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AN ARRAY OF 1-TO 2-GHz ELECTRODES FOR STOCHASTIC COOLING

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Introduction

Described is an array of directional-coupler loop-pairs that are to be used as either pickup or kicker electrodes for the frequency range of 1 to 2 GHz. Each coupler pair is a λ/4 long parallel-plane transmission line that is arranged to be flush with the upper and lower surfaces of a rectangular beam pipe. As pickups, the coupler pairs are used in arrays and are operated at 80 degrees Kelvin for improving the signal-to-noise ratio. The loop output power is added in stripline combiner networks before being fed to a low noise preamplifier. When the couplers are used as kickers, the combining network serves to split power and distribute it uniformly to each electrode.

Mechanical Features Of The Prototype Array

The beam pipe, 3 cm x 30 cm in cross section, is constructed of stainless sheets attached to a pair of stainless bars, one above the other, that serve as the backbone of the device. Machined into the bars are sixteen, 6 cm x 6 cm x 2.5 cm deep cavities spaced one centimeter apart. Loops, mounted in the cavities, face each other. (See Figure 1) The loops, fabricated from flat plates, are supported on specially shaped legs. Two holes are drilled in the bottom of each cavity. One is tapped for a screw-in stud, to which is soldered a 100 ohm resistor. The free end of the resistor terminates in a pin that engages a socket in the leg of the loop. A circuit board behind the bar supports another pin that passes through the second hole and engages a socket in the other leg of the loop. The hole and the pin make up a short 100 ohm transmission line. The loop and the cavity constitute a parallel-plane transmission line with a characteristic impedance of approximately 100 ohms. The legs are shaped to match the parallel-plane line to both the 100 ohm coaxial line and the 100 ohm resistor. (See Figure 2)

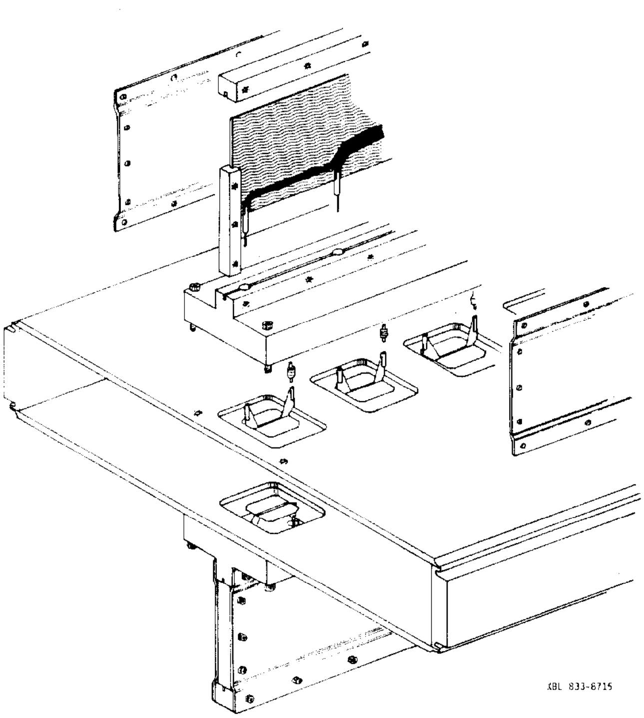

Figure 1. Exploded View of Pickup Array

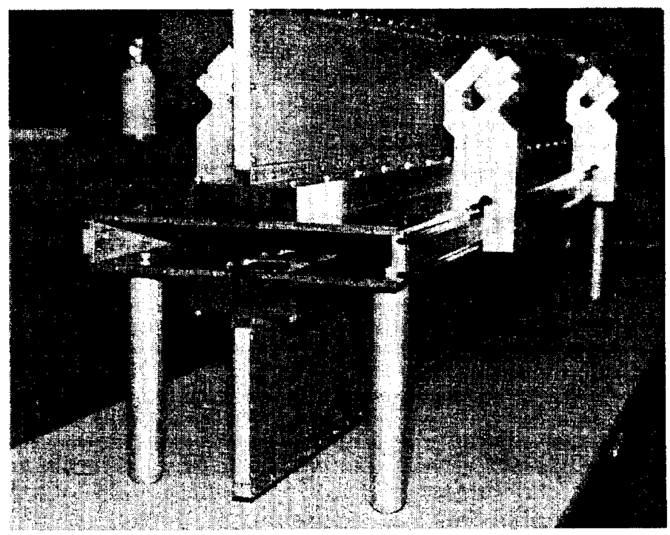

Figure 2. 1 to 2 GHz Pickup Array

The circuit board behind each bar has copper strips on both sides. In combination with ground planes spaced 1/2 cm away, these constitute a stripline network that combines the signals from each loop. The stripline features combiners that have λ/4 transformer sections in the legs. Two loop outputs on a 100 ohm line are paralleled and deliver power into the 50 ohm input of a combiner. The impedance is transformed to 100 ohms and paralleled with another 100 ohm output. The final output of 16 upper loops appears on a 50 ohm coaxial connector. Similarly, the output of the lower 16 loops also appears on a 50 ohm connector.

Test Set Up

The prototype is located in the center of a 15 inch diameter experimental vacuum tank that is attached to a 2 MV electron Van de Graaff. A special electron gun that can be modulated at frequencies from 1 to 4 GHz is installed in the terminal of the Van de Graaff allowing projection of a modulated beam of electrons through the pickup array into a Faraday cup. The beam of electrons, smaller than 1 cm in diameter, can be focused so that more than 99% of it is captured in the Faraday cup.

The outputs from the upper and lower loops brought from the vacuum tank are added together in another combiner and fed into a low-noise preamplifier. The signal passes through a second amplifier and 90 feet of Heliax cable to an attenuator and a HP 436b Power Meter in the control room. The signal from the Faraday cup passes through an ac/dc tee (to monitor the dc current), through an isolator, and then through

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a similar amplifier chain and Heliax cable to an attenuator and a second power meter. The attenuators are chosen to give approximately the same gain (31 dB) from the vacuum tank to the power meters. The power meters have HP-IB busses connecting them to an HP 85 computer. A potentiometer in the control room is synchronized with a similar potentiometer in the terminal that controls the electron gun modulation frequency. Its output is available to the computer. The computer can either display on its scope, or on a print-out, the frequency, the power in the pickup and Faraday channels, and a computed value of the transfer impedance between the beam current and the pickup output.

Preliminary measurements were made on a model consisting of a one loop-pair in a fixture that was manufactured by the same techniques previously described and shown in Figure 1. A 0.05 inch wire was stretched through the fixture's center and supported on each end by coaxial connectors. The wire and the beam pipe walls constitute a 200 ohm transmission line. With an HP network analyzer, transfer parameter measurements were taken through the 200 ohm line, and from the wire through the loop-pair to a 50 ohm output. From these values the transfer impedance, Z_s, was calculated as a function of frequency. The combiners used in the 16 loop-pair array add power, so 4 times ($\sqrt{16}$) as large a value of Z_s for the array is expected.

Measurements were made with a relativistic electron beam (1.2 MV at 10 microamps) in a similar manner. The modulated beam was passed through the pickup array and steered into a Faraday cup terminated in 50 ohms. This signal was compared with the signal induced in the pickup array as the modulation frequency was varied. The transfer impedance was calculated from the ratio of these signals.

Steering the approximately 1 cm diameter beam through the pickup array was difficult because of residual magnetic fields. Scintillators at each end of the array determined the beam position at the ends, but the beam traveled in a curved path with a sagitta of approximately 1.5 cm. The Van de Graaff beam had a very small 1 Hz oscillation in beam position that proved to be useful in locating the beam. When the beam overlapped the edge of an individual loop-pair, a 1 Hz oscillation in the pickup signal was observed. The beam was steered to pass through the array's center by minimizing this signal. Vertical positioning was more difficult to determine, but the information was obtained by observing the signal reduction when the beam was occulted on the upstream end of the array, and by observing the "shine" on the second scintillator from beam hitting the downstream end of the array.

Results

With 10 microamps of dc beam, the signal from the Faraday cup was from 7 to 10 dB larger than the amplifier input noise level of the preamplifier. The electron gun modulation varies with frequency in this model, but it will be improved in the next model. The signal from the pickup was about 20 dB larger than its preamplifier noise level, and had a repeatable fine structure as frequency was varied. This fine structure causes a large variation in the calculated value of Z_s. This variation could be caused by reflection in the connectors, but is most likely caused by extra signal from TE modes in the beam pipe. These extraneous will add to or subtract from the value of Z_s. The correct value is probably the mean of the values of Z_s. (See Figure 3)

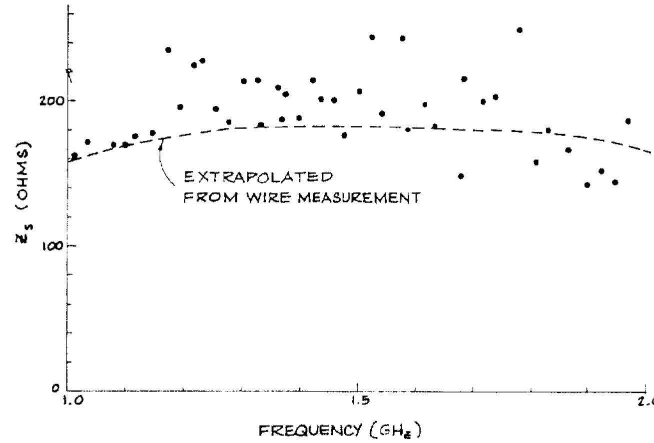

Figure 3. Measured Z_s vs Frequency

The value of Z_s, extrapolated from the wire measurements, falls below the mean value and leads one to think that the pickup array couples at least as well as predicted. There are some complications, however. The observed fine structure is typical of the behavior of our models when a single loop couples to the TE modes in the beam pipe cavity. Similarly, when the beam was steered vertically, the pickup signal became stronger in the up direction. This evidence, plus its fine structure, implies that the lower loops were not operative.

If half the loops were not working, the signal is too strong by a factor of the $\sqrt{2}$. When the prototype array was removed from the experimental tank, a probe inserted in the beam pipe showed that both the lower and the upper loops had equal response. Measurements were taken the weekend before sending the prototype to Argonne National Laboratory; unfortunately, the ambiguity was not solved in the available time.

A second prototype array with a slightly different combiner network is nearing completion, and we will study the response in more detail when it is ready. Meanwhile, the first prototype will be measured with a pulsed electron beam from the ANL electron linac.

Acknowledgments

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