DESIGN OF A STRIPLINE KICKER FOR TUNE MEASUREMENT IN SESAME STORAGE RING

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Abstract

In this paper the SESAME[*] storage ring tune measurement system is described. Travelling wave electrodes are commonly used in synchrotron light sources as a tool for both excitation and beam sensing for tune measurement. Normal longitudinally symmetric stripline has a positive sine wave response in the frequency domain. An exponentially tapered stripline has a constant coupling impedance versus frequency and better frequency response, but complicated in manufacturing. In this paper the design of stripline kicker for the purpose of tune measurement in the SESAME storage ring is reported.

INTRODUCTION

In SESAME the electrons are injected from a 20 MeV microtron into a 800 MeV booster synchrotron, with a repetition rate of 1 Hz. The 800 MeV beam is transported through the transfer line to the main storage ring and after accumulation, accelerated to 2.5 GeV[1,2]. During the normal operation , injection and ramping period in the storage ring, the betatron and synchrotron tunes in the storage ring will be measured frequently. The tune as well as time structure measurements could be done with the kicker-pickup striplines combination.

HARDWARE DESCRIPTION

Betatron and synchrotron motion in circular machines is usually incoherent, except in presence of an instability, therefore their values can not be easily measured. In order to make the measurement of the tunes, it is necessary to make the motion coherent by exciting the beam at the proper frequency. At SESAME storage ring the betatron tune measurement is performed by exciting the beam externally in the horizontal and vertical planes simultaneously through a stripline as a shaker and detect the excitation by another stripline as a detector. The main components for tune measurement in the storage ring consist of stripline shaker, stripline detector, low frequency voltage amplifier, network analyzer and the associated electronics for the detector. Figure.1 shows a simplified block diagram of the storage ring tune measurement. The overall tune monitoring system provides the capability of monitoring the storage ring tunes, ν_x and ν_y during ramping and stored beam operation.

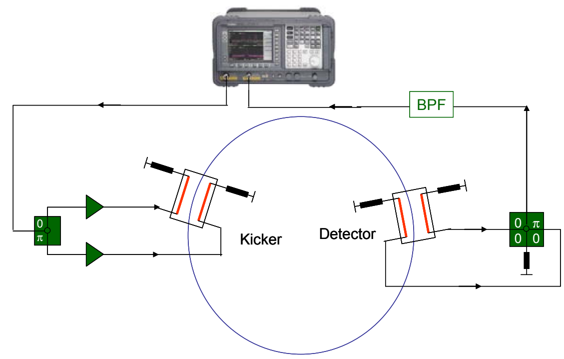

Figure 1: Simplified block diagram for tune measurement.

The horizontal/vertical tunes and other related parameters are given in Table1.

Table 1. Various tune related parameters

Injection Energy (GeV)	0.8
Stored Beam Energy (GeV)	2.5
RF frequency (MHz)	499.654
Revolution Frequency (MHz)	2.25
ν_x	7.23
ν_y	6.19
Fractional Tunes (kHz)	
$\Delta\nu_x$	517
$\Delta\nu_y$	427

STRIPLINE DESIGN

To simplify the design and minimize the manufacturing and development costs, two striplines with the same mechanical structure and dimensions will be used. One stripline for the excitation of the beam as the shaker and the other as the pickup to detect the excitation resonances. The stripline has four strips, one pair in each plane. For horizontal betatron tune (in order to measure directly the displacement relatively to the centre), the left pair of strips will be 180^0 out of phase with the right pair, and for y-tune the top and bottom pair will be out of phase. The strip has N-type vacuum feed through at the end and has a length of 150 mm. By a suitable choice of the ratio between the strip width and distance from the wall, the characteristic impedance is made 50 Ω [3]. The possibility of a design by means of using exponentially tapered strips in order to have smooth frequency domain response also has been investigated, but the difficulties come into the mechanical dimensions which makes extra cost. However the initial design was based on a pipe radius of 35mm, but due to the problems of radiation

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[*] Synchrotron-light for Experimental Science and Applications in the Middle East is an independent intergovernmental organization developed under the auspices of UNESCO It involves at present the following member states: Bahrain, Cyprus, Egypt, Israel, Jordan, Pakistan, Palestinian Authority and Turkey. Iran is in the process of finalizing its formal membership.

and wall heating absorption, the final design is based on the pipe radius of 52 mm. The width of strip is 23.75 mm and the covering angle for each strip is 29.6^0. The thickness and the distance from the wall are 2 mm and 5 mm respectively (see Fig. 2).

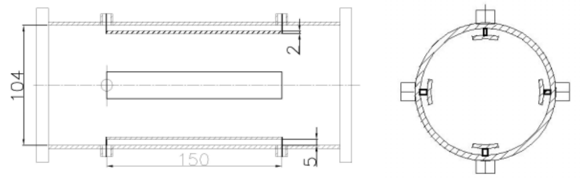

Figure 2: Schematic of stripline side view and cross section.

FREQUENCY RESPONSE AND SPECIFICATION [4,5]

Electromagnetic analysis in 2D and 3D has been performed by the SUPERFISH and ANSYS codes. Figure.3 shows the cross section , electric and magnetic field lines of the TEM deflecting mode. The polarity of the strips pair is opposite by means of 180º phase difference, and the particle beam travels in the opposite direction with respect to the TEM wave.

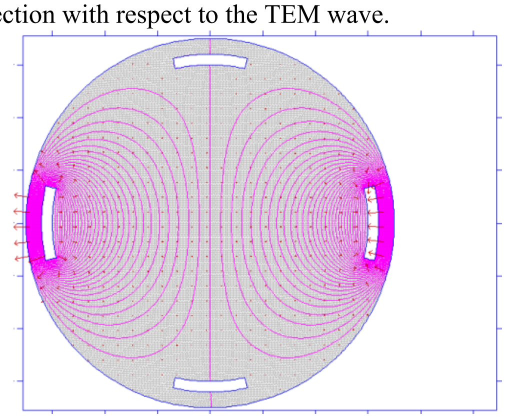

Figure 3: Full cross section of the stripline and EM field lines.

The geometry of stripline in 2D has been selected in order to give a 50 Ω rf impedance for the whole structure. The stripline frequency response up to 3 GHz has been analyzed and the transfer impedance is shown in Fig.4.

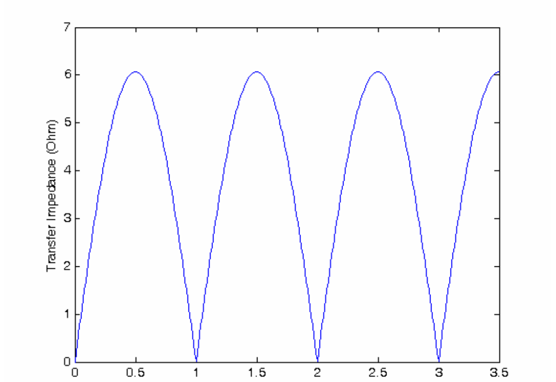

Figure 4: Stripline frequency response

The length of the strip is such that the transfer impedance is maximum at odd harmonics of storage ring rf frequency.

TRANSVERSE IMPEDANCE

However the effects of wake fields for the stripline is ignorable, since there is no HOM trapped in the structure, but in order to have a clear idea about the magnitude of the first mode of transverse dipole wake field impedance, the imaginary and real part of transverse wake fields are shown in Fig.5-6. The analysis is based on the analytical and numerical models given in [6].

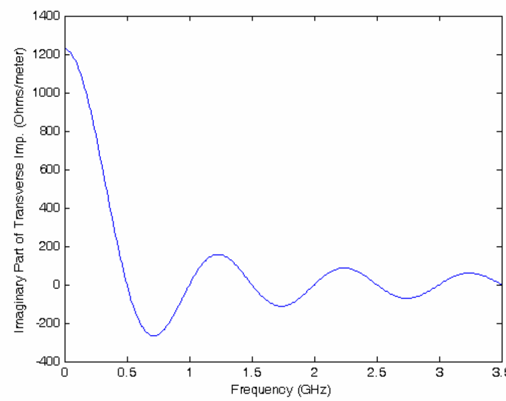

Figure 5: Imaginary part of transverse impedance vs. frequency.

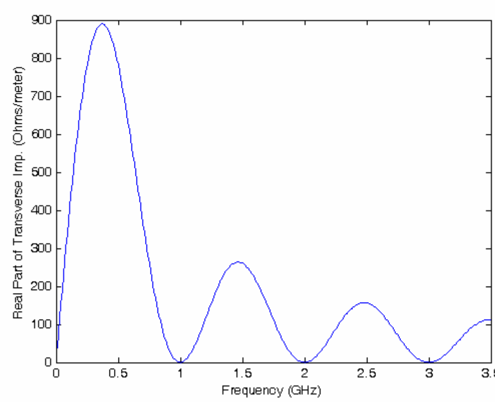

Figure 6: Real part of transverse impedance vs. frequency.

ELECTRICAL MODEL

The equivalent circuit for the terminated transmission line detector is shown in Fig.7. The problem is simplified by assuming that the velocity of the wall current is equal to the velocity of the beam, which is approximately true in the absence of dielectrics and/or magnetic materials for relativistic beams [7]. R_L, R_R, are the loads at two sides of stripline, Z_0 is the stripline characteristic impedance and i_w is the induced current. In our case $R_L=Z_0=50\ \Omega$ and $R_R=0$.

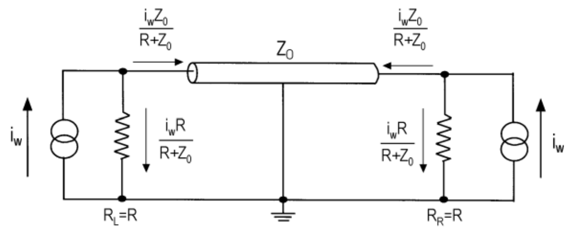

Figure. 7: Equivalent circuit for the stripline as a transmission line.

The time domain response of the stripline to a short bunch (shorter than the stripline length l) is a pulse doublet. The second pulse has the opposite polarity of the first pulse with a time delay of 2l/c. In a time period of λ/4c , the total voltage appearing across R_L is calculated by:

$$V_{RL} = \frac{i_w}{2}(1 - e^{-j2wt})R \qquad (1)$$

It is essential that the tune measurement process should not disturb the photon beam experiments. This is accomplished by keeping transverse beam motion below a few microns. As a result a power of 10 dBm will be sufficient in order to excite a few micron the stored beam at full energy.

CONCLUSION

Different types of striplines have been studied, considering the manufacturing and development point of views. Exponentially tapered and slot-coupled pick up due to the difficulties in manufacturing were not selected for the purpose of tune measurement in SESAME storage ring. As a result the normal symmetric pick up has been selected to be the proposed stripline for the storage ring and the design is based on the latter type.

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