Theoretical and Experimental Study of Linear Collider Accelerating Structures Impedance Characteristics

N.P.Sobenin, S.V.Ivanov, V.E.Kaljuzhny, S.N.Plotnikov
Moscow Engineering Physics Institute
Moscow

Abstract

The relations between resonance frequency, Q-factor and coupling coefficient between a coupler and a disk loaded waveguide (DLW) and DLW electrodynamic parameters were obtained on basic of equivalent circuit. When this relations are carried out an input impedance of accelerating structure is real positive value at all passband. The VLEPP accelerating structure impedance characteristic calculations are carried out by different values of sizes tolerances and a coupler resonant frequency.

Let's consider an infinite uniform lossless accelerating section consisting of identical cells. The first cell acts as an input coupler, i.e. it connects the accelerating section with the input rectangular waveguide. Let's find the expression for the section impedance characteristics on the basis of equivalent circuit shown in fig.1.

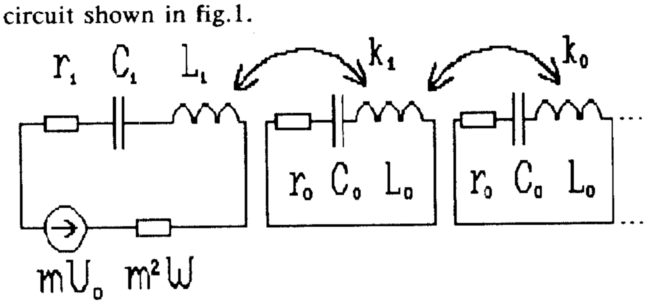

Figure 1. Equivalent circuit model

Here r, L, C are cell parameters which determine the cell resonant frequency $\omega_c=(LC)^{-1/2}=2\pi f_c$ as well as their Q-factors $Q_0=(L/C)^{1/2}/r$. $k_0/2$ is the coefficient of coupling between adjacent cells. For the first cell or the input coupler the corresponding parameters are $=2\pi f_1=(L_1/C_1)^{-1/2}$, $Q_1=(L_1/C_1)^{1/2}/r_1$ and $k_1/2$. The coupling with the input waveguide is represented by an ideal transformer having the transformation coefficient m. This coupling is estimated by the coupling coefficient $\beta_1=m^2W/r_1$, where W is the input waveguide wave impedance. The m^2W and the complex value of emf mU_0 in the equivalent scheme represent correspondingly the generator emf and resistance and is the complex amplitude at the generator emf.

Mesh currents complex amplitudes I_n are related to each cell electromagnetic field stored energy by the expression $W_n=1/2LI_nI_n^*=1/2x_nx_n^*$, where $x_n=\sqrt{L}\cdot I_n$, x_n^* is the conjugate of x. The complex number x_n argument represents the initial phase φ_n of the magnetic field strength. The module of this number is $x_n=(2W)^{1/2}$.

Suppose that the accelerating section is made on the basis of a circular disk loaded guide in which all coupling except the coupling between adjacent cells are negligible. The coupling coefficient $k_0/2>0$ and $k_1/2>0$. The quality factor $Q_0=\infty$

Under these assumptions there is the equation set describing the lossless infinite disk loaded guide [1]. It can be obtained the expression for normalized accelerating section impedance on basic of this set:

$$Z=\frac{\beta_1}{1+A_1A_2\sin\varphi_0+jA_1(1-f_1^2/f^2+A_2\cos\varphi_0)} \qquad (1)$$

where $A_1=Q_1f/f_1$, $A_2=(k_0/2)(k_1/k_0)^2$

Thus from obtained expressions it follows that the section normalized impedance at operating frequency f_0 equals unity. Its dependance on frequency f is minimal if

$$(k_1/k_0)^2=2,$$

$$f_1=f_0(1+k_0\cos\varphi_0)^{1/2} \qquad (2)$$

$$_1=1+Q_1(f_0/f_1)k_0\cos\varphi_0.$$

Let's consider the computation results of impedance characteristics of disk loaded guide with a coupler of VLEPP [2] on basic of mentioned relations. The passband characteristics of accelerating section that consists of 70 cooper cells (Q_c=6000) and 20 steel cells (Q_{st}=500) are shown in fig.2.

The random error of cells resonator frequency equals ±2.25MHz and corresponds to the installed dimensions tolerances. We are examining the coupler shape as optimal, i.e. the relation (2) is satisfied. Q-factor of a coupler cell is equal 2340. This Q-factor value was measured by two-poles method with detuned first waveguide cell. Others coupler characteristics were obtained using this method: loaded Q-factor Q_L=100, external Q-factor Q_{ex}=105 and coupling between the coupler cavity and input waveguide is equal β=22.

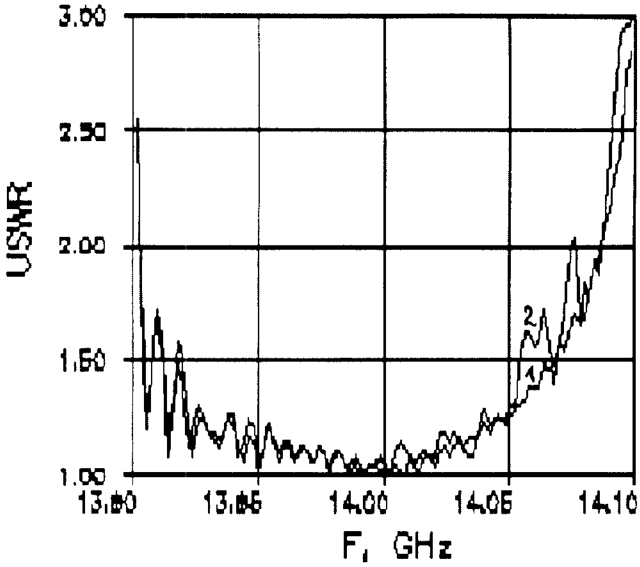

Figure 2. The passband characteristics of accelerating section (1 -δF=0, 2 -δF=±2.25 MHz)

A set of passband characteristics is shown in fig.3 each corresponding of different values of coupler frequency. USWC at the working frequency 14 GHz for the case f_1=13.911 GHz is reduced to a minimum in the broad frequency band.

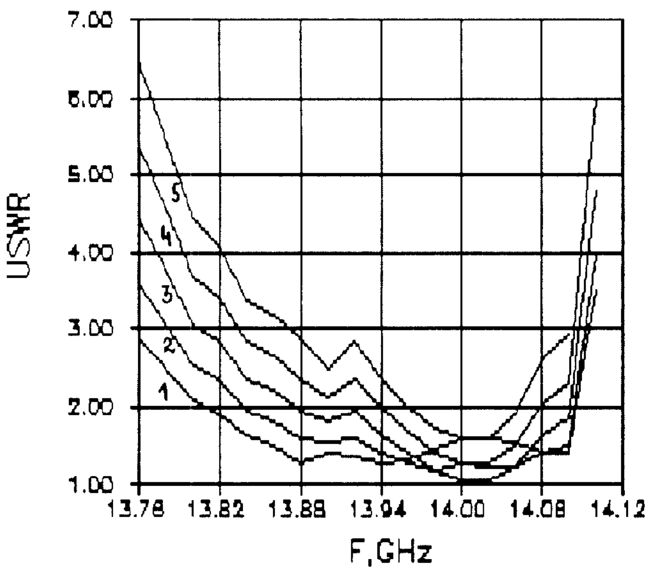

Figure 3. A set of passband characteristics of different values of coupler frequency (Coupler frequency: 1 - 13.85 GHz, 2 - 13.87 GHz, 3 - 13.89 GHz, 4 - 13.91 GHz, 5 - 13.93 GHz).

Other set of passband characteristics is shown in fig.4 each corresponding to different values of coupling between the input guide and the coupler cavity.

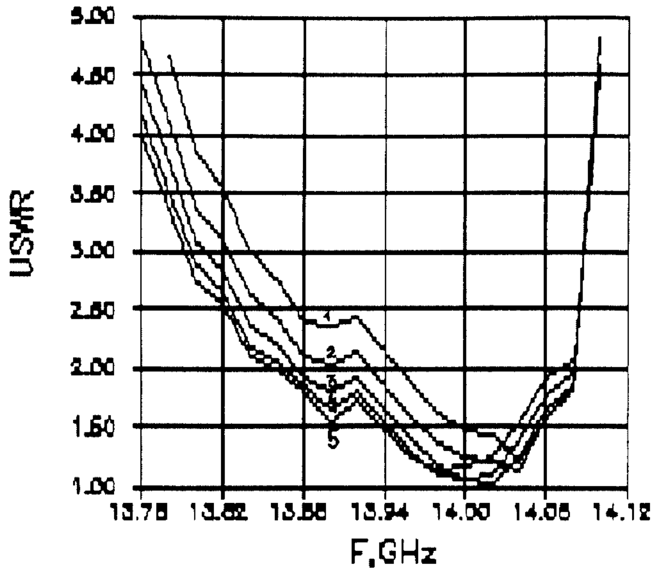

Figure 4. A set of passband characteristics for different values of coupling between the input waveguide and the coupler cavity (1 - BETA=53, 2 - BETA=63, 3 - BETA=73, 4 - BETA=83, 5 - BETA=93).

The developed technique possibilities were demonstrated in the process of impedance characteristic computation carried out for SLAC accelerating section with constant gradient and accelerating section for Japanese linear collider (JLC). Corresponding results are shown in fig.5 and fig.6 in assumption that there are resonant frequency and coupling coefficient deviations.

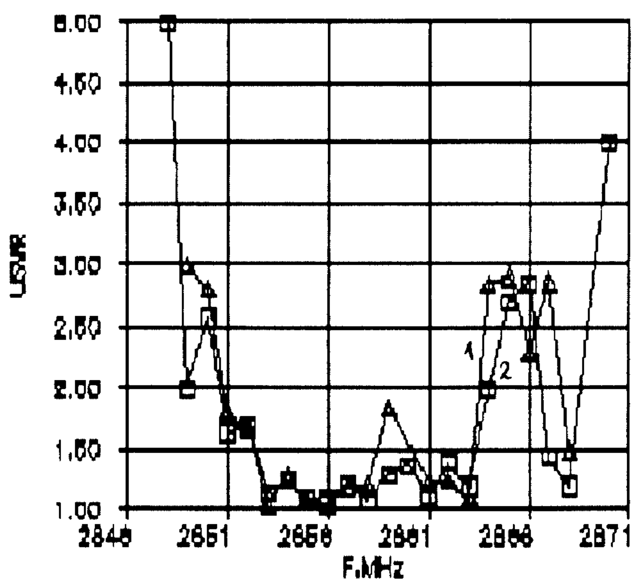

Figure 5. The computing impedance characteristic of SLAC accelerating section (1 - δF=±0.2 MHz, δK=0%; 2 - δF=0.0 MHz, δK=5%).

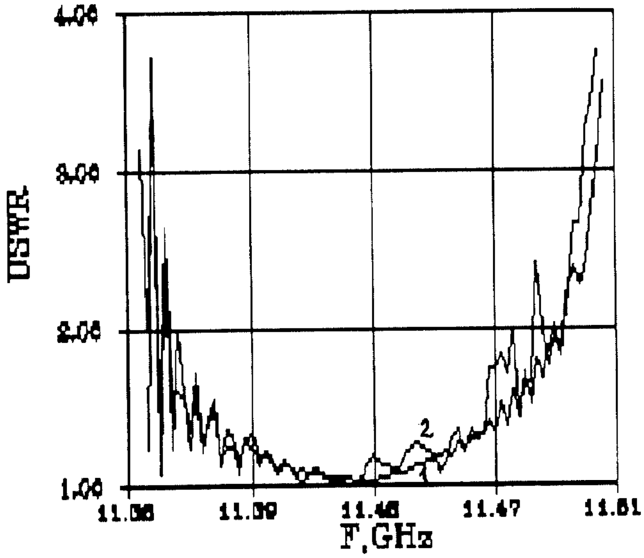

Figure 6. The computing impedance characteristic of JLC accelerating section (1 - δF=0.0 MHz, 2 - δF=±2.5 MHz).

REFERENCES

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