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EXPERIENCE ON OVERCOMING BEAM RF INTERFERENCE TO DCCT*

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Summary

A 200 mA DCCT has been built for Aladdin, an 800 MeV storage ring at the University of Wisconsin, and is working very reliability now. But at the beginning of the single pulse operation the high harmonics of the 3 MHz beam revolution frequency was causing a big interference and made the reading unbelievable when the first harmonic cavity was turned on. This paper will describe the effort which has been made to overcome the interference.

Introduction

The DCCT measures DC current by the second harmonic method. This DCCT was developed using the SLAC circuit as a model. The operation principle is shown in Figure 1. The DCCT consists of two identical toroids which are wound of 0.001 inch thick supermalloy tape with very high permeability and a very small residual magnetic field. Each one of the two toroids has a coil which is driven by a 1.7 kHz square wave signal. A copper shield surrounds the two coils and leaves an open circle slit around the inner surface to cut off the eddy current. The sense coil and the feedback coil are wound around the package by the bifilar twisted wires in order to make them equal so that there will be no other parasitic signals due to the feedback signal's distortions. Since the two toroids are magnetized in opposite directions by the square wave signal, the magnetic fields induced in the two toroids are modulated with the same signal. The square wave signal has basic frequency and odd harmonics frequencies. The second harmonic frequency of the drive signal picked up by the sense coil is only produced by the asymmetry of the two toroids due to the bias of the beam current or the manufacturer. Since the two toroids are magnetized in opposite directions, if they are completely identical, the sense coil which is wound outside the drive coils will see no signal when there is no beam going through. But the two toroids cannot be identical, so that an additional coil is necessary to compensate this offset. This coil is called a calibration coil. When the toroids are driven into saturations, the signal picked up by the sense coil will be distorted, so that the second harmonic frequency of the drive signal will be produced. The amplitude of it is related on the extent of the saturation. It is very important that the two toroids are driven into deep saturation to ensure the range for measuring the beam current.

When the beam goes through the toroids, the beam current biases the two toroids, the changes of the difference between the two toroids will be related to the beam current change. An N channel FET is used as a switch for demodulator use to take out only the second harmonic signal.

A feedback coil is used to make a negative loop to balance the second harmonic signal change. The DC component of the current flowing through the loading resistor of the feedback coil represents the DC component off the beam current. The feedback coil inductance and its loading resistor together with the amplifier give of an RL integration. To get DC frequency response the time constant of the RL integrator should be long enough.

RF Interference

Before the present DCCT was installed into the ring the circuit on a breadboard had been temporarily used for a few months. There was no special electrical shielding used to prevent RF frequencies from interference only a magnetic shield was used to avoid magnetic stray field. The DCCT worked very well under this condition as long as the 15th harmonic RF cavity which had 50 MHz frequency was turned on. Once the 3.3 MHz first harmonic cavity was turned on, the DCCT showed unbelievable readings which were much higher that the other current monitors like photodiodes and static-electronic pick up electrode (Q-meters) indicated. Obviously when the beam was showing synchrotron oscillations as was observed form the syn-

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chrotron light monitor, DCCT readings were always jumping up and down. A bench test was set up in order to find out if there were resonant points with the DCCT circuits itself. The grid-dip radio frequency radiator affected the DCCT reading substantially at frequencies around 15 MHz to 25 MHz, when the DCCT could read up to 200 mA although there was no beam going through the toroids. The effect could happen when the grid-dip was put close to the coil leads or center part of the toroids, but it didn't happen when the grid dip meter was put close to the circuit board.

There was a copper sleeve inside the pipe of the ceramic gap which was connected to the beam pipe at one end and the other end was left free, preventing the synchrotron radiation from hitting the ceramic gap and preventing the RF frequency from escaping out of the ceramic gap. But for the low frequency the wavelength is too long for the sleeve to block it.

To solve this problem, before the present DCCT replaced the old one, a 1 mm Ti layer was coated to the inner surface of the ceramic gap. The gap is 2 inches long, with a 3 inch diameter. The resistance of the coating is 11.4 Ω. The wall current goes through two big copper braids which connect two flanges at both ends of the gap with extremely small resistance. All leads are shielded by the copper braids and go through the feedthrough capacitors to the circuits. All connectors are shielded with aluminum foil. The grid-dip does not affect it anymore. This solved the RF interference completely. Since then, DCCT reading has been reliable, and consistent with the results of the other method.

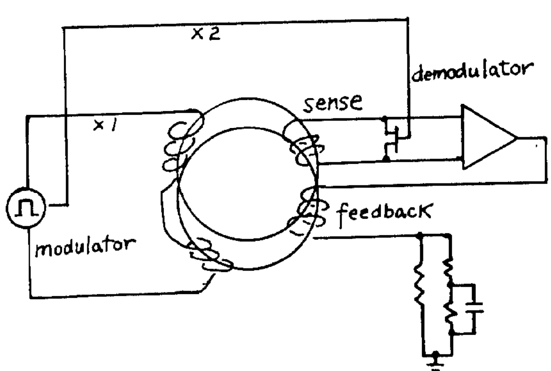

Fig. DCCT

Since the DCCT works with the magnetic field of the beam current, so the stray field can affect it also. When we put the DCCT close to the bending magnet, we had to make a calibration curve of the relation between the zero offset and the bending magnet field, so that when the ring is ramped from 100 MeV to 800 MeV, the offset can be determined from the curve.

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References

1. K. B. Unser, "Beam Current Transformer with DC to 200 MHz Range", IEEE Transactions on Nuclear Science, Vol. NS-16, pp. 934-938, June 1969.
2. K. B. Unser, "A Toroidal DC Beam Current Transformer with High Resolution", IEEE Transactions on Nuclear Science, Vol. NS-28, No. 3, pp. 2344-2346, June 1981.