EXPERIMENTAL RESULTS OF HIGH POWER DUAL FREQUENCY RESONANT MAGNET EXCITATION AT TRIUMF

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Summary

We present some results of dual frequency resonant magnet excitation at full power using the old NINA synchrotron dipoles. These tests will simulate a typical resonant cell as proposed for the accelerating rings of the TRIUMF KAON Factory[1]. These tests have two main purposes:

a) to verify circuit parameters and component ratings for the dual frequency resonant power supply system;
b) to directly measure electrical losses in a transverse magnet field, such as eddy current losses in magnet conductors, vacuum tubes and core losses in laminations.

This data will be required for the detailed design of the accelerator system components.

Introduction

Magnet excitation for the TRIUMF KAON Factory Booster and Driver rings take the form of a dc biased dual frequency current with a rise to fall time ratio of 3 to 1. To reduce disturbances on the ac grid a resonant form of excitation has been chosen where most of the system energy is stored in the resonant circuit with make up energy for ac losses being supplied by the grid. Repetition rates for the Booster and Driver are 50 and 10 Hz respectively. To study circuit parameters and losses, a test stand has been constructed as shown in Fig. 1. Four NINA magnets are used with three connected in series to form the dc bypass choke with the remaining magnet serving as the beam line element. Two banks of capacitors are used to create the dual frequency resonant circuit with the larger of the two banks ultimately being switched in and out to create the two desired frequency components.

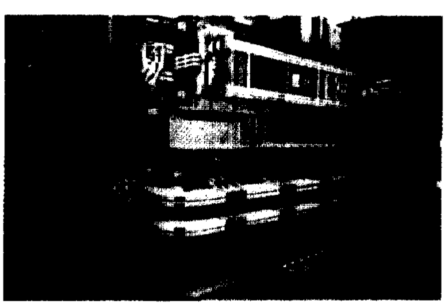

Fig. 1. Resonant Test Stand

Magnet Excitation

The Booster will run at repetition rate of 50 Hz with a ramp up at 33.33 Hz and ramp down at 100 Hz. Capacitor switching during each cycle will be achieved by means of a thyristor-GTO-diode switch. Initial work has been done at the two required frequencies with the test circuits shown in Figs. 2 and 7 for 33.33 Hz and 100 Hz respectively. Magnet excitation is provided by means of a 130 Kw dc power supply which has been modified to act as a power amplifier to provide a composite dc bias current and sinusoidal forcing function.

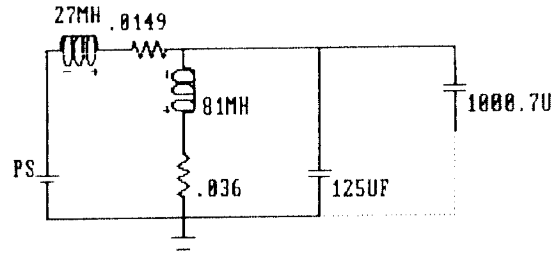

Fig. 2. 33.3 Hz Resonant Test Circuit

The resonant circuit is driven by the power supply shown as PS in series with the test magnet. The resultant parallel inductance of the beam line magnet and the dc bypass choke resonates with the two banks of capacitors both connected in parallel. This circuit configuration relies on the voltage swing of the power supply being amplified by the effective Q of the resonant circuit to generate the high voltages required to generate the desired di/dt through the test magnet. The resonant components were chosen to stay within the capabilities of the excitation supply.

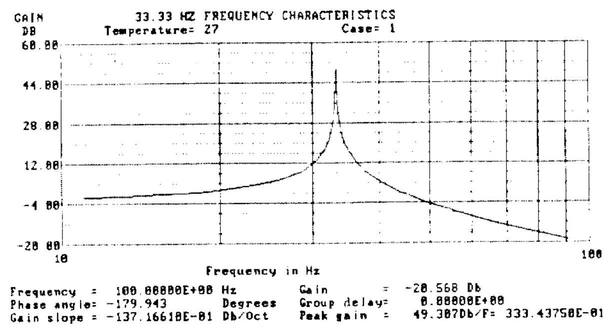

Fig. 3. Resonant Frequency Characteristics

Test Procedure

For the 33.33 Hz case with both capacitor banks connected a dc bias current was established and the ac component at low amplitude was tuned until a maximum response of the power supply output current was achieved. The ac amplitude was subsequently increased and adjustments of frequency and dc bias current were made to maintain this maximum current response. Data observed is presented in Table. 1.

Table 1 33.3 Hz Resonance Results

dc Bias current	p/p current	Frequency
240	40	34.79
240	60	33.77
240	80	33.56
240	120	33.26
240	160	32.46
240	240	32.98
240	320	32.71
300	400	32.40
300	500	32.82
350	550	32.82
350	600	32.77

In making adjustments to ac amplitude and dc bias current it was found that the excitation at some points had to be detuned from resonance to stay within the dynamic linear operating range of the power supply and then tuned again to resonance for test purposes.

In Subsequent tests the peak to peak current swing was increased to 750 A about a 400 A dc bias current. Further increase was limited by the output capability of the power supply. Observed current and magnetic field variation are shown in Figs. 4 and 5. An FFT analyser was used to look at the frequency components of the magnetic field as measured by a Hall probe device. As shown in Fig. 6 the wave form is very clean with a center frequency in this case of 32.88850 Hz and 30% signal level occurs at ±0.008 Hz about this frequency.

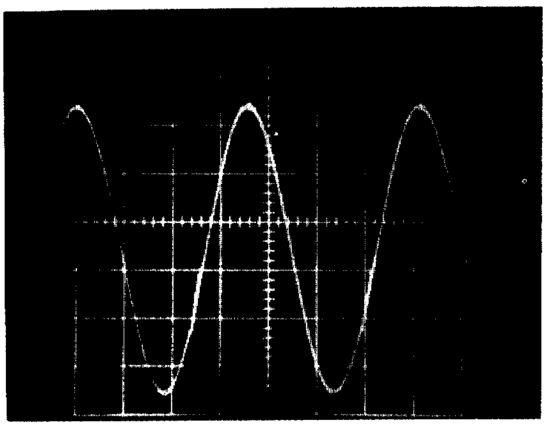

Fig. 4. Magnet Current

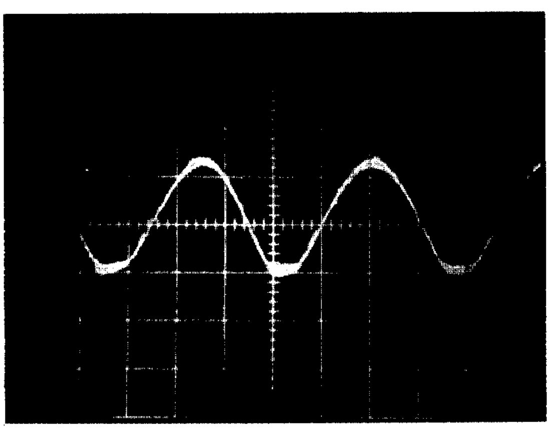

Fig. 5. Magnetic Field

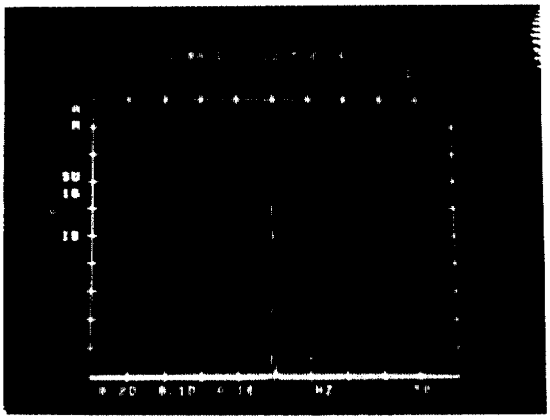

Fig. 6. RMS Spectrum of Magnetic field Signal

The experiment was repeated for the 100 Hz case and the resonance at maximum excitation was found to occur at 97.114 Hz with a peak to peak swing of 300 A about a bias current of 500 A. Frequency variation of 97.85 Hz at low excitation to 97.114 at maximum were observed. The test circuit and FFT waveform of the magnetic field variation are shown in Figs. 6 and 8.

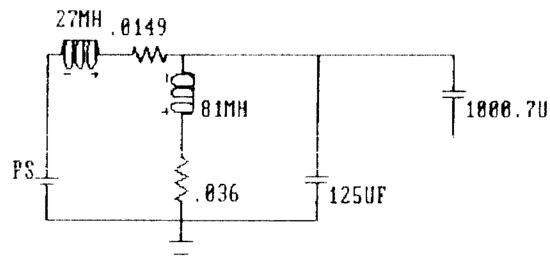

Fig. 7. 100 Hz Resonant Test Circuit

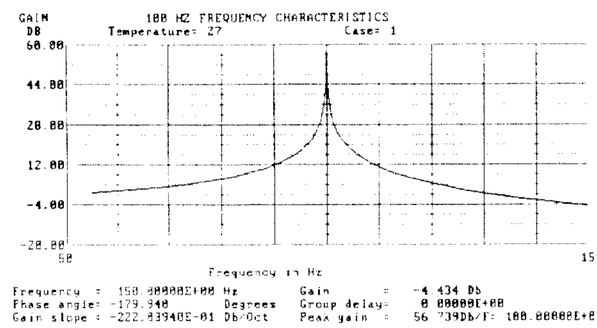

Fig. 8. Resonant Frequency Characteristics

Figure 9 shows a center frequency of 97.11400 Hz with the 30% signal at ±0.004 Hz about this frequency.

Figures 3 and 8 show the theoretical frequency response of the resonant networks and would show an apparent Q of these networks of 402 and 1207 for the 33.3 Hz and 100 Hz networks. Experimental results however showed that both values were severely degraded due to eddy current and other system losses present in the test circuit. This degradation is currently under investigation.

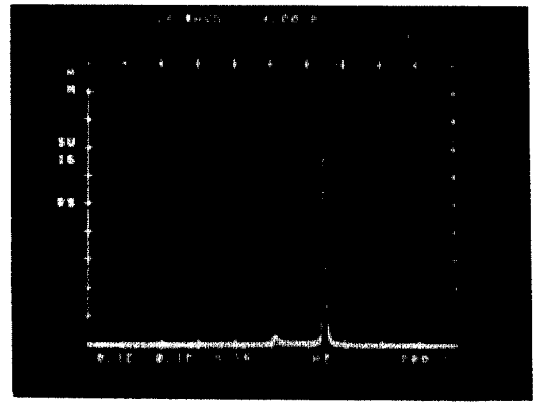

Fig. 9. RMS spectrum of Magnetic Field Signal

Conclusion

The resonant frequency of the system under test appears to depend both on magnitude of the dc bias current and the magnitude of the ac excitation. It was found that at a given operating point the system remained quite stable in terms of its characteristics. An operational system which has a narrow dynamic range should prove to be viable with resonant frequency adjustment by means of trimmer capacitors. For full ring series operation great care must be taken to assure that all the cells are matched in terms of their characteristics to achieve the desired system response in terms of synchronization and amplitude etc.

Alternately one could run the system on an independently driven individual cell bases, slightly detuned from natural resonance for synchronization, with independent amplitude control.

References

[1]KAON Factory Proposal TRIUMF, September 1985.