MINIATURE BAND REJECT FILTERS FOR SATELLITE APPLICATIONS

J. Bowes, S. J. Fiedziuszko, J. Redd, C. Ziegler

Ford Aerospace & Communications Corp., Western Development Lab. Div.
3939 Fabian Way, Palo Alto, Ca. 94303

ABSTRACT

The rejection of spurious or unwanted signals appearing in the input of a satellite transponder is necessary. Miniature, low-cost, temperature stable, band rejection filters which were developed for these applications utilize high performance dielectric resonators mounted in Space Shuttle thermal tile material. The design and achieved performance of the actual flight unit is presented.

Introduction

Present communication satellites use cavity type band reject filters as e.g. beacon reject filters. To meet the required electrical performance specifications over space environmental conditions such filters are usually implemented utilizing INVAR or in some cases much lighter GFRP (Graphite Fiber Reinforced Plastic) material. Recent advances in the development of low-loss and temperature stable dielectric materials indicate that microwave dielectric resonators may be used in place of waveguide type metallic cavities, with low loss characteristics approaching those of waveguide cavities and temperature stability approaching or exceeding INVAR. Additionally, inherent properties of the dielectric resonators such as very small size and relatively light weight make these devices extremely well suited for use in space and weight constrained satellite applications.

Dielectric Resonator

If the permittivity of the dielectric object is sufficiently high, the electric and magnetic fields will be confined in and near the object and will resonate in various modes. Because of the absence of metallic walls in a resonator, the unloaded Q (quality factor) will be limited mainly by losses in the dielectric material. For the same reasons, the temperature performance of such resonators will be determined by temperature properties of the dielectric material(1). At present, low-loss, temperature stable ceramics are available from several manufacturers. Additionally through proper adjustments of the ceramic composition, the dielectric material can be tailored to have a specific resonant frequency temperature coefficient (e.g. -2, 0, +2 ppm/^{o}C materials are available). The material used in this application was manufactured by Murata Mfg. Co. under the brand name Resomics. Basic properties of the material are presented in Table I.

Table I
Properties of Resomics Ceramic Material(3)

Dielectric Constant	36.8 to 38.9
Loss Tangent	.0001
Thermal Expansion Coefficient	.000006
Composition	(Zr-Sn) TiO_9 adj.

Additional tests were also performed by FACC to determine the suitability of this material for space applications. The tests for outgassing and for radiation damage were performed and no changes were detected. Long term stability test conducted by Murata also indicated excellent long term properties of the material.

Shuttle Thermal Tile Material

In an actual filter configuration the Q-factor of the dielectric resonator is dependent not only on properties of the dielectric material, but also on properties of the selected mounting, which is necessary to assure good mechanical integrity of the assembly (vibration, temperature performance). Therefore, to achieve minimal degradation of the resonator Q, an extremely low loss, temperature and vacuum stable mounting is necessary. For these reasons a silicon dioxide foam was selected to support the individual resonators mounted in small circular, evanescent mode cavities. This particular material is used primarily as a thermal tile on the Space Shuttle. However, it was found that it has surprisingly good electrical and mechanical properties. Some of these are presented in Table II. The material can be machined to precise tolerances and due to the open cell structure, its performance in vacuum is very good.

Table II
Properties of Space Shuttle Thermal Tile Material(4)

Dielectric Constant	1.15
Loss Tangent	.0004
Thermal Expansion Coefficient	-.00001 to .00006
Composition	99.7 pure SiO_2

Band-Reject Filter

Considering the advantages of dielectric resonators and characteristics of Shuttle thermal tile material a 6.26 GHz beacon reject filter was designed and realized. The requirement was to notch out (with 12 dB rejection) two beacon signals spaced 4 MHz around frequency of 6.26 GHz. Because beacon frequencies were placed between communication channels, minimal distortion of group delay and amplitude at band edges of adjacent channels was also required. The dielectric resonators were designed using a method developed by Atia & Bonnetti(2), and tile material was machined (Fig. 1) to support the resonators in small, circular evanescent mode cavities. Two such cavities mounted on top & bottom of the standard 6 GHz waveguide were used. Coupling was achieved with a Bethe type coupling aperture. A photograph of the filter is presented in Fig. 2. The filter was extensively tested in vacuum and excellent thermal and electrical characteristics were obtained in this very compact device (Fig. 3). In addition the filter was subjected to high levels of vibration and no frequency shifts were detected, demonstrating excellent mechanical integrity of the assembly. In conclusion, a new family of band reject filters for satellite applications was developed utilizing dielectric resonators and Shuttle thermal tile material. This particular approach enables very fast, low cost realization of miniature band stop filters with excellent electrical and mechanical performance.

References

(1) J.K. Plourde, C.L. Ren "Application of Dielectric Resonators in Microwave Components" IEEE Trans. Microwave Theory Tech. Vol.MTT-29, pp.754-769, August 1981.

(2) R. Bonnetti, A. Atia "Design of Cylindrical Dielectric Resonators in Inhomogeneous Media" IEEE Trans. Microwave Theory Tech. Vol.MTT-29, pp.323-327, April 1981.

(3) Murata Mfg. Co - Catalog.

(4) Properties of Lockheed LI-900 Material - Int. Report.

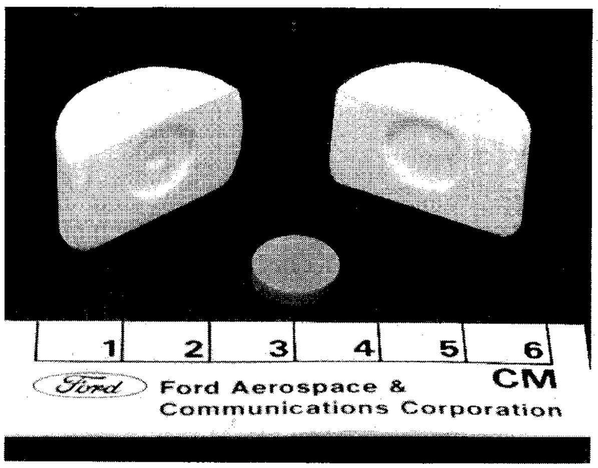

Figure 1
Shuttle Tile Mounting And A Dielectric Resonator

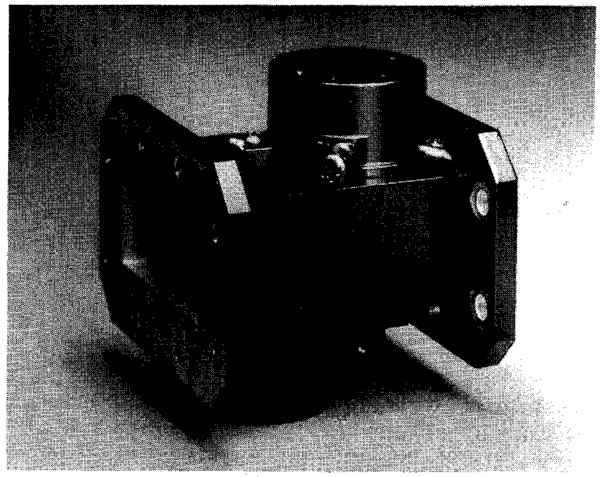

Figure 2
6 GHz Band Reject Filter

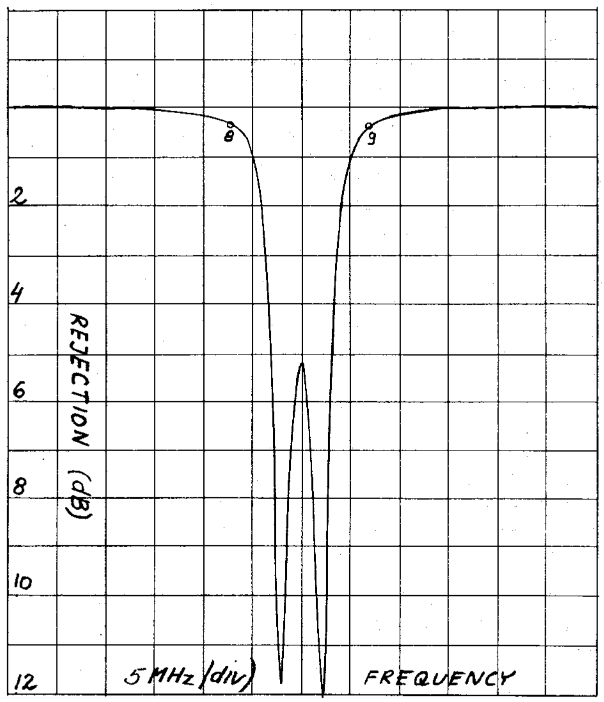

Figure 3
Rejection Of The 6 GHz Beacon Reject Filter