Design of passive microwave components for radio astronomy applications using HFSS

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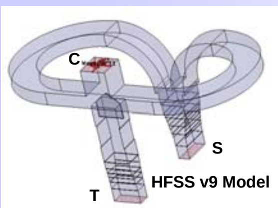
ABSTRACT

In this contribution the design of passive components for radio astronomy receiver front-end is presented. In particular three devices are shown: A 100GHz orthomode transducer, a 22GHz polarizer and a 22GHz circular waveguide coupler. The first device has been studied to demonstrate the potentiality of the electroformation for the fabrication of passive components at the higher frequencies of the microwave spectrum, in the framework of a project funded by the Italian Space Agency (ASI). The second and the third ones are prototypes developed in the sphere of the FARADAY radio astronomy project, funded by the European Commission. Both devices are designed for a 22GHz multibeam receiver to be installed in the under construction new Sardinia Radio Telescope. Preliminary tests highlight the validity of HFSS as a powerful design instrument for this kind of microwave components.

100GHz ORTHOMODE TRANSDUCER

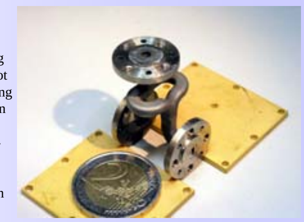


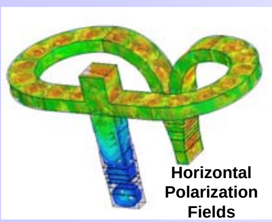
HFSS v9 Model

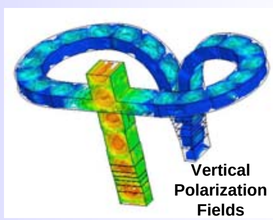
The OMT is based on the dual junction in rectangular waveguide introduced and accurately described by Bøifot. This design presents a thin septum and two matching pins, all these items would be too small at these high frequencies to be fabricated and to be mechanically stable. To make OMT fabrication possible the original Bøifot configuration has hence been here revised with the aim to avoid such critical mechanical parts. Basically a quite thick septum is adopted and the two side arm matching pins are eliminated. Matching is then attained via a pair of symmetrical E-plane steps. Four physical ports are present corresponding to five electrical ports: a common port C carrying both the Vertical and the Horizontal polarization, a side port S and a through port T.

A 0.1mm thickness septum has been used, constituting from an electromagnetic point of view a *finite thickness septum*. This have a significant contribution on the V-polarization channel, mainly in terms of return loss, and a symmetrical double E-plane step is used to control the input matching over about a 32% bandwidth. The septum shape is designed in order to have a good H-polarization return loss.

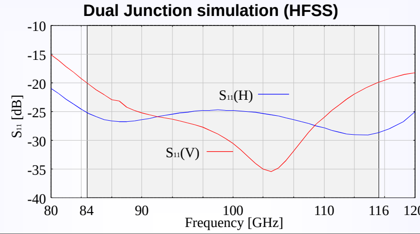
The dual junction has been designed by using Ansoft HFSS. In the design phase a return loss pretty better than 20dB was achieved for both polarizations (as shown in the S_{11} plots where the operative bandwidth is also highlighted.


Prototype. Court. of Media Lario S.r.l

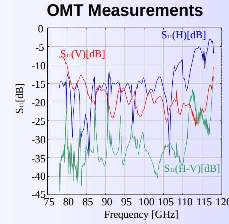

Horizontal Polarization Fields


Vertical Polarization Fields

Dual Junction simulation (HFSS)



OMT Measurements



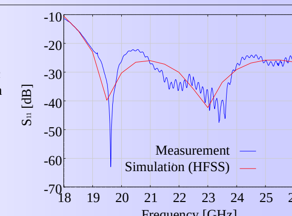
Reference

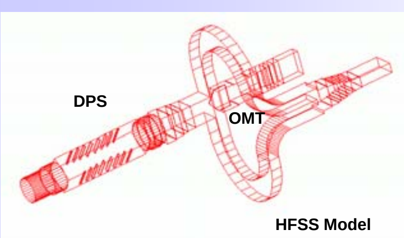
R. Banham, L. Lucci, V. Natale, R. Nesti, G. Pelosi, S. Selleri, G. Tofani, G. Valsecchi, "Electroformed Front-End at 100 GHz for Radio-Astronomical Applications," *Microwave Journal*, Vol. 48, No. 8, pp. 112-122, August 2005.

22GHz POLARIZER

A 22 GHz polarizer operating in the 18-26GHz band is here presented. The design aim is to obtain a quite broad band device to separate two incoming circular polarizations, the *Left Handed Circular Polarization* (LHCP) and the *Right Handed Circular Polarization* (RHCP), in two orthogonal linear polarizations being the output of two single moded WR22 standard rectangular waveguides. This device will be replicated in seven parts to constitute the heart of a seven elements array receiver to be used for the new Sardinia Radio Telescope (SRT).

The design has been decomposed into two parts: the *Differential Phase Shifter* (DPS) and the *Orthomode Transducer* (OMT). Each part design has been separately addressed and then transition sub-parts are used to connect them together. Most of the device has been developed with HFSS as the analysis tool. A prototype has been fabricated by direct machining aluminum material. Results concerning an accurate electromagnetic test of the device are presented.



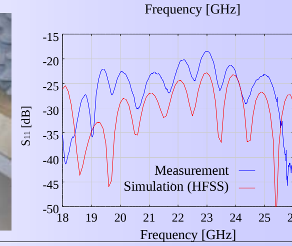


HFSS Model

OMT prototype

DPS prototype

Whole assembly under test



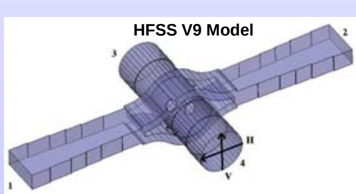
22GHz CIRCULAR WAVEGUIDE DIRECTIONALCOUPLER

A 22GHz Circular Directional Coupler (CDC) operating in the 18-26GHz band is here presented. The device is a microwave junction between a rectangular waveguide and a circular waveguide. The major requirement for the CDC is the broad band operation with high performances. The CDC can be placed between the feed horn and the polarizer allowing the coupling of reference signals. This device has been designed for a receiver array of seven elements to be installed in the new Sardinia Radio Telescope (SRT). With respect to the standard Rectangular Directional Coupler (RDC), the most important advantage in dual polarization systems, is that the required CDCs are half of RDCs. In this particular application a Circular Corrugated Horn (CCH) is used as first element of the front-end of each receiver of the array and a CDC can be attached directly at the CCH feeding waveguide. Instead RDCs have to be placed after the OrthoMode Transducer (OMT) were the channels are doubled, as the OMT splits the two polarizations of the common waveguide signal into two separate waveguides. Thus RDCs are two times the CDCs.

While this is not a problem for standard single-element receivers, in a seven-elements array, like the present one, the choice of CDCs instead of RDCs has a dramatic impact in the simplification of the reference signal distribution to the elements. A further advantage in this particular application, requiring system calibration by means of an appropriate reference signals, is that CDCs allow to calibrate also the polarizer.

On the contrary, the performances of CDCs are a bit worse with respect to the RDC ones. The coupling and isolation curves are less pretty flat and an amount of spurious cross-talk is introduced between the two orthogonal polarizations in the main branch.

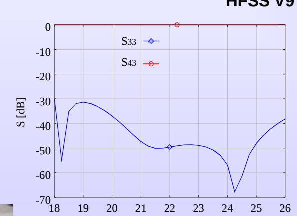
HFSS V9 Model

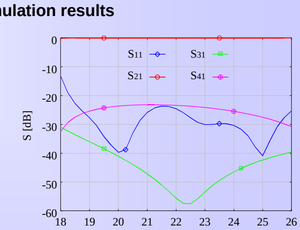


CDC prototype

Based on the electromagnetic model here shown the device has four physical ports (two rectangular 1, 2 and two circular 3, 4) corresponding to 6 electrical ports named 1, 2, 3V, 3H, 4V and 4H. Since circular ports allows dual polarization signals one vertical (V) and one horizontal (H), each polarization is assigned to an electrical port.The principal branch is assumed to be the circular waveguide, with port 3 connected to the horn and port 4 to the polarizer. The side branch is the rectangular waveguide, the reference signals are injected from port 1 and port 2 is terminated with a matched load. In this configuration the reference signal from port 1 excites only the V polarization in circular waveguide and port 1 is coupled to port 4V (reciprocally port 2 is coupled to port 3V).

HFSS V9 Simulation results





Measurements