A 4 GHZ DIELECTRIC CONTIGUOUS OUTPUT MULTIPLEXER FOR SATELLITE APPLICATIONS

S. C. Holme, S.J. Fiedziuszko

Space Systems/Loral, Palo Alto, CA

Abstract

A 4 GHz output multiplexer is described which significantly reduces the size and weight of satellite transponders. The multiplexer utilizes dielectrically loaded cavities, mounted and tuned in a novel way to increase power handling up to 80 watts per channel. A coaxial T-junction coupled manifold eases tuning and results in a very small and light multiplexer unit.

Introduction

Communications satellite transponders typically employ low loss waveguide multiplexers to combine the output of many power amplifiers for transmission to the ground. In the past, these multiplexers have typically been constructed using air filled waveguide cavities, most commonly fabricated from INVAR or Graphite Fiber Reinforced Plastic(GRFP). Although these multiplexers perform well electrically, they are large and heavy(in the case of INVAR), especially at lower frequencies. A 5 channel output multiplexer at 4 GHz constructed in this way takes up over 400 sq. in. of mounting area, and weighs almost 5 kg. Smaller footprint is rapidly becoming a critical issue for many spacecraft designs.

Recently, input multiplexers have benefitted from the use of dielectrically loaded cavities as a replacement for air filled cavities, with little or no performance degradation[1]. Figure 1 shows a size comparison of dual mode dielectric resonator, dual mode cylindrical waveguide(TE111), and TE01 waveguide post filters. Volume decreases of 80% and weight decreases of 50% are typical when comparing dielectric resonator and waveguide filters. However, this technique has not typically been employed for output multiplexers. The primary reasons for this were difficulties of finding suitable resonator mounting arrangements to reduce resonator heating, adequate coupling mechanisms(inadequate bandwidth) to the waveguide manifold, and the possibility of discharge failure(such as multipaction) due to the filter's relatively small size. To his point, only lower frequency[2] or lower power[3] multiplexers have been constructed. In this paper, a new dielectric resonator multiplexer is described which addresses each of these problems, resulting in a very attractive output multiplexer package.

Dielectric Resonator 4 GHz Output Multiplexer

A common transmit band for satellite transponders is in the 3.7-4.2 GHz region. Output filters for this band usually use TE111 dual mode waveguide cavities, most typically fabricated out of INVAR or GFRP. The most common dielectric resonator modes are TE01δ and HE11δ*. The TE01δ mode, although otherwise suitable for high power operation, realizes only one pole per resonator, and thus requires one ceramic disc per pole. In addition, tuning and coupling to this mode is generally limited. Previous researchers have concluded that the dual mode HE11δ(dielectric resonator counterpart to the TE111 mode)cavities used for low power applications are not suitable for very high power and have pursued other solutions. One uses half cut resonators at 4 GHz, enabling power dissipation through the metal wall[4]. However, this design is limited in potential Q factor due to losses in the contacting metal wall.

The design described in this paper employs the HE11δ mode, but makes some novel design, construction and tuning changes, enabling very high power handling along with good Q factor. In addition, a novel multiplexer design enables easier tuning with the ability to couple strongly to a waveguide manifold.

* Mode nomenclature is not yet resolved

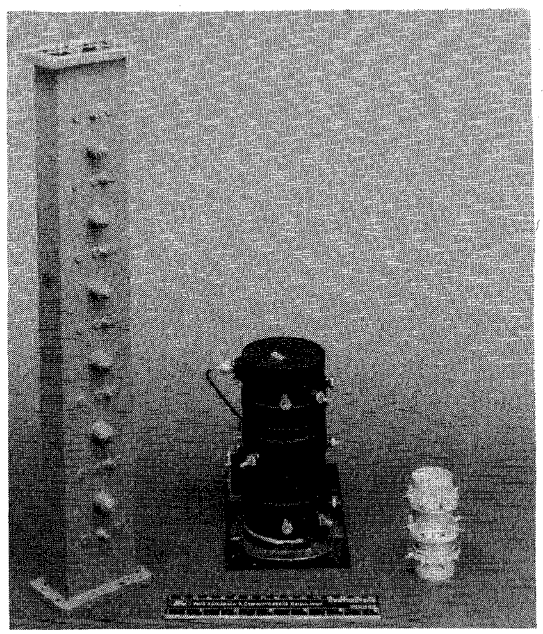

Figure 1 Size Comparison of Filter Designs(Waveguide post, TE111 Waveguide, Dielectric Resonator)

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High Power Dielectric Resonator Output Filter Design

Several issues limit the power handling of the conventional(HE11δ) input multiplexer dielectric resonator filter. First, RF dissipation causes the resonator to heat up significantly, and in time may become hot enough to damage the resonator holder(typically made from a very low RF loss material) or effect an unacceptable shift in the filter's frequency. Second, tuning screws penetrating close to the resonator may arc to the resonator in a noise producing or damaging discharge.

In this design, optimized mounting, mounting material, and tuning of the resonator has virtually eliminated these problems. The filter design chosen for this multiplexer utilized a 4 pole elliptic function design to minimize insertion loss and reduce weight. Figure 2 shows the configuration of the filter.

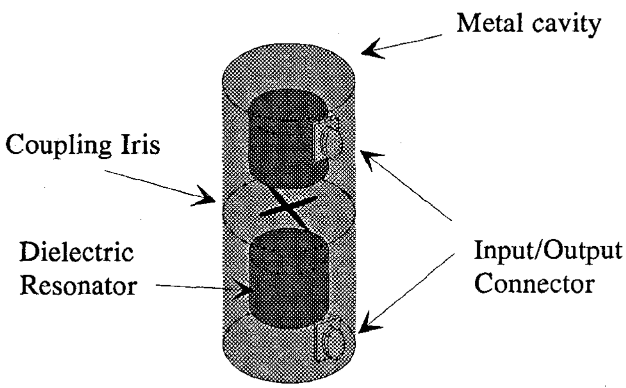

Figure 2 Configuration of 4 Pole Dielectric Resonator Filter

Dielectric Resonator Multiplexer Design

It is often difficult to couple a dielectric resonator filter to a waveguide by using traditional inductive irises, especially if wider bandwidth responses are required. The output multiplexer described uses coaxial T-junction probe coupling instead, placing an ~½ wavelength stub between the filter and the manifold. In this way, the manifold can be made shorter(~ 0 λ between adjacent filters), and is thus easier to tune. This technique is not feasible for TE111 waveguide filters since their diameter does not offer sufficient clearance between adjacent cavities. Figure 3 demonstrates the manifold coupling technique, and compares the size of the dielectric resonator output multiplexer with a conventional waveguide multiplexer.

The realized multiplexer used 6 contiguous 72 MHz bandwidth communications channels, along with 2 narrow band telemetry channels. The coax/waveguide junction was characterized and the multiplexer was computer optimized for best performance.

Experimental Results

Figure 4 shows the fabricated multiplexer. Figure 5 shows the measured performance of the eight channel multiplexer. The multiplexer was tested with 4 channels operating, at ~80 watts per channel without evidence of multipactor breakdown or excessive thermal stress. Individual filters have been tested to over 100W average(limited by high power source availability) without damage or breakdown. Typical Q factor is about 7000, but this is currently being improved through optimization of the resonator holder. Some extra losses are contributed by the coaxial junction, but these can be minimized by using a larger diameter coaxial connection.

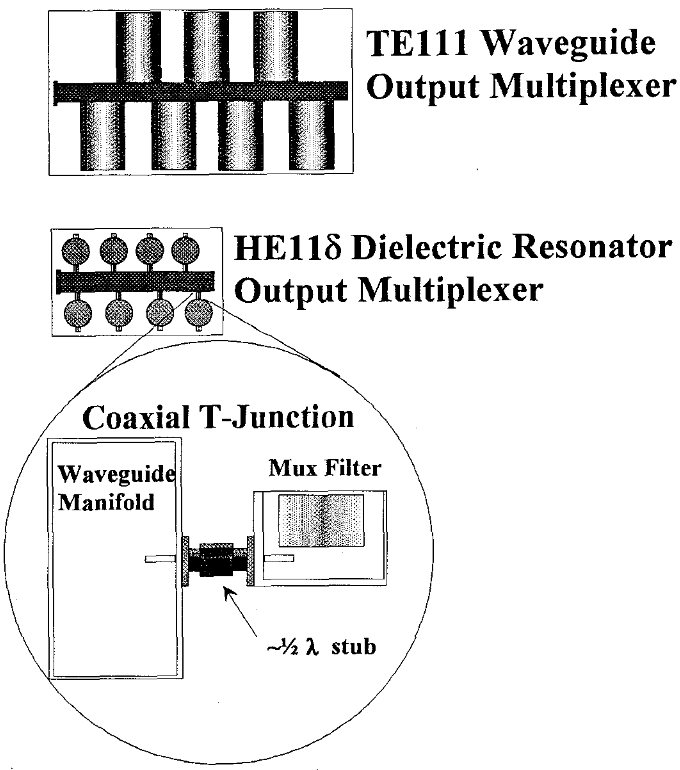

Figure 3 Size Comparison of TE111 Dual Mode Waveguide and HE11δ Dielectric Resonator Output Multiplexers

Conclusion

The dielectric resonator output multiplexer presented offers a very attractive alternative to conventional waveguide multiplexer designs. Advantages include substantially smaller size, light weight, and lower cost of manufacture. Qualification of this design to high power levels and launch vibration has shown it to be at the leading edge of output multiplexer design.

References

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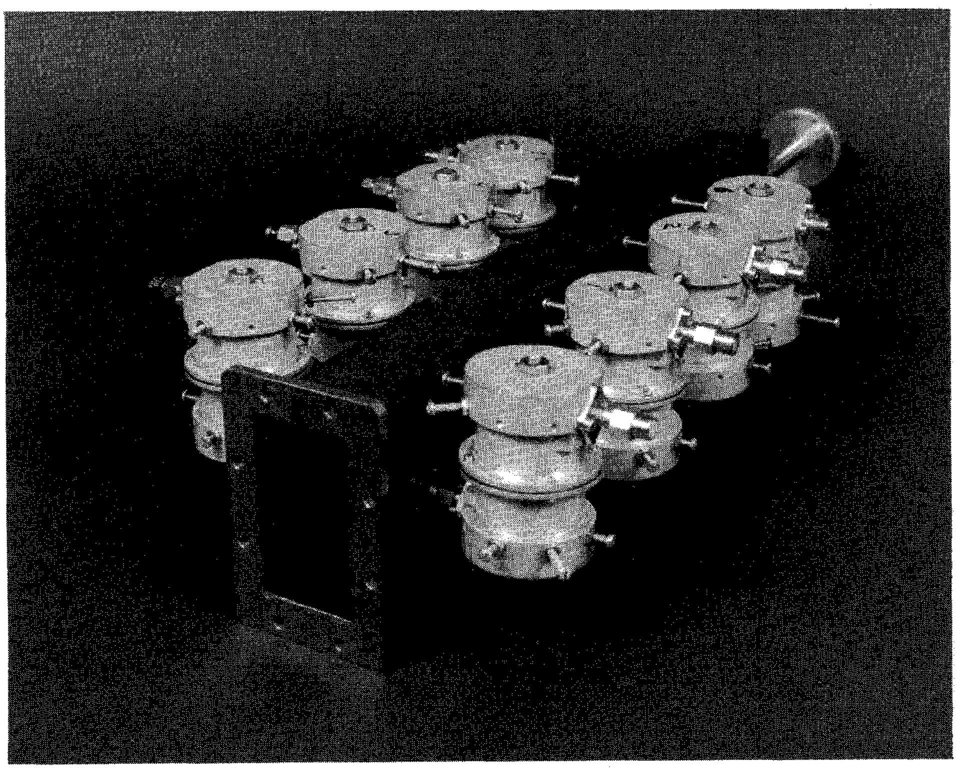

Figure 4 Dielectric Resonator Output Multiplexer

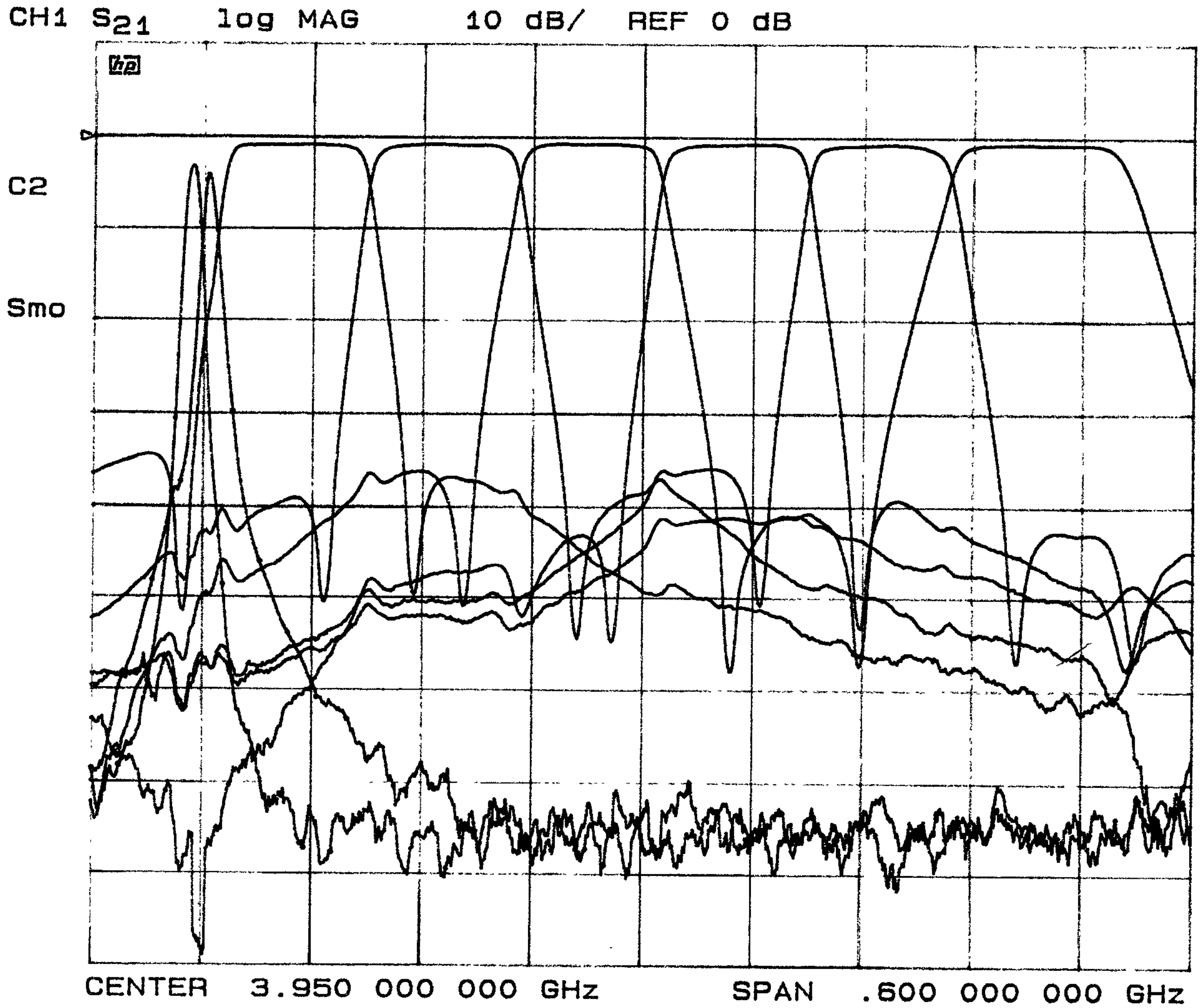

Figure 5 Measured Performance of the Dielectric Resonator Output Multiplexer