# Mode Suppressor for Dielectric Resonator Filters

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C. L. Ren
Bell Telephone Laboratories
North Andover, MA 01845

ABSTRACT

The presence of tuning screws can shift spurious modes resonance of the dielectric resonators to frequency close to or even equal to resonant frequency of the principal mode, therefore interfering with the filter's performance. A simple mode suppressing scheme is presented to solve this potentially serious problem.

## I. Introduction

The circular electric $H_{011}$ mode, shown in Figure 1, is the principal mode of resonance for circular cylindrical dielectric resonators in filter applications, Figure 2. The resonant frequency of the principal mode as well as spurious modes are determined by the physical dimensions and the dielectric constant of the resonator. Many undesirable spurious modes may be excited by physical imperfections in the filter. Under certain tuning conditions the resonant frequencies of some of these spurious modes may be very close to or exactly at the resonant frequency of the principal mode of the filter, thereby interfering with the filter's performance. The excitation and resonance of spurious modes due to imperfections in manufacture can be illustrated by the example of a filter with two displaced filter housings as shown in Figure 3. Resonances of these spurious modes appear in the passband, Figure 4. The spurious mode resonances disappear or decrease in magnitude after the displacement is corrected. Other possible imperfections are due to mounting tolerances of the dielectric resonators, misalignment of tuning screws, dielectric resonators with large chipped edges, dielectric resonator's surfaces contaminated with metallic particles or lossy material, and perhaps even inhomogeneous dielectric resonators (impurities embedded in the dielectric resonator). When a spurious mode resonance is observed in manufacture, the filter involved must be disassembled for diagnosis and repair, which can be tedious and costly. In this paper, a simple mode suppressing device is described which, when inserted in the filter, will remove the spurious mode resonance from the frequency band of interest.

## II. Effects of Spurious Modes in Dielectric Resonator Filters

The spurious modes whose resonant frequencies are closest to the natural resonant frequency of the principal mode are either $TM_{on\delta}$ or $HE_{mn\delta}$ modes.[1,2,3,4] To eliminate their interference, the aspect ratio of dielectric resonators (diameter to thickness) can be properly chosen to place the resonance of spurious modes[5] outside the operating frequency band.[5] But practical design work showed that this can be accomplished only if the filter requires little or no frequency tuning, because $TM_{on\delta}$ modes and $HE_{mn\delta}$ modes are far more sensitive to frequency tuning screws (Figure 2) than the principal mode.[1] For example, the same amount of tuning, which shifts the principal mode of a 6 GHz filter by 25 MHz, can move the resonant frequency of $TM_{on\delta}$ or $HE_{mn\delta}$ modes in the opposite direction across the entire 500 MHz radio band. Therefore, in spite of careful design of the aspect ratio of the dielectric resonator, spurious modes which are excited due to imperfections in manufacture, can interfere with the filter performance in practice.

A typical example of this problem can be shown in the performance of a seven-resonator Butterworth bandpass filter. Instead of a flat insertion loss passband response, the interference of a spurious mode ($HE_{21}$) appeared in the form of a large insertion loss fluctuation with a magnitude of several tenths of a dB as shown in Figure 5a. Another interference ($TM_{01}$) occurred at about 400 MHz above the passband in Figure 5b, shown by the dotted line. These two spurious resonances were nominally designed to be outside the filter's operating band by proper design of the aspect ratio, but were brought into the band by the necessary tuning nevertheless.

## III. Mode Suppressor

To avoid interference by spurious modes of the dielectric resonators, various schemes have been reported in the literatures.[5,6,7,8,9,10] One scheme is to widen the mode separation by using different dielectric resonators, such as the ring-shaped dielectric resonators[6], the TEM dielectric resonators[7], and the cylindrical rod with $TM_{01}$ as the principal mode.[8] A different approach proposed[9] adding thin air gap or mode suppressing element to the surface of the


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resonator to prevent resonance of spurious modes.[9] However the trade-off of these schemes is a degradation of the intrinsic Q or both the intrinsic Q and the temperature stability. They can also increase the cost of the dielectric resonators because of the added complexity in the resonator design. In this paper a different mode suppressing scheme is proposed which, unlike those discussed above, does not involve any modification of the dielectric resonators thus preserving the high-Q and temperature stable characteristics of the dielectric-resonator filter. The proposed mode suppressing device as shown in Fig. 6 is a thin metal plate being inserted between two dielectric resonators in the filter in an orientation such that its surface is parallel to the coupling magnetic fields of the principal mode of the resonator while perpendicular to the magnetic fields of the spurious modes to be suppressed. The boundary conditions of the electromagnetic fields of the spurious modes in the filter will be altered by the mode suppressing device which, however, does not perturb the fields of the principal mode, thus affecting only the spurious modes and preserving the filter performance. One mode suppressor, when inserted nearest to the center of the filter (Figure 6), is sufficient to provide adequate suppression for a multi-resonator filter. Figures 5a and 5b show the improvement obtained by use of this device.

## IV. Conclusion

An effective mode suppressing device, as proposed in this paper, has been built and tested successfully to eliminate the spurious mode resonances caused by imperfections in manufacture. Instead of tedious and costly repairs for eliminating the spurious mode resonances, this device proves to be not only more effective, but also quite economical. It also requires no modifications to the existing filter housing and the existing filter assembling procedure.

## REFERENCES


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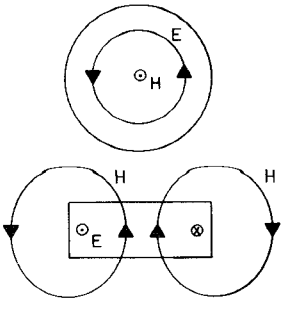


Figure 1 $H_{011}$ mode

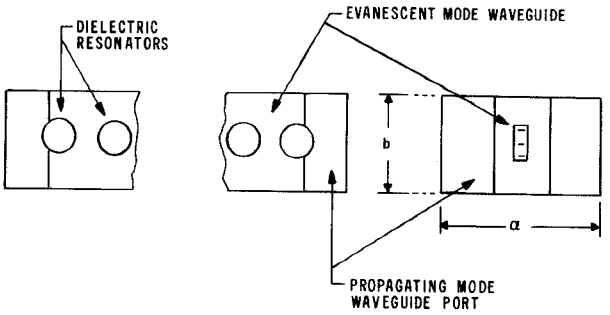


Figure 2 Dielectric-resonator bandpass filter

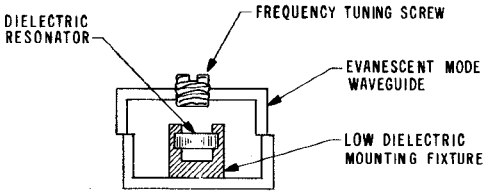


Figure 3 Cross section of bandpass filter with displaced filter housing

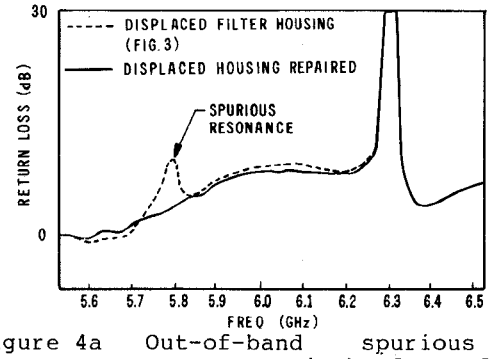


Figure 4a Out-of-band spurious mode resonance in bandpass filter due to displacement of filter housing

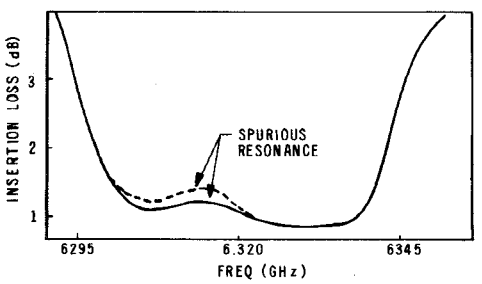


Figure 4b Passband spurious mode resonance in bandpass filter due to displacement of filter housing

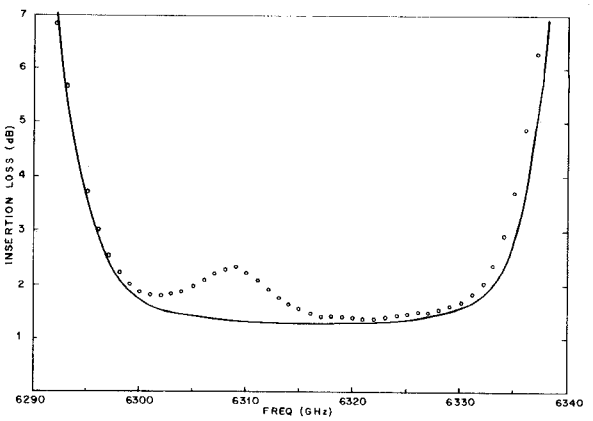


Figure 5a Suppression of spurious mode from passband using mode suppressor

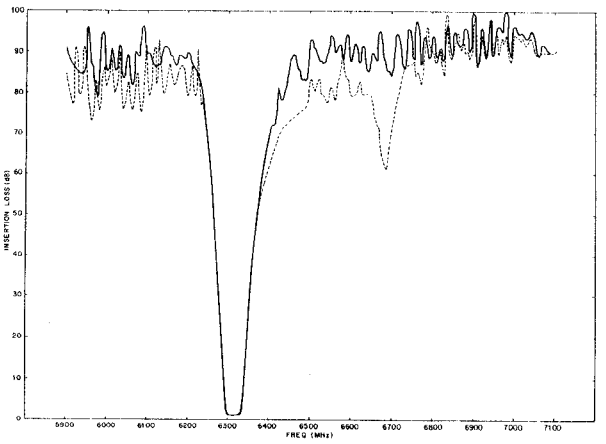


Figure 5b Suppression of out-of-band spurious mode using mode suppressor

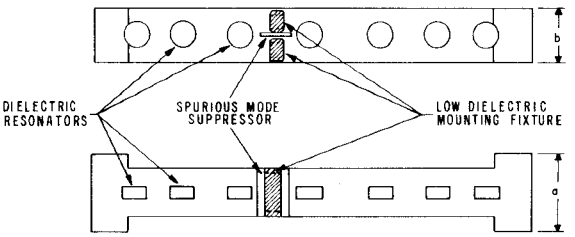


Figure 6 Bandpass filter with spurious mode suppressor