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Radar Cheff: A Bibliography

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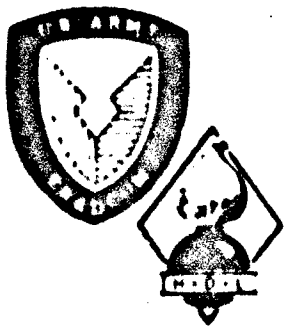

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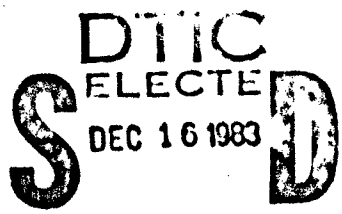

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Chaff bistatic cross section	Chaff reflectivity

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A search has been conducted to find unclassified literature citations related to the electromagnetic wave scattering properties of radar chaff. Over 155 specific citations (not including books) were found and compiled chronologically, with abstracts, in a main bibliography. They were also separately listed into 1 or more of 10 specific categories according to content.

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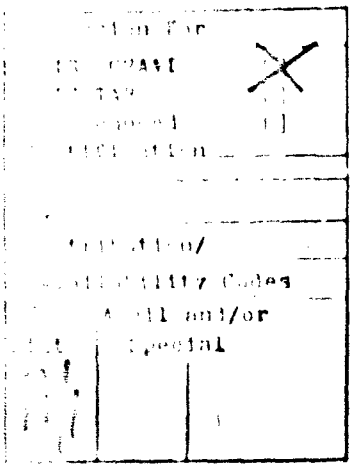

1. INTRODUCTION

Chaff has been an important consideration in radar systems almost since the beginnings of radar. Chaff usually consists of a collection of highly reflecting elemental scatterers dispersed over a volume in space for the purpose of confusing a radar so that its ability to track or observe other objects (targets) is impaired. The volume is often referred to as a chaff cloud.

The principles on which radar impairment is based are similar whether the radar system is monostatic or bistatic. The main idea is to cause a relatively large amount of energy, dispersed in both angle and range, to be reflected to the receiver; the energy is ideally large enough to dominate (mask) that due to target scattering.

Clearly, many variables enter into a determination of the effectiveness of chaff in achieving its goal. Some of the variables that relate to the radar only are range, doppler, and angle resolution of the system; type of system (surveillance, tracking, track-while-scan); type of signal processing (pulse compression, MTI) and other items (power, frequency, bandwidth, integration times allowed, etc.). Some of the variables that relate to the chaff alone are scattering properties of the chaff elements, physical properties of the elements (fall rates, mass, size, material), density (elements per unit volume of space), and distribution (uniform, Gaussian, columnar, globular, etc.). Some variables affecting chaff effectiveness are neither radar or chaff related; most of these variables are weather related. Some examples are: wind average directions and speed; wind variations (shear-productions); and presence of rain, hail, sleet, snow, etc.

The principle purpose of this report is to furnish a bibliography of literature citations that relate mainly to chaff. For the most part, articles related to radar have been omitted; for example, a paper dealing with ordinary radar signal detection in the presence of chaff would be omitted. Similarly, papers dealing with the physics of weather phenomena are omitted. In some cases, however, papers were found that were difficult to omit even though they were radar or weather related. For example, a paper dealing with a special method of polarization processing that, in the opinion of the author, may have future merit when applied to the chaff problem would be included. Similarly, a paper that deals with the wind-caused translation of chaff elements would be included.

In order to make the overall bibliography more useful and to aid in categorizing the applications of the citations, each citation has been placed in one or more separate bibliographies according to the following categories (see section 4, Bibliographies By Category):

(a) Dipole Monostatic Reflectivity

(b) Dipole Bistatic Reflectivity

(c) Chaff Monostatic Reflectivity

(d) Chaff Bistatic Reflectivity

(e) Dipole Impedance

(f) Dipole Losses

(g) Chaff/Dipole Wave Attenuation

(h) Chaff Dispensation

(i) Chaff Physical Properties

(j) Other

Because most chaff elements are dipoles, special attention was given to papers giving theory and/or measurements relating to field scattering cross sections of these elements. Some citations relate only to monostatic scattering (category (a)); others relate to bistatic scattering (category (b)) which, in some papers, includes the monostatic case. When a citation dealt mainly with the overall chaff (cloud) scattered fields or cross section (reflectivity) it was placed in categories (c) or (d).

Since impedance plays an important role in the scattering properties of a dipole, papers dealing specifically with this subject were listed in category (e). Similarly, papers that considered dipoles of finite conductivity (loss) were listed in category (f).

Papers in category (g) deal in some way with the attenuation of a wave as it progresses through a chaff cloud.

Category (h) identifies articles that give some information on techniques of dispensing chaff elements to form a cloud. Category (i) is reserved for citations that deal with various physical properties of chaff elements, such as effects of dense versus sparse clouds, characteristics of elements during fall (rotation rates, fall rates, etc.), power spectrum, correlations, element shape, etc.

Finally, category (j) lists those citations that seemed to apply, or might apply, to the chaff problem, but were not directly applicable to categories (a) through (i).

The overall bibliography is reasonably comprehensive. It is the result of a search of only the unclassified (open) literature, including mainly journals, conference proceedings, and company, university, and government reports. Should the reader know of omitted citations that should be added, the author would be most happy to receive them. Although a listing of book citations was not a significant thrust of the literature search, a very selective short list is included of those books most frequently cited in the entries of the main bibliography.

2. METHODS OF LITERATURE SEARCH

The search was conducted in three basic parts:

(1) Electronic Data Base Searches

1. INSPEC BASE, Files 12 and 13
2. COMPENDEX BASE, File 8
3. NTIS BASE, File 6

(2) IEEE Publications Searches

(3) Citations Contained in References

2.1 Electronic Data Base Searches

The INSPEC data base spans time periods from 1969 through 1976 (file 12) and 1977 to date (file 13). All electronic searches were initiated either on 16 March 1983 or 17 March 1983. The base contains over 2,000,000 citations, with updates monthly. It covers over 2,600 journals, plus many other sources, such as conference proceedings, patents, etc.

The COMPENDIX data base spans the time period from 1970 to date (file 8) and contains over 1,100,000 citations with monthly updates; it covers approximately 3,500 journal sources, plus numerous conference proceedings and selected reports.

The NTIS data base spans the time period from 1964 to date (file 6) and contains over 950,000 citations with biweekly updates. This data base covers U. S. Government sponsored reports (no journals) that are not issued by the Government Printing Office.

All three electronic data bases were searched with three key word combinations: (chaff/radar), (dipole/scatter/radar), and (dipole/attenuate/radar). A total of 140 citations were generated; some duplicate entries occurred, and some entries were not considered applicable and were excluded.

2.2 IEEE Publications Searches

Nearly all publications of the Institute of Electrical and Electronics Engineers (IEEE), and its predecessor, the Institute of Radio Engineers (IRE), were searched by use of variously available cumulative and yearly indexes, special cumulative (radar) indexes, and issue-by-issue searches. The overall coverages of these efforts were Proceedings of IRE/IEEE from 1913 through March 1983; all IRE/IEEE publications, 1948-1971 and 1975-1981; IEEE Transacations on Antennas and Propagation, 1969 through January 1983; IEEE Transactions on Microwave Theory and Techniques, 1953-1982; and IEEE Transactions on Military Electronics/Aerospace and Electronic Systems, 1951 through March 1983.

2.3 Citations Within References

As references were developed from the above searches, their citation lists were examined, and applicable entries were obtained. The references of the new citations were, in turn, examined until the applicable sources were exhausted.

3. GENERAL BIBLIOGRAPHY

Entries in the following general bibliography are listed chronologically by year, and, as much as possible, chronologically within each year. Each citation is keyed at its end according to whether it is mainly theoretical (T), contains measured data (M), or both (T,M). Entries with the key (X) are those for which no hard copy was available for examination at the time of writing, but were included on the basis of title only.

Finally, we note that some citations have been taken from an unclassified part of a classified bibliography on chaff.[†] These citations have been classified based on title only and are keyed by the symbol (PA). They were not available in hard copy at the time of writing.

1982

1982 Medgyesi-Mitschang, L. N., and C. Eftimiu, "Scattering from Wires and Open Cylinders of Finite Length Using Entire Domain Galerkin Expansions," IEEE Trans. on Antennas and Propagation, v. AP-30, no. 4, July 1982, pp. 628-636, (T,M).

ABSTRACT: Electromagnetic (EM) scattering by finite-length, perfectly conducting open cylinders (i.e., ducts or tubes) with circular cross sections is considered. The case of a straight wire, viewed as a thin cylinder, is examined in this context. The salient features of this study are a) use of the electric field integral equation (EFIE) as a starting point, b) solution of this equation by the Galerkin method, and c) representation of the axial variation of the currents on the scatterer by an entire domain (Fourier series) expansion. Edge modes are considered in the expansion set and their effect is examined. The open cylinder backscatter cross section is computed as a function of aspect angle for various radii and lengths and is compared with measured data.

1982 Butters, B. C. F., "Chaff," IEE Proceedings, vol. 129, Pt. F, no. 3, June 1982, pp. 197-201, (T,M).

ABSTRACT: The paper reviews the development of chaff as an electronic-countermeasures (ECM) technique and describes the basic principles of chaff as reflectors of radar waves. The various common types of chaff are described, including their main physical and aerodynamic characteristics. Some illustration of the use of chaff is given in naval and airforce applications.

[†]Alexander, P., "Chaff Literature Survey," Harry Diamond Laboratories (U. S. Army) Report DELHD-RT-AD, R-11400-83-2, April 1983.

1981 Knott, E. F., D. J. Lewinski, and S. D. Hunt,
"Chaff Theoretical/Analytical Characterization and Validation Program,"
Georgia Institute of Technology, Final Report on Project No. A-2516,
30 September 1981, also DTIC document no. ADA105893, (T,M).

ABSTRACT: This report describes the modeling of radar returns from chaff. The dipoles are allowed to follow helical paths as they fall, and the signal scintillation characteristics of the entire chaff cloud are assumed to be the same as those of a small collection of up to 1000 dipoles. The dipole motion model is based upon the solution of the aerodynamic force equations over small time intervals. The scintillation signal is normalized with respect to the contribution of a single dipole.

The mean amplitude of the return from the entire cloud is computed assuming a bivariate Gaussian distribution for the dipole number density in a plane transverse to the axis of a plume of chaff. The computation of the amplitude requires a numerical integration of the product of the radar antenna radiation pattern and the dipole density in a spherical shell centered on the radar. When this is done for several concentric shells, the range dependence of the return can be displayed. The antenna need not be pointed at the cloud.

Unfortunately, the numerical integration consumes large blocks of CPU time and the program was used to study a limited sample of test dipoles. The bandwidth of the signal received from collections of 16 to 1024 dipoles was less than 150 Hz and was essentially independent of the number of dipoles. It is, in fact, the dipole motion characteristics, and not the dipole spacing, that influences and signal bandwidth. Local wind turbulence will expand the spectrum somewhat.

Because of the long running time, adequate running time needs to be allocated for the evaluation of tactical situations. The program is useful for diagnostic applications but future efforts need to be given to improving the dipole concentration description: Empirical descriptions could be devised if adequate measurement data were available.

1981 Streable, G. W., and L. W. Pearson,
"A Numerical Study on Realizable Broad-Band and Equivalent Admittances for Dipole and Loop Antennas," IEEE Trans on Antennas and Propagation, v. AP-29, no. 5, September 1981, pp. 707-717, (T).

ABSTRACT: Some realizable broad-band equivalent circuits for straight-wire and wire-loop structures are developed. The realizability of the circuits is explored in terms of the positive-real (PR) function properties of the circuit admittances. The postulate of PR "terminal eigen-admittances" as couched by Pearson and Wilton [8] is generally supported in the numerical examples, but a potential counterexample---that of the quarter-driven wire---occurs as well. A "dominant pole-pair" approach leads to a quite satisfactory approximate synthesis for the structures studied here. The conduct of this approximate synthesis is described in the context of the Bott-Duffin synthesis procedure. The circuits developed are tested by comparing their computed transient response with the response of electrodynamic models for the same structures.

1981b Traci, R. M., et al.,
"Study of Chaff Dispersal from Aircraft," Science Applications, Inc. La Jolla, CA, report SAI-023-81-290LJ, August 1981, (PA).

ABSTRACT: The author abstract is not available.

1981b Heath, G. E.,
"Properties of the Linear Polarization Bistatic Scattering Matrix," IEEE Trans. on Antennas and Propagation, v. AP-29, no. 3, May 1981, pp. 523-525, (T).

ABSTRACT: When the propagation plane containing the transmitter and receiver lines of sight is used as the polarization plane, the scattering matrix characterizing linearly polarized bistatic scattering from plane-symmetric targets exhibits scattering geometry symmetries which can be exploited to reduce the time and expense in obtaining bistatic scattering data from static range measurements and theoretical or computer calculations. In this communication the linear polarization symmetry relations are derived and used to determine the minimum number of measurements needed for the complete characterization of target scattering.

1981a Heath, G. E.,
"Bistatic Scattering Reflection Asymmetry, Polarization Reversal Asymmetry, and Polarization Reversal Reflection Symmetry," IEEE Trans. on Antennas and Propagation, v. AP-29, no. 3, May 1981, pp. 429-434, (T).

ABSTRACT: Circularly polarized bistatic scattering from plane-symmetric targets with otherwise arbitrary electrical properties exhibits reflection asymmetries, polarization reversal asymmetries, and polarization reversal reflection symmetries which are useful for bistatic polar data interpretation. Familiarity with these bistatic scattering polarization properties will also facilitate the interpretation of depolarization and beam displacement phenomena in off-set reflector antenna characteristics. In addition, the symmetries can be used to reduce the time and expense in obtaining data from bistatic-scattering radar measurements, offset reflector antenna measurements, and theoretical or computer calculations. The reflection asymmetry, polarization reversal asymmetry, and polarization reversal reflection symmetry relations are derived. The symmetry relations are then combined with the principle of electromagnetic reciprocity to determine the minimum number of measurements needed to characterize target scattering.

1981 Poelman, A. J.,
"A Study of Controllable Polarization Applied to Radar," Professional Paper STC PP-180, SHAPE Technical Centre, The Hague, April 1981, also DTIC document no. ADB057311, (T,M).

ABSTRACT: The ratio of the average target signal power to the average unwanted signal power at the input of a radar detection receiver can be significantly increased by applying the method of clutter/interference suppression described in this paper.

The polarization state of the emissions, the object-backscatter field, and the interference field, are all taken into account in a technique referred to as "virtual adaptation" of the polarization state

Poelman, A. J., (cont.)

of the transmit and receive antennae. This technique can be used to complement filtering techniques in the frequency and space domains.

Attention is specifically drawn to the potential advantages of simple n-th order polarization suppression filters of the "logic-product" type, which might have applications in cases where there are uncertainties regarding the polarization state of unwanted signals that are to be suppressed.

The paper concludes with a brief overview of the general benefits of using the polarization state as an element of information in radar applications.

1981 Beeker, C. W., and A. P. Dean,
"System for Multistage, Aerial Dissemination and Rapid Dispersion of Preselected Substances," patent application filed 9 April 1981, serial no. 252632, also DTIC document no. ADD008708, (T).

ABSTRACT: A system for multistage aerial dispersion of materials or substances in minute form to provide an aerial array of interspaced clouds or cloud-like patterns of such materials or substances. Although the materials or substances may be in the nature of fertilizers, pesticides, herbicides and the like, suitable for domestic applications, there is basically disclosed a system for military applications. In this latter regard, rapid multipositional aerial dispersion of decoy material, such as thin metallic strips, chaff, or the like, to deceive or confuse enemy radar is achieved by packaging the decoy material in a carrier missile structured to carry a plurality of separate frangible canisters or modules respectively containing the decoy material in the form of a myriad of such metallic strips or chaff. The carrier missile while airborne is adapted to explosively shatter the canisters or modules in predetermined, times sequence and thereby widely scatter their contents of metallic strips, or chaff, as a multitude of discrete dipolar elements to form a series of separate interspaced clouds or cloud-like regions of decoy material with each possessing the electronic or radar tracking characteristics simulating an airborne object, such as a helicopter or the like, desired to be protected from detection. Thus, the series of clouds or regions of decoy material conceal the actual locational position of the airborne object desired to be protected by producing multiple confusing tracking signals to devices relying upon such signals for detection and/or aiming purposes and thereby affording delay time to permit the real, or actual, airborne target to advance out of range of accurate detection and/or enemy weaponfire.

1981 Boerner, W-M., M. B. El-Arini, C-Y. Chan, S. Saatchi, W-S. Ip, P. M. Mastoris, and B-Y. Foo,
"Polarization Utilization in Radar Target Reconstruction," University of Illinois at Chicago Circle, Communications Laboratory, Technical Report UICC, CL-EMID-NANRAR-81-01, 15 January 1981, also DTIC document no. ADA097990, (T).

ABSTRACT: Basic theories for polarization utilization in radar target reconstruction are presented and a general literature review is given.

Boerner, W-M., M. B. El-Arini, C-Y. Chan, S. Saatchi, W-S. Ip, P. M. Mastoris, and B-Y. Foo, (cont.)

It is shown that a scattering phenomenon can be uniquely expressed given the elements of either one of [S], [M], [M_m] or the coordinates of the optimal polarization, i.e. unique inversion relations among the four equivalent representations exist which is relevant to target polarization synthesis. The developed theories are verified by computer computation using measurement and/or model scattering data as inputs.

1981a Traci, R. M., et al.,
"Chaff Dispersion Analysis: Preliminary Development and Scoping Studies," Science Applications, Inc., La Jolla, CA, report SAI-093-81-069LJ, January 1981, (FA).

ABSTRACT: Results are presented for a program of engineering research which involved the preliminary assessment, model development and parametric examination of relevant aspects of the radar reflecting chaff dispersion problem. The ultimate goal, to which the program contributes, is the development of an analysis method which quantitatively describes the time history of the three-dimensional chaff cloud development from deployment in the airstream to times for which the cloud is of operational interest. To account for the disparate spatial scales and transport mechanisms of interest, the problem is separated into a "nearfield" problem which focuses attention on the dominant mechanisms effecting the early time "blooming" of the chaff cloud, namely the turbulent wake and trailing vortex system of the dispersing aircraft and a "farfield" problem with emphasis on the motion, distortion and growth of the cloud under the influence of atmospheric transport and diffusion mechanisms. In addition to accounting for these complicating mechanisms, the chaff cloud must be described in sufficient parametric detail to satisfy the rather extreme requirements of an eventual radar cross-section analysis. Hence the modeling effort is directed at providing not only the distribution of dipole mean concentrations within the cloud but also quantitative information on the probability and size of "hotspots" as well as the distribution of dipole orientation (or polarization).

The approach made use of state-of-the-art computational fluid dynamics and turbulent flow analysis techniques as well as available evidence and analytical estimates of dipole dynamics and turbulent response. In the nearfield, results are presented for dipole transport in a turbulent wake and in a simplified model for the aircraft vortex system for various parametric conditions. The present study concentrated largely on the development, testing and demonstration of an approach for the farfield dispersion problem which resulted in the CHAFF model and its computer implementation. The model describes the evolution of the chaff cloud in response to atmospheric processes in terms of the mean concentration of various dipole "classes" (defined by dipole type and mean orientation), the root-mean-square (RMS) fluctuation in concentration due to turbulence, the mean orientation of each dipole class and the RMS fluctuation in dipole orientation. The principal approximations in the model, quasi-equilibrium approximation for dipole turbulent response, are confirmed via analytic studies of dipole rectilinear and rotational response to a turbulent airflow. These studies also resulted in preliminary correla-

Traci, R. M., et al. (cont.)

tions for dipole settling rate, settling mode or orientation and probability density function with respect to dipole orientation for use in the dispersion model. Finally, the model was demonstrated and results presented for a parametric study of the effect of real atmospheric processes on cloud evolution.

1980

1980 Cherenaky, S.,
"Preliminary Report on Computer Simulations of Chaff and Processor Response to Chaff," Br. 11400, Harry Diamond Laboratories, Adelphi, MD, August 1980, (PA).

ABSTRACT: The author abstract is not available. In its place the author introduction is presented.

Any radar system must be able to function in environments simultaneously composed of two types of scatterers--targets and clutter. Targets are objects we wish to locate and/or track, and clutter is the name given to sources of undesirable radar echoes--that is, everything other than targets. Clutter can be detrimental to radar performance in two ways: it can cause prefunction (false alarms), or desensitization (suppression of target). Clutter may result from reflections from trees, land, sea surfaces, meteorological and numerous other sources. Another form of clutter, commonly employed as a passive ECM tactic, is due to chaff. Chaff consists of large numbers of small metallic scatterers used to confuse enemy radars. In its most common configuration, chaff is dispensed from behind an aircraft forming a corridor effectively "cloaking" the dispensing and/or other aircraft.

Chaff was one of the first forms of ECM to be used (Skolnik), but its importance was believed to have been diminished after World War II when much faster aircraft came on the scene. Recent evidence seems to indicate that chaff is indeed a serious threat to radar performance and deserving of detailed investigation.

This paper describes a mathematical model for the spatial and time dependent characteristics of chaff as seen by airborne radar. A series of FORTRAN programs was written which allows the user to define an array of chaff and fuze parameters and generate a representation of a chaff cloud. The LEGS model of the PATRIOT processor was implemented and can be flown through the cloud at a desired trajectory. Processor and dipole statistics are displayed graphically at the conclusion of each simulated flight.

1979

1979b Ioannidis, G. A.,
"Model for Spectral and Polarization Characteristics of Chaff," IEEE Trans. on Aerospace and Electronic Systems, vol. 5, AES-15, no. 5, September 1979, pp. 723-726, (T).

Ioannidis, G. A., (cont.)

ABSTRACT: A stochastic model which describes the spectral and polarization characteristics of radar echoes from a chaff cloud consisting of a collection of rotating dipoles, which may have either completely random or preferred orientations, is presented.

1979a Ioannidis, G. A., and D. E. Hammers,
"Optimum Antenna Polarizations for Target Discrimination in Clutter," IEEE Trans. on Antennas and Propagation, vol. AP-27, no. 3, May 1979, pp. 357-363, (T).

ABSTRACT: The concept of Stokes vectors and Stokes target operators is used to obtain optimum antenna polarizations for target discrimination in the presence of background clutter. The analysis involves a constrained maximization of the ratio of two bilinear forms, representing the signal-to-interference power ratio.

1978

1978 Dube, V.,
"XM-130 Continued Development, Final Technical Report," Tracor, Inc., Austin, TX, document no. T-78-AU-9042-U, Revision A, 13 September 1978, also DTIC document no. ADA060496, (M).

ABSTRACT: The U. S. Army Armament R & D Command, ARRADCOM, awarded Contract DAAK10-77-C-0048 on 15 April 1977 for the continued development of the M-130 Aircraft General Purpose Dispenser including the fabrication and delivery of associated payload, the M-1 chaff, M-796 Impulse Cartridges, and M-206 Flares.

1978 Garbacz, R. J.,
"Chaff Radar Cross Section Studies and Calculations," Ohio State University, ElectroScience Laboratory, Columbus, OH, Technical Report AFAL-TR-79-1114, May 1978, also DTIC document no. ADA080989, (T,M).

ABSTRACT: The objective of Contract F33615-76-C-1024 has been to analytically and experimentally investigate chaff scattering and the reduction of antenna-related radar corss section. This final report summarizes results obtained during the interim 1 January 1976 through 30 June 1977 on the chaff aspect of the effort. Included are summaries of 1) an investigation of scattering by a long wire excited by either a plane wave or by a nearby short dipole with sinusoidal current distribution and 2) an experimental study of small foam shapes very densely coated with chaff filaments.

1978 Dedrick, K. G., A. R. Hessing, and G. L. Johnson,
"Bistatic Radar Scattering by Randomly Oriented Wires," IEEE Trans. on Antennas and Propagation, vol. AP-26, no. 3, May 1978, pp. 420-426,(T).

ABSTRACT: Formulas and numerical results are presented for the bistatic-radar scattering cross section of an atmosphere of randomly oriented conducting wires. The work is based on the Stokes parameter description of the general radiation field, so that the polarization of transmitter

Dedrick, K. G., A. R. Hessing, and G. L. Johnson, (cont.)

and receiver antenna arrays can be chosen in any desired combination. The wires in the atmosphere can be of arbitary length, and the second order expressions due to Einarsson are used for the cross section of a single wire. The average over wire orientations is generally evaluated using a Monte Carlo method, but for wires that are very long compared to the wavelength, an approximate analytical averaging method can be used. For long wires, the final results show strong scattering in the forward direction for most antenna polarization combinations and for short wires, the scattering is more nearly isotropic.

1978 Rivers, W. K.,
"Radar Clutter," Appendix III (Revision 1) of Volume II (Radar Clutter) of Book II (Appendixes) of Assessment of Requirements of 1985-2000 Era U. S. Navy Surface Ships for Surveillance Radar Information (Report FS-77-144, Revision 1, Johns Hopkins University, Applied Physics Laboratory, March 1978) also DTIC document no. ADA061136, (T,M).

ABSTRACT: No abstract available.

1978 Carignan, D. J., et al.
"Contaminant and Release Device for Fluids," patent application filed 3 January 1978, serial no. 866 741, also DTIC document no. ADD004692, (T).

ABSTRACT: A dispenser retains a hermetically sealed metal canister which holds a pyrophoric fluid, radar chaff, other electronic countermeasure materials or a combination thereof for ejection from an aircraft. Several openings in the canister are sealed with Pyrofuze foil material closures and a Pyrofuze wire braid is connected from each closure to a Pyrofuze delay braid. When a gas producing squib on the dispenser is fired, the canister is forced from the dispenser and the Pryofuze delay braid is ignited by the flame front from the squib. The delay braid then ignites the Pyrofuze wire braid which burns to each of the closures causing them to burn away thereby releasing and igniting the pyrophoric material from the canister. A safety tab on one corner of the canister protects the delay braid and prevents ignition until the canister is ejected from the dispenser.

1977

1977 Elia, A. D.,
"High Sensitivity Chaff Measurement System," U. S. Naval Research Laboratory Memorandum Report 3571, October 1977, also DTIC document no. ADA048768, (T,M).

ABSTRACT: A system is described which measured the Radar Cross Section of very small chaff elements. The system consists of an anechoic chamber, transmit and receive circuitry with associated antennas, and a special circuit used to reduce system noise. The system and measurement procedure is described and some typical measurements are shown. Alternate uses for the system are also described.

1977 Brunk, J. E.,
"Chaff Element Redesign," DTIC document ADC011717, August 1977, (PA).

ABSTRACT: The redesign of chaff dipoles for improved doppler response was investigated. Improvements in the chaff element dynamics during both the transient phase of flight (immediately following aircraft release) and the steady-state descent phase were considered. For the steady-state descent phase, both improved and new dipole shapes were evaluated as a means of achieving specified magnitudes of azimuth rotation rate, radius of spiral, and attitude. From aerodynamic analyses and six-degrees-of-freedom simulations the motion characteristics of the conventional dipole configurations were determined as a function of the element cross-section, planform, thickness, twist, bend, and C. G. offset. Two characteristic types of motion were identified; for low values of the cross-section Reynolds number (RN less than 50) the angular motion was found to be predominately a flat spin, with the angular rate depending primarily upon element twist; at high Reynolds numbers the elements exhibited autorotation about their longitudinal axis, and the angular motion was determined by the magnus force and C.G. offset. Several new configurations and concepts appear promising as means of improving the chaff cloud dispersion and doppler return.

1977 Silverman, G. A.,
"Chaff Polarization," DTIC document no. ADB018658L, May 1977, (PA).

ABSTRACT: The results of an experimental study of the polarization and spatial orientation of G-band, half-wavelength dipoles are reported. Some knowledge of the polarization and, by inference, the spatial orientation of the dipoles provides information about the dynamic behavior of a chaff cloud and its observed radar cross section. Tentatively, it is concluded that the polarization varies from a near-vertical state toward an isotropic state as time develops. The results obtained are based on a study of aluminum-coated, glass fibers (one-mil diameter, approximately one-inch long) dispensed from an AN/ALE-38 chaff pod at 16,000 feet, mean sea level (MSL).

1977 Robillard, P. E., and R. H. Herrett,
"Circular Polarized Static RCS Patterns for Bistatic Scattering," Volumes I and II, Delco Electronics, Goleta, GA, April 1977, (X).

ABSTRACT: No abstract available.

1976

1976 Sundaram, G. S.,
"Expendables in Electronic Warfare — Proven Decoys for Survival," International Defense Review, December 1976, pp. 1045-1050, (T,M).

ABSTRACT: No abstract available.

1976 Poelman, A. J.,
"Cross Correlation of Orthogonally Polarized Backscatter Components," IEEE Trans. on Aerospace and Electronic Systems, vol. AES-12, no. 6, November 1976, pp. 674-682, (T).

ABSTRACT: The backscattering of an elliptically polarized plane wave from two kinds of complex radar objects is considered from the standpoint of coherency theory, and the antenna polarizations that give rise to maximum correlated and uncorrelated orthogonally polarized components in the receiving channels are discussed. The resulting observations may find application in radar systems which use the correlation between the received orthogonally polarized components for detecting targets in natural and man-made interference.

1976 Adrian, D. J.,
"Chaff Discrimination System," DTIC document no. ADD002394, May 1976, (PA).

ABSTRACT: This invention relates to a chaff discrimination system for a missile fuze and more particularly to a means for discriminating between a target and chaff by using the difference in polarization properties of the echoes in a radio fuze system.

1975

1975 Garbacz, R. J., V. Cable, R. Wickliff, R. Caldecott, J. Buk, D. Lam, K. Demarest, and A. Yee,
"Advanced Radar Deflector Studies," Ohio State University, ElectroScience Laboratory, Report AFAL-TR-75-219, December 1975, also DTIC document no. ADB013005, (T,M).

ABSTRACT: The purpose of this effort was to develop user-oriented computer programs for the investigation of the electromagnetic scattering and extinction characteristics of clouds of linear metallic resonant wires for chaff applications, including the effects of mutual coupling between wires. Programs based upon Crout-like algorithms working on matrices generated by the method of moments were developed to accommodate up to 200 wires; sparse matrix and iterative algorithms were programmed for larger numbers of wires All programs are documented in this report.

Data generated during the course of the effort are also presented in this report, including curves of the reduction (due to coupling) in average scattering cross section as a function of number density of chaff elements.

1975 Brunk, J., D. Mihora, and P. Jaffe,
"Chaff Aerodynamics," Alpha Research, Inc., report AFAL-TR-75-81 for Air Force Avionics Laboratory, November 1975, (T,M).

ABSTRACT: The aerodynamic characteristics of thirteen distinct chaff dipole configurations were determined from drop tests of individual elements in a special enclosed test chamber. The dipole motion and trajectory were recorded by multi-image photographs taken by orthogonal still cameras equipped with specially designed synchronized rotating shutters.

Brunk, J., D. Mihora, and P. Jaffe, (cont.)

The dynamic behavior and descent rate of the dipoles was found to depend greatly upon the principal cross-section dimensions of the filaments.

Aerodynamic forces and moment coefficients for each dipole configuration were computed from the photographic multi-image motion data using photogrammetric and aerodynamic data reduction programs developed as part of the effort. The resulting aerodynamic coefficient data were successfully correlated with Reynolds number, angle of attack, and various other parameters. While the force coefficients were found to be large and in general agreement with the various theories for creeping flow, the moment coefficients were extremely small and resulted primarily from configurational asymmetries.

Using both the experimental data and theory, aerodynamic coefficient tables for representative dipole configurations, suitable for 6-DOF simulation of dipole motion, were prepared. These aerodynamic data were subsequently used in conjunction with a 6-DOF Monte Carlo trajectory program, modified for inclusion of stochastic atmospheric turbulence, for preliminary simulations of chaff dipole motion in both quiescent and turbulent atmospheres.

Turbulence was found to have a large effect on the translational motion of the dipole, but only a small effect on its angular motion.

1975 Pinson, C. C.,
"Chaff Cloud Signature," International Symposium on Electromagnetic Compatibility Record, San Antonio, TX, October 7-9, 1975, (M).

ABSTRACT: No abstract available.

1975 Puskar, R. J.,
"Chaff Cloud RCS Studies and Measurements Using a High Resolution Radar," DTIC document no. ADB007252L, July 1975 (PA).

ABSTRACT: A series of chaff cloud radar cross section (RCS) measurements were performed on a static radar range using both a long pulse (200 ns) and a short pulse (2 ns) H-band radar system. The long pulse tests were used to measure the RCS of the entire chaff cloud, while the short pulse tests were used to obtain fine grained RCS data on the chaff RCS as a function of depth into the chaff cloud. A high PRF, 15,750 Hz, was used so that the rapid amplitude scintillations of the chaff RCS could be measured. Pyrotechnic dispensers positioned on the ground in front of the radar were used to launch the chaff. The RCS data are processed to obtain autorelation functions and power spectral (scintillation) densities, which show correlation times on the order of 10 ms and scintillation rates up to 250 Hz. By measuring the RCS of a secondary target located behind the chaff cloud, the data show that as dipole density is decreased by diffusion of the elements with time, the chaff cloud becomes completely transparent to the radar. Measurements of both the horizontal and verticle polarization, provide some insight into the aerodynamics behavior of the chaff elements, in that the horizontally polarized RCS is found to be greater in magnitude than the vertically polarized RCS and persists for longer period of time.

Pyati, V. P., (cont.)

radar cross section and phase are obtained. All the mathematical derivations are explained in full detail. For the simple case of a spherically uniform distribution of relative speed of the dipoles, it is shown that an integral relation exists between the speed distribution function and the intensity auto-correlation function. The utility of second order statistics in studying the effects of chaff clutter fluctuations on advanced radars such as moving target indicator is demonstrated. Finally, numerical results are included both from an actual experiment and calculations based on assumed dipole velocities. Although it was not possible to compare the two unrelated events, there were definite trends of similarity in the data.

1974

1974b Wickliff, R., and R. Garbacz,
"Addendum to "The Average Backscattering Cross Section of Clouds of Randomized Dipoles,"" IEEE Trans. on Antennas and Propagation, vol. AP-22, no. 6, November 1974, pp. 842-843, (T).

ABSTRACT: No abstract available.

1974 Stanton, R. A., et al.,
"Chaff Cloud Signature II Measurements Program," DTIC document no. AD923520L, August 1974, (PA).

ABSTRACT: This program was performed to determine: (1) the definition of characteristics of 'optimum' dynamic measurement facilities for chaff evaluation; (2) the survey of existing facilities to evaluate their adequacy; (3) the definition of changes which would make existing facilities adequate if not already so; and (4) the provision of test data on chaff clouds, using the best available facilities, as a basis for evaluating theoretical results provided by other programs. It was concluded that no existing facilities could provide the detailed chaff echo data required to evaluate chaff effectiveness against advanced radar systems. The practical solution developed is a self-contained transportable auxiliary receiving and data processing system which can be hooked on to any existing radar system. This unit will provide practical, useful data such as radar cross section, phase and their scintillation spectra in near real time. Furthermore, it will eliminate the need for major modifications to existing systems.

1974a Wickliff, R. G., and R. J. Garbacz,
"The Average Backscattering Cross Section of Clouds of Randomized Resonant Dipoles," IEEE Trans. on Antennas and Propagation, vol. AP-22, no. 3, May 1974, pp. 503-505, (T,M).

ABSTRACT: The average backscattering cross section of clouds of linear metallic dipoles of resonant length and random oreintation is investigated. The effects of mutual coupling among dipoles is included in the analysis by use of computer techniques currently available or being developed. Average backscattering cross sections are presented for random clouds containing up to 200 dipoles with average spacings from 0.5λ

Wickliff, R. G., and R. J. Garbacz, (cont.)

to 2.0λ. Results show that coupling is insignificant at the largest spacings but causes a 2-3-dB degradation in average echo area at the smallest spacings.

1974 Puskar, R. J.,
"Radar Reflector Studies," Proc. of the IEEE 1974 National Aerospace and Electronics Conference, May 13-15, 1974, pp. 177-183, (T,M).

ABSTRACT: In an effort to thoroughly understand chaff and its characteristics, the Air Force Avionics Laboratory is extensively investigating the electromagnetic and aerodynamic properties of chaff.

Aerodynamic studies have identified the six dominant steady-state descent modes of some aluminum foil chaff elements. RCS data will be presented that shows the agreement between laboratory measurement and the theoretical electromagnetic analysis, which accounts for the interaction between closely spaced dipoles. Results of measurements on actual chaff clouds illuminated with 200 ns and 2 ns pulse radar for both H-H and V-V (transmit-receive) polarizations are presented. In addition, a measure of chaff cloud attenuation has been provided by the RCS measurement of a secondary target located behind the chaff cloud. Correlation functions and power spectral densities have been derived from the pulse-to-pulse data so that scintillation rates can be examined. Lastly, three dimensional plots of chaff cloud and secondary target RCS as functions of both time and range are provided from the 2 ns radar data.

1974 Richmond, J. H., L. M. Schwab, and R. G. Wickliff,
"Tumble-Average Radar Backscatter of Some Thin-Wire Chaff Elements," IEEE Trans. on Antennas and Propagation, vol. AP-22, no. 1, January 1974, pp. 124-126, (T,M).

ABSTRACT: With sinusoidal bases and Galerkin's method, the tumble-average radar backscatter is computed for parallel wires, crossed wires, a planar tripod, and a regular quadripod. This communication presents calculated and measured results. One of the configurations, the quadripod, demonstrates attractive tumble-average properties for use as a chaff element.

1973

1973 Garbacz, R. J., et al.,
"Annual Summary Report on Chaff Cloud Scattering," Ohio State University, Electroscience Lab., Report 3401-1, July 1973, (X).

ABSTRACT: No abstract available.

1973 Kajfez, D., and R. L. Dube,
"Measurement of Impedance Transformation on Practical Dipoles," IEEE Trans. on Antennas and Propagation, vol. AP-21, no. 4, July 1973, pp. 544-549, (T,M).

ABSTRACT: The measured input impedance of a practical dipole antenna is shown to be related to the theoretical input impedance of a delta-gap cylindrical dipole through a bilinear transformation. In order to determine the three complex constants which specify the transformation, the impedance of a dipole in front of a ground plane is measured and compared with the theoretical impedance. The comparison is performed by a curve-fitting procedure for bilinear transformation on a complex plane. The same measurement yields also the receiving efficiency of the antenna and its feeding network. Experiments show that the input impedance of a practical folded dipole, incorporating a balun transformer, may be predicted with an accuracy of better than four percent.

1973 Toulios, P. P., and E. W. Weber,
"Determination of Antenna Reactance from the Far-Field Expressions," Proc. IEEE, vol. 61, no. 2, February 1973, p. 245, (T,M).

ABSTRACT: Using the Hilbert transform, a simple expression is derived for the reactance of a dipole antenna in terms of the radiation resistance which is assumed known. Since the radiation resistance can be found from the far-field equations (i.e., Fourier transform of the antenna current distribution), it is shown that it is not necessary to determine the near field to obtain the antenna reactance. Numerical results are in excellent agreement with those available in the literature.

1973 Stanton, R. A., et al.,
"Chaff Cloud Signature I Measurements Program," DTIC document AD525550L, February 1973, (PA).

ABSTRACT: The objective of the chaff cloud signature measurement program was to obtain quantitative data on the radar backscattering characteristics of atmospherically dispensed chaff clouds. The approach to the problem of obtaining quantitative data was to organize the program effort into four phases: (1) the specification of those measurements essential to evaluation of atmospherically dispensed chaff clouds, (2) a survey of existing facilities and comparison of these facility capabilities with the specifications of (1) above, (3) plan and conduct a one time test series of the best available facility, and (4) the demonstration of an inexpensive, reliable, non-aircraft technique for the controlled atmospheric deployment of test payloads. The primary conclusion of the program effort is that with the available instrumentation facilities, the task of making high confidence quantitative chaff measurements is nearly impossible. While the deficiencies in existing facilities lie both in the area of radar transmitter/receivier hardware and in the area of data recording systems, the greatest potential for near term improvement lies in the upgrading of data recording systems to more fully utilize existing radar transmitter/receiver systems.

1972 Kuo, D. C., H. H. Chao, J. R. Mautz, B. J. Strait, and R. F. Harrington, "Analysis of Radiation and Scattering by Arbitrary Configurations of Thin Wires," IEEE Trans. on Antennas and Propagation, vol. AP-20, no. 6, November 1972, pp. 814-815, (T).

ABSTRACT: No abstract available.

1972 Kukainis, J.,
"Separation Characteristics of the ALE-38 Chaff Dispenser from the F-4C and F-4E Aircraft," DTIC document no. AD900189, June 1972, (PA).

ABSTRACT: A test was conducted in the aerodynamic wind tunnel (4T) to investigate the spearation characteristics of the ALE-38 Chaff dispenser from the F-4C and F-4E aircraft. Captive-trajectory store-separation data were obtained for four aircraft/weapons loading configurations with store separations from the right-wing inboard pylon of the F-4C and F-4E aircraft. Data were obtained at Mach numbers from 0.42 to 0.90 at a simulated altitude of 5000 ft. At each test mach number, data were obtained for both full and empty simulated store-model weights. The data obtained show that separation without parent-to-store model contact was achieved at all test conditions.

1972 Poelman, A. J., and J. P. van der Voort,
"The Polarization Dependence of Received Backscattered Power from a Random Dipole Cloud," SHAPE Technical Center, The Hague, The Netherlands, Tech. Memo. TM-276, May 1972, also DTIC document no. AD520934, (X).

ABSTRACT: No abstract available.

1972 Seltzer, J. E.,
"Response of Airborne-Short-Pulse Radar to Chaff," HDL-TR-1590, Harry Diamond Laboratories, Adelphi, MD, April 1972, (PA).

ABSTRACT: Radar backscatter from a chaff cloud is examined for the case in which the radar approaches the cloud from above and moves into and through the cloud. The chaff cloud is modelled as a collection of randomly distributed and randomly oriented dipoles having a mean volume density that is a function of altitude but invariant in a horizontal plane. The statistics of the chaff echo power when the number of dipoles in the resolution volume is large are reviewed. The impulse response, which approximates the short-pulse radar response, and the radar return signal for a specific range resolution cell as a function of the position of the radar relative to the cloud are derived for several chaff cloud configurations and antenna patterns. Power spectral density functions for range-gated chaff-return signals and correlation functions for the signals following squarelaw detection are also derived.

1972 Knott, E. F., and V. V. Liepa,
"Comments on Phase Properties of Backscattered Fields from Thin Rods," IEEE Transactions on Antennas and Propagation, vol. AP-20, March 1972, p. 223, (PA).

ABSTRACT: Abstract not available.

1971

1971 Mack, R. B.,
"Phase Properties of Backscattered Fields from Thin Rods," IEEE Transactions on Antennas and Propagation, vol. AP-19, May 1971, pp. 450-451, (PA).

ABSTRACT: Numerical and analytical calculations show the phase of backscatter fields from thin perfectly conducting rods at constant distance from the scatterer to become essentially independent of aspect angle for rod lengths less than $\lambda/2$, to approach a limit near 180° for shorter rods, and in broadside directions to depend only on rod thickness when rod lengths are an integral multiple of λ.

1971 Varshavchuk, M. L., and V. O. Kobak,
"Cross Correlation of Orthogonally Polarized Components of Electromagnetic Field Scattered by an Extended Object," Radio Engineering and Electronic Physics, vol. 16, no. 2, February 1971, pp. 201-205, (T).

ABSTRACT: The scattering of an elliptically polarized plane electromagnetic wave at an extended object is investigated. A relation is obtained which describes the mean scattering cross section of the object for different polarizations of the transmitted radio waves. The conditions for the existence of uncorrelated orthogonally polarized components of the scattered field are discussed.

1971 Turpin, R. H.,
"Average Radar Cross Section for Arbitrary Transmitter and Receiver Polarizations with Application to Wire Scatterers," IEEE Trans. on Antennas and Propagation, vol. AP-19, no. 1, January 1971, (T).

ABSTRACT: An expression is derived for the average backscattering cross section of an obstacle for arbitrary transmitter and receiver antenna polarizations. Results are given for straight wires, circular loops, and one-turn helices.

1970

1970 DilPare, A. L.,
"Chaff Primer," Microwaves, vol. 9, no. 12, December 1970, pp. 46-47, (T).

ABSTRACT: No abstract available.

1970 Mullin, C. R.,
"Errors Inherent in Chaff Centroid Tracking," General Research Corporation, Memorandum IMR-1333, July 1970, and DTIC document no. AD886132, (T).

ABSTRACT: An analysis of the errors inherent in tracking the radar-cross-section centroid of a chaff cloud shows the centroid to have a

Mullin, C. R., (cont.)

random motion in addition to its long-term motion with the chaff cloud. This random motion can lead to errors in cloud trajectory estimation. There is a further error caused by the fact that the centroid does not exactly follow a Keplerian orbit. The deviation is slight, however, and can be neglected.

1970 Mott, D. L.,
"On the Radar Cross Section of a Dipole," Proc. IEEE, vol. 58, no. 5, May 1970, pp. 793-794, (T).

ABSTRACT: Literature references dealing with the radar cross section of a dipole target contain a possible source of confusion in that two definitions of cross section have been used. To clarify this situation, the radar cross section of a randomly oriented half-wave dipole is considered using both definitions.

1970 Kao, C. C.,
"Electromagnetic Scattering from a Finite Tubular Cylinder: Numerical Solutions," Radio Science, vol. 5, no. 3, March 1970, pp. 617-624, (T).

ABSTRACT: The method of approximate product integration is applied to solve numerically the integral equations of the total currents on the surfaces of the finite tubular cylinder with complete generality both in radius and length. Procedures have been devised to take care of the square-root singularity of the transverse total current at the end of the cylinder. Both total currents and scattering cross sections are presented for three special cases with $ka = 1.0$ and $kh = 0.5\pi$, 1.0π, and 1.5π. A complete set of the computer program in Fortran 4 has been prepared for the IBM 7094 at Harvard Computing Center. It can solve simultaneously for cylinders of the same radius but discrete and different lengths.

1970 Taylor, C. D., S-M. Lin, and H. V. McAdams,
"Scattering from Crossed Wires," IEEE Trans. on Antennas and Propagation, vol. AP-18, no. 1, January 1970, pp. 133-136, (T).

ABSTRACT: The electromagnetic scattering from two straight wires, which intersect perpendicularly, is considered. First, the current distribution on the wires is obtained by solving numerically a system of integral equations. Then the scattered fields and backscattering cross sections are obtained using standard techniques.

1970 Pollon, G. E.,
"Statistical Parameters for Scattering from Randomly Oriented Arrays, Cylinders, and Plates," IEEE Trans. on Antennas and Propagation, vol. AP-18, no. 1, January 1970, pp. 68-75, (T).

ABSTRACT: The statistical distribution of backscattering S from some randomly oriented simple configurations is considered in terms of the log-normal distribution. The log-normal parameters (mean and variance of $\ln S$), for arrays, cylinders, and plates are obtained and shown to afford an accurate description of their backscattering statistics over a wide range, for sizes in excess of a few wavelengths.

Pollon, G. E., (cont.)

A reason for this correspondence is obtained by noting that the backscattering pattern of an array may be expressed as a product of factors which are uncorrelated with respect to random sampling. A product of independent factors leads to the log-normal distribution.

Finally, results for some randomly sampled simple antenna patterns are given.

1969

1969 Kao, C. C.,
"Three-Dimensional Electromagnetic Scattering from a Circular Tube of Finite Length," Journal of Applied Physics, vol. 40, no. 12, November 1969, pp. 4732-4740, (T,M).

ABSTRACT: An electromagnetic plane wave in either E or H polarization is normally incident on a cylinder which is assumed to be an infinitely thin-walled, perfectly conducting, circular tube of finite length with complete generality both in radius and length. For either polarization both axial and transverse currents are induced. The problem is transformed into determining an infinity of Fourier components by expanding each function of θ into a Fourier series. For each Fourier component a pair of integral equations for the total currents is obtained. These are decoupled in a special sense permitting the transverse total current to be obtained first, followed by the axial total current. The difference current is then defined and expressed in terms of the total current, making possible the determination of the inside and outside total current. These are experimentally measurable quantities. The theoretical formulas for the scattered fields, the far field patterns, and the scattering cross sections are also derived in terms of the total current. Finally, sample results, both theoretical and experimental, are included.

1969 Mott, D. L.,
"Stokes-Parameter Description of Backscattering from a Randomly Oriented Dipole," Proc. IEEE, vol. 57, no. 11, November 1969, pp. 2067-2068, (T).

ABSTRACT: The Stokes-parameter transformation operator for a randomly oriented dipole radar target is derived. Using the operator, the polarization of the backscattered wave is determined for incident waves that are linearly and circularly polarized. The results give an insight into the way target radar cross section depends on antenna polarization.

1969 Diggs, J. F., et al.,
"Cross Section Studies of X-Band Chaff," DTIC document no. AD505385L, October 1969, (PA).

ABSTRACT: The Naval Research Laboratory participated in Development Assist Test (D/S) 433 during the period July 29 to August 1, 1967. NRL's purpose was to provide radar measurements of some of the parameters necessary to evaluate specific ECM decoy devices in a fleet tactical environment. Contained in this report is a listing of cross sections of numerous chaff clouds and the three ships (including a carrier) participating in D/S 443. The cross sections were obtained using X-band

Diggs, J. F., et al., (cont.)

(8910 MHz) transmissions with both horizontal and vertical polarizations. It was observed throughout the test that the chaff and ships were quite distinguishable, on two counts. First, the ship gave back a narrower and much cleaner signal. Second, the chaff signals had an obvious and distinctive scintillation. Further conclusions drawn from the analysis of D/S 443 is that the cross section of untreated chaff is relatively insensitive to changes in load weight, but very sensitive to wind velocity and incident polarization.

1969 Taylor, C. D.,
"Electromagnetic Scattering from Aribtrary Configurations of Wires," IEEE Trans. on Antennas and Propagation, vol. AP-17, no. 5, September 1969, pp. 662-663, (T).

ABSTRACT: A general formulation is presented for the treatment of electromagnetic scattering from an arbitrary configuration of thin wires. A system of integral equations is derived for obtaining the currents in the wires.

1969 Miller, E. K., G. J., Burke, B. J. Maxum, G. M. Pjerrou, and A. R. Neureuther,
"Radar Cross Section of a Long Wire," IEEE Trans. on Antennas and Propagation, vol. AP-17, no. 3, May 1969, pp. 381-384, (T,M).

ABSTRACT: Monostatic radar cross-section (RCS) results for five- and eleven-wavelength straight wires are presented. The numerical RCS values which are obtained from solving Pocklington's integral equation for the induced current by collocation fall with 1 dB of the experimental measurements over all major lobes of the RCS pattern. The computer times required for the computations are 1.2 and 7.6 seconds for the five- and eleven-wavelength cases, respectively.

1969 Thiele, G. A.,
"The Maximum Echo Area of Imperfectly Conducting Dipoles," IEEE Trans. on Antennas and Propagation, vol. AP-17, no. 3, May 1969, pp. 379-381, (T).

ABSTRACT: The question has often been raised as to when the effects of imperfect conductivity must be taken into account when studying the echo area of a wire scatterer such as the dipole. The conditions under which the echo area is sensitive to the conductivity are shown.

1969 Mitchell, R. L.,
"Radar Cross Section Statistics of Randomly Oriented Disks and Rods," IEEE Trans. on Antennas and Propagation, vol. AP-17, no. 3, May 1969, pp. 370-371, (T).

ABSTRACT: No abstract available.

1969 Einarsson, O.,
"Electromagnetic Scattering by a Thin Finite Wire," Acta Polytechnica Scandinavica, Electrical Engineering Series No. 23, UDC 538.566, 621.396.67, Stockholm, May 1969, (f,M).

ABSTRACT: Scattering of a plane electromagnetic wave by a straight, perfectly conducting circular cylinder, whose radius is small compared to both its length and to the wavelength, is investigated theoretically. The surrounding medium is air (vacuum) and the incident wave is linearly polarized with the magnetic field perpendicular to the cylinder axis. The work is based on the traveling wave solution for scattering by a circular, finite, thin-walled tube, obtained by repeated use of the Wiener-Hopf method. A closed form expression for the far field, for arbitrary angles of incidence and observation, is obtained by expanding this solution asymptotically in negative powers of a quantity of order $\ln ka$, where $k = 2\pi/\lambda$ is the wave number and a is the cylinder radius. Second order terms are included in the expansions and to improve the numerical accuracy the original form instead of an asymptotic expression is used for some numerically sensitive quantities. Scattering cross sections are computed and compared to existing theoretical and experimental results.

1969 Seltzer, J. E.,
"The Statistics of the Chaff Return to a Moving Pulsed Radar Altimeter," Harry Diamond Laboratories (U. S. Army) report R240-69-3, 14 March 1969, (T).

ABSTRACT: The probability density, mean, and variance of the power return from chaff to a moving pulsed radar altimeter are derived under the assumption that the dipoles are randomly oriented and randomly distributed within the radar resolution volume.

In order to provide a measure of the envelope correlation from pulse to pulse, the power spectral density and covariance function of the chaff return signal are also derived.

1968

1968 Garbacz, R. J., and G. A. Thiele,
"Scattering and Absorption by Short, Thin Metallic Filaments," Radio Science, vol. 3 (New Series), no. 11, November 1968, pp. 1045-1050, (T).

ABSTRACT: There has arisen recently some interest in absorptive obstacles possessing low scattering cross sections. One such obstacle is the very thin, short metallic filament which can absorb, typically, 20 to 30 dB more energy than it scatters. To calculate simply and quickly the broadside backscattering and absorption cross sections versus conductivity of such filaments and to explain their nature, a Thevenin equivalent circuit is postulated which yields reasonably accurate results under suitable restrictions on filament size. The cross sections so derived are checked by an independent computer calculation based on the point matching technique.

1968 Thiele, G. A.,
"The Maximum Echo Area of Imperfectly Conducting Dipoles," Ohio State University, ElectroScience Laboratory Technical Report 2409-7, 11 October 1968, and DTIC document no. AD678198, (T).

ABSTRACT: Recently, the question has often been raised as to when the effects of imperfect conductivity must be taken into account when studying the echo area of a wire scatterer such as the dipole. This paper clearly shows the conditions under which the echo area is sensitive to the conductivity.

Curves for imperfectly conducting resonant dipoles are presented that show the dependence of the maximum echo area upon conductivity, frequency and dipole diameter. The maximum echo area is defined to be the peak echo area at first resonance.

The maximum echo area is related to the penetration of the electric field into the dipole. This makes it possible to obtain a universal curve that may be used to determine the maximum echo area of a specified dipole without actual computation of its resonance curve.

1968 Shen, L-C. S., T. T. Wu, and R. W. P. King,
"A Simple Formula of Current in Dipole Antennas," IEEE Trans. on Antennas and Propagation, vol. AP-16, no. 5, September 1968, pp. 542-547, (T,M).

ABSTRACT: A simple and quantitatively accurate representation of the current distribution in a dipole antenna is derived. Numerical data are given and are found to be in good agreement with the experiment when $h \geq 0.15\lambda$.

1968 Chen, C-L.,
"On the Scattering of Electromagnetic Waves from a Long Wire," Radio Science, vol. 3 (New Series), no. 6, June 1968, pp. 585-598, (T,M).

ABSTRACT: A study is made of the scattering of a plane electromagnetic wave by a long and thin metallic wire in which the case of arbitrary incidence is considered. The Wiener-Hopf technique is used to solve the integral equation. Explicit and rather simple expressions for the induced current, the far-field pattern, and the backscattering cross sections are found; numerical results are presented. These results are in reasonable agreement with existing experimental data.

1968 Shen, L-C.,
"Current Distribution on a Long Dipole Antenna," IEEE Trans. on Antennas and Propagation, vol. AP-16, no. 3, May 1968, pp. 353-354, (T,M).

ABSTRACT: No abstract available.

1967

1967b Mayer, A.,
"Mean Radar Cross Section of Finite Cylindrical Wires: Dependence on Conductivity and Frequency," (correction), Proc. IEEE, vol. 55, no. 12, December 1967, p. 2197, (T).

ABSTRACT: No abstract available.

1967 Richmond, J. H.,
"Scattering by Imperfectly Conducting Wires," IEEE Trans. on Antennas and Propagation, vol. AP-15, no. 6, November 1967, pp. 802-806, (T).

ABSTRACT: An integral equation is developed for the current induced in a slender, imperfectly conducting wire of finite length by an incident plane wave. A system of linear equations is generated by enforcing the integral equation at a discrete set of points on the axis of the wire, and these equations are solved to determine the current distribution. The scattered fields and the echo area are then calculated in a straightforward manner.

Numerical results are presented for the backscatter echo area of copper, platinum, and bismuth wires at the broadside aspect with lengths up to 1.8λ. These calculations show good agreement with experimental measurements. In addition, graphs are included to show the current distributions on these wires at the second resonance, the echo-area patterns for oblique incidence, and the broadside echo-area curves for perfectly conducting wires and copper wires with lengths up to 3.54λ.

1967 Shen, L-C.,
"An Experimental Study of Imperfectly Conducting Dipoles," IEEE Trans. on Antennas and Propagation, vol. AP-15, no. 6, November 1967, pp.782-784, (T,M).

ABSTRACT: Input admittances of dipole antennas with moderately high internal impedance were measured in the UHF range with the antenna lengths varying from one-tenth wavelength to such a value that the antenna behaved as if infinitely long. The measured results are compared with the three-term theory of King and Wu and with the theoretical values obtained by Shen and Wu for an infinitely long antenna.

1967 Weissman, I.,
"Peak-Average and Average-Peak Radar Cross Sections of Wakes (or Chaff)," Columbia University, Electronics Research Laboratories, Technical Memorandum TM-6/331, 27 October 1967, and DTIC document no. AD663432, (T).

ABSTRACT: Expressions are given comparing the "peak-average" to "average-peak" radar cross section for random distributed scatterers such as reentry wakes or chaff. In order to relate the peak-average (which is a conventional measure) to the average-peak (which is more-simply determined), the form and extent of the scatterer must be known. Ratios of these quantities are computed for three different forms of "average pulse shape": uniform, triangular, and exponential.

1967 Shen, L-C., T. T. Wu, and R. W. P. King,
"A Simple Theory of Dipole Antennas," Harvard University, Gordon McKay Laboratory, Scientific Report no. 10, September 1967, (T,M).

ABSTRACT: A simple and quantitatively accurate representation of the current distribution in a dipole antenna is derived. Numerical data are given and are found to be in good agreement with the experiment when $h \geq 0.15\lambda$.

1967a Mayer, A.,
"Mean Radar Cross Section of Finite Cylindrical Wires: Dependence on Conductivity and Frequency," Proc. IEEE, vol. 55, no. 8, August 1967, pp. 1502-1504, (T).

ABSTRACT: A general formula is presented for the mean radar cross section, $\bar{\sigma}$, of a long, thin, straight, cylindrical metallic wire of finite length, radius, and conductivity at radar frequency f. Curves of $\bar{\sigma}$ versus f for bismuth (poor conductor) and for perfectly conducting wires, having length 3.14 meters (10 feet) and radius 0.0127 cm (5 mils), illustrate the dependence of $\bar{\sigma}$ on conductivity.

1967 Harrington, R. F., and J. R. Mautz,
"Straight Wires with Arbitrary Excitation and Loading," IEEE Trans. on Antennas and Propagation, vol. AP-15, no. 4, July 1967, pp. 502-515, (T).

ABSTRACT: A general analysis of straight wire antennas and scatterers, with arbitrary excitation and loading, is given. The resulting formulas are in matrix notation, in a form suitable for programming on a digital computer. Many numerical results for input admittances, current distributions, radiation patterns, and scattering cross sections of various antennas and scatterers are included.

1967 Kownacki, S.,
"Screening (Shielding) Effect of a Chaff Cloud," IEEE Trans. on Aerospace and Electronic Systems, vol. AES-3, no. 4, July 1967, pp. 731-734, (T).

ABSTRACT: No abstract available.

1967 Breithaupt, R. W.,
"Bistatic Scattering by a Thin, Lossy Cylindrical Wire," Canadian Journal of Physics, vol. 45, no. 6, June 1967, pp. 1965-1980, (T).

ABSTRACT: A variational solution to the problem of bistatic scattering by a thin, lossy, solid, circular wire of length 2ℓ is given. The amplitude of the far scattered electric field is given by an expression stationary for small differences between the assumed and actual axial current distribution. The ratio of absorbed to scattered power is calculated using the forward scattering theorem, and the result compared with that of FitzGerrell. Solutions are given for zero and first-order assumed current distributions.

1967 Chang, S., and V. V. Liepa,
"Measured Backscattering Cross Section of Thin Wires," University of Michigan Report 8077-4-T, May 1967, (M).

ABSTRACT: A set of measured back scattering patterns is presented for a thin wire ($a/\lambda = 6.27 \times 10^{-3}$) for $\ell/\lambda = 0.3(0.025)0.55(0.05)1.60(0.10)5.42$, where a is the radius of the wire, ℓ is the length, and λ is the wavelength. The measurements were performed in an anechoic chamber at 2.370 GHz. From this set of patterns a number of curves has been extracted showing the amplitude and position of each back scattering lobe as a function of the wire length. These curves provide a convenient means of cross section estimation and may be used to reconstruct with reasonable accuracy the back scattering pattern for any value of ℓ/λ, $\ell/\lambda \leq 5.42$.

1967 Fialkovskii, A. T.,
"Scattering of Plane Electromagnetic Waves by a Thin Cylindrical Conductor of Finite Length," Soviet Physics-Technical Physics, vol. 11, no. 10, April 1967, pp. 1300-1304, (T).

ABSTRACT: An asymptotic solution is obtained to the classical problem concerning the diffraction of plane electromagnetic waves by a perfect conductor of radius a and length $2l$ (a dipole) subject to the conditions $ka << 1$, $a/l << 1$, where $k = \omega/c$ is the wave number. The expressions obtained coincide with Ufimtsev's equations, which were derived by the boundary-wave technique. The latter equations are consequently provided with a proper theoretical foundation.

1967 Borison, S. L.,
"Bistatic Scattering Cross Section of a Randomly-Oriented Dipole," IEEE Trans. on Antennas and Propagation, vol. AP-15, no. 2, March 1967, pp. 320-321, (T).

ABSTRACT: No abstract available.

1967 Wong, J. L., I. S. Reed, and Z. A. Kaprielian,
"A Model for the Radar Echo from a Random Collection of Rotating Dipole Scatterers," IEEE Trans. on Aerospace and Electronic Systems, vol. AES-3, no. 2, March 1967, pp. 171-178, (T,M).

ABSTRACT: A theoretical model for the radar echo from a random collection of dipole scatterers is presented. The analysis of the model takes into account the effects of scatterer rotation which have been neglected in previous related work. It is shown that rotational motion of the scatterers can have significant effects upon the echo waveform. The fluctuating characteristics of clutter echoes are also investigated. The theory and some experimental results in the literature are shown to be in relatively good agreement.

1967 Harrington, R. F.,
"Matrix Methods for Field Problems," Proc. IEEE, vol. 55, no. 2, February 1967, pp. 136-149, (T).

ABSTRACT: A unified treatment of matrix methods useful for field problems is given. The basic mathematical concept is the method of moments, by which the functional equations of field theory are reduced to matrix equations. Several examples of engineering interest are included to illustrate the procedure. The problem of radiation and scattering by wire objects of arbitrary shape is treated in detail, and illustrative computations are given for linear wires. The wire object is represented by an admittance matrix, and excitation of the object by a voltage matrix. The current on the wire object is given by the product of the admittance matrix with the voltage matrix. Computation of a field quantity corresponds to multiplication of the current matrix by a measurement matix. These concepts can be generalized to apply to objects of arbitrary geometry and arbitrary material.

1966

1966b Mayer, A.,
"Handbook I. Radar Cross Section as Function of Frequency for Long Wires of Specified Conductivity, Length and Radius," National Engineering Science Co., Pasadena, CA, NESCO Report SN379-1, November 1966, (X).

ABSTRACT: No abstract available.

1966 DiCaudo, V. J., and W. W. Martin,
"Approximate Solution to Bistatic Radar Cross Section of Finite Length, Infinitely Conducting Cylinder," IEEE Trans. on Antennas and Propagation, vol. AP-14, no. 5, September 1966, pp. 668-669, (T,M).

ABSTRACT: No abstract available.

1966e King, R. W. P., and S. S. Sandler,
"Driving-Point Impedance and Current for Long Resonant Antennas," IEEE Trans. on Antennas and Propagation, vol. AP-14, no. 5, September 1966, pp. 639-641, (T,M).

ABSTRACT: No abstract available.

1966d King, R. W. P., C. W. Harrison, Jr., and E. A. Aronson,
"The Imperfectly Conducting Cylindrical Transmitting Antenna: Numerical Results," IEEE Trans. on Antennas and Propagation, vol. AP-14, no. 5, September 1966, pp. 535-542, (T).

ABSTRACT: The complex wave number, the distribution of current, the admittance, and the radiating efficiency of cylindrical antennas made of imperfect conductors are evaluated numerically from a previously derived theory. The quantity $2\lambda r^i/\zeta_0$ (where r^i is the resistance per unit length, λ is the free-space wavelength, and $\zeta = 377$ ohms) is used as the parameter in a range that extends from zero to 200. Extensive graphs are given.

1966c King, R. W. P., and T. T. Wu,
"The Imperfectly Conducting Cylindrical Transmitting Antenna," IEEE Trans. on Antennas and Propagation, vol. AP-14, no. 5, September 1966, pp. 524-534, (T).

ABSTRACT: The properties of a cylindrical antenna with a continuous ohmic resistance along its length are of interest in the design of certain types of directive broadband antennas and in the determination of the efficiency of dipole antennas. Conventionally, the contribution of ohmic resistance to the distribution of current and the impedance is contained in a particular integral that is either ignored or treated as a higher-order correction to formulas derived for perfectly conducting antennas. An alternative and more useful form has been developed in which the integral equation for the current is rearranged to permit the introduction of a complex wave number k. An approximate solution of this equation is then obtained in terms of the three trigonometric functions, $\sin k(h-|z|)$, $\cos kz - \cos kh$, and $\cos \frac{1}{2}k_0z - \cos \frac{1}{2}k_0h$, where k_0 is the free-space wave number. Expressions are derived for the coefficients of these functions and for k. Explicit formulas are given for the distribution of current and the admittance.

1966a Mayer, A.,
"Radar Reflection from Long, Lossy, Wires, Tubes and Metallic Strips," National Engineering Science Co., Pasadena, CA, NESCO Report SN379A, July 1966, (X).

ABSTRACT: No abstract available.

1966b King, R. W. P., E. A. Aronson, and C. W. Harrison, Jr.,
"Determination of the Admittance and Effective Length of Cylindrical Antennas," Radio Science, vol. 1 (New Series), no. 7, July 1966, pp. 835-850, (T,M).

ABSTRACT: The apparent admittance of a cylindrical antenna depends critically on the structure of the conductors near the junction of the antenna and the feeding line. For thin cylinders and closely spaced lines an ideal admittance can be defined in the hypothetical limit of "zero" line spacing. The approximate theoretical equivalent is the admittance seen by a delta-function generator with the infinite susceptance of the knife-edge capacitance subtracted.

The iterated theoretical admittance of a cylindrical antenna with a delta-function generator is examined for from one to 30 iterations. It is shown that for $\beta_0\alpha \leq 0.1$ or $\alpha/\lambda \leq 0.016$ (where α is the radius, $\beta_0 = 2\pi/\lambda$ the wave number) the conductance converges rapidly, but the susceptance increased continually with the added iterations by an amount proportional to the circumference of the antenna. The more accurate the solution, the nearer the susceptance approaches infinity. A simple empirical correction is combined with the second-order iterated value to provide a good approximation of the ideal independent susceptance of the antenna. When $\beta_0\alpha \leq 0.1$, the second-order corrected admittance is essentially the same when calculated with either the exact kernel for the tubular antenna or the commonly used average kernel.

Tables of the admittance Y, impedance Z, radian effective length $\beta_0 h_e$, and directivity D are given. When combined with the terminal-zone network for a particular transmission line, the measurable apparent admittance and impedance of a cylindrical antenna are obtained with essentially as great an accuracy as is possible in terms of an "independent" admittance for the antenna. More accurate values depend on the individual analysis of each transmission-line-antenna configuration.

1966a King, R. W. P., and C. W. Harrison, Jr.,
"Current Distribution and Impedance per Unit Length of a Thin Strip," IEEE Trans. on Antennas and Propagation, vol. AP-14, no. 2, March 1966, p. 252, (T).

ABSTRACT: No abstract available.

1966 Wong, J. L., I.S. Reed, and Z. A. Kaprielian,
"A Model for Radar Echoes from a Random Collection of Rotating Dipole Scatterers," Air Force Systems Command, Space Systems Division, Los Angeles, CA, Report SSD-TR-66-36, January 1966, and DTIC document no. AD480737, (T,M).

ABSTRACT: A new theoretical model for the radar echo from a random collection of dipole scatterers is presented. The analysis of the model

Wong, J. L., I. S. Reed, and Z. A. Kaprielian, (cont.)

takes into account the effects of scatterer rotation which have been neglected in previous related work. It is shown that rotational motion of the scatterers can have significant effects upon the echo waveform. The results derived can be applied to the determination of the fluctuating characteristics of clutter echoes. Comparisons between the theory and some available experimental results in the literature are shown to be in relatively good agreement.

The theory developed appears to have useful military applications, particularly in the area of signal detection in the presence of clutter interference.

1965

1965 Huynen, J. R.,
"Measurement of the Target Scattering Matrix," Proc. IEEE, vol. 53, no. 8, August 1965, pp. 936-946, (T).

ABSTRACT: The scattering matrix of a target generalizes the scattering properties to include a description of their dependence upon radar polarization. The matrix may be determined directly through two successive transmissions at orthogonal polarizations, with reception of each at both of the polarizations. In the laboratory, it is possible to eliminate the requirement for phase measurement by an indirect technique using successive measurements at six polarizations (five of which may be linear). In the case where results are to be applied to linearly polarized radars, it is sufficient to determine the "linear restricted matrix" by six linear measurements. Analysis is provided and measurement technology described and evaluated for both classes of indirect measurement.

1965 Garbacz, R. J.,
"Modal Expansions for Resonance Scattering Phenomena," Proc. IEEE, vol. 53, no. 8, August 1965, pp. 856-864, (T).

ABSTRACT: This paper very briefly reviews certain approaches commonly used to predict scattering in the region between those amenable to either high or low frequency approximations. As an alternative to extensions of such approximations into this so-called "resonance region," the suggestion is made that the concept of modal expansions of fields be investigated. The existence of such characteristic modes is reasoned heuristically and certain speculations are presented concerning their properties and their determination.

1965 Palermo, C. J., and L. H. Bauer,
"Bistatic Scattering Cross Section of Chaff Dipoles with Applications to Communications," Proc. IEEE, vol. 53, no. 8, August 1965, pp. 1119-1121, (T,M).

ABSTRACT: The variational method of computing radar scattering cross sections has been applied to the bistatic scattering cross section for chaff dipoles. The average cross section was calculated for three distributions of dipole orientation; uniform, horizonal, and vertical.

Palermo, C. J., and L. H. Bauer, (cont.)

The geometry considered was for dipoles located near one terminal of a two terminal radio link such that the azimuth and elevations angles of the far terminal were small. Measured values of bistatic cross section were within about 3 dB of predicted values for measurements at a frequency 5652 MHz. Fading rates from 5 Hz to 25 Hz were measured. Space diversity distances were of the order of 2 to 5 feet for this particular 50-mile link.

1965 Senior, T. B. A.,
"A Survey of Analytical Techniques for Cross Section Estimation," Proc. IEEE, vol. 53, no. 8, August 1965, pp. 822-833, (T,M).

ABSTRACT: To serve as a general introduction to the theoretical papers immediately following, the analytical techniques available for estimating the backscattering cross section of a metal target are reviewed. These are classified according to the dimension-to-wavelength ranges for which they are appropriate, and an attempt is made to interpret them in the light of the scattering processes involved. Some examples are discussed.

1965 Richmond, J. H.,
"Digital Computer Solutions of the Rigorous Equations for Scattering Problems," Proc. IEEE, vol. 53, no. 8, August 1965, pp. 796-804, (T,M).

ABSTRACT: A survey of recently developed techniques for solving the rigorous equations that arise in scattering problems is presented. These methods generate a system of linear equations for the unknown current density by enforcing the boundary conditions at discrete points in the scattering body or on its surface. This approach shows promise of leading to a systematic solution for a dielectric or conducting body of arbitrary size and shape.

The relative merits of the linear-equation solution and the variational solutions are discussed and numerical results, obtained by these two methods, are presented for straight wires of finite length.

The computation effort required with the linear-equation solution can be reduced by expanding the current distribution in a series of modes of the proper type, by making a change of variables for integration, and by employing interpolation formulas.

Solutions are readily obtained for a scattering body placed in an incident plane-wave field or in the near-zone of a source. Examples are included for both cases, using a straight wire of finite length as the scattering body.

The application of these techniques to scattering by a dielectric body is illustrated with dielectric rods of finite length.

1965 Mei, K. K.,
"On the Integral Equations of Thin Wire Antennas," IEEE Trans. on Antennas and Propagation, vol. AP-13, no. 3, May 1965, pp. 374-378, (T).

ABSTRACT: The feasibility of direct numerical calculations of antenna integral equations is investigated. It is shown that integral equation

Mei, K. K., (cont.)

of Hallen's type is the most adequate for such applications. The extension of Hallen's integral equation to describe thin wire antennas of arbitrary geometry is accomplished, and results are presented for dipole, circular loops, and equiangular spiral antennas.

1965 FitzGerrell, R. G.,
"Radiation Efficiencies of Half-Wave Dipole Antennas," IEEE Trans. on Antennas and Propagation, vol. AP-13, no. 2, March 1965, pp. 326-327, (T).

ABSTRACT: No abstract available.

1965 Fulton, F. F., Jr.,
"The Combined Radiation Pattern of Three Orthogonal Dipoles," IEEE Trans. on Antennas and Propagation, vol. AP-13, no. 2, March 1965, pp. 323-324, (T).

ABSTRACT: No abstract available.

1965 Andreasen, M. G.,
"Scattering from Bodies of Revolution," IEEE Trans. on Antennas and Propagation," vol. AP-13, no. 2, March 1965, pp. 303-310, (T).

ABSTRACT: The problem of scattering of a plane electromagnetic wave from an arbitrary metallic body of revolution is solved by a theoretical method for arbitrary incidence and polarization. The method permits numerical computations by high-speed digital computers, and examples are given. The incident wave is expanded in cylindrical modes, and an integral equation is solved for the induced current distribution of each mode. The scattering cross section, including the back-scattering or radar cross section, is found by summation of the mode scattered fields. The method is limited to a maximum perimeter length of twenty wavelengths.

While the cases discussed in the paper pertain to perfectly conducting bodies, other surface boundary conditions, an arbitrary surface impedance or coatings by lossy dielectrics, can also be treated with equal precision.

1965 Borison, S. L.,
"Statistics of the Radar Cross Section of a Volume of Chaff," Massachusetts Institute of Technology, Lincoln Laboratory, Group report 1965-10, 10 February 1965, and DTIC document no. AD612887, (T).

ABSTRACT: The average and standard deviation of the radar cross section of chaff is computed under the assumptions that dipoles are randomly oriented and randomly distributed within a radar resolution volume. For a single type of chaff, the standard deviation approaches the average value as the average number of dipoles increases. When the number of dipoles per resolution volume is small, the statistics of the single dipole cross section are important. The results are then generalized to the case of several types of dipoles distributed in space. The average cross section is simply the sum of the average cross sections for each type; however, the standard deviation involves additional terms which are not small. These terms are just sufficient to again provide the Rayleigh limit $\delta s / \langle s \rangle - 1$ as the number of dipoles increases.

1964

1964c Harrington, R. F.,
"RF Characteristics of Thin Dipoles," Proc. IEEE, vol. 52, no. 12, December 1964, pp. 1736-1737, (T).

ABSTRACT: No abstract available.

1964 La Pointe, A. E.,
"Chaff Dispenser," Patent 3,143,965, granted August 11, 1964, (T).

ABSTRACT: No abstract available.

1964 Borison, S. L.,
"Probability Density for the Radar Cross Section of One or More Randomly-Oriented Dipoles," Group Report 1964-33, 22 June 1964, Massachusetts Institute of Technology, Lincoln Laboratory, (T).

ABSTRACT: An examination was made of the electromagnetic scattering from low-density, randomly-oriented chaff. Exact integral expressions for the radar cross section probability density for one or more dipoles, $P_N(\sigma)$, are derived. Using an approximate expression for the angular dependence of the cross section, the density for one dipole is found to be a simple analytic expression. For two dipoles, numerical integrations were performed. It is concluded that the Rayleigh density is a good approximation for $N > 1$ if σ is at least greater than $\sigma_{avg} = N\frac{\sigma_0}{5}$, where σ_0 is the peak cross section of a single dipole.

1964 Mack, C. L., Jr., and B. Reiffen,
"RF Characteristics of Thin Dipoles," Proc. IEEE, vol. 52, no. 5, May 1964, pp. 533-542, (T).

ABSTRACT: This paper considers the average bistatic scattering cross section of thin cylindrical dipoles as a function of frequency, bistatic angle, and transmitting and receiving polarization. The averaging is over all orientations of the dipole with all orientations equally likely.

Section II is essentially tutorial, approaching the problem of scattering cross section from the equivalent circuit point of view. Using this approach, the maximum scattering cross sections of lossless dipoles in the Rayleigh region and at the first and second resonances are derived. Section III presents a novel method of predicting cross section at the first resonance with the effect of loss included. Numerous measurements indicate that this method is widely applicable. Section IV describes our microwave scattering range and the results of measurements made on dipoles resonant at X band. In Section V the averaging of cross sections is considered. The average bistatic cross sections for resonant half-wave and full-wave dipoles are plotted vs bistatic angle for various transmitting and receiving polarizations. These results, which are new, were obtained using a digital computer. The average cross section for short (Rayleigh region) dipoles is also obtained as a function of bistatic angle for various polarizations. Section VI is a summary of parameters of the West Ford dipoles.

1964b Harrington, R. F.,
"Theory of Loaded Scatterers," Proc. IEE, vol. 111, no. 4, April 1964, pp. 617-623, (T).

ABSTRACT: A general formulation is given for the problem of electromagnetic scattering by an object having *N* terminal pairs (or ports) to which *N* loads or an *N*-port network is connected. The theory is applicable to back scattering and bistatic scattering, reciprocal and nonreciprocal media, near-field and far-field scattering and passive and active loads. The representation is made in terms of both open-circuit impedance parameters and short-circuit admittance parameters. Variational formulas for all parameters are given. Specialization to the case of planewave scattering is made. Relationships between scattering parameters and commonly defined antenna parameters are given. Several examples of applications of the theory are included.

1964a Harrington, R. F.,
"Some Bounds on the Behavior of Small Resonant Scatterers," IEEE Trans. on Antennas and Propagation," vol. AP-12, no. 1, January 1964, p. 126, (T).

ABSTRACT: No abstract available.

1963

1963 Childers, D. G., and I. S. Reed,
"A Model for the Power Spectrum of Returned Echoes from a Random Collection of Moving Scatterers," University of Southern California School of Engineering Report 102, December 1963, (X).

ABSTRACT: No abstract available.

1963 Harrington, R. F.,
"Electromagnetic Scattering by Antennas," IEEE Trans. on Antennas and Propagation, vol. AP-11, no. 5, September 1963, pp. 595-596, (T).

ABSTRACT: No abstract available.

1963 Harrison, C. W., Jr., and R. O. Heinz,
"On the Radar Cross Section of Rods, Tubes, and Strips of Finite Conductivity," IEEE Trans. on Antennas and Propagation, vol. AP-11, no. 4, July 1963, pp. 459-468, (T).

ABSTRACT: A formula is derived for the radar cross section of solid-wire, tubular, and strip chaff of finite conductivity approximating one-half wavelength or less in length. The results obtained may be summarized as follows: 1) The back-scattering cross section for parallel polarization of solid-wire chaff of nonvanishing internal impedance per unit length is not significantly affected by a reduction in the conductivity of the constituent metal provided the conductor is not too thin. 2) Tubular chaff having a wall thickness less than a skin depth has a greater back-scattering cross section than strip chaff of the same thickness. 3) Strip chaff consisting of vacuum deposited aluminum on mylar, when the coating thickness is small compared to the skin depth, has an extremely small radar cross section and its use should be avoided.

1963 Jiusto, J. E., and W. J. Eadie,
"Terminal Fall Velocity of Radar Chaff," Journal of Geophysical Research, vol. 68, no. 9, May 1963, pp. 2858-2861, (T,M).

ABSTRACT: No abstract available.

1963 Iizuka, K., R. W. P. King, and S. Prasad,
"The admittance of very Long Cylindrical Antennae," Proc. IEE, vol. 110, no. 2, February 1963, pp. 303-309, (T,M).

ABSTRACT: The admittances of long cylindrical antennae ranging in electrical half-length from $\beta h = 0.3$ to $\beta h = 63.1$ have been determined experimentally when the antennae are centre-driven by a 2-wire line. The measured values are in good agreement with the King-Middleton second-order theory for the shorter antennae and with Wu's theory for the longer ones. Particular care has been taken to avoid an unbalanced current on the feeding and measuring line, since such a current can lead to serious errors in the measured driving-point admittance.

The measured admittance of the long antenna was extrapolated to infinite length and found to be in agreement with the theoretical values reported by Papas and by King and Schmitt.

1962

1962 Mack, C. L., Jr.,
"Microwave Cross Section of Thin Dipoles," M. I. T. Lincoln Laboratory Tech. Report 36E-2, November 1962, (X).

ABSTRACT: No abstract available.

1962 Twersky, V.,
"On Scattering of Waves by Random Distributions. I. Free-Space Scatterer Formalism," Journal of Mathematical Physics, vol. 3, no. 4, July-August 1962, pp. 700-715, (T).

ABSTRACT: Approximations are derived for the bulk parameters of the coherent multiple scattered field in a slab region of randomly distributed arbitrary scatterers. (The one-, two-, and three-dimensional cases are treated simultaneously.) The propagation number K, and, e.g., ϵ and μ, are given explicity in terms of conventional free-space isolated scattering amplitudes; these results generalize existing special forms for monopoles, dipoles, cylinders, and spheres. Corresponding approximations are obtained for the differential-scattering cross section per unit volume (i.e., the incoherent scattering), such that the total flux (coherent plus incoherent) fulfills the energy principle explicitly. Scattering and reciprocity theorems are derived for a "multiple scattering amplitude" of a scatterer within the distribution, and these are used to trace the energy "losses" of the coherent field which "reappear" as incoherent scattering. Several applications are considered.

1962 Harrington, R. F.,
"Small Resonant Scatterers and Their Use for Field Measurements," IRE Trans. Microwave Theory and Techniques, vol. MTT-10, no. 3, May 1962, pp. 165-174, (T).

Harrington, R. F., (cont.)

ABSTRACT: A general formulation for the back-scattered field from loaded objects is given. It is shown that small resonant objects produce a much greater back-scattered field than small nonresonant ones. The theory is applied to short dipoles and small loops. The use of small resonant scatterers to measure electric and magnetic fields by scattering techniques is discussed. Resonant scatterers are found to have several advantages over nonresonant scatterers when used for field measurements.

1962 Chen, Y. M., and J. B. Keller,
"Current on and Input Impedance of a Cylindrical Antenna," Journal of Research of the National Bureau of Standards--D. Radio Propagation, vol. 66D, no. 1, January-February 1962, pp. 15-21, (T).

ABSTRACT: The electric current on a finite antenna is expressed as the sum of a current emanating from the gap and two currents reflected from the ends. These currents are determined for a perfectly conducting hollow pipe of circular-cross section. The antenna is excited by an electric field parallel to the axis applied across a gap of finite width which encircles the antenna. The currents are also determined for a thin antenna of any cross section. From the results the current on and the input admittance of the antennas are determined. It is shown that the thin antenna theory yeilds an incorrect result for the admittance because it ignores a boundary layer effect near the gap.

1961

1961 de Bettencourt, J. T.,
"Bistatic Cross Sections of Cylindrical Wires," Pickard and Burns, Inc., Needham, MA, Scientific Report RADC-TDR-61-285, 1961, (X).

ABSTRACT: No abstract available.

1961 Wu, T. T.,
"Theory of the Dipole Antenna and the Two-Wire Transmission Line," Journal of Mathematical Physics, vol. 2, no. 4, July-August 1961, pp. 550-574, (T,M).

ABSTRACT: The properties of the dipole antenna are studied by an approximate procedure that makes use of the Wiener-Hopf integral equation. In particular, the input admittance and the radiation pattern are found. The present results thus supplement the existing theories, which are concerned mostly with short dipoles. The same procedure is then applied to several related problems. First, the back-scattering cross section of a dipole antenna is found approximately for normal incidence. Secondly, the two-wire transmission line is studied in detail by considering it to be two coupled dipole antennas. The capacitive end correction for an open end is evaluated, and the radiated power and the radiation resistance are found for a resonant section of transmission line with both ends open. Finally, the dielectric-coated antenna is considered briefly.

1961 Garbacz, R. J., and D. L. Moffatt,
"An Experimental Study of Bistatic Scattering from Some Small, Absorber-Coated, Metal Shapes," Proc. IRE, vol. 49, no. 7, July 1961, pp. 1184-1192, (M).

ABSTRACT: Experimental data are presented on the bistatic scattering cross sections of some small metal bodies, uncoated and coated with a resonant, lossy layer. All of the targets--spheres, cylinders, and cones--are of a size to be in the resonant region at wavelengths of approximately 3 cm. All of the bodies indicate a similar trend--the coated bodies are effectively camouflaged in the back hemisphere, but not in the forward hemisphere. In the forward direction, the scattering cross sections of the coated bodies are at least as large as, or larger than, those of the uncoated bodies. The bistatic angles beyond which this enhancement is effective become smaller as the electrical size of the body decreases, i.e., as frequency decreases.

1961 Hessemer, R. A., Jr.,
"Scatter Communications with Radar Chaff," IRE Trans. on Antennas and Propagation, vol. AP-9, no. 2, March 1961, pp. 211-217, (T).

ABSTRACT: The first part of this paper is concerned with finding an analytical expression for the scattering cross section of chaff oriented randomly within a vertical cone. The dipoles are allowed to take on all the angles within this cone. A vertically-polarized receiver is assumed off on the horizon and the transmitter on ghe ground below the chaff. The cross section is a function of the conical angle of the configuration and the angle between a normal to the ground and the incident electric field from the transmitter. Fig. 2 is a plot of the scattering cross section as a function of these two angles.

Half-wave chaff randomly distributed within a conical angle about a vertical is not the most effective ensemble, but is a practical one at the lower frequencies. Cutting all these half-wave dipoles into very short ones makes it practical to place them in a horizontal position which has an ensemble gain over the conical but a reradiation loss, since short dipoles are less effective scatters than half-wave ones. The second part of this paper compares the reradiation loss and horizontal ensemble gain.

1960

1960 Duncan, R. H., and F. A. Hinchey,
"Cylindrical Antenna Theory," Journal of Research of the National Bureau of Standards--D. Radio Propagation, vol. 64D, no. 5, September-October 1960, pp. 569-584, (T).

ABSTRACT: A partial survey of cylindrical antenna theory pertaining to a tubular model with a narrow gap is presented. The survey includes discussion of the theories of Hallén, King and Middleton, Storm, and Zuhrt. A conceptual relation between theory and experiment is described. The latter part of the article is concerned with a new Fourier series solution of the Hallén equation. This solution is developed in

Duncan, R. H., and F. A. Hinchey, (cont.)

such a way that the expansion coefficients are the unknowns of a system of linear equations. The elements of the coefficient matrix are given by a highly convergent series. Numerical results are given for half and full wavelength antennas with half length to radius ratios of 60 and 500π. These results compare quite closely with those obtained from King-Middleton theory.

1960 Copeland, J. R.,
"Radar Target Classification by Polarization Properties," Proc. IRE, vol. 48, no. 7, July 1960, pp. 1290-1296, (T).

ABSTRACT: The polarization properties of radar targets are studied as a parameter related to, but quite distinct from, echo area. It is found that targets are divided into several different classes. The polarization properties may be measured by rotating a linearly polarized radar antenna around the line of sight, and measuring the complex voltage presented at the receiving antenna terminals.

It is shown that the polarization properties of any target so measured can be represented by a 3-parameter model (excluding echo area), and the parameters of such a model can be used as the basis for discriminating between targets of the same or different classes.

1960 Krevsky, S.,
"A Note Concerning the Precise Measurements of Dipole Antenna Impedance," IRE Trans. on Antennas and Propagation, vol. AP-8, no. 3, May 1960, pp. 343-344, (T).

ABSTRACT: No abstract available.

1960 Cassedy, E. S., and J. Fainberg,
"Back Scattering Cross Sections of Cylindrical Wires of Finite Conductivity," IRE Trans. on Antennas and Propagation, vol. AP-8, no. 1, January 1960, pp. 1-7, (T,M).

ABSTRACT: The back scattering cross sections of fine wires, taking the effect of finite conductivity into account, have been found. The variational procedure is used to find theoretical expressions for the cross section and it is concluded that the zeroth and the first-order solutions of Tai converge to one another with the addition of loss, in the region of first resonance. For fine copper, platinum and bismuth wires, experimentally determined cross sections agree with the theoretical results calculated from the zero-order solution to within 4 per cent in peak resonant values and 1.5 per cent in bandwidth.

1959

1959 De Hoop, A. T.,
"On the Plane-Wave Extinction Cross Section of an Obstacle," Applied Scientific Research, Section B, vol. 7, The Hague, 1959, pp. 463-469, (T).

ABSTRACT: A time-harmonic plane electromagnetic wave is incident upon an obstacle of finite dimensions. The properties of the obstacle are such that electromagnetic power is both absorbed and scattered. A close

De Hoop, A. T., (cont.)

relation exists between the extinction cross-section of the obstacle and the amplitude and phase of the scattered wave in the direction of propagation of the incident wave. The exact form of this relation, the "cross-section theorem", is proved by making use of an explicit representation of the scattered field. The result is valid for a plane wave with arbitrary elliptic polarization. Finally, a similar relation for the scattering of sound waves is given.

1959 Siegel, K. M.,
"Far Field Scattering from Bodies of Revolution," Applied Scientific Research, Section B, vol. 7, The Hague, 1959, pp. 293-328, (T,M).

ABSTRACT: By use of approximations based on physical reasoning radar cross-section results for bodies of revolution are found. In the Rayleigh region (wavelength large with respect to object dimensions) approximate solutions are found. Examples given include a finite cone, a lens, an elliptic ogive, a spindle and a finite cylinder. In the physical optics region (wavelength very small with respect to all radii of curvature) Kirchhoff theory and also geometric optics can be used. When the body dimensions are only moderately large with respect to the wavelength, Fock or Franz theory can be applied, and examples of the circular and elliptic cylinder are presented. In the region where some dimensions of the body are large with respect to the wavelength and other dimensions are small with respect to the wavelength, special techniques are used. One example, the finite cone, is solved by appropriate use of the wedge-like fields locally at the base. Another example is the use of traveling wave theory for obtaining approximate solutions for the prolate spheroid and the ogive. Other results are obtained for cones the base perimeter of which is of the order of a wavelength by using known results for rings of the same perimeter.

1959 Franz, F., and P. A. Mann,
"The Conductance of Dipoles of Arbitrary Size and Shape," IRE Trans. on Antennas and Propagation, vol. AP-7, no. 4, October 1959, pp. 353-358, (T).

ABSTRACT: The real part of either the impedance or the admittance of dipoles of arbitrary size and shape can be computed rigorously without solving a boundary value problem of a partial differential equation. In analogy to a well-known method of potential theory, fields of standing waves can be generated by integrals over current filaments so that for a given frequency there exist dipole shaped surfaces normal to the electric field surrounded by distant surfaces of vanishing electric field strength. Boundaries of perfect conductors may be supposed to coincide with a dipole shaped surface and a distant closed surface. The transients of such fields of standing waves are intimately related to the steady state of the free radiating dipole, since, before the first waves reflected from the distant enclosure have come back, the dipole cannot know whether or not it is enclosed. Corresponding to the type of current filament, either the resistance, or the conductance, of the radiating dipole can be calculated by direct integrations, while the shape of the dipole is determined by an ordinary differential equation of first order. As an example, we compute a family of dipoles that all

Franz, F., and P. A. Mann, (cont.)

have the same conductance $G = (254\Omega)^{-1}$ and a length $2h$ between limits $\lambda/2 \leq 2h \leq 1.36\ \lambda/2$.

1959 Bryan, J. H.,
"Chaff Countermeasures and Air Defense Radar Design," Technical Report 6, Stanford Research Institute, April 1959, and DTIC document no. AD354894L, (T,M).

ABSTRACT: Chaff may be used in a variety of ways to protect attacking bombers from air defense radars. This report considers the operational problem of chaff as a threat to U. S. radars by first surveying the technical characteristics of chaff and of anti-chaff techniques and then examining a characteristic tactical chaff defense problem in the light of these technical characteristics.

1959 Wu, T. T., and R. W. P. King,
"Driving Point and Input Admittance of Linear Antennas," Journal of Applied Physics, vol. 30, no. 1, January 1959, pp. 74-76, (T).

ABSTRACT: An infinity in the input admittance of linear antennas owing to the use of an idealized delta-function generator is investigated. It is shown that the infinity may be interpreted in terms of an infinite capacitance between the two halves of the antenna. The conclusion is reached that conventionally used iterative procedures are not invalidated by difficulties with respect to the driving point.

1958

1958 Hu, Y-Y.,
"Back-Scattering Cross Section of a Center-Loaded Cylindrical Antenna," IRE Trans. on Antennas and Propagation, vol. AP-6, no. 1, January 1958, pp. 140-148, (T,M).

ABSTRACT: A solution of the broadside back-scattering cross section, σ, of a center-loaded cylindrical antenna with any load impedance, Z_L, is obtained by a variational method through a four-terminal network approach. A simple formula for σ, in terms of Z_L and the parameters Z_{11}, Z_{12}, and Z_{22} associated with the antenna has been derived. The impedances Z_{11}, Z_{12}, and Z_{22} are independent of the load and they are determined by using the variational principle. Numerical results of the first order approximation are presented, and they are in good agreement with some measured results available in the literature.

1957

1957 Stone, M.,
"Preliminary Investigations of Mortar Shell Dispensed Chaff," Technical Memorandum no. M-1952, December 1975, U. S. Army Signal Engineering Laboratories, Fort Monmouth, NJ, and DTIC document no. AD301969, (T,M).

ABSTRACT: No abstract available.

1957 Bohn, E. V.,
"The Current Distribution and Input Impedance of Cylindrical Antennas," IRE Trans. on Antennas and Propagation, vol. AP-5, no. 4, October 1957, pp. 343-348, (T).

ABSTRACT: This paper treats both the formulation of the problem and its solution in a fundamental way permitting only approximations which appear evident. A system of four integro-differential equations is derived and these are applied to the cylindrical antenna problem. An integral equation of Hallen's type occurs and this is solved exactly by transform methods. The input impedance of a full wave antenna is computed numerically to show that the present theory is consistent with other results.

1956

1956 Hallén, E.,
"Exact Treatment of Antenna Current Wave Reflection at the End of a Tube-Shaped Cylindrical Antenna," IRE Trans. on Antennas and Propagation, vol. AP-4, no. 3, July 1956, pp. 479-491, (T).

ABSTRACT: No abstract available.

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"A Mathematical Model for the Radar Echo from a Random Collection of Scatterers," M.I.T. Lincoln Laboratory R port 123, June 15, 1956, (X).

ABSTRACT: No abstract available.

1956 Emerson, C. L., Jr., and G. E. Niles,
"Production of Metallized Fibers for Dipole Chaff," Wright Air Development Center (WADC), Tech. Report 55-255, Materials Laboratory, April 1956, and DTIC document no. AD99182, (M).

ABSTRACT: The development of a metallized nylon fiber suitable for dipole chaff has been completed. The finished fiber is approximately 2.9 mils in diameter. It consists of a nylon monofilament 2.8 mils in diameter coated first with silver and then with nylon deposited from solvent. The electrical resistance is continuously less than 15 ohms/inch. Abrasion resistance and non-clumping is good. The cost of the packaged product is less than 0.01¢/foot of length.

1956 Graves, C. D.,
"Radar Polarization Power Scattering Matrix," Proc. IRE, vol. 44, no. 2, February 1956, pp. 248-252, (T).

ABSTRACT: Because the polarization sense of an electromagnetic wave is changed when the direction of propagation is reversed, a new type of polarization vector which is directionally dependent is introduced. The scattering matrix formulation is then introduced in terms of directional vectors and directional transformation matrices, and the transformation of the scattering matrix under a unitary change of polarization basis transformation is shown to be a congruent transformation. The congruent sub-group of unitary transformations of the

Graves, C. D., (cont.)

polarization basis is then discussed, and it is shown that the scattering matrix can be reduced to diagonal form by this sub-group of transformations. A new matrix, called the polarization power scattering matrix, is then introduced and its relation to the scattering matrix is discussed. The power matrix gives the total power back-scattered from the target for any transmitted polarization. It specifies the scattering matrix up to two phase angles (one of which is of no importance), and is more easily measured. The total power scattering matrix can be determined for any target by measuring only the total power in the backscattered return; no phase measurement is necessary and only plane polarizations need be transmitted.

1955

1955 Lindroth, K.,
"Reflection of Electromagnetic Waves from Thin Metal Strips," Transactions of the Royal Institute of Technology, Stockholm, no. 91, UDC621.396.968, 1955, (T).

ABSTRACT: No abstract available.

1955 Siegel, K. M., H. A. Alperin, R. R. Bonkowski, J. W. Krispin, A. L. Maffett, C. E. Schensted, and I. V. Schensted,
"Bistatic Radar Cross Sections of Surfaces of Revolution," Journal of Applied Physics, vol. 26, no. 3, March 1955, pp. 297-305, (T).

ABSTRACT: The results obtained by applying the current-distribution method to the problem of approximating the scattering cross section, when the transmitter and receiver are separated, are presented for several simple geometric configurations. The method is applied for the case in which the transmitter is located on the axis of revolution and the ratio l/λ is large, where l is a "characteristic dimension" of the body and λ is the wavelength. These results indicate that in most of the cases considered the cross section increases as the angle between the receiver and the transmitter increases.

1954

1954 Storer, J. E., and J. Sevick,
General Theory of Plane-Wave Scattering from Finite, Conducting Obstacles with Application to the Two-Antenna Problems," Journal of Applied Physics, vol. 25, no. 3, March 1954, pp. 369-376, (T).

ABSTRACT: In this paper the variational techniques of Levine and Schwinger are used to obtain an approximate solution for the free-space scattering by a number of finite, perfectly conducting obstacles in which the mutual interactions or coupling are taken into account. The far-zone scattered field is found in terms of the obstacle currents. Variational principles for the total and backscattering cross sections are included. The special case of two parallel wires of finite length is worked out, and the results agree well with experiment.

1953

1953 Dike, S. H., and D. D. King
"Discussion on: The absorption Gain and Backscattering Cross Section of the Cylindrical Antenna," Proc. IRE, vol. 41, no. 7, July 1953, pp. 926-934, (T,M).

ABSTRACT: No abstract available.

1952

1952 Tai, C. T.,
"Electromagnetic Back-Scattering from Cylindrical Wires," Journal of Applied Physics, vol. 23, no. 8, August 1952, pp. 909-916, (T).

ABSTRACT: The problem of electromagnetic back-scattering or radar response from cylindrical wires has been investigated using a variational method. The relation between this method and the induced emf method is discussed. To demonstrate the flexibility of the variational calculation different trial functions have been used to determine the numerical values of the back-scattering cross ection for the case of broadside incidence. The boundary condition regarding the currents at the end of the wire is also carefully examined.

1952 Dike, S. H., and D. D. King,
"The absorption Gain and Back-Scattering Cross Section of the Cylindrical Antenna," Proc. IRE, vol. 40, no. 7, July 1952, pp. 853-860, (T,M).

ABSTRACT: The method of Hallén as modified by King and Middleton is applied to the case of the receiving dipole antenna whose axis is parallel to the electric vector of a far-zone field. First-order formulas are given for gain and broadside back-scattering cross section. Measured values of broadside gain and of broadside back-scattering cross section for both unloaded and matched-loaded dipoles are compared with the theory.

1952 Moullin, E. B., and F. M. Phillips,
"On the Current Induced in a Conducting Ribbon by the Incidence of a Plane Electromagnetic Wave," Proc. IEE, vol. 99, Part IV, no. 3, (Monograph 26, Radio Section), July 1952, pp. 137-150, (T).

ABSTRACT: No abstract available.

1952 Sevick, J.,
"Experimental and Theoretical Results on the Back-Scattering Cross Section of Coupled Antennas," Harvard University, Cruft Laboratory, Technical Report no. 150, May 26, 1952, (T,M).

ABSTRACT: This paper presents the theoretical and experimental results of the back-scattering from two coupled antennas. The theoretical development was presented in Technical Report No. 149. In order to provide a basis for comparison, results are also given for the single antenna case.

1948

1948 Hallén, E.,
"Properties of a Long Antenna," Journal of Applied Physics, vol. 19, no. 12, December 1948, pp. 1140-1147, (T).

ABSTRACT: Although exact integral expressions for the outgoing current waves on a long antenna have long existed, they have never been brought in such a form that a numerical or graphical description of the wave has been possible. The author shows how to transform them into good series expansions valid for all distances from the feeding point. Graphs show the result. The traveling current waves can also be extracted from the author's expression for the current on a finite transmitting antenna published in Nova Acta Upsal, 1938. Both ways give identical series.

1947

1947 Van Vleck, J. H., F. Bloch, and M. Hammermesh,
"Theory of Radar Reflection from Wires or Thin Metallic Strips," Journal of Applied Physics, vol. 18, no. 3, March 1947, pp. 274-294, (T).

ABSTRACT: Knowledge of the radar response of wires or thin metallic strips, as a function of their length and thickness, and of the radar frequency is important in the design of relfectors for radar. In view of the difficulty of this theoretical problem and the necessity of making approximations, as well as the dearth of adequate experimental data, two independent procedures for solution are presented. Detailed quantitative results are obtained for the angular dependence of the cross section, and also for the mean cross section, of randomly-oriented wires or, more generally, of metallic strips, which behave electromagnetically like cylindrical wires of a certain "equivalent radius." When expressed in terms of a unit of area equal to the square of the wave-length, these cross sections depend on the dimensions of the wire only through the two ratios.

1946

1946 King, D. D.,
"The Measured Impedance of Cylindrical Dipoles," Journal of Applied Physics, vol. 17, no. 10, October 1946, pp. 844-852, (M).

ABSTRACT: The input impedance of cylindrical dipoles is considered from the experimental point of view. Errors in measuring methods are considered and the results of a recent determination of dipole impedance are displayed.

1946 King, R., and D. Middleton,
"The Cylindrical Antenna; Current and Impedance," Quarterly of Applied Mathematics, vol. III, no. 4, 1946, pp. 302-335, (T).

ABSTRACT: No abstract available.

1946 Middleton, D., and R. King,
"The Thin Cylindrical Antenna: A Comparison of Theories," Journal of Applied Physics, vol. 17, no. 4, April 1946, pp. 273-284, (T,M).

ABSTRACT: The solutions of Hallén's integral equation for the cylindrical antenna given by Hallén, Bouwkamp, Gray, King and Middleton are compared. Comparison is also made with the transmission-line theory of Schelkunoff and with experiment.

1946 Fink, D. G.,
"Radar Countermeasures," Electronics, vol. 19, January 1946, pp. 92-97, (M).

ABSTRACT: Equipment for detecting enemy radars, determining their location, analyzing their characteristics and then jamming them electronically or by means of chaff is described. Many of the devices used, such as shf direction-finders, wideband radiators, and the resnatron tube, have postwar applications.

1945

1945 Brown, G. H., and O. M. Woodward, Jr.,
"Experimentally Determined Impedance Characteristics of Cylindrical Antennas," Proc. IRE, vol. 33, no. 4, April 1945, pp. 257-262, (M).

ABSTRACT: Measurements of resistance and reactance of cylindrical antennas operated against ground have been made, with a wide variation of both antenna length and diameter. These data are displayed by means of a series of graphs.

The maximum values of resistance encountered are displayed. The shortening effect near the quarter-wave resonance point is also shown.

Terminal conditions, such as capacitance of the base of the antenna to ground, are briefly considered, and a series of measurements shows the wide variation in impedance for varying terminal conditions.

Measurements made in the course of the investigation show that the impedance of the antenna is independent of whether the top of the radiator is open or closed. The measured impedance data are also directly applicable to the case of a center-fed dipole.

1944

1944 Bloch, F., M. Hamermesh, and M. Phillips,
"Return Cross Sections from Random Oriented Resonant Half-Wave Length Chaff," Harvard University, Radio Research Laboratory, Technical Memorandum 411-TM-127, June 19, 1944, (T).

ABSTRACT: The return cross section observed with parallel receiver and transmitter antennas is determined for chaff of length $\lambda/2$, λ being the wave-length of the radiation. If the chaff is very thin, the lengthwise distribution of the current will be determined from the conservation of energy. It is found:

a) If the chaff is oriented at an angle θ with respect to the direction of incidence and if its common plane with the direction of in-

Bloch, F. M. Hamermesh, and M. Phillips, (cont.)

cidence is inclined at an angle ϕ to the plane of polarization, the cross-section is given by

$$\sigma = .892\lambda^2\left(\frac{\cos\phi\,\cos((\pi/2)\cos\theta)}{\sin\theta}\right)^4$$

with a maximum value

$$\sigma_{max} = .892\lambda^2$$

if $\phi = 0$ and $\theta = \pi/2$, i.e., if the chaff is oriented perpendicular to the direction of incidence and parallel to the electric field of the incident radiation.

b) If all orientations of the chaff are equally probable, i.e., for spherically random oriented chaff, the average value of the cross-section becomes

$$\sigma_s = \frac{\sigma_{max}}{5.66}$$

c) If the chaff is oriented in the plane of polarization and all orientations in that plane are equally probable, i.e., for chaff, randomly oriented in the plane of polarization, the average value of the cross-section becomes

$$\sigma_p = \frac{\sigma_{max}}{3.08} .$$

1943

1943 Kuiper, G. P.,
"A Study of Chaff Echoes at 515 Mc," Radio Research Lab., Harvard University, Cambridge, MA, Report 411-73, December 19, 1943, (X).

ABSTRACT: No abstract available.

1943 Siegert, A. J. F.,
"On the Fluctuations in Signals Returned by Many Independently Moving Scatterers," M. I. T. Radiation Laboratory Report 465, November 12, 1943, (T).

ABSTRACT: The joint probability $W_2(I_1, I_2t)$ of obtaining two return signals of intensities I_1 and I_2 a time t apart from N equal scatterers has been calculated under the following assumptions:

(1) The return signals from all N scatterers are received simultaneously at both instances of time.

(2) The scatterers move independently of each other in random directions, the distribution function of speeds is given as q(v)dv.

(3) The computation is carried out in the limit $N \to \infty$, while the power returned by the individual scatterers goes to zero as $\frac{1}{N}$. The joint probability is found to be

Siegert, A. J. F., (cont.)

$$W_2(I_1,I_2,\,t)\,dI_1\,dI_2 = \frac{1}{I_0{}^2(1-g^2)}\,e^{-\frac{I_1+I_2}{I_0(1-g^2)}}\,J_0\left(\frac{2ig\sqrt{I_1I_2}}{I_0(1-g^2)}\right)$$

where I_0 is the average signal intensity and g the correlation factor defined by

$$g^2 = \frac{\overline{I_1I_2} - I_0{}^2}{I_0{}^2}\,,\quad g \geq 0\,.$$

g is a function of t, and is expressed in terms of the wavelength λ and the distribution function q(v) by

$$g(t) = \int_0^\infty q(v)\,\frac{\sin\left(\frac{4xvt}{\lambda}\right)}{\left(\frac{4xvt}{\lambda}\right)}\,dv$$

One easily verifies that

$$\int_0^\infty dI_2\,W_2(I_1,I_2,t) = \frac{e^{-I_1/I_0}}{I_0} = W_1(I_1)$$

The conditional average, $\bar{I}_2^{I_1} = \frac{1}{W_1}\int_0^\infty I_2\,dI_2\,W_2$ was found to be

$$\bar{I}_2^{I_1} = g^2\,I_1 + (1-g^2)\,I_0$$

so that the average of all values I_2, occurring a time t after I_1 was found, lies between I_1 and I_0.

The spectrum of $I-I_0$, considered as a function of time, has been computed for the case that all particles have the same speed v_0. It was found to contain frequencies up to $\frac{4v_0}{\lambda}$ (cycles/sec.).

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1971 Mack
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1970 Mott
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1969 Miller, et al.
1969 Thiele
1968 Garbacz, et al.
1968 Chen
1967b Mayer
1967 Richmond
1967a Mayer
1967 Chang, et al.
1966b Mayer
1966a Mayer
1964a Harrington
1963 Harrison, et al.
1963 Harrington
1962 Mack
1962 Harrington
1961 Wu
1960 Cassedy, et al.
1958 Hu
1953 Dike, et al.
1952 Tai
1952 Dike, et al.
1947 Van Vleck, et al.

(b) DIPOLE BISTATIC REFLECTIVITY

1981 Medgyesi-Mitschang, et al.
1981b Heath
1981a Heath
1975 Tew
1972 Kuo, et al.
1970 Kao
1969 Kao
1969 Einarsson
1967 Harrington, et al.
1967 Breithaupt
1967 Borison
1966 Di Caudo, et al.
1965 Palermo, et al.
1965 Richmond
1964b Harrington
1964a Harrington
1964 Mack, et al.
1961 de Bettencourt
1961 Garbacz, et al.
1955 Lindroth

(c) CHAFF MONOSTATIC REFLECTIVITY

1982 Butters
1979a Ioannidis
1978 Garbacz
1978 Rivers
1976 Poelman
1975 Pinson
1975 Puskar
1975b Pyati
1974b Wickliff, et al.
1974 Stanton, et al.
1974a Wickliff, et al.
1974 Puskar
1973 Stanton, et al.
1972 Poelman, et al.
1969 Diggs
1969 Seltzer
1967 Wong, et al.
1966 Wong, et al.
1965 Borison
1956 Kelly, et al.
1947 Van Vleck, et al.
1944 Bloch, et al.
1943 Kuiper

(d) CHAFF BISTATIC REFLECTIVITY

1978 Dedrick, et al.
1977 Robillard, et al.
1975 Garbacz, et al.
1973 Garbacz, et al.
1967 Borison
1965 Palermo, et al.
1962 Twersky
1961 Hessemer

(e) DIPOLE IMPEDANCE

1981 Streable, et al.
1973 Kajfez, et al.
1973 Toulios, et al.
1968 Garbacz, et al.
1968 Shen, et al.
1968 Shen
1967 Shen
1967 Shen et al.
1967 Harrington, et al.
1966e King, et al.
1966d King, et al.
1966c King, et al.
1966b King, et al.
1966a King, et al.
1963 et al.
1962 Chen
1961 Wu
1960 Duncan, et al.

(f) DIPOLE LOSSES

1978 Rivers
1969 Thiele
1968 Garbacz, et al.
1968 Thiele
1967a Mayer
1967 Richmond
1967b Mayer
1967a Mayer
1967 Breithaupt
1966e King, et al.
1966c King, et al.
1965 FitzGerrell
1964 Mack, et al.
1963 Harrison, et al.
1962 Harrington
1960 Cassedy, et al.

DIPOLE IMPEDANCE (cont.)

1960 Krevsky
1959 Franz, et al.
1959 Wu, et al.
1957 Bohn
1946 King
1946 Middleton, et al.
1946 King, et al.
1945 Brown, et al.

(g) CHAFF/DIPOLE WAVE ATTENUATION

1978 Rivers
1975 Carbacz, et al.
1974 Puskar
1968 Garbacz, et al.
1967 Kownacki
1962 Twersky
1959 De Hoop

(h) CHAFF DISPENSATION

1981 Knoff, et al.
1981 Beeker, et al.
1978 Dube
1978 Carignan
1976 Sundaram
1974 Puskar
1972 Kukainis
1970 DilPare
1964 La Pointe
1959 Bryan
1957 Stone
1946 Fink

(i) CHAFF PHYSICAL PROPERTIES

1982 Butters
1981 Knott, et al.
1981b Traci, et al.
1981a Traci, et al.
1978 Rivers
1977 Brunk
1976 Sundaram
1975 Brunk, et al.
1975 Pinson
1975 Schiff
1974 Puskar
1970 DilPare
1963 Harrison, et al.
1963 Jiusto, et al.
1961 Hessemer
1959 Bryan
1956 Emerson, et al.
1946 Fink

(j) OTHER

1981 Knott, et al.
1981 Poelman
1981 Boerner, et al.
1980 Cherenshy
1979b Ioannidis, et al.
1977 Elia
1977 Silverman
1976 Adrian
1975a Pyati
1974 Richmond, et al.
1972 Seltzer
1971 Varshavchuk
1970 Mullin
1970 Pollon
1969 Taylor
1969 Mitchell
1969 Seltzer
1968 Shen
1967 Weissman
1967 Fialkovskii
1967 Shen, et al.
1967 Harrington
1965 Huynen
1965 Garbacz

OTHER (cont.)

1965 Senior
1965 Mei
1965 Fulton
1965 Andreasen
1964 Borison
1964b Harrington
1963 Childers, et al.
1960 Duncan, et al.
1960 Copeland
1959 Siegel
1957 Bohn
1956 Hallén
1956 Graves
1955 Siegel, et al.
1954 Storer, et al.
1952 Moullin, et al.
1952 Sevick
1948 Hallén
1946 Middleton, et al.
1946 King, et al.
1943 Siegart

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