High-performance low power front-end for multi-band satellite navigation systems

ESTEC Contract nr 13982/99/NL/FB

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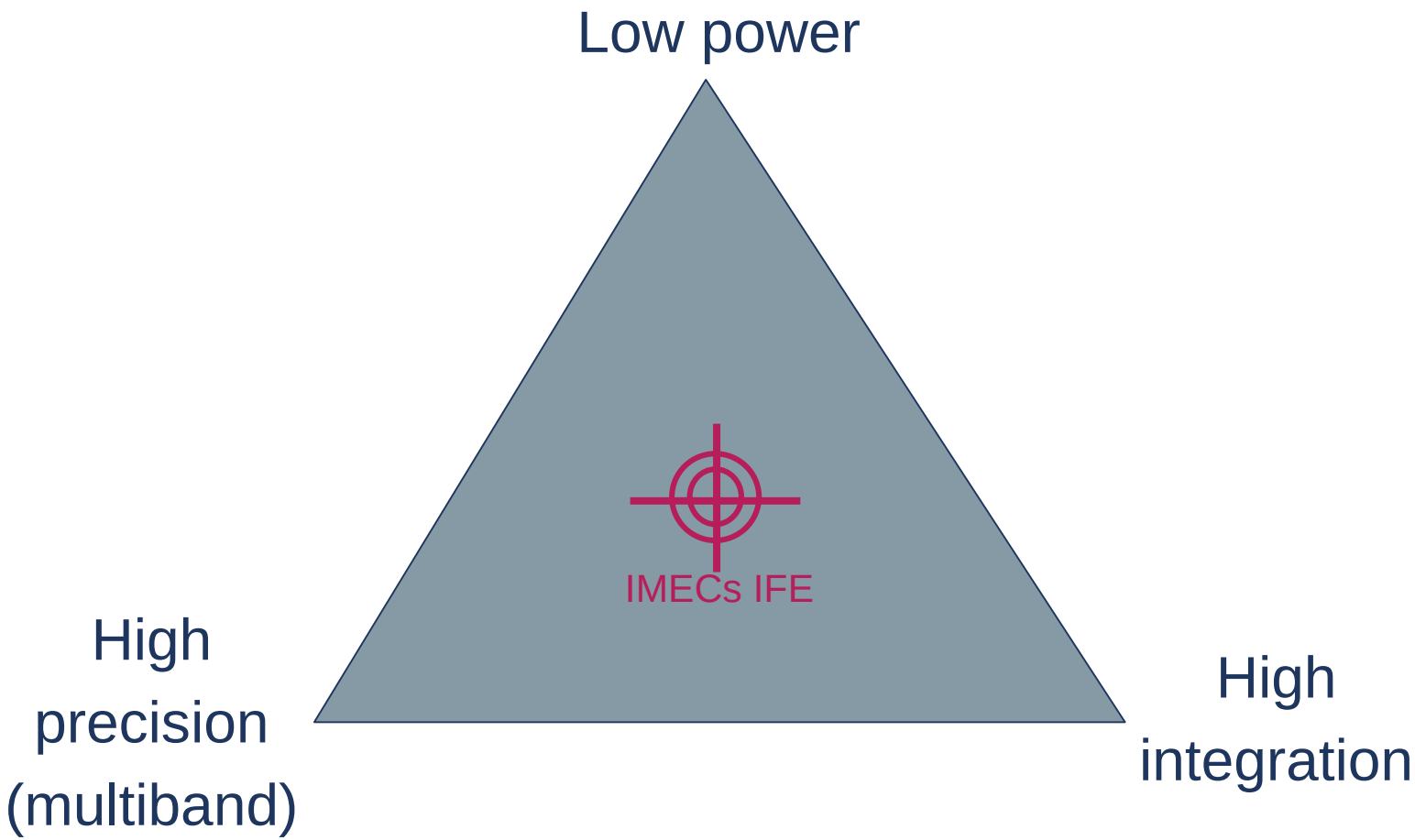
on behalf of IMECs GPS/GLONASS team

SEEDS FOR TOMORROW'S WORLD

Satellite systems face contradictory targets



IMEC focuses on integration, power and performance

- Multi-channel subsampling RF front-end
- Supports 5 signal bands
- Maximum integration using System-in-a-package: no external filters required
- Low power:

  55 mW per channel
- High performance: 5 channels + low noise

  Cascaded NF RF module: 2.2 dB (3.5 dB incl. diplexer)

High-performance low power front-end for multi-band satellite navigation systems

- Coverage of 5 channels
- Integrated Front-End (IFE)
- System integration
- Multi-path mitigation and Semi-codeless
- Conclusions

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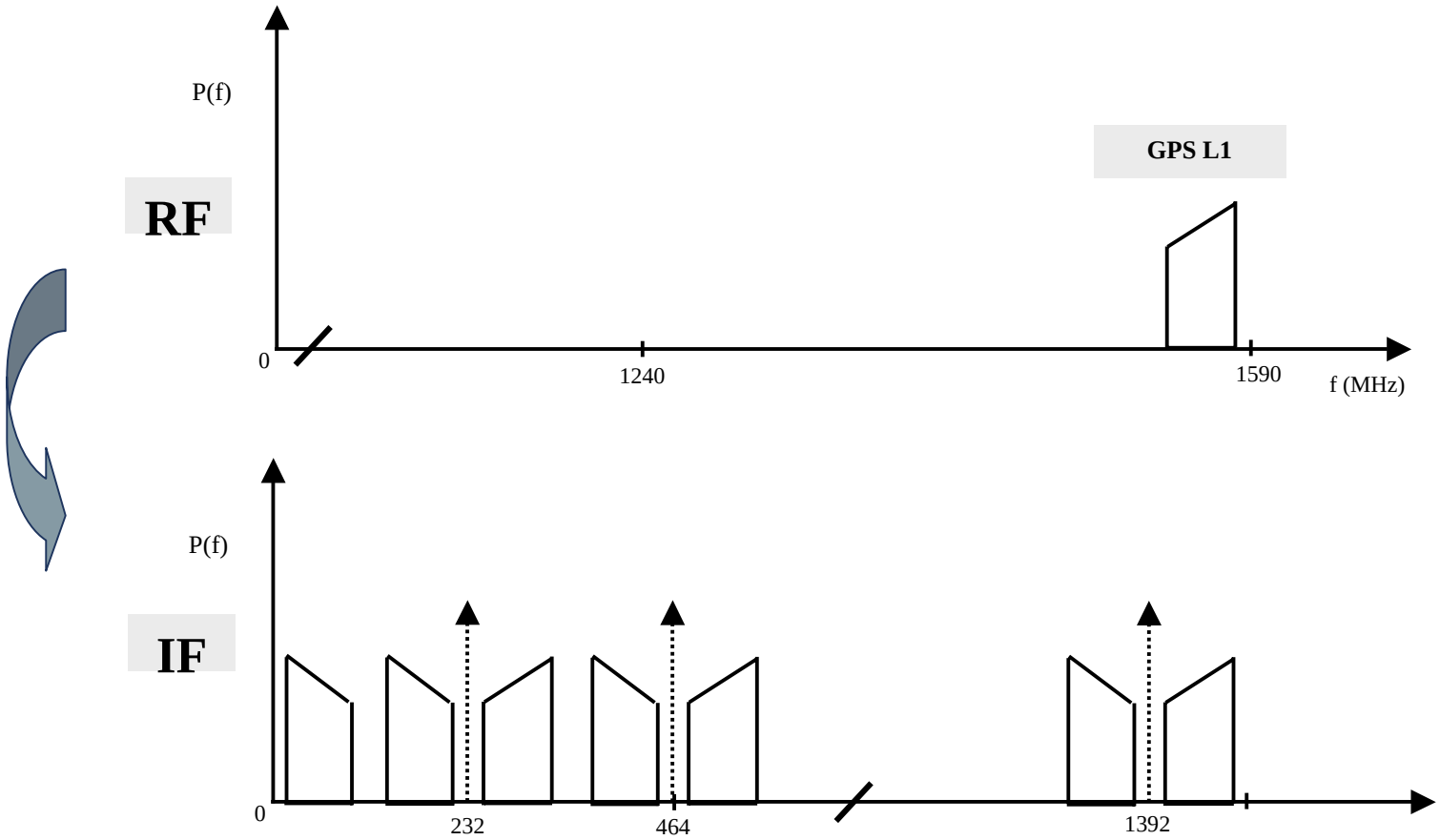
Front-End uses subsampling @ 232 MHz

RF satellite signals sampled at 232 MHz

⇒ aliasing occurs and RF signal is converted to IF

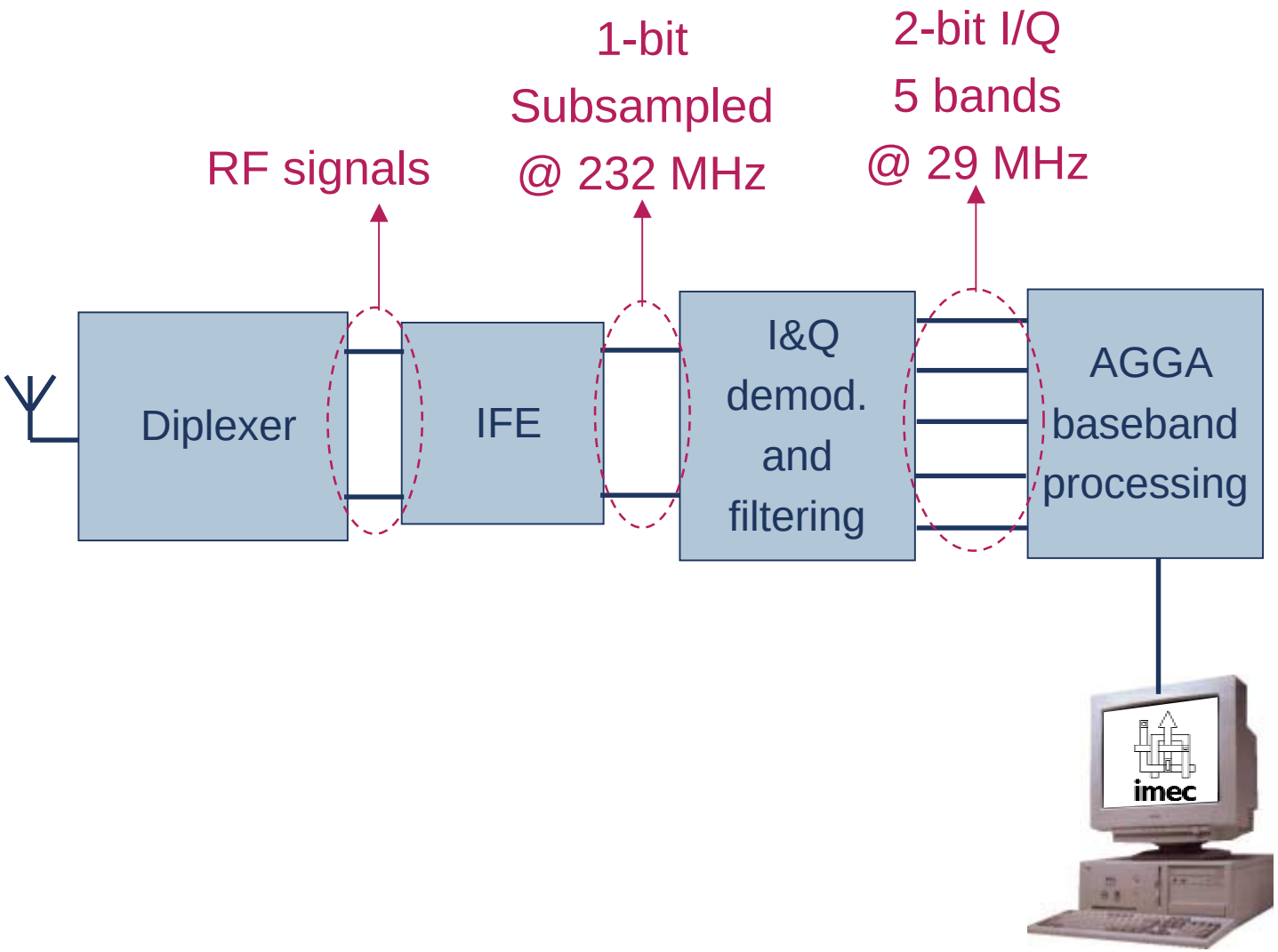


One sampling frequency allows downconversion of all 5 bands

Channel	RF input frequency [MHz]		Digital IF frequency [MHz]		
	Low	High	Low	High	
GPS L5	1164.4	1188.5	4.5	28.5	Lower band
GPS L2	1217.37	1237.83	57.37	77.83	
GLO L2	1241.33	1256.36	77.83	96.36	
GPS L1	1565.19	1585.65	38.35	58.81	Upper band
GLO L1	1592.95	1613.86	10.14	31.05	

- oversampling will provide a possibility to have extra accuracy.
- Subsampling requires good pre-filtering of the signal

One IFE is used for all 5 bands



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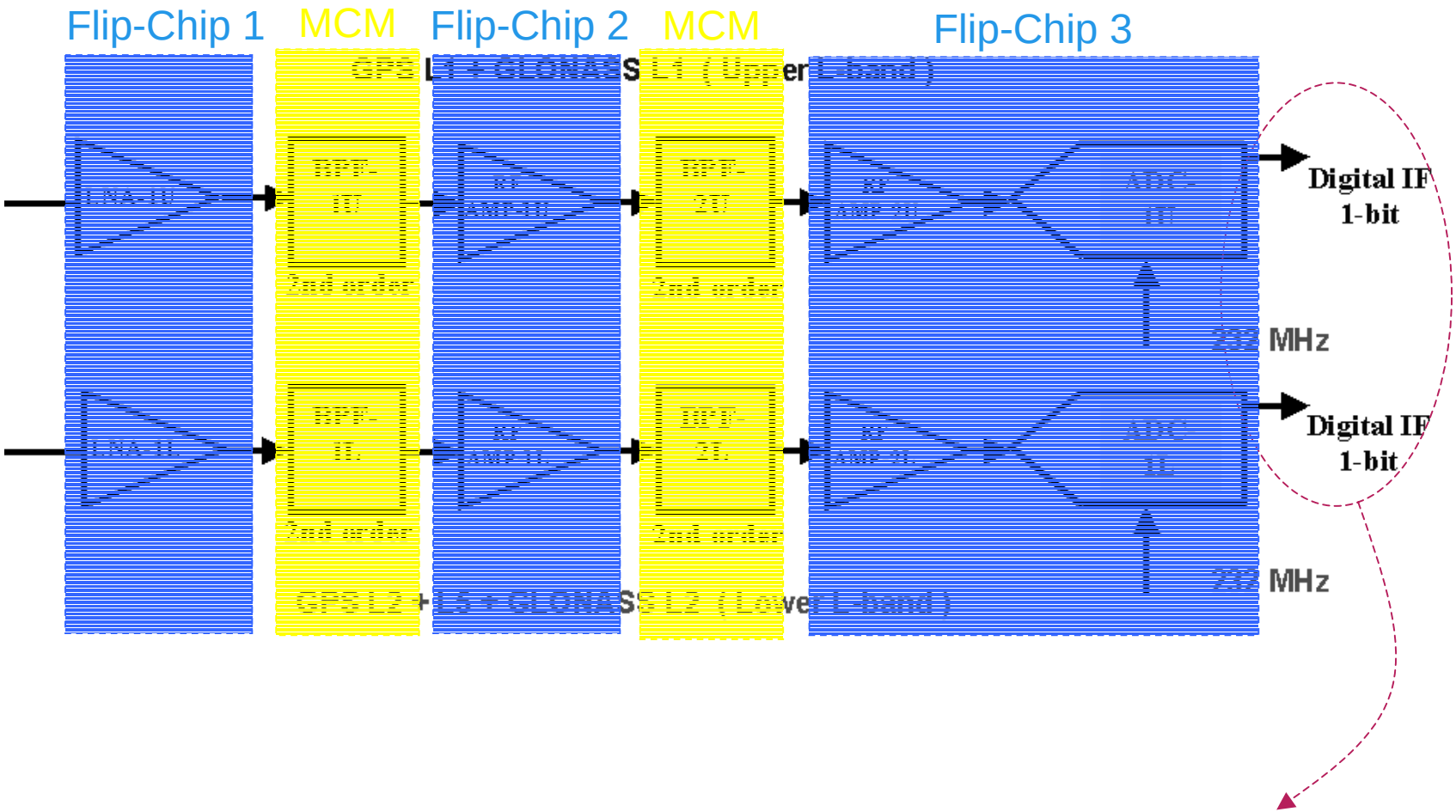
Separate RF branch for upper and lower band

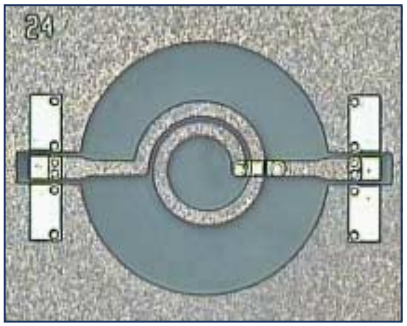


Outputs are LVDS compliant

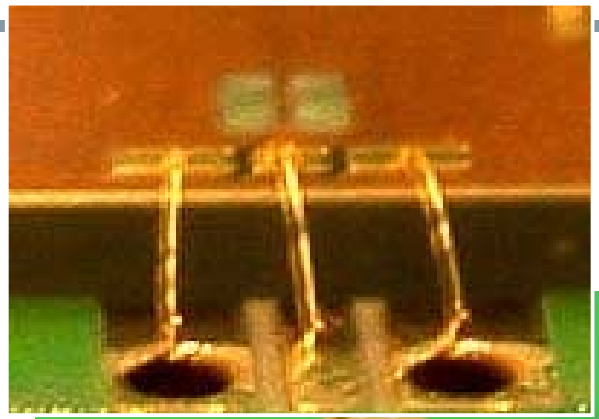
The dual-band RF amplifier chain consumes only 80 mW @3V including on-chip biasing

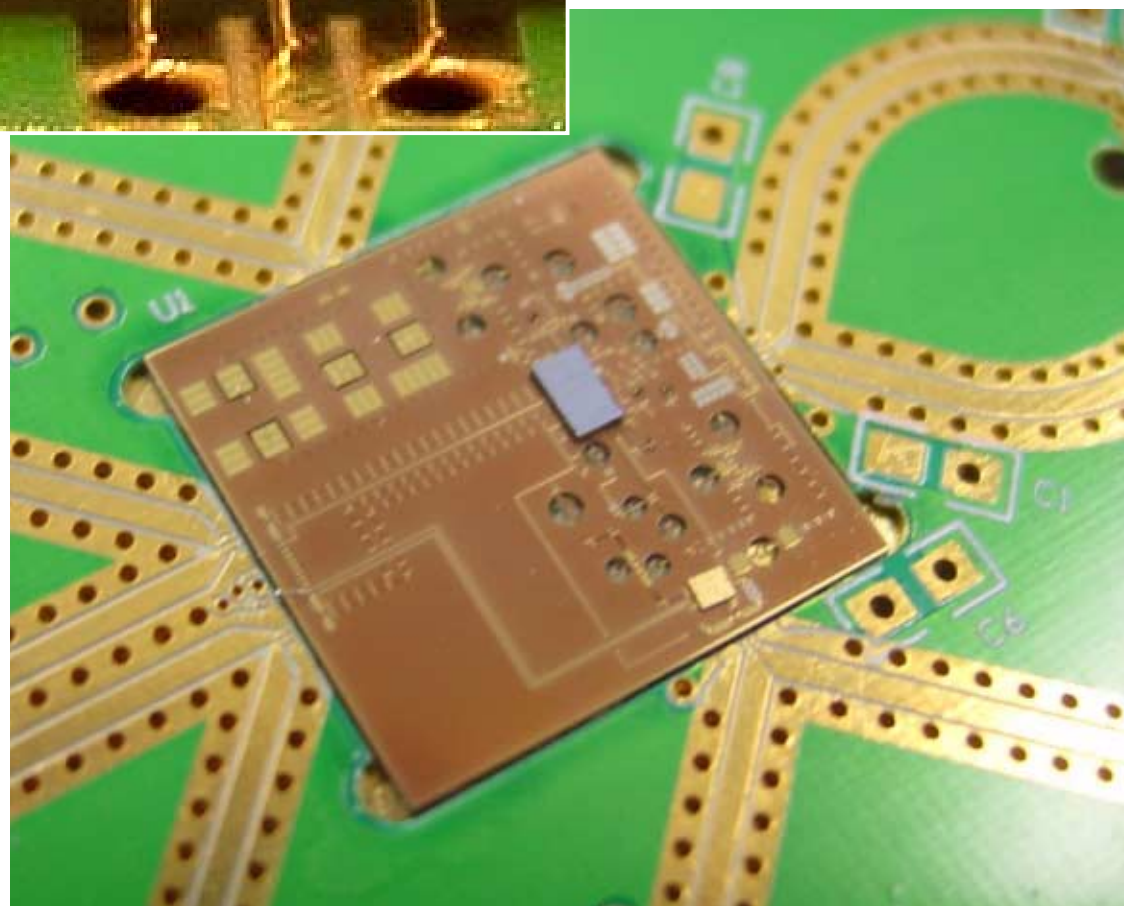
	Chip1		*Chip2*		*Chip3 incl ADC*	
Amplifier	LNA1LV2	LNA1UV2	RF1LV2	RF1UV2	RF2LV2	RF2UV2
AREA	2060 x 1570 um		2070 x 1890 um		2110 x 1800 um	
Gain (typ)	27.7 dB	27.1 dB	30.4 dB	29.7 dB	40.5 dB	42.3 dB
BW	1164-1299 MHz	1559-1614 MHz	1164-1299 MHz	1559-1614 MHz	1164-1299 MHz	1559-1614 MHz
NF	2.1 dB	2.1 dB	2.0 dB	1.9 dB	2.4 dB	2.1 dB
Compression point (typ)	-20.7 dBm	-19.7 dBm	-11.5 dBm	-13.5 dBm	0.2 dBm	0.2 dBm
IP_3 (typ)	-6.7 dBm	-6.4 dBm	4.2 dBm	0.2 dBm	14.3 dBm	14.4 dBm
Power consumption	11.7 mW	11.7 mW	17.7 mW	14.1 mW	15.5 + 14.1 mW	16.0 + 14.1 mW
	23.4 mW		31.8 mW		31.5 + 28.2 mW	

High integration possible due to IMECs MCM-D technology



Inductor Q up to 100

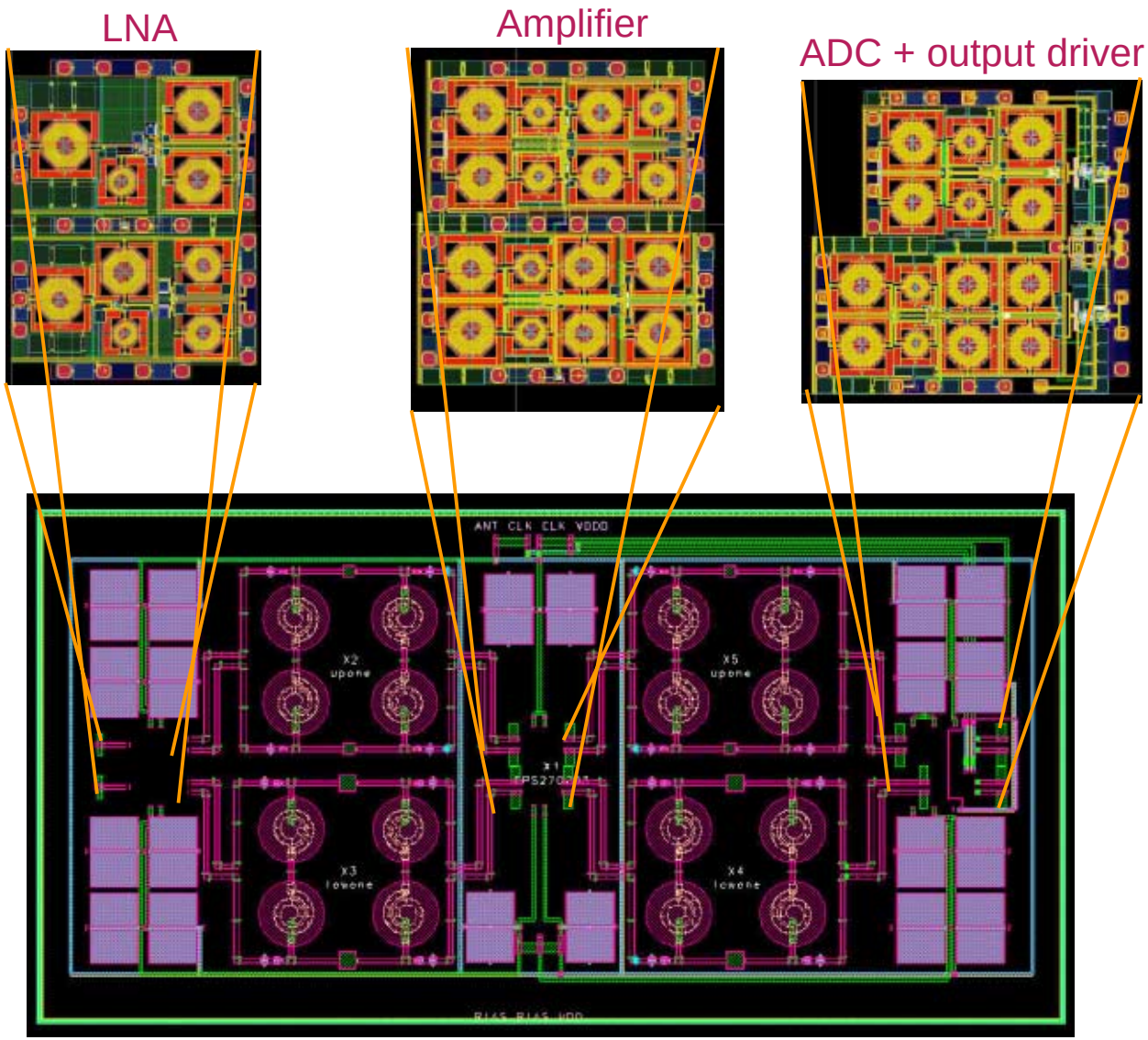




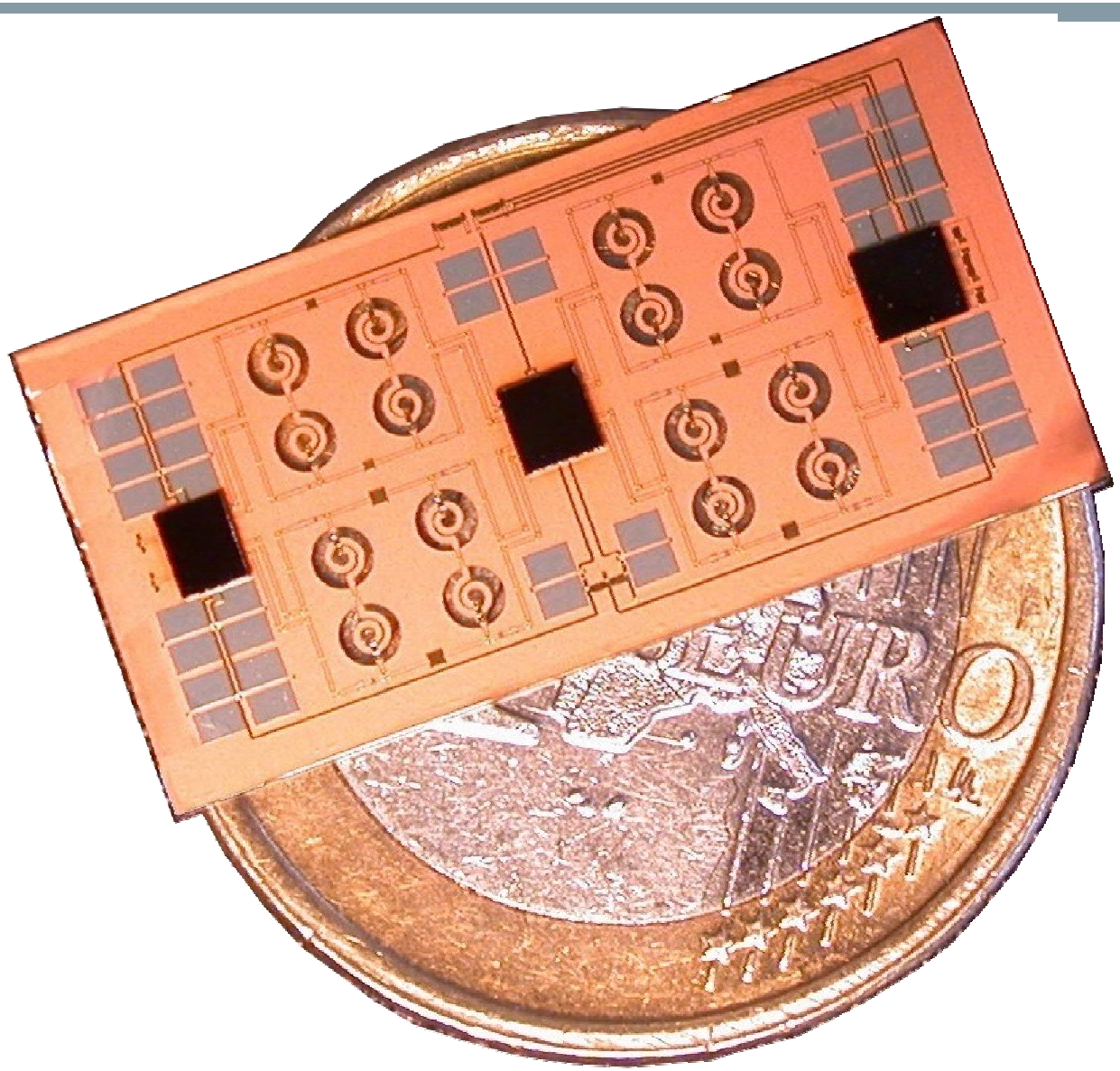
RF MCM-D technology

- glass substrate
- flip-chip mounting
- high-quality embedded passives

Amplifiers with 1-bit ADC onto MCM



Integrated Front-end measures 22x11 mm



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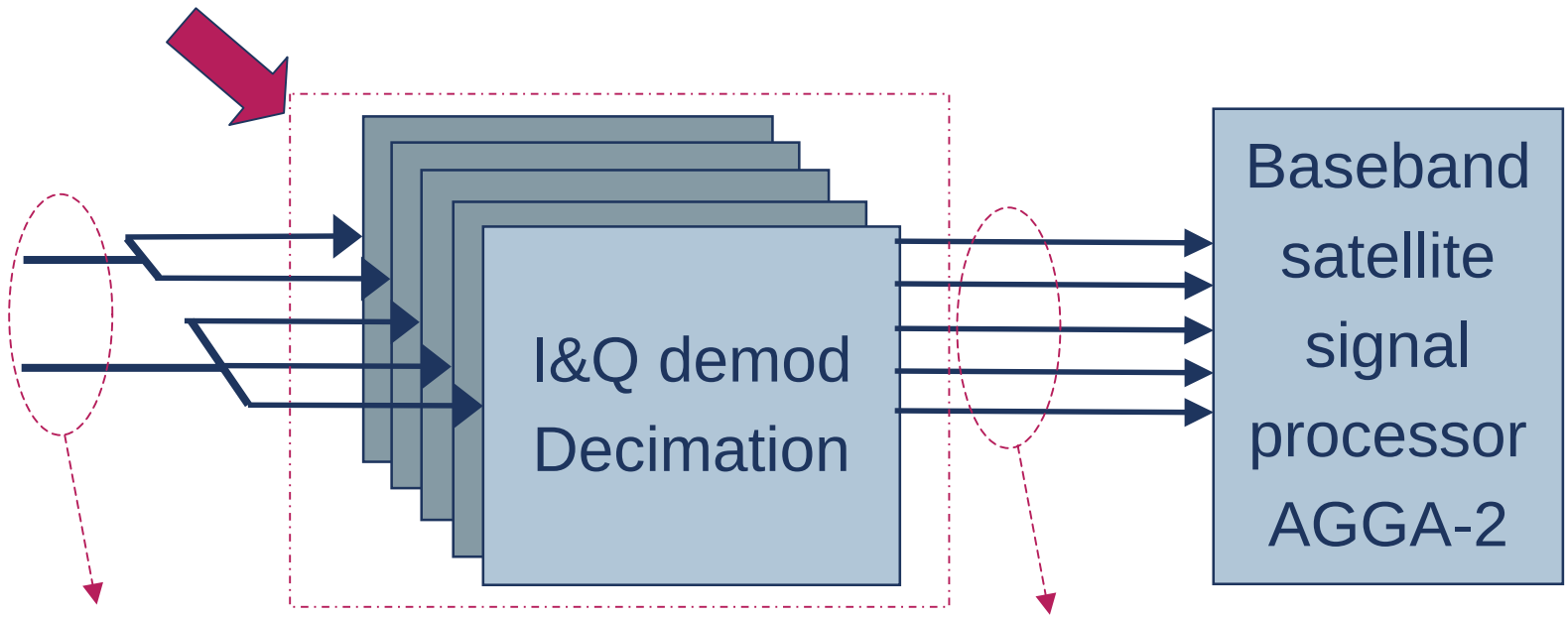
IMEC builds on previous baseband satellite signal processor

- Existing baseband processor will be used, focus on signal treatment

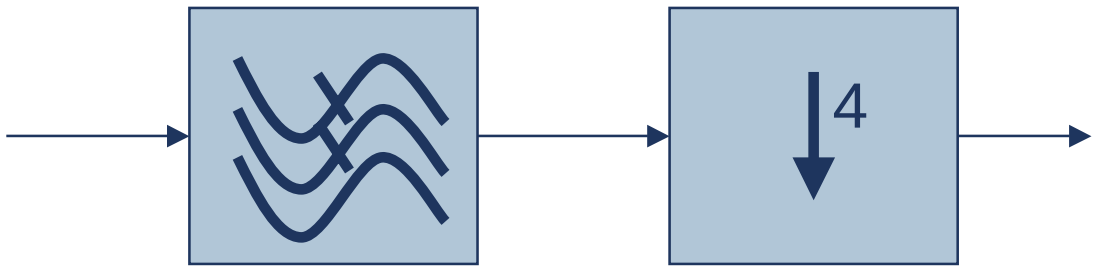


1-bit @ 232 MHz
Upper/lower band

2-bit I&Q @ 29 MHz
For each satellite subband

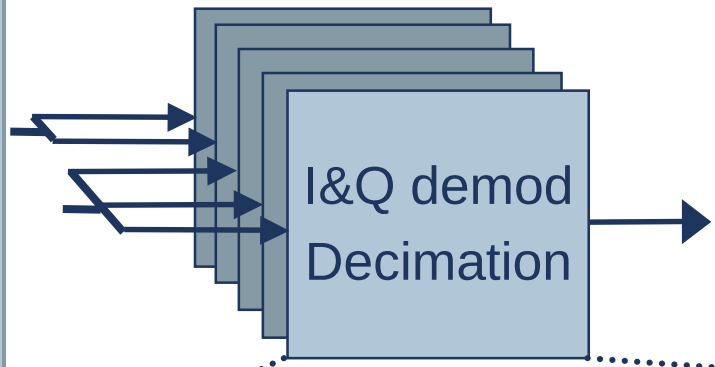
Oversampling enables a gain of 1-bit

- Signal of interest is oversampled with a factor > 4
- Low pass filters removes the quantization noise and reduce the sampling rate



- One extra bit of resolution is gained through decimation

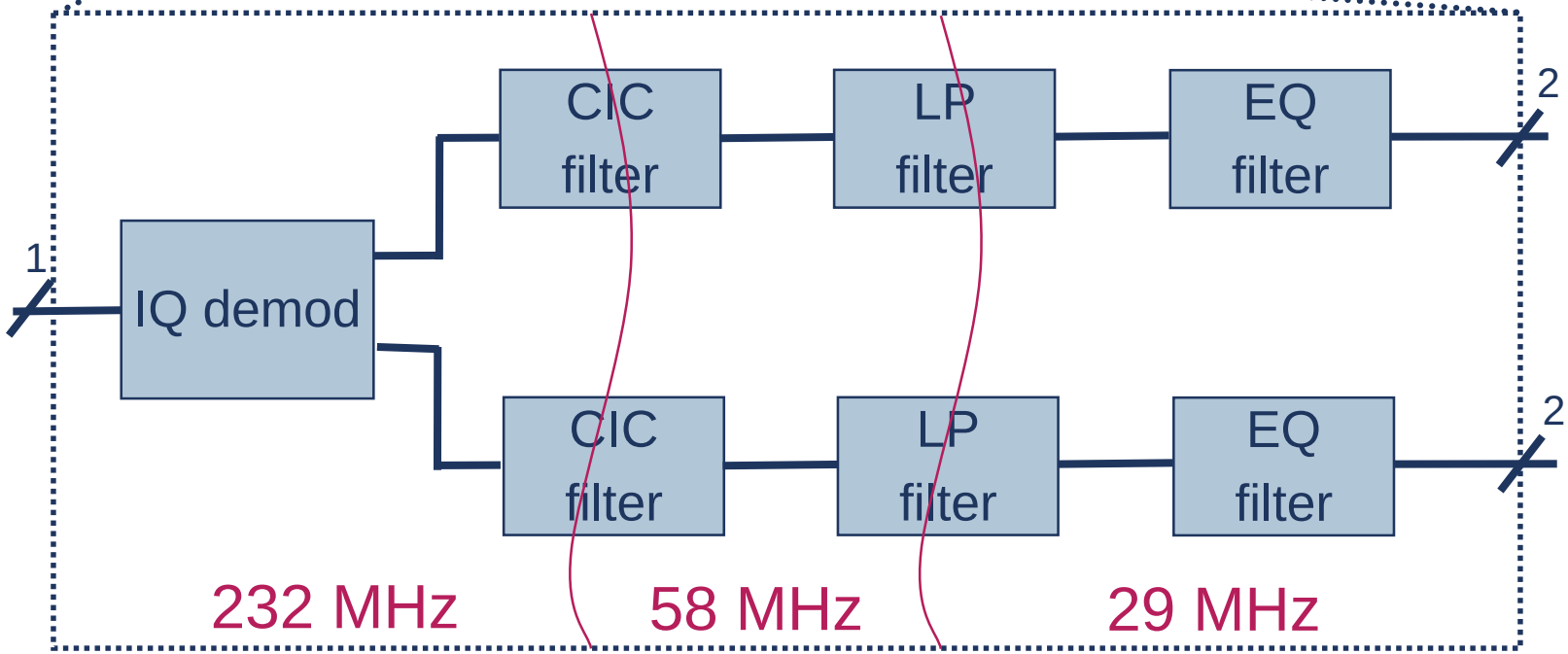
Multistage decimation reduces the power



Multistage decimation

⇒ reduced filter complexity & operating frequency

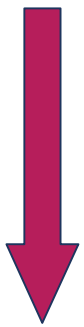
⇒ reduced power dissipation



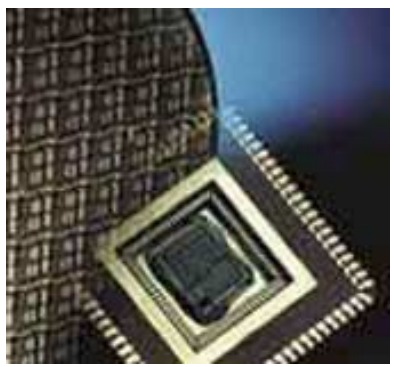
Implementation done on FPGA

FPGA (VirtexII) chosen because of flexibility, but an FPGA is not a power efficient solution:

FPGA: 100 mW/channel



ASIC 0.18 um : 25 mW/channel (estimate)



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Improved accuracy with multipath and semi codeless techniques

Multipath mitigation

Canceling the multipath effects

Almost all multipath interference can be cancelled

Semi codeless

Dual frequency measurements using the encrypted P-code using an adaptive scheme

Simulation and field test where performed on GReCo chip (functional equivalent to AGGA) by Septentrio

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Integrated high-performance low-power Front-end build

- Multi-channel subsampling RF FE implemented
- Complete system is supporting 5 signal bands for (future) GPS and GLONASS frequencies
- Maximum integration using System-in-a-package approach
- Total power per channel:
  - IFE module: 22 mW per channel
  - Digital part: 25 mW per channel (0.18um ASIC)
- High performance: 5 channels + low noise
  - Cascaded NF RF module: 2.2 dB (3.5 dB including diplexer)
  - 2-bit accuracy available to AGGA

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