IMPROVED WAVEGUIDE FILTERS FOR APPLICATIONS INVOLVING CIRCULAR POLARIZATION

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Abstract: Improved circular waveguide filters with responses having attenuation poles close to the passband are presented. Well-known circular iris filters, which are suited for circular polarization applications, are modified by replacing one or more irises by larger circular waveguide sections. The inverter values of such radial stubs are highly dependent on frequency and can generate attenuation poles in addition to the required passband inverter value. Two Ka-band examples demonstrate that attenuation poles can be created on both sides of the passband.

I. INTRODUCTION

Advanced satellite communication systems frequently employ filter structures in circular waveguide technology, e.g. [1]. For applications involving circular polarization, circular iris filters are usually the preferred choice. While the mechanism to generate attenuation poles at finite frequencies in the filter response is well understood in standard dual-mode filters, e.g. [1], [2], such a task becomes close to impossible if rotational or, at least, ninety-degrees sectoral symmetry of the entire filter structure needs to be maintained.

Therefore, this paper focuses on a different method to generate attenuation poles. Based on recent investigations involving rectangular waveguide filters with frequency-dependent inverters [3], [4], we propose to modify one or more coupling sections of a standard circular waveguide iris filter. The respective irises are replaced by radial stubs (c.f. Fig. 1) which satisfy inband inverter requirements and, at the same time, produce attenuation poles close to the passband. Since only one or two irises need to be replaced, the main part of the filter can be designed using standard procedures; i.e., a rigorous field-theory-based technique, here the coupled-integral-equations technique, is used to calculate and synthesize iris and resonator sections. The dimensions of the radial stub sections are determined by optimization such that both the required inband inverter value and the locations of prescibed attenuation poles are produced.

II. THEORY

The discontinuity problem between two circular waveguides has been analyzed by many researchers, e.g., [5], [6], and applications to all-circular iris flters are presented, among others, in [6], [7]. The preferred method of analysis for these components has been the mode-matching technique (MMT). The well-known drawbacks of the MMT have more recently been eliminated by the introduction of the coupled-integral-equations technique (CIET). The underlying principle of extracting the generalized scattering matrix from a CIET algorithm in circular-

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cylindrical coordinates is outlined in [8]. For the interested reader, a more detailed presentation of this technique can be found in [9].
One of the salient features of the CIET is the possibility to simultaneously include appropriate edge conditions at all discontinuities. For the analysis of on-axis circular waveguide components, the respective basis functions are given by

$$\vec{\Phi}(\rho, \varphi) = \sum_r \left\{ \frac{\nabla T^0_{hr}(\rho, \varphi) \times \vec{e}_z}{[1-(\rho/r_0)^2]^{1/3}} \right\} c_r + \sum_s \left\{ \frac{-\nabla T^0_{es}(\rho, \varphi)}{[1-(\rho/r_0)^2]^{1/3}} \right\} c_s . \qquad (1)$$

where T^0_{hr} and T^0_{es} are the TE- and TM-mode, respectively, cross-section functions of the common aperture of radius r_0 between two on-axis connected circular waveguides. The axial unit vector is denoted by $\vec{e}_z$, and c_r and c_s are the coefficients of the basis functions. Equ. (1) covers the general case of $TE/TM_{mn} \rightarrow TE/TM_{ik}$ mode coupling. Here, however, we are dealing with circularly polarized TE_{11} modes at the input and output ports and, therefore, $m = i = 1$. The CIET algorithm in circular-cylindrical coordinates has been verified by comparison with results obtained by reference data, e.g. [8], [10], and inhouse MMT codes [9]. Therefore, we refrain from presenting a direct comparison here.
For the design of the improved circular iris filters, optimization is required in two stages: first, to determine the dimensions of individual radial stubs and, secondly, to fine tune the entire component with respect to inband return loss.

III. RESULTS

We present two examples of the improved circular iris filter designs. Both components are designed for applications covering the 29 to 30 GHz passband.
The first example is a symmetric six-resonator filter, and its response is shown in Fig.2. Compared to the regular iris filter design according to Fig. 1 (top), the first and last iris have been converted to radial stubs in the improved design. While the return loss level is comparable, the new design introduces attenuation poles at 31.48 GHz and 34.27 GHz. Optimization parameters were set to produce a 30 db stopband to at least the same frequency as achievable with the regular circular iris filter. Note that the little dip at 34.47 GHz ist just above the 30 dB margin.
The second example is used to demonstrate that attenuation poles can indeed be introduced at frequencies below the passband. This is a asymmetric five-resonator design according to Fig. 1 (bottom). The improved design achieves a reduced return loss of 24 dB (compared to 27 dB of the regular circular iris filter) but introduces attenuation poles at frequencies both below (28.14 GHz) and above the passband (35.42 GHz) while otherwise closely resembling the performance of the regular iris filter.

IV. CONCLUSIONS

Regular circular iris filters can be modified to create attenuation poles at frequencies close to the passband. by replacing one or more irises by radial stubs. The inverter behaviour of those stubs becomes highly dispersive and thus permits attenuation poles to be generated while maintaining the required inband inverter value. The improved designs are applicable for circularly polarized signals due to their rotational symmetry. Two Ka-band examples demonstrate the advantages of this new design strategy.

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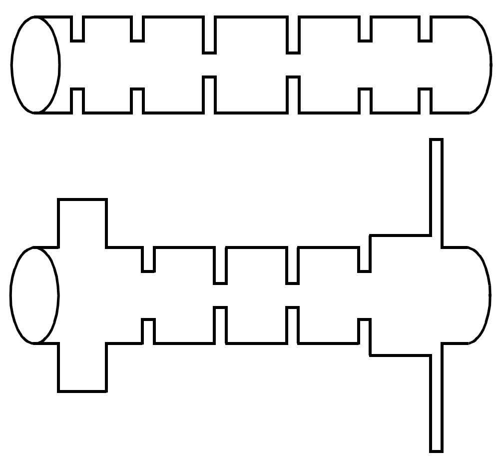

Fig. 1 Regular (top) and improved (bottom) five-resonator circular iris filter. The radial stubs can be asymmetric (shown here) or symmetric with stubs at input and output being identical.

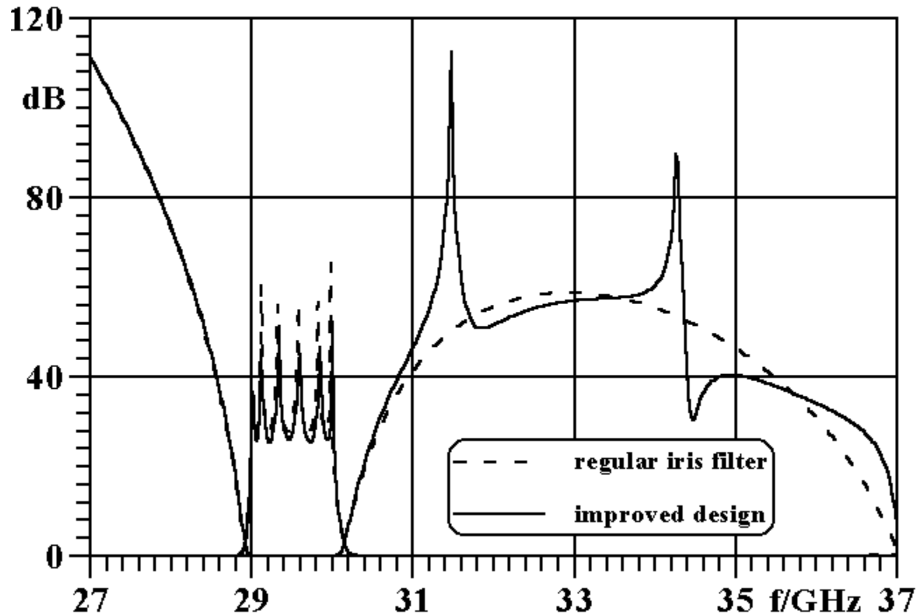

Fig. 2 Performance of symmetric six-resononator circular iris filters. Regular iris filter (dashed lines); improved design (solid lines).

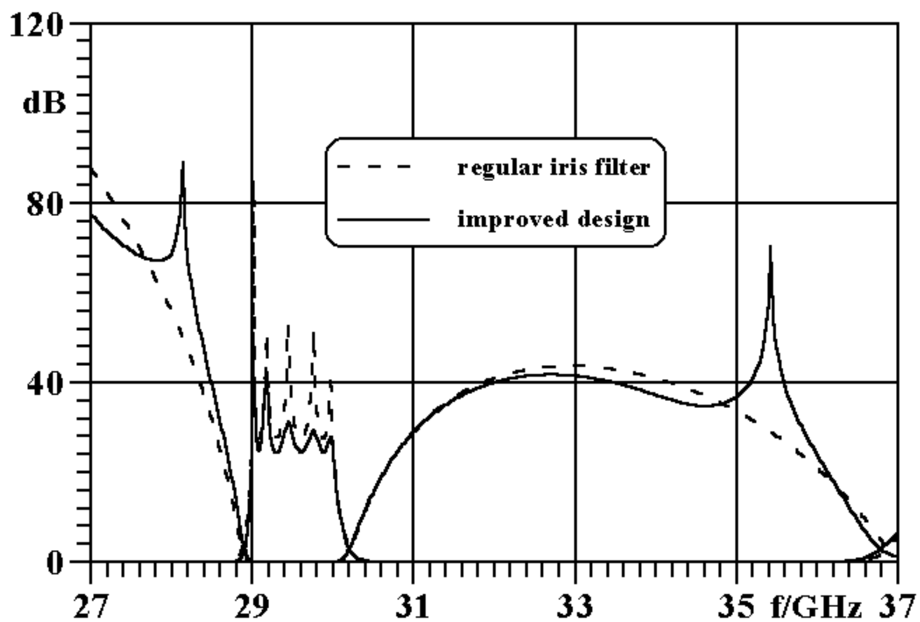

Fig. 3 Performance of five-resononator circular iris filters. Regular iris filter (dashed lines); asymmetric improved design according to Fig. 1 (solid lines).