PRACTICAL ASPECTS AND LIMITATIONS OF DUAL MODE DIELECTRIC RESONATOR FILTERS

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ABSTRACT.

In-line configuration of dual-mode dielectric resonator filters is discussed from practical point of view. Available ceramics , mounting arrangements and materials , size limitations , temperature stability and power handling capabilities are addressed. Examples of realized filters for 1.8 GHz , 4 GHz and 12 GHz frequencies are presented.

INTRODUCTION.

Miniature , dual mode dielectric resonator filters were succesfully introduced for communication satellite 4 GHz input multiplexer applications [1,2] . Continuing development of materials for dielectric resonators makes possible extension of this technology not only to lower frequencies (e.g. L-band) where size of the available ceramics is a limiting factor but also to higher frequencies (10 GHz and above) where loss characteristics of the ceramics are critical. In this paper various practical design and performance aspects associated with this implementation will be discussed.

DISCUSSION.

At present, two types of high performance ceramics are commercially available zirconium stanate $(ZrSn)TiO_4$ and advanced perovskite added material $Ba(NiTa)O_3$ - $Ba(ZrZnTa)O_3$. Basic properties of these ceramics are listed in Table I. [3] Perovskite added material due to its Q and dielectric constant is more suited for high frequency applications (e.g. 4 GHz and above).
A disadvantage of this material is its density - dielectric resonators are 50% heavier compared to those utilizing zirconium stanate ceramics. Zirconium stanate gives acceptable performance up to 6 GHz and very good results were obtained at frequencies below 2 GHz. In a dual mode dielectric resonator filter, the dielectric resonators are mounted in the center of circular , evanescent mode, metal cavities. Therefore, a mounting structure is necessary to support these resonators. The mounting has to be mechanically stable to assure temperature stability as well as good vibration performance. Available materials for such supports have to meet specific criteria such as low loss , low dielectric constant,and excellent mechanical properties . In addition, for space applications, low outgassing properties are very important. A wide variety of support materials were evaluated. At present , two materials ; crosslinked polystyrene (rexolite) and silicon dioxide foam [4] (Space Shuttle Thermal Tile) were found to give satisfactory performance. The polystyrene foam commonly used in experimental filters , while excellent electrically , has poor mechanical properties . Also ,due to its closed cell structure foam has poor outgassing properties and performance in vacuum is not acceptable. Alumina and forsterite substrates were evaluated for support materials (especially for high power applications) . However , these materials have a relatively high dielectric constant . Moreover , they have very poor temperature stability($\approx$ 100 ppm/deg.C). These combined properties result in significant degradation of the excellent temperature properties of the dielectric resonators. For example , use of alumina or forsterite discs degrades the $\approx$ 0 ppm/deg.C frequency coefficient of the dielectric resonators to a totally unacceptable $\gtrsim$12 to $\gtrsim$18 ppm/degree C (almost as poor as aluminum , which has a $\gtrsim$23 ppm/degree C frequency coefficient). Compensated alumina , recently developed by NTK [5], should help to overcome this problem.

Silicon dioxide SiO_2 foam(Space Shuttle) exhibits excellent electrical properties especially at higher frequencies and was used to realize 12 GHz filters. This particular material is relatively easy to machine , however it is fragile and extra care has to be used during handling and assembly. Also due to its insulation properties only low power applications in vacuum are possible (input filters).

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EXPERIMENTAL RESULTS.

A number of in-line filters in dual mode dielectric resonator configuration was built and tested. Frequencies ranged from as low as 1.5 GHz to more than 14 GHz with further extension possible. In Fig.1 1.8 GHz, 4 GHz and 12 GHz filters are shown. A 4 -pole filter with center frequency 1843 MHz was realized and tested. Zirconium stanate material (Transtech D8516) with a rexolite support was used. The electrical performance of the filter is presented in Fig.2. Equivalent Q of the filter is about 16,000 and its temperature coefficient is ≈ 0ppm/degree C. proper selection of D/L ratio (~2.5) assured excellent out of band response which is presented in Fig.3. A large number of filters was realized @ 4 GHz frequencies. The ceramic materials used were zirconium stanate (Murata Resomics 04C) or advanced perovskite added material (Murata Resomics 03C). The typical mounting used rexolite as a base material. Typical temperature performance of the filters is in a range 0-2ppm/degree C. Performance of one of the filters is presented in Fig. 4. (6-pole asym.canonic output filter). The filter was high power tested in vacuum. The temperature of the dielectric resonators was monitored using a sophisticated fiber optic probe and also using a boron nitride sensor probe. Power handling of 20 W was achieved with temperature rise of ≈25 degrees C. At present , experimental output multiplexers are being built , using this power tested configuration.

At higher frequencies , the dielectric resonator assembly becomes very small and associated hardware such as connectors , tuning screws, etc... play a significant role in weight and size of the filter. A 6-pole asymmetric canonical filter was realized using perovskite added material (Panasonic)and Space Shuttle tile supports . Its performance is presented in Fig.5 Equivalent Q ≈ 10,000 was achieved. Temperature performance was ≈ 2ppm/degree c with further improvement possible.

CONCLUSIONS:

The bandpass filters which have been developed compare favorably with metallized (or metal) cavity implementations. This particular configuration can provide excellent results in a wide range of frequencies (from 1.5 GHz to 18-20 GHz). Lower frequency limit is determined by practical sizes of the resonators- it is difficult to make large ceramic discs. Upper frequency limits are governed by dielectric losses in ceramics and also by the fact that resonators become too small and difficult to handle. Mounting arrangements and support materials have significant influence on overall filter performance and usually degrade the excellent characteristics of the dielectric resonators.

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TABLE I

	R-04C (ZrSn)TiO_4	R-03C $Ba(NiTa)O_3$ -$Ba(ZrZnTa)O_3$
K	37.3 ~ 38.0	28.7 ~ 29.8
Q(at 7 GHz)	6,300	13,000
τ_f (ppm/°C)	0 ~ 4	0 ~ 4
Resistivity (Ω.cm)	>1 x 10^{14}	>1 x 10^{14}
Thermal coefficient of expansion (ppm/°C)	6.5	10.2
Thermal conductivity (cal/cm·sec·°C)	0.0046	0.0063
Specific heat (cal/g·°C)	0.15	0.07
Water absorption (%)	<0.01	<0.01
Density (g/cm^3)	5.0	7.7
Flexural strength (Kg/cm^2)	1,000	800

Fig.1 In-line, dual-mode dielectric resonator loaded cavity filters.

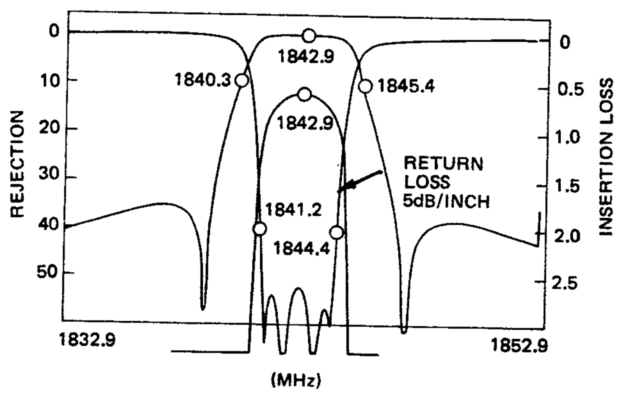

Fig.2 Typical performance of 1.8 GHz , 4-pole dielectric resonator filter.

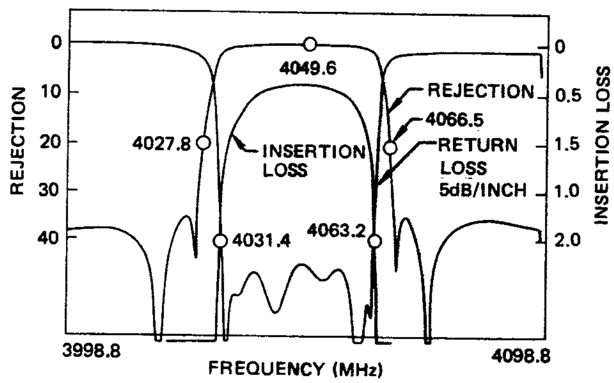

Fig.4 Typical performance of 4 GHz , 6-pole asymmetric canonical dielectric resonator filter.

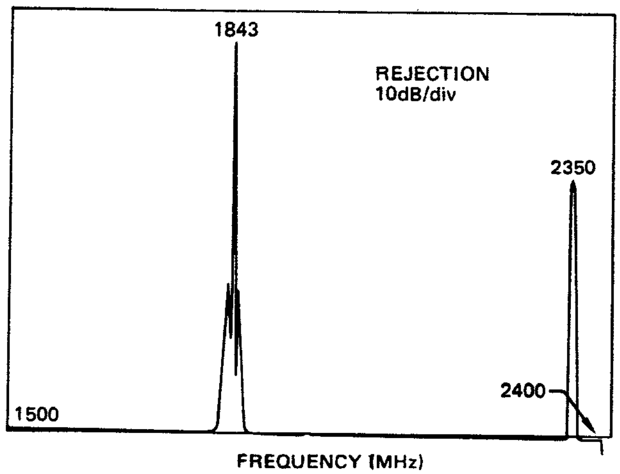

Fig.3 Out-of-band response of 1.8 GHz, 4-pole dielectric resonator filter.

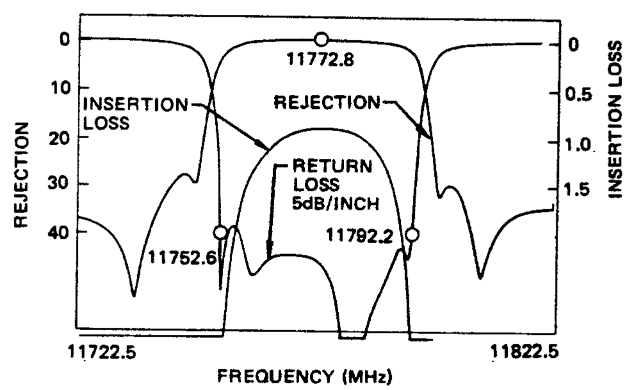

Fig.5 Typical performance of 12 GHz , 6-pole asymmetric canonical dielectric resonator filter.