LINAC CAVITY FIELD CALCULATIONS*

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I. Introduction

The resonant frequency and the electromagnetic fields of linac cavities can be computed by mesh-relaxation computer programs. It is of interest to establish the accuracy of these computer programs. It is difficult to establish the accuracy from theoretical considerations. An estimate of the accuracy can be made by comparing the results of the computer programs with experimentally measured results.

The mesh-relaxation computer programs used were the JESSY program developed by G. Parzen and K. Jellett at Brookhaven National Laboratory (BNL) and the MESSYMESH program developed by T. Edwards and R. Christian of the Midwestern Universities Research Association (MURA). The results of these computer programs were compared with the results of experiments done by D. Young and C. Owen at MURA and by S. Giordano and J.P. Hannwacker at BNL.

II. Comparison of JESSY and MESSYMESH Results

In this section, results obtained using the JESSY and MESSYMESH mesh-relaxation computer programs are compared. Computations were done for various linac cavities with different geometries.

In Table 1, results for the resonant frequency and various field parameters are compared for linac cells having the lengths, L/2 = 3.5, 11.25, and 26.0 cm.

The corresponding gaps are G/2 = 0.75, 3.5, and 9.5 cm. The other geometrical parameters are d/2 = 9.0, A/2 = 1.0, R = 47.0, RC = 2.0, and RHC = 1.0 cm. These parameters are defined in Figure 1.

The results given by the two mesh-relaxation programs are in good agreement; the one possible exception is the result for the transit time factor, T, for the short cavity with L/2 = 3.5. This difference in the transit time factor is associated with a difference in the computed electric field variation along the axes of the cavity. The electric field on the axis is plotted in Figure 2.

III. Comparison with Experimental Results

In Table 2, computer results for the resonant frequency of several linac cavities that were constructed at BNL are compared with the experimentally measured frequencies. The geometry of the three linac cavities is given in Section II.

In Table 3, computer results for the resonant frequency of several linac cavities that were constructed at MURA are compared with the experimentally measured frequencies. The linac cells have the lengths L/2 = 3.500, 4.0390, 4.717, 5.565 and 6.364 cm. The corresponding drift tube gaps, G/2, are given in the table. The other geometrical parameters are d/2 = 9.0, RC = 2.0, A/2 = 1.0, RHC = 1.0 and R = 49.62 cm.

IV. Conclusions

The difference between computed and measured results for the resonant frequency ran from 0.95% to 0.13%. In Fig. 3, the percent difference between the measured and computed results are plotted. The maximum percent difference between JESSY and MESSYMESH results for the resonant frequency is about 0.25%.

It is difficult to summarize the results shown in Fig. 3 by a single number. Qualitatively, one might say that comparison with measured results indicates an error in the computer results for the frequency of about 0.5%, with most cases having errors below 0.5% and a few cases having errors above 0.5%.

DISCUSSION

F. PARZEN, BNL

MILLER, SLAC: If you averaged your transit time factors over some finite diameter such as the beam might cover, would this remove the disagreement? Could this disagreement be due to problems right at the axis in your mesh with cylindrical symmetry?

PARZEN: Yes, that is quite possible. If one averaged, the agreement might be better.

GLUCKSTERN, Univ. of Massachusetts: What is the bore radius in the case that you have the bad disagreement?

PARZEN: The full-bore radius was 1 cm.

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GLUCKSTERN: Then what you have are two radial mesh points in the radial direction to represent the solution of the differential equation. Isn't it quite likely that the errors occur because the information about the radial dependence of the field along the axis as you enter a drift tube bore is just not sufficiently accurate?

PARZEN: One might mention that the MESSYMESH results have four mesh units--twice as many as JESSY has in the radial direction--since they use 1/4 cm radially. That doubles the mesh units in that direction. I can't really answer your question with certainty.

GLUCKSTERN: Then let me direct my question to someone who has some experience with the MURA calculation. Was there any difference between runs for a 1/2-cm unit and a 1/2-cm mesh unit?

PARZEN: This comparison cannot be made because the JESSY runs were done with 1/2 cm in the radial direction, but with 1/8 cm in the longitudinal direction; whereas, when a MESSYMESH run is done with a 1/2 cm, one has 1/2 cm in both directions.

YOUNG, MURA: When we make MESSYMESH runs with smaller mesh dimensions, we do not see a difference in the transit time or the field on the axis. Our usual practice is to run with as fine a mesh as is possible within the storage limitations of our computer. I would like to comment on the point concerning the large 1% difference of that one point when compared with the measured result. We have checked a geometry in our precision cavity that has an L of 7.0 cm. The error between the measured frequency and the computed frequency was 0.3% not 0.9% as indicated in Fig. 3.

LAPOSTOLLE, CERN: What is the mesh-size ratio you can use for a rectangular mesh? Can it be as large as one likes, or must it be limited?

PARZEN: They are entirely unrelated. Our main restriction is in the number of mesh units we can have.

LAPOSTOLLE: M. Promé will speak sometime later about a program written at Saclay by A. Katz, somewhat similar to MESSYMESH, and I would like to make a few comments about the results it gives. The transit time factor has been computed, not only on the axis, but also along different lines apart from the axis, and the values compared with the I_0 type of theoretical variation. The various points agree extremely well with the I_0 variation, except at the axis where the difference can reach 5%, especially for short cells. Concerning the accuracy, comparisons have been made of this program with experimental measurement carried out in the Rutherford Laboratory. The agreement in frequency was much better than what has just been reported, say about 150 kHz.

PARZEN: Has this been published somewhere?

CARNE, RHEL: It will be discussed in my paper tomorrow.

MONTAGUE, CERN: In connection with this 1% point: What is the scatter in the experimental measurements with which you have compared the computations taking into account the accuracy of the geometry in the experimental work?

PARZEN: You want the scatter in the experimentally measured frequencies?

MONTAGUE: Yes.

PARZEN: Sal Giordano, can you answer that question?

GIORDANO, BNL: Actually, I didn't make the measurements, but I did see the results. Both the electrical measurement and mechanical tolerance were better than 0.1%.

PARZEN: Could I make just one comment? Although that one point with 1% error sticks out like a sore thumb, I am rather reluctant to just throw it out, because there is reason to believe the fields are in considerable error for low-L cells, and that error is possible.

CARNE: With respect to the measurements that were done at the Rutherford Laboratory, we worked at 1000 MHz. Tolerances on the dimensions were such that we were able to get all our final (full-scale) frequencies to well within 300 kHz at 200 Mc; in other words, a frequency tolerance of <0.15%. It is interesting to remark that this is a linac which goes from 0.5 MeV to 10 MeV in 42 cells, the dimensions of some of which were obtained by a very smooth interpolation. Subsequently, these cells were calculated by the program written at Saclay by Mr. Katz. All of these agreed within about 150 kHz of the figures that we gave, which is remarkably good.

PARZEN: 150 kHz out of 200 MHz is very good.

LAPOSTOLLE: Just a small point I forgot to mention. In this program from Katz, another source of possible error in the field values has been found to come, perhaps, from the way in which the fields are normalized. Two ways have been used in this program. One was a field integration on the axis, another was by a surface integration. Nobody can demonstrate which is best, but there is a large suspicion that the integration on the axis may not be very good. The difference between the two normalization factors is usually a few percent, up to 5% in a few exceptional cases, but always in the same direction. I wonder if MESSYMESH and JESSY were not using the same normalization, and if this would explain some of the differences observed?

PARZEN: The transit-time factor is independent of the normalization, and it does not matter how the fields are normalized. However, the normalization problem is a difficult one and while most of our results show that the two ways of computing the normalization differ by only a few percent, every now and then we get a case which differs by large amounts--about 15%.

(Ed. Note : See further discussion of this point in the comments following the paper by H. Hoyt, "Designing Resonant Cavities with the LALA Computer Program.")

TABLE 1

A comparison of the results of the JESSY and MESSYMESH mesh-relaxation computer programs. T is the transit time factor. ZS is the shunt impedance. PW and PDT are the power losses in the outer wall and drift tube. PT is the total power loss. All quantities in MKS units.

	L/2	3.5	11.25	26.0
Frequency	JESSY	200.48	201.36	202.56
	MESSYMESH	200.34	201.09	202.40
T	JESSY	0.7075	0.8194	0.7629
	MESSYMESH	0.6519	0.8068	0.7484
ZTT	JESSY	32.06	52.44	37.92
	MESSYMESH	28.25	48.36	35.72
PW	JESSY	571.3	1811	4064
	MESSYMESH	630.3	1986	4234
PDT	JESSY	521.4	1070	3918
	MESSYMESH	421.4	1039	3909
PT	JESSY	1092	2881	7982
	MESSYMESH	1052	3025	8143
Q	JESSY	80892	93434	78239
	MESSYMESH	84340	93891	77946
ZS	JESSY	64.06	78.09	65.14
	MESSYMESH	66.47	74.29	63.78

TABLE 2

A comparison of measured and computed resonant frequencies for several linac cavities constructed at BNL.

	L/2	3.5	11.25	26.0
Frequency	Measured	198.58	200.61	201.32
	JESSY	200.48	201.36	202.56
	MESSYMESH	200.34	201.09	202.40
Percent Difference	JESSY	0.95	0.37	0.62
	MESSYMESH	0.88	0.24	0.54

TABLE 3

A comparison of measured and computed resonant frequencies for several linac cavities constructed at MURA.

	L/2	3.350	4.039	4.717	5.565	6.304
Frequency	Measured	202.47	200.70	198.81	200.57	198.94
	JESSY	203.07	201.64	199.59	200.24	199.23
	MESSYMESH	203.06	201.16	199.24	200.19	199.20
Percent Difference	JESSY	0.30	0.47	0.39	-0.17	0.14
	MESSYMESH	0.29	0.23	0.21	-0.18	0.13
	G/2	0.947	1.128	1.293	1.633	1.864

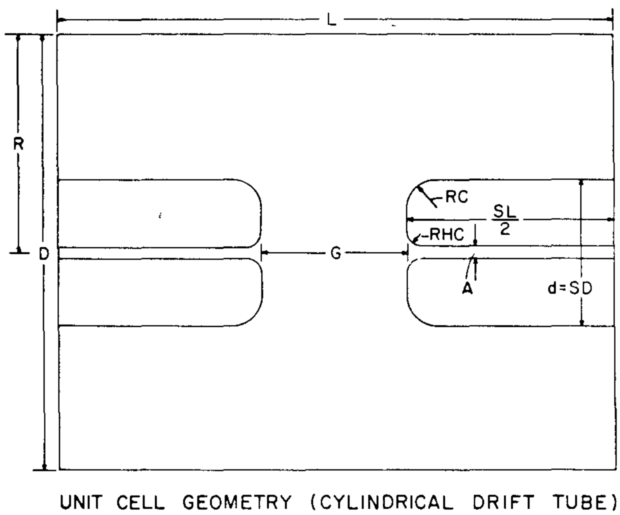

Fig. 1. The geometry of a linac cell.

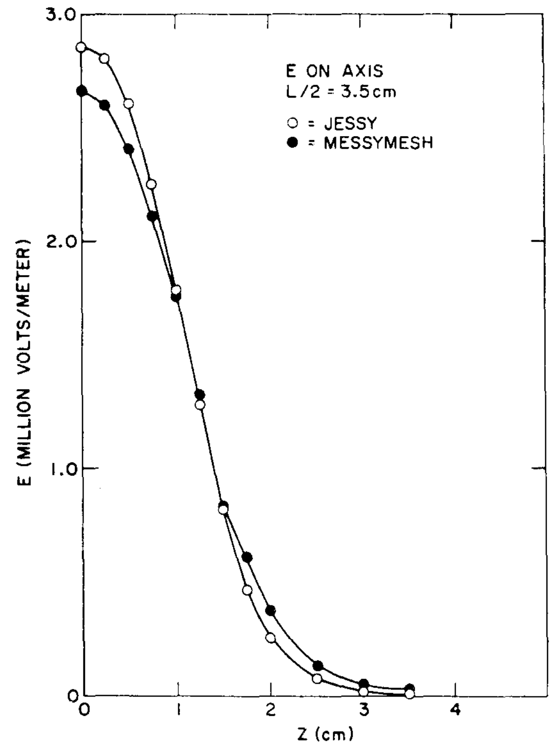

Fig. 2. The electric field on the linac cell axis for the case L/2 = 3.5 cm.

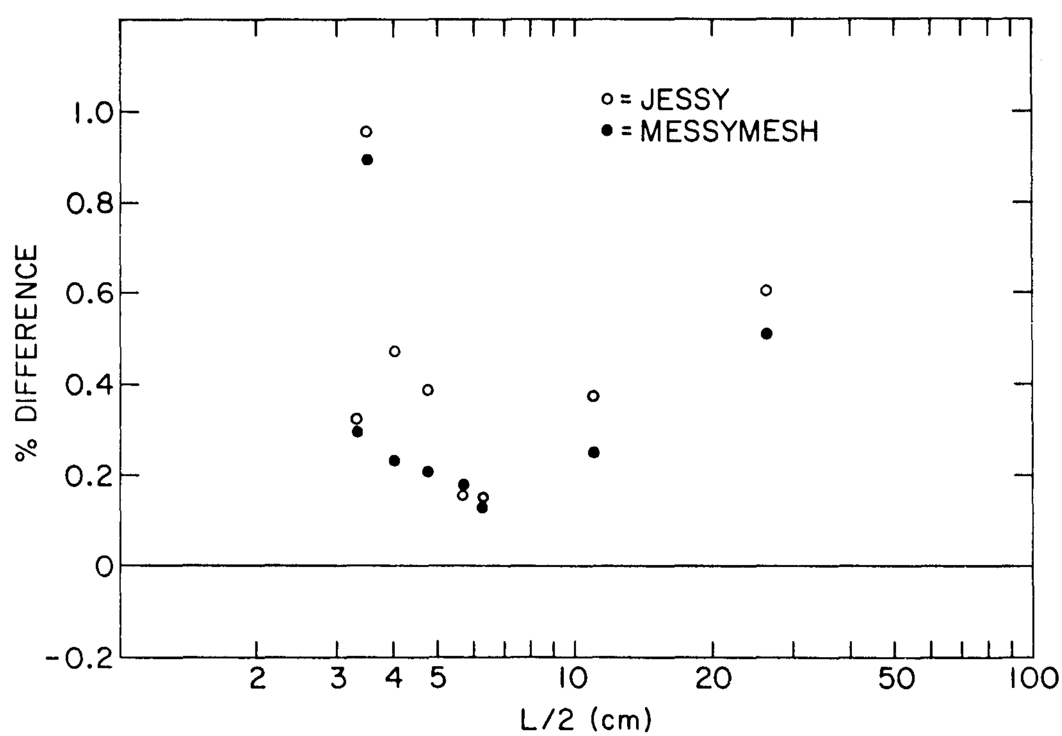

Fig. 3. A plot of the percentage difference between measured and computed results for the resonant frequency against linac cell length, L/2.