APPLIED ELECTRONICS FOR SURVEYORS

by

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Abbreviations

World War II accelerated the trend of forming new words out of a suitable composition of established terms, e.g. RADAR from RAdio Detecting And Ranging. Dictionaries or Encyclopaedias of Technical Sciences provide sufficient information on the meaning of these terms. Here is a selection:-

EDM Electro-magnetic (incl. optical) Distance Measurement
CW Continuous Wave
P Pulse

EDM is time measurement. A CW or P is sent out by transmitter, reflected, received back and the time interval between transmission and reception is measured and often expressed in NANO seconds (10^{-9}s). Technical solutions differ and depend on circumstances and requirements of

range, accuracy, unique, solution, simplicity
two-dimensional fix e.g. intersecting patterns of hyperbolae or circles and spheres.

White light, red light (Laser) or blue light is used in Electro-Optical instruments (EO). The range and accuracy depend on power output, wavelength, topography and in most cases on meteorological conditions influencing the velocity of electro-magnetic waves (EMW). Here are some popular terms:-

TERM	MEANING	TYPE	YEAR
ABC	Airborne Control System	T	1959
ABSC	(Australian) Airborne Survey Corps Control System	T,L	1966
AERIS	Airborne Electric Ranging Instr. System (U.S.A.)	Ra	1963
AERODIST	AEROplane DISTance Measurement	T	1961
DECCA	D-Navigator, originally for aerial navig; Two-range Decca giving circular patterns.	Ra,CW	
DECOMETER	Phase delay counter, part of automatic track plotter		1957
DECTRA	DECca TRAcking and ranging (4 stationary transmitters)	Ra,CW	1957
DISTOMAT	DISTance auTOMATically recorded	G	1962
ELECTRO - TAPE	ELECTROnic TAPE	G	1962
EDS	Electro Optische-Streckenmessung	G	1966
EPI	Electric Positioning Indicator (Shoran)	Ra,P	
GEE	Gee H, H_2S, Oboe, guiding aircraft	Ra,P	1940
GEODIMETER	Geos-earth, geodetic measuring	G	1943
HIFIX	HIgh frequency FIXing	Ra,CW	1960
HIRAN	HIgh frequency RAdar Navigation or HIgh precision RANging	Ra,P	1950
HYDRODIST	HYDROgraphic DISTance measurement	T	1960
LAMBDA	Position fixing, Low AMBiguity DeccA	Ra,CW	1957
LASER	Light wave Amplification by Stimulated Emission of Radiation	L,CW	1960

LORAN	LOng RANging or LOng RAdar Navigation	Ra,P	1940
LODAR	Direction finder in LORAN	Ra,P	
LORAC	LOng RAnge (American Decca)	Ra,CW	
LRSS	Long Range Survey Systems, U.S.A.	Ra,	
MASER	Molecular Amplification by Stimulated Emission of Radiation	G	1953
MINIFIX	MINImum range FIX, small ships onshore	Ra,CW	1960
OBOE	radar guidance of military aircraft, reflector only on aircraft	Ra,P	1941
PPI	Plan Position Indicator, shipradar	Ra,P	1940
RACOM	RApid COMbat mapping system	Ra	
RACON	RAdar responder beaCON, electronic reflector	Ra,P	
RADAR	Radio Detecting and Ranging	Ra,P	1935
RADUX	long distance cont.wave, low frequency system of phase comparison, hyperbolic system (U.S.A.)	Ra	
RAMARK	RAdar sea MARK, gives dist. and bearing	Ra,P	
RAYDIST	American RAdar (?) for DISTance measuring	Ra,CW	
SEAFIX	SEAborne tellurometer FIXing	T	
SECOR	SEquential COllation of Range		
SHIRAN	similar to HIRAN but 4 station operation and part of complex airborne mapping equipment	Ra	1964
SHORAN	SHOrt RANge Navigation, or SHOrt wave RAdar Navigation	Ra,P	1945
SMll	electro-optical Strecken Messung, Zeiss Oberkochen	G	1967
SVV-1	Russian pulsed light range finder	G,P	
TELLUROMETER	Tellurius = earth	T	1954
TERRAFIX	Decca-type	Ra,CW	
TERRAMETER	Swedish Radar	Ra	

Historical Dates

A detailed study may be commenced with Whittaker (8142) and Asimov (R112). A quick glance at these books allows a random selection of the following well-known names to be connected with the theory of light:

Aristoteles, Descartes, Galilei, Fermat, Hooke, Newton, Huygens, Fraunhofer, Nicol, Maxwell, Lorentz, Planck. There are, of course, many more whose mention is beyond the purpose of this calendar.

- 4th Aristoteles, the act of a transparent body is to enable it to transmit light.

+ 13th Aristotelian philosophy theory on light promoted by Thomas Aquinas, but rejected by F. Bacon (1561-1626), Galilei (1564-1642), and especially by Descartes (1596-1646). This stimulated a rapid
16th - expansion of the knowledge of physical sciences through thought and
17th - experiment.

1611 Kepler wrote on refraction through lenses.

1621 Snell (ius) (1591-1676) found the law of refraction of light experimentally.

1638 Galilei experimented in vain with lanterns a distance apart to ascertain the speed of light (B142, 22).

1661 Fermat (1601-65) "Principle of Least Time" of travel theory of light.

1665 F.M. Grimaldi (1613-63) reported to have coined the words "diffraction of light".

1664 Hooke's (1635-1703) "Micrographia" published in 1667, gave a mechanical explanation of the travel theory of light, being a rapid vibratory motion of small amplitude emitted from a luminous body; coined the term "wave front".

1666 Newton (1642-1727) rejected Hooke's theories on the colour of light and aether and published his ideas between 1671-86 in his papers Principia, Opticks - ; he established the theory of emission of light particles and had some notion on polarisation.
Torricelli had shown that light travels through vacuum. (1650?)

1678 Huygens (1629-95) supplanted Newton's light theory by that of a wave theory (publ. 1690) "the wave a circumstance of matter, light itself not a matter - space filled with ligthether" - explained diffraction, interference.

1675 Romer determined the speed of light at 303 000 km/sec. by observing eclipses of one of Jupiter's satellites and proved that light propagated instantaneously. Delambre, 1817, Glasenapp 1848, 1870, Sampson 1909 et al. repeated Romer's exercise and reduced R's value of 11 min. to 498.7 sec.

1727 Bradley determined the velocity of light from the aberration of stars.

1728-1820 Young, Fresnel, interference of light.

1800 Volta, electric current.

1828 Nicol, polarised light, light does not travel in longitudinal waves like sound.

1834 Wheatstone suggested the use of a rotating mirror to determine the velocity of light; this was used by Foucault 1860 and by Michelson on 200 determinations between 1890-1930.

1842 Doppler described how the frequency of sound (light) waves changes if the source of sound (light) or the observer moves.

1844-55 Faraday (1791-1867), field theory, electro-magnetic rotation, galvanic and magnetic induction, self induction, die-electrics, diamagnetism, rotation of plane of polarization through a magnetic field, electrolyse, Faraday-effect, a magneto-optical phenomenon.

1847 Fizeau, velocity of light at 313 000 km/sec. from terrestrial sources by using a rotating wheel as a modulator to mark off a portion of a beam. (1849?)

1850 Foucault, Fizeau, propagation of light in water smaller than in vacuo.

1856 Kohlrausch, Weber, speed of light from ratio of values of capacity of condenser measured in electro-static and electro-magnetic units.

1859 Cathode rays discovered by Plucker, further work by Hittorf, Crookes, Goldstein, Perrin, Kaufmann, des Condres.

1865 Electro-magnetic wave theory by Maxwell (1831-79) replaced periodical oscillation of ether by alternating changes of electric and magnetic fields; this allowed uniform explanation of electrical, magnetic and optical properties of light; it did not explain the role of electrons and the dispersion of light. Huygens' theory of light propagating in waves generally accepted.

1874 Boltzmann refractive indices for gases.

1875 Kerr, of Glasgow, investigated double refraction of light caused by induction (Kerr-effect).

1879 Stephen, energy radiation a function of temperature. $K = \gamma . T^4$

1881 Helmholtz pointed out that atom theory ought to be applied to electricity.

1884 Boltzmann - electro-dynamic and thermo-dynamic emission of energy radiation of a black body proportional to T^4 (cf. Stephan 1879).

1887-92 Michelson, later joined by Benoit in Paris, determined the metre in terms of length of light waves (R89).

1888 Maxwell's spherical waves proved experimentally by Hertz(G).

1890 Braun, Strassburg invested the Cathode-Ray Tube (CRT).
Lenard (1862-1930?) thought that energy of light was restricted to certain places, discussed a quantum theory (depending on colours) i.e. returning to Newton's emission theory, worked on cathode rays, phosphorescence, luminance.

1892 Marconi, wireless telegraphy over small distances, 1903 England - U.S.A.

1892-1909 Lorentz (H), (1853-1928) applied atomic theory to electricity and broadened Maxwell's theory, inter alia 'refractive index is a function of frequency", also explained Faraday's electrolyse.

1896 Wien, further work on Stephan's law.

1900 Planck continued and developed Stephan's, Boltzmann's and Wien's work on quantum theory, i.e. a theory concerned with light reception and emission of atoms; Planck formed a simple equation to describe the distribution of radiation over the whole range of frequency, "energy is not infinitely subdivisible, it exists in quantums (fr. Latin, "how much").

1904 Hulsmeyer, German patent on "method to detect distant metallic objects by electro-magnetic waves".

1907 Rosa, Dorsey, velocity of light from ratio of electric charge measured in electrostatic and electro-magnetic units, v = 299 784 km/sec.

1916 Telefunken, bridged 20 000 km with a 13 km wave.

1917 Black, A.E.F., US Air Force pilot on the Western Front, used the coil aerial detection finder of his radio as a direction finder for a blind landing.

1919 Watson-Watt, British patent on radio location by means of short-wave radio.

1920 Armstrong, U.S.A., interested in detecting aircraft by EMW designed a circuit, called "super-heterodyne receiver", used in radio sets (R112, article 442).

1922 Taylor, Young (U.S.A.) detection of ships through interference phenomena in radiowaves.

1923 Michelson's new determination of the velocity of light on Mt. Wilson, geodetic comparison distance obtained by Garner, Bilby, Hough and others of the U.S. Coast and Geodetic Survey. Hale, astronomer on Mt. Wilson, Lester-Jones,director USCGS,supported Michelson, Lester-Jones envisaged geodetic distance measurement by light waves.
(see report by Bowie, R89).

1925 Impulse modulation (important for distances) by Breit, Tuve (U.S.A.)

1923 Mercier, velocity of EMW on wires 299 782 km/sec.

1926 Karolus, modern Kerr-cell by using nitro-benzine.
Planck, further to quantum and wave mechanics.

1927 Jelstrup (Sweden) suggested distance measurement for geodetic purposes by RADAR principle after the reflection of EMW from the Ionosphere was discovered in the early 1920's.

1928 Karolus, Mittelstaedt and Huettel used an optical shutter provided by a Kerr-cell and determined the speed of light at a geodetic base near Leipzig.

1932 Hull (U.S.A.) Habann, (G), constructed a magnetron (B97, 211).

1933 Taylor (U.S.A.), radio navigation.
Attempts to locate icebergs by reflected EMW on the French liner "Normandie", Testing of 13.5 cm wave equipment by Pintach in German Navy.

1934 German firm Gema located ships by EMW, range 12 km, aircraft at 700 m.

1935 Telefunken, location of aircraft Junkers Ju 52 by EMW, range 5 km, no impulse generator, no proper distance measurement but proper EDM to ground targets at 20 km.

1935 Watson-Watts radar research led to a demonstration of reflected "death rays" from an EMW to aircraft at Daventry airport on 26.2.35. The British Air Ministry had offered £1,000 in 1934 to any owner of a BLACK BOX who could kill a sheep at a range of 100 yds. (R111,6). Watson-Watt did not get the prize.

1935 Radar to ground targets, range 20 km, in Germany.

1936 March, British Radar (λ = 10 - 12 m), range 100 km. April, German microwave Radar, range over sea to Junkers W34 60 km.

1938 Radar, (λ = 2.5m), spotted Ju 52 at 90 km.
German Navy introduced 80 cm Radar "Seetact"
First German anti-aircraft Radar equipment, range 30 km.

1940 Randall and Boot of Birmingham University constructed the Cavity Magnetron for the Cathode Ray Tube thus allowing a centimetre wave length to be used in English Radar. This was used for constructing the Plan Position Indicator (P.P.I.) called "Jagdschloss" and "Wassermann" in the German Air Force (λ = 2m); the Gee-method was tested by British bombers; later developments were Gee-H, H_2S (1941) and several other methods, e.g. in America, Raydist was developed, A.L. Loomis suggested LORAN (R8), German Funkmessgerat "Wurzburg" was delivered to the airforce in 1940, (range 40 km), four other models, designed in 1941, worked on a 50 cm wavelength.
Oboe came into use in Britain in 1941-2; it is not strictly RADAR because the plane position is obtained by signals transmitted from the plane.

1943 Hart (E) developed RADAR further, Aslakson (U.S.A.) defined RADAR procedures for geodetic purposes, practical experiments were made under the name SHORAN incl. the line-crossing method. (160-497 km sidelength, ± 15 m).

1943 Bergstrand, Sweden, developed the Geodimeter.

1945 SHORAN tests in Italy on 619 Km side; relative error 1:13 000 at C = 299 774 km/s.
Importance of correct speed of light seen from change of meteorological conditions which caused a change of length equivalent to a change of relative accuracy of 1:27 000 in three days.

1945-7 SHORAN connection Florida-Bahama, 164-379 km lines, errors < ± 4 m.

1946 U.S. SHORAN tests yielded between 1:21 000 and 1:292 000.
SHORAN used for hydrographic surveys by USCGS.

1947 Electric eye for theodolites by Gigas.

1948 Shockley, Bell Labs., U.S.A. invented the transistor.

1948 Radio-astronomy discovered with ex-war Radar in Holland.

1949 OBOE, with computer at ground station.

1949 SHORAN in Australia, precision between 1:9 500 and 1:77 000.

1949-1950 SHORAN projects covered wide stretches of Canada.
Radar Profile Recording in Canada, Australia, U.S.A.
precision claimed at ± 30ft. at best.

1950 HIRAN testing in Florida proved that speed of light (in vacuo) of 299 777.6 km/s should be corrected to 299 794 km/s (now 299 792.5 km/s)
HIRAN trilateration chains introduced in Canada and USA, difficulty to obtain reliable azimuths, (RADAR distances must also be reduced for slope, elevation above sea level and curvature). HIRAN easier to manipulate and more accurate than SHORAN; it helped to discover an eleven metre error in an old Florida triangulation side; was used on sides 65-515 km at an accuracy of approx. 2 metres; the HIRAN-connection Florida-Trinidad-Barbados is claimed to be accurate within ± 5 m , azimuth

Puerto Rico - Trinidad (1,610 Km) reported to agree within 0".8 of the known value, positioning ± 4 m on 10 sides ranging from 500 - 758 Km.

1950 Idea of tunnel cross sections by supersonic method advanced by Inst. for Applied Geodesy, Frankfurt, (R8,498).

1951 Idea of MASER by Townsend, U.S.A., work begun 1953 (R112, article 526), purpose: atomic clock, i.e. accurate time measurement; he constructed several types and thought of a pink ruby maser in 1957, constructed it and used it in 1960, then called LASER, to disprove Aristoteles' aether theory by observing in different directions.

1953 HIRAN linked Crete and Africa, sides 134-355 km , ± 5 m , thus meridian (MAM) Capetown - Nordkapp closed.

1953-6 HIRAN America - Europe, 141 sides averaging 440 km , max. 884 km , ± 4 mper side, all work done by U.S. Airforce.

1954 Raydist, U.S.A., more accurate than SHORAN and of larger range, λ = 100 - 200 m , IUGG (IAG) resolved to have European geodetic baselines re-measured by invar-tape and again by Geodimeter after 1958; interesting results, see DGK, 1966, (R75), R113,248).

1954 Tellurometer by Wadley, South Africa, enabled work in daylight, contrary to Geodimeter; 1967 versions of both types transistorized, hence much lighter,more reliable; essentially the Tellurometer had been the "workhorse" in surveying while the Geodimeter has served the geodesist uniquely.

1956 National Bureau of Standards, Washington, concluded research in Hawaii to assess variations of speed of EMW propogation; test line 25 km , "average" (?) error before correction for refractive index 0.29 m , after correction 0.24 m for terminal points and 0.12 m for 5 intermediate stations. (ZfV).

1956-7 HIRAN covered the whole of Canada, line crossings, usually repeated 12 times, six crossings at each of two altitudes.

1957 Two-range Decca for Canadian sea-charting at 1:72 688 scale,decometer and master aboard ship,precision range 5 - 100 m, automatic track plotting.

1960 Electronic equipment rapidly invading photogrammetric laboratories (see Ch. VI)

1960 Decca becoming more accurate ± 1? m in 600 km; Hydrodist fixes at ± 1.5 m.

1960-1963 Australian surveyors of the National Mapping Division replaced triangulation by tellurometer traversing and achieved excellent results over continental distances.

1961-1964 Mekometer by Froma and Bradsell (E), (R113,261), range up to 1 mile, modulated lightray, 500 MHz accurate to 1:3 x 10^5, cavity resonators determine mod. wavelength independently of knowledge of speed of light, hence refract. index not required.

1963 Distance earth-moon by various EDM methods agree within 20 Km.

1964 SECOR and Doppler Satellite Geodesy.

1964-1967 Ever improving versions of the "firsts" (Geodimeter, Tellurometer) and a host of others appearing on the market, e.g. DISTOMAT, ELECTROTAPE, EOS, SMII, MOM, Russian instruments. Service maintenance, cost and varying zero errors remain frustrating problems; surveyors wanted cheap black boxes for short ranges from 100 - 500 metres.

1965 SHIRAN - improved HIRAN, frequency 3,000 MHz is part of complex equipment for mapping control; only for surveyors who can buy a Boeing 707.

1965 Sonar equipment to show underwater contours.

1965 EOS, Zeiss Jena (R113,287), sound modulation of light wave. Laser interferemetry for distance and alignment, (R113, - Laser applications 391 - 441).
Precise Level Tester utilizing capacitance radio by Makow, U.S.A. (B 37), range 18 cm. precision ± 0.6 µm.

1966 ABSC used by Australian Survey Corps on distances up to 35 mls and height above ground up to 4 000 ft.

1966 Digigon, a digital theodolite, developed at the University of Bonn by Zetsche, produced by Breithaupt (ZfV 1/1968 , p.22),article by

Zetsche), Electrolevel by British Aircraft Corp. has three scales and enables to read tilts of 1" of arc.

1967 Laser Terrain Profiler by U.S. Army Map Service attached to tracking camera, coupled with Rosemont transducer to record variations of the isobaric surface. Also similar equipment for mapping control in Australia.

1967 60° pendulum Astrolabe with electronic transit detector, used in U.S.A., requires only approx. levelling up similar to Zeiss Jena 003 Universal theodolite.

1967 Laser atop theodolite by Spectra-Physics of California for alignment work, called Transit-lite Model LT-2, weight 35 lb., beam 6 inch per mile, range 5 mls. in daylight.
Second model called "Geodolite", Model 3G for distance measuring only, range 100 m - 80 km at night and at least 30 km in sunlight, total weight 175 lb., continuous wave phase comparison helium-neon tube, corner cube reflector, accuracy,claimed,$1:10^6$ based on invar-taped geodetic comparison baseline; if used without any reflector, but on a reflecting surface, the range is 3 - 5 miles, Cassegrain telescope an ideal component. Cost in 1967 U.S. $77,000 less ideal. Other lasers, one by Siemens, the rest (6 in 1968) by American firms. Investigations on electronic transit detector equipment for gyrotheodolites conducted in several firms and Universities, e.g. U.N.S.W.

1967 Zeiss-Oberkochen electro-optical distance measuring instrument SM11, direct modulation, range 0-500 m, readout in 18^s of time to nearest mm, accuracy ± 5 mm semi-conductor-lightsource, Gallium-Arsenid = GaAs diode, requiring reflector prisms, (ZPV, 1/1960, 31 "Der Elektro-optische Entfernungsmesser Zeiss SM11).

1968 Wenzel, Aachen, automatic registration of staff reading by Laser.

1968/9 Tellurometer "workhorse models MR4, MRB3".

NOTE: An excellent reference is "Zur Geschichte d.Radartechnik in Deutschland" by Brandt in Ortung u.Navigation,Heft IV, 1967.