LOW SIDELOBE REFLECTOR ANTENNAS

H.E. Schrank, Advisory Engineer
Westinghouse - Systems Development Divisions
Baltimore, Maryland

INTRODUCTION

Although the first ultralow sidelobe antennas were phased arrays, a number of recent reflector designs have achieved noteworthy success in sidelobe suppression. This article is a sequel to "Low Sidelobe Phased Array Antennas" which was featured in the April 1983 AP-S Newsletter, and surveys the development of low sidelobe reflector antennas using various techniques by workers in the USA, Europe, and Japan.

The aperture distributions necessary to produce ultralow sidelobes (below -40 dB) have been known for many years, but being able to achieve these distributions in actual antenna designs has proven difficult, especially for reflector antennas. The reasons that the successful breakthroughs in low sidelobe technology took place on phased array designs rather than on reflectors is not surprising, and is discussed in reference (2).

For either type of antenna, the same basic principle holds: provide the necessary aperture distributions (amplitude and phase) and you shall get the desired low sidelobe pattern. Success or failure in either case depends on how well various error sources can be controlled in the design, fabrication, and assembly of the antenna.

Before getting into the main discussion, I would like to clarify one point, namely, that while there are three basic techniques in use for controlling antenna sidelobes, only one will be covered in this article:
(I) SIDELOBE SUPPRESSION (or Optimization)
(II) SIDELOBE BLANKING (or Cancellation)
(III) ADAPTIVE CANCELLING (or Nulling, Null Steering).

In the first technique, the antenna is designed for low sidelobes. In the second technique, an auxiliary broad-beam "guard" antenna is used to blank out signals coming into the sidelobes of the main antenna. In the third technique, the antenna pattern is dynamically changed (adapted) by means of feedback circuits.

Although all three of these techniques have useful application, in this article we are limiting our discussion exclusively to technique (I). Perhaps techniques (II) and (III) can be discussed in future articles by other authors.

BASIC REFLECTOR LIMITATIONS

Figure 1 illustrates a basic axisymmetric reflector (paraboloidal dish) antenna with a point-source feed at the focus. The feed illuminates the reflector with its primary pattern to produce an amplitude (and phase) distribution in the aperture plane, which then Fourier transforms into a secondary pattern in the far field. The primary illumination that misses the reflector produces spillover lobes at angles corresponding to the F/D ratio geometry, and diffraction effects at the reflector edge produce wide-angle and rearward lobes. The feed, which is typically a simple waveguide horn at microwave frequencies, produces a monotonically-shaped amplitude distribution as shown solid, whereas a low sidelobe distribution generally requires an inflected shape as shown dashed. The distribution shape and the edge taper determine the near-in sidelobe.
levels achievable. However, further degradation of achievable near-in sidelobe suppression is caused by blockage of the antenna aperture by the feed and its support structure.

Another factor which contributes to the basic limitations of sidelobe control is the reflector surface accuracy. This affects both the phase and amplitude distributions in the aperture plane, and can degrade wide-angle lobes as well as the near-in sidelobes.

Figure 2 (from an old classic reference (4)) illustrates a typical pattern produced by early focal-fed axisymmetric paraboloids. Near-in sidelobe levels of -20 to -25 dB were typical, with -30 dB or lower difficult to achieve. Front-to-back lobe ratios were generally about 40 to 50 dB, depending on the antenna size (gain) and the edge illumination (taper).

In summary, we see that the generic axisymmetric single reflector antennas with simple feeds have four basic limitations in terms of sidelobe suppression:

1. Feed pattern shaping limitations
2. Aperture blockage effects
3. Spillover and edge diffraction effects
4. Surface accuracy effects.

Dual reflector systems, such as the axisymmetric Cassegrain and Gregorian geometries, essentially suffer from the same limitations, except that spillover and edge diffraction can occur at both the primary and the subreflector edges. However, some improvements can be realized; for example, aperture blockage can be avoided by application of polarization twist schemes, and low sidelobe amplitude illuminations can be more precisely designed by special shaping of the two reflectors. These techniques will be discussed later in this article.

EARLY SIDELOBE SUPPRESSION EFFORTS

A number of reflector edge treatments have been used to reduce spillover and diffraction backlobes. As shown in figure 3, lining the rim of the dish with microwave absorber provides some minor improvement, and "castellating" the rim can improve the front-to-back ratio significantly. Similar backlobe suppression along with spillover reduction has been achieved for many years by the use of absorber-lined shrouds or

Figure 1. Basic Axisymmetric Reflector Showing Typical Amplitude Distribution from a Simple Feed Compared with Desired Low Sidelobe Distribution (Dashed)

Figure 2. Typical Pattern for Focal-Fed Axisymmetric Paraboloid (from Cutler, King, and Kock)
Figure 3. Reflector Edge Treatments to Reduce Spillover and Diffraction Lobes

Figure 4. Patterns of Dish with and without Long Absorber Lined Tunnel (from Dybdal and King)
"tunnels." These are cylindrical tubes of metal (or dielectric) lined on the inside with microwave absorbing material to catch the spillover radiation and reduce diffraction effects. Although this technique is not new, some relatively recent work by Dybdal and King at 92 GHz shows impressive results (see figure 4) for a tunnel whose length is twice the aperture diameter. Better than 60 dB front-to-back ratios can be achieved.

Another successful technique for reducing wide-angle and rear lobes is the well-known horn-parabola, which is an offset-fed portion of a paraboloid fed by a flared waveguide horn whose walls extend to the parabola, except at the exit aperture (see figure 5). Rectangular horn-parabolas are commonly used for commercial microwave links, allowing back-to-back antennas with well over 70 dB isolation. A characteristic diffraction lobe at 90 degrees was successfully reduced by means of sawtooth (multiple-edge) blenders at the sides of the horn aperture. Note that the resulting sidelobe envelope is superior to a comparable dish with an absorber-lined shroud.

Although the near-in sidelobes of horn-parabolas are not very low (about -20 dB), the wide-angle sidelobes are extremely low, such that a conical horn-parabola antenna designed at Bell Telephone Laboratories...
had one of the lowest noise temperatures ever achieved. According to Blake(11), this antenna (oriented toward the zenith) achieved a noise temperature of 4.5° Kelvin (at 5.65 GHz), of which only 2°K was caused by ground radiation entering through minor holes. The remaining 2.5°K was the zenith "sky" noise (tropospheric and cosmic). This illustrates the fact that for some systems, wide-angle suppression is much more critical than the levels of the first few near-in sidelobes.

Another early effort to reduce sidelobes in one preferred plane (cut) is by the method of aperture shaping. An example of this method is seen in comparing the sidelobe levels of a uniformly illuminated square aperture, where the sidelobes in the principal planes are -13 dB, but in the diagonal planes the highest lobes are -26 dB. Thus a diamond-shaped aperture (the square turned 45 degrees) provides lower sidelobes in one preferred plane (usually azimuth) at the expense of higher sidelobes in other planes. Various other shapes, including cosine-squared and Koch(12) have been used to achieve single-plane sidelobe levels below -30 dB, but for most system applications this approach is not satisfactory. Most systems require low sidelobes in all angular space, not just in one plane.

MORE RECENT APPROACHES

The polarization twist technique has been successfully used(13) to avoid blockage effects on near-in sidelobes of Cassegrain and similar dual reflector antennas. Figure 6 from Dahlhsjo(14) shows a monopulse antenna design that achieved low sidelobes in both the main and cross-polar patterns. However, this technique is limited to single linear polarization antennas, and thus cannot be used for systems requiring polarization diversity or circular polarization.

Another way to avoid aperture blockage is by means of offset feeding, as illustrated for single and dual reflector antennas in figure 7. Offset feeding, together with the use of more advanced feeds, has proven to be a very effective way of achieving low and ultralow sidelobe reflector antennas. An excellent tutorial review of this technology has been published by Rudge and Adatia(15) in the 1978 IEEE Proceedings.

While offset feeding complicates the analysis and the construction of such antennas, its potential for achieving high performance reflectors is
significant, particularly using dual reflectors. Not only are the sidelobe limitations of aperture blockage avoided, but larger, more sophisticated (multimode, corrugated, and array) feeds can be used to achieve the desired low sidelobe aperture distributions. In addition, the synthesis technique of Galindo-Israel et al\(^\text{(*)}\) can be applied to achieve not only low sidelobes, but also low cross-pol and high aperture efficiency. Better than \(-32\) dB first sidelobes and aperture efficiencies approaching 70 percent are reported by Rudge\(^{17}\) for both predicted and measured results. Quoting Rudge\(^{17}\):

"These results indicate that a good efficiency sidelobe compromise is realizable with offset systems. Computer-aided design methods ... combined with accurate vector-radiation models for the primary feed, are now developed to the point where fine optimization ... is both practical and realistic. ... Performance in the near-in region can be predicted to good accuracy for low sidelobe application. ... the far-field sidelobes decay rapidly with angle from the boresight and the wide-angle radiation can be largely attributed to primary feed spillover ... this can be dealt with by a combination of primary feed design and hooding techniques ... ." Here "hooding" means use of absorber-lined shields.

A POSSIBLE ALTERNATIVE TO OFFSET FEEDING

An interesting alternative to offset feeding is suggested by A.C. Ludwig.\(^{18}\) For circular apertures with circular central blockage, Ludwig has derived modified Taylor distributions (called doughnut and displaced distributions) that provide low wide-angle sidelobes in the presence of blockage, at the cost of allowing the first near-in sidelobe to be higher. Figure 8 shows the computed patterns for three cases of blockage radius, i.e., \(r_b = 0.05, 0.10, \) and \(0.20\). Note that beyond the first sidelobe, very low levels are achieved compared to the blocked 40-dB Taylor case. Ludwig argues that in many practical systems, having low wide-angle sidelobes is most important, and high first and second sidelobes can be tolerated. For such cases, axisymmetric Cassegrain antennas can be used with these modified displayed Taylor distributions designed into the feed-reflector system. His memo also considers displaced Blackman distributions, and draws the following conclusions:

1. Low wide-angle sidelobes can be achieved despite blockage, and the doughnut and displaced distributions are one means of doing it.
2. Of the distributions considered, the displaced Blackman is best for reducing the wide-angle sidelobes, but it is worse in terms of aperture efficiency and close-in sidelobes.
3. The displaced \(p = 1\) Taylor provides a dramatic reduction in wide-angle sidelobes, good aperture efficiency, and good close-in sidelobes, with the exception of the first sidelobe.

SOME SUCCESSFUL DESIGNS

In the low sidelobe reflector designs described briefly here, the first by Fante is a basic analytic study with experimental verification, and the second by Scudder and Yorinks is a developmental design for a surveillance radar application. The remaining examples are all for satellite communication applications, where a strong motivation for low sidelobe designs is the recent decision to decrease the spacing of geosynchronous satellites from 4 to 2 degrees.

The work by Fante\(^{19}\) at RADC (Rome, NY) is a basic analytical study aimed at designing an offset parabolic cylinder and feed to obtain a secondary radiation pattern with \(-50\) dB sidelobes at S-Band (3.1 to 3.6 GHz). The experimental model achieved this by means of a multi-probe-fed rectangular waveguide feed in which only the \(TE_{10}\) and \(TE_{30}\) modes were excited in their proper proportions. Measured patterns came very close to the desired sidelobe level.

R.M. Scudder and L.H. Yorinks\(^{20}\) at RCA (Moorestown, NJ), developed an offset-fed single reflector antenna with multiple stacked elevation beams for a tactical radar system operating at S-band. Their design was tested using a model scaled to 36 GHz, as shown in figure 9. A cross section diagram of this design, figure 10, shows the multiple waveguide feed and the use of absorber-lined shields to achieve the typical azimuth pattern shown for one of the six elevation beams. The 24-by 14.4-inch elliptical aperture produced a peak directivity of 45.5 dB,
Figure 8. Computed Patterns for Blocked Circular Apertures, Using Displaced \( p = 1 \) Taylor Distribution. (a),(b) \( r^0 = 0.05 \); (c),(d) \( r^0 = 0.1 \); (e),(f) \( r^0 = 0.2 \) (from Ludwig)
with an azimuth beamwidth of 1.4 degrees. Azimuth sidelobes were less than -50 dB beyond the first two, which were -38 and -44 dB, or lower. This design was for a tactical radar similar to the operational AN/TPS-43 built by Westinghouse.

A low sidelobe earth station antenna for the 4- to 6-GHz band was designed by Burdine and Wilkinson at GTE (Waltham, MA). Their design incorporates an offset-fed dual reflector system with a concave Gregorian subreflector, as shown in figure 11. A full-size demonstration model of this design was built and tested. It is illustrated on the cover of this Newsletter. Its 7.6-meter diameter circular aperture produces gains of 47.9 and 50.8 dB at the 4- and 6-GHz bands, corresponding to aperture efficiencies of 62 and 55 percent, respectively. The antenna can operate with dual linear, rotatable linear, or either sense circular polarizations. By the combination of offset feeding to eliminate aperture blockage, reflector shaping with good surface accuracies, and the use of strategically located absorber-lined shields, the azimuth and elevation pattern sidelobes have been successfully suppressed well below the $G = 32 - 25 \log \theta$ maximum sidelobe envelope recommended by FCC/INTELSAT/ICCR regulations at the time (1979) of this demonstration. (Recently this requirement has been tightened to $29 - 25 \log \theta$, which the GTE design also meets by a good margin.) A typical azimuth pattern measured at 6 GHz is shown in figure 12. Cross-pol is better than -34 dB in both bands.
In Japan some successful designs have also been achieved. M. Mizusawa, S. Urasaki, and H. Tanaka of Mitsubishi (Kamakura) have demonstrated an offset-fed dual reflector Cassegrain antenna for earth-terminal application. Their design is shown in figure 13 along with a table summarizing some results measured at 21.6 GHz for a 1-meter diameter circular aperture. Their design incorporated a corrugated conical feedhorn, a shaped convex subreflector, and a shaped concave main reflector to achieve an aperture distribution with rotational symmetry about the antenna axis and good cross-pol cancellation. Typical measured patterns in figure 14 show excellent sidelobe suppression for both linear polarizations in the transverse (azimuth) plane.

Another successful Japanese design is reported by Y. Mizuguchi et al of Kokusai Denshin Denwa Co., Ltd. (Tokyo). This is an offset-fed dual reflector Gregorian antenna having a circular aperture 66 wavelengths in diameter. By using a concave ellipsoidal subreflector, this design achieves a more favorable geometry compared with an equivalent Cassegrain design. The subreflector can be larger and the main reflector can be smaller for the same projected aperture diameter. Also, the bandwidth is improved. Optimum placement of the feed and reflectors is used to achieve low cross-pol. This results in cancellation of the cross-pol components otherwise generated by the asymmetric illumination of the offset reflector.

A comparison is made by Mizuguchi et al between using a conventional conical horn and a dielectric loaded horn. The dielectric loaded horn produced better axial symmetry of the main beam, lower cross-pol lobes, and better sidelobe characteristics. The sidelobes with this design are also shown to be better than those of an equivalent Cassegrain antenna by about 3 to 5 dB. The authors attribute this to the reduced spillover around the larger Gregorian subreflector. The use of absorber shielding to improve sidelobes in the longitudinal (elevation) plane is also presented.

A number of British designs of dual reflector antennas with fairly low sidelobes are described by Rudge and Adatia in their excellent review paper, among which is an interesting open Cassegrain antenna based on a Bell Laboratory design and built as a 6-meter diameter aperture earth station antenna at the University of Birmingham for satellite communication experiments with the U.K. Post Office. The
MEASURED PERFORMANCE

<table>
<thead>
<tr>
<th>Frequency</th>
<th>21.6 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>First Sidelobe Level</td>
<td>-27 dB</td>
</tr>
<tr>
<td>Gain</td>
<td>45.5 dB</td>
</tr>
<tr>
<td>Cross polarization efficiency</td>
<td>70%</td>
</tr>
<tr>
<td>Component (peak)</td>
<td>-31 dB</td>
</tr>
</tbody>
</table>

Figure 13. Low Sidelobe Dual Reflector Cassegrain Antenna; Dimension Shown is mm (from Muzusawa et al)

near-in sidelobes of this design are not impressive (about -25 dB) but wide-angle levels are well below -40 dB. A more recent British paper by R.I. Henderson\(^{(25)}\) of Marconi provides an exceptionally well-written discussion of the design of an offset Gregorian antenna for transportable earth stations operating in the 11- to 14-GHz bands. This excellent paper reviews the new FCC/CCIR requirements for sidelobe envelope suppression (G < -25 log \( \theta \) for \( 1^\circ \leq \theta \leq 4^\circ \), and G < -13 dB for \( 48^\circ \leq \theta \leq 180^\circ \)) and develops the design rationale for meeting these levels. The Gregorian dual reflector geometry illustrated in figure 15, is shown to be superior to the Cassegrainian, and design details are clearly presented. The advantage of an elliptical rather than circular aperture outline are presented in terms of not only the mechanical packaging considerations for transport, but also in terms of the rate of decay of sidelobes in the preferred plane of the geostationary orbit (i.e., horizontal plane). The resulting design has a main reflector 5.6 m wide by 2.8 m high, giving it a gain equivalent to that of a 4-m circular aperture (nominally 52 dB), with enhanced sidelobe performance in the preferred horizontal plane. Subreflector spillover is virtually eliminated by the use of an absorbing "guard ring" between the feed and the subreflector. A picture of the full-scale antenna is shown in figure 16, and measured radiation patterns are shown in figure 17.

Up to now we have described only ground-based antenna designs. A low sidelobe satellite antenna design for the joint Franco-German direct broadcast satellites (project TV-SAT/TDF-1) is described in a recent paper by Fasold and Lieke\(^{(26)}\) of the MBB Space Division (Munich). This antenna operates in the 11- to 12-GHz band and must provide an elliptical coverage of France and Germany from the -19-degree West synchronous orbit position. Its circularly polarized (LHC) pattern must comply with the 1977 WARC conference requirements for transmit pattern shape, sidelobe levels, and polarization purity (as well as pointing accuracy and EIRP). In addition, it must fit under the ARIANE rocket shroud. The resulting transmit antenna design is an offset-fed single reflector illuminated by an elliptical cross section corrugated feedhorn. The reflector has an elliptical outline 2.7 m wide by 1.4 m high, with a 1.5-m focal length. Sidelobes are suppressed well below the required -31 dB first sidelobe level, and cross-pol is well below -33 dB. The antenna also provides a beacon tracking mode at 17 GHz. Effects of reflector surface distortions are discussed. A separate similar receiving antenna is also mentioned. Both antennas have their reflectors hinged for deployment in orbit.

CONCLUSIONS

In the above design examples we have seen significant advancements in the design of low sidelobe reflector antennas. As mentioned by Rudge and Foster\(^{(17)}\), "The ultimate sidelobe performance which can be achieved with these [offset reflector] antennas has yet to be determined; in theory at least there is no fundamental reason why offset reflector antennas cannot equal or even exceed the best available sidelobe performance of arrays."

While the above prediction may very well come true in terms of principal plane pattern performance, my array design colleagues at Westinghouse are of the opinion that the intercardinal sidelobe performance of (substantially) rectangular aperture arrays will be very difficult to duplicate with circular or elliptical aperture reflectors. Perhaps this will just challenge the reflector designers to prove the array designers wrong.

It can be concluded that low sidelobe reflector antennas can be designed by using the following design principles:
1. **Blockage elimination** (unless Ludwig's approach is used)
2. Good surface accuracies
3. Special feeds
4. Some absorber shielding

**ACKNOWLEDGEMENTS**

Many persons contributed to this article, but special thanks are due to Bob Livolsi of GTE, Dr. W. Patton of RCA, Dr. Fasold of MBB, Dr. Rudge of ERA, and Dr. A. Ludwig of GRC for sending me photos and other materials for this article. I also appreciate the comments of my Westinghouse colleagues, especially those of E.R. Mittelman.

**REFERENCES**


Chapter News

Bill Scott
Associate Editor
Chapter News
Ford Aerospace and Communications Corp.
3939 Fabian Way
Palo Alto, CA  94303
(415) 832-5812

Atlanta
15 January 1985: "20-30 GHz, Satellite Communications Antennas" by James Cook of Scientific Atlanta, Inc.
19 February: 1985 "Radio Astronomy, A Challenge To The Microwave Engineer" by Dr. Sander Weinreb of the National Radio Astronomy Observatory.

Chicago
19 November 1984: "Millimeter Wave Monolithic Technology" by Dr. Barry Spielman of the Naval Research Laboratory.

Columbus

Dallas
20 September 1984: "Triple Frequency Patch Array" by Norma Montgomery of Texas Instruments, Inc.
18 October 1984: "Radar Scattering Direct and Inverse" by Dr. Raj Mittra of the University of Illinois.
15 November 1984: "MM Wave Research at U.T. by Dr. Tatsuo Itoh of the University of Texas.
December: "Christmas Party"
09 February 1985: "Workshop Direction Finding Systems", "System Overview" by Dr. Charles Turner of Texas Instruments, "Radar Techniques" by Dean Howard, Consultant to Naval Research Laboratory, "Receiver Technology" by Charles Frey of Texas Instruments, "Broadband Circuit Components" by Leroy Milligan formerly with Texas Instruments, "Antenna Technology" by Joseph Mosko of Naval Weapons Center.
21 February 1985: "Radio Astronomy" by Dr. Sander Weinreb of the National Radio Astronomy Observatory.
21 March 1985: "Time Domain Scattering" by Dr. K.K. Mei of the University of California, Berkeley.
18 April 1985: "Numerical Methods" by Dr. Don Wilton of the University of Houston.
16 May 1985: "Polarimetric Radar Technology" by Lloyd Root of Microm, Redstone.

IEEE Antennas and Propagation Society Newsletter, April 1985
<table>
<thead>
<tr>
<th>Date</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 December 1984:</td>
<td>&quot;Christmas Party&quot;.</td>
</tr>
<tr>
<td>19 February 1984:</td>
<td>&quot;Extrapolation of Point Rain-Rate Distributions&quot; by T.S. Chu of AT&amp;T Bell Laboratories.</td>
</tr>
<tr>
<td>27 March 1985:</td>
<td>&quot;FCC Authorization Testing Program&quot; by Art Wall.</td>
</tr>
<tr>
<td>21 May 1985:</td>
<td>&quot;Feasibility of Remotely-Sensing Ocean Currents from Satellite Platforms&quot; by Professor Robert McIntosh of the University of Massachusetts.</td>
</tr>
<tr>
<td>20 September 1984:</td>
<td>&quot;Terrestrial Microwave Imaging at Great Distances&quot; by Professor Bernard Steinberg of the University of Pennsylvania.</td>
</tr>
<tr>
<td>29 November 1984:</td>
<td>&quot;Synthetic Aperture Radar Imaging from an Inclined Geosynchronous Orbit&quot; by Dr. Kiyo Tomiyasu of General Electric Company.</td>
</tr>
<tr>
<td>23 January 1985:</td>
<td>&quot;Radio Astronomy - A Challenge to the Microwave Engineer&quot; by Dr. Sander Weinreb of the National Radio Astronomy Observatory.</td>
</tr>
<tr>
<td>16 April 1985:</td>
<td>&quot;High Speed Digital IC Performance Outlook&quot; by Dr. Paul T. Greiling of Hughes Research Laboratories. MTT-S National Lecturer.</td>
</tr>
<tr>
<td>20 September 1984:</td>
<td>&quot;Reports on AP-S Symposium/National Radio Science Meeting&quot; by Professor Hisamatsu Nakano of Hosei University, Mr. Tadashi Numazaki of Mitsubishi Electric Corporation, Mr. Yoshihide Yamada of Nippon Telegraph and Telephone Public Corporation and Mr. Jun Awaka of Ministry of Posts and Telecommunications.</td>
</tr>
</tbody>
</table>

**New AP-S Chapter Chairmen**

<table>
<thead>
<tr>
<th>Location</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Syracuse</td>
<td>James C. Rautio</td>
</tr>
<tr>
<td></td>
<td>General Electric Co.</td>
</tr>
<tr>
<td></td>
<td>EP-3, 220</td>
</tr>
<tr>
<td></td>
<td>Box 4840</td>
</tr>
<tr>
<td></td>
<td>Syracuse, N.Y., 13221</td>
</tr>
<tr>
<td></td>
<td>(315) 456-2261</td>
</tr>
<tr>
<td>Tokyo</td>
<td>Dr. Masaaki Shinji</td>
</tr>
<tr>
<td></td>
<td>Yokosuka Electrical and Communications Laboratories</td>
</tr>
<tr>
<td></td>
<td>Nippon Telegraph and Telephone Public Corporation</td>
</tr>
<tr>
<td></td>
<td>1-2356 Take, Yokosuka-shi, Kanagawa 238, Japan</td>
</tr>
</tbody>
</table>

Masaaki Shinji received the B.S., M.S. and Ph.D degrees in Electrical Engineering from Kyoto University, Kyoto, Japan, in 1958, 1961 and 1984, respectively.

Since 1961 he has been with Electrical Communication Laboratories, Nippon Telegraph and Telephone Public Corporation, Tokyo, Japan, where he has been engaged in the research and development of various radio transmission systems. His main research and development activities were on antennas for radio transmission systems. He initiated the development of antenna systems given below, while making parts of research work himself and succeeded in bringing into commercial use by directing the way of technical breakthroughs in design and fabrication process to achieve cost-effectiveness.

- Offset Cassegrain earth station antenna with 11.5 m effective aperture diameter for the Japanese satellite communication system operating in 30/20 GHz bands;
- Shaped beam horn-reflector antenna for communication satellite CS-2 operating in 30/20/6/4 GHz bands simultaneously;
- Cassegrain antenna with low cross-polarization discrimination for 20 GHz 400 Mbit/s microwave long-haul radio-relay system.

He is presently the director of the Integrated Transmission System Development Division in Yokosuka Electrical Communication Laboratory, NTT.

Dr. Shinji is a member of the Institute of Electronics and Communication Engineers in Japan. He was awarded the Inada Award by IECE of Japan in 1964 and the John T. Bolljahn Award by IEEE C-AP in 1966.
Minutes of the AP-S AdCom Meeting

02 FEBRUARY 1985
WASHINGTON, DC

Attendance

D.G. Bodnar
K.R. Carver
D.C. Chang
R.S. Cohen
L.J. Cooper
E.S. Gillespie
R.C. Hansen
W.K. Kahn
A.W. Love
R.J. Mailloux
R.E. McIntosh (presiding)
E.K. Miller
P. Neyret
Y. Rahmat-Samii
A.J. Simmons
W.R. Stone
W.L. Stutzman
K. Tomiyasu
R.I. Wolfson

Key: M-motion, S-second, P-passed, D-defeated

1.0 PRESIDENT'S WELCOME AND DISCUSSION OF AGENDA (McINTOSH)

President McIntosh called the meeting to order and welcomed members and guests, including Division IV Director Kiyo Tomiyasu. New committee chairperson assignments were announced and President McIntosh discussed his desire to "energize" some of the committees that deal with new technologies and ways to serve the members needs in these areas.

The agenda for the meeting was accepted.

2.0 MINUTES OF 24 JUNE 1984 ADCOM MEETING (SCHAUBERT)

The minutes of the last AdCom meeting were accepted.

3.0 CONSENT AGENDA

3.1 MEMBERSHIP (COOPER)
3.2 NOMINATIONS (MAILLoux)
3.3 CONSTITUTION AND BYLAWS (WOLFSON)
3.4 JOINT COMMITTEE ON NUCLEAR EMP (BAUM)
3.5 COMAR (CAIN)
3.6 AP-S HISTORIAN (HIATT)
3.7 WAVE PROPAGATION STANDARDS (SMITH)
3.8 CHAPTER ACTIVITIES (SCOTT)
3.9 EDUCATION (LO)
3.10 ANTENNA STANDARDS (BODNAR)
3.11 DISTINGUISHED LECTURERS (CHANG)
3.12 ANTENNA MEASUREMENTS (GILLESPIE)

These reports were accepted without discussion (M-Mailloux, S-Miller, P).

4.0 ACTION ITEMS

4.1 AWARDS AND FELLOWS (ISHIMARU)

Alan Simmons reported a proposal that the Best Applications Paper Award be renamed the Harold A. Wheeler Applications Paper Award (M-Simmons, S-Love, P) and that the Bylaws be so amended (M-Wolfson, S-Bodnar, P).

AdCom approved the committee's selection for the 1985 AP-S Distinguished Achievement Award and invited the recipient and his wife to be our guests at the 1985 symposium in Vancouver.

Stan Gillespie raised the issue of establishing "Engineering Merit Awards" to be given in recognition of excellence in engineering practice that is not necessarily suitable for Transactions or symposium publications. Several issues related to the implementation of such an award were discussed, but a definitive proposal was not formed and the discussion was tabled.

Bob Hansen noted that AP-S members have not received their fair share of IEEE Field Awards, and it was suggested that the awards committee appoint a member to concentrate on this.

4.2 TRANSACTIONS (FANTE)

The Transactions is proceeding smoothly and a 1985 page budget of 1400 pages for technical papers plus two cumulative indices was approved (M-Hansen, S-Mailloux, P).

4.3 COMMITTEE BUDGETS (SCHAUBERT)

The following operating budgets were approved for committees (M-Hansen, S-Mailloux, P):

Antenna Standards 1,100
Wave Propagation Standards 2,850
Chapter Activities 90
Membership 8,500
Awards and Fellows 75
Education 4,600
Publications 200
President 2,500
Secretary-Treasurer 500
Transactions Editor 11,500
Distinguished Lecturers 37,000
Antenna Measurements 300

4.4 PUBLICATIONS (KAHN)

A reviewer appreciation luncheon will be held at the Vancouver symposium (M-Kahn, S-Bodnar, P).

Walter Kahn entered a proposal that the 1985 IEEE Membership Directory be sent to all regular and higher grade AP-S members at AP-S expense. A special incremental cost of $7/member ($40K total) has been discussed with HQ (M-Kahn, S-Carver, D). The value of this action to the majority of members was questioned, as was the appropriateness of the 1985 directory which many have already ordered. AdCom will reconsider this in the future after receiving member opinions on this and other options, such as publishing an AP-S only directory.
5.0 DISCUSSION ITEMS

5.1 DIVISION IV DIRECTOR'S REPORT (TOMIYASU)

Director Tomiyasu reported the following items of interest to AP-S:

John Kraus has been selected to receive the 1985 IEEE Edison Medal.

14 AP-S members were elected to Fellow grade.

A proposal to have an IEEE Annual Conference at which IEEE Awards would be presented is being considered.

An explicit fee for management of society investment funds is being considered by IEEE and revisions in the present procedure may be adopted.

As a means of serving our members, Director Tomiyasu suggested that the society could distribute free of charge a copy of the annual symposium digest to all members. This would provide to all members a portion of the information available at our annual symposium. Keith Carver will investigate the impact of this proposal and means of implementing it.

5.2 MEETINGS (LONG)

a. Boston '84 (Schell)

Alan Simmons, Treasurer of the Boston symposium, reported that attendance exceeded 830 and that the surplus will exceed $30K, of which AP-S will receive approximately $18K.

b. Vancouver '85 (Jull)

Preparations for the meeting are progressing well. An additional advance of $2,800 was approved (M-Love, S-Hansen, P). AdCom expressed its desire that a more critical screening of papers be performed at this and future symposiums.

It was reported that AMTA will conduct a workshop on RCS during the last day.

c. Philadelphia '86 (Allen)

President McIntosh informed the AdCom that Charlie Allen has assumed the role of general chair of the meeting and that the date and location of the meeting has been changed to 6-13 June 1986 at the Franklin Plaza Hotel. Dormitory housing will be available to symposium attendees.

d. Blacksburg '87 (Stutzman)

Warren Stutzman has assumed the chair of the meeting and he has completed most of his committee assignments. He was asked by AdCom to thoroughly check the availability of meeting rooms and lodging to accomodate the symposium.

e. Syracuse '88 (Adams)

No report.

5.3 ALL TRANSACTIONS COST (LOVE)

Allan Love followed up on AdCom's desire to investigate reduction of the all-Transactions subscription, which will cost institutional subscribers $3,295 in 1985. He found the other IEEE societies have no desire to reduce this rate, which they feel is a bargain. A unilateral reduction of the AP-S non-member subscription would have little impact on the all Transactions cost to libraries, so the AdCom decided not to change the AP-S rate.

5.4 NEW MEMBER SERVICES (LOVE)

Lengthy discussions of new services suggested by Allan Love that could be offered to AP-S members produced several proposals, but a consensus on many of these proposals did not evolve. A proposal to develop specific methods for implementing AP-S funded fellowships drew some support as a means to help deserving members pursue graduate studies, but there was concern about the very limited number of members who would directly benefit from the program.

Another proposal to sponsor and subsidize a one-day short course in conjunction with the annual symposium or as a touring group was discussed and referred to the Education committee to bring a proposal to AdCom that would implement the idea in a manner that may be considered an extension of the Distinguished Lecturer program (M-Kahn, S-Hansen, P).

The high cost to authors and their organization of the $110 per page voluntary publication fee in the Transactions was also discussed. A proposal to reduce the voluntary page charge from $110 to $55 was defeated after discussion that included concerns such as the willingness or ability of HQ to provide a timely support needed and the fact that worthy papers are still published without payment of voluntary charges after a short delay to await acceptance. A proposal to direct the Transactions' Editor not to delay papers for nonpayment of voluntary page charges was defeated (M-Simmons, S-Wolfson, D) after AdCom decided it lacked the data needed to determine the impact of the proposal on authors and AP-S finances.

5.5 COMPUTER FOR SYMPOSIUM MANAGEMENT (STONE)

Ross Stone reported several possible configurations for computer equipment to assist in symposium management. His proposals generally included the use of modified versions of the software developed by Bill Richards for the 1983 Houston symposium. AdCom approved the principle of developing a computer and generalized software for handling symposium administration, and the President appointed a committee to make a specific recommendation (M-Hansen, S-Carver, P). The committee consists of Bob Hansen, Ross Stone, and Lee Cooper.

5.6 NEW ANTENNA TECHNOLOGY (PATTON)

The committee had no report, but President McIntosh informed AdCom that he was establishing an ad hoc committee, to be chaired by David Chang, for the purpose of promoting basic research in electromagnetics. This committee will complement the society's activities in new technology and will work with other IEEE societies. An initial meeting of representatives from AP-S and MTT with program directors at NSF was productive and plans are under way to conduct a workshop for the purpose of identifying critical problem areas and means of stimulating basic research funding. Interested persons in industry, government and universities may contact David Chang at the University of Colorado for information.

5.7 IEEE ENERGY COMMITTEE (COHEN)

Bob Cohen discussed the role of the IEEE Energy Committee and solicited inputs from AdCom and AP-S members on anything they want the energy committee to consider.
5.8 NEWSLETTER (STONE)

Bob Stone reported that publication delays are greatly reduced and that the time from the deadline for material to the receipt of an issue by West Coast members is approximately 7 weeks. This is acceptable for purposes of the Newsletter.

5.9 URSI (STONE)

AdCom was informed of recent events in URSI including a report on the General Assembly in Florence, Italy. The next meeting of USNC will be at the summer meeting in Vancouver.

5.10 PACE (SCHRANK)

Bob Stone presented a brief report of PACE activities by Hal Schrank.

5.11 LONG RANGE PLANNING (MAILLOUX)

Bob Mailloux recently became chair of the committee and he acknowledged the new directive for long-range planning to emphasize technology issues that AP-S should support and means to do this. He noted that several items discussed at the meeting provided tasks for his consideration.

6.0 NEW BUSINESS

Ed Miller, new chair of the Education Committee, outlined an extensive list of topics that his committee will consider, including tutorial papers, video lectures, computer graphics, internships, and special sessions at symposiums. The committee consists of Y.T. Lo, A.T. Adams, W.L. Stutzman, S.J. Kubina, P.W. Barber, D.G. Dudley and L. Medgyesi-Mitschang.

7.0 NEXT ADCOM MEETING

The next AdCom meeting will be held at 1:00 p.m., Sunday, 16 June 1985 in Vancouver, BC.

---

Antenna Designer’s Notebook

Hal Schrank
Associate Editor
Antenna Designer’s Notebook
Westinghouse Electric Corp.
Box 746 MS 333
Baltimore, MD 21203
(301) 765-2973

EFFECTS OF RANDOM ERRORS ON SIDELOBES OF PHASED ARRAYS

This useful nomograph relates the random RMS sidelobe levels of phased array patterns to various independent random error sources. My good friend Theo C. Cheston derived this chart and was kind enough to submit it to our Designer’s Notebook. He is with the Naval Research Labs, Code 5370, in Washington D.C.

INTRODUCTION

The sidelobes of phased arrays with many elements may be grouped into three kinds, of which only the last applies to this chart.

1. Near-in Sidelobes are functions of the aperture distribution and have values related to the peak gain.
2. Sidelobes Caused by Systematic Errors are related to peak gain when the error is systematic over the entire aperture (e.g. spherical or quadratic phase error) or they may be related to the radiating element gain, properly weighted, if systematic over a group of elements.
3. Sidelobes Caused by Random Errors are randomly distributed over the wide-angle regions and have RMS values that are related to the gain of an element (expressed in dB). The RMS values are independent of the number of elements and of the amplitude distribution. The average pattern of these sidelobes follows the element patterns which have a peak gain at broadside of close to 5 dBi (relative to isotropic) for close to half-wavelength spacing.

USING THE CHESTON CHART

The chart gives the RMS values of random sidelobes caused by three common error sources, namely (1) random amplitude error, (2) random phase error, and (3) randomly distributed failed elements.

The amplitude errors are expressed on the left-hand scales in fractional voltage (v/v) form, along with some equivalent decibel (dB) values.

The phase errors are expressed on the right-hand scale in RMS or ± peak forms, both in degrees. A third scale is provided for quantization errors in terms of the number of bits in digital phase shifters.

The number of failed elements is given by the inner scales, expressed in terms of either blocked radiators or failed phase shifters. The most likely failure of elements is the failure of their phase shifters, which cause RMS sidelobes 3 dB higher than those caused by randomly blocked elements. It is assumed that blocked elements absorb power and do not radiate, while failed phase shifters radiate with random phase errors.

EQUIVALENT ERROR EFFECTS

The chart can be used to find the values of random errors that cause equivalent random sidelobes. For example: RMS sidelobes of ~10 dB can be caused by a 10° RMS phase error; or by a 1.5 dB RMS amplitude error, or by the failure of 1.5% of the phase shifters, provided these failures are randomly distributed.

MULTIPLE ERRORS

If multiple independently random errors exist simultaneously, an equivalent composite error is given by the square root of the sum of their squares. This can be done by expressing all errors in terms of the equivalent amplitude values (v/v) as read from the chart.

ACKNOWLEDGEMENT

Many thanks to Theo Cheston for submitting this nomograph and permitting us to share it with our members. Mr. Cheston has been an AP-S member for many years and was recently made an IEEE Fellow.
IDEAS FOR ANTENNA DESIGNER'S NOTEBOOK are needed for future issues of the Newsletter. Please send your suggestions to Hal Schrank (address above) and they will be considered for publication as quickly as possible. Topics can include antenna design tips, equations, nomographs, or short-cuts as well as ideas to improve or facilitate measurements. Propagation topics are also welcome, in fact we strongly urge our propagation members to help us balance the coverage in this column.
David M. Pozar Named Centennial Young Engineer by IEEE

David M. Pozar was honored as a Centennial Young Engineer by the IEEE, representing the Antennas and Propagation Society. Dr. Pozar was recognized at a special banquet concluding the IEEE's Centennial Year. It was attended by some 700 engineers and scientists, as well as leaders from government, industry, and academe. He received a "Centennial Key to the Future" from 1984 IEEE President Richard J. Gowen. The "Keys to the Future" were presented to 34 individuals representing the Institute's 33 technical societies. Each recipient was identified as an individual in the early stages of his/her career "who best demonstrates sound understanding of the evolving technologies" in the individual's chosen field and whose "progress shows the greatest promise for applying these technologies to the development of new industrial products and systems for the improvement of society." The keys were laser cut from a three-inch silicon disc composed of metal oxide semiconductor material.

Dr. Pozar received the BSEE and MSEE degrees from the University of Akron in 1975 and 1976, and the PhD from Ohio State University in Columbus in 1980. He is currently an Assistant Professor in the Department of Electrical and Computer Engineering at the University of Massachusetts. He has received a 1984 National Science Foundation Presidential Young Investigator Award.

AP-S Members!!!

Your suggestions are solicited for names of candidates to be nominated for the 1986 AP Society Administrative Committee (Adcom) and for the position of Vice-President. Our by-laws require that any candidate for Vice-President must be, or have been, a member of the Adcom. Please call or write to me before May 15th.

Allan W. Love,
Chairman, Nominating Committee
Satellite Systems Division
Rockwell International
P. O. Box 3644
Sensi Beach, CA 90740

(213) 394-3369
Chapter I, the introduction, also provides a historical review as seen from the perspective of the staff of Queen Mary College. Chapter II sets the stage for the entire volume by reviewing some of the basic concepts of reflector antenna systems. Chapter III, entitled "Cylindrical Corrugated Waveguides" gives the analysis of the propagation and radiation properties of these structures and defines the balanced hybrid condition. The stage is set herein to use the surface impedance model where it is adequate and to supplement it with the more exact space harmonic approach as needed, particularly for the cross polarization treatment. Much useful design data is given. It is noted, for example, that Fig. 3.21 defines dimensions only in terms of ratios. Thus, in this particular case, the horn is still undefined.

Chapter IV, "Conical Corrugated Waveguides," makes use of spherical mode expansions to obtain the radiation patterns and compares these with those from integration over a spherical cap. It is this reviewer's opinion that these patterns could also be obtained from a GTD approach which would also give the back lobe radiation. Indeed, almost any approach would yield accurate co-polar main beam patterns. Indeed, several other approaches are given.

Chapter V, "Design of Cylindrical and Conical Corrugated Horns," applies the results of the preceding two chapters to horn design. This is done in such a way that the designer need not, as the authors state, "cross all the theoretical bridges of earlier chapters." Designs are presented that include a variety of parameters and the pertinent design curves. These include use of multiple modes and multiple operational frequencies.

Chapter VI, "Manufacture and Testing of Corrugated Horns," focuses attention on the cylindrical and conical horns. They observe that the construction of such horns is difficult. They overlook one relatively inexpensive mass production technique that would be applicable to rectangular horns, i.e., extrusion of flat corrugated surfaces to be made into corrugated horns.

Chapter VII, "Rectangular and Elliptical Corrugated Horns," again observes that there is no suitable theory for describing the modal configuration within the horn and shows no radiation patterns even though the GTD has been applied for this purpose (ref. 98). They are quite correct in stating that the cylindrical and conical horns certainly have superior polarization properties. This reviewer suggests that the GTD could also be used to obtain cross polarization patterns of such horns since it would be dictated by the horn edge more than by the modal structure.

Reviewed by:
LEON PETERS, JR.
1320 Kinnear Road
ElectroScience Laboratory
The Ohio State University
Columbus, OH 43212
One of the reasons I bought an APPLE II+ several years ago was the graphics capabilities offered by that computer. Besides providing two graphics modes, "a Lo-Res" 40x40 pixel, 16-color screen, and a "Hi-Res" 280x192 pixel, 6-color screens, there are a number of straightforward commands that make the graphics environment relatively easy to use. In addition, shape tables can be defined which permit animation effects to be achieved. Thus, for example, straight-lines are plotted using the single command (in HI-RES), H PLOT x1,y1 to x2,y2 to ... For shape N from the shape table, the various commands include SCALE to change the size of the plotted shape, ROT to establish the rotational position, and DRAW shape #N at x,y to put the shape given by N at x,y. These capabilities can be useful not only for arcade-type displays, but for plotting engineering and scientific data, and producing symbolic-oriented graphics. Such features evidently are not easily achieved in some of the widely used mini- and main-frame graphics packages.

Although the on-screen graphics that the APPLE and similar computers can generate are quite impressive, even by today's standards, there remains the problem of obtaining hard copy output. For some purposes, color photos of the display may be adequate. This can be an inexpensive, but less convenient, alternative to more costly computer-hardware options, which might include color dot-matrix and ink-jet printers and pen plotters. Prices for the latter devices have dipped below $1000. All of these options have the characteristic that they are relatively slow and unsuited for handling the large amounts of data that even modest computations can generate.

In choosing an APPLE for its graphics capabilities, I was partially motivated by the possibility of experimenting with using computer movies for teaching purposes and for displaying computer modeling results. At the time (mid 1981) I bought my APPLE, I had the fuzzy idea of perhaps using an 8 mm camera for photographing the screen image, and in that way, making some crude computer movies. For various reasons, I've never gotten around to doing that, but advancing technology now offers another more convenient way to make computer-graphic movies.

That technology involves an editing video-cassette recorder (VCR) teamed up with a computer. The computer generates the graphics images, which can be displayed on the TV/monitor and which are also sent to the VCR which runs under computer control. As each graphics image is finished, N copies are recorded on the VCR, where N > 1 is selected to produce the desired effect when the recorded tape is played back. The frames are electronically numbered, and the edit feature of the VCR ensures that each new frame will be recorded "glitch-free" in the appropriate place on the tape. This is especially important where the graphics images can not be generated "real time," but where a continuous dynamic presentation is desired for subsequent viewing.

This kind of capability has been available for some time. Here at LLNL, we have been using a VCR to record the black and white images provided on our TMDS (Television Monitor Display System) monitors to make movies available on a quick-turnaround basis to computer modelers. These movies were typically used for overnight runs to permit next-day viewing of the computation. While the picture quality achieved with this system is not as good as the 35 mm film output provided by our Dicomed-camera system, the latter's turnaround time can be two weeks or longer. The responsiveness of the TMDS recording is a great asset, and when archival records are needed, the film medium is available as an alternative.

More recently, we implemented a similar system to service the Electronics Engineering Department Applied Computational Engineering (ACE) Laboratory. The ACE Lab is part of a VAX-based EE computer network, and it was desired to give engineers using this network the option of using computer movies to display their modeling results. Most of our present ACE Lab modeling activity is electromagnetics oriented, including radiation, propagation and scattering problems involving linear and nonlinear media, as well as field-particle problems. These models incorporate differential-equation treatments in the time domain, and can generate an extremely large volume of output data, making movie data presentation very effective. The VAX-controlled VCR employs a Sony 3/4 inch V05850 editing recorder, and provides presently 16 colors from a palette of 256. Our initial system could generate about 20 minutes of recorded tape in 12 hours of operation, due primarily to a 9600 baud limit imposed by the computer port and control interface for the VCR. A planned upgrade will increase the number of colors to 2^24 to provide continuous tone images, as well as to increase the throughput by a factor of 10 or so. The basic system cost for this capability was about $40,000, with the upgrade estimated to cost about $50,000 more.

Our first application of the ACE-Lab movie system was in connection with a summer 1984 program at LLNL on "Computer and Computer Graphic Applications in Engineering Education." The purpose of this program was to develop computer movies for use in teaching various EE subjects at the college level. Movies of nominally 5-10 minutes in length, together with a written text that contains stills from the movie and some appropriate discussion of what it showed, would form a "module." Several modules were developed during our first summer. More discussion on this general topic may be suitable for another column.

"But what," you ask, "is the connection between the ACE-Lab movie system and PCs for AP?" That's a good question, the answer to which I think it is now possible, and for a relatively modest cost, to achieve this same movie-making capability on a PC. What is required is some appropriate interface/controller board and software for the PC, and an editing video recorder. The price for these two items together is around $5,000 to $6,000, a substantial reduction in cost from our ACE-Lab systems, but with relatively little sacrifice in performance.

The editing video recorder is a 1/2 inch VHS format, which JVC and Panasonic currently produce, at a list
price of $3,500 or so, but I've been told that discounts are available. Hardware for controlling the VCR is available from BCD Associates, Inc. (205 Broadway Tech Center, 7510 North Broadway Ext., Oklahoma City, OK 73116, (405) 843-4574). Among the products they offer is the BCD Video Link 232, which provides a standard RS-232 Serial Port for controlling an editing VCR. It will work with Sony, Panasonic, and JVC VCRs, and costs $2,195 with option 02, with which the Video Link can read standard SMPTE time code as well as the BCD Frame Number Code. This unit makes it possible to do single-frame editing and insertion. I haven't yet had the opportunity of seeing this system operate, but it sounds like what I've been looking for.

A users group has started and a newsletter called BCD Interact is now being published. One of the applications of the BCD hardware is in producing and running interactive video-tape and video-disc instructional material. In the next column, I'll cover more aspects of PC applications in education, focusing on the use of graphics, both stored and real time.

---

**Report of the AP-S Transactions Editor**

Ronald L. Fante  
AVCO Systems Division  
201 Lowell Street  
Wilmington, MA 01887

Dear Readers:

Harold Raemer (Guest Editor) tells me that he has finally received all the papers he invited from the 1984 Symposium. With a little luck in the review cycle, these papers will probably be published in the Fall of 1985. There is little chance of an earlier date because at present (1/26/85), I am working on the June, 1985 issue. For your information, there is about a four-month delay between the time I mail all the manuscripts in an issue to New York and the publication of that issue.

I also thought it would be interesting to cite a few statistics. From July, 1983 through June, 1984, a total of 325 papers were received by the Transactions. All of these have now completed the review cycle, and the acceptance statistics are as follows: 6% accepted as is, 34% accepted with minor revision, 37% required major revision, and 23% were rejected. Several of those papers sent to the authors for major revision were ultimately rejected because the authors were unable to ultimately convince the reviewers and Associate Editor that their results were correct. This, however, is the exception.

Finally, I would like to remind authors that, if possible, a copy of a signed copyright form should accompany each new paper. Copies of these forms are printed at the back of the Transactions every few months.

Ron Fante, Editor  

---

**Future Contents of the Transactions on Antennas and Propagation**

The following list of advance contents is provided as a service to those who may have an immediate need for the information in the articles. The NEWSLETTER regrets that space limitations permit the listing of only the corresponding author. Interested readers may contact the authors directly to request preprints or additional information.

June 1985

"Electromagnetic Coupling to a Conducting Wire Behind an Aperture of Arbitrary Size and Shape"  
R. Harrington  
Dept. of EE  
Syracuse University  
Syracuse, NY 13210

"Directly-Coupled Multiple Resonator Wideband Microstrip Antennas"  
G. Kumar  
Dept. of EE  
Univ. of Manitoba  
Winnipeg, Canada

"Analysis of Maximum Entropy Processing in the Space-Angle Domain: Two Target Case"  
B. Steinberg  
Dept. of EE  
Univ. of Pennsylvania  
Philadelphia, PA 19104

"Dipole and Slot Elements and Arrays on Semi-infinite Substrates"  
D. Schaubert  
Dept. of EE  
Univ. of Massachusetts  
Amherst, MA 01003

"Renormalization of EM Fields in Application to Large Angle Scattering from Randomly-Continuous Media and Sparse Particle Distributions"  
D. DeWolf  
Dept. of EE  
Virginia Polytechnic Institute  
Blacksburg, VA 24061

"Current Induced on a Conducting Cylinder Located Near the Planar Interface Between Two Semi-Infinite Half Spaces"  
C. Butler  
Dept. of EE  
Univ. of Houston  
Houston, TX 77004

"Abrupt Changes in Cross Polarizations Observed During Thunder"  
O. Furuta  
Kokusai Denshin Deniva Ltd.  
2-1-23 Nakameguro, Meguro-ku  
Tokyo 153, Japan

"Monopole Antenna on Circular Disk Over Flat Earth"  
J. Richmond  
Dept. of EE  
Ohio State Univ.  
1320 Kinnear Road  
Columbus, OH 43212
"Far-Field Patterns of Spaceborne Antennas from Plane-Polar Near-Field Measurement"
Y. Rahmat-Samii
Jet Propulsion Lab.
Pasadena, CA 91109

"Response of a Source on Top of a Vertically Stratified Half-Space"
W. C. Chew
Schlumberger
Old Quarry Road
Ridgefield, CT 06877

"A Microstrip Array of Concentric Annular Rings"
A. Bhattacharyya
Indian Institute of Technology
Kharapur, India 721302

"An Offset Reflector Antenna with Low Sidelobes"
N. Gunesekaran
College of Engineering
Anna Univ.
Madras 600025, India

"Validation of FD-TD Modeling of the Radar Cross Section of Three-Dimensional Structures Spanning up to 9 Wavelengths"
A. Taflove
Dept. of EE
Northwestern Univ.
Evanston, IL 60201

"Aperture Efficiency of Villaneuve Arrays"
R. Hansen
Box 215
Tarzana, CA 91356

"Pattern Nulling in Difference Pattern by Amplitude Control"
T. Vu
Dept. of EE
Univ. of New South Wales
Sydney, Australia

"Hybrid Solutions at Internal Resonances"
L. N. Medgyesi-Mitschang
McDonnell Douglas Res. Lab
St. Louis, MO 63166

"Numerical Evaluation of Complex Resonances of an Elliptic Cylinder"
R. Naishdham
Dept. of EE
Univ. of Mississippi
University, MS 38677

"Numerical Analysis of Asymmetrical Spiral Antenna"
H. Nakano
Hosei Univ.
3-7-2 Kajino-cho
Kaganei City
Tokyo, 184 Japan

"Simple Expressions for a Function Occurring in Diffraction Theory"
J. Volakis
Radiation Lab.
Univ. of Michigan
Ann Arbor, MI 48109

"Scattering from a Finite Length Rod with End Point Contribution"
L. Ersoy
Ford Aerospace
3939 Fabian Way
Palo Alto, CA 94303

"Correction to 'On Expansion of Cylindrical Bessel Function'"
M. Narasimhan
TRW's newest commitment to the future of satellite communications is the revolutionary Advanced Communication Technology Satellite (ACTS). Designed to provide cost-effective communications capability across 20/30 GHz-frequency bands, ACTS promises to deliver unparalleled performance and provide unmatched opportunities for the Satellite Antenna System Design Engineers involved.

TRW's Antenna Systems Laboratory is proud of its pioneering role in sophisticated satellite antenna technologies. We're building our reputation on projects like the Fleet Satellite Communication System (FLTSATCOM), the Communication Payloads for the MILSTAR spacecraft and a diversity of other state-of-the-art assignments. We have openings at all levels for talented Antenna System and Microwave Component Engineers.

TRW offers an excellent salary and benefits package. For immediate consideration, call collect to Dr. S. J. Hamada at (213) 535-7471. Or, if unable to call, send your resume including salary history to:


A Company Called TRW
Transactions.


The Remote Sensing Laboratory of the University of Kansas Center for Research, Inc., has a new supplement to their Publications List. It includes publication data and abstracts of all technical reports and published articles written by RSL members from 1981 through 1983, with 60 pages of entries plus indices. The volume is available for $8.00 including postage of Kansas Center for Research, Inc., 2291 Irving Hill Drive, Lawrence, Kansas 66045-2969.

New Program in Radar Systems at Kansas

The University of Kansas Department of Electrical and Computer Engineering announces a formal M.S. program in Radar Systems as a companion to its existing program in Telecommunications Engineering. This program formalizes the graduate work in radar systems that has been a mainstay of the Kansas Graduate program for 20 years.

The program is designed to allow a student to obtain the M.S. in one calendar year, although students employed on research projects often will take an additional semester.


For more information, contact Prof. R.K. Moore, Director, Radar Systems and Remote Sensing Laboratory, The University of Kansas, 2291 Irving Hill Drive, Lawrence, Kansas 66045-2969.

Acknowledgment

Prof. George L. Kramerich's Hidden Name Puzzle, "Events in Electrical History", appeared in the February, 1985 AP-S Newsletter. It should have been noted that it first appeared in the Newsletter of the Industry Applications Society.

Pre-Publication Offer on 1985 IEEE U.S. Salary Survey

The "1985 IEEE US Membership Salary and Fringe Benefit Survey" report is to be published by the IEEE United States Activities Board Survey Task Force on May 11, 1985. The Survey report is based on information gathered from a questionnaire mailed in early January 1985 to a sample of US IEEE Fellows, Senior Members, Members, and Associates. 30,000 questionnaires were mailed. According to the Task Force, data derived from the returns can be applied to the full non-student membership of over 170,000 with a 95% degree of confidence.

The printed report will incorporate data on IEEE members' salaries as they relate to job function, supervisory responsibility, type of employer, company size, years of experience, level of education, geographic area, level of responsibility, plus many other variables. The Survey displays 25 variables through tables, charts, and graphs showing relationships which include the following: Income vs. engineering experience by highest degree earned; income vs. geographical region and area by industry or service of employer; income vs. years with present employer by organization job function; income vs. professional and supervisory level of responsibility.

The Survey report will also contain a section on fringe benefits. Responses were analyzed with respect to pension coverage, vesting requirements and supplementary retirement plans, and employer contributions to insurance for employees and dependants.

Prices for orders for the Survey postmarked prior to May 11, 1985 are $29.95 for IEEE members and $49.95 for nonmembers. Subsequent orders are priced at $49.95 for members and $69.95 for nonmembers. A $2.00 charge is added to all non-prepaid orders of under $100.00. The Survey can be ordered from the IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08854.

FIVE OUTSTANDING BOOKS

by John Kraus
Ohio State University

1. ELECTROMAGNETICS New 3rd edition. The standard text on electricity and magnetism now with much more on transmission lines, guides and antennas plus fiber optics, remote sensing and bio-engineering. A thousand illustrations and 1500 examples and problems. 800 pages. Hard (1H) $35.00

2. ANTENNAS The antenna bible. A classic book covering the basics of antenna theory by a world authority. Hundreds of diagrams, 553 pages. Hard (2H) $45.00

3. RADIO ASTRONOMY Basic theory of radio astronomy techniques and observations. The only complete text on the subject. 486 pages. Soft (3S) $22.50

4. OUR COSMIC UNIVERSE A profusely illustrated introduction to the new astronomy in simple terms. "Every phase of modern astronomy is covered in systematic flowing detail. The organization is superb." 297 pages. Soft (4S) $9.50. Hard (4H) $12.50

5. BIG EARTH "Takes you to the frontiers of astronomy with a sense of great adventures to come." "Fascinating, alarming, enlightening." John Kraus' own science-adventure from the early days of radio to the most distant known objects in the universe. For all ages. Illustrated. 228 pages. Soft (5S) $4.50. Hard (5H) $7.50

CYGNUS-QUASAR BOOKS
P.O. Box 85, Powell, Ohio 43065

Price

Send
Ohio residents add 5½% tax . . . . . . .
Shipping: $1 per book . . . . . . . . . .
Total
The 1985 North American Radio Science Meeting and International IEEE/AP-S Symposium are jointly sponsored by the United States and Canadian National Committees for the International Union of Radio Science (URSI) and the Institute of Electrical and Electronics Engineers Antennas and Propagation Society (IEEE/AP-S). All commissions of URSI have been invited to participate. The technical sessions will be held from Monday June 17 to Friday June 21, 1985 on the campus of the University of British Columbia, Vancouver, Canada.

For many years Canadian radio scientists and AP-S members have found a welcome forum for their work at the annual meetings of the USNC/URSI and IEEE/AP-S and on a few previous occasions they have been hosts. Joint US/Canadian URSI meetings were held in Ottawa in 1961 and 1967. IEEE/AP-S cosponsored an URSI symposium on Electromagnetic Wave Theory in Toronto in 1959. Only once before has the annual joint meeting between USNC/URSI and IEEE/AP-S been held in Canada: at Laval University, Quebec, in 1980.

Vancouver has one of the finest natural settings of any city and the University of British Columbia at the tip of Point Grey is particularly fortunately situated. The social arrangements will take advantage of these surroundings. On Monday there will be an evening dinner cruise in Vancouver Harbour. Tuesday's luncheon cruise is to the site of the Expo '86 World's Fair. On Tuesday evening there is to be a salmon barbeque on the grounds of the Museum of Anthropology, dedicated to West Coast Indian culture. Wednesday's banquet is Chinese and with entertainment. There will be tours of Vancouver, and by bus and ferry to Victoria, including the renowned Butchart Gardens on Vancouver Island.

Canadian radio scientists and regional members of IEEE/AP-S take this opportunity to extend a warm welcome to their colleagues from the U.S. and abroad. We hope your visit to the Canadian west coast will be useful and enjoyable.
Meetings and Symposia

Raymond P. Wasky
Science Applications
International Corporation
1010 Woodman Drive
Dayton, OH 45432
(513) 256-1170

Editor's Note: The address in the February AP-S Newsletter was incorrect. Please send all notices for meetings, symposia, and short courses to: R.P. Wasky, S.A.I. Corp., 1010 Woodman Drive, Dayton, OH 45432.

2nd JORDAN INTERNATIONAL ELECTRICAL AND ELECTRONIC ENGINEERING CONFERENCE
28 April - 1 May 1985
University of Jordan
Amman, Jordan

Contact: Dr. M.K. Abdelazaaz
Conference Vice Chairman
Electrical Engineering Dept.
University of Jordan
Amman, Jordan

IEEE AP/MTT-S 5th ANNUAL BENJAMIN FRANKLIN SYMPOSIUM
4 May 1985
Philadelphia, PA

Contact: Ms. Helen Yonan
Moore School of E.E.
University of Pennsylvania
Philadelphia, PA 19104
(215) 890-0106

INTERNATIONAL RADAR CONFERENCE
6-9 May 1985
Marriott Crystal Gateway Hotel
Crystal City, Arlington VA

Contact: Dr. R.T. Hill
2002 Birdseye Lane
Bowie, MD 20715
(301) 262-8792

NATIONAL AEROSPACE & ELECTRONICS CONFERENCE (NAECON) '85
21-23 May 1985
Dayton Convention Center
Dayton, OH

Contact: Patricia V. Weaver
NAECON '85
110 E. Monument Ave.
Dayton, OH 45402
(513) 253-1133

1985 IEEE MTT-S INTERNATIONAL MICROWAVE SYMPOSIUM
4-6 June 1985
Stouffer's Riverfront Towers
St. Louis, MO

Contact: Dr. Fred J. Rosenbaum
Central Microwave Co.
12180 Pritchard Farm Rd.
St. Louis, MO 63043
(314) 291-5270

1985 NORTH AMERICAN RADIO SCIENCE MEETING AND INTERNATIONAL IEEE/AP-S SYMPOSIUM
17-21 June 1985
University of British Columbia
Vancouver, BC

Contact: Mr. K. Charbonneau
Conference Services
National Research Council
Ottawa, Ontario
Canada K1A OR6
(613) 993-9009

1985 INTERNATIONAL SYMPOSIUM ON MICROWAVE TECHNOLOGY IN INDUSTRIAL DEVELOPMENT-
BRAZIL
22-25 July 1985
Campinas, Sao Paulo
Brazil

Contact: Attilio Jose Giarola
SBMO Symposium Committee
UNICAMP-CCPG (Retorial)
CP 1170
13100 Campinas, SP, Brazil

FIFTH INTERNATIONAL CONFERENCE ON MATHEMATICAL MODELLING
29-31 July 1985
University of California
Berkeley, CA

Contact: Xavier J.R. Avula
Institute for Applied Sciences
Branch Office
P.O. Box 1488
Rolla, MO 65401

SNOW SYMPOSIUM V
13-15 August 1985
Army C.R.R.E.L.
Hanover, NH

Contact: George W. Attken
Army Cold Regions Research and Engineering Laboratory
Attn: CRREL-RG
72 Lyme Road
Hanover, NH 03755-1290

1985 INTERNATIONAL SYMPOSIUM ON ANTENNAS AND PROPAGATION, JAPAN
20-22 August 1985
Kyoto, Japan

Contact: Prof. Kazuaki Takao
Department of Electrical Engineering
Kyoto University
Kyoto 606, Japan

INTERNATIONAL SYMPOSIUM ON ANTENNAS AND EM THEORY
26-28 August 1985
Beijing, Peoples Republic of China

Contact: Prof. Mao Yukuan
Northwest Telecommunication Engineering Institute
Xi'an, Shaanxi Province, China
Cable No. 1331, Xi'an, China

2ND INTERNATIONAL CONFERENCE ON SURFACE WAVES IN PLASMAS AND SOLIDS
5-11 September 1985
Ohrad, Yugoslavia

Contact: Prof. Slobodan Vukovic
Institute of Physics
PO Box 57
YU-11001 Beograd
Yugoslavia
Telephone: (011) 212-219
Telex: YU-11002 INFIZ

1985 INTERNATIONAL GEOSCIENCE AND REMOTE SENSING SYMPOSIUM (IGARSS '85) AND USNC/URSI COMMISSION F MEETING
7-9 October 1985
Amherst, MA

Contact: Prof. Calvin T. Swift
Technical Program Chairman
Department of Electrical and Computer Engineering
University of Massachusetts
Amherst, MA 01003
MELECON '85
8-10 October 1985
Madrid, Spain
Contact: Prof. Antonio Luque
Instituto de Energia Solar
E.T.S.I. Telecommunicacion - 
UPM
Ciudad Universitaria
Madrid 3, Spain

PHASED ARRAYS '85
15-18 October 1985
Bedford, MA
Sponsors: RADC, MITRE, University of Massachussets
Contact: Dr. Hans Steyskal
RADC/EEA
Hanscom AFB, MA 01731
(617) 861-2052

COMPUTATIONAL METHODS IN ELECTROMAG-
NETICS
1-4 April 1985
Monterey, CA
Contact: Southeastern Center for Electrical Engineering
Education
Central Florida Office
11th & Massachusetts Ave.
St. Cloud, FL 32769
Attn: Ann Beekman
(305) 892-6146

ANTENNAS AND ARRAYS: ANALYSIS, SYN-
THESIS, AND APPLICATION
29 April - 3 May 1985
George Washington University
Washington, D.C.
Contact: Continuing Engineering Education Program
George Washington Univ.
Washington, D.C. 20052
(800) 424-9773

ADAPTIVE ANTENNA SIGNAL PROCESSING FOR
INTERFERENCE REJECTION
13-17 May 1985
UCLA, Los Angeles, CA
Contact: Dept. of Engineering and Science
10995 Le Conte Ave., Rm 637
Los Angeles, CA 90024
(213) 825-1296

COMPUTER AIDED DESIGN OF MICROSTRIP
CIRCUITS AND ANTENNAS
28-31 May 1985
University of Colorado
Boulder, CO
Contact: K. C. Gupta
Electrical Engineering Dept.
University of Colorado
Campus Box 425
Boulder, CO 80309
(303) 492-7498

MODERN ANTENNAS
4-7 June 1985
Technology Service Corp.
Silver Spring, Maryland
Contact: Helmut E. Schrank
Westinghouse Electric Corp.
Box 746 MS 333
Baltimore, MD 21203
(301)-765-2973

REFLECTOR ANTENNA ANALYSIS, COMPUTATION
AND DESIGN
10-14 June 1985
University of Southern California
Los Angeles, CA
Contact: W.V.T. Rusch
Dept. of Electrical Engineering
University of Southern California
Los Angeles, CA 90007
(213) 743-5549

ANTENNA PARAMETER MEASUREMENT BY NEAR-
FIELD TECHNIQUES
10-14 June 1985
Boulder, CO
Contact: Richard L. Lewis
Section 723.05
Electromagnetic Fields Div.
National Bureau of Standards
Boulder, CO 80303
(303) 497-1196

SYNTHETIC APERTURE RADAR TECHNOLOGY
AND APPLICATIONS
8-12 July 1983
Ann Arbor, MI
Contact: Adam Kozma
College of Engineering
Chrysler Center/North Campus
The University of Michigan
Ann Arbor, MI 48109-2092
(313)-764-8490

WORKSHOP ON MEASUREMENT, PROCESSING, AND
ANALYSIS OF RADAR TARGET SIGNATURES
10-13 September 1985
Columbus OH
Contact: Jonathan D. Young
ElectroScience Laboratory
1320 Kinnear Road
Columbus OH 43212
(614)-422-6194

MODERN GEOMETRICAL THEORY OF DIFFRACTION
16-20 September 1985
Columbus OH
Contact: Leon Peters, Jr.
ElectroScience Laboratory
1320 Kinnear Road
Columbus OH 43212
(614)-422-6194

COMPUTATIONAL METHODS IN ELECTROMAG-
NETICS
1-4 April 1985
Monterey, CA
Contact: Southeastern Center for Electrical Engineering
Education
Central Florida Office
11th & Massachusetts Ave.
St. Cloud, FL 32769
Attn: Ann Beekman
(305) 892-6146

ANTENNAS AND ARRAYS: ANALYSIS, SYN-
THESIS, AND APPLICATION
29 April - 3 May 1985
George Washington University
Washington, D.C.
Contact: Continuing Engineering Education Program
George Washington Univ.
Washington, D.C. 20052
(800) 424-9773

ADAPTIVE ANTENNA SIGNAL PROCESSING FOR
INTERFERENCE REJECTION
13-17 May 1985
UCLA, Los Angeles, CA
Contact: Dept. of Engineering and Science
10995 Le Conte Ave., Rm 637
Los Angeles, CA 90024
(213) 825-1296

COMPUTER AIDED DESIGN OF MICROSTRIP
CIRCUITS AND ANTENNAS
28-31 May 1985
University of Colorado
Boulder, CO
Contact: K. C. Gupta
Electrical Engineering Dept.
University of Colorado
Campus Box 425
Boulder, CO 80309
(303) 492-7498

MODERN ANTENNAS
4-7 June 1985
Technology Service Corp.
Silver Spring, Maryland
Contact: Helmut E. Schrank
Westinghouse Electric Corp.
Box 746 MS 333
Baltimore, MD 21203
(301)-765-2973

REFLECTOR ANTENNA ANALYSIS, COMPUTATION
AND DESIGN
10-14 June 1985
University of Southern California
Los Angeles, CA
Contact: W.V.T. Rusch
Dept. of Electrical Engineering
University of Southern California
Los Angeles, CA 90007
(213) 743-5549

ANTENNA PARAMETER MEASUREMENT BY NEAR-
FIELD TECHNIQUES
10-14 June 1985
Boulder, CO
Contact: Richard L. Lewis
Section 723.05
Electromagnetic Fields Div.
National Bureau of Standards
Boulder, CO 80303
(303) 497-1196

SYNTHETIC APERTURE RADAR TECHNOLOGY
AND APPLICATIONS
8-12 July 1983
Ann Arbor, MI
Contact: Adam Kozma
College of Engineering
Chrysler Center/North Campus
The University of Michigan
Ann Arbor, MI 48109-2092
(313)-764-8490

WORKSHOP ON MEASUREMENT, PROCESSING, AND
ANALYSIS OF RADAR TARGET SIGNATURES
10-13 September 1985
Columbus OH
Contact: Jonathan D. Young
ElectroScience Laboratory
1320 Kinnear Road
Columbus OH 43212
(614)-422-6194

MODERN GEOMETRICAL THEORY OF DIFFRACTION
16-20 September 1985
Columbus OH
Contact: Leon Peters, Jr.
ElectroScience Laboratory
1320 Kinnear Road
Columbus OH 43212
(614)-422-6194
INSTITUTIONAL LISTINGS

The IEEE Antennas and Propagation Society is grateful for the assistance given by the firms listed below and on the inside back cover and invites application for Industrial Listings from other firms interested in the field of Antennas and Propagation.

DORNE & MARGOLIN, INC.
Bohemia, NY 11716
Aircraft Antennas, Search & Rescue Products, ECM, General Aviation, Airline, SATCOM, Communications, Navigation, Tactical, Manpack, Mobile, ELT's

Electronics Eaton Advanced HF Products to direct
The Systems EW/SIGINT Antennas, Pedestals and Turnkey
Missile Telemetry Antennas

NewTech Executive Search
Search Consultants/Microwave, EW & Communications Industry
ED DORT
Antenna & Propagation Specialist
Senior Search Consultant
65 No. Broadway, Suite D, Salem, NH 03079, (603) 893-5080

EATON Advanced Electronics
Eaton Corporation AIL Division
Commack Road
Deer Park, N.Y. 11729
Research, Development, and Production of Antenna, Radar Air Traffic Control, and Electronic Warfare Systems

THE AEROSPACE CORPORATION
Electronics Research Laboratory
P.O. Box 93957, Los Angeles CA 90009
H. E. King (213) 648-6843
Communications, Radar, Radiometry, Antenna R & D

TRANSCO PRODUCTS, INC.
4241 Glencoe Ave., Marina del Rey, CA 90291
(213) 822-8086
Products to direct RF energy - Coaxial & Waveguide Switches, Antennas, Filters, Hybrids, Couplers, Multiplexers, Power Dividers, RF & Antenna Subsystems

R. C. HANSEN, INC.
Box 215, Tarzana, CA 91356
818-345-0770
Consulting Engineer in Antennas, Slot Arrays, Phased Arrays, & Multiple Beam Antennas.

TECOM Industries, Inc. 21526 Osborne Street, Canoga Park, CA 91304
(213) 341-4010 • TLX 69-8476
• EW/SIGINT Antennas, Pedestals and Turnkey Systems
• Missile Telemetry Antennas

ENGINEERING RESEARCH GROUP
Mentor Park, CA 94025
Research in Electromagnetic Phenomena Devices and Techniques

Antenna Products Corp.
P.O. Box 520, Mineral Wells, TX 76067
(817) 325-3301
TELEX 882163
HF Antennas, Baluns, Transformers, and UHF Collinear, Corner Reflector and LP Antennas NAV Aids, Localizers and Glideslope Antennas

Aerospace Systems Division
P. O. Box 1062
Boulder, CO 80306
Contact R. E. Munson
(303) 441-5254
Microstrip Antenna Systems for Aircraft Missiles and Satellites Conformal Phased Arrays Antenna R&D and Production

ElectroSpace Systems, Inc.
Box 1359
Richardson, TX 75080
214-231-9303
Antennas, Masts, and Positioners Antenna Pointing Systems and Switching Systems

Radio-Research Instrument Co., Inc.
2 Lake Ave. Ext., Danbury, CT 06811
TEL: (203) 792-6666 • TELEX 59244 RADA DURY

ANTENNAS 18" TO 60 FT. DIA.
TRACKING MOUNTS • RADAR SYSTEMS
THREAT EMITTERS 200 KHz to 35 Ghz.
SEND FOR FREE CATALOG

DAMASKOS, INC. (215) 358-0200
P. O. Box 469
Concordville PA 19331
Research and Development in Electromagnetic Scattering, Radiation, Materials Design, Analysis, Computations, Measurements

Dayton-Granger Antenna Research & Design, Inc.
Dayton-Granger, Inc. (HQ)
812 NW 1st St., POB 14070
Ft. Lauderdale, FL 33302
Tel: (305) 463-3451
TWX: 510-955-9760
WE DESIGN ANTENNAS TO MEET ANY NEED
AIRCRAFT ANTENNAS • ANTENNA R&D
ELECTROSTATICS • LIGHTNING R&D
Dayton-Granger Western Division
(Costa Mesa, CA)
Dayton-Granger Ltd. (United Kingdom)
EMPLOYMENT OPPORTUNITIES

Antenna and Microwave Instrumentation
Scientific Atlanta
P.O. Box 105027
Atlanta, GA 30348
Tel: 404 925-5050
RESEARCH, DESIGN AND PRODUCTION OF MICROWAVE ANTENNAS AND RADOMES
NURAD
2165 Druid Park Dr. Baltimore, MD 21211
TELEPHONE (301)489-1700 TWX/TELEX (710)234-1071

The charge for six Institutional Listings is $300.00 or $350.00 for twelve consecutive listings. Agency fee is not granted on Institutional Listings. Applications and checks (made payable to “IEEE”) should be sent to Mel Bonaviso, Finance Administrator, IEEE Technical Activities, 345 East 47th Street, New York, N.Y. 10017.