RF DISTRIBUTION SYSTEM FOR THE DIAMOND MASTER OSCILLATOR

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Abstract

A modular RF distribution system has been designed and built at Diamond Light Source to distribute the master oscillator (MO) signal. The system will deliver a low noise, phase stable 500 MHz signal to multiple points of use around the synchrotron facility. Providing phase stability and preserving noise performance over the distances required have been the main design challenges. A modular approach provides future flexibility and this paper describes each component, outlines design choices, components used, construction details and test results.

COMPONENT PARTS

A simplified block diagram of the master oscillator distribution system is shown in Fig. 1 below.

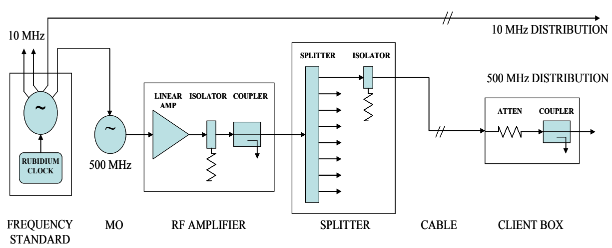

Figure 1: RF Distribution Block Diagram.

Master oscillator

The master oscillator was chosen for its low phase noise close to the synchrotron oscillation frequency (see Fig. 3) and its ability to change phase in a smooth, phase continuous fashion for small frequency changes.

The MO takes its reference from a low phase noise 10 MHz output from the DLS rubidium clock (Stanford Research Systems), which is also distributed around the synchrotron. Both the MO and the time standard are located in the Linac area, close to the Diamond timing system components. Fig. 2 shows the MO, distribution amplifier and RF Splitter mounted in the RF Distribution rack.

Figure 2: RF Distribution Rack

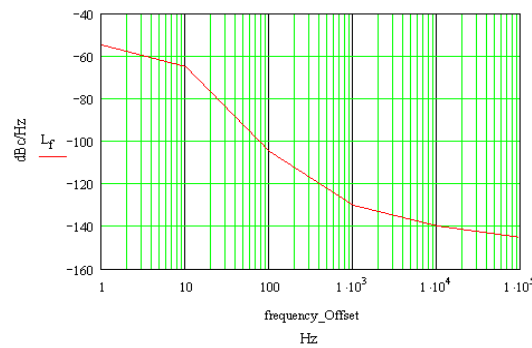

Figure 3: MO (IRF2040) Phase Noise at 500 MHz

Distribution Amplifier

In order to overcome the losses incurred by splitting the signal and sending it over a coaxial cable network, the MO RF signal needs to be boosted to a level of around +33 dBm (or 2 Watt). This is done with a linear amplifier (Fig. 4), built with off-the-shelf components: ASC311 450-860 MHz linear amplifier, low-noise 12V switching PSU, circulator for output protection and a coupler for output level monitoring. Remote monitoring of PSU voltage, amplifier temperature and RF output level is planned as a future upgrade, using an Agilent 34970A data acquisition unit.

Figure 4: Distribution RF Amplifier

Distribution Splitter

In order to deliver the MO RF signal to multiple points around the synchrotron facility, the signal is split 8 ways by the Distribution Splitter (see Fig. 5). This provides signals for:

- RF Hall
- Event generator (produces Diamond timing signals)
- Linac area
- Booster area
- Optics Hutch (for synchrotron light detector)
- Diagnostics (e.g. for Beam Position Monitors)
- 2 spare outputs for future use

Outputs are protected by magnetic isolators, which also afford a high degree of isolation between channels.

Figure 5: Front, Rear and Plan view of Splitter

RF Cabling

With the master oscillator placed in the Linac area, the required lengths of coaxial cable required to route the MO signal are shown in Table 1 below. The phase stabilised version of Andrew 5/8" Heliax (see Table 2) was chosen as a compromise between low loss and stiffness for laying over long distances (up to 275m unbroken length). Andrew ¼" Heliax (LDF1) is used for the 10 MHz distribution. The cables are run in open conduit within the main experimental hall area of the synchrotron. Keeping the cable within a temperature controlled area, rather than taking the shortest route, was considered the best option.

With different lengths of cable between Linac, Booster and Storage Ring RF, the problem of differential phase shift occurs with physical cable changes (principally with temperature) and changes in MO frequency. For efficient injection into the storage ring, it is required to keep the phase shift between booster and synchrotron below 10 degrees and preferably lower. Amplitude variation is less likely to be an issue, as it will be small, and most systems are level tolerant or have some automatic level control.

Table 1: Cable Lengths for RF Distribution

Destination	**Cable Length**
Linac	10 m
Booster	40 m
Diagnostics CIA	155 m
Optics Hutch	80 m
Storage Ring RF Hall	275 m

To terminate the 5/8" cable, patch panels were constructed and hung above racks requiring the MO signal (see Fig. 6). From such a panel a more flexible coaxial cable is used to take each signal down into the rack. N-type connections are used throughout the distribution network.

Table 2: Coaxial Cable Specifications

Parameter	**Value**
Cable type	LDF4.5RN-50 Phase stabilised
Attenuation @500MHz	3.5 dB/100 m
Propagation velocity	89 %
Phase stability	< 20 ppm/ºC
Connector return loss	better than 33 dB
Diameter/bend radius	22 mm OD / 20 cm min.

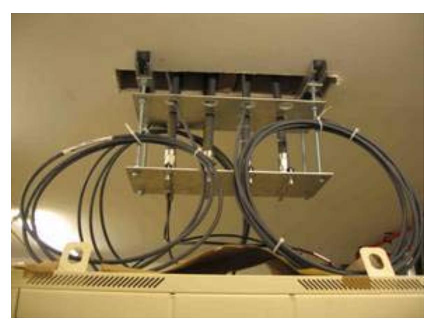

Figure 6: Termination of Coaxial Cables

Client-End Box

At the point of use, each user of the MO signal is supplied with a client-end box (see Fig. 7). Within the box is one or more attenuators and a coupler both with coaxial N-type connectors.

The attenuator adjusts the level to that requested by the end user. The coupler is generally a 10dB type and this enables the level and purity of the signal to be monitored locally.

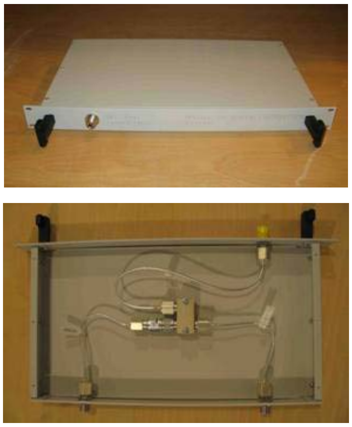

Figure 7: Front and Plan View of Client-End Box

TEST RESULTS

The following paragraphs give measured performance values of the RF Distribution components.

RF Amplifier Performance

The distribution RF amplifier performance is summarised in Table 3.

Table 3: RF Amplifier Performance

Parameter	**Value**
Gain	24 dB
Frequency range	450 - 860 MHz
Output at 1dB compression	+39 dBm
Input return loss	14 dB
Noise figure	7 dB
Monitor coupling	-31 dB

Splitter Performance

The splitter performance is summarised in Table 4.

Table 4: Splitter Performance

Parameter	**Value**	**Comment**
Input match	24 dB	return loss
Output match	29 dB min	return loss
Transmission loss	4 to 17 dB	branch dependant
O/P to O/P isolation	72 dB min	Typically 80 dB

Phase Stability

Refer to Table 5 for phase stability performance. Figure 8 gives a plot of phase change for the 275 m cable to the RF Hall against temperature for a period of 16 hrs overnight.

Table 5: Cable Phase Change

Phase change mechanism	**Change for 275m cable**
Temperature	-1.2° / degC (6 ppm)
Frequency	0.4° / kHz

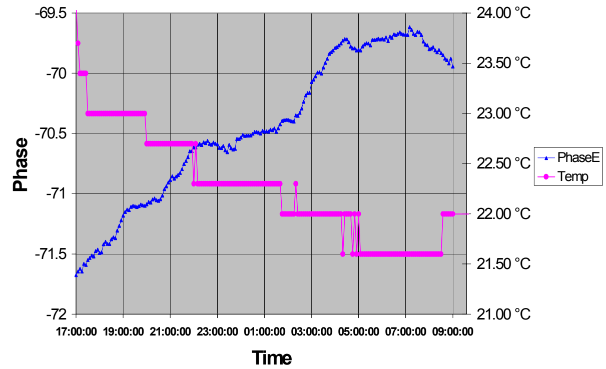

Figure 8: Cable Phase Change with Temperature

Phase Noise and Harmonic Content

Table 6 gives the measured harmonic and spurious levels at the delivery point of the signal, in this case the RF Hall. A spectrum analyser plot of phase noise at the same point is shown in Fig. 9.

Table 6: Harmonic and Spurious Levels

Frequency	**Level in RF Hall**	**Comment**
500 MHz	+18 dBm	Fundamental
1.0 GHz	-63 dBc	Harmonic 2
1.5 GHz	-78 dBc	Harmonic 3
2.0 GHz	-108 dBc	Harmonic 4
500 MHz ± 100 kHz	-74 dBc	PSU spurious

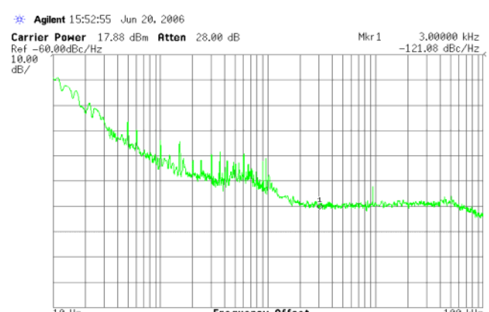

Figure 9: Phase Noise Plot of the Delivered Signal

CONCLUSIONS

The MO distribution system as described above has now been in use for some 3 months during Diamond's initial storage ring commissioning, with no problems or performance issues. Of particular note is that the measured phase change with temperature of the 5/8" (LDF4.5) cable is 6 ppm/ºC, which is much better than the data sheet value of 20 ppm/°C. This means that additional efforts to temperature stabilise individual cables should not be necessary.

REFERENCES

[1] M.R.F. Jensen, "Status of the Diamond Storage Ring Radio Frequency System", EPAC'06.