

60 GHz Transmit/Receive (Tx/Rx) Development System



USER GUIDE

PEM009-KIT

Development System Features

- Easiest way to interface with the waveguide modules
- Coaxial baseband connections using MCX and SMA cables
- Power supply voltages provided
- Reference clock provided
- Separate Tx board and Rx board, brackets, tripods
- USB cables for PC - 5V power is derived from USB
- GUI software for easy configuration and module control



Pasternack Enterprises, Inc is the exclusive merchant of the VubIQ® Development System

Click the following link (or enter part number in "SEARCH" on website) to obtain additional part information including price, inventory and certifications: [60 GHz Transmit/Receive \(Tx/Rx\) Development System PEM009-KIT](#)

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Datasheets / Software

Data sheets for the Development System and the Transmitter/Receiver waveguide modules are available at:

www.pasternack.com

The specific links are:

User Guide (this document):

Development System GUI (1.95):

Transmitter Waveguide Module (PEM010):

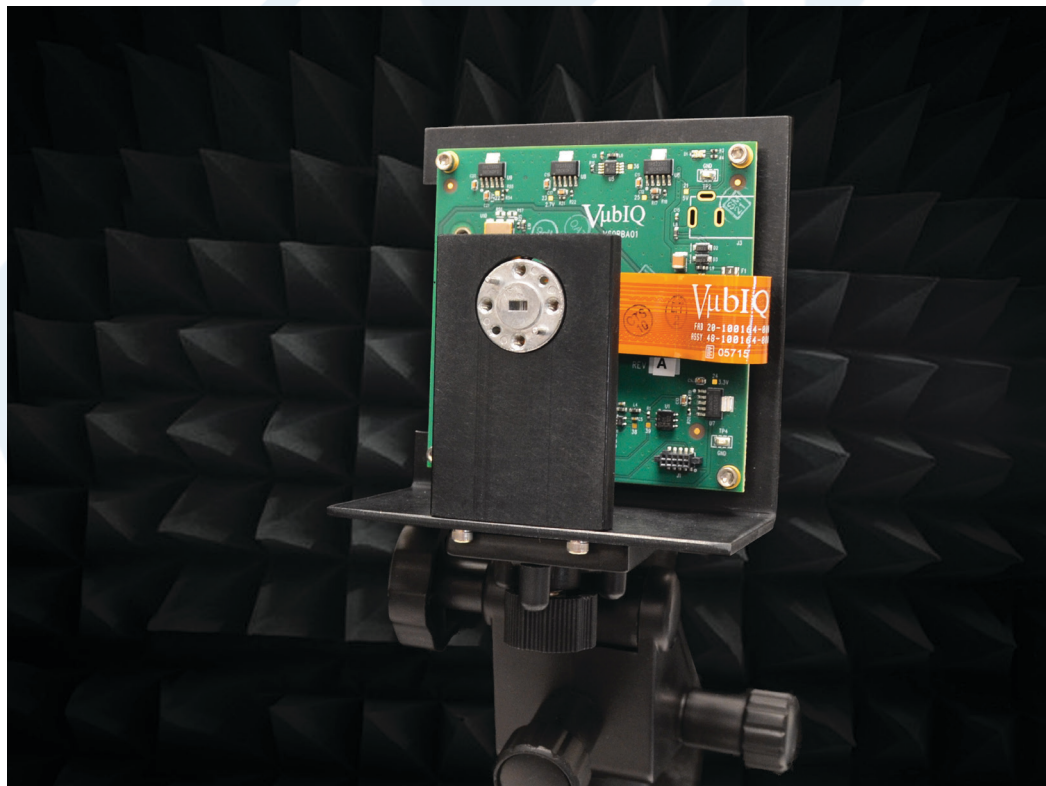
Receiver Waveguide Module (PEM002-MIM):

<http://www.pasternack.com/images/ProductPDF/PEM009-KIT.pdf>

http://www.pasternack.com/images/ProductPDF/PEM009-KIT_60_GHz_Dev_System_GUI.zip

<https://www.pasternack.com/images/ProductPDF/PEM010.pdf>

<http://www.pasternack.com/images/ProductPDF/PEM002-MIM.pdf>



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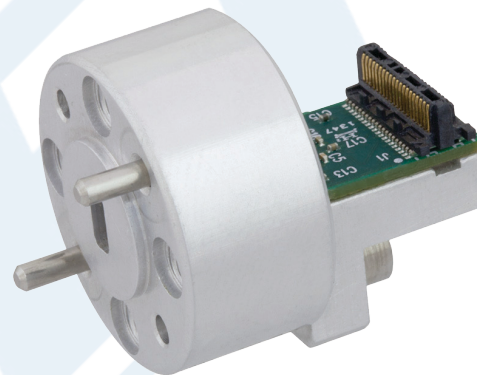
PEM009-KIT

Overview

The PEM009-KIT development system is composed of a millimeter wave transmitter board and receiver board that can be set up and operated using a PC via a simple USB interface on each board. The Rx and Tx board assemblies have built-in reference crystal oscillators (default) which exhibit very good phase noise performance. The Rx and Tx boards also support expansion ports if system level applications may involve the transmitter and/or receiver to be phase locked to an external source. This could involve a User designed baseband system or a programmable arbitrary waveform generator (AWG). The objective of the system is to enable 60 GHz experimentation and product development focused on the use of an integrated transmitter waveguide module and integrated receiver waveguide module with standard WR15/WG25 flange interfaces.

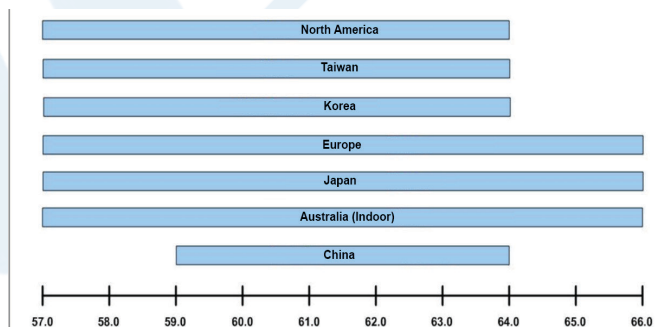


Board Assembly on Tripod



Waveguide Module

Potential applications range from multi-gigabit communications systems such as GigE wireless LAN, 802.15.3c, 802.11ad development, SDI video products, radar, and radiometry. The 60 GHz spectrum is now allocated as unlicensed in many countries world wide.



International Unlicensed Spectrum Allocation for the 60 GHz Band

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Development System Contents

The PEM009-KIT contains the following:

- Transmitter Waveguide Module PEM010
- Receiver Waveguide Module PEM002-MIM
- Transmitter board (1)
- Receiver board (1)
- Board/waveguide module mounting bracket (2)
- Bench top tripod (2)
- USB cable (2)
- GUI software (downloadable from web site)
- Documentation and data sheets (downloadable from web site)
- MCX coaxial connector expansion board (2)
- Power Supply (2)
- Phased matched coaxial cables, MCX to SMA (8)

The transmitter and receiver boards are shipped attached to the mounting brackets. The brackets accept a standard 1/4-20 thread fastener for use with included tripods.

Optional Accessories:

- **PEM004:** [60 GHz Baseband I/Q Module](#)
- **PEM005:** [60 GHz Waveguide Module Flex Circuit Cable \(Replacement\)](#)
- **PE9881-20:** [WR-15 Waveguide Horn Antenna 50 GHz-75 GHz \(20 dBi Gain\)](#)
- **PE9881-24:** [WR-15 Waveguide Horn Antenna 50 GHz-75 GHz \(24 dBi Gain\)](#)
- **PE9881-34:** [WR-15 Waveguide Horn Antenna 56 GHz-66 GHz \(34 dBi Gain\)](#)
- **PE9881-42:** [WR-15 Waveguide Horn Antenna 50 GHz-75 GHz \(42 dBi Gain\)](#)
- **PE-W15A001:** [WR-15 Waveguide Horn Antenna 58 GHz - 63 GHz \(0 dBi Gain\)](#)

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System Setup / Interconnection

The development system boards communicate with a PC (running the GUI software) using USB as the interface. Each board derives its power from the USB connection (standard operation). The control processor on each board communicates with the PC through the USB port.

Baseband signals are connected via the high speed baseband connector on the rear side of each board. The baseband connector is a Samtec QSE. The mating connector required is a Samtec QTE-020-01-L-D-A. The expansion board mounts onto the Samtec QSE connector and is attached to the main board with the supplied hardware, 2 x 4-40 socket head screws.

The expansion board transitions the QSE connector to a set of MCX coaxial connectors for baseband and optional external reference clock signals (see Figure 1). Also supplied with the expansion board is a set of eight phase-matched cables for baseband test equipment interconnection.



Figure 1 RF Board Rear View with Expansion Board Attached

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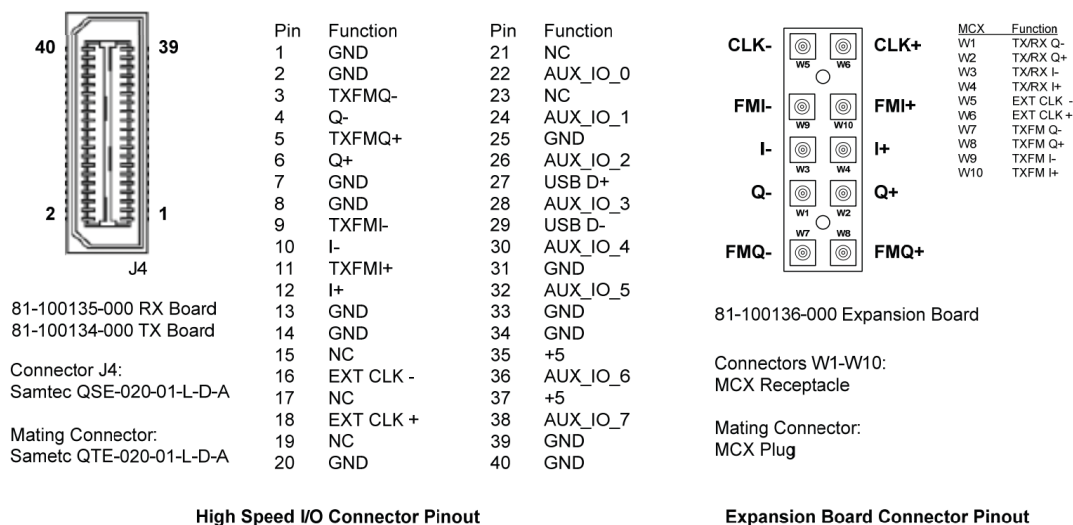


Figure 2 Baseband High Speed Connector and Expansion Board Connectors

Figure 2 shows the pinout of the high speed baseband connector and the expansion board coaxial connectors. For higher level system integration, direct connection via the Samtec high speed connector can be facilitated using the mating Samtec connector as shown.

A typical test set up is shown in Figure 3 below. Here the transmitter baseband source is either a user designed baseband system, or a programmable arbitrary waveform generator (AWG). A two channel AWG can create any form of vector modulation (I and Q baseband) with appropriate programming or selectable standard modulation formats (such as BPSK, QPSK, etc.). The receiver baseband scheme is again either user defined or a signal analysis test system.

By using a programmable AWG for the transmitter baseband source, user defined vector modulation schemes can be created along with various error correction coding, equalization testing, etc. Most AWG products available today work with MATLAB and other tools that provide a convenient method of baseband signal generation.

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GUI Control Software

As shown in Figure 3, the transmitter and receiver boards are set up and controlled from a host PC running the GUI software. The software can be downloaded using [this link](#) as a ZIP file. Unzip the files and place into a convenient directory on the PC that will be used with the development system test setup. With a transmitter and receiver board connected via the USB cables to the PC, run the software (VubiqGUI.exe). A transmitter window and a receiver window will appear showing the block diagrams. The transmitter board LED will illuminate red, and the receiver LED will illuminate blue.

Each GUI window provides the user with the ability to set up various control parameters for the transmitter and receiver boards. Board voltages and temperatures are also monitored. The window images are shown on the following pages, Figures 4 and 5.

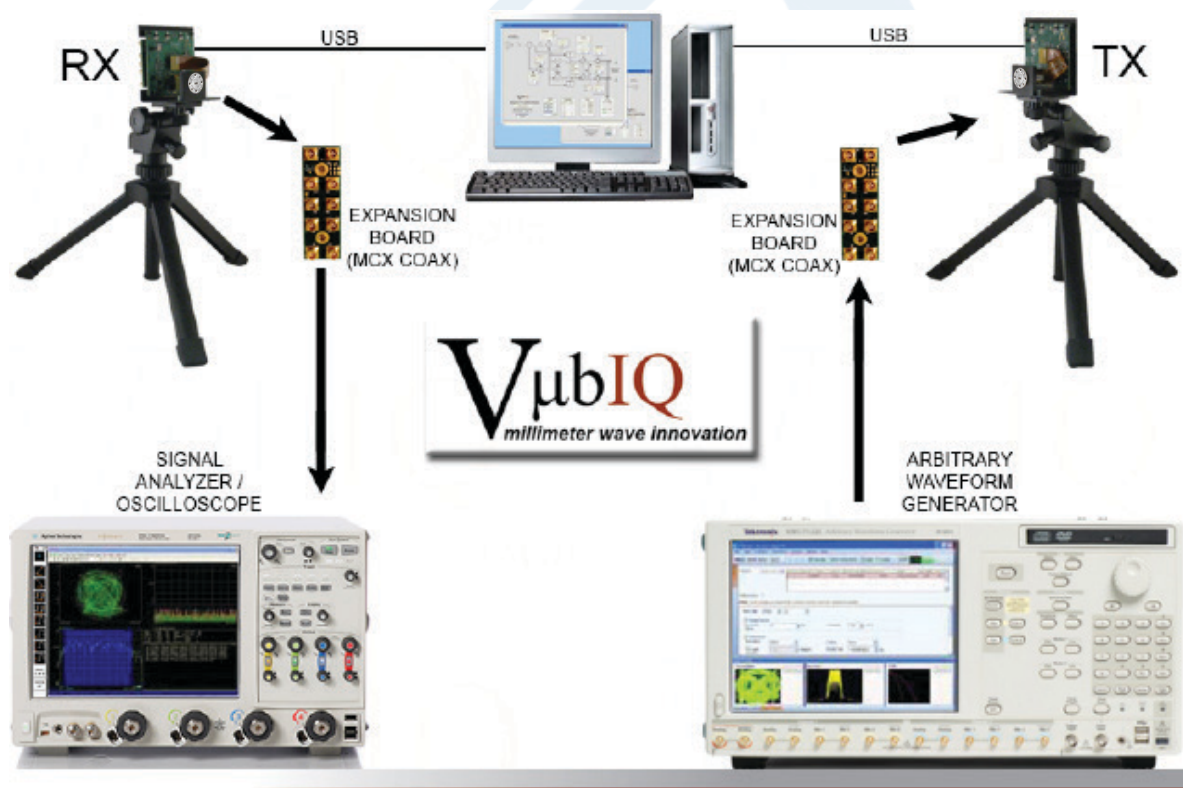


Figure 3 Various Test and Development Scenarios

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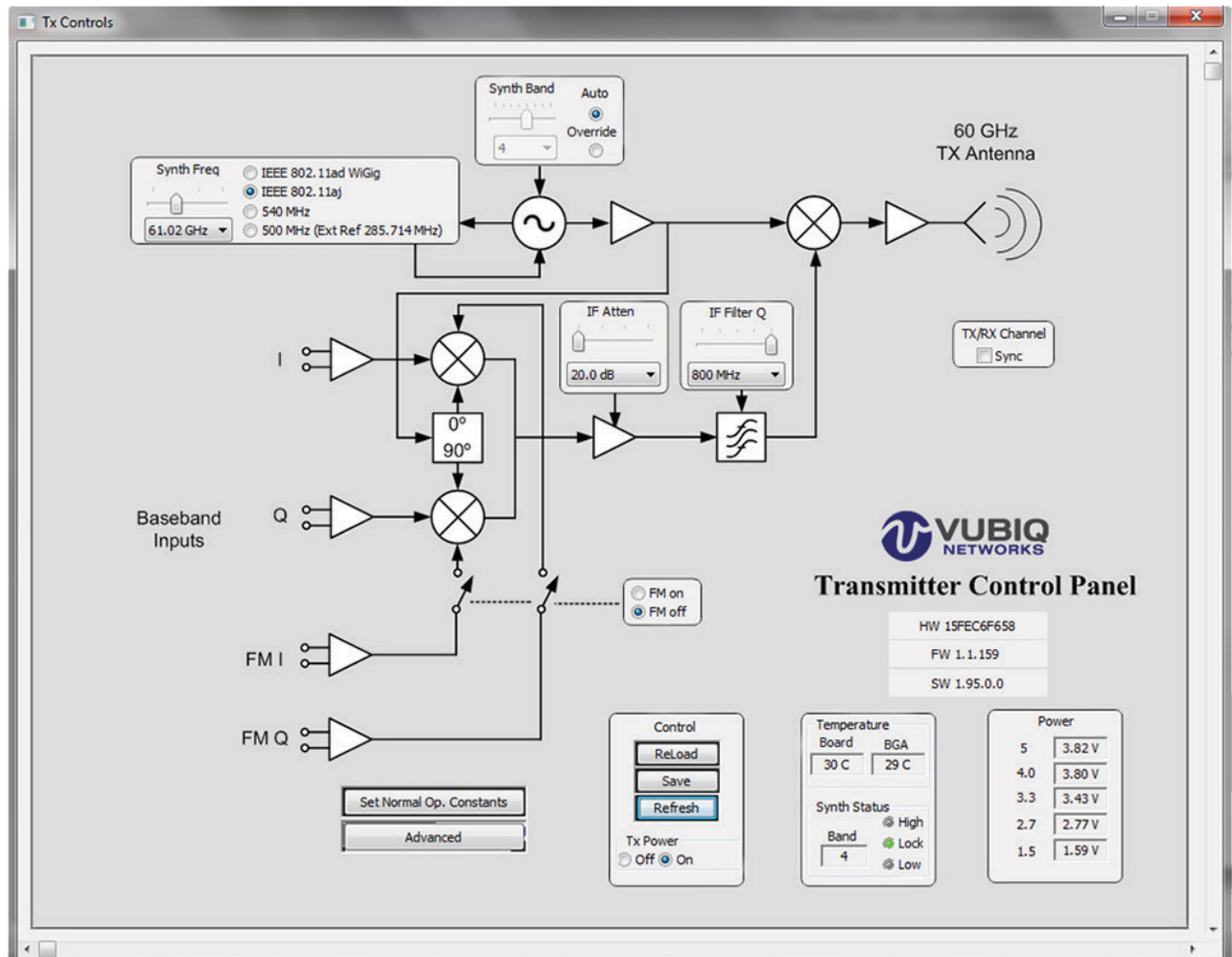


Figure 4 Transmitter GUI Window

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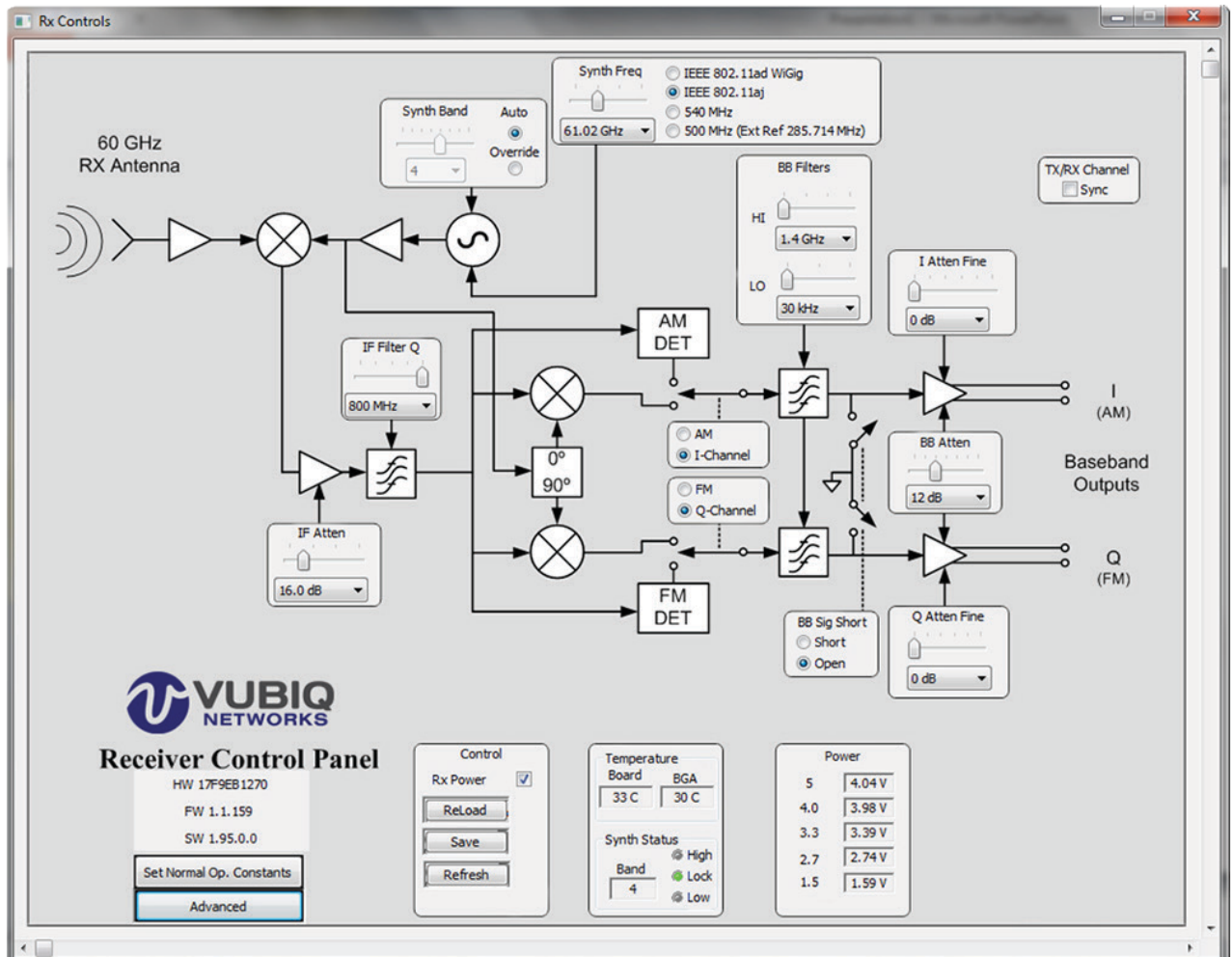


Figure 5 Receiver GUI Window

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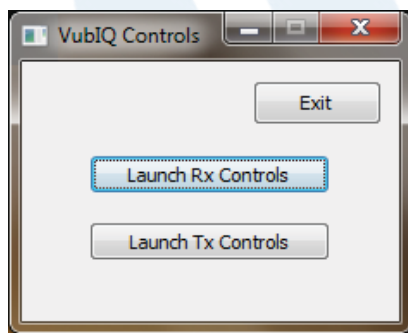
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The window layouts are designed as intuitive block diagrams of the transmitter and receiver waveguide module circuits. There are separate boxes for control and monitoring functions. The following chart (Figure 6) shows the transmitter and receiver functions for each box.

Window Box	TX	RX
Control	X	X
Temperature	X	X
Power	X	X
Baseband		X
Synth Freq	X	X
Synth Band	X	X
IF Atten	X	X
IF Filter Q	X	X
FM on/off	X	
AM/I-Channel		X
FM/Q-Channel		X
BB Filters		X
BB Sig Short		X
BB Atten		X
I Atten Fine		X
Q Atten Fine		X
Baseband		X
Serial Number/Firmware Version	X	X
Set Normal Op. Constants	X	X
Advanced	X	X

Figure 6



The window shown to the left is used to exit the GUI entirely and is generated when the GUI is initialized from the executable. Disregard the "Launch Rx Controls" and "Launch Tx Controls" buttons as these two windows are automatically launched by GUI initialization.

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Control

Rx Power ☒

Reload

Save

Refresh

The Control box (RX shown) provides basic controls for the board which includes following functions:

- Power on/off for the waveguide module
- Reload parameters from FLASH memory
- Save current parameters to FLASH memory
- Refresh GUI display

Note: upon power up, the last set of parameters saved to FLASH memory are used to configure the transmitter or receiver.

Temperature

Board	Module
32 C	31 C

Synth Status

Band ☐ High

6 ☒ Lock

☐ Low

The Temperature/Synth box monitors the board temperature and the RF module temperature in °C. The synth status section indicates the synthesizer lock status and the band tuning status.

Power

5	4.35 V
4.0	3.98 V
3.3	3.31 V
2.7	2.69 V
1.2	1.55 V

Power supply voltages are monitored in this box. Note: the 5 volt supply is measured from the USB source and typically runs at about 4.1 to 4.4 V.

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Synth Freq

62.64 GHz

☒ IEEE 802.11ad WiGig
☐ IEEE 802.11aj
☐ 540 MHz
☐ 500 MHz (Ext Ref 285.714 MHz)

The module's operating frequency is set with the Synth Freq box shown above. This control sets the synthesizer digital divisor ratio in the RF module. The standard frequency range can be set from 57.24 GHz to 64.80 GHz in 0.54 GHz steps. Optionally, the RF modules can be set from 57.0 GHz to 64.0 GHz in 0.5 GHz steps with a reference oscillator clock of 285.714 MHz. The synth frequency box has pre-configured frequency subsets corresponding to 802.11ad/WiGig, 802.11aj, or fixed spacing at 540 MHz (optionally 500 MHz). The frequency can be selected with either the slider control or the drop down menu. Occasionally, when selecting a frequency, the module may not respond to the first requested input. This can be remedied by selecting the desired frequency from the drop down menu a second time.

Synth Freq

57.24 GHz

☐ IEEE 802.11ad WiGig
☐ IEEE 802.11aj
☒ 540 MHz
☐ 500 MHz (Ext Ref 285.714 MHz)

57.24 GHz

57.78 GHz

58.32 GHz

58.86 GHz

59.40 GHz

59.94 GHz

60.48 GHz

61.02 GHz

61.56 GHz

62.10 GHz

62.64 GHz

63.18 GHz

63.72 GHz

64.26 GHz

64.80 GHz

Synth Freq

58.32 GHz

☒ IEEE 802.11ad WiGig
☐ IEEE 802.11aj
☐ 540 MHz
☐ 500 MHz (Ext Ref 285.714 MHz)

58.32 GHz

60.48 GHz

62.64 GHz

64.80 GHz

Synth Freq

59.94 GHz

☐ IEEE 802.11ad WiGig
☒ IEEE 802.11aj
☐ 540 MHz
☐ 500 MHz (Ext Ref 285.714 MHz)

59.94 GHz

61.02 GHz

62.10 GHz

63.18 GHz

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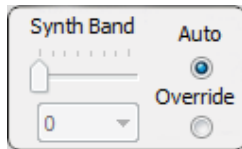
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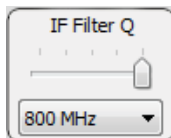
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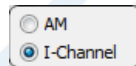
The Synth Band box is typically set in Auto mode, and will track the Synth Freq settings. This box allows separate tuning adjustment of the VCO tank circuit for experimentation (Override Mode).



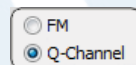
IF Atten box sets the IF attenuation for either the TX or RX board. The lower the attenuation level (in dB), the higher the gain setting. When this control is set to 0.0 dB, the IF gain is at maximum. The slider control or drop down menu can be used; there are 16 settings from 0 dB to 20 dB.



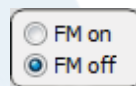
The IF Filter Q box is a coarse IF bandwidth control, providing highest Q (narrowest bandwidth) at 800 MHz, and lowest Q (widest bandwidth) at 1.2 GHz. There are 5 settings from 800 MHz to 1.2 GHz.



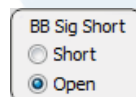
The AM / I-Channel control box (RX only) selects the I-channel demodulator (default) or the AM detector. When the AM detector is selected, its output signal is routed through the I baseband channel.



The FM / Q-Channel control box (RX only) selects the Q-channel demodulator (default) or the FM detector. When the FM detector is selected, its output signal is routed through the Q baseband channel.



The FM on/off control box (TX only) activates the additional FM switching modulators in the I/Q modulation stage. When selected, FSK type modulation can be set up by using the FMI and FMQ baseband signal inputs in conjunction with the I and Q signal inputs.



The baseband signals can be removed from the output stages (effectively shorted to ground) using the BB Sig Short box (RX only). This feature may be helpful during testing if no signals are desired (quiet channel) at the baseband outputs.

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BB Filters

HI

LO

The bandwidth of the two baseband channels can be set with the BB Filters box (RX only). The high frequency roll off selection (HI) is set with either its slider control or the drop down menu (settings at 200 MHz, 300 MHz, 500 MHz and 1.4 GHz). The low frequency roll off selection (LO) is set with either its slider control or drop down menu (settings at 30 kHz, 300 kHz and 1.5 MHz). Note: these filters are very broad, approximately 2nd order Butterworth response.

BB Atten

The BB Atten box (RX only) is used to set the gain of the baseband amplifiers. The lower the attenuation level (in dB), the higher the gain setting. When this control is set to 0.0 dB, the baseband gain is at maximum. The slider control or drop down menu can be used; there are 7 settings from 0 dB to 36 dB

I Atten Fine

Q Atten Fine

There are two attenuators for fine gain adjustment of the I and Q channels, the I Atten Fine and Q Atten Fine boxes (RX only). These provide a convenient method for balancing the I and Q receive baseband levels or for fine adjustment in 1 dB steps. The slider controls or drop down menus can be used to adjust the attenuation in 1 dB increments from 0 dB to 5 dB (6 settings).

These two controls, common to the TX and RX, are used to reset the default register data to the RF modules (Set Normal Op. Constants) and to bring up a detailed RF module register screen (Advanced).¹

HW 15FEC6F658

FW 1.1.159

SW 1.95.0.0

Each transmitter board and receiver board has a unique serial number (HW). Also, the firmware release version (FW) and the software release version (SW) are shown in the same box.

¹ The Advanced screen provides access to individual data registers for the RF modules. Changing these register values through the Advanced screen is not normally required since the GUI interface provides the most commonly used control functions.

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Reference Oscillator Source Options

The transmit and receive boards come with built-in low phase noise crystal oscillators that provide the clock reference frequency for the TX/RX synthesizers. The frequency of the on-board oscillator is 308.571 MHz (540 MHz channel spacing) and has a stability rating over temperature of 25 ppm. There may be certain system level applications that require the transmitter and/or receiver to be phase locked to an external source. Also, if 500 MHz channel spacing is desired, the external reference clock must be 285.714 MHz. The TX/RX RF boards are set up to provide the following options for oscillator reference source:

1. Internal, separate crystal oscillators (default)
2. External 308.571 MHz or 285.714 MHz signal source such as a laboratory signal generator (0 dBm typical)
3. Transmitter sourcing the receiver (TX master/RX slave) from the TX on board oscillator

The optional reference oscillator settings are implemented via zero-ohm resistor (or wire jumper) modifications on the TX and RX RF boards as required. The schematics and pictures on the following pages are provided to illustrate the modifications for the desired settings (Figures 7 through 10).

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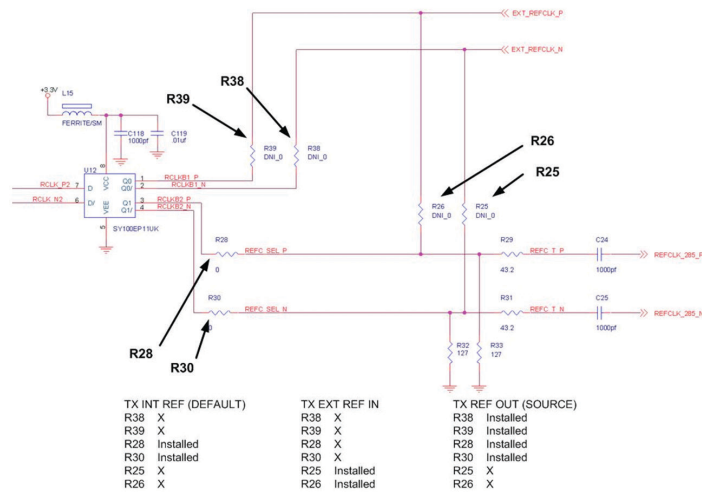


Figure 7 Transmit Board Reference Oscillator Configurations

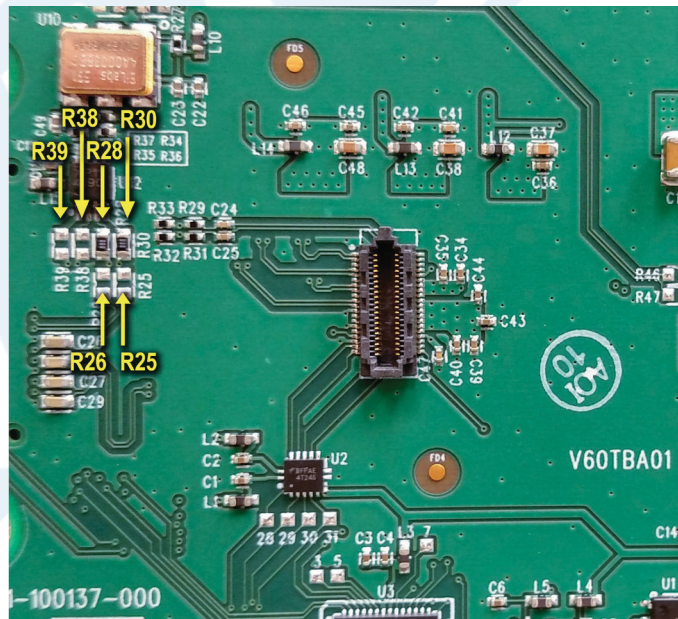


Figure 8 Transmit Board Reference Oscillator Resistor Locations

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60 GHz Transmit/Receive (Tx/Rx) Development System

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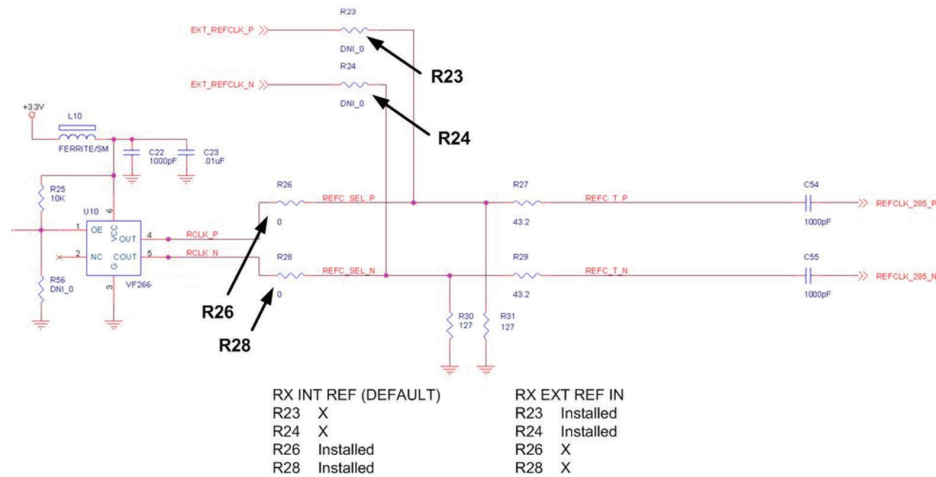


Figure 9 Receive Board Reference Oscillator Configurations

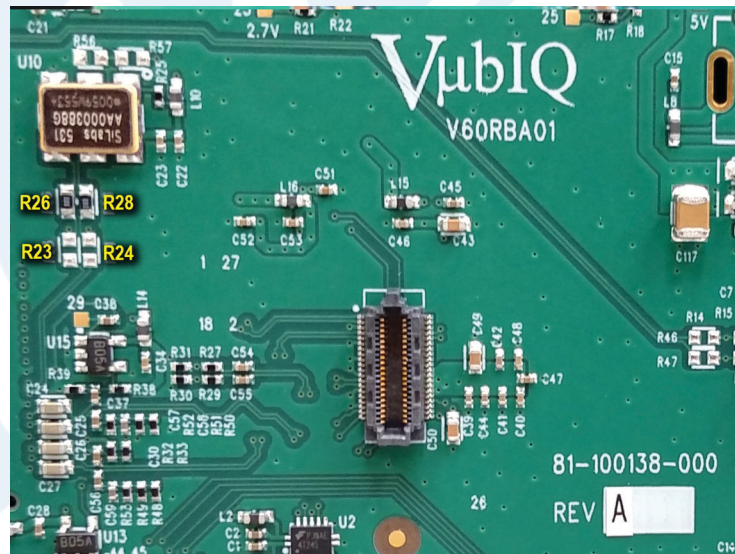


Figure 8 Receive Board Reference Oscillator Resistor Location

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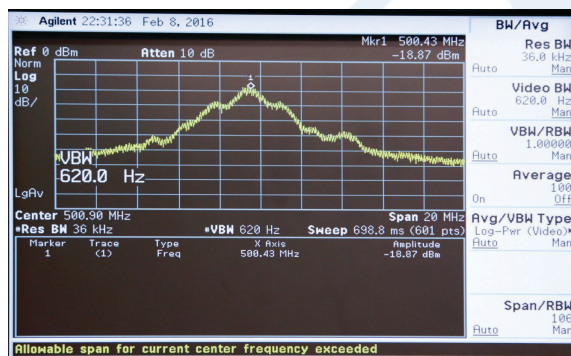
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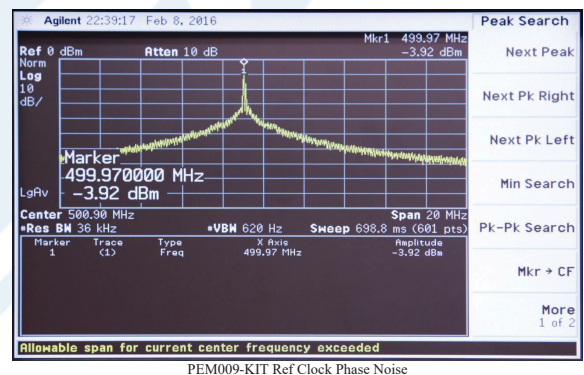
Internal Reference Oscillator Source used for simple (CW) Signal Transmission

The internal reference Oscillator source (308.571 MHz) is enabled by setting the preconfigured Synthesizer Frequency box to 540 MHz channel spacing. A standard frequency range can be set from 57.24 GHz to 64.80 GHz in 0.54 GHz steps. In situations where a simple continuous wave (CW) carrier signal from the 60 GHz transmitter needs to be demonstrated or diagnosed for testing purposes, the optional PEM004 60 GHz Baseband I/Q Module can be used as a signal source to provide a stable, clean 500 MHz waveform with tightly controlled phase between the I and Q outputs, that will cancel out the carrier and lower sideband frequencies and only transmit the upper sideband frequency. As an example, if the PEM009-KIT transmitter carrier is set at 58.32 GHz, and the PEM004 is connected to the I and Q baseband inputs, the resulting frequency at the transmitter output will be $58.32 \text{ GHz} + 500 \text{ MHz} = 58.82 \text{ GHz}$. The original carrier frequency at 58.32 GHz will be suppressed as well as the lower sideband at 57.82 GHz.

Rx Single Sideband Carrier Measurements (same settings) for PEM003-KIT (Original Design) and PEM009-KIT (New Design) using the PEM004 I/Q Module Accessory



- Original PEM003-KIT design virtually masks the Rx Carrier Signal Reponse
- Noise Floor is elevated due to added noise contribution from internal reference Oscillator
- Rx Carrier Level: Marker 1 = 500.43 MHz @ -19.15 dBm



- New PEM009-KIT design displays more pronounced output carrier amplitude response due to the improved signal to noise performance
- Better Rx sensitivity due to improved local oscillator phase noise performance for both Tx and Rx PWB's
- Rx Carrier Level: Marker 1 = 499.97 MHz @ -3.89 dBm

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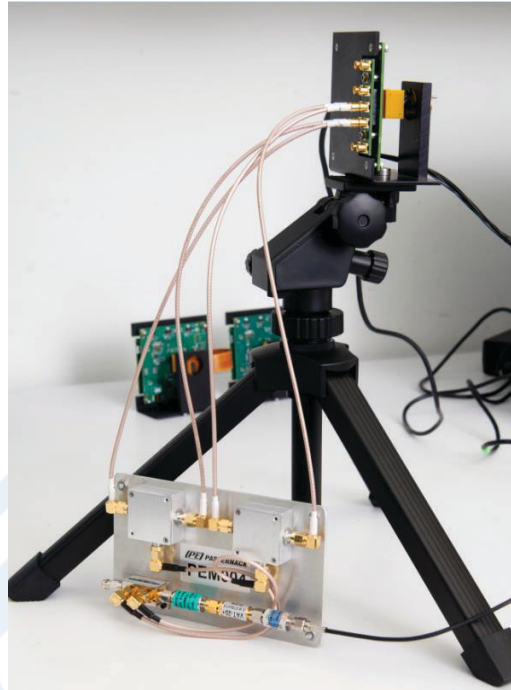
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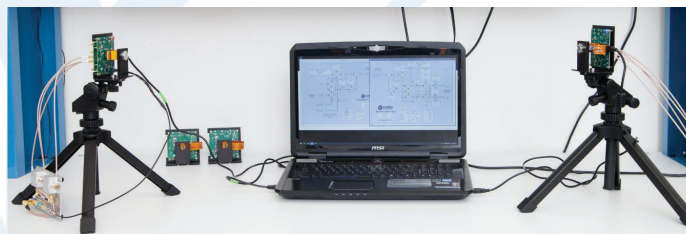


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PEM004 input to PEM009-KIT



PEM009-KIT System with PEM004



PEM009-KIT System with PEM004 input and Q+ Channel output to Analyzer

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Development System PEM009-KIT Antenna Selection Guide 60 GHz Link Budget Analysis w/ O₂ Factor

Lab test	
Distance	PE Part Number
3 meters	PE9881-20
10 meters	PE9881-24

Outdoor test	
Distance	PE Part Number
100 Meters	PE9881-34
500 Meters	PE9881-42

60 GHz Link Budget with O₂ Attenuation Factor

Freq		60	GHz	
Oxygen		15	dB/km	
Tx Pwr	Tx Ant Gain	Rx Ant	Distance	Rcv Pwr
dBm	dBi	Gain dBi	m	dBm
5	20	20	3	-32.59
9.8 feet				
PE9881-20				

Freq		60	GHz	
Oxygen		15	dB/km	
Tx Pwr	Tx Ant Gain	Rx Ant	Distance	Rcv Pwr
dBm	dBi	Gain dBi	m	dBm
5	24	24	10	-35.15
32.8 feet				
PE9881-24				



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Freq		60	GHz
Oxygen		15	dB/km
Tx Pwr	Tx Ant Gain	Rx Ant	Distance
dBm	dBi	Gain dBi	m
5	34	34	100
			328 feet

PE9881-34

Freq		60	GHz
Oxygen		15	dB/km
Tx Pwr	Tx Ant Gain	Rx Ant	Distance
dBm	dBi	Gain dBi	m
5	42	42	500
			3281 feet

PE9881-42



60 GHz Transmit/Receive (Tx/Rx) Development System from Pasternack Enterprises has same day shipment for domestic and International orders. Our RF, microwave and fiber optic products maintain a 99% availability and are part of the broadest selection in the industry.

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URL: [http:// www.pasternack.com/60-ghz-test-development-system-pem009-kit-p.aspx](http://www.pasternack.com/60-ghz-test-development-system-pem009-kit-p.aspx)

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