# A Dual Linear Polarization Feed Antenna System for Satellite Communications

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**Abstract**— A dual lineal polarization feed antenna system for satellite communication will be described. It consists of a turnstile-based orthomode transducer (OMT) and two identical duplexers formed by a plane T-junction and of two iris filters. This 4-ports subsystem transmits and receives radio frequency signals in double track in which the transmission Tx is made through two ports having as access the standard rectangular waveguide WR229 while the reception Rx is made through two ports having as access the standard rectangular waveguide WR159. The proposed subsystem overcomes the current practical bandwidth limitations by using a very compact octave bandwidth OMT along with two robust duplexers. The subsystem is working in the extended C-band, the 5.8–7.1 GHz range is used for the uplink, whereas the 3.6–4.8 GHz range is set to the downlink. The presented architecture exhibits a return loss better than 20 dB in all ports, an isolation between the different rectangular ports better than 70 dB and a transmission loss less than 0.15 dB in both frequency bands (3.6–4.8 GHz and 5.8–7.1 GHz) which represents state-of-the-art achievement in terms of bandwidth.

## 1. INTRODUCTION

With the increased communication capacity and versatility of the antenna systems, an orthogonal dual polarization operation is often required. One of the key components for orthomode operation is the orthomode transducer (OMT) [1–4]. The OMT is a RF device often used to combine or separate orthogonally polarized signals, thus providing polarization discrimination. The double polarization systems are normally used for satellite communication systems, where an orthomode polarization operation is used to increase the traffic capability of a given link. Another interesting application can be found in the recipients of radio astronomy [1–4]. Unfortunately, most OMTs today are not fully satisfactory. For example, they may not be effective in preventing the generation of undesired higher order modes or providing sufficiently high isolation between ports or their often excessive bulk and thickness may impede many important applications. In [2–5] several configurations of OMTs have been published focusing on the physical symmetries of the structure and making clear the distinction between OMTs of narrow- and broad- band. The criteria used to compare the performance of the different OMTs are the return losses, the insertion losses and the isolation between polarizations which is associated to the specifications of the cross-polarization for the system including the antenna and the feeders. In addition, the symmetry is a key question in the design of OMTs since it determines the high order mode generated in the structure and, therefore, the bandwidth of work.

Our main aim in this work is to increase in the quantity of information to be transmitted or received for solving the saturation problems of the available spectral bands. We solved this problem in two different ways: either by the widening of the frequency bands available of the subsystems, or by the use of the double ways for Tx and Rx by using the orthomode polarization operation to increase the traffic capability of the link, or by both of them at the same time. For this reason, we have used a waveguide OMT based in a turnstile junction [5, 6] which provides a good return loss (30 dB) along with an isolation of 60 dB across a very broadband frequency (2 : 1). The very wide bandwidth is achieved mainly due to the use of a double symmetry turnstile junction reduced height waveguide arms along with the use of a reduced height $E$-plane power combiners/dividers and simple mitered 90° bends. This facilitates the design and the construction of these OMTs. Moreover, two wideband diplexers have been designed and constructed to demonstrate the feasibility of using stepped waveguide junctions for duplexer designs. It consists of two channel filters and a Tee $E$-plane junction. The relative bandwidth of the whole diplexer is about 64%. The inputs and outputs return losses were better than 25 dB, the isolation is better than 80 dB and the transmission loss was less than 0.1 dB. Furthermore, experimental measurements of the whole 4-port subsystem (see Fig. 1 for the proposed 4-ports subsystem) exhibit very good agreement with the simulation results.

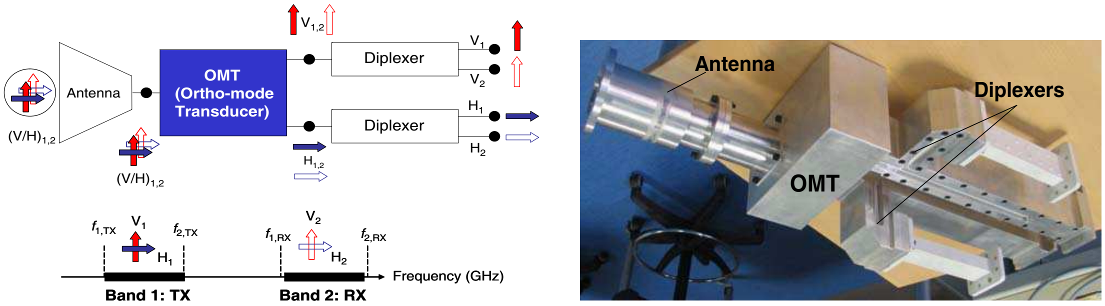


Figure 1: Extended C-band feed assembly and block diagram: dual-polarization horn antenna, proposed OMT and two diplexers.

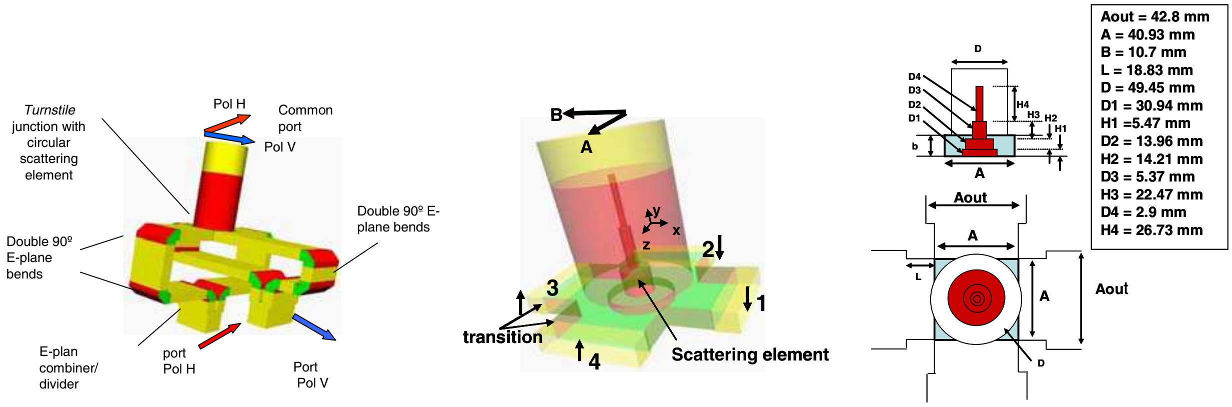


Figure 2: Turnstile junction OMT: internal structure of the complete OMT (left), turnstile junction side view and top view (sketch and dimensions).

## 2. THEORY AND DESIGN

### 2.1. A-Turnstile Junction Orthomode Transducer (OMT)

The turnstile junction OMT is working according to the following manner: signals split by the turnstile junction exit in opposite waveguides 180° out-of-phase. These signals are recombined using a power combiner that is also 180° out-of-phase; implemented using a single step $E$-plane divider assures 3 dB/180° power division in more than one octave bandwidth operation along with $-50$ dB return loss at the input port. In the first design we have used one input step divider which allows to increase the waveguide height in order to obtain reduced height waveguide ports in the outputs divider [5]. We have used the easiest form divider which provides an extremely good result in contrast to other [2–4] full height combiners in which multi-step transition is necessary to obtain a full height at the output ports combiner. For each polarization, a pair of identical 90 $E$-plane single mitred waveguide bends in reduced height configuration link, from the turnstile junction outputs to the $E$-plane junction inputs, can be easily designed for return loss better than 48dB in more the 68% bandwidth. A matching element may be provided at the base of the cavity formed by the rectangular waveguide ports and the main waveguide to enhance a very wide band operation of the turnstile junction with a low reflection coefficient.

**Figure 2** shows an internal view of a four-section reduced- height turnstile junction. The internal diameters and heights of the scattering element are optimized for a specific frequency band as a function of the rectangular input waveguide dimension "$a$". The number of cylindrical sections can be reduced if the application needs a restricted band. The optimisation procedure aims for good return losses for the two orthogonal modes $\mathrm{TE}_{11}$ at the common circular waveguide. Two fundamental modes (designated as A and B) can propagate in this circular guide as independent orthogonal linear polarization states when the frequency is above the cutoff frequency value (frequencies above 3.5 GHz). The turnstile junction splits A equally between the reduced-height rectangular waveguide outputs 2 and 4, but does not couple it to ports 1 and 3. Similarly, B is split equally between ports 1 and 3, but does not couple it to ports 2 and 4. The operating mode is explained according to Fig. 3. Taking as example the vertical polarization with the polarized electric field according to

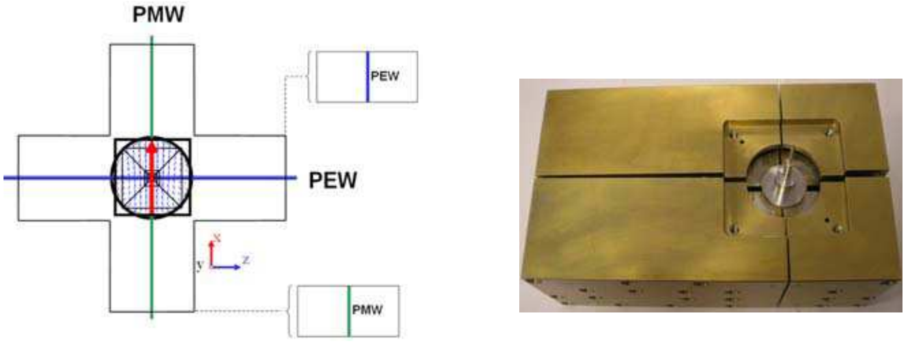
$x$-axis, the only modes generated in the junction are those with symmetry of the perfect magnetic wall (PMW) in the plane $xy$ and those with symmetry of the perfect electrical wall (PEW) in the plane $yz$.

In the PMW rectangular ports propagate the $TE_{10}$ fundamental mode over a bandwidth of almost 76% before the excitation of the first higher order $TM_{11}$ mode. The first higher order mode excited in PEW rectangular ports is the $TE_{20}$ mode (which appears in 66.66% of bandwidth from the fundamental mode $TE_{10}$).

If we can match the incident $TE_{11}$ mode, from which the electric field is polarized according to the $x$-axis Fig. 2, all the power will be divided between ports 2 and 4 with no power coupled to ports 1 and 3. This operation is valid between the cutoff frequency of the fundamental $TE_{10}$ mode of the rectangular waveguide and the first higher order mode $TE_{20}$ excited in the rectangular ports 1 and 3 (PEW). Therefore, the maximum bandwidth that a turnstile junction can achieve is an octave bandwidth $((F_{cTE_{20}}/F_{cTE_{10}}) = 2)$. Due to the symmetry of the turnstile structure, the behaviour is the same for the other incident $TE_{11}$ mode, in which the electric field is polarized according to $z$-axis. Apart from the fundamental $TE_{11}$ mode propagated in the circular common port, the first higher order mode propagated in the common circular port is the $TM_{11}$ mode, which existed in 72.6% bandwidth from the fundamental $TE_{11}$ modes.

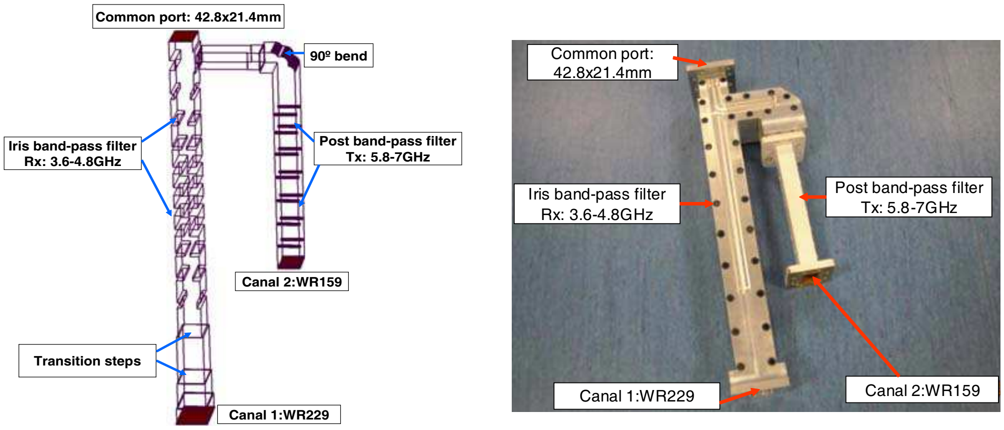
### 2.2. B-Diplexers

Basically the structure of the diplexer consists of a T junction $E$-plane, and two band-passes filters one for the Tx and the other for the Rx. Fig. 4 shows an internal view of the total diplexer. The rectangular common port dimensions of the diplexer are $42.8 \times 21.4\,\text{mm}$ ($fc = 3.5\,\text{GHz}$) which allows the propagation of $TE_{10}$ mode in the whole frequency band 3.6–7 GHz, where the Tx port is in standard waveguide WR159 ($fc = 3.7\,\text{GHz}$) and the Rx one is in standard waveguide WR229



(a) (b)

Figure 3: Operating mode of the (a) turnstile junction and (b) designed OMT. External dimensions are $240 \times 140 \times 94\,\text{mm}^3$.



(a) (b)

Figure 4: (a) Internal structure and (b) designed diplexer.

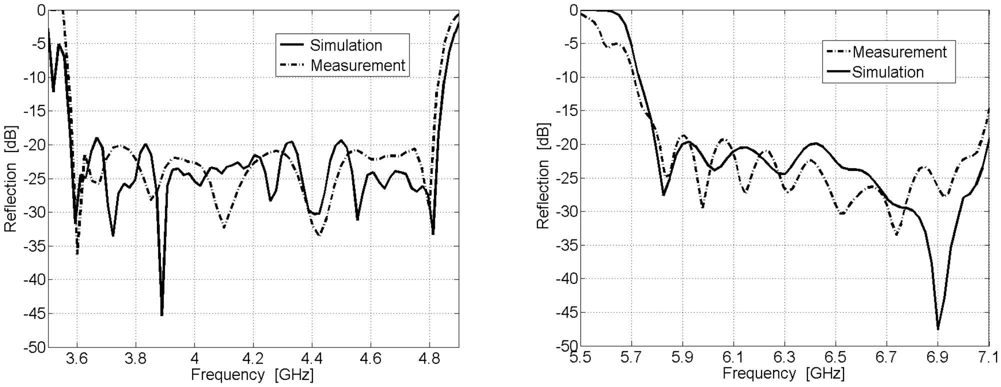


Figure 5: Measured and simulated reflection coefficients of the designed 4-ports subsystem in both Rx band (3.6–4.8 GHz) and Tx band (5.8–7 GHz).

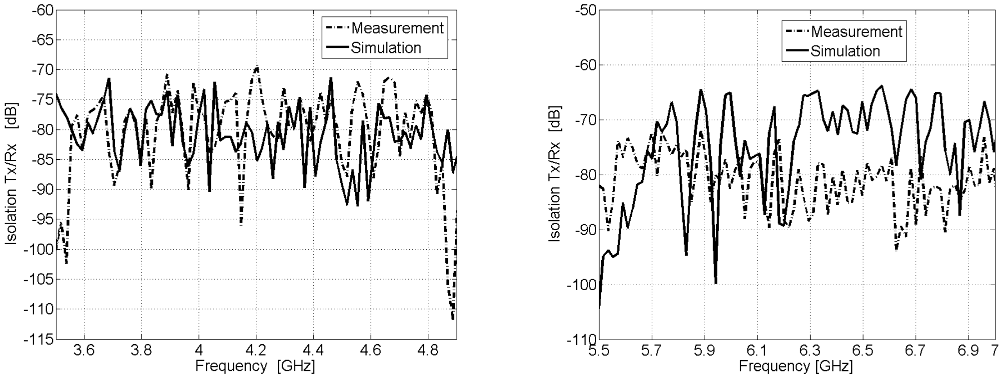


Figure 6: Measured and simulated isolation Tx/Rx in both bands.

($fc = 2.57$ GHz). The relative bandwidth of the whole diplexer is about 64%. The channel of filter 1 (Tx) has a relative bandwidth of 19% and the channel of filter 2 (Rx) has a relative bandwidth of 29%. The filter of the high frequency band (Tx) is based in rectangular waveguide with inductive cylindrical posts and the other of the low frequency band is made in rectangular waveguide with inductive irises. Both filters are well matched; provide a return loss better than 25 dB in case of the low band and 35 dB in the high band along with an insertion loss less than 0.05 dB in both bands. In order to have a TX and RX access in the same plane, we have used a 90° $E$-plane bends with small curves that exhibit a return loss better than 42 dB.

## 3. SIMULATED AND MEASURED RESULTS

In Figs. 5 and 6, we illustrate the comparison between the measured and simulated results of the whole 4-ports subsystem depicted in Fig. 1. In these graphs, we can observe that the return loss in the various ports of the system is better than 20 dB and the isolation is better than 70 dB. The measured insertion loss does not exceed 0.15 dB in the two frequency bands of interest.

## 4. CONCLUSIONS

The electrical and mechanical design along with the measurements of very broadband 4-ports feed antenna is presented. Experimental data shows a return losses better than 20 dB in both Tx and Rx bands included in the 3.6–7 GHz (64% bandwidth) and an isolation between Tx and Rx ports better than 70 dB along with an insertion losses lower than 0.04 dB in the two separated bands of interest. To date, the designed OMT has the best measurement performance reported in literature along with a reduced size (very challenging for this type of structures), being a more robust design than devices existing previously. These OMTs are well-suited to very wide bandwidth and very separated dual band applications with good performances and good manufacturability mechanical tolerances.

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## ACKNOWLEDGMENT

This work was supported by the Ministerio de Educacion y Ciencia (Spain), Plan Nacional de I+D+I, Astronomy and Astrophysics program AYA2007-68058-C03-03, and the FPI grant BES-2005-6730. The authors like to thank Spanish MICINN and AECID through their codes TEC-2008-06684-C03-01, CSD2008-68, and D/018607/08 for their human capital support. The authors wish also to thank the staff of the Spanish Agency for International Development Cooperation (AECID).

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