NOVEL LOWPASS HARMONIC FILTERS FOR SATELLITE APPLICATION

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ABSTRACT

A new class of lowloss spurious-free lowpass filters in ridged waveguide have been developed for space application. These filters are currently being incorporated for INTELSAT VI at 4 GHz and SATCOM K satellites at 12 GHz and will likely replace the present generation of Zolotarev stepped-impedance or waffle- iron filter networks for future spacecraft.

INTRODUCTION

The payload in a communications satellite requires lowpass harmonic filters in the output circuits to augment isolation over the receive band and provide high attenuation for the second and third harmonics of the high level TWTAs. With the growing number of satellites and frequency bands, it is becoming necessary to provide high isolation all the way from the receive band to third harmonic to control spurious emissions and hence minimize interference to other satellite systems.

The present generation of lowpass harmonic filters use Zolotarev function in a tapered corrugated waveguide structure [1,2]. Such a structure requires low impedance sections to minimize spurious responses. This, in turn, results in small gap spacings in the low impedance section and consequently has a relatively low power handling capability. The spurious problem can be reduced by introducing coaxial slots in the impedance sections of the filter [3]. This results in the waffle-iron filter. The power handling capability of the waffle-iron structure is higher than the corresponding stepped-impedance type filter but it also has spurious modes in certain frequency bands. The proposed class of evanescent mode ridged waveguide lowpass filter overcomes the spurious mode problem very effectively and can be sized for different power handling capabilities in the space environment. The three alternative structures have been developed and measured data is described in this paper.

NEW CLASS OF EVANESCENT MODE RIDGED WAVEGUIDE FILTERS

The ridged waveguide filters are based on Chappelle's [4] approach that used a double ridge waveguide to construct a distributed shunt capacitance and evanescent mode waveguide to realize the series inductance. Higher filter impedance can be achieved by this technique while using Chebyshev or Zolotarev lowpass filter prototype. In this paper three different ridge waveguide structures have been developed and optimized for high power handling capability in vacuum and spurious free response up to at least third harmonic.

Single Ridge Structures

A single ridge structure which has been developed is described in Figure 1(a). The distributed shunt capacitor in the ridge sections are designed to support one mode (TE_{10}) in both the pass band and stop band. This constraint causes ridge gaps to be small with power limitation. On the other hand it is a very simple structure and quite adequate for most applications.

Triple Ridge Structure

This structure, described in Figure 1(b), was developed to increase the ridge gap and hence the power handling capability. This is achieved by adding two auxiliary ridges. The functions of these auxiliary ridges are to control the cut-off frequency of the TE_{20} and TE_{30} modes to be not only outside of the passband of the filter but also outside the important stopbands. This ensures very superior rejection characteristics and at the same time be able to survive very high powers in a vacuum environment [5].

Single Ridge Structure with TM Couplings

The single and triple ridge structures described above can realize the all-pole Chebyshev or Zolotarev functions only. For certain applications one requires sharper cut-off at the expense of a little lower isolation in stopband regions. The proposed structure to achieve this is described in Figure 1(c). By adding small T-sections onto the ridges analoguous to ridge antennas series capacitances in parallel with a seized inductance is achieved by the TM_{11} mode coupling. This, in effect, gives rise to the possibility of realizing finite transmission zeros and hence quazi-elliptic responses. Such a structure leads to reduced filter length, higher ridge gaps

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and hence higher power handling capability. However, the structure is a bit more complex and requires closer tolerances in the design and fabrication.

MEASURED DATA AND COMPARISON WITH EXISTING DESIGNS

A summary of the measured data for the three new lowpass filters in ridge waveguide structures are described in Table 1 and compared with the typical response of the conventional stepped-impedance and waffle-iron filters. Figures 2 to 4 describe the configurations of the units and the measured plots of the responses. Measured data correlates closely with the theoretical design and hardware. As can be seen from the table the performance is superior to the present generation of lowpass filters.

CONCLUSIONS

A new class of lowpass harmonic filters have been developed for space application. These designs, based on ridged waveguide structure and evanescent mode, are optimized for spurious free response to at least third harmonic and for high power handling capability in the space environment. Typically, at 12 GHz, the ridge structure has a measured performance of <0.25 dB loss over 12.2 to 12.7 GHz, isolation of >60 dB across 14 to 38.1 GHz (except 35 dB spikes at 27.1 & 28.5 GHz) and power handling capability in excess of 800 W in vacuum. This new class of filters is currently being incorporated for INTELSAT VI at 4 GHz and SATCOM K satellites at 12 GHz. These filters will likely replace the present generation of Zolotarev stepped-impedance or waffle-iron filter networks for future spacecraft.

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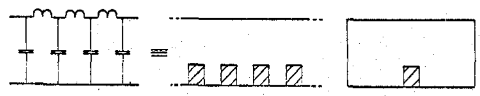
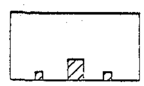
Table 1 : Measured Performance Comparison of Stepped Impedance/Waffle-Iron Filters and the New Class of Ridged Evanescent Mode Filters

Parameter	Conventional Stepped-Impedance or Waffle-Iron Filter	New Class of Ridged Waveguide Structures: Single Ridge	Triple Ridge	Single Ridge with TM Coupling
Response Function	Zolotarev or Chebyshev	Zolotarev or Chebyshev	Zolotarev or Chebyshev	Zolotarev with transmission zeros
Passband, GHz	11.7 - 12.2	11.7 - 12.2	12.2 - 12.7	11.7 - 12.2
Return Loss, dB	>26	>26	>26	>26
Insertion Loss, dB	<.25	<.2	<.25	<.15
Rejection, dB				
14 - 14.5 GHz	>55	60	60	60
14.5 - 20 GHz	-	-	-	>60
14.5 - 23.4 GHz	>20	60	>65	-
23.4 - 24.4 GHz	>70	80	>65	-
24.4 - 35.1 GHz	>20	60	>65*	-
35.1 - 36.6 GHz	>70	80	>65	-
Power Handling Capability in Vacuum, W	>200	>250	>800	>1000
Size	3.5"x1.5"x1.5"	3.5"x1.5"x1.5"	4.5"x1.5"x1.5"	3"x1.5"x1.5"
Weight, g	60	55	75	50

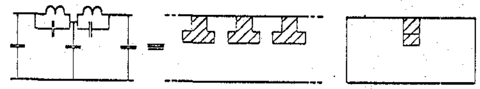
* Measured data in Figure 3 shows a very narrow spike of 35 dB at 27.1 & 28.5 GHz.



(a) Single Ridge Structure



(b) Triple Ridge Structure



(c) Single Ridge Structure with TM Couplings

Figure 1 : Novel Lowpass Evanescent Mode Filter Configuration in Ridged Waveguide Structures

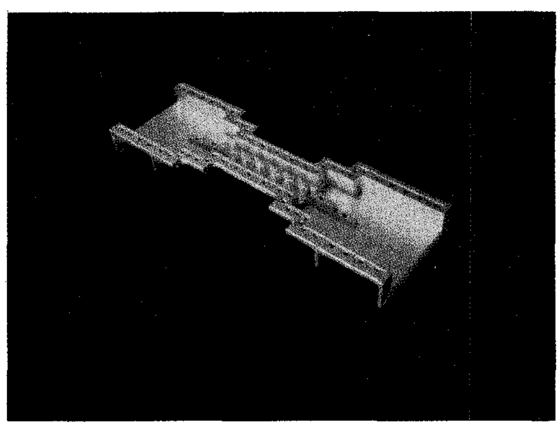


Figure 2(a) : Single Ridge Lowpass Filter at 4 GHz Flight Configured Unit

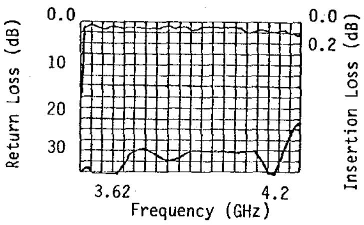


Figure 2(b) : Single Ridge Lowpass Filter at 4 GHz
Passband Response

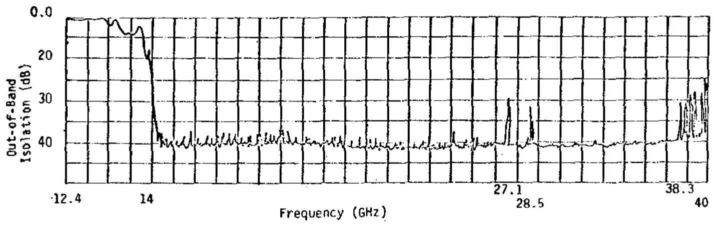


Figure 3(c) : Triple Ridge Lowpass Filter at 12 GHz
Measured Isolation Response over 12.4 - 40 GHz.

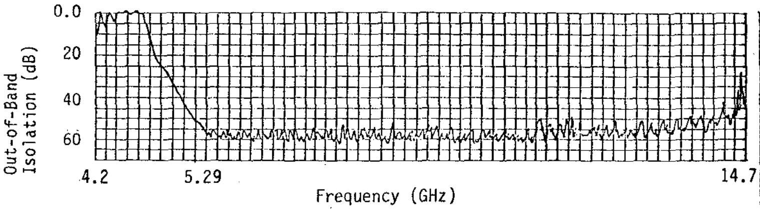


Figure 2(c) : Single Ridge Lowpass Filter at 4 GHz
Measured Isolation Response over 4.2 - 14.8 GHz

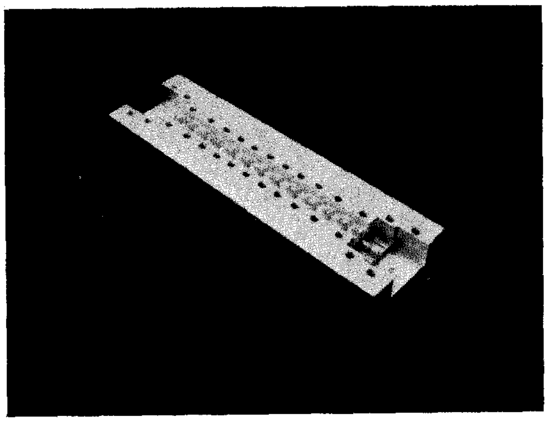


Figure 3(a) : Triple Ridge Lowpass Filter at 12 GHz
Flight Configured Unit

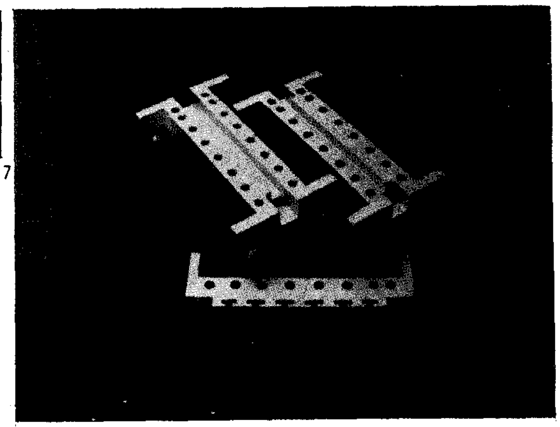


Figure 4(a) : Single Ridge with TM Coupling Lowpass Filter at 12 GHz
Flight Configured Unit

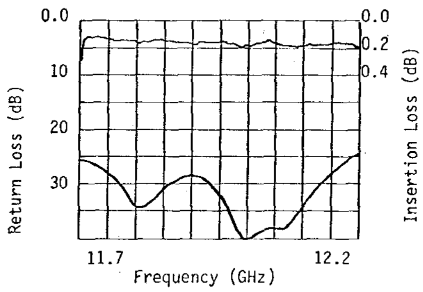


Figure 4(b) : Single Ridge with TM Coupling Lowpass Filter at 12 GHz
Passband Response

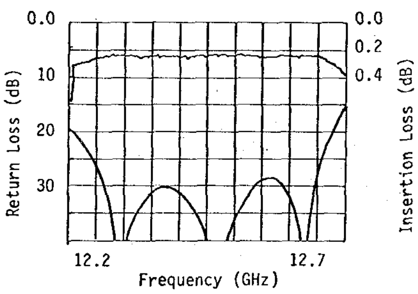


Figure 3(b) : Triple Ridge Lowpass Filter at 12 GHz
Passband Response

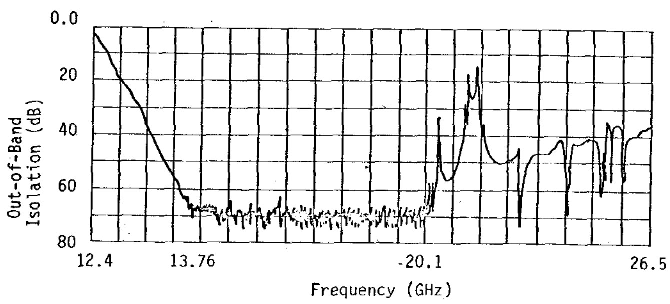


Figure 4(c) : Single Ridge with TM Coupling Lowpass Filter at 12 GHz
Measured Isolation Response over 12.4 - 26.5 GHz.