COMPUTER AIDED FIELD MEASUREMENTS OF THE SUPERHILAC ALVAREZ CAVITIES*

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Abstract

Recent field measurements in the first of the six cavities that comprise the SUPERHILAC post stripper have indicated an accelerating field imbalance that is low at the entrance and high at the cavity exit. Closer inspection of this problem has revealed a displacement of the end wall drift tubes. It is believed that the sudden "letting up to air" of the whole post stripper in the vicinity of the fifth of the six cavities has caused all cavity end walls to be displaced, thereby causing all cavities to have similar or mirror image field imbalances.

Realignment of the cavity fields will require many repetitive field measurements. To reduce documentation errors, eliminate user interpretation of data, and speed the measuring process, a computer program is being written to control the HP 8753A Network Analyzer. Data is transferred to disc for further analysis, thereby providing an immediate presentation of the cavity fields.

Limited manpower prevents attempting the alignment of all cavities at this time. As such, the results of a single cavity alignment will be reported. Included will be:

- Computer controlled Network Analyzer -System design and performance
- Alignment techniques
- Monitor port calibration - Requirements, methods, and results

Introduction

There were seven monitor ports installed in cavity 3. The support flanges, to which the loop assemblies are mounted, the spacer plates, which provide a course adjustment of the RF output signal level, and the loop assemblies, which house the inductive loop, series resistor, and RF output connector, were machined and assembled in the summer of 1988. The seven holes drilled in the cavity were equally spaced, by distance L, along the cavity wall. The distance, L, between each hole was halved and used to determine the distance from the cavity end walls to hole positions 1 and 7. The support flanges were slipped through the drilled holes from the outside and copper welded at the internal cavity wall. All welds were vacuum tested and the spacers and loop assemblies, which were previously leak checked, were mounted to the support flanges.

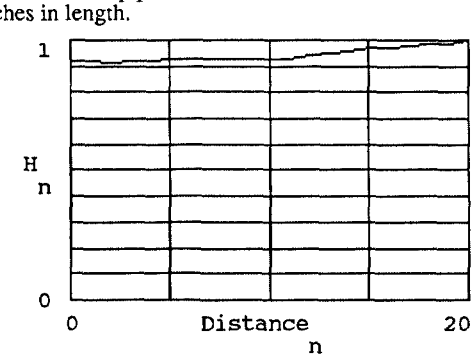
Measurements of the mechanical positions of the drift tube faces in all cavities have been made. A steel tape measure was anchored outside the poststripper set of cavities on the cavities center line, and then pulled through the drift tube apertures. The values at the faces were then recorded without the errors associated with an interference type measurement. This data, and the previously documented drift tube stem positions values, have been entered into a LOTUS 123 file, where based on these numbers, the expected electric fields at the drift tube faces have been calculated.

The field distributions in each cavity have been measured by perturbing the H field at the cavity wall, in successive steps, and recording the resultant frequency shifts. A program was written in HP Basic to control the HP 8753A network analyzer, from an HP 9816 personal computer, via the HPIB bus. As each successive data point is measured, the network analyzer data is transferred, via bus, to an HP 9122C disk drive. While only the frequency and measurement position data is used for the field calculations, cavity Q and relative magnitude are stored on the disk and, while unrelated to this project, may be referred to at a later date. A maximum of 30 cavity measurements can be used to describe the field distribution in a single cavity. This amount of data can fill a single disk and as such, a single disk is allotted to store the information for each cavity.

When all measurements for a given cavity are completed, the frequency data is recalled from the disk by the HP 9816, where the cavity H field distribution is computed. These calculations are based on the perturbed frequency shift at each position compared to the unperturbed cavity frequency. The results of the calculations are normalized, where the maximum field value is equal to 1. The H field distributions, in the absence of local disturbances at the cavity wall, predict the E field distributions, and are graphically represented as a percent of the maximum field, either directly to the computer monitor or to a printer.

Field Measurements

A sled, consisting of a fiber glass mounting plate and TEFLON runners, was used to support a section of brass rod. The end of the rod, measuring 3 inches in diameter and 2 inches in length, was secured to the sled mounting plate. A string was attached to the sled and the sled assembly was installed in the cavity at the furthest end wall. The nearest cavity end wall was secured with the sled string extending outside the cavity. The sled was pulled in 1 foot increments, along the cavity wall, and the frequency data recorded. The sled was then removed, the cavity end wall resecured, and the cavity frequency recorded. The size of the brass rod had to be adjusted upwards as the first measured frequency was lower than the unperturbed cavity frequency instead of higher. This anomaly was caused by the cavity frequency shift due to temperature being greater than the shifts caused by the brass rod. The final perturber was made of brass pipe and measured 8 1/2 inches in diameter and 6 7/8 inches in length.



Measured H Field Distribution In Cavity 3

The figure above, showing the graphic output of the relative fields, describes a field distribution much flatter than the fields calculated from previous measurements. The larger perturbing mechanism and the increased speed with which the measurements were taken should reduce the amount of frequency drift due to temperature changes and increase the frequency shift due to perturbation. The fields, as predicted above, should be more accurate, as they benefit from this effective increase in signal to noise ratio.

Calculated Field Distributions

The following data sheets reflect the original specifications and recently measured dimensions for cavity 3.

The specified data, from the Mechanical Engineering Notes, gives the dimensions for the drift tube widths, the stem positions along the wall of the cavity, and the position of the drift tube on the stem. The latter being labeled, DT Center. The gaps between the drift tubes are

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best defined in terms of upstream and downstream directions; where, upstream is a larger "DT Stem Position" value. The gap in question is then defined as the difference between the up and down stream DT centers less the sum of 1/2 the up and down stream DT widths. The center to center dimensions are the differences between the up and down stream "DT Stem Positions".
The measured data gives only the measurements of the down and up stream drift tube faces. Gaps are calculated by subtracting the downstream dimension of DT #(n) from the upstream value of DT#(n+1). The calculations are performed in LOTUS 123. The data below is imported from that LOTUS program as a .PRN file.

Cavity 3 Drift Tube Schedule

DT #	DT Width	DT Stem Position	DT Center	Calc. DT Gap	Calc. Stem ctr-ctr
0	3.056			2.315	8.490
1	6.397	8.490	8.569	2.305	8.743
2	6.492	17.233	17.319	2.380	8.946
3	6.605	26.179	26.247	2.432	9.077
4	6.739	35.256	35.351	2.498	9.287
5	6.827	44.543	44.632	2.569	9.472
6	6.954	54.015	54.091	2.631	9.638
7	7.058	63.653	63.728	2.719	9.920
8	7.132	73.573	73.542	2.802	9.950
9	7.249	83.523	83.534	2.847	10.149
10	7.394	93.672	93.703	2.903	10.335
11	7.494	104.007	104.050	2.972	10.531
12	7.610	114.538	114.574	3.036	10.697
13	7.721	125.235	125.276	3.116	10.893
14	7.805	136.128	136.155	3.190	11.044
15	7.928	147.172	147.212	3.254	11.233
16	8.030	158.405	158.445	3.327	11.418
17	8.138	169.823	169.856	3.398	11.579
18	8.242	181.402	181.444	3.476	11.770
19	8.336	193.172	193.209	3.547	11.979
20	4.227	205.151	205.151		

Data taken from ME notes M4388D and M4411D

Cavity 3 Drift Tube Schedule

DT #	Calc. DT Width	Upstream Inches	Dwnstream Inches	Calc. DT Gap	Calc. DT ctr-ctr
0	2.900	N/A	14.340	2.240	8.375
1	6.470	16.580	23.050	2.230	8.725
2	6.520	25.280	31.800	2.370	8.945
3	6.630	34.170	40.800	2.390	9.105
4	6.800	43.190	49.990	2.500	9.300
5	6.800	52.490	59.290	2.600	9.480
6	6.960	61.890	68.850	2.630	9.640
7	7.060	71.480	78.540	2.720	9.810
8	7.120	81.260	88.380	2.820	10.010
9	7.260	91.200	98.460	2.850	10.180
10	7.400	101.310	108.710	2.850	10.290
11	7.480	111.560	119.040	3.000	10.545
12	7.610	122.040	129.650	3.060	10.725
13	7.720	132.710	140.430	3.080	10.855
14	7.830	143.510	151.340	3.180	11.070
15	7.950	154.520	162.470	3.330	11.310
16	8.010	165.800	173.810	3.220	11.300
17	8.150	177.030	185.180	3.420	11.620
18	8.250	188.600	196.850	3.500	11.790
19	8.330	200.350	208.680	3.580	12.930
20	10.370	212.260	222.630	3.290	13.015
21	9.080	225.920	235.000		

Data as measured on September 15,1988

A program, intended to calculate the electric field strengths at the drift tube faces, in an Alvarez accelerator, was written in MathCad. The MCAD calculations are based on the DT Gap and DT center to center values listed in the LOTUS file. The distance between the gaps defines a value inversely proportional to the circuit capacity, while the distance between the stems defines a value proportional to the circuit inductance. The program computes relative values of the distributed fields and frequencies and assumes a homogeneous distribution of the inductance and capacity in the cavity. It does not address localized effects such as tuner loops, end wall disturbances, differences in the drift tube stems or changing drift tube diameters.

The values for L and G below are recalled from the LOTUS 123 file, ME Notes.

The distance between the drift tube stems, center to center:

$$L := \mathrm{READPRN}\left[\mathrm{L3spec}_{\mathrm{PRN}}\right]$$

The distance between the drift tube faces:

$$G := \mathrm{READPRN}\left[\mathrm{C3spec}_{\mathrm{PRN}}\right]$$

$n := 0 \,..20$

A value proportional to the cutoff frequency of each cell is defined as:

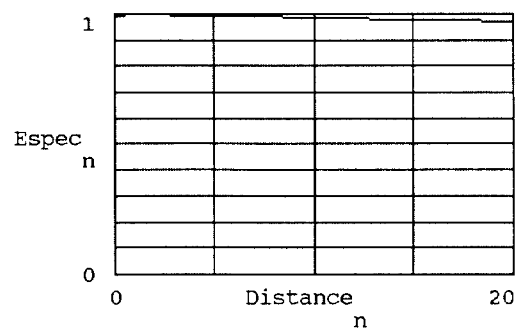
$$f_n := \sqrt{\frac{G_n}{L_n}}$$

The method of calculation is based on the cutoff frequencies of each cell within the cavity and supposes that the cell with the lowest frequency has the highest field. All other frequencies are normalized to the lowest frequency. Relative cell field strengths are then the square root of the normalized cell frequencies.

Relative drift tupe gap field strength is defined as:

$$Ec_n := \sqrt{\frac{\min(f)}{f_n}}$$

The graph shown below represents the calculated, relative field strengths vs. position in Cavity 3, based on the data specified in the Mechanical Engineering Notes.



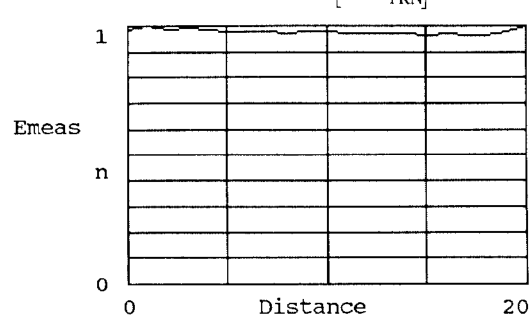
The new files below, recall the calculated distances from recent measurements of the cavities. The graph represents the calculated field strengths based on this data.

The distance between the drift tube stems:

$$L := \mathrm{READPRN}\left[\mathrm{L3m}_{\mathrm{PRN}}\right]$$

The distance between the drift tube faces:

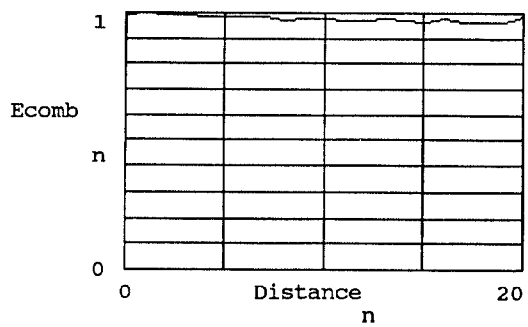
$$G := \mathrm{READPRN}\left[\mathrm{C3m}_{\mathrm{PRN}}\right]$$



As can be seen in the previous two figures, the contours of the graph based on the measured data are rougher,but the same general field distributions apply in both cases.

As previously stated, the distances that describe the inductance in the measured case, are based on dimensions measured down the center line of the cavity. This method of measurement cannot reflect the true cell lengths, as there is no information present to determine the off-center dimension of the drift tube placement on the stem. Since the drift tube stem positions, at the cavity wall, are not subject to interpretation or, likely to have moved from the original position at installation, the dimensions in the Mechanical Engineering Notes that describe the "DT Stem Position" reflect a more accurate representation of the cell length. The file below recalls this data, where it is used in conjunction with the gap distances from the measured data file,to compute the electric fields shown below.

$$L := \mathrm{READPRN}\left[\mathrm{L3spec}_{\mathrm{PRN}}\right]$$



MONITOR PORTS

Measurements, using the HP 8753A network analyzer, were taken, at each of the seven recently installed monitor loop ports in cavity 3, to determine the relative fields at each location. These values were recorded and used as the reference for setting the final monitor loop positions. As the distributed field strength was expected to vary with the "Tuner Loop" position, the tuner was initially set to the full coupled position and left there until the permanent monitor loop positions were set. A special loop was used for making the relative field measurements at each monitor port. To minimize field measurement errors caused by dimensional differences in the cavity wall at the monitor ports, this loop was of sufficient length to completely penetrate the cavity wall at all positions. Before recording data, to minimize errors due to coupling, the monitor loop was "rocked" to maximize the reading. To increase the signal to noise ratio and to speed the measuring process, an AVANTEK, wideband, 30db amplifier was installed at the input to the network analyzer.

The final loop settings incorporate an absolute measure of attenuation through the cavity. To directly measure this value, there can be no reflected power in the drive system. As such, prior to making the relative field measurements, the drive loop was rotated to set the input impedance to 50 ohms.

The data files of the measurements taken, shown below, have been recalled from a LOTUS file where they were entered as a basis for calculations to determine the normalized field strengths. The desired output of the monitor port loops, with 1 megawatt of RF input power to the cavity, is 7.07 volts peak. As shown below, Position 4 provides the minimum signal. As such, it has been chosen to provide 63 db of attenuation from the drive loop, when the drive loop is set to 50 ohms. All other monitor ports will be set relative to this value.

As seen in the following tables, the probes are set to within .01 db of the required value and the readings are reproducible to within .01 db with the tuner loop at the full coupled position. The tuner loop was then moved to the "center" and then to the "decoupled" positions. The graph depicts the maximum changes in the field distribution vs. tuner loop position.

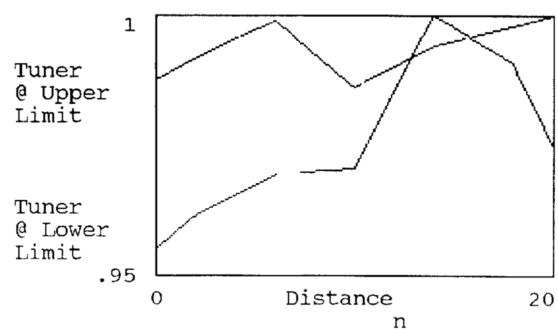
Relative Field Strength

Port #	Magnitude db	Magnitude volts *	Magnitude norm. *
1	-0.78	0.91	0.99
2	-0.76	0.92	0.99
3	-0.69	0.92	1.00
4	-0.81	0.91	0.99
5	-0.72	0.92	1.00
6	-0.69	0.92	1.00
7	-0.69	0.92	1.00

Absolute Field Attenuation

Port #	Required *	Actual .1	Actual .2
1	-62.97	-62.98	-62.98
2	-62.95	-62.95	-62.94
3	-62.88	-62.88	-62.88
4	-63.00	-62.99	-62.99
5	-62.92	-62.92	-62.92
6	-62.89	-62.89	-62.89
7	-62.88	-62.88	-62.87

* Indicates a calculated value
T3 H field wall measurements as of Oct 18, 1988
The headings, "Actual.1 and Actual.2", reflect repeat measurements of the same positions.



H Field Distribution vs. Tuner Loop Position

CONCLUSIONS

The preceeding graphs show that, irrespective of method, the determined field distributions are essentially flat and as such, no attempts to realign the field distributions in cavity 3 were made or are now contemplated.

ACKNOWLEDGEMENTS

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