Omnisys

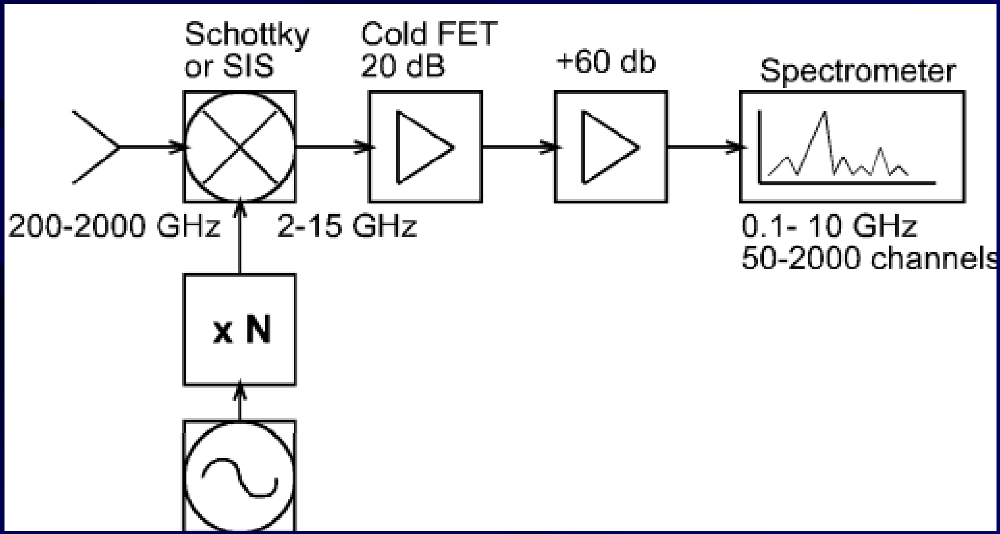
Dr. Anders Emrich: ae@omnisys.se / www.omnisys.se

- 12 employees, 11 engineers from B. Sc. to Ph. D.
- Designed and delivered a large part of the ODIN radiometer system
  - 119 GHz and four receivers between 450-600 GHz
  - hybrid spectrometers
  - front-end and IF control, LO generation....
- Are involved with SMILES, TELIS and other projects
- Designed and delivered the power system to SMART-1, ESA mission
- Focus on design and development of new systems to solve new demands
- Developing a 300-360 GHz heterodyne radiometer with 4 GHz, 4000 channels resolution.
  - less than 2 kg, less than 15 W, tunable without moving parts
- Have developed 4-5 generations of correlator ASIC's and spectrometers.

OMNISYS INSTRUMENTS

Spectrometers

- In its most general form, a spectrometer can be considered to be a device that receives an input signal, which is variable in time, and estimates its power spectral density.

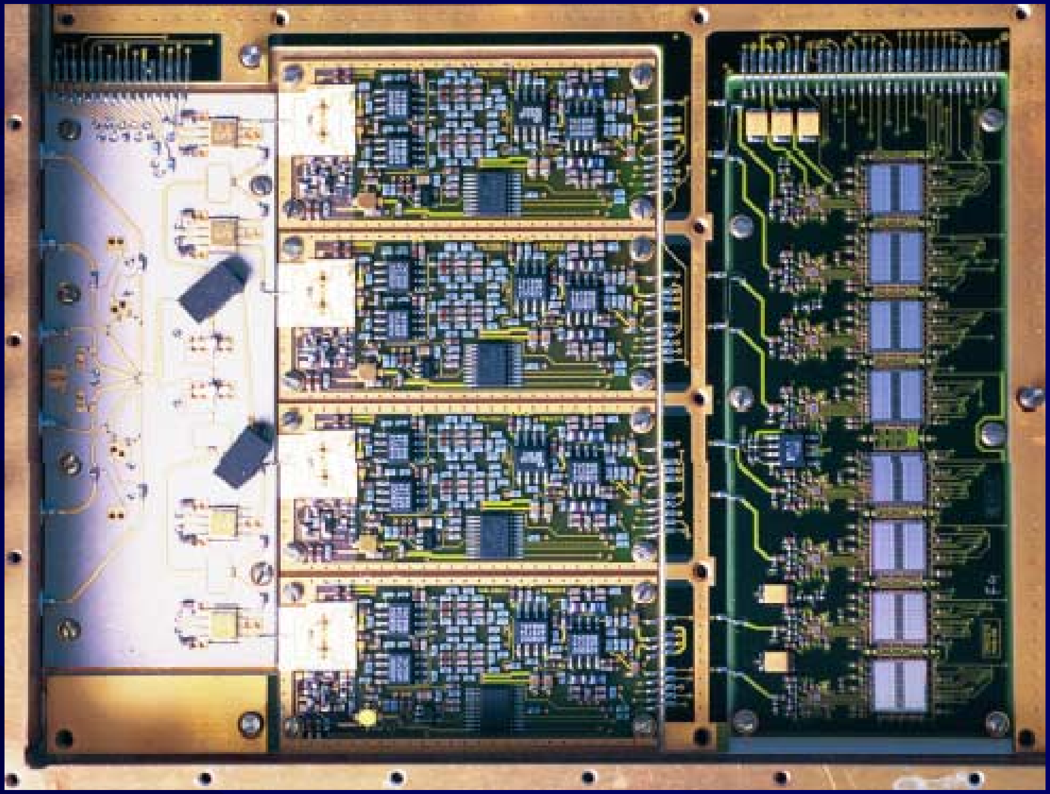


OMNISYS INSTRUMENTS

ODIN (1997)

- BW: 100-800 MHz
  in steps with
- resolution: 0.13-1.1 MHz
- mass: 1050 grams
- size (mm): 220x180x30
- power: 18 W

- 2 spectrometers in orbit since feb 2001
- two full custom ASIC’s
- providing aeronomy as well as astronomy spectra

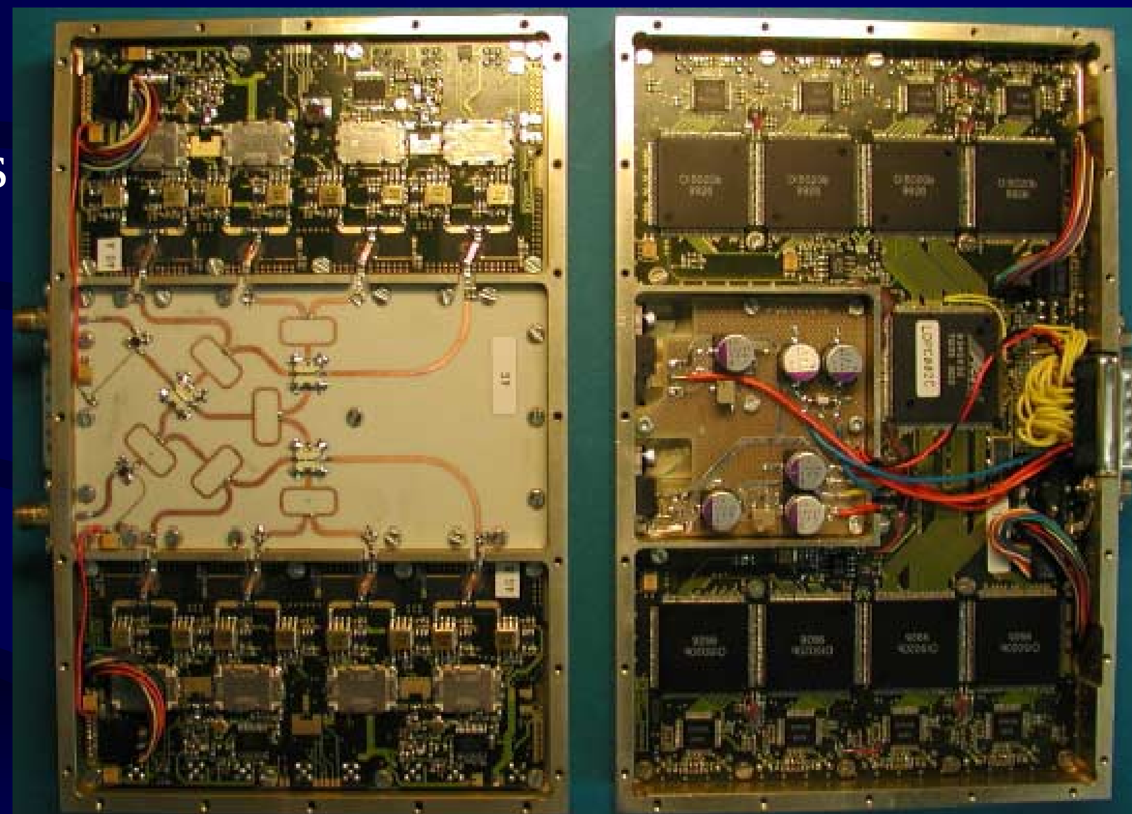


OMNISYS INSTRUMENTS

Telis (1999)

- 2x 2 GHz
- 2 x 1024 channels
- 20 W
- 950 grams

- two full custom ASIC’s
- 2 spectrometers will fly on TELIS (balloon)

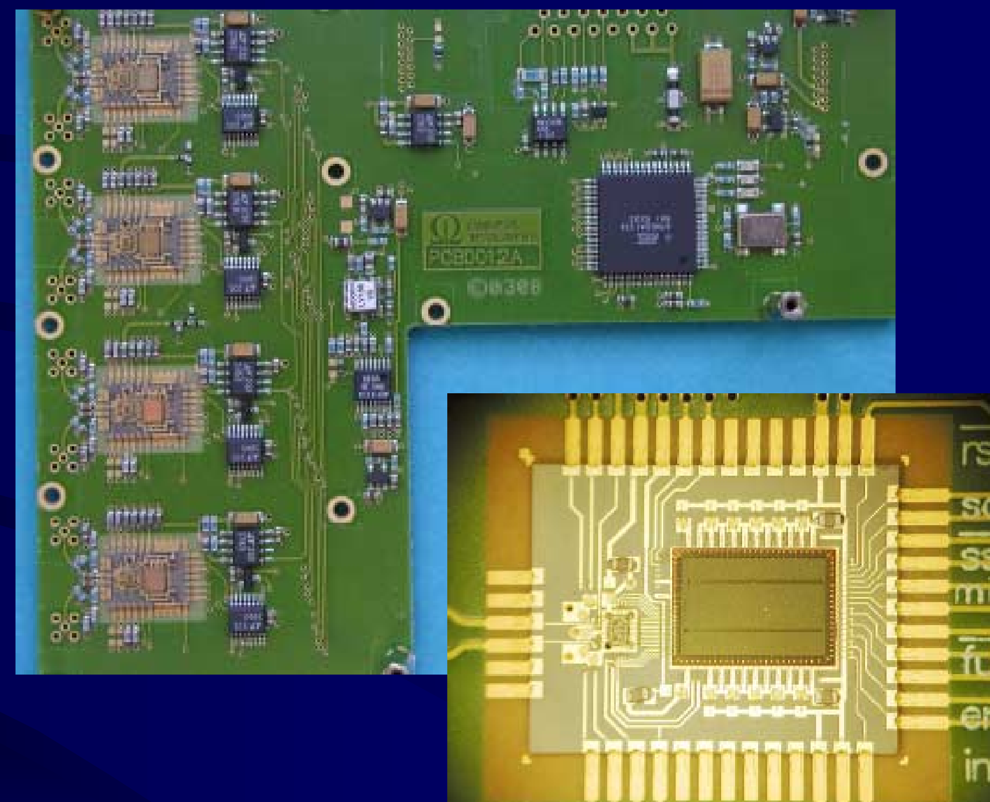


OMNISYS INSTRUMENTS

Current

- 12 GHz bandwidth
- 1024 channels
- 110x170x30 mm
- 800 grams
- 8 Watt

- two full custom ASIC's
- Future flights???
- More chips needed



OMNISYS INSTRUMENTS

Chip and spectrometers

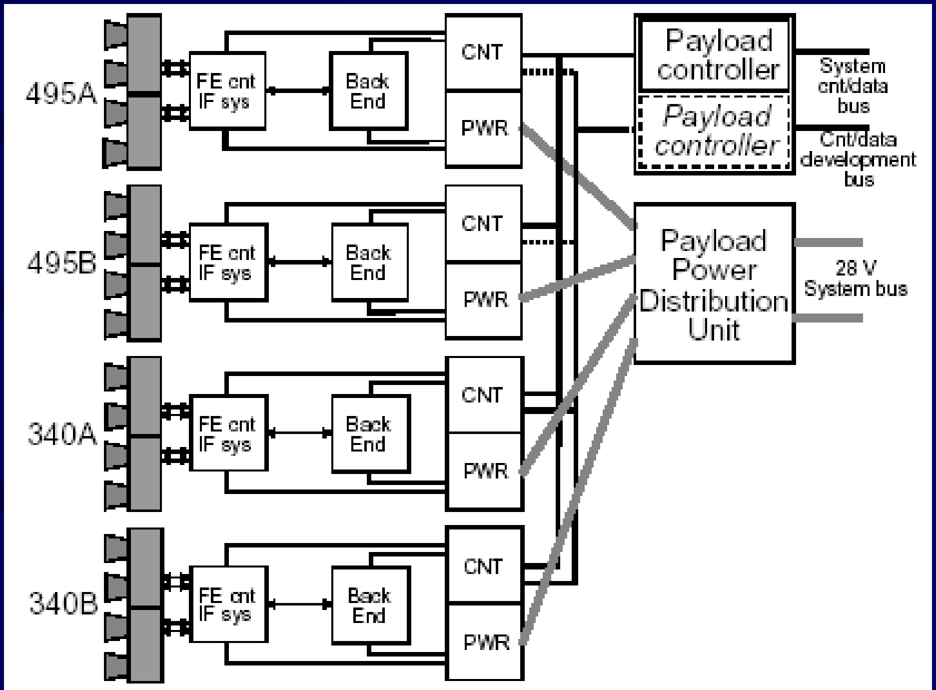
	mW	#	GHz	mW/#/GHz	pwr	
Bos	1000	16	**0.02**	**3125.00**	**3657**	*1992 state of the art*
Omnisys-ODIN	400	96	**0.1**	**41.67**	**49**	*2 chips, works in space, 1996*
Omnisys&ESA	1100	256	**0.6**	**7.16**	**8**	*2 chip, 1999*
French HIFI	500	128	**0.2**	**19.53**	**23**	*3 chip, 2001??*
Omnisys&ESA: S	230	128	**2**	**0.90**	**1**	*2 chip, 2002*
Omnisys&ESA: L	1750	1024	**2**	**0.85**	**1**	*2 chip, 2002*
Spaceborne	5500	128	**2**	**21.48**	**25**	*1 chip, 2003*
Omnisys SCS	*1200*	*1024*	***4***	**0.29**	**0.34**	*1 chip, planned*

Instrument level					
Feature	**Omnisys**	**XXX**	**ratio**	**Now**	**Tomorrow**
Chip set	2 types	3 types	cost++	2 types	1 type
Assembly	soldering	multiple MCM's	cost++	small MCM	soldering
Chip set power	25 W	65 W	2.6	6 W	2 W
Instrument power	45 W	235 W	5.2	15 W	8 W
Size	2 liter	10 liter	5	0.7 liter	0.4 liter
Mass	2 kg	14 kg	7	0.7 kg	0.4 kg
Comment	ODIN	no history		WBS as well, +10 W	WBS as well, +2 W

OMNISYS INSTRUMENTS

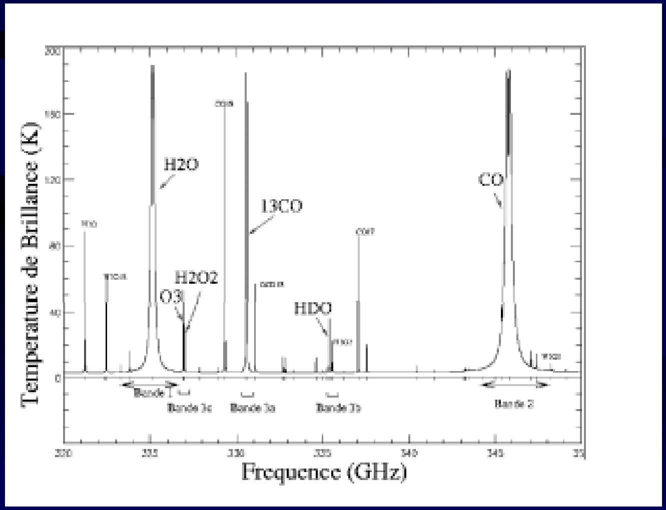
STEAM (Earth Limb sounding)

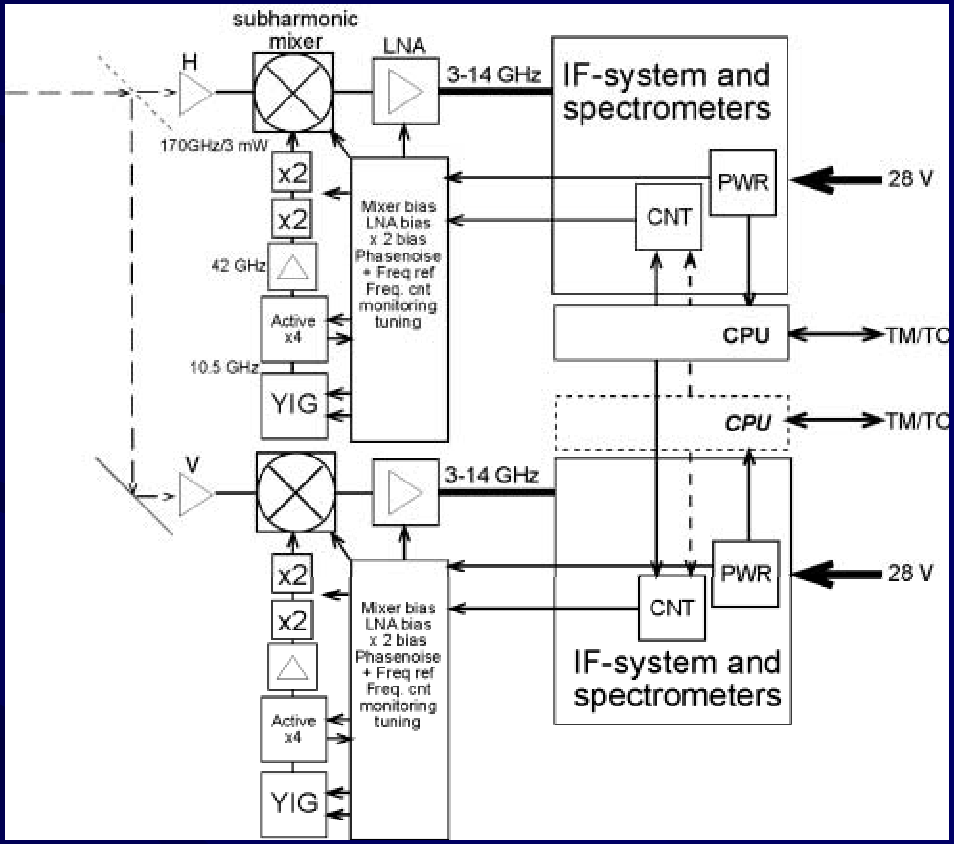
- Multibeam (simplified optics)
- Developed as an integrated instrument
- 8 front-ends at 320-360 GHz, DSB
- 8 front-ends at 490-505 GHz, DSB
- 8x8 GHz + 8x4 GHz = **96 GHz of spectrometers**
- **HIFI/Herschel = 8-10 GHz???**
- operation in ambient temperature (simplified system)
- 2000 K T_{sys} (prel)
- a few kgs, 60-70 W
- on-board, near real-time signal processing (Linux)



Mambo (Mars and Venus)

- CO at 345.796 GHz
- 13CO at 330.588 GHz
- H2O at 325.153 GHz
- HDO at 335.395 GHz
- O3 at 326.901 GHz
- H2O2 at 326.981 GHz





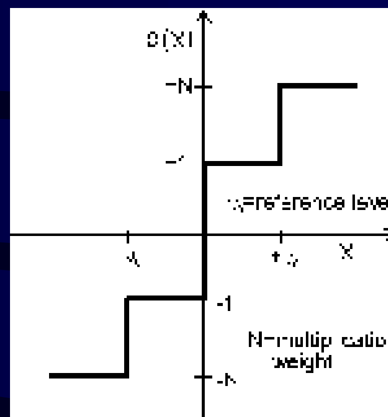
15-20 W, 2-3 kg

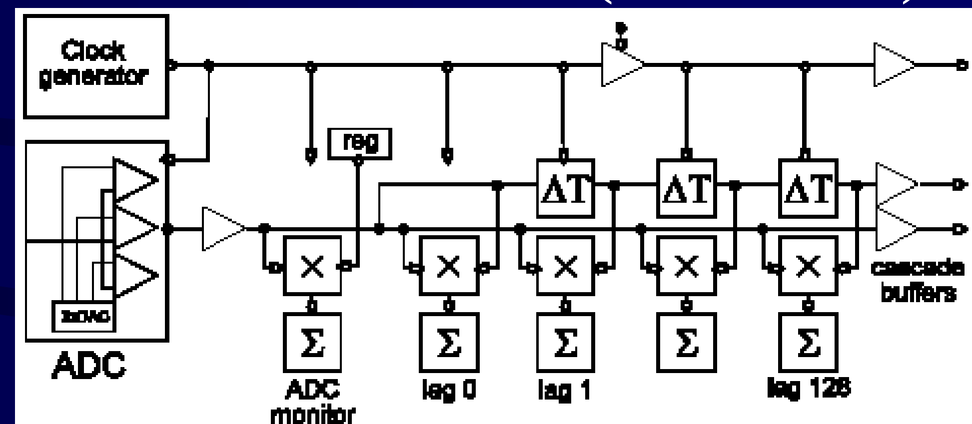
OMNISYS INSTRUMENTS

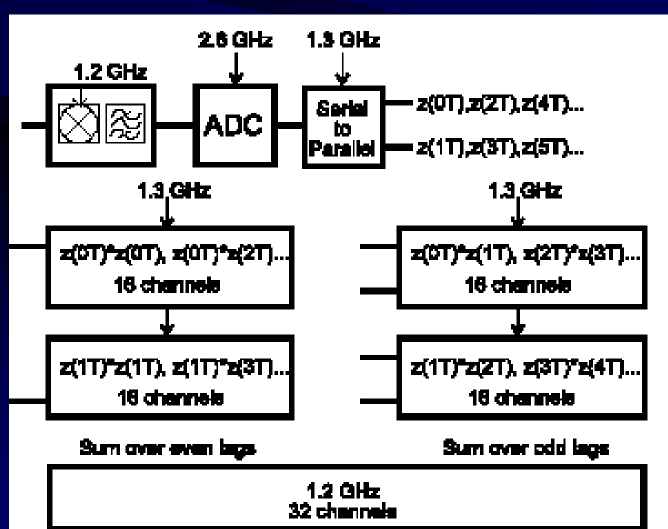
Basics

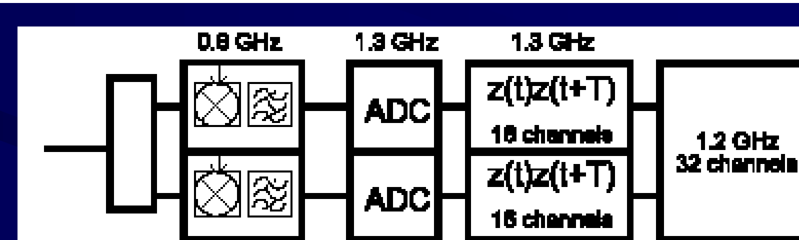
1963 (S. Weinreb)

1969 (many)





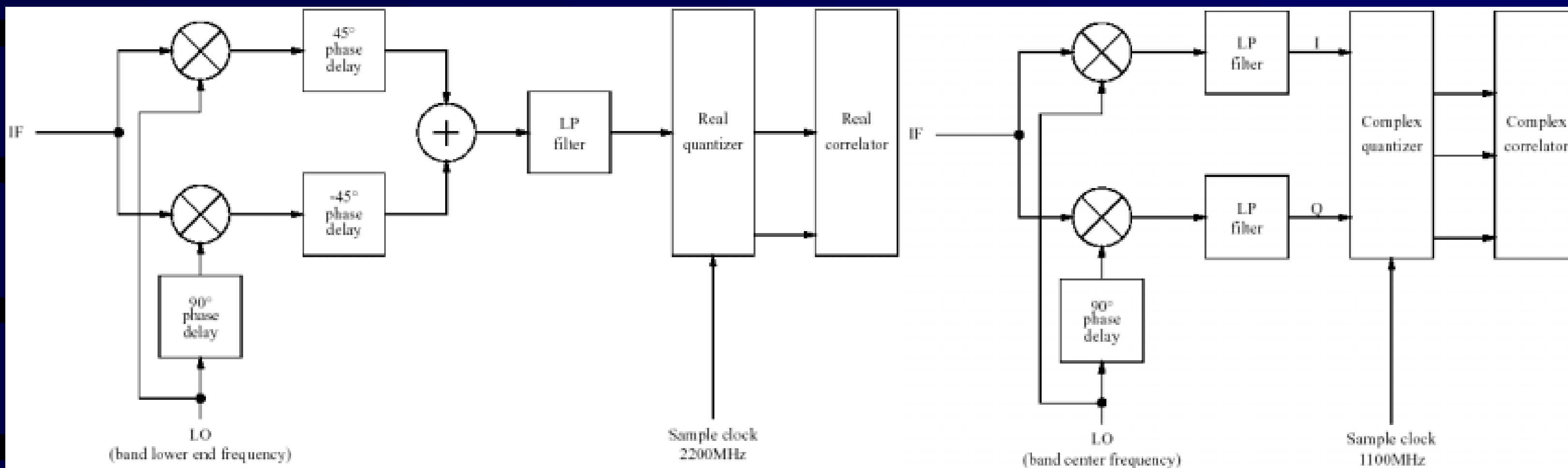




1985 (S. Weinreb)

OMNISYS
INSTRUMENTS

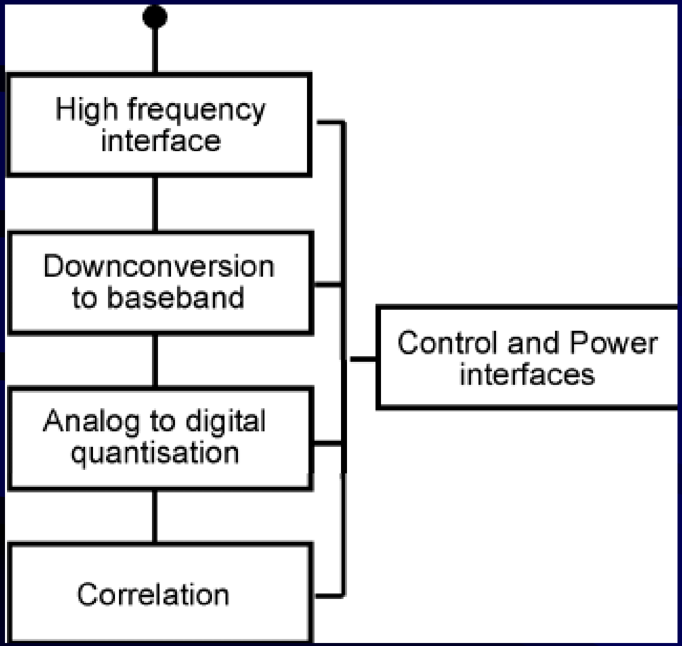
Complex design (1997 Omnisys)

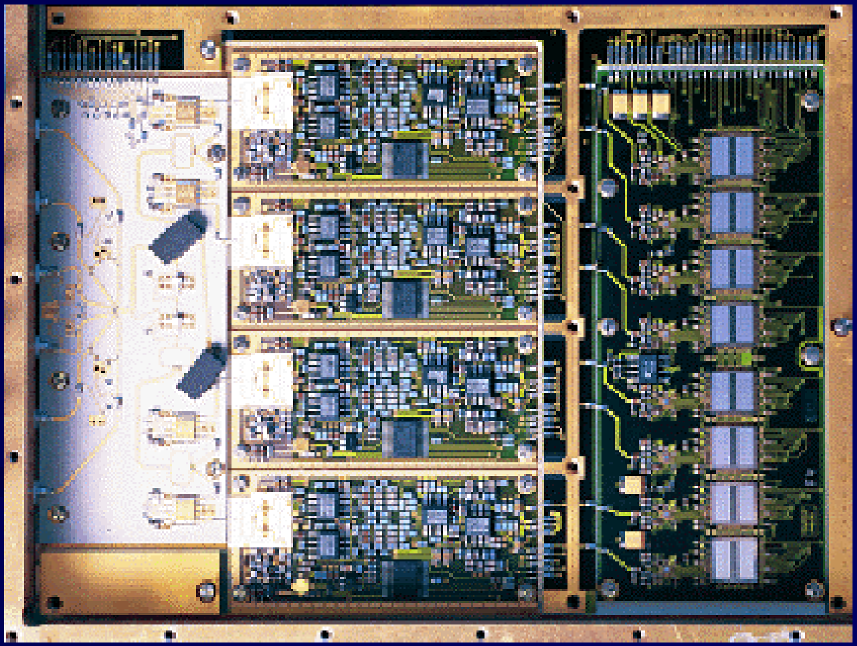


- The complex sampler does not require high quality single-sideband filtering
- This can significantly reduce the design effort when building a spectrometer.
- The complex sampling frequency is half the sampling frequency used by a real quantizer. The effective sampling frequency will remain the same, since twice as much data is produced per sample.

OMNISYS INSTRUMENTS

Spectrometers





- all parts must be realised in a spectrometer
- this project has focused on 40-50 % of a spectrometer

OMNISYS INSTRUMENTS

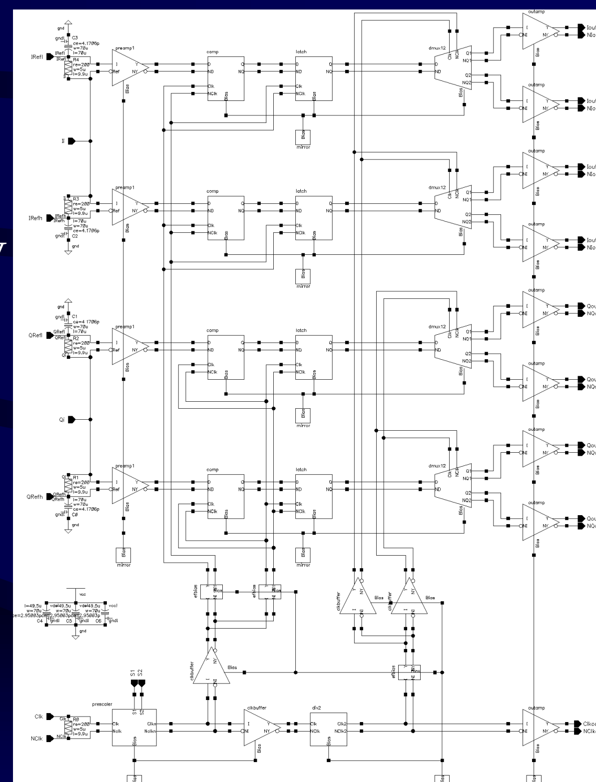
Complex digitizer

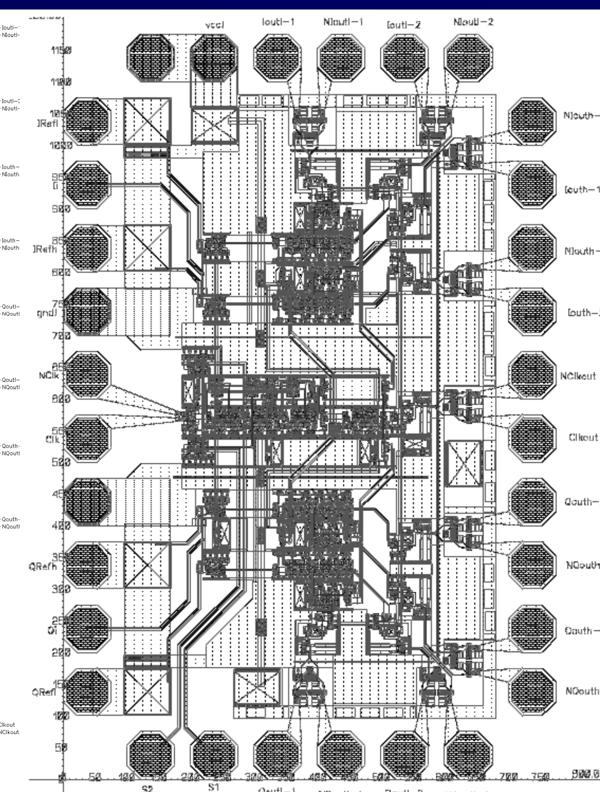
- Speed is the most important design goal
  - clock speed result = 4 GHz (spec = 2.2 GHz)
- High speed analog inputs
  - result = 2 GHz (spec = 750 MHz, 4 GHz bandwidth)
- Analog reference inputs
- High speed digital outputs
- Pinout to ease PCB layout and improve signal integrity

OMNISYS INSTRUMENTS

Digitizer

• Min supply	2.2 V
• Current	75 mA
• rise/fall time	200 ps
• Output swing	>350 mV
• Input	2 GHz
• Clock	4 GHz
• Sensitivity	100 µV
• **780 x 1200 µm**	



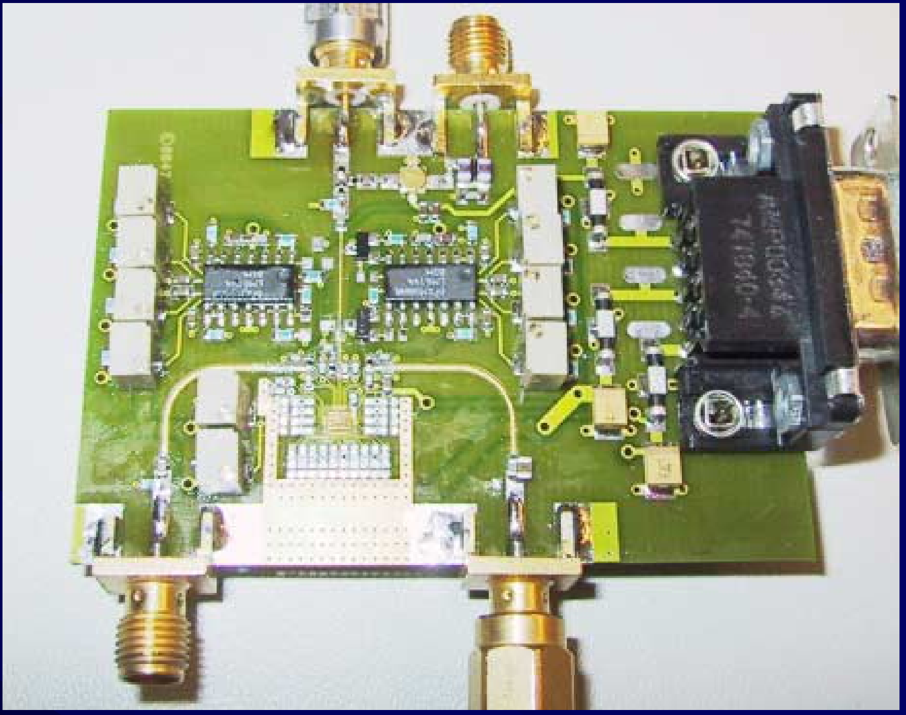


OMNISYS INSTRUMENTS

Digitizer tests

- Rail: 2.2-2.7 V
- Consumption: 75 mA
- rise/fall time: 200 ps
- Output swing: >350 mV
- Bandwidth: > 4 GHz
- Sensitivity 100 µV

- better sensitivity??



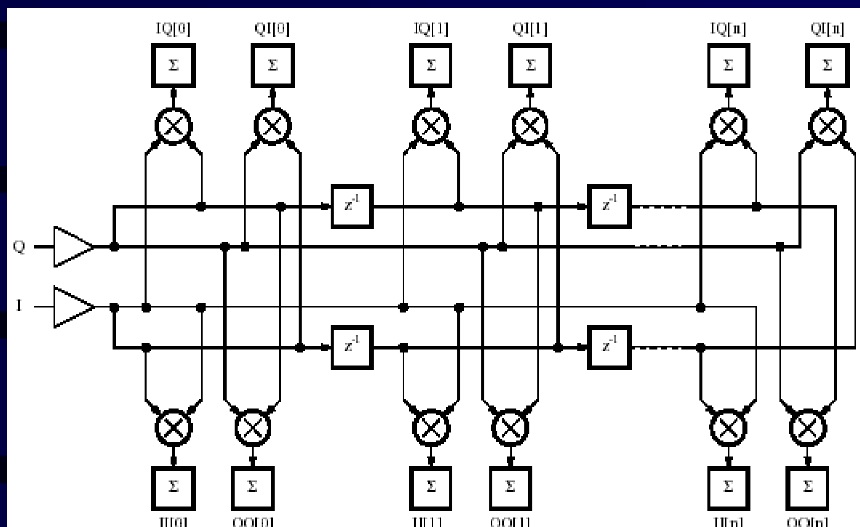
OMNISYS INSTRUMENTS

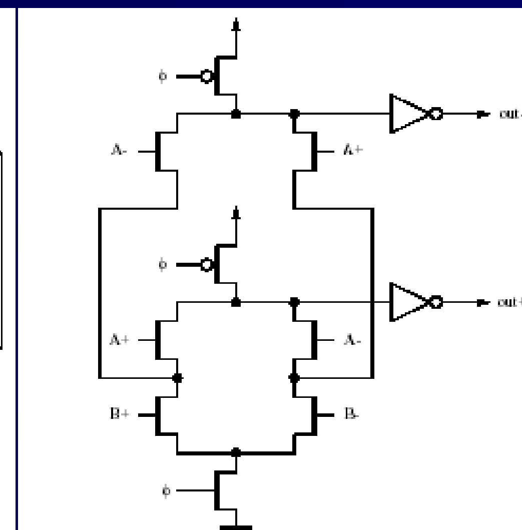
Correlator chip

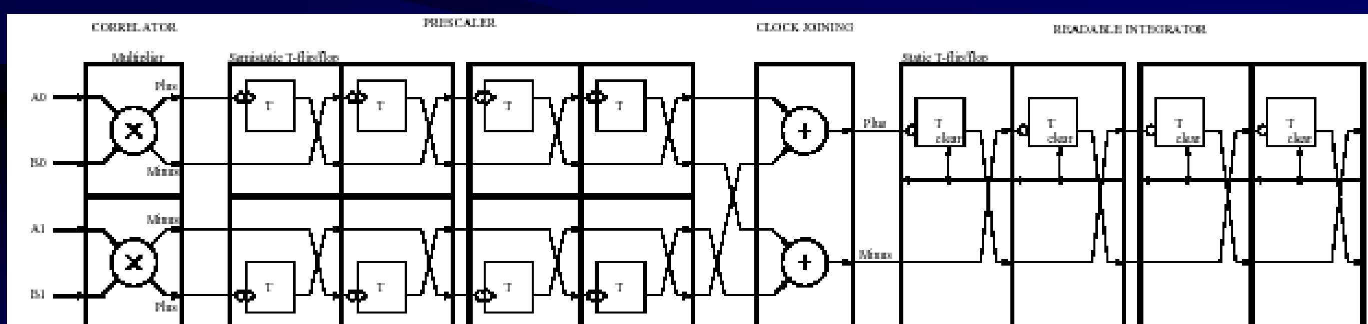
- Speed is the most important design goal
- Low power consumption is essential
- Differential high speed inputs
- Integrator length
  - around 1 sec integration time
- Data readout scheme
  - support electronics complexity
- Pinout to ease PCB layout

OMNISYS INSTRUMENTS

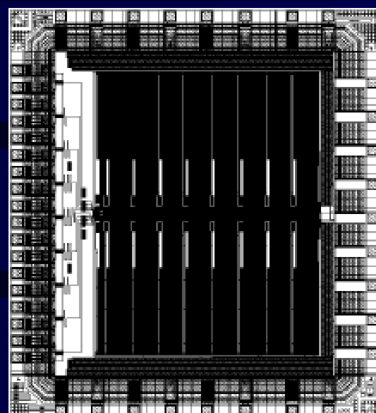
Correlator

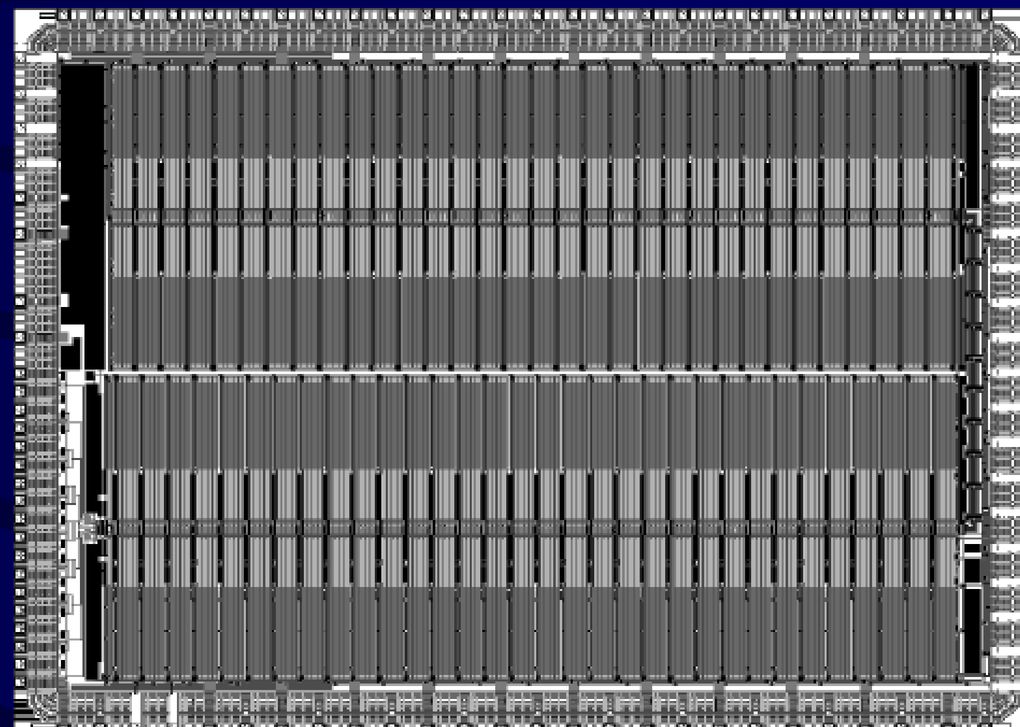

IQ[0]
QI[0]
IQ[1]
QI[1]
IQ[n]
QI[n]
Q
I
II[0]
QQ[0]
II[1]
QQ[1]
II[n]
QQ[n]


φ
A-
A+
out-
out+
B+
B-


CORRELATOR
PRESCALER
CLOCK JOINING
READABLE INTEGRATOR
A0
B0
A1
B1
Plus
Minus
T
clear

Correlator layout





- *spec: 1mW/GHz*
- **result: 0.5mW/GHz**
- *spec: 550MHz*
- **result:1000 MHz**

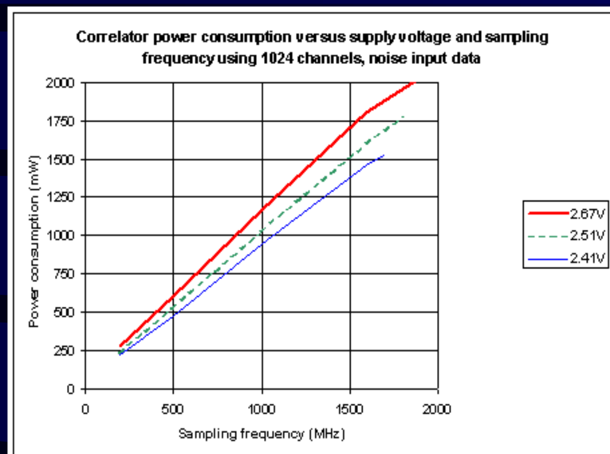
OMNISYS
INSTRUMENTS

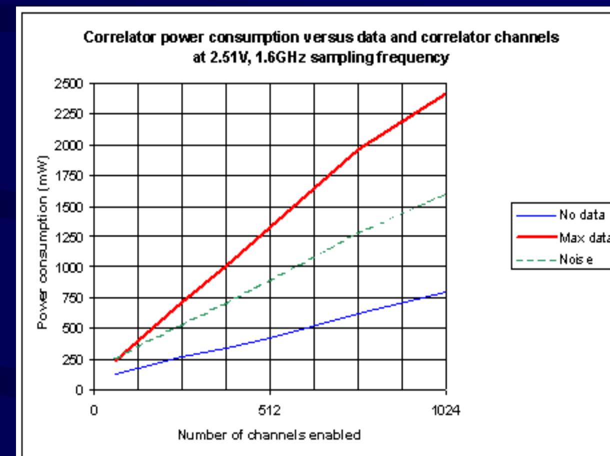
Correlator chip tests

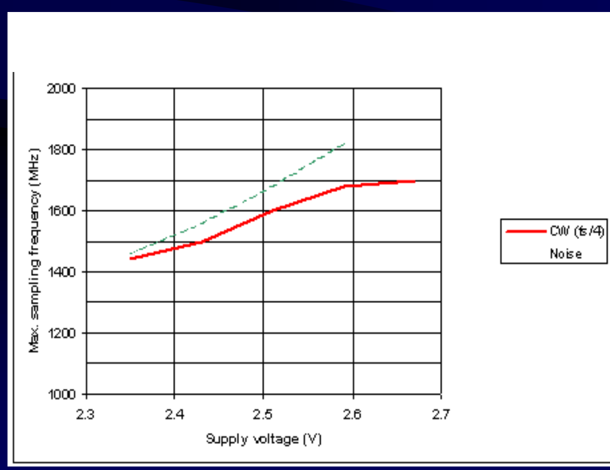
Parameter	Specification	Simulation/design result	Measured
Power consumption per channel and effective sampling frequency	*1mW/GHz*	*~0.5mW/GHz @ 1.1GHz complex sampling clock, 2.5V*	*0.51mW/GHz @ 1.1GHz complex sampling clock, 2.51V*
Clock frequency	*550MHz min.*	*~1GHz*	*>~800MHz*
Area, correlator core	-	*25.8mm²*	-
Area, with pads	-	*35mm²*	-
Number of channels	*1024*	*64, 128, 256, 384, 512, 768 or 1024*	*64, 128, 256, 384, 512, 768 or 1024*

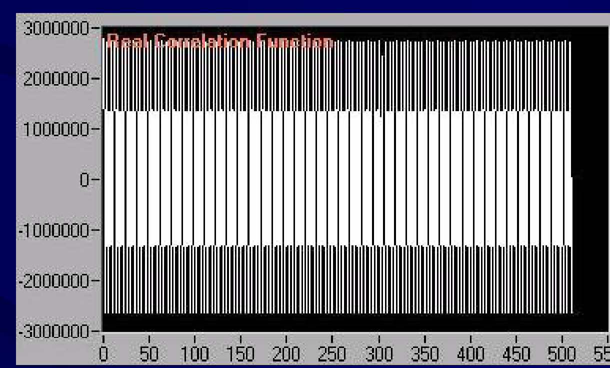
OMNISYS INSTRUMENTS

Some results

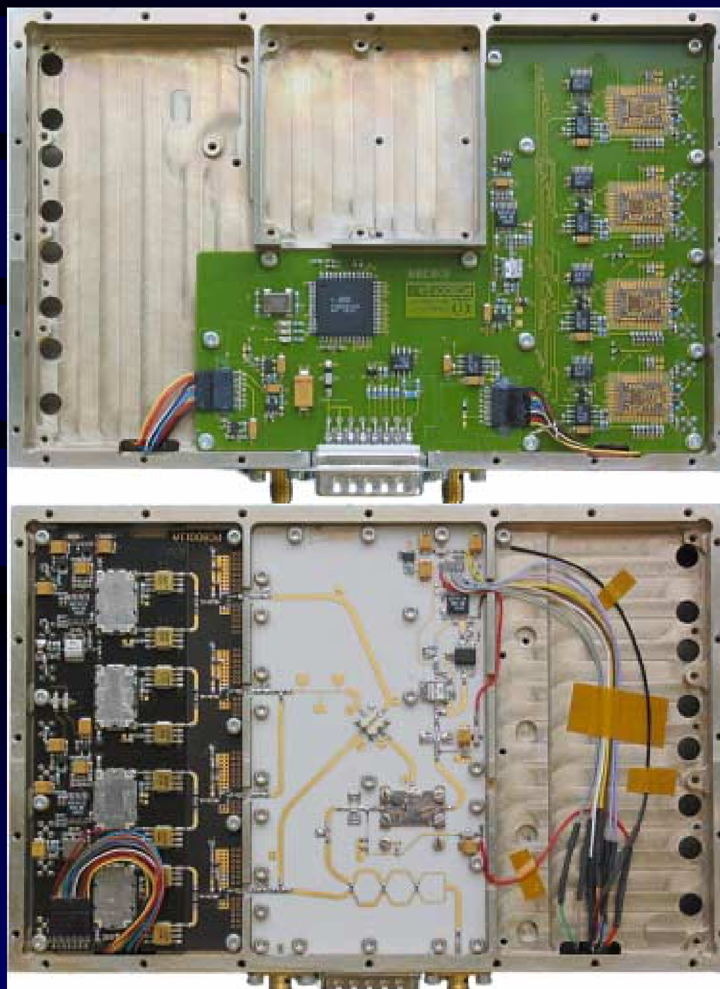


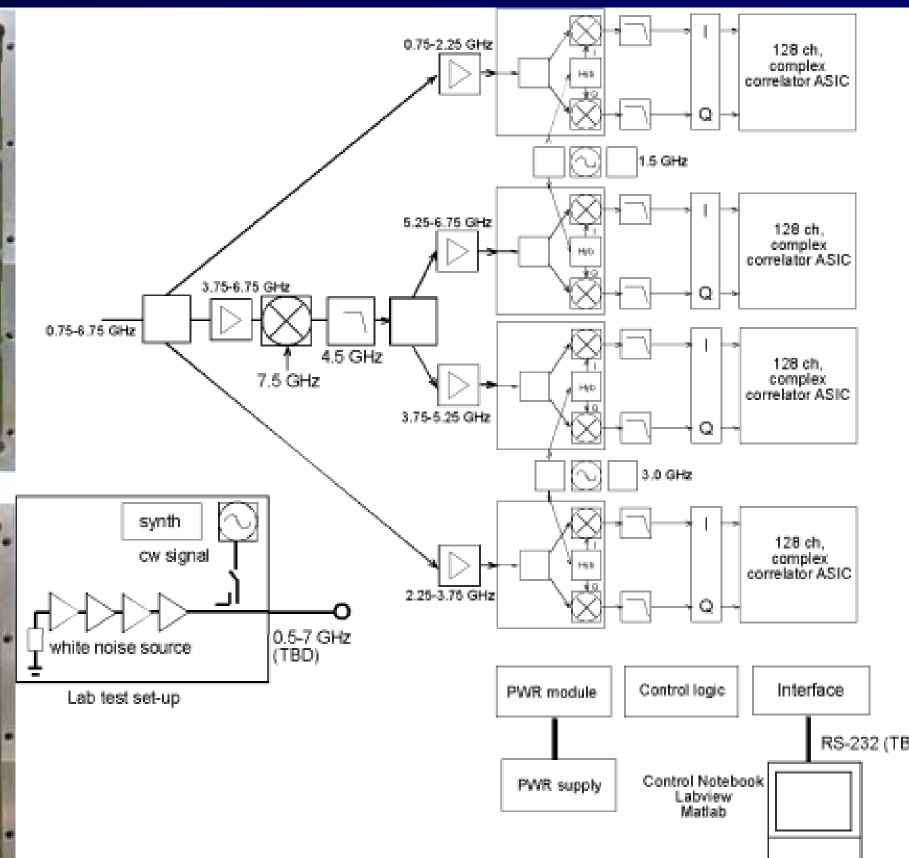






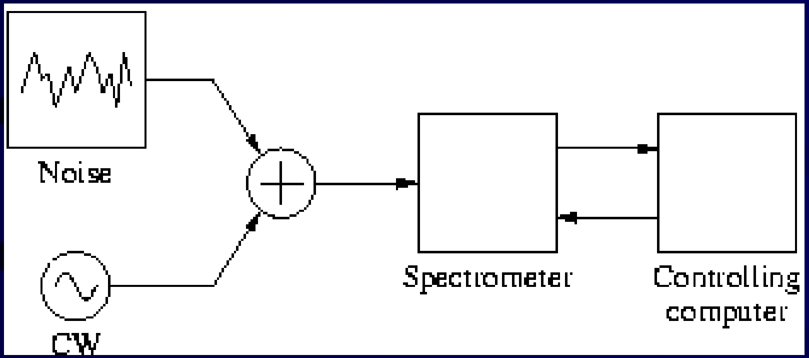
Demonstrator

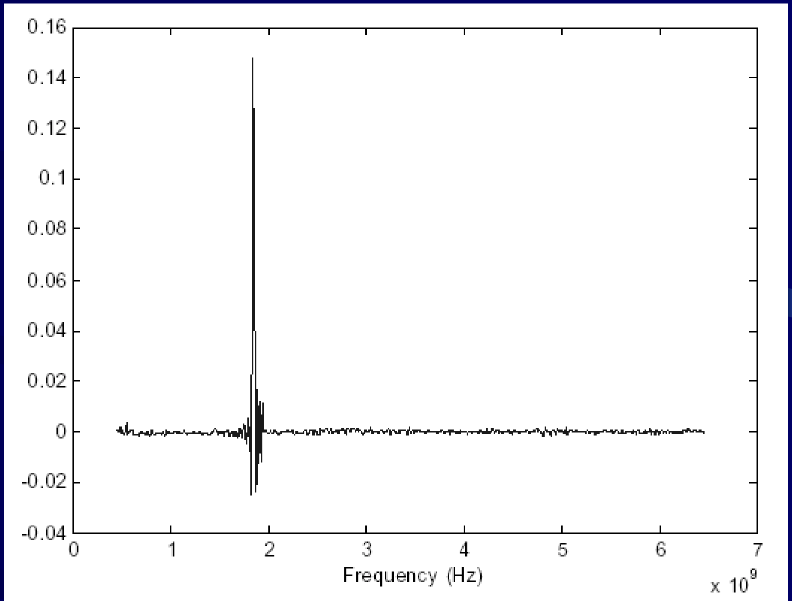




OMNISYS INSTRUMENTS

Lab tests

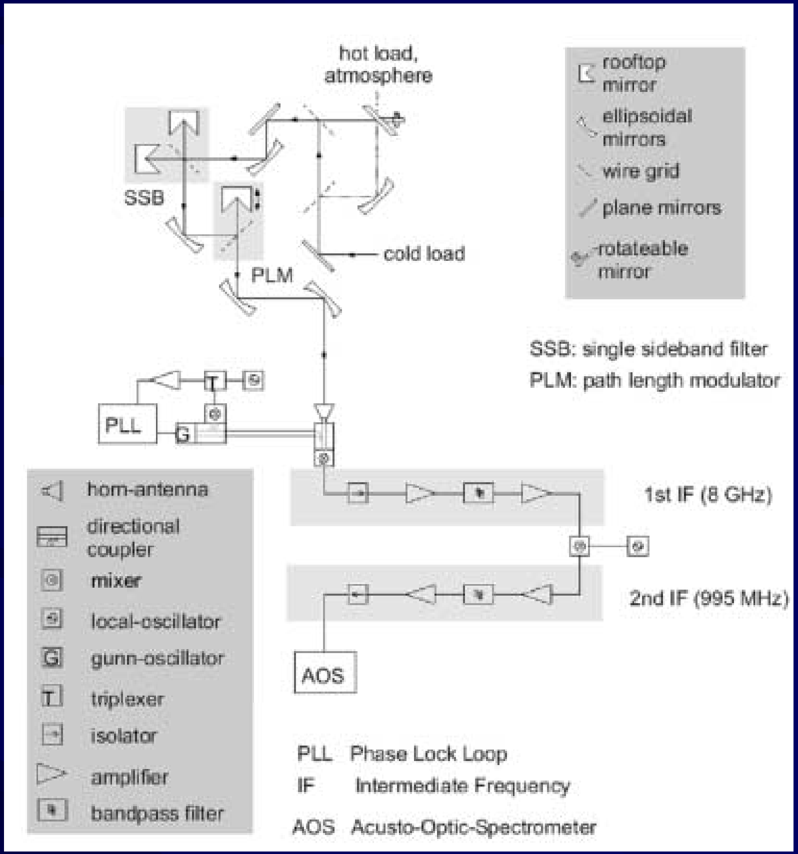




mass:	0.74kg
supply :	+5V
power :	6.2W
bandwidth:	6 GHz
resolution:	13MHz/channel

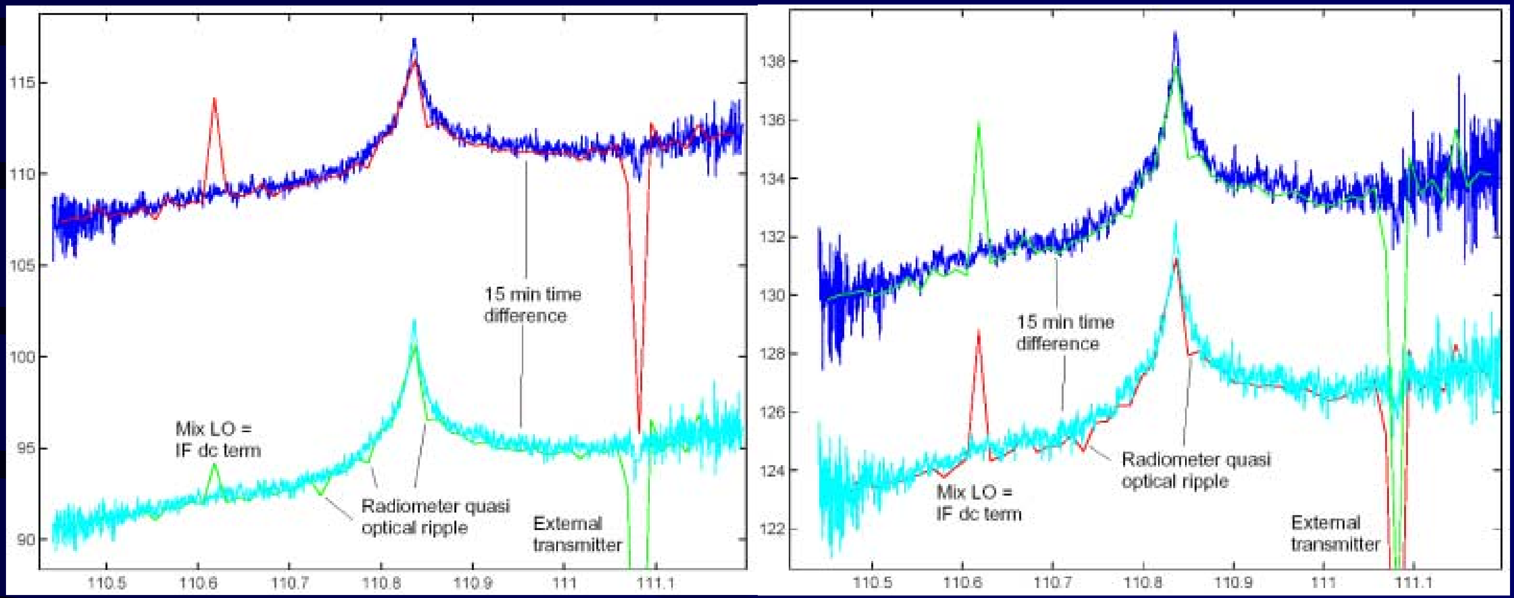
OMNISYS INSTRUMENTS

Instrument tests



OMNISYS INSTRUMENTS

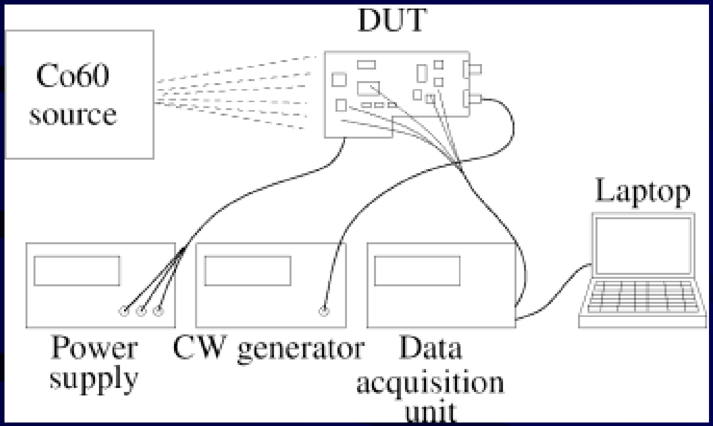
Results

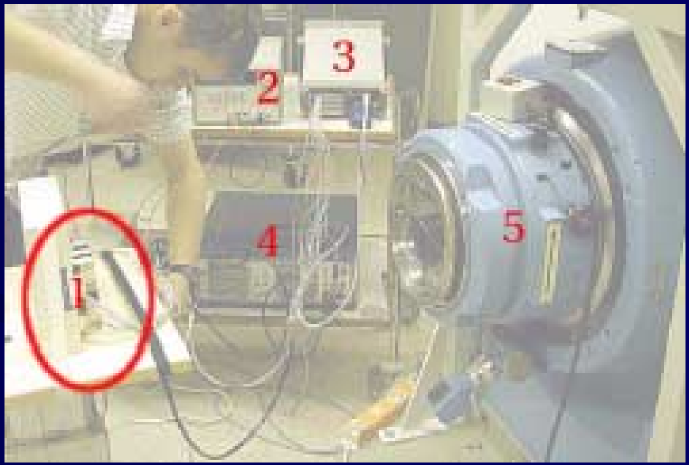


– Good agreement in offset, amplitude and shape
– deviations in parts of the spectra, causes investigated and explained
– AOS integrated into the system, tested and debugged for several years
– ACS integrated into the system in 4 hours, no debugging

OMNISYS INSTRUMENTS

Radiation tests

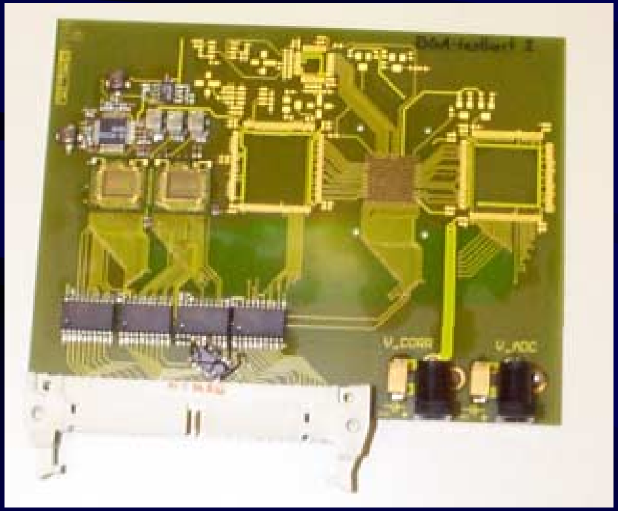


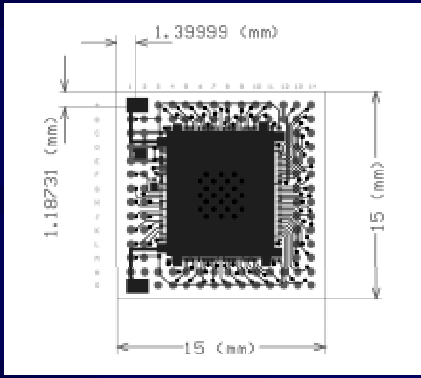


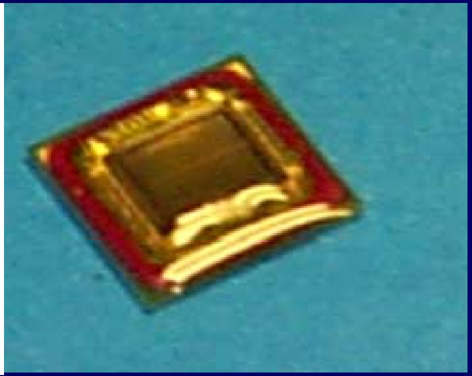
- Tested to 31 kRAD total dose
- No measured change in function, nor performance
- No change in power consumption
- Should comply with most planned space mission reuirements

OMNISYS INSTRUMENTS

CSP







- **Chip** **Raw clock** **Supply**
- Naked chip 0 1100 MHz 3.3 V
- CSP chip 0 920 MHz 3.3 V
- Naked chip 0 1200 MHz 3.75 V
- CSP chip 0 1310 MHz 3.75 V
- Naked cascade 1200 MHz 3.75 V
- CSP cascade 900 MHz 3.75 V
- CSP cascade 1000 MHz 3.6 V(cooled)
- **cooling the main limitation!!**

OMNISYS INSTRUMENTS

Conclusion

- Now, as a result from the development at Omnisys, a general conclusion is that autocorrelation spectrometers are very competitive with other type of spectrometers for space and ground based (sub)millimeter radiometry.
- The main advantages are
  - compact implementations
  - scalability and versatility in bandwidth and resolution,
  - combined with potentially very high stability.
- In terms of size, the correlator is clearly much more compact than the Chirp or the AOS
  - an optimised CSP being 2-3 times the size of a correlator, while an AOS is at least 10 times larger.
- In terms of power consumption:
  - the CSP is comparable to the ACS for narrow bandwidth,
  - while the AOS consumes 2-4 times more than the ACS for wide bandwidth applications.
  - The CSP can not compete for wide bandwidth applications, while the AOS is not competitive for high resolution use.
- In terms of flexibility in bandwidth and resolution, the CSP and the AOS have very limited capabilities.
- The ACS uses no special technologies and components, such as lasers, CCD's, Bragg Cell's or Chirp filters
  - with concerns regarding availability, radiation tolerance.....
- The only special technology is the full custom design of the chip set
  - a $1000 Billion industry helping in the production line set-up.

OMNISYS INSTRUMENTS

Conclusion

  - The power consumption is 8 times better than previous generation of chip sets, and 23 times better than any other results shown and makes new missions and applications possible
  - A demonstrator has been tested by an independent group
  - An ACS based on the chip set has been baseline in a NASA/SMEX mission
  - Two ground based and one NASA mission proposals will be based on the chip set.
  - For 1 GHz+ bandwidths, there is really no realistic alternative to the ACS within the foreseeable future
- We need a production run of chips to supply the users
  - Omnisys has started a design for 6 GHz bandwidth single chip spectrometer, and has a $100k offer for limited production, i.e. a few houndred chips
  - Omnisys can not handle design as well as production…..
- Broadband spectrometers are needed for many future earth observation missions
  - this improves vertical resolution, among other things
  - improved handling of interference

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