INTERNATIONAL JOURNAL OF MICROWAVE AND OPTICAL TECHNOLOGY

VOL. 3, NO. 3, JULY 2008

20/30GHz compact dual band circular polarizer for satellite feed systems

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***Abstract*- A compact solution for a dual band OMT polarizer that avoids the use of additional iris loaded corrugated sections is discussed here. The proposed device is based on a conventional septum type polarizer-OMT in waveguide technology covering two separate bands, were an extension of its normal (rather narrow) frequency band of operation has been achieved to meet restringing specifications for the 20/30 GHz 5% fractional bandwidth satellite link communication bands. The septum type OMT-polarizer consists of three physical ports: two of them in rectangular waveguide and another common port in circular or square waveguide. A given signal coming from a rectangular port is split into two 3dB orthogonal signals at the common port with a time delay of 90º between them. This produces a circular polarized signal: a RHCP associated to one of the rectangular ports and a LHCP associated to the second rectangular port. This compact design exhibits good return losses (>25dB) at the rectangular and circular ports as well as high isolation (>40dB) between modes. Furthermore, axial ratio is kept as low as 0.5dB in both communication bands.**

***Index Terms*- Septum polarizer, circular polarization, satellite communication.**

*** (A preliminary report about this manuscript has appeared in ISMOT'07)**

I. INTRODUCTION

Several technologies are currently used to excite high purity left-hand or right-hand circular polarizations in a circular waveguide. The association of several distinct devices such as orthomode transducers (OMT), polarizers and square-to-circular waveguide transitions is too bulky for tightly packed feed arrays. The septum polarizer is a well-known device, widely employed in satellite antennas, which combine in a single element the functions of orthomode transducer and polarizer, thus reducing volume and weight.
The septum polarizer (SP) is a four electrical ports device as illustrated in its basic form in Fig2. The square waveguide at one end consists of two ports because it can support the two orthogonal modes. A stepped septum divides the square waveguide into two standard rectangular waveguides sharing a common broadwall. With a properly designed septum, this device has interesting and useful properties.

A signal fed into one of the rectangular waveguide ports is transformed into a circularly-polarized field in the square waveguide, hence the name "septum polarizer". A field component parallel to the septum transforms into two odd-mode signals in the rectangular ports, while a perpendicular component transforms into even-mode signal. If both components coexist simultaneously, cancellation can occur in one rectangular port, provided the amplitudes are identical and the phases are correct. The septum region is equivalent to single-ridged waveguide for the vertical component, whereas the horizontal component remains unaffected by the septum (other than that it is split into two equal parts of the septum). The vertical component

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propagates at a slower phase velocity than the horizontal component, because the ridge lowers the cutoff frequency. This means that β_v (vertical) $\succ \beta_h$ (horizontal). Therefore the vertical component of the input circular polarized field is delayed relative to the horizontal. By designing the septum to make this differential delay equal to 90º, the two resulting fields cancel completely in the one of the rectangular ports, and add to the other. Thus, RHCP couples only to one rectangular port, and similarly the LHCP couples only to the other rectangular port.

The basic H-plane sloping-septum polarizer was studied experimentally several years ago [1], [2] and thus the concept of stepped-septum in square waveguide technology is well known for its application as orthomode transducer [3] and polarization measurement equipment [4]. A critical aspect for this design is the achievement of low input reflection values for the TE10 and the TE01 modes as well as a 90º phase shift between the two orthogonal electric field components. The first design published [3] satisfied the input reflection criteria but required an additional dielectric-slab phase shifter to adjust the phase difference. Consequently, later designs, which were based on scaling of dimensions [3] but lacking the component for phase adjustment, failed to produce an acceptable phase response [5].

The phase linearization of this component has been attempted by adding a corrugated waveguide polarizer [6]. Results for a five-step design without additional phase adjustment are presented in [7], and an investigation on stepped septums in a circular waveguide enclosure is reported in [8]. A stepped notch design based on the ridge waveguide short-end effect is shown to produce too much phase variation [9] over an acceptable bandwidth of ten percent. Another stepped-ridge waveguide polarizer [10] discussed the optimization of the septum thickness over a bandwidth of twenty percent.

The similarity between dual-mode filters and polarizers has been pointed out in [11] and remains as a solution being commonly adopted for ease design and manufacturing of circular feeds [12]. A further design of wide-band waveguide SP considered a full wave analysis and optimization of the transition between the rectangular (bifurcation and edge waveguide) and the transition (square to circular waveguide) is presented in [13], and more recently a study of a developed CAD for SPs having a circular output waveguide by using the mode-matching analysis technique and the moment method is reported in [14].

In this paper we present an alternative design septum polarizer which differs from the other by demonstrating to work in dual band achieving extremely good results in both of them, return losses (>25dB), high isolation (>40dB) between modes. Furthermore, axial ratio is kept as low as 0.5dB in both communication bands. To achieve axial ratio over a broad bandwidth or over two widely separated bands, the septum configuration is the preferred approach shown in Fig.1.

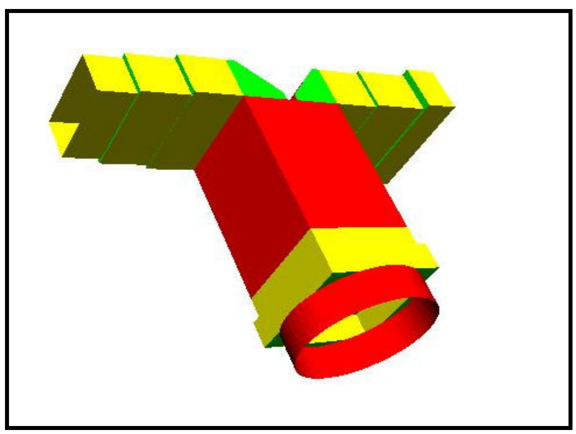

Fig.1. 3D model of the dual-band septum OMT Polarizer

II. CIRCUIT DESIGN

In order to meet link requirements, the septum structure is formed by, Fig.2, five

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decreasing sections having an internal thickness of 1mm. Fig.3 shows the performances of such subsystem in terms of return losses and isolation. Two E plane 90º bends, two simple stepped rectangular impedance transformers: one towards the standard waveguide dimensions WR28, Fig.4, and the other towards the lower band WR42, Fig.5, output waveguides along with a carefully designed squared to circular waveguide transition for the common port complete the polarizer design.

A square cross-section was used because it has been usually preferred for broadband applications [15]. The use of a square waveguide polarizer is recommended in dual-band applications even to excite conical horns where an additional squared to circular waveguide transition, Fig.6, has to be included [16].

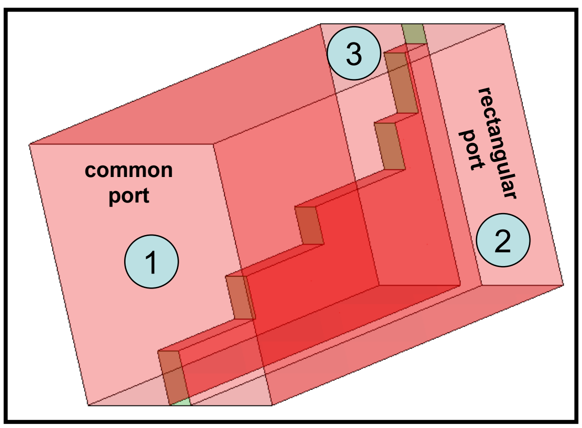

Fig.2. 3D view of the internal structure

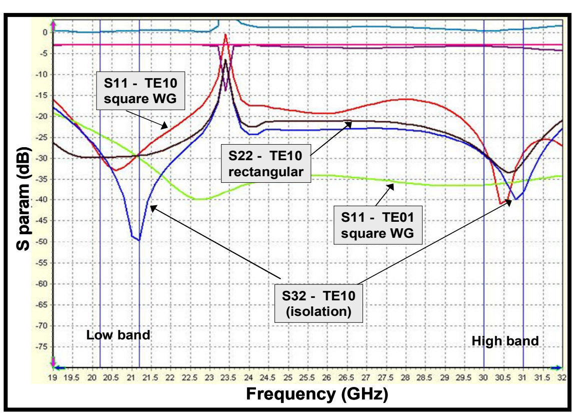

Fig.3. Multi-stepped Septum: Simulated performances

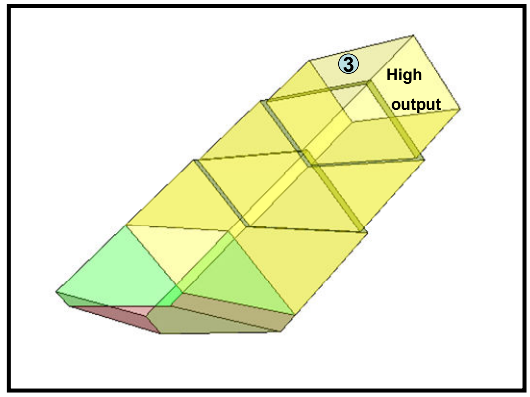

Fig.4. WR28 output waveguide: High band frequency

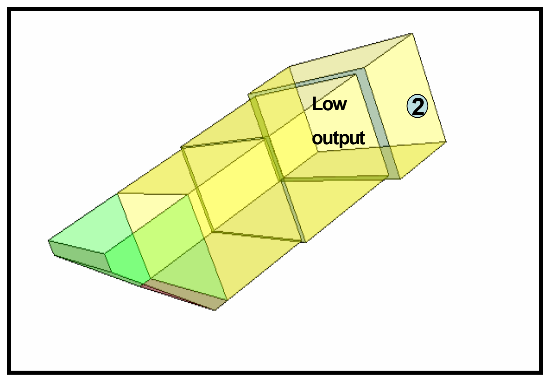

Fig.5. WR34 output waveguide: Low band frequency

Using Mode matching techniques implemented in MICIAN software, right angle waveguide bends and waveguide transformers are optimized at its own frequency band. Conversely, the squared to circular transition is designed in the sense of dual band operation.

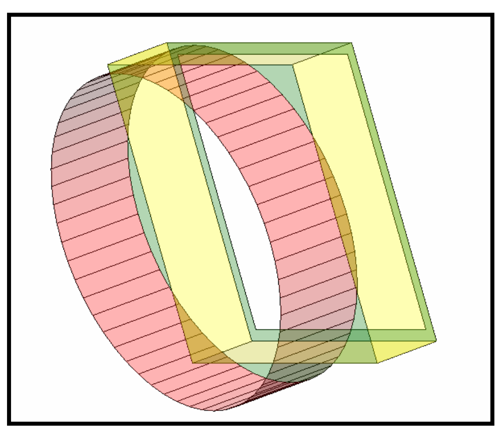

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Fig.6. Squared - circular waveguide transition for the common port

The main advantage of this design is that all the fixed objectives can be achieved with a compact structure. Traditional designs based on Turnstile Junction, multiport feed to circular waveguide or conventional OMTs need to include the corresponding differential phase shifter at the output thus making the structure much more complex and critical against fabrication tolerances. Another proposals as a dual band/wide band waveguide polarizer based on iris or corrugated configuration whose design can seem easier, it would have the disadvantage in front of the proposed solution to need a lot of more physical space to achieve the same results.

III. EXPERIMENTAL RESULTS

The circular polarized was constructed by dividing the structure of Fig.1 into two main blocks. This allows an easy milling path for the main body. Furthermore, electroforming techniques were used for the impedance transformers as well as for the square to circular transition.

Fig.7 shows the obtained performances at the rectangular ports. An intrinsic isolation between input ports is found because the WR28 port is bellow cutoff for the 20GHz band.

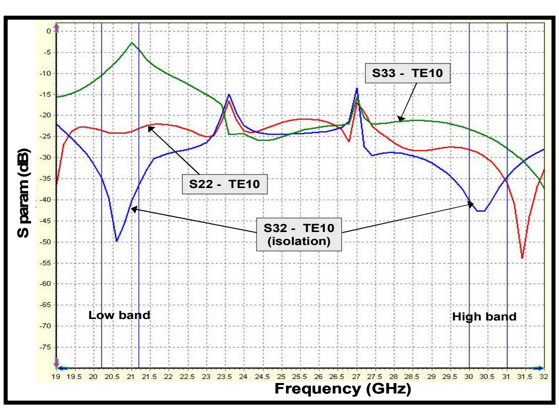

Fig.7. Polarizer performance at the rectangular ports

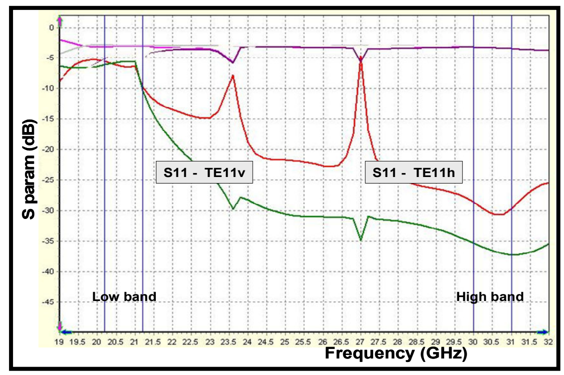

Fig.8. Polarizer performance at the circular ports

In Fig.8, TE11 circular mode performances are shown. Return losses better than 25dB have been achieved in the high frequency band and around 6dB have been achieved in the low frequency band respectively. These can be explained by the fact that in the low frequency band the high frequency port (WR28) is considered as a short circuit because the waveguide WR28 is below cutoff frequency, hence the device behave like a three port network (impossible to match the three port at the same time). In contrast, in the high frequency band the device is considered as a four ports network (simultaneous matching can be obtained at the four ports at the same time).

Finally an axial ratio as low as 0.5dB has been obtained, Fig.9, which means a cross polarization better than 31dB.

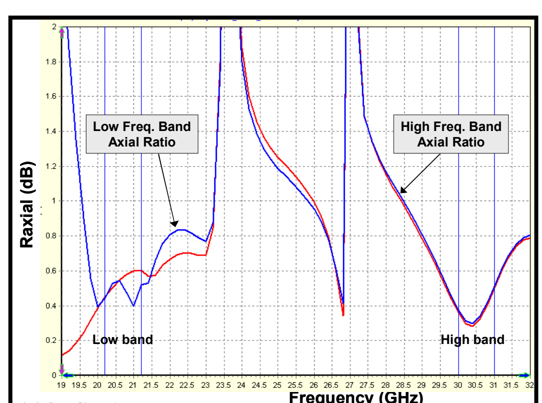

Fig.8. Axial Ratio of the septum polarizer

To estimate the degradation in the performance that mechanical errors would cause, numerical simulation with ±0.05mm tolerances in both bands were performed. Fig.9 shows the simulation of the overall device by applying these errors to all variables present in the geometry of the component. We found that in the worst case the return loss do not exceed -21dB.

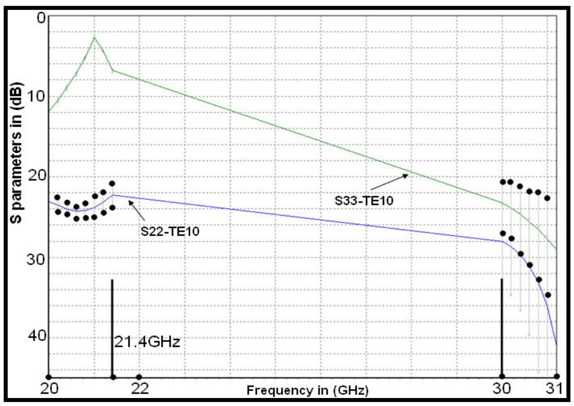

Fig.7. Yield analysis with ± 0.05 mm tolerances

VI. CONCLUSION

A compact solution for a dual band OMT polarizer that avoids the use of additional iris loaded corrugated sections has been designed and fabricated. The achieved performance indicates that the proposed structure is very useful for compact dual polarizers, especially for very distant frequency bands.

An interesting property of the proposed compact OMT-polarizer is that it can be easily designed, and therefore a very compact antenna feed system without any additional taper can be easily achieved.

The structure meets all the restringing requirements for satellite link feeders both in terms of performances and cost.

ACKNOWLEDGMENT

The authors would like to express their gratitude to the Spanish Agency AECI though its program “Becas para Extranjeros No Iberoamericanos para Estudios de Postgrados,Doctorado y Postdoctorado en Universidades y centros superiors en España ”.
Also, the authors would like to think to the Spanish Ministerio de Educación y Ciencia for help the PCI-A-3566-05 and PCI-A-4238 2006-projects.

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