Technical Note

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# RF SYSTEM FOR SESAME

Arash Kaftoosian, Habib Azizi


## Abstract

This paper presents an overview of the whole RF distribution system, the proposed RF plant for the storage ring using 80 kW IOTs and the methods of upgrading high power RF system by combining IOTs. In future the details of each part will be presented in separated reports.


## 1 - Introduction

The SESAME accelerator complex consists of a microtron, a booster synchrotron and a main storage ring. Each accelerator has its own RF system: all the RF systems are driven by a master oscillator.
It was initially decided for SESAME to adopt an RF system similar to ANKA, based on ELETTRA type cavities, but it has been decided to use RF power plants based on 80 kW CW IOT transmitters, planning to increase the power up to 150 kW for each plant in a second phase.
The storage ring RF system in its initial phase will be composed of four 80 kW plants. The system is of modular construction, and each plant is connected to a single 500 MHz ELETTRA type cavity.
The main RF parameters of SESAME are summarized in Tab.1 [1].

Table1: SESAME RF design parameters.

| | |
|---|---|
| Frequency (MHz) | 499.954 |
| Harmonic number | 222 |
| Maximum Peak voltage (MV) | 2.4 |
| Maximum current (mA) | 400 |
| Number of cavities | 4 |

## 2 - Overall RF System

A simplified block diagram of the proposed SESAME RF system and RF distribution is shown in Fig.1.

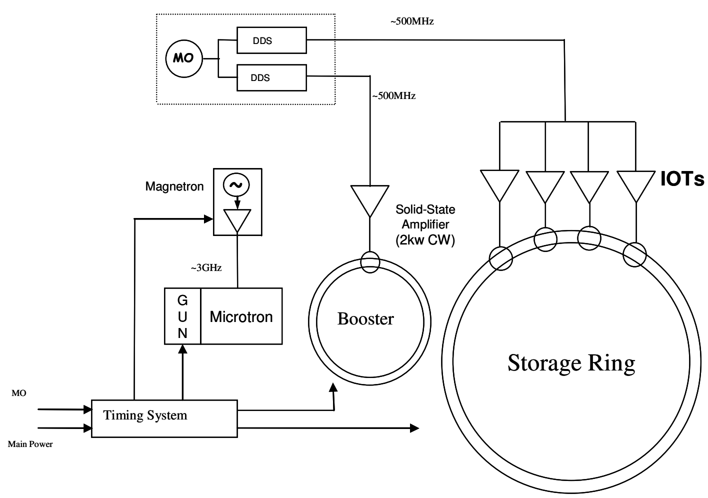



Figure 1: Simplified block diagram of the proposed SESAME RF system.

A common precise master oscillator (MO) must be used for the storage ring and the booster. This RF generator can be implemented by a very low noise, stable and temperature stabilized crystal oscillator mixed with the output of two DDSs to generate the 500MHz RF signals. The advantage of using two DDSs and a common MO is that the booster oscillator may be tuned independently or phase-locked to the main ring oscillator.
A 50 ns coasting beam current, controlled by two pulses coming from the timing system, is produced by the electron gun and will be bunched at 3GHz by the Microtron RF. This electron bunches train is extracted from the Microtron and injected into the Booster.
The Booster RF system consists of a single 500MHz accelerating cavity, an amplifier and electronic circuits. It is intended to use existing equipments where possible. Therefore, a DORIS type cavity including feedthroughs for the driving loop and plunger mechanism will be used. [2]
The radiation loss at 800 MeV is about 14 KeV/turn and with an accelerated current of ~5 mA the power delivered to the beam will be ~70 W. The peak cavity voltage will be 50 kV and with a shunt impedance of 3 M$\Omega$ the dissipation power in the cavity will be 415W. So the total RF power will be 485 W CW at 500 MHz.
In order to have a safe margin we can select a 2kW CW RF amplifier (as it was in BESSY I) for feeding the cavity via a coaxial cable. In this case, using a solid-state amplifier instead of a tube will have many advantages like low voltage power supplies, more reliability, more MTBF, etc.

## 3 - Main Ring RF System

The RF system which is proposed for the SESAME initial phase is based on the use of conventional, well-experienced equipments. It consists of four 500MHz plants, each one comprising a normal conducting single-cell cavity of the ELETTRA type, powered with an 80 kW CW IOT amplifier via a WR1800 waveguide line.
Four single-cell cavities of ELETTRA type, with a shunt impedance of 3.4M$\Omega$, will provide the required RF voltage and power. With beam energy of 2.5 GeV, a loss/turn of 589.7 KeV (without insertion devices) and using 4 cavities, some possible RF operating scenarios are listed in Tab. 2 for 1 and 2 IOT/cavity.

Table 2: Voltage and power for the RF system of SESAME.

| $P_{total}$ (Per cavity) | $V_{RF}$ [kV] (For 4 cavities) | $P_{cavity}$ [kW] (Each cavity) | $P_{beam}$ [kW] ($P_{tot} - P_{cav}$) | $I_{beam}^{Max}$ [mA] |
|---|---|---|---|---|
| 80 kW (Phase I) | 2400 | 53 | 27 | 183 |
| | 2100 | 40 | 40 | 275 |
| | 1800 | 30 | 50 | 340 |
| 150 kW (Phase II) | 2400 | 53 | 97 | 658 |

The parameter values in Tab. 2 show that, using four cavities, the RF system has the potential for achieving the SESAME requirement with the cavity input powers ($P_{total}$) equal to 80 kW, but either the RF voltage or beam current should be reduced. In case of increasing RF power as it has been foreseen in Phase II, the machine can work at full beam current and maximum RF voltage simultaneously. In this last case, there are enough margins to compensate the additional losses due to the insertion devices also at full current.
The four cavities will be accommodated in one 4 meter long straight section of the storage ring.
The RF power delivered by the IOT is fed into the cavity input coupler via a WR1800 waveguide line including monitoring directional couplers as well as a circulator to isolate the klystron from the

variable (beam loaded) cavity impedance. All these waveguide components are commercially available.
The input coupler must be capable to feed into the cavity a CW RF power of at least 160 kW (forward) and also to handle the full reflection. It will be similar to those operating in ELETTRA which are of the coaxial type, terminated by a coupling loop. This coupler has successfully been tested in ELETTRA up to 330 kW and therefore should be capable to fulfill the SESAME requirement in the initial phase and in phase II.

## 4 - Low Level RF System

Each one of the four RF plants of the SESAME RF system has to be equipped with four low level loops. The temperature loop for stabilizing the reference temperature of the cavity, a mechanical tuning loop and an amplitude loop for beam loading compensation, while a phase loop must be used to maintain the phase stable. All of these loops interact with each other and will be coupled trough the beam.
Basically, the operation of the RF plants is strongly influenced by the loading due to the circulating beam current. At high current the system stability may be affected. Moreover, during the various phases of machine operation (injection, ramping, beam storage), which require different power levels from the amplifiers, amplitude and phase of the cavity fields must be kept stable for a proper operation of the system. To compensate these effects, three feedback loops have to be installed: a tuning loop, an amplitude loop and a phase loop. Besides these loops, a temperature feedback will stabilize the reference temperature of the cavity.
A simplified block diagram which is proposed for SESAME is shown in Fig. 2.

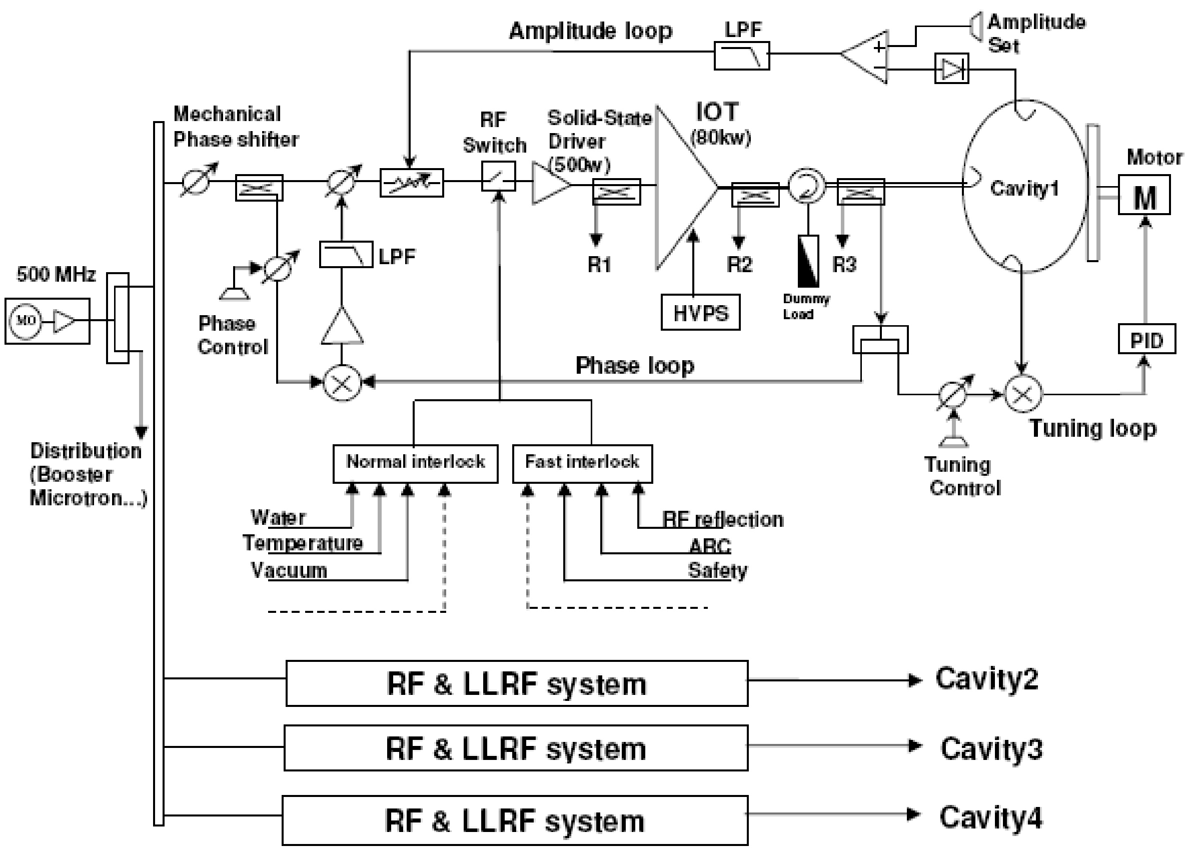
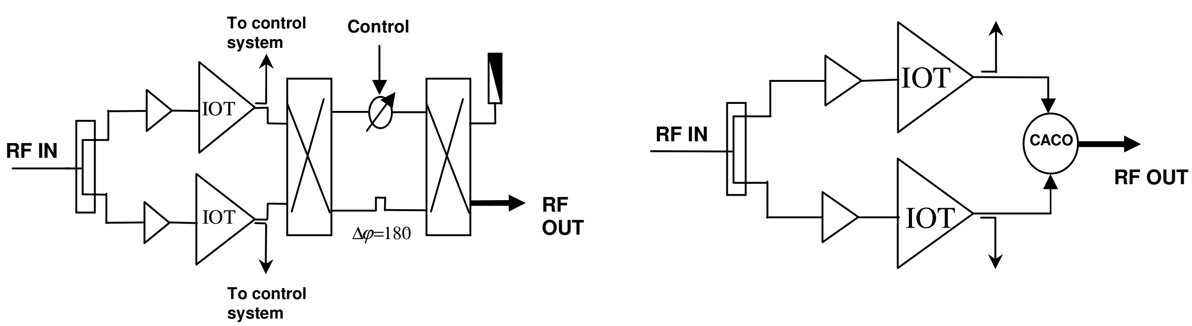



Figure 2: Simplified block diagram of SESAME low level RF system.

SESAME low level electronic system is based on the system operating in ELETTRA with minor modifications for the SESAME purpose.
The frequency regulation loop must have a tuning range of about ± 200 kHz which corresponds to a reasonable change in cavity length. From the experience of similar system in SLS, this allows to handle cavity temperature variations of about ± 20 °C with a sufficient margin for the compensation of the largest beam loading effect (around 25 KHz as reported from similar systems).The maximum tuning speed must be fast enough for injecting the full beam in proper time and the sensitivity of the loop has to be adjustable in order to make a smooth tuning.
The 3dB bandwidth of amplitude loop should be adjustable up to 5 kHz to regulate the cavity accelerating voltage with stability better than 1 % by controlling the drive power.
The option for modulating the tube anode voltage (instead of the drive power) can be used as an alternative scheme of amplitude regulation.
The phase loop should compensate for the phase changes in the amplification chain with variable power. It also has to have a 3 dB bandwidth adjustable up to 5 kHz and must ensure a phase stability of ± 0.5 °.
The bandwidth of both phase and amplitude loops must be optimized to provide enough damping while remaining insensitive to the synchrotron frequency.
In the driving chain the signal from the 500 MHz master oscillator, after being split, phase and amplitude regulated, is amplified with a 500 W solid state amplifier to drive IOT.
A fast RF switch at the input of the chain should remove within a few ms the driving RF signal under certain conditions such as RF reflections, Arcs, safety, or any problem in water, vacuum, temperature and so on.

## 5 - Further Upgrading

The RF system described before should be capable to achieve the SESAME nominal requirements.
The aims of upgrading RF system are to increase the available power for the beam, also in view of future installation of insertion devices and increase the stored beam current and also getting higher beam lifetime.
To achieve higher RF power in the cavities, the best solution is to combine IOTs. By combining two 80 kW IOTs in each plant, we will have 150 kW RF power as input of each cavity.
Two conventional solutions for combining are shown in Fig. 3.




(a) Switchless combiner method (b) Cavity combiner method

Figure 3: Two methods for IOT combining.

Using the switchless combiner method has many advantages such as: just 3 dB power loss when one amplifier is out of service instead of 6 dB in case of normal hybrid combiner, ability of working in

four modes of operation that it allows hot adjustment of the system, and maintenance of one amplifier can be done while the other is in service. But the disadvantage of this method is to increase cost and complexity [3].
In case of using cavity combiner, the system will be simple and less expensive, but we can not operate the system in single IOT mode. It means if one amplifier in an RF plant is out of service, this plant and its cavity will be down [4].

**References**

[1] G. Vignola, "SESAME Lattice" SESAME Tech. Note **O-1**, Dec. 2004
[2] Scanditronix, BESSY 1 booster documents, 1978-09-21.
[3] A. Fabris, "status of the ELETTRA RF system upgrade project", 6th ESLS RF meeting, 2001
[4] B. Baricevic, "Design of a 150 kW Cavity Combiner (CaCo) for RF power sources of the ALBA Synchrotron", 9th ESLS RF meeting, 2005