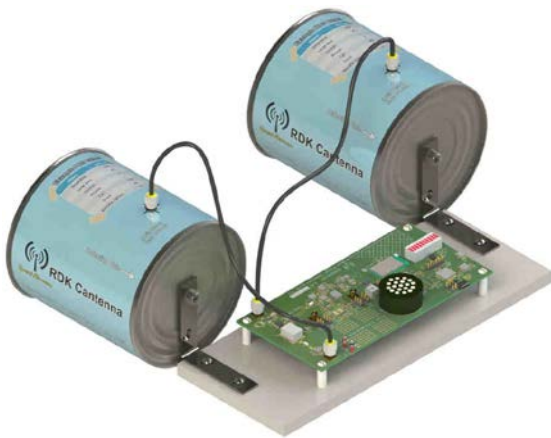


Radars Demonstration Kit Documentation



- 1. PEM11002-KIT Quick Start Guide and Application Notes**
 - 2. PEM11002-KIT Control GUI Manual**
 - 3. PEM11002-KIT Complete User Guide**
-

PEM11002-KIT Quick Start Guide and Application Notes

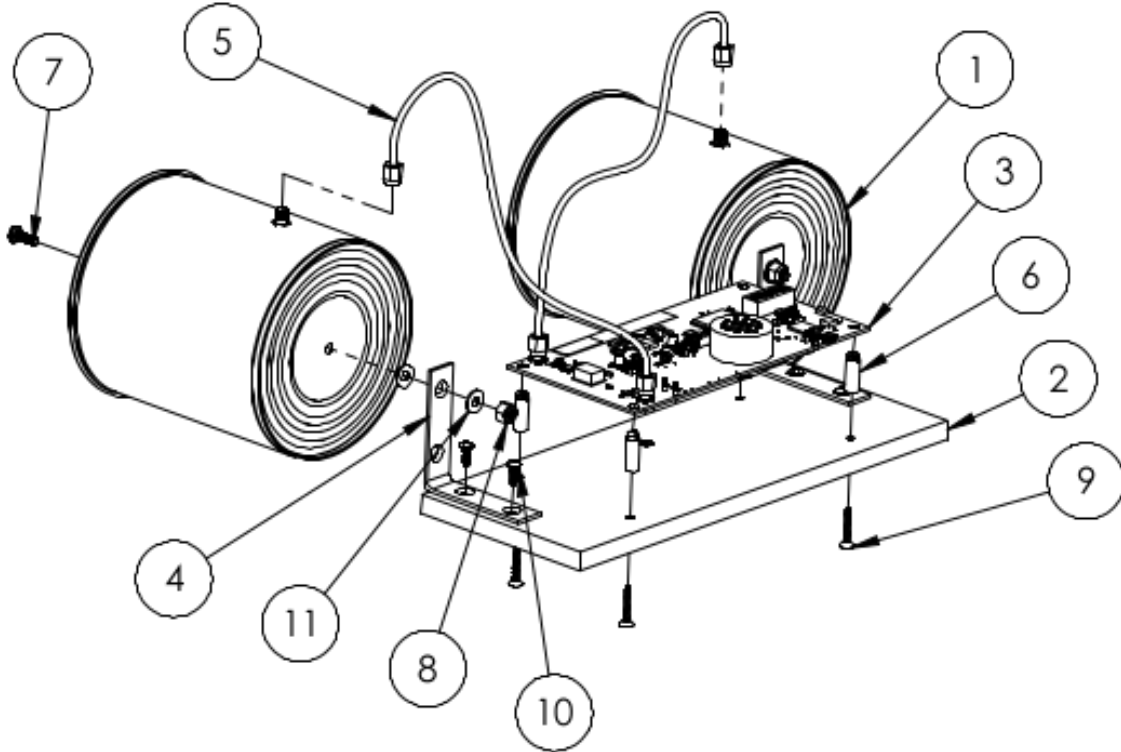


Figure 1: Assembly Diagram

1) Assemble the PEM11002-KIT

- a. Assembly will vary based on the kit you have ordered. Order of hardware assembly is not important but the recommended order is as follows:
 - i. Loosely mount the 4X plastic standoffs [6] to the mounting plate [2] using 4X #6-19 X $\frac{3}{4}$ " self-tapping flat head Philips screws [9] as shown. The mounting plate comes with clearance holes pre-drilled and countersunk from the bottom side.
 - ii. Carefully push the board [3] onto the four standoffs. Hand-tighten the 4X mounting screws until the standoffs are firmly seated onto the mounting plate.
 - iii. Attach the L-brackets [4] to the Cantennas [1] as shown in the assembly diagram using a #8-32 X $\frac{1}{2}$ " pan head Philips screw [7], 2X #8 washers [11], and #8-32 nylon nut [8]. Be sure to place one washer on either side of the L-bracket.
 - iv. Screw the L-bracket/Cantenna assembly to the mounting plate using 2X #8-18 X $\frac{3}{8}$ " self-tapping pan head Philips screws [10]. Holes are pre-drilled into the mounting plate to accept these screws. **DO NOT** over-torque these screws.
 - v. Connect each Cantenna to the board's TX and RX ports using the supplied SMA cables [5].

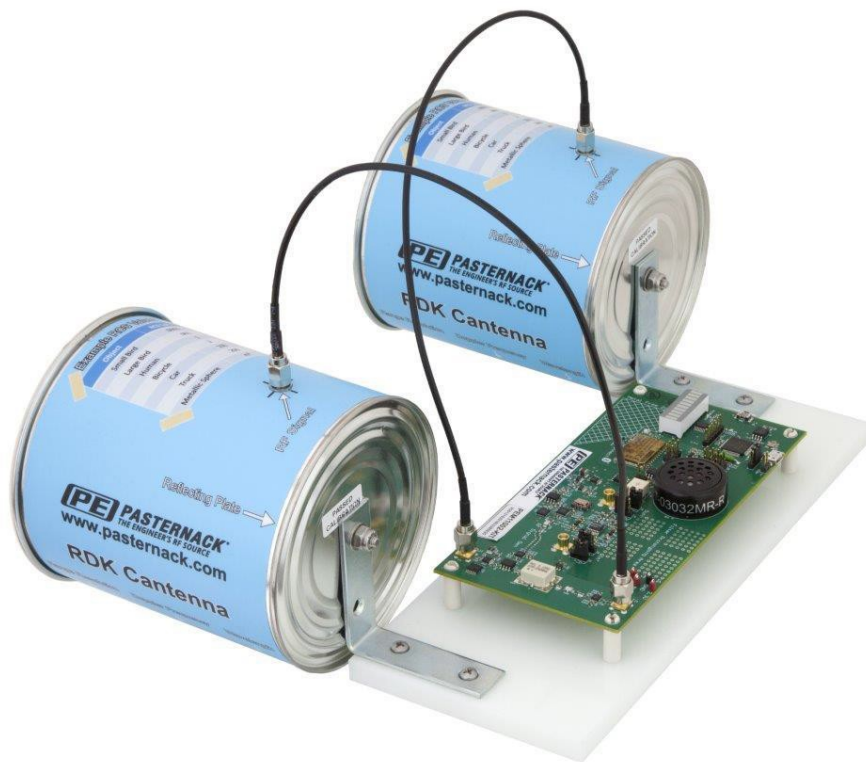


Figure 2: Assembled PEM11002-KIT

- b. The kit should resemble Figure 2 above. You are now ready to connect your PEM11002-KIT to your computer.

2) Connecting the PEM11002-KIT to a Windows Computer Using USB

- a. Before connecting the PEM11002-KIT, install the Control GUI (available at www.pasternack.com). Follow the installation guide on the screen. When asked to install the NI-VISA Runtime Engine, be sure to say yes if you do not have any VISA drivers installed on your computer. If you are not sure, click yes.
- b. After the Control GUI is installed, connect the PEM11002-KIT to your computer using the supplied micro USB cable.



Figure 3: PEM11002-KIT Connected to Laptop Using a USB Cable

- c. If this is the first time connecting the PEM11002-KIT to a computer, Windows will find the new hardware and install the appropriate drivers. Once the hardware is installed, three LEDs should be powered 'ON' on the board, as shown in Figure 4.
-



Figure 4: Power, USB and Connect LEDs

- d. After confirming all three LEDs are lit, run the Control GUI.
- e. The Control GUI will ask how your PEM11002-KIT is connected, Click on the USB icon.

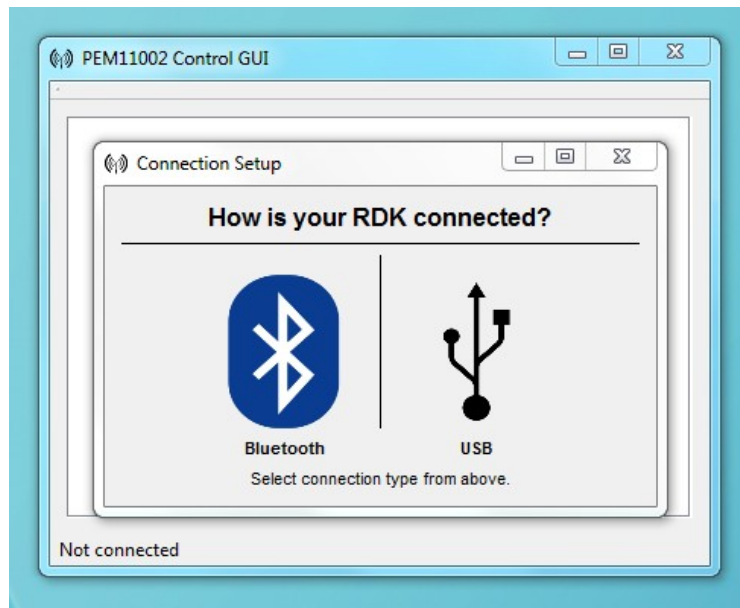


Figure 5: GUI Connection Prompt

- f. If your PEM11002-KIT is connected correctly the main GUI window will be displayed and you can now collect and plot data using the GUI. If clicking the USB icon does not display the GUI's Main Window, your USBTMC VISA drivers may not be installed properly. Use of the National Instruments Measurement & Automation Explorer (NI MAX), must be installed separately from the NI website, can be used to manually find the PEM11002-KIT. Please contact technical support (techsupport@pasternack.com) if you have issues connecting to your board.

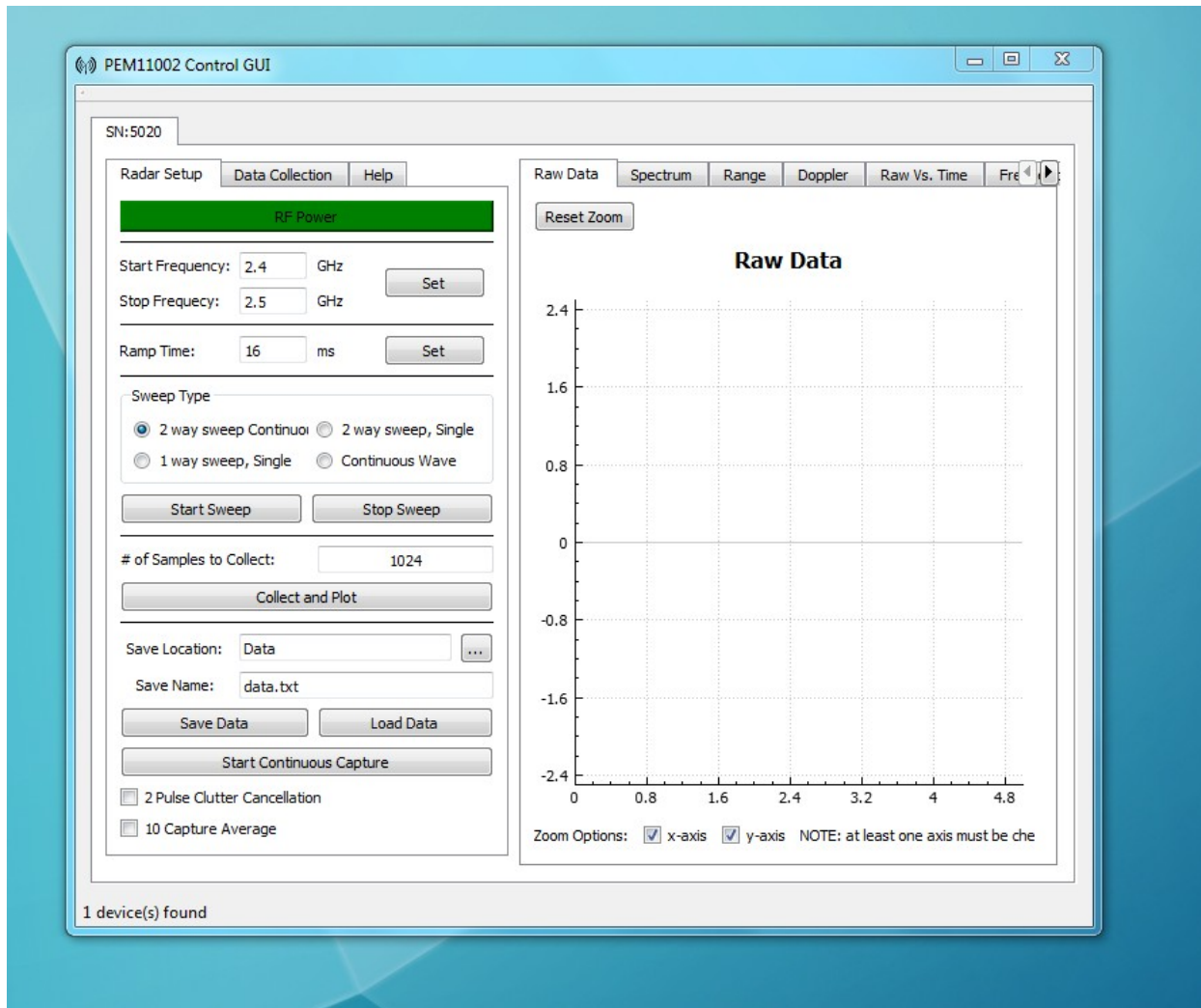


Figure 6: PEM11002-KIT GUI Main Window

1) Connecting the PEM11002-KIT to a Windows Computer Using Bluetooth

- a. First, power the PEM11002-KIT by connecting the USB port on the Board to a 5 volt USB socket. The USB socket can be a computer, wall adapter, or USB battery.
- b. After the Board is powered up (no LEDs flashing), press the push-button (sw1) located at the edge of the board between the USB connection and LED light bar. This enables Bluetooth communication on the board. If sw1 is not pressed you will be able to connect to the board over Bluetooth, but you will **NOT** be able to communicate with it.
- c. The board can now be paired with your Bluetooth enabled computer. This process will vary from computer to computer but the basic process is as follows:
 - i. Open the Bluetooth configuration window/program
 - ii. Search for nearby devices (Your device will show up as your device's serial number)
 - iii. Pair with the PEM11002-KIT
 - iv. Set up your newly paired PEM11002-KIT as a serial port (consult your Bluetooth provider for details)
 - v. Be sure to make note of the ports name (ex. "COM11")
- d. Your Board should now be paired and configured as a serial port on your computer. Start the PEM11002-KIT Control GUI (see section 2a for installation).
- e. When asked how to connect, select Bluetooth.
- f. Next, choose the port associated with the PEM11002-KIT (from part c above).
- g. Click Connect. The GUI's main window should be displayed and you can now control the PEM11002-KIT over Bluetooth.
- h. Similar methods can be used to control the PEM11002-KIT using serial object in Matlab.

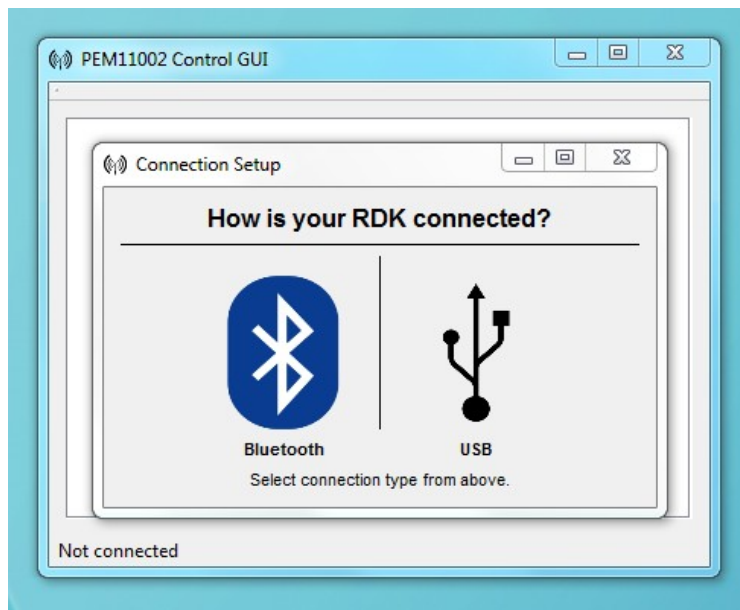


Figure 7: Select Bluetooth Connection

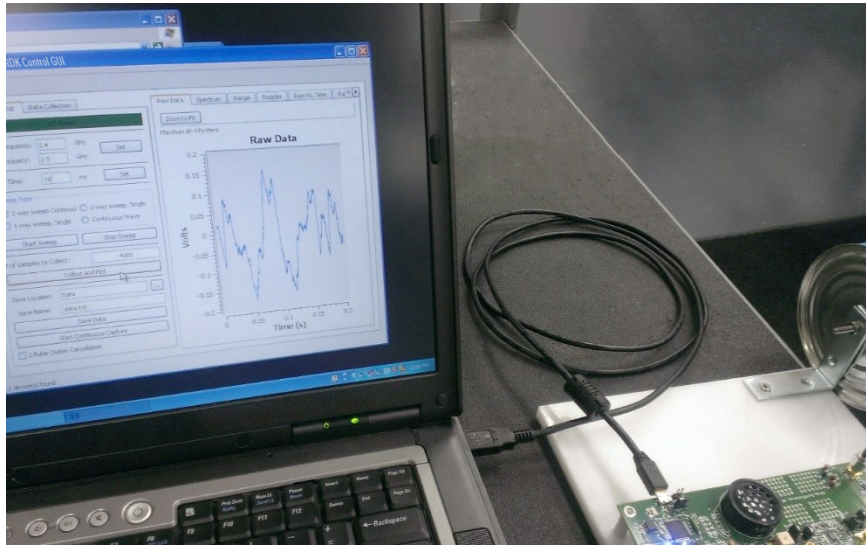


Figure 8: Data captured with the PEM11002-KIT GUI

For more information on the Control GUI, see the PEM11002-KIT Control GUI Manual below.

Doppler Experiment

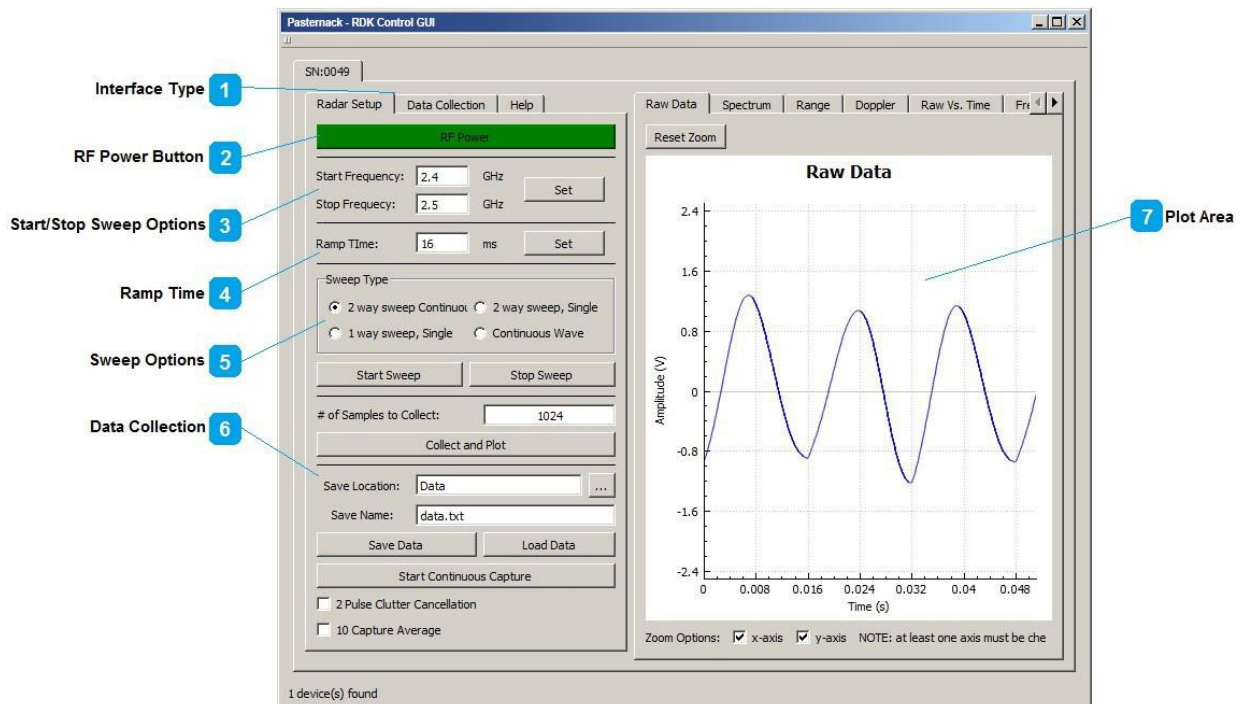
The following assumes that you are able to connect to the PEM11002-KIT using USB or Bluetooth on a Windows computer and control the PEM11002-KIT using the Control GUI software.

1. Configure the CW Frequency
 - a. In CW mode the transmit frequency is equal to the Start frequency, the Stop frequency can be ignored
2. Change the Sweep Type to Continuous wave
3. The PEM11002-KIT is now transmitting a CW
4. Collecting data with no moving targets will return all zeroes. If a moving target is present, the Doppler frequency shift will be visible. It is sometimes best to collect a high number of samples in order to get a full period of the frequency shift (4096 max for USB, 40000 max for BT)
5. Clicking on the Doppler tab will show the spectrum of the raw data collected.

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PEM11002-KIT Control GUI Manual

Main Window



The PEM11002-KIT Control GUI allows you to easily interact with Pasternack's Radar Demonstration Kit. The radar parameters can be adjusted, and data can be collected, plotted and saved. Below you will find descriptions of various components of the PEM11002-KIT Control GUI and how to use them.

1 Interface Type



There are two interface types in the Desktop application; Radar Setup and Data Collection. The Radar Setup interface is used to set Radar parameters and obtain single data captures. The Data Collection interface is used to perform more advanced collections. In the Data Collection interface a group of captures can be collected. The number of samples, number of captures, and time between captures can be specified.

2 RF Power Button



This button turns RF power ON and OFF. When RF Power is ON, the button will be green. When RF power is OFF, the button will be red.

3 Start/Stop Sweep Options

Start Frequency:	<input type="text" value="2.4"/>	GHz	<input type="button" value="Set"/>
Stop Frequency:	<input type="text" value="2.499"/>	GHz	

The Start and Stop frequency can be set using the Start/Stop sweep options. After entering the desired frequency into the text box, click "Set" to send the values to the PEM11002-KIT.

4 Ramptime

Ramp Time:	<input type="text" value="64"/>	ms	<input type="button" value="Set"/>
------------	---------------------------------	----	------------------------------------

The ramptime can be changed using the 'Ramp Time' text box and the corresponding "Set" button. Valid ramptimes are 1-65536 ms, integers only.

5 Sweep Options

Sweep Type			
<input checked="" type="radio"/>	2 way sweep Continuous	<input type="radio"/>	2 way sweep, Single
<input type="radio"/>	1 way sweep, Single	<input type="radio"/>	Continuous Wave
<input type="button" value="Start Sweep"/>		<input type="button" value="Stop Sweep"/>	

The PEM11002-KIT is capable operating in four different sweep modes; 2 way sweep (continuous), 2 way sweep (single), 1 way sweep (single), and Continuous Wave. Clicking the desired radio button will set the radar to that sweep type. At any point in time a sweep may be stopped or started by using the Start Sweep and Stop Sweep buttons.

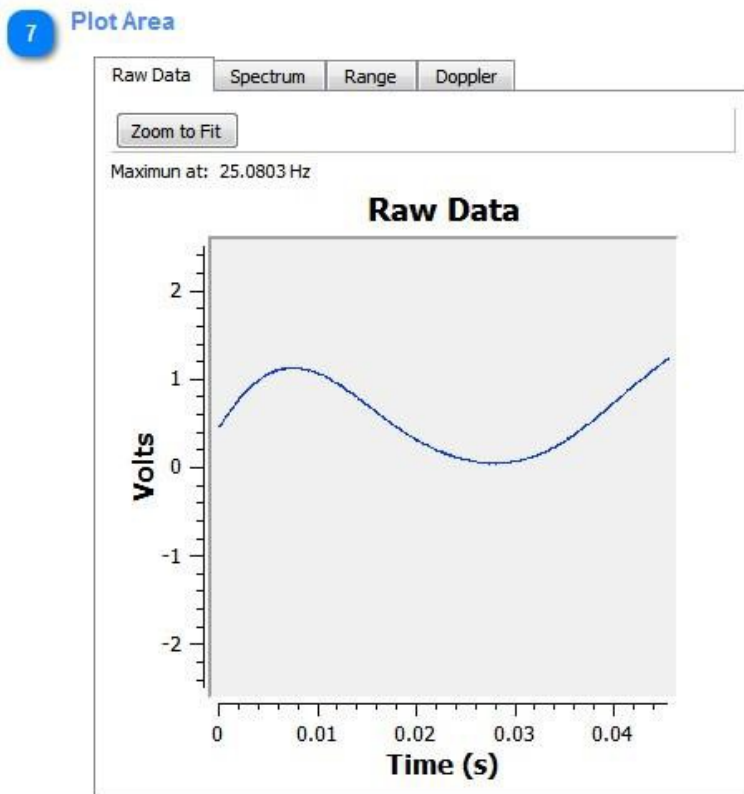
6 Data Collection

of Samples to Collect:

Save Location: ...

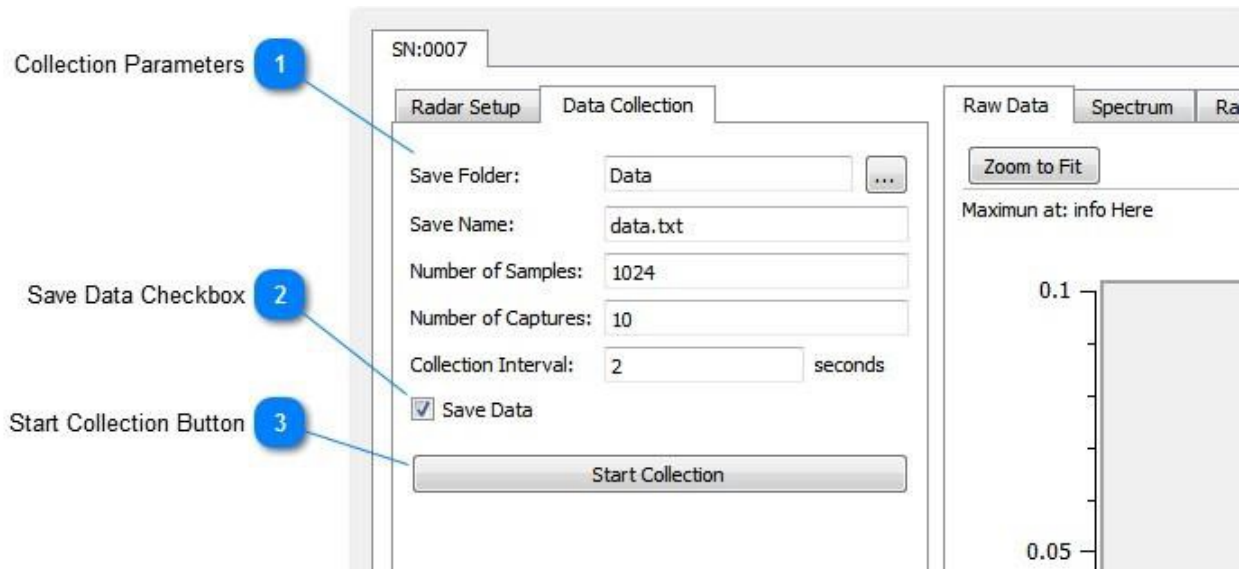
Save Name:

Data can be collected by clicking the "Collect and Plot" button. The default number of samples to collect is 1024. This can be changed by editing the "# of Samples to Collect" text box. After collecting data, the data can be saved by clicking the "Save Data" button. The previously collected raw data will be saved in the selected folder with the chosen save name. The format of the saved data is a text file with each sample separated by a new line.

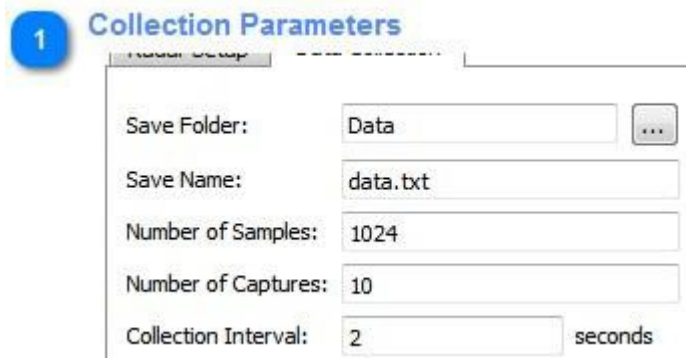


Data that has been collected will be plotted in the plot area. The collected data can be viewed as raw data, spectrum, range plot, or Doppler plot. To zoom in on the plot left click and drag the mouse to select the area you wish to zoom to. To return to a previous zoom right click. To pan hold the middle mouse button.

Data Collection Tab



The Data Collection tab allows the user to collect multiple captures at a set interval. Below is a brief description of the parameters and buttons used on this tab.



Various parameters can be set on the Data Collection tab. These include: where to save the data, how many samples to collect, the number of captures to perform, and the collection interval. The save location and number of samples operate the same as in the Radar Setup tab. The number of captures specifies how many times to collect data from the PEM11002-KIT. The collection interval is the time between each capture. The collection interval can be any number greater than 0, but it is recommended to use values greater than .5 seconds.

2 Save Data Checkbox

Save Data

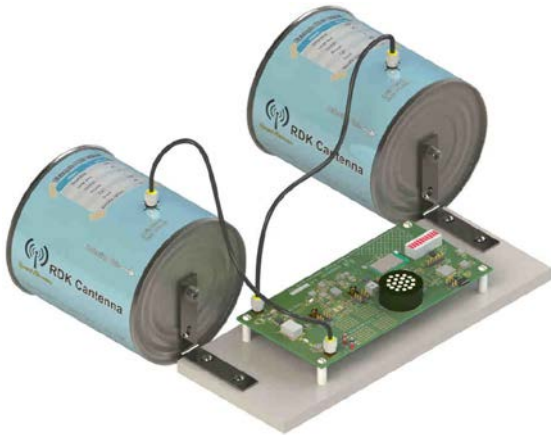
The save data checkbox allows you to choose to save captured data, or to view the data without saving.

3 Start Collection Button

Start Collection

Clicking this button will start the collection using the specified parameters.

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PEM11002-KIT
Radar Demonstration Kit

User Manual

Revision 1.1, October 2016

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This is a Safety Class I product (provided with a protective earthing ground incorporated in the power cord). The mains plug shall only be inserted in a socket outlet provided with a protective earth contact. Any interruption of the protective conductor, inside or outside the product, is likely to make the product dangerous. Intentional interruption is prohibited. If this product is not used as specified, the protection provided by the equipment could be impaired. This product must be used in a normal condition (in which all means of protection are intact) only.

No operator serviceable parts inside. Refer servicing to qualified personnel. To prevent electrical shock, do not remove covers. For continued protection against fire hazard, replace the line fuse(s) only with fuses of the same type and rating (for example, normal blow, time delay, etc.). The use of other fuses or material is prohibited.

General Safety Information

The following general safety precautions must be observed during all phases of operation of this product. Failure to comply with these precautions or with specific warnings elsewhere in this manual or any manual associated with this product violates safety standards of design, manufacture, and intended use of the product. Pasternack assumes no liability for the customer's failure to comply with these requirements.

WARNING

BEFORE APPLYING POWER TO THIS PRODUCT OR MAKING ANY CONNECTIONS TO THIS PRODUCT ensure that all instruments are connected to the protective (earth) ground. Any interruption of the protective earth grounding will cause a potential shock hazard that could result in personal injury or death.

CAUTION

- Use this device with the cables provided.
- Do not attempt to service this device. This device should be returned to Pasternack for any service or repairs.
- Do not open the device.

User Environment

- This instrument is designed for *indoor* use only.
- Operating Temperature Range: 10 – 30 C
- Storage Temperature Range: -40 – 85 C

Markings

The following markings may appear on the equipment or in any related documentation.



This marking indicates that a device, or part of a device, may be susceptible to electrostatic discharges (ESD) which can result in damage to the product. Observed ESD precautions given on the product, or in its user documentation, when handling equipment bearing this mark.



Part 15

This marking indicates that the device complies with applicable sections of part 15 of the FCC rules.



This marking indicates that the device conforms with applicable EC directives.



This marking indicates that the device is equipped with Bluetooth.



This marking indicates that the device is a dual-mode device equipped with both standard and Low Energy Bluetooth.

VISA

This marking indicates that the device complies with the Virtual Instrument Software Architecture (VISA) specification.

SCPI

This marking indicates that the device complies with the Standard Commands for Programmable Instrumentation (SCPI) specification.

USBTMC
USB488

This marking indicates that the device complies with the USB Test & Measurement Class (USBTMC) and the USB 488 subclass specifications.



This marking indicates that the device complies with the VME eXtensions for Instrumentation (VXI) specification.



This marking indicates that the device complies with the LAN eXtensions for Instrumentation (LXI) specification.



This marking indicates that the device communicates over the RS232 Serial Bus.



This marking indicates that the device communicates over the Universal Serial Bus (USB).



This marking indicates that the device communicates over Ethernet.



This marking indicates that the device is USB Low Speed and Full Speed certified.



This marking indicates that the device is USB On The Go (OTG) Low Speed and Full Speed certified.



This marking indicates that the device is USB High Speed certified.



This marking indicates that the device is USB On The Go (OTG) High Speed certified.

Revision Control

Revision	Description of Changes	Date
0.0.0	Initial Creation	08/10/2016
0.0.1	Minor Edits	08/29/2016
1.0.0	Initial Release	09/01/2016
1.1.0	Kit Number Edits	10/05/2016

Acronyms

ADC	Analog-to-Digital Converter
CW	Continuous Wave
FMCW	Frequency Modulated Continuous Wave
ISM	Industrial, Scientific and Medical
PLL	Phase Lock Loop
SCPI	Standard Commands for Programmable Instrumentation
USBTMC	USB Test and Measurement Class
VCO	Voltage Controlled Oscillator
VISA	Virtual Instrument Software Architecture

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1 PEM11002-KIT Radar Demonstration Kit

The PEM11002-KIT Radar Demonstration Kit from Pasternack is an ideal tool for use in the classroom for learning about Radar and for the DIY enthusiast. The PEM11002-KIT is controlled either through the onboard USB port or a Bluetooth connection. The PEM11002-KIT operates in the 2.4 GHz Industrial, Scientific and Medical (ISM) band so no special licensing is required. The PEM11002-KIT Radar Demonstration Kit is available in three configurations. All kits include a User and Programming Manual, Lesson Guide, and control GUI for Windows.

2 Markings Applied

The following markings apply to the Radar Demonstration Kit family of products.

Table 1.1: Applicable markings

 ESD Sensitive		
		
		

3 Interference

The PEM11002-KIT Radar Demonstration Kit has been designed for operation in the international 2.4 GHz ISM band, and as such, the PEM11002-KIT is classified as an unlicensed transmitter. Operating in the 2.4 GHz band, while not requiring any special licensing to use, makes the PEM11002-KIT susceptible to interference from other radiators operating in the 2.4 GHz band including interference from WiFi devices. When using the PEM11002-KIT, ensure that there is no interference from outside radiators by first measuring the ambient field strength. This can be

the PEM11002-KIT by terminating the Tx port of the Radar Board in a 50Ω load while connecting a Cantenna to the receive port and taking a sweep measurement. If a signal is detected, then there is a source of interference nearby and the PEM11002-KIT should not be used until it has been relocated to an area free of interference.

Special Note regarding the use of Bluetooth: The Bluetooth radio on the PEM11002-KIT operates in the same 2.4 GHz ISM band as the PEM11002-KIT. However, the PEM11002-KIT uses directional antennas mounted to the front of and facing away from the Bluetooth radio which minimizes any interference. To maximize the Bluetooth connection with the PEM11002-KIT, always keep the connected device behind the PEM11002-KIT.

4 Kits

The PEM11002-KIT Radar Demonstration Kit is available in two kit configurations as listed in **Table 1.2**.

Table 1.2: PASTERNAK kit options

PEM11000-KIT	PEM11002-KIT
<ul style="list-style-type: none"> • Radar Board • Cantenna (X2) • Cable Kit 	<ul style="list-style-type: none"> • Radar Board • Cantenna (X2) • Cable Kit • Mounting Plate • Tripod • USB Battery Pack

4.1 Radar Board

The Radar Board, shown in **Figure 1.1**, is the main component of the Radar Demonstration Kit and contains all of the digital and RF hardware along with all of the interface connections for power, control, and connecting to the Cantennas.

4.2 Cantenna

The Cantenna is made from a small tin can which has been modified to accept an SMA connector, as shown in **Figure 1.2**. A small metal rod is soldered to the SMA connector to act as a launch for the RF signal. The SMA connector is located such that the back wall of the can acts as a reflector and the reflected signal is in phase with the injected signal at the SMA connector location (constructive interference).

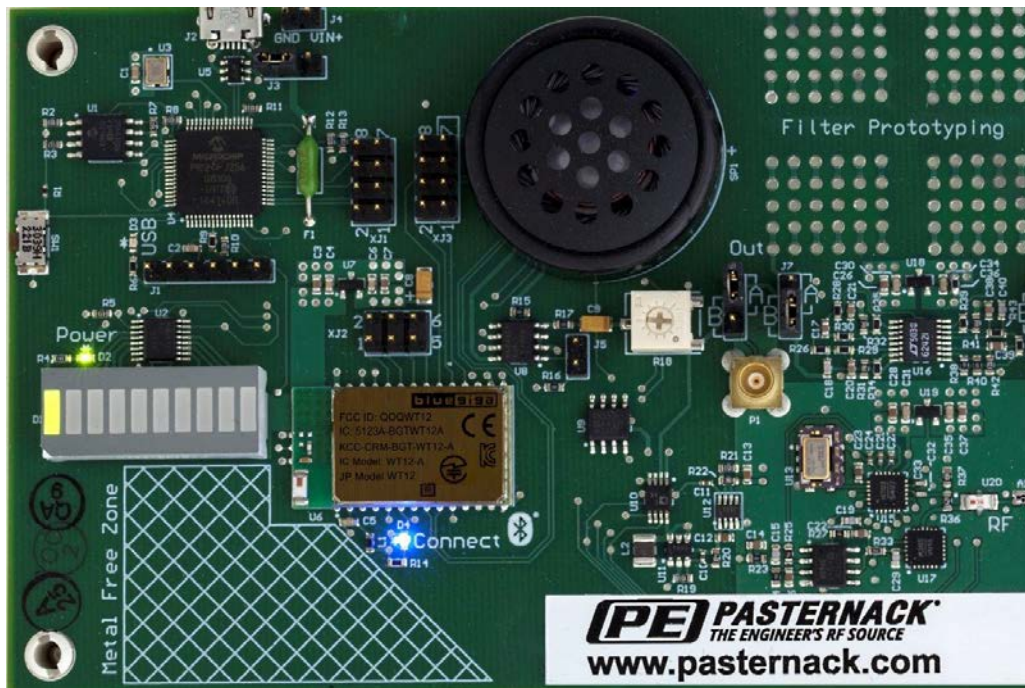


Figure 1.1: Radar board



Figure 1.2: Cantenna

Every PEM11002-KIT kit comes with two (2) Cantennas. Replacement Cantennas are also available for purchase from Pasternack in either assembled or unassembled. When purchasing an unassembled Cantenna, the Cantenna comes with all parts necessary for operation including the SMA connector and the small metal rod (ready for soldering). The Cantenna comes undrilled; however, instructions are included on the Assembly Sheet and the label is marked with the drill location for the SMA connector.

4.3 Mounting Plate

The Mounting Plate, included in Kit PEM11002-KIT or purchased separately, provides a platform for mounting the Radar Board and Antennas as shown in **Figure 1.3**. The Mounting Plate is made of plastic and comes pre-drilled with mounting locations for the Radar Board and Antennas, as well as tri-pod mount on the bottom side of the plate. Included with the Mounting Plate are two mounting brackets [4] for the Antennas [1] and four standoff mounts [6] for the Radar Board [3].

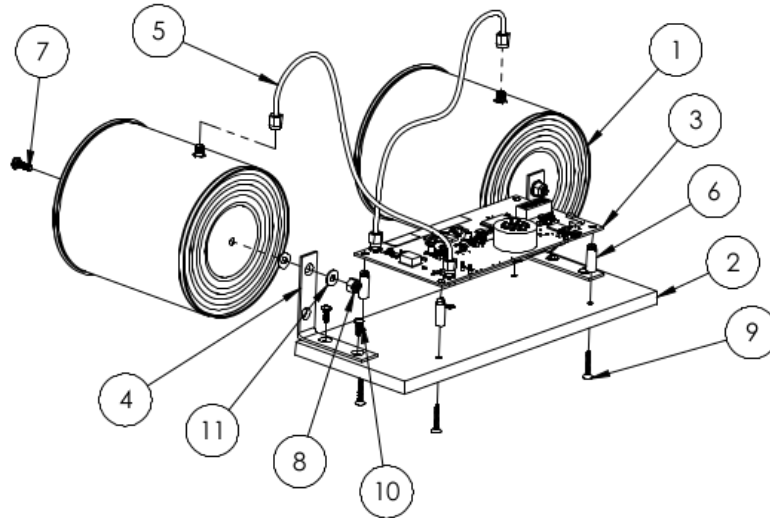


Figure 1.3: Radar board and Antennas assembled to Mounting Plate

When ordering PEM11002-KIT, a tripod is included in the kit. The manufacturer, model, and color of the tripod which ships with the PEM11002-KIT is subject to change.

4.4 USB Battery Pack

When ordering PEM11002-KIT, a USB Battery Pack is included for powering the PEM11002-KIT. When using the USB Battery Pack, a Bluetooth connection must be used for interfacing with the Radar Board. The USB Battery Pack provided in PEM11002-KIT is guaranteed to be compatible with the PEM11002-KIT and provide a minimum of two hours of operating time. The manufacturer and model of the USB Battery Pack which ships with the PEM11002-KIT is subject to change.

5 System Requirements

The Radar Demonstration Kit has been designed to connect to the computer through USB as a Test & Measurement Device (USBTCM) or through a Bluetooth connection, and therefore can be used on any computer running the Windows, Linux, or MAC operating system as well any compatible device

equipped with Bluetooth v. 2.1 (see Section 5.2).

5.1 USB Communications

USB communication with the Radar Demonstration Kit is accomplished through the Virtual Instrument Software Architecture (VISA) libraries and only requires that the VISA libraries be installed on the computer.

If you do not have a copy of the VISA libraries on your machine, a legal copy can be purchased from any of the following vendors:

- National Instruments (NI-488.2 or NI-VISA)
- Agilent Technologies (IO Suite)
- Tektroniks (TekVISA)

NOTICE

Pasternack's products are designed to communicate through the VISA libraries, but do not ship with a copy of the VISA libraries. The customer is responsible for ensuring that they have a legal copy of the VISA libraries installed on the target computer. Pasternack assumes no liability, either explicit or implied, for the use of an illegal or invalid copy of the VISA libraries.

5.2 Bluetooth Communications

The Radar Demonstration Kit is equipped with a Bluetooth v 2.1 radio which can be used to interface with the PEM11002-KIT and stream data to a compatible Bluetooth device. Any Bluetooth equipped computer running the Windows, Linux, or MAC operating system can be used to connect to the PEM11002-KIT through Bluetooth. Any mobile device (tablet or phone) which runs the Android operating system (version 2.3 and above) can be interfaced to the PEM11002-KIT using the free App from Pasternack.

NOTICE

The Radar Demonstration Kit is **not** compatible with any version of iOS or Windows Phone and can only be used with Android mobile devices at this time.



2 Using the Radar Demonstration Kit

In This Chapter

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1 Operating Specifications

Table 2.1: Operating Specifications

Parameter	Min.	Typ.	Max.	Units
Operating Frequency	2.4		2.5	GHz
Output Power				
Sweeping			1	Watt
CW Mode			0.125	Watt
Operating Voltage		5		Volts
Operating Current			0.5	Amps
ADC		16		Bits
ADC Sampling Frequency		20,000		Hz
Bluetooth Version	2.1 + EDR			

2 Radar Board

The Radar Board is the main component of the Radar Demonstration Kit and is subdivided into five major sections: Digital, Bluetooth Radio, Audiovisual Feedback, RF, and Filter Prototyping. Each of the sections of the Radar Board are described in more detail in the following subsections along with a description of the connectors and jumpers on the Radar Board.

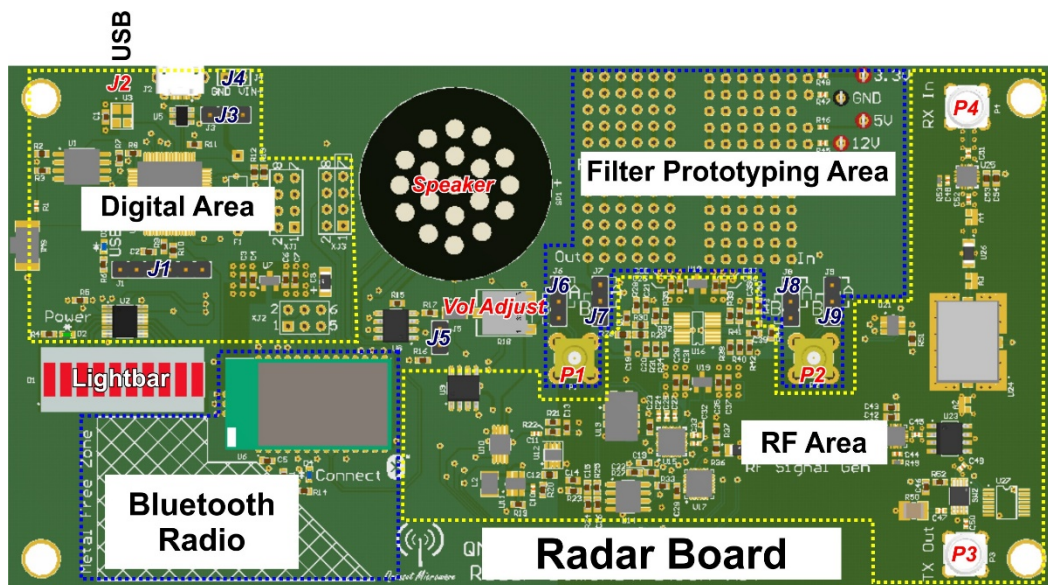


Figure 2.1: The Pasternack Radar board, as viewed from above

2.1 Digital Section

The Digital section of the Radar Board contains the PIC micro-controller and Analog-to-Digital Converter (ADC) along with the USB and power interface. The PIC micro-controller serves as the brains of the Radar Board, controlling all functions of the Radar Board as well as responding to all control commands and data requests received through either the USB or Bluetooth connections. An ADC is connected to the PIC which allows the received signal, after proper filtering and conditioning, to be digitized and either stored in memory or streamed over the Bluetooth connection.

2.2 Bluetooth Radio Section

This section of the Radar Board contains the Bluetooth Radio which permits compatible devices to remotely connect to the PEM11002-KIT through a Bluetooth connection and interact with the PEM11002-KIT. The Bluetooth Radio section includes the actual Bluetooth Radio as well as the chip antenna.

CAUTION

The cross-hatched area of the Radar Board around the Bluetooth Radio has been designated as a metal free zone, and as such, all metal must be kept away from this area. Failure to keep this area free of metal will result in interference which will prevent communication with the Radar Board using Bluetooth.

2.3 Audiovisual Feedback

The PEM11002-KIT Radar Board is equipped with both audio and visual feedback. The lightbar on the Radar Board provides visual feedback of the received signal strength to the user. When an error has been encountered, the lightbar will flash, alerting the user that an error has occurred. The Radar Board has been designed such that the IF frequency of the received signal is in the audio band. An onboard speaker allows the user to listen to the changes in the received frequency. A potentiometer located below and to the right of the speaker allows the user to adjust the output volume.

2.4 RF Section

The function of the RF section of the Radar Board is to generate and output the transmit signal and to downconvert the received signal to a frequency range which can be easily digitized using the onboard ADC. The transmit waveform is generated using an onboard Voltage Controlled Oscillator (VCO) and Phase Lock Loop (PLL) combination which generates a known frequency. The PLL serves to frequency lock the output of the VCO using the onboard reference to

provide a stable and repeatable output frequency. The output of the VCO is amplified prior to being passed to the transmit Antenna.

The signal from the receive Antenna is first mixed with a sample of the transmit signal to produce a frequency offset, known as the beat frequency, and is then filtered to remove unwanted signals generated as a result of the mixing process before being passed to the ADC. For more information on how the beat frequency is used to determine the distance to an object, see Section 2.

2.5 Filter Prototyping Area

The PEM11002-KIT RF section incorporates all of the necessary filtering of the received and downconverted IF signal in order to allow for out of the box operation. A Filter Prototyping Area has been incorporated on the board to allow for the design and implementation of your own passive or active filters. To bypass the onboard filtering and use the Filter Prototyping Area, connect jumpers J8 and J7 to position A. The Filter Prototyping Area has access to +3.3 V, +5 V, +12 V and GND through the test points located to the upper right of the Filter Prototyping Area.

Two MCX connectors, P2 and P1 in **Figure 2.1**, have been provided to allow for in situ testing of the IF filter. These connectors allow for the injection of a test signal directly into the filter and extracting the output of the filter, bypassing the rest of the RF and IF chain. In order to enable P2 and P1, connect J9 and J6 to position A.

2.5.1 Connectors

The type and function of the connectors located in the PEM11002-KIT Radar board is given in **Table 2.2**. For the connector ID, please see **Figure 2.1**.

Table 2.2: PEM11002-KIT RF board connectors

ID	Description	Type
P4	Receive Antenna	SMA-Female
P3	Transmit Antenna	SMA-Female
P2	MCX Filter Debug Input	MCX Female
P1	MCX Filter Debug Output	MCX Female
J2	USB Power and/or Control	USB Micro B

2.5.2 Connector Care

CAUTION

The RF connectors deteriorate when contacted with hydrocarbon compounds such as acetone, trichloroethylene, carbon tetrachloride, and benzene. Pasternack recommends only using isopropyl alcohol to clean the RF connectors.

Keeping in mind its flammable nature, a solution of pure isopropyl or ethyl alcohol can be used to clean the connector.

Clean the connector face using a cotton swab dipped in isopropyl alcohol. If the swab is too big, use a round wooden toothpick wrapped in a lint-free cotton cloth in place of the cotton swab.

CAUTION

Clean the connector only at a static free workstation. Electrostatic discharge to the center pin of the connector will render the Radar Demonstration Kit inoperative.

2.6 Jumper Configuration

Table 2.3: PEM11002-KIT RF board jumpers

ID	Description
J3	Selects the power sources
J4	External power input
J5	Mutes/Unmutes the speaker
J6	Selects the ADC input
J9	Selects the IF input
J8	Selects the filter path
J7	Selects the filter path

2.6.1 Jumper J3 : Power Source




The setting of Jumper J3 determines the power source for the board. Using this jumper, the user can choose between powering the board from the USB port or

an externally applied +5 V source using J4. The jumper configurations are shown in **Table 2.4**.

NOTICE

A jumper must be set in order for the board to receive power and operate.



Table 2.4: Jumper J3 settings

 <p>A B</p>	<p>Not Used - Without jumper board will not receive power</p>
 <p>A B</p>	<p>Powered from the USB port</p>
 <p>A B</p>	<p>Powered from an external +5 V source</p>

2.6.2 Jumper J5 : Speaker Mute

Jumper J5 controls the output of the speaker. When a jumper is present, the speaker will be muted and when the jumper is removed, the speaker will be unmuted. The jumper configurations are shown in **Table 2.5**.

Table 2.5: Jumper J5 settings

	<p>Speaker is enabled</p>
	<p>Speaker is muted</p>




2.6.3 Jumper J6 : ADC Test Signal Injection

Jumper J6 allows the user to inject a known test signal into the ADC through an on- board MCX connector (P2), bypassing the mixer and filter. The jumper configurations are shown in **Table 2.6**.

NOTICE

A jumper must be set in order to select the signal source for the ADC. Failure to set a jumper will result in an open circuit at the ADC.

Table 2.6: Jumper J6 settings

 <p>A B</p>	<p>Not Used - Without jumper ADC will not receive a signal</p>
 <p>A B</p>	<p>Input from the filter output (normal operation)</p>
 <p>A B</p>	<p>External input from the MCX connector</p>




2.6.4 Jumper J9 : IF Test Signal Injection

Jumper J9 allows the user to inject a known IF test signal into the filtering section through an onboard MCX connector (P1), bypassing the mixer. The jumper configurations are shown in **Table 2.7**.

NOTICE

A jumper must be set in order to select the IF signal source. Failure to set a jumper will result in no signal being passed into the filtering section.

Table 2.7: Jumper J9 settings

 <p>A B</p>	<p>Not Used - Without jumper filter will not receive a signal</p>
 <p>A B</p>	<p>Input from the mixer (normal operation)</p>
 <p>A B</p>	<p>External input from the MCX connector</p>

2.6.5 Jumpers J8 and J7 : Filter Path Selection

Jumpers J8 and J7 allow the user select between the onboard IF filter and the Filter Prototype area. Configuring the jumpers for the Filter Prototype Area allows the user to design and implement their own IF filter, bypassing the onboard filter. The jumper configurations are shown in **Table 2.8**.




NOTICE

A jumper must be set in order to choose the filter path. Failure to set a jumper will result in no signal being passed into or out of the filtering section.

NOTICE

Jumpers J8 and J7 must be set in tandem. Choosing different jumper positions for Jumper J8 and J7 will result in an open circuit on the board and no signal will be passed to the ADC.

Table 2.8: Jumper J8 and J7 settings

 <p>A B</p>	<p>Not Used - Without jumper ADC will see an open circuit</p>
 <p>A B</p>	<p>Route through Filter Prototyping Area</p>
 <p>A B</p>	<p>Route through the onboard IF filter</p>

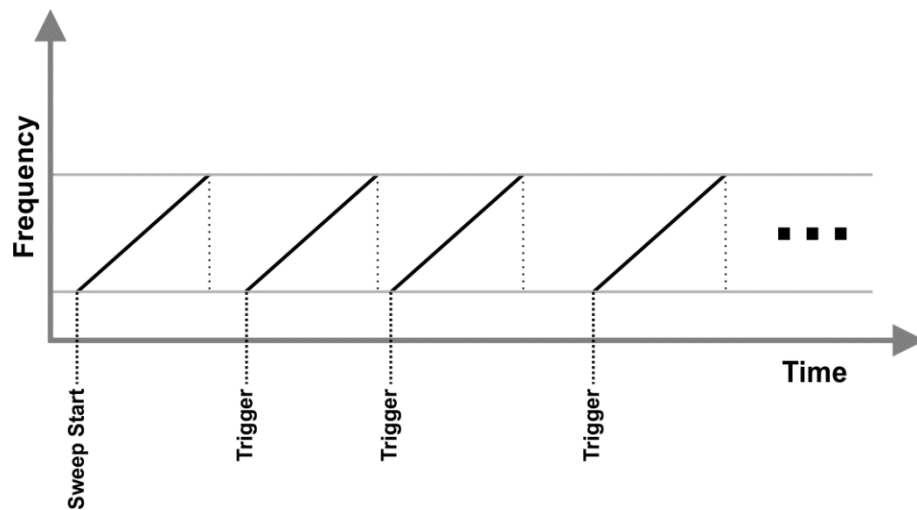
2.7 Control and Power

The PEM11002-KIT Radar Board is equipped with two control interfaces, USB for control through desktop or laptop computers and Bluetooth for control through Android mobile devices or computers equipped with Bluetooth. The PEM11002-KIT Radar Board is powered over the USB connection and can be operated from any standard powered USB 2.0 port. When communicating with the board through the Bluetooth connection, the board power must still be supplied through the USB port by either a computer or external power source such as a USB charger or battery pack.

3 Configuring the Output Frequency Sweep

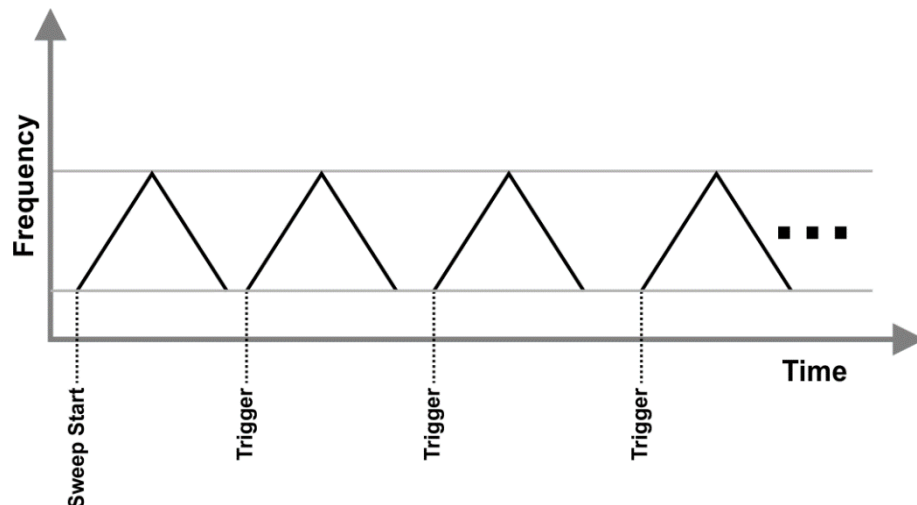
The output frequency sweep profile of the PEM11002-KIT is controlled by three parameters: the start frequency, stop frequency, and sweep type. The sweep type determines the ramp profile of the outputted waveform. With the PEM11002-KIT, you can choose between four available sweep types: Ramp, Triangle, Automatic Triangle, and Continuous Wave (CW).

Ramp



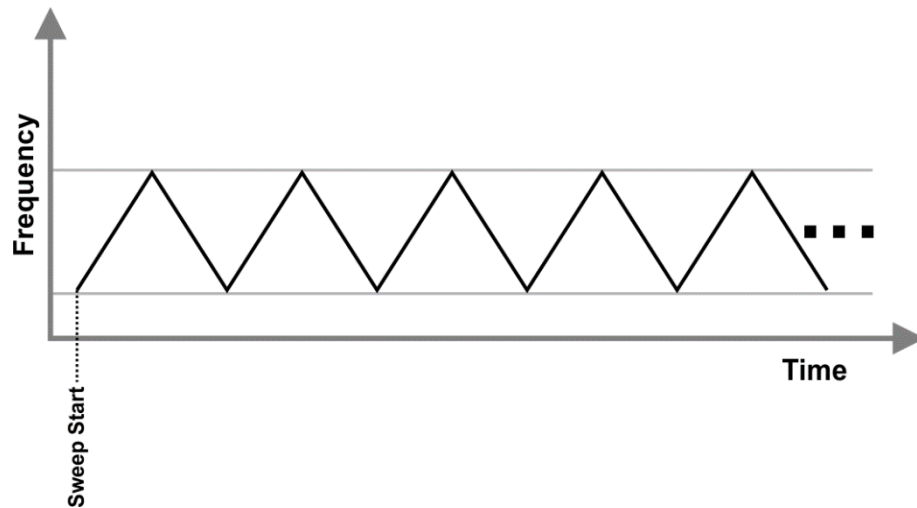
When configured for the *RAMP* sweep type, the PEM11002-KIT linearly sweeps between a specified start and stop frequency. Once the stop frequency has been reached, the frequency of the PEM11002-KIT jumps to the start frequency and the ramp begins again once a hardware or software trigger is received.

Triangle



When configured for the *TRI* sweep type, the output frequency of the PEM11002-KIT starts from the start frequency and increases linearly until the stop frequency is reached. Once the stop frequency is reached, the output frequency of the PEM11002-KIT is linearly decreased until the start frequency is reached. The process repeats every time a hardware or software trigger is received.

Automatic Triangle



When configured for the *AUTO* sweep type, the output frequency of the PEM11002-KIT starts from the start frequency and increases linearly until the stop frequency is reached. Once the stop frequency is reached, the output frequency of the PEM11002-KIT is linearly decreased until the start frequency is reached. The process automatically repeats without requiring a hardware or software trigger until a stop command is received.

Continuous Wave



When configured for the *CW* sweep type, the Radar Demonstration Kit outputs a single frequency tone at the specified start frequency.

For all sweep types except for *Continuous Wave*, the time that it takes to sweep the output of the PEM11002-KIT between the start and stop frequency is known as the Ramp Time.

3.1 Calculating the Ramp Time

The time that it takes for the output frequency of the PEM11002-KIT to move from the start frequency to the stop frequency is known as the Ramp Time. The PEM11002-KIT allows the user to set the *Ramp Time* to any integer value between 1 and 65,536 ms; however, the maximum usable Ramp Time is determined by the start frequency, stop frequency, reference frequency, and reference divider. The relationship between the maximum Ramp Time and these parameters is shown in Eq.(2.1).

$$ramptime_{max} = \frac{(f_{stop} - f_{start}) * refDiv * 2^{25}}{reference^2} [ms] \quad (2.1)$$

where the start and stop frequency are in GHz, the reference is in MHz, and the reference divider (refDiv) is an integer value between 1 and 256. The PLL used on the PEM11002-KIT for generating the RF output signal uses an onboard 20 MHz reference, thus *reference* in Eq.(2.1) is equal to 20. In order to adjust the maximum Ramp Time for a given start and stop frequency, the reference divider value should be adjusted.

A more useful equation for deciding what reference divider value to use is given in Eq.(2.2) which computes the minimum kHz per ms ramp step. For example, with the reference divider set to 2, the minimum ramp step of the PEM11002-KIT is 5.96 kHz/ms.

$$\frac{kHz}{ms} = \frac{reference^2}{refDiv * 1E6 * 2^{25}} \quad (2.2)$$

3.2 Controlling the RF Output

The PEM11002-KIT is equipped with ability to mute the RF output, allowing the user to stop all signal transmissions. The RF output is controlled remotely either over the Bluetooth or USB control connection. See the POWER:RF command (Chapter 8) for details.

4 Example Uses

The Radar Demonstration Kit can be used for a variety of functions and can be paired with other hardware or systems to provide additional or enhanced functionality. A few examples include object detection, motion detection, and determining the range to objects.

4.1 Object Detection

Object detection can be accomplished in one of two ways. For objects that are

either at rest or in motion, the PEM11002-KIT operated in any of the sweep modes can be used to detect the object. When wishing to only detect objects which are in motion, the PEM11002-KIT can be configured for CW mode and the resulting Doppler frequency used to determine the speed of the object. When operated in the CW mode, objects at rest will not be detected as they have a zero Doppler frequency.

4.2 Motion Detection

To detect only an object which is in motion, the PEM11002-KIT can be used in either the CW or sweep mode. The CW mode is the most straight forward way to detect an object in motion as the Doppler frequency is being directly measured. Using the sweep mode of the PEM11002-KIT to detect objects in motion requires more processing by the user as changes in the distance to the object over time must be tracked to detect an object which is in motion.

4.3 Determining Range to Objects

Another example use for the PEM11002-KIT is to determine the range to object. This can be accomplished by operating the PEM11002-KIT in the *Ramp* mode and monitoring the beat frequency. For example, the PEM11002-KIT can be setup in a room and used to determine the distance to a person who has entered the room once the person has been detected by the PEM11002-KIT.



3 Theory of Operation

In This Chapter

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2	FMCW Radar	20
	2.1 Analysis	22
3	Doppler Radar	24

This Chapter will provide a very basic overview of how the FMCW Radar operates. For a more in depth discussion, please see the Lesson Guide for the Radar Demonstration Kit.

1 Background

Radar is an acronym that stands for Radio Detection And Ranging. In its simplest form, a Radar transmits a signal with a known waveform and receives signals that have bounced off of objects which are located in line of sight of the Radar. By comparing the transmitted and received waveforms, information about the objects, or targets, which reflected the signal from the Radar can be determined, such as the speed of the target, the direction the target is moving, the distance to the target, or properties of the target. The type of information that can be learned about a target is largely dependent on the Radar hardware configuration and transmitted waveform. Typical types of Radars used include Doppler, Frequency Pulsed, and imaging. The Radar Demonstration Kit has been configured to operate as an FMCW Radar but can also be used as a Doppler Radar by placing it in the CW sweep mode.

2 FMCW Radar

The Radar Demonstration Kit transmits a FMCW signal. A simplified block diagram of an FMCW system is shown in **Figure 3.1**. The VCO in **Figure 3.1** serves as both the transmit frequency generator and the LO for the mixer. The VCO is linearly swept across a frequency band in order to create the FMCW signal. The output of the VCO is passed through a power splitter which provides both the LO signal for the mixer and the transmit signal which is passed to the transmit Antenna. The returned signal, or echo, from the target is received T_p seconds later and is mixed with a portion of the transmitted signal to produce a beat signal of frequency f_b , which is proportional to the received signals round trip time, T_p . This beat frequency is sampled by an onboard ADC and can be processed either immediately or stored for processing at a later time.

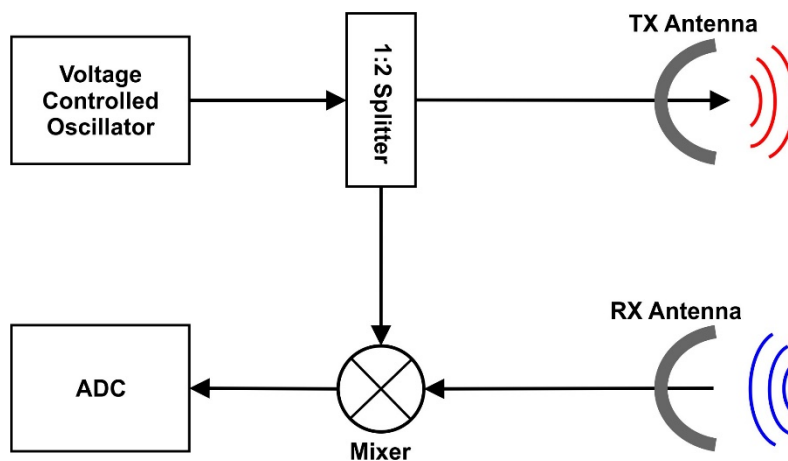


Figure 3.1: Simplified FMCW Radar block diagram

An example of the transmitted and receive signals as a function of time are shown in the frequency and timing diagram in **Figure 3.2**. From examining the frequency and timing diagram, the following definitions can be made; Δf is the difference between the start and end frequencies, T_p is the time delay from when the signal is transmitted until it is received, and f_b is the beat frequency produced when the received signal is mixed with the signal being transmitted. Since the received signal is delayed in time, there will exist a frequency offset, or beat frequency, between the frequency being received and the frequency being transmitted at that instance in time.

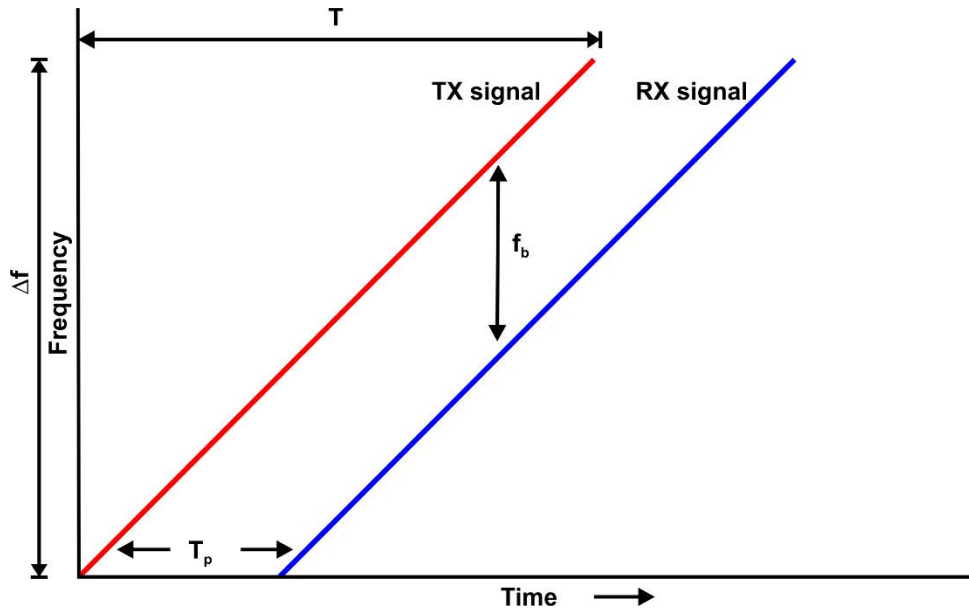


Figure 3.2: FMCW Radar frequency and timing diagram

The relationship between f_b and T_p is given by Eq.(3.1), where T is the ramp time of the transmitted signal.

$$f_b = \frac{\Delta f * T_p}{T} \quad (3.1)$$

T_p can be derived using the target range, and the speed of light as shown in Eq.(3.2), where R is the range to the target and c is the speed of light.

$$T_p = \frac{2 * R}{c} \quad (3.2)$$

Substituting Eq.(3.1) into Eq.(3.2) gives the classical FMCW formula that relates the beat frequency to the target range.

$$f_b = \frac{\Delta f * 2 * R}{T * c} \quad (3.3)$$

Rearranging the above equation to solve for R yields:

$$R = \frac{c * f_b}{2 * (\Delta f / T)} \quad (3.4)$$

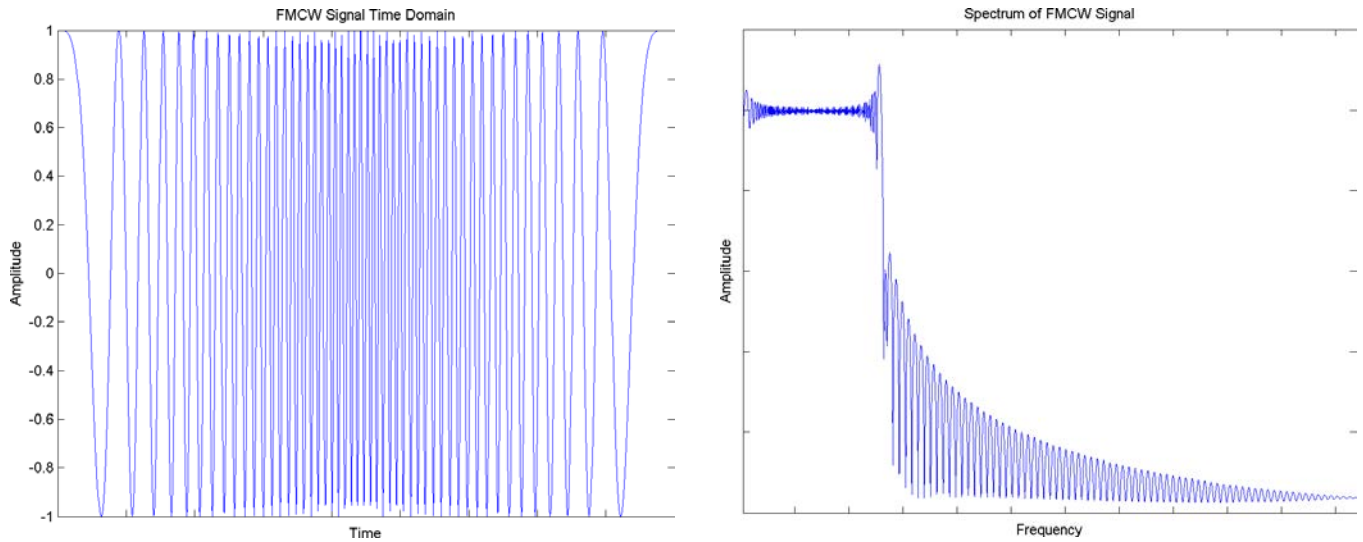
Another important radar parameter is range resolution. Radar range resolution is the minimum distance two objects must be separated by in order to differentiate them. For FMCW radars this is defined by,

$$\Delta R = \frac{c}{2 * (f_{stop} - f_{start})} = \frac{c}{2 * B} \quad (3.5)$$

where B is the bandwidth of the FMCW signal and is defined as $f_{stop} - f_{start}$. Examination of Eq.(3.5) shows that the range resolution is inversely proportional to the bandwidth of the signal. To be able to discern between targets in close proximity to one another, you should use a very large bandwidth.

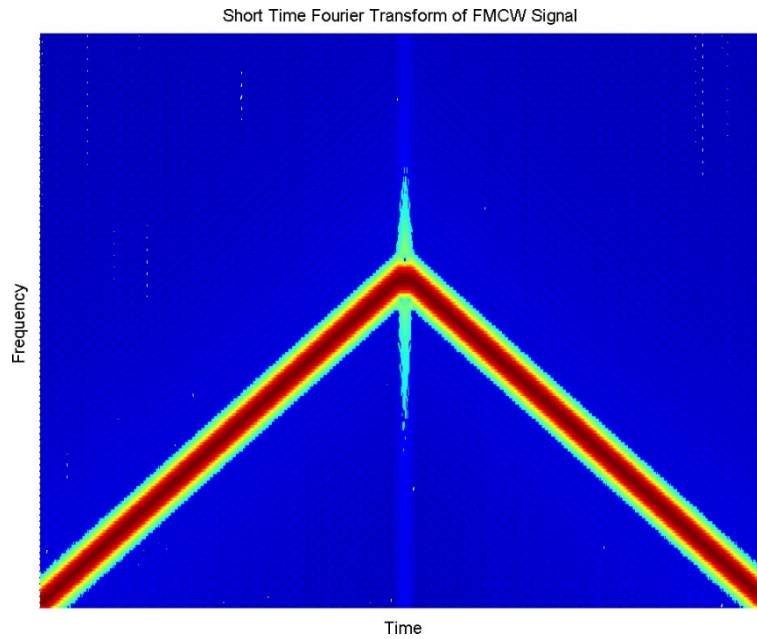
2.1 Analysis

An example of an FMCW waveform as a function of time (time domain) is shown in **Figure 3.3 (a)** and the resulting frequency spectrum is shown in **Figure 3.3 (b)**. In the example waveform shown, the output of the FMCW Radar starts from the lowest frequency and linearly increases to the highest frequency and then decreases back to the lowest frequency. This waveform contains both frequency up and down ramps and is typically referred to as a triangular wave as a frequency versus time plot would look like a triangle. This is best demonstrated by observing the short time Fourier Transform in **Figure 3.3 (c)**.



a) Time Domain

b) Frequency Spectrum



c) Short Time Fourier Transform

Figure 3.3: An example FMCW waveform as a function of time

3 Doppler Radar

The Radar Demonstration Kit may also be operated in CW mode. When operated in CW mode, a single frequency tone is radiated and the output of the mixer represents the change in frequency observed by the radar due to the Doppler Effect. The speed of the object can be determined from the frequency shift in the received signal as demonstrated in Eq.(3.6).

$$\Delta v = \frac{\Delta f * c}{f_o} \quad (3.6)$$

Where Δv is the speed of the object relative to the transmitting radar, and f_o is the transmit frequency of the PEM11002-KIT. The PEM11002-KIT cannot differentiate between positive and negative frequency changes; therefore, the detected object's direction must be determined by other means, such as observation.



4 Programming

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1 Introduction

1.1 USB Configuration

The Pasternack PEM11002-KIT Radar Demonstration Kit has been designed to configure as a USB Test and Measurement Class (USBTMC) device. No additional drivers are required.

The PEM11002-KIT has been designed to be Virtual Instrument Software Architecture (VISA) and Standard Commands for Programmable Instrumentation (SCPI) compliant and as such, all you need in order to communicate with the Radar Demonstration Kit is a VISA library installed on your machine. The PEM11002-KIT will work with any of the three major providers of VISA; National Instruments, Agilent, and Tektronics. If you do not have a VISA library installed, please visit one of the three vendors listed above to obtain a legal copy of the VISA library.

1.2 Command Syntax

In this manual, the following command syntax conventions are used:

- Square brackets ([]) indicate multiple keywords, one of which must be used
- Bars(|) can be read as "or" and are used to separate parameter options.

1.2.1 Mnemonic Forms

Each keyword has both a long and short form. A standard notation is used to differentiate the short form and long form keyword. The long form of the keyword is shown, with the short form of the keyword shown in uppercase letters and the rest of the keyword is shown in lowercase letters. For example, the short form of *FREQuency* is *FREQ*.

1.2.2 Using a Semicolon (;)

Use a semicolon to separate two commands within the same command string.

1.2.3 Using Whitespace

You *must* use whitespace characters, [tab], or [space] to separate a parameter from a keyword.

1.2.4 Using "?" Commands

The bus controller may send commands at any time, but a SCPI instrument may only send a response when specifically instructed to do so. Only commands that end with a "?", henceforth referred to as queries, instruct the instrument to send a response message. Queries can return either measured values, instrument settings, or internal status codes.

Note: *If you send multiple queries without reading the response between queries, only the result of the last query will be returned when the response is read. The query buffer is a first-in first-out configuration.*

1.2.5 Using "*" Commands

Commands starting with a "*" are called common commands. They are required to perform identical functions for all instruments that are compliant with the IEEE-488.2 interface standard. The "*" commands are used to control reset, self-test, and status operations in the Radar Demonstration Kit.

1.3 Diagram Syntax Conventions

- Solid lines represent the recommended path
- Ovals enclose command mnemonics. The command mnemonic must be entered exactly as shown in the oval.
- Dotted lines indicate an optional path for passing secondary or optional keywords.
- Arrows and curved intersections indicate command path direction.
- All diagrams flow from left to right. A path may not travel to the left except in a bypass loop.

1.4 Default Units

Unless otherwise specified, the following units are assumed:

Table 4.1: Default Units

Current	mA
Frequency	GHz
Power	dBm
Time	ms
Temperature	°C
Voltage	Volts

1.5 Status Reporting

Status reporting is used to monitor the Radar Demonstration Kit to determine which events have occurred. Status reporting is accomplished by configuring and reading status registers.

The Radar Demonstration Kit has the following main registers:

- Status Register
- Standard Event Register
- Operation Status Register
- Questionable Status Register
- Device Status Register

Status and Standard Event registers are read using the IEEE-488.2 common commands.

Operation and Questionable Status registers are read using the SCPI *STAT* subsystem.

1.6 SCPI Data Types

The SCPI language defines different formats for use in program messages and response messages. Instruments are flexible listeners and can accept commands and parameters in various formats. However, SCPI instruments are precise talkers. This means that SCPI instruments *always* responds to a particular query in a predefined, rigid format.

1.6.1 <boolean> Definition

Throughout this document <*boolean*> is used to represent *ON|OFF| <NRf>*. Boolean parameters have a value of *0* or *1* and are unitless. *ON* corresponds to *1* and *OFF* corresponds to *0*.

On input, an <NRf> is rounded to an integer. A nonzero result is interpreted as *1*. Queries always return a *1* or a *0*, never *ON* or *OFF*.

1.6.2 <character_data> Definition

Throughout this document, <character_data> is used to represent character data, that is, A-Z, a-z, 0-9 and *_* (underscore). *STOP* and *A4_U2* are examples of character data. The first character must be alphanumeric, followed by either alphanumeric or underscore characters up to a maximum of 12 characters.

1.6.3 <NAN> Definition

Not a number (NAN) is represented as *9.91 E37*. Not a number is defined in IEEE 754.

1.6.4 <non-decimal numeric> Definition

Throughout this document, <non-decimal numeric> is used to represent numeric information in bases other than 10 (that is, hexadecimal, octal, and

binary). Examples of non-decimal numeric include #HFF4, #hff4, #Q25, #q25, and #B101011.

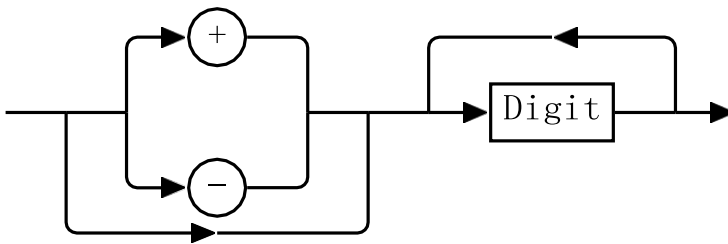
1.6.5 <NRf> Definition

Throughout this document, <NRf> is used to denote a flexible numeric representation. The following show examples of <NRf>

- +185
- -10
- +1.2E09

1.6.6 <NR1> Definition

Throughout this document, <NR1> numeric response data is defined as:

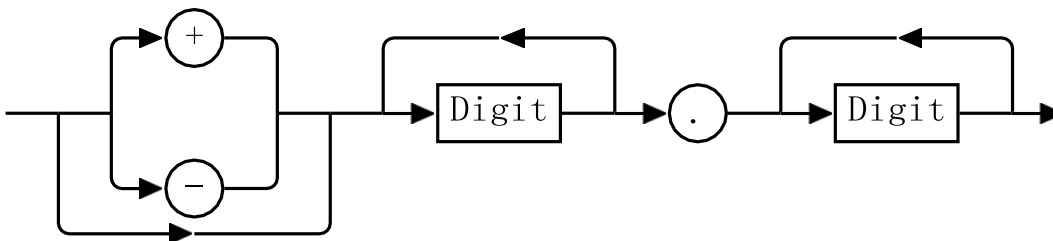


The following shows the examples of <NR1>:

- 127
- +127
- -12345

1.6.7 <NR2> Definition

Throughout this document, <NR2> numeric response data is defined as:

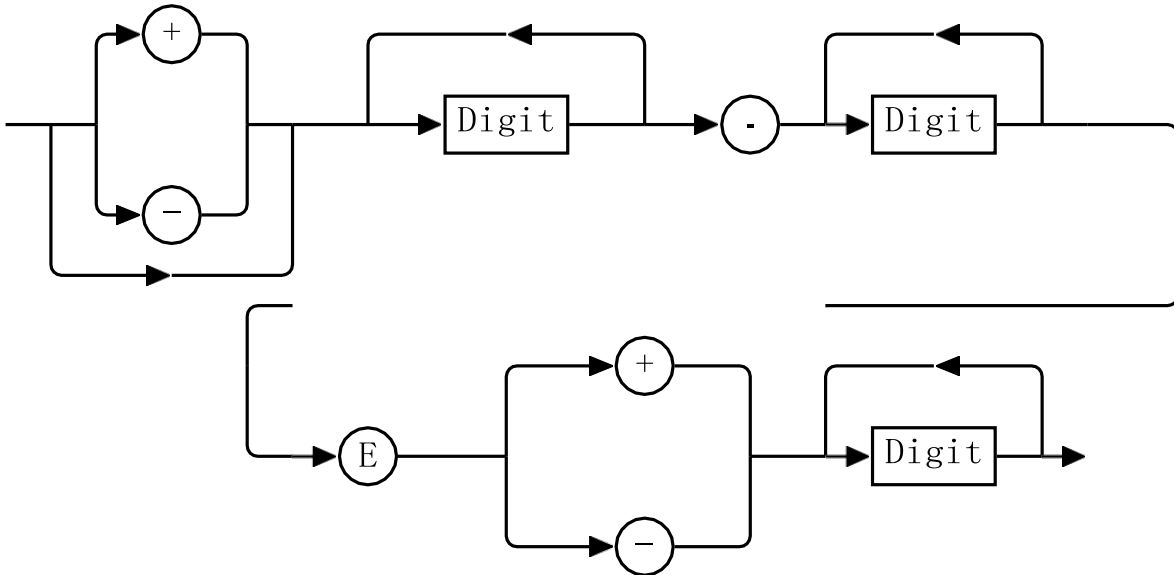


The following shows the examples of <NR2>:

- 12.7
- +127
- -1.2345
- -0.123

1.6.8 <NR3> Definition

Throughout this document, <NR3> numeric response data is defined as:



The following shows the examples of <NR3>:

- 1.23E+4
- 12.3E-45

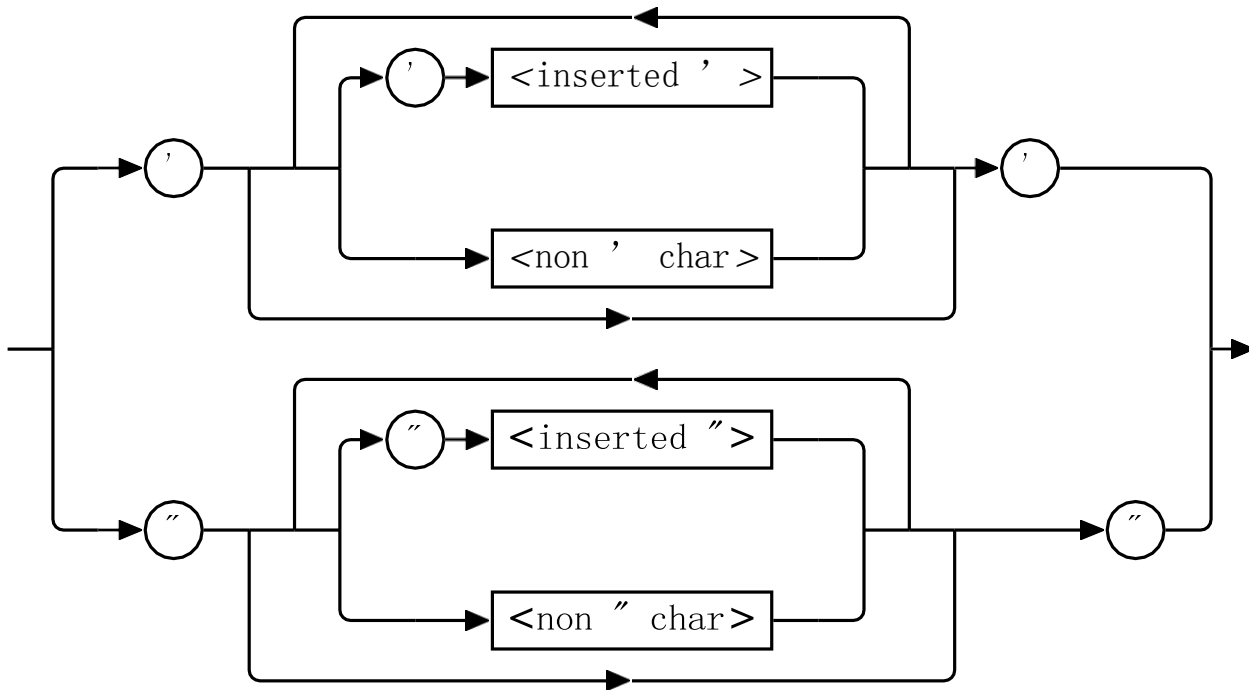
1.6.9 <numeric_value> Definition

Throughout this document, the decimal numeric element is abbreviated to <numeric_value>.

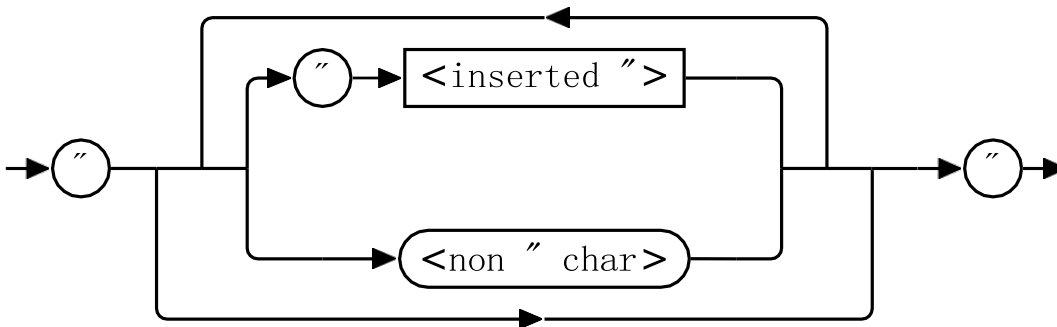
1.6.10 <string> Definition

Throughout this document, <string> is used to represent the 7-bit ASCII characters. The format is defined as:

Program Data



Response Data



1.7 Input Message Terminators

Program messages sent to a SCPI instrument *must* terminate with a <newline> character. The IEEE.488 EOI (end or identify) signal is interpreted as a <newline> character and may also be used to terminate a message in place of the <newline> character. A <carriage return> followed by a <newline> character is also accepted. Many programming languages allow you to specify a message terminator character or EOI state to be automatically sent with each bus transaction. Message termination **always** sets the current path back to the root-level.

1.8 Compliance Information

1.8.1 IEEE-488.2 Compliance

The Radar Demonstration Kit complies with the rules and regulations of the of the IEEE 488.2 standard which are applicable to USB controlled devices.

1.8.2 SCPI Compliance

The Radar Demonstration Kit complies with the rules and regulations of the of the SCPI (Standard Commands for Programmable Instruments). You can determine the SCPI version which the Radar Demonstration Kit complies with by sending the *SYSTem:VERSion?* command from the remote interface.

1.8.3 USBTMC Compliance

The PEM11002-KIT Radar Demonstration Kit complies with the rules and regulations of the of the USBTMC (USB Test and Measurement Class). When connected to a USB bus, the PEM11002-KIT will configure as a USB Test and Measurement device.

1.8.4 VISA Compliance

The PEM11002-KIT Radar Demonstration Kit complies with the rules and regulations of the of the VISA (Virtual Instrument Systems Architecture) standard. Communication with the PEM11002-KIT is accomplished through VISA libraries, providing portability between different operating systems. *No additional drivers are required.*



5 Command Quick Reference Guide

In This Chapter

1	Common (*) Commands	34
2	CAPTure Subsystem	35
3	FREQuency Subsystem.....	35
4	POWER Subsystem.....	36
5	SWEEP Subsystem.....	36
6	SYSTEM Subsystem.....	37

1 Common (*) Commands

Table 5.1: Common () Command Summary*

Command	Page	Description
*CLS	73	Clears the data structures. The SCPI registers are cleared.
*ESE <NRf>	74	Sets the Standard Event Status Enable Register.
*ESE?	74	Returns the Standard Event Status Enable Register.
*ESR?	75	Returns the contents of the Standard Event Status Register and then clears it.
*IDN?	76	Returns the identification of the device connected to the computer (Host).
*OPC	77	Causes the Radar Demonstration Kit to set the operation complete bit in the Standard Event Status Register when all pending operations have completed.
*OPC?	77	Returns the operation complete bit in the Standard Event Status Register when all pending operations have completed.
*OPT?	78	Returns the Radar Demonstration Kit installed options.
*RCL <NRf>	79	Recalls the state of the Radar Demonstration Kit from the specified register (memory location).
*RST	80	Returns the Radar Demonstration Kit to its initial power up state.
*SAV <NRf>	81	Saves the state of the Radar Demonstration Kit to the specified register (memory location).
*SRE <NRf>	82	Sets the Service Request Enable register bits.
*SRE?	82	Returns the Service Request Enable register bits.
*STB?	83	Returns the Radar Demonstration Kit status byte.

Command	Page	Description
*TRG	85	Triggers the Radar Demonstration Kit.
*TST?	86	Performs a self-test of the Radar Demonstration Kit.
*WAI	87	Causes the Radar Demonstration Kit to wait until either all pending commands are complete, the Device Clear command is received, or the power is cycled before executing any subsequent commands or queries.
DCL	88	Causes all USB instruments to assume a cleared condition.

2 CAPTure Subsystem

Table 5.2: CAPTure subsystem Command Summary

Command	Page	Description
CAPTure:FRAME	39	Initiates or returns a frame of captured data over USB.
CAPTure:STREAm	40	Initiates streaming of data over Bluetooth. The command returns the last specified number of samples to stream.

3 FREQUency Subsystem

Table 5.3: FREQUency subsystem Command Summary

Command	Page	Description
FREQUency:LOCK	42	Returns the lock status of the device.
FREQUency:REFerence:DIVider	43	Sets or Returns the reference divider value for the PLL of the device.

4 POWER Subsystem

Table 5.4: POWER subsystem Command Summary

Command	Page	Description
POWER:RF	45	Turns on or off the RF output of the device

5 SWEEP Subsystem

Table 5.5: SWEEP subsystem Command Summary

Command	Page	Description
SWEEP:FREQuencySTART	47	Sets or returns the sweep start frequency.
SWEEP:FREQuencySTOP	48	Sets or returns the sweep stop frequency.
SWEEP:RAMPTIME	49	Sets or returns the sweep ramp time.
SWEEP:START	50	Starts a sweep using the set frequency start, frequency stop, mode, and ramp time.
SWEEP:STOP	51	Stops the current sweep and disables the RF output.
SWEEP:TYPE	52	Sets or returns the sweep type.

6 SYSTEM Subsystem

Table 5.6: SYSTem subsystem Command Summary

Command	Page	Description
SYSTem:BLUEtooth	56	Returns the Bluetooth connection status.
SYSTem:CLeaRMemory	57	Clears the contents of the specified memory location.
SYSTem:ERRor	58	Returns the contents of the error queue of the device.
SYSTem:FIRMware	63	Returns the firmware version of the device.
SYSTem:IDENtify	64	Returns the identification string of the device.
SYSTem:MODElNUMBER	65	Returns the model number of the device.
SYSTem:PRESet	66	Returns the device to its initial power-up state.
SYSTem:RESTore	67	Restores the device to the factory default state. Memory location is overwritten with the factory defaults.
SYSTem:SERialNUMBER	68	Returns the serial number of the device.
SYSTem:STATus	69	Returns the status of the device.
SYSTem:TEMPerature	70	Returns the maximum temperature reading from the device.
SYSTem:VERSion	71	Returns the version of SCPI used by the device.



6 CAPTure Subsystem

In This Chapter

1	CAPTure:FRAMe <integer>	39
2	CAPTure:STREAm <integer>	40

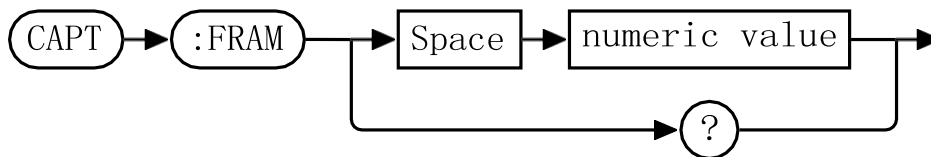
1 CAPTure:FRAMe <integer>

This command captures a frame of data consisting of the number of samples specified. The valid range for the number of samples is from 1 to 4096. To transfer the captured frame of data, issue the *CAPTure:FRAMe?* command. The *CAPTure:FRAMe?* command will return up to 31 samples of previously collected data in the form of 4 digit hex values, 124 characters total. *CAPTure:FRAMe?* must be called until all data has been transferred. If the *CAPTure:FRAMe?* command is issued prior to the data being ready, the query will return "Not Ready".

NOTICE

The *CAPTure:FRAMe* command is only recommended for use when connected to the PEM11002-KIT through USB. When connected through Bluetooth, use the *CAPTure:STREAm* command for real-time data streaming.

Syntax



Example

`CAPT:FRAM 2400` *This command captures a frame of data consisting of 2400 data samples*

Query

`CAPT:FRAM?` *This query returns a string of up to 124 characters corresponding to 31 data points of the previously collected frame. For example, if the command `CAPT:FRAM 2400` is issued, `CAPT:FRAM?` must be called 78 times in order to transfer all data points ($\text{ceil}(2400/31)$). Every group of four characters is one data point represented in hex. Each four digit hex value can be converted to decimal to obtain the data point values. If the query is issued before the frame of data is complete, the query will return "Not Ready".*

Error Messages

If the number of samples entered is out of the operational range of the specified device, an error message of 201, *"Parameter specified out of Device's operating range"* is placed in the device's error queue.

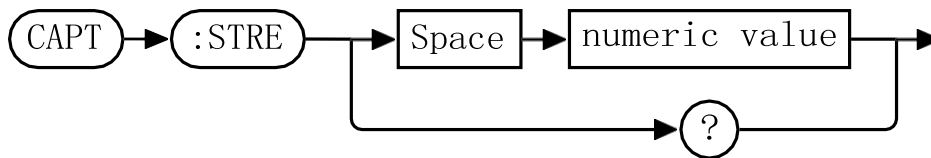
2 CAPTure:STREAm <integer>

This command streams the specified number of samples over Bluetooth. The valid range for the number of samples is from 1 to 65536.

NOTICE

Streaming is only available to devices connected through Bluetooth. When connected through USB, please use the *CAPTure:FRAME* command to capture and transfer data.

Syntax



Example

`CAPT:STRE 2400` *This command streams 2400 data samples over Bluetooth*

Query

`CAPT:STRE?` *This query returns the number of samples to be streamed*

Error Messages

If the number of samples entered is out of the operational range of the specified device, an error message of 201, *"Parameter specified out of Device's operating range"* is placed in the device's error queue.



7 FREQuency Subsystem

In This Chapter

1. FREQuency:LOCK? 42
2. FREQuency:REFeRence:DIVider <numeric value > 43

1. FREQUency:LOCK?

This command returns the lock status of the Radar Demonstration Kit. A lock status of *0* indicates that the device is unlocked, while a lock status of *1* indicates that the device is locked.

Syntax



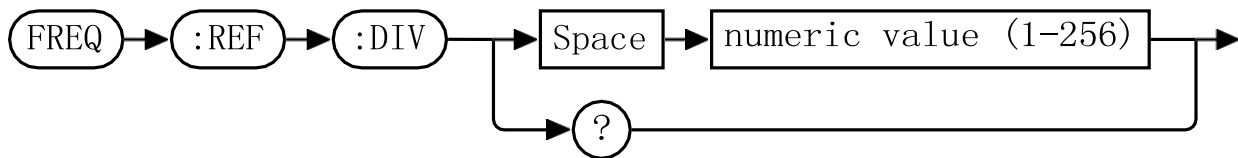
Query Example

FREQ:LOCK? *This query returns the lock status of the device*

2. FREQUency:REFErence:DIVider <numeric value>

This command allows the user to set the frequency reference divider of the Radar Demonstration Kit. The reference frequency divider is used to provide finer resolution steps in integer mode. The acceptable range for the reference divider is 1 through 256.

Syntax



Allowed Values

The reference frequency divider value can be set to any integer value between 1 and 256.

Example

FREQ:REF:DIV 10 *This command sets the reference divider value to 10.*

Default Condition

On power up, or when a *SYST:PRES* or **RST* command is issued, the reference divider value defaults to the value stored in memory location 0, unless otherwise specified in the product's Operation Manual.

Query

FREQ:REF:DIV? This query returns the reference divider value



8 POWER Subsystem

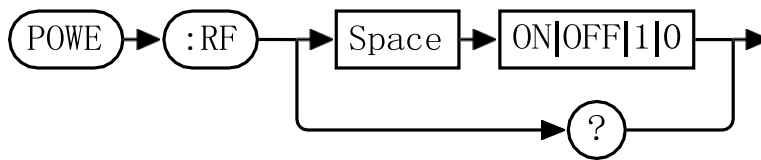
In This Chapter

1. POWER:RF [ON OFF 1 0]	45
--------------------------------	----

1. POWER:RF [ON/OFF/1/0]

This command allows the user to turn on and off the RF output of the Radar Demonstration Kit.

Syntax



Example

`POWE:RF 0` *This command turns off the RF.*

Default Condition

On power up, or when a `SYST:PRES` or `*RST` command is issued, the Radar Demonstration Kit RF output defaults to the *RF OFF* state, unless otherwise specified in the product's Operation Manual.

Query

`POWE:RF?` *This query returns power output state of the device.*

- 0 is returned if the RF output is *OFF*
- 1 is returned if the RF output is *ON*

Error Messages

If the device does not have an integrated mute capability, an error message of 110, *"Invalid Command For Specified Device"* is placed in the device's error queue.



9 SWEEP Subsystem

In This Chapter

1. SWEEP:FREQuencySTARt <numeric value >	47
2. SWEEP:FREQuencySTOP <numeric value >	48
3. SWEEP:RAMPTIME <integer >.....	49
4. SWEEP:START.....	50
5. SWEEP:STOP.....	51
6. SWEEP:TYPE[RAMP TRI AUTO CW 0 1 2 3].....	52

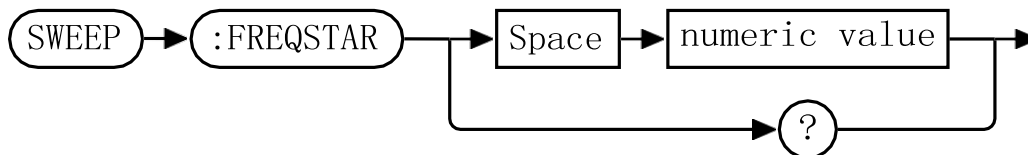
1. SWEEP:FREQuencySTARt <numeric value>

This command sets the frequency start value for the sweep in GHz.

NOTICE

When in CW mode, the sweep stop frequency can be set without generating an error, but the command will be ignored.

Syntax



Example

SWEEP:FREQSTAR 2.45

This command sets the sweep start frequency of the device to 2.45 GHz.

Default Condition

On power up, or when a *SYST:PRES* or **RST* command is issued, sweep start frequency defaults to 2.4 GHz.

Query

SWEEP:FREQSTAR?

This query returns the sweep start value for the current sweep mode in GHz

Error Messages

If the sweep start frequency entered is out of the operational range of the device, an error message of 201, *"Parameter specified out of Device's operating range"* is placed in the device's error queue.

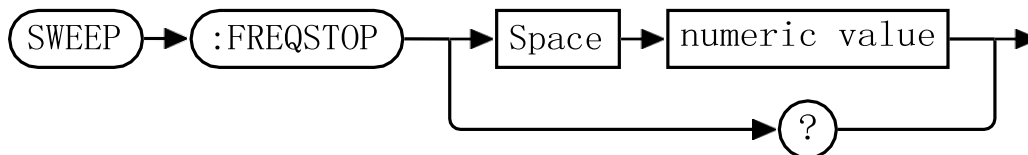
2. SWEEP:FREQuencySTOP <numeric value>

This command sets the frequency stop value for the sweep in GHz.

NOTICE

When in CW mode, the sweep stop frequency can be set without generating an error, but the command will be ignored.

Syntax



Example

SWEEP:FREQSTOP 2.49 *This command sets the sweep stop frequency of the device to 2.49 GHz.*

Default Condition

On power up, or when a *SYST:PRES* or **RST* command is issued, the sweep stop frequency defaults to 2.5 GHz.

Query

SWEEP:FREQSTOP? *This query returns the sweep stop value for the current sweep mode in GHz*

Error Messages

If the sweep stop frequency entered is out of the operational range of the specified device, an error message of 201, "*Parameter specified out of Device's operating range*" is placed in the device's error queue.

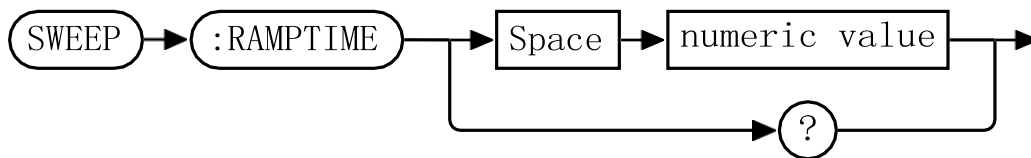
3. SWEEP:RAMPTIME <integer>

This command sets the ramp time of the PEM11002-KIT in milliseconds. The maximum allowed ramp time is 65536ms.

NOTICE

When in CW mode, the sweep ramp time can be set without generating an error, but the command will be ignored.

Syntax



Example

SWEEP:RAMPTIME 2400 *This command sets the sweep ramp time to 2.4 s.*

Default Condition

On power up, or when a *SYST:PRES* or **RST* command is issued, the sweep ramp time defaults to 16 ms.

Query

SWEEP:RAMPTIME? *This query returns the sweep stop value for the current sweep ramp time in ms*

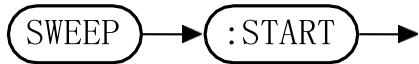
Error Messages

If the sweep ramp time entered is out of the operational range of the specified device, an error message of 201, *"Parameter specified out of Device's operating range"* is placed in the device's error queue.

4. SWEEP:START

The *SWEEP:START* command starts a sweep using the set frequency start, frequency stop, type, and ramp time. When operating in sweep mode 0|SAWtooth or 1|TRIngle, issuing the *SWEEP:START* command will perform one sweep cycle and then place the PEM11002-KIT in a wait state until the next *SWEEP:START* command is received.

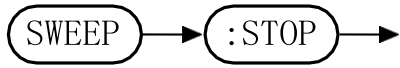
Syntax



5. SWEEP:STOP

The `SWEEP:STOP` command stops the current sweep, and turns off the RF power.

Syntax



6. SWEEP:TYPE[RAMP/TRI/AUTO/CW/0/1/2/3]

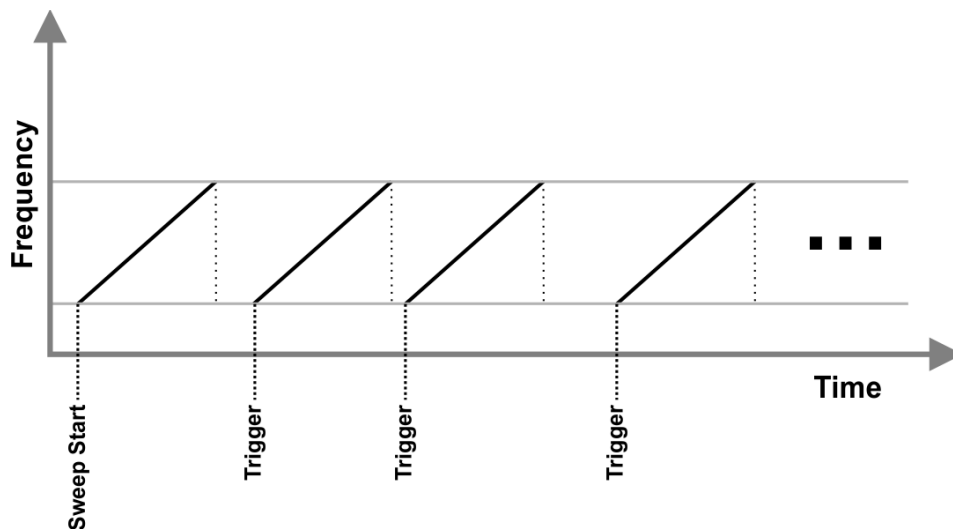
This command sets sweep type of the Radar Demonstration Kit.

NOTICE

When the sweep type is changed, the current sweep is stopped and the Radar Demonstration Kit is put into a powered down state. Sweeping can be restarted by issuing the *SWEEP:START* command.

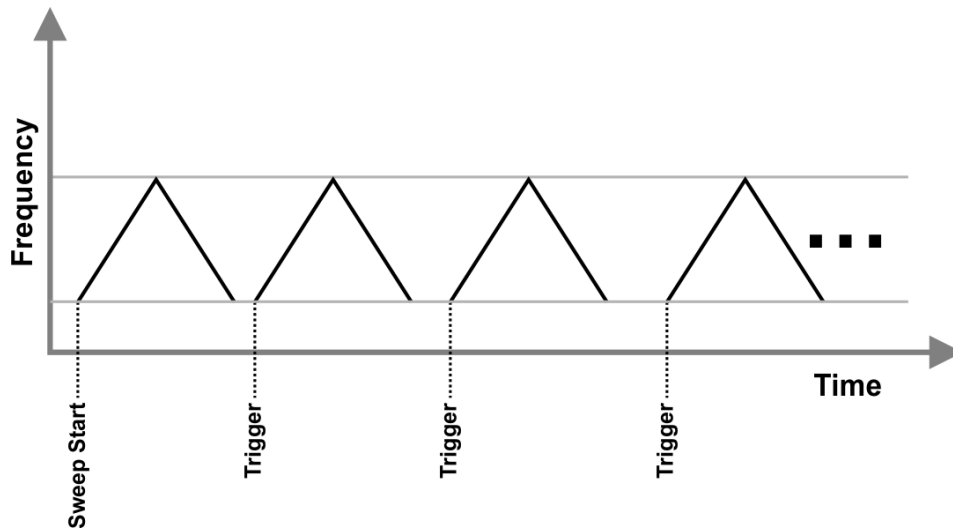
There are four sweep types available:

Ramp [RAMP/0]



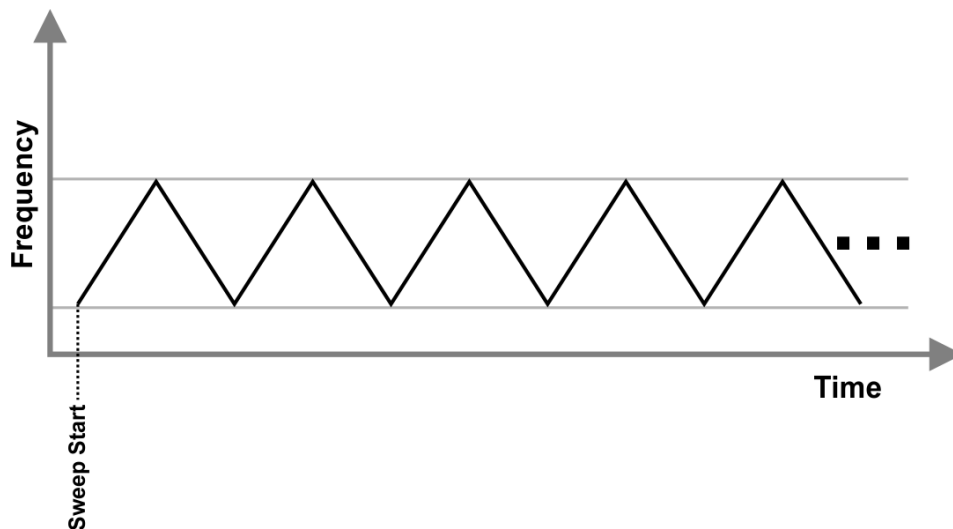
When configured for the *RAMP* sweep type, the Radar Demonstration Kit linearly sweeps between a specified start and stop frequency. Once the stop frequency has been reached, the frequency of the Radar Demonstration Kit jumps to the start frequency and the ramp begins again once a hardware or software trigger is received.

Triangle [TRI/1]



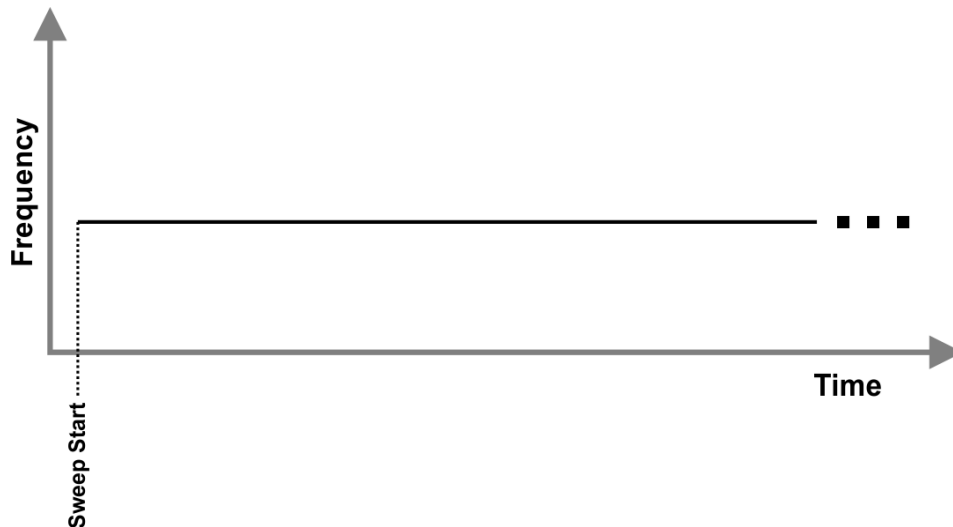
When configured for the *TRI* sweep type, the output frequency of the Radar Demonstration Kit starts from the start frequency and increases linearly until the stop frequency is reached. Once the stop frequency is reached, the output frequency of the Radar Demonstration Kit is linearly decreased until the start frequency is reached. The process repeats every time a hardware or software trigger is received.

Automatic Triangle [AUTO/2]



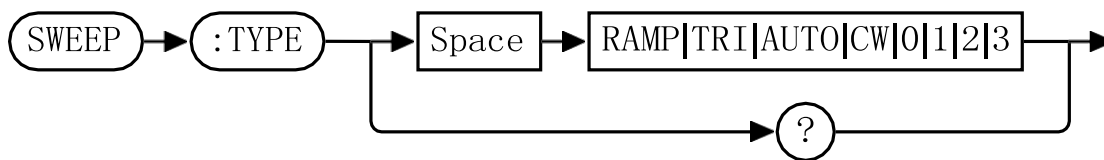
When configured for the *AUTO* sweep type, the output frequency of the Radar Demonstration Kit starts from the start frequency and increases linearly until the stop frequency is reached. Once the stop frequency is reached, the output frequency of the Radar Demonstration Kit is linearly decreased until the start frequency is reached. The process automatically repeats without requiring a hardware or software trigger.

Continuous Wave [CW/3]



When configured for the *CW* sweep type, the Radar Demonstration Kit outputs a single frequency tone at the specified start frequency.

Syntax



Example

`SWEEP:TYPE 2` *This command sets the sweep type of the device to Automatic Tri- angle.*

Default Condition

On power up, or when a `SYST:PRES` or `*RST` command is issued, the sweep type setting defaults to Automatic Triangle (type = 2).

Query Example

`SWEEP:TYPE?` *This query returns sweep type setting of the device.*

- 0 is returned when the sweep type setting is *RAMP*
- 1 is returned when the sweep type setting is *TRI*
- 2 is returned when the sweep type setting is *AUTO*
- 3 is returned when the sweep type setting is *CW*



10 SYSTEM Subsystem

In This Chapter

1	SYSTEM:BLUEtooth?.....	56
2	SYSTEM:CLearMemory [1-9].....	57
3	SYSTEM:ERRor?	58
4	SYSTEM:FIRMware?	63
5	SYSTEM:IDENtify?	64
6	SYSTEM:MODElNUMBER?.....	65
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8	SYSTEM:RESTore	67
9	SYSTEM:SERialNUMBER?.....	68
10	SYSTEM:STATus?	69
11	SYSTEM:TEMPerature?.....	70
12	SYSTEM:VERSion?	71

1 SYSTem:BLUEtooth?

This command returns the Bluetooth connection status. A connection status of 0 indicates that a device is not connected to the PEM11002-KIT, while a connection status of 1 indicates that a device is connected to the PEM11002-KIT.



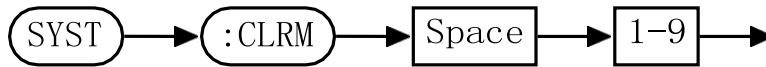
Query Example

SYST:BLUE? *This query returns the Bluetooth connection status of the PEM11002-KIT.*

2 **SYSTem:CLearMemory [1-9]**

This command clears the specified memory location. Memory location 0 is a protected memory location and cannot be cleared. To erase the parameters stored in Memory location 0, use the *SYSTem:REStore* command to overwrite the parameters stored in Memory Location 0 with the factory defaults.

Syntax



Example

SYST:CLRM 3 *This command clears memory location 3.*

3 SYSTem:ERRor?

This query returns error numbers and messages from the PEM11002-KIT error queue. When an error is generated by the PEM11002-KIT, the error number and corresponding error message is stored in the error queue. Each time the error queue is queried, the first error in the error queue is returned. The errors are read out in the order of first-in first-out. To clear all errors in the error queue, use the *CLS command.

When the error queue is empty, a query of the error queue will return a 0, "No error" message. The error queue has a maximum capacity of 10 errors.

Syntax



Query Example

SYST:ERR? *Queries the system error.*

Error queue messages have the following format:



For example, 100, "Syntax Error"

Reset Condition

On reset, the error queue is cleared.

Error Message List

Table 10.1: Error Codes and Messages

-101	Invalid character Invalid character was found in the command string
-102	Syntax error Invalid syntax was found in the command string
-103	Invalid separator Invalid separator was found in the command string

-
- 105 GET not allowed
A Group Execute Trigger (GET) is not allowed within a command string
-
- 108 Parameter not allowed
More parameters were received than expected for the command
-
- 109 Missing parameter
Fewer parameters were received than expected for the command
-
- 112 Program mnemonic too long
A command header was received which contained more than the maximum 12 characters allowed.
-
- 113 Undefined header
A command was received that is not valid for the Radar Demonstration Kit
-
- 121 Invalid character in number
An invalid character was found in the number specified for a parameter value
-
- 123 Exponent too large
A numeric parameter was found whose exponent was larger than 32,000.
-
- 124 Too many digits
A numeric parameter was found whose mantissa contained more than 255 digits.
-
- 128 Numeric data not allowed
A numeric value was received within a command which does not accept a numeric value
-
- 131 Invalid suffix
A unit was incorrectly specified for a numeric parameter.
-

-
- 134 Suffix too long
A unit used contained more than 12 characters.
-
- 138 Suffix not allowed
A unit was received following a numeric parameter which does not accept a unit.
-
- 141 Invalid character data
An invalid character was received.
-
- 148 Character data not allowed
A discrete parameter was received but a character string or numeric parameter was expected
-
- 151 Invalid string data
An invalid string was received.
-
- 158 String data not allowed
A character string was received but not allowed for the command.
-
- 161 Invalid block data
A block data element was expected but was invalid.
-
- 168 Block data not allowed
A legal block data element was encountered but not allowed by the product.
-
- 178 Expression data not allowed
A legal expression data element was encountered but not allowed by the product.
-
- 200 Execution error
Indicates that an execution error has occurred.
-

-211 Trigger ignored

Indicates that a trigger command was received but ignored because the Radar Demonstration Kit was not in the wait for trigger state.

-213 Trigger ignored

Indicates that a trigger command was received but ignored because the Radar Demonstration Kit was not in the wait for trigger state.

-222 Data out of range

A numeric parameter value is outside the valid range for the command.

-224 Illegal parameter value

A discrete parameter was received which was not a valid choice for the command.

-230 Data corrupt or stale

This occurs when a measurement command is attempted and either a reset has been received or the state of the Radar Demonstration Kit has changed such that the measurement is no longer valid.

-241 Hardware missing

The Radar Demonstration Kit is unable to execute the command because the hardware does not support that feature.

-310 System error

This error indicates a failure with the Radar Demonstration Kit

-330 Self-test failed

The -330, "Self-test failed" error indicates a problem with the Radar Demonstration Kit-

-350 Queue overflow

The error queue is full and another error has occurred which could not be recorded.

-410 Query INTERRUPTED

A command was received which sends data to the output buffer, but the output buffer contained data from a previous command. The output buffer is cleared when power has been off or after a *RST or SYST:PRES command has been issued.

-420 Query UNTERMINATED

The Radar Demonstration Kit was addressed to talk but a command has not been received which sends data to the output buffer.

-430 Query DEADLOCKED

A command was received which generates too much data to fit in the output buffer and the input buffer is also full. Command execution continues but data is lost.

-440 Query UNTERMINATED after indefinite response

The *IDN? command must be the last query command within a command string.

-0 No error

No errors in the error queue. Device is operating normally.

+110 Invalid command for specified device

The issued command is invalid for the specified device.

+201 Parameter specified out of device's operating range

The parameter specified is outside of the device's operating range.

4 SYSTem:FIRMware?

This command returns the current software firmware of the PEM11002-KIT.

Syntax



Query Example

SYST:FIRM? *This query returns the current firmware version of the Radar Demonstration Kit.*

5 SYSTem:IDENtify?

This query returns the ID string of the device. This command is equivalent to issuing the **IDN?* command.

Syntax



Query Example

`SYST:IDEN?` *Returns the ID string of the device.*

6 SYSTem:MODElNUMBER?

This command returns the model number of the device.

Syntax



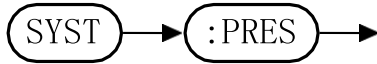
Query Example

SYST:MODNUM? *This query returns the model number of the device.*

7 SYSTem:PRESet

The SYSTem:PRESet command returns the Radar Demonstration Kit to its initial power-up state.

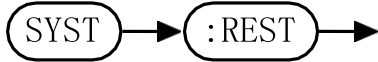
Syntax



8 SYSTem:REStore

This command restores the PEM11002-KIT to the factory default state. Memory location 0 is overwritten with the factory default settings. For a detailed description of the parameters saved, see your product's Operation Manual.

Syntax



Example

SYST:REST *This command restores the factory default setting to memory location 0.*

9 SYSTem:SERialNUMBER?

This command returns the serial number of the device.

Syntax



Query Example

SYST:SERNUM? *This query returns the serial number of the device.*

10 SYSTem:STATus?

This command returns the status of the Radar Demonstration Kit.

Syntax



Query Example

SYST:STAT? *This query returns the status of the Radar Demonstration Kit*

Status messages have the following format:



For example, 0, "Operational"

Status Message List

Table 10.2: Status Codes and Messages

0	Operational Device is operating normally.
1	Device has been reset The device has been recently reset.
2	Awaiting user input Unit is awaiting user input.
100	Recoverable error has occurred An error has occurred from which the device can recover.
101	Non-Recoverable error occurred An error has occurred from which the device cannot recover.
110	Over temperature The operating temperature of the device exceeds safe operating temperatures.

11 SYSTem:TEMPerature?

This command returns the maximum temperature reading from the PEM11002-KIT.

Syntax



Query Example

SYST:TEMP? *This query returns the maximum temperature reading from the Radar Demonstration Kit*

12 SYSTem:VERSion?

This query returns the version of SCPI used in the Radar Demonstration Kit. The response is in the format XXXX.Y, where XXXX is the year and Y is the version number.

Syntax



Query Example

SYST:VERS? *This query returns the version of SCPI used in the Radar Demonstration Kit.*



11 IEEE 488.2 Command Reference

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1 SCPI Compliance Information

This chapter contains information on the IEEE-488 Common Commands that the Radar Demonstration Kit supports.

The IEEE-488.2 Common Command descriptions are listed below.

Table 11.1: IEEE 488.2 common commands

<i>*CLS</i>	Clear Status	Page 73
<i>*ESE</i> and <i>*ESE?</i>	Event Status Enable	Page 74
<i>*ESR?</i>	Event Status Register	Page 75
<i>*IDN?</i>	Identify	Page 76
<i>*OPC</i> and <i>*OPC?</i>	Operation Complete	Page 77
<i>*OPT?</i>	Options	Page 78
<i>*RCL</i>	Recall	Page 79
<i>*RST</i>	Reset	Page 80
<i>*SAV</i>	Save	Page 81
<i>*SRE</i> and <i>*SRE?</i>	Service Request Enable	Page 82
<i>*STB?</i>	Status Byte	Page 83
<i>*TRG</i>	Trigger	Page 85
<i>*TST?</i>	Test	Page 86
<i>*WAI</i>	Wait	Page 87

2 *CLS

The **CLS* (Clear Status) command clears the data structures. The SCPI registers are all cleared.

Syntax

**CLS* →

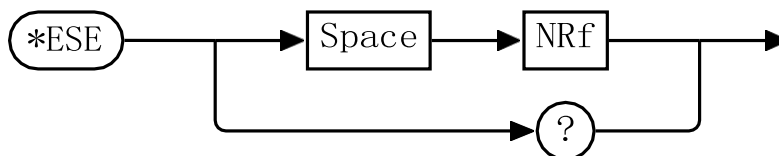
3 *ESE <NRf>

The **ESE* (Event Status Enable) command sets the Standard Event Status Enable Register. This register contains a mask value for the bits to be enabled in the Standard Event Status Register. A *1* in the enable register enables the corresponding bit in the Status Register, a *0* disables the corresponding bit in the Status Register. The parameter value when expressed in base 2, represents the bit values of the Standard Event Status Enable Register. **Table 11.2** shows the contents of this register.

Table 11.2: *ESE bit mapping

Bit	Base 2	Meaning
0	1	Operation Complete
1	2	Request Control (not used)
2	4	Query Error
3	8	Device Dependent Error
4	16	Execution Error
5	32	Command Error
6	64	Not Used
7	128	Power On

Syntax



Allowed Values

The *NRf* parameter can be any integer in the range of 0 to 255.

Query

ESE? *This query returns the contents of the Standard Event Status Enable Register.*

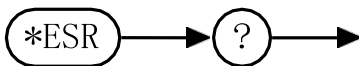
4 *ESR?

The *ESR? query returns the contents of the Standard Event Status Register then clears it. The returned value is in the range of 0 to 255. **Table 11.3** shows the contents of this register.

Table 11.3: *ESR? mapping

Bit	Base 2	Meaning
0	1	Operation Complete
1	2	Not Used
2	4	Query Error
3	8	Device Dependent Error
4	16	Execution Error
5	32	Command Error
6	64	Not Used
7	128	Power On

Syntax



5 *IDN?

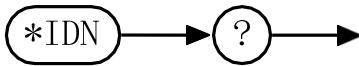
The **IDN?* query allows the connected device to identify itself. The string returned is:

Pasternack, <Product Number>, <Serial Number>, <Firmware>, <Device Id>

where:

- <Product Number> identifies the product number of the host
- <Serial Number> uniquely identifies the host
- <Firmware> returns the firmware of the host
- <Device Id> returns the device id of the host

Syntax



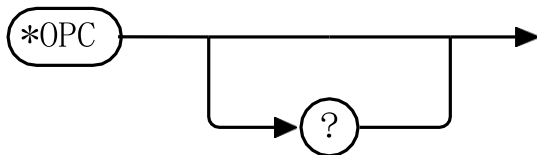
6 *OPC

The *OPC (Operation Complete) command causes the Radar Demonstration Kit to set the operation complete bit in the Standard Event Status Register when all pending device operations have been completed.

Table 11.4: *OPC mapping

Bit	Base 2	Meaning
0	1	Operation Complete
1	2	Not Used
2	4	Query Error
3	8	Device Dependent Error
4	16	Execution Error
5	32	Command Error
6	64	Not Used
7	128	Power On

Syntax



Query

*OPC? *This query places a 1 in the output queue when all device operations have been completed.*

7 *OPT?

The **OPT?* query reports the options installed in the PEM11002-KIT Radar Demonstration Kit and returns " " empty string if no options have been installed.

Syntax



8 *RCL <NRf>

The *RCL (ReCaLI) command restores the state of the PEM11002-KIT Radar Demonstration Kit from the specified save or recall register. Valid register addresses are 0 to 9. A configuration must have been stored previously in the specified register.

Syntax



Allowed Values

The *NRf* parameter can be any integer in the range of 0 to 9.

Error Message

If the register does not contain a saved state, error 115, "*Illegal parameter value*" occurs.

9 *RST

The **RST* (ReSeT) command returns the PEM11002-KIT Radar Demonstration Kit to its initial power-up state.

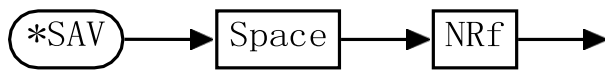
Syntax

 *RST →

10 *SAV <NRf>

The *SAV (SAVe) command restores the state of the PEM11002-KIT Radar Demonstration Kit from the specified save or recall register. Valid register addresses are 0 to 9. A configuration must have been stored previously in the specified register.

Syntax



Allowed Values

The *NRf* parameter can be any integer in the range of 0 to 9.

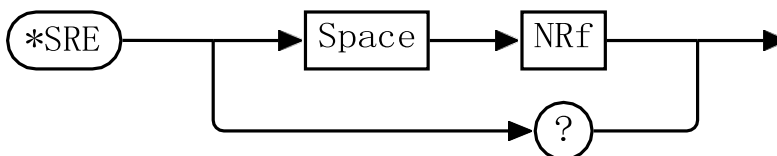
11 *SRE <NRf>

The *SRE command sets the Service Request Enable register bits. This register contains a mask value for the bits to be enabled in the Status Byte Register. A 1 in the enable register enables the corresponding bit in the Status Register, a 0 disables the corresponding bit in the Status Register. The parameter value when expressed in base 2, represents bits 0 to 5 and bit 7 of the Service Request Enable Register. Bit 6 is not used and is always 0. **Table 11.5** shows the contents of this register.

Table 11.5: *SRE bit mapping

Bit	Base 2	Meaning
0	1	Not used
1	2	Not Used
2	4	Device Dependent
3	8	Questionable Status Summary
4	16	Message Available
5	32	Event Status Bit
6	64	Not Used
7	128	Operation Status Summary

Syntax



Allowed Values

The *NRf* parameter can be any integer in the range of 0 to 255.

Query

*SRE? *This query returns the contents of bits 0 to 5 and bit 7 of the Service Request Enable Register. Bit 6 is always 0.*

12 *STB?

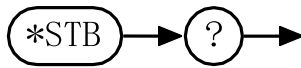
The *STB? (STatus Byte) query returns bit 0 to 5 and bit 7 of the PEM11002-KIT Radar Demonstration Kit status byte and returns the Master Summary Status (MSS) as bit 6. The MSS is inclusive OR of the bitwise combination (excluding bit 6) of the Status Byte and the Service Request Enable registers. The format of the return is an integer between 0 and 255. **Table 11.6** shows the contents of this register.

Table 11.6: *STB mapping

Bit	Base 2	Meaning
0	1	Not used
1	2	Device Dependent 0 – No device status condition has occurred 1 – A device status condition has occurred
2	4	Error/Event Queue 0 = Queue empty 1 = Queue not empty
3	8	Questionable Status Summary 0 – No QUEStionable status conditions have occurred 1 – A QUEStionable status condition has occurred
4	16	Message Available 0 – no output messages are ready 1 – an output message is ready
5	32	Event Status Bit 0 – no event status has occurred 1 – an event status condition has occurred

Bit	Base 2	Meaning
6	64	Master Summary Status 0 – Radar Demonstration Kit not requesting service 1 – there is at least one reason for requesting service
7	128	Operation Status Summary 0 = No OPERation status condition have occurred 1 = An OPERation status condition has occurred

Syntax



13 *TRG

The **TRG* (TRiGger) command triggers the PEM11002-KIT Radar Demonstration Kit when it is in the waiting for trigger state.

Syntax

 *TRG →

Error Message

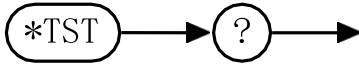
If the Radar Demonstration Kit is not in the wait-for-trigger state, error 210, *"Trigger Ignored"* occurs.

14 *TST?

The **TST?* query causes the PEM11002-KIT Radar Demonstration Kit to perform a self-test. The result of the self-test is placed in the output queue.

- 0 is returned if the test passes
- 1 is returned if the test fails

Syntax



15 *WAI

The **WAI* (WAIt) command causes the PEM11002-KIT Radar Demonstration Kit to wait until either:

- All pending operations are complete
- The *Device Clear* command is received
- Power is cycled

before executing any subsequent commands or queries.

Syntax

 *WAI →

16 USBTMC/USB488 Universal Commands

DCL

The *DCL* (Device Clear) command causes all USB instruments to assume a cleared condition. The definition of Device Clear is unique for each instrument. For the PEM11002-KIT:

- All pending operations are halted
- The parser (the software that interprets the programming codes) is reset and is waiting for the first character of a programming code.
- The output buffer is cleared.
- The ARI expansion bus is scanned for attached modules. Any modules found on the ARI expansion bus are identified.

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