RA4W1 Group

Tuning procedure of Bluetooth dedicated clock frequency

Introduction

This document describes a tuning procedure of a clock frequency for RF transceiver.

Target Device

RA4W1 Group

Note: The contents of this document are provided as a reference and do not guarantee the signal quality in the system. When designing the actual system, thoroughly evaluate the product in the overall system and apply these contents on your own responsibility.

Contents

1. Overview

This document describes a tuning procedure of Bluetooth dedicated clock frequency.

1.1 Related documents

The following documents are related to this application note. Also refer to these documents when using this application note.

[1] Host Controller Interface Firmware (R01AN5429).

[2] Guidelines for 2.4 GHz Wireless Board Design (R01AN4886).

[3] RA4W1 User's Manual: Hardware (R01UH0883).

2. Bluetooth dedicated clock oscillator

Figure 2-1 shows circuit of Bluetooth dedicated clock oscillator. RA4W1 has two load capacitors (CL) internally for the tuning Bluetooth dedicated clock frequency. The internal capacitors are connected to terminals XTAL1_RF and XTAL2_RF respectively. The capacitance of CL can be adjusted in a range of 2-15 pF typically. The oscillation frequency error can be minimized with the appropriate capacitor setting (CLVAL).

The capacitance of PCB pattern between the crystal oscillator and RA4W1 or the parasitic capacitance of the pads for solder mount (Cp1, Cp2) will be factors of oscillation frequency variation. The optimum capacitor setting will be vary depending on the PCB layout as well as the adopted crystal oscillator.

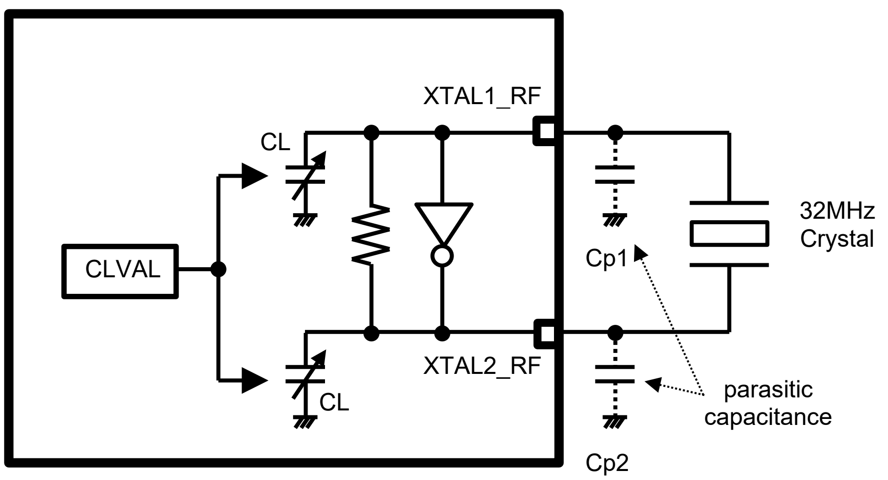

Figure 2-1. Circuit of Bluetooth dedicated clock oscillator.

As shown in Figure 2-2, the obtained “CLVAL” should use as “Bluetooth dedicated clock” configuration in “Bluetooth Abstraction Driver on rm_ble_abs” of RA configurator.

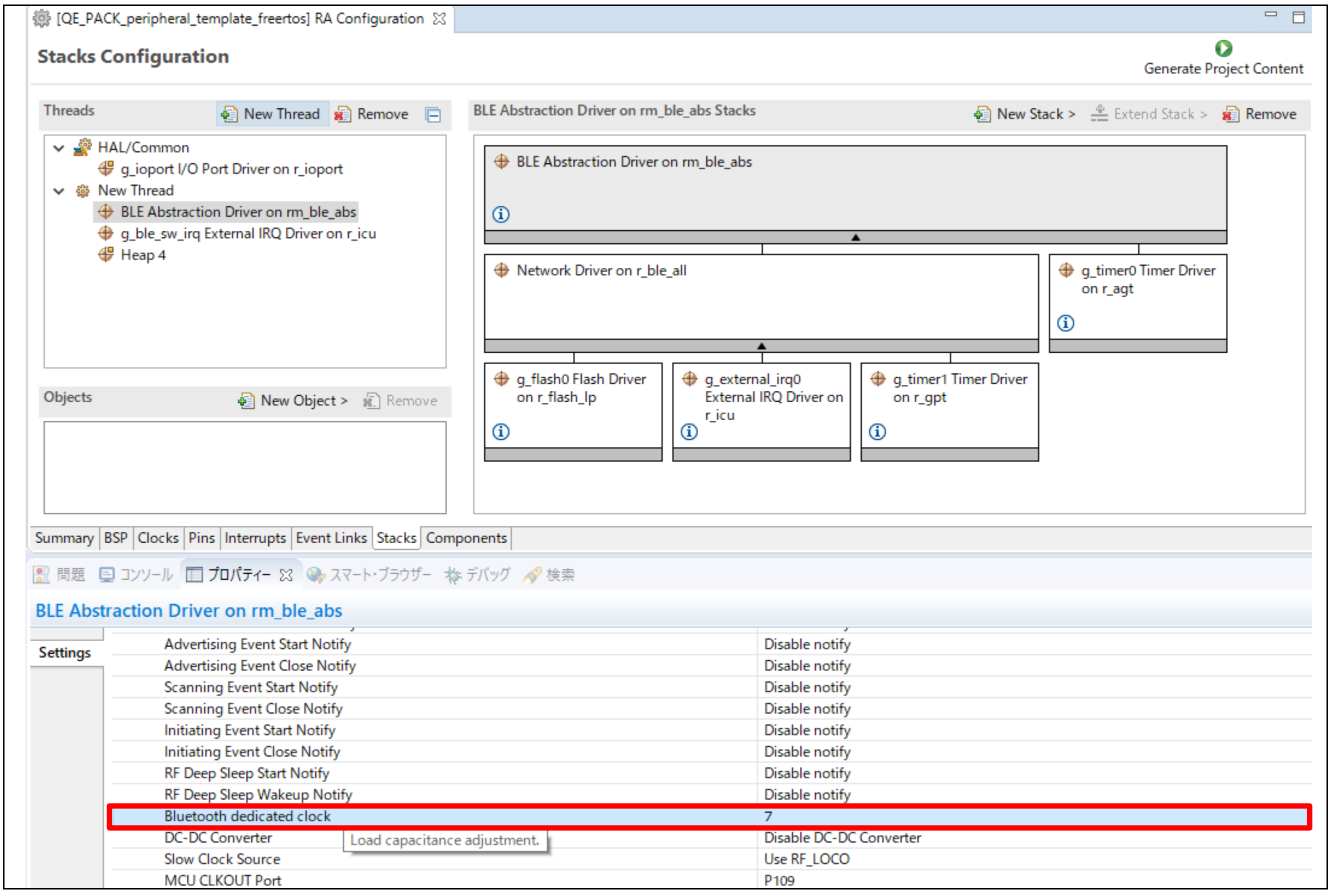

Figure 2-2. RA configurator

3. Frequency tuning procedure

This section describes a tuning procedure of Bluetooth dedicated clock frequency.

3.1 Required software

Required software for Bluetooth dedicated clock frequency tuning is following.

- UART-HCI mode firmware
  Download a “Host Controller Interface Firmware” (R01AN5429 [1]) from Renesas website. Build and program the firmware to RA4W1 which can be executed in a measurement environment.

- CLVALTune.exe
  This software is included in this document (./bin/ CLVALTune.exe).

3.2 Measurement setup

3.2.1 Observing ANT output frequency via cable connection

In the setup of Figure 3-1, 2440 MHz unmodulated signal is output from ANT port, and the signal frequency is measured by spectrum analyzer via coaxial cable connection. The spectrum analyzer is set to the frequency count mode.

- Required equipment
  - RA4W1 evaluation board (PCB)
  - Spectrum analyzer with frequency counter function (over 3GHz)
  - Coaxial cable
  - PC for evaluation
  - USB to UART cable

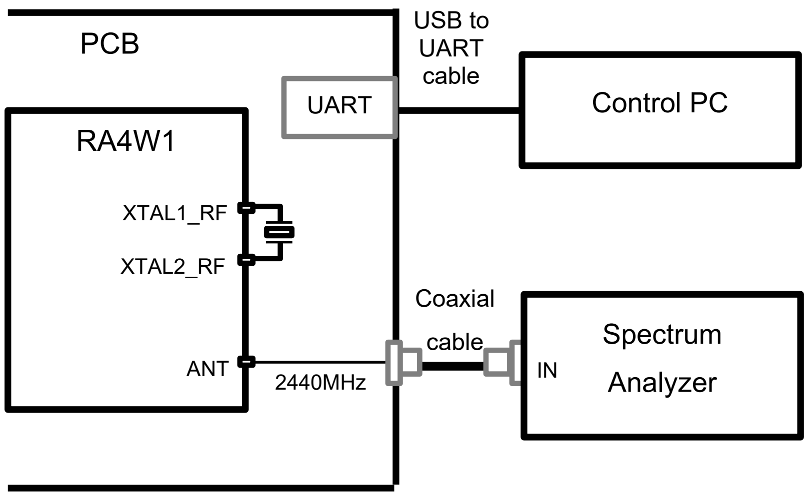

Figure 3-1. Measurement setup of ANT frequency (cable connection)

3.2.2 Observing ANT output frequency via wireless signal

In the setup of Figure 3-2, 2440 MHz unmodulated signal is output from ANT port, and the signal frequency is measured by spectrum analyzer via wireless interface. When this measurement setup is selected, measure the frequency in a noiseless environment without immunity from other 2.4GHz band signal. And keep ANT port of RA4W1 and RF input port of spectrum analyzer as close as possible in order to obtain an enough input amplitude at the RF input port.

If the frequency measurement is unstable, solder a coaxial cable to signal line pattern of ANT directly and connect the coaxial cable to the spectrum analyzer like section 3.2.1.

- Required equipment
  - RA4W1 evaluation board (PCB)
  - Spectrum analyzer with frequency counter function (over 3GHz)
  - Antenna for Bluetooth
  - PC for evaluation
  - USB to UART cable

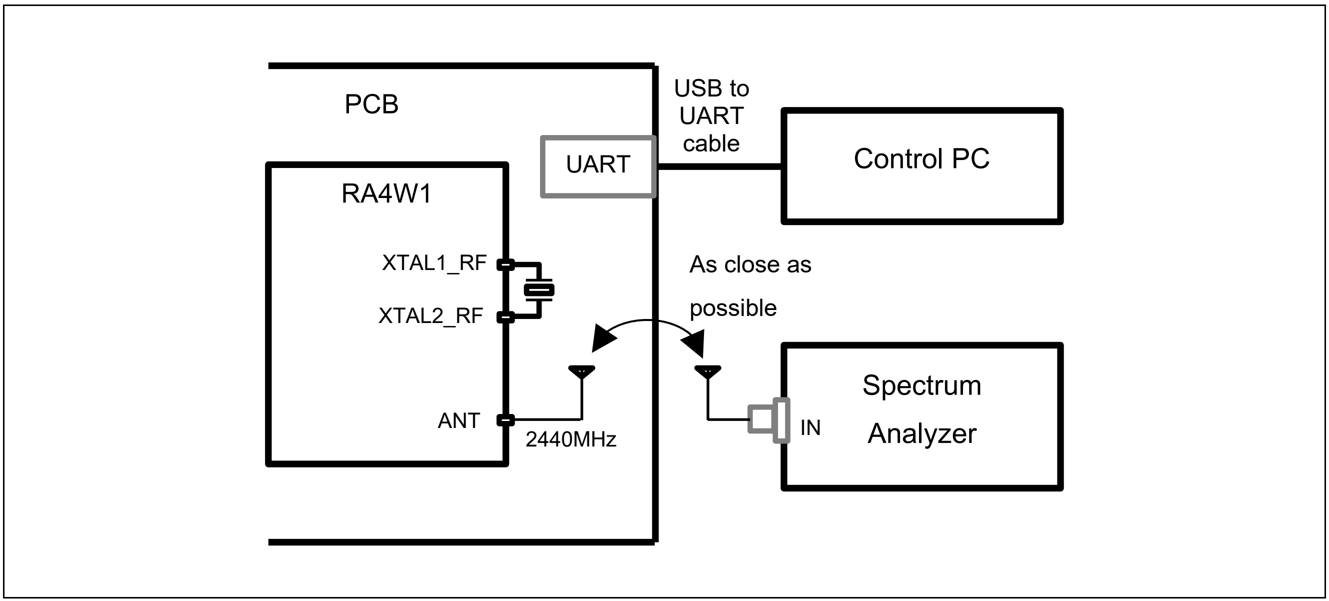

Figure 3-2. Measurement setup of ANT frequency (wireless connection)

3.3 How to use “CLVALTune.exe”

This section describes how to use “CLVALTune.exe”. When using “CLVALTune.exe”, UART-HCI mode firmware which can be executed in the measurement environment is necessary.

Note: When a UART port doesn’t exist in the measurement environment, “CLVALTune.exe” is not available. In this case, refer to Chapter 6.

Figure 3-3 shows “CLVALTune.exe” setting. The setting is common for the cable and wireless connection.

COM port : Depends on PC configuration

Baudrate : Depends on UART-HCI mode firmware (default: 115200 bps)

CLVAL : Capacitor setting for frequency tuning, select an arbitrary value from 0 to 15 (default: 5)

CLKOUT_RF : Select “No output”

Continuous Wave Tx : Select “19ch (2440 MHz)”

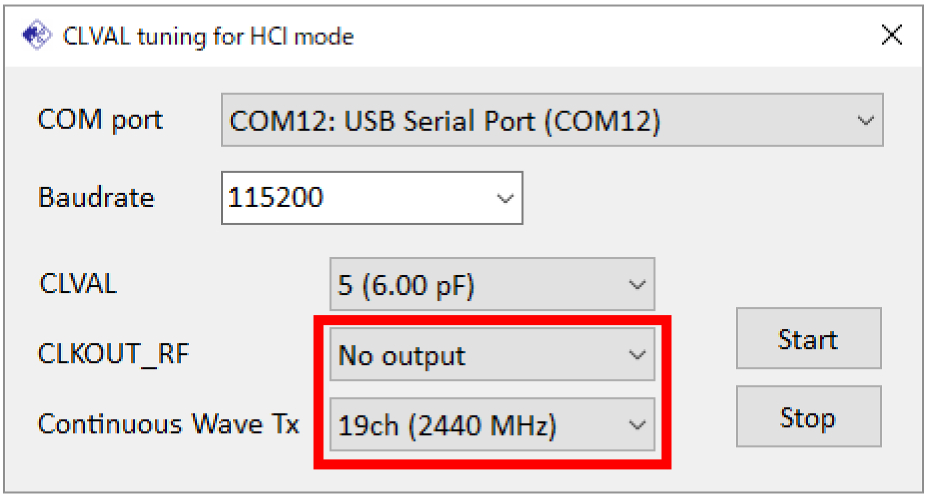

Figure 3-3. Program setting for frequency measurement on ANT port

3.4 Tuning procedure of Bluetooth dedicated clock frequency

A tuning procedure of Bluetooth dedicated clock frequency to determine an optimum capacitor setting (CLVAL) is as follows:

1. Run “CLVALTune.exe” with setting shown in Figure 3-4.
2. Select an arbitrary “CLVAL” setting.
3. Click “Start” button. And then unmodulated signal will output from ANT port.
4. Record the frequency count value on the spectrum analyzer display. Then click “Stop” button. The unmodulated signal from ANT port will stop.
5. When the measured frequency is lower than target frequency (2440 MHz) on ANT port, change value of “CLVAL” to smaller. When the measured frequency is higher than target frequency (2440 MHz), change value of “CLVAL” to larger.
6. Repeat steps from 3 to 5 until the difference between measurement frequency and target frequency (2440 MHz) is minimized and determine an optimal “CLVAL” setting.

When determined “CLVAL” setting value by above procedure, the “CLVAL” should use as “Bluetooth dedicated clock” configuration in “Bluetooth Abstraction Driver on rm_ble_abs” of RA configurator.

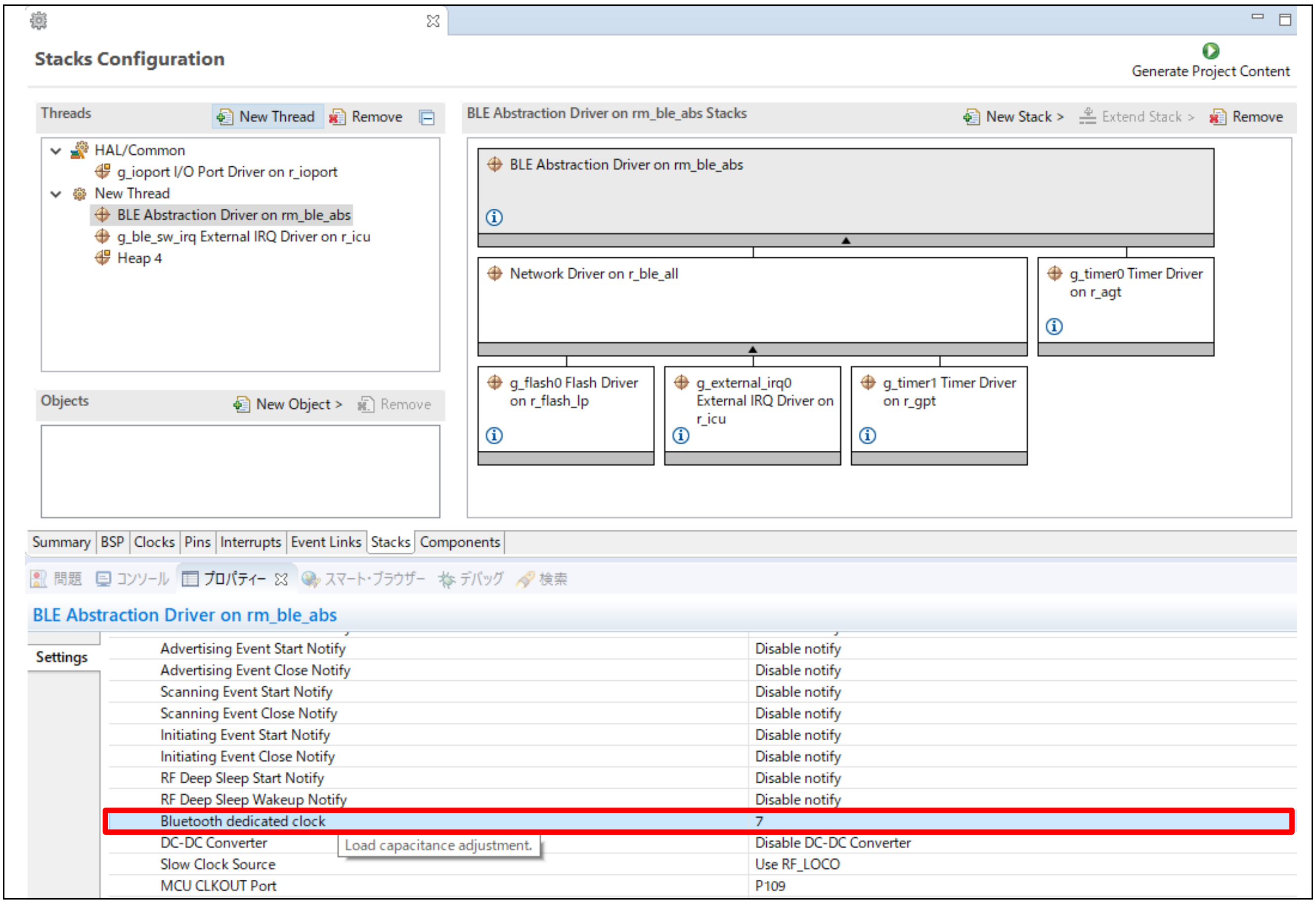

Figure 3-4. Example of a description to configuration parameter

4. Crystal resonator for the RF transceiver

Carefully consider and determine your crystal resonator in consultation with a crystal resonator manufacturer because the oscillation characteristics depend on several factors. This section shows the notification when selecting the crystal resonator.

- A crystal resonator should be selected to meet requirements of your application regulations
  - For example, in the case of the Bluetooth 5.0 standard, the transceiver clock frequency tolerance which includes an initial error, a temperature drift, and an ageing effect should be less than or equal to +/– 50 ppm.

- Recommended electrical characteristics of a crystal resonator are followings:
  - Equivalent series resistance (ESR) ≤ 100 ohm
  - Drive level ≤ 100 uW
  - Load capacitance ≥ 5 pF, ≤ 8 pF
  - Frequency tolerance ≤ +/– 30 ppm

- ESR should not be greater than the recommended parameter. Using a crystal resonator with higher ESR decreases a negative resistance of the oscillator and may be cause of unexpected start-up failure or longer start-up times.

- Selecting a crystal resonator with a small frequency fluctuation against changes in load capacitance, it helps to improve margins for frequency accuracy requirements of your applications. The amount of frequency fluctuation for the load capacitance is different for each crystal oscillator. Please refer to a datasheet of crystal manufacturers and/or contact them for details.

- A performance of crystal oscillator depends on a board design. Please refer to the board design guideline [2].

- Table 4-1 shows candidates of the 32 MHz crystal resonator for the RF transceiver.

Table 4-1. The 32 MHz crystal resonators for RF transceiver

Manufacturer	Parts number	Size code in mm	Tolerance[1] (ppm)	MAX ESR[2] (Ohm)	Load Capacitance (pF)
NDK	NX1612SA-32.000MHZ-CHP-CIS-3	1612	+/– 30	100	6
NDK	NX1210AB-32.000MHZ-CHP-CIX-3	1210	+/– 30	100	6
Kyocera	CX1612DB32000 A0WPNC1	1612	+/– 25	100	5
Kyocera	CX1210SB32000 B0GPJC1	1210	+/– 30	80	6
Murata	XRCMD32M000FZQ52R0	1612	+/– 30	60	6
Murata	XRCTD32M000N1P00R0	1210	+/– 30	120	6

Notes: 1. Where “Tolerance” is a total of “Frequency Tolerance” and “Frequency Stability”.
2. MAX ESR: Maximum Equivalent Series Resistance.

5. Reference

5.1 Example of frequency tuning

This section shows example of frequency tuning. Measurement environment is shown in Table 5-1.

Table 5-1. Environment of frequency tuning

Item	Value
DUT	RA4W1 56pin QFN
Crystal oscillator	NX1612SA-32.000MHZ-CHP-CIS-3 (NDK)
Measuring instrument	E4440A PSA spectrum analyzer (Keysight)
Monitor port	ANT with cable connection

The frequency error plot changing the CLVAL setting is shown in Figure 5-1. The graph shows when CLVAL is 7, the frequency error is minimal.

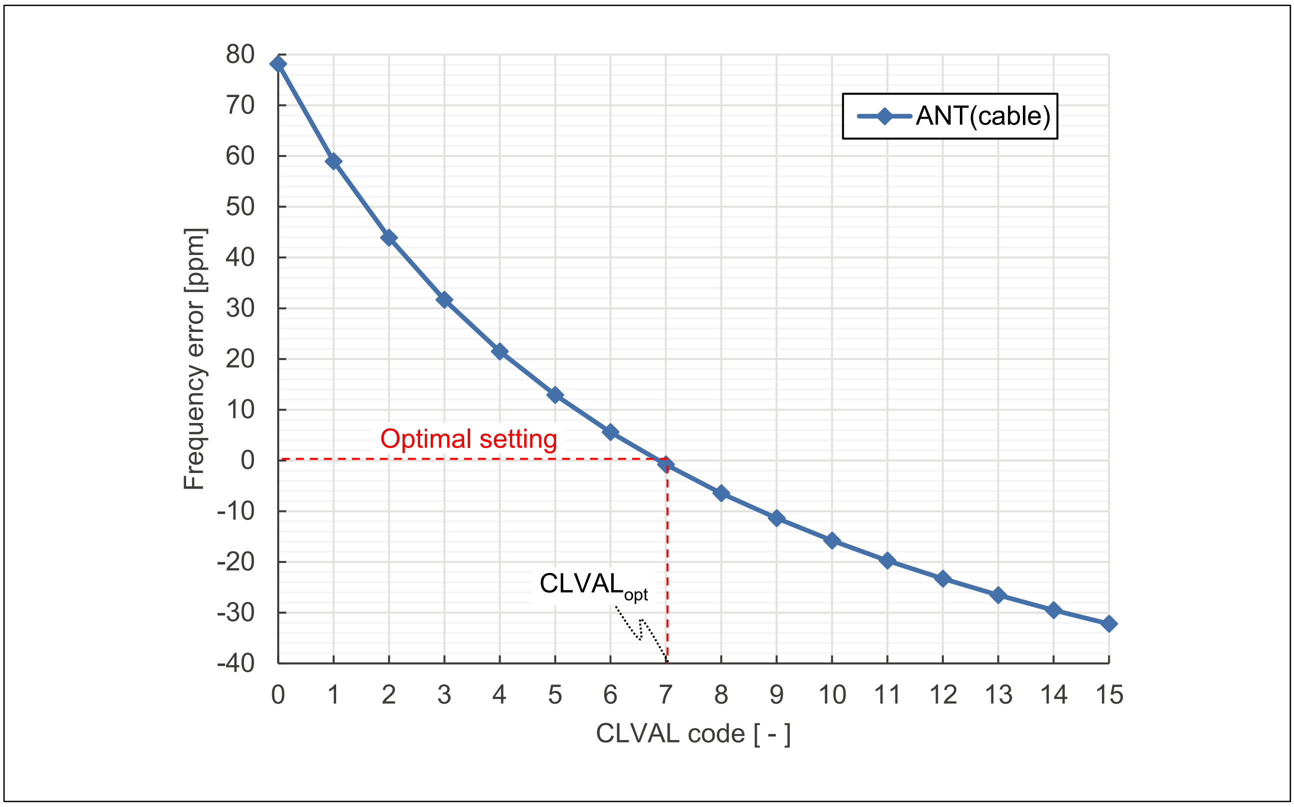

Figure 5-1. Frequency error vs. CLVAL setting

Figure 5-2 is a sample of frequency count display when CLVAL is set to $CLVAL_{opt}$. The frequency count value is 2439.9993MHz and the initial frequency tuning error is (2439.9993−2440)/2440= –0.3 ppm.

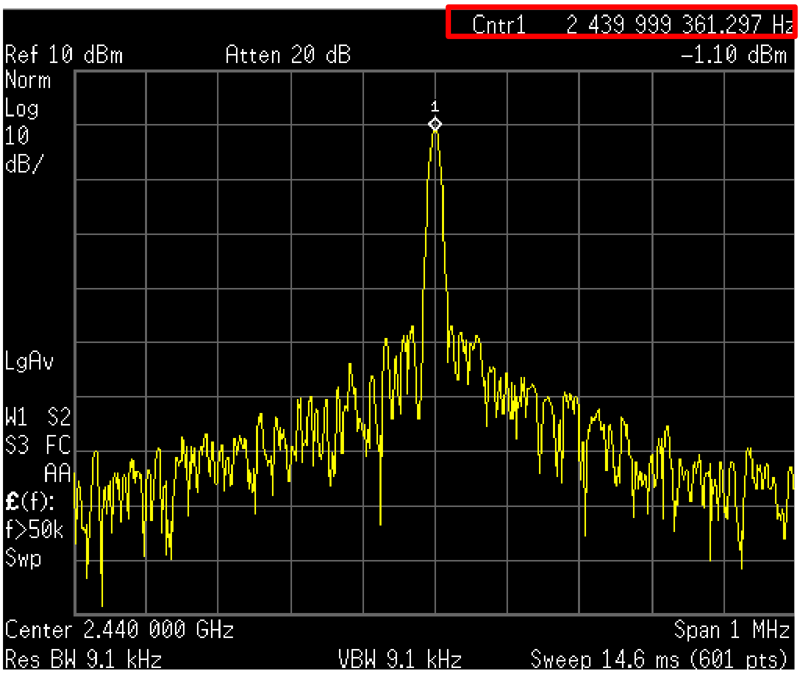

Figure 5-2. E4440A frequency count display

6. Appendix Tuning procedure of Bluetooth dedicated clock frequency without UART

This chapter describes tuning procedure of Bluetooth dedicated clock frequency without UART. In this case, it is necessary to repeat choosing one “CLVAL” from 16 “CLVAL” by using “FrequencyTuningEmbedded.zip” which include this document. The actual procedure is as follows:

1. Make frequency measurement environment according to section 3.2
2. Put “FreqnencyTuningEmbedded.zip” into any folder
3. Launch e^{2}studio (Figure 6-1)

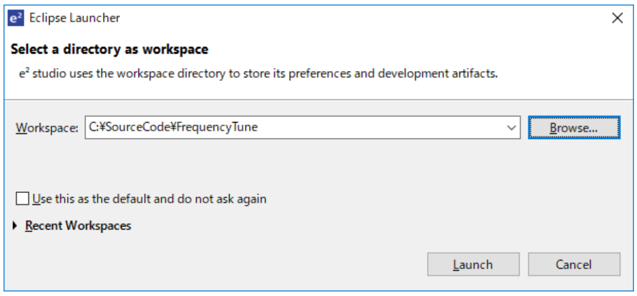

Figure 6-1. Launch e^{2}studio

4. Click [file] → [Import] and then following dialog will appear (Figure 6-2)

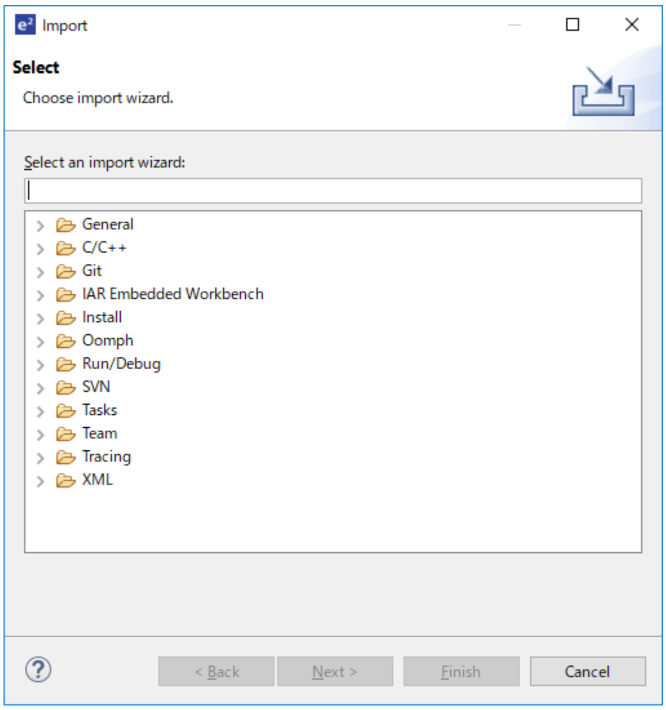

Figure 6-2. Import dialog

5. Select [General] → [Existing Project into workspace] and then following dialog will appear (Figure 6-3)

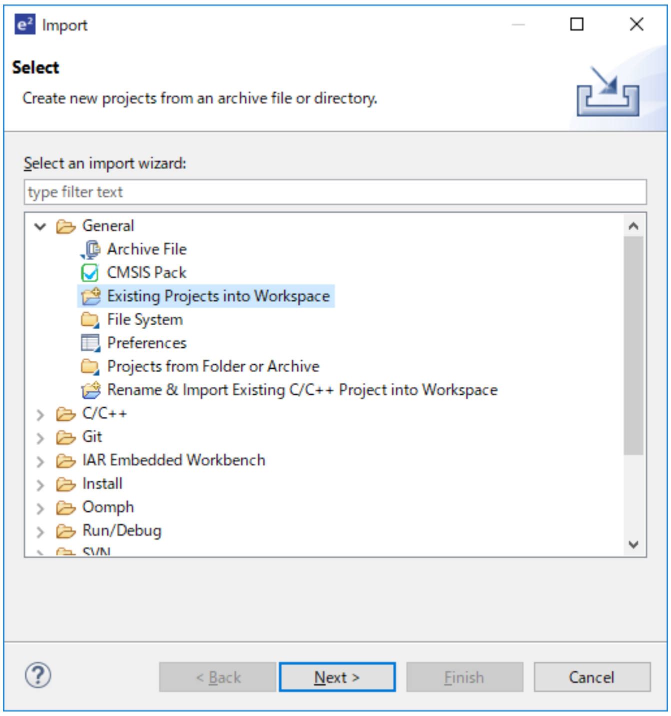

Figure 6-3. Select import wizard

6. Click [Next] and then following dialog will appear (Figure 6-4)

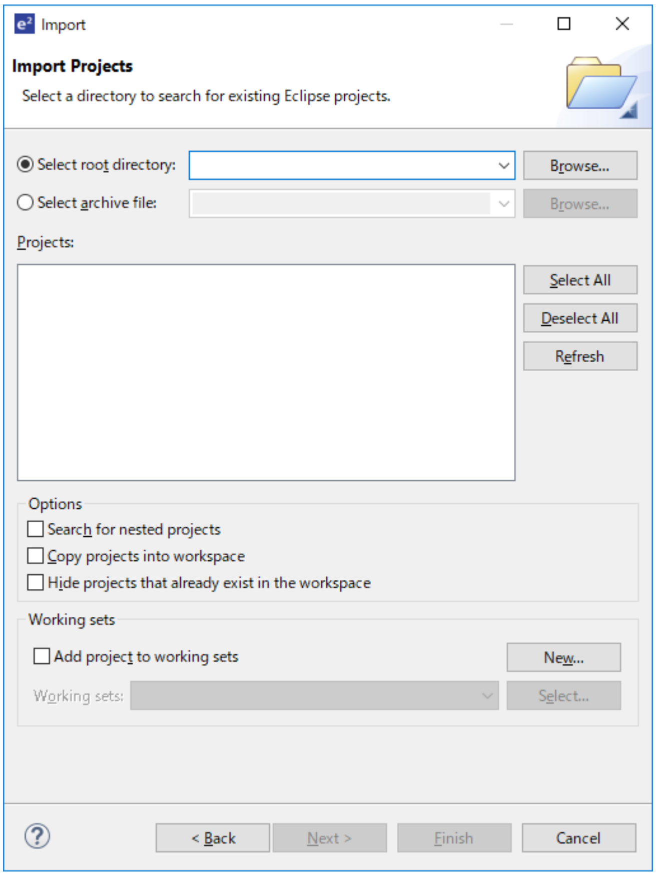

Figure 6-4. Import project dialog

7. Click [Select archive file] and select “FreqnencyTuningEmbedded.zip” which put in step 1 (Figure 6-5)

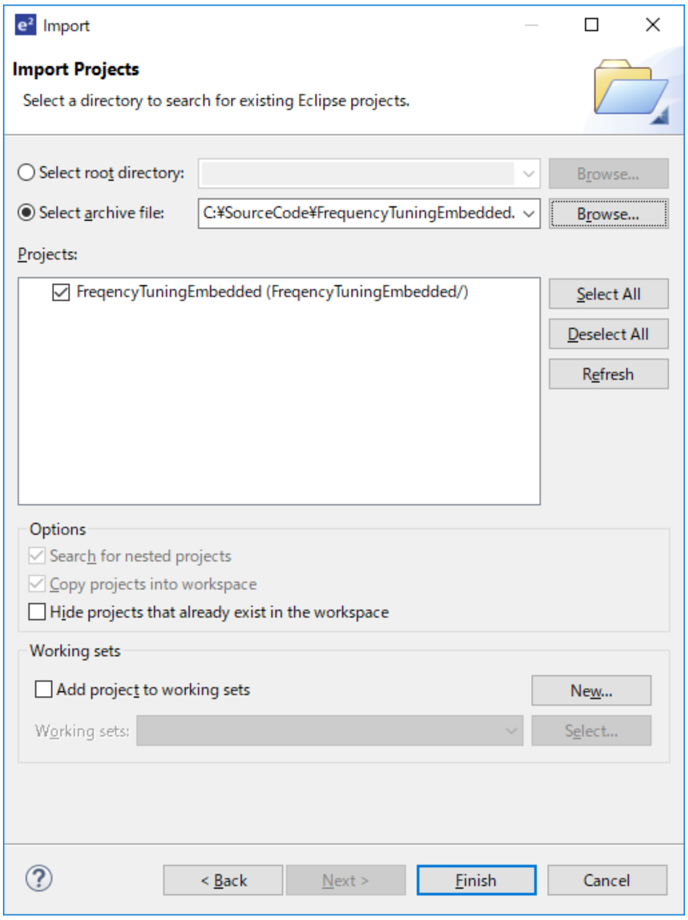

Figure 6-5. Import project from archive file

8. Click [Finish] and then project for frequency tuning will load into e2studio (Figure 6-6)

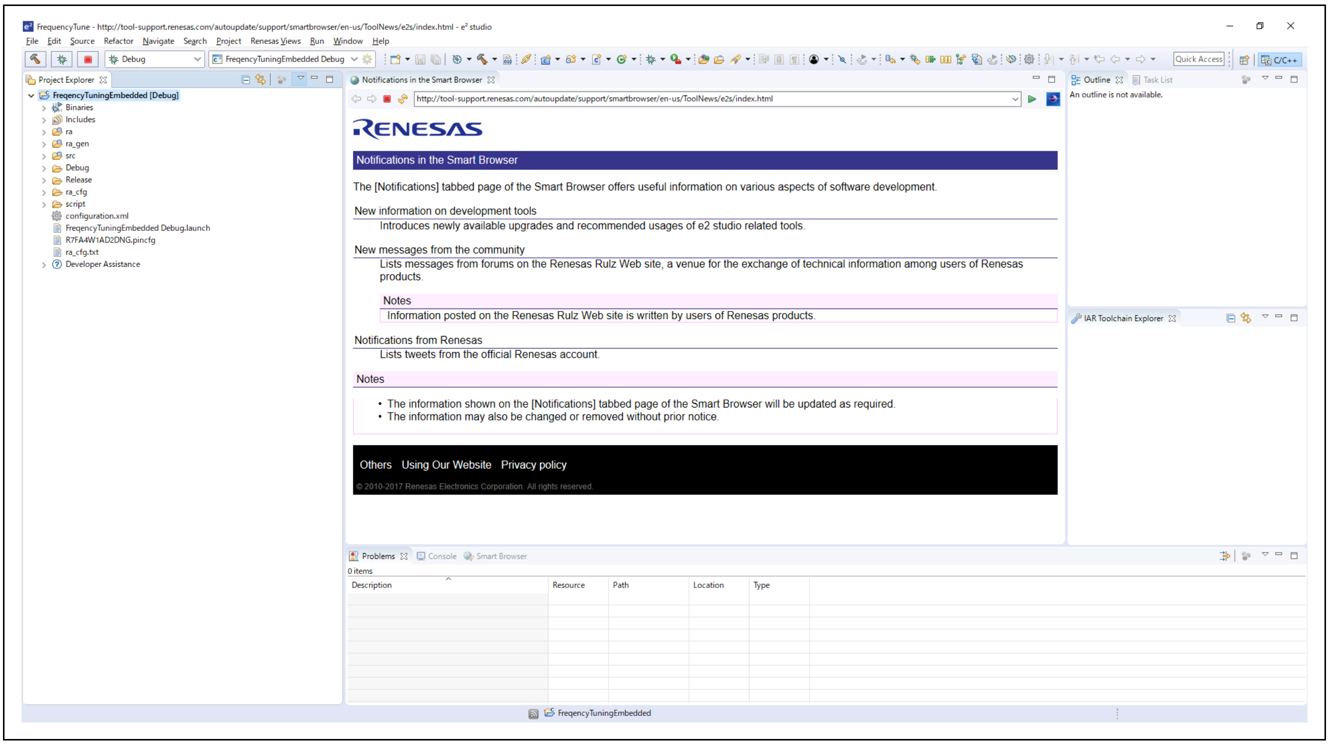

Figure 6-6. e2studio after import project

9. Click [Project] → [RA configurator] and then following dialog will appear (Figure 6-7)

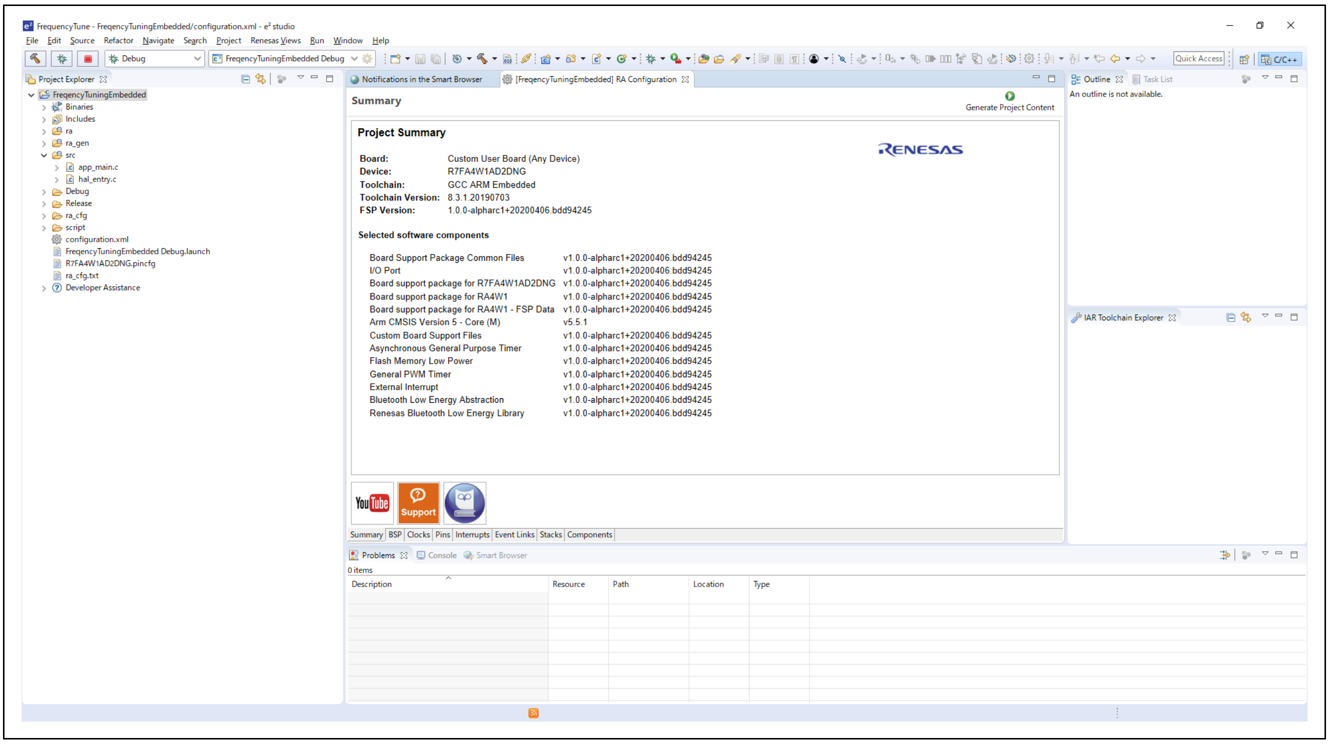

Figure 6-7. RA configurator after import project

10. Select [Stacks] Tab and then following dialog will appear (Figure 6-8)

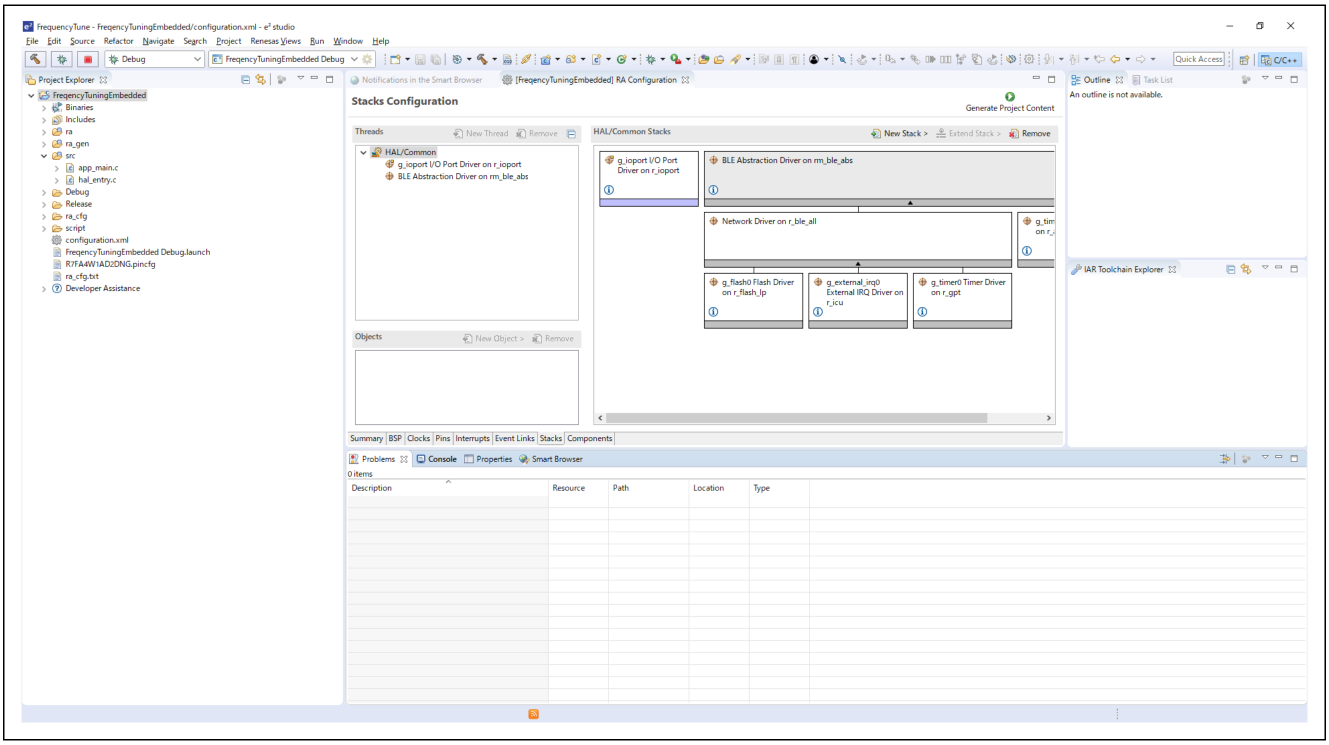

Figure 6-8. Stacks Tab of RA configurator

11. Click “BLE Abstraction Driver on rm_ble_abs” and select “Properties” Tab (Figure 6-9)

    If there are not “Properties” Tab, Click [Window] → [Show View] → [Properties]

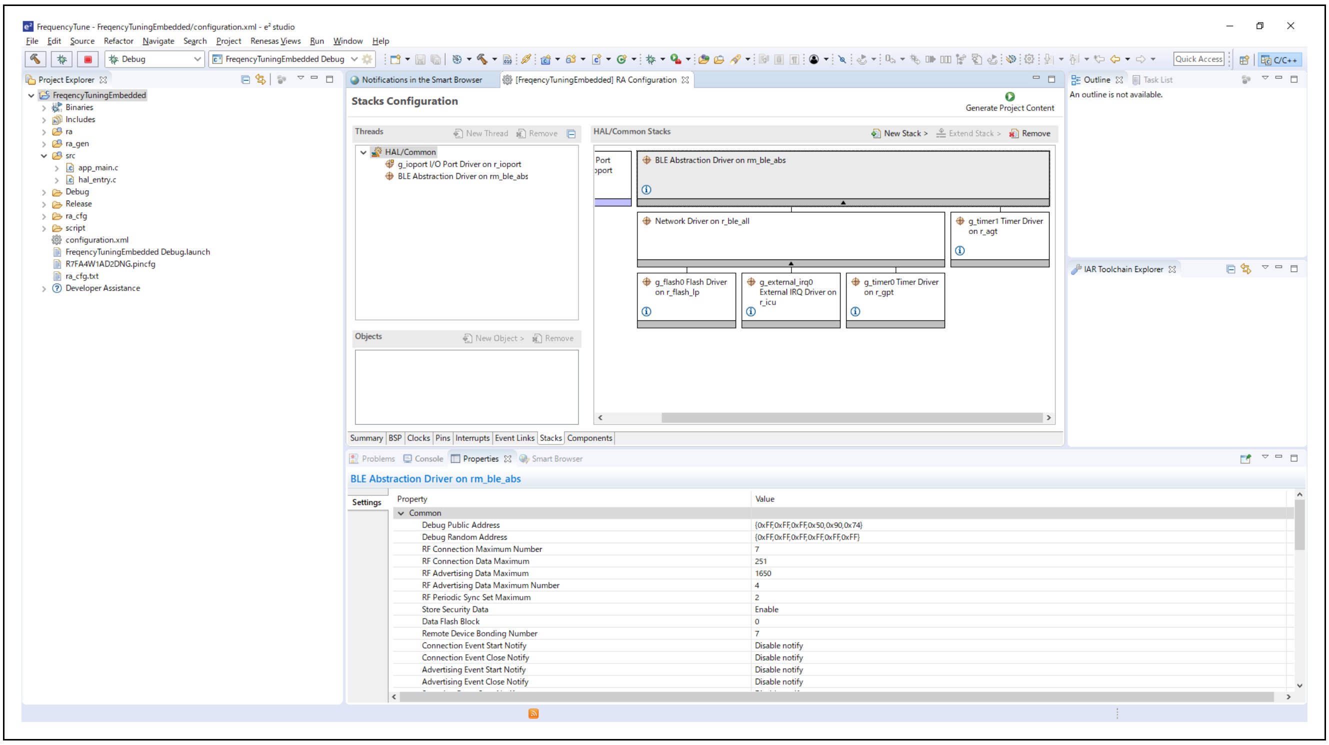

Figure 6-9. Properties of “rm_ble_abs”

12. Choose an “Bluetooth dedicated clock” value between 1 and 16 (Figure 6-10)

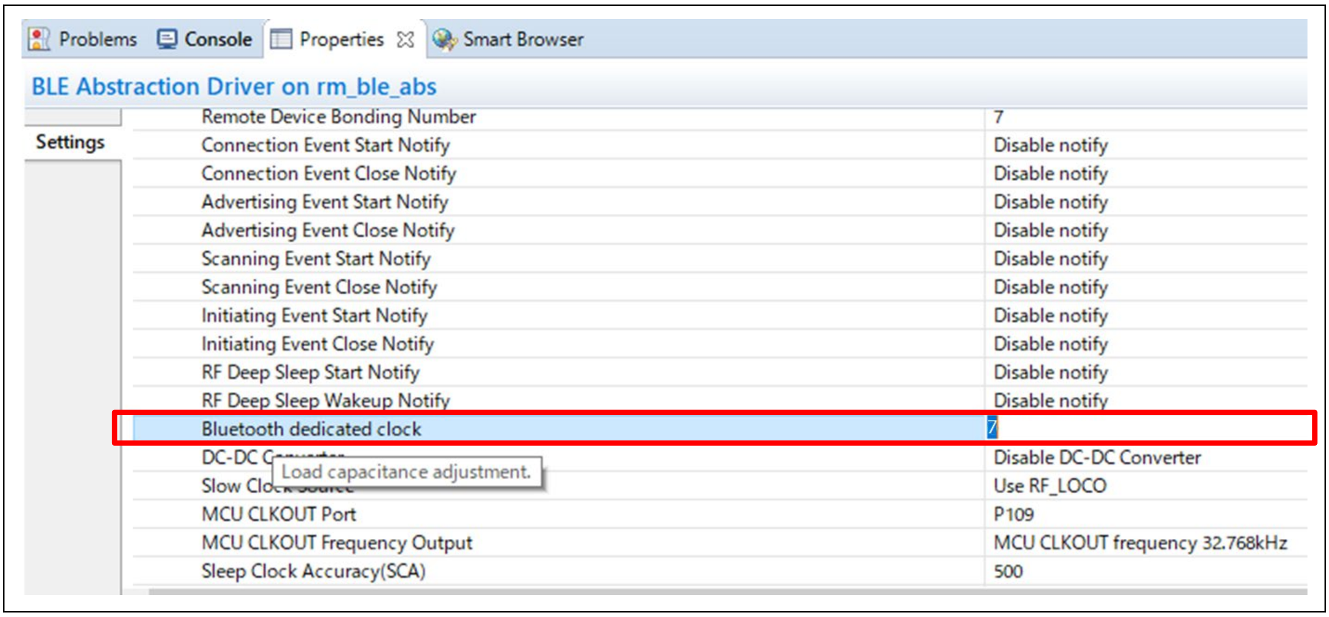

Figure 6-10. Bluetooth dedicated clock

13. Click “Generate Project Contents” and then related code will automatically generate.
14. Build project and program generated binary file.
15. Record the frequency count value on the spectrum analyzer display.
16. When the measured frequency is lower than target frequency (2440 MHz) on ANT port, change value of “Bluetooth dedicated clock” to smaller. When the measured frequency is higher than target frequency (2440 MHz), change value of “Bluetooth dedicated clock” to larger.
17. Repeat steps from 12 to 16 until the difference between measurement frequency and target frequency (2440 MHz) is minimized and determine an optimal “Bluetooth dedicated clock” setting.

Revision History

Rev.	Date	Description	
		Page	Summary
1.00	May.07.20	—	First edition issued

General Precautions in the Handling of Microprocessing Unit and Microcontroller Unit Products

The following usage notes are applicable to all Microprocessing unit and Microcontroller unit products from Renesas. For detailed usage notes on the products covered by this document, refer to the relevant sections of the document as well as any technical updates that have been issued for the products.

1. Precaution against Electrostatic Discharge (ESD)

   A strong electrical field, when exposed to a CMOS device, can cause destruction of the gate oxide and ultimately degrade the device operation. Steps must be taken to stop the generation of static electricity as much as possible, and quickly dissipate it when it occurs. Environmental control must be adequate. When it is dry, a humidifier should be used. This is recommended to avoid using insulators that can easily build up static electricity. Semiconductor devices must be stored and transported in an anti-static container, static shielding bag or conductive material. All test and measurement tools including work benches and floors must be grounded. The operator must also be grounded using a wrist strap. Semiconductor devices must not be touched with bare hands. Similar precautions must be taken for printed circuit boards with mounted semiconductor devices.
2. Processing at power-on

   The state of the product is undefined at the time when power is supplied. The states of internal circuits in the LSI are indeterminate and the states of register settings and pins are undefined at the time when power is supplied. In a finished product where the reset signal is applied to the external reset pin, the states of pins are not guaranteed from the time when power is supplied until the reset process is completed. In a similar way, the states of pins in a product that is reset by an on-chip power-on reset function are not guaranteed from the time when power is supplied until the power reaches the level at which resetting is specified.
3. Input of signal during power-off state

   Do not input signals or an I/O pull-up power supply while the device is powered off. The current injection that results from input of such a signal or I/O pull-up power supply may cause malfunction and the abnormal current that passes in the device at this time may cause degradation of internal elements. Follow the guideline for input signal during power-off state as described in your product documentation.
4. Handling of unused pins

   Handle unused pins in accordance with the directions given under handling of unused pins in the manual. The input pins of CMOS products are generally in the high-impedance state. In operation with an unused pin in the open-circuit state, extra electromagnetic noise is induced in the vicinity of the LSI, an associated shoot-through current flows internally, and malfunctions occur due to the false recognition of the pin state as an input signal become possible.
5. Clock signals

   After applying a reset, only release the reset line after the operating clock signal becomes stable. When switching the clock signal during program execution, wait until the target clock signal is stabilized. When the clock signal is generated with an external resonator or from an external oscillator during a reset, ensure that the reset line is only released after full stabilization of the clock signal. Additionally, when switching to a clock signal produced with an external resonator or by an external oscillator while program execution is in progress, wait until the target clock signal is stable.
6. Voltage application waveform at input pin

   Waveform distortion due to input noise or a reflected wave may cause malfunction. If the input of the CMOS device stays in the area between V_{IL} (Max.) and V_{IH} (Min.) due to noise, for example, the device may malfunction. Take care to prevent chattering noise from entering the device when the input level is fixed, and also in the transition period when the input level passes through the area between V_{IL} (Max.) and V_{IH} (Min.).
7. Prohibition of access to reserved addresses

   Access to reserved addresses is prohibited. The reserved addresses are provided for possible future expansion of functions. Do not access these addresses as the correct operation of the LSI is not guaranteed.
8. Differences between products

   Before changing from one product to another, for example to a product with a different part number, confirm that the change will not lead to problems. The characteristics of a microprocessing unit or microcontroller unit products in the same group but having a different part number might differ in terms of internal memory capacity, layout pattern, and other factors, which can affect the ranges of electrical characteristics, such as characteristic values, operating margins, immunity to noise, and amount of radiated noise. When changing to a product with a different part number, implement a system-evaluation test for the given product.

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