LOW-LOSS BANDPASS FILTERS AT 80 GHz USING CYLINDRICAL TE_{111}-MODE CAVITIES

Takakiyo Nakagami and Sadao Takenaka
Fujitsu Laboratories Ltd.
Nakahara, Kawasaki, (211) Japan

Abstract

Multi-section bandpass filters with cylindrical TE_{111}- mode cavities have been constructed at 80GHz with a new mechanical construction. The low insertion loss and the other performance are consistent with design without any adjustment.

Introduction

The bandpass filter is very important for the millimeter-wave communication system to eliminate spurious signal of frequency converters or to reduce the interference between transmitters and receivers.[1 2] This paper describes multi-section bandpass filters using cylindrical TE_{111}- mode cavities. Since more than one hundred kinds of bandpass filters will be used in a practical system, whose center frequencies range from 40 to 90GHz, good producibility is required in addition to low insertion loss and high precision of dimension. In order to satisfy this requirement, a new mechanical construction has been employed, whose component parts are precisely fabricated and inspected separately and assembled together afterwards. The early paper reported rectangular waveguide filters of this structure in the frequencies from 40 to 80GHz.[3] But filters using cylindrical cavities are more suitable in such high frequencies as 80 GHz and above, because they have higher unloaded Q and can be fabricated more precisely. Whereas the TE_{01n}-mode resonance has the highest unloaded Q in the cylindrical cavity, the characteristics of the filter using this mode will be deteriotated due to the spurious resonance of adjacent modes which are more strongly coupled to the external circuit. Considering the strict specifications required for use in a practical system, the TE_{111}-mode resonance has been employed in view of design and electrical performance.

Description of filter structure

Fig. 1 shows a cutaway view and Fig. 2 a photograph of the completed 4-section bandpass filter. Thin coupling plates and circular waveguides are piled up alternately and screwed together with rectangular waveguide input and output flanges. This structure, in which all components are fabricated separately, enables to achieve high accuracy of dimensions. The circular waveguides and the coupling plates are fabricated with tolerances as small as 10 to 20 microns. The coupling plate is prepared by etching the coupling aperture on a 20 micron thick brass plate by the photolithographic technique. All components are plated with pure silver to reduce the loss in the metal wall of the structure and are subsequently subjected to microscopic inspection of dimensions. Finally, they are aligned accurately along the central axis with the aid of an external guide cylinder.

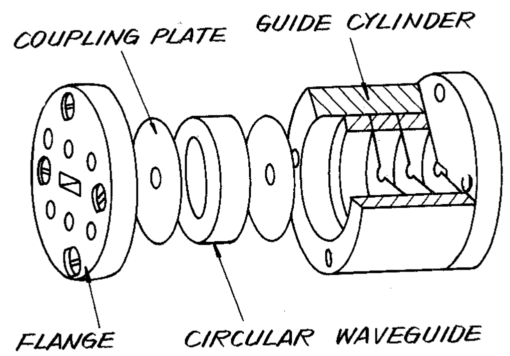

Fig. 1 Structure of bandpass filter using TE_{111}- mode cavities

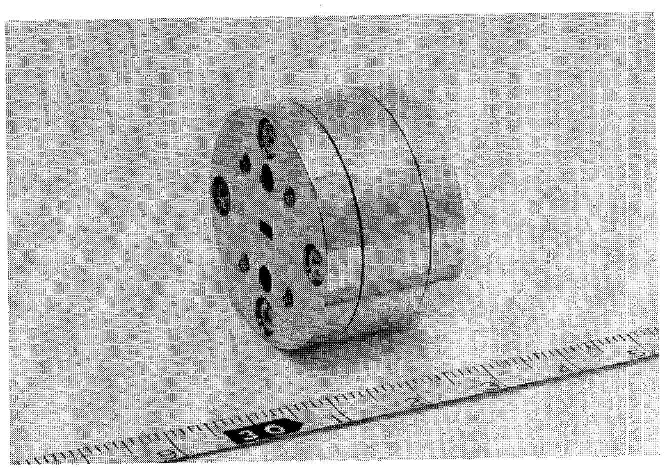

Fig. 2 4-section bandpass filter at 80GHz

Design of filter

For automatic designing, a CAD program has been developed, which permits printing-out actual sizes when specifications of the filtr are given as input data. The design is performed on the basis of the theory of direct-coupled waveguide filter[4] which is advantageous for the simplification of construction and the achievement of low loss. The theory has been modified in order to take into account of the difference of characteristic impedances between circular waveguide in the filter structure and rectangular waveguide in the input and output ports.

As the size of each element is very small porportionally to the millimeter wavelength, the wall thickness of coupling aperture has substantial influences on the overall performance. Accordingly, the dimensions of coupling aperture and the cavity

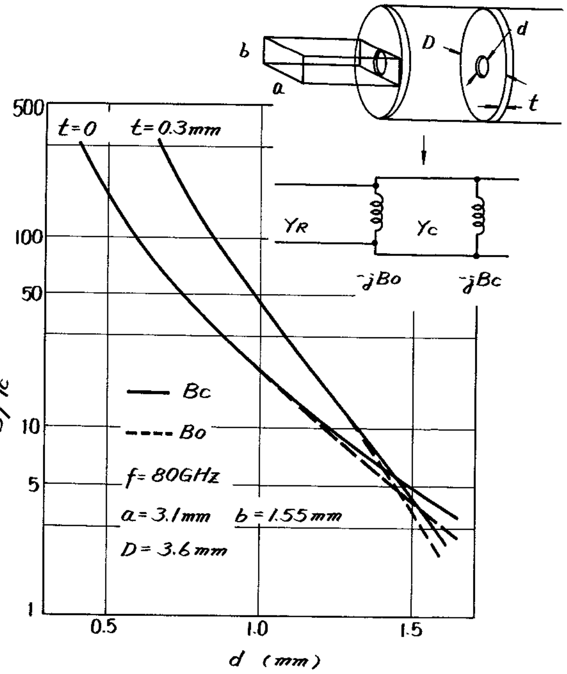

Fig. 3 Calculated susceptance of coupling aperture

lengths are determined by considering the thickness of coupling plate. Fig. 3 shows the calculated susceptance of coupling aperture for different wall thickness by using the equation based on the small hole approximation. The accuracy of these values has been confirmed by constructructing trial 1-section filters in 50GHz band, whose performances were in agreement with the design.

The actual frequency characteristics is usually different from that of an ideal bandpass filter because of dispersive characteristics of the waveguide and frequency dependence of the susceptance of the coupling aperture. Consequently, a calculation program of frequency response based on the designed dimensions was incorporated in the CAD program so that the adequacy of the designed filter to required specification could be checked.

Electrical Characteristics

Two kinds of maximally-flat response bandpass filters, one is 2-section filter of $Q_L = 116$ and the other 4-section of $Q_L = 40$, were constructed at the frequency of 80GHz. The characteristics of these filters are shown in Figs. 4 (a) and (b). The numerical data are compared in Table I with the calculated values. These characteristics, which have been obtained without any adjustments after construction, show fair agreement with designed specification. The insertion losses have been found to be smaller than those of rectangular waveguide filters.[3] The achieved value of unloaded Q was about 50% of the theorectical value, which is fairly high at such high frequency as 80GHz compared with the value of 60 to 80% obtained with microwave filters.

	2-Section Filter		4-Section Filter	
	Calculated	Measured	Calculated	Measured
Center frequency (GHz)	78.97	79.0	80.67	80.5
3dB Bandwidth (MHz)	680	643	1920	2010
Insertion loss (dB)	0.31	0.75	0.21	0.50
Unloaded Q	4500	2000	4500	2000

Table I Measured data of constructed filters in comparison with calculated values

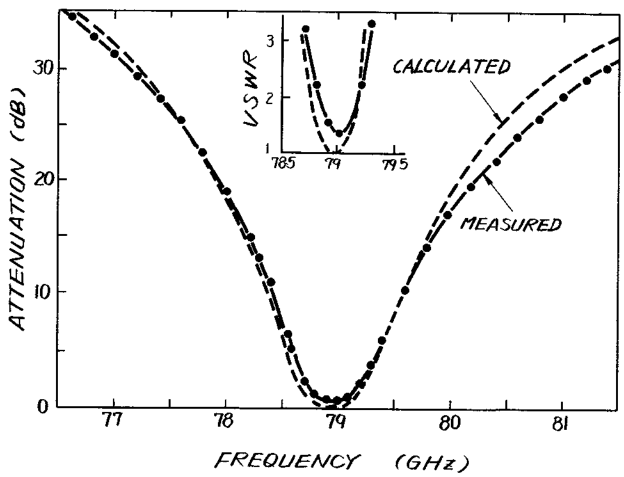

Fig. 4(a) Frequency characteristics of 2-section filter

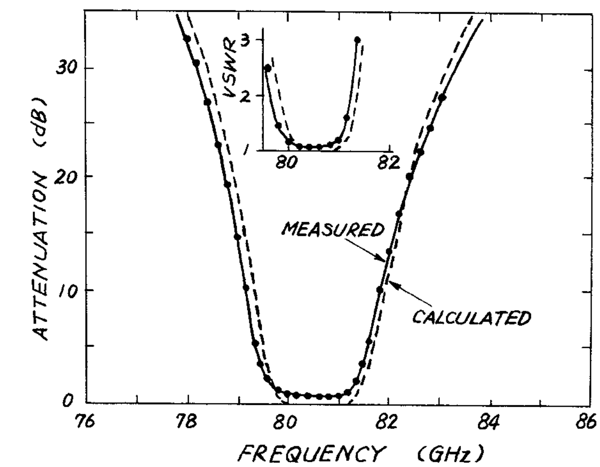

Fig. 4(b) Frequency characteristics of 4-section filter

Many resonance modes in cylindrical cavity may cause spurious response. Fig. 5 shows the measured frequency characteristics of the 4-section filter with a center frequency of 50.1 GHz and Q_L of 28.5 having the same structure as above. Arrows in the figure indicate resonant frequencies of the respective modes.

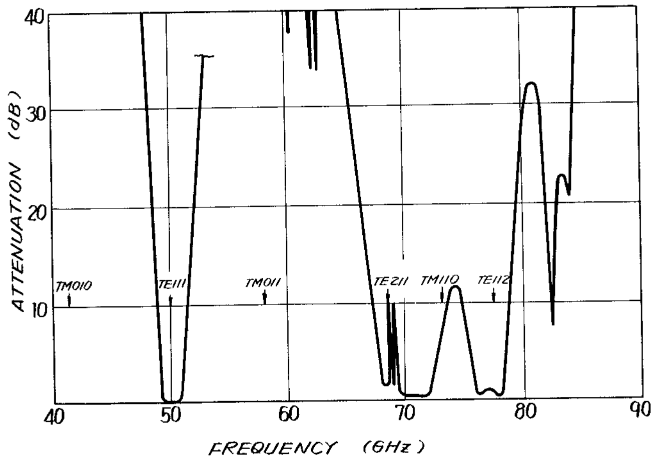

Fig. 5 Spurious response of 4-section filter with the center frequency of 50.1 GHz

The responses of TM_{010} and TM_{011} modes adjacent to the TE_{111} mode were not observed because of weak coupling in the present structure. The result shows that there is no deterioration of characteristics due to spurious response in the frequency range below that of the TE_{211}-mode resonance.

Conclusion

80GHz bandpass filters using cylindrical TE_{111}-mode cavities have been constructed with satisfactory characteristics. These filters have already been put to the practical use in a 80GHz band repeater of the millimeterwave communication system.[2]

Many bandpass filters having the same structure have already been constructed in the frequency range from 40 to 100GHz. Satisfactory results have been also obtained as in the case of 80GHz band described here. The structure presented in this paper, whose component parts are separately fabricated and assembled together afterwards, has proven to be feasible for high-precision filters in the millimeter-wave frequencies.

References

(1) K. Miyauchi, to be presented in special session on "Millimeter Wave Communication in Japan" of this symposium.

(2) M. Akaike et al, "A Trial 80-GHz Band Transmitter-Receiver Panel", paper of the TGMW, IECE of Japan, MW73-79 (Sept. 1973).

(3) T. Nakagami et al, "Rectangular Waveguide Bandpass Filter For Millimeter Waves", Trans. IECE, Vol. 55-B, No. 12, p.699 (Dec. 1972).

(4) S. B. Cohn, "Direct Coupled Resonator Filters", PIRE Vol. 42, No. 2, p.187 (Feb. 1957).