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APPLIED RESEARCH

A New Monitor and Control Power Supply PCB for Biasing LNAs of Large Radio Telescopes Receivers

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ABSTRACT The biasing of low noise amplifiers (LNA) is of paramount importance for the receivers of large radio telescopes. High stability, optimal trade-off between gain and noise figure, remote control, and mitigation of the radio frequency interferences (RFIs) are all desirable features in the choice of the electronic board devoted to power supply the LNAs. In this paper, we propose the design and characterization of a multilayer printed circuit board (PCB), named GAIA, able to meet all the aforementioned requirements. The GAIA board is a 3-Unit, four-layer, rack-mountable, programmable PCB for the remote biasing of the LNAs, with monitor and control capabilities, specifically designed to operate in the receivers of the 64-m diameter Sardinia Radio Telescope (SRT). We describe the architecture, layout, and measurements of the GAIA board. Our results show that the GAIA power supply provides high stability of the output bias voltages and, in comparison with the old analogic biasing board used so far in the SRT receivers, it shows comparable or better frequency stability, other than a remarkable mitigation of the RFIs.

INDEX TERMS Low noise amplifiers, power supply board, printed circuit board, radio frequency interference, radio telescopes, receivers.

I. INTRODUCTION

Large radio telescopes are equipped with sophisticated radio frequency receivers devoted to collecting the weak electromagnetic radiation generated by celestial bodies, through proper amplification, filtering, and frequency down-conversion. One of the key parameters of a radio receiver is its sensitivity [1], which represents the minimum power level that the receiver can detect. It should be kept as low as possible by reducing the overall noise temperature [1], [2] of the receiver, which depends on the noise added by all active and passive components according to the Friis Formula [1], [3]. For this reason, usually, the first device in the receiving chain of radio-receivers is a low noise amplifier (LNA), featuring high gain to reduce the noise contribution of the subsequent stages of the receiver chain.

As a result of both technological and industrial evolution, modern LNAs employ High-Electron Mobility Transistors (HEMTs) based on Indium Phosphide (InP), Gallium Arsenide (GaAs), and Silicon Germanium (SiGe) technologies. The optimum tuning of the LNA parameters requires reaching the optimal bias point of the HEMT. This bias point depends on the gate and drain voltages, which are strictly tied to the LNA gain, and on the physical temperature. As a consequence, the electronic board devoted to the power supply of the LNAs covers a primary role in setting proper voltages to obtain the best trade-off between a suitable gain and the reduction of the noise figure. Another important feature that the biasing board must guarantee is the stability of the bias voltages that affects the amplifier gain

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stability, and, in turn, the receiver stability and the overall instrument performance. The power supply control unit of LNAs employed in the receivers of the most important radio telescopes around the world is commonly performed using commercial or tailored analog boards.

The amplifier bias boards are normally part of the receiver bias module, which also incorporates boards for other receiver equipment. The receiver bias module is either bolted to the ambient side of the receiver base plate or located in a separate rack, away from the receiver.

Using analog supply boards, the optimization of the HEMTs bias point is performed in the laboratory, prior to the installation of the LNAs in the radio astronomy receiver. In this case, the bias point cannot be modified without physically accessing the receiver, since analog boards provide only the monitoring of the correct operation of each of the LNA stages, but are devoid of remote control.

For each of the amplifier stages, the available parameters are the drain voltage V_d, the drain current I_d, and the gate voltage V_g. Feedback bias supplies, of the type described in [4], are normally used in radio astronomy receivers, where V_d is set and V_g is automatically adjusted to provide the desired I_d. The feedback system of these analog boards adopts operational amplifiers for each HEMT amplifier stage, where the desired drain voltage and drain current are set with manually controlled variable resistors (trimmer potentiometer), until the adequate value of the gate voltage is achieved. In this way, any changes in the transconductance of the HEMT are compensated by changing the gate voltage, keeping the drain current constant.

Information on this type of analog bias supply boards is limited and cannot be found in the open literature, mainly because the available LNAs biasing methods rely on custom state-of-the-art solutions. To the best of the authors' knowledge, these architectures cannot be remotely controlled. However, remote control of the LNA bias is a critical feature since the large radio telescopes receivers are often difficult to be physically accessed for setting or maintenance operations. Specifically, by way of example, the receivers of the Sardinia Radio Telescope (SRT) installed in the primary focus position, can be reached only by means of a moving platform (see Fig. 1).

Moreover, analog bias boards provide power supply, when switching on the LNA, by means of a step function, leading to rapid transient variations of the supply current/voltage that could potentially compromise the integrity of the semiconductors, unless suitable protection boards are used. In this regard, a slope supply function, where the voltage is gradually increased over an assigned timescale to the final value, would be preferable to preserve the device functionality.

In this context, also the solution adopted so far for biasing the LNAs of the SRT receivers employs a basic analog board based on trimmer potentiometers and a general-purpose digital board connected to the ethernet, allowing remote monitoring of the bias voltages. In this configuration, the

FIGURE 1. The Sardinia Radio Telescope during maintenance operations.

analog potentiometers should be set manually, prior to the installation of the LNA in the radio astronomy receiver, since remote control is not allowed and the analog board can only be remotely switched on/off (using a step function).

All the above limitations can be overcome by migrating to a power supply printed circuit board (PCB) that takes advantage of the flexibility of microcontrollers and digital electronic components.

In this paper, we present the design, development, and testing of a new power supply PCB with remote control capabilities, named GAIA, specifically developed to bias the LNAs of the Sardinia Radio Telescope (SRT) [5], [6], [7] and the Sardinia Deep Space Antenna (SDSA) [8] receivers.

The GAIA board is composed of a three-unit (1 rack unit being 44.45 mm), four-layer, rack-mountable programmable PCB, based on a microcontroller and on digital potentiometers designed for remote biasing, monitoring, and control of the gate voltage (V_d) and drain voltage (V_g) of the LNAs. Specifically, one single GAIA board can control up to 10 V_d and 10 V_g, and monitor 10 V_d, 10 V_g, and 10 drain currents (I_d). Based on these features, GAIA enables continuous monitoring of the supply voltages and failure checking of the receiver active stages to preserve the efficiency and integrity of the system.

Moreover, GAIA allows setting the optimal values of the V_g and V_d bias voltages of the HEMTs ensuring a time slope supply mode and it can be used to de-tune the LNA bias to lower the LNA gain. The latter feature could be useful to avoid the receiver saturation during observation of strong radio astronomical sources, like the Sun.

It should be noted that PCBs equipped with a microcontroller are usually the source of unwanted radio frequency emissions that could be detrimental to the weak received signals. In this regard, the GAIA board has been designed to mitigate radio frequency interferences (RFIs). Specifically, this key characteristic has been implemented following some of the most common techniques to reduce the emissions in PCB design, such as using multi-layer technology and avoiding sharp bends on the traces [9].

The GAIA bias module is powered by commercial +/− 12 Vdc supplies for its analog section, and a +5 Vdc supply for the serial interface. These power units have been properly selected to minimize RFI emissions (linear power supplies are favored over switching ones).

Finally, though developed as a bias and monitor and control board for the LNAs of the radio telescope receivers, GAIA can also be employed for the bias optimization of custom LNAs and their laboratory characterization in terms of gain/noise figure vs. bias point.

In the next sections, we will discuss the general architecture and block diagram of the GAIA board, focusing on the layout and PCB design. Then, the experimental characterization is presented, including the stability measurements of the gate and drain voltages and the evaluation of the phase noise added by this board by means of frequency stability measurements using the Allan deviation. Finally, the electromagnetic emissions generated by the GAIA board are compared with the emission of the old power supply system used so far in the receivers of the SRT, showing a significant reduction of the RFIs.

II. GAIA ARCHITECTURE

The GAIA board is composed of four main blocks, as reported in the block diagram in Fig. 2:

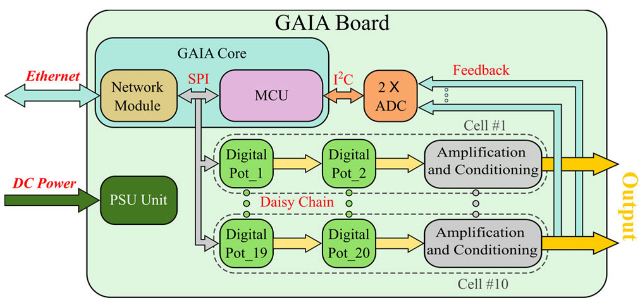

FIGURE 2. Block diagram of the GAIA board.

1) The GAIA core, including the microcontroller unit (MCU) and a network module for Ethernet communication. This block is responsible for the board communication via Serial Peripheral Interface (SPI), Universal Asynchronous Receiver/Transmitter (UART), and Inter-Integrated Circuit (I2C) protocols. The board electronics are organized to implement RFI mitigation and a compact design.
2) A cluster of 10 cells for signal amplification, filtering, and conditioning able to bias up to 10 LNAs independently of each other. Each cell allows to set the drain and gate voltages by means of two digital potentiometers and has been designed with short circuit protection.
3) The analog to digital converter (ADC) module, enabling the reading of output currents and voltages, on-board temperatures, and reference voltages.
4) The Power Supply Unit (PSU), for power supply, filtering and protecting from high voltages, high temperatures, and short circuits.

TABLE 1. Characteristics of the GAIA board.

Item	Value
No of amplification stages	10 (5 per polarization channel)
Drain voltage range V_d	$0 \text{ V} \leq V_D \leq 5 \text{ V}$
Gate voltage range V_g	$-6.5 \text{ V} \leq V_G \leq 5 \text{ V}$
Maximum drain current	$I_{Dmax} \leq 50$ mA (per channel)
Maximum power out	≈ 6 W
Max total power consumption (with all channels on)	≈ 7 W
ADC characteristics	16 bit with 15 Hz sampling rate
V_d - voltage resolution	≈ 5 mV
V_g - voltage resolution	≈ 11 mV
Max capacitive load	1 μF
Communication port	Auto-negotiated 100 Mb LAN with RJ45 connector

In Table 1, we report a summary of the main features of the GAIA board and, in the following, we will describe in detail the above blocks.

A. GAIA CORE

The GAIA core is the heart of the board. Its main function is to enable the remote control of the LNAs. This feature is of paramount importance specifically when the receiver location is not easily accessible, as it is common in large-scale radio telescopes. The core design is devoted to easing integration and versatility, promoting the possibility to employ the board on different control systems for radio observations other than those of the SRT/SDSA. Meticulous attention has been paid to the choice of components, so as to achieve the best trade-off between RFI mitigation and performance. The core is based on the Atmel ATMega2560 microcontroller and on the Wiznet W5100 Ethernet controller. Communication between these two chips is enabled through Serial Peripheral Interface (SPI) protocol. The Wiznet W5100 Ethernet controller employs a clock at 25 MHz, whereas the Atmel ATMega2560 is an 8-bit, high-performance low-power RISC (reduced instruction set computer) microcontroller equipped with a 16 MHz clock. The clock frequency determines the frequency and amplitude of the harmonics generated by the clock square wave tone, which produce unwanted RFIs. A low clock frequency is preferred, when possible, to mitigate the RFIs in the frequency bands of interest that, for the SRT, start with the P-band at 300 MHz [6], [7]. In this context, aiming for RFI reduction, the ATMega2560 has been preferred to more performing chips with a faster clock, such as, e.g., the ARM microcontrollers with 32 bit, which are the state-of-the-art solution for the development of modern control boards [10]. In fact, in our case, thanks to a thorough optimization of the ATMega2560 firmware, only low-complexity instructions are required to perform remote biasing, monitoring, and control of the LNAs, and a general-purpose high-performance chip is unnecessary since it would increase RFIs without benefits for the operation of the board.

B. AMPLIFICATION CELLS

The main task of the GAIA board is to provide the proper bias to the LNAs of radio receivers. This pivotal task is performed by 10 amplification and conditioning cells. They are independent of each other and communicate with the MCU via SPI serial bus for setup and enabling commands. A single cell is composed of two AD5231 digital potentiometers by Analog Devices [11] in a daisy chain configuration plus an amplification and conditioning stage (see Fig. 2). The digital potentiometers tune the gain and drain voltages needed for the LNAs biasing (basically the board's output). Before the output, these voltages are amplified, filtered, and conditioned through a network of four LT6018 operational amplifiers (OPA) by Analog Devices [12], which constitute the amplification and conditioning block (see Fig 2).

The digital potentiometers should guarantee a minimum output resolution to provide the correct values of the drain and gate voltages according to the biasing specification of the LNAs. A subsequent calibration of the board will ensure the corresponding output accuracy. Since the selected resolution should also allow a secondary function of GAIA, namely the thorough bias optimization of custom LNAs and their laboratory characterization in terms of gain/noise figure vs. bias point, we decided to set the minimum output resolution required to the potentiometers at around 10 mV. Specifically, to comply with this specification, we have used the digital potentiometer AD5231, which has a 1024-step resolution. Accordingly, the resolution of the drain voltage is about 5 mV (1 to 1024 are associated, respectively, with the minimum and maximum values of the drain voltage, i.e. 1 corresponding to 0 V, 1024 corresponding to +5 V) and the resolution of the gate voltage is about 11 mV (1 to 1024 are associated, respectively, to the minimum and maximum values of the gate voltage, i.e. 1 corresponding to -6.5 V, 1024 corresponding to +5 V).

The AD5231 potentiometer is also equipped with non-volatile memory that we have used to save the digital value corresponding to a 0 V output of the amplification and conditioning cells for both the drain and gate. This allows protecting the LNAs against possible failure when the board is switched on. As for the amplification and conditioning block, based on the operational amplifiers LT6018, it is worth mentioning that this device has been selected thanks to the ultra-low noise performance (30 nVP-P from 0.1 to 10 Hz and 1.2nV/$\sqrt{}$Hz typical at 1kHz), the high Common Mode Rejection Ratio (CMRR) (124 dB), and the low power shutdown (6.2 μA). The LT6018 model is also equipped with some protections, such as overtemperature, overload, and short-circuit protection. Moreover, the ENABLE pin of the LT6018 [12] is set low (off) when the board is switched on to avoid accidental damage, and it is used to switch on the amplifier when required by normal operation.

Finally, at the output of the amplification and conditioning cells, we have inserted a Schottky barrier diode to protect the LNAs against possible overshoot and undershoot.

C. ADC MODULE

The GAIA board is able to monitor and control 10 drain voltages and 10 gate voltages, and to monitor 10 drain currents. Moreover, two reference voltages have been generated with low-dropout regulators at 5 V and 2.5 V. Therefore, a total of 32 values should be read by an analog-to-digital converter (ADC) to provide the required output and reference feedback. To this purpose, we have used two 16-channel ADCs LTC2495 by Analog Devices [13] with 16-bit resolution (see Fig. 2). The ADCs communicate with the MCU using a 2-wire I^2C interface. The LTC2495 ADC is also equipped with a high-accuracy temperature sensor, which is employed to detect possible overheating.

D. PSU

The GAIA board needs three power supply voltages, namely +5V TTL for the digital and logic portion of the board, and ±12 VDC for the analog blocks. These are provided by three DC power supplies, for which the linear architecture has been preferred to the switching one to limit self-generated RFIs. Then, a power stage unit (PSU) handles, filters, and delivers the supply incoming from the external DC power to the board circuitry. The PSU module is equipped with a self-healing fuse for short-circuit protection of the digital portion of the board. The maximum power absorption of the board (without load) has been about 191 mA for the +5V TTL supply and 327 mA for the ±12 VDC supply. Of course, the total absorption of the board in operating conditions depends on the number of cells employed.

III. FIRMWARE

The firmware of the GAIA board has been designed and developed to comply with the required functionalities of two operating modes:

- the board is used to power supply the LNAs of a radio receiver dedicated to radio astronomy or space applications;
- the board is employed for the bias optimization of custom LNAs and their laboratory characterization in terms of gain/noise figure vs. bias point.

The firmware accepts atomic commands and complex instructions through user datagram protocol (UDP). The firmware default status is the read mode, which only allows reading the LNAs bias and the board temperature. To enable/disable channels and set/modify the output voltages, a setting status is enabled through a specific and explicit command.

The firmware enables the following main functions:

- It provides suitable and safe switching procedures to prevent accidental enabling of the channels during the operation of the receiver, which is handled by non-qualified operators. This protects LNAs in case of an unexpected reboot of the system due to a power failure.
- When required by the LNA characteristics, the GAIA firmware is able to generate a slope supply function for V_d and V_g to preserve the LNA integrity. This functionality is implemented by approximating the ramp by a set of samples, which are transmitted to the digital potentiometers to generate the output voltages.
- For each of the 10 channel/cell of GAIA, the firmware saves in an EEPROM memory all the operating parameters of the LNAs, allowing to enable/disable a single channel using high-level command.

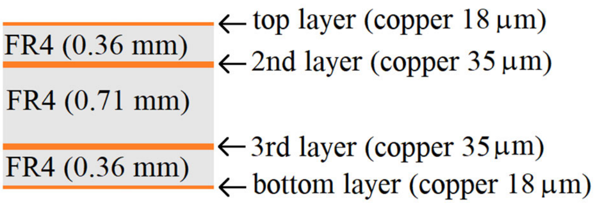

FIGURE 3. Sketch of the board layers.

IV. LAYOUT OF THE GAIA BOARD

The board has been organized into four layers (see Fig. 3):

1) Digital layer: the first layer (on the top) hosts the digital devices of the board and the PSU.
2) Analog layer: the bottom layer hosts the 10 amplification and conditioning cells.
3) Two intermediate layers (the 2$^{\text{nd}}$ and 3$^{\text{rd}}$ layers) host the bus communication and the connection between the digital and the analog layers.

It is worth noting that all the layers of the GAIA board have been used for grounding to avoid any kind of ground loops and to allow an effective shielding of the internal traces, thus reducing the board's susceptibility to Electromagnetic Interferences (EMI) and RFI. Moreover, the layer design has been optimized to reduce the average crossing of the traces in adjacent layers, mainly to avoid crosstalk between analog and digital signals. Finally, sharp 90° trace angles are avoided to mitigate the reflections.

The size of the board is 100 mm × 160 mm (3U standard Eurocard size) and the four layers are shown in Figs. 4-7 according to the sketch in Fig. 3.

Then, a 3D rendering of the board (see Fig. 8) has been realized to verify its vertical overall dimension for the mechanical dimensioning before production. In Fig. 8, the main devices are indicated. Finally, a photo of the realized prototype is reported in Fig. 9.

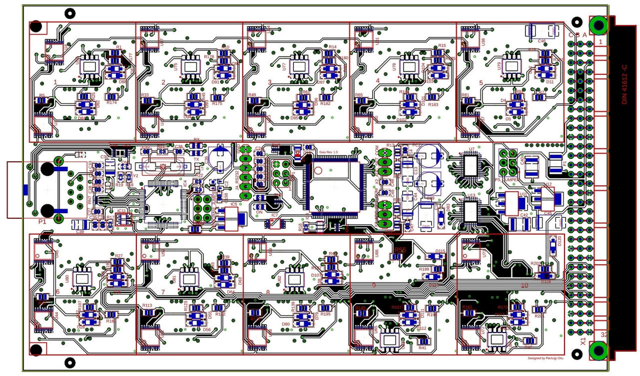

FIGURE 4. Layout of the top layer.

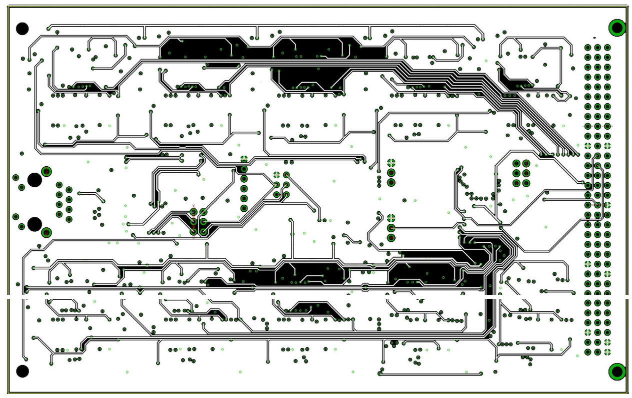

FIGURE 5. Layout of the second layer.

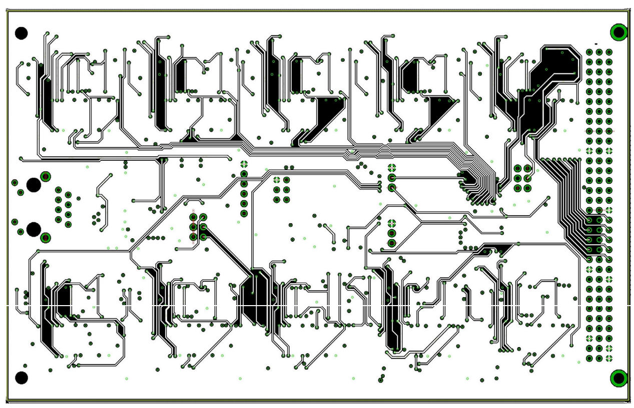

FIGURE 6. Layout of the third layer.

V. GAIA OUTPUT STABILITY

The amplitude and phase stability of modern low-noise receivers are affected by the amplitude and phase noises introduced by active devices, such as oscillators, mixers, and biasing circuits. Phase noise is one of the most critical factors in communications systems, radar systems, and radio astronomy receivers [14], [15]. Indeed, it generates channel interference, amplitude variation of the received signals, spectral regrowth, and affects the doppler shift and the range, the spectral analysis, and time domain radio astronomy observations.

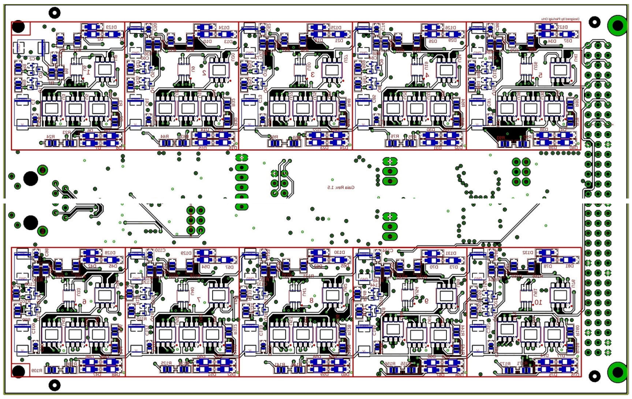

FIGURE 7. Layout of the bottom layer.

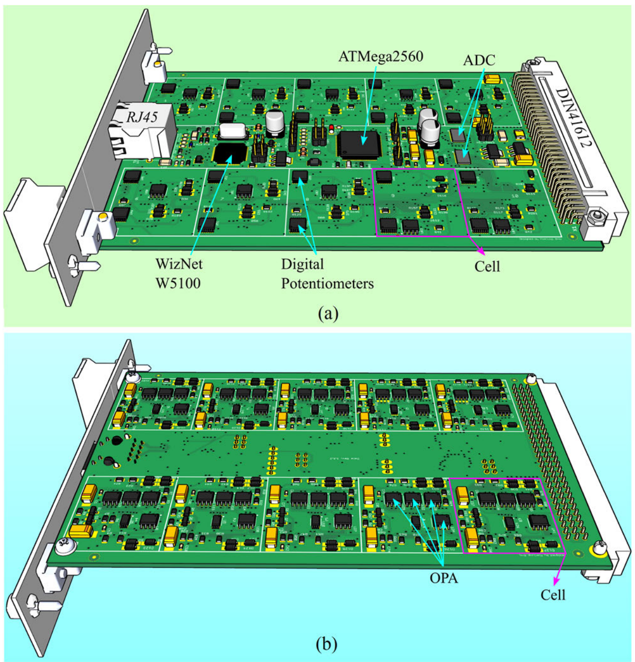

FIGURE 8. 3D rendering of the GAIA board: a) front, b) back.

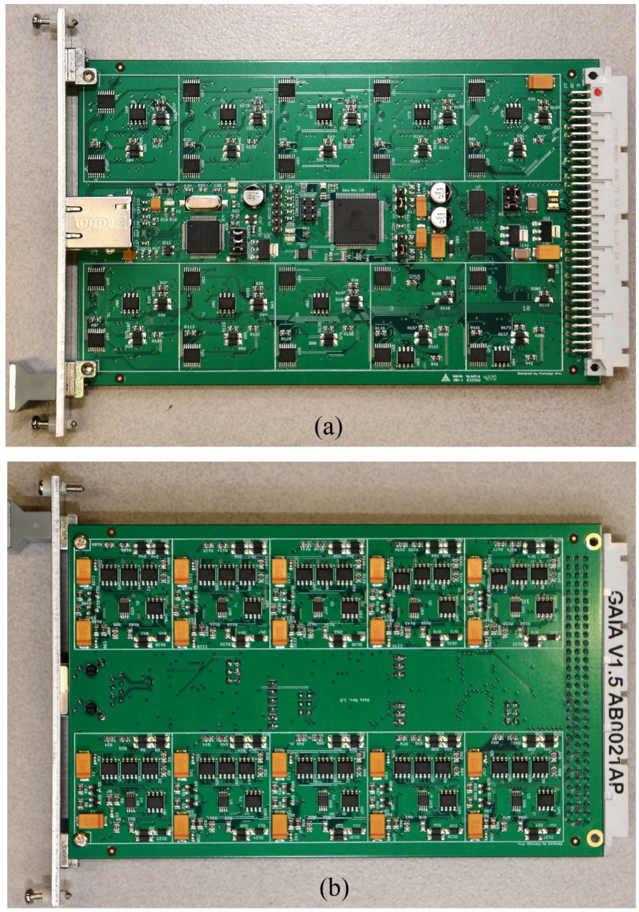

FIGURE 9. Photo of the GAIA board: (a) front, (b) back.

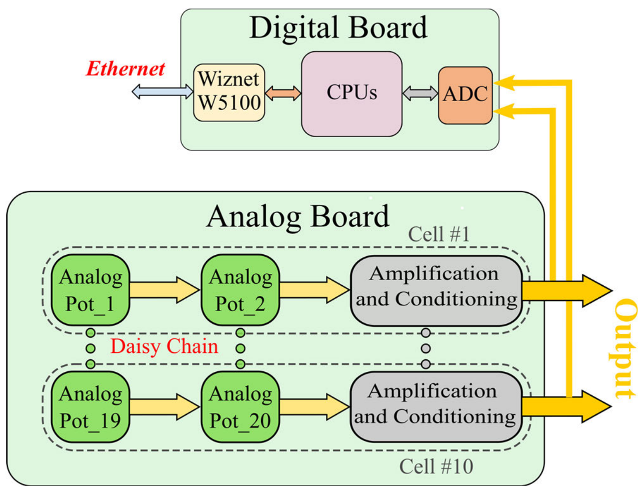

FIGURE 10. Generic block diagram of the analog LNAs biasing system.

To evaluate the GAIA board stability, in this section, we will perform two separate experiments: first, we will analyze the stability of the bias voltages; secondly, we will perform a comparative measurement estimating the phase noise added by a generic LNA biased either by the GAIA board or by the power supply system used so far in the receivers of the SRT (named in the following ALI-SRT). The latter employs a basic analog board composed of operational amplifiers and analog potentiometers that provide the required bias to the LNAs. Then, a general-purpose digital board, connected to the ethernet through a RJ45 plug, allows to remote monitor the values of the bias voltages. In this configuration, the remote control is not allowed and the potentiometers should be set manually. The sketch of this configuration is reported in Fig. 10.

A. STABILITY OF THE OUTPUT VOLTAGES

The output voltages of all the 10 outputs of the GAIA board, V_d and V_g, have been measured over a 90-minute time window at the sampling rate of 1 sample per second. During the measurement, the room temperature was in the range 24.7 – 26.4 °C. This experiment has been carried out using a source-meter unit, model Keithley 2450, and by setting, for each cell, the potentiometers of GAIA to obtain the center value of the output range, i.e. 2.5 V for V_d and -0.75 V for V_g.

The plots of the output voltages are reported in Fig. 11. The average value and the standard deviation of V_d and V_g for all the GAIA cells are summarized in Table 2.

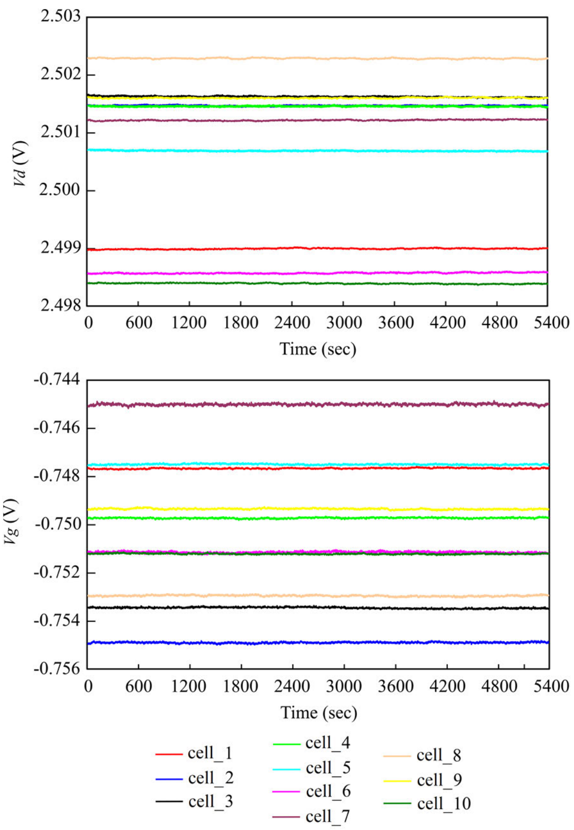

FIGURE 11. Measured output voltages of the GAIA board.

TABLE 2. Output voltages of the GAIA board.

Cell no.	V_d (Avg.) (V)	V_d (St. Dev.) (μV)	V_g (Avg.) (V)	V_g (St. Dev.) (μV)
1	2.4990	9.4	0.7477	21
2	2.5015	7.8	0.7549	26
3	2.5016	10.5	0.7534	29
4	2.5015	8.4	0.7497	22
5	2.5007	8.1	0.7475	23
6	2.4986	9.9	0.7511	33
7	2.5012	9.5	0.7450	36
8	2.5023	9.2	0.7529	28
9	2.5016	7.9	0.7493	25
10	2.4984	8.3	0.7512	20

As apparent from Fig. 11 and Table 2, all the 10 channels are very stable, and the measurement resolution is consistent with the 1024-step resolution of the potentiometers, i.e. ±2.44 mV for V_d, and ±5.61 mV for V_g.

B. PHASE NOISE ANALYSIS

Phase noise analysis is generally provided by means of frequency stability measurements using the overlapped Allan deviation [16], [17], [18]. In this sub-section, the Allan deviation has been computed using the Symmetricom TSC5115A phase noise test set. The block diagram of the measurement setup is reported in Fig. 12.

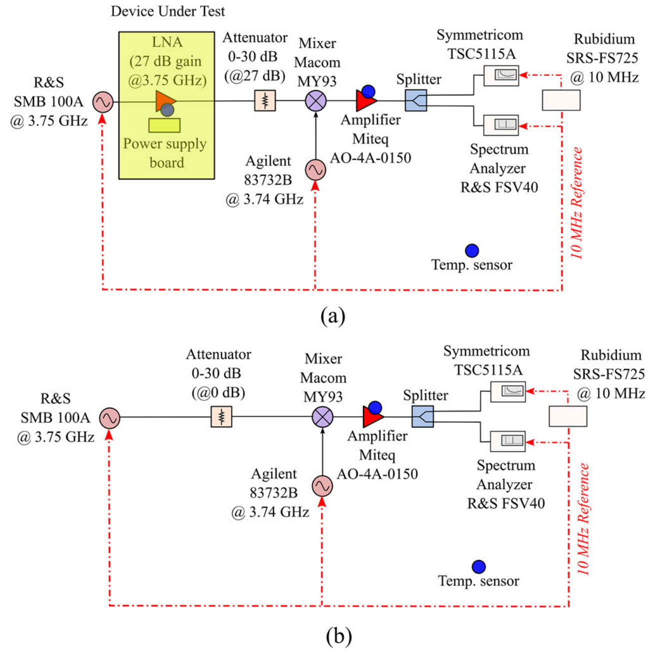

FIGURE 12. Block diagrams of the Allan deviation measurement setup: (a) the DUT is the GAIA board or the ALI-SRT board; (b) conditioning circuit (mixer and IF amplifier, without DUT).

A customized two-stage LNA for radio astronomy and space applications (operating between 2.2 GHz and 4.5 GHz with a nominal gain of 27 dB at room temperature and 1 dB input compression point IP1 equal to -40 dBm), has been biased either by the GAIA board or by the ALI-SRT board. This block is the device under test (DUT).

Then, a monochromatic RF signal at 3.75 GHz is generated using the R&S®SMB100A signal generator and injected in the DUT. The output of the LNA has been down-converted to 10 MHz and sent to one of the input ports of the Symmetricom TSC5115A. The other input of this instrument is a reference signal at 10 MHz, generated by the Rubidium Frequency Std. SRS FS-725.

A first measurement of the Allan deviation has been performed using the setup depicted in Fig. 12b, to evaluate the stability of the conditioning circuit (mixer and intermediate frequency (IF) amplifier, without the DUT). In this case, the variable attenuator is set to 0 dB to maintain the same operating conditions as in the setup for the stability measurement of the DUTs (Fig. 12a) wherein, conversely, the variable attenuator is set to 27 dB to compensate for the LNA gain at 3.75 GHz.

The measured Allan deviation of the DUTs and IF chain is shown in Fig. 13. Using the TSC5115A phase noise test set, we have performed a 60-minute measurement at the sampling rate of 1000 samples per second. During the experiment, the room temperature was in the range 28.6 – 28.9 °C. Accordingly, the observing averaging time is set to a

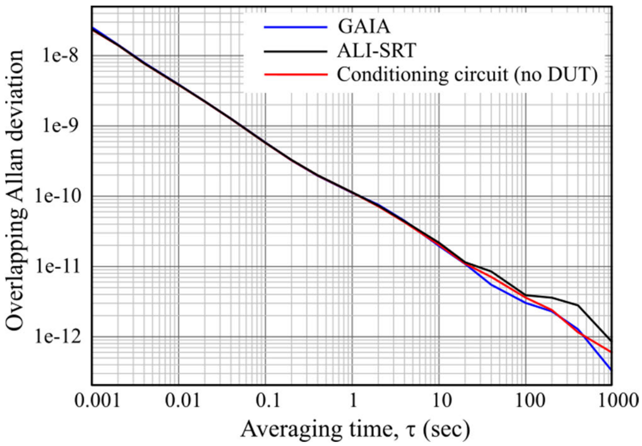

FIGURE 13. Frequency stability (Allan deviation) of the DUTs (LNA biased with GAIA or ALI-SRT) and of the conditioning circuit (mixer and IF amplifier without DUT).

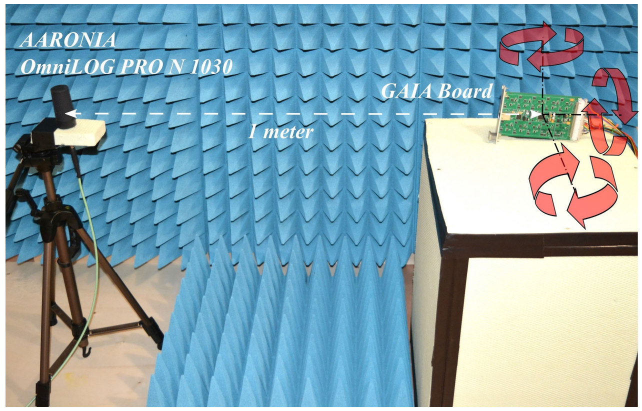

FIGURE 14. Measurement setup for the estimation of the GAIA board RFI emission.

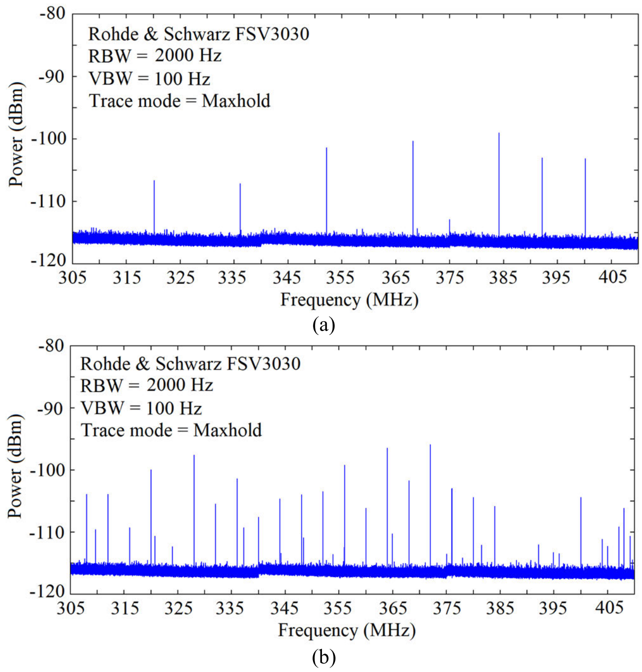

FIGURE 15. RFI emission in the P band of the: a) GAIA; (b) ALI-SRT board.

maximum of 1000 sec, which can be considered adequate for most radio astronomy and radio science experiments [2], [3], [19], [20].

The curves reported in Fig. 13 show both the small phase noise added by the DUT with the GAIA board, and comparable or better stability of the GAIA board with respect to the ALI-SRT board.

VI. RFI EMISSION

PCB equipped with MCUs are the source of unwanted radio frequency emissions, which could be significant at low frequency and up to the lower microwave bands (mainly P, L, S, and C frequency bands) and, therefore, they can also affect the signals received at these frequencies. In general, the frequency and the amplitude of the electromagnetic emission depend on the clock frequency of the board CPUs, on the architecture of the clock distribution networks, and also on the packaging and materials [21], [22]. Mitigation of RFIs, mainly in radio astronomy, is a critical aspect that should not be undervalued, since RF emission from external sources can seriously alter the received electromagnetic radiation and, in extreme cases, it could also damage the receiver.

The GAIA board, when used to power supply the LNAs of a radio telescope receiver, is installed in close proximity to the receiver feed aperture. If, for example, we refer to the LP receiver of the SRT [6], the distance between the feed aperture and the GAIA board is about 1 meter. In this context, the GAIA board has been designed to mitigate the RFIs as specified in the description of the layout (Section IV).

The evaluation of the RFI emission of the GAIA board has been performed in a shielded room using the Rohde & Schwartz FSV3030 spectrum analyzer connected to a broadband omnidirectional antenna (model OmniLOG®PRO N 1030 by AARONIA AG). The board under test is placed at a distance of 1 meter from the measuring antenna and rotated along x, y and z axes, while setting the spectrum analyzer in max-hold acquisition mode (see Fig. 14). To evaluate the ability of the GAIA board to mitigate the RFIs, using the same setup depicted in Fig. 14, we have performed a comparative experiment with the power supply system ALI-SRT, used so far to bias the LNAs of the SRT receivers. From a preliminary measurement, we have found that the emission of both the boards is below −125 dBm for frequencies greater than 1.8 GHz. Then we have compared in detail the emission of the boards in the P and L frequency bands of the SRT, i.e. between 305 and 410 MHz, and between 1.3 and 1.8 GHz, respectively.

As apparent from the spectrum in Fig. 15, the emission of the GAIA board in the P band is strongly reduced in comparison with the old solution, showing a significantly lower number of harmonics, with peak power 3 dB lower (−99 dBm *vs* −96 dBm). In the L band (Fig. 16), the emission

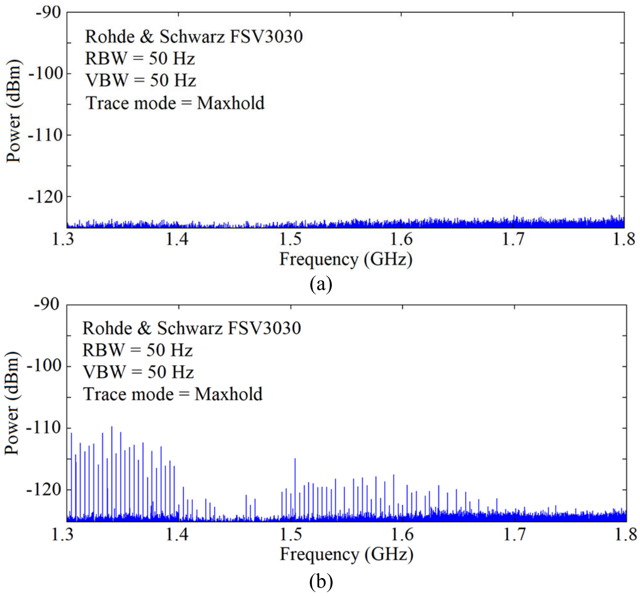

FIGURE 16. RFI emission in the L band of the: (a) GAIA; (b) ALI-SRT board.

of the old board is still significant, whereas the GAIA board emission is lower than −125 dBm.

VII. CONCLUSION

We reported on the design and performance of a power supply printed circuit board suitable for biasing LNAs of large radio telescope receivers. This 3-unit 4-layers PCB, named GAIA, features high amplitude and phase stabilities and will be employed for biasing and remote monitoring and control of the LNAs installed in the low-noise high-performance receivers of the 64-m diameter Sardinia Radio Telescope. It is able to control up to 10 V_d and 10 V_g, and monitor 10 V_d, 10 V_g, and 10 drain currents I_d.

The board firmware has been designed to enable a double function: besides power supplying the LNAs of a radio receiver dedicated to radio astronomy or space applications, the board can be employed for the bias optimization of custom LNAs and their laboratory characterization in terms of gain/noise figure vs. bias point.

The GAIA board has been designed to generate low RFI emissions. In this regard, it has been equipped with a low clock frequency microcontroller running a firmware optimized to handle low-complexity instructions. Moreover, all the board layers have been used for grounding to avoid ground loops and to provide an effective shielding of the internal traces.

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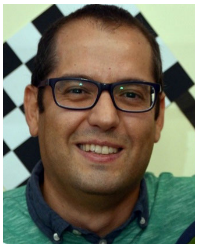

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