PIP2IT Test Facility 650 MHz RF Distribution System Functional Requirements Specification

Document number: ED0012138

**Document Approval**

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| Signatures Required | Date Approved |
| Originator: James Steimel, L3 Manager for HPRF |  |
| Approver: Elvin Harms, L2 Manager for Accelerator Systems |  |
| Approver: Alex Martinez, Integration Coordinator |  |

Revision History

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| --- | --- | --- |
| Revision | Date of Release | Description of Change |
| - | TBD | Initial version |
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# Purpose

After the completion of PIP2IT beam operations, the PIP2IT cave will be converted to a test facility for high power testing of PIP-II linac cryomodules. Both LB650 and HB650 cryomodules will be tested using the same RF system installed in PIP2IT. This document specifies functional requirements of the 650 MHz RF distribution system for the PIP2IT test facility.

# Scope

The PIP2IT test facility 650 MHz RF distribution system consists of six separate distribution lines (Figure 1). Each distribution line connects the output port of an RF power amplifier on one end and the input port of the input coupler of a cavity on the other end; and transports RF power from the amplifier to input coupler of the cavity. The 650 MHz RF distribution system functional requirements defined in this document apply to all six distribution lines’ functions.



Figure 1. Scope of PIP2IT Test Facility 650 MHz RF Distribution System

# Acronyms

|  |  |
| --- | --- |
| CMTF | Cryomodule Test Facility |
| CW  | Continues Waves |
| FCC | Federal Communications Commission |
| FESHM | Fermilab Environment Safety & Health Manual |
| FRCM | Fermilab Radiological Control Manual |
| FRS | Functional Requirements Specification |
| HPRF | High Power Radio Frequency |
| HB650 | High Beta 650 |
| IEC | International Electrotechnical Commission |
| LB650 | Low Beta 650 |
| LLRF | Low Level Radio Frequency |
| NFPA | National Fire Protection Association |
| PA | Power Amplifier |
| PIP | Proton Improvement Plan |
| PIP2IT | PIP-II Injector Test |
| RF | Radio Frequency |
| SSA | Solid State Amplifier |

# Reference

|  |  |  |
| --- | --- | --- |
| **#** | **Reference** | **Document #** |
| 1 | PIP-II HPRF L3 FRS | ED0008023 |
| 2 | PIP-II LB650, 650 MHz RF Amplifier Functional Requirement Specification | ED0003413, Rev. A |

# Key Assumptions

5.1

* The RF system has interlock mechanism to shut off the amplifier’s output power during operation when reflected RF power exceeds a threshold or sparking is detected.
* The RF system has an interlock mechanism to disable amplifier output power when the RF distribution is at risk of damage.

5.2

* There is sufficient cooling water supply to meet cooling requirements of RF devices and there is an instrument to monitor/process the required water parameters for device to function safely.
* Testing of the cavity peak gradient will occur while the RF system frequency is locked to the cavity resonant frequency. The power required can be modeled as if the cavity is always on resonance.

# Functional Requirements

## Primary Requirements

|  |  |
| --- | --- |
| **Requirement #** | **Requirement Statement** |
|  | The distribution system should be able to transport power sufficient to test HB650 cryomodule cavities to 15% above their specified gradient. This should assume operation with fully reflected RF power at any phase when each cavity is operated in either pulsed or CW mode. |

## Personnel Safety Requirements

|  |  |
| --- | --- |
| **Requirement #** | **Requirement Statement** |
|  | Provide reflected power isolator to keep reflected power under maximum specifications for SSA. |
|  | RF leakage at any joint of the distribution system should meet the RF leakage limitation requirement from FCC. |

## Self-Preservation Requirements

|  |  |
| --- | --- |
| **Requirement #** | **Requirement Statement** |
|  | Provide necessary signals to SSA interlocks to protect distribution system from RF power. |

## Cavity Protection Requirements

|  |  |
| --- | --- |
| **Requirement #** | **Requirement Statement** |
|  | Provide forward and reflected power signals for each cavity that have sufficient isolation to meet LLRF system specifications. |

## Control & Diagnostics Requirements

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| --- | --- |
| **Requirement #** | **Requirement Statement** |
|  | The RF distribution should not interfere with the operation and maintenance of any other CMTF gallery equipment. |

## Installation and Integration Requirements

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| --- | --- |
| **Requirement #** | **Requirement Statement** |
|   | The RF distribution system should not interfere with cryomodule and related cryogenic equipment. |

## Physical Placement

|  |  |
| --- | --- |
| **Requirement #** | **Requirement Statement** |
|   | The RF distribution system should not interfere with existing cable tray populated with cables inside the PIP2IT cave. |
|  | The RF distribution system layout should make the cryomodule swapping (connecting/disconnecting to the cryomodule, moving the cryomodule into/out of its final test position) relatively easy. |
|   | The RF distribution system should have its own, adequate support structure. |

# Safety Requirements

The system shall abide by all Fermilab ES&H (FESHM) and all Fermilab Radiological Control Manual (FRCM) requirements including but not limited to:

|  |
| --- |
| Structural Safety |
| * FESHM Chapter 5100 Structural Safety
 |
| Electrical Safety |
| * FESHM Chapter 9110 Electrical Utilization Equipment Safety
 |
| * FESHM Chapter 9160 Low Voltage, High Current Power Distribution Systems
 |
| * FESHM Chapter 9190 Grounding Requirements for Electrical Distribution and Utilization Equipment
 |
| General Safety |
| * FESHM Chapter 2000 Planning for Safe Operations
 |

Any changes in the applicability or adherence to these standards and requirements require the approval and authorization of the PIP-II Technical Director or designee.

In addition, the following codes and standards in their latest edition shall be applied to the engineering, design, fabrication, assembly and tests of the given system:

|  |
| --- |
| FCC OET Bulletin 65, Edition 97-01 ANSI ASC A14.3-2000 Safety Requirements for Fixed Ladders |
| NFPA 70 – National Electrical Code |
| IEC Standards for Electrical Components |

In cases where International Codes and Standards are used the system shall follow FESHM Chapter 2110 Ensuring Equivalent Safety Performance when Using International Codes and Standards and requires the approval and authorization of the PIP-II Technical Director or designee.

Additional Safety Requirements that are not listed in the general list above shall be included in the Requirements table in the Functional Requirements section.

Any changes in the applicability or adherence to these standards and requirements require the approval and authorization of the PIP-II Technical Director or designee.

# Quality Assurance

|  |  |
| --- | --- |
| **Requirement #** | **Requirement Statement** |
|   | The critical geometric data --- 3D distance between SSA output ports and PIP2IT cave penetration holes and 3D distance between PIP2IT cave penetration holes to input ports of couplers of cavities on cryomodule ---- should be measured by Fermilab survey group to the accuracy of 0.05”or less before the start of final system assembly. |
|  | All critical devices (isolators and dual directional couplers) used in this rf distribution system should be measured before being used in the distribution system.  |
|   | Each RF distribution line should be calibrated, and high power tested before final connection to the cavity. |