Antenna and RCS Measurement Configurations Using Agilent's New PNA Network Analyzers

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Welcome to a presentation on using Agilent's new PNA network analyzers in antenna and RCS measurement configurations

We'll see that this new analyzer has significant benefits in antenna/RCS ranges, and can result in significantly reduced test times, improved productivity, reduced cost of test, greater profitability, and enhanced competitiveness.

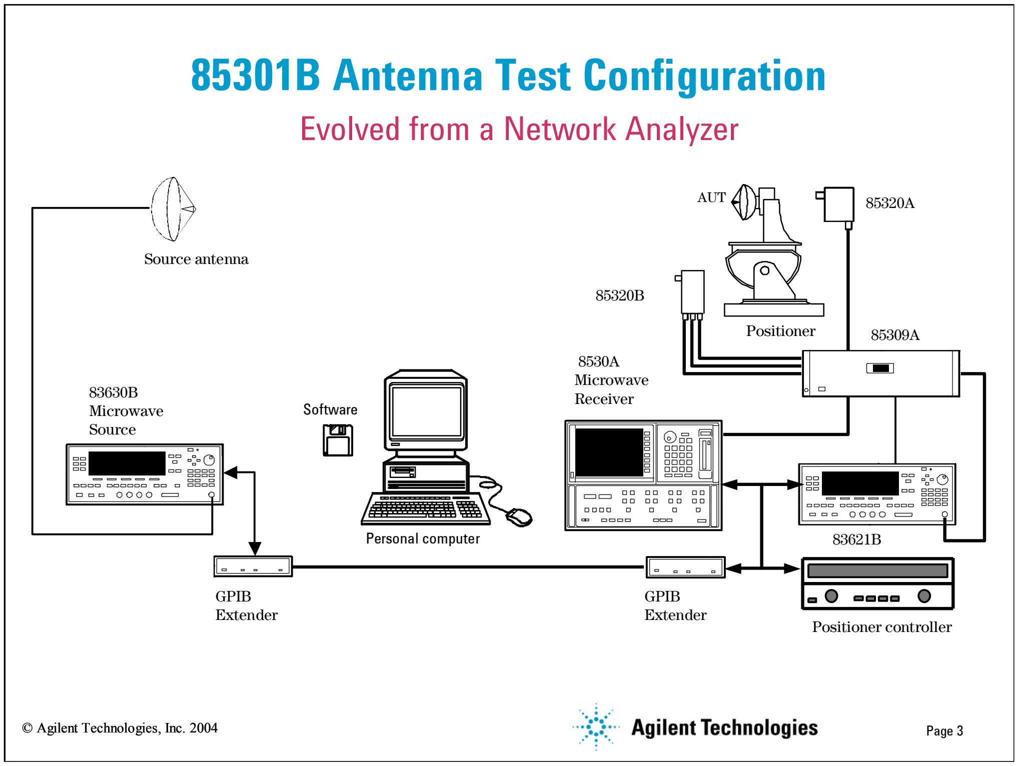
As antenna test professionals, we should all be very interested in these economic benefits.

Presentation Outline

- **Introduction**
- **Historical perspective**
- **Introducing the PNA series of network analyzers**
- **Near-field antenna configuration**
- **Far-field antenna configuration**
- **Radar Cross-Section configuration**
- **Typical performance comparisons**
- **Summary and conclusions**

In this presentation...

- A brief historical perspective
- Introduce the PNA series of network analyzers
- Typical antenna/RCS configurations using the PNA network analyzer
- Provide typical performance comparisons



We work in a high-technology industry, where technology constantly changes and improves the way of doing things. To remain competitive in this industry, we need to evolve and change with the technology, or get left behind.

Prior to the mid-1980s, antenna/RCS test engineers were using dedicated microwave receivers.

In the mid-1980s, utilizing a network analyzer in an antenna or RCS application was a new and novel idea.

Companies and individuals who adopted using the new network analyzer technology to make antenna/RCS measurements were leading innovators; and many others came to follow this technology lead in later years.

With the next generation of network analyzers now available to the industry, the antenna test community needs to evaluate this new technology to see if it can provide similar gains in improved performance, accuracy, and speed, to provide a better value for the antenna test community.

This paper examines how Agilent's new PNA series of network analyzers can be utilized in various antenna and RCS measurement applications.

Introducing the Next Generation Network Analyzer

- ✓ Completely new design
- ✓ New features
- ✓ User selectable bandwidths
- ✓ Faster measurement speeds
- ✓ Faster frequency agility
- ✓ Faster data transfers
- ✓ Enhanced reliability
- ✓ Same accuracy, repeatability, and stability

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<u>Introducing the next generation of network analyzers (from Agilent Technologies):</u>

This is a completely new family of network analyzers, with a completely new design, the latest technology and modern components.

While there are many new and modern features in this network analyzer, several which are shown here are of particular importance to antenna/RCS test applications.

Many of the key features relate to making faster measurements, such as faster data acquisition speeds, faster frequency agility, and faster data transfers.

The faster measurement speeds all relate to improving productivity, lowering the cost of test, and enhancing the competitiveness of a company or organization.

The new design and components provide for enhanced reliability, and you still get the same accuracy, repeatability, and stability you have come to expect.

PNA Features for Antenna/RCS Measurements

Sensitivity:
Greater than 30 dB improvement over 8530A/8511A & 8720 systems

Wide dynamic range:
> 90 dB at 67 GHz

Measurement speed:
As fast as 26 micro-seconds per data point

Fast frequency agility:
120 micro-seconds per frequency point

Fast data transfer:
COM/DCOM is ~100 times faster than 8530A

User selectable bandwidths: Optimize sensitivity and measurement speed

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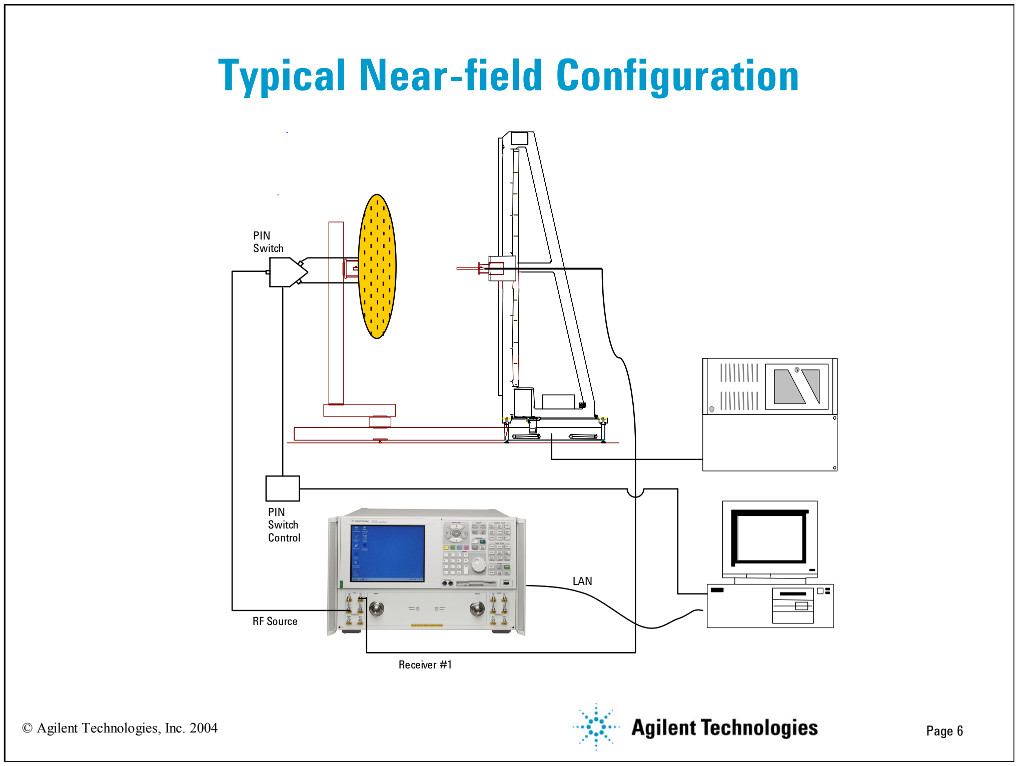

This figure illustrates a basic near-field antenna measurement configuration utilizing a PNA network analyzer. It is very similar to a configuration utilizing an 8720 network analyzer.

Performance enhancements of the PNA are as follows:

1. Faster data acquisition:

   PNA is 2.6 Times faster than the 8720
   PNA is 119 uS vs 8720 is 310 uS

2. Improved measurement sensitivity:

   24 dB improvement in measurement sensitivity over the 8720

   PNA uses mixer-based downconversion

   8720 uses harmonic sampler based downconversion

3. User selectable bandwidth:

   Optimize the measurement speed vs. measurement sensitivity.

4. Faster frequency agility:

   Typical PNA frequency stepping speeds are 20 times faster than 8720.

5. Bi-directional Frequency Sweep: PNA Arbitrary Segment Sweep function (Firmware revision 4.2).

Summary: For basic near-field measurements that are not data intensive, there will be little noticeable difference in total measurement times between PNA and 8720. However, for data intensive near-field measurements, the performance enhancements of the PNA will significantly reduce the total measurement time.

Advantages of a PNA in Near-field Applications

Faster data acquisitions:

PNA is 2.6 times faster than the 8720

Improved measurement sensitivity:

24 dB improvement in measurement sensitivity over the 8720

User selectable bandwidth:

Optimize the measurement speed vs. measurement sensitivity

Faster frequency agility:

Typical PNA frequency stepping speeds are 20 times faster than 8720

Bi-directional Frequency Sweep:

Using the PNA arbitrary segment sweep function (Firmware revision 4.2)

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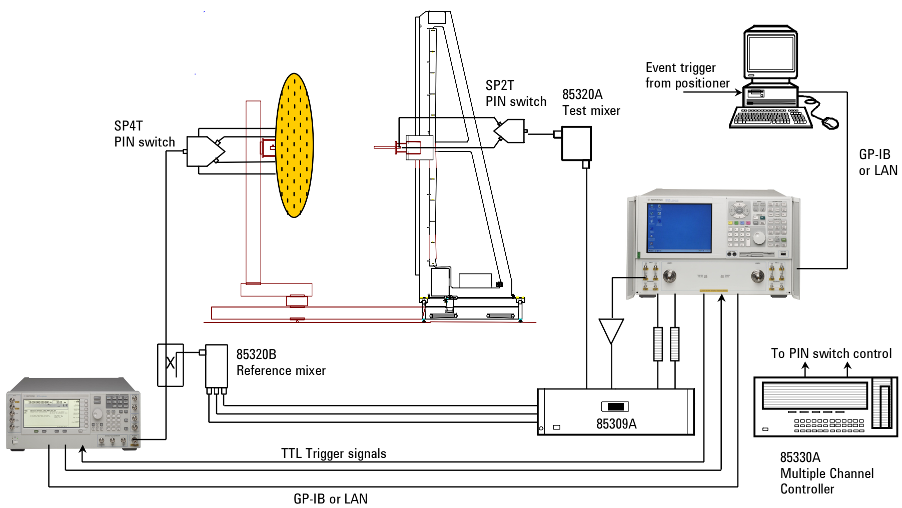
Large Scale Near-field Configuration



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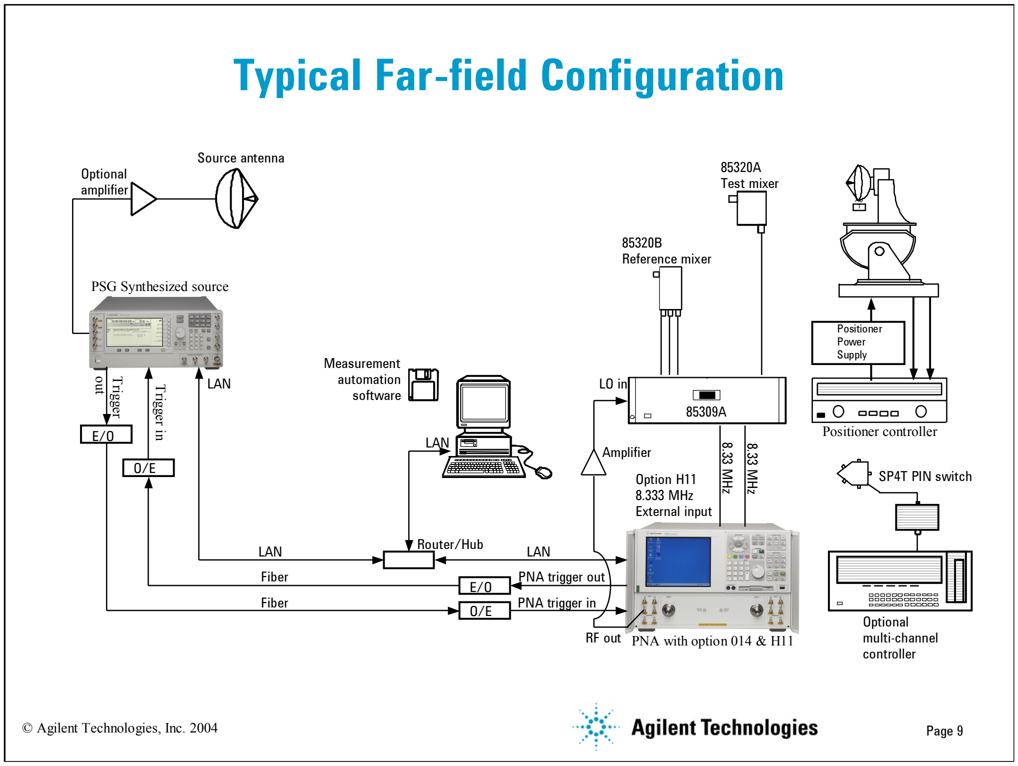
For large-scale near-field configurations where cable losses become significant, an external source and external mixer configuration such as shown here can be utilized. This overcomes the cable loss concerns, and provides very good performance.

Utilizing the source frequency list and direct trigger signals between the PNA and source provides the best frequency stepping speed. The system measurement speed is often determined by the remote source which is the slowest resource in the system. This could be enhanced with a faster microwave source or possibly utilizing a second PNA for the remote source.



<u>The configuration for a PNA in a far-field antenna configuration is as shown here:</u>

The configuration is very similar to the existing 85301B systems, with some slight differences.

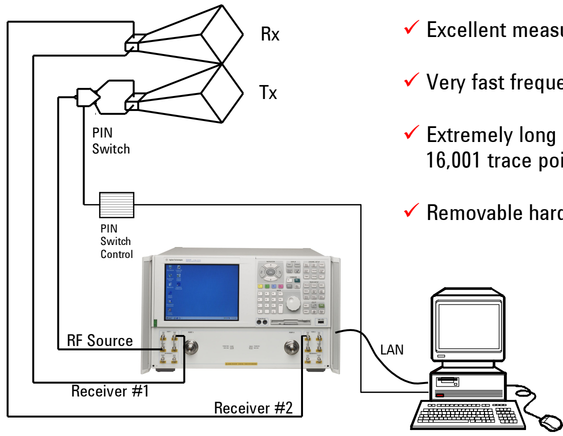
The far-field PNA configuration utilizes the same 85320A/B external mixers, and the 85309A LO/IF distribution unit to provide the first downconversion. However, the first downconversion is to an IF frequency of 8.333 MHz, which is the second IF frequency of the PNA. Utilizing option H11 on the PNA allows direct access to the second downconversion stage in the PNA via rear panel connectors. By utilizing this second IF downconversion technique in the PNA, the noise figure is reduced, which allows achieving the excellent measurement sensitivity.

As is the case for all far-field antenna ranges, controlling a remote microwave source across a significant distance is always a concern. This configuration utilizes a PSG microwave source, utilizing TTL handshake triggers between the PNA and the PSG source.

With the advent of relatively low-cost fiber optic transducers, this is a technology that could/should be investigated to provide long-distance TTL transmission signals across a far-field antenna range.

The frequency stepping speed of a far-field antenna range will be source dependent. There are many different sources which could be utilized. With the PSG source, we measured frequency stepping speeds of between 4-6 mS depending on step sizes.

Typical Radar Cross-Section Configuration



Features well suited for RCS applications:

- ✓ Excellent measurement sensitivity; -114 dBm
- ✓ Very fast frequency agility; 119 uS per point
- ✓ Extremely long alias-free down-range resolution; 16,001 trace points
- ✓ Removable hard drive for security issues

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Shown here is a typical RCS measurement configuration. It is very similar to the hundreds of 8720 and 8530 configurations currently in use.

RCS measurements require: Excellent sensitivity, fast frequency agility, and fast data acquisition times.

Prior network analyzer based RCS configurations utilized either a harmonic sampler or mixer based frequency downconversion. When choosing between the two, one could either optimize measurement speed, or measurement sensitivity.

Mixer downconversion (85301B): provided the best sensitivity of –113 dBm, but at the cost of a relatively slow stepped frequency agility speed of 6-8 mS per point.

Harmonic sampler downconversion (8511): Provides the best ramp sweep frequency agility of 230 uS per point, but at a tradeoff of a lower measurement sensitivity of –98 dBm.

The new family of PNA network analyzers makes a significant contribution to RCS measurements, providing both excellent measurement sensitivity and fast frequency agility. The PNA utilize mixer based downconversion technology to provide excellent measurement sensitivity of –114 dBm, and very fast frequency agility speeds of 119 uS per frequency point.

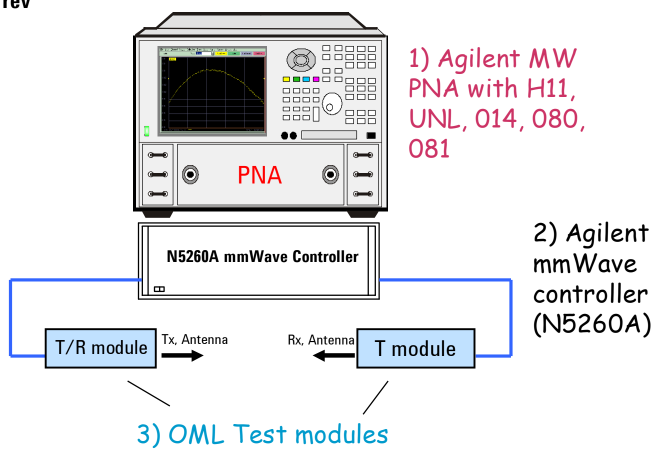
Summary: The RCS range designer no longer has to choose between fast frequency agility or optimizing measurement sensitivity. The new PNAs provide both the excellent sensitivity, fast frequency agility, and fast data acquisition speeds required by RCS ranges in one new instrument.

PNA Sub-Milli-meter Wave Configuration

Supported OML heads (with rev 4.0 of Firmware):

- **WR-15: 50-75 GHz**
- **WR-12: 60-90 GHz**
- **WR-10: 75-110GHz**
- **WR-8: 90-140 GHz**
- **WR-6: 110-170 GHz**
- **WR-5: 140-220 GHz**
- **WR-4: 170-260 GHz**
- **WR-3: 220-325 GHz**

System Component:



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PNA wave guide band configuration is based on MW PNA with Oleson Microwave Lab (OML) test modules as shown on the slide. This configuration allows greater than 110 GHz frequency coverage.

Measurement Time Comparisons

Antenna Test Description		Measurement Times: PNA Configuration	Measurement Times: 85301B/C Configuration	Measurement Times: 8720 Configuration
Near-field Example: 3 test ports Co-polarized response only 5 frequencies 256 electronic beam states Sampling grid: 100 x 100		34 minutes	2 hrs, 13 min.	5.0 hours
Far-field Example: 4 test ports, 2 polarizations 128 electronic beam states 5 frequencies in X-band Theta movement: ±40° in 0.1° increments Elevation movement: ±20° in 0.1° increments		1 hr., 45 min.	5 hours	**Not applicable**
RCS Example: Down-range resolution: 8-12 GHz, 801 points Cross-range resolution: ±30° in 0.25° increments	STEP Sweep	72 sec. 0.139 RPM	20 min. 0.009 RPM[1]	**Not applicable**
	RAMP Sweep	30 sec. 0.333 RPM	45 sec. 0.226 RPM	34 sec. 0.296 RPM

[1] This slow of a positioner rotation speed is not practical; it would require stepped motion, and this would increase the measurement time

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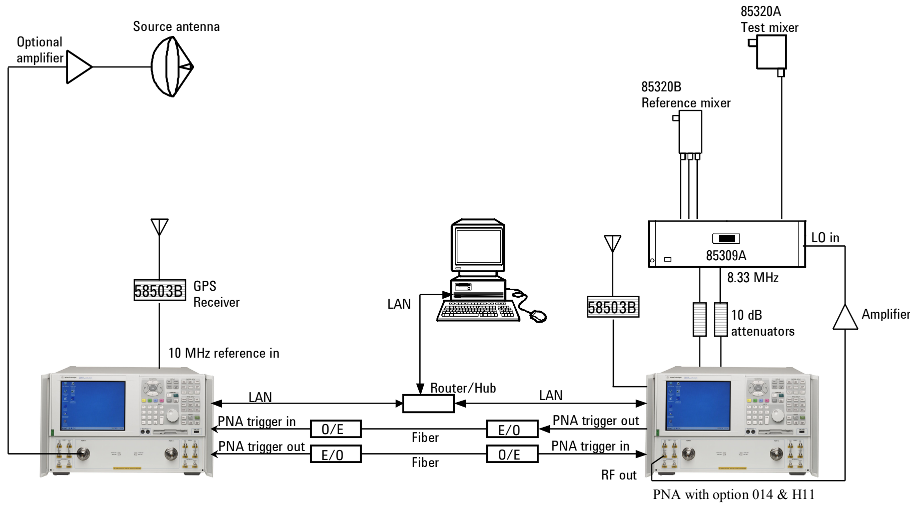
Shown here is a comparison of measurement times for three different measurement scenarios.

Note that the total measurement times for the PNA configurations are significantly less than with the other configurations.

All three examples are for data intensive scenarios, where the differences in data acquisition speeds will be the most significant. Simple measurement scenarios may not have significant differences in total measurement times.

A Dual PNA Configuration

For a far-field or near-field application



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Shown here is a concept that has not been fully verified by Agilent Technologies, but holds good promise for applications which would require extremely fast frequency stepping capability.

By utilizing two PNAs as shown in this configuration, this could potentially allow extremely fast frequency stepping capability of approximately 120 uS per frequency step, in addition to all the other benefits of a PNA system.

This configuration could be utilized in either a far-field or near-field application.

If you have an application which requires extremely fast frequency stepping capability, this is a configuration that deserves some further consideration.

Perhaps you will be an early adopter and innovator.

Typical Performance Comparisons

Receiver/network analyzer	PNA	PNA	85301B	85301C	8720
Downconversion	Internal mixers	Remote mixers	Remote mixers	Harmonic Sampler	Harmonic Sampler
Bandwidth and averaging	10 kHz, 1	10 kHz, 1	10 kHz, 1	10 kHz, 1	6 kHz, 1
Sensitivity (dBm)	-104	-114	-113	-98	-90
Dynamic range (dB)	94	90	89	88	85
<u>Data acquisition time:</u>					
CW mode (uS/pt.)	119	119	230	230	310
RAMP sweep (uS/pt.)	119[1]	119[1]	N.A.	230[2]	310[2]
STEP sweep (/pt.)	<400 uS	<400 uS	6-8 mS	N.A.	90 mS
With remote source[3]	4-6 mS	4-6 mS	6-12 mS	N.A.	N.A.

[1] Bandcrosses add typically 2-3 mS; retrace time is typically 11 mS

[2] Typical times without a bandcross; bandcrosses add typically 100 mS

[3] Dependent on source

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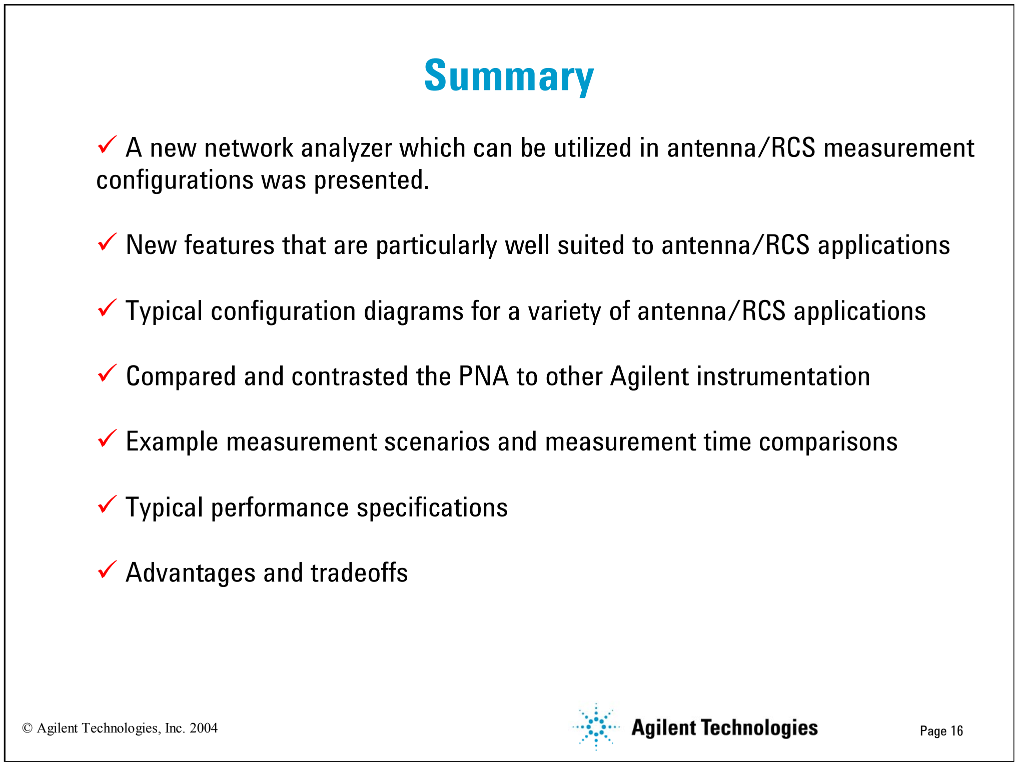
Shown here is a comparison of the typical performance of the new PNA configurations to the familiar 85301B, 85301C, and 8720 systems which are being used in many existing antenna/RCS ranges.

The PNA with its mixer based downconversion has excellent sensitivity that is comparable to the 85301B, and significantly better than the harmonic sampler based receivers.

The dynamic range is comparable; sensitivity is the more important factor.

Where the PNA has significant advantages is in the much faster data acquisition speeds, which can significantly reduce the total test times, reducing the overall cost of test. This provides test range operators with a significant productivity enhancement, and significant cost savings.

Also note that with the previous systems, the test range operator had to choose between a configuration that provided the best sensitivity with a tradeoff of reduced frequency agility, or the best frequency agility with a tradeoff of reduced sensitivity. With the PNA the operator achieves the best sensitivity <u>and</u> the best frequency agility!



<u>In summary:</u>

• A new network analyzer which can be utilized in antenna/RCS measurement configurations was presented.

• The new PNA analyzer has many features that are well suited to antenna/RCS applications.

• Typical configuration diagrams were presented for a variety of antenna/RCS applications.

• Compared and contrasted the new PNA to other Agilent instrumentation.

• Example measurement scenarios and measurement time comparisons were presented.

• Typical performance specifications were presented.

• The advantages and tradeoffs of the new PNA were presented.

Conclusions

- ✔ The new PNA network analyzer can provide significant performance enhancements to antenna/RCS measurements
- ✔ Key economic benefit is faster data acquisition speeds that can reduce total measurement times, providing a more cost effective measurement solution.

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The conclusions are clear:

The new PNA network analyzer can provide significant performance enhancements to antenna/RCS measurements.

The key economic benefit to antenna range operators is faster data acquisition speeds that can reduce total measurement times, providing a more cost effective measurement solution.

Appendix (Following are reference slides)

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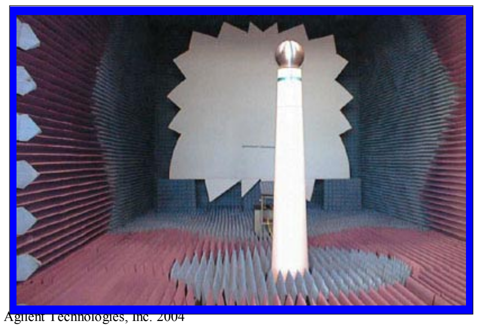
The conclusions are clear:

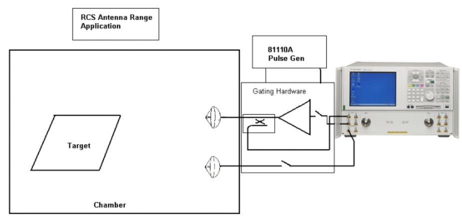
The new PNA network analyzer can provide significant performance enhancements to antenna/RCS measurements.

The key economic benefit to antenna range operators is faster data acquisition speeds that can reduce total measurement times, providing a more cost effective measurement solution.

Pulsed-RF Market Overview - Pulsed Antenna Test

- About 30% of antenna test involves pulsed-RF stimulus
- Test individual antennas or complete systems
- Radar Cross Section (RCS) measurements often require gating to avoid overloading receiver





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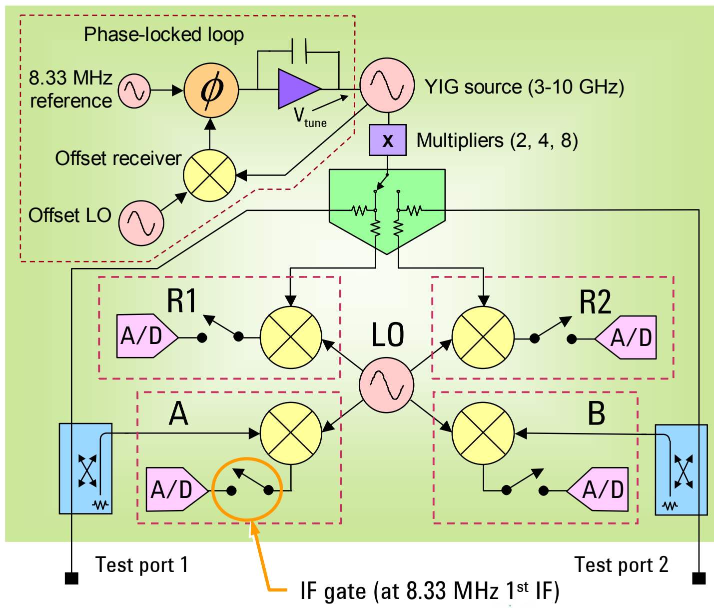
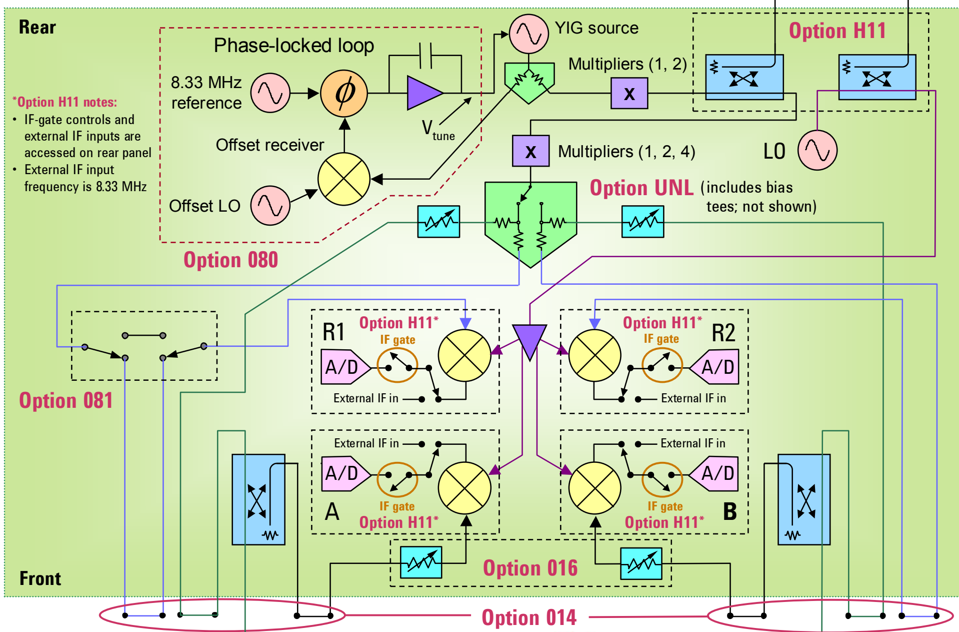
PNA Block Diagram with Internal Receiver Gates



Hardware Options H11



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H11 – What is it?

- **Rear Panel IF Mux Access (includes Opt 014,UNL,080 and 081)**
  - **IF connectors: A, R1, R2, B**
  - **IF Connector input frequency: 8.333 MHz**
  - **Damage Level: -20 dBm**
  - **0.1 dB Compression point: -27 dBm**
- **Provides Rear Panel RF & LO Ports:**
  - **RF Port, 1.7 - 20 GHz**
  - **LO Port, 1.7 - 20 GHz**
- **Provides Rear Panel Pulse Inputs With Opt H08:**
  - **Pulse Input connectors: A, R1, R2, B**
  - **Drive voltage: TTL (0, +5.0) Volts**

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General H11 Rear panel Typical Specifications:

LO Port: -7 dBM to –16 dBM (typical)

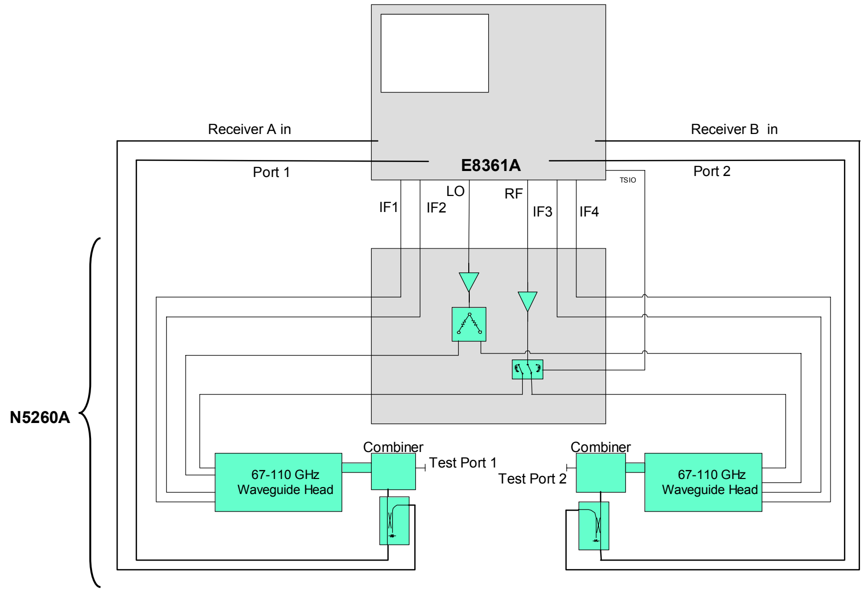
RF Port: Power level varies with MW PNA models, typically it covers a power level range of –5 dBm to –12, -16 dBm

IF connectors:		A, R1, R2, B
IF Connector input frequency:	8.333 MHZ	
Damage Level to IF connector inputs:	-20.0 dBm	
0.1 dB Compression point:		-27.0 dBm

Pulse Input connectors:	A, R1, R2, B
Drive voltage:	TTL (0, +5.0) Volts

Note: Pulse input connects non operational without Pulse Measurement Capability option H08 enabled.

N5250A System Block Diagram



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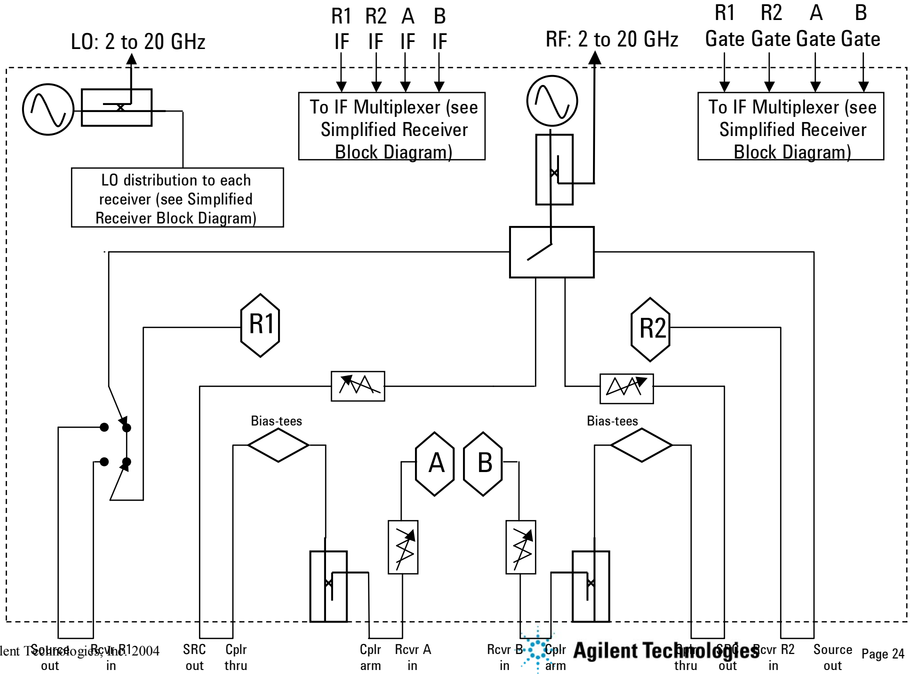
Test Set Block Diagram



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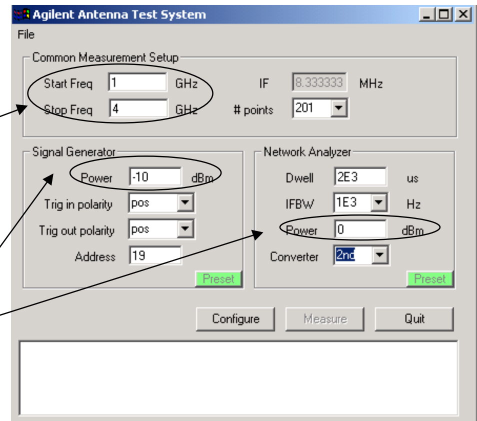
Program Example (Macro)

uW PNA Applications: Remote Mixing for Antenna Test

Set-up Utility to configure external source and PNA network analyzer

Set start & stop frequency of both external and network analyzer

Set power levels of both external source and network analyzer



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