CIRCULAR ARC POLYGONAL TYPE TEon MODE FILTER

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Abstract

A circular TEon mode filter using a deformed circular waveguide has been developed. The theoretical analysis of the filter and the experimental results of TE_{02}-TE_{03} mode filter are presented in this paper.

Introduction

When many corner waveguides are used in a millimeter waveguide line, it is necessary to absorb unwanted modes to be caused by the corner waveguides. It is very difficult, however, to eliminate TEon modes with $n \geqq 2$.

Various types of mode filters have been proposed for absorption of these TEon modes; for instance, distribution coupling[1], long slit[2], resonant slot[3] and phase inverted type[4] filter. The mode filter presented here has the following advantages over these former types:

1) The structure is very simple.
2) TE_{01} mode loss is very small.
3) There is no limitation in diameter.

Theoretical Analysis

The structure of the circular are polygonal type mode filter is quite similar to that of a conventional helix waveguide or dielectric lined waveguide. The cross-section is slightly deformed to have a circular arc polygonal shape. The radius R is given by equation (1), where α is a mean radius, δp is the deformation factor and ϕ is the angle, as shown in Figure 1 (a).

$$R = \alpha\left(1 + \sum_{p=1}^{\infty} \delta p \cos p\phi\right) \quad (1)$$

When a TEon mode is incident in this polygonal waveguide, many coupled modes are generated by the sectional deformation. The propagation constants of the coupled modes generated in this polygonal waveguide are affected by the surface impedance Zz in the axial direction. On the other hand, the propagation constant of the TEon mode is not affected. Therefore, by selecting the wall impedance properly, the phase constant of one of the coupled modes can be made equal to that of the TEon mode. The complete power transfer is achieved between these two modes. A TE_{01} mode conversion loss is very small because the phase constant of the TE_{01} mode is sufficiently apart from those of the coupled modes.

The propagation constant γ_i of coupled i-th mode in the helix waveguide is obtained from the following characteristic equation:

$$j\omega\epsilon\alpha Zz - \frac{X_i J_p(X_i) J'_p(X_i)}{\frac{p^2 \gamma_i^2}{X_i^2 k^2} J_p^2(X_i) + J'_p{}^2(X_i)} = 0 \quad (2)$$

$$\left(\frac{X_i}{\alpha}\right)^2 = k^2 + \gamma_i^2, \quad k^2 = \omega^2\mu\epsilon \quad (3)$$

where

- ω : Angular frequency
- μ : Permeability of the waveguide interior
- ϵ : Permittivity of the waveguide interior
- X : Wave number of the -th mode
- $J_p(X_i)$: Bessel function of the first kind

Figure 1 (b) shows the wall structure of the helix TE_{02} mode filter. The value of the wall impedance Zz is determined by the capacitance of the helix wires and by the thickness and the dielectric constant of the matching layer. When the matching layer in Figure 1 (b) has no loss, the propagation constants are purely imaginary.

Figures 2 and 3 show the relation between X_i and $j\omega\epsilon\alpha$ Zz, where p is 5 and 8 respectively. When the value of $j\omega\epsilon\alpha$ Zz is 4.3, the X_i of the TE_{51} is 7.0 and thus becomes the same as that of the TE_{02} mode. The TE_{02} mode is converted completely into the TE_{51} mode if a relation of $C\ell = \pi/2$ is satisfied:

where

- C: Coupling coefficient between the TE_{02} mode and the TE_{51} mode.
- ℓ: Length of mode filter.

In the same manner, the TE_{03} mode is converted into the TE_{81} mode. The converted modes are easily absorbed in an ordinary helix waveguide connected to the mode filter.

When the deformation is constant in an axial direction, the frequency which has maximum mode conversion loss of the TEon mode is virtually proportional to the length of the filter. Figure 4 shows the relation between the conversion loss and frequency as a parameter of the length of the filter, where $\alpha = 25.5$ mm, $p = 5$, $\delta 5 = 0.04$.

If the deformation of the radius has two components such as 5 and 8, the TE_{02} and TE_{03} modes are converted into the TE_{51} and TE_{81} modes respectively in a single mode filter. Figure 5 shows an example of a cross section which has two components of 5 and 8. We call such a mode filter a mixed type filter.

In order to achieve the high attenuation of the TEon mode over a wide band, it is necessary to maintain $j\omega\epsilon\alpha$ Zz constant over a wide band. Zz is required to be inversely proportional to the frequency in wide band. In general, impedance of capacitance is inversely proportional to the frequency. The optimum value of the $j\omega\epsilon\alpha$ Zz is 4.3 for TE_{51} or 3.5 for TE_{81}, and at that value, the Zz is capacitive in the required frequency range.

When the wall surface of the mode filter is not a helix wire but is a lined dielectric, the surface impedance is inductive, and the X_i of i-th mode is reduced by the lined dielectric. In this case, it is also possible to make the phase constants of the TE_{61} and TE_{91} modes equal to those of the TE_{02} and TE_{03} modes respectively. In this lined waveguide, however, it is impossible to maintain a constant value for $j\omega\epsilon\alpha$ Zz over a wide band.

Experimental Results

Figure 6 shows the measured results of TE_{01}, TE_{02} and TE_{03} mode losses of the helix wall TE_{02} - TE_{03} mixed type filter, where $j\omega\epsilon\alpha$ Zz = 4.0, length = 1.0 m, $\alpha = 25.5$ mm, $\delta_5 = 0.02$ and $\delta_8 = 0.01$. The value of $j\omega\epsilon\alpha$ Zz is slightly different from the optimum value of 4.3 and 3.5, and then the maximum attenuation of TE_{02} or TE_{03} is not infinite. These measured results are in agreement with the theoretical values.

Conclusion

As discussed above, the circular arc polygonal type TEon mode filter has remarkable properties. The filter can absorb both the TE_{02} and TE_{03} modes. The loss of the TE_{01} mode is less than 0.1 dB over the required frequency range. By increasing the length of the mode filter and decreasing the deformation factor, it is possible to reduce the TE_{01} mode loss without changing the TEon mode attenuation.

References

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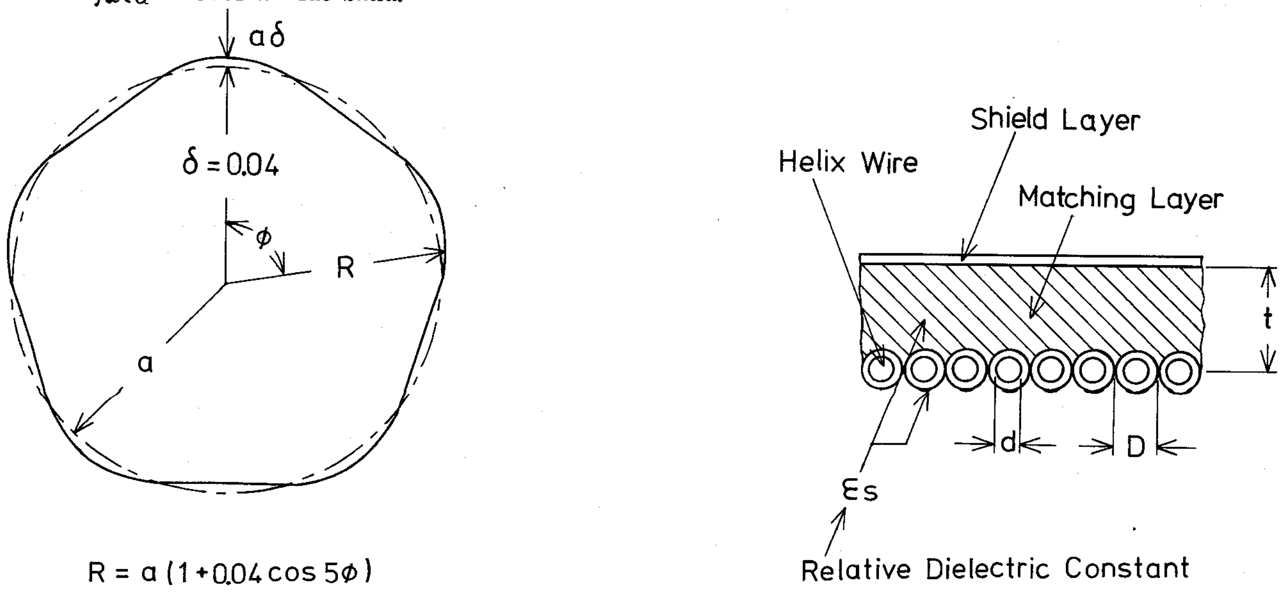


(a) (b)

Fig. 1 Cross section and wall structure of the helix TE_{02} mode filter

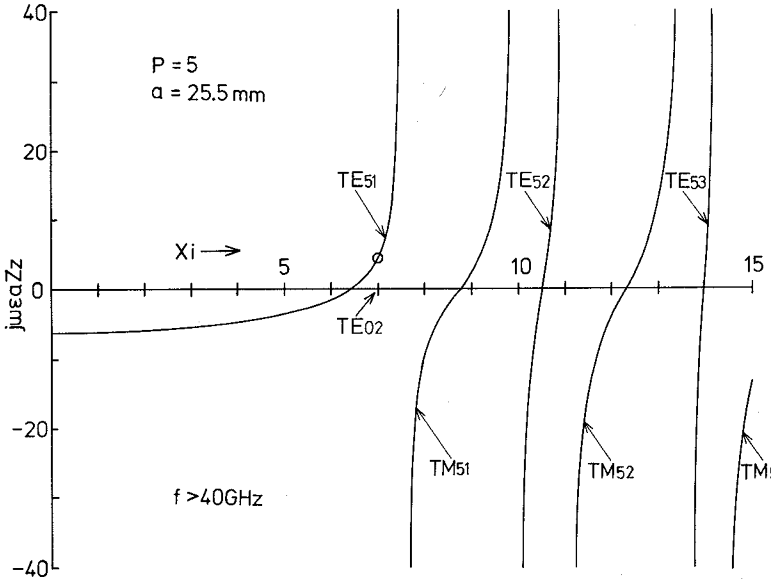
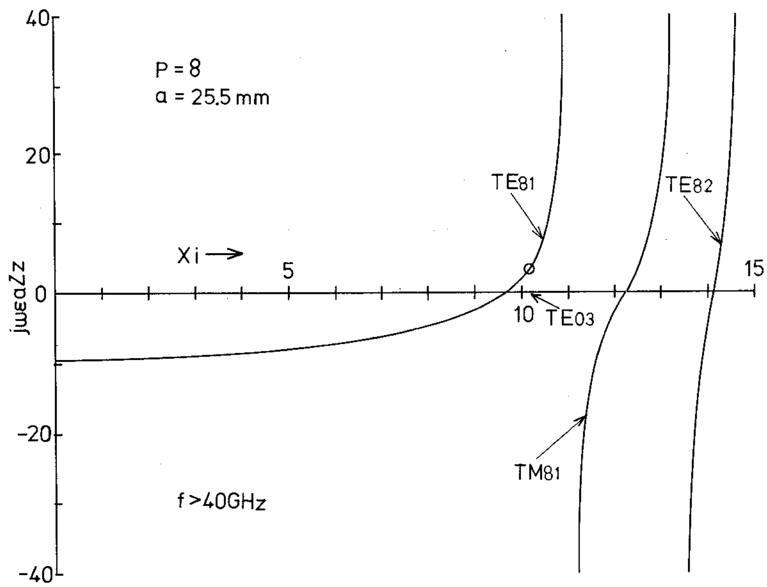


Fig. 2 Relation between X and Zz where = 5 and = 25.5 mm

Fig. 3 Relation between X and Zz where = 8 and = 25.5 mm



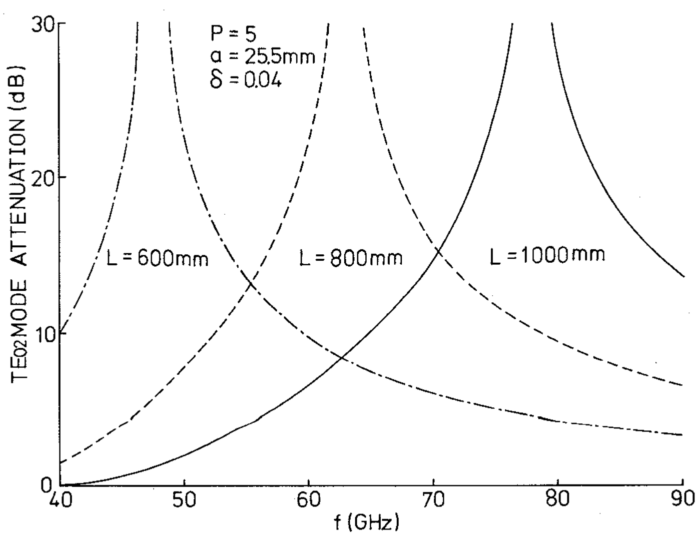


Fig. 4 Theoretical TE_{02} mode attenuation versus frequency as a parameter of the length of the filter

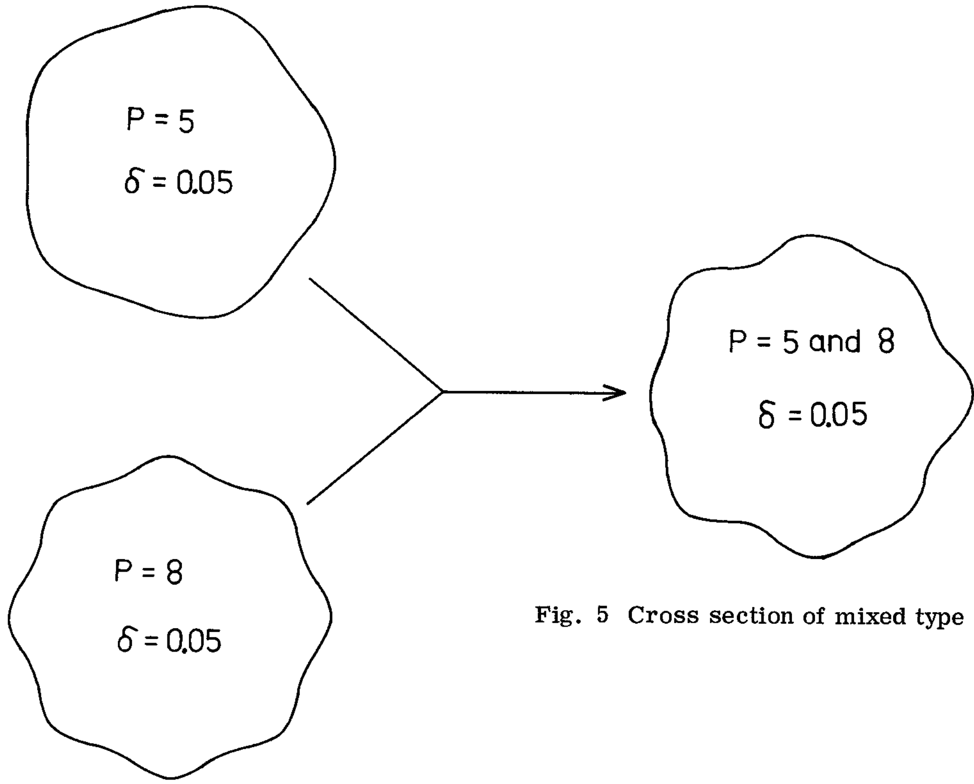


Fig. 5 Cross section of mixed type mode filter

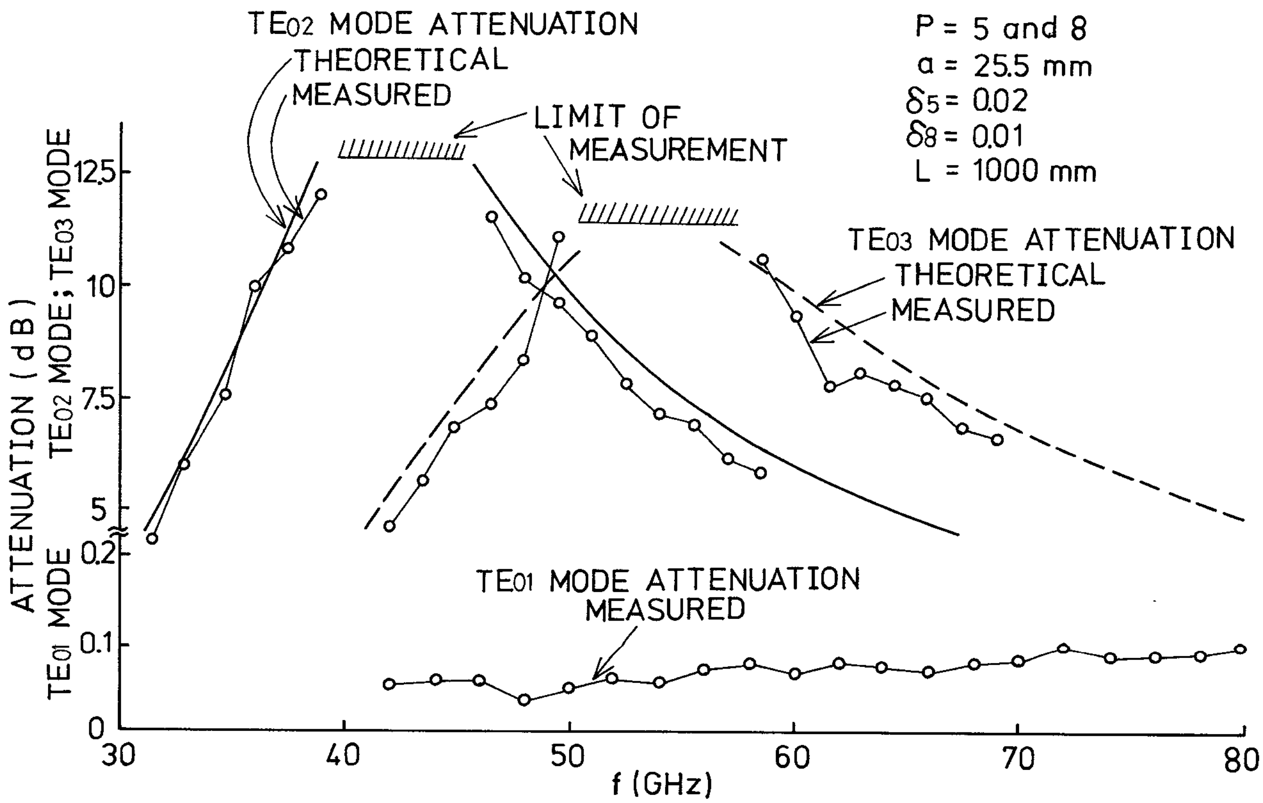


Fig. 6 Result of the measurements of TE_{01}, TE_{02} and TE_{03} mode losses of the helix wall TE_{02} - TE_{03} mixed type filter