CHARACTERISTIC CALCULATION OF DIRECTIONAL COUPLER FOR ACCELERATOR HIGH-POWER FEEDERS

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The calculation results of directional couplers with connection via the waveguide common narrow wall with a coupling factor of 3.0 decibels, directivity no less than 20 decibels, adjustment of coupling factor at ±1 decibels are presented. The adjustment is carried out with the help of cylindrical plungers, moving inside of waveguides on the part of broad walls in the location of the connection slot, and prismatic plungers, moving in rectangular waveguides connected to narrow walls opposite to a slot of connection. The device as a magic tee with movable throttle pistons in E- and H-plane arms permitting to match any load is designed too. The calculations are executed for devices operating at frequencies of 2.797 and 1.3 GHz.
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The RF transmission line of the linear electron - positron collider TESLA [1] should be constructed in such a way to ensure independent adjustment of the external Q-factor of each superconducting cavity at 10 times, and also independent adjustment of wave phase at cavities. For this purpose it is necessary to use in one of the circuits (schemes) alongside with a phase shifter also directional couplers of 3 and 12.5 decibels with adjustment of a power level at superconducting cavity input in the range of ±1 decibels, when the directivity should not be less than 20 decibels. In other schemes a waveguide magic tee with movable short connectors in E- and H-plane arms is used, that allows independently to change the reflection coefficient introduced by this device from 0 to 1, as well as the phase of reflected wave on $\pm 180^0$.

Main requests to directional couplers are: high electrical strength, use reliability, simplicity of manufacturing. The auxiliary condition can be the possibility of adjustment of coupling factor in some range for want of preservation of high directivity.

Directional couplers with waveguide connection via the common narrow wall have the highest electrical strength in the class of devices. Such a typical construction of a directional coupler represents two waveguides, joined with each other by a rectangular slot with a height equal to the height of waveguides. For coupler tuning in a middle of the connection slot the pin is installed. The application of the tuning pin results in decreasing the directional coupler electrical strength and thickening its construction. The calculation of electrodynamical characteristics of the coupler, having a coupling factor close to 3 dB shows, that the definite choosing of a slot length and a waveguide width in the connection region makes it possible to get a directivity no less than 20 dB [2]. The transitions of geometric sizes of a standard rectangular waveguide to a size of a broad wall in the connection region can be done with the help of smooth or step transitions. The calculations of such a construction of directional couplers designed for operation at various frequencies (~ 1.3, 2.8, 3.2 GHz) showed, that application of standard waveguides provides a coupling factor 3 dB and a directivity not less than 20 dB in the range ±0,5 % of operational frequency.

In the number of accelerator RF systems, in particular, at a collider TESLA, it is necessary to have a possibility to adjust a power level transmitted via waveguide. The well-known directional coupler constructions with an adjustable coupling factor are rather complicated and bulky.

There were proposed and researched two variants of adjustable directional couplers. In the first variant two cylindrical movable plungers are interposed through waveguide narrow walls opposite to each other in front of the connection window. The plunger diameter is equal to the narrow wall width. In the second variant these plungers are through broad walls of waveguides opposite to the connection window in an average plane between waveguides. The interposing of plungers inside of waveguides allows to adjust parameters of the directional coupler.

The calculated parameters of the directional coupler, manufactured with a cross section of 72x34 mm^2, rectangular waveguide at frequency 2.797 GHz are shown in Fig. 1 and 2 (for the first variant) and Fig. 3 and 4 (for the second variant). From these figures it is seen, that the plunger moving allows to adjust a S-matrix coupling factor S_{13} from 2 up to 3.4 dB for want of a reflection coefficient S_{11} not worse 15 dB (for the first variant) and a coupling factor D from 2 up to 4 dB for want of a directivity D not worse than 18 dB (for the second variant)

In Fig.5 the magic tee is represented. It is adjusted with a reflection coefficient less than 0.01 from the E and H arms (arms 3 and 4, respectively) by means of inductive irises. Movable shorts are connected to these arms, its position can be smoothly changed on a distance of half-wavelength in a waveguide. In Fig. 6,7 the calculation results of scattering matrix elements S_{11} and S_{12} under the program HFSS are represented. These results show dependencies of coupler characteristics on the plunger position in the arm 4 for discrete positions of the similar plunger in the arm 3 through 20 mm. The calculations were conducted at a frequency of 1.3 GHz with rectangular waveguide cross section 165.1x82.55 mm^2, and at frequency of 2.8 GHz with waveguide cross-section 72x34 mm^2. As follows from data represented on a Smith Chart for frequency 1.3 GHz, such E-H of the device (E-H tuner) can ensure any resistance. Placing it between the RF source and accelerating cavity, one can install independently the necessary significance of the reflection coefficient module and wave phase at the accelerating cavity. It is necessary to note that in case of unmatched waveguide magic tee (see Fig. 8) there is a resistance region, which can not be accommodated by means of such a device. The experimental tuning diagrams for the E-H tuner based on the waveguide 72x34 mm are shown in figure 9 and 10. Fig. 9 represents the matched tuner and Fig. 10 – the unmatched tuner.

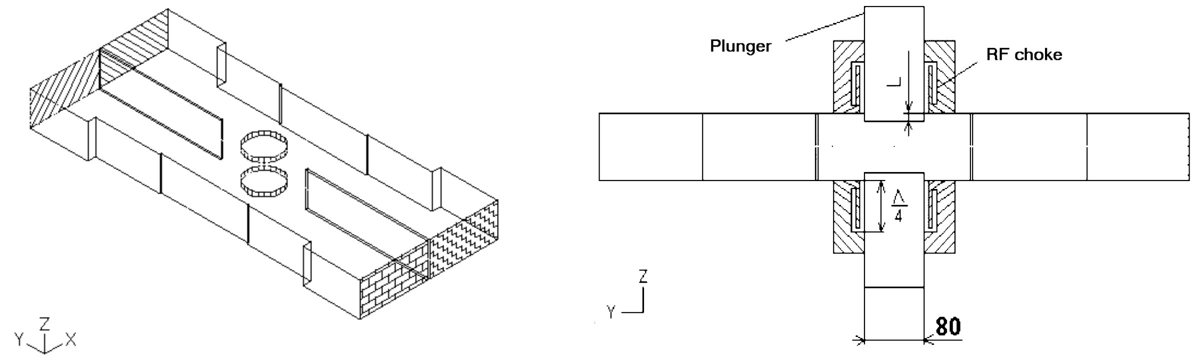

Fig. 1.

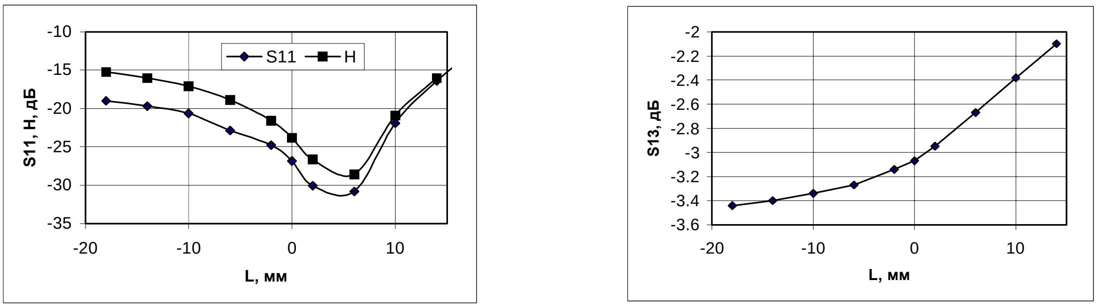

Fig. 2.

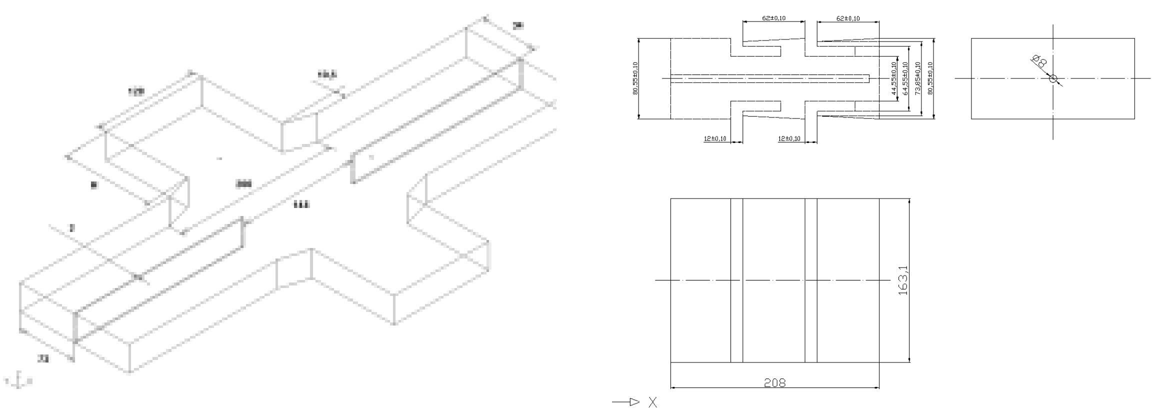

Fig. 3.

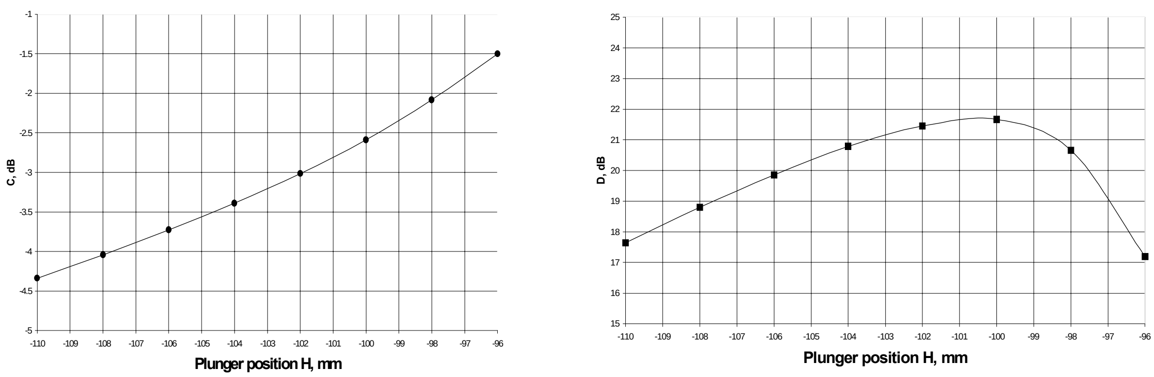

Fig. 4.

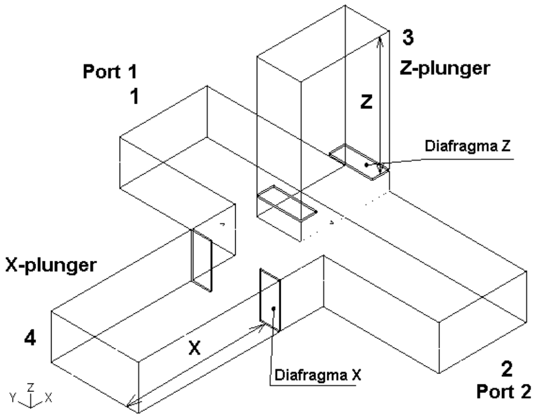

Fig. 5.

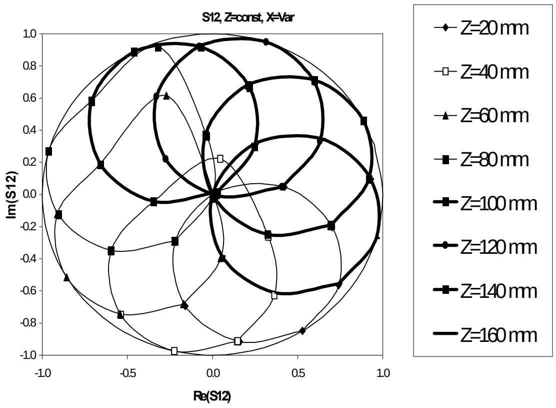

Fig. 6.

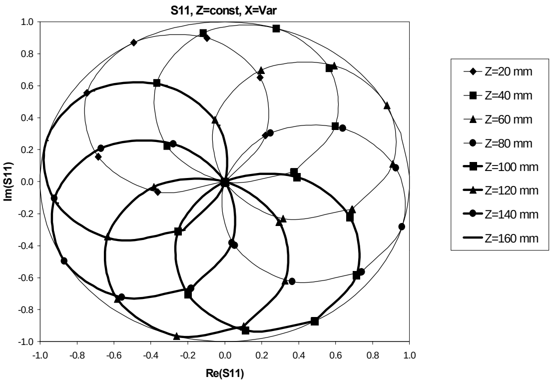

Fig. 7.

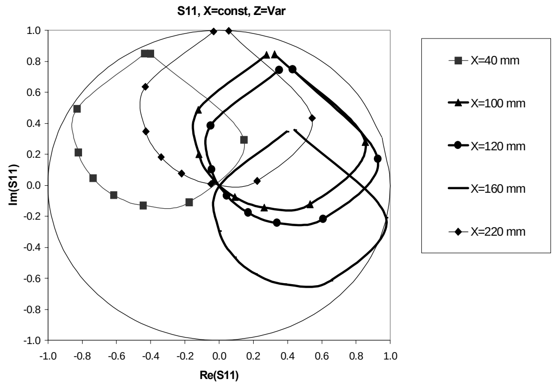

Fig. 8.

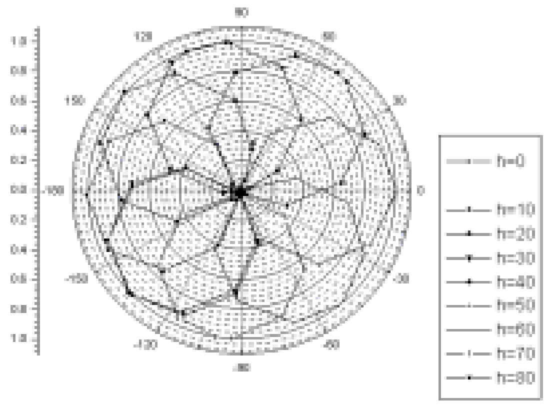

Fig. 9.

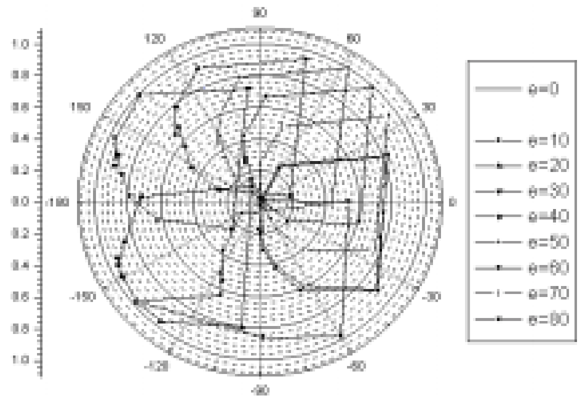

Fig. 10.

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