SEPTUM POLARIZER DESIGN FOR ANTENNA FEEDS PRODUCED BY CASTING

Jens Bornemann and **Smain Amari**

Laboratory for Lightwave Electronics, Microwaves & Communications (LLiMiC)
Department of Electrical and Computer Engineering
University of Victoria, Victoria B.C. Canada V8W 3P6

I. INTRODUCTION

The original septum polarizer design by Chen and Tsandoulas[1] has found many applications, e.g. [2] - [4], and some modifications, e.g. [5] - [7]. As is obvious from these references, a fair amount of numerical modelling procedures is required to reliably estimate the component's performance with respect to return loss, isolation and axial ratio. Consequently, previous design guidelines have been developed under conditions which simplify the analysis procedure. Those are constant housing dimensions, a constant thickness of the septum, and the noticable absence of any matching elements at the two rectangular waveguide input ports. Only recently has a varying septum thickness been considered [8] in order to keep the overall design short.

In practice, however, many septum polarizer components are manufactured by casting. A parameter inherent to this production process is the draft angle, which leads to a linear reduction of housing dimensions with component length and which has been neglected in many polarizer designs over the years. With 25 dB return-loss/isolation and 0.5 dB axial-ratio specifications, however, the draft angle can no longer be neglected, since a slight increase in, e.g., septum thickness can already result in a considerable performance degradation [8].

Therefore, this paper takes the casting manufacturing process fully into account. Moreover, a matching transformers are incorporated under the same restrictions (Fig. 1).

II. THEORY

The method of analysis used is mode matching in its generalized impedance matrix form, and optimization is carried out by evolutionary strategies. For details, the reader is referred to [8].

According to Fig. 2, the septum polarizer is first modelled by assuming a single step per individual polarizer section. Due to the draft angle, the cross-section areas decrease from left to right, and for given section lengths, the housing and septum dimensions are taken as the average between the larger and smaller values.

For given aperture dimensions $a_a x b_a$, minimum septum thickness t_{min},draft angle α (Fig. 2) and number of polarizer sections, the polarizer (without transformer) is optimized with lengths $l_{(i)}$ and slot widths $s_{(i)}$ as parameters, respecting the successive change of cross-section dimensions during optimization. While $a_{(i)}=b_{(i)}$ throughout the polarizer section, these quantities differ in the transformer section, once an initial transformer has been designed [9] to match the two polarizer input ports to the feeding rectangular waveguides of apertures $a_f x b_f$. Note that the discontinuity, which exist at the junction to the feeding waveguides is incorporated in the transformer design and in all subsequent analyses. The maximum overall length L_{max} is given by specifying the antenna port $a_a x b_a$ and feeding waveguide $a_f x b_f$ cross-sections since

$$L_{max} = \min\left\{ \frac{b_a - a_f}{2\tan\alpha}, \frac{a_a - 2b_f - t_{min}}{4\tan\alpha} \right\} \quad (1)$$

However, since approximately a quarter-wavelength section is needed for at least a single transformer section, the maximum allowable length for the pure polarizer has to be reduced accordingly.

Once this design has been completed, i.e. a design with the minimum amount of staircasing has been reached (a five-section design for the example in Fig.2), the individual sections are further subdivided, such that, e.g. in Fig. 3,

$$s_{(k)} = s_{(k-1)} - [l_{(k-1)} + l_{(k)}]\tan\alpha \quad (2)$$

in order to check the convergence with respect to the continuously varying dimensions owing to the draft angle. At this point, it is expected that the performance slightly decreases, as certain discontinuities, which were previously (in the optimization process) used to compensate for unwanted higher-order mode effects, are now disappearing. (It is well known, e.g. [10], that, within a certain frequency range, a well-designed stepped approach can outperform continuous tapers.)

III. DESIGN EXAMPLE

We refrain from presenting validation of the software code, as this has been demonstrated before, e.g. [8] - [10]. Instead, we focus on an example showing the different stages of the design.

Let us assume that 25 dB return loss / isolation and 0.5 dB axial ratio are specified for a five-percent bandwidth centered at 19.25 GHz under the restriction of a one-degree draft angle and a 0.5 mm minimum septum width. Since the polarizer must operate between TE_{10}- and TE_{11}-mode cutoff, the antenna port cross-section is chosen as 10 mm x 10 mm. The cutoff frequency of the feeding waveguides can only be slightly higher for dispersion reasons (e.g. a_f=9 mm), and reduced-height waveguides are assumed (e.g. b_f=2.25 mm). Given the maximum length according to (4) and assuming that a single quarter-wavelength transformer section will be sufficient, the maximum number of polarizer (ridge waveguide) section is set to three. After scaling initial parameters from [8], optimization, the incorporation of a single transformer section and its matching to the polarizer ports under draft-angle consideration, a three-step septum polarizer satisfying the specifications is obtained. However, this is still a design consisting of fivehomonegeous cross-sections (c.f. Fig.2).

Figs. 4 finally demonstrate the influence of better staircase approximations (nine and 17 steps, according to Fig. 3) of the draft angle on the polarizer performance. It is observed that the return loss is reduced but also broadened. Isolation and axial ratio vary slightly according to the interactions of the different discontinuities involved in finer staircasing. However, even with the 17-step approximation, the performance is well within specification. The final polarizer dimensions are given in Table I. Since all presumably horizontal lines in Fig. 2 run at the same one-degree angle, other dimensions can be calculated immediately. Note that the values given in Table I are those at the centers of the individual sections and that a housing step for the transformer is only required in the a-dimension, i.e. is only visible in the top view, whereas housing lines in the side view continue. Finally, once all dimensions are recalculated from Table I and Fig. 2, there will still be a discontinuity left between the polarizer input cross-sections and those of the feeding waveguides. Note that this discontinuity is part of the design, as it has been considered in the design and analysis process.

Table I: POLARIZER DIMENSIONS (mm)

$a_a=b_a=10.0$ $a_f=4b_f=9.0$
$t_{min}=0.5$ $\alpha=1^o$
$s_{(1)}=7.736$ $l_{(1)}=5.442$
$s_{(2)}=5.539$ $l_{(2)}=5.404$
$s_{(3)}=3.094$ $l_{(3)}=2.399$
$s_{(4)}=0.000$ $l_{(4)}=1.001$
$a_{(5)}=7.357$ $l_{(5)}=7.250$

IV. CONCLUSIONS

A design strategy for septum polarizers to be fabricated by casting is presented. A mode-matching analysis and evolution-based optimization is used to optimize the component and matching transformers, which are first roughly stepped to represent the draft angle. The influence of further staircasing is shown to be minor, so that the component performs according to specifications. A 19 GHz design example with ready-to-built dimensions is presented.

REFERENCES

[1] M.H. Chen and G.N. Tsandoulas, "A wide-band square-waveguide array polarizer", *IEEE Trans. Antennas Propagat.*, Vol. AP-21, pp. 389-391, May 1973.

[2] H.E. Schrank, "Polarization measurements using the septum polarizer", in *1982 IEEE AP-S Int. Symp. Dig.*, pp. 227-230.

[3] T. Ege and P. McAndrew, "Analysis of stepped septum polarisers", *Electronics Lett.*, Vol. 21, pp. 1166-1168, Nov. 1985.

[4] J. Esteban and J.M. Rebollar, "Field theory CAD of septum OMT-polarizers", in *1992 IEEE AP-S Int. Symp. Dig.*, pp. 2146-2149.

[5] N.C. Albertsen and P. Skov-Madsen, "A compact septum polarizer", *IEEE Trans. Microwave Theory Tech.*, Vol. MTT-31, pp. 654-660, Aug. 1983.

[6] R. Behe and P. Brachat, "Compact duplexer-polarizer with semicircular waveguide", *IEEE Trans. Antennas Propagat.*, Vol. 39, pp. 1222-1224, Aug. 1991.

[7] R. Ihmels, U. Papziner and F. Arndt, "Field theory design of a corrugated septum OMT", in *1993 IEEE MTT-S Int. Microwave Symp. Dig.*, pp. 909-912.

[8] J. Bornemann and V.A. Labay, "Ridge waveguide polarizer with finite and stepped-thickness septum", *IEEE Trans. Microwave Theory Tech.*, Vol. 43, pp. 1782-1787, Aug. 1995.

[9] J. Uher, J. Bornemann and U. Rosenberg, *Waveguide Components for Antenna Feed Systems. Theory and CAD.* Artech House Inc., Norwood 1993.

[10] J. Bornemann and F. Arndt, "Optimum field theory design of stepped E-plane finned waveguide transformers of different inner cross-sections", in *1990 IEEE MTT-S Int. Microwave Symp. Dig.*, pp. 1071-1074.

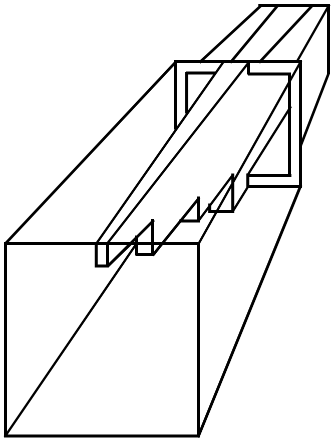

Fig. 1 Septum polarizer with waveguide transformer for production by casting. Note that all (presumably horizontal) lines run under the same draft angle.

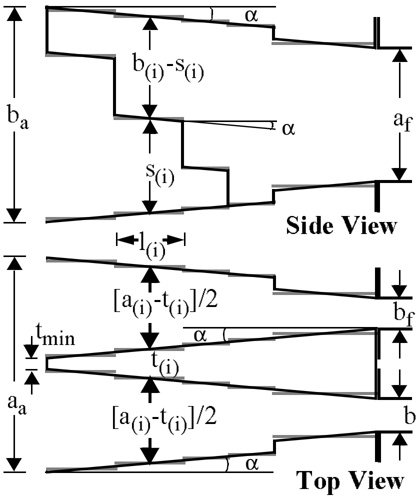

Fig. 2 Side view and top view of polarizer with initial staircase approximation of one step per individual waveguide section.

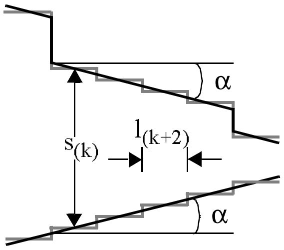

Fig. 3 Subdivision of individual sections to approximate draft angle.

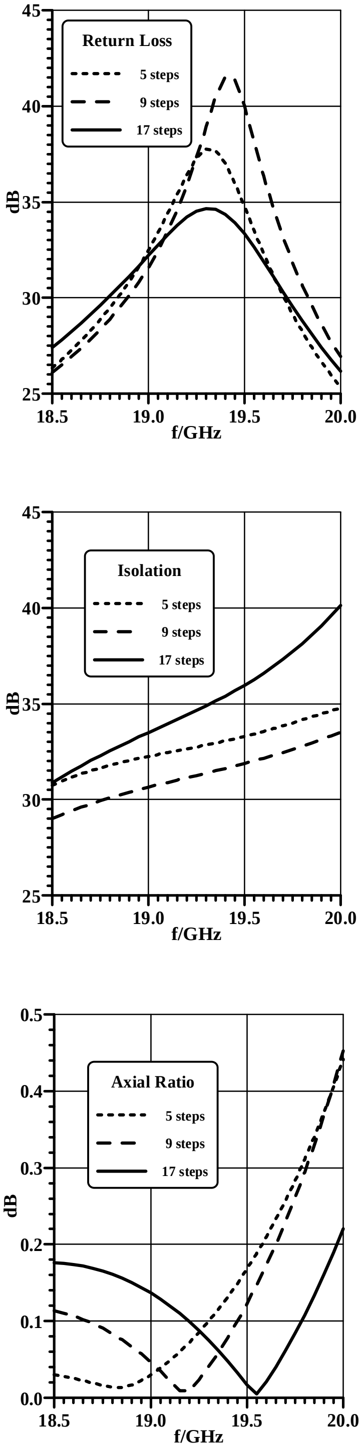

Fig. 4 Influence of staircasing on return loss (top), isolation (middle) and axial ratio (bottom).