ALL GFEC DUAL MODE QUASI ELLIPTIC MULTIPLEXERS FOR SATELLITE TRANSPONDERS

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Abstract

This paper describes lightweight GFEC 4 GHz multiplexers, consisting of dual mode quasi elliptic filters mounted on a waveguide manifold. These filters are for use in communications satellites to meet the high performance requirements with state-of-the-art technology. Experimental results of a typical channel are given, and spurious performance of these filters is discussed. Thermal results of the filters indicate an average frequency shift of about 0.5 MHz over 50°C.

Introduction

Communication satellites have always placed very stringent requirements on multiplexers, both in terms of performance and size/weight. This has essentially led to the realization of the DMQE (dual mode quasi elliptic)[1,2,3] filter which firstly exhibits more optimum filter characteristics from the use of elliptic functions and secondly results in smaller size and lighter weight multiplexers by virtue of the cavity re-use feature. Its use in Intelsat IV A[4] in preference over the conventional but flight proven rectangular, waveguide Chebishev filter is evidence of its attractiveness.

In parallel to the switch to dual mode filters there is also a growing preference for lightweight GFEC (graphite fibre epoxy composite) over invar as the basic material for fabrication of the temperature sensitive multiplexers. This has been dictated by the ever present need to conserve weight, especially in the 4 GHz band where significant savings can be made. Thus, in the twenty-four-channel RCA SATCOM domestic communication satellites, first launched in late 1975, both the input and the output multiplexers have GFEC rectangular Chebishev filters and aluminum manifolds, resulting in a weight saving of over 40 lb.[5]

Spar Technology Limited has now developed and qualified DMQE input multiplexers completely fabricated out of GFEC. These multiplexers are being used in communications subsystems presently under production.

Mechanical Design

The approach adopted in the design of the multiplexers is dictated by a number of considerations:

a) Weight - to be lightweight without jeopardizing structural integrity,
b) Size - to minimize occupied space in order to simplify layout,
c) Flexibility and simplicity - to allow for easy rework, if necessary, and to ease problems of inspection.

These considerations result in a design with the following features:

a) All GFEC construction for minimum weight. Circular waveguide, manifold, connecting flanges, coupling obstacles, are all in GFEC. Weight of triplexer is only 1.95 lb. It is estimated that for a twelve-channel transponder the total saving in weight over the use of four weight-relieved invar triplexers will be at least 10 lb.

b) Cavities are flange-mounted together for easy replacement and rework. Design also eases the problems of inspection.

c) Filters on same side of the manifold, to minimize occupied space.

d) Standard waveguide/coaxial transition at each filter output replaced by coaxial probe inserted directly into end cavity.

A photograph of a GFEC triplexer is shown in Figure 1.

Electrical Design

The procedure used to design dual mode quasi elliptic filters has been semi-automated with the aid of a set of computer programs. The available programs fall into two categories; filter response analysis (FILTER) and filter design (DUAL).

FILTER - Determination of Theoretical Filter Performance:

The program input involves choosing the correct design parameters (e.g., bandwidth, return loss, unloaded Q, waveguide type and size). These are choosen to meet the filter response specifications. The output of program FILTER is the theoretical bandpass filter frequency response for amplitude and phase. The response can be requested for any frequency range in any number of frequency steps (up to a maximum of 101 points for a single run). After a few iterations of the program the final optimum design is usually determined. The quasi elliptic design is finalized after taking into account temperature and tuning misalignment effects.

DUAL - Computer Design of Filter:

Having selected the appropriate filter, the design follows. Design techniques are based on the extensive literature already published.[1,2,3,6,7] For determination of the filter cavity coupling slot dimensions, use is made of a set of measured results on slot susceptance versus dimensions which enables greater design accuracy to be realized. The design procedure has been implemented in a set of computer programs called DUAL(N), where N stands for the number of resonators. The output gives the physical dimensions of the filter.

Measured Results

Typical measured results of a triplexer are given in Figure 2 and Figure 3, together with performance specification constraint points. Figure 2 gives out-of-band isolation of one channel at ambient. Figure 3 shows the group delay response of a channel at -5°C and 45°C. It is seen that the requirements are met. The average frequency shift of the filters is approximately 0.5 MHz which is comparable to that of invar.

Spurious Suppression

A waveguide filter essentially consists of half wavelength resonant cavities appropriately coupled to realize a desired characteristic. Besides the unwanted resonance, typically $\lambda g/2$ resonance, other resonances (spurii) will occur in each cavity whenever it is a multiple of half wavelengths. This applies to all the modes that can be supported by the waveguide at that frequency. Another spurious mechanism is the TM mode resonance at its cut-off frequency.

The relative abundance of spurious passbands (compared to rectangular waveguide filters) in dual mode filters is a consequence of the use of circular or square waveguide which has;

a) lower cut-off frequencies for the higher order modes which when propagating will generate passbands in the same manner as the dominant mode,

b) increased cavity length (in circular waveguide) which results in closer spacing between the resonances.

It has also been observed that in general the spurious level increases when the filters are multiplexed. This is shown in Fig. 4 where the level of the TM_{010} resonance (4.25 GHz in 2.126" ID waveguide) can be up to -40 dB. Another high level spurious is due to the TM_{011} mode.

As shown in Fig. 5, the triplexer design has virtually eliminated the TM_{010} spurious and reduced the level of the TM_{011} spurious.

Conclusions

The principal features and measured results of DMQE 4 GHz multiplexers built in GFEC have been presented. These multiplexers have now been qualified for use in satellite communications systems. Their superior performance and lighter weight make them highly attractive for aerospace applications. It is envisaged that such multiplexers will be incorporated into many future satellite transponders.

Acknowledgements

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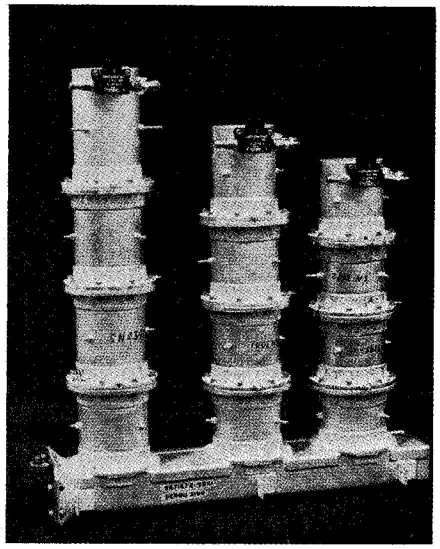

Fig. 1: Flight Model GFEC
4 GHz Triplexer

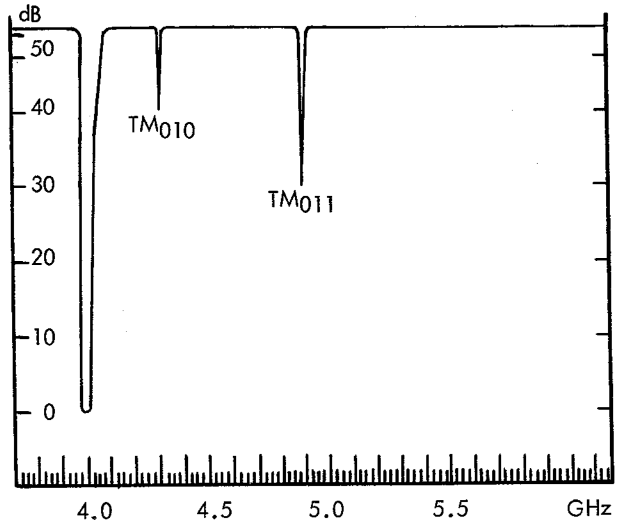

Fig. 4: Initial Spurious Performance

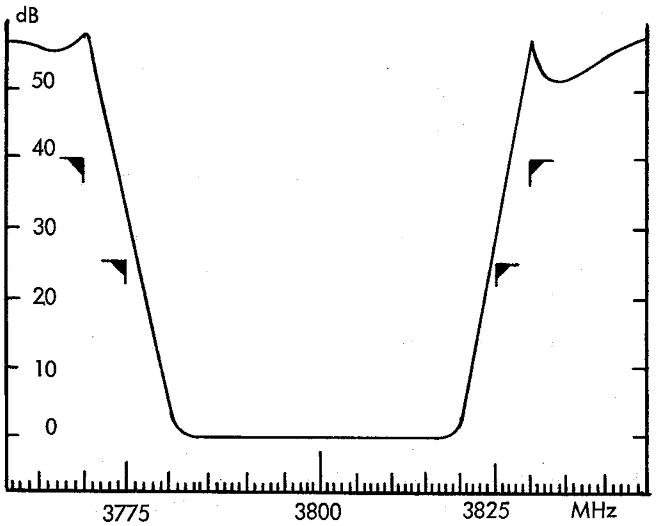

Fig. 2: Measured Out-of-Band Response

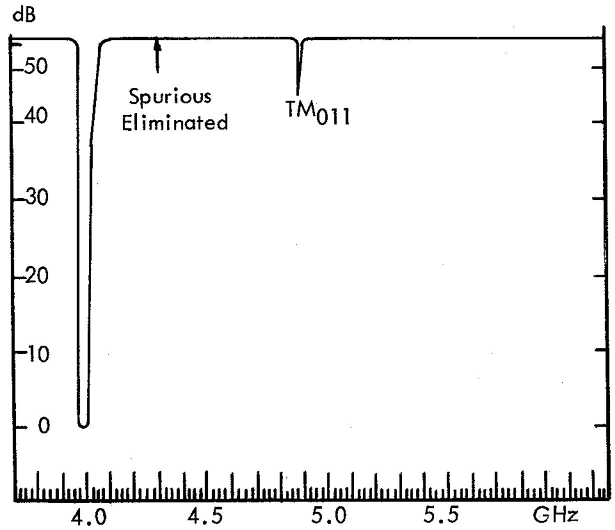

Fig. 5: Final Spurious Performance

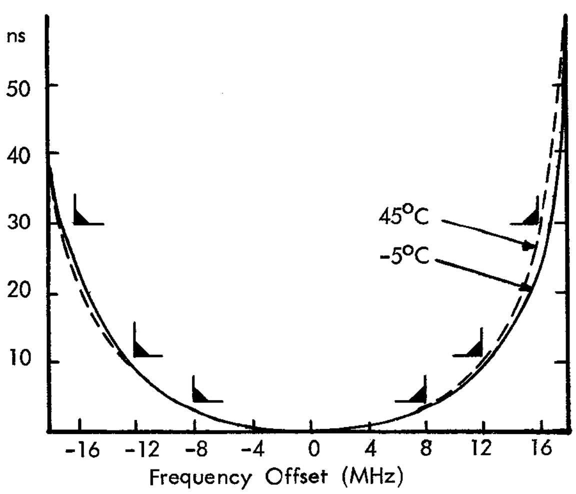

Fig. 3: Measured Group Delay