"MODERN DYNAMIC RCS AND IMAGING SYSTEMS"

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This paper presents a conceptual overview of the instrumentation system and signal processing involved in dynamic RCS and Imaging measurement systems.

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Introduction

The target detection systems of today have become highly sophisticated and consequently have imposed demanding requirements on the design of vehicles and on the measurement of their radar characteristics. Adequate definition of a target's signature is much more complex than just defining the total radar cross section. Other RCS parameters such as engine modulation, plume cross section, polarization, and frequency dependence of signatures are very important. Furthermore, high resolution RCS images in one, two, and even three dimensions have become increasingly important for both identifying and diagnosing targets.

Static RCS measurements alone are not sufficient. It is important to know the dynamic characteristics of the vehicle in motion. Without sophisticated dynamic testing, one cannot be sure that a specific "low-observable" vehicle will really be as "invisible" to enemy radar as it has been estimated to be. The only way to make such a determination reliably is to get actual data on the vehicle in motion utilizing a Dynamic RCS and Imaging System (DRIS). Furthermore, both monostatic and bistatic information must be obtained if vulnerability to both monostatic and bistatic detection is to be determined.

The following sections will discuss the major components of a DRIS as well as the general functions required. The features and capabilities necessary to perform these functions will also be discussed.

DYNAMIC MEASUREMENTS

Dynamic measurements are made while the target is moving which requires the antenna system to be positioned with sufficient accuracy to maintain the beam centers on the target during the measurement. This imposed tracking requirement of the dynamic case adds considerable complexity over static measurement systems.

Although dynamic measurements are more complex and consequently more costly than for the static case, in some instances it is the only practical alternative. For example, it is extremely difficult to mount operational aircraft on low cross section target support pylons without major modifications to the target structure. Foam supports have been used in the past for such measurements (e.g., at RATSCAT), however, the RCS background for such mounts has not produced encouraging results. Ground effects can also corrupt the measurement. In addition, changing the roll or pitch angle for a foam mounted operational aircraft is a major (and risky) operation.

Dynamic measurements have practical advantages over static in that the instrumentation system measures the real thing. For the case of aircraft, the dynamic shape (which may be different from static) is observed. Engine plume and engine modulation are also included in the dynamic measurement. These parameters would be virtually impossible to duplicate on a low cross section static pylon. The target support RCS background, which is a major concern for static ranges, is not a factor for dynamic measurements. Also, ground plane effects can be eliminated.

The major components of a dynamic system are shown in Figure 1.

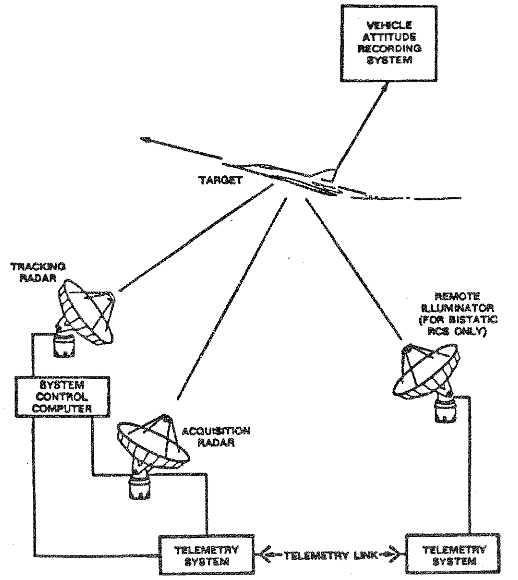


FIGURE 1: DYNAMIC RCS MEASUREMENT SYSTEM

The operational cost involved in dynamic measurement programs usually justifies a multiband instrumentation system to collect all the data simultaneously. A dynamic measurement system that covers the frequency range of 100 MHz through 18 GHz with spot frequencies at 35 GHz and 95 GHz is shown in Figure 2. The system utilizes a tracking radar to track the measurement target and provide angle and range data for the instrumentation radar system.

This example shows a Scientific-Atlanta 2090 Instrumentation Radar configured with three tracking pedestals that are slaved to the tracking radar. The tracking radar positions the instrumentation antennas via a parallax computer such that the beam centers are on target. The instrumentation antenna sizes are selected to provide a good balance between field taper and system sensitivity for a given range geometry.

For this system, a 60 foot antenna provides a frequency coverage of 100 MHz through 1 GHz and a 10 meter antenna provides coverage from 1 GHz through 2 GHz. A multi-antenna pedestal with six antennas provides coverage as follows:

Antenna Size	Frequency Coverage
5 meter	2 GHz - 4 GHz
12 foot	4 GHz - 8 GHz
10 foot	8 GHz - 12.4 GHz
10 foot	12.4 GHz - 18 GHz
4 foot	35 GHz
2 foot	95 GHz

The radar utilizes a time division multiplexing scheme to provide "simultaneous" operation of all bands. Once each system period, a pulse train with one pulse for each band is generated with a slight time delay between pulses. The appropriate frequency is applied to the antenna system for transmission and target reception. The received returns are range gated by the range unit with the same pulse stagger that was used for transmission. This technique allows only target returns within the desired range cell to enter the receiver.

The 2090 radar system utilizes a STALO and COHO for stability and image rejection. The COHO generator operates at a frequency of 1.5 GHZ to produce the pulse and phase code modulation for the system. The STALO signals are generated by computer controlled high speed synthesizers. One synthesizer for each band is required to maintain phase coherency between transmit and receive. The STALO and COHO signals are mixed in the RF up/down converters to produce the desired frequency for each band.

RF units mounted on the pedestals near the antennas provide power amplification and polarization selection for the transmitted signals. The RF units also contain the duplexer and receiver low noise amplifiers. Two receiver channels are provided for full polarization matrix capability.

Received signals from the RF units are converted in the downconverter to produce IF signals of 1.5 GHz. These converted pulse train signals, one for each frequency, are applied to the coherent detector.

The coherent detector mixes the received IF signals with the coherent reference to produce I and Q pairs that represent the amplitude and phase of the target returns. An I and Q pair is generated for each frequency (and polarization) and are sampled in the high speed sample and hold unit by triggers from the range tracking unit. The same stagger sequence is used as for transmission.

The sampled I and Q signals are converted to digital signals by the analog to digital converters. There are 16 parallel channels to achieve the desired dynamic ranges and data rates. The 16 digital signals are sent to the system control unit (SCU).

The SCU performs high speed I and Q correction on the data (on a pulse by pulse basis). Correction coefficients which are generated during system calibration are applied to each pulse to eliminate gain or quadrature imbalance in I and Q (imbalance would produce spurious components and contaminate the data).

The data may be processed by an FFT processor for real-time display. The data are recorded in the data collection system for later reduction. Coherent digital filtering of the data will provide both coherent integration gain and clutter rejection.

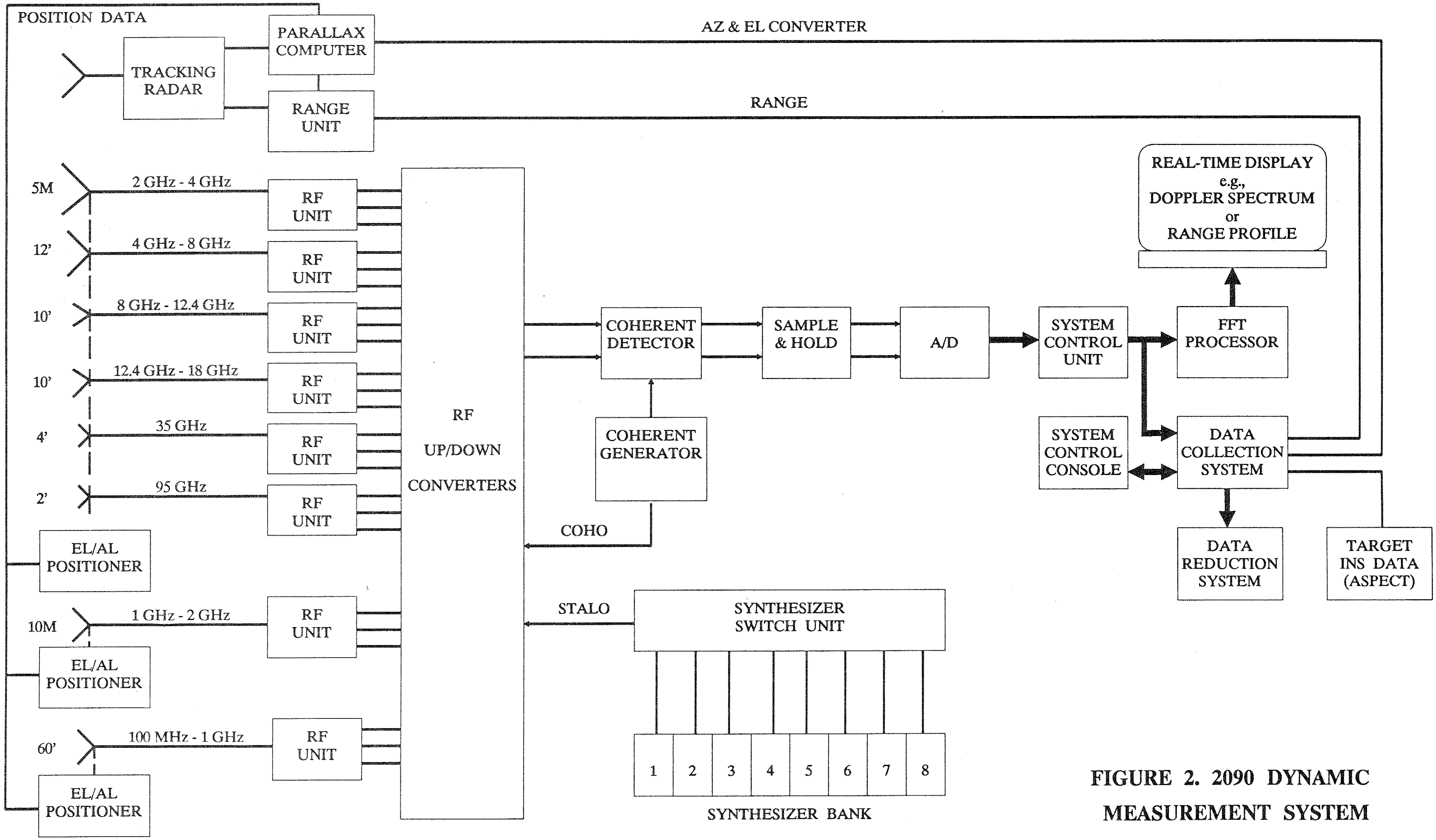


FIGURE 2. 2090 DYNAMIC MEASUREMENT SYSTEM

The system generates target image data by applying a stepped frequency waveform on the target. The frequency synthesizers used in the 2090 radar system change frequency in less than one microsecond. This capability permits each band to change frequency each system period.

In general, dynamic measurement scenarios make it necessary to carefully plan a flight program to insure that all of the desired measurement aspects of the target are presented to the radar. This process requires a detailed knowledge of the flight characteristics of the target, the geometry of the range and the tracking capabilities of the instrumentation system.

A common device used to collect target coordinate data is an inertial navigation system mounted on the target. The INS records target roll, pitch and yaw also as a function of time. The radar data and target coordinate data must be merged to produce the end product. If a telemetry system can be mounted on the target vehicle, target coordinate data can be sent to the data collection system and merged in near real time.

DYNAMIC IMAGING

Fourier transforms may be used to get the doppler spectrum and this doppler spectrum can be used to separate certain phenomena such as engine modulation, target motion, plume effects, and stationary clutter. Although this doppler processing is relatively straightforward, it is typically not found in dynamic systems literature.

The desirable RCS and imaging information about dynamic targets would include:

- full polarization measurements (e.g., HH, HV, VH, and VV)
- RCS vs aspect, RCS vs frequency, and RCS vs frequency and aspect
- one dimensional images (i.e., high range resolution)
- two dimensional images (i.e., ISAR images) and
- three dimensional monopulse images

All of this desirable information can be obtained from measurements that are achievable and practical with today's technology. As an example, the Scientific-Atlanta 2090 Instrumentation Radar provides more than enough performance (e.g., accuracy, frequency agility, dynamic range, stability, image rejection, etc.) to make these kinds of measurements.

Making these dynamic measurements and processing the data is conceptually similar to that for the static case. See Figure 3 for a typical static measurement configuration. There are only three fundamental (but costly) differences between the dynamic and static cases:

- the tracking requirement (range and angle)
- motion determination (aspect angle and range)
- motion compensation (for range changes and for non-uniform sampling in aspect angle)

Although these differences are easy to state, they do introduce complexity and cost.

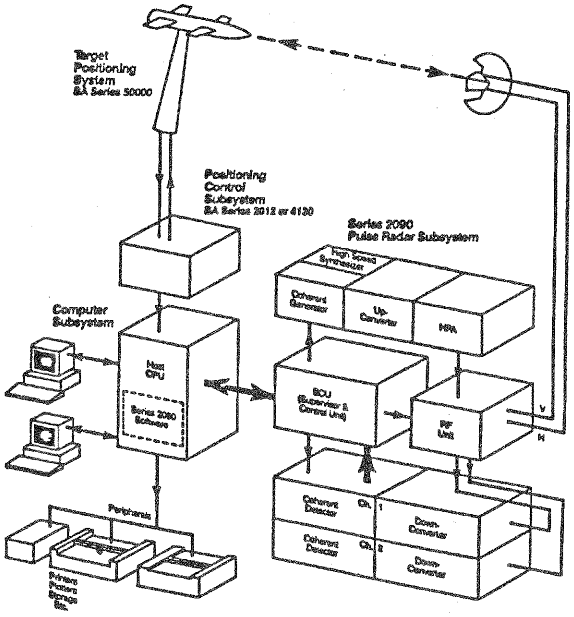


FIGURE 3: STATIC MEASUREMENT CONFIGURATION

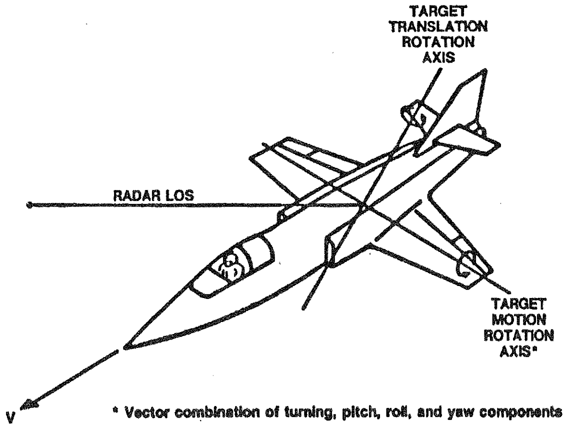
The solutions to the tracking problems can be quite expensive but these problems have been solved many times in the past. The main cost drivers are:

- tracking accuracy
- tracking range
- target RCS (minimum)
- the clutter environment and
- whether there is some form of "tracking beacon" or whether the target must be "skin tracked"

Target motion, in the six degrees of freedom (three linear and three angular), can be determined in a variety of ways. Each has advantages and disadvantages including more or less accuracy. Among some of the (not mutually exclusive) methods of determining target motion are:

- using a precision INS (Inertial Navigation System) on board the target
- using one or more beacon(s)/transponder(s) on the target
- using passive reflectors at known locations on the target
- using auxiliary information from cameras, theodolites, etc.
- and/or using the radar returns alone.

After the target motion has been determined as a function of time it is relatively straightforward to do the coordinate transformations to get range and aspect angle as a function of time. Figure 4 illustrates the required motion decomposition. Since the radar data exists as a function of time, the data can be put into the form of I and Q values as a function of aspect angle. Once the data is phase corrected for the linear motion along the radar lime-of-sight (LOS), complex interpolation can be used to produce uniform samples as a function of aspect angle.



* Vector combination of turning, pitch, roll, and yaw components

TARGET MOTION CAN BE DECOMPOSED INTO LINEAR MOTION ALONG RADAR LOS AND ANGULAR MOTION ABOUT AN AXIS PERPENDICULAR TO THE RADAR LOS.

FIGURE 4: MOTION DECOMPOSITION

Once the data exists as a function of aspect angle it can then be processed by any of the standard product 2090 software (plus any special purpose software as well). This existing software will save many man-years of software development for dynamic imaging.

Among the many (existing and under development) capabilities of the standard product software are:

- calibration
- drift correction
- I/Q circularity correction
- polarization correction
- focused and/or unfocused images
- statistics
  - sliding geometric means
  - sliding arithmetic means
  - sliding maximum values
  - percentiles
  - probability distributions
- windowing
  - rectangular
  - triangular
  - hanning
  - hamming
  - blackman
  - user specified
- image combination
- image editing
- zoom and pan
- near-field and far-field transformations
- high speed (real-time) images
- a myriad of graphics and display capabilities

Among the graphics and display capabilities are:

- RCS vs frequency
- RCS vs aspect
- RCS vs frequency vs aspect
- RCS vs range
- RCS vs range vs aspect
- RCS vs cross range
- unfocused ISAR images
- focused ISAR images
- doppler displays
- linear plots
- polar plots
- contour plots
- color fill plots
- multiple plots per page
- plot overlays
- target overlays
- zooming and panning
- image combination (coherent and incoherent)

DYNAMIC SYSTEMS - THE WAVE OF THE FUTURE

It seems reasonably clear that cost-effective dynamic systems will be the wave of the future. Scientific-Atlanta is committed to being the clear choice for acquiring Dynamic Systems capability. We invite anyone interested in acquiring dynamic capability (no matter how distant in the future) to discuss your requirements with us. We can provide very cost effective solutions.

NOTES