commercial unit

Measurements @ 15 K, 4-12 GHz	CAY (3 units)	Pasternack (best)
Return loss [dB]	**< -22**	< -19
Amplitude unbalance [dB]	**± 0.3**	± 0.9
Phase unbalance [º]	**± 2**	± 3



CONCLUSIONS

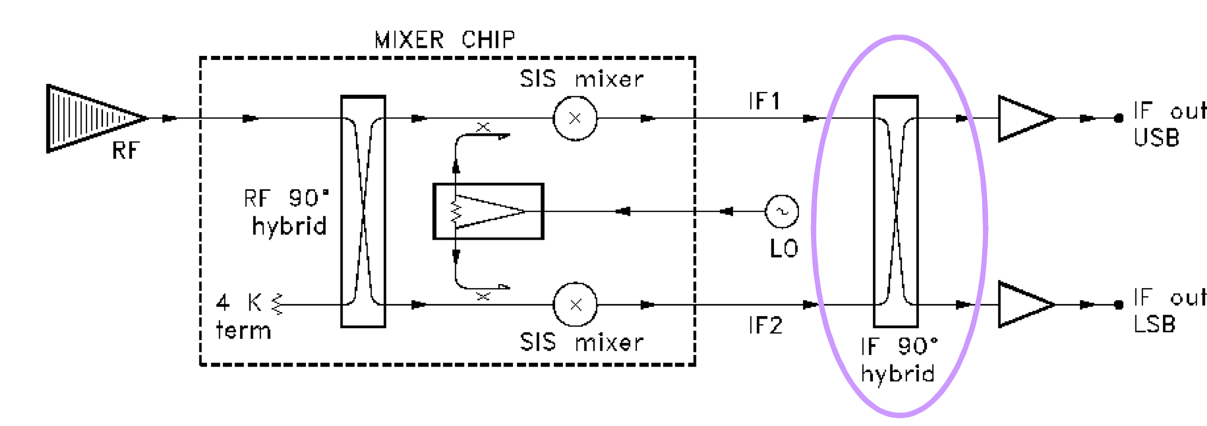
Radio astronomy receivers require the use of devices that can operate at cryogenic temperatures to obtain extremely high sensitivity.

We have completed the design, manufacture and measurement of a 3 dB 90º hybrid for the 4-12 GHz band specially conceived to survive and fulfill accurate specifications when cooled to 15 K. Coupling and reflection show very little temperature dependence. The result is a very compact, low loss, reliable, repetitive and low thermal mass device, able to survive extreme thermal cycling.

The utility of the hybrid developed is demonstrated in a cryogenic balanced amplifier where the noise temperature obtained (6 K) shows clear advantage (about 33%) over the classical isolator-amplifier combination normally used in radio astronomy receivers. Besides, a superior insensitivity of the noise to the input termination mismatch is obtained.

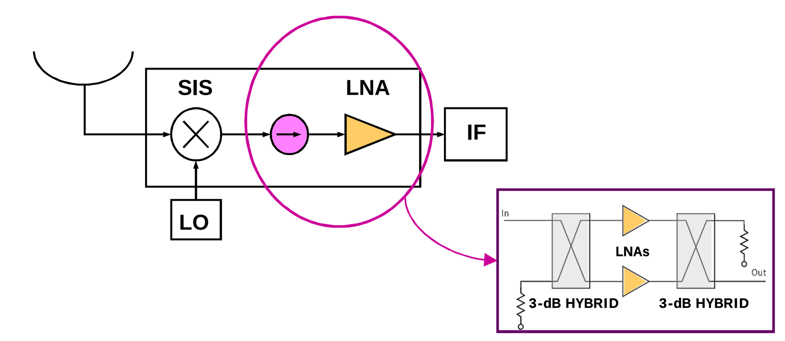
Radio astronomy APPLICATIONS

"Side band separating receivers (2SB)"



IF balanced amplifier in "millimeter and submilimeter coherent heterodyne receivers (SIS)"

A way to improve the poor input Mismatch of the IF LNAs, replacing traditional amplifier with input isolator configuration.



Advantage of 2.8 K (33%) in noise.