DIGITAL BEAM-FORMING ANTENNA RANGE

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Abstract

Toshiba Corporation, working with Nearfield Systems Inc., has developed a fully digital antenna measurement system for digital beam-forming (DBF) antennas. The DBF test facility is integrated with the large 35m x 16m vertical near-field range installed at Toshiba in 1997 [3], and includes the NSI Panther 6500 DBF Receiver as the primary measurement receiver. The DBF system was installed in March 1999 and has been used extensively to test and characterize a number of complex, high performance DBF antennas.

A DBF antenna typically incorporates an analog-to-digital (A/D) converter at the IF stage of the transmit/receive (T/R) module. The digital IF signals are transferred to a digital beam-forming computer, which digitally constructs, or forms, the actual antenna pattern, or beams. Since the interfaces to the DBF antenna are all digital, the usual microwave mixers and down-converters are incompatible.

The NSI Panther 6500 is designed to interface directly with DBF antennas and allows up to 8 channels of I and Q digital input (16 bits each) with 90 dB dynamic range per channel. The NSI DBF receiver solves the DBF interface problem while providing enhanced performance over conventional microwave instrumentation [2].

Keywords: Antenna Measurements, Near-field, Digital Receiver, Digital Beamforming, Digital Signal Processing, A/D Converters

1.0 Introduction

This paper presents a description of the Toshiba DBF receiver measurement system, discusses the types of digital beam-forming antennas tested, presents a sample of the test data generated by the measurement system, and includes the following sections:

1. Introduction
2. DBF Antenna Configuration
3. NSI Panther 6500 DBF Receiver
4. DBF Measurement Facility
5. DBF Antenna Test Results
6. Summary

2.0 DBF Antenna Configuration

Figure 1 shows a typical DBF [1] radar antenna configuration. In transmit mode, RF signals are amplified by high power amplifiers (HPAs) in each transmit/receive (T/R) module. In receive mode, RF signals are amplified by a low noise amplifier and summed to one dimension by a RF combiner. These signals are converted to an intermediate frequency (IF) signal and digitized by an analog-to-digital (A/D) converter. The antenna beam is then generated digitally by the beamformer. Since the antenna beam is output as digital data, the near-field system instrumentation must be capable of directly measuring the digital data.

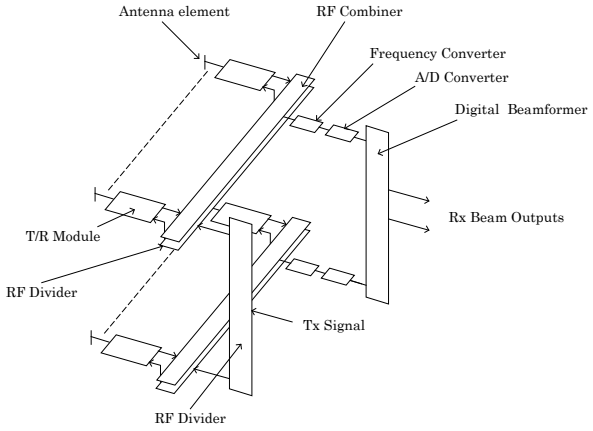

Figure 1.0 Typical DBF Antenna

3.0 NSI Panther 6500 DBF Receiver

The NSI Panther 6500 Digital Beam Forming (DBF) Receiver is designed specifically to test antennas that directly output digital data [4]. The Panther 6500 offers improved sensitivity, dynamic range, noise immunity and speed over most analog receivers available today, and eliminates many of the problems associated with conventional antenna measurement systems. An 8-channel model of the Panther DBF Receiver is shown in Figure 2 below.

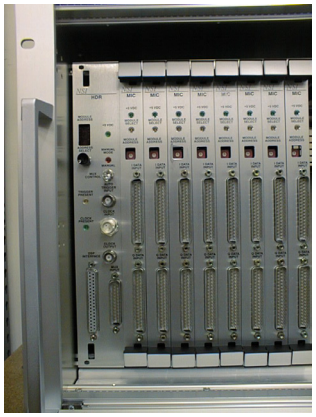

Figure 2 NSI Panther 6500 Receiver

The Panther 6500 DBF Receiver operating with the NSI 6002 High Speed Beam Controller (HSBC) is capable of receiving up to 16 channels of digital I (16-bit In-Phase) and Q (16-bit Quadrature) data in random order at rates up to 312,500 measurements per second. The digital input data is capable of being coherently clocked at rates up to 5 MHz. The I and Q channels are multiplexed into a High-Speed Digital Receiver module, which performs x16 integration, and then transferred from the Panther directly to the PC in real-time. A block diagram of the Panther 6500 signal flow is shown in Figure 3.

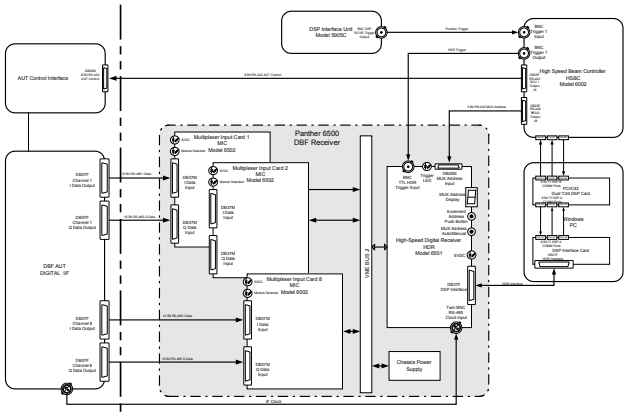

Figure 3 Panther 6500 Block Diagram

The Panther HSBC provides real-time control over the DBF measurement process by controlling the selection of the digital input multiplexer and providing 8-bits for AUT beam-forming control. Specifications for the Panther 6500 are shown in Table 1.

Table 1 Panther 6500 DBF Specifications

Panther 6500 DBF Receiver	
Sensitivity (1 average)	AUT dependent
Measurement speed (max)	312,500 points per second (no averages)
Receiver integration time (1 average)	4.2 usec
IF Bandwidth (for minimum integration time)	160,000 kHz
Number of Channels	2 (test and reference)
Buffer size (memory available for single cut)	2,000,000 measurement points
IF clock rate	5 MHz
Dynamic Range (1 average)	90 dB
Size	(9U) 15.75”H x 17”W x 15”D
Power Requirements	100 – 240 VAC, 47-63 Hz, 35W
Controls and Indicators	Power on/off switch, Mux Select Sw, Local/Auto Sw, Mux LEDs, IF Clk LED,

Panther 6002 High Speed Beam Controller	

Measurement speed (max)	80,000 points per second
Beam setup time (min)	4.2 usec
Timing resolution	1.0 usec
Multiplexing capacity	9,000 measurements per trigger
Switch control unit ports	Three (3) ports, 8-bits per port, RS-422 differential outputs
Frequency control	Two (2) ports, 44-bits per port, RS-422 differential outputs
Trigger inputs	One (1) single-ended trigger input
Trigger outputs	Four (4) single-ended trigger outs Four (4) differential trigger outs
Size	3.5"H x 17"W x 12"D
Power Requirements	100 – 240 VAC, 47-63 Hz, 100W
Controls and Indicators	Power switch, DC Power, State, Trigger LED

A typical system block diagram using the Panther 6500 is shown in Figure 4.

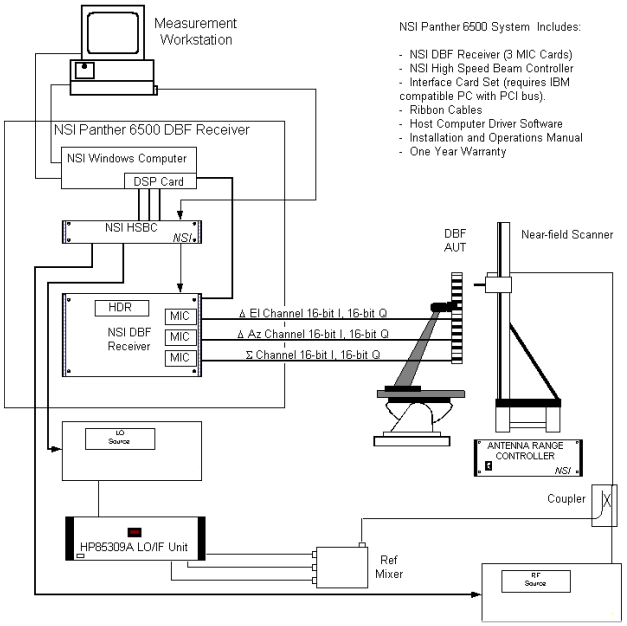

Figure 4 Near-field System with Panther 6500

Since the digital inputs should provide perfect linearity with 90 dB dynamic range, a linearity test was performed to insure performance. Figure 5 shows the receiver results of a stepped input from 0 to –90 dB.

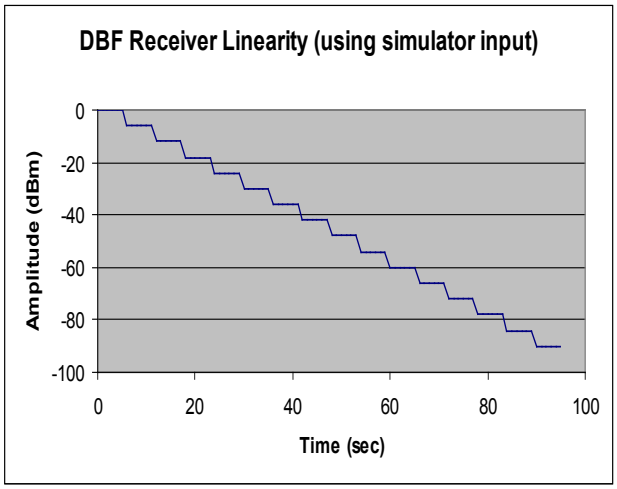

Figure 5 Panther 6500 DBF Receiver Linearity

4.0 DBF Measurement Facility

Figure 6 shows a block diagram of a typical DBF antenna system at the Toshiba near-field measurement facility.

The existing near-field measurement instrumentation has been upgraded to include the Panther 6500 DBF Receiver including an 8-channel digital multiplexer, High Speed Beam Controller (HSBC), and Windows based measurement workstation with NSI 97 software. The digital data from the DBF antenna is output in serial form and converted to parallel by the transform unit for input to the digital multiplexer. The scanner control, data acquisition process, and the DBF receiver are all controlled by the NSI 97 software.

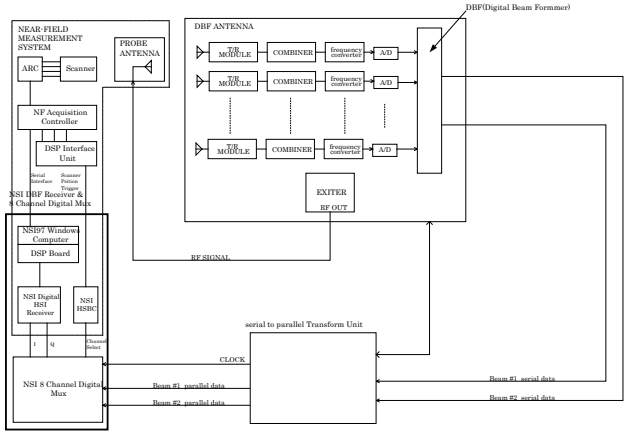

Figure 6 Typical DBF Antenna System

Photographs of the existing scanner subsystem, measurement software display, and DBF near-field measurement system are shown in Figures 7 – 9 respectively.

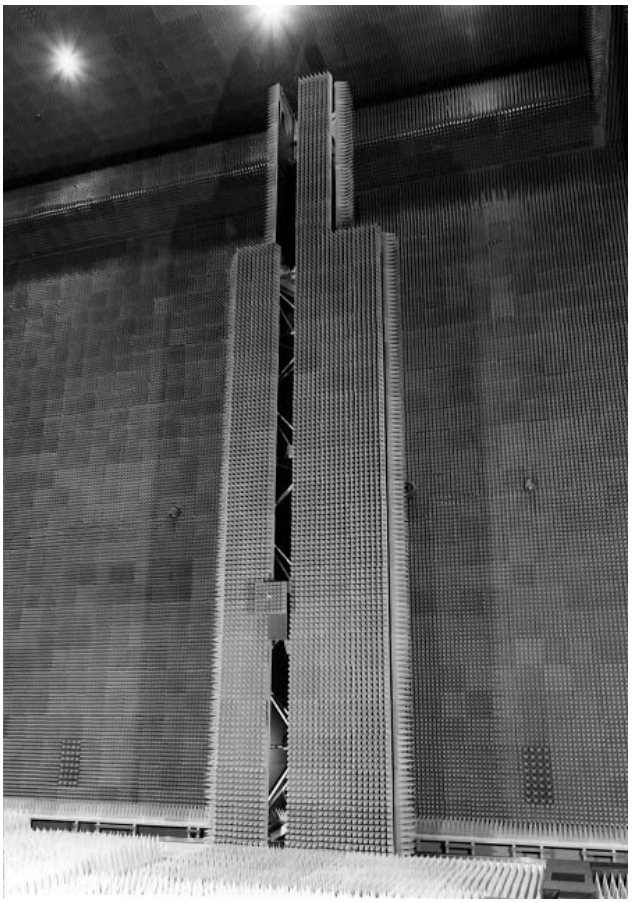

Figure 7 Existing 35m x 16m Near-field Scanner

Figure 8 Measurement Software Display

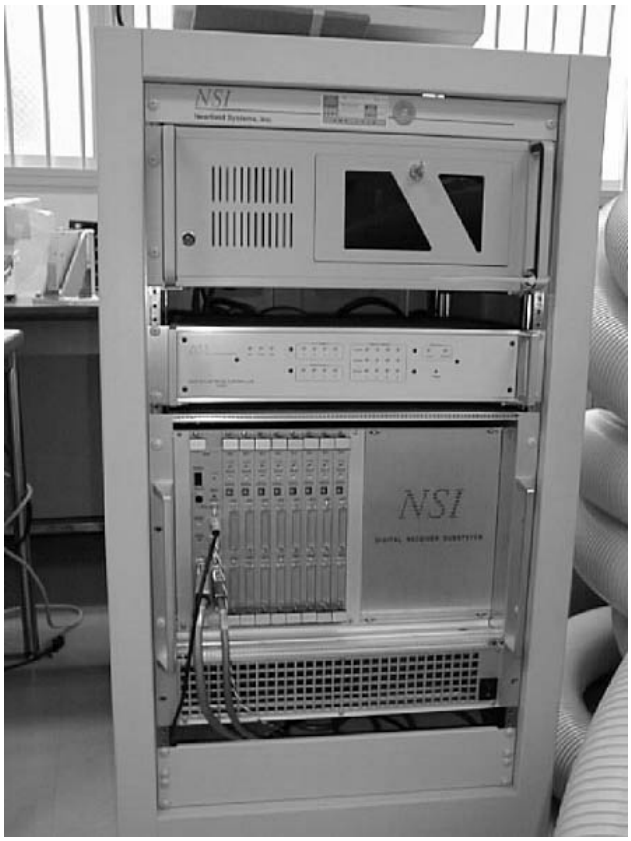

Figure 9 DBF Near-field Measurement System

5.0 Toshiba DBF Antenna Test Results

In order to verify the performance of the DBF measurement system, a standard gain horn (SGH) was used as an AUT. The SGH was measured on the near-field range using the standard microwave instrumentation. The same SGH was then connected as a single DBF element and measured using the same near-field scan parameters. Note that all unused DBF elements were disabled for this test. Figures 10 and 11 show the greyscale plots of the RF and DBF near-field pattern. Preliminary results show very good agreement.

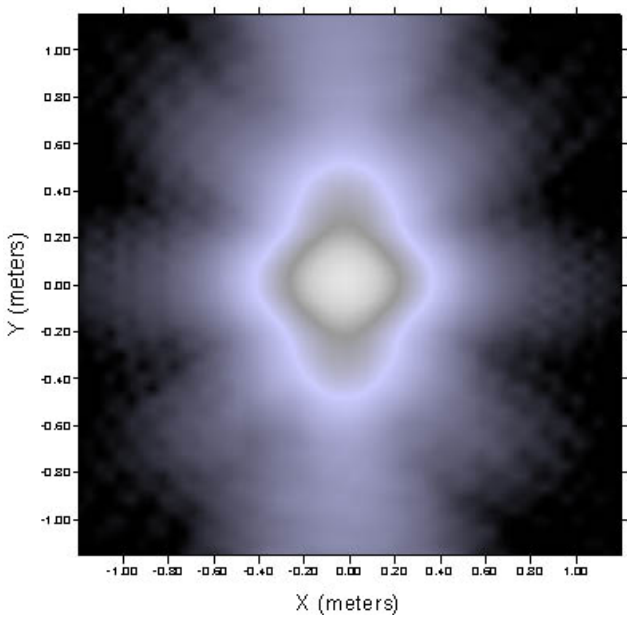

Figure 10 DBF Near-field Measurement

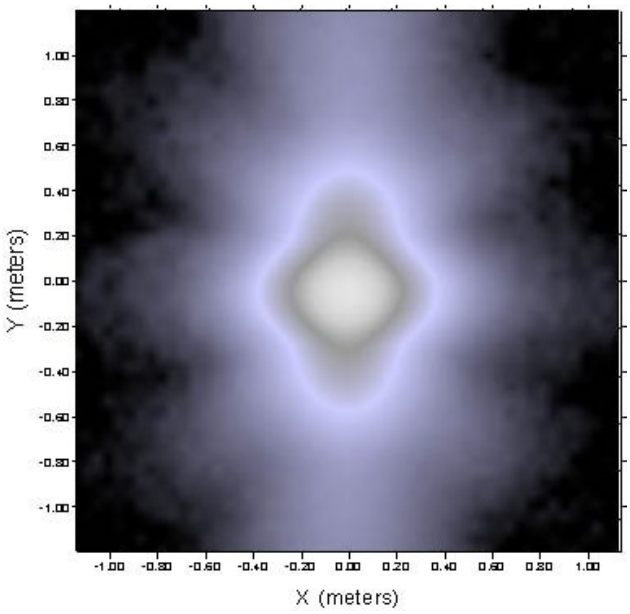

Figure 11 RF Near-field Measurement

6.0 Summary

The Toshiba DBF test facility provides an excellent example of applying high speed digital signal processing technology to the test and characterization of DBF antennas. The NSI Panther 6500 digital receiver system represents a significant improvement in receiver technology for high-performance digital beam-forming antenna measurement applications. The Toshiba DBF test facility represents a state-of-the-art advancement in the test of complex, high performance DBF antennas.

References

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