SOME THOUGHTS ON LOW-VELOCITY TRAVELING WAVES

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Higher Order Floquet Modes in a Periodic Waveguide

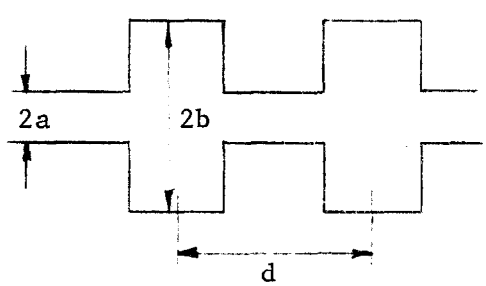
In a periodically loaded waveguide with period d and phase difference μ per period, the principal wave has a velocity

$$\beta = \frac{2\pi}{\mu}\frac{d}{\lambda} . \tag{1}$$

On the basis of Floquet's theory, there exist simultaneously other waves having velocities

$$\beta = \frac{2\pi}{2\pi k \pm \mu}\,\frac{d}{\lambda} \tag{2}$$

where k is any integer. An attempt was made to find configurations in which the modes with k = 1 would have substantial amplitudes; these modes have lower velocities than the one with k = 0 and might therefore be suitable for the acceleration of protons in the range β = 0.4 to 0.9. The configurations examined were of the type illustrated below.



The sections with the small radius might be considered to be drift tubes with reduced reversed fields.

In a quick examination of the problem, no configurations were found that would be more efficient than the standard iris-loaded guide. It was found necessary, in order to obtain fair efficiencies, to make the "drift tubes" long and narrow, essentially leading to the case of separate, almost uncoupled, cavities.

Very Thin Irises

A large proportion of the power loss in iris-loaded waveguides is due to the currents flowing in the iris walls. The loss is proportional to

$$\int H_\varphi^2 ds$$

integrated over all surfaces, since the surface current density is proportional to the discontinuity in magnetic field.

If the phase shift between adjacent periods is small, the magnetic fields on the two sides of the iris will be similar, and the currents flowing on the two sides will be almost equal and opposite. Therefore if the iris thickness were reduced to the order of a skin depth the currents would partially cancel, and the losses would be reduced. On the other hand if the iris is too thin its resistance goes up, and the losses increase again. It was found that there is an optimum thickness, of the order of one skin depth, at which shunt impedances are increased over the thick-iris case by at best a factor of 2.

It is, of course, impractical to make such thin irises unless they are supported on some insulating base; the rather small gain in shunt impedance hardly seems to make this worthwhile. An alternative might be to replace the foil by a grid with sufficiently few wires so that the total metal surface area is small. The losses will be low then. The extreme case is a "grid" consisting of just two supporting stems and a ring. No calculations were done on such a system, but since considering this it became known that work on such structures has been done at Harwell.

Discussion

R.B. Neal (Stanford): May I comment briefly on this? We investigated the grid type structure which has two parallel bars, both vertically and horizontally, placed periodically along the length, first two vertical, then two horizontal, then two vertical. Also the ring structure was considered. The general situation in all of these cases was that it was possible to obtain approximately twice the shunt impedance per unit length using the grid type structure or the ring and bar type structure. However, in each of these cases, the group velocity was excessive. The next step was to try to reduce the group velocity by putting in septums and fins at proper places in the structure. This reduced the group velocity to acceptable values. In the process of doing this it turned out that in every case the shunt impedance would be reduced to values that were obtained with the disk loaded structure. This, added to the additional complication of manufacturing such a structure, led us ultimately back to the disk loaded structure. The grid or ring type structure might still be acceptable if feedback is being used, because in that case it is possible to tolerate a high group velocity by recirculating the power many times.