Interaction Application Memos

Memo 35

Scale Model Measurements of the F-16A

ABSTRACT

Frequency domain data are presented for the surface currents and charges measured in an anechoic chamber on F-16A models to simulate the aircraft response in free space environment. Models 1/48 and 1/32 in scale were measured over the frequency range 118 to 4400 MHz, simulating 2.46 to 91.7 MHz full scale. A total of 78 measurements are presented. These include eight test points measured on the 1/48 and 1/32 scale models and three excitations chosen to correspond to those used in the ATHAMAS I (HPD) and ATHAMAS II (VPD) full scale measurements.

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PREFACE

The author is indebted to C. Bickley, D. Brown and R. Wang who assisted with the measurements, J. Travis who supervised the measurements and was responsible for the scheduling, W. Rasey who typed the manuscript and, last but not least, W. Prather of AFWL/NTMOP for his support and encouragement.
SECTION I
INTRODUCTION

The data presented here were obtained for the Air Force Weapons Laboratory and TRW Systems to determine the surface response extrapolation function [1] for the F-16A aircraft. The test points and excitation conditions were therefore chosen to correspond to those of the full scale measurements made in the ATHAMAS I (Horizontally Polarized Dipole) and ATHAMAS II (Vertically Polarized Dipole) simulators at Kirtland AFB.

Data are presented for eight locations or test points on the aircraft under three different excitation conditions: (i) top incidence, E parallel to the fuselage; (ii) top incidence, E perpendicular to the fuselage; and (iii) nose-on incidence, E vertical. The measured quantities are the axial surface current density component $J_a$, the circumferential surface density component $J_c$, and the normal electric field component $E_n$. Of the 72 measurement situations possible, 39 were selected, and since the measurements were made on two different size scale models, a total of 78 data sets were generated. The results are presented in the form of amplitude and phase plots as functions of the full scale frequency, and have been furnished to the AFWL and TRW in digital form on punched cards for further analysis.

SECTION II
MODELS

The two scale models of the F-16A aircraft that were selected were 1/48 scale (Scalecraft SC-4010) and 1/32 scale (Minicraft 100). Each came in the form of a plastic kit with a complement of armament that was full apart from the B-61 weapon. The models were good scale replicas of the F-16A, but did require some modification to make them electrically equivalent to the aircraft used in the full scale tests at AFWL. These modifications included cutting back the nose to STA:F60 to simulate the non-metallic radome, adding a metallic pitot tube, and modelling the radar antenna on the smaller model (the larger one had the radar antenna included in the kit). The cockpit canopies were also removed, since this is non-conducting on the actual aircraft. Both models had Sidewinder missiles (included in the kits) on each wing tip, but from the sketches and photographs supplied by AFWL it was necessary to construct models of the B-61 weapon and pylon that were attached under the right wings only.

After the models were assembled and the above modifications made, the joins and any surface imperfections were filled in with auto body putty, which was then filed and sanded to a smooth surface. Apart from the radome and canopy, the entire aircraft was regarded as metallic, and several coats of silver paint (Dupont No. 4817) were applied to the models to make them conductive. Finally, the lengths
and wingspans of the models were very carefully measured to determine the scale factors to be used in translating the measured frequencies to the full scale ones. The scale factors are listed in Table 1. Figure 1 gives pertinent aircraft dimensions used in preparation of the models.

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<td>Large (L)</td>
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The scale factors are based on full scale dimensions of overall length 15.085 m and width 10.008 m, including Sidewinder missiles.

Models such as those used here are seldom perfect replicas of the full scale aircraft. As seen from Table 1, the scale factors derived from the fuselage length and the wingspan differ slightly, and though we could use the average to process the data, it is possible to obtain more accurate results by using the scale factor for that portion of the structure which supports the measured field. Thus, for the axial current on top of the fuselage (top incidence, E parallel to fuselage), the fuselage scale factor was used in processing the data, whereas for the circumferential current on top of the fuselage (top incidence, E perpendicular to fuselage) the scale factor derived from the wingspan is appropriate.
Figure 2 is a photograph of the large (1/32) model, and Figure 3 is a closeup showing the bulkhead, radar and pitot tube. The diameter of the pitot tube is not to scale. We initially used a wire that did have the right diameter, but it was so fragile that it kept getting bent when the model was handled. It is not felt that the larger diameter has a measurable effect on the electromagnetic response of the aircraft.
SECTION III
MEASUREMENTS AND DATA

3.1 Facility and Instrumentation

The measurements were made in the Radiation Laboratory's anechoic chamber, a facility especially designed, constructed, and instrumented for this type of surface field measurement. The measurement procedures were similar to those used in previous programs [2 through 7] apart from changes resulting from the continued upgrading of the facility and the measurement techniques.


Figure 4 shows a block diagram of the facility as it exists now. When these measurements started the instrumentation and procedures were as described in [7], but as the program progressed, numerous changes were made. These include extending the low frequency operation from 125 MHz to 118 MHz, increasing the number of frequency bands from 3 to 4, and incorporating a calculator-controlled switching of the power amplifiers and low pass filters. The last two changes reduced the "between band" jumps evident in previously obtained data [5,6]. We have also experimented with rectangular data recording instead of the standard phase/log recording which produces ambiguities near ±180 degrees, but this change was not made because of the limited dynamic range of the amplitude recording that this new procedure has.

3.2 Measurements

Current and charge measurements were made at eight locations on the model as indicated in Fig. 5. On the fuselage the locations are identified by a station number given in terms of the full scale distance in inches from the bulkhead (STA:F60). Thus, F239T is 179 inches from the bulkhead. The wing stations were located on the line bisecting the wing at a distance (in inches) given by the station number measured perpendicularly from the center line of the fuselage. Table 2 lists the station numbers of the test points and describes their locations.

The measurements were made for three different illuminations each having a prescribed polarization referenced to the fuselage of the aircraft (see Fig. 6). In our measurements the directions of
<table>
<thead>
<tr>
<th>Test Point</th>
<th>Stations</th>
<th>Location</th>
</tr>
</thead>
</table>
| 1          | F76T     | Upper Surface, Forward of Canopy  
FS = 76  
WL = Top Surface  
BL = 0 (centerline) |
| 2          | F239T    | Upper Surface, Behind Canopy  
FS = 239  
WL = Top Surface  
BL = 0 (centerline) |
| 3          | W352R    | Upper Surface, Right Wing  
FS = 352  
WL = Top Surface  
BL = 96 (right) |
| 4          | F488B    | AFT Fuselage, Bottom  
FS = 488  
WL = Bottom Surface  
BL = 0 (centerline) |
| 6          | F76RS    | FWD Avionics Bay, Right Side  
FS = 76  
WL = 88  
BL = Right Surface |
| 7          | F100B    | FWD Fuselage, Bottom Surface  
FS = 100  
WL = Bottom Surface  
BL = 0 (centerline) |
| 8          | W352B    | Lower Surface, Left Wing  
FS = 352  
WL = Lower Surface  
BL = 96 (left) |
| 9          | F257B    | Mid-Fuselage, Bottom Surface  
FS = 257  
WL = Bottom Surface  
BL = 0 (centerline) |
illumination and polarization are often referred to as orientations since these are fixed relative to the chamber and can be changed only by suitably orienting the model. Figure 6 also shows the direction of the measured current on the top and bottom of the aircraft. In all cases the component $J_c$ is perpendicular to $J_a$. The data presented are normalized relative to the incident field, i.e., $J/H_0$ for the surface current data and $E_n/E_0$ for the charge data. The phase is referenced to that of the incident field at the station where the measurement was made, based on the $e^{i\omega t}$ time convention.

All of the current and charge measurements were made using miniature surface-mounted probes [8]. To mount the probes, holes were drilled in the model and the probe lead passed through to the other side. When not in use a hole was taped over with conductive adhesive copper tape (see Figs. 2 and 3) and as far as we can ascertain, the taping had no effect on the measurements.

3.3 Data

The data presented were measured in the anechoic chamber with the model supported by a styrofoam pedestal using specially prepared styrofoam supports to orient the model appropriately in relation to the incident field.

For each measurement situation the data were obtained using both models over either three or four bands of frequencies, depending on the system in use at the time. The bands of data were then combined to give single data sets for the large (L) and small (S) scale models. Because different numbers of sampling points were used

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in each frequency band, and because the measured frequencies were
divided by the model scale factors to obtain the full scale
frequencies, the sampling rate is not uniform throughout the data
plots, nor was it uniform in the data delivered to AFWL and TRW.
For the data recorded over three frequency bands, 187 points were
used in Band 1 (118 to 1100 MHz), 122 in Band 2 (950 to 2200 MHz),
and 144 in Band 3 (2000 to 4400 MHz). For the four band recording,
90 points were used in Band 1 (118 to 546 MHz), 95 in Band 2 (550 to
1000), 116 in Band 3 (1000 to 2100 MHz) and 138 in Band 4 (3100 to
4400 MHz). Thus, with some overlap, 453 data points were recorded
with the three band system, and 439 with the four band system.
However, due to the occasional failure of the network analyzer to
properly lock onto the signal, a few (perhaps half a dozen) points
were sometimes omitted from a data set. The result is that a data
set generally contains about 430 data points regardless of the system.
For any particular data set the exact number of points and the frequency
range covered are given, with other information, in line 5 of a data
file (see Table 4). Typically, the full scale frequency range for
the F-16A obtained using the small (1/48) model is 2.46 to 91.7 MHz,
and using the large (1/32) model, 3.7 to 137.5 MHz.

Table 3 summarizes the cases for which data have been obtained
and gives the figure numbers where the plots for each case can be
found. The figure numbers are the same as those of the data files
with the letter 'S' (small model) or 'L' (large model) specifying the
particular model used for the measurement. The (digital) data files
are also identified in the first line of the data set.
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Note: Each measurement has two data sets, one measured on the small model (S) and one on the large model (L).

*Data set F11L is inconsistent with that of F11S and is believed to be inaccurate. Do not use F11L.
Plots of the data are given in the following section. In addition to the plots the data has also been furnished to AFWL and TRW in digital form on punched cards and is stored on IBM compatible magnetic tape at the University of Michigan. The format used for the data is as follows:

Line 1  FILENAME (4A4)
2  Comments (18A4)
3  Comments (18A4)
4  TITLE used in plotting (18A4)
5  FMIN, FMAX, AMPMIN, AMPMAX, PHASEMIN, PHASEMAX, NN (4F8.3, 2F8.2, I5)
6  F(1) AMP(1) PHASE(1) F(2) AMP(2) PHASE(2) F(3) AMP(3) PHASE(3) 3(2F8.3, F8.2)
 +
data
 +  .................. F(NN) AMP(NN) PHASE(NN)

where NN is the number of data points in the set. Table 4 is an example of a typical data file for the F-16A.
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**HEAD OF FILE**

**TABLE 4**

**SAMPLE DATA FILE**

**LIST F-16A**
Notes:  
(1) Radome and plastic canopy removed.  
(2) Radar and pitot tube simulated.  
(3) Sidewinder missiles at each wing tip.  
(4) B-61 plus pylon, right wing only.

Fig. 1: Pertinent Aircraft Specifications.
Fig. 2: Photograph of the Large Model (1/32 Scale).

Fig. 3: Closeup of the Bulkhead Showing Radar and Pitot Tube.
Fig. 4: Block Diagram of the Present Facility.
Fig. 5: Location of Measurement Stations. (See Table 2 for details.)
1. E parallel to fuselage, top incidence.
2. E perpendicular to fuselage, top incidence.
3. E vertical, nose-on.

Note: Dashed lines indicate bottom surface current components.

Fig. 6: Illumination Directions (Orientations) and the Measured Current Components.
SECTION IV
DATA
Figure 01S. Axial Current at STA:F76T, Excitation 1, 1/48 Model.
Figure 01L. Axial Current at STA:F76T, Excitation 1, 1/32 Model.
Figure 02S. Normal Electric Field at STA:F76T, Excitation 1, 1/48 Model.
Figure 02L. Normal Electric Field at STA;F76T, Excitation 1, 1/32 Model.
Figure 03S. Axial Current at STA:F76T, Excitation 2, 1/48 Model.
Figure 03L. Axial Current at STA:F76T, Excitation 2, 1/32 Model.
Figure 045. Normal Electric Field at STA: F76T, Excitation 2, 1/48 Model.
Figure 04L. Normal Electric Field at STA:F76T, Excitation 2, 1/32 Model.
Figure 05S. Axial Current at STA:F76T, Excitation 3, 1/48 Model.
Figure 05L. Axial Current at STA:F76T, Excitation 3, 1/32 Model.
Figure 06L. Normal Electric Field at STA:F76T, Excitation 3, 1/32 Model.
Figure 06S. Normal Electric Field at STA:F78T, Excitation 3, 1/48 Model.
Figure 07S. Axial Current at STA:F239T, Excitation 1, 1/48 Model.
Figure 07L. Axial Current at STA:F239T, Excitation 1, 1/32 Model.
Figure O8L. Normal Electric Field at STA:F239T, Excitation 1, 1/32 Model.
Figure 08S. Normal Electric Field at STA:F239T, Excitation 1, 1/48 Model.
Figure 09S. Axial Current at STA:F239T, Excitation 2, 1/48 Model.
Figure 09L. Axial Current at STA:F239T, Excitation 2, 1/32 Model.
Figure 10S. Circumferential Current at STA:F239T, Excitation 2, 1/48 Model.
Figure 10L. Circumferential Current at STA:F239T, Excitation 2, 1/32 Model.
Figure 11S. Axial Current at STA:F238T, Excitation 3, 1/48 Model.
Figure 11L. Axial Current at STA:F239T, Excitation 3, 1/32 Model.

Data inconsistent with the small model measurement. DO NOT USE THIS DATA.

Incorrect phase, it should be near zero degrees. See Fig. 11S.
Figure 12S. Normal Electric Field at STA:F239T, Excitation 3, 1/48 Model.
Figure 12L. Normal Electric Field at STA:F239T, Excitation 3, 1/32 Model.
Figure 13S. Axial Current at STA: W352T, Excitation 1, 1/48 Model.
Figure 13L. Axial Current at STA:W352T, Excitation 1, 1/32 Model.
Figure 145. Circumferential Current at STA: W352T, Excitation 1, 1/48 Model.
Figure 14L. Circumferential Current at STA:W352T, Excitation 1, 1/32 Model.
Figure 15S. Normal Electric Field at STA:W352T, Excitation 1, 1/48 Model.
Figure 15L. Normal Electric Field at STA: W352T, Excitation 1, 1/32 Model.
Figure 16S. Axial Current at STA:W352T, Excitation 2, 1/48 Model.
Figure 16L. Axial Current at STA:W352T, Excitation 2, 1/32 Model.
Figure 17S. Axial Current at STA:W352T, Excitation 3, 1/48 Model.
Figure 17L. Axial Current at STA:W352T, Excitation 3, 1/32 Model.
Figure 18S. Axial Current at STA:F257B, Excitation 1, 1/48 Model.
Figure 18L. Axial Current at STA:F257B, Excitation 1, 1/32 Model.
Figure 195. Normal Electric Field at STA:F257B, Excitation 1, 1/48 Model.
Figure 19L. Normal Electric Field at STA:F257B, Excitation 1, 1/32 Model.
Figure 205. Axial Current at STA:F257B, Excitation 2, 1/48 Model.
Figure 20L. Axial Current at STA:F257B, Excitation 2, 1/32 Model.
Figure 21S. Circumferential Current at STA:F257B, Excitation 2, 1/48 Model.
Figure 21L. Circumferential Current at STA:F257B, Excitation 2, 1/32 Model.
Figure 22S. Axial Current at STA:F257B, Excitation 3, 1/48 Model.
Figure 22L. Axial Current at STA:F257B, Excitation 3, 1/32 Model.
Figure 23S. Normal Electric Field at STA:F257B, Excitation 3, 1/48 Model.
Figure 23L. Normal Electric Field at STA:F257B, Excitation 3,1/32 Model.
Figure 24S. Axial Current at STA:F352B, Excitation 1, 1/48 Model.
Figure 24L. Axial Current at STA:F352B, Excitation 1, 1/32 Model.
Figure 25S. Circumferential Current at STA:F352B, Excitation 1, 1/48 Model.
Figure 25L. Circumferential Current at STA:F352B, Excitation 1, 1/32 Model.
Figure 26S. Axial Current at STA:F352B, Excitation 2, 1/48 Model.
Figure 26L. Axial Current at STA:F352B, Excitation 2, 1/32 Model.
Figure 27S. Axial Current at STA:F352B, Excitation 3, 1/48 Model.
Figure 27L. Axial Current at STA:F352B, Excitation 3, 1/32 Model.
Figure 28S. Axial Current at STA:F100B, Excitation 1, 1/48 Model.
Figure 28L. Axial Current at STA:F100B, Excitation 1, 1/32 Model.
Figure 295. Normal Electric Field at STA:F100B, Excitation 1, 1/48 Model.
Figure 29L. Normal Electric Field at STA:F100B, Excitation 1, 1/32 Model.
Figure 305. Axial Current at STA:F100B, Excitation 2, 1/48 Model.
Figure 30L. Axial Current at STA:F100B, Excitation 2, 1/32 Model.
Figure 31S. Axial Current at STA:FLOOB, Excitation 3, 1/48 Model.
Figure 31L. Axial Current at STA:F100B, Excitation 3, 1/32 Model.
Figure 32S. Normal Electric Field at STA:F100B, Excitation 3, 1/48 Model.
Figure 32L. Normal Electric Field at STA:F100B, Excitation 3, 1/32 Model.
Figure 33S. Axial Current at STA:F488B, Excitation 1, 1/48 Model.
Figure 33L. Axial Current at STA:F488B, Excitation 1, 1/32 Model.
Figure 34S. Normal Electric Field at STA:F488B, Excitation 1, 1/48 Model.
Figure 34L. Normal Electric Field at STA:F488B, Excitation 1, 1/32 Model.
Figure 35S. Circumferential Current at STA:F488B, Excitation 2, 1/48 Model.
Figure 35L. Circumferential Current at STA:488B, Excitation 2, 1/32 Model.
Figure 36S. Normal Electric Field at STA:F488B, Excitation 2, 1/48 Model.
Figure 36L. Normal Electric Field at STA:F488B, Excitation 2, 1/32 Model.
Figure 37S. Axial Current at STA:F488B, Excitation 3, 1/48 Model.
Figure 37L. Axial Current at STA:F488B, Excitation 3, 1/32 Model.
Figure 38S. Normal Electric Field at STA:F488B, Excitation 3, 1/48 Model.
Figure 38L. Normal Electric Field at STA:F488B, Excitation 3, 1/32 Model.
Figure 39S. Normal Electric Field at STA:F76RS, Excitation 1, 1/48 Model.
Figure 39L. Normal Electric Field at STA: F76RS, Excitation 1, 1/32 Model.