Impedance Characteristics of a Magnetron Powered Linear Electron Accelerator

N.P.Sobenin, V.E.Kaljuzhny, S.N.Plotnikov, B.V.Zverev
Moscow Engineering Physics Institute
A.V.Gryzlov, V.A.Vovna
Scientific-Industrial Amalgamation "Thory"
Moscow

Abstract

The expressions of accelerating section impedance characteristics for electron linac working in travelling wave, standing wave or combine regimes are obtained. The impedance characteristics of these three schemes are compared at the example of 10 MeV electron linac feeding from 10MW magnetron generator at frequency 1885 MHz.

Analysis the impedance characteristics of acceleration sections are based on the model of equivalent circuit. Let's consider acceleration section consisting of N identical cells including a cell of input coupler. The power input is realized through a cell with a number g ($1 \leq g \leq N-j$, g - odd number, and j are the last cells forming the absorption loading). Every cell are determined the resonant frequency f_n, Q-factor Q_n and coefficients of coupling $(k_n/2)$ and $(k_{n-1}/2)$ between adjacent cells (n=1,...,N; $k_0=k_N=0$). Input coupler connecting the acceleration section with the rectangular waveguide are marked .

The following expression characterizes a normalized acceleration section input impedance at the operating frequency f [1]:

$$Z_{in}=\frac{\beta}{1+jQ_g f/f_g[1-(f_g/f)-B_1-B_2]}$$

where $B_1=(k_{g-1}/2)\dfrac{(A_1--A_{g-2})}{(A_1--A_{g-1})}$,

$$B_2=(k_g/2)\frac{(A_{g+2}--A_N)}{(A_{g+1}--A_N)},$$

$A_n=1-(f_n/f)-j(f_n/f)/Q_n$, $n=g$, $j=-1$

(A_m--A_p) is three-diagonal determinant, where $A_m, A_{m+1},...,A_p$ are placed on the main diagonal and $k_m/2, k_{m+1}/2,...,k_{p-1}/2$ are placed on the neighboring diagonals. There are the next expressions $(A_p--A_p)=A_p$, $(A_{p-1}--A_p)=1$, $(A_{p-2}--A_p)=0$.

The input normalized impedance will be equal unit ($Z_{in}=1$) at operating frequency f_0 if the coupler frequency f_g and the coupler coefficient β are satisfied the next expressions:

$$f_g=f_0\{1-\mathrm{Re}[B_1+B_2]\}^{1/2}$$

$$c=1+Q_g f_0/f_g \mathrm{Im}[B_1+B_2]$$

where Re and Im are real and imaginary square brackets part expressions.

The expression (1) may be used for calculation input normalized impedance next three regimes of linacs: travelling wave, standing wave and combine (the initial part of such section with a standing wave)

Let's consider the impedance characteristics of every indicated accelerator with 10MeV energy and great efficiency. All such accelerators are feeded from 10MW magnetron at frequency 1885 MHz.

The travelling wave linacs with circular disk loaded waveguide (DLW) and $\pi/2$ mode consist of the 2λ section (λ- length wave in DLW) with variable phase velocity and of the 12λ section with phase velocity equals light velocity. The last four cells are absorbing loading with Q-factor 360, 200, 160 and 50. The efficiency linacs is 70%, the energy spectrum is ±3.5% and bunch length is 12°. Very important parameters this accelerator concerning to impedance characteristic is a/λ where a is the disk aperture radius and λ is a generator wavelength. This parameter varies from 0.14 at the beginning section through 0.15 to 0.11 at the end section of section.

The imaginary part of the input DLW impedance versus frequency is shown in fig.1 for three cases: $\delta f=\delta k_c=0$; $\delta f=\pm 0.25$MHz, $\delta k_c=0$ and $\delta f=\pm 0.5$MHz, $k_c=1\cdot 10^{-4}$. The random error of $\pi/2$ mode frequency $\delta f=$ 0.5MHz and random error of coupler coefficient $k_c=1\cdot 10^{-4}$ were obtained with using of sensitivity functions and dimensions tolerances (±12 μm). The imaginary part of the magnetron cavity impedance is shown also at this fig.1 and was calculated from the equation:

$$B_m = 0.834(f-f_0)/F_0$$

where F_0=5MHz (line B_{m1}) and F_0=3MHz (line B_{m2})

Analysis of magnetron stability feeding such section are carried out in accordance with recommendation of work [2].

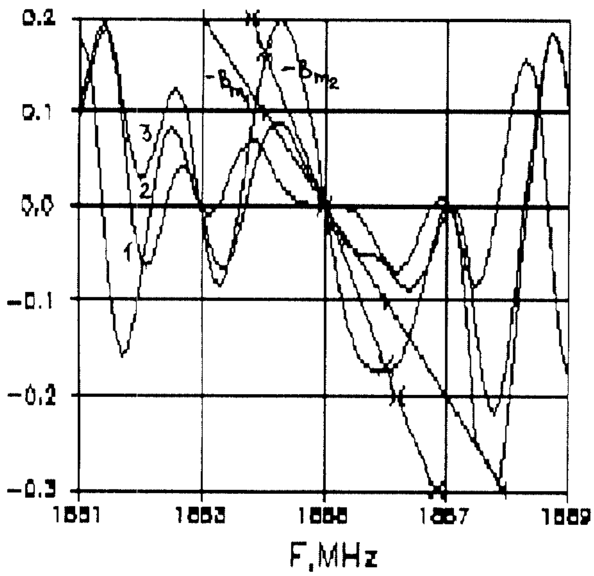

Figure 1. The imaginary part of the input DLW impedance versus frequency (1 -δF=0.0 MHz, 2 -δF=$\pm$0.2, 3 -δF=$\pm$0.5 MHz).

The input coupling coefficient of the acceleration section with the rectangular waveguide without loading beam was chosen for the standing wave linacs β_0=2.5. We may obtain 10 MeV energy with efficiency 60% if will it will be choose a shunt impedance $R_{sh.eff.}=r_{sh.eff.}L$ near 60 MΩ. In the case of biperiodic structure with shunt impedance at unit length $r_{sh.}$=65 MΩ/m at the frequency 1885 MHz the section length will be about 1.0m. The impedance characteristic of this accelerator is a circle at the impedance diagram [3].

The combine accelerator linac section consists of a buncher with four cells biperiodical structure (1.6λ) and DLW with β_{ph}=1 (12λ).

There is a transitional cell between standing and travelling wave parts of section. It is feeded from magnetron and only 40 kW are branched off to standing wave part. The typical dependence of a imaginary part of impedance versus frequency is shown in fig.2. The imaginary part of the magnetron cavity impedance was calculated with F_0=5MHz. Analysis of magnetron stability are carried out in the travelling wave case now.

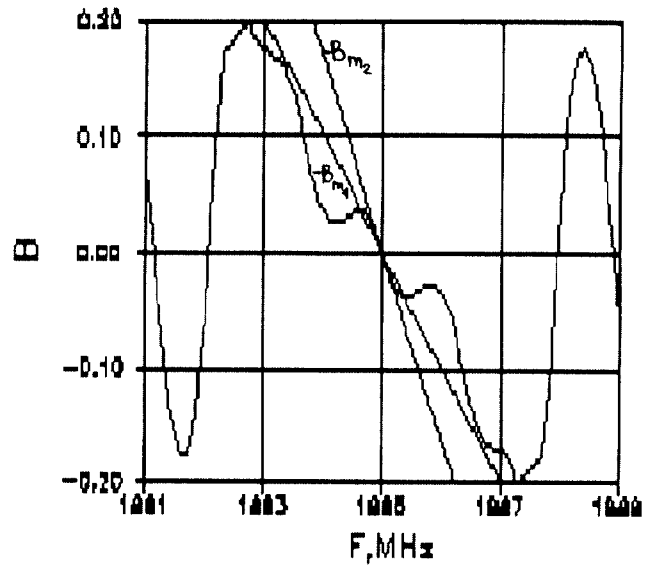

Figure 2. The typical dependence of a imaginary part of impedance versus frequency for the combine accelerator linac section.

References

[1] N.P.Sobenin, S.V.Ivanov, V.E.Kaljuzhny, S.N.Plotnikov "Calculation and Experimental Study of Circular Disk Loaded Waveguide Impedance Characteristics", this conference.

[2] O.S.Milivanov, A.V.Shalnov, "Opredelenie ustoichivosti raboty magnetrona na chastotnozavisimuju nagruzky tipa vysokochastotnogo tracta uskoritely electronov", Uskoritely, Moscow, Gosatomizdat, 1962, vol. p.86-99

[3] N.P.Sobenin "Malogabaritnye linenye uskoritely electronov so stojachey volnoy",Teoreticheskoe i eksperimentalnoe issledovanie uskoriteley zarjazhnyhh chastic, Moscow, Energoatomizdat, 1985, p.8-13