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SOME DESIGN CONSIDERATIONS FOR THE NEW BAND II SINGLE GAP CAVITY

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Some Design Considerations for the New Band II Single Gap Cavity.

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Introduction.

The change in the design of the Band II cavity from double to single gap raised questions about the possibility of scaling the parameters used in the previous design to the values needed in the new scheme. One of the most discussed questions was weather the new ferrite stacks, which are now twice the original length, can still be considered as lumped inductors, as the actual length of the stack approaches the electrical length of a quarter wave resonator. We will show that in our case this effect is still not dramatic and therefore it should not effect the successful operation of the cavity. Some comments will also show how the choice of a single gap will make the operation of the Band II cavity even easier.

The electrical length of the cavity.

The Band II cavity can be modeled as a coaxial transmission line where the dielectric between the two conductors is a combination air-ferrite-air. From the magnetic point of view, the permeability of the SY7 ferrite chosen for these cavities is dominating, whereas in order to study the electric behavior, a rough approximation is to consider it as a combination of three series capacitors. The dielectric constant of the ferrite is about 60 at the initial frequency of 600 kHz (the dielectric constant of the ferrite is a function of frequency, rf amplitude and dc bias).

Fig. 1 shows the model used to estimate the effective dielectric constant of the structure. The capacitance between the conductors of a coaxial line is:

$$C = K \frac{\epsilon}{\ln R_2/R_1}$$

and, as all the capacitances are in series, the total capacitance is:

$$1/C_{tot} = 1/C_1 + 1/C_2 + 1/C_3$$

Using the parameters and the dimensions as in Fig. 1, we get:

$1.335/\epsilon_{tot} = 0.414 + 0.145 + 0.013 = 0.572$

and therefore

$\epsilon_{tot} = 1.335/0.572 = 2.33$

where ϵ_{tot} is the dielectric constant of the equivalent dielectric that yields, in the same coaxial structure, the same total capacitance.

The electrical length of the cavity can now be determined, choosing as a worst case the lowest frequency, when μ is highest, assuming that ϵ does not change.

At 600 kHz the quarterwave length in air is

$$L_0 = \frac{c}{f} = 125 \text{ m}$$

The actual electrical length of the Band II cavity, knowing that μ at this frequency is about 1200, is:

$$L_{BII} = \frac{v}{f} = \frac{L_0}{\sqrt{\epsilon_{tot}\,\mu}} = \frac{125}{52.9} = 2.36 \text{ m}$$

The physical length of each stack of ferrite is about 0.89 meters, when we use 34 rings per stack, each of them being 2.62 cm. thick.

This means that:

$$0.89/2.36 * 90 = 34 \text{ deg}$$

is the cavity length in degrees.

Comments

In our configuration, the cosine function is a direct indication of the voltage across each ferrite ring and, since cos 34 = 0.83, it is possible to conclude that the variation of the rf voltage across the ferrite ring nearest to the gap will see a voltage which is 17% lower than the ring at the opposite end, which will be at the shorted end of the cavity. All the others will be in between.

In order to have the same gap voltage, we must keep the same average flux density and, since the power lost in the ferrite goes approximately as the square of the flux density, it is possible to estimate that a 17% difference in the flux will correspond to an increase in the peak losses of less than 20%. This effect is significant and will be partially compensated by the fact that the stacking order is chosen so that the least lossy ring will go in the spot with the highest rf flux density.

The quality factor Q is defined as:

$$Q = \frac{E_{stored}}{2 \pi P_{lost}}$$

Since the energy stored is proportional to the voltage across the ring, the quality factor Q is a direct measurement of how good the material is. So the stacking order will be done so that the highest Q ring will go in the spot with the biggest losses, in order to minimize the differences of power dissipated among the rings. An additional sort may be made by placing the rings with a higher permeability closer to the gap and the lower permeability rings near the shorted end. This will result in an increase of the stored energy in the rings (with a higher μ) closer to the gap, therefore working towards a linearization of the losses in the cavity.

Another factor that works in our favor is the fact that a single gap cavity has its full voltage available to the beam, whereas a double gap resonator is bound, especially for the acceleration of heavy ions, to have a Transit Time Factor (TTF) that will reduce the effective voltage capabilities of the cavity. This implies that the actual gap voltages required in a double gap cavity are higher then the voltages needed for acceleration and to create the bucket area.

Let us consider, for the sake of the argument, a double gap cavity similar to the one build for Band III. The Transit Time Factor for a resonator that operates in a 0 mode is:

$$TTF = \cos \frac{\pi h L}{2 \pi R}$$

where h is the harmonic number and L is the inter-gap distance.
If we consider the case of h = 12, and L = 1.4 m, we get:

$$TTF = 0.966$$

The effect would therefore have been less than 4%.

Finally, we should always consider that, since the new Band II scheme calls for two identical resonators, more voltage is now available at the same frequency from two resonators. The tests of the final system will tell us what are the real voltage limitations of these resonators, but we can certainly conclude now that this scheme guarantees at least the same performance as the one that was originally proposed.

Acknowledgment

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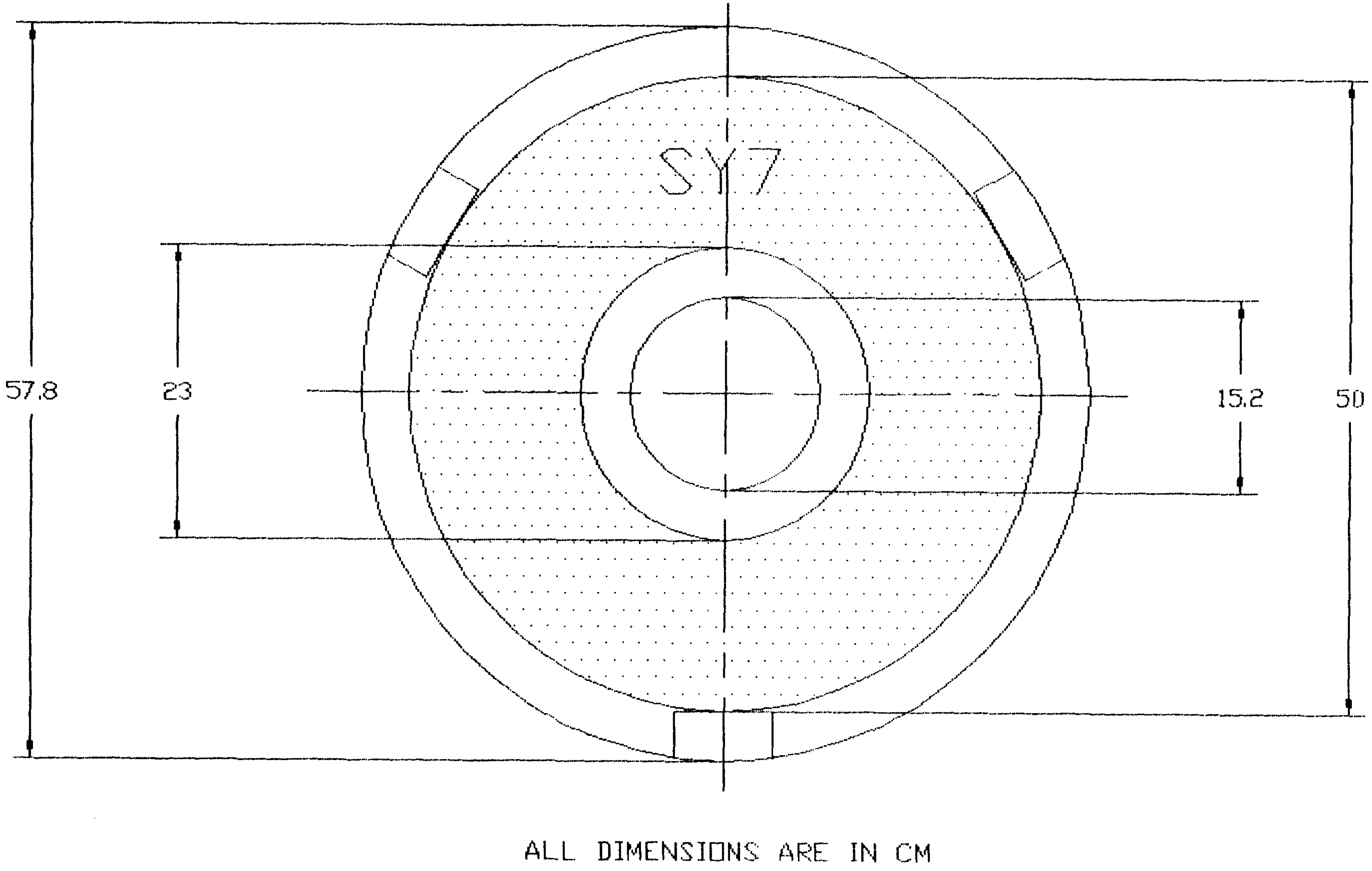

Fig. 1 - Cross-section of the Band III rf cavity.