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# Tune Measurement and Correction Systems

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This document contains information about discussions and experiments done about tune measurement and correction systems. Its intention is to help in the comprehension about these two systems, using as an example the systems from UVX, the current operating particle accelerator at the Brazilian Synchrotron Light Laboratory (LNLS).



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# 1 Systems

## 1.1 Signal analyzer system

This is a **measurement** system.

The measurement is done by a signal analyser operating in spectrum mode. Its OUT pin is connected to an amplifier, which is connected to one of the eight connectors available on a stripline. The signal generated by the signal analyzer is a sinusoid with fixed amplitude and variable frequency (generally, this variation follows a sawtooth function).

- An amplifier is needed because the signal from the signal analyzer has not enough power to excite the beam.
- The opposite connector of the stripline is connected with an  $50\Omega$  load so the excess power could dissipate (the beam absorb only a few percent of the excitation power).
- To determinate the frequency range of the excitation signal, an initial and a final frequencies should be define. For tune measurement application, those two frequencies should be chosen in a way that the range contains the horizontal and vertical betatron frequencies.
- The amplifier gain could be adjusted remotely, but this is not considered in the measurement loop yet.

The signal received by the stripline excites the beam over a predefined frequency range. But is known that the beam oscillation amplitudes grow at the betatron frequencies, so its frequency response should be something like Figure 1.

The tunes can be obtained by the distance between the betatron frequencies ( $f_{\nu_x}$  e  $f_{\nu_y}$ ) and their respective revolution harmonic. Dividing that distance by the revolution frequency, you can obtain the tune fractional part.

The beam oscillations are measured by a beam position monitor (BPM), stripline type. One of its connections is connected to the OUT pin of the signal analyzer.

- On both excitation and measurement processes, only one antenna is used. This configuration is sufficient because the antennas inside the striplines are positioned across de major axis (in other words, they're positioned like an X over tha vacuum chamber) in a way that its signal contains both plane information.
- The fact mentioned above is only possible because the bean trajectory oscillations (the ones caused by the betatron and dispersion functions) occurs

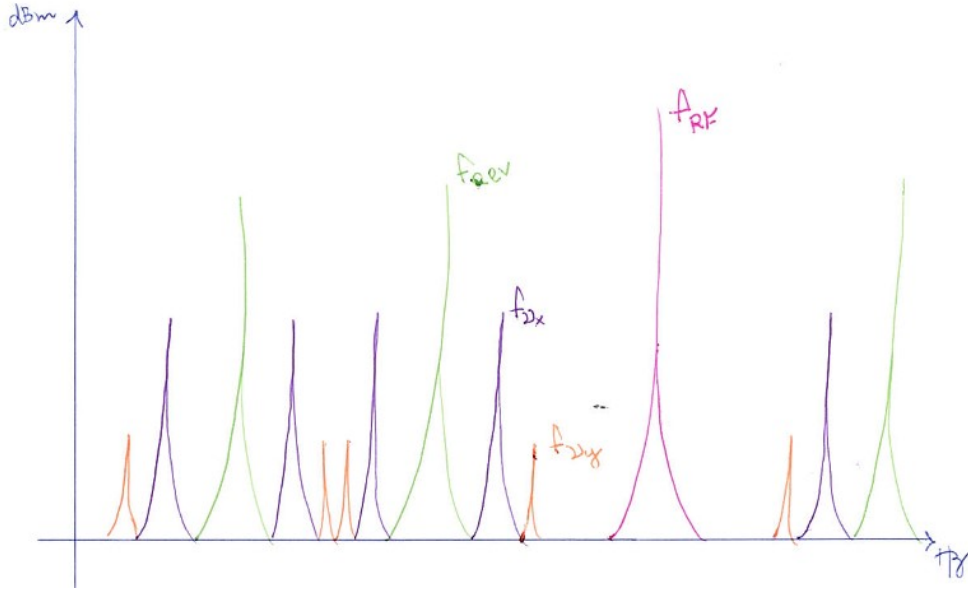


Figure 1: Rough sketch of the beam oscillation frequency response.

in a frequency much smaller than the excitation range of frequencies. Regarding that the excitation signal comes from the signal analyzer, this one knows exactly in which frequency it should analyze the signal, so it filters the measurement only over the predefined frequency range. In other cases, would be necessary collect the measurement from two opposite antennas and subtract their signals to obtain information only from the excitation oscillations.

#### 1.1.1 Notes

It's important to emphasize one characteristic of this system. The excitation signal excites **all bunches**, no exception. But the power absorbed by them is so little that this don't affect the beam dynamics in a significant proportion. Still, it's sufficient to compute the tune measurement due to the great sensibility of the signal analyzer.

#### 1.1.2 Possible issues and solutions

##### Plane identification

The signal analyzer system from UVX works with both planes at the same time, so both x-axis and y-axis frequency responses are displayed on the screen together. In that configuration, sometimes could be difficult for the tune measurement algorithm to identify which peak belongs to which axis.

A possible solution to that would be working with each plane separately, exciting and measuring one plane at a time with a switch to do that shift. The benefits would be that x-axis and y-axis measurements would be more isolated from each other, but the shifting process would make impossible to measure both planes simultaneously like the actual system does. Also, the measurement process would become slower.

Another possibility that could have all the benefits of the two listed above would be use two signal analyzers simultaneously, one for each plane. But this solution implies in buy another signal analyzer and develop a system to group the excitation signal from each device in just one that go to the stripline and then do the opposite with the measurement signal.

### **Peak tracking when operating with low-current**

When the machine is operating with low-current, the beam frequency response generated by the excitation process could be so small that, if the tune measurement algorithm is based on a peak tracking logic, it could not be able to distinguish the right peak from noise.

A way to increase the frequency response amplitude is to increase the amplifier gain, transferring more energy to the beam during the excitation process. So, a good solution to this problem would be adding the amplifier gain in a control loop that identifies if the machine is operating with low-current. If it is, the amplifier gain is increased to make the tune measurement possible.

### **Peak tracking when operating at high chromaticity**

At high chromaticity, sidebands of similar amplitude could appear near the betatron frequencies, causing the same peak tracking problem mentioned earlier. While studying the oscillations eigenmodes, an idea to solve this problem occurred.

At each eigenmode, the frequency response amplitudes could be different. That said, could exist an eigenmode where the amplitudes at the betatron frequencies are higher, maybe higher than the sidebands caused by the high chromaticity. If this happens, the peak tracking logic would be able to measure the tune again. To do this, it should be enough measuring the tunes at these higher amplitude harmonics.

## 1.2 UVX devices

Here are described some characteristics of the devices from UVX used in any of the systems presented in this document.

### 1.2.1 Signal analyzer system

- **Excitation device**

Device: Stripline

Name: AEX08

Available connectors: 8

Length: 15 cm

- **Measurement device**

Device: BPM Stripline type

Name: AMP11B

Available connectors: 4 (4 others internally short-circuited)

Length: 6 cm



## References

- 1 SANDS, M. **The physics of electron storage rings: an introduction.**  
[S.l.]: Stanford Linear Accelerator Center Stanford, CA 94305, 1970.