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A High-Power Dielectric-Rod Resonator for Microwave Pulse Compression

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Abstract

Another technique for raising the cavity Q for high-power microwave compression involves a dielectric waveguide for the cavity. It must be low loss and properly matched into the rest of the hardware.

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1. Introduction

Recent papers [1-7] have explored some concepts for high-power microwave pulse compression. One of the most significant problems concerns obtaining a high Q for the resonant cavity. This cavity is often a length of waveguide fed through an iris with a shorting switch to change the position of maxima/minima and dump the cavity energy in a round-trip transit time (at the group velocity [5]). As discussed in [1], it is this cavity Q that is a limiting factor. Thus one is encouraged to look for lower-loss cavity schemes which are not limited by the usual skin-effect losses in conventional waveguide [3, 6, 7].

It is the purpose of the present paper to consider yet another approach based on the low-loss properties of a dielectric waveguide.

2. Dielectric Waveguide

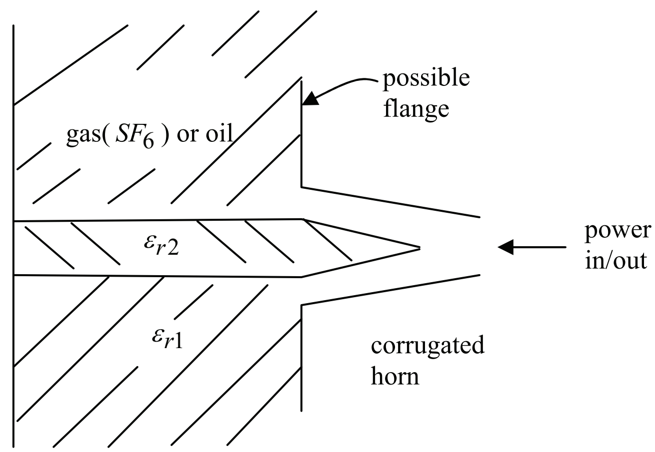
Pursuing waveguiding structures with lower loss than metal waveguide, [7] has given a technique based on a Gaussian beam in an etalon geometry. Over most of the length of the beam there are no metal walls, leaving the reflector and feed geometry for any losses.

Let us now consider a low-loss cylindrical dielectric waveguide operating in the $HE_{1,1}$ mode (lowest propagating mode [13]) as in Fig. 2.1. The propagation constant lies between those of the rod and the surrounding medium [8-10].

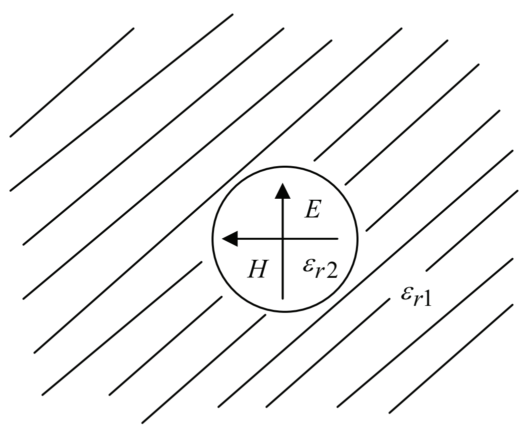
Of course, one needs a low-loss dielectric for this application. If the outer medium is air or gas (e.g., SF_6), then polyethylene or Teflon are candidate rod materials. These are used in high-quality coaxial cables where the losses are dominated by copper (or silver) skin effect. If, on the other hand, the outer medium is transformer oil, then rod materials with higher ε_{r2}, such as for some kinds of glass, are required.

The reflector size should encompass essentially all the power in the guided wave for high Q. How far the fields extend beyond the rod is a matter of detailed computation. The reflector skin-effect losses are similar to those discussed for the half etalon [7 (Section 3)]. As the frequency is raised to make the propagation constant approach that of the rod, the fields are more tightly bound outside the rod, minimizing the required reflector size. However, we may wish to avoid the next higher order propagating mode. This will limit how high one goes in frequency for a given rod radius. One may also wish to have a significant amount of the energy in the external medium to minimize dielectric losses.

Comparing this to the half etalon [7], one can see that it is somewhat similar. There is a reflector, but, instead of the wave approximately spherically expanding and contracting, it is guided along a low-loss dielectric rod.



A. Side view



B. Cross-section view

Fig. 2.1 Circular-Cylindrical Dielectric-Rod Waveguide for $HE_{1,1}$ Mode

3. Launching and Retrieving Mode

The mode must be well (low-loss) launched and received. Typically one envisions some kind of horn. Now the dielectric rod can extend into the horn, perhaps with some kind of taper (See, e.g., [12].)

An interesting type of horn for this application is the corrugated horn [11]. This has the property of having the same pattern in E and H planes for proper corrugation depth. Since the $HE_{1,1}$ mode has a similar property, it should be a better match. Furthermore, the fields being small at the corrugation boundary, there may be less discontinuity at the horn aperture.

As indicated in Fig. 2.1A, there is the question of how to taper the dielectric rod into the horn. We need to match the $HE_{1,1}$ rod mode into the corresponding corrugated waveguide mode with very little power scattered away from the rod at the interface. Much calculation and/or experiment is in order.

Going back from the horn toward the source, one can gradually transition into a standard rectangular waveguide (not overmoded). Then one can feed in and switch out the power by various techniques, including a magic tee and switch as discussed in [7 (Fig. 2.2)]. The $HE_{1,1}$ mode has two orthogonal polarizations (doubly degenerate). A single-mode rectangular waveguide will select the proper one of the polarizations. If needed there are techniques to suppress the unwanted polarization.

4. Concluding Remarks

This is yet another approach to raising cavity Q for microwave pulse compression. It brings its own benefits and problems. It has some similar design problems to the half etalon. Much computation and/or experiment would be very useful.

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