ELBARA II, L-band Radiometer for SMOS Cal/Val Purposes

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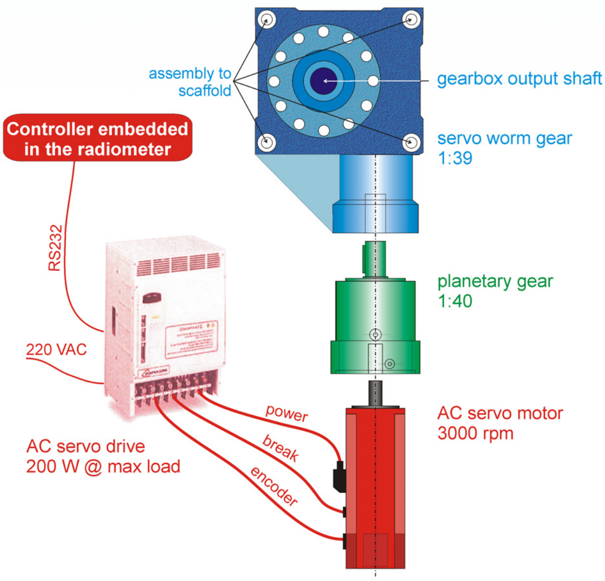
Introduction

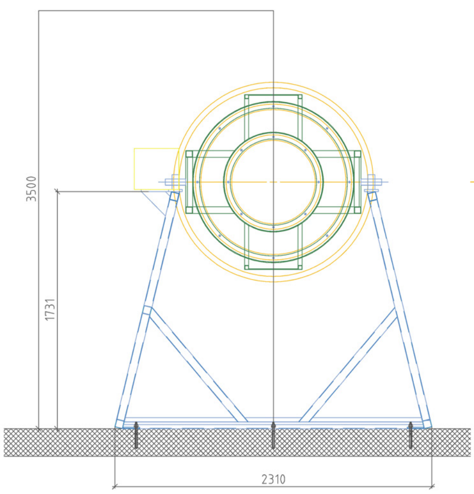
L-band (1 - 2 GHz) microwave radiometry is an important remote sensing technique to monitor soil moisture over land surfaces at the global scale. The ESA L-Band SMOS radiometer mission aims at providing global maps of soil moisture, with accuracy better than 0.04 m^3m^{-3} every 3 days, with a spatial resolution better than 50 km.
To improve the used models and for verifying the accuracy of the aimed global soil moisture data product, ground based radiometer campaigns before launch, during the commissioning phase and during the operative SMOS mission are important. Furthermore, the availability of ground based L-band data simultaneously measured with the over flying SMOS satellite are required for calibration and validation purposes. To address these needs three ELBARA II radiometers are built by Gamma Remote Sensing (Gümligen, Switzerland) by order of ESTEC in the framework of the contract ESTEC 21013 / 07 / NL / FF "L-band Radiometer Systems to be deployed for SMOS Cal / Val Purposes".
The radiometer systems rely on the proven architecture of the ELBARA radiometer with improvements on the user interface, the mechanics, and the microwave electronics. The development of an Active Cold Load as cold reference noise source is expected to improve the radiometric accuracy. Furthermore, the mitigation of Radio Frequency Interferences is improved by digitizing the signals after the detector and sampling with 800Hz.
The ELBARA II systems will be operated by the successful applicants selected from the *Announcement of opportunity for the use of an L-band radiometer from ESA SMOS Project*. At the end of April 2009 the instruments will be supplied to the users, accompanied by a two-day workshop held at the Swiss Federal Institute WSL in Birmensdorf (Switzerland). This workshop allows the users to perform basic measurements with the ELBARA II system on a test site.
This poster presents the main characteristics of the ELBARA II system and presents examples of laboratory measurements performed on the electronics.

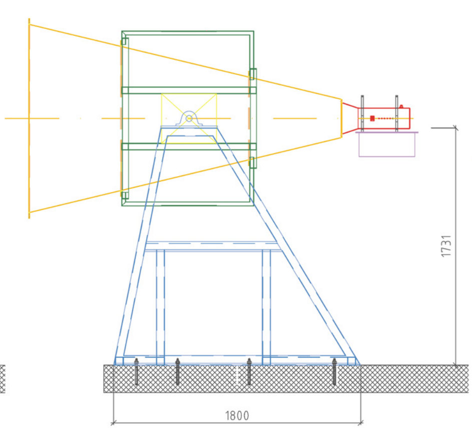
Mechanical Layout

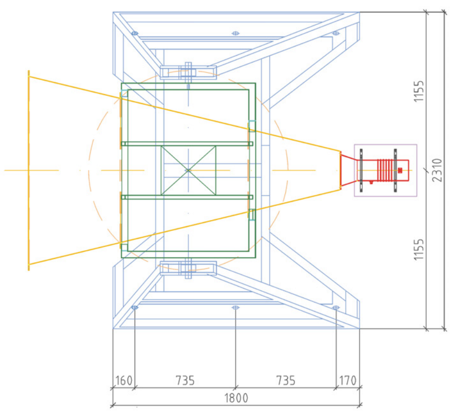
The mechanical components of the ELBARA II system are shown in the figure below. The setup consists of:
i) The Picket horn antenna consisting of the antenna cone (dark yellow) and the antenna feed (red)
ii) The antenna holder (green)
iii) The tracker (yellow)
iv) The scaffold (blue)
v) The Peli-case containing the radiometer electronics (violet).
The antenna is highly directive with -3 dB beamwidth of 12° and provides H- and V-polarization and symmetrical and identical beams with small side lobes.
The base of the scaffold features several borings (for M16 screwing) allowing for most flexible deployment either on a tower platform or on the cantilever of a crane.
The present scaffold construction and the tracker allows for rotating the antenna from nadir to zenith direction corresponding to observation angles 35° $\leq \alpha \leq$ 315°. $\Rightarrow$ Observing two opposite field sites without rotating the instrument around its vertical axis is possible.
The construction weights approximately 330 kg and can be mounted in any orientation (rectangular at a wall or even upside-down).

The components of the elevation scanner are sketched in the Figure below. The total reduction of the gears is 1:1560 yielding the high maximal mechanical torque of 1080 Nm and the maximal rotational speed of 2 rpm (revolutions per minute) at the gearbox output shaft attached to the antenna holder. The operational temperature is -20°C to +80 °C.
The servo motor is equipped with an encoder and an integrated break. The motor is powered and controlled by the AC servo driver comprising a RS-232 interface connected to the Instrument Computer (IC) of the ELBARA II.









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SMOS

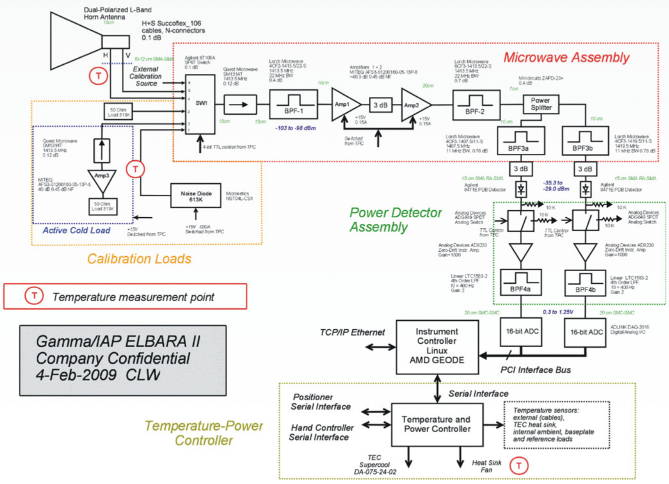
Design of the Electronics

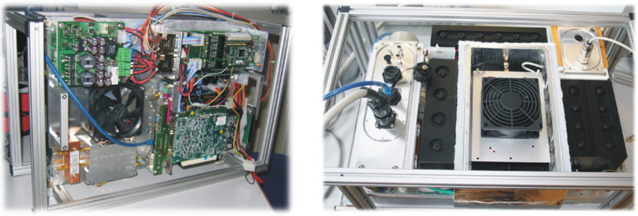
The block diagram shown below is subdivided into the following sub-systems: **1)** microwave assembly (red); **2)** power detector assembly (green); **4)** calibration loads (orange) and; **5)** temperature power control (yellow).

Pictures of the electronics design are shown below the block diagram. Special attention has been directed at both identification and mitigation of possible Radio Frequency Interference:

Mitigation: a) Highly directive antenna (6° at -3dB).
b) Narrow-band input band-pass (1413.5 MHz, 22 MHz).

Detection: c) Frequency domain; two microwave channels (1407.5 MHz and 1419.5 MHz, 11 MHz bandwidth).
d) Time domain; statistical analysis of the digitized signals after power detection.





Layout of the ELBARA II electronics.

The calibration sources and the antenna horizontal and vertical polarizations are connected to a mechanical low loss precision switch. A measurement cycle consists of measuring the detector power for each noise source connected at the input switch. Besides the two antenna channels, three calibration loads and a 6[th] position for connection to an external calibration load can be selected.

1) Active cold source with: $T_{cold} \approx 40$ K

2) Active hot load with: $T_{hot} \approx 613$ K

3) Resistive load (50 Ω) at: $T_R \approx 300$ K

The calibration sources are mounted on a separate copper block (1.7 kg) allowing to operate them independently for cross calibration among the ELBARA II systems and other L-band radiometers.

⇒ High heat capacity of 655 JK^{-1}

⇒ Excellent thermal stability of 30 ± 0.1 °C

Measured Power Levels at the Diode Detector Inputs are:

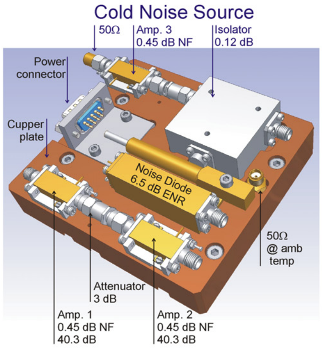
Upper Channel

Hot source:	-29.12 dBm	(1.22 μW)
Cold source:	-35.46 dBm	(0.284 μW)
Resistive Load:	-31.59 dBm	(0.698 μW)

Lower Channel

Hot source:	-28.99 dBm	(1.26 μW)
Cold source:	-35.35 dBm	(0.292 μW)
Resistive Load:	-31.46 dBm	(0.714 μW)

Cold Noise Source



Microwave Characteristics

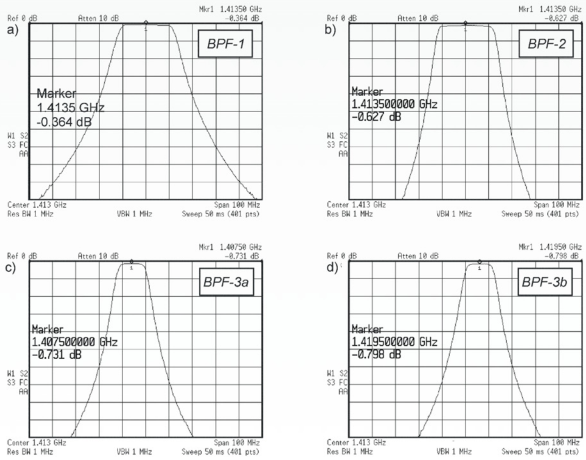
Filters:

The figure below shows measured spectral responses of the four Band-Pass (BP) filters along the microwave path:

a) Input 4-section BP filter BPF-01.
Bandwidth at f_0 = 1413.5 MHz is 22 MHz at -3 dB.
Insertion loss is 0.364 dB.

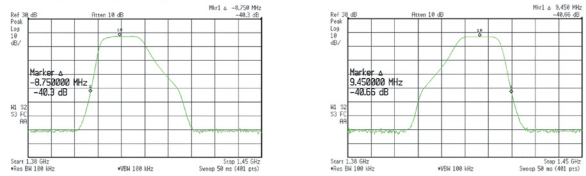
b) Second BP filter BPF-01.
Bandwidth is 22 MHz.
Insertion loss is 0.627 dB.

c) and d) The two 11 MHz BP filters BPF-3a and BPF-3b.
Insertion losses at the center frequencies 1407.5 MHz and 1419.5 MHz are 0.798 dB and 0.731 dB, respectively.



Total transfer function:

The total measured transfer functions of the low-frequency channel a) and of the high-frequency channel b) are shown below.

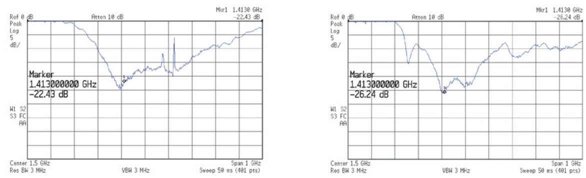


$f_{0\,low}$ = 1407.5 MHz
-3 dB @ +6.65 MHz and -5.08 MHz
BW: 11.72 MHz

$f_{0\,high}$ = 1419.5 MHz
-3 dB @ +5.60 MHz and -6.30 MHz
BW: 11.90 MHz

Antenna Match:

Return losses of the (sky looking) antenna feed measured for 1 - 2 GHz. The return losses measured for H- and V- polarization were clearly smaller than the specified -20 dB.



H-polarization @ 1413 MHz ⇒ -22.43 dB

V-polarization @ 1413 MHz ⇒ -26.24 dB

Controlls

Two embedded computers are implemented, the Temperature and Power Controller (TPC) and the Instrument Computer (IC):

1) The TPC monitors the power used by the radiometer, controls the Peltier heating and cooling element, and starts the IC.

2) The IC controls the ELBARA II system, schedules the data acquisition, and permits the remote control.

Flash drive is used for data storage.
16-bit ADC PCI card is used for digitizing after the detectors with 800 Hz.
RS232 serial lines to control the servo driver of the elevation tracker.

The system can be controlled locally via a control panel or remotely via Ethernet.