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BREAKDOWN AND RESONANCE BEHAVIOUR OF THE SRS WAVEGUIDE

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1. Introduction

During the early running of the SRS storage ring the energy was limited to 1.8 GeV because of unexpected electrical breakdown in the waveguide-cavity system. This occurred at half the rated power of the klystron, i.e. approximately 120 kW.

High power tests showed an unacceptably large amount of third harmonic generated by the klystron, which was found to be produced by a faulty component in the feeder system.

Low power investigations indicated that the waveguide-cavity system had a rich resonance spectrum, which could be tuned by changes to any of the movable system components. With the system as initially set, one particular mode could be readily tuned to the third harmonic frequency.

The faulty component was replaced, and the waveguide system rearranged. Detailed changes are reported elsewhere[1]. With these changes and the system adjusted to avoid any third harmonic modes, the r.f. system was immediately able to operate at full power. The SRS has since operated consistently at its design energy of 2 GeV with no r.f. trips from these effects.

The low power tests also revealed that the magic tees only provide good isolation at the 500 MHz operating frequency thus the waveguide system forms a feedback loop at higher order mode frequencies with the circulating beam and the cavities. This may explain some of the beam instabilities observed in the SRS.

2. Measurement Technique

Figure 1 shows the layout of the waveguide system before the investigations took place. Major waveguide components and the places where the waveguide system was broken are shown.

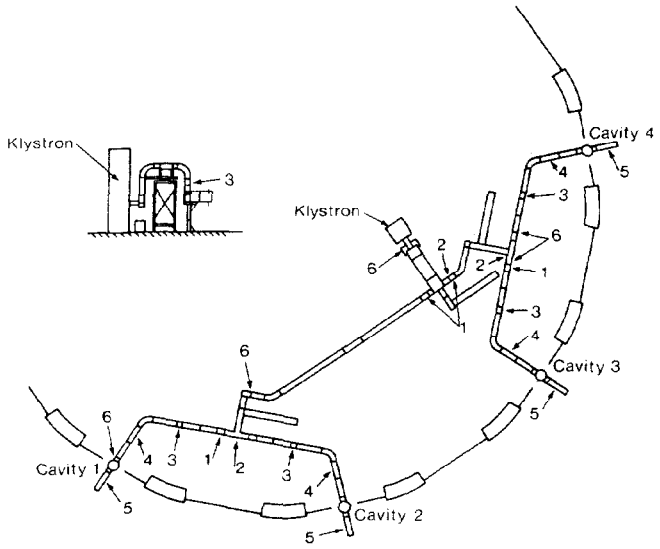

Figure 1. SRS waveguide layout, important components marked.
1. Fixed Phase Shifter
2. Magic Tee
3. Directional Coupler
4. Variable Phase Shifter
5. Cavity Matching Unit
6. Points where waveguide broken for low power measurement

A. High Power Tests

High power tests were confined to looking at the output of the various directional couplers, both forward and reverse, under varying beam conditions, with an Ailtech type 707 spectrum analyser, and using various light detection systems to look for sparks in the waveguide.

B. Low Power Tests

The waveguide was broken at various points and then terminated in a coax-waveguide transition. Figure 2 shows a typical set-up used to measure the particular sub-section reflection coefficient as a function of frequency. The HP 8660C was used as the frequency source and the HP 8410B network analyser in reflection test mode as the detector.

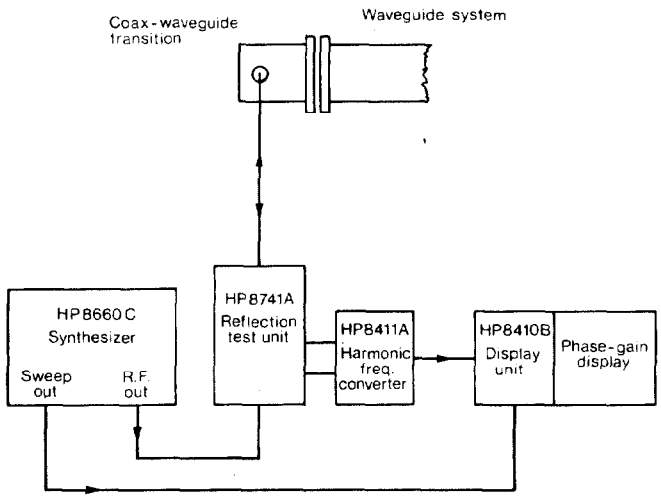

Figure 2. Reflection coefficient measurement layout.

3. Results

A. High Power Measurements

The third harmonic from the klystron was less than 30 db down on the fundamental, both with and without beam. Although the harmonic content of the klystron had not previously been measured, this was higher than had been expected[1].

During removal of the klystron coax-waveguide transition, to allow for low power measurements, signs of burning and arcing were found on the matching post. After replacement all harmonics were measured to be much lower, in particular the third harmonic content was reduced by ~ 20 dB taking it ~ 40 dB below the fundamental. Figure 3 shows the harmonic content of the klystron output a) with the damaged matching post and b) with a replacement matching post.

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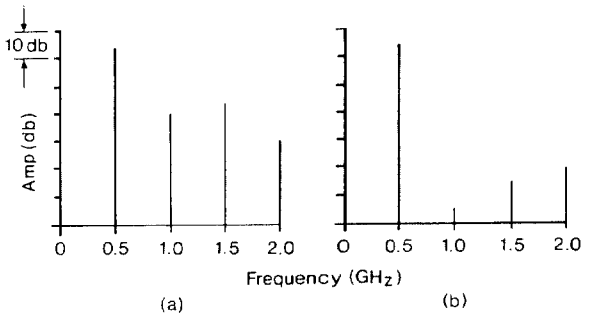


Figure 3. Comparison of klystron harmonic content a) with damaged matching post and b) with replaced post.

B. Low Power Measurement

i) System A. Figure 4 shows a schematic of the test set up. An enormous amount of structure in the subsection reflection coefficients was evident, and

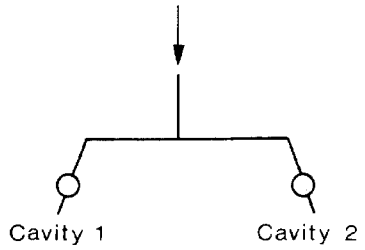


Figure 4. Schematic of test set up

when the cavities were shorted out, it was apparent that most of the structure was associated with the waveguide only. It was also apparent that the waveguide had a high Q resonance at exactly 3 times the fundamental frequency, and that this resonance could be damped by movment of either cavity matching unit or variable phase shifter. The photographs in Fig.5 show the effects.

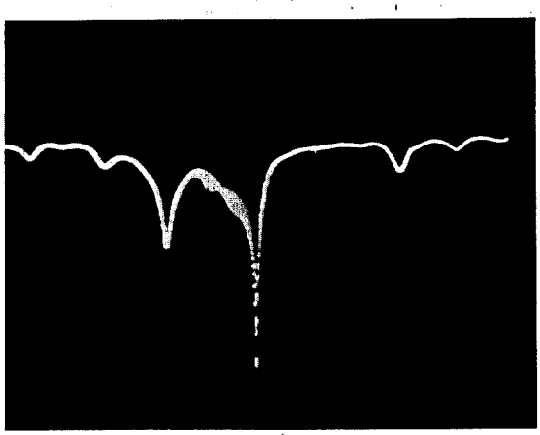
ii) System B. Figure 6 shows a schematic of the test set up. This system was used to study the effects of the magic tee. The photographs in Fig.7 show that the isolation effect of the magic tee is only good in a narrow frequency band around 500 MHz, above that frequency the scans are similar to those of system A.

iii) System C. Figure 8 shows a schematic of the test set up. The photographs in Fig.9 illustrate the effects of moving the variable phase shifter and the tuner on particular resonances associated with cavity 2 and its associated waveguide components.

4. Conclusion

Waveguide resonances have been found to occur at many frequencies and they can be readily shifted by the cavity tuners, cavity matching units and the high power variable phase shifters. Under particular conditions the waveguide can resonate at the third harmonic of the machine frequency, and with the initial settings it did.

The klystron output was particularly high in third harmonic, because of a faulty component. The above factors were the cause of the breakdown at the 120 kW



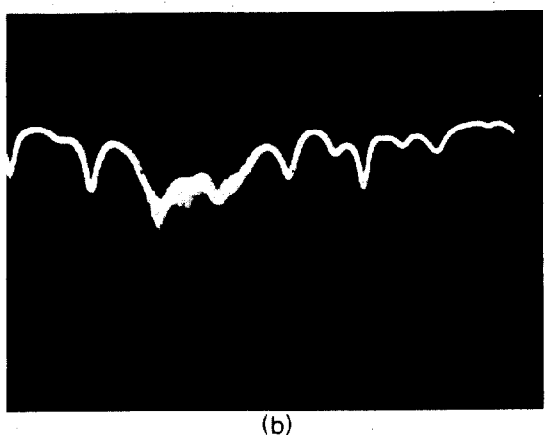


Figure 5. Reflection coefficient frequency sweep 5 MHz centre frequency 1498.2 MHz Amp 10 db/div.
a) initial setting of waveguide components
b) cavity matching unit moved a small arbitary amount

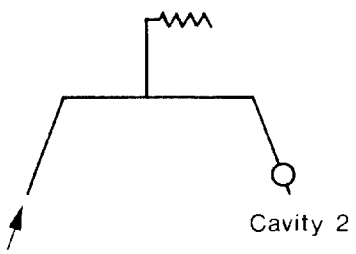


Figure 6. Schematic of test set up.

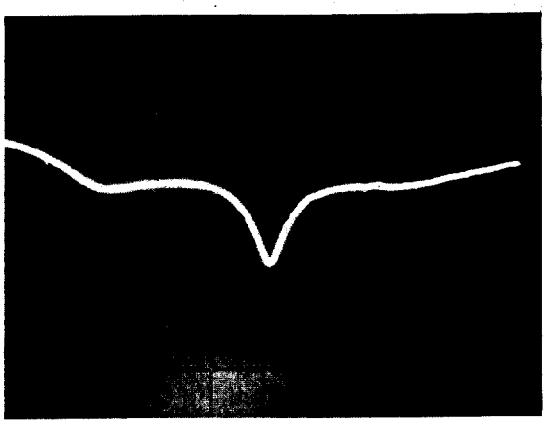


Figure 7. Reflection coefficient: frequency sweep 50 MHz, 500 MHz centre frequency, Amp 10 db/div.

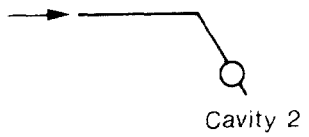
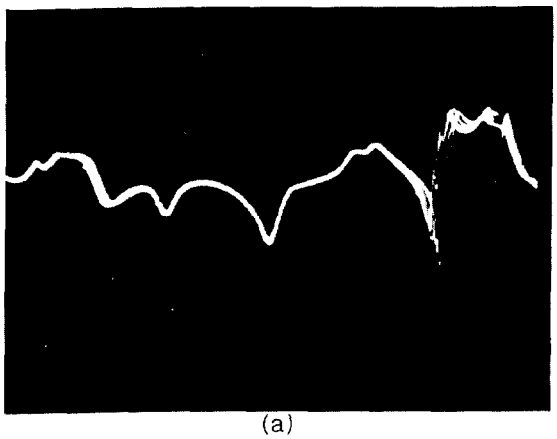
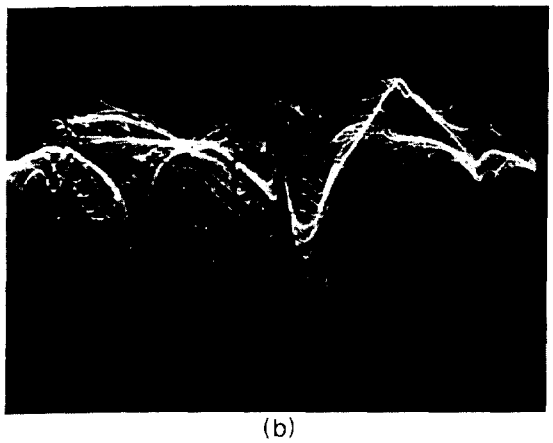


Figure 8. Schematic of test set up.



(a)



(b)

Figure 9a. Multiple exposure as tuner moves over normal operational range. Sweep 5 MHz centre frequency 1496 MHz Amp 10 db/div.

Figure 9b. Multiple exposure as phase shifter moved over full range. Sweep 15 MHz, centre frequency 1261 MHz Amp 10 db/div.

level. However, breakdown does still occur, but at a higher output level, if the waveguide components are mis-set.

The magic tees have no isolation properties at any other frequency than 500 MHz, and since the beam can induce other frequencies into the waveguide, the waveguide acts as a direct coupler between the cavities. This may be the cause of some of the beam instabilities observed in the SRS.

References

1. D.M. Dykes and B. Taylor. Development of a High Power R.F. System for the Daresbury SRS. Paper presented at this conference.