DESIGN OF ACTIVE WAVEGUIDE OMT FOR RADIO ASTRONOMY RECEIVER ARRAY IN THE 3 MM BAND

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Abstract

We describe the design of an integrated cryogenic receiver module based on an "active" waveguide Orthomode Transducer (OMT) for dual-polarization radio astronomy observations across 75-116 GHz (3-mm band). The receiver module consists of passive and active sections that can be incorporated in a very compact mechanical assembly suitable for integration in a focal plane array.

The passive section of the receiver module employs a broadband backward-coupler waveguide OMT while the active section consists of ultra-low noise MMIC (Monolithic Microwave Integrated Circuit) amplifiers.

Index Terms – Orthomode Transducer (OMT), MMIC, Low Noise Amplifier (LNA), integrated receiver, millimeter-wave radio astronomy.

I. INTRODUCTION

Orthomode Transducers (OMTs) are key components of dual-polarization receivers for radio astronomy [1]. An OMT has three physical ports but exhibits electrical properties of a four-port device. The input common port, usually a waveguide with a square or a circular cross-section, has two electrical ports carrying two orthogonal independent linearly polarized RF signals. Symmetric OMT structures allow achieving large relative bandwidth with $\Delta\nu/\nu_c$>30%. Wideband waveguide OMT designs that have proved to work well at millimeter wavelengths are based on Boifot junction [2], turnstile junction [3] and dual-ridge designs [4]. An OMT based on reverse-coupling waveguide junction was proposed in [5]. Here, we describe the design of a dual-polarization receiver module based on a waveguide OMT employing the broadband symmetrical reverse-coupling OMT structure presented in [6]. The OMT integrates MMIC LNAs (Low Noise Amplifiers,) designed and fabricated at IAF [7], and waveguide-to-microstrip transitions to be fabricated at IRAM.

This active waveguide OMT is developed in the framework of Work Package 1 of the AETHRA (Advanced European Technologies for Heterodyne Receiver for Astronomy) programme, aiming at investigating the new 35 nm gate length mHEMT (Metamorphic High Electron Mobility Transistor) technology for improving MMIC LNA performance. Our goal is to develop a prototype of dual-polarization receiver array and to install it on the focal plane of the IRAM 30-m radio telescope on Pico Veleta, Spain.

II. DESIGN OF THE DUAL-POLARIZATION RECEIVER MODULE

Fig. 1 shows the inner section of the symmetric reverse-coupling waveguide OMT described in [6]. The OMT consists essentially of: 1) a square waveguide input (size 2.54×2.54 mm^2) carrying Pol 1 and Pol 2; 2) a dual-step transition to rectangular waveguide output for Pol 1 (forward coupling); 3) two 90 deg hybrid couplers based on 3 dB E-plane branch-line waveguide coupling structures with four branches for Pol 2. The outputs of both 90 deg hybrid couplers are terminated with reactive loads so that Pol 2 input signal is backward coupled to two rectangular waveguide outputs parallel to the square waveguide input. The signals in the two Pol 2 rectangular waveguide outputs are out-of-phase and carry half of the power (-3 dB) of the Pol 2 signal in the square waveguide. The Pol 2 outputs are combined with a 180 deg power combiner (not shown).

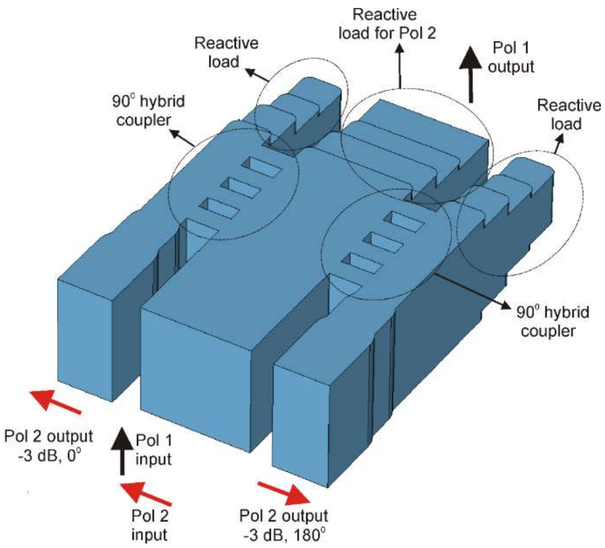

FIG. 1 – 3D view of the inner part of the symmetric reverse-coupling waveguide OMT. The incoming Pol 1 signal at the square waveguide input is forward-coupled to a single rectangular waveguide output through a dual-step transition. The incoming Pol 2 signal at the square waveguide input is backward-coupled to two rectangular waveguide outputs at 3 dB with 180 deg phase difference.

Fig. 2 and Fig. 3 show the block diagram and the design of the dual-polarization active waveguide OMT receiver module, respectively. The device consists of the "passive" OMT based on the backward coupler waveguide structure shown in Fig. 1 and of an "active" waveguide circuitry with MMIC LNAs packaged in a single mechanical module. The passive waveguide OMT utilizes a square input for connection to a dual-polarization feed-horn. The OMT separates the two orthogonal linearly polarized input signals in two independent waveguides with oval shape located inside the module (visible in Fig. 3).

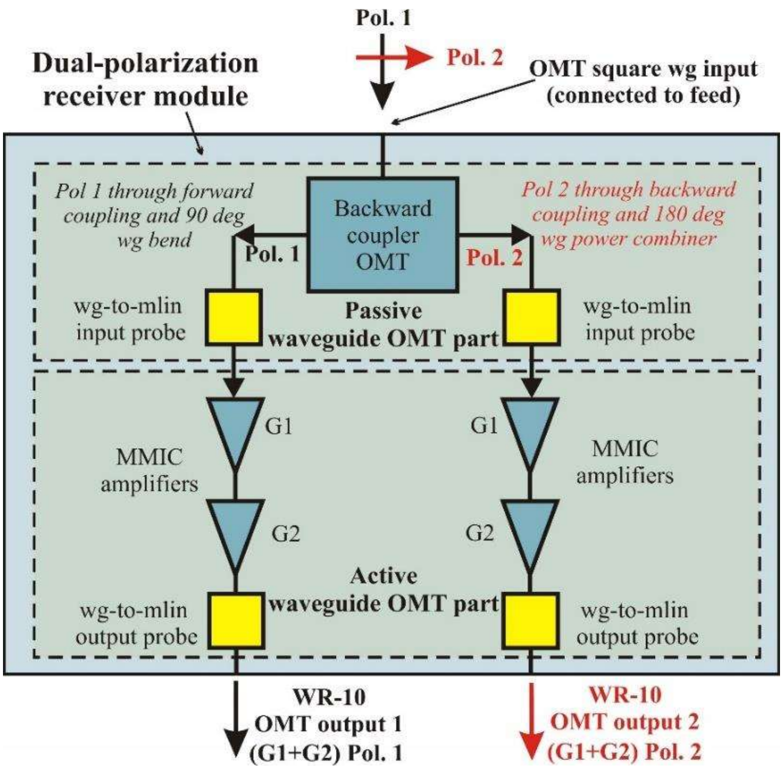

FIG. 2 – Block diagram of dual-polarization receiver module based on a passive OMT part and on an active part integrating MMIC LNAs.

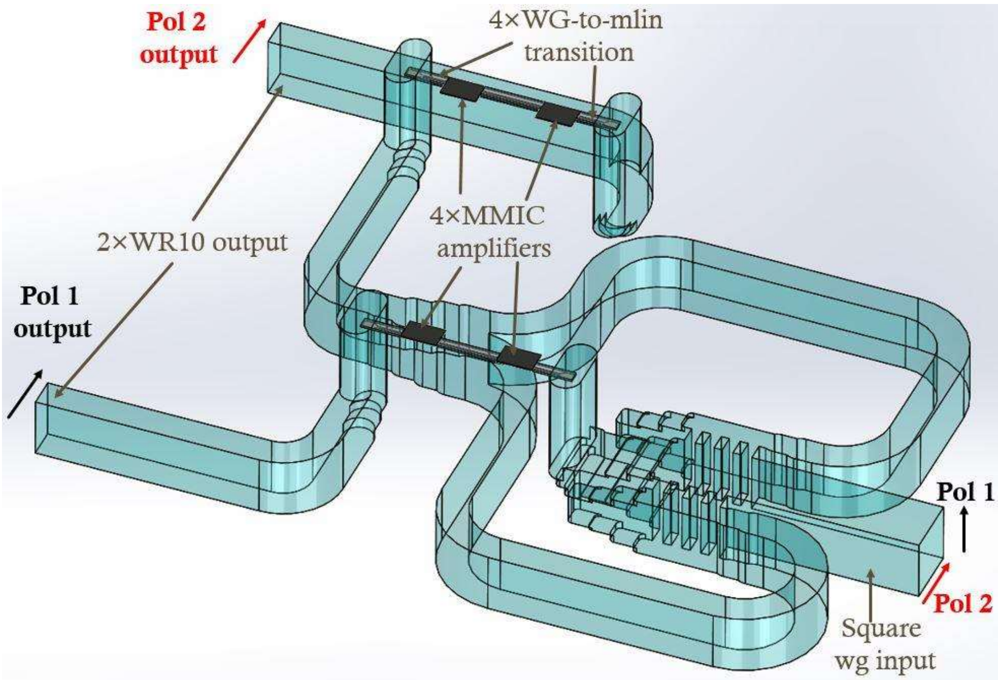

FIG. 3 – 3D view of the inner part of the dual-polarization receiver module showing the passive and active waveguide OMT parts, including the waveguide circuitries and the MMIC amplifiers. The square waveguide input at OMT input (on the figure right) has size 2.54×2.54 mm^2; it will be connected to a dual-polarization feed-horn. The two WR10 waveguides (2.54×1.27 mm^2) at OMT output with amplified Pol 1 and Pol 2 signals are parallel and in-line with the input.

Each polarization signals is coupled to the “active” circuitry consisting of a cascade of two MMIC amplifiers through waveguide-to-microstrip transitions based on quartz substrate with Gold beam-lead interconnection. The two MMICs of each cascade are interconnected through a microstrip line fabricated on quartz and located inside a channel. The signals at the output of the second MMIC amplifier of the cascade is coupled back to waveguide through a microstrip-to-waveguide transition. Sections of standard WR10 waveguides are used to route the signals amplified by the MMICs to suitable positions at the output of the module. The waveguide outputs are parallel and in-line with the waveguide input. Two amplified signals, one per polarization channel, are available at the WR10 waveguide outputs of the receiver module.
The dual-polarization receiver module shown in Fig. 3 can be fabricated in three mechanical blocks and assembled in a compact unit with external dimension 43×25×35 mm^3, thus allowing to mount two standard UG387 waveguide flanges at the device outputs. The waveguide circuitry of the OMT passive part would be incorporated in two of the mechanical blocks, while the active part in a single block of the three-block unit.

III. ACKNOWLEDGEMENTS

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