Electrodynamic Characteristics of Structures with Non-Axisymmetrical Apertures

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Abstract

The structures with non-axisymmetrical apertures for beam path were carried out. The programs for resonance frequency calculating of disk loaded rectangular and elliptic waveguides were created. For structures with disk slot apertures the focussing gradient values have been measured at a broad range of slot height change.

The investigation of electrodynamic characteristics of structures with non-axisymmetic slots for beam path is very essential for high-energy linear electron-positron collider design. Such structures has RF focussing feature [1]. For a structure focussing properties determination it's essential to know the electromagnetic field configuration in the beam channel. Such a problem can be solved either numerically by considering three-dimensional models or experimentally.

Disk loaded rectangular (DLRW) and elliptic (DLEW) waveguides were used as models for study of RF focussing by means of external fields. The semianalytical partial regions technique was used for resonant frequencies and electrodynamic characteristics determination. Numerical techniques were used for solving the dispersion relations. Structure sizes and oscillating modes are considered to be know in the programs for dispersion relation solving. The chosen mode frequency is to be determined. For DLRW with dimension 110*55 mm^2 and rectangular slot sizes 104.5*15*5 mm^3 the calculated value of $2\pi/3$ mode was 3185 MHz while the experimental one appeared to be 3171 MHz. The focussing field gradient value has been determined by [2]:

$$G(0,0)/E_0=(\pi\lambda/c)/a^2/8$$

where a - slot half-height, λ- the wave length. The calculated value of $G(0,0)/E_0$ was $0.5\cdot10^{-7}$ s/m^2 while the experimental one defined by the reactive probe technique [2] was $0.4\cdot10^{-7}$s/m^2.

The calculation and measurements of 2 /3 mode frequency for DLEW were carried out. The parameters of the waveguide were as follow: the ratio of the big to small ellipse axes are equal to 1.9:1.284 and 3.85:3.59 for disks and for the guide correspondingly, the structure period 26 mm, the disk thickness equals 2.5 mm. The calculated frequency value appeared to be 3445.6 MHz as compared to the experimental one 3416.4 MHz.

Elliptic nonaxisymmetric structures are considered to be rather complicated for a fabrication. The circular waveguide loaded disks with rectangular slots is preferable. The numerical investigation of such structures was carried out by 3D-Mafia code [3]. The experimental study of such structures was made at the a/λ change range from 0.075 to 0.20 . The operating mode is $2\pi/3$ and β_{ph}=1.

The most interest characteristic is a transverse field gradient

$$G_x(x,0)=-\frac{1}{\omega}\frac{\partial^2 E_{z0}(x,0)}{\partial x^2}\sin\varphi_0$$

$$=-\frac{1}{\omega}E_{z0}(x,0)\cdot G_x(x,0)_n\sin\varphi_0$$

$$G_y(0,y)=\frac{1}{\omega}\frac{\partial^2 E_{z0}(0,y)}{\partial y^2}\sin\varphi_0$$

$$=\frac{1}{\omega}E_{z0}(0,y)\cdot G_y(0,y)_n\sin\varphi_0$$

$$G_x(x,0)_n=\frac{\partial^2[E_{z0}(x,0)/E_{z0}(0,0)]}{\partial x^2}$$

$$G_y(0,y)_n=\frac{\partial^2[E_{z0}(0,y)/E_{z0}(0,0)]}{\partial y^2}$$

It's necessary to define the dependence $G_x(x,0)_n/f^2$=F(a/λ) and $G_y(0,y)_n/f^2$=F(a/λ) because $G_x(x,0)_n$ and $G_y(0,y)_n$ depends on the frequency as f^2

The validity of such focussing gradient conception is supported by the results of measurement of structures scaled at a frequency 0.6 GHz and 3 GHz. The correspond values of $G_x(0,0)_n/f^2$ were equals -2.2$\cdot10^{-16}$ s^2/m^2 and -2.1$\cdot10^{-16}$ s^2/m^2

The transverse gradient in non-axisymmetic structure was determined on the basis of measurement results. The measurements were conducted by the reactive probe technique. A rather tiresome procedure of measurement results treatment with the aim of transverse gradient calculation prompted to develop a system connecting the measurement installation with the personal computer as well as an experimental data treatment program.

Typical dependences of $E_{z0}(x,0)/E_{z0}(0,0)=F(x)$ and $E_{z0}(0,y)/E_{z0}(0,0)=F(y)$ are shown in fig.1.

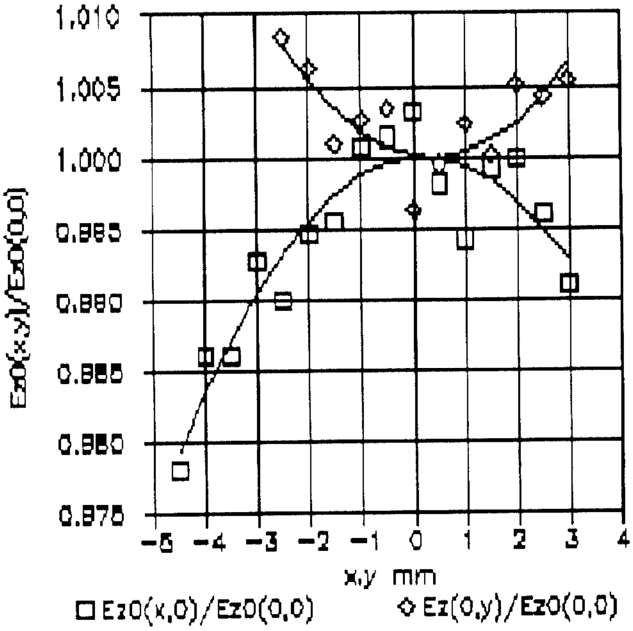

Figure 1. Typical dependences of $E_{z0}(x,0)/E_{z0}(0,0)=F(x)$ and $E_{z0}(0,y)/E_{z0}(0,0)=F(y)$

Each curve point is the averaged result of many measurements [4]. The experimental values of transverse field gradient are presented in Table 1 and the fig2.

Table 1
Values of normalized transverse focussing gradient $G_x(x,0)_n$, $G_y(0,y)_n$ for non-symmetrical slot structures ($\beta_{ph}=1, \theta=2\pi/3$, $a/\lambda=0.07...0.19$, $t/\lambda=0.045$) at S-band.

$h=2a$ mm	a/λ	$G_x(x,0)_n$ 1/m	$G_y(0,y)_n$ 1/mm	$G_x(x,0)_n/f_0^2$ 10^{-16}, s^2/m^2	$G_y(0,y)_n/f_0^2$ $\cdot 10^{-16}$, s^2/m^2
15	.07	-1770	2270	-2.26	2.90
20	.09	-1720	2190	-2.19	2.80
25	.11	-1650	2100	-2.10	2.45
30	.14	-1640	1920	-2.10	2.69
35	.16	-1560	1720	-2.00	2.23
40	.19	-1480	1570	-1.92	2.01

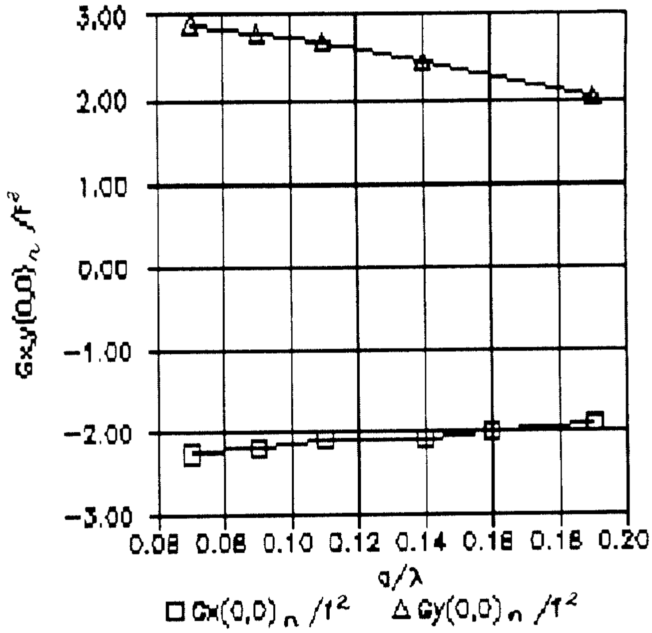

Figure 2. Dependences of $G_x(x,0)_n/f^2=F(a/\lambda)$ and $G_y(0,y)_n/f^2=F(a/\lambda)$ for the non-symmetical slot structures ($\beta_{ph}=1, \theta=2\pi/3$, $f=2796$ MHz)

If a/λ =.15, the focussing gradient value is equal to $G_x(0,0)$=-97(-90) T/m, $G_y(0,0)$=110(87) T/m, if a/λ =.20 - $G_x(0,0)$=-87(-83) T/m, $G_y(0,0)$=93(81) T/m (E_{z0}=100 MV/m; f=29GHz). The data from [3] are shown at the brackets.

References

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