HDI flexible front-end hybrid prototype for the PS module of the CMS tracker upgrade

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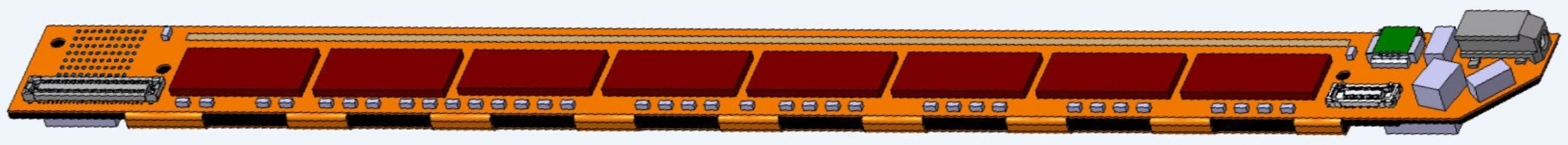
Abstract

The CMS tracker upgrade for the HL-LHC relies on different module types, depending on the position of the respective module. They are built with high density interconnection flexible circuits that are wire bonded to silicon strip sensors. The Front-End hybrids will contain several flip-chip bonded readout ASICs that are still under development. Mock-up prototypes are used to qualify the advanced flexible circuit technology and the parameters of the hybrids. This paper presents the PS mock-up hybrid in terms of testing, interconnection, fold-over, thermal properties and layout feasibility. Plans for circuit testing at operating temperature are also presented.

Project introduction

New silicon sensor modules with modern readout electronics are under development for the CMS phase 2 upgrade. To speed up the development, the module mechanical supports, assembly procedures and the electronics are developed in parallel. The Short Strip ASIC (SSA), the Macro Pixel ASIC (MPA) and the data Concentrator ASIC (CIC) are the three ICs required to build a Front-End Hybrid (FEH) for the Pixel Strip (PS) modules. Since these ASICs are still under development, but a hybrid was required, therefore a mock-up hybrid was designed for module construction and other test purposes.



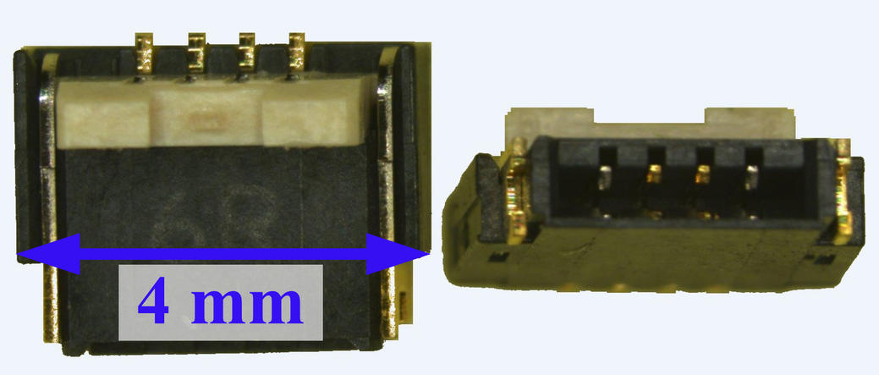
3D model of the assembled and folded PS-MCK hybrid.

Requirements

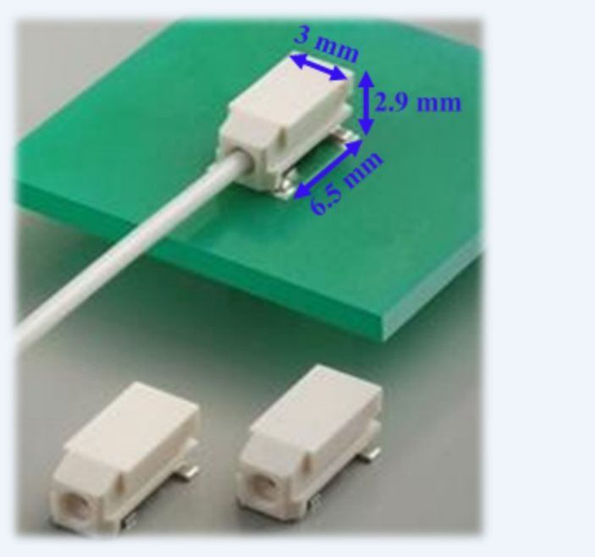
The PS mock-up hybrid (PS-MCK) circuit must fit into the current mechanical design of the PS module. The assembly procedure of the Carbon Fiber (CF) stiffeners have to be defined and tested on this circuit. The circuit has to have the thermal and mechanical properties similar to the final PS FEH and it has to provide test structures for the quality inspection. A High Voltage (HV) biasing and filtering circuit that fulfills the requirements of the sensors is needed. Different functional test methods have to be evaluated in terms of reliability, difficulty of implementation, testing time and cost. Each circuit has to be marked with individual identification number which is readable by a scanner. The PS-MCK has to provide solutions for the electrical and mechanical integration of the hybrid in the PS module.

High voltage circuit and low voltage supply connectors

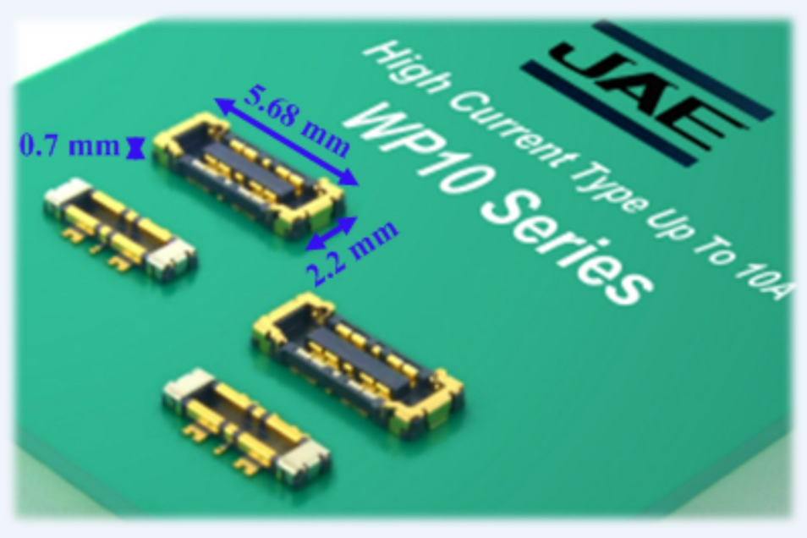
A single wire connector is used as HV input. This part of the circuit is conformal coated and component pads are rounded to stand 1 KV. A flat flexible connector connects the bias voltage to the strip sensor and an ultra small connector provides the low voltage power supply to the hybrid.



Panasonic YBW5 FPC connector



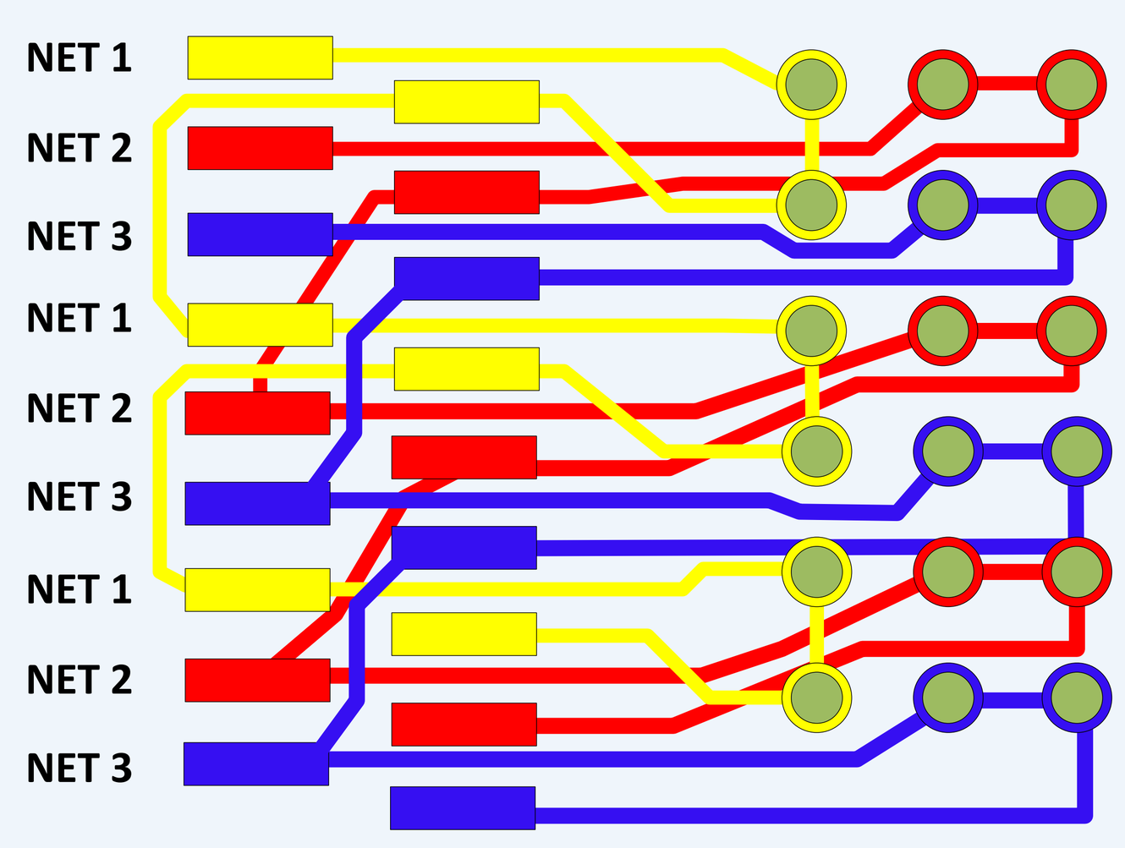
JAE ES3 with a single wire



JAE WP10 power connector

Dummy CBC flip-chips with daisy chain routing

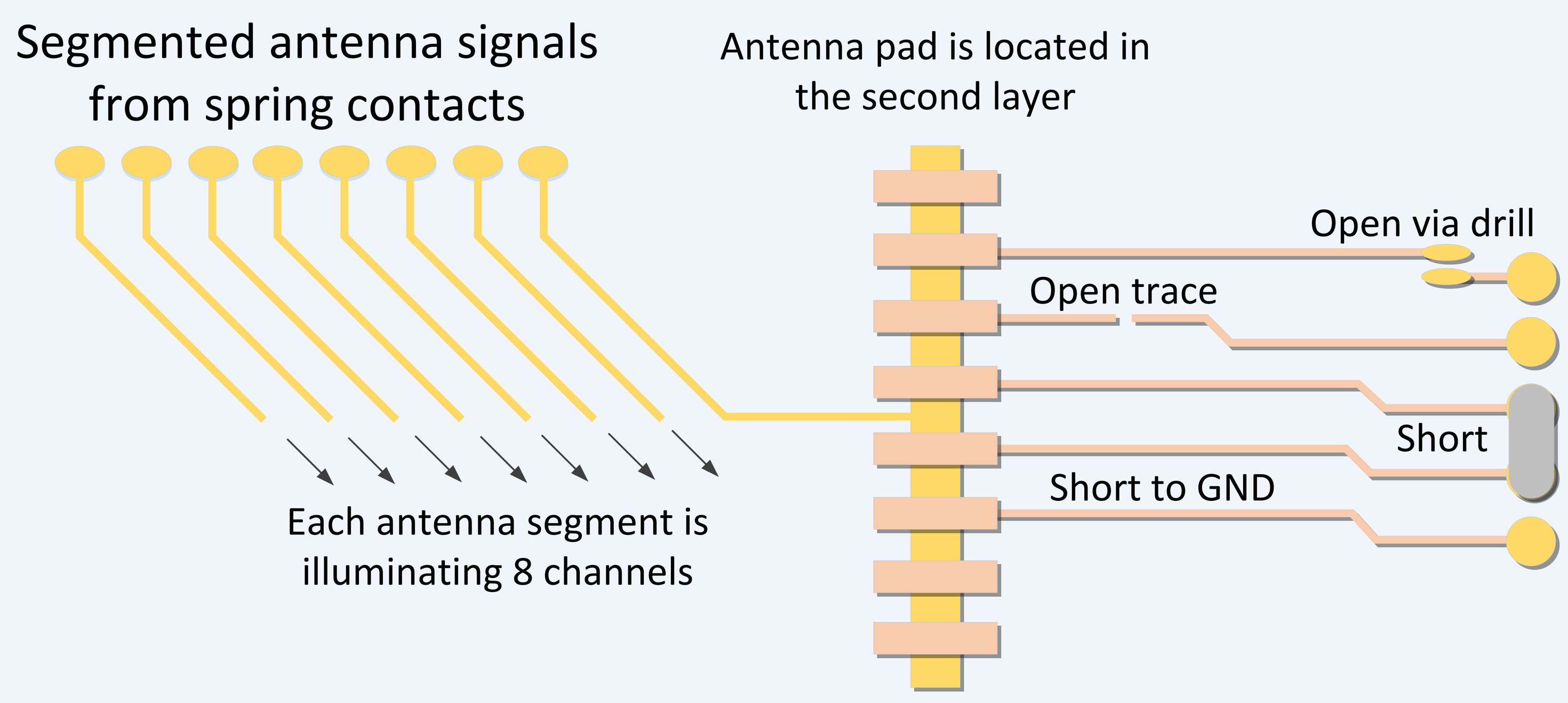
Dummy flip-chips with electrically isolated bumps are used to substitute the mechanical properties of the SSA ASICs. Three nets are routed in a daisy chain with fine traces to mimic the sensor interconnection of the real PS-FEH. This daisy chain is useful to find short circuits and open circuits resulting from manufacturing problems.



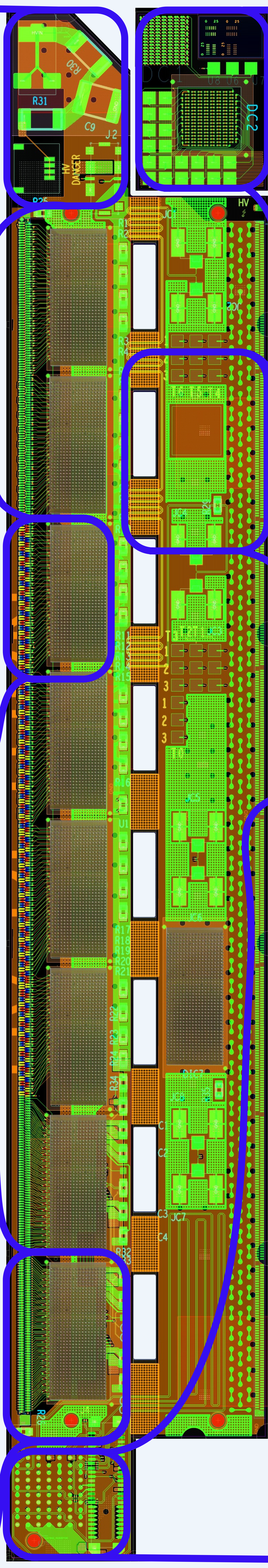
Fine line daisy chain pattern to test PCB quality

Antenna test evaluation circuit

Two CMS Binary Chips (CBC2) are placed on the PS-MCK in order to validate a new input channel connectivity test method. The method is based on an antenna which couples capacitively a signal into the wirebond pads located on the hybrid. The signal should be recognized by the CBC2 if the interconnection is continuous. In order to demonstrate that the method can find the defects with a good efficiency, known failures are implemented in the hybrid. Shorted traces, shorted bumps, shorts to GND, broken vias and broken traces are implemented in several known locations. The antenna can be external or internal. One of the CBC2 chips is designed with internal antenna and the second one is designed with external antenna. The control logic is implemented on the PS-MCK interface board developed for the cold test setup.



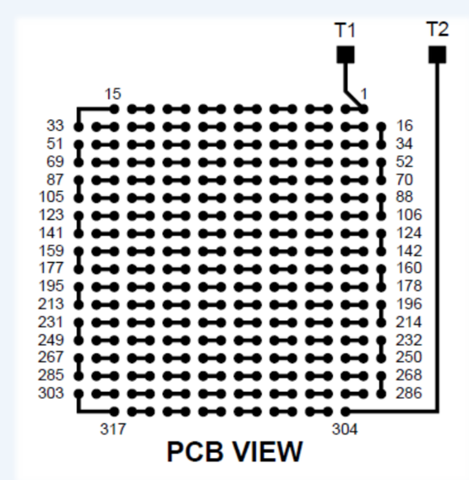
Schematic diagram of the antenna test system with the implemented failures



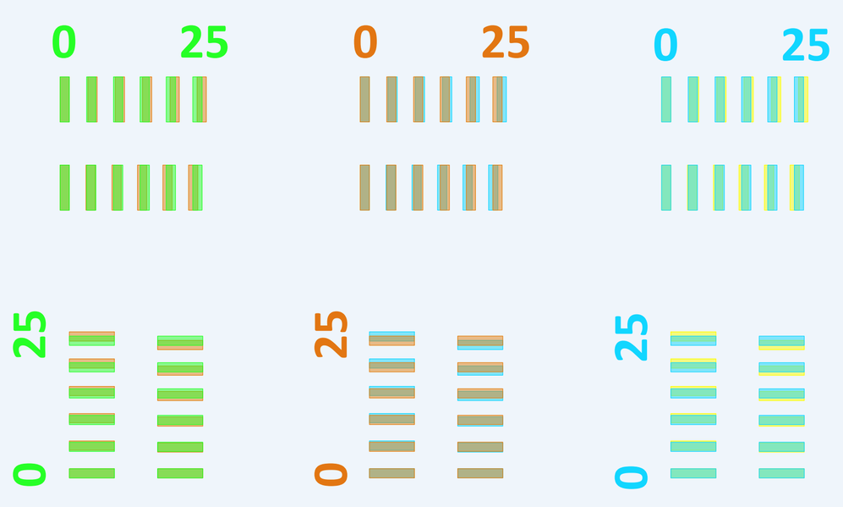
PS-MCK layout top view

Test coupon

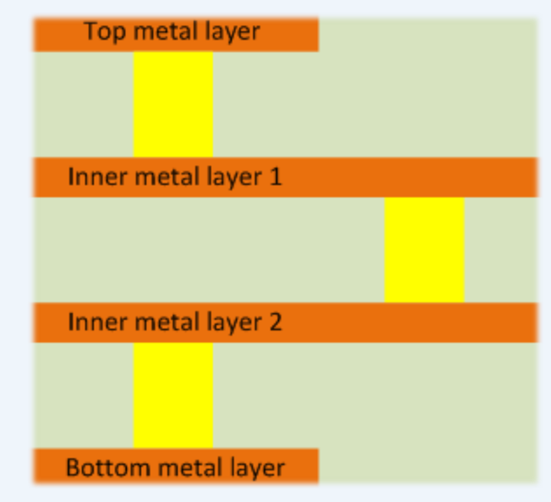
A test coupon is designed to evaluate the quality of the circuit manufacturing. The coupon has a via daisy chain, a fine line tester structure, a daisy-chain flip-chip and a layer alignment test structure. The coupon is separated from the main circuit after the assembly.



Footprint of the daisy-chain flip chip



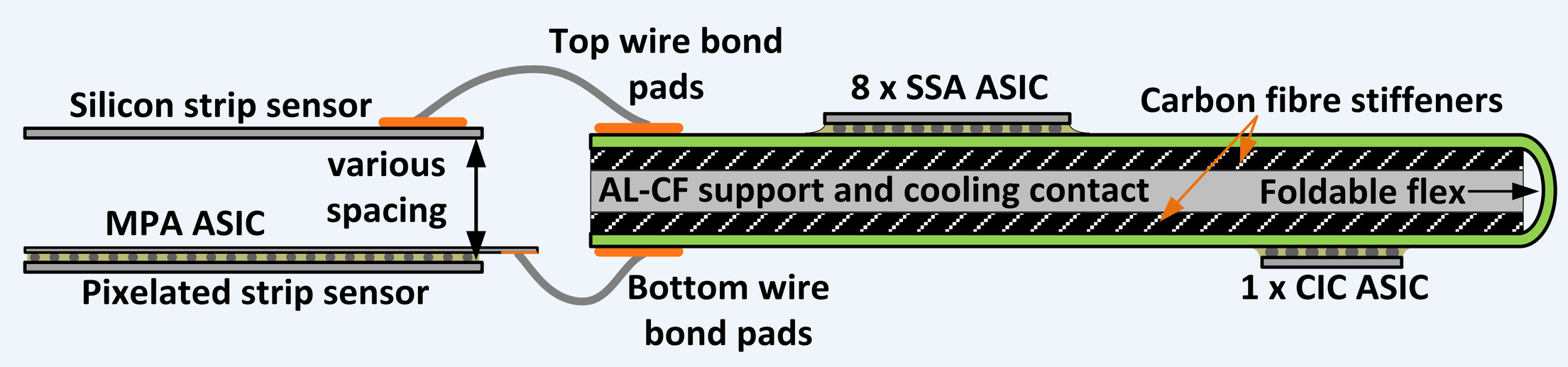
Optical layer alignment test



Via structure of the via daisy chain

Data matrix and fold-over

A maximum 5 x 5 mm^2 size data matrix can be placed on the circuits to test the usability of such an identifier. Each PS-FEH will be folded over to set the wirebond pads to the level of the silicon sensor wirebond pads. Voids are designed in the flexible area of the circuit to enhance the flexibility. The impedance changing effect of the folding is tested on this hybrid.



Cross section of the planned construction of the PS FEH

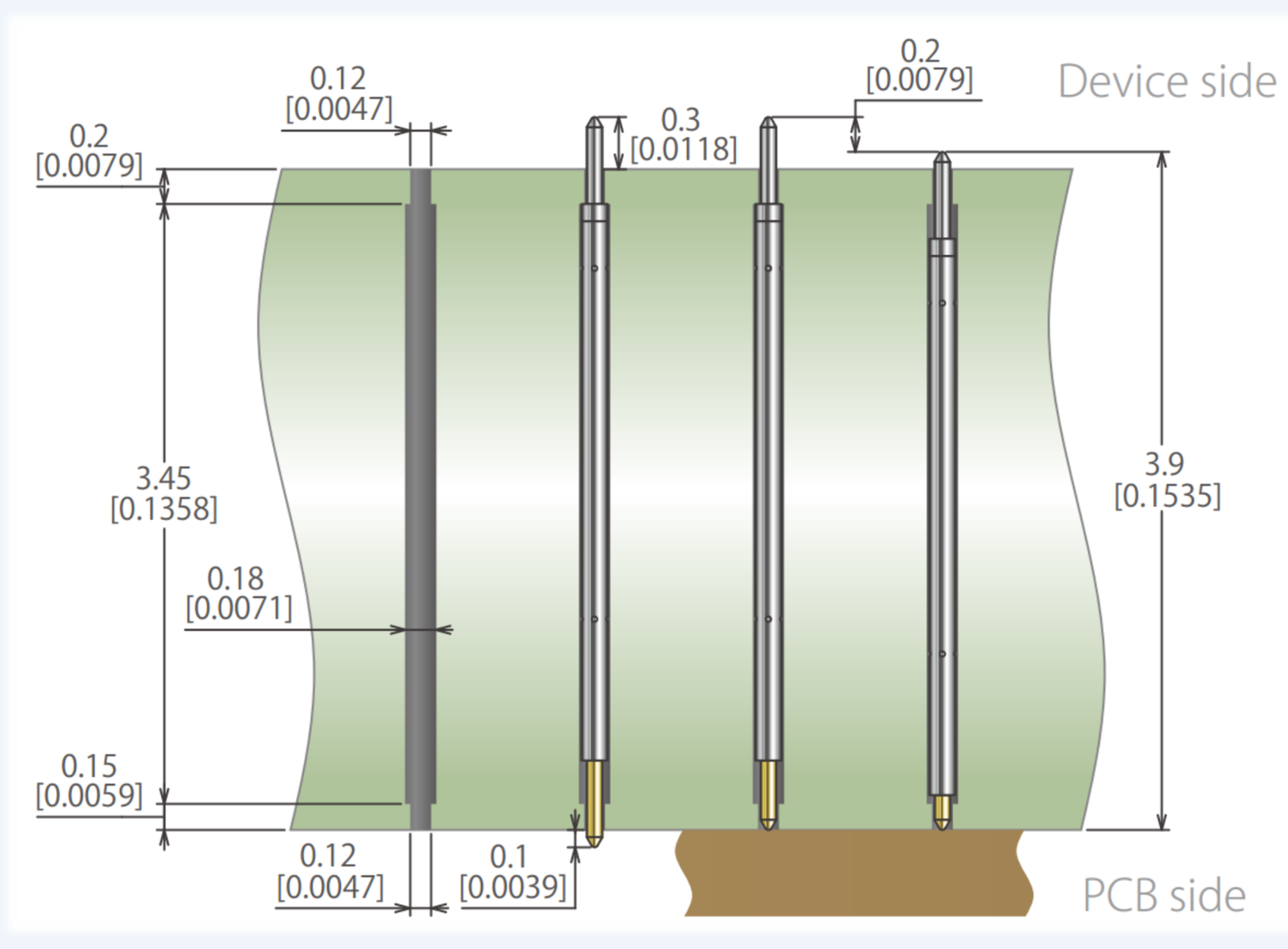
Plated data matrix on flex substrate

Spring loaded needle probe contacts

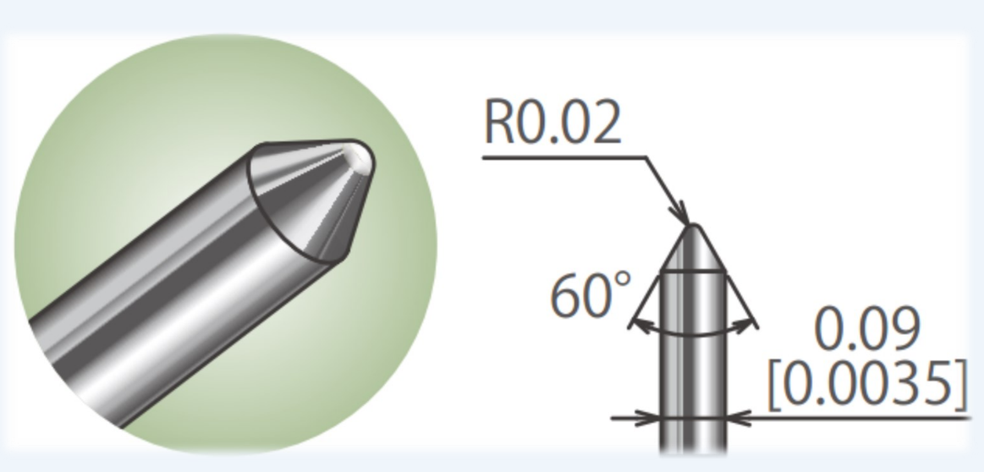
The functional testing of the FEH circuits is essential. One possible method to interface is to use spring loaded contact needles aligned in a test setup. As the probe pattern has less than 1 mm pitch and 350 + 70 test points, the alignment becomes very demanding. The alignment, repeatability, electrical properties and reliability will be tested on the PS-MCK. A prototype setup which can cool down and test the hybrid at the nominal operating temperature (-20°C) is being developed. For more information about this cold test setup, please check the poster: "Testing of hybrid circuits for the CMS Tracker Upgrade of front-end electronics", T. Gadek et al.TWEPP 2016. Another option is to use a small mezzanine connector for interconnection and test purposes. The performance of a connector which has a mating part for testing is also evaluated on the PS-MCK.

Spring force at operating travel	**14N @ 0.3mm Travel**
Operating temperature	**-40 to 120 °C**
Life span at operating travel	**80K Cycles**
Current rating	**0.3A**
Self inductance	**1.71nH**
Bandwidth at –1dB	**>30GHz**
DC resistance	**≤ 0.5 ohm**

Properties of a Kita Marathon needle



Needle probes fitted in a test socket



Cap of the Kita Marathon needle

Future work

A test interface board, which hosts the needle probe tester socket and other conversion and data acquisition hardware, has to be designed and produced. The reliability and radiation tolerance of the proposed mezzanine connectors are unknown and therefore they have to be carefully evaluated before the connectors are set as a baseline solution for interconnection. The test coupons have to be tested for reliability, the via metallization and the circuit buildup will be checked by cross section grinding. The efficiency of the antenna test method has to be evaluated with the PS-MCK.

Conclusion

The PS-MCK is required in order to study several unknown parameters of the final PS FEH. The assembly procedure, the geometry and the outline of the hybrid is well defined now. The circuit will enable the creation of dummy modules for assembly studies and cooling tests. The hybrid will help validating several test routines and electrical contact methods. Despite it is a mockup design, the complexity will result in a difficult manufacturing and assembly procedure.