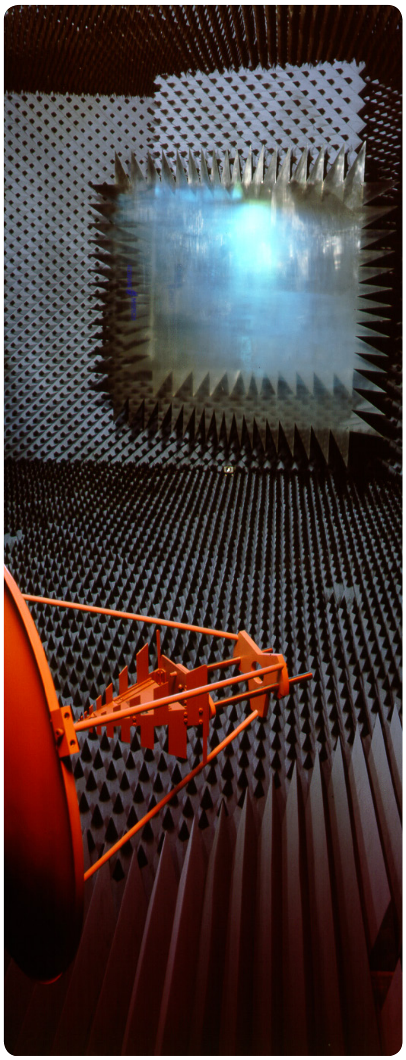
Reducing Measurement Times and Improving Economic Competitiveness in Antenna and RCS Applications

Application Note



In today's most advanced antennas, enhanced performance goes hand-in-hand with greater complexity—and this leads to increasingly challenging test requirements. At the same time, concerns about organizational competitiveness and time-to-market are driving the need to reduce the total cost of test. These conflicting forces can put tremendous strain on the entire test function: personnel, resources and facilities.

Fortunately, measurement technology is improving in ways that can relieve the strain. When properly applied, these advances can help shorten total test times, reduce the cost of test, improve test range productivity and increase manufacturer competitiveness.

As examples of these advanced capabilities, this application note highlights the use of Agilent PNA-X vector network analyzers (VNAs) and Agilent MXG vector signal generators in antenna and radar cross section (RCS) applications. When compared to previous-generation Agilent instruments, the improvements are remarkable:

- Far- and near-field antenna measurements can be up to 50 times faster
- RCS measurements can be up to 45 times faster

To help you achieve these speed improvements, this note describes test range configurations and typical measurement scenarios. It also presents the equations used to determine measurement times and provides the key instrument parameters that affect test times. Collectively, this material will help you estimate the levels of improvement in throughput and productivity that may be possible with your test range and measurement needs.

Agilent Technologies

Scanning the technical challenges

Real-world needs are driving designers to create complex, high-performance antennas that have increasingly challenging test requirements. As an example, new designs that contain large, multi-element arrays must be tested across numerous frequencies and beam states. This produces tremendous amounts of data that must be thoroughly analyzed for complete characterization of the design.

Because test ranges vary widely in size and physical layout, equipment selection and configuration can be challenging. Fortunately, advances in measurement technology offer new opportunities to optimize existing facilities and boost test throughput. These improvements can often be achieved by replacing just a few system elements—and this is especially effective when existing antenna-test software can be used without modification.

When considering instrument changes, it is often necessary to assess the interactions and tradeoffs between parameters such as measurement sensitivity, system performance and test throughput. For example, system performance depends on specifications such as dynamic range, receiver linearity and a high signal-to-noise ratio. Fortunately, the performance of current-generation measurement technology reduces the need for such tradeoffs in antenna test facilities.

Summarizing the economic challenges

Even as antennas are becoming more complex and more time-consuming to characterize, the economic realities of modern competition are creating conflicting imperatives centered on metrics such as time-to-market and manufacturing cost. A company that can develop high-quality antennas in less time is more likely to win more development contracts. Producing those antennas with acceptable margins—technical and financial—depends on factors such as test times and the cost of test. In all cases—development time, test time, cost of test—the smaller the number, the better.

The ability to achieve consistently high quality at a competitive price requires the cost-efficient acquisition of sufficient test data to enable accurate characterization of antenna performance. As with the technical challenges, there are tradeoffs. On the economic side, these include the time and expense of adequate test coverage, sufficient measurement data and accurate data analysis.

Once again the performance of current-generation measurement technology helps balance the tradeoffs when designers face the dilemma of acquiring greater amounts of data in less time than was allocated in the past. It is possible to meet these requirements and still produce antennas that provide the levels of quality, integrity and functionality being demanded by end users.

Introducing the PNA-X family

For antenna and RCS measurements, the most important attributes of suitable measurement instrumentation are sensitivity, frequency agility and data acquisition times. Agilent has introduced the PNA-X family of vector network analyzers and the N5264A microwave receiver, which is based on the PNA-X. These instruments are ideally suited for antenna and RCS applications because they include multiple receiver channels as well as internal sources with excellent frequency agility.

Prior to the introduction of the PNA-X family, many antenna/RCS ranges used either the Agilent (HP) 8530A/8511 or 8720 microwave receivers. The hallmark of these receivers is fast frequency sweeps with good sensitivity, which are enabled by harmonic-sampling downconversion technology. However, the harmonic-sampling approach is less sensitive (–89 dBm) than fundamental or low-harmonic external-mixing downconversion technologies. While both the harmonic-sampling and external-mixing approaches have been widely used, test engineers had to choose between a receiver downconversion technology that was optimized for either frequency agility or measurement sensitivity.

Today, the PNA-X offers the best of both worlds by using mixer-based downconversion technology that delivers excellent measurement sensitivity while maintaining very fast frequency agility. Other key attributes include user-selectable bandwidths of up to 5 MHz, four simultaneous receiver channels, up to 32,001 data points per test channel, and a fast microprocessor. The PNA-X also offers the economic advantage of dual-use capability: It can either perform antenna/RCS measurements or function as a high-performance network analyzer.

Highlighting the N5264A

Derived from the PNA-X, the N5264A omits the RF sources, couplers and test ports. For antenna and RCS measurements, it offers five simultaneous receiver channels, a 500-Mpt data buffer and data acquisition speeds of up to 400,000 data points per second (option 118) on each of the five measurement channels.

To protect software investments and minimize transition time, the N5264A is a drop-in replacement for the 8530A, including a code-emulation function that allows the N5264A to run with existing measurement-automation software. The N5264A is also compatible with all existing Agilent antenna/RCS system components.

To facilitate solution creation, Agilent maintains relationships with all of the leading antenna/RCS solution providers. Our solution partners have developed drivers for the N5264A and the rest of the PNA-X family, and these drivers utilize many of the built-in features that increase measurement throughput.

Comparing past and present

The PNA-X and N5264A have many of the essential features found in Agilent's previous-generation receivers. For example, the multiple-channel receivers can eliminate the need for PIN switches when testing multiple-channel devices such as monopulse antennas. This simultaneous measurement capability can reduce data acquisition times.

The improvements begin with a versatile arbitrary segment mode that allows ascending, descending, arbitrary and random frequency sweeps. A reverse (arbitrary) sweep enables bi-directional scans, minimizing the time required for near-field data acquisition and scanning. Also for near-field applications, user-selectable bandwidth allows configurations that trade off lower measurement sensitivity for shorter data acquisition time.

For buffering and transferring of acquired data, the PNA-X and N5264A have 32,001 data points per measurement channel and a 500-Mpt FIFO buffer. For data-intensive acquisitions, fast transfers to an external computer can be accomplished using DCOM over the LAN port. Example speeds are in the range of 1601 data points in 2.1 milliseconds and 16,001 data points in 13 milliseconds. For active-array antennas and similar applications, the PNA-X can perform pulsed measurements.

Additional capabilities include a removable hard drive and an optional built-in 25.6 GHz source (option 108).

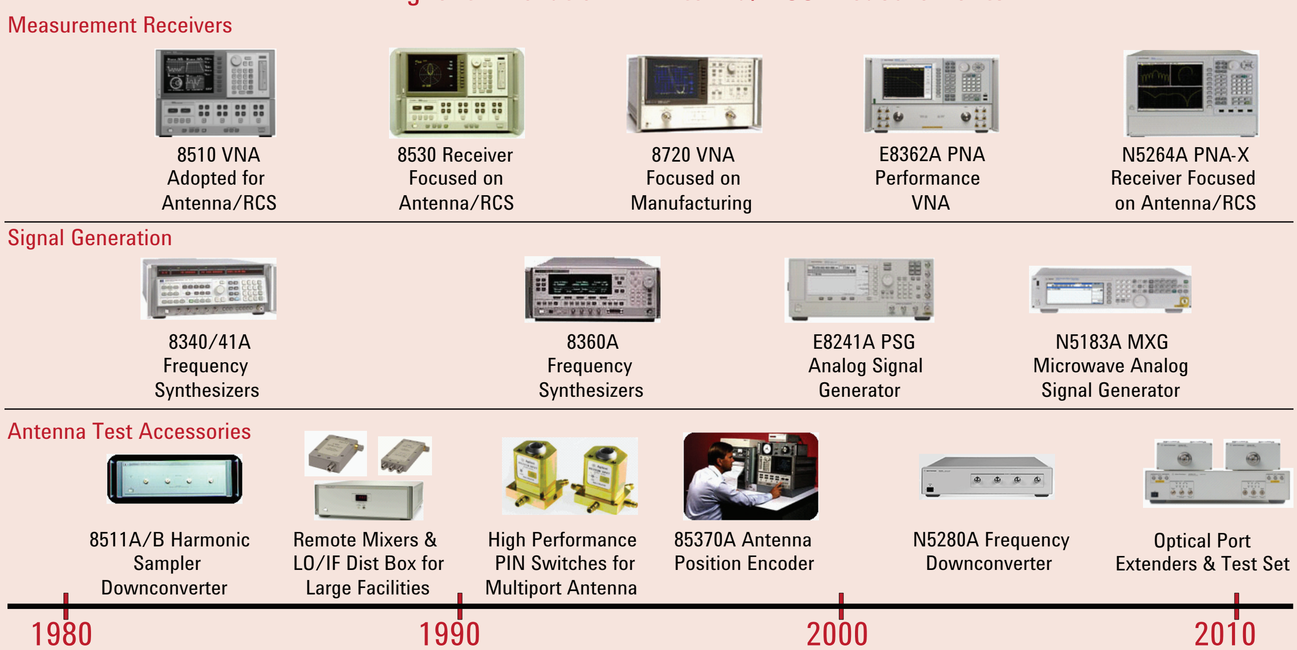
30 years of innovation in antenna and RCS testing

Prior to the 1980s, antenna test engineers were using dedicated microwave receivers for antenna test applications. In 1985, a few innovative companies began using the Agilent (HP) 8510 network analyzer as the receiver. This type of commercial, off-the-shelf (COTS) instrument brought new levels of stability, accuracy, repeatability and reliability to antenna and RCS measurements.

The next step was the Agilent (HP) 8530 microwave receiver, which was designed specifically for antenna and RCS measurements. Related innovations included remote mixing capabilities for large-facility testing, switching technologies for multiport test antennas, and millimeter-wave modules that extend reliable test capabilities up to 110 GHz.

Similar to the evolution of the 8510 and 8530, today's PNA-X is the foundation of the N5264A microwave receiver. As the replacement for the 8530, the N5264A is equipped to provide further gains in performance, accuracy, speed and productivity for the antenna-test community.

Agilent Innovation in Antenna/RCS Measurements



Accelerating far-field measurements

Far-field antenna measurements require that the antenna-under-test (AUT is radiating in the far-field or Fraunhofer zone. In general, antennas produce a spherical wavefront; however, at great distances the spherical wavefront becomes almost planar across the aperture of the receive antenna. These planar waves are required for far-field testing. The generally accepted far-field criteria are as follows:

$$R > \frac{2D^2}{\lambda}$$

Where:

R = required minimum separation between source and AUT
D = maximum dimension of antenna aperture
λ = wavelength at highest frequency of antenna operation

This criterion allows 22.5 degrees of phase variation across the aperture of the AUT. For low-performance antennas, 22.5 degrees of phase taper provides acceptable errors in the antenna nulls and sidelobes. However, the required far-field distance usually depends on the amount of measurement error that is acceptable in the null depths and sidelobes. When trying to accurately measure a very deep monopulse null or a very low sidelobe, $10D^2/\lambda$ may be required to satisfy the far-field conditions necessary for adequate measurement results.

With a far-field antenna measurement, the radiated energy is measured in real time as the AUT is rotated through azimuth and elevation coordinates. The resulting data is a measure of amplitude, phase, or both, as a function of angular position. The rotation of the antenna is usually accomplished with a mechanical positioner, which determines the exact position in the coordinate system and typically restricts movement to a single axis at a time.

There are two main types of far-field test facilities (Figure 1). A traditional outdoor site positions the source and AUT at a distance (R) greater than that defined by the equation. The test facility footprint can range from 10 to 1,000 meters, depending on the size of the antenna (D) and the minimum wavelength. In urban environments, factors such as real estate costs, RF noise pollution and security concerns may present challenges for this type of test facility.

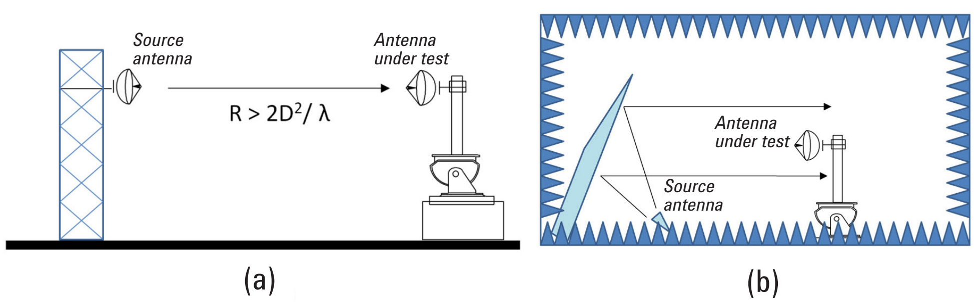


Figure 1. The most common forms of far-field test facilities are outdoor (a) and compact indoor (anechoic chamber) (b)

The compact range is another type of far-field facility. These are typically located indoors, using anechoic material and large reflectors. Once the radiated energy passes the focal point of the reflector, the signal is considered to be in the far-field. Compact antenna chambers have a "quiet zone" that defines an area in which planar waves meet the far-field criteria.

Determining throughput in far-field testing

The following measurement equations will help you calculate the potential throughput advantages in far-field testing. Instrument parameters are provided in the test scenario examples (and the appendix) to complete the calculations for either our latest test offerings or your installed Agilent equipment.

The first step is to determine the measurement time per angular increment or MTPA:

$$MTPA = (((R \times C \times P + ABD) \times BP + S) \times F) + (N \times BC)$$

Where:

MTPA = measurement time per angular increment in seconds
R = receiver data acquisition time in seconds
C = channels of data to be measured (or number of antenna test ports)
P = number of polarization states to be measured
ABD = additional beam dwell time in seconds, if required
BP = number of electronic beam positions
S = source settling time or frequency switching time in seconds
F = number of frequencies to be measured
N = number of band crossings across measured frequency range
BC = band-crossing time in seconds

Note that when the required frequencies include a band crossing, then the band-crossing value (BC) should be used in place of the receiver acquisition time (R) to allow for source-settling time. The table in the appendix shows the band-crossing frequency points for the signal sources discussed in this application note.

Next, calculate the fastest possible speed for the antenna positioner in revolutions per minute (RPM):

$$RPM = \left(\frac{P_{inc}}{MTPA}\right)\left(\frac{1\ rev}{360°}\right)\left(\frac{60\ s}{1\ min}\right)$$

Where:

RPM = positioner velocity or revolutions per minute
P_{inc} = theta, elevation increment or angular step size in degrees

At this point it can be determined if throughput will be measurement-limited or positioner-limited. If the calculated RPM value is between 0.1 and 3 RPM then the facility is measurement-limited and the equation shown below can be used to determine potential advantages of upgrading the measurement system.

If the calculated RPM value is greater than 3, then the facility is positioner-limited and the equation should be used with RPM set equal to 3. If the calculated RPM is less than 0.1 RPM, then the positioner must be operated in stepped motion to allow the required measurement time.

Note that this example assumes that the typical range of an antenna positioner speed is between 0.1 and 3 RPM. Please use the positioner's actual specifications in your analysis.

$$Throughput = (Az \times 2 + 1)(El \times 2 + 1)\left(\frac{P_{inc}}{RPM}\right)\left(\frac{1\ rev}{360°}\right)$$

Where:

Throughput = total measurement time in minutes
Az = theta movement in the azimuth plane, ±X°
El = theta movement in the elevation plane, ±Y°

Configuring far-field testing with remote mixers

Many different configurations are used in either type of far-field test facility. These may be defined based on factors such as budget; required antenna size or frequency; and the required performance level.

Here, we show two of the more common far-field configurations. Each example includes typical test scenarios and measurement times, and these are provided to help you determine the potential throughput advantage achievable in your measurement facility.[1]

Historically, there have been long distances between the source antenna and the AUT. Consequently, far-field ranges have commonly used remote-mixing techniques to minimize RF signal loss and therefore maximize measurement sensitivity. Our first example is based on this technique. While there are many aspects to (and variations in) communication between test equipment in this example, we're focusing on the RF paths as they relate to measurement throughput.

The key advantage of this configuration is higher measurement sensitivity. This is accomplished by strategically placing system components to minimize RF path loss (Figure 2). For example, placing an external source near the transmitting antenna increases the strength of the transmit signal. This configuration connects the remote mixers to the AUT and reference antenna, which down-convert the RF signal to lower frequencies and thereby minimize the RF signal loss that typically occurs over long cable runs.

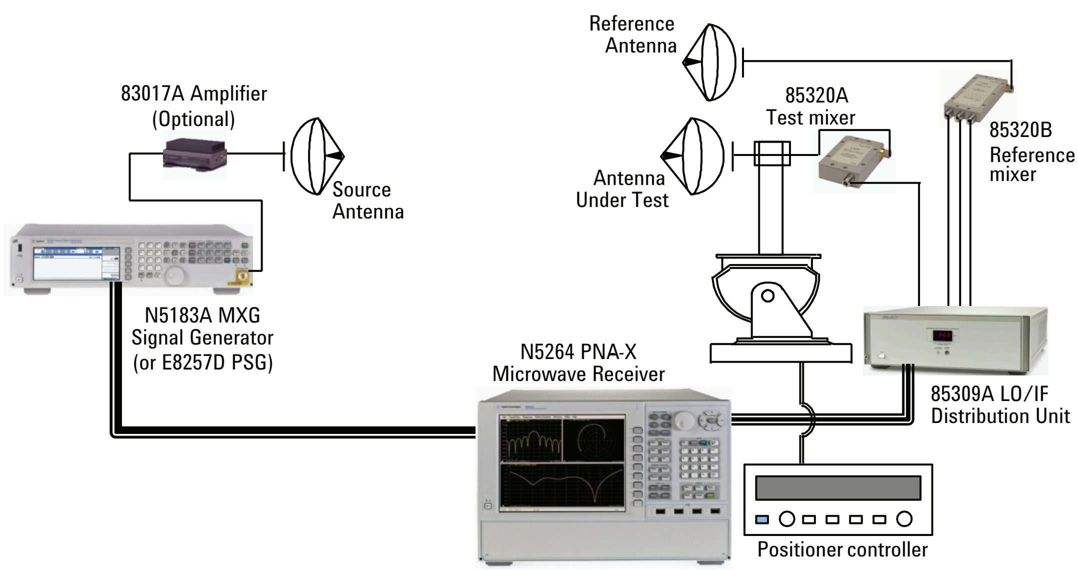


Figure 2. Far-field remote-mixing configuration using Agilent's MXG signal generator and N5264A microwave receiver

When using this technique for far-field measurements, two factors tend to limit the maximum possible measurement speeds. One is the frequency agility of the remote sources; the other is the maximum rate of positioner rotation (typically 3 RPM). For simple antenna measurements, the measurement speed may be very fast and the antenna positioner often becomes the limiting factor in measurement throughput.

1. *Actual measurement times will vary with facility configuration.*

As the complexity and volume of required data increases, the measurement system becomes the limiting factor. Positioners typically have a minimum speed of 0.1 RPM, after which they must be used in step mode. In such cases the total test time is a combination of the positioner step time plus the measurement dwell time.

For antenna facilities that use remote-mixing techniques with an 8530, the following sections should be helpful in calculating your potential throughput improvements. If your facility is experiencing throughput limitations caused by the current measurement system, the potential speed advantages may help justify a system upgrade.

Scenarios: Throughput with remote mixing

In this section we apply the far-field throughput equations to a few example test scenarios that use the remote-mixing configuration with the N5264A microwave receiver and the MXG signal generator. Table 1 presents seven different test scenarios: Cases 1-3 assume far-field testing of a simple antenna (e.g., one used for weather radar or airport surveillance radar) while cases 4-7 show throughput examples for the testing of electronically-steered antennas on far-field ranges.

Table 1. Far-field measurement scenarios for remote mixing

Test Scenarios Using MXG Signal Generator and N5264A Microwave Receiver							
	Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
Receiver Settling time (R in sec)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
# of Data Chan or Ant Test Ports (C)	3	3	3	3	3	3	3
# of Polarizations (P)	1	1	1	1	1	1	1
Additional Beam Dwell Time (ABD in sec)	0	0	0	0	0	0	0
# of Electronic Beam Positions (BP)	1	1	1	64	64	256	512
Source Settling time (S in sec)	0.00065	0.00065	0.00065	0.00065	0.00065	0.00065	0.00065
# of Measured Frequencies (F)	2	10	100	2	4	2	2
Band Crossing Time (BC in sec)	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Pos Inc or Ang Step Size (P_{inc} in Deg)	1	1	1	1	1	1	1
Azimuth Pos. Movement (Az in ± deg)	30	30	30	30	30	30	30
Elevation Pos. Movement (Az in ± deg)	10	10	10	10	10	10	10
Speed Calculations Using MXG Signal Generator and N5264A Microwave Receiver							
# of Bandcrossings = 0	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
MTPA (P_{inc}/sec)	0.00190	0.00950	0.00950	0.03970	0.07940	0.1549	0.3085
RPM (Rev/min)	87.719	17.544	1.754	4.198	2.099	1.076	0.540
RPM (must be ≤ 3)	3.000	3.000	1.754	3.000	2.099	1.076	0.540
Throughput (min)	1.19	1.19	2.03	1.19	1.70	3.31	6.59
# of Bandcrossings = 1	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 5**
MTPA (P_{inc}/sec)	0.01530	0.06850	0.66700	0.77130	1.54060	3.0753	6.14730
RPM (Rev/min)	10.893	2.433	0.250	0.216	0.108	0.054	0.027
RPM (must be 0.1 ≤ RPM ≤ 3)	3.000	2.433	0.250	0.216	0.108	0.054	0.027
Throughput (min)	1.19	1.46	14.24	16.47	32.89	65.66	131.24

Positioner-limited   Stepped mode (est)

Cases 1-3 show the effects of adding additional frequencies to the test plan: It's clear that this approach becomes measurement-limited only when the number of test frequencies increases.

Cases 4-7 highlight the throughput challenges of testing electronically-steerable antennas at multiple beam positions. The required test times become significant as the number of beam positions increases from just a few with a fairly simple electronically-steered antenna to significantly more with a complex antenna.

Table 2 compares the N5264A/MXG configuration with an 8530/8360-based system. The number of band crossings has an effect on measurement times and is determined by the specific frequencies required for testing. This example includes two cases, one with no band crossings and one with a single band crossing.[1] For greater numbers of frequencies, the throughput advantages over the 8530/8360 solution are particularly noticeable.

Table 2. Speed comparisons of past and present instrumentation in a far-field remote-mixing configuration

MXG/N5264A versus 8360/8530 Throughput Comparisons (Minutes)			
Assumes No Band Crossings			
Far-Field Test Scenario	**N5264A /MXG**	**8530/8360**	**Speed Improvement (x times faster)**
Case 1	1.19	1.28	1.1
Case 2	1.19	6.41	5.4
Case 3	2.03	64.05	32
Case 4	1.19	41.63	35
Case 5	1.70	83.27	49
Case 6	3.31	164.61	50
Case 7	6.59	328.58	50
Assuming One Band Crossing			
Far-Field Test Scenario	**N5264A /MXG**	**8530/8360**	**Speed Improvement (x times faster)**
Case 1	1.19	8.11	6.8
Case 2	1.46	36.30	25
Case 3	14.24	353.34	25
Case 4	16.47	411.63	25
Case 5	32.89	822.19	25
Case 6	65.66	1641.39	25
Case 7	131.24	3281.07	25

Positioner-limited   Stepped mode (est)

In all cases, most of the differences in measurement times can be attributed to the improved frequency agility speeds of the external sources. For complex far-field measurements with more than 10 test frequencies or with a large number of beam positions, upgrading the measurement system with faster external sources will provide the greatest reduction in total measurement time and provide the best productivity gains.

1. *Please refer to the appendix to determine the number of band crossings for your specific frequencies of interest.*

Configuring far-field testing with optional optical extenders

There are several advantages to using a small-range configuration versus a remote-mixing configuration—and the key advantage is the elimination of remote mixers and sources. In this case the complement of measurement hardware is reduced to just a network analyzer, which helps minimize cost, space and complexity by providing the source and the required receiving channels.

The mixers and sources can be eliminated by using optical extenders to convert signals from RF to optical at the network analyzer's test-set interface. Once converted, the signal can be sent through fiber optic cable with a loss of only 0.3 dB per kilometer. The signals are converted from optical back to RF at the source antenna or AUT.

Agilent offers optical extenders that bring the advantages of the PNA-X network analyzer to any facility currently using remote-mixing techniques.[1] Figure 3 shows an example block diagram. The optical port extenders and test set are shown for potential use in larger facilities. While optical extenders have a modest impact on output power, they do not influence the throughput calculations shown in the examples below.

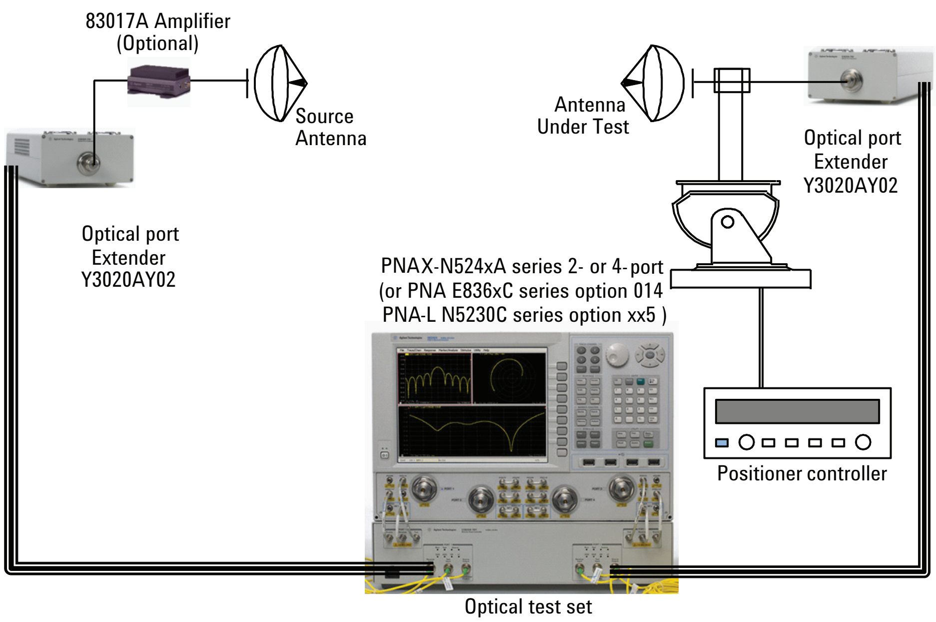


Figure 3. Far-field configuration using the Agilent PNA-X and optional optical extenders for larger facilities

1. *Currently, the optical extender capability is limited to applications between 10 MHz and 50 GHz.*

Scenarios: Throughput with PNA-X

This section applies the same equations and measurement scenarios used with the remote-mixer configuration. The key difference is in the instrument values, which are based on the PNA-X alone. These values are shown in Table 3 and the appendix.

Table 3. Far-field measurement scenarios for basic configuration with optional optical extenders

Test Scenarios Using PNA-X							
	Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
Receiver Settling time (R in sec)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
# of Data Chan or Ant Test Ports (C)	3	3	3	3	3	3	3
# of Polarizations (P)	1	1	1	1	1	1	1
Additional Beam Dwell Time (ABD in sec)	0	0	0	0	0	0	0
# of Electronic Beam Positions (BP)	1	1	1	64	64	256	512
Source Settling time (S in sec)	0.00013	0.00013	0.00013	0.00013	0.00013	0.00013	0.00013
# of Measured Frequencies (F)	2	10	100	2	4	2	2
Band Crossing Time (BC in sec)	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Pos Inc or Ang Step Size (P_{inc} in Deg)	1	1	1	1	1	1	1
Azimuth Pos. Movement (Az in ± deg)	30	30	30	30	30	30	30
Elevation Pos. Movement (Az in ± deg)	10	10	10	10	10	10	10
Speed Calculations Using PNA-X							
# of Bandcrossings = 0	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
MTPA (P_{inc}/sec)	0.000860	0.004300	0.043000	0.038660	0.077320	0.153860	0.307460
RPM (Rev/min)	87.719	17.544	3.876	4.311	2.156	1.083	0.542
RPM (must be ≤ 3)	3.000	3.000	3.000	3.000	2.156	1.083	0.542
Throughput (min)	1.19	1.19	1.19	1.19	1.65	3.28	6.56
# of Bandcrossings = 1	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
MTPA (P_{inc}/sec)	0.007260	0.032300	0.314000	0.385260	0.769520	1.537260	3.073260
RPM (Rev/min)	22.957	5.160	0.531	0.4326	0.2166	0.01084	0.0542
RPM (must be 0.1 ≤ RPM ≤ 3)	3.000	3.000	0.531	0.4326	0.2166	0.1084	0.1000
Throughput (min)	1.19	1.19	6.70	8.23	16.43	32.82	35.58

Positioner-limited   Stepped mode (est)

In Cases 1-3, the PNA-X-based configuration shows more frequencies can be collected before testing becomes positioner-limited. What's more, the fast settling time of the PNA-X allows a large volume of data to be collected without requiring use of the positioner's step mode. Cases 4-7 highlight the throughput challenges of testing multiple beam positions on electronically-steerable antennas.

Table 4 compares the PNA-X results with those of an 8360/8530 configuration. The examples cover two scenarios: one with no band crossings and one with a single band crossing.[1] Throughput is improved even in the positioner-limited cases, and there are clear advantages as the required number of test frequencies increases.

Table 4. Speed comparisons of past and present instrumentation in a basic far-field configuration

PNA-X versus 8360/8530 Throughput Comparisons (Minutes)			
Assumes No Band Crossings			
Far-Field Test Scenario	**PNA-X**	**8530/8360**	**Speed Improvement (x times faster)**
Case 1	1.19	1.28	1.1
Case 2	1.19	6.41	5.4
Case 3	1.19	64.05	54
Case 4	1.19	41.63	35
Case 5	1.65	83.27	50
Case 6	3.28	164.61	50
Case 7	6.56	328.58	50
Assuming One Band Crossing			
Far-Field Test Scenario	**PNA-X**	**8530/8360**	**Speed Improvement (x times faster)**
Case 1	1.19	8.11	6.8
Case 2	1.19	36.30	31
Case 3	6.70	353.34	53
Case 4	8.23	411.63	50
Case 5	16.43	822.19	50
Case 6	32.82	1641.39	50
Case 7	35.58	3281.07	92
Assuming PNA-X # of BC=1, 8360 # of BC=0			
Far-Field Test Scenario	**PNA-X**	**8530/8360**	**Speed Improvement (x times faster)**
Case 1	1.19	1.28	1.1
Case 2	1.19	6.41	5
Case 3	6.70	64.05	10
Case 4	8.23	41.63	5
Case 5	16.43	83.27	5
Case 6	32.82	164.61	5
Case 7	35.58	328.58	9

Positioner-limited   Stepped mode (est)

Similar to the remote-mixer case, the advantages follow from the improved frequency settling times of the PNA-X sources. Consequently, the PNA-X-based configuration can collect more data while staying within the limits of typical positioner performance. For complex far-field testing, upgrading the measurement system with the PNA-X would provide significant reductions in total measurement times. This can help developers gain a more detailed understanding of antenna performance while allowing manufacturing personnel to optimize the productivity gains.

1. *Please refer to the appendix to determine the number of band crossings for your specific frequencies of interest.*

Accelerating near-field measurements

Far-field ranges have been in use for over 60 years. However, as antennas have become larger in size—or higher in performance—the far-field range distance has increased. In recent years, various factors have affected the viability of longer far-field antenna ranges: an increase in undesired reflections from man-made structures; congestion in the electromagnetic spectrum; and inflated real estate prices. These factors and others drove the need for an alternative to far-field testing.

The most compelling choice is near-field testing, which has been around for many years but wasn't widely accepted until the 1990s when adequate computing power became readily available. The near-field method measures amplitude and phase data at half-wavelength intervals across the radiating aperture of an antenna. It then uses a two-dimensional Fourier transform to derive an equivalent far-field radiation pattern from measured near-field data. Today, near-field measurements are widely used because they offer several important benefits:

- A much smaller physical footprint
- Decreased susceptibility to electromagnetic interference
- Minimal contribution to electromagnetic interference
- Generally immune to weather conditions
- Enable secure testing of proprietary antennas
- Smaller, better-understood errors than for far-field antenna ranges

There are three main types of near-field test facilities: planar, cylindrical, and spherical (Figure 4). Depending on the nature of the antenna, different scan patterns are used to collect the radiated energy from the AUT.

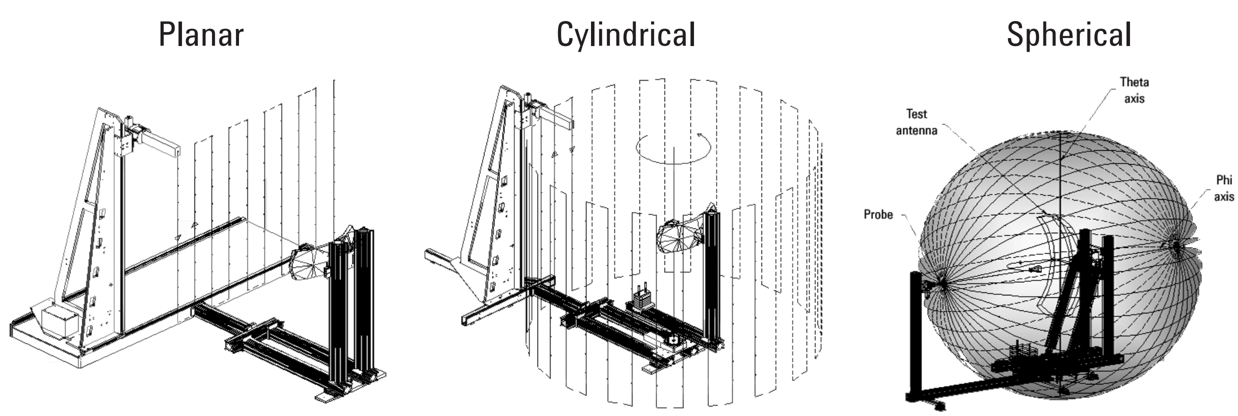


Figure 4. The three common forms of near-field test facilities are planar, cylindrical and spherical

Because near-field measurements use half-wavelength intervals, the distances are shorter between the source and receiving antennas. Very near the antenna plane, the field is reactive in nature and falls off more rapidly than the radiating near-field region. Near-field measurements are made in the radiating near-field region or Fresnel region.

The generally accepted near-field criteria are as follows:

$$\frac{\lambda}{2\pi} < R < \frac{D^2}{4\lambda}$$

Where:

R = required separation between probe and AUT
D = maximum dimension of antenna aperture
λ = wavelength at highest frequency of antenna operation

To minimize test time, the frequency can be multiplexed during each data scan. However, this can result in a misalignment of the rectangular near-field grid between the forward and reverse data scans, producing errors in the computed far-field pattern result. These errors can be eliminated by collecting data measurements in the same scan direction; however, this doubles the test time.

Alternatively, the frequencies can be scanned in the opposite order in a reverse sweep. Using the reverse scan in conjunction with correct triggering between the forward and reverse passes ensures that each frequency set is spatially aligned on the rectangular near-field grid. This technique requires an RF source that supports a "reverse frequency list" mode of operation. The Agilent MXG and PSG signal generators and PNA-X network analyzer include reverse-sweep and edge-triggering capabilities specifically designed for antenna measurements.

Determining throughput in near-field testing

The following measurement equations make it possible to calculate the potential throughput advantages in near-field testing. Instrument parameters are provided in the test scenario examples (and the appendix) to complete the calculations for Agilent's latest test offerings and your installed Agilent equipment.

The first step is to determine the measurement time per grid (MTPG):

$$MTPG = (((R \times C \times P + ABD) \times BP + S) \times F) + (N \times BC)$$

Where:

MTPG = measurement time per grid increment in seconds
R = receiver data acquisition time in seconds
C = channels of data to be measured (or number of antenna test ports)
P = number of polarization states to be measured
ABD = additional beam dwell time in seconds, if required
BP = number of electronic beam positions
S = source settling time or frequency switching time in seconds
F = number of frequencies to be measured
N = number of band crossings across measured frequency range
BC = band-crossing time in seconds

Note that when the required frequencies include a band crossing then the band-crossing value (BC) should be used in place of the receiver acquisition time (R) to allow for source settling time. The table in the appendix shows the band-crossing frequency points for the signal sources discussed in this application note.

Next, calculate the fastest possible speed for the near-field probe positioner in centimeters per second or P_v:

$$P_V = \left(\frac{D}{MTPG}\right)$$

Where:

P_v = near-field probe positioner velocity in cm/s
D = required distance between grid sample points; D is defined to be one-half the wavelength of the maximum frequency in centimeters

At this point it becomes possible to determine if the throughput is going to be measurement-limited or positioner-limited. If the calculated P_v value is less than 15 cm/s then the facility is measurement-limited and the following equation can be used to determine the potential advantages of upgrading the measurement system.

$$Throughput = \frac{(H \times V \times D)}{(3600 \times P_V)}$$

Where:

Throughput = total measurement time in hours
H = horizontal axis grid sample number
V = vertical axis grid sample number

If the calculated P_v is greater than 15 cm/s, then the facility is positioner limited and the equation should be used with the 15 cm/s value. Note that this example assumes a maximum near-field probe positioner speed of 15 cm/s. Please check your positioner's specification before performing this calculation.

The following sections show two common near-field test configurations. The example test scenarios and measurement times are intended to help you determine the potential throughput advantages that can be achieved in your facility.[1] It is hoped that one of the provided configurations will provide a close enough approximation to enable you to determine the potential throughput gains.

1. *The actual times will vary with different facility configurations.*

Configuring basic near-field measurements

Near-field configurations typically use a network analyzer as the primary piece of test equipment (Figure 5). The network analyzer operates both as the source and the receiver while an external software application controls positioner movement, switching of AUT polarization, and data collection by the network analyzer.

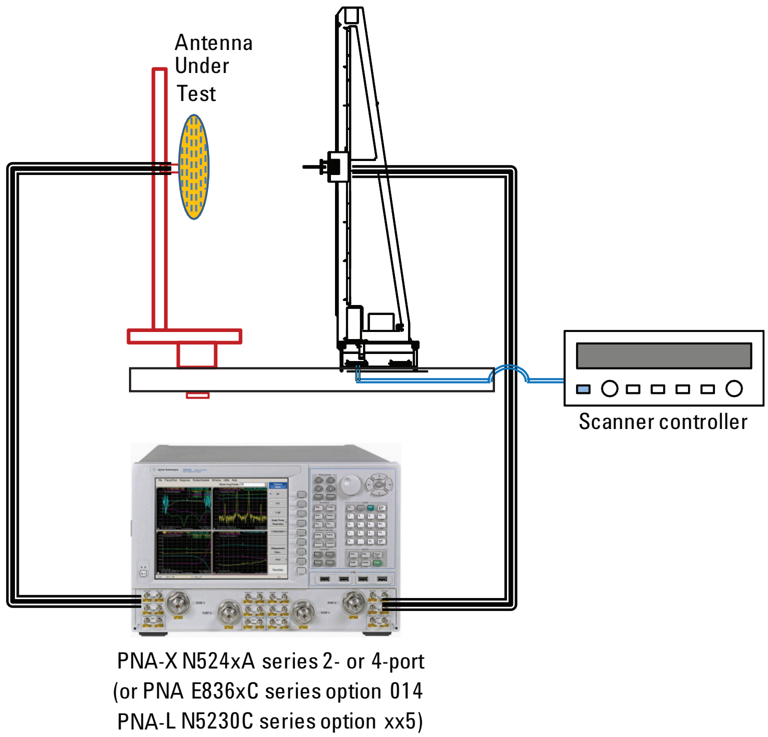


Figure 5. Basic near-field configuration using the Agilent PNA-X

The network analyzer-based approach enables significant improvements in speed and cost, even with the large quantities of near-field data that must be collected. This is especially true with the PNA-X because it includes multiple test channels, a large data buffer and an internal source with fast frequency agility.

As with far-field measurements, two factors tend to limit measurement speeds: the frequency agility of the remote sources and the maximum velocity of the probe positioner (typically 15 cm/s). Because basic antenna measurements can proceed very quickly, the probe positioner can become the limiting factor in measurement throughput.

Scenarios: Throughput with PNA-X

The following scenarios use the near-field equations and a basic near-field configuration that includes the PNA-X. Table 5 presents seven different test scenarios. Cases 1 and 2 assume a simple 1m x 1m antenna scan at a few frequencies of interest (e.g., a flat-plate weather-radar antenna from a commercial aircraft). Cases 3 and 4 assume either production testing of a somewhat larger antenna array that requires fewer beam states or selective testing of some but not all beam states. Cases 5-7 assume a verification test of a transmitter/receiver module-based antenna design that requires measurements of many beam positions at many frequencies. Note that the throughput values are measured in hours, reflecting the greater volume of data collected in these tests.

The number of band crossings has an effect on measurement times and is determined by the required test frequencies. In this example we look at two cases, one with no band crossings and one with a single band crossing.[1]

Table 5. Near-field measurement scenarios for basic configuration

Test Scenarios Using PNA-X							
	Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
Receiver Settling time (R in sec)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
# of Data Chan or Ant Test Ports (C)	3	3	3	3	3	3	3
# of Polarizations (P)	1	1	1	1	1	1	1
Additional Beam Dwell Time (ABD in sec)	0	0	0	0	0	0	0
# of Electronic Beam Positions (BP)	1	64	256	256	1024	2048	4096
Source Settling time (S in sec)	0.00013	0.00013	0.00013	0.00013	0.00013	0.00013	0.00013
# of Measured Frequencies (F)	2	3	3	10	2	2	2
Band Crossing Time (BC in sec)	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Max Test Frequency in GHz	12.4	12.4	12.4	12.4	12.4	12.4	12.4
Req dist between grid sample points (D in cm)	1.210	1.210	1.210	1.210	1.210	1.210	1.210
Horizontal Sampling Grid (H)	100	100	150	100	100	100	100
Vertical Sampling Grid (V)	100	100	150	100	100	100	100
Speed Calculations Using PNA-X							
# of Bandcrossings = 0	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
MTPG (seconds)	0.000860	0.057990	0.230790	0.769300	0.61466	1.22906	2.45786
Probe Positioner Velocity (P_v in cm/sec)	1406.602	20.860	5.241	1.572	1.968	0.984	0.492
P_v (max is 15cm/sec)	15.000	15.000	5.241	1.572	1.968	0.984	0.492
Throughput (hours)	0.224	0.224	1.44	2.14	1.71	3.41	6.83
# of Bandcrossings = 1	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
MTPG (seconds)	0.007260	0.577390	2.305390	7.682300	6.14526	12.28926	24.57726
Probe Positioner Velocity (P_v in cm/sec)	166.622	2.095	0.525	0.157	0.197	0.098	0.049
P_v (max is 15cm/sec)	15.000	2.095	0.525	0.157	0.197	0.098	0.049
Throughput (hours)	0.224	1.60	14.41	21.34	17.07	34.14	68.27

Positioner-limited

1. *Please refer to the appendix to determine the number of band crossings for your specific frequencies of interest.*

Table 5 summarizes a range of data acquisition times achieved with the PNA-X network analyzer. One point stands out: As expected, measurement time increases along with measurement complexity.

In Cases 1 and 2, the PNA-X-based configuration offers more test complexity before becoming positioner-limited. Only when large numbers of frequencies or beam states are tested does the measurement system become the limiting factor.

Cases 3 and 4 highlight the throughput challenges for production testing of electronically-steerable antennas. The fast settling time of the PNA-X allows a large volume of data to be collected in a reasonable amount of time.

Cases 5-7 show it is possible to collect very large data sets for the detailed performance analysis often needed by development engineers.

Table 6. Speed comparisons of past and present instrumentation in a basic near-field configuration

PNA-X versus 8360/8530 Throughput Comparisons (Hours)			
Assumes No Band Crossings			
Near-Field Test Scenario	**PNA-X**	**8530/8360**	**Speed Improvement (x times faster)**
Case 1	0.22	0.22	1.0
Case 2	0.22	8.13	36.3
Case 3	1.44	72.28	50
Case 4	2.14	107.08	50
Case 5	1.71	85.42	50
Case 6	3.41	170.75	50
Case 7	6.83	341.42	50
Assuming One Band Crossing			
Near-Field Test Scenario	**PNA-X**	**8530/8360**	**Speed Improvement (x times faster)**
Case 1	0.22	1.06	4.7
Case 2	1.60	80.26	50
Case 3	14.41	720.59	50
Case 4	21.34	1067.22	50
Case 5	17.07	853.56	50
Case 6	34.14	1706.89	50
Case 7	68.27	3413.56	50
Assuming PNA-X # of BC=1, 8360 # of BC=0			
Near-Field Test Scenario	**PNA-X**	**8530/8360**	**Speed Improvement (x times faster)**
Case 1	0.22	0.22	1.0
Case 2	1.60	8.13	5
Case 3	14.41	72.28	5
Case 4	21.34	107.08	5
Case 5	17.07	85.42	5
Case 6	34.14	170.75	5
Case 7	68.27	341.42	5
		Positioner-limited	

Table 6 compares the PNA-X results with those from an 8360/8530-based system. This shows that significant throughput improvements can be realized even in positioner-limited cases. There are also clear advantages as the required test complexity increases. Finally, the comparison highlights the power of the PNA-X: Collecting huge volumes of near-field data is an unrealistic notion when using older-generation instrumentation.

Configuring near-field testing with remote mixers

Even though the distance (R) required for near-field testing is substantially less than that of far-field, some cases still require long cable runs. Examples include very large antennas that may require large probing distances or low-sidelobe antennas that may require greater distances from the chamber walls to minimize reflections. In these cases, it is not uncommon to use the same instrumentation and remote-mixing techniques that were discussed in the far-field section. Once again, the use of mixers can offset cable loss and improve measurement sensitivity.

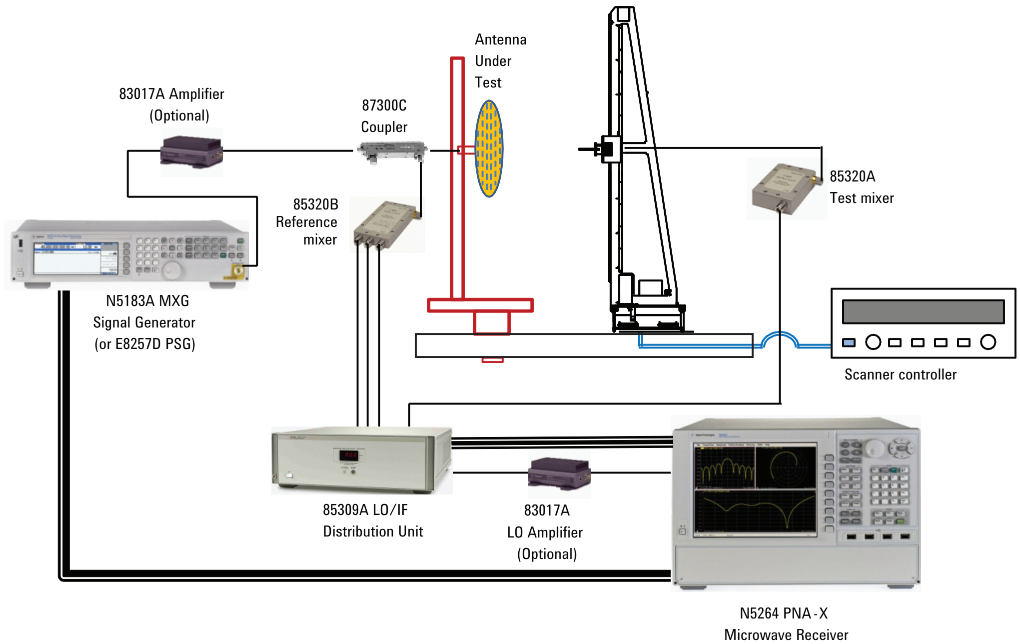


Figure 6. Near-field configuration for remote mixing technique using the Agilent MXG and N5264A microwave receiver

Scenarios: Throughput with remote mixing

This configuration uses the same equations and measurement scenarios as before, but with new instrument values for the MXG and N5264A. These values are shown in both Table 7 and the appendix. Depending on the frequencies of interest, the band crossing specifications for the MXG must be factored into the overall throughput. This example considers two cases: one has no band crossings and the other has a single band crossing.[1]

Table 7. Near-field measurement scenarios for remote mixing

Test Scenarios Using MXG Signal Generator and N5264A Microwave Receiver							
	Case 1	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
Receiver Settling time (R in sec)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
# of Data Chan or Ant Test Ports (C)	3	3	3	3	3	3	3
# of Polarizations (P)	1	1	1	1	1	1	1
Additional Beam Dwell Time (ABD in sec)	0	0	0	0	0	0	0
# of Electronic Beam Positions (BP)	1	64	256	256	1024	2048	4096
Source Settling time (S in sec)	0.00065	0.00065	0.00065	0.00065	0.00065	0.00065	0.00065
# of Measured Frequencies (F)	2	3	3	10	2	2	2
Band Crossing Time (BC in sec)	0.002	0.002	0.002	0.002	0.002	0.002	0.002
Max Test Frequency in GHz	12.4	12.4	12.4	12.4	12.4	12.4	12.4
Req dist between grid sample points (D in cm)	1.210	1.210	1.210	1.210	1.210	1.210	1.210
Horizontal Sampling Grid (H)	100	100	150	100	100	100	100
Vertical Sampling Grid (V)	100	100	150	100	100	100	100

Speed Calculations Using MXG Signal Generator and N5264A Microwave Receiver							
# of Bandcrossings = 0	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
MTPG (seconds)	0.001900	0.059550	0.232350	0.774500	0.615700	1.230100	2.458900
Probe Positioner Velocity (P_v in cm/sec)	636.672	20.314	5.206	1.562	1.965	0.983	0.492
P_v (max is 15cm/sec)	15.000	15.000	5.206	1.562	1.965	0.983	0.492
Throughput (hours)	0.224	0.224	1.45	2.15	1.71	3.42	6.83
# of Bandcrossings = 1	**Case 1**	**Case 2**	**Case 3**	**Case 4**	**Case 5**	**Case 6**	**Case 7**
MTPG (seconds)	0.0153	1.1560	4.6120	15.3685	12.2913	24.5793	49.1553
Probe Positioner Velocity (P_v in cm/sec)	79.064	1.046	0.262	0.079	0.098	0.049	0.025
P_v (max is 15cm/sec)	15.000	1.046	0.262	0.079	0.098	0.049	0.025
Throughput (hours)	0.224	3.211	28.82	42.69	34.14	68.28	136.54

Positioner-limited

Table 7 provides a summary of the data acquisition times achieved with the MXG/N5264A in a variety of different near-field measurement scenarios. With zero band crossings, these results are very similar to those achieved with the PNA-X. With one band crossing the speed advantages for cases 3-7 is cut in half.

1. *Please refer to the appendix to determine the number of band crossings for your specific frequencies of interest.*

Once again, cases 1 and 2 show that the measurement system becomes the limiting factor only when large numbers of frequencies or beam states are tested. Cases 3 and 4 highlight the difficulty of achieving high throughput in production testing when working with electronically-steerable antennas; however, the fast settling time of the MXG ensures that the large volume of near-field data can be collected in a reasonable amount of time. Cases 5-7 show it is possible to collect the very large data sets needed for detailed performance analysis.

Referring to the comparison in Table 8, the desired throughput benefits are again realized even in the positioner-limited cases, and there are clear advantages as test complexity increases. With a 50x or better speed advantage, the new technology offers a substantial benefit in production-test applications. Finally, cases 5-7 once again show that the speed advantages of current-generation instrumentation make near-field testing a realistic alternative.

Table 8. Speed comparisons of past and present instrumentation in a remote-mixing configuration

MXG/N5264A versus 8360/8530 Throughput Comparisons (Hours)			
Assumes No Band Crossings			
Near-Field Test Scenario	**N5264A/MXG**	**8530/8360**	**Speed Improvement (x times faster)**
Case 1	0.22	0.22	1.0
Case 2	0.22	8.13	36
Case 3	1.45	72.28	50
Case 4	2.15	107.08	50
Case 5	1.71	85.42	50
Case 6	3.42	170.75	50
Case 7	6.83	341.42	50
Assuming One Band Crossing			
Near-Field Test Scenario	**N5264A/MXG**	**8530/8360**	**Speed Improvement (x times faster)**
Case 1	0.22	1.06	4.7
Case 2	3.21	80.26	25
Case 3	28.82	720.59	25
Case 4	42.69	1067.22	25
Case 5	34.14	853.56	25
Case 6	68.28	1706.89	25
Case 7	136.54	3413.56	25

Positioner-limited

Improving RCS measurements

From the radar range equation, RCS (σ) has a direct effect on the ability of a radar system to detect a specified target at a defined range. Although the cross section of the target cannot be controlled, the objective in modeling RCS is to develop simulation tools capable of predicting the behavior of radar receivers in a realistic environment.

A target's RCS is a measure of its reflectivity in a given direction, and there are three main contributors:

- Specular scattering: Localized scattering dependent on the surface material/texture and geometry
- Diffraction scattering: Incident signal scattering at target edges and discontinuities
- Multiple bounce: Reflections among target elements at offset angles

Improvements in technology have enabled a deeper understanding of how to minimize an object's reflected energy. As designers become more adept at minimizing σ for the smallest possible return, the received signals are very small. The level of the returned signal is also affected by the need to use large distances with large objects (e.g., full-sized aircraft) to ensure a planar wavefront.

Under these conditions, the actual returned signal levels are so small that they can be acquired only with highly sensitive measurement instrumentation. To achieve high sensitivity, instruments such as the PNA-X use mixer-based receivers. These provide better sensitivity than sampler-based converters.

To compound the situation, the signals are so tiny that small reflections caused by elements in the range itself can contribute a significant amount of reflected energy. To solve this problem, advanced network analyzers such as the PNA-X provide a time-gating feature that can remove the unwanted signals. This is achieved by computing an inverse fast Fourier transform (IFFT) on the measured frequency data, mathematically removing the unwanted signals, and then computing an FFT to restore the frequency result.

Computing the IFFT on a finite-length sample produces a noteworthy artifact: It creates repetitions or "aliases" of the fundamental signal in time. These aliases can be minimized or eliminated through a process of testing to find an alias-free measurement span. The width of this span will depend partly on the number of data points the analyzer is able to measure and process.

As with far-field testing, there are two main types of RCS facilities: a traditional outdoor test facility and the compact range (Figure 7). RCS testing tends to be sensitive from a security perspective, so outdoor test facilities are often in remote locations. Indoor test facilities offer optimum security but may become large and expensive depending on the size of the target.

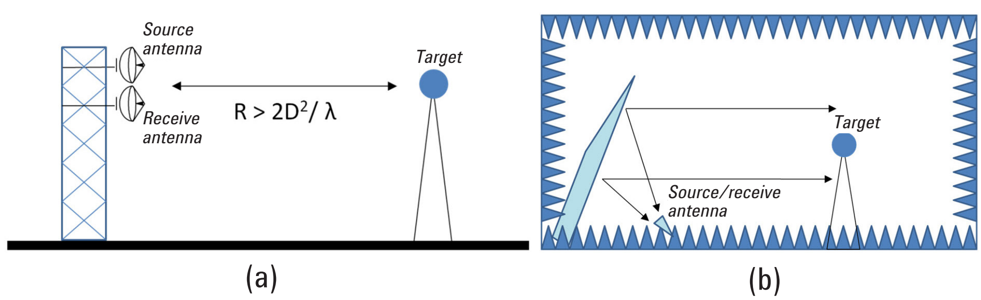


Figure 7. There are two common forms of RCS test facilities: outdoor far-field (a) and compact anechoic chambers (b)

Determining throughput in RCS testing

You can use the following measurement equations to calculate the potential throughput advantages in RCS testing. The instrument parameters are provided in the test scenario examples (and the appendix) to help you complete the calculations for our latest offerings or your installed Agilent equipment.

The first step is to determine the receiver tuning time in seconds:

$$T = \frac{(F_{stop} - F_{start})}{900}$$

Where:

T = Receiver tuning time in seconds
F_{start} = Start or minimum frequency of interest in gigahertz
F_{stop} = Stop or maximum frequency of interest in gigahertz

Determine the required number of down-range scans:

$$DR_{scans} = \frac{60}{CRR} + 1$$

Where:

DR_{scans} = Number of required down-range scans
CRR = Required cross-range resolution in degrees

Calculate the total number of measurement points:

$$T_m = DR_{scans} \ x \ VNA_{pts}$$

Where:

T_m = Total number of required measurement points
VNA_{pts} = Number of points collected by the network analyzer

Find the alias-free range or A:

$$A = \frac{(0.3 \ x \ VNA_{pts})}{(F_{stop} - F_{start})}$$

Where:

A = Alias-free range in meters

Determine the down-range response resolution:

$$DRR_{res} = \frac{1}{(F_{stop} - F_{start})}$$

Where:

DRR_{res} = Down-range response resolution in seconds
F_{start} = Start or minimum frequency of interest in hertz
F_{stop} = Stop or maximum frequency of interest in hertz

Compute the measurement time per cross-range resolution:

$$MTPCR = ((R \times VNA_{pts}) \times PST + (BC \times N) + RT + T) \times 2$$

Where:

MTPCR = Measurement time per cross-range resolution in seconds
R = Receiver data acquisition time in seconds
VNA_{pts} = Number of points collected by the network analyzer
PST = Pre-sweep time in seconds
BC = Band-crossing time in seconds
N = Number of band crossings across measured frequency range
RT = Retrace time in seconds
T = Receiver tuning time in seconds

Note that RCS measurements tend to be very wide frequency sweeps, ensuring the presence of band crossings.[1] The band-crossing value (BC) should be used in place of receiver acquisition time (R) to allow for source-settling time. In these cases both PST and RT can be approximated as zero because they are much smaller than BC.

Determine the positioner speed:

$$RPM = \left(\frac{CRR}{MTPCR}\right)\left(\frac{1\ rev}{360°}\right)\left(\frac{60\ s}{1\ min}\right)$$

Finally, calculate the total measurement time in minutes:

$$Total\ Measurement\ Time = \frac{(CRR \times DR_{scans})}{(360 \times RPM)}$$

In the following sections a common RCS configuration is used as an example. The examples provide typical test scenarios and measurement times to help you determine the potential throughput advantages for your measurement facility. The actual measurement times will vary with different facility configurations.

1. *The table in the appendix shows the band-crossing frequency points for the signal sources discussed in this application note.*

Configuring the RCS measurement

Figure 8 shows a simplified RCS measurement configuration using a PNA-X analyzer. In this arrangement, two of the PNA-X receivers may be used to measure the vertical and horizontal returned components simultaneously. Also, the analyzer's internal transfer switch may be used to direct the internal source to either the vertical or horizontal input of the transmit-horn antenna. This eliminates the need for an external PIN switch. Additionally, up to 32,001 data points are available per measurement trace, providing extremely long alias-free down-range resolution for RCS measurements.[1] Using multiple PNA-Xs to cover different frequency ranges has proven to be very cost effective in RCS applications.

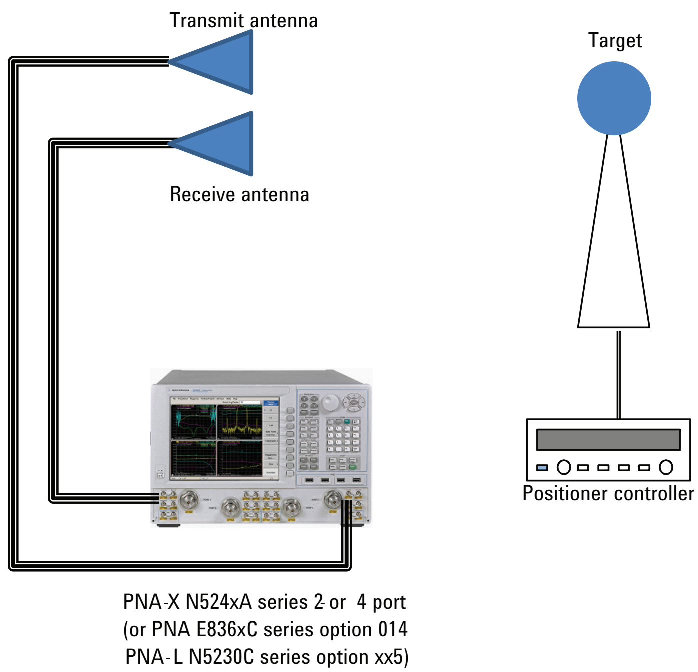


Figure 8. RCS configuration using the Agilent PNA-X

As with far-field antenna measurements, the RCS measurement system often becomes the limiting factor as the complexity and volume of required data increases. As the measurement complexity in the RCS scenario increases, the positioner's minimum velocity (typically 0.1 RPM) begins to limit the total data acquisition time. When data acquisition requirements become so intensive that the positioner must be slowed below this speed, the positioner will have to be operated in a stepped mode. In such cases, total test time is determined by the stepped speed rather than the speed of the measurement instrumentation.

For RCS facilities using an Agilent 8530, the following sections should be helpful in calculating your potential throughput improvements. If your facility is experiencing throughput limitations associated with the current measurement system, the potential speed advantages may help justify a system upgrade.

1. *Data can be saved to the internal hard drive, which is removable to meet the data security requirements often associated with RCS measurements.*

Scenarios: RCS throughput

The following test scenarios apply the RCS equations and use the PNA-X-based measurement configuration. Table 9 presents four different test scenarios. Cases 1 and 2 show a typical RCS scenario performed with the Agilent 8530, which has limited down-range resolution (i.e., number of VNA data points). Case 3 assumes the use of an expanded number of VNA data points. Case 4 assumes an extremely data-intensive scenario in which very fine resolution is desired in the down-range data. It should be noted that there is not a corresponding resolution in the cross-range resolution in this case.

Table 9. RCS measurement scenarios

Test Scenarios Using PNA-X				
	Case 1	**Case 2**	**Case 3**	**Case 4**
Start Frequency (F_{start} in GHz)	1	1	1	1
Stop Frequency (F_{stop} in GHz)	26.5	26.5	26.5	26.5
Cross Range Resolutin (CRR in deg)	0.1	0.1	0.25	0.1
# of VNA Points (VNApts)	801	801	1601	16001
Data Acquisition Time (R in sec)	0.0001	0.0001	0.0001	0.0001
Pre-sweep time (PST in sec)	0.00003	0.00003	0.00003	0.00003
Band Crossing Time (BC in sec)	0.001	0.001	0.001	0.001
# of Band Crossings (N)	20	20	20	20
Retrace Time (RT in sec)	0.015	0.015	0.015	0.015
Speed Calculations Using PNA-X				
	Case 1	**Case 2**	**Case 3**	**Case 4**
Tuning Time (T in sec)	0.0283	0.0283	0.0283	0.0283
# of Down range scans (DR_{scans})	601	601	241	601
Total # of Meas Points (T_m)	1925604	1925604	1543364	38466404
Alias Free Range (A in meters)	9.42	9.42	18.84	188.25
Alias Free Range (A in feet)	37.10	37.10	74.15	741.13
Down Range Resp Res (DRR_{res} in cm)	1.176	1.176	1.176	1.176
Down Range Resp Res (DRR_{res} in sec)	3.922E-11	3.922E-11	3.922E-11	3.922E-11
Meas Time per Cross Range Res (MTPCR in sec)	1.729	1.729	3.329	32.129
RPM (Rev/min)	0.010	0.010	0.013	0.001
RPM (must be $0.1 \leq$ RPM ≤ 3)	0.010	0.010	0.013	0.001
Total Measurement Time (Min)	17.316	17.316	13.370	321.823
	Positioner-limited		Stepped mode (est)	

Table 10 compares the PNA-X results with an 8530/8360-based solution. Because these tests were performed over a defined frequency range, the number of band crossings was factored in to the PNA-X and 8530/8360 calculations.[1]

Only cases 1 and 2 apply because the 8530 has a limit of 801 measurement points. Both cases highlight the benefits of the PNA-X, which provides a speed improvement of 45x or better when collecting data over a wide frequency range.

1. *Please refer to the appendix to determine the number of band crossings for your specific frequencies of interest.*

Cases 3 and 4 show the throughput possibilities in scenarios that are not currently possible with 8530-based solutions. By overcoming past limitations, these new capabilities expand the possibilities of RCS testing.

Table 10. Speed comparisons of past and present instrumentation in RCS measurements

PNA-X versus 8360/8530 Throughput Comparisons (Minutes) — Assumes No Band Crossings			
RCS Test Scenario	**PNA-X**	**8530/8360**	**Speed Improvement (x times faster)**
Case 1	17.32	323.69	18.7
Case 2	17.32	807.21	46.6
Case 3	13.37	N/A	N/A
Case 4	321.82	N/A	N/A

Stepped mode (est)

Conclusion

Whether you choose to use the PNA-X or the MXG/N5264A combination, either of these next-generation solutions will provide significant upgrades to existing antenna and RCS test facilities. The key advantages are faster test speeds, new measurement capabilities, and enhanced features that can make antenna and RCS ranges more productive.

As one specific example, the likely reductions in total measurement time will pay large economic dividends. The expected benefits include improved product quality, faster time-to-market, shorter development time, reduced cost-of-test and enhanced product competitiveness.

Appendix: Equation parameters for Agilent instruments

	PNA-X		MXG	PSG	8360	8530
FF Receiver Settling time (R in sec)	0.0001		N/A	N/A	N/A	0.005
Source Settling time (S in sec)	0.00013		0.00065	0.008	0.015	N/A
Band-Crossing Time (BC in sec)	0.001		0.002	0.012	0.05	N/A
Band-Crossing Ranges	500 MHz to 628 MHz	10.664 to 12 GHz	100 kHz to < 250MHz	250 kHz to 250MHz	10 Mz to < 2 GHz	
	628 MHz to 1 GHz	12 to12.8 GHz	250 to <375 MHz	> 250 to 500 MHz	2 to < 7 GHz	
	1 to 1.5 GHz	12.8 to 13.51 GHz	375 to < 750MHz	> 500 MHz to 1 GHz	7 to < 13.5 GHz	
	1.5 to 2 GHz	13.51 to 15.4 GHz	750 MHz to < 1.5 GHz	> 1 to 2 GHz	13.5 to < 20 GHz	
	2 to 3 GHz	15.4 to 16 GHz	1.5 to < 3.0 GHz	> 2 to 3.2 GHz	20 to < 26.5 GHz	
	3 to 3.2 GHz	16 to 18 GHz	3.0 to < 6.0 GHz	> 3.2 to 10 GHz	26.5 to < 38 GHz	
	3.2 to 4 GHz	18 to 20 GHz	6.0 to < 12.0 GHz	> 10 to 20 GHz	38 GHz to 50 GHz	
	4 to 5.332 GHz	20 to 21.328 GHz	12.0 to < 24.0 GHz	> 20 to 40 GHz		
	5.332 to 6.752 GHz	21.328 to 22.5 GHz	24.0 to < 40.0 GHz	> 40 GHz		
	6.752 to 8 GHz	22.5 to 24 GHz				
	8 to 8.5 GHz	24 to 27 GHz				
	8.5 to 10.664 GHz					

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