Jennic

TECHNOLOGY FOR A CHANGING WORLD

Production Test User Guide

JN-UG-3047

Revision 1.1

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Contents

About this Manual

This document serves as a guide to the implementation of a production test system, using the functions of the Jennic Production Test API, to test products based around the JN51xx series wireless microcontrollers.

Organisation

This manual consists of 6 chapters, as follows:

- Chapter 1 provides an introduction to production testing
- Chapter 2 outlines the hardware required
- Chapter 3 describes the software required
- Chapter 4 provides details of how to perform the primary tests
- Chapter 5 provides details of how to perform the secondary tests
- Chapter 6 covers issues regarding test system calibration

Conventions

Files, folders, functions and parameter types are represented in **bold** type.

Function parameters are represented in *italics* type.

Code fragments are represented in the `Courier` typeface.

Acronyms and Abbreviations

ARB	Arbitrary Waveform Generator
API	Application Programming Interface
DUT	Device under test
PER	Packet Error Rate
RF	Radio Frequency

Related Documents

[R1]	Production Test API Reference Manual [JN-RM-2027]
[R2]	Integrated Peripherals API Reference Manual [JN-RM-2001]
[R3]	JN51xx Flash Programmer User Guide [JN-UG-3007]

Feedback Address

If you wish to comment on this manual, or any other Jennic user documentation, please provide your feedback by writing to us (quoting the manual reference number and version) at the following postal address or e-mail address:

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1 Introduction

The development of a production test system for a new product is often overlooked or left until the last minute, at which point it may seem like a daunting task. This manual aims to serve as a guide to the development of a simple production test system to test a Jennic JN51xx wireless microcontroller IC and its associated support circuitry.

For simplification, this document assumes that the product to be tested will take the form of a module similar to those offered by Jennic. The subjects covered also apply to products which directly incorporate a wireless microcontroller IC. However, since applications vary considerably, it is not realistic to attempt to cover the test requirements of all kinds of product.

1.1 Objectives

The production test system should aim to meet at least the following objectives:

- Ensure that the product has been assembled correctly
- Ensure that all components used are performing correctly
- Ensure that the product meets its specifications

1.2 Which Tests Should Be Performed?

Ideally, a suite of tests should be chosen which exercise every component and function of the product. The tests are split into primary and secondary groups. Primary tests are those which are required to guarantee that the product communicates reliably, whilst secondary tests are those which test other areas of the product. Application-specific function tests are left for implementation by the reader. This document covers the following tests for the Jennic JN51xx chip and its associated support circuitry.

Primary Tests

- Crystal oscillator frequency measurement
- PER measurement

Secondary Tests

- Connectivity/loopback tests
- Current measurements
- Transmit output power measurement
- Programming Flash memory with an application and MAC address/license key

1.3 The Test System

Here, we will assume that the test is being controlled by a PC, connected to various pieces of test equipment and the DUT (device under test) via either GPIB or serial UART connection.

An example of the system proposed in this document is shown in the diagram below:

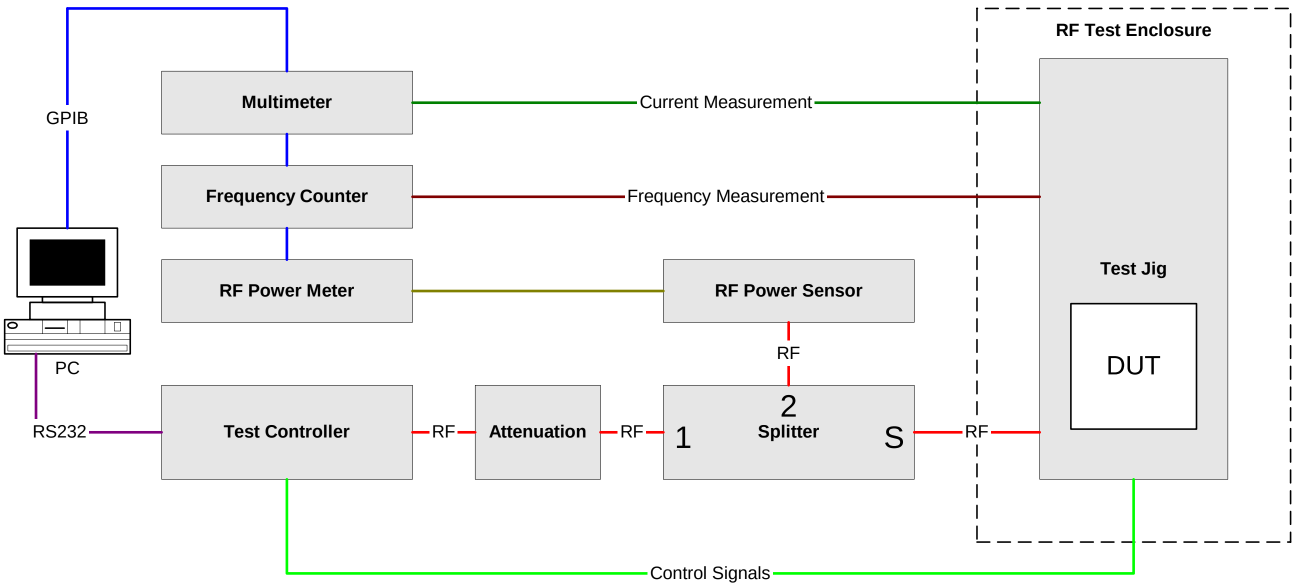

Figure 1: Test System Configuration

Jennic

2 Test System Hardware

2.1 Introduction

The choice of tests to be performed and the nature of the product being tested will ultimately dictate the equipment required for the production test system. For the system proposed here, the equipment can be divided into standard off-the-shelf test equipment and equipment specific to the product being tested.

2.2 Standard Test Equipment

For the proposed system, the following pieces of off-the-shelf equipment would be required:

- PC to control the test and record/display the results
- GPIB interface for the PC to allow it to communicate with the test equipment, e.g. Agilent 82357A USB to GPIB Adapter
- GPIB multimeter, e.g. Agilent 34401A
- GPIB frequency counter, e.g. Agilent 53181A
- GPIB RF power meter with associated power sensor, e.g. HP 437B with HP 8481D power sensor
- RF power splitter to allow both power and PER tests to be performed, e.g. Mini-Circuits ZN2PD2-50
- Attenuator(s)
- RF test enclosure in which to place the DUT, e.g. Ramsey Electronics STE4400
- Assorted RF cables and connectors

2.3 Custom-Built Test Components

2.3.1 Test Controller

The test controller (sometimes referred to as a “Golden Unit”) is a piece of custom-developed hardware that should serve the following functions:

- Act as an interface between the PC and DUT
- Act as a reference device with which the DUT can test its RF link when performing the PER test
- Provide any external circuitry required to test input/output connections on the DUT

A block diagram showing the test controller used to test Jennic modules during production is provided in Figure 2. The device consists of a Jennic module, an RS232 to TTL interface, a 4 channel SPI DAC with which to stimulate the analogue inputs on the DUT, and various control signals to control circuitry on the test jig.

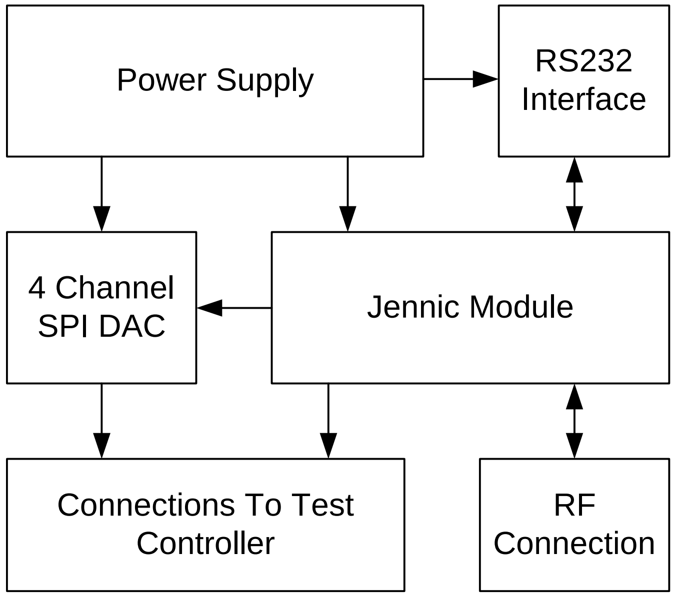

Figure 2: Test Controller Block Diagram

A photograph showing the test controller in detail is provided in Figure 3. The RS232 connector to the PC can be seen on the left of the screening enclosure, and the RF and control signals connector to the test jig on the right.

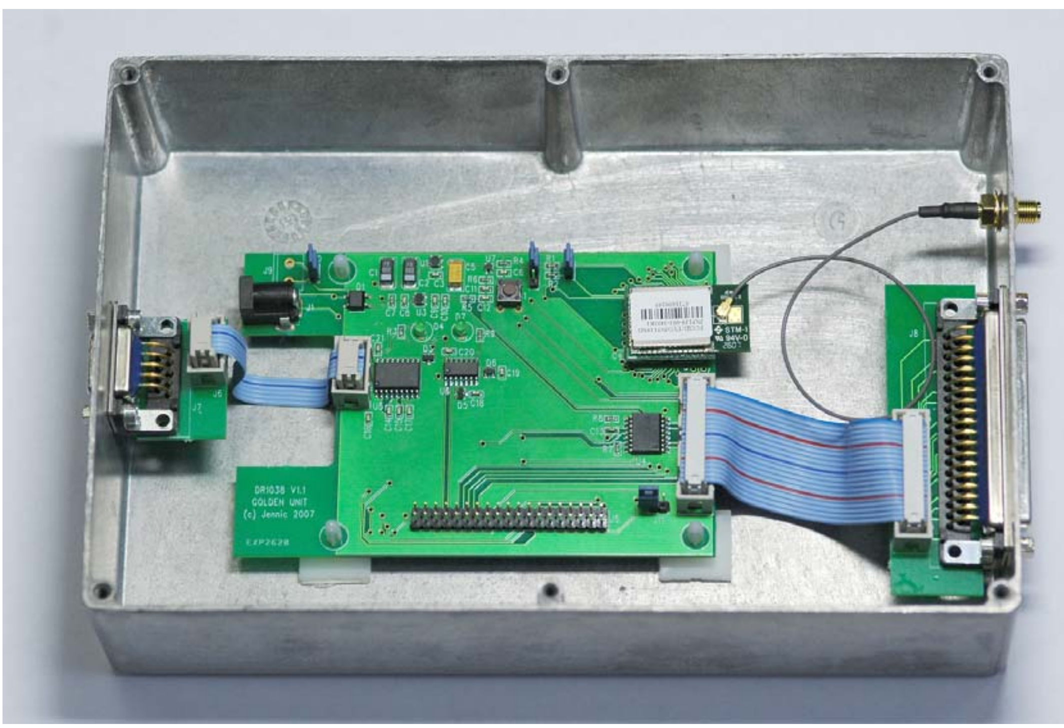

Figure 3: Jennic's Test Controller

A schematic diagram of the test controller used to test Jennic modules is provided in Figure 4, and wiring details for the control signal cable to the test jig in Figure 5. Note that the cable is split into two parts so that the cable can enter the shielded RF test enclosure via a filtered connector.

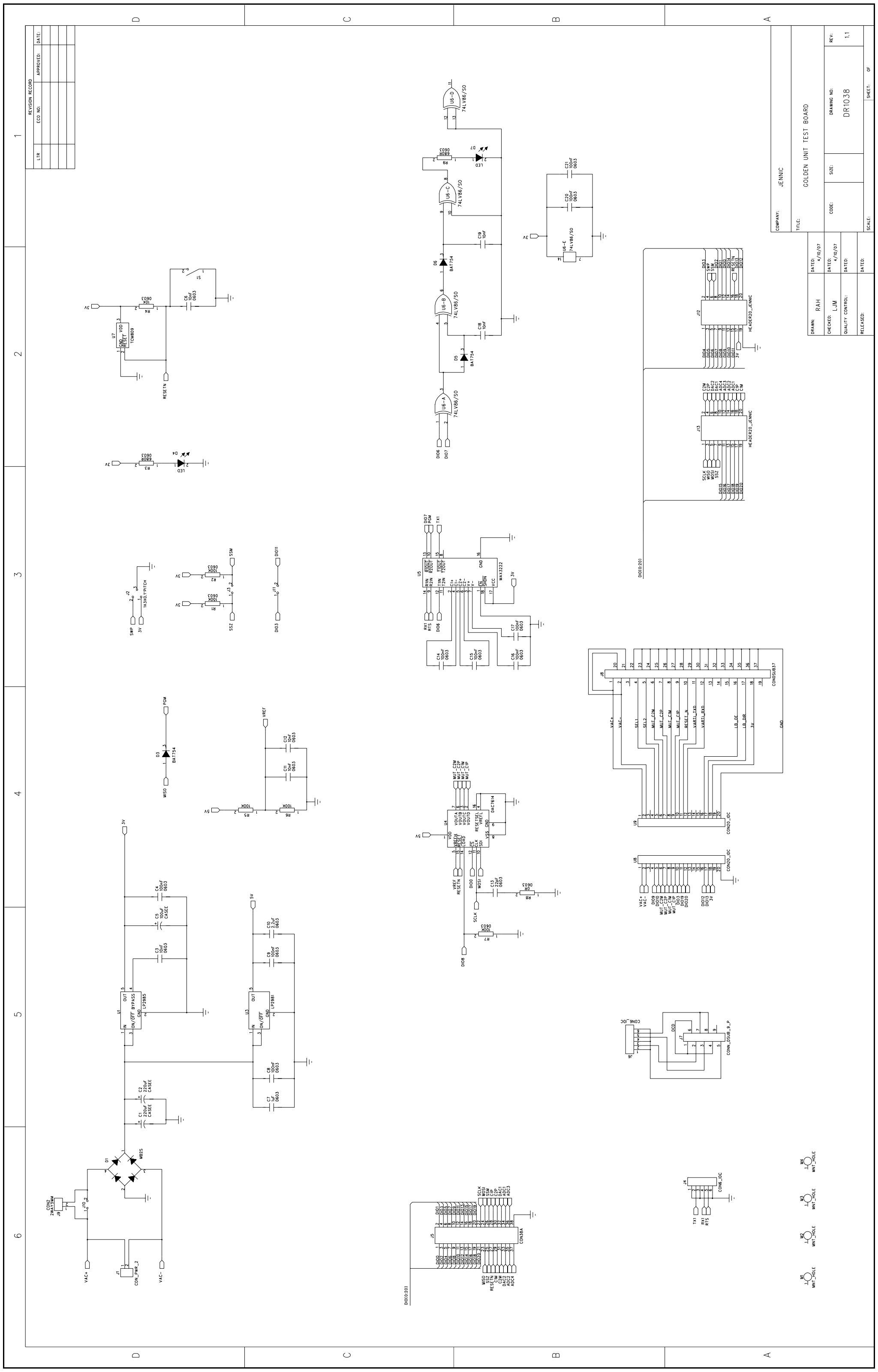

Figure 4: Test Controller Schematic

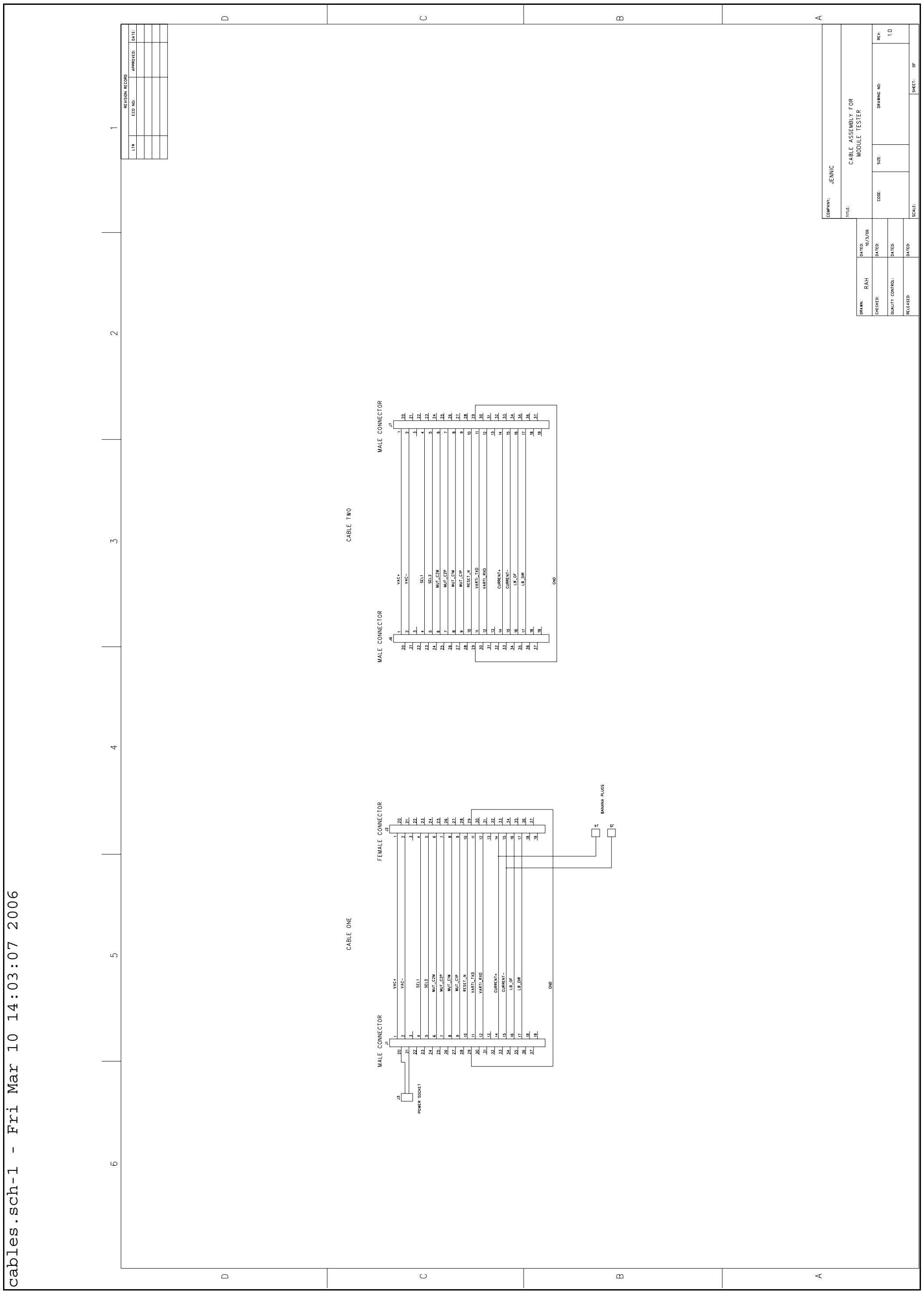

Figure 5: Test Controller to Test Jig Interconnecting Cables

2.3.2 Test Jig

The design of the test jig will vary depending on the nature of the product to be tested. However, its purposes remains the same:

- Provide a way to connect to the DUT
- Provide any external circuitry required to test the features of the DUT
- Provide an RF connection to the DUT (either connect directly to the RF output, or use a pick-up antenna)

The test jig used in the production testing of Jennic modules consists of a machined plastic receptacle with a toggle clamp to retain the DUT on a 'bed of nails' arrangement of test probes. The underside of the test jig houses a PCB containing the following:

- A power supply
- Support circuitry to allow the IO signals of the modules to be tested
- A second Flash device with logic that allows the test controller to connect the DUT to its on-board Flash memory or to the Flash device on the test jig containing the DUT application
- An RF connection - this can be either a connection to a pick-up antenna to couple to a DUT with on-board antenna, or a direct connection to a DUT's RF connector

A block diagram showing the elements of the test jig is provided in Figure 6.

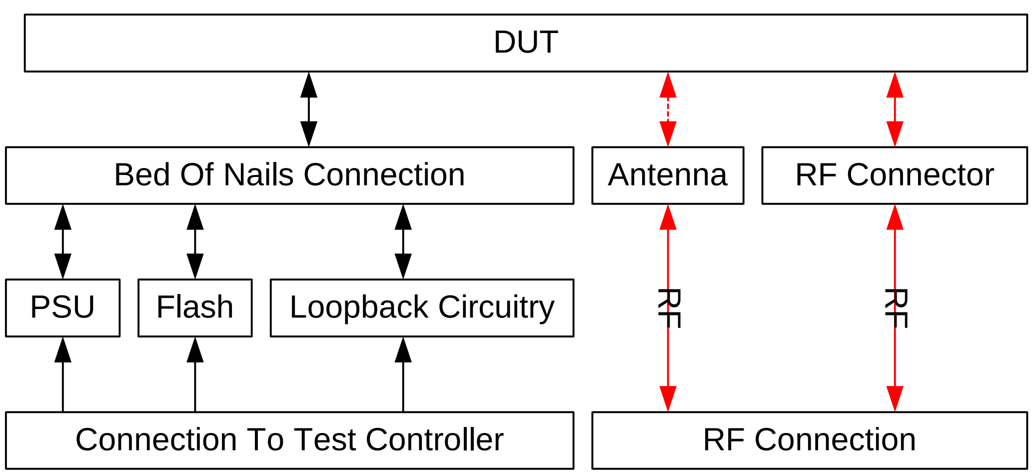

Figure 6: Test Jig Block Diagram

Figure 7 shows Jennic’s test jig, viewed from above, with the toggle clamp holding in place the module to be tested.

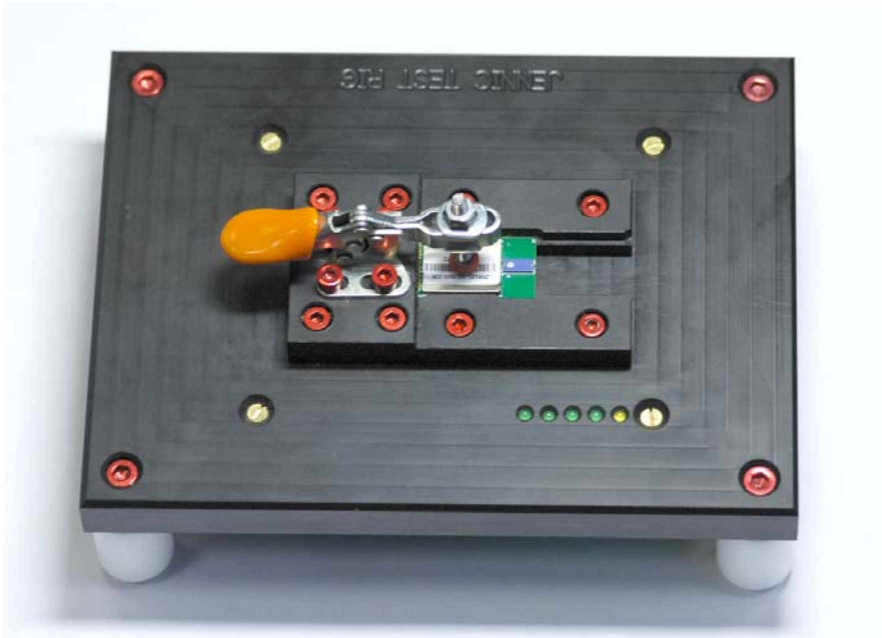

Figure 7: Jennic’s Test Jig (viewed from above)

Figure 8 shows the 'bed of nails' connection to the DUT. The 'nails' are, in fact, sprung test probes that are positioned to mate directly with the connection pads on the underside of Jennic modules. Each test probe consists of a receptacle that is permanently fixed to the PCB on the underside of the test jig, as well as a sprung probe insert (shown in Figure 9) that can be removed for replacement once it has worn out.

Figure 8: 'Bed of Nails' Connection to the DUT

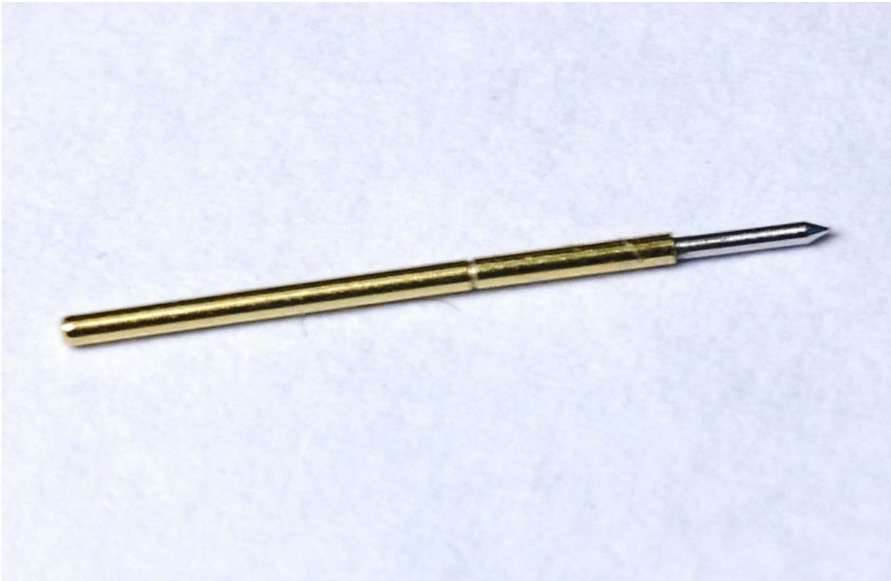

Figure 9: Sprung Test Probe

Figure 10 shows the underside of the test jig. On the left of the image is the D-connector, which forms the control signal connection to the test controller. In the centre of the image is the pick-up antenna with SMA connection - this is used as an RF connection to couple to the DUT when testing devices that have an on-board antenna. When testing devices with an RF connector, a direct connection is made.

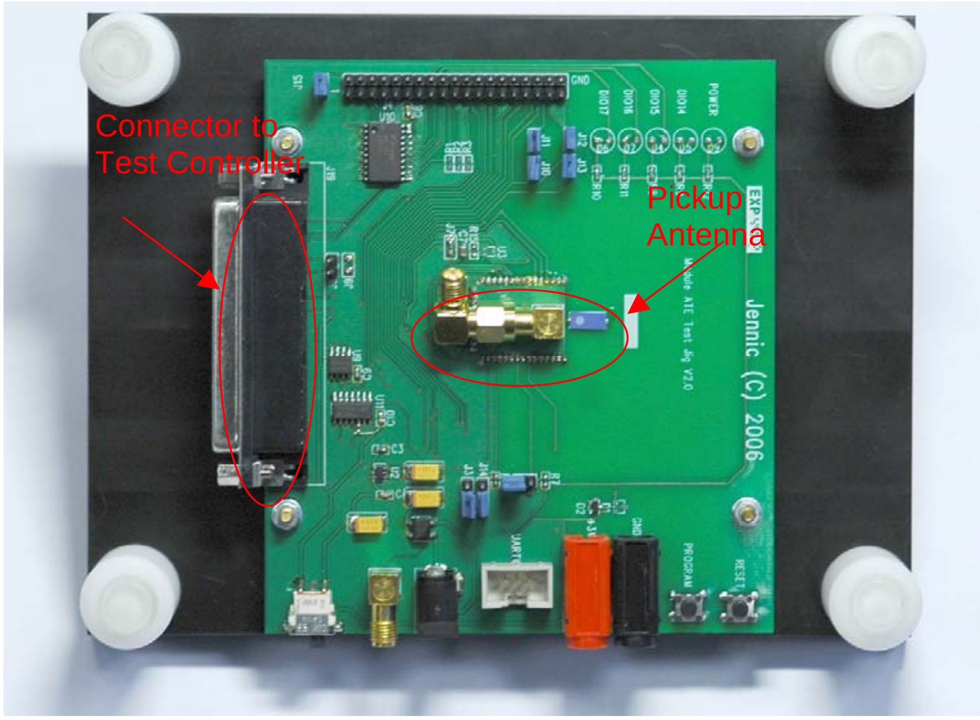

Figure 10: Jennic's Test Jig – PCB

The schematic of the PCB in Figure 10 is shown in Figure 11

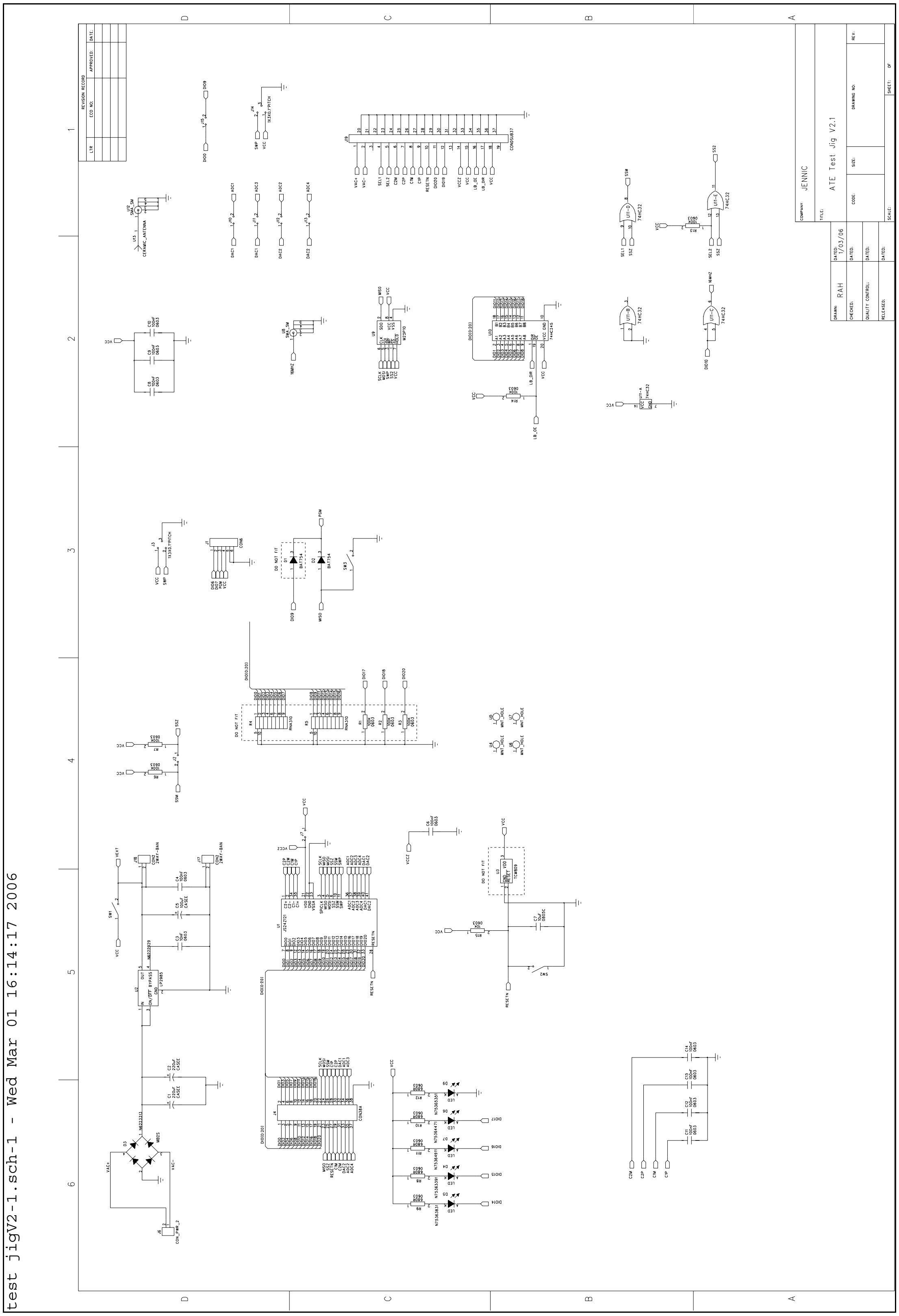

Figure 11: Test Jig Schematic

3 Test System Software

3.1 Introduction

Whilst the production test software development is ultimately left to the reader, Jennic provides a library of functions known as the Production Test API to speed up this development process. This API, combined with the functions in the Integrated Peripheral API, provides a simple way of putting the Jennic device into the various modes required for production testing.

To implement the test system proposed in this document, three pieces of software will be required:

- An application to control the test to be run on the PC
- An application to perform the tests to be run on the DUT
- An application to control the test controller

3.2 The Production Test API

The Jennic Production Test API provides the developer with a library of functions to streamline the development process for the test software. Functions are included to provide the following tests:

- Crystal oscillator frequency test
- Transmit output power test
- PER test

The Production Test API is detailed in the *Production Test API Reference Manual (JN-RM-2027)*.

> **Note:** The Production Test API uses test features built into the wireless microcontroller that are not compatible with the features provided by the networking stacks available from Jennic. Therefore, it is not possible to combine features from the Production Test API with the network stacks.

3.3 The PC Application

The PC application is required to co-ordinate the test. It should provide the following functions:

- Provide a simple interface to the production test operator
- Send and receive commands to/from the test controller and the GPIB test equipment
- Compare test results with pre-set limits
- Record the results from the test to allow product traceability

The application could either take the form of an application developed in a conventional programming language or a test application developed in a package such as National Instruments LabView.

3.4 The Test Control Application

A simple application will be required to run on the test controller and perform the following functions:

- Provide a means of receiving/sending data from/to the PC application
- Allow the PC to indirectly control signals to the DUT, i.e. reset
- Allow the PC to indirectly stimulate inputs to the DUT
- Allow the device to perform a PER test with the DUT

The application should be developed in the C programming language and, once compiled, executed in the Golden Unit.

3.5 The DUT Application

The DUT application should provide the following functions:

- A means of receiving/sending data from/to the test control application on the PC
- Place the DUT in states suitable for taking the required measurements
- Perform any tests that can be carried out by the DUT itself

The application should be developed in the C programming language and, once compiled, executed on the DUT.

There are two ways of getting the application into the DUT:

- Download the application to the Flash memory of the DUT

  This option requires that the test application is programmed into every single device being produced. This adds considerable time to product test and is therefore undesirable.

- Boot the DUT from a second Flash device on the test jig containing the application

  This option is far more convenient since the application only needs to be programmed into a second Flash device once. However, in order to implement this option, it must be possible to break the chip-select connection between the wireless microcontroller and its Flash device. This is possible on modules produced by Jennic, since the chip-select signal from the wireless microcontroller is brought out to the module edge connector as the signal SPISSZ, and the chip-select signal to the Flash device is brought out as SPISSM. These connections must be connected together to allow the module to boot from its internal Flash memory, but during production the module is tested by booting from the second Flash device.

4 The Primary Tests

4.1 Crystal Oscillator Frequency Test

Since the accuracy of the crystal oscillator plays a large part in the correct operation of the radio, it is advisable to measure the oscillator's running frequency and verify that it is within acceptable limits.

The Production Test API contains a function to place the wireless microcontroller IC in a test mode whereby the crystal oscillator frequency is output to a DIO pin as a square wave that can then be measured.

4.1.1 Equipment Required

To measure the oscillator frequency, a frequency counter with a resolution of 1 Hz at the measurement frequency should be chosen - for example, an Agilent 53181A GPIB frequency counter.

4.1.2 Test Limits

Since the crystal oscillator must have a tolerance of ±40 ppm or better, including the effects of temperature and aging, realistic limits at production test should be narrower, e.g. ±25 ppm. Therefore, for a 16-MHz oscillator, the test limits would be as follows:

Parameter	Lower Limit	Upper Limit
Crystal oscillator frequency	15.9996 MHz	16.0004 MHz

Table 1: Crystal Oscillator Test Limits

4.1.3 Implementation

Refer to the function **bTestCrystalOscillator()** in the accompanying file **ExampleSource.c** for an example of how to use the Production Test API to place the DUT in a mode suitable for measuring the crystal oscillator frequency.

4.2 Packet Error Rate (PER) Test

The PER test is the single most useful test that can be performed to verify correct operation of the wireless microcontroller and its associated support circuitry.

The test requires the DUT to communicate with another known ‘good’ device over an attenuated radio link to simulate transmission over a great distance, and is a measure of measure of successful packets transferred.

4.2.1 Equipment Required

The following equipment will be required to perform the PER test:

- Test controller with which to test the RF link
- Attenuators to simulate transmission over a large distance
- RF signal generator for system calibration
- Assorted RF cables and connectors

4.2.2 Test Limits

Ideally, the system should have a 100% throughput (0% PER). However, this is only likely to be achieved using an ideal signal source (e.g. an ARB) in controlled conditions.

The attenuator should be chosen to attenuate the received signal at the DUT and test controller to around 3 dB above the receiver sensitivity level, taking into account all extra losses in the system (i.e. baluns, connectors, cables).

A production test environment is likely to be a much noisier RF environment, therefore expectations must be lowered. The values in the table below show limits that are more realistic.

Parameter	Lower Limit (%)	Upper Limit (%)
Throughput	95	100

Table 2: Packet Error Rate Test Limits

4.2.3 Implementation

Refer to the functions **u32TestPERMaster()**, **bTestPERSlaveStart()** and **vTestPERSlaveStop()** in the accompanying file **ExampleSource.c** for an example of how to use the Production Test API to perform a PER test between the DUT and test controller.

5 Secondary Tests

5.1 Connectivity Test

If the product under test takes the form of a module, or sub-circuit to form a component of a larger system, then it is advisable to perform some sort of continuity or loopback test of the IO pins that form the interface to the external world.

For example, such tests are recommended for products that take the form of a module similar to those offered by Jennic. In this case, since all of the IO pins from the wireless microcontroller are taken to connector pads on the edge of the module, it is beneficial to check that the pins on the IC are actually connected to the edge connections on the module and that there are no dry or broken joints preventing continuity.

In the case of the DIO pins, this check can be done by performing a loopback test between any IO pins that are not being used for control of the test.

5.1.1 Equipment Required

The equipment required to perform this test is completely dependent on the device being tested. For Jennic modules, the equipment takes the form of circuitry on the PCB of the test jig that can be configured to connect various DIO pins together.

5.1.2 Test Limits

In the case of digital signals, the test should either pass or fail. However, if analogue signals are to be tested, appropriate pass/failure levels should be chosen.

5.1.3 Implementation

Refer to the function **bCheckDioPins()** in the accompanying file **ExampleSource.c** for an example of how to perform a loopback test on DIO pins using the Integrated Peripherals API (described in the *Integrated Peripherals API Reference Manual (JN-RM-2001)*).

5.2 Current Measurements

Measuring the current drawn by a product in various states can provide a very quick method of identifying a fault in the product. By writing software to exercise parts of the circuit while taking current measurements, faults can be traced to specific areas.

5.2.1 Equipment Required

To measure the current consumption, a GPIB-capable digital multimeter will be required - for example, an Agilent 34401A.

5.2.2 Test Limits

Since the current consumption is entirely dependent on the device's design, these test limits must be decided by the developer.

5.2.3 Implementation

The implementation should consist of a number of functions that do nothing other than place the DUT in a given state while the PC application takes a measurement of current using the GPIB digital multimeter.

5.3 Transmit Output Power

Measuring the output power of the transmitter can be a simple way of ensuring the connectivity of components in the transmit RF path (for example, the balun, external power amplifiers or matching circuitry). The test can be performed relatively quickly, so adds little to the overall test time.

5.3.1 Equipment Required

To measure the RF output power of the DUT, the following pieces of equipment will be required:

- GPIB RF power meter (e.g. HP 437B)
- RF power sensor (e.g. HP 8481D)
- RF power splitter (e.g. Mini-Circuits ZN2PD2-50)
- RF signal generator for system calibration
- Assorted RF cables and connectors

5.3.2 Test Limits

For a standard implementation with no external RF power amplification, a system based on a JN513x device should typically generate a signal of around 0.5 dBm.

The upper test limit can be set according to whatever radio standard is in place for maximum output power. A JN513x device without any external RF amplification is unlikely to be able to generate a signal exceeding this level, therefore the upper limit can be ignored.

The lower limit can be chosen by looking at the power that can be realistically expected at the output due to losses in components in the RF path. Around 1.5dB will be lost due to the balun insertion loss and if the DUT is fitted with an SMA connector then at least another 0.1 dB to 0.5 dB due to its insertion loss. These losses combined with the inaccuracies in the power meter (drift over time, etc) require the test limits to be set relatively wide, therefore the limits shown below would be realistic:

Parameter	Lower Limit	Upper Limit
Transmit Output Power	-3dBm	N/A

Table 3: Power Test Limits

5.3.3 Implementation

Refer to the function **bTestTxOutputPower()** in the accompanying file **ExampleSource.c** for an example of how to use the Production Test API to place the DUT in a mode suitable for taking a power measurement.

5.4 Flash Programming

Programming the DUT with its end application code can be performed once the functional tests have been completed. This can be done either using the:

- Jennic JN51xx Flash Programmer tool, or
- functions built into the test applications to get the DUT to reprogramme itself

These methods are expanded on below.

5.4.1 Using the Jennic JN51xx Flash Programmer

If the Jennic JN51xx Flash Programmer is to be used to write the binary image to the DUT then the test system must meet the following requirements:

- There must be a serial connection directly from the PC to the UART 0 connections on the wireless microcontroller.
- The test controller must be able to manipulate the reset signal on the DUT.
- The test controller must be able to hold the SPIMISO signal on the DUT low during device reset to put the wireless microcontroller into programming mode.

This Flash programming tool is described in the *JN51xx Flash Programmer User Guide (JN-UG-3007)*.

5.4.2 Using the DUT to Programme Itself

When using the DUT to programme itself, the PC can pass the binary file to the test controller via the serial connection, which can then pass it on to the DUT, which writes it to Flash memory. In this case, the **.bin** file created by the Jennic toolchain is an image that can be written directly to the Flash memory starting at address zero.

5.4.3 MAC Address and License Key Programming

A unique 64-bit MAC address and, in the case of ZigBee devices, a 128-bit license key must be programmed into the Flash memory at the same time as the application. If using the Jennic JN51xx Flash Programmer, this can be done automatically, reading the MAC and license key from a file on the PC. However, if the DUT is to reprogramme itself, MAC address and license key programming must done by the developer. Flash memory addresses for programming this information is provided in Table 4.

The **.bin** file containing the application has bytes reserved and set to 0xFF at these locations. Therefore, it is possible to write the application binary image to Flash memory, verify it and then, as a second stage, write the MAC address and license keys over the top.

	Location in Flash Memory	
Device	**MAC Address**	**License Key**
JN5121	0x00000024	0x0000002c
JN5139R	0x00000024	0x0000002c
JN5139R1	0x00000030	0x00000038

Table 4: MAC Address and License Key Locations in Flash

5.4.4 Implementation

Refer to the accompanying files **Flash.c** and **Flash.h** for a range of functions that can be used to interact with the SPI Fash memories used with Jennic wireless microcontroller IC's.

6 Test System Calibration

6.1 Introduction

Before any testing can commence, all test equipment should be checked and, if necessary, sent for calibration. Losses in the RF path will also require measurement so that they can be taken into account when performing PER or RF Power measurements.

6.2 Equipment Required

The equipment required to calibrate the RF system is as follows:

- An RF signal generator
- An RF power meter with associated sensor head (e.g. HP 437B with HP8481D power sensor)
- Optionally, a calibration antenna

The RF signal generator is required to inject a signal of a known level into the system, so that losses can be then measured with the RF power meter.

If the DUT has no on-board RF connector, testing must be performed via a pick-up antenna, therefore the signal injected from the signal generator must also be radiated from a calibration antenna in place of the DUT. An example of a calibration antenna is shown in Figure 12.

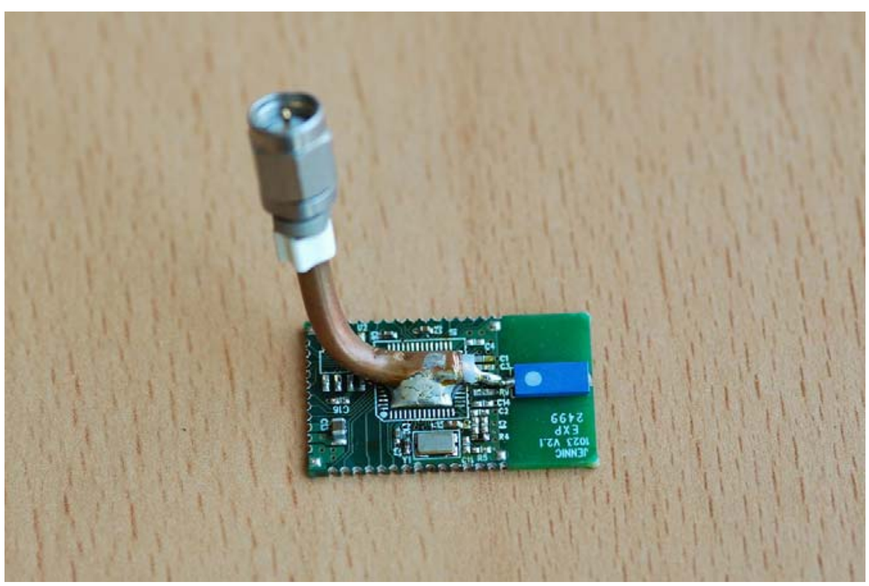

Figure 12: Calibration Antenna

6.3 Calibrating the Power Measurement Path

The following procedure can be used to calibrate the power measurement path:

1. Ensure that all equipment has been recently calibrated and that the power meter has been zeroed.
2. Substitute the RF signal generator in place of the product and inject a signal of around the same amplitude as that expected at the output of the product. For example, if the product is expected to produce an output signal of around 0 dBm, inject a 0 dBm signal and make a note of the actual measured power. This should be done for each operating frequency that the product will support. If the product to be tested has no RF connector then a calibration antenna should be used to inject the signal.
3. Once the measurements have been taken, calibration factors can be calculated so that later, when the product is tested, the true output power can be determined.

For example, if a 0 dBm signal was injected on Channel 11 and the actual measured power at the power meter was –5 dBm, it will be necessary to add 5 dBm to any power measurements taken on Channel 11 to compensate for losses in the measurement path.

Note: Take care to perform the calibration measurement on all channels, since it is possible that the figure will vary from one channel to the next.

Note: Some RF power sensors have a very low maximum input power. It may be necessary to add extra attenuation at the power sensor head to prevent the maximum input power threshold being exceeded. Extra attenuation will then be accounted for during the system calibration process.

Note: If using a splitter in the RF path, ensure any unused ports are terminated with a 50-ohm load.

6.4 Calibrating the PER Measurement Path

The following procedure can be used to calibrate the PER measurement path (the losses in the RF path between the transceiver in the test controller and the DUT):

1. Ensure that all equipment has been recently calibrated and that the power meter has been zeroed.
2. Substitute the RF signal generator in place of the product and inject a signal of around the same amplitude as that expected at the output of the product. For example, if the product is expected to produce an output signal of around 0 dBm, inject a 0 dBm signal and make a note of the actual measured power. This should be done for each operating frequency that the product will support. If the product to be tested has no RF connector then a calibration antenna should be used to inject the signal.
3. Substitute a power meter in place of the test controller and measure the received power level for each channel. The measured value can then be used to calculate the amount of attenuation to add for the PER test.

For example, if a 0 dBm signal was injected on Channel 11 and the actual measured power at the power meter was –5 dBm, and the desired attenuation for the PER test is 80 dB, an attenuator of 75dB would be required.

Note: Take care to perform the calibration measurement on all channels, since it is possible that the figure will vary from one channel to the next.

Note: Some RF power sensors have a very low maximum input power. It may be necessary to add extra attenuation at the power sensor head to prevent the maximum input power threshold being exceeded. Extra attenuation will then be accounted for during the system calibration process.

Note: If using a splitter in the RF path, ensure any unused ports are terminated with a 50-ohm load.

Revision History

Version	Date	Description
1.0	20-Dec-2007	First release
1.1	03-Jan-2008	Cross-references resolved

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