



IEEE Recommended Practice for Radar Cross-Section Test Procedures

IEEE Antennas and Propagation Society

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IEEE Recommended Practice for Radar Cross-Section Test Procedures

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**Antenna Standards Committee
of the
IEEE Antennas and Propagation Society**

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Abstract: This recommended practice describes the process of the measurement of the radar cross section of objects using a test range. The term “radar cross section” is defined, and the characteristics of different types of test ranges are given. The responsibilities of the test range operators are shown to involve test and calibration of the measurement range systems as well as accurately carrying out the measurements. Techniques are described for each stage of this process.

Keywords: radar cross section (RCS), radar test range

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Introduction

This introduction is not part of IEEE Std 1502-2007, IEEE Recommended Practice for Radar Cross-Section Test Procedures.

The measurement of radar cross section began to be a very important science in the 1960s and 1970s. Many test ranges were designed and built during that time. In the 1980s and 1990s, radar cross-section test ranges and the procedures to test, calibrate, and use them remained individualized. The operators of each test range used practices developed by the scientists and engineers that designed the test ranges. This recommended practice for radar cross-section test procedures is an attempt to provide a standard of practice across this community. It is developed for the test range operator, manager, and user of test range data.

The IEEE Standards Board first approved this recommended practice as a new project on 20 March, 1997.

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Contents

1. Overview	1
1.1 Scope	1
1.2 Purpose	1
2. The radar cross-section measurement process	1
2.1 Introduction	1
2.2 Radar cross-section measurement background	2
2.3 Standardized test procedures	4
3. Measurement techniques	5
3.1 General	5
3.2 Outdoor ranges	5
3.3 Indoor ranges	10
3.4 Test zone plane wave characterization	14
3.5 Clutter and noise reduction techniques	16
3.6 Target support concepts	21
3.7 Drift	25
3.8 I/Q balance	25
3.9 Linearity	27
3.10 Waveforms	28
3.11 Spatial and frequency averaging	31
4. RCS imaging concepts	32
4.1 General	32
4.2 Image quality	33
4.3 Noise	35
4.4 Selection of measurement parameters	36
4.5 Range ambiguities	36
4.6 Cross-range ambiguities	36
4.7 Windowing and discretization	37
4.8 Experimental design for a two-dimensional imaging measurement task	37
5. Organizing radar cross-section range documentation	38
5.1 Introduction	38
5.2 Background	39
5.3 An Introduction to ANSI/NCSL Z-540	39
5.4 ANSI/NCSL Z-540-1994-1: A brief overview of Part I by clause	40
5.5 Supplementary documentation sections	42
5.6 Organizing the RCS range book to comply with ANSI/NCSL Z-540	42
5.7 Self-registration and third-party certification review of the range book	43
5.8 Summary	44
6. RCA uncertainty analysis	44
6.1 Uncertainty and error	44
6.2 Reasonable and uniform analysis	44
6.3 Reporting measurement uncertainty	45
6.4 Uncertainty analysis	48
6.5 Overall uncertainty	54

7. Test planning	54
7.1 General	54
7.2 Overview	54
7.3 Reasons for a test plan	55
7.4 The test plan process.....	55
7.5 Conclusions	57
8. Summary	57
Annex A (informative) Bibliography	58

IEEE Recommended Practice for Radar Cross-Section Test Procedures

1. Overview

1.1 Scope

This recommended practice establishes processes for the measurement of the electromagnetic scattering from objects. It is written for the personnel responsible for the operation of test ranges, and not for the design of such ranges. It recommends procedures for testing and documenting the quality of the measurement system, for calibrating the measurement system, for carrying out the radar scattering measurements, and for delivering the measurement data in a useful format to the end user.

The document defines radar cross section (RCS), describes different types of test ranges, and reviews methods of characterizing and operating radar scattering measurement ranges. Issues related to test object support systems, types of test ranges, instrumentation, signal polarization, calibration, data analysis, and range uncertainty are also discussed.

1.2 Purpose

Most radar scattering measurement ranges are built for a specific localized purpose. Methods of characterizing the ranges and performing the measurements are developed for the specific needs of each particular test range. This recommended practice is intended to establish guidelines so that operators and users of such ranges can provide results that are useful across the larger community of users.

2. The radar cross-section measurement process

2.1 Introduction

Radar scattering is typically represented as the RCS of the test object. This term evolved from the basic metric for radar scattering as the ratio of the power scattered from an object in units

of power per solid angle (steradian) normalized to the plane wave illumination in units of power per unit area. The RCS is thus given in units of area (or effective cross-sectional area of the target, thus, the name). Note that the RCS of the test object is a property of the test object alone, and not a function of the radar system or the distance between the radar and the test object, as long as the object is in the far field. Often, this cross-sectional area is expressed in units of decibels with respect to a square meter and is abbreviated as dBsm (sometimes DBSM). Using this definition, the RCS of a radar target is a scalar ratio of powers. If the effects of polarization and of phase are included, the scattering can be expressed as a complex scattering matrix.

The measurement of the RCS of a test object requires the test object to be illuminated by an electromagnetic plane wave and the resultant scattered signal to be observed in the far field. After calibration, this process yields the RCS of the test object in units of area, or the full scattering matrix as a set of complex scattering coefficients.

The responsibilities of the range operators from the perspective of this document are listed as follows:

- Establish and document procedures for performing test measurements and follow those procedures
- Carry out radar scattering measurements
- Process the raw measurement data for quality assurance.
- Calibrate the system to obtain data in standard units of RCS
- Establish the overall accuracy of the measurement range (the error bars on the RCS measurements)
- Determine the accuracy of the measurement instrumentation
- Determine the quality of the illuminating plane wave
- Determine the accuracy of the calibration reference standards
- Deliver the data and documentation to the end user

2.2 Radar cross-section measurement background

2.2.1 Measurement history

Radar reflectivity measurements go back to the earliest days of radar. What are now known as RCS measurements began to be more openly discussed in the literature in the late 1950s and early 1960s (Bachman et al. [B2] Cummings [B8], Kennedy [B21], and Radar Reflectivity Measurements Symposium [B48]¹), although much of that work was under the auspices of the military and thus not readily available. This situation began to change with the 1965 publication of a special issue of the *Proceedings of the IEEE* [B42] devoted to the topics associated with radar reflectivity.

Several of the 1965 papers in this issue were specifically oriented toward the requirements of RCS measurements, including an overview of the state of the art in RCS measurements (Blacksmith et al. [B4] and Blacksmith and Mack [B5], as well as papers on such specialized topics as range requirements (Kouyoumjian and Peters [B31]), target support issues (Freeny [B10]), and measurement techniques (Bachman [B3] and Huynen [B14]). Also included were discussions of typical facilities, both static (Marlow et al. [B34]), and dynamic (Olin and Queen [B39]). With the publication of this issue, a growing open-source literature base on RCS measurements became available to those working in the field.

¹ The numbers in brackets correspond to those in the bibliography in Annex A.

The ensuing period marked the beginnings of two measurement trends: the rapid development of new approaches to making measurements, and the desire to make measurements of targets with low radar cross section. There was a major push to significantly reduce the radar scattering from military vehicles with such programs as the U-2 and SR-71. Along with the objective to produce vehicles with reduced RCS came the requirement to accurately measure these smaller signal levels. In addition, many applications required the full complex polarimetric scattering matrix. Thus, there were significant efforts made to improve the technology of RCS measurements, including increased dynamic range and complex phasor measurements.

During this same time period, significant research was being conducted on the theory of electromagnetic scattering. Universities such as Syracuse University, the University of Michigan, The Ohio State University, and Georgia Institute of Technology were engaged in understanding the foundations of scattering, with the objective of making better measurements as well as being able to analytically and numerically predict the scattering from increasingly complex objects. Many tools in current use, such as the method of moments (MOM), the geometrical theory of diffraction (GTD), and physical optics (PO) were developed during this period. The development of these tools was significant for the measurement process, because modern calibration methods require the ability to predict the scattering from calibration targets to a high degree of accuracy. Significant progress in RCS reduction requires progress in the areas of theory, prediction, and measurement.

Although the technical community has made great strides in its ability to make RCS measurements, there are still some areas in need of improvement. Among these areas is the need for community-wide recognized reference standards that can be used for calibration of RCS measurements. Additionally, there is a need for a readily available standardized process for making RCS measurements. Although there is currently no internationally accepted set of RCS procedures for characterizing the performance of an RCS measurement range, Clause 7 provides guidance to organize the documentation for the operation and characterization of a range in accordance with ANSI-Z-540-1994-1 [B1], which is the U.S. version of ISO/IEC 17025 [B17].

This document discusses these issues and presents some approaches to addressing these deficiencies. The development of standards and standardized practices and procedures will be discussed. Measurement targets are often aircraft, although the development of this standard can be applied to any type of target. Before measurement standards, procedures, and practices can be discussed, it is important to understand the origin of the requirements, which will be addressed in 2.2.2.

2.2.2 Radar cross-section measurement requirements

The facility used to verify RCS values should have the capability to measure RCS values that are 10–20 dB below the lowest scattering level to be encountered while illuminating an area the full size of the object.

Although these capabilities may be achievable with the current state of the art, care should be taken to accurately and repeatedly achieve results. The obvious questions that can be raised include “How is the RCS test range accuracy defined?” “How close to the exact value does the measured value have to be?” “How is the exact value defined?” “How close does a value have to be to be repeatable?” These questions and others should be addressed to develop standards and standardized practices.

2.2.3 The need for a standardized radar cross-section measurement process

Making RCS measurements will likely always be as much an art as it is a science. Each measurement facility is unique in terms of layout, equipment, capabilities, etc. Training at each facility varies, based upon the perceived needs of the facility. The targets being measured can vary from test to test. Without a recognized standard for RCS measurements, each range should independently determine how to ensure that the measurements are accurate, repeatable, and verifiable. The use of recognized RCS measurement standard procedures helps insure that the test measurements are accurate within stated uncertainties.

2.2.4 Developing a standardized radar cross-section measurement process

The remainder of this clause is devoted to laying out procedures and practices that make up a standardized RCS measurement system. The first requirement is to define the RCS measurement process. Key issues are the proper characterization of the range and its environment, the development of a range uncertainty budget, and an examination of the issues associated with calibrating the RCS measurements. Finally, an approach to implementing these standards is provided.

2.3 Standardized test procedures

2.3.1 Purpose

The development of standardized test procedures provides a framework for many measurement process components. Important components of the measurement process that are to be standardized include:

- Data collection
- Range calibration
- Post-processing
- Range characterization
- Range error budget

By developing standardized procedures for these and other components of the measurement process, several advantages can be realized. One important advantage is that the technical approach will be consistent from range to range, which means that users of the data know what to expect during the testing process. Preparation for additional measurements or follow-on tests is easier, and it becomes significantly easier to make comparisons between ranges. This last point should not be minimized. This type of comparison is often desired, but usually it is not carried out because the procedural differences between ranges (even of the same type) are sometimes considered too great to overcome.

Another advantage that will result from standardization is a minimization of error, especially human error. By developing and following standardized procedures, there is less chance of incorrect procedures being used. It also helps in the verification process if standard procedures are followed at different ranges. By using the same basic procedures in multiple ranges, the experience base for that type of procedure is increased, which leads to greater confidence that the procedure is robust and will produce the correct results under a variety of circumstances. Finally, by using standardized procedures, there is less chance that the application of a particular process will be called into question if there is a problem (or legal challenge) with the results at a later date.

2.3.2 Approach

Since there are several types of ranges, and many examples of each type, it is important to organize the test procedures to cover the unique features of each possible range type while maintaining as much commonality in procedures between the different range types as possible.

One way of accomplishing this goal is to identify the essential features of each range type and to decide which features are common to other range types and to what degree. Arranging the different range types in a hierarchical structure has several advantages. For instance, any procedures that apply to ranges at the “top” of the structure (the most common range features) should also apply to those “lower” in the structure (ranges with more specific features). This approach implies that test plans developed for higher levels can

be specialized for lower levels, which keeps the procedures used common to many different range types. This approach also minimizes the work required to develop test plans and facilitates comparisons between different ranges.

3. Measurement techniques

3.1 General

The purpose of the test range is to provide an environment that simulates free-space, far-field conditions. Measurements of objects placed in these environments obtained by precision instrumentation radars can yield accurate measures of their RCS.

3.2 Outdoor ranges

3.2.1 Introduction

To approximate the desired free-space, far-field conditions in an outdoor environment, it is common to physically separate the source radar from the targets with “sufficient separation” in a measurement environment that is free of unnecessary monostatic and bistatic radar clutter. The approximation to a plane wave is obtained by the range length and the approximation to free space by the absence of spurious signals originating from clutter multipath that eventually propagates to the desired test zone as an undesired interference term. The amplitude field taper in the test zone is determined by the radiation pattern of the instrumentation radar; the phase taper is determined by the distance between the radar and the test zone; the amplitude ripple is determined by interference with the direct signal caused by spurious reflections. In the special case of the ground plane range, which is described in 3.2.2, the amplitude taper in the vertical direction is also determined by the ground-bounce geometry. Given surrounding areas free of obstacles, the principal source of contamination to the incident field is the reflection from the ground surface. The control of signal reflections from the ground surface constitutes the principal design objective of the range.

Several techniques are used for the control or mitigation of ground reflections. These techniques include the use of reflecting or absorbing fences to shield the signal path directed to the ground bounce region, the elevating of the receiving and transmitting antennas sufficiently so that the ground bounce is off the main lobe of the antenna, the use of shaped berms running the length of the range to deflect the ground reflection away from the test zone, and the exploitation of the ground bounce to combine with the direct signal in a constructive manner. Each technique is reviewed in 3.2.3 through 3.2.5.

In addition to controlling the detrimental effects of ground reflections, significant range geometry parameters that drive the performance of outdoor ground plane ranges are as follows: phase and amplitude taper in the test zone and range clutter, which are each summarized in the following paragraphs.

The outdoor range should be long enough so that the spherical wave radiated by the antenna becomes an approximation to a plane wave in the test zone. A spherical wavefront incident on a normal plane located a distance R from the source results in a phase taper that varies with the lateral distance from the incidence axis. The deviation of the incident phase $\Delta\theta$ for a lateral offset x is $\Delta\theta = (2\pi/\lambda) \cdot (x^2 + R^2)^{1/2}$. The measurement distance for a desired maximum phase taper over an extent D is given by:

$$R = kD^2 / \lambda \quad (1)$$

The relation in Equation (1), with $k = 2$, allows a maximum of 22.5° of phase taper in the incident field. When applied to RCS measurements, the relation allows a maximum two-way phase taper of 45° . Although the criterion has been historically used as a general guideline for antenna and RCS measurements, some applications can require or tolerate lesser or greater tapers. When the guideline is applied for measurements of large objects at high frequencies, the required range length can exceed the available real estate, thus requiring a compromise. The consequence of larger phase tapers is a reduction in the magnitude of specular peaks and an increase in the side-lobe response for near-specular angles. Because even moderate-phase tapers strongly influence sidelobe levels, measurements of radiation patterns of low-sidelobe antennas can require $k > 2$. For RCS measurements, however, the levels of sidelobes surrounding specular peaks are of lesser interest and greater phase tapers can be tolerated. In summary, although Equation (1) with $k = 2$ provides a general guideline, the allowable phase taper for a measurement should be determined for specific targets and test objectives.

The amplitude taper over the test zone is primarily a function of the measurement radar antenna pattern. The antenna beamwidth is selected such that the amplitude taper over the target zone is typically less than 0.5 dB at the highest operating frequency. As the frequency is reduced, the beamwidth of the antenna increases and the amplitude taper is improved at the expense of illuminating additional clutter sources. In addition to the influence of the antenna pattern, the amplitude taper in the vertical extent of the test zone is also influenced by reflections from the ground surface that interfere with the direct signal.

Several outdoor ground plane ranges are currently in use by the RCS measurement community. It is typical for these ranges to be located in remote and sparsely populated areas because of economic factors such as the cost of real estate, security, and electromagnetic interference (EMI) considerations.

Subclauses 3.2.2 through 3.2.5 outline the significant parameters that govern the performance of various types of ranges.

3.2.2 Ground plane ranges

In the presence of a ground plane, the target is illuminated by two distinct fields: one arriving directly from the transmitting antenna and the other via a reflection from the ground, constituting a multipath condition. Energy scattered by the target reaches the receiver by the same two paths. Rather than mitigating the effects of ground reflections, the design of the ground plane range uses the ground-reflected signal by arranging the target and antenna heights so that the signal reflected from the ground is in phase with the direct path signal. By this technique, the ground-reflected signal contributes to the target illumination in a controlled manner. In general, the ground plane range produces an acceptable illumination field over the target that is large in the horizontal plane but limited in the vertical plane. The ground plane geometry is an attractive choice for aircraft measurements where the target has large horizontal and small vertical dimensions.

The vertical amplitude taper in the test zone is primarily a function of the ground plane. The received signal power P_r using the free-space radar range equation is expressed as follows:

$$P_r = \frac{P_t G^2 \lambda^2 \sigma}{(4\pi)^3 R^4} \quad (2)$$

where

P_t is the transmitted power

R is the distance from radar to target

G is the radar antenna gain

λ is the wavelength

σ is the RCS of the radar target

If a smooth ground surface is illuminated by an antenna located at point A , the incident field reflected from a specular point P joins the direct signal at the target located at point T as shown in Figure 1.

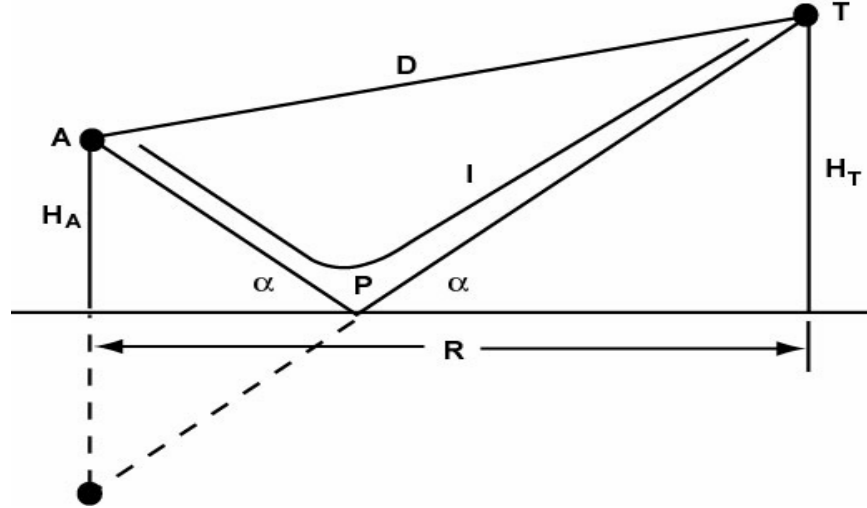


Figure 1—Geometry of signal paths for ground plane range

The received signal consists of the combination of four distinct components traveling along paths ATA , $ATPA$, $APTA$, and $APTPA$, respectively. The first component is the direct signal, the second and third components undergo a single ground reflection, and the fourth component undergoes a double reflection. If the antenna gains in the direction of points T and P are identical, the four components have equal magnitudes. Because the components add as field quantities, the effective RCS is given by:

$$\sigma^{1/2} = \sigma_0^{1/2} \left[e^{j2kD} + 2\rho e^{jk(D+I)} + \rho^2 e^{j2kI} \right] \quad (3)$$

where D and I are the lengths of the direct and indirect paths, respectively, ρ is the ground reflection coefficient, and k is the wavenumber $2\pi/\lambda$. The value of σ_0 , the intrinsic RCS of the target, is assumed to be the same for the direct path and the indirect paths.

Equation (3) can be rewritten as:

$$\sigma^{1/2} = \sigma_0^{1/2} e^{j2kD} \left[1 + 2\rho e^{jk(I-D)} + \rho^2 e^{j2k(I-D)} \right] \quad (4)$$

For a reflection coefficient of -1 , Equation (4) reduces to:

$$\sigma^{1/2} = \sigma_0^{1/2} e^{j2kD} \left[1 - 2e^{jk(I-D)} + e^{j2k(I-D)} \right] \quad (5)$$

The bracketed term, representing the magnitude of the enhancement factor or gain over the free-space field, is maximum and equals four for $(I-D) = m(\lambda/2)$, where m is an odd integer. From geometric considerations following the treatment by Knott [B29], Equation (5) for $m = 1$ leads to the relation:

$$H_A H_T = R\lambda/4 \quad (6)$$

where H_A and H_T are the antenna and target heights, respectively, and R is the ground range between radar and target.

The criterion of Equation (6) places the target at the center of the first of multiple vertically displaced multipath lobes with the field falling to zero at ground level and at a height $2H_T$. Because the multipath lobe extends over twice the target height, the taper across a given target decreases with target height. The best amplitude taper in the vertical plane is therefore achieved when the target is mounted as high as possible and the instrumentation antenna as low as practical while satisfying Equation (6). Mounting large targets high in the air can be a difficult problem and practical trade-offs generally have to be made. It is common on outdoor ground plane ranges to use truncated antennas for the higher frequencies. The top and bottom sections of a parabolic reflector are cut off to allow the antenna to be lowered closer to the ground in order to minimize the H_A term.

The ground plane geometry arranged to maximize the received signal at the operating frequency as given in Equation (6) theoretically produces a 12 dB increase (two-way path) in received signal over a free-space condition. This feature is an attractive advantage because it increases the achievable sensitivity for a given transmitted power. The advantage is somewhat offset by the center of the vertical lobe being frequency-dependent; achieving the limiting performance requires the antenna height to be adjusted with frequency, which is a condition of significance for wide-band measurements.

Modern RCS ranges generally require an inverse synthetic aperture (ISAR) imaging capability. Imaging requires a wide frequency band, but this produces a wide variation in vertical taper. In this case, some trade-off in vertical field taper can be made. A technique used to minimize this effect is to use two or more antennas located at different heights and to electronically switch the antennas as the frequency is varied.

Because the ground plane range inherently makes use of strong illumination of the ground surface, irregularities of the surface in the vicinity of the specular point can scatter signals into the test zone and thus adversely influence the illuminating field. In order to minimize effects of this bistatically scattered clutter, the surface is made as smooth as possible in the vicinity of the specular point. The elliptical region of the ground surface for which the phase of scattered signals is within 180° is termed a Fresnel zone; successive Fresnel zones form concentric elliptical footprints on the surface. The requirement for smoothness is most stringent for the central Fresnel zones and less stringent for the outlying ones. A controlled surface spanning 15 to 20 Fresnel zones may be required with more stringent tolerances for central zones and less stringent tolerances for the outer ones.

An additional consequence of the ground plane range is the requirement to use separate test ranges for the different radar bands. This requirement is a consequence of practical antennas, target, and antenna mounting heights. For example, if a given geometry has a range length of 914 m and a target height of 18 m, the antenna height for 12 GHz would be approximately 30 cm, but for 150 MHz, the antenna height would be 25 m.

3.2.3 Inverted-V range

The inverted-V outdoor range derives its name from a berm that runs along the center axis of the range and is shaped as an inverted-V. The antenna is centered over the apex of the berm at one end, and the target is centered over the berm at the other end.

The purpose of the inverted-V shaped berm is to scatter most of the ground reflected energy away from the target zone and thus substantially reduce the level of reflected energy. The sensitivity performance is predicted by the free space radar range equation which does not benefit from the ground plane gain. The other sensitivity and performance parameters are essentially the same as the ground plane range.

The field taper at the target zone is determined essentially by the antenna pattern, which allows the system to be operated over a wide frequency range while maintaining a uniform field over the target.

The inverted-V berm adds significant cost to the range. To obtain satisfactory performance, the berm apex should be straight and the sloping sides smooth.

For best performance, the antenna needs to be centered over the V and the operational bandwidth of the system should be obtained using only one antenna.

3.2.4 Elevated range

The elevated range concept requires that the antenna and target be mounted high enough to reduce the ground illumination to an acceptable level. The elevated range concept is used extensively for antenna measurement ranges but is rarely used for RCS measurements. Directive antennas can be mounted high above the ground on steel tower structures, and the main lobe can be measured with good accuracy. RCS measurements usually require the target to be mounted on a low cross-section support structure. It is difficult to design a tall support structure with low RCS.

3.2.5 Dynamic test range

Dynamic RCS measurements are made while the target is in flight. Although more complex and consequently more costly, this method is often the only practical measurement technique for some classes of targets. For example, it is difficult to mount a large operational aircraft on low RCS support without making major structural modifications to the aircraft. Sometimes large dielectric foam column supports are used, but changing the pitch and roll angles is then a difficult undertaking. Dynamic measurements have several significant benefits over static measurements because they include all the contributors to the radar cross section such as engine plumes, rotating engine, or propulsion components. Far-field conditions are typically more achievable in dynamic systems, and scattering from support structures, typically the limiting factor in static measurements, is not present. The operational costs of performing dynamic measurements usually justify making the system multiband so that all measurements can be made with a minimum number of flights.

Dynamic measurement systems should rely on a system to accurately track the target and provide the necessary angle and range information. The angle information (with appropriate parallax correction) is used to synchronize the instrumentation antenna pedestal(s) to the tracking radar to maintain the antenna beam patterns over the target, and the range information is used to position the instrumentation system range gate on the target echo.

Although measuring RCS as a function of aspect angle is readily accomplished on a static range, this task is considerably more difficult in dynamic measurements. Dynamic measurement scenarios require careful planning of flight programs to ensure that all the desired aspects angles of the target are presented to the radar. This requires a detailed knowledge of flight characteristics of the target, range geometry, and tracking capability of the instrumentation system.

The measurement radar will perform over a wide variation of ranges during a typical flight sequence; this imposes a compromise in the selection of antennas to provide acceptable taper at close ranges and system sensitivity at long ranges.

During the course of the RCS measurement, the dynamic system may also measure the amplitude and phase, elevation and azimuth angle, and range as a function of time. To obtain the target aspect angle, these parameters can be merged with the target roll, pitch, and yaw data, obtained from the cooperative targets' inertial navigation system data as a function of time. The data are then merged to obtain RCS (or other desired parameters) as a function of aspect angle.

The dynamic radar can be calibrated using a disposable sphere dispensed from a helicopter or aircraft. The system tracks the sphere and calibrates the system at each frequency used in the measurement. Because measurements can span an extended period between calibration and completion of the mission, the instrumentation radar may require a drift correction system to minimize system drift errors.

3.3 Indoor ranges

Indoor ranges are enclosures lined with radar absorbing materials. The objectives of indoor RCS ranges are identical to those of outdoor ranges, namely to simulate free-space, far-field conditions. The principal advantages of indoor ranges are as follows: isolation from weather, immunity from external electronic interference, and physical/ visual security. The disadvantages are restrictions imposed by the physical size and cost of the enclosure. Several types of indoor ranges are described in 3.3.1 through 3.3.4.

3.3.1 Indoor compact ranges

The compact range is the workhorse of the modern RCS range indoor facilities. The compact range uses a reflector system to collimate a spherical wave emitted from the feed antenna into a planar wave in a relatively short distance, hence the term "compact." The several types of reflector systems in current use are as follows:

- Offset feed: An offset parabolic reflector with a feed located at the prime focus, but the feed is rotated to "off-set feed" the reflector.
- Dual Cylindrical: Two cylindrical parabolic reflectors used to create the plane wave. The "folded optics" configuration permits the effective path length to be longer and thus the polarization purity to be improved over the prime focus range. The two reflectors are two-dimensional cylindrical shapes, and thus can be manufactured at a lower cost, and preserve a higher degree of cross-polarization isolation when compared with the Prima Focus reflector.
- Cassegraine dual reflector system: An offset parabolic reflector is fed by a convex-shaped secondary reflector, which in turn is illuminated by a feed. The subreflector can be shaped to optimize the illumination of the main reflector, and the geometry can be designed to marginally improve the polarization purity.
- Gregorian dual reflector: A type of dual-reflector system that produces a virtual image of the feed at the focus of the main parabolic by using a convex subreflector between the two reflectors to minimize blockage effects. If designed properly, this geometry provides the best cross-polarization isolation of the three above designs.

The diagrams of these types of compact ranges are shown in Figure 2.

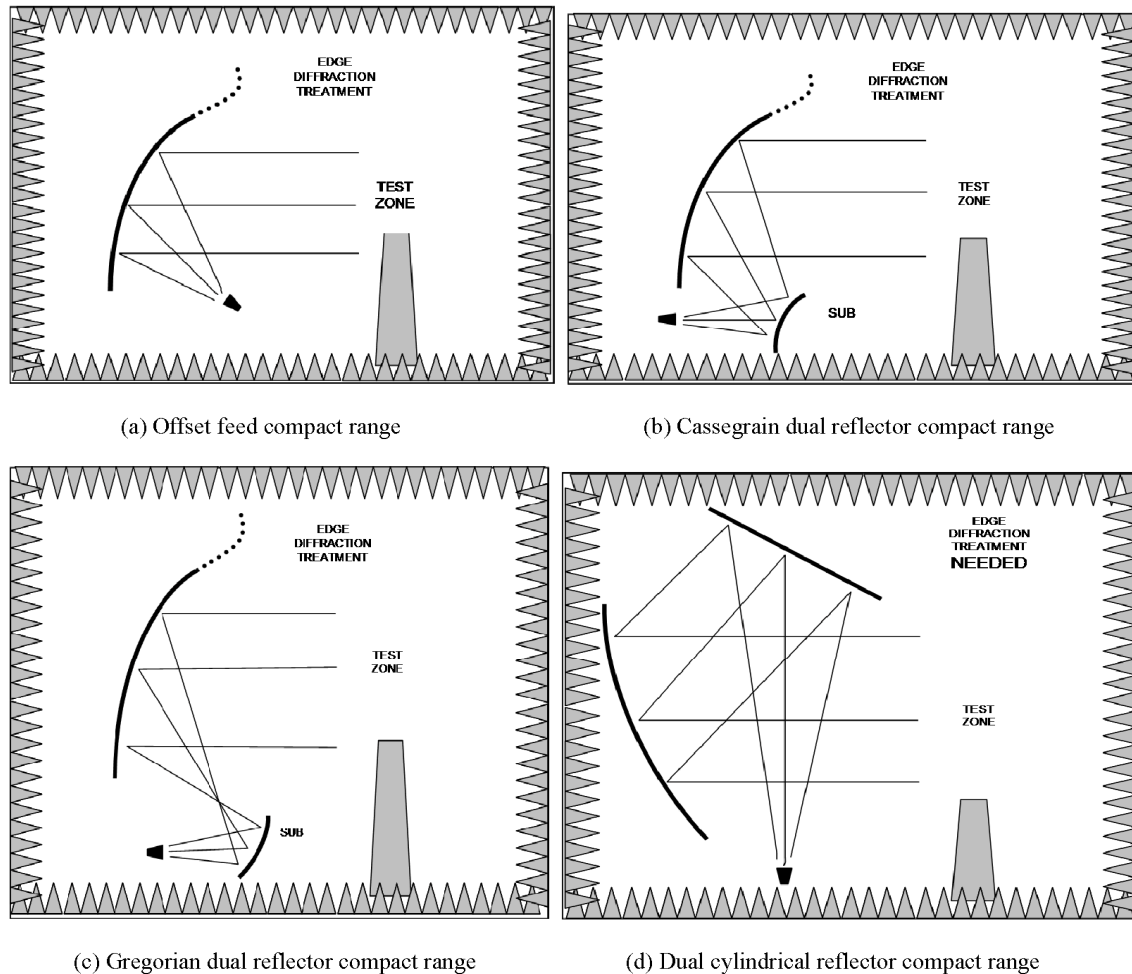


Figure 2—Types of compact ranges

The limitations of compact range systems can result from surface irregularities, wall reflections, reflector edge diffraction, feedback lobe, and feedforward scattering. A fundamental limitation ensues from unavoidable diffraction from the edges of reflectors that scatter energy into the test zone and thus contaminate the incident field. To control these errors, the edges of the reflectors are shaped as serrations, using curved (rolled) extensions, or by resistive card terminations. Spherical wave illumination uniformity by the feed can be a problem because most feeds have a frequency-dependent phase center and beam width. These feed problems have been largely overcome based on work done by industry and universities leading to the development of some excellent wide-band, phase-stable feeds.

3.3.2 Indoor tapered chamber

Tapered chambers have a rectangular-shaped test zone that tapers as a pyramid at a throat section that contains the illuminating antenna. The feed is at the apex of the tapered section, which should be long enough so that the spherical wave generated by the feed becomes a useful approximation to a plane wave in the test zone. The tapered walls present a small grazing angle to the radiated signal, which reduces the side wall reflections that enter the test zone. The pyramid-shaped section with the feed at the apex reduces dependence on the performance of the absorber on the tapered section side walls and requires a thick absorber only on the rear wall and side walls of the test zone. A sketch of such a chamber is shown in Figure 3.