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Editorial Comment on the Scientific Papers of Lord Rayleigh (John William Strutt)

With the great outpouring of published papers on radio physics, it is worthwhile to return to the works of Lord Rayleigh (1842–1919). Many of the current ideas in electromagnetics, acoustics, and optics have germs in the original papers by Lord Rayleigh. It is a pity that many present-day authors prefer to refer to some available textbook or current journal article rather than giving the basic reference.

As a service to the readers and prospective authors of *Radio Science*, we list here the papers of Lord Rayleigh which appear to be closely related to the subject of the journal. No attempt is made to classify the papers according to subject. However, it is believed that the following list includes those of special interest to researchers in electromagnetic wave propagation at all frequencies:

On the light from the sky, its polarization and colour, Phil. Mag. **XLI,** 107–120, 274–279 (1871).
On the scattering of light by small particles, Phil. Mag. **XLI,** 447–454 (1871).
On double refraction, Phil. Mag. **XLI,** 519–528 (1871).
On the reflection of light from transparent matter, Phil. Mag. **XLII,** 81–97 (1871).
Notes on Bessel's functions, Phil. Mag. **XLIV,** 328–344 (1872).
On the reflection and refraction of light by intensely opaque matter, Phil. Mag. **XLIII,** 321–338 (1872).
An experiment to illustrate the induction on itself of an electric current, Nature **VI,** 64 (1872).
Some general theorems relating to vibrations, Section I. The natural periods of a conservative system, vibrating freely about a configuration of stable equilibrium, fulfill the stationary condition, Section II. The dissipation function, Section III., Proc. London Math. Soc. **IV,** 357–368 (1873).
On a permanent deflection of the galvanometer-needle under the influence of a rapid series of equal and opposite induced currents, Phil. Mag. **III,** 43–46 (1877).
On the relation between the functions of Laplace and Bessel, Proc. London Math. Soc. **IX,** 61–64 (1878).
On reflection of vibrations at the confines of two media between which the transition is gradual, Proc. London Math. Soc. **XI,** 51–56 (1880).
On the resolving-power of telescopes, Phil. Mag. **X,** 116–119 (1880).
Note on the theory of the induction balance, British Assoc. Report, Swansea, 472–473 (1880).
On the electromagnetic theory of light, Phil. Mag. **XII,** 81–101 (1881).
On the velocity of light, Nature **XXIV,** 382–383; **XXV,** 52 (1881).
On a question in the theory of lighting, British Assoc. Report, 526 (1881).
On the infinitesimal bending of surfaces of revolution, Proc. London Math. Soc. **XIII,** 4–16 (1881).
On the determination of the ohm [B. A. Unit] in absolute measure, Part I. (by Lord Rayleigh), Part II. (by Arthur Schuster), Proc. Roy. Soc. London **XXXII,** 104–141 (1881).
Experiments to determine the value of the British Association unit of resistance in absolute measure, Phil. Trans. Roy. Soc. London **CLXXIII,** 661–697 (1882).
Experiments, by the method of Lorenz, for the further determination of the absolute value of the British Association unit of resistance, with an appendix on the determination of the pitch of a standard tuning-fork (by Lord Rayleigh and Mrs. H. Sidgwick), Phil. Trans. Roy. Soc. London **CLXXIV,** 295–322 (1883).
On the mean radius of coils of insulated wire, Proc. Cambridge Phil. Soc. **IV,** 321–324 (1883).
On the invisibility of small objects in a bad light, Proc. Cambridge Phil. Soc. **IV,** 4 (1883).
On the imperfection of the galvanometer as a test of the evanescence of a transient current, British Assoc. Report, 444–445 (1883).
On the measurement of electric currents, Proc. Cambridge Phil. Soc. **V,** 50–52 (1883).
On the measurement of the electrical resistance between two neighbouring points on a conductor, Proc. Cambridge Phil. Soc. **V,** 133–134 (1884).
On the electro-chemical equivalent of silver, and on the absolute electromotive force of Clark cells (by Lord Rayleigh and Mrs. H. Sidgwick), Phil. Trans. Roy. Soc. London **CLXXV,** 411–460 (1884).
On telephoning through a cable, British Assoc. Report, 632–633 (1884).
On a galvanometer with twenty wires, British Assoc. Report, 633 (1884).
Über die Methode der Dämpfung bei der Bestimmung des Ohms, Ann. Physik Chem., Band **XXIV,** 214–215 (1885).
On the self-induction and resistance of straight conductors, Phil. Mag. **XXI,** 381–394 (1886).
On the intensity of light reflected from certain surfaces at nearly perpendicular incidence, Proc. Roy. Soc. London **XLI,** 275–294 (1886).
On the existence of reflection when the relative refractive index is unity, British Assoc. Report, 585–586 (1887).
Wave theory of light, Encyclopoedia Britannica **XXIV** (1888).
On the reflection of light at a twin plane of a crystal, Phil. Mag. **XXVI,** 241–255 (1888).
On achromatic interference-bands, Phil. Mag. **XXVIII,** 77–91, 189–206 (1889).
Remarks on Maxwell's investigation respecting Boltzmann's theorem, Phil. Mag. **XXXIII,** 356–359 (1892).
On the intensity of light reflected from water and mercury at nearly perpendicular incidence, Phil. Mag. **XXXIV,** 309–320 (1892).
On the interference bands of approximately homogeneous light; in a letter to Prof. A. Michelson, Phil. Mag. **XXXIV,** 407–411 (1892).
On the influence of obstacles arranged in rectangular order upon the properties of a medium, Phil. Mag. **XXXIV,** 481–502 (1892).
On the theory of stellar scintillation, Phil. Mag. **XXXVI,** 129–142 (1893).
On the reflection of sound or light from a corrugated surface, British Assoc. Report, 690–691 (1893).
On a simple interference arrangement, British Assoc. Report, 703–704 (1893).
On the minimum current audible in the telephone, Phil. Mag. **XXXVIII,** 285–295 (1894).
An attempt at a quantitative theory of the telephone, Phil. Mag. **XXXVIII,** 295–301 (1894).
On the passage of electric waves through tubes, or the vibrations of dielectric cylinders, Phil. Mag. **XLIII,** 125–132 (1897).
On the passage of waves through apertures in plane screens, and allied problems, Phil. Mag. **XLIII,** 259–272 (1897).
On the measurement of alternate currents by means of an obliquely situated galvanometer needle, with a method of determining the angle of lag, Phil. Mag. **XLIII,** 343–349 (1897).
On the incidence of aerial and electric waves upon small obstacles in the form of ellipsoids or elliptic cylinders, and on the passage of electric waves through a circular aperture in a conducting screen, Phil. Mag. **XLIV,** 28–52 (1897).
On the propagation of electric waves along cylindrical conductors of any section, Phil. Mag. **XLIV,** 199–204 (1897).
Note on the pressure of radiation, showing an apparent failure of the usual electromagnetic equations, Phil. Mag. **XLV,** 522–525 (1898).
On the transmission of light through an atmosphere containing small particles in suspension, and on the origin of the blue of the sky, Phil. Mag. **XLVII,** 375–384 (1899).
The theory of anomalous dispersion, Phil. Mag. **XLVIII,** 151–152 (1899).
The mutual induction of coaxial helices, British Assoc. Report, 241–242 (1899).
The law of partition of kinetic energy, Phil. Mag. **XLIX,** 98–118 (1900).
On the law of reciprocity in diffuse reflexion, Phil. Mag. **XLIX,** 324–325 (1900).
On Balfour Stewart's theory of the connexion between radiation and absorption, Phil. Mag. **I,** 98–100 (1901).
On the magnetic rotation of light and the second law of thermodynamics, Nature **LXIV,** 577–578 (1901).
On the induction-coil, Phil. Mag. **II,** 581–594 (1901).
On the spectrum of an irregular disturbance, Phil. Mag. **V,** 238–243 (1903).
On the bending of waves round a spherical obstacle, Proc. Roy. Soc. London **LXXII,** 40–41 (1903).
On the theory of optical images, with special reference to the microscope, J. Roy. Microscop. Soc., 474–482 (1903).
Some measurements of wave-lengths with a modified apparatus, Phil. Mag. **XI,** 685–703 (1906).
On the experimental determination of the ratio of the electrical units, Phil. Mag. **XII,** 97–108 (1906).
On the dynamical theory of gratings, Proc. Roy. Soc. London, Ser. A **LXXIX,** 399–416 (1907).
Note on the remarkable case of diffraction spectra described by Prof. Wood, Phil. Mag. **XIV,** 60–65 (1907).
On the light dispersed from fine lines ruled upon reflecting surfaces or transmitted by very narrow slits, Phil. Mag. **XIV,** 350–359 (1907).
Further measurements of wave-lengths, and miscellaneous notes on Fabry and Perot's apparatus, Phil. Mag. **XV,** 548–558 (1908).
On the aberration of sloped lenses and on their adaptation to telescopes of unequal magnifying power in perpendicular directions, Proc. Roy. Soc. London, Ser. A **LXXXI,** 26–40 (1908).
On reflexion from glass at the polarizing angle, Phil. Mag. **XVI,** 444–449 (1908).
The theory of Crookes's radiometer, Nature **LXXXI,** 69–70 (1909).
To determine the refractivity of gases available only in minute quantities, Nature **LXXXI,** 519 (1909).
Colours of sea and sky, Proc. Roy. Inst. G. Brit., Feb. 25, 1910, Nature **LXXXIII,** 48 (1910).
The incidence of light upon a transparent sphere of dimensions comparable with the wave-length, Proc. Roy. Soc. London, Ser. A **LXXXIV,** 25–46 (1910).
The problem of the Whispering Gallery, Phil. Mag. **XX,** 1001–1004 (1910).
On a physical interpretation of Schlömilch's theorem in Bessel's functions, Phil. Mag. **XXI,** 567–571 (1911).
Aberration in a dispersive medium, Phil. Mag. **XXII,** 130–134 (1911).
On the propagation of waves through a stratified medium, with special reference to the question of reflection, Proc. Roy. Soc. London, Ser. A **LXXXVI,** 207–266 (1912).
On departures from Fresnel's laws of reflexion, Phil. Mag. **XXIII,** 431–439 (1912).
On the self-induction of electric currents in a thin anchor-ring, Proc. Roy. Soc. London, Ser. A **LXXXVI,** 562–571 (1912).
Electrical vibrations on a thin anchor-ring, Proc. Roy. Soc. London, Ser. A **LXXXVII,** 193–202 (1912).
The effect of junctions on the propagation of electric waves along conductors, Proc. Roy. Soc. London, Ser. A **LXXXVIII,** 103–110 (1913).
On the approximate solution of certain problems relating to the potential—II, Phil. Mag. **XXVI,** 195–199 (1913).
On the passage of waves through fine slits in thin opaque screens, Proc. Roy. Soc. London, Ser. A **LXXXIX,** 194–219 (1913).
Reflection of light at the confines of a diffusing medium, Nature **XCII,** 450 (1913).
Further applications of Bessel's functions of high order to the Whispering Gallery and allied problems, Phil. Mag. **XXVII,** 100–109 (1914).
On the diffraction of light by spheres of small relative index, Proc. Roy. Soc. London, Ser. A **XC,** 219–225 (1914).

On the electrical capacity of approximate spheres and cylinders, Phil. Mag. **XXXI,** 177–186 (1916).
On Legendre's function $P_n(\theta)$, when n is great and θ has any value, Proc. Roy. Soc. London, Ser. A **XCII,** 433–437 (1916).
The theory of anomalous dispersion, Phil. Mag. **XXXIII,** 496–499 (1917).
On the reflection of light from a regularly stratified medium, Proc. Roy. Soc. London, Ser. A **XCIII,** 565–577 (1917).
On the colours diffusely reflected from some collodion films spread on metal surfaces, Phil. Mag. **XXXIV,** 423–428 (1917).
On the scattering of light by spherical shells, and by complete spheres of periodic structure, when the refractivity is small, Proc. Roy. Soc. London, Ser. A **XCIV,** 296–300 (1918).
On the dispersal of light by a dielectric cylinder, Phil. Mag. **XXXVI,** 365–376 (1918).
On the light emitted from a random distribution of luminous sources, Phil. Mag. **XXXVI,** 429–449 (1918).
On the possible disturbance of a range-finder by atmospheric refraction due to the motion of the ship which carries it, Trans. Optical Soc. **XX,** 125–129 (1919).

The complete set of scientific papers of Lord Rayleigh (John William Strutt) has been published by Cambridge University Press in six volumes extending from 1869 to 1919. More recently (1964) there have been reissues by Dover Publications, Inc., New York (Library of Congress Catalog Card No. 64-18368).

JAMES R. WAIT, *Editor*

Reviews and Selected Abstracts in Radio Science*

Magnetic properties of mixed metal oxides containing trivalent cobalt, G. Blasse, *J. Appl. Phys.* **36,** *No. 3, part 2, 879–883 (Mar. 1965).*

In oxidic lattices the Co^{3+} ($3d^6$) ion has been found both in the diamagnetic low-spin state and in the paramagnetic high-spin state. The factors influencing the equilibrium between high- and low-spin Co^{3+} ions are discussed.
New compounds are presented in which the change of the equilibrium distribution among these two states is measurable because the energy difference between the two states is small. It is then possible to change the equilibrium by varying the temperature. The temperature dependence of the magnetic susceptibility of such a compound is anomalous as has been derived by Ballhausen and Liehr.

Saturation ion currents to Langmuir Probes, F. F. Chen, *J. Appl. Phys.* **36,** *No. 3, part 1, 675–678 (Mar. 1965).*
The parabolic variation of saturation ion current with probe potential observed in dense plasmas is fortuitous and is not directly related to the effects of orbital motion. Agreement between measured and computed saturation ion characteristics is illustrated. The discussion is in the framework of collisionless, magnetic-field-free theories; they apply to the experiments only if the ion Larmor radius is much larger than the probe radius.

Electrical resistivity of metals and alloys containing localized magnetic moments, A. J. Dekker, *J. Appl. Phys.* **36,** *No. 3, part 2, 906–912 (Mar. 1965).*
In metals and alloys containing localized magnetic moments, an important contribution to the electrical resistivity can be associated with disorder of the atomic spin system. This contribution is ascribed to a scalar interaction between the spins of the conduction electrons and the atomic spins. Assuming a simple form for this interaction, the experimental and theoretical situation concerning the spin-disorder resistivity is reviewed for pure metals, dilute alloys, and concentrated binary alloys.

Magnetization, resonance, and optical properties of the ferromagnet CrI_3, J. F. Dillon, Jr., and C. E. Olson, J. Appl. Phys. **36,** *No. 3, part 2, 1259–1260 (Mar. 1965).*
CrI_3, noteworthy as one of the few insulating ferromagnets, is one of a series of presumably isomorphous compounds ($CrCl_3$, $CrBr_3$, and CrI_3) which show similar or closely related magnetic ordering. CrI_3 samples containing some single crystals (plates a few square millimeters in area) were made by reacting chromium metal and iodine in a sealed quartz tube. Magnetization measurements of the powder were made by Williams and Sherwood at several fields up to 15300 Oe over the range of 1.5° to 300° K. In addition, $M(H)$ was plotted at 4.2° up to 70000 Oe. The ferromagnetic Curie temperature is 68° K, and the paramagnetic Curie temperature is 70° K. The low-temperature saturation magnetization is 3.10 μ_B/Cr^{+++}, corresponding to $4\pi M = 2690$ G. The field for ferromagnetic resonance was measured at 86, 91, and 99 Gc/sec. The spectroscopic splitting factor $g = 2.07$, and the anisotropy field $2K/M = 28.6$ kOe at 1.5° K. Optical transmission measurements on CrI_3 single crystals showed a very strong absorption band down to a band edge near 10000 cm^{-1}. The specific magnetic rotations associated with the band edge are almost as large as those observed in the tribromide. Evidence of domain diffraction was seen.

Resistivity of xenon plasma, J. H. Goncz, *J. Appl. Phys.* **36,** *No. 3, part 1, 742–743 (Mar. 1965).*
By measuring voltage drop in xenon flashtubes the resistivity of intense xenon plasmas is found to bear an inverse square root relation to the current density. A weak dependence on pressure is discussed.

Electronically variable delay of microwave pulses in single-crystal YIG rods, I. Kaufman and W. A. Robinson, *J. Appl. Phys.* **36,** *No. 3, part 2, 1245–1246 (Mar. 1965).*
Experiments on electronically variable time delay of microwave pulses by transmission through single-crystal YIG rods are discussed. One type of delay, recently discussed by Olson and Buchmiller and by Kaufman and Soohoo and attributed to magnetostatic waves, occurs with unpolished ends, has rapidly increasing delay with increasing H_{dc}, and has severe pulse dispersion. The second, found here, requires parallel and polished ends, has a slowly decreasing delay with increasing H_{dc}, and usually has at least two pulses spaced by less than the round-trip time through the rod. Characteristics are similar to those described by Strauss, except that his experiments were of pulse reflection.
The two aspects of magnetostatic wave pulse delay to be discussed are: (1) Additional experimental verification of Schlömann's theory of wave excitation by nonuniform demagnetizing fields, by grinding a rod into ellipsoidal shape, and by measure coupling. (2) A nonreciprocal microwave time delay has been constructed utilizing magnetostatic waves in a YIG rod to couple two rectangular waveguides. The coupling is between the positions in the waveguide where the magnetic field is circularly polarized. The directionality of the coupling was found to be greater than 15 dB with delays of 4 μsec at 2500 Mc/sec.

Microwave magnetoelastic resonances in a nonuniform magnetic field, T. Kohane, E. Schlömann, and R. I. Joseph, *J. Appl. Phys.* **36,** *No. 3, part 2, 1267–1268 (Mar. 1965).*
A new magnetoelastic resonance effect is described. A dc magnetic field was applied in the long direction of YIG slabs (1 cm long, 0.5 cm wide, and 0.1 or 0.07 cm high), each end of which was inserted in a stripline cavity. Under appropriate conditions a pulse of microwave power applied to one cavity resulted in a pulse in the second cavity delayed by several microseconds. Small variations were observed in the amplitude of the delayed pulse as the dc field was varied. Similar variations with the same periodicity (~ 1 Oe) were also observed in the undelayed reflection from the input cavity. The amplitude variation is attributed to the excitation of magnetoelastic resonances in the nonuniform magnetic field near the endface of the sample. Because of the strong coupling between spin waves and elastic waves, the turning point (at which $k_{\text{spin waves}} = 0$) and the endface of the sample define a magnetoelastic quasi-cavity whose resonances give rise to the effect noted. According to this interpretation the separation of adjacent peaks should be $\delta H = |H'_{\text{dem}}|\lambda/2$, where H'_{dem} is the gradient of the demagnetizing field evaluated at the crossover point ($k_{\text{spin wave}} = k_{\text{phonon}}$) and λ the wavelength of transverse elastic waves. Measurements have been made showing the dependence on dc field, slab thickness, and frequency. Agreement with theory is satisfactory.

Angular momentum compensation in narrow linewidth ferrimagnets, R. C. LeCraw, J. P. Remeika, and H. Matthews, *J. Appl. Phys.* **36,** *No. 3, part 2, 901–905 (Mar. 1965).*
Studies are described of the ferrimagnetic garnet system $Eu_3Fe_{5-x}Ga_xO_{12}$. It is shown that a compensation point of the net angular momentum occurs at $x \cong 1.2$, at which the resonance linewidth remains narrow. In all previously observed ferrimagnetic systems

with angular momentum compensation points, e.g., GdIG, strong line broadening occurs. The reasons for this are discussed together with the relaxation processes involved. Application of the resulting large g factors to millimeter wave harmonic generation is considered.

Spin waves and neutron scattering, R. D. Lowde, *J. Appl. Phys.* **36,** *No. 3, part 2, 884–892 (Mar. 1965).*
A review is given of the problems in this field, and of the possibilities opened up by the fact that neutron scattering gives access to the time-dependent spin-correlation function in magnets over virtually the whole range of q, t, and T. New experimental results are given in connection with magnon energy linewidth and renormalization, and some data are presented for the spin-wave stiffness of bcc 3*d* transition-metal alloys as a function of electron concentration, showing effects explained by the electronic density-of-states curve. It is pointed out that the ground-state fluctuations of magnets give rise to effects in the formulas for neutron scattering.

Investigation of hot opaque arc plasmas by microwave cavity techniques, W. T. Maloney, *J. Appl. Phys.* **36,** *No. 3, part 1, 703–711 (Mar. 1965).*
The behavior of a steady-state argon arc plasma flowing through a cold 1-cm circular copper pipe at pressures from 0.1 to 1 atm and gas flow rate of 2600 ml/min is studied by microwave cavity techniques. The high electron density ($n_e > 10^{16}$ cm^{-3}) and large density gradients in the arc preclude the usual simple interpretation of the data. At this density it is however possible to interpret the cavity resonant frequency as a measure of the "diameter" of the arc column. Experimental results show the dependence of this diameter on pressure, arc current, and the presence of contaminant gases in concentrations as small as 10 ppm. A simple explanation of the influence of diatomic contaminants is given which attributes column contraction to enhanced thermal conductivity brought about by diffusion of dissociation energy. Dilation of column caused by krypton is attributed to enhanced electron concentration in the cooler regions of the plasma due to krypton's lower ionization potential. Calculations of thermal conductivity of argon-contaminant mixtures are shown to correlate well with the experimental results. The microwave technique appears in a new role as monitor and judge of the plasma behavior.

Generation of intense magnetic fields, D. B. Montgomery, *J. Appl. Phys.* **36,** *No. 3, part 2, 893–900 (Mar. 1965).*
The advent of high-field superconducting magnets has made magnetic fields above 30 kG available to the entire scientific community. Small diameter coils to 60 kG cost considerably less than conventional 12-in. iron magnet systems. Fields to 80 kG, and in a few recent instances to 100 kG, even in multicentimeter bores, are now economically within the reach of most research budgets. The current and future status of superconducting magnets, their economic advantages and associated problems are presented. Other methods of generating fields, such as water-cooled continuous magnets, millisecond pulse magnets, and long-pulse cryogenic magnets, will find their principal use in reaching even higher fields, supplementing superconducting magnets, or in circumventing problems which preclude the use of superconductors. Pulse magnets are presented as a relatively simple and inexpensive method of producing millisecond fields up to 500 kG and long pulses to 250 kG. Relationships between energy, time, and volume are given for pulse magnets. The current and future status, and the problems associated with conventional continuous field magnets in the 100 to 250 kG range are given and the availability of such magnets at the National Magnet Laboratory discussed. New critical current-critical field data for niobium-tin materials measured in continuous fields up to 180 kG is presented.

Loss associated with magnetoelastic waves in yttrium iron garnet, W. Strauss, *J. Appl. Phys.* **36,** *No. 3, part 2, 1243–1244 (Mar. 1965).*
Room-temperature magnetoelastic waves have been observed in yttrium iron garnet from 1.6 to 8.5 Gc/sec. The minimum observed insertion loss, which includes conversion, transmission, and reconversion loss, was 15 dB at 1.6 Gc/sec; at 8.5 Gc/sec the smallest insertion loss was 46 dB. The transmission attenuation increases approximately linearly with frequency from about 6 to 20 dB/μsec over this frequency range. The experimentally observed conversion loss from electromagnetic to magnetoelastic energy ranges from 3 to 13 dB and is compared with theoretical values.

Production rates and electron densities in the lower ionosphere due to solar cosmic rays, G. W. Adams and A. J. Masley, *J. Atmospheric Terrest. Phys.* **27,** *No. 3, 289–298 (Mar. 1965).*
The ratio, ψ, of Q (the production rate of electron-ion pairs) to N^2 (the steady-state electron density squared) has been calculated for solar cosmic ray event conditions over the altitude range $40 < Z < 80$ km. The calculations were accomplished by determining the production rate from direct measurements of the particle spectra and using electron density values determined by multifrequency riometers. The ratio, ψ, is shown as a function of altitude and of the number density of neutral molecules. A comparison with theoretical values for ψ shows a disagreement not easily explained.

Rays in magnetoionic theory, K. G. Budden and G. J. Daniell, *J. Atmospheric and Terrest. Phys.* **27,** *No. 3, 395–415 (Mar. 1965).*
In a homogeneous magnetoionic medium the refractive index for a radio wave is given by the Appleton-Hartree formula which assumes that the angle between the wave normal and the superimposed magnetic field is known. But a radio signal travels along a path known as the "ray" which in general has a different direction from the wave normal, and in some problems it is the ray direction which is known and the wave normal direction is at first unknown. A formula is given for finding the refractive indices when the ray direction is given. There are then six different possible waves whose characteristics are determined by the solutions of an equation of degree six. The properties of this question are illustrated by discussing some real solutions when electron collisions are neglected, although the theory is valid also when the refractive indices and wave normal directions are complex. The six solutions give directly the saddle points of an integrand used by some authors to express the "far field" of a point source of radio waves within the medium.

The effect of scintillations on the polarization of satellite transmissions near 20 Mc/s, R. S. Roger, *J. Atmospheric Terrest. Phys.* **27,** *No. 3, 335–348 (Mar. 1965).*
Some of the differences between the scintillation of radio stars and that of satellite transmissions are outlined. One of these is due to the polarized nature of satellite transmissions. Two manifestations of the effects of small ionospheric irregularities on the linear polarization of 20 Mc/s transmissions are described; first, the disappearance of the regular Faraday fading nulls, and secondly, the lack of correlation of scintillation fluctuations observed on crossed polarized receiving aerials. Two mechanisms by which the scintillation affects the polarization are suggested. The more probable of these is one in which the ordinary and extraordinary components of the ray path are separated at the height of the irregularities by an amount sufficient to cause the two rays to scintillate independently. Expressions are developed which give an estimate of the separation to be expected from the differential refraction of the two component rays. Results of ray tracing computations of the separation by Haselgrove are quoted. The implications of effects described on the studies of the scintillations of radio stars and of satellite transmissions are discussed.

Radar observations of weak field-aligned ionisation at a frequency of 300 Mc/s, C. D. Watkins and H. K. Sutcliffe, *J. Atmospheric Terrest. Phys.* **27,** *No. 3, 309–320 (Mar. 1965).*
Observations of ionisation elongated along the earth's magnetic field have been carried out with a sensitive radar at a frequency of 300 Mc/s. A very weak signal was detected from a height of about 104 km and this was found to be present almost continuously even during very quiet magnetic conditions. The weak signals are believed to originate from field-aligned ionisation of meteoric origin. This means that in certain parts of the E-region there is a radar noise level much greater than that set by incoherent backscatter from the free electrons of the ionosphere.

Auroral zone emissions centered at 700 cycles per second, A. Egeland, G. Gustaffson, S. Olsen, J. Aarons, and W. Barron, *J. Geophys. Res.* **70,** *No. 5, 1079–1082 (Mar. 1965).*
An emission band between 500 and 1000 cps has frequently been recorded at the Kiruna Geophysical Observatory (geomagnetic lati-

tude 65.3 °N) by a swept frequency battery-operated analyzer. The most important characteristics of this enhanced electromagnetic radiation are the following: (1) The maximum signal strength is observed at a fixed frequency (700 ± 100 cps). (2) The bandwidth of the emission is normally less than 500 cps. (3) The shape of the emission band is asymmetrical. The hypothesis advanced is that this emission band may be due to radiation at the gyrofrequency of protons. Propagation conditions determine the latitude where this band emission can be detected on the ground.

Multiple scatter effects on the radar return from large hail, B. M. Herman, *J. Geophys. Res.* **70,** *No. 5, 1215–1225 (Mar. 1965).*
A modified form of the equation of radiative transfer is solved numerically in order to estimate the effects of multiple scattering on the backscattered radar signal. The returned signal from a hypothetical hailstorm composed of spherical hailstones of approximately 3-cm diameter is computed by means of the transfer equation, and the result is compared with that computed for the same storm but utilizing the conventional equation which neglects all multiple scattering. Results for optical depth $\tau = 0.48$ show that multiple scattering effects enhance the backscattered signal by about 30 percent. This correction increases with optical depth, and for the larger hailstorms is probably quite significant.

Pearl-type micropulsations associated with magnetic storm sudden commencements, R. R. Heacock and V. P. Hessler, *J. Geophys. Res.* **70,** *No. 5, 1103–1111 (Mar. 1965).*
Two years of continuous telluric current micropulsation records from College were scanned for evidence of a significant relationship between magnetic storm sudden commencements and pearl-type events that follow closely after the ssc's. Thirteen of 24 ssc's were followed by pearl events. Ten of these events occurred between 1200 and 2000 LMT, during which time there were 11 ssc's. Eight structured pearl events were found. The most prominent pearl events followed the ssc's that were preceded by very quiet magnetic field conditions.

A mathematical technique for the conversion of radio wave interaction data to *D*-region electron density profiles, F. V. Hellrich and A. J. Ferraro, *J. Geophys. Res.* **70,** *No. 5, 1195–1205 (Mar. 1965).*
In this paper a method for the conversion of amplitude and phase interaction data to electron density profiles is developed. The method, using an iterative least squares error technique, synthesizes electron density profiles having a piece-wise linear functional form. With model studies the method is evaluated with respect to the errors that may be produced in the synthesized profile arising from uncertain values of collision frequency, disturbing pulse power, energy loss coefficient, and coefficients of interaction. Also, a demonstration of the effectiveness of the combined use of amplitude and phase interaction in producing a more accurate profile than could be obtained with amplitude data alone is presented. The method has been very successful in the synthesis of electron density profiles from actual interaction data and is presently being used for the reduction of data procured at the Ionosphere Research Laboratory during the International Quiet Sun Year. Some of these preliminary *D*-region profiles are presented.

Theory of collective spikes observed by the Alouette topside sounder, J. Nuttall, *J. Geophys. Res.* **70,** *No. 5, 1119–1125 (Mar. 1965).*
A theory is advanced to explain the spikes at the plasma frequency ω_p and the Pythagoras frequency $[(\omega_p^2+\omega_b^2)^{1/2}]$ observed in ionograms of the Alouette topside sounder. It is based on the properties of Green's function for a uniform mangetoplasma, which may be cold or warm, and it disregards possible sheath effects. The theory predicts the absolute strength of the observed signal, its asymptotic time behavior, and its dependence on the orientation of the satellite antenna, but the present experimental data are insufficient to make detailed comparisons.

Hydromagnetic whistlers, T. Obayashi, *J. Geophys. Res.* **70,** *No. 5, 1069–1078 (Mar. 1965).*
Hydromagnetic emissions consisting of a series of overlapping wavetrains of rising frequency are explained by hydromagnetic waves of anisotropic mode propagating along the field-aligned paths in the magnetosphere. The rising frequency of emission is attributed to the dispersive nature of the velocity of waves; the repetitive period of wavetrains is associated with the transit time of the wave packet bouncing between geomagnetic conjugate points along the line of force. It is suggested that an initiating wave is triggered by spontaneously injected high energy particles of superluminal motion and that the wave is subsequently amplified by plasma beams through the mechanism of cyclotron instabilities.

On the harmonics of the gyrofrequency observed on topside ionograms, G. Wallis, *J. Geophys. Res.* **70,** *No. 5, 1113–1117 (Mar. 1965).*
The plasma resonances appearing on topside ionograms at the plasma frequency, at the "hybrid frequency" ω_M and the harmonic $2\omega_M$, and at the gyrofrequency ω_H and the harmonics $p \cdot \omega_H$ are discussed on the basis of the kinetic theory (linearized Vlasov equation), including the thermal motion of the electrons. The results are compared with those of the dispersion relation for a cold plasma (magnetoionic theory).

Selected Abstracts and Publications of the Staff of the National Bureau of Standards

Abstracts

Precision detector for complex insertion ratio measuring systems, C. M. Allred and R. A. Lawton, *IEEE Trans. Instr. Meas.* **Im–13,** *Nos. 2 and 3, 76–81 (June-Sept. 1964).*
A precision, low-noise, highly sensitive, synchronous RF detector is described that permits simultaneous phase and level nulling in complex insertion ratio measuring systems. This insertion ratio is a measure of both the phase shift and magnitude change produced by a network when inserted in a transmission path.

A dc-RF substitution error in dual-element bolometer mounts, G. F. Engen, *IEEE Trans. Instr. Meas.* **IM–13,** *Nos. 2 and 3, 58–64 (June–Sept. 1964).*
Most of the coaxial type bolometer mounts in current use employ a pair of bolometer elements which are connected in series for the dc or audio-frequency bias posers, and in parallel at radio or microwave frequencies.
In the frequency range where these techniques are most often employed, the dc-RF substitution error has been generally believed to be negligible. It is quite possible, however, for this to be true of the elements individually, and yet fail to be true of a pair of these elements as used in a typical coaxial mount. If only the sum of the resistances of the two elements is maintained at a constant value, and if the resistance division between the two elements changes with the application of RF power, an error is introduced which is given by the equation: $e = [(1/\gamma b) - (1/\gamma a)]\Delta r$, where γa and γb are the "ohms per milliwatt" coefficients of the two bolometer elements, and Δr is the shift in resistance division.
An experimental study indicates that, in the existing state-of-the-art, this error may be ignored in many applications but is large enough to be important in others, particularly at the higher power levels.

Further analysis of the modulated subcarrier technique of attenuation measurement, W. E. Little, *IEEE Trans. Inst. Meas.* **IM–13,** *Nos. 2 and 3, 71–76 (June–Sept. 1964).*
The modulated subcarrier technique of attenuation measurement offers an accurate and convenient means of calibrating rotary vane attenuators. The technique also presents the possibility of being extended to other types of attenuation measurement. This paper gives an analysis of the output of the microwave detector, assuming it is completely linear; an error analysis of the technique; and a comparison of the technique with the 30-Mc IF substitution technique of attenuation measurement.

A study of auroral absorption events at the South Pole, 2. Conjugate properties, J. K. Hargreaves and H. J. A. Chivers, *J. Geophys. Res.* **70,** *No. 5, 1093–1102 (Mar. 1965).*
At South Pole and Frobisher Bay, a magnetically conjugate pair of high-latitude stations, the auroral absorption events observed with riometers have many points of similarity. Yet there are also some significant differences, which have been brought out in this study by a detailed, event-for-event comparison. First, systematic changes have been detected in the relative intensity of the events, and they are such that the absorption tends to be relatively greater in local winter; there is also a diurnal change in the relative intensity. Second, there is good evidence that the event maximums appear in the conjugate regions at slightly different times; for individual events the time differences are correlated with the relative intensities. The results suggest that auroral absorption might be either produced or modulated by hydromagnetic disturbances propagating in the magnetosphere.

The use of electromagnetic signals emitted from nuclear explosions to study long-range VLF propagation, A. G. Jean and J. R. Wait, *J. Geophys. Res.* **70,** *No. 5, 1258–1261 (Mar. 1965).*
The electromagnetic signals radiated from nuclear detonations are used to obtain basic information on the propagation of VLF radio waves. (Characteristics of the source are explicitly not given as they are essentially "normalized out" in the data analysis. The geographical location, time of the events, and other pertinent data are taken from a published paper by Griggs and Press [1961].)

Atlas of Fourier coefficients of diurnal variation of *foF*2. Part II. Distribution of amplitude and phase, W. B. Jones and R. M. Gallet, *NBS Tech. Note 305 (Feb. 14, 1965), 60 cents.*
This atlas is devoted to the study of amplitude and phase from the diurnal analysis of *foF*2 monthly median. It is concerned with their variations—both systematic and random—as functions of latitude, season and solar activity. The atlas contains a series of graphs of the distribution of amplitude and phase and tables of phase distribution for four seasonal months of high and low years of solar activity. Emphasis is placed on the study of the phase distributions for determining the optimum separation of harmonics produced mainly by noise from those representing mostly real physical variation.

A method for the computation of the error function of a complex variable, O. N. Strand, *Math. Computation* **19,** *No. 89, 127–129 (Jan. 1965).*
This paper presents a method of computing erf $z \equiv (2/\sqrt{\pi}) \int_0^z e^{-u^2} du$, where z is complex. It is shown that erfc $z \equiv 1 - \text{erf } z$ has no zeros in the right-hand half plane. An estimate of $|\text{erfc } z|$ is derived.

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Effects of thermal shrinkage on built-up roofing, W. C. Cullen, NBS Mono. 89 (Mar. 4, 1965), 10 cents.
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The examination of weighing equipment, M. W. Jensen and R. W. Smith, NBS Handb. 37 (Mar. 1, 1965), $3.00. (Supersedes H37.)
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Standard Reference Materials: Accuracy of solution x-ray spectrometric analysis of copper-base alloys, R. Alvarez and R. Flitsch, NBS Misc. Publ. 260–5 (Mar. 15, 1965), 25 cents.
Thermal properties of aqueous uni-univalent electrolytes, V. B. Parker, NSRDS–NBS 2, (Apr. 1, 1965), 45 cents.
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