A COMPARISON OF FOUR OVERMODED CANONICAL NARROW BANDPASS FILTERS AT 12 GHz

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ABSTRACT

The relative merits of four waveguide modes, square TE_{103} and TE_{105} and cylindrical TE_{113} and TE_{011}, in constructing small, lightweight, low loss, narrow bandpass canonical filters for use at 12 GHz and above are presented in this paper. The TE_{113} mode is the choice of the present study.

The advent of channelized 14/12 GHz satellite repeaters and the promise of 30/20 GHz systems have generated considerable interest in small, lightweight, low loss, narrow bandpass filters for use at 12 GHz and above. Since fundamental mode filters often have unacceptably high insertion loss at these frequencies, emphasis has been placed on overmoded filters. In this paper we report the results of a study in which we attempted to assess the relative merits of four waveguide modes by constructing filters from the same electrical prototype design using each mode. Our choice of modes for study has been influenced by the following considerations: a strong preference for dual mode over single mode filters, a survey of the literature, and our experience with fundamental mode filters. We have chosen square modes TE_{103} and TE_{105} and cylindrical mode TE_{113}, all logical extensions of fundamental modes, and the cylindrical TE_{011} mode, which has the highest theoretical unloaded Q to volume ratio of all cylindrical modes. TE_{103} and TE_{011} modes have appeared prominently in the literature; the TE_{113} mode was suggested by Seymore Cohn.

The electrical design (see Table 1) is a six-section, four finite frequency loss pole canonical design typically required for a 14/12 GHz satellite output filter. We limited this study to canonical filters because of the large performance penalty often imposed when less than canonical response is attained. No rejection is required in the receive band (typically 14 to 14.5 GHz) because sufficient rejection is generally provided by a receive reject filter placed in series with the output multiplexer.

It is important to note that while there are an infinite number of waveguide modes with arbitrarily large unloaded Q, these modes invariably appear in crowded regions of the mode chart. The practical maximum unloaded Q selected is determined mainly by the frequency range over which the filter must be free of spurious passbands due to neighboring modes (11.7 to 12.2 GHz for our requirement).

TABLE 1. ELECTRICAL PROTOTYPE FILTER DESIGN SUMMARY

Center frequency	11.7 – 12.2 GHz depending on the channel
0.01 dB ripple passband	47 MHz
30 dB rejection bandwidth	60 MHz
Spurious free region	11.7 – 12.2 GHz
Number of sections	6
Number of loss poles	4

The six-section 12 GHz canonical filters, shown in Figure 1, are constructed (using the waveguide modes indicated in the figure) in brass or aluminum with a 16μ in. rms finish and periodic reverse current plated with 0.0002 inch of silver. No burnishing or polishing was used. Pressure ridges were employed on flanges to assure good electrical contact with replaceable copper irises. The TE_{103} and TE_{105} mode filters are similar to those described by Kallianteris and O'Donovan,[1] except that we have used the canonical dual mode structure first reported by Atia and Williams[2,3] for fundamental mode filters. The TE_{113} filter is also canonical dual mode. This structure is compared to standard dual mode[4,5] in Figure 2. The numbered arrows in the figure indicate the polarization of each resonator. Note that all bridge couplings in the canonical dual mode filter are realized using coupling screws, while the coupling screws in standard dual mode control mainline couplings. The symmetry of canonical dual mode allows the use of circular irises. This structure requires that the input/output ports be coupled to the same cavity at one end of the filter. One port is sidewall

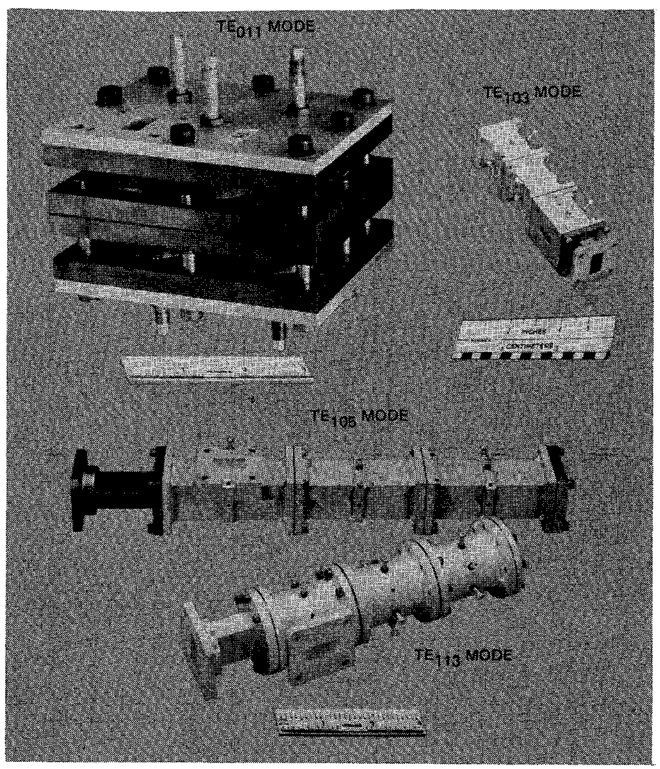

FIGURE 1. SIX SECTION 12 GHZ CANONICAL FILTERS

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coupled and the other is endwall coupled, each to orthogonal polarizations in the end cavity.

To our knowledge, these are the first reported canonical dual mode filters utilizing higher order modes. We experienced no unexpected problems associated with the use of higher order modes in canonical dual mode filters. Although spurious modes are less attenuated than with standard dual mode filters due to the proximity of the input/output ports, no mode suppression was necessary in the three canonical dual mode filters.

The six-section canonical TE_{011} filter is a single mode folded waveguide structure somewhat similar to that described by Atia and Williams.[6, 7] TM_{111} mode suppressors were used on the endwalls as described by Atia and Williams.

All filters met the design rejection requirements. The insertion loss versus frequency of three of the filters is shown in Figure 3. The TE_{103} mode filter response (not shown) was similar to the TE_{105} response. The midband loss and calculated unloaded Q for each filter are shown in Table 2. Wideband insertion loss data showing the spurious passbands of four filters are seen in Figure 4. The TE_{113} mode filter has the lowest insertion loss and is least subject to spurious passbands. As would be expected, TE_{105} is lower loss, but has more spurious modes than TE_{103}.

Using TE_{011} mode, we achieved unloaded Q's in excess of 20, 000 at 12 GHz for filter bandwidths of less than 0. 15 percent. However, as the bandwidth is increased, the unloaded Q degrades rapidly as

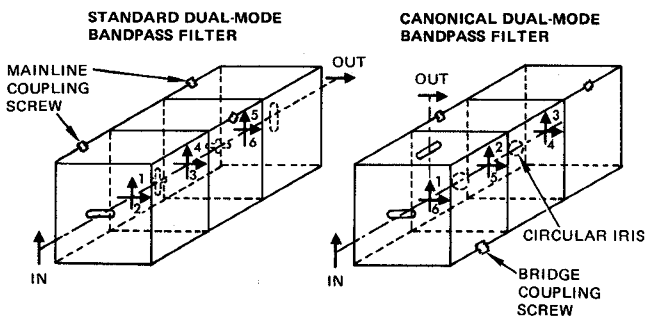

FIGURE 2. CANONICAL VERSUS STANDARD DUAL MODE FILTERS

TABLE 2. MIDBAND LOSS, UNLOADED Q, AND RESONATOR VOLUME COMPARISON

Waveguide Mode	Filter Type	Midband Loss*	Calculated Unloaded Q*	Total Resonator Volume, in^3
Square TE_{103}	Canonical dual mode	0.80	7,300	4.4
Square TE_{105}	Canonical dual mode	0.60	9,700	7.3
Cylindrical TE_{011}	Folded waveguide	0.50	11,600	9.2
Cylindrical TE_{113}	Canonical dual mode	0.36	16,300	4.8

*Accuracy is ±10 percent.

illustrated by the unloaded Q of less than 12, 000 quoted in Table 1 for a 0. 38 percent bandwidth. This degradation, which has been described as due to input iris resonance breakdown,[3] does not appear to be associated with bridge couplings, the choice of end-wall versus sidewall coupling, or the thickness of the irises. Unless this degradation can be overcome, TE_{011} mode will probably be used only in very narrow bandwidth applications or in applications where the relative ease of temperature compensation of the mode can be exploited.

Filter size and ruggedness with lightweight construction are extremely important for satellite application. The total resonator volume for each filter is given in Table 1. TE_{103} and TE_{113} filters are considerably smaller than TE_{105} or TE_{011}. For a given wall thickness of construction, the cylindrical TE_{113} filter is mechanically more stable than the square TE_{103} or TE_{105} filters which will allow lighterweight hardware. In terms of performance to volume, the TE_{113} mode filter has the highest performance by a wide margin.

We have attempted to accurately compare several higher order mode narrow bandpass canonical 12 GHz filters, including the modes which have been prominent in the literature, and the TE_{113} mode which to our knowledge has been unreported. The TE_{113} canonical dual mode filter appears to be the clear choice among the filter configurations investigated for use as a low loss, narrow bandpass filter at 12 GHz.

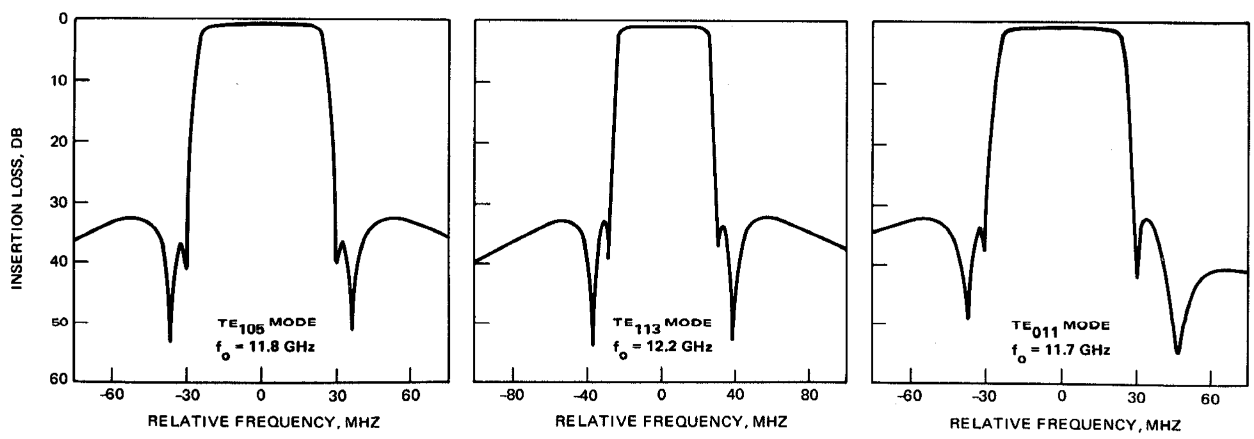

FIGURE 3. INSERTION LOSS FOR INDIVIDUAL FILTERS

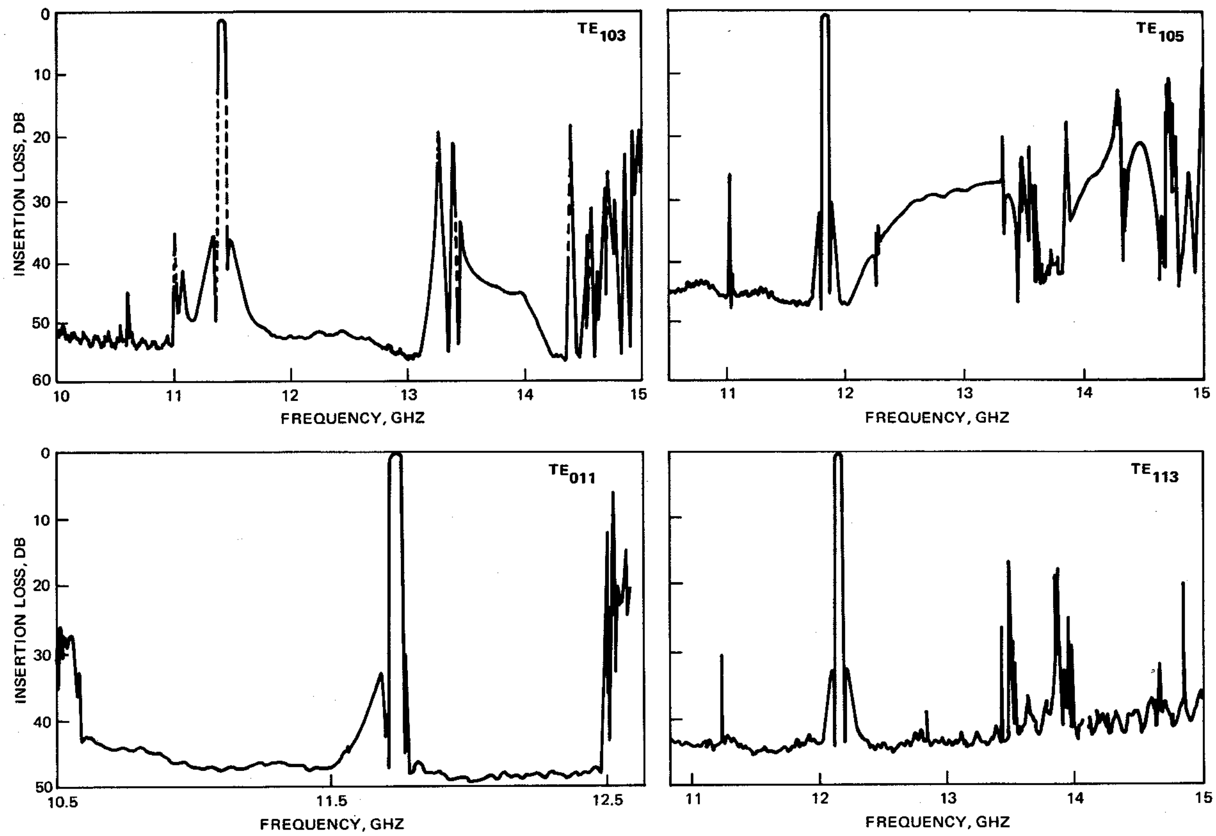

FIGURE 4. WIDEBAND INSERTION LOSS WITH SPURIOUS MODES

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