WAVEGUIDE COMPONENTS FOR MILLIMETER-WAVE COMMUNICATIONS AT 40-90GHz

Susumu Kitazume and Hiroyuki Ishihara
Millimeter-Wave and Video Communications
Laboratory, Nippon Electric Co., Ltd.
No. 4035, Ikebe-cho, Midori-ku,
Yokohama-shi, 226, Japan

Abstract

This paper describes the methods of construction and performance characteristics of millimeter-wave components applicable to the 40-90GHz band with particular reference to simple and novel methods of manufacture.

Introduction

Transmitter-receivers[1] in the frequency range of 43-86GHz have been designed and manufactured for use in "W-40G" guided millimeter-wave transmission system,[2] presently under development at the NTT Electrical Communication Laboratories, Japan.

Waveguide components in the frequency range of 40-90GHz have been developed for these transmitter-receivers.

This paper describes the construction and measured characteristics of these components such as circulators, waffle-iron filters, band-pass and band-stop filters, and a flexible waveguide. A novel band-pass filter with harmonic-rejection function which is constructed at 4GHz for scaling into millimeterwave frequency is also described.

Circulator

Circulators are frequently used in waveguide circuits for transmitter-receivers. It is important to minimize the insertion loss and enlarge the isolation bandwidth as much as possible.

At millimeter-wave frequencies, the increase of the insertion loss is caused by frequency dependent losses of magnetic materials, waveguides and adhesives.

The relative isolation bandwidth is narrower on account of lack of ferrites with higher saturation magnetization.

Hence materials intended for circulator applications at millimeter-wave frequencies must exhibit low dielectric loss and low off resonance magnetic loss and should have high saturation magnetization.

The Curie temperature should be relatively high. Therefore, Nickel zinc ferrites with high saturation magnetization are used for millimeter-wave circulator. These ferrites are carefully prepared to decrease porosity. Some important constants for such ferrites are summarized in table 1.

Table-1

$4\pi Ms$	Tan δ	Δ H	Tc
5300 Gause	$<2 \times 10^{-3}$	$\simeq$100 oersted	370°C

The ferrite is processed into a triangular rod with precise mechanical tolerances. A triangular metal sheet is used as a transformer to enlarge the isolation bandwidth. The dimension of the ferrite and transformer are determined by experiment. The construction is shown in Fig. 1.

The triangular transformer is placed on the junction and ferrite, supported by teflon spacers on either side, is placed on the transformer.

The junction is milled in brass and silver plated. The transformer is formed by photoetching. The transformer and the dielectric loaded ferrite are carefully assembled on the center of the junction using epoxy adhesive. Fig. shows the measured characteristics of such circulators in the frequency range of 30-86GHz.

Harmonic-rejection filter

In millimeter-wave communication systems, harmonic frequency components due to nonlinearities in up and down-converters can cause spurious so-channel signals via the local oscillator circuits, or channel interferences via the multiplexing networks.[3] Thus, harmonic-rejection filters are needed.[4]

(1) Waffle-iron filter[5]

A waffle-iron filter will attenuate such harmonic frequencies but it is difficult to construct in the millimeter-wave region because of the small dimensions and precise mechanical tolerances required. A simple and economical method of construction is presented. As shown in Fig. 3, a waffle-iron filter designed using image parameter method is constructed from three kinds of sections; - the capacitive sections A, the inductive sections B and the two end sections C. The thickness of each section is typically less than 0.4mm in the millimeter-wave region and photo-etching techniques can be used to form each section. These sections are then assembled as shown in Fig. 3. The transforming section to standard waveguide is constructed from 2-section quarter-wave transformers which are made by electroforming. The measured response is summarized below:

	43-54GHz	55-65GHz	76-86GHz
Pass band Insertion Loss	<0.25dB	<0.3dB	<0.4dB
Stop band Attenuation	> 40dB	> 40dB	> 40dB

A typical response for a 50GHz waffle-iron filter is shown in Fig. 3. Here, the dimensions of the filter are determined by scaling the 7GHz filter to 50GHz. The dotted line shows the estimated response from the 7GHz waffle-ironfilter.

(2) Harmonic-rejection Bandpass Filter[6]

A novel band-pass filter is presented which has sufficiently high rejection characteristics in the second harmonic region. In this filter, the waveguide height is lowered to prevent the excitation of the TEom and TElm modes in the second harmonic region. Therefore only the TElon mode exists. The resonant conditionfor the TElon mode is shown in Fig. 4. For example, the passband frequency fo is selected by fo=1.6fc. If 1/2a is selected in the range from 0.2 to 0.3, higher modes on the second harmonic 2fo do not exist and the resonant frequency for the fundamental mode is higher than fo.

Capacitive rods are inserted at positions A and A as shown in Fig. 4 to lower the TE_{101} resonant frequency without changing the resonant frequency of the higher modes. For scaling into the millimeter-wave region, an experimental 4GHz band-pass filter is constructed and its measured response is shown in Fig. 4.

Band-pass Filter,[7] Band-stop Filter[8]

Band-pass filters and band-stop filters have been manufactured in the frequency range of 40-90GHz. They are constructed by electroforming, using inductive windows as coupling susceptances. The mandrels are manufactured carefully to obtain precise mechanical tolerances. Fig. 5 shows the measured responses of a band-pass filter and a band-stop filter. The insertion loss of such a band-pass filter is 0.85dB, and the unloaded Q is 1500 (about 50% of the theoretical value for a TE_{101} cavity.)

The measured attenuation of a 4-resorator maximally-flat band-stop filter at 84GHz is more than 50dB and the passbnad insertion-loss is less than 0.3dB for a frequency 1.7GHz higher than the stop-band center frequency.

Flexible Waveguide

The measured characteristics of an experimental flexible waveguide at 60GHz are shown in Fig. 6.

The insertion loss is less than 0.3dB/10cm and the VSWR is less than 1.1 in the frequency range of 60-75GHz. These characteristics do not change when the waveguide is bent. The flexibility of this waveguide is due to the corrugations of the thin metal walls. The details are shown in Fig. 6. The bellows are formed by Ni and Cu electroforming. The metal wall thickness is about 50 micron.

Conclusion

The methods of construction and performance characteristics of waveguide components in the frequency range of 40-90GHz hae been discussed.

Electroforming and photo-etching techniques are effectively used to construct these components.

The performance characteristics are well agreed with responses predicted by frequency scaling.

Acknowledgement

The authors would like to express their hearty thanks to Dr. Miyauchi, and those concerned in the Yokosuka Electrical Communication Laboratories, NTT for their continuing guidance and advice on the development of waveguide components. Thanks are also to Mr. Kuroda, Manager of the Millimeter-Wave and Video Communications Development Laboratory of Nippon Electric Company, Ltd.

References

(1) K. Miyauchi, et al, "Transmitter-Receivers for the Millimeter-Wave Transmission System in the 43-87GHz" 4th European Microwave Conference, C9-2 Montreux 1974.

(2) K. Miyauchi, et al, "A Guided Millimeter-Wave Transmission System Using High-Speed PSK Repeaters" Digest of IEEE 1972, G-MTT Symposium pp128-130 May, 1972.

(3) K. Yamamoto, et al, "Spurious Interferences in a Guided Millimeter-Wave Transmission System "W-40G" " Paper of the TGCS, IECE of Japan, CS73-70 Sept. 1973.

(4) K. Yamamoto, et al, "Off-Band Characteristics of a Millimeter-Wave Wageguide Bandpass Filter". Paper of the TGM, IECE of Japan, MW-73-93 Oct. 1973.

(5) G.L. Matthaei, et al, "Microwave Filters, Impedance-matching Networks and Coupling Structures" McGraw-Hill, 1964.

(6) S. Kitazume, et al, "Microwave Bandpass Filter with Higher Harmonics Rejection Function". United States Patent 3,657,670 Apr. 1972.

(7) W.W. Mumford, "Maximally Flat Filters in Waveguide". Bell System Technical Journal, Vol. 27 pp648-714 Oct. 1948.

(8) L. Young, et al, "Microwave Band-Stop Filters with Narrow Stop Bands" IRE Trans. on Microwave Theory and Techniques, Vol. MTT-4 pp416-427 November, 1962.

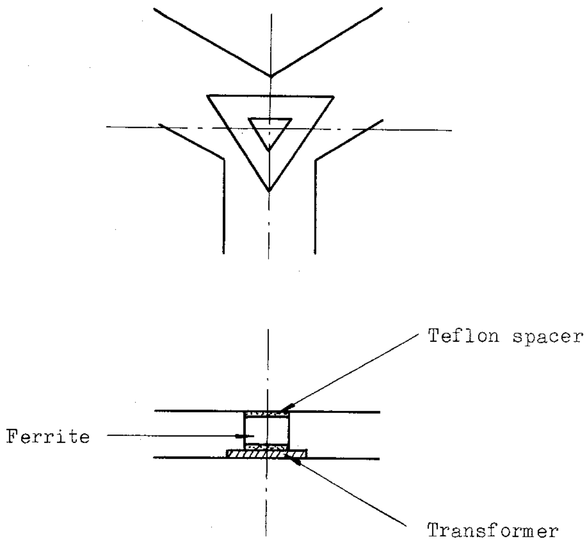


Fig. 1 Cross-section of a circulator

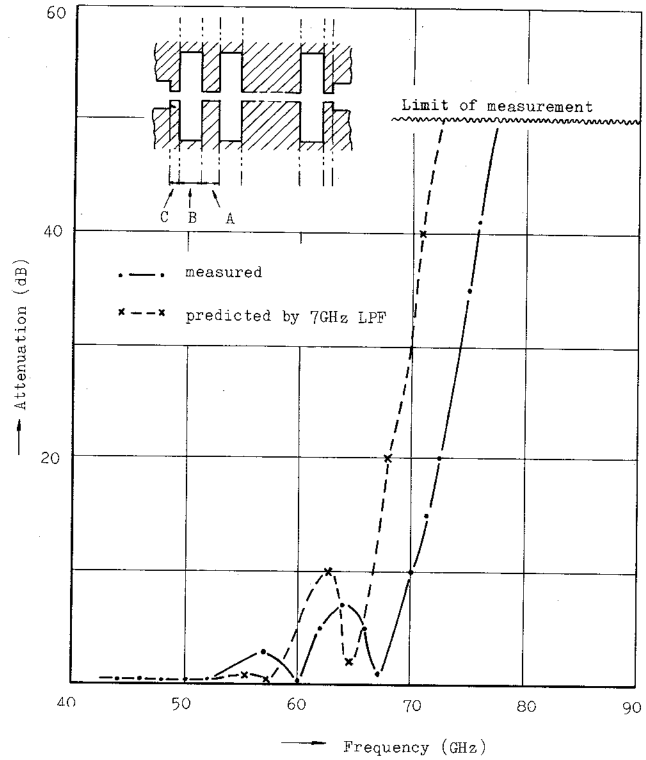


Fig. 3 Measured response of a waffle-iron filter

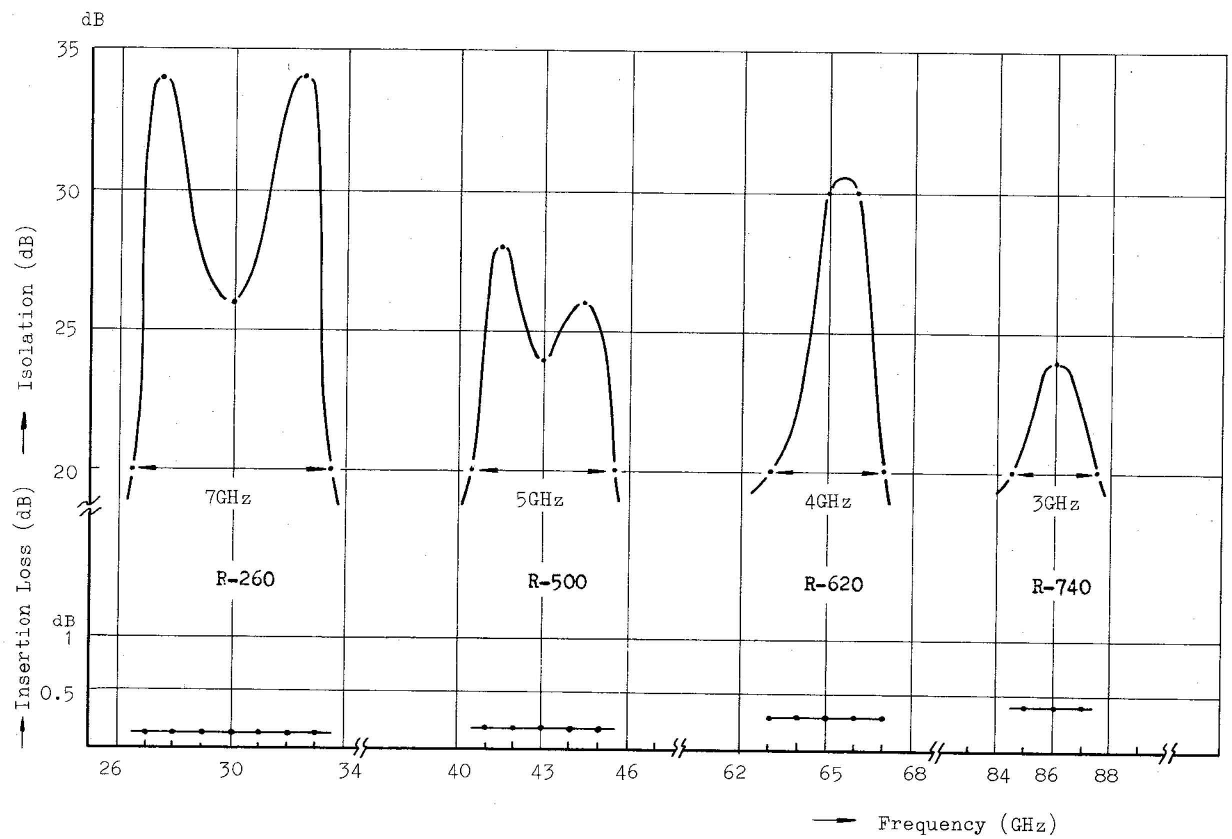


Fig. 2 Measured response of waveguide circulators

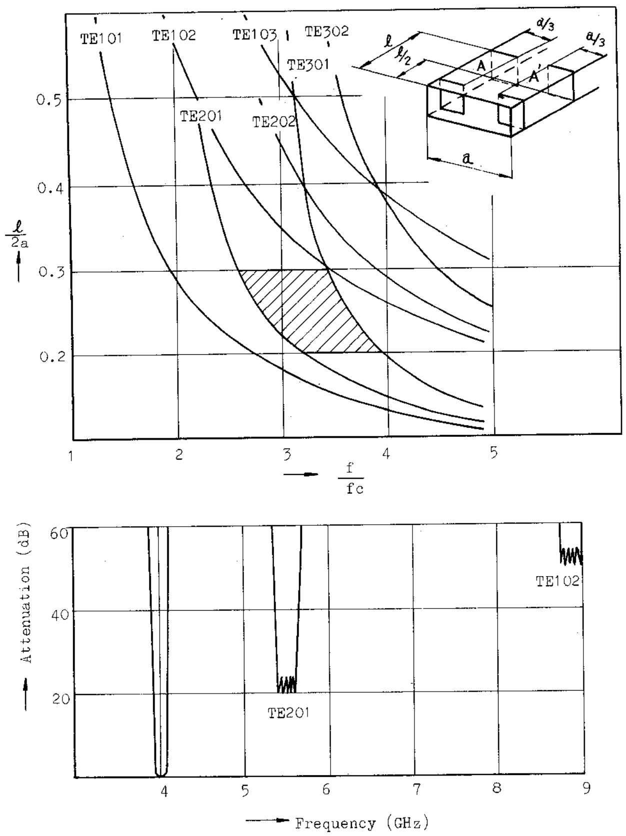


Fig. 4 Mode chart for TElon cavity and measured performance of 4GHz harmonic-rejection BPF

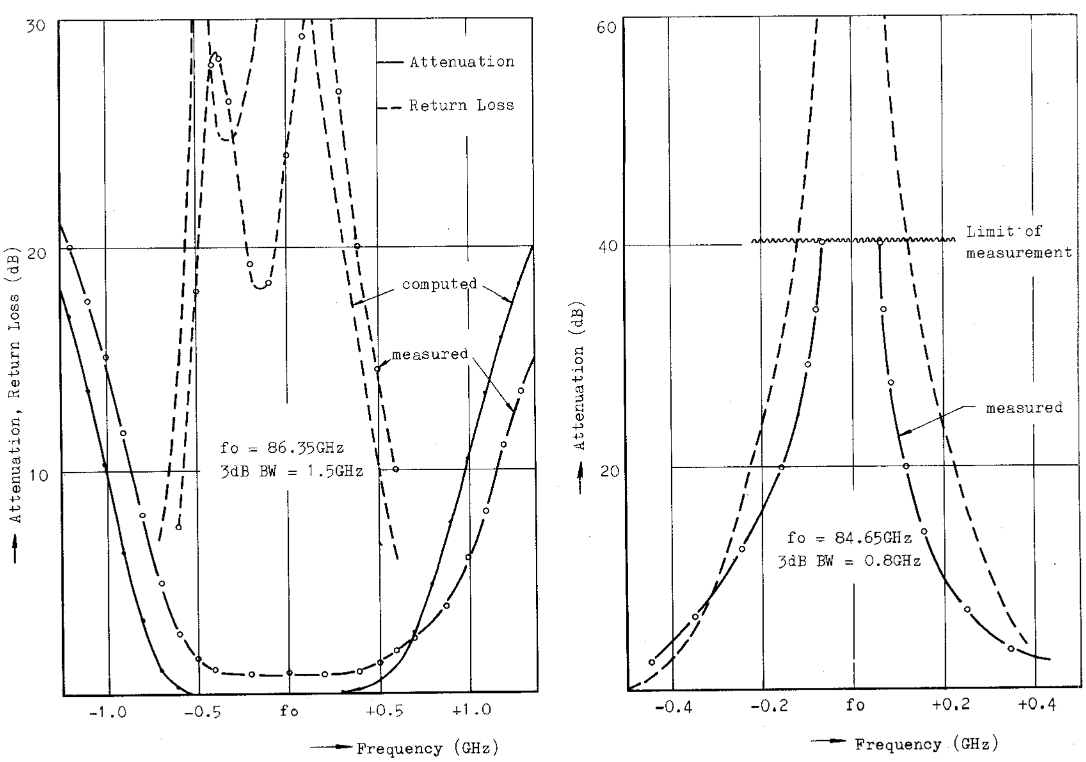
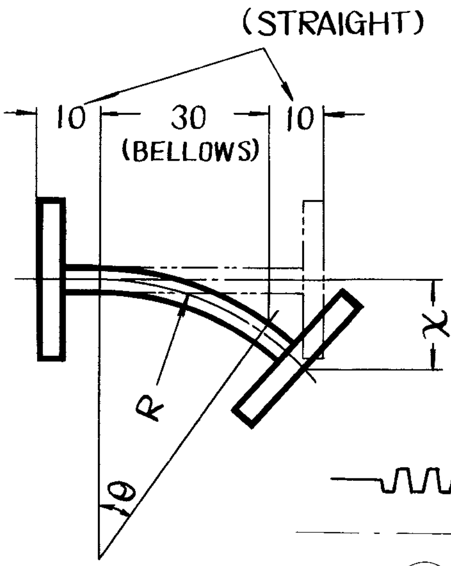


Fig. 5 Measured response of waveguide BPF and BSF



BEND	H-PLANE	E-PLANE
χ (mm)	15 MAX.	30 MAX.
R (mm)	50 MIN.	26 MIN.
θ (DEGREE)	(33°)	(60°)

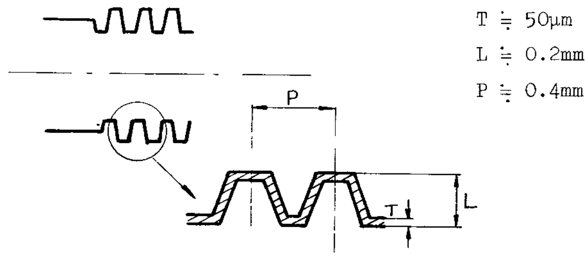


Fig. 6 Details of a flexible waveguide and its characteristics