400-kW Harmonic Filter

R. L. Leu
R. F. Systems Development Section

The low-power test data of the new 400-kW harmonic filter design shows that the new filter meets or exceeds the performance of the existing filters. This will not insure that the fourth harmonic from the 400-kW transmitter will not affect the X-band receiver performance. Additional fourth harmonic filters may be required.

I. Introduction

A new procurement was initiated to provide high-power harmonic filters for the overseas 64-m antennas. Since the 20-kW transmitter also uses this harmonic filter, the filter is required to be installed in conjunction with the 20-kW transmitter. In an effort to improve the performance of the harmonic filter, design changes were made. However, these new filters are physically interchangeable with the existing harmonic filters at DSS 14. This report describes the new design and the test results of the first filter.

II. Design Constraints

The new filter design was to be physically interchangeable with the existing filters and was not allowed to exceed the envelope dimensions of the existing design.

The new filter design was to incorporate the orthogonal mode (TE_{on}) converters, orthogonal mode rejection, and scattering elements. The use of a harmonic rejection waffle-iron was not allowed. The waffle-iron design requires the use of many discontinuances in the waveguide and considerable reduction in waveguide height. Both of these items are conducive to breakdown under high-power operation.

III. Design Requirements

The electrical requirements are given in Table 1. Two important points are:

(1) The filter is only specified in the TE_{10} mode.

(2) An incentive was offered for improvement in the fourth and fifth harmonic stopbands, up to 50 dB.

IV. Design Concept

Based on the design constraints and requirements, the new filter consists of two harmonic absorber sections, as illustrated in Fig. 1. The input section (on the left) is standard WR430 waveguide containing broadwall coupling slots, secondary waveguides, diagonal rods, and a septum section. The input section was designed primarily to attenuate the second harmonic.

The coupling slots are used to couple the harmonic power into the secondary rectangular waveguides. Each slot couples to one secondary waveguide that is orthogonal to the primary waveguide. The input coupling slot widths are tapered to provide a good impedance match to the harmonic frequencies and provide a more uniform distribution of the harmonic power dissipation. Calculations indicate that most of the harmonic power is dissipated in the first third of the filter.

The secondary waveguides are beyond the cutoff of the fundamental and, therefore, absorb very little of the fundamental frequency. The broadwall coupling slots primarily couples the TE_{mo} modes. However, there will be some harmonic power in the TE_{on} modes which does not directly couple to the broadwall secondary waveguides. The function of the diagonal rods as illustrated in Fig. 1 is to convert the TE_{on} modes to TE_{mo} modes. The rods are placed at an angle to reduce reflection (increased VSWR) and also to convert the TE_{on} modes to an orthogonal mode. The six rods and their spacing is critical for maximum conversion of the TE_{on} harmonic modes. Tests were conducted using additional rods with no significant improvement in the attenuations. However, tests revealed that less than six rods and/or different spacing resulted in reduced harmonic attenuation.

The septum portion is located at the output of the filter input section as illustrated in Fig. 1, section C–C. This section consists of three equally spaced splates or septa. The septum area provides rejection of any TE_{on} modes that exist at this point (this is a modified version of the waffle-iron filter). The reflected modes will then pass through the diagonal rods, again providing further attenuating of the harmonics.

The output section of the harmonic filter is the normal width of WR430 waveguide, but the height has been reduced to 60% (2.98 cm or 1.25 in.) of the normal height. The height reduction was used to improve harmonic attenuation by preventing propagation of some harmonic higher order modes. The coupling slots on each broadwall of this section are in three rows providing better attenuation of the third harmonic.

The input section of the filter was designed primarily for second harmonic attenuation, the output section primarily for third harmonic attenuation. The fourth and fifth harmonics are attenuated throughout the filter. Although the filter design requirements are for the TE_{10} mode, the use of the diagonal rods, septa plates, and reduced height waveguide provide some attenuation of the TE_{on} modes.

To improve the performance of the filter, especially at the fourth harmonic, would require the design of a multimode harmonic filter.

V. Measurements

The measured low-power performance characteristics of the first new design filter delivered are illustrated in Figs. 2 through 6. Only one out of specification condition existed, as can be seen from the second harmonic attenuation curve. The broken line curves represent the performance of the two existing harmonic filters and are included for reference.

VI. Summary

The low-power test data of the new filter design shows that the new filter meets or exceeds the performance of the existing filter. (Figures 2 through 6 show a comparison of the two existing filters and the new filter.) This still will not insure that the fourth harmonic from the 400-kW transmitter will not affect the X-band receiver performance. In the past, all harmonic filters have been designed primarily for TE_{10} mode attenuation of the transmitter harmonics with an attempt to attenuate the TE_{on} modes. This has proved to be adequate in the past, and we have not been able to measure harmonic modes other than the TE_{10} mode.

To obtain a better knowledge of the various harmonic modes that exist in the microwave system, we are procuring a harmonic multi-mode analyzer. With the harmonic analyzer, we would be able to better evaluate the performance of a multi-mode harmonic filter. Also, the analyzer will provide a measure of the fourth harmonic level so that if required, due to interference with the X-band receiver, an additional fourth harmonic multimode filter could be obtained.

Table 1. Electrical specifications, TE_{10} Mode

Passband	
Frequency range	2.100 to 2.120 GHz
Insertion loss across frequency range	0.10 dB maximum
Input VSWR	1.05:1 maximum
Power capacity	500 kW minimum CW
Stop bands	
Total input reflected power for all modes in the stop bands	500 W maximum
Second harmonic stop band	
Frequency range	4.200 to 4.240 GHz
Attenuation across frequency range	60 dB minimum
Power absorbing capacity	2 kW maximum
Third harmonic stop band	
Frequency range	6.300 to 6.360 GHz
Attenuation across frequency range	60 dB minimum
Power absorbing capacity	2 kW maximum
Fourth harmonic stop band	
Frequency range	8.400 to 8.480 GHz
Attenuation across frequency range	40 dB minimum 50 dB design goal
Power absorbing capacity	500 W
Fifth harmonic stop band	
Frequency range	10.500 to 10.600 GHz
Attenuation across frequency range	40 dB minimum 50 dB design goal
Power absorbing capacity	500 W

Noise generation: Arcing, corona, breakdown, and other noise generating phenomena, excluding thermal noise, shall not exceed −180 dBmW/Hz in the frequency range of 2.270 to 2.300 GHz.

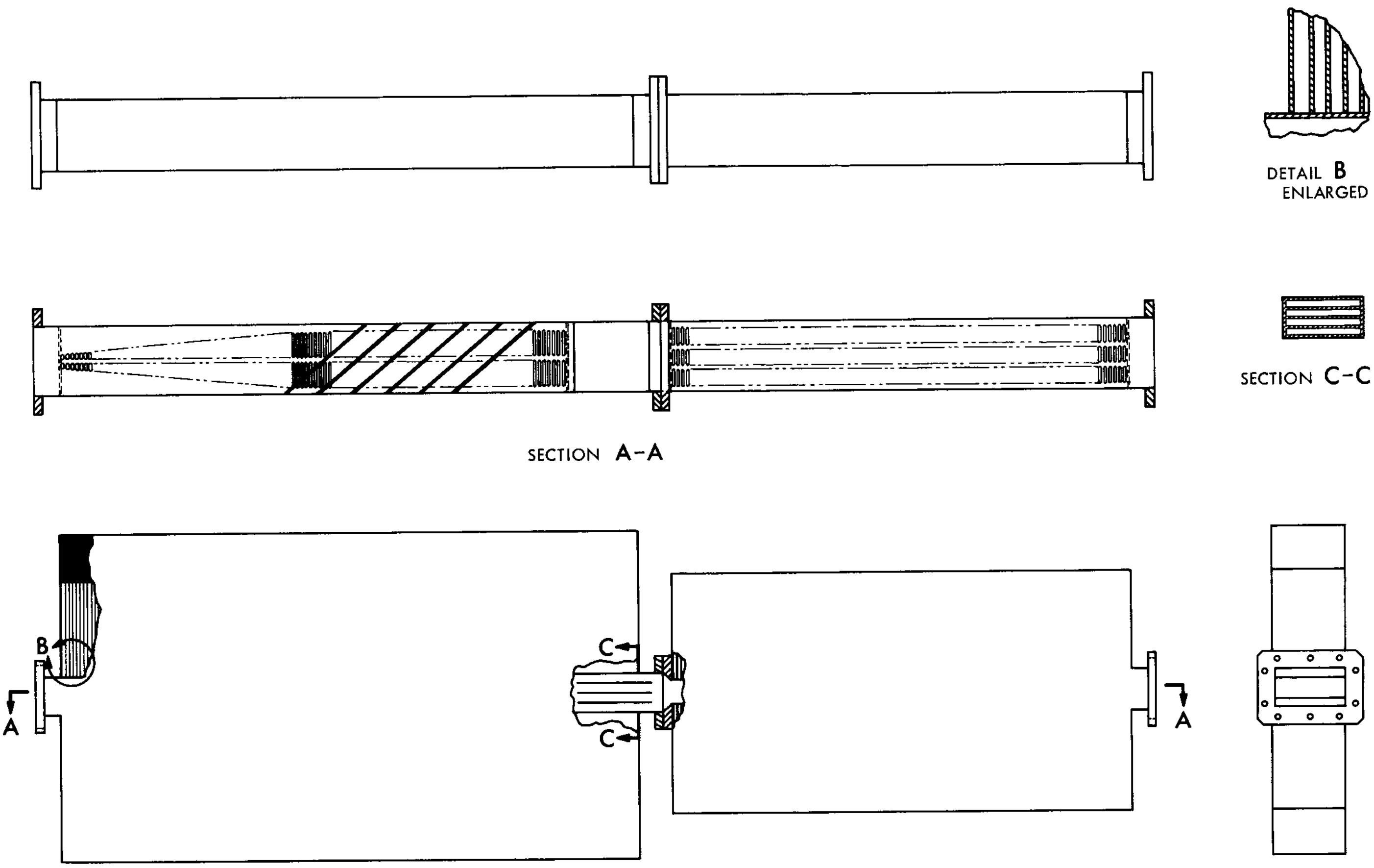

Fig. 1. Harmonic filters

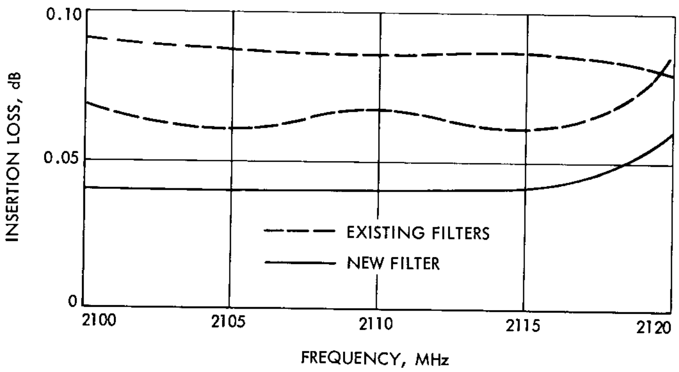

Fig. 2. Pass-band insertion loss

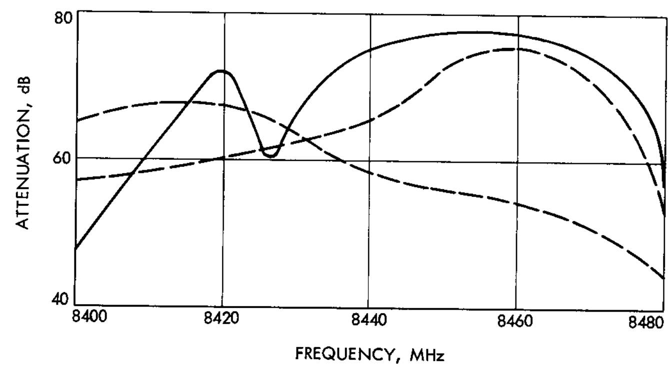

Fig. 5. 4th Harmonic stopband attenuation

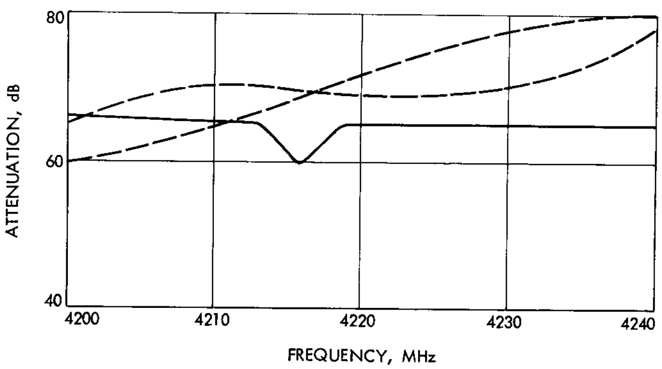

Fig. 3. 2nd Harmonic stopband attenuation

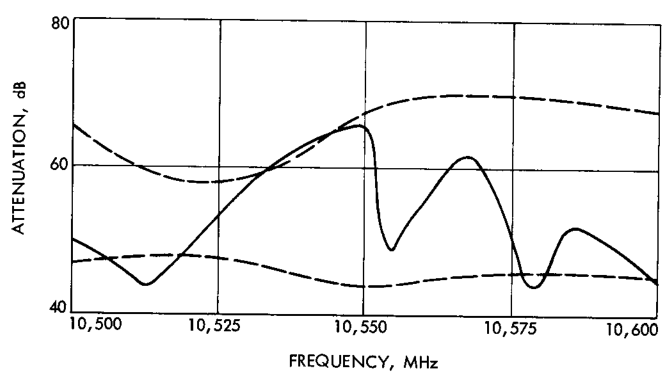

Fig. 6. 5th Harmonic stopband attenuation

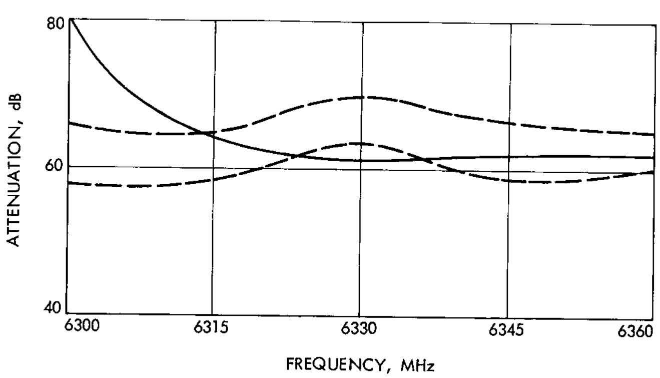

Fig. 4. 3rd Harmonic stopband attenuation