Special Session on Image Reconstruction Using Real Data

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1. Introduction

The search for an efficient, accurate means to recover the shape, size, and composition of an unknown object, from scattered-field measurements exterior to the body, has been going on for many years. Researchers in this field have made much progress in developing theoretical algorithms, but have been hampered by the lack of controlled scattered-field measurements from actual, but sometimes unknown, objects, on which to test them.

It has been customary to test one's algorithm on either synthetic data (scattered-field data obtained by numerical solution of the direct-scattering problem from a known object), or measured data from a known object. Although reconstructions obtained this way can sometimes be surprisingly good, there is a lingering suspicion that knowledge of the actual scatterer may have been inadvertently incorporated into the inversion algorithm to effect a favorable outcome. Often, synthetic data leads to the commission of an "inverse crime," which Colton and Kress [1] describe as occurring when the forward solver used to generate the data is also used in the inversion algorithm, and/or when the same discretization is used in both numerical procedures. An unbiased observer is left to wonder if the positive identification would be so readily made if the object were a complete unknown. This is not to be construed as a criticism of current inversion algorithms. In fact, just the opposite is intended. When viewed objectively, the fact that any meaningful results can be gleaned from so little information is remarkable. Having said that, however, it is still true that if inversion or reconstruction techniques are ever to be accepted by–much less find practical applications in–the real (read commercial) world, they will have to produce useful answers from independently generated data sets. This will have to be done without much of the a priori information either consciously or unconsciously used in self-generated "tests."

It was decided to create such a databank of independent, experimentally measured scattered fields from a variety of simple objects, which could form a set of standard problems on which all researchers could test their algorithms. Only when performance is measured on the same data can objective, meaningful comparisons of algorithms be made. As a step toward disseminating the data, as well as calling attention to its existence, we devised the idea of a friendly "contest" between researchers having a serious interest in image reconstruction. The idea was to provide a common set of measurements, on some simple objects, that any interested party could obtain. Some of the objects would be completely described, while others would remain "mystery" targets.

The researchers could test and calibrate their algorithms on the known objects, and then try their skill on the mystery targets. The results would then be presented during a special session at the IEEE AP-S/USNC URSI Symposia. We say symposia because, if successful, we envisioned this endeavor as ongoing.

2. The Ipswich Data

The measured data were acquired at the USAF Rome Laboratory Electromagnetic Measurement Facility, in Ipswich, Massachusetts. The objects were some of those used in the course of other research. To establish a common terminology, and for ease of identification, we refer to the data provided as the Ipswich Data.

The measurements were made in an anechoic chamber, using the swept-bistatic system described in [2]. This system was designed and built in 1981, and has been in use continuously since. Figure 1 shows the layout of the measurement system, and defines the angles used to describe the data.

After the raw data were measured, they were processed to remove the effects introduced by the chamber walls and the mounting devices. They were then calibrated, by comparing them to similar measurements on targets with known scattering behavior. Computer files containing the measured data were placed on a workstation that is accessible via the FTP procedure.

This FTP server is found at ercthp1.rl.af.mil (IP address 146.153.124.231), and is available for anonymous login. The information available comprises a welcome message, a description of the structure of the server, a Postscript file with an illustration

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describing the measurement geometry (see Figure 1), and a number of subdirectories containing the data files (see Figure 2). There are three data subdirectories, named pec, pen, and hybrid, containing measurements on perfectly conducting objects, penetrable objects, and combinations of the two, respectively. There is also an index listing the objects for which measurements are available. For each target, we provide the file names, a brief description of the object (if it is not a mystery target), and the date it was added to the server.

The makeup of the database is not constant. We are adding to the Ipswich Data more or less regularly. As either people experience success in reconstructing our mystery targets, or we spill the beans at the symposia, we will change the status of some targets to "known." At the same time, some of the new targets will be posted as mystery targets until they, too, are identified.

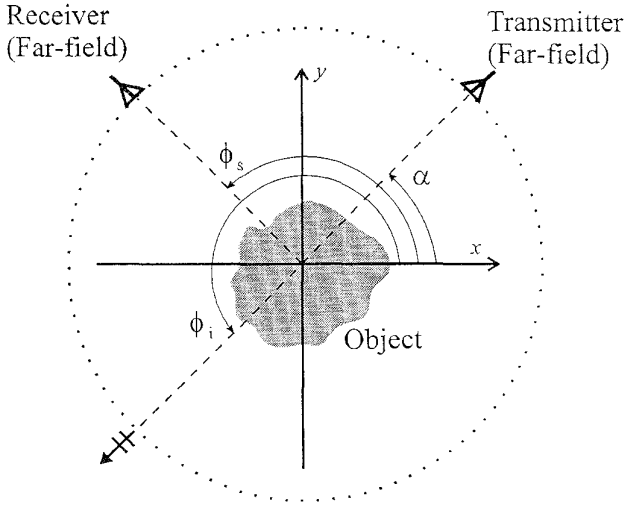
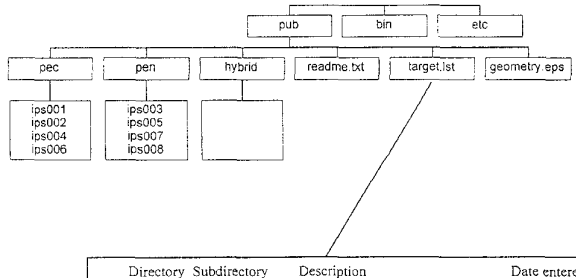


Figure 1. The two-dimensional target-oriented coordinate system used for the Ipswich data. All angles are referenced to the x axis. α is the angle of incidence, ϕ_s is the receiver direction (known as phi_scat **in the data files), and ϕ_i is the illuminating plane-wave direction or view.**



Directory	Subdirectory	Description	Date entered
pec	ips001	Cylinder, circular, aluminum	10/31/94
pec	ips002	Plate, rectangular, aluminum	10/31/94
pen	ips003	Cylinder, square, polystyrene	12/05/94
pec	ips004	Dihedral, aluminum	11/28/95
pen	ips005	Mystery	12/19/95
pec	ips006	Cylinder, circular, aluminum	01/29/96
pen	ips007	Mystery	03/26/96
pen	ips008	Mystery	03/26/96

Figure 2. The directory structure of the data files on the FTP server.

ips001	ips002	ips003	ips004	ips005	ips006	ips007	ips008
ips001.txt	ips002.txt	ips003.txt	ips004.txt	ips005.txt	ips006.txt	ips007.txt	ips008.txt
ips001vv.180	ips002vv.180	ips003vv.000	ips004hh.000	ips005vv.000	ips006vv.000	ips007vv.000	ips008vv.000
ips001vv.185	ips002vv.185	ips003vv.060	ips004hh.010	ips005vv.010	ips006vv.010	ips007vv.010	ips008vv.010
ips001vv.190	ips002vv.190	ips003vv.120	ips004hh.020	ips005vv.020	ips006vv.020	ips007vv.020	ips008vv.020
ips001vv.195	ips002vv.195	ips003vv.180	ips004hh.030	ips005vv.030	ips006vv.030	ips007vv.030	ips008vv.030
ips001vv.200	ips002vv.200	ips003vv.240	ips004hh.040	ips005vv.040	ips006vv.040	ips007vv.040	ips008vv.040
ips001vv.225	ips002vv.225	ips003vv.300	ips004hh.050	ips005vv.050	ips006vv.050	ips007vv.050	ips008vv.050
ips001vv.240	ips002vv.240		ips004hh.060	ips005vv.060	ips006vv.060	ips007vv.060	ips008vv.060
ips001vv.270	ips002vv.270		ips004hh.070	ips005vv.070	ips006vv.070	ips007vv.070	ips008vv.070
ips001hh.180	ips002hh.180		ips004hh.080	ips005vv.080	ips006vv.080	ips007vv.080	ips008vv.080
ips001hh.185	ips002hh.185		ips004hh.090	ips005vv.090	ips006vv.090	ips007vv.090	ips008vv.090
ips001hh.190	ips002hh.190		ips004hh.100	ips005vv.100	ips006vv.100	ips007vv.100	ips008vv.100
ips001hh.195	ips002hh.195		ips004hh.110	ips005vv.110	ips006vv.110	ips007vv.110	ips008vv.110
ips001hh.200	ips002hh.200		ips004hh.120	ips005vv.120	ips006vv.120	ips007vv.120	ips008vv.120
ips001hh.225	ips002hh.225		ips004hh.130	ips005vv.130	ips006vv.130	ips007vv.130	ips008vv.130
ips001hh.240	ips002hh.240		ips004hh.140	ips005vv.140	ips006vv.140	ips007vv.140	ips008vv.140
ips001hh.270	ips002hh.270		ips004hh.150	ips005vv.150	ips006vv.150	ips007vv.150	ips008vv.150
			ips004hh.160	ips005vv.160	ips006vv.160	ips007vv.160	ips008vv.160
			ips004hh.170	ips005vv.170	ips006vv.170	ips007vv.170	ips008vv.170
			ips004hh.180	ips005vv.180	ips006vv.180	ips007vv.180	ips008vv.180
			ips004hh.190	ips005vv.190	ips006vv.190	ips007vv.190	ips008vv.190
			ips004hh.200	ips005vv.200	ips006vv.200	ips007vv.200	ips008vv.200
			ips004hh.210	ips005vv.210	ips006vv.210	ips007vv.210	ips008vv.210
			ips004hh.220	ips005vv.220	ips006vv.220	ips007vv.220	ips008vv.220
			ips004hh.230	ips005vv.230	ips006vv.230	ips007vv.230	ips008vv.230
			ips004hh.240	ips005vv.240	ips006vv.240	ips007vv.240	ips008vv.240
			ips004hh.250	ips005vv.250	ips006vv.250	ips007vv.250	ips008vv.250
			ips004hh.260	ips005vv.260	ips006vv.260	ips007vv.260	ips008vv.260
			ips004hh.270	ips005vv.270	ips006vv.270	ips007vv.270	ips008vv.270
			ips004hh.280	ips005vv.280	ips006vv.280	ips007vv.280	ips008vv.280
			ips004hh.290	ips005vv.290	ips006vv.290	ips007vv.290	ips008vv.290
			ips004hh.300	ips005vv.300	ips006vv.300	ips007vv.300	ips008vv.300
			ips004hh.310	ips005vv.310	ips006vv.310	ips007vv.310	ips008vv.310
			ips004hh.320	ips005vv.320	ips006vv.320	ips007vv.320	ips008vv.320
			ips004hh.330	ips005vv.330	ips006vv.330	ips007vv.330	ips008vv.330
			ips004hh.340	ips005vv.340	ips006vv.340	ips007vv.340	ips008vv.340
			ips004hh.350	ips005vv.350	ips006vv.350	ips007vv.350	ips008vv.350

Figure 3. The contents of the lower-level directories on the FTP server.

3. The special session

The first such "contest" was conducted during 1994-1995, and the results were presented at the 1995 AP-S/URSI Symposium in Newport Beach, California. There were eleven papers presented, not all of which dealt directly with the Ipswich data. In spite of some procedural glitches, inevitable in starting such an endeavor, the response was gratifying, and the presented results were quite promising.

The results from those people who attempted to reconstruct the data are presented below, in alphabetical order by first author. These results are taken from write-ups provided by the authors, for which we are grateful.

After discussing the pros and cons of the session, and taking into account the comments and suggestions of the participants, we decided that there was sufficient reason to hold a second round. Thus, there will be another special session on image reconstruction in Baltimore. Because of the lateness of our decision to hold the second session, there was not time to announce it properly, for which we apologize. However, the data are available to all, and given that we fully intend to hold a third annual session, please feel free to start honing your entries for 1997.

4. References

1. Colton and Kress, *Inverse Acoustic and Electromagnetic Scattering Theory*, Berlin, Springer-Verlag, 1992.

2. Marc G. Cote, "Automated Swept-Angle Bistatic Scattering Measurements Using Continuous Wave Radar," *IEEE Transactions on Instrumentation and Measurement*, **IM-41**, 2, April 1992, pp. 185-192.