Keysight - N5224/5A Add 4-Port Capability Upgrade Kit For Version 6 Synthesizers

(For Models With Single Source Synthesizers)

- Installation Guide

To Upgrade N5224/5A Series
Option 201 to Option 401 –
(900 Hz/10 MHz - 43.5 GHz)
(900 Hz/10 MHz - 50 GHz)
Upgrade Kit Order Numbers:
N5224AU- 601 and N5225AU- 601
Keysight Kit Number: N5225-60121

This is the Installation Guide for the N5224/5A Series Microwave Network Analyzers.

KEYSIGHT

Notices

Trademark Acknowledgments

Manual Part Number

N5225-90121

Edition

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Warranty

Technology Licenses

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Safety Notices

CAUTION

A **CAUTION** notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in damage to the product or loss of important data. Do not proceed beyond a CAUTION notice until the indicated conditions are fully understood and met.

WARNING

A **WARNING** notice denotes a hazard. It calls attention to an operating procedure, practice, or the like that, if not correctly performed or adhered to, could result in personal injury or death. Do not proceed beyond a WARNING notice until the indicated conditions are fully understood and met.

Keysight Add 4-Port Capability Upgrade Kit
Upgrade Kit Order Number: N5225-60112
Installation Note

Description of the Upgrade

This upgrade converts your N5224A or N5225A Option 201 2-port analyzer to a N5224A or N5225A Option 401
4-port analyzer by adding:

— an additional source

— an additional source synthesizer

— two additional doublers

— an additional mixer brick

— two additional receiver

— couplers

— two additional test port couplers

— a splitter

— a modified front panel

— new cables

Refer to "Overview of the Installation Procedure" on page 12.

| CAUTION | This repair must be done at a service center or a self-maintainer service center! Refer to "Getting Assistance from Keysight" on page 4. |

KEYSIGHT
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Getting Assistance from Keysight

Installing this upgrade kit requires special skills and experience. If you think you may not be qualified to do the work, or need advice, contact Keysight.

Contacting Keysight

Assistance with test and measurements needs and information on finding a local Keysight office are available on the Web at:
http://www.keysight.com/find/assist

If you do not have access to the Internet, please contact your Keysight field engineer.

NOTE	In any correspondence or telephone conversation, refer to the Keysight product by its model number and full serial number. With this information, the Keysight representative can determine whether your product is still within its warranty period.

If You Have Problems With the Upgrade Kit Contents

Keysight stands behind the quality of the upgrade kit contents. If you have problems with any item in the kit, refer to www.keysight.com and the **Contact Keysight** ( ) link.
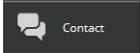
Getting Prepared

CAUTION	The PNA contains extremely sensitive components that can be ruined if mishandled. Follow instructions carefully when making cable connections, especially wire harness connections. The person performing the work accepts responsibility for the full cost of the repair or replacement of damaged components.

To successfully install this upgrade kit, you will need the following:

— A license key - refer to **"License Key Redemption"** below.

— A PDF copy or a paper copy of the PNA Service Guide - refer to **"Downloading the Online PNA Service Guide"** below.

— An ESD-safe work area - refer to **"Protecting Your Workspace from Electrostatic Discharge"** below.

— Correct tools - refer to **"Tools Required for the Installation" on page 8**.

— Enough time - refer to **"About Installing the Upgrade" on page 8**.

— Test equipment for the post-upgrade adjustments and full instrument calibration. To view the equipment list, click the Chapter 3 bookmark "Tests and Adjustments" in the PDF Service Guide[1].

License Key Redemption

NOTE	The enclosed Option Entitlement Certificate is a receipt, verifying that you have purchased a licensed option for the PNA of your choice. You must now use a Keysight Web page to request a license key for the instrument that will receive the option.

To enable the option product, you must request a license key from: http://www.keysight.com/find/softwarelicense. To complete the request, you will need to gather the following information:

— From the certificate

    — Order number

    — Certificate number

— From your instrument

    — Model number

    — Serial number

    — Host ID

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1. See **"Downloading the Online PNA Service Guide" on page 7**.

The instrument information is available on the network analyzer – on the analyzer's Help menu, click About Network Analyzer.

If you provide an email address, Keysight will promptly email your license key. Otherwise, you will your receive your license key via postal mail.

Verify the License Contents

Refer to the license message you received from Keysight:

If the model number, serial number, or option number do not match those on the license message you received from Keysight, you will not be able to install the license key file. If this is the case you received from Keysight, you will not be able to install the license key file. If this is the case, contact Keysight for assistance. Refer to "Getting Assistance from Keysight" on page 4.

Verify the Model/Version of HMA26.5 Installed

This upgrade kit contains components for use with PNA models using the legacy HMA26.5 part number 5086-7765. If your PNA has the newer HMA26.5 part number N5240-60101 installed you may discard these parts:

— A26 splitter 5067-4086

— W52 N5245-20013

— W53 N5245-20023

— W54 N5245-20022

(If you have the legacy 5086-7765 HMA26.5, please discard the N5245-20195 semi-rigid cables. Refer to Figure 1 on page 7.)

The new N5240-60101 HMA26.5 has the splitter integrated into the assembly. Refer to Figure 1 on page 7.

Figure 1   Comparison of Legacy HMA26.5 (5087-7765) and New HMA26.5 (N5240-60101)

New HMA26.5 -- N5240-60101
Requires (x1) Cable.

Legacy HMA26.5 -- 5087-7765
Requires A26 Splitter and (x3) Cables.
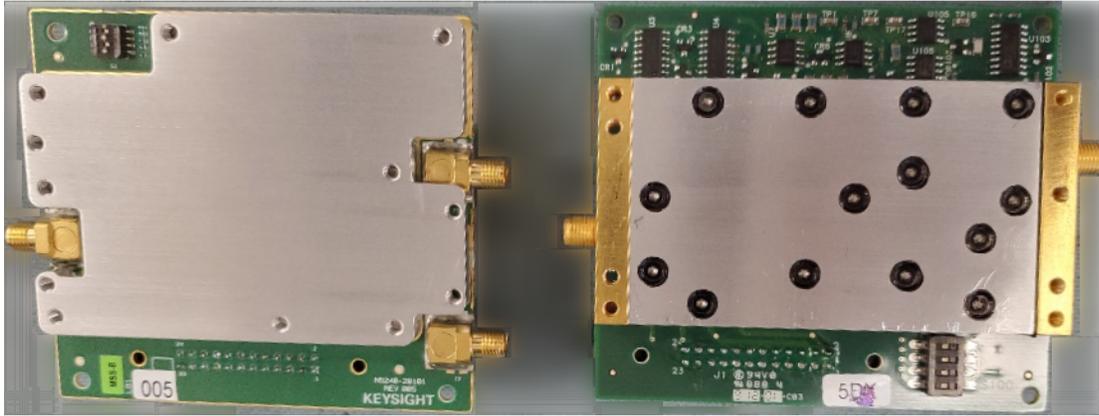
Downloading the Online PNA Service Guide

To view the online Service Guide for your PNA model number, use the following steps:

1. Go to www.keysight.com.

2. In the Search box, enter the model number of the analyzer (Ex: N5242A) and click Search.

3. Click Technical Support > Manuals.

4. Click Service Manual.

5. Click the service guide title to download the PDF file.

6. When the PDF of the Service Guide is displayed, scroll through the Contents section bookmarks to locate the information needed.

Protecting Your Workspace from Electrostatic Discharge

For information, click on the Chapter 1 bookmark, "Electrostatic Discharge Protection" in the PDF Service Guide[1].

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1. See "Downloading the Online PNA Service Guide" on page 7.

ESD Equipment Required for the Installation

Description	Keysight Part Number
ESD grounding wrist strap	9300-1367
5-ft grounding cord for wrist strap	9300-0980
2 x 4 ft conductive table mat and 15-ft grounding wire	9300-0797
ESD heel strap (for use with conductive floors)	9300-1308

Tools Required for the Installation

Description	Qty	Part Number
T-6 TORX driver - set to 4 in-lbs (0.45 N.m)	1	N/A
T-10 TORX driver - set to 9 in-lbs (1.02 N.m)	1	N/A
T-20 TORX driver - set to 21 in-lbs (2.38 N.m)	1	N/A
5/16-in (8 mm) nutsetter or open end torque wrench - set to 10 in-lbs (1.13 N.m)	1	N/A
3/16-in (5 mm) nutsetter or open end torque wrench - set to 6 in-lbs (0.68 N.m)	1	N/A
5/8-in (16 mm) nutsetter or open end torque wrench - set to 21 in-lbs (2.38 N.m)	1	N/A
9 mm nutsetter or open end torque wrench - set to 21 in-lbs (2.38 N.m)	1	N/A
1-in (25.4 mm) torque wrench - set to 72 in-lbs (8.15 N.m)	1	N/A

CAUTION Use a 5/16-in torque wrench set to 10 in-lbs on all cable connections except the front and rear panel bulkhead connectors. On these, use a 9 mm nutsetter or open end torque wrench set to 21 in-lb.

About Installing the Upgrade

Products affected	N5224A and N5225A Option 201
Installation to be performed by	Keysight service center or personnel qualified by Keysight
Estimated installation time	5 hours
Estimated adjustment time	0.5 hours
Estimated full instrument calibration time	4.5 hours

Items Included in the Upgrade Kit

Check the contents of your kit against the following list. If any part is missing or damaged, contact Keysight Technologies. Refer to "Getting Assistance from Keysight" on page 4.

Table 1   Contents of Upgrade Kit N5225-60112

Ref Desig.	Description	Qty	Part Number
-	Installation note (this document)	1	N5225-90121
A10	26.5 GHz source (2) board	1	5087-7342
A12	40 GHz doubler assembly port 3	2	5087-7349
A13	40 GHz doubler assembly port 4		
A17	13.5 GHz (source 2) synthesizer board	1	N5240-60074 Was N5242-60150
A26[a]	Splitter	1	5067-4086
A28	Mixer brick (2)	1	5087-7417
A30	Test port 3 receiver coupler	2	5087-7760
A31	Test port 4 receiver coupler		
A34	Test port 3 coupler	2	5087-7793
A35	Test port 4 coupler		
-	Front frame, 4-port	1	N5247-20141
-	Machine screw, M3.0 x 6, flat head (to attach front frame to coupler plate)	3	0515-1946
-	Machine screw, M2.0 x 6, flat head (8 to attach two receiver couplers to brackets)	10	0515-1602
-	Machine screw, M2.5 x 20, pan head (4 to attach A34 and A35 receiver coupler assemblies to test set deck)	5	0515-0374
-	Machine screw, M4.0 x 10, pan head (2 each to attach the following boards to the analyzer chassis: A17 13.5 GHz synthesizer board, A10 26.5 GHz source board, A12 40 GHz doubler assembly port 3, and A13 40 GHz doubler assembly port 4.)	10	0515-0380
-	Machine screw, M3.0 x 12, pan head (1 to attach cable bracket to test set deck.	2	0515-0664
-	Machine screw, M3.0 x 8, pan head (3 to attach shield to A28 mixer brick; 8 to attach two src attn and two rcvr attn to brackets)	13	0515-0372
-	Machine screw, M2.5 x 16, pan head (2 to attach splitter to mixer brick)	3	0515-2007
-	Machine screw, M3.0 x 25, pan head (3 to attach A28 mixer brick to block)	4	0515-0667
-	Machine screw, M3.0 x 20, flat head (2 to attach bracket to A10 26.5 GHz source)	3	0515-2078
-	Machine screw, M3.0 x 18, pan head (1 to attach bracket to A10 26.5 GHz source)	2	0515-0666

Table 1   Contents of Upgrade Kit N5225-60112

Ref Desig.	Description	Qty	Part Number
-	Front panel overlay (label), 4-port	1	N5227-80005
-	Keypad overlay (label)	1	N5242-80005
-	Power button overlay (label)	1	N5242-80007
-	Nameplate, N5224A	1	N5224-80001
-	Nameplate, N5225A	1	N5225-80001
-	Test set front plate, 4-port	1	N5224-00005
-	Gap pad (between mixer brick A28 and shield)	4	N5245-20125
-	Gap pad (between each test coupler and the test set front plate)	4	E4403-20033
-	Shield, mixer brick	1	N5245-00023
-	50 ohm load, attached to A13 40 GHz doubler	1	1250-4261
-	Vibration mount (between couplers 1 & 3, and 2 & 4)	2	0460-2725
-	Mounting nuts (for port 3 & 4 test port couplers)	2	5022-1087
-	Cable guard, center jumper cables	1	N5242-00030
-	Cable clamp, to secure W33 (N5245-20108); to secure W40 (N5245-20042); to secure W25 (N5245-20016); to secure W21 (N5245-20110).	12	1400-1334
-	Cable tie wrap, to secure W44 (N5245-20020); to secure W21 (N5245-20008).	6	1400-0249
-	2.4 mm dust cap for A28 mixer brick	1	N5247-20138
-	Bracket for receiver coupler	2	N5245-00017
-	Bracket for cables	1	N5245-00022
-	Bracket for A10 26.5 GHz source (2) board	1	N5247-20136
W2	RF cable, A10 source (2) P1 to A17 13.5 GHz source (2) synthesizer J1207 (4-port)	1	N5245-20100
W7	RF cable, A10 source (2) P5 to A12 port 3 doubler	1	N5245-20034
W8	RF cable, A10 source (2) P3 to A13 port 4 doubler	1	N5245-20035
W9	RF cable, A10 source (2) P4 to A12 port 3 doubler	1	N5245-20032
W10	RF cable, A12 port 3 doubler to A13 port 4 doubler	1	N5245-20033
W13	RF cable, A12 port 3 doubler to W14	1	N5245-20036
W14	RF cable, A30 port 3 receiver coupler to W13	1	N5245-20043
W15	RF cable, A13 port 4 doubler to W16	1	N5245-20036
W16	RF cable, A31 port 4 receiver coupler to W15	1	N5245-20044

Description of the Upgrade
Items Included in the Upgrade Kit

Table 1   Contents of Upgrade Kit N5225-60112

Ref Desig.	Description	Qty	Part Number
W20	RF cable, Front panel port 1 CPLR THRU to A33 port 1 coupler	1	N5245-20099
W21	RF cable, A29 port 1 receiver coupler to A37 reference mixer switch	1	N5245-20110
W22	RF cable, A33 port 1 coupler to front-panel Port 1 CPLR ARM	1	N5245-20014
W23	RF cable, A30 port 3 rcvr coupler to front-panel Port 3 SOURCE OUT	1	N5245-20051
W24	RF cable, Front panel port 3 CPLR THRU to A34 port 3 coupler	1	N5245-20098
W25	RF cable, A30 port 3 receiver coupler to front-panel REF 3 SOURCE	1	N5245-20016
W26	RF cable, A34 port 3 coupler to front-panel Port 3 CPLR ARM	1	N5245-20015
W27	RF cable, A31 port 4 rcvr coupler to front-panel Port 4 SOURCE OUT	1	N5245-20052
W28	RF cable, Front panel port 4 CPLR THRU to A35 port 4 coupler	1	N5245-20096
W29	RF cable, A31 port 4 receiver coupler to front-panel REF 4 SOURCE OUT	1	N5245-20017
W30	RF cable, A35 port 4 coupler to front-panel Port 4 CPLR ARM	1	N5245-20018
W32	RF cable, Front panel port 2 CPLR THRU to A36 port 2 coupler	1	N5245-20097
W33	RF cable, A32 port 2 receiver coupler to front-panel REF 2 SOURCE OUT	1	N5245-20108
W34	RF cable, A36 port 2 coupler to front-panel Port 2 CPLR ARM	1	N5245-20019
W36	RF cable, Front panel jumper	6	N5245-20155
W38	RF cable, Port 3 RCVR C IN to A28 mixer brick (C)	1	N5245-20037
W39	RF cable, Port 4 RCVR D IN to A28 mixer brick (D)	1	N5245-20038
W44	RF cable, REF 3 RCVR R3 IN to A28 mixer brick (R3)	1	N5245-20020
W45	RF cable, REF 4 RCVR R4 IN to A28 mixer brick (R4)	1	N5245-20191
W52[a]	RF cable, A25 HMA26.5 to A26 splitter	1	N5245-20013
W53[a]	RF cable, A26 splitter to A27 mixer brick	1	N5245-20023
W54[a]	RF cable, A26 splitter to A28 mixer brick	1	N5245-20022
W62	RF cable, A27 mixer brick (R1) to A24 IF multiplexer (P411)	1	N5242-60021
W63	RF cable, A27 mixer brick (R2) to A24 IF multiplexer (P412)	1	N5242-60022
W65	RF cable, A28 mixer brick (D) to A24 IF multiplexer (P801)	1	N5242-60024
W66	RF cable, A28 mixer brick (R4) to A24 IF multiplexer (P414)	1	N5242-60019
W67	RF cable, A28 mixer brick (R3) to A24 IF multiplexer (P413)	1	N5242-60020
W68	RF cable, A28 mixer brick (C) to A24 IF multiplexer (P601)	1	N5242-60023
W70	RF cable, A24 IF multiplexer board P203 to A16 SPAM board J2	1	N5242-60013

Table 1   Contents of Upgrade Kit N5225-60112

Ref Desig.	Description	Qty	Part Number
W72	RF cable, A24 IF multiplexer board P603 to A16 SPAM board J5	1	N5242-60015
W77	RF cable, A14 frequency reference board J7 to A17 13.5 GHz (source 2) synthesizer board J5 (Located on bottom of board.)	1	N5242-60030
W203[b]	RF cable, A25 HMA26.5 (top) to A28 mixer brick (top)	1	N5245-20195
-	Ribbon cable, A23 test set motherboard J552 to A28 mixer brick (2) J52	1	N5247-60015

a. The A26 splitter (5067-4086) and N5245-20013, N5245-20022, N5245-20023, N545-20101, and N5245-20150 cables are only used with a legacy HMA26.5 p/n: 5087-7765. If you are unclear which HMA26.5 assembly your PNA has installed, refer to Chapter 7 Repairs and Figure 1 on page 7 and for details on A26 splitter and cabling, refer to your option-model in Chapter 6 "2-Port Configurations, Serial Number Prefix ‹6021" and "4-Port Configuration, Serial Number Prefix ‹6021".

b. The N5245-20195 cable is used only with instruments that have a newer HMA26.5 installed. If your PNA has a legacy 5087-7765 HMA26.5 assembly installed, then this cable can be discarded. If you are unclear which HMA26.5 assembly your PNA has installed, refer to Figure 1 on page 7.

NOTE	Extra quantities of items such as protective plastic caps, screws, cable ties, and cable clamps may be included in this upgrade kit. It is normal for some of these items to remain unused after the upgrade is completed.

Installation Procedure for the Upgrade

The network analyzer must be in proper working condition prior to installing this option. Any necessary repairs must be made before proceeding with this installation.

WARNING	This installation requires the removal of the analyzer's protective outer covers. The analyzer must be powered down and disconnected from the mains supply before performing this procedure.

Overview of the Installation Procedure

"Step 1. Obtain a Keyword and Verify the Information."

"Step 2. Remove the Outer Cover."

"Step 3. Remove the Inner Cover."

"Step 4. Remove the Front Panel Assembly."

"Step 5. Remove the A23 Test Set Motherboard."

"Step 6. Remove Some Bottom-Side (Test Set) Cables."

"Step 7. Remove the A27 Mixer Brick Assembly."

"Step 8. Assemble the A28 Mixer Brick Assembly."

"Step 9. Install the A27/A28 Mixer Brick Assemblies."

"Step 10.Assemble the A34 and A35 Receiver Coupler Assemblies."

"Step 11. Install the A34 and A35 Receiver Coupler Assemblies."

"Step 12. Assemble the A33 - A36 Test Port Coupler Assemblies."

"Step 13. Install the LED Boards and Test Port Coupler Assemblies to the 4-Port Test Set Front Plate."

"Step 14. Install the 4-Port Coupler Plate Assembly to the Deck."

"Step 15. Assemble and Install the A12 and A13 40 GHz Doubler Assemblies."

"Step 16. Install Bracket to A10 Source Assembly."

"Step 17. Assemble the A10 26.5 GHz Source 2 Assembly."

"Step 18. Install the A10 26.5 GHz Source 2 Assembly and Cables."

"Step 19. Install the A17 13.5 GHz (Source 2) Synthesizer Board and Cables."

"Step 20. Install the Cable Bracket Mount."

"Step 21. Install the Test Set Cables."

"Step 22. Secure the Front Panel Bulkhead Connectors."

"Step 23. Reinstall the A23 Test Set Motherboard."

"Step 24. Install Cable on the A23 Test Set Motherboard."

"Step 25. Replace the Front Frame in the Front Panel Assembly."

"Step 26. Reinstall Front Panel Assembly."

"Step 27. Install the Overlays and Nameplate."

"Step 28. Install the Front Panel Jumper Cables."

"Step 29. Position the Cables and Wires to Prevent Pinching."

"Step 30. Reinstall the Inner Cover."

"Step 31. Reinstall the Outer Cover."

"Step 33. Enable Options P04 and 401."

"Step 34. Perform Post-Upgrade Adjustments and Calibration."

"Step 35. Prepare the PNA for the User."

Step 1. Obtain a Keyword and Verify the Information

Follow the instructions on the Option Entitlement Certificate supplied to obtain a license key for installation of this upgrade. Refer to "License Key Redemption" on page 5.

Verify that the model number, serial number, and option number information on the license key match those of the instrument on which this upgrade will be installed.

If the model number, serial number, or option number do not match those on your license key, you will not be able to install the option. If this is the case, contact Keysight for assistance before beginning the installation of this upgrade. Refer to "Contacting Keysight" on page 4.

Once the license key has been received and the information verified, you can proceed with the installation at step 2.

Step 2. Remove the Outer Cover

For instructions, click the Chapter 7 bookmark "Removing the Covers" in the PDF Service Guide[1].

Step 3. Remove the Inner Cover

For instructions, click the Chapter 7 bookmark "Removing the Covers" in the PDF Service Guide[1].

Step 4. Remove the Front Panel Assembly

For instructions, click the Chapter 7 bookmark "Removing and Replacing the Front Panel Assembly" in the PDF Service Guide[1].

Step 5. Remove the A23 Test Set Motherboard

For instructions, click the Chapter 7 bookmark "Removing and Replacing the A23 test set motherboard" in the PDF Service Guide[1].

Step 6. Remove Some Bottom-Side (Test Set) Cables

CAUTION Be careful not to damage the center pins of the semirigid cables. Some flexing of the cables may be necessary but do not over-bend them.

NOTE When removing a cable, also remove the plastic cable clamp, if present. It is normal for some of the cable clamp's adhesive to remain.

1. Place the analyzer bottom-side up on a flat surface.

1. See "Downloading the Online PNA Service Guide" on page 7.

2. Remove the following cables. To see an image showing the location of these cables, click the Chapter 6 bookmark "Bottom RF Cables, Standard 2-Port Configuration, Option 201, S/N Prefixes <6021" in the PDF Service Guide[1].

These cables may be discarded - they will not be reinstalled.

— W20   (N5245-20045) Front panel port 1 CPLR THRU to A33 port 1 coupler

— W21   (N5245-20120 A29 port 1 receiver coupler to A37 reference mixer switch

— W22   (N5245-20025) A33 port 1 coupler to front-panel REF 1 CPLR ARM

— W32   (N5245-20106) Front panel port 2 CPLR THRU to A36 port 2 coupler

— W34   (N5245-20024) A36 port 2 coupler to front-panel REF 2 CPLR ARM

— W35   (N5245-20121) A32 port 2 receiver coupler to front-panel REF 2 SOURCE OUT

— W62   (N5242-60025) A27 mixer brick (R1) to A24 IF multiplexer (P601)

— W63   (N5242-60026) A27 mixer brick (R2) to A24 IF multiplexer (P801)

— W70   (N5247-60024) A24 IF multiplexer board P203 to A16 SPAM board J5

— W72   (N5247-60023) A24 IF multiplexer board P603 to A16 SPAM board J2

— W80   (N5245-20048) A25 HMA26.5 to A27 mixer brick

These cables must be saved - they will be reinstalled.

— W12   (N5245-20109) A29 port 1 receiver coupler to W11

— W18   (N5245-20111) A32 port 2 receiver coupler to W17

— W40   (N5245-20042) Front panel port 2 RCVR B IN to A27 mixer brick (B)

— W36 (N5245-20155) Front panel jumpers (quantity = 6)

NOTE: Remove and save the cable guards for the front panel jumpers.

## Step 7. Remove the A27 Mixer Brick Assembly

Remove the A27 mixer brick assembly from the PNA. For instructions, click the Chapter 7 bookmark, "Removing and Replacing the A27 and A28 Mixer Bricks" in the PDF Service Guide[1].

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1. See "Downloading the Online PNA Service Guide" on page 7.

Step 8. Assemble the A28 Mixer Brick Assembly

1. Follow the instruction shown in Figure 2. New parts are listed in Table 1 on page 9 of this document.

Figure 2   A26 and A27 Test Port Bridge Assembly (5087-7417, N5245-20125, 0515-0667, N5247-20138)
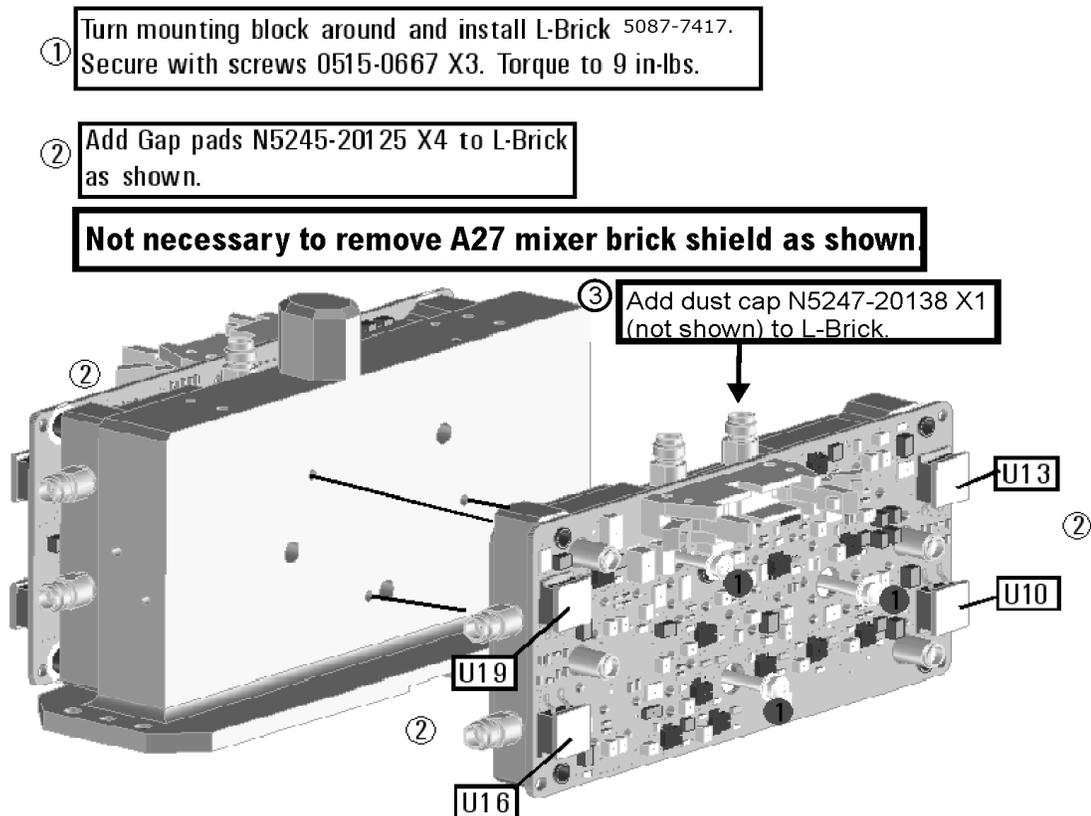
① Turn mounting block around and install L-Brick 5087-7417. Secure with screws 0515-0667 X3. Torque to 9 in-lbs.

② Add Gap pads N5245-20125 X4 to L-Brick as shown.

Not necessary to remove A27 mixer brick shield as shown.

③ Add dust cap N5247-20138 X1 (not shown) to L-Brick.

U13

U10

U19

U16

N5225_124_04_nw

2. Follow the two instructions shown in Figure 3.

Figure 3   A26 and A27 Test Port Bridge Assembly (N5245-00023, 0515-0372)

① Add L-Brick Shield N5245-00023 X1 to A28 Mixer Brick as shown.

② Secure with Screws 0515-0372 X3. Torque to 9 in-lbs.
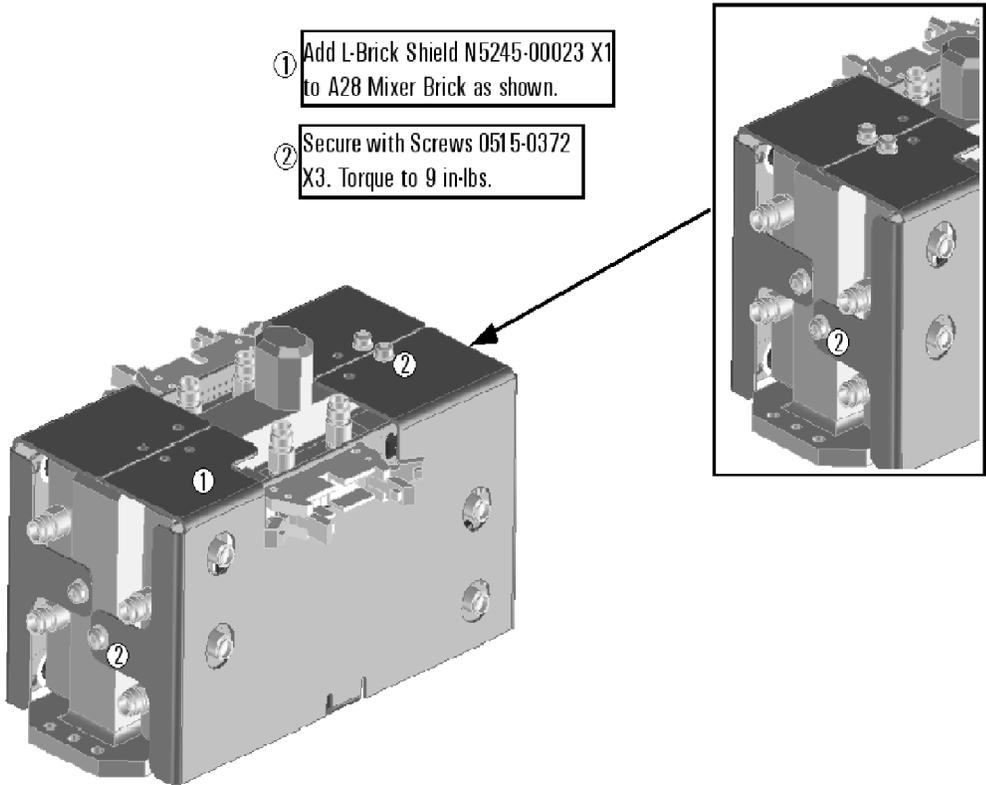
N5225_124_05

3. Follow the two instructions shown in Figure 4.

Figure 4   A26 Splitter[1] Installation (5067-4086, 0515-2007)
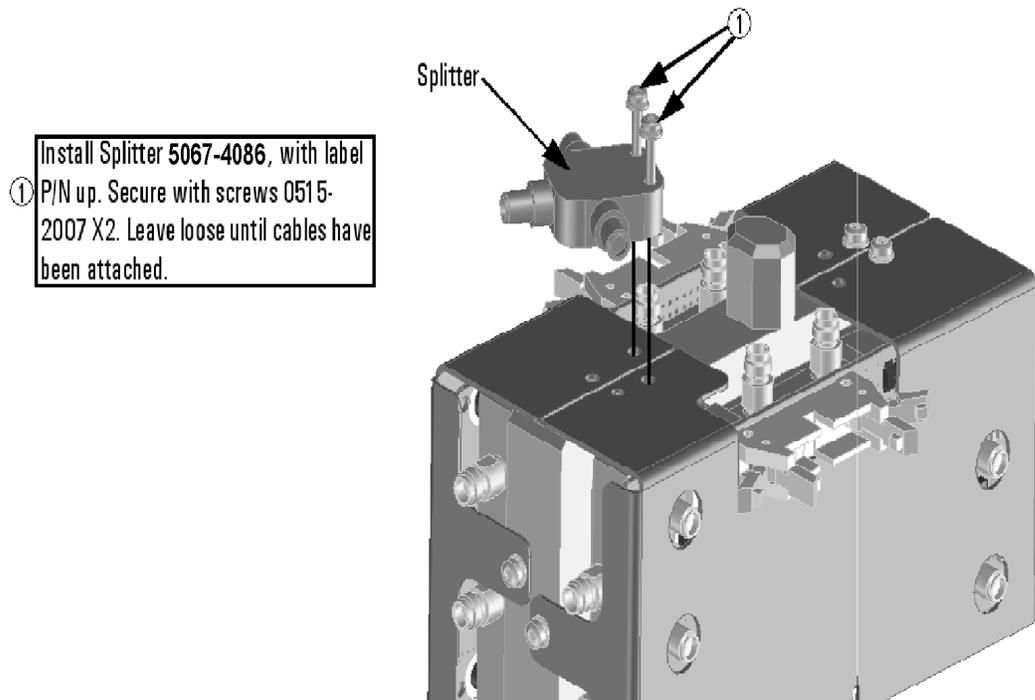
Install Splitter **5067-4086**, with label
① P/N up. Secure with screws 0515-
2007 X2. Leave loose until cables have
been attached.

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1. The A26 splitter (5067-4086) and N5245-20013, N5245-20022, N5245-20023, N545-20101, and N5245-20150
   cables are only used with a legacy HMA26.5 p/n: 5087-7765. If you are unclear which HMA26.5 assembly your
   PNA has installed, refer to Chapter 7 Repairs and Figure 1 on page 7 and for details on A26 splitter and cabling,
   refer to your option-model in Chapter 6 "2-Port Configurations, Serial Number Prefix <6021" and "4-Port Config-
   uration, Serial Number Prefix <6021".

4. Connect the gray flexible cables to the A28 mixer in the order shown in Figure 5. The other ends of the cables will be connected when the IF board is reinstalled later.

Figure 5   A26 and A27 Test Port Bridge Assembly (N5242-60019, N5242-60020, N5242-60023, N5242-60024)[1, 2]
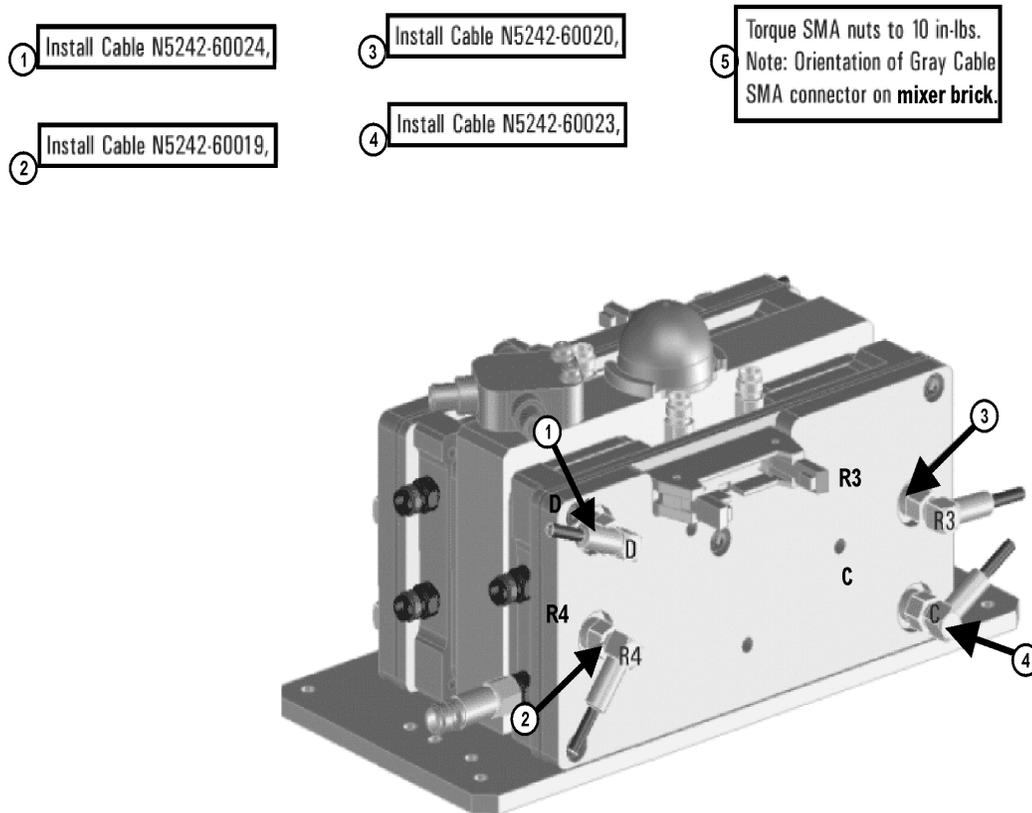
N5225_124_07

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1. The A26 splitter (5067-4086) and N5245-20013, N5245-20022, N5245-20023, N545-20101, and N5245-20150 cables are only used with a legacy HMA26.5 p/n: 5087-7765. If you are unclear which HMA26.5 assembly your PNA has installed, refer to Chapter 7 Repairs and Figure 1 on page 7 and for details on A26 splitter and cabling, refer to your option-model in Chapter 6"2-Port Configurations, Serial Number Prefix ‹6021" and "4-Port Configuration, Serial Number Prefix ‹6021".
2. Attenuator 08490-60039 is shown in the figure, but is not included in this upgrade and not required with the A28 mixer brick (5087-7417).

## Step 9. Install the A27/A28 Mixer Brick Assemblies

Reinstall the A27 mixer brick cables, and then install the A27/A28 mixer brick assembly, reusing the four existing screws. For instructions, click the Chapter 7 bookmark, "Removing and Replacing the A27 and A28 Mixer Bricks" in the PDF Service Guide[1]. New parts are listed in Table 1 on page 9 of this document.

Step 10.Assemble the A34 and A35 Receiver Coupler Assemblies

Follow the instructions shown in Figure 6 and Figure 7-1. New parts are listed in Table 1 on page 9 of this document.

Figure 6   A34 Receiver Coupler Port 3 Assembly (5097-7760, N5245-00017, 0515-1602)

N5225_124_09


1. See "Downloading the Online PNA Service Guide" on page 7.

Figure 7   A35 Receiver Coupler Port 4 Assembly (5097-7760, N5245-00017, 0515-1602)

Prefab internal Coupler 5087-7760 to Bracket N5245-00017. Secure with Screws 0515-1602 X4.
Note orientation of coupler to bracket. Torque to 4 in-lbs.

Note Orientation

Coupler Port 4

Screw X4
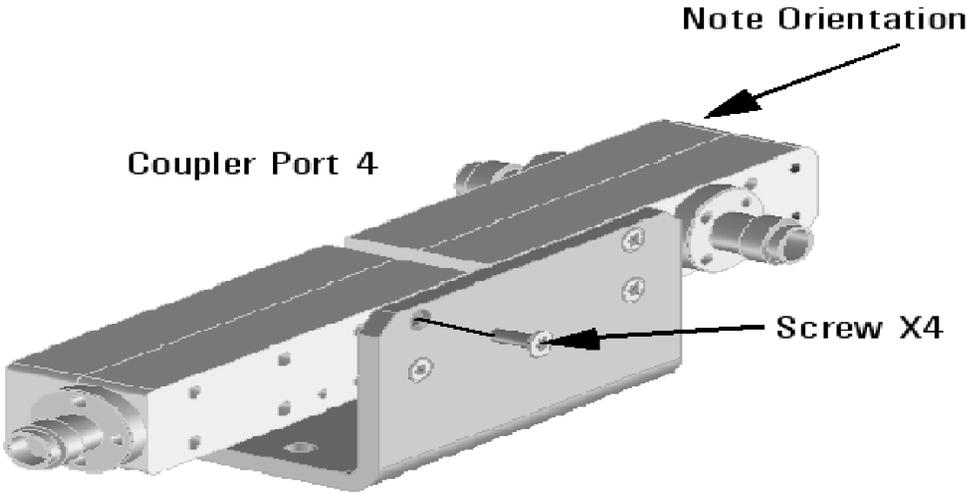
N5225_124_11

Step 11.Install the A34 and A35 Receiver Coupler Assemblies

Follow the instructions shown in Figure 7-1. New parts are listed in Table 1 on page 9 of this document.

Figure 7-1   A34 and A35 Receiver Coupler Assemblies Installation (0515-0374)[1, 2]
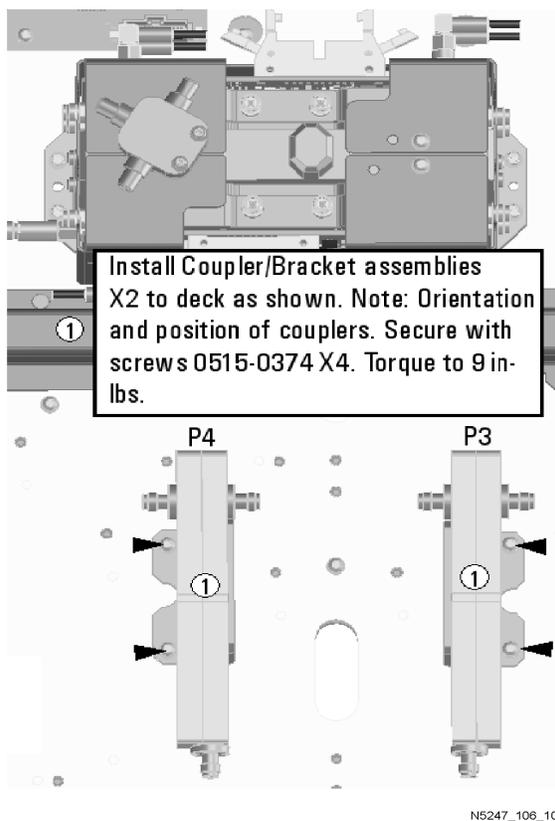
Install Coupler/Bracket assemblies X2 to deck as shown. Note: Orientation and position of couplers. Secure with screws 0515-0374 X4. Torque to 9 in-lbs.

N5247_106_10

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1. The A26 splitter (5067-4086) and N5245-20013, N5245-20022, N5245-20023, N545-20101, and N5245-20150 cables are only used with a legacy HMA26.5 p/n: 5087-7765. If you are unclear which HMA26.5 assembly your PNA has installed, refer to Chapter 7 Repairs and Figure 1 on page 7 and for details on A26 splitter and cabling, refer to your option-model in Chapter 6"2-Port Configurations, Serial Number Prefix <6021" and "4-Port Configuration, Serial Number Prefix <6021".
2. Attenuator 08490-60039 is shown in the figure, but is not included in this upgrade and not required with the A28 mixer brick (5087-7417).

Step 12.Assemble the A33 – A36 Test Port Coupler Assemblies

1. Remove the A33 test port 1 coupler and A36 test port 2 coupler from the PNA. For instructions, click the Chapter 7 bookmark, "Removing and Replacing the A33 – A36 Test Port Couplers" in the PDF Service Guide[1].

2. Using pliers, remove the adhesive bumper on the A33 test port 1 coupler and on the A36 test port 2 coupler.

3. Follow the two instructions shown in Figure 8. New parts are listed in Table 1 on page 9 of this document.

Figure 8   A33 – A36 Test Port Coupler Assembly (E4403-20033, 0460-2725, 5087-7793)

gap pad
E4403-20033

vibe mount
0460-2725

Reuse 2x coupler, 5087-7793

① Remove tan adhesive liner from 4x gap pad E4403-20033.
Adhere to 4x coupler **5087-7793**.
Remove blue adhesive liner

② Remove adhesive liner from 2x vibe mount 0460-2725.
Adhere to 2x couplers. Center vibe mount on coupler body
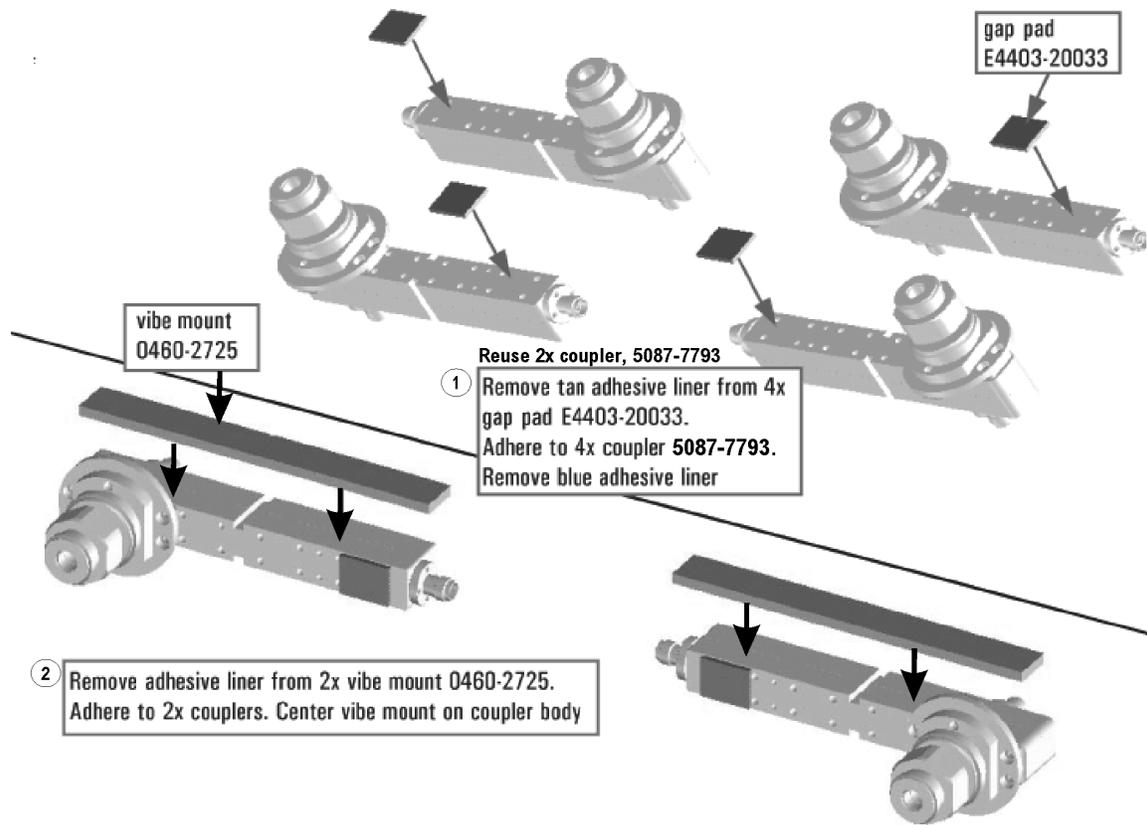
N5225_124_18

Step 13.Install the LED Boards and Test Port Coupler Assemblies to the 4-Port Test Set Front Plate

1. Remove two screws from each LED board and remove the boards from the 2-port test set front plate of the PNA.

2. Remove the 2-port test set front plate from the test set deck. Keep the screws for reuse later.

3. Follow the two instructions shown in Figure 9.

Figure 9   LED Board Assemblies and Test Port Coupler Assemblies Installation (0515-1521, 5022-1087, 5087-7793, N5240-60058, N5224-00005, N5225-60001)

Reuse LED boards and screws

① Prefab 2x LED boards **N5240-60058** to test set front plate **N5224-00005** using 4x screws 0515-1521 @ 9 **in-lbs**.

Reuse 2x couplers and 2x mounting nuts

② Prefab 4x couplers **5087-7793** onto front plate. Note: Port 1/3 and 2/4 couplers must be installed at the same time. **Hand-tighten** 4x mounting nuts 5022-1087.

Reuse harnesses

③ Install LED harness **N5225-60001 X2** to **LED** boards.

port 2/4

Port 1/3

N5225_124_19

Step 14.Install the 4-Port Coupler Plate Assembly to the Deck

Follow the four instructions shown in Figure 10.

Figure 10   Coupler Plate Assembly Installation (0515-0372, 0515-1227)
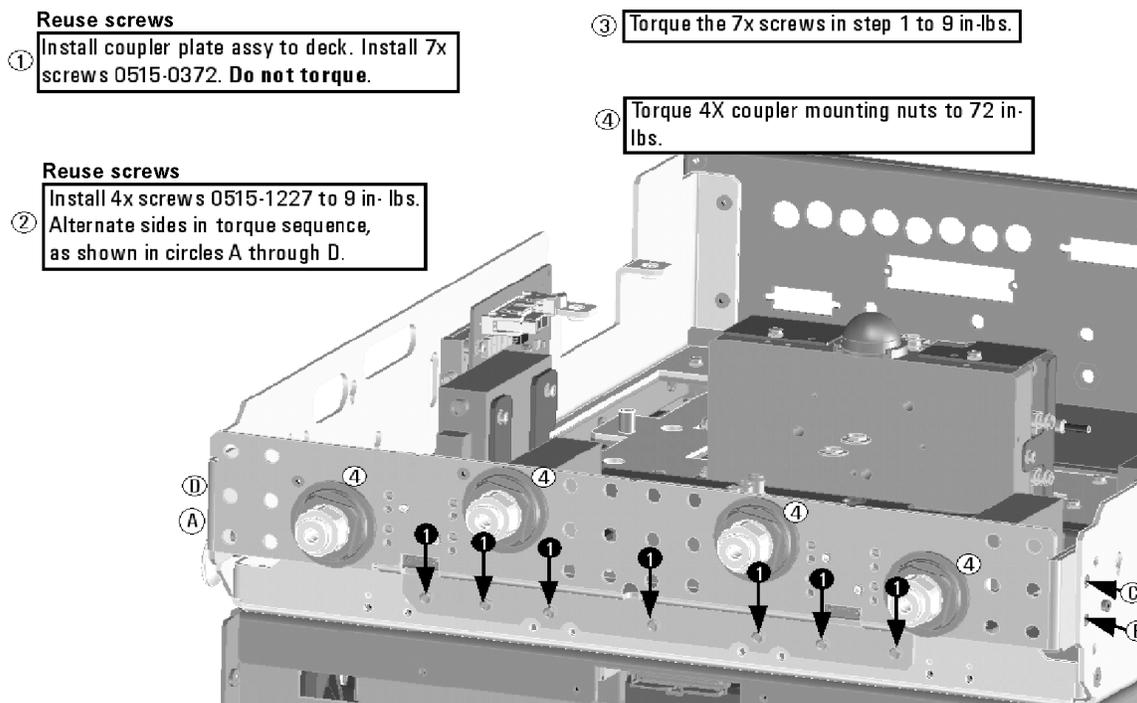
N5225_124_20

Step 15.Assemble and Install the A12 and A13 40 GHz Doubler Assemblies

Follow the instructions shown in Figure 11.

Figure 11   A12 and A13 40 GHz Doubler Installation (5087-7349, 1250-4261, N5245-20036)

N5225_124_24

Installation Note N5225-90121
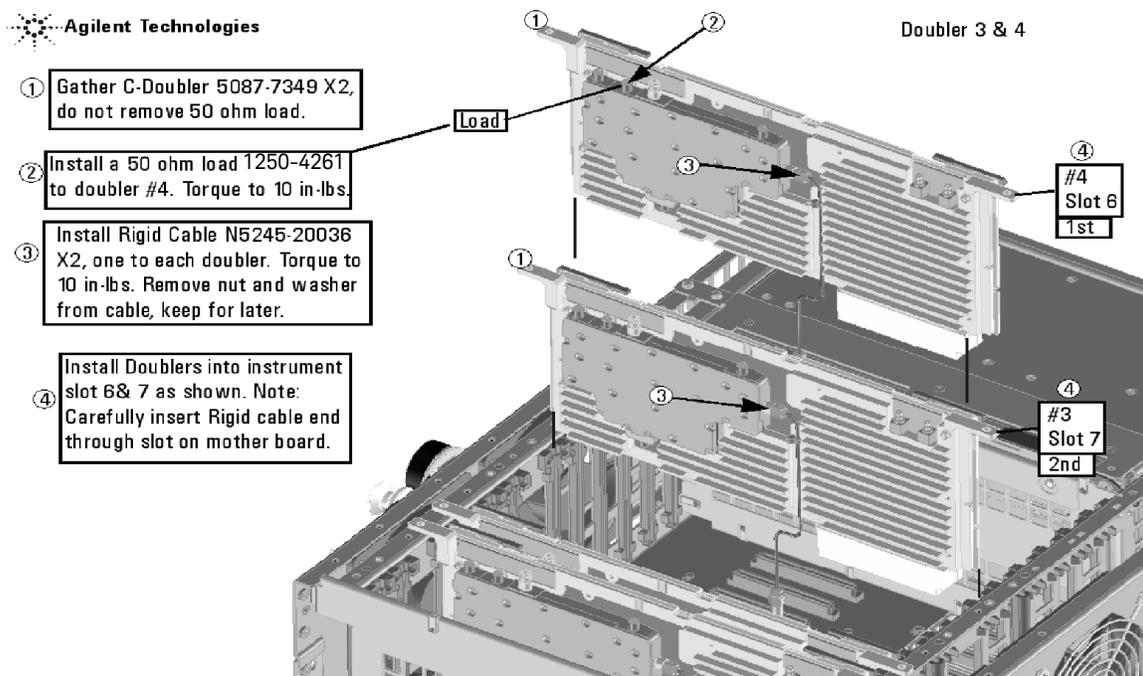
Step 16. Install Bracket to A10 Source Assembly

Follow the two instructions shown in Figure 12.

Figure 12   A10 Source 2 Assembly Bracket Installation (5087-7342, N5247-20136, 0515-0375, 0515-2078, 0515-0666)

Gather Source Assembly **5087-7342**, and install Bracket N5247-20136 as shown. Remove 3 screws 0515-0375 from source before installing bracket.

Secure bracket with Screws 0515-2078 X2, and 0515-0666 X1. Torque to 9 in-lbs.

0515-2078
X2

Bracket
0515-0666
X1
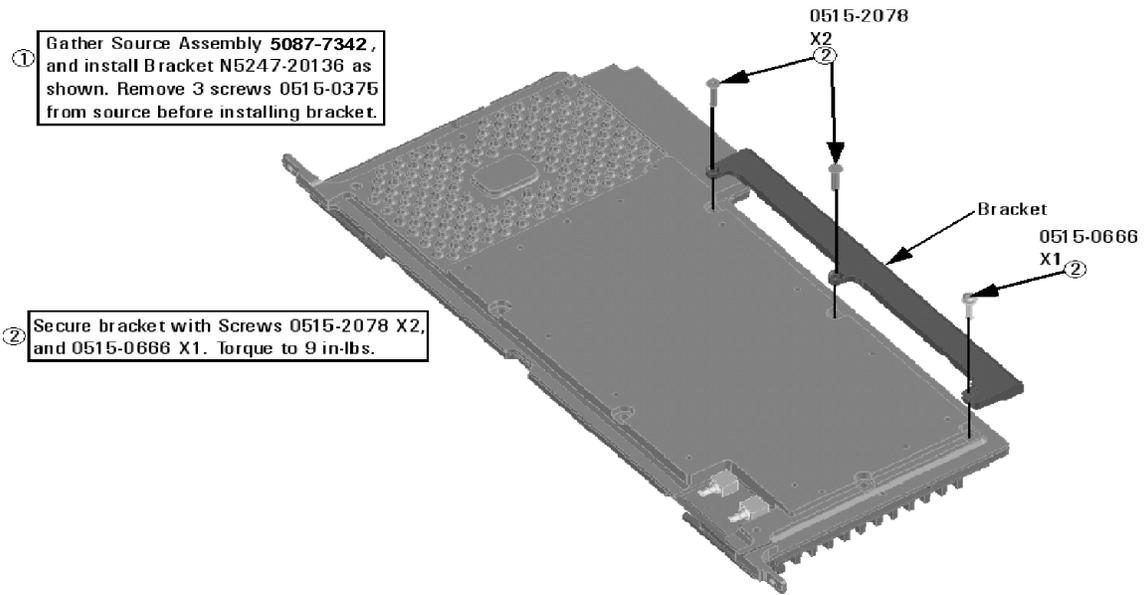
N5225_124_21

Step 17. Assemble the A10 26.5 GHz Source 2 Assembly

Follow the two instructions shown in Figure 13.

Figure 13   A10 Source 2 Assembly (5087-7342, N545-20032, N5245-20034, N5245-20035)

① Gather Source **5087-7342.**

② Remove SMA Load, and Install Rigid cable N5245-20032. Torque to10 in-lbs. Keep the SMA Load for later use at rear panel

③ Install Rigid Cable N5245-20034. Torque to 10 in-lbs.

④ Install Rigid Cable **N5245-20035** . Torque to 10 in-lbs.
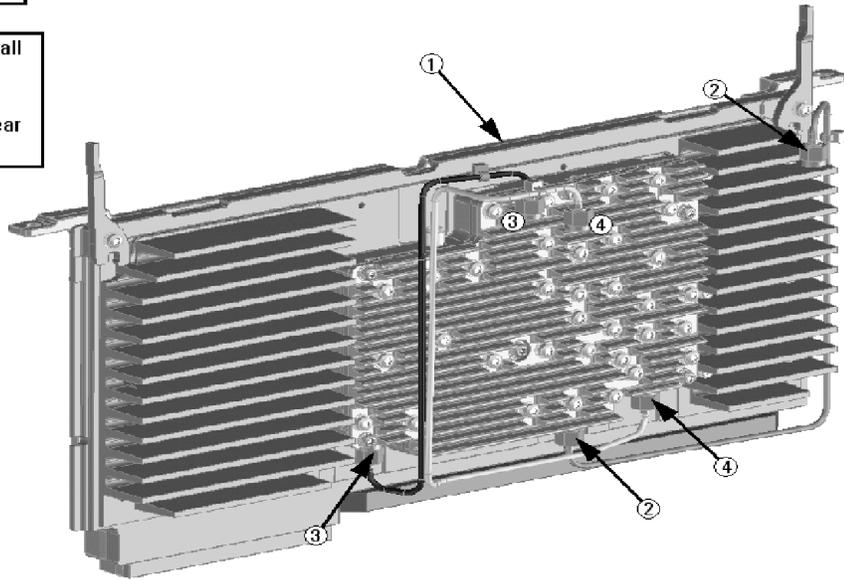
N5225_124_22

Step 18.Install the A10 26.5 GHz Source 2 Assembly and Cables

Follow the four instructions shown in Figure 14.

Figure 14   A10 Source 2 Assembly Installation (N5245-20033, 0515-0380)
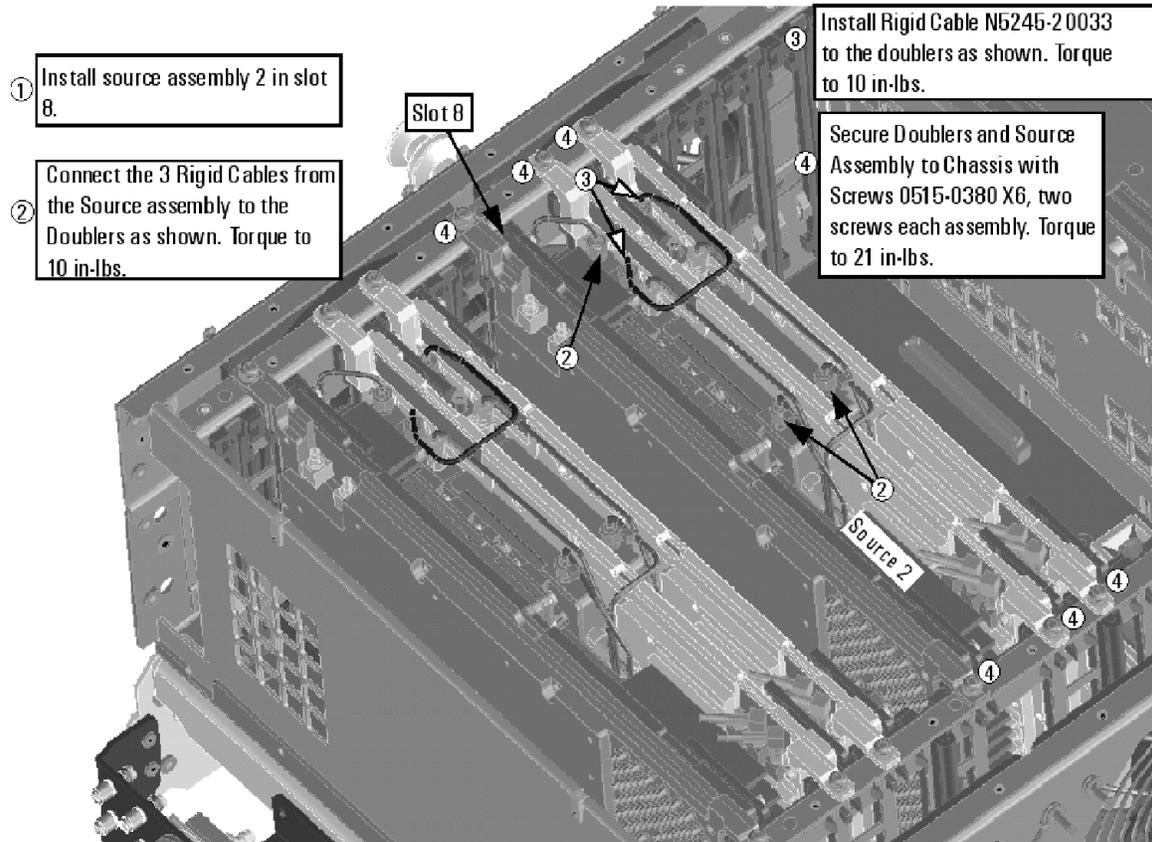
N5225_124_26

Step 19.Install the A17 13.5 GHz (Source 2) Synthesizer Board and Cables

1. Install new gray cable W77 (N5242-60030) to connector J5 of the new A17 (source 2) synthesizer board (N5240-60074). The loose end of the cable will be connected on the A14 frequency reference board (J7) after the A17 board has been installed in the analyzer.

2. Install the A17 board into slot 2 in the motherboard. Secure the board into the chassis using two screws (0515-0380). To see an image showing the location of the A17 board in the motherboard, click the Chapter 6 bookmark "Top Assemblies, All Options" in the PDF Service Guide[1].

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1. See "Downloading the Online PNA Service Guide" on page 7.

3. Connect cable W2 (N5245-20100) between the A10 source 2 board and the A17 (source 2) synthesizer board, positioning the cable in the wire looms. Tighten the cable connectors to 10 in-lbs using a 5/16-in torque wrench.

4. Connect the loose end of new gray flex cable W77 (N5242-60030) on the A14 frequency reference board (J7). (The other end of this cable was previously connected to J5 of the source 2 synthesizer board.)

Step 20.Install the Cable Bracket Mount

1. Follow the two instructions shown in Figure 15. New parts are listed in Table 1 on page 9 of this document.

Figure 15   Cable Bracket Mount Installation (N5245-00022, 0515-0664, N5245-20036)

1

Install bracket N5245-00022 X1.
Secure with screw 0515-0664 X1.
Torque to 9 in-lbs.

N5245-20036

2

Secure 2X rigid cables N5245-20036
(on A12 & A13 doublers) to bracket
with cable hardware previously set
aside. Torque to 21 in-lbs.

1

Alignment Pin
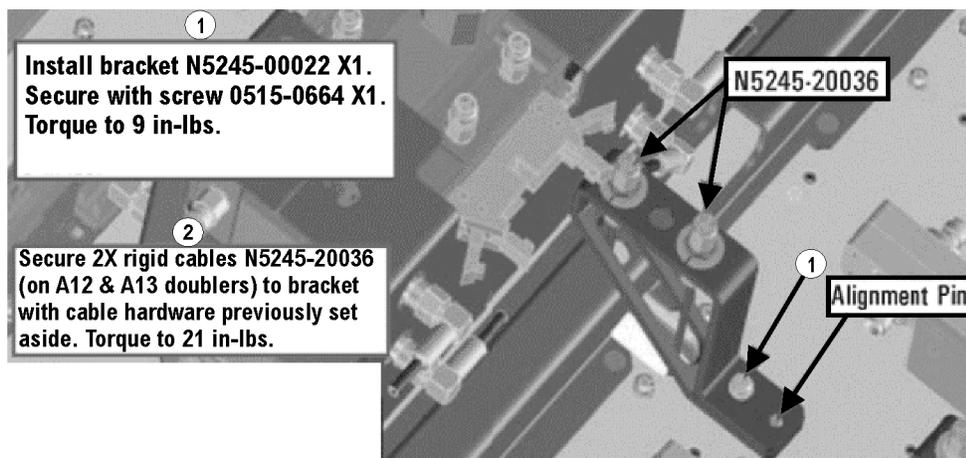
N5225_124_25

Step 21.Install the Test Set Cables

CAUTION	Follow instructions carefully when making cable connections, especially wire harness connections. Incorrect connections can destroy components, resulting in additional customer costs

CAUTION	Be careful not to damage the center pins of the semirigid cables. Some flexing of the cables may be necessary but do not over-bend them.

CAUTION	Use a 5/16-in torque wrench set to 10 in-lbs on all cable connections except the front and rear panel bulkhead connectors. On these, use a 9 mm nutsetter or open end torque wrench set to 21 in-lb.

CAUTION	Cables that are to be reinstalled are designated with "reuse."

Flexible Cables Required for Upgrading to an Option 401 PNA

Install the following gray flexible cables in the order listed. Mixer brick cables were connected to the mixer bricks earlier in this procedure, but the other ends of these cables still require a connection. To see images showing the location of these cables, click either of the Chapter 6 bookmarks "Bottom RF Cables, 4-Port, Option 401, **S/N Prefixes** <**6021**" in the PDF Service Guide[1]. New parts are listed in Table 1 on page 9.

— W70 (N5242-60013) A24 IF multiplexer board P203 to A16 SPAM board J2

— W72 (N5242-60015) A24 IF multiplexer board P603 to A16 SPAM board J5

— W62 (N5242-60021) A27 mixer brick (R1) to A24 IF multiplexer (P411)

— W63 (N5242-60022) A27 mixer brick (R2) to A24 IF multiplexer (P412)

— W65 (N5242-60024) A28 mixer brick (D) to A24 IF multiplexer (P801)

— W66 (N5242-60019) A28 mixer brick (R4) to A24 IF multiplexer (P414)

— W67 (N5242-60020) A28 mixer brick (R3) to A24 IF multiplexer (P413)

— W68 (N5242-60023) A28 mixer brick (C) to A24 IF multiplexer (P601)

Semirigid Cables Required for Upgrading to an Option 401 PNA

To see images showing the location of these cables, click the Chapter 6 bookmark "Bottom RF Cables, 4-Port, Option 401, **S/N Prefixes** <**6021**" in the PDF Service Guide[1]. New parts are listed in Table 1 on page 9.

— W33 (N5245-20108) A32 port 2 receiver coupler to front-panel REF 2 SOURCE OUT

* As shown in Figure 16, install clamp (part number 1400-1334) to secure W33 (N5245-20108).

Figure 16   Location of Cable Clamps for W33 (N5245-20108)
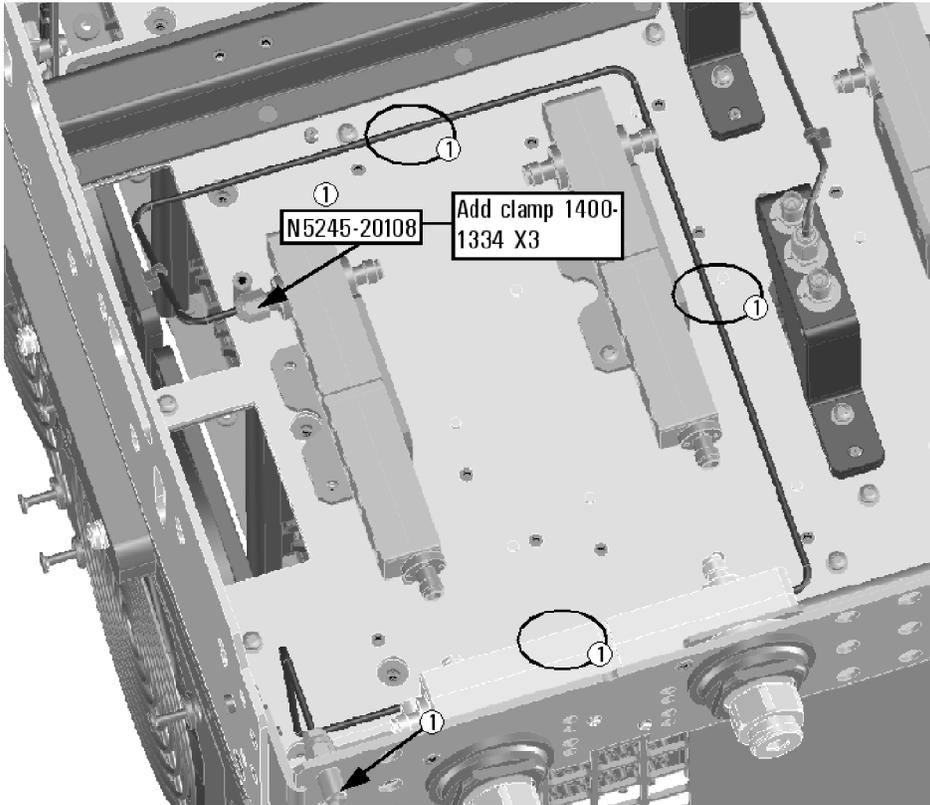
— W40 (reuse)(N5245-20042)Port 2 RCVR B IN to A27 mixer brick (B)

* As shown in Figure 17, install clamp (part number 1400-1334) to secure W40 (N5245-20042).

Figure 17   Location of Cable Clamp for W40 (N5245-2004, 1400-13342)[1, 2]
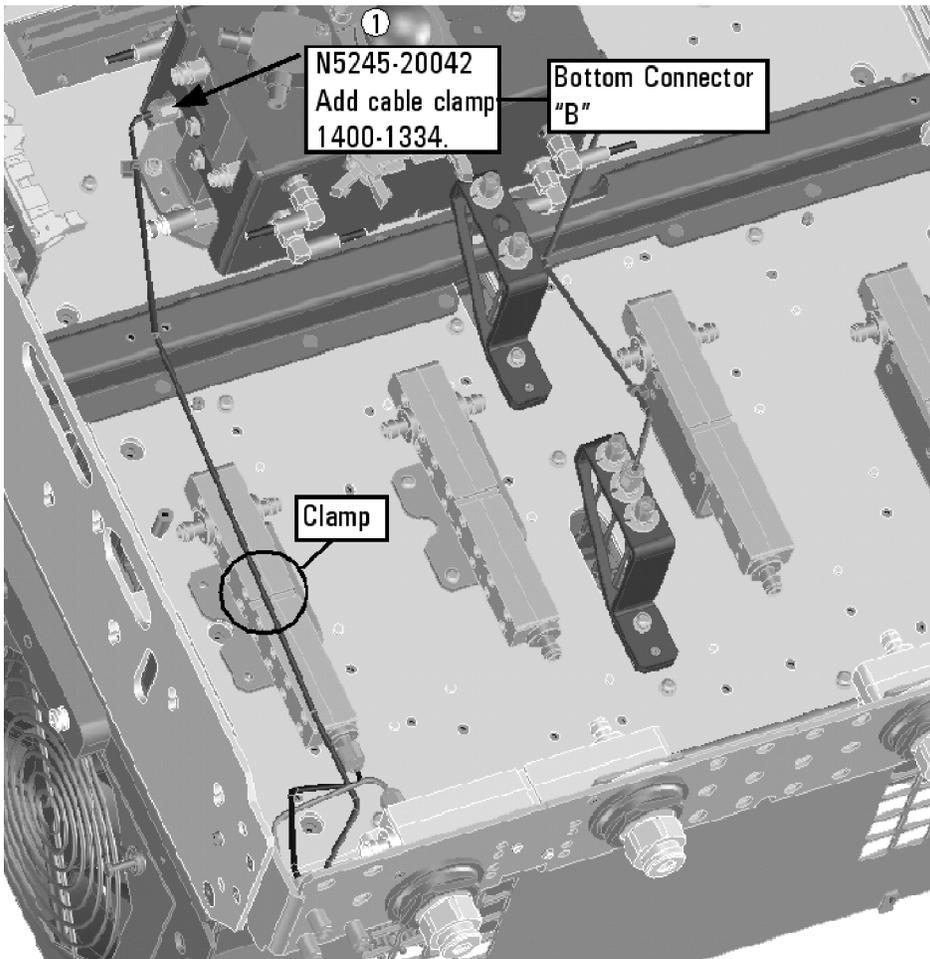
— W34 (N5245-20019) A36 port 2 coupler to front–panel Port 2 CPLR ARM

— W32 (N5245-20097)Port 2 CPLR THRU to A36 port 2 coupler

— W28 (N5245-20096)Port 4 CPLR THRU to A35 port 4 coupler

— W39 (N5245-20038) Port 4 RCVR D IN to A28 mixer brick (D)

— W45 (N5245-20191) REF 4 RCVR R4 IN to A28 mixer brick (R4)

— W30 (N5245-20018)A35 port 4 coupler to front–panel port 4 CPLR ARM

— W27 (N5245-20052)A31 port 4 rcvr coupler to front–panel Port 4 SOURCE OUT

1. The A26 splitter (5067-4086) and N5245-20013, N5245-20022, N5245-20023, N545-20101, and N5245-20150 cables are only used with a legacy HMA26.5 p/n: 5087-7765. If you are unclear which HMA26.5 assembly your PNA has installed, refer to Chapter 7 Repairs and Figure 1 on page 7 and for details on A26 splitter and cabling, refer to your option-model in Chapter 6"2-Port Configurations, Serial Number Prefix ‹6021" and "4-Port Configuration, Serial Number Prefix ‹6021".
2. Attenuator 08490-60039 is shown in the figure, but is not included in this upgrade and not required with the A28 mixer brick (5087-7417).

— W29 (N5245-20017)A31 port 4 receiver, coupler to front-panel REF 4 SOURCE OUT

— W18 (reuse) (N5245-20111)A32 port 2 receiver coupler to W17

— W38 (N5245-20037)Port 3 RCVR C IN to A28 mixer brick (C)

— W44 (N5245-20020)REF 3 RCVR R3 IN to A28 mixer brick (R3)

— W12 (reuse) (N5245-20109)A29 port 1 receiver coupler to W11

— W20 (N5245-20099)Port 1 CPLR THRU to A33 port 1 coupler

— W24 (N5245-20098)Port 3 CPLR THRU to A34 port 3 coupler

— W26 (N5245-20015)A34 port 3 coupler to front-panel Port 3 CPLR ARM

— W23 (N5245-20051)A30 port 3 rcvr coupler to front-panel Port 3 SOURCE OUT

— W25 (N5245-20016) A30 port 3 rcvr coupler to front-panel REF 3 SOURCE OUT

* As shown in Figure 18, install clamp (part number 1400-1331) to secure W25 (N5245-20016).

Figure 18   Location of Cable Clamp for W25 (N5245-20016, 1400-1334)
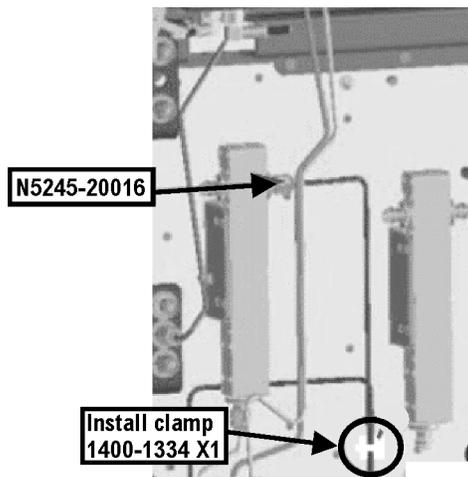
— W22 (N5245-20014)A33 port 1 coupler to front-panel Port 1 CPLR ARM

— W21 (N5245-20110)A29 port 1 receiver coupler to A37 reference mixer switch

* If the screws that attach the reference mixer switch to the test set deck were loosened, torque these screws now to 9 in-lbs.

* As shown in Figure 19, install two clamps (part number 1400-1334) to secure W21 (N5245-20110).

Figure 19   Location of Cable Clamps for W21 (N5245-20110, 1400-1334)
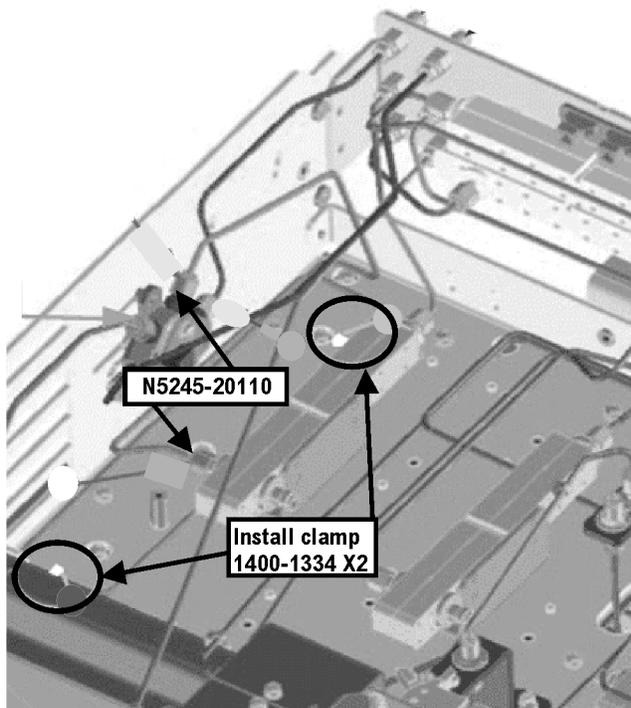
— W14 (N5245-20043)A30 port 3 receiver coupler to W13

— W16 (N5245-20044)A31 port 4 receiver coupler to W15

Install New Cable(s) – A21 HMA26.5 to A23/A24 Mixer Brick

If your instrument has a new HMA26.5 (N5240-60101) installed:

(If you have a legacy HMA26.5 (5087-7765) installed, you can discard this cable.)

— W203 (N5245-20195) RF cable, A24 mixer brick (top connector) to A21 HMA25.6 A24 mixer brick (top connector)

NOTE You will need to remove the cap that is installed on the HMA26.5 top connector, before connecting the other end of the W203 cable. You can discard the cap.

See also, "Verify the Model/Version of HMA26.5 Installed" on page 6.

If your instrument has a legacy HMA26.5 (5087-7765) installed:

(If you have a new HMA26.5 (N5240-60101) installed, you can discard these cables.)

— W52 (N5452-20013) A21 HMA26.5 to A22 splitter
NOTE: Tighten both screws on the splitter to 9 in-lbs.

— W53 (N5245-20023) A22 splitter to A24 mixer brick

— W54 (N5245-20022) A22 splitter to A23 mixer brick

(If you have the legacy 5086-7765 HMA26.5, please discard N5245-20195[1] semi-rigid cable. Refer to Figure 1 on page 7.)

See also, "Verify the Model/Version of HMA26.5 Installed" on page 6.

1. The N5245-20195 cable is used only with instruments that have a newer HMA26.5 installed. If your PNA has a legacy 5087-7765 HMA26.5 assembly installed, then this cable can be discarded. If you are unclear which HMA26.5 assembly your PNA has installed, refer to Figure 1 on page 7.

Step 22. Secure the Front Panel Bulkhead Connectors

Follow the instruction shown in **Figure 20** in this document.

Figure 20   Bulkhead Connections, Front Panel

① Secure 24x hex nuts on the front panel bulkhead connectors to 21 in-lbs using a "9mm" nut bit

② Go back and re-torque all 24 nuts to 21 in-lbs using a manual torque wrench
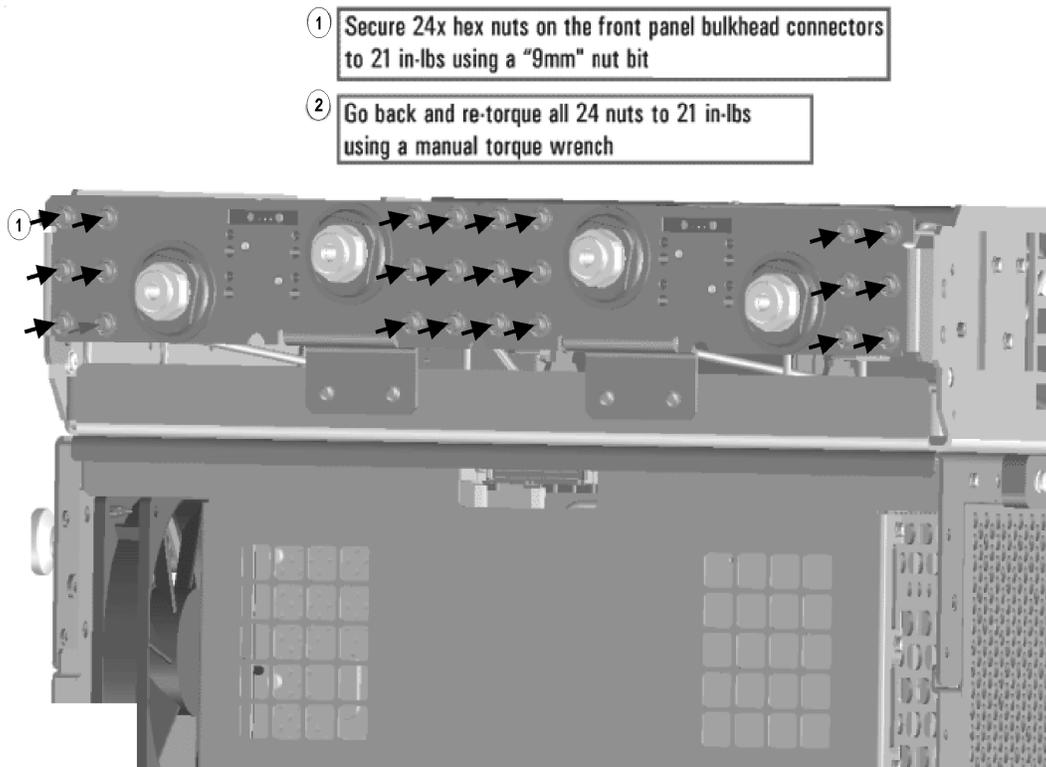
N5245_015_31

Step 23.Reinstall the A23 Test Set Motherboard

For instructions on reinstalling the board, click the Chapter 7 bookmark "Removing and Replacing the A23 test set motherboard" in the PDF Service Guide[1].

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1. See "Downloading the Online PNA Service Guide" on page 7.

Step 24. Install Cable on the A23 Test Set Motherboard

CAUTION	Follow instructions carefully when making cable connections, especially wire harness connections. Incorrect connections can destroy components, resulting in additional customer costs.

If not already done in a previous step, install the following new ribbon cable. To see an image showing the location, click the Chapter 6 bookmark "Bottom Ribbon Cables and Wire Harnesses, 4-Port, Option 417" in the PDF Service Guide[1]. New parts are listed in Table 1 on page 9.

— Ribbon cable (N5247-60015) from A28 mixer brick (2) J52 to A23 test set motherboard J552

Step 25. Replace the Front Frame in the Front Panel Assembly

Before the front frame can be replaced, the items making up the back side of the front panel assembly must be removed. For instructions on removing these items, click the Chapter 7 bookmark "Removing and Replacing the A1-A3 and Other Front Panel Subassemblies" in the PDF Service Guide[1]. New parts are listed in Table 1 on page 9.

1. In the section "Removing the A2 USB Board," perform the only step.

2. In the section "Removing the A1 Front Panel Interface Board and Keypad Assembly," perform steps 1 - 5.

3. In the section "Removing the Power Switch Board and Power Button Keypad," perform only step 1.

4. Remove the braided gasket from the backside edges of the 2-port front frame and install it in the 4-port front frame.

5. Reassemble the front panel assembly with the new 4-port front frame (N5247-20141) by reversing the order of the instructions previously followed.

Step 26. Reinstall Front Panel Assembly

1. For instructions on reinstalling the front panel assembly, click the Chapter 7 bookmark "Removing and Replacing the Front Panel Assembly" in the PDF Service Guide[1].

2. Be sure to install the two new screws (0515-1946) in the front panel, next to test ports 3 and 4. Torque these screws to 9 in-lbs.

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1. See "Downloading the Online PNA Service Guide" on page 7.

Step 27. Install the Overlays and Nameplate

To see an image of the front panel overlay (N5227-80004), keypad overlay (N5242-80005), and power button overlay (N5242-80007), click the Chapter 6 bookmark "Front Panel Assembly, Front Side, All Options" in the PDF Service Guide[1]. New parts are listed in Table 1 on page 9.

1. Remove the protective backing from the new front panel overlay (N5227-80005).

2. Loosely place the overlay in the recess on the lower front panel.

3. Placing two fingers at the middle, press the overlay firmly onto the frame while sliding your fingers in opposite directions towards the ends of the overlay. Repeat on all areas of the overlay.

4. Repeat steps 1-3 to install the keypad overlay (N5242-80005).

5. Repeat steps 1-3 to install the power button overlay (N5242-80007).

6. Repeat steps 1-3 to install the nameplate (N5224-80001 for model N5224A or N5225-80001 for model N5225A).

Step 28. Install the Front Panel Jumper Cables

Install twelve W36 front panel jumper cables (N5245-20155) – use 6 new jumpers and reuse 6 old jumpers. To see an image of the front panel jumper cables, click the Chapter 7 bookmark "Removing and Replacing the Front Panel Assembly" in the PDF Service Guide[1].

Step 29. Position the Cables and Wires to Prevent Pinching

On the top side of the PNA, carefully position the grey flex cables so they can't be pinched between the covers and the rails.

On the bottom side of the PNA, carefully fold or push down the ribbon cables and wires so they can't be pinched between the hardware and the outer cover. Ribbon cables and wires must never be positioned on top of hardware.

Step 30. Reinstall the Inner Cover

For instructions, click the Chapter 7 bookmark "Removing the Covers" in the PDF Service Guide[1].

Step 31. Reinstall the Outer Cover

For instructions, click the Chapter 7 bookmark "Removing the Covers" in the PDF Service Guide[1].

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1. See "Downloading the Online PNA Service Guide" on page 7.

Step 32. Remove Option 201 License

Procedure Requirements

— The analyzer must be powered up and operating to perform this procedure.

— The Network Analyzer program must be running.

— A keyboard and mouse must be connected to the network analyzer.

Option 201 License Removal Procedure

1. To start the Keysight License Manager, press Start > Keysight License Manager > Keysight License Manager. A Keysight License Manager dialog box will appear.

2. Right click the on the desired option and click **Delete**.

3. In the Keysight License Manager dialog box that appears, press or click **Yes** to confirm delete.

4. A message displays stating that the option removal was successful.

Step 33. Enable Options P04 and 401

Procedure Requirements

— The analyzer must be powered up and operating to perform this procedure.

— The network analyzer program must be running.

— A keyboard and mouse must be connected to the network analyzer.

Option Enable Procedure

1. To start the option enable utility, press UTILITY System , then Service , then Option Enable . An option enable dialog box will appear.

2. Click the arrow in the Select Desired Option box. A list of available options will appear.

3. In the Select Desired Option list, click P04 - 4-Ports.

4. Using the keyboard, enter the license key in the box provided. The license key is printed on the license message you received from Keysight. Enter this key exactly as it is printed on the message.

5. Click Enable.

6. Click Yes in answer to the displayed question in the Restart Analyzer? box.

7. Repeat steps 3-6 to enable Option 401, clicking 401 - Config TS + Attens in step 3.

8. When the installation is complete, click Exit.

Option Verification Procedure

Once the analyzer has restarted and the Network Analyzer program is again running:

1. On the analyzer's Help menu, click About Network Analyzer.

2. Verify that "P04," and "401" are listed after "Options:" in the display. Click OK.

NOTE	If the options have not been enabled, perform the "Option Enable Procedure" again. If the options are still not enabled, contact Keysight Technologies. Refer to "Getting Assistance from Keysight" on page 4

Step 34. Perform Post-Upgrade Adjustments and Calibration

Adjustments

The following adjustments must be made due to the hardware changes of the analyzer.

— 10 MHz freq adjustment

— EE default adjustment: Src 2 Synth Only

— synthesizer bandwidth adj. (only run when EE default adjust is not sufficient)

— source adjustment

— IF gain adjustment

— receiver adjustment

— receiver characterization

— IF Response Adjustment (Option 090 Only)

These adjustments are described in the PNA Service Guide and in the PNA on-line HELP. A list of equipment required to perform these adjustments is also found in the service guide.

After the specified adjustments have been performed, the analyzer should operate and phase lock over its entire frequency range.

EEPROM Backup

The analyzer uses arrays of correction constants to enable the analyzer to produce accurate, leveled source signals and receive clean test signals. These constants are stored in non-volatile EEPROM memory and in flash memory files.

The adjustments listed here generate new correction constants. The analyzer must have a backup of this new data in case any of the data becomes corrupted.

To store the backup data, perform these steps:

— Navigate to the EEPROM Backup Utility, located at:

— Windows 7 -- `C:\Program Files (x86)\Keysight\Network Analyzer\Service\eebackup.exe`

 — Windows 10 -- `C:\Program Files\Keysight\Network Analyzer\Service\eebackup.exe`

— Run the program.

— Click Backup EEPROM.

— Click Backup TSMB Mem.

— Click Backup Synth Mem. (Applies to Version 7 Synthesizers Only)

— Click Exit when the program has finished.

Figure 21   EEPROM Backup Menu
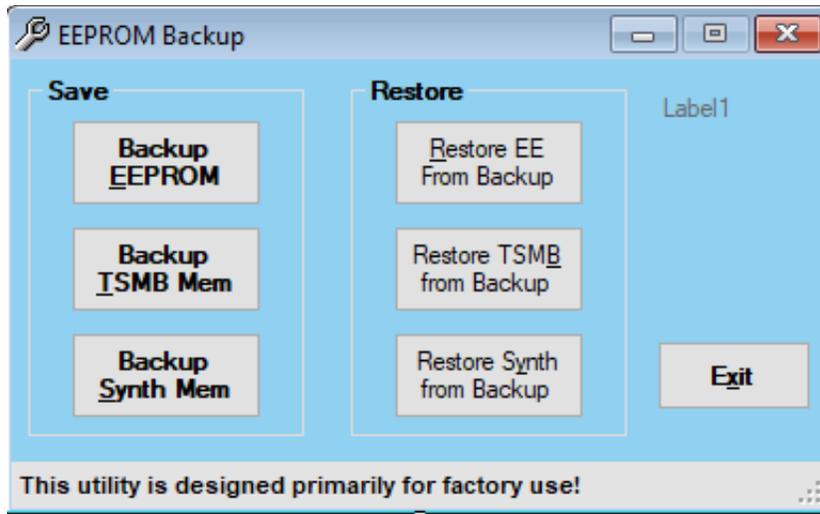
Operator's Check

Perform the Operator's Check to check the basic functionality of the analyzer. For instructions, click the Chapter 3 bookmark "Tests and Adjustments" in the PDF Service Guide[1].

If you experience difficulty with the basic functioning of the analyzer, contact Keysight. Refer to "Contacting Keysight" on page 4.

Calibration

Although the analyzer functions, its performance relative to its specifications has not been verified. It is recommended that a full instrument calibration be performed using the analyzer's internal performance test software. To view information on the performance test software, click the Chapter 3 bookmark "Tests and Adjustments" in the PDF Service Guide[1].

1. See "Downloading the Online PNA Service Guide" on page 7.

Step 35. Prepare the PNA for the User

1. If necessary, reinstall front jumper cables.

2. Install the cable guards, pushing them over the front jumper cables until the cushioning material touches the front panel of the PNA.

3. Install the dust caps on the test ports.

4. Clean the analyzer, as needed, using a damp cloth.

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