THE NEW APPROACH TO DESIGNING W-BAND Y-JUNCTION CIRCULATOR WITH SMALL INSERTION LOSS.

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Abstract.

The simple ferrite waveguide Y-junction W-band low loss circulator construction is realized. 0.15 dB loss level is achieved at the expense of microwave fields concentration in the ferrite area with homogeneous transversal magnetization.

I Introduction.

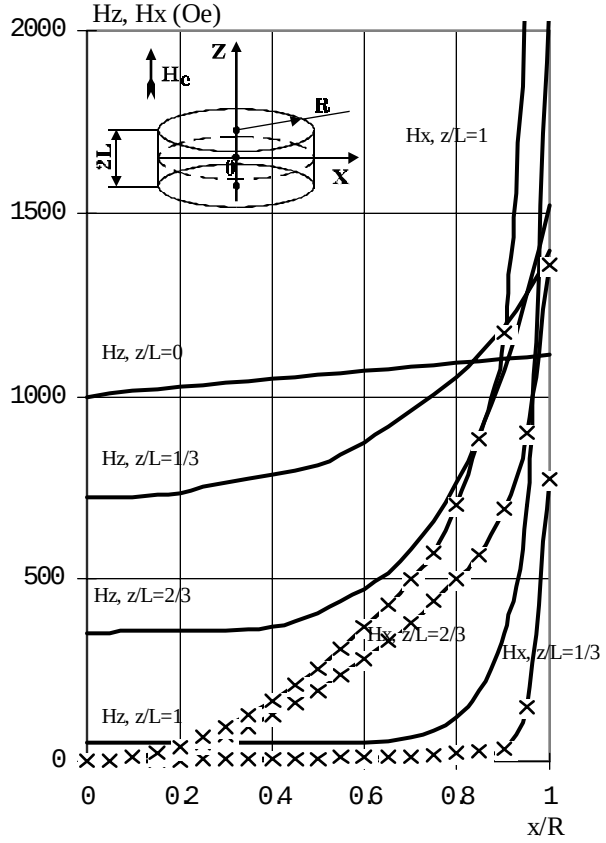
The improvement of W-band Y-junction circulator parameters were reached mainly by construction complication [1,2]. We propose to reduce circulator insertion loss at the expense of simple construction solution, ensuring effective interaction of microwave power with gyromagnetic material.

II Physical premises of low loss Y-junction circulator creation.

One of the conditions to get small insertion loss in Y-circulator is to supply a homogeneous transversal ferrite magnetization [3]. However, for any nonellipsoidal ferrite sample in homogeneous magnetic field the magnetization is inhomogeneous and is function of coordinates [4].

Fig. 1 and Fig. 2 show calculated distribution of transversal (H_z) and tangent (H_x) bias magnetic field components in the ferrite cylinder. Calculations are made for "short" and "long" cylinders in homogeneous magnetic field, directed along cylinder axis. With ratio L/R magnification (where: L - cylinder halflength, R - radius) cylinder central site enlarge, in which H_z (ensuring circulator operating) is homogeneous, and H_x value (that impair circulator parameters) is close to zero.

Fig. 1: Bias magnetic field transversal (H_z) and tangent



(H_x) components in "short" ferrite cylinder, when L/R=0.5.

Ferrite cylinder length and radius define it own resonance frequencies. Under various boundary conditions on ferrite cylinder face surfaces operating modes are nonsymmetric $HE_{11\delta}$ modes, where δ=0.5; 1.5; 2.5 …etc. [5]. From [5] follows, that for $HE_{111.5}$

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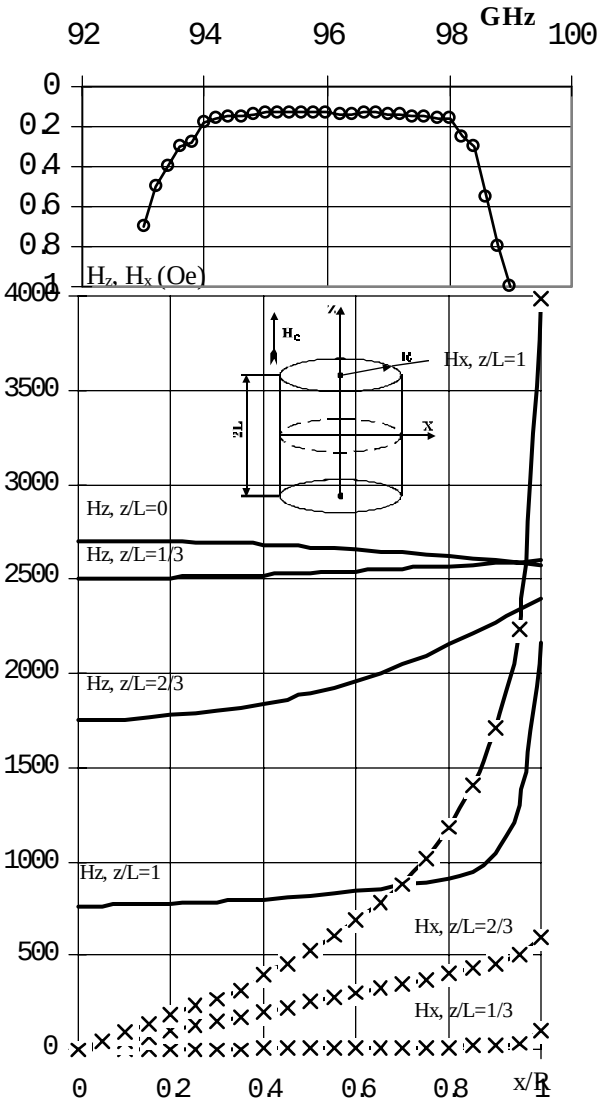


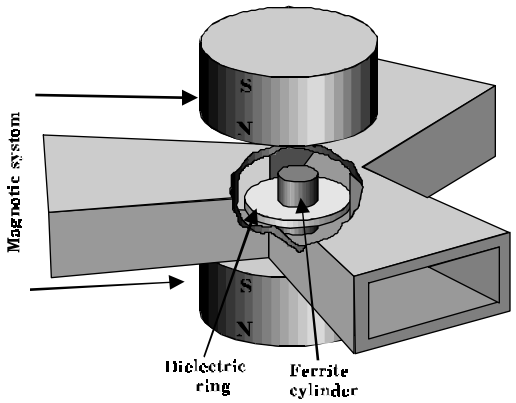
mode , the best value of 2L/R should be more than 3.06, and for $HE_{112.5}$ more than 5.14. $HE_{112.5}$ mode is difficult to use, because the ferrite cylinder height can exceed waveguide height.

Fig. 2: Bias magnetic field transversal (H_z) and tangent (H_x) components in "long" ferrite cylinder, when L/R=2.

Calculations (Fig. 1, 2) show, that when 2L/R>3.06 central cylinder part length where transversal magnetization is homogeneous is more than 1/3 of cylinder length. Authors propose to concentrate microwave field in the indicated ferrite cylinder part and to improve circulator parameters by that.

III Circulator construction and parameters.

The circulator is made as H-plane waveguide Y-junction. Transversally magnetized ferrite cylinder is placed in Y-junction center, dielectric ring is mounted (Fig. 3) on it. The ring is equally spaced from ferrite cylinder face surfaces. Waveguide internal dimensions are $2.54\times1.27mm^2$ but in the Y - junction center



dimensions are narrowed up to $2.1\times1.27mm^2$.

Fig. 3: Y-circulator view.

Nickel ferrite was used ($4\pi M_s$=5000 Gs, ε=12.5; $tg\delta \le 5\times10^{-4}$) for cylinder, the dielectric ring is made of teflon. The ferrite cylinder sizes were calculated according to [5] with due account for $L/R \ge 1.53$. The sizes improvement were made experimentally. For central operating frequency 96 GHz ferrite cylinder diameter is 0.63 mm, length is 1.14 mm. The thickness of dielectric ring is equal 0.33 mm. The interior ring diameter is equal to the ferrite cylinder diameter, and exterior is equal to inscribed circle diameter of narrowed waveguide Y-junction.

a)

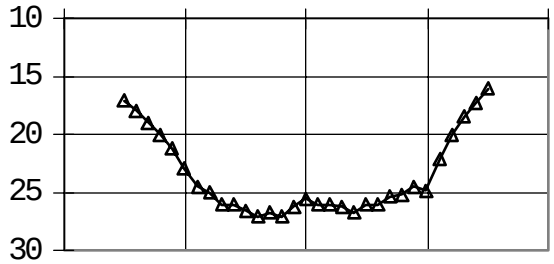
b)

Fig. 4: Insertion loss (a) and Return loss (b) of W-band circulator.

dB

Fig. 4 show insertion loss and return loss of the sample. In frequency bandwidth 3.5% circulator insertion loss is less than 0.15 dB, return loss is more than 25 dB. In frequency bandwidth 5% insertion loss is less than 0.3 dB, return loss is more than 20 dB.

The VSWR level corresponds to return loss level. Circulator parameters are stable in temperature



range -50…+85°C.

With movement of a dielectric ring to one of ferrite cylinder extremities, insertion loss increases to >1db. The authors consider, that it happens due to basic wave mode transformation to dissipating wave modes in the ferrite cylinder extremities.

IV. Conclusions.

The proposed waveguide Y - junction circulator construction , due to small insertion loss level (less than 0.15 dB) and simplicity, is promising for creation of Y - junction circulators in short-wave part of W - band. The authors consider, that taking into account internal magnetic field distribution in the ferrite element is necessary not only for W-band waveguige circulators, but also for other microwave ferrite devices, including thin-film devices.

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