CHAPTER SEVEN

DATA

Kilocycle - Wavelength Conversion Table — Frequency Allocation Table— Underwriters Rules—Safety Rules—Definitions— Abbreviations—Morse Code—Formulas—Capacity and Inductance Calculations—Tube Characteristics.

CONVERSION TABLE

Meters to Kilocycles, or Kilocycles to Meters

The trend of the best modern practice is to use frequency in kilocycles instead of wave-length. The following conversion table will be of use to this end. It is reversible; that is, for example, 50 kilocycles is 5996 meters and also 50 meters is 5996 kilocycles. The range of the table is easily extended by shifting the decimal point; for example, one cannot find 223 in the first column, but its equivalent is obtained by finding later in the table that 2330 kilocycles or meters is equivalent to 134.4 meters or kilocycles, from which 223 kilocycles or meters is equivalent to 1344 meters or kilocycles. To get kilocycles, divide 29982 by meters and vice-versa.

10...	29982	320...	936.9	630...	475.9	940...	319.0
20...	14991	330...	908.6	640...	468.5	950...	315.6
30...	9994	340...	881.8	650...	461.3	960...	312.3
40...	7496	350...	856.6	660...	454.3	970...	309.1
50...	5996	360...	832.8	670...	447.5	980...	305.9
60...	4997	370...	810.3	680...	440.9	990...	302.8
70...	4283	380...	789.0	690...	434.5	1000...	299.8
80...	3748	390...	768.8	700...	428.3	1010...	296.9
90...	3331	400...	749.6	710...	422.3	1020...	293.9
100...	2998	410...	731.3	720...	416.4	1030...	291.1
110...	2726	420...	713.9	730...	410.7	1040...	288.3
120...	2499	430...	697.3	740...	405.2	1050...	285.5
130...	2306	440...	681.4	750...	399.8	1060...	282.8
140...	2142	450...	666.3	760...	394.5	1070...	280.2
150...	1999	460...	651.8	770...	389.4	1080...	277.6
160...	1874	470...	637.9	780...	384.4	1090...	275.1
170...	1764	480...	624.6	790...	379.5	1100...	272.6
180...	1666	490...	611.9	800...	374.8	1110...	270.1
190...	1578	500...	599.6	810...	370.2	1120...	267.7
200...	1499	510...	587.9	820...	365.6	1130...	265.3
210...	1428	520...	576.6	830...	361.2	1140...	263.0
220...	1363	530...	565.7	840...	356.9	1150...	260.7
230...	1304	540...	555.2	850...	352.7	1160...	258.5
240...	1249	550...	545.1	860...	348.6	1170...	256.3
250...	1199	560...	535.4	870...	344.6	1180...	254.1
260...	1153	570...	526.0	880...	340.7	1190...	252.0
270...	1110	580...	516.9	890...	336.9	1200...	249.9
280...	1071	590...	508.2	900...	333.1	1210...	247.8
290...	1034	600...	499.7	910...	329.5	1220...	245.8
300...	999.4	610...	491.5	920...	325.9	1230...	243.8
310...	967.2	620...	483.6	930...	322.4	1240...	241.8

1250...	239.9	1970...	152.2	2690...	111.5	3820...	78.49
1260...	238.0	1980...	151.4	2700...	111.0	3840...	78.08
1270...	236.1	1990...	150.7	2710...	110.6	3860...	77.67
1280...	234.2	2000...	149.9	2720...	110.2	3880...	77.27
1290...	232.4	2010...	149.2	2730...	109.8	3900...	76.88
1300...	230.6	2020...	148.4	2740...	109.4	3920...	76.49
1310...	228.9	2030...	147.7	2750...	109.0	3940...	76.10
1320...	227.1	2040...	147.0	2760...	108.6	3960...	75.71
1330...	225.4	2050...	146.3	2770...	108.2	3980...	75.33
1340...	223.7	2060...	145.5	2780...	107.8	4000...	74.96
1350...	222.1	2070...	144.8	2790...	107.5	4020...	74.58
1360...	220.4	2080...	144.1	2800...	107.1	4040...	74.21
1370...	218.8	2090...	143.5	2810...	106.7	4060...	73.85
1380...	217.3	2100...	142.8	2820...	106.3	4080...	73.49
1390...	215.7	2110...	142.1	2830...	105.9	4100...	73.13
1400...	214.2	2120...	141.4	2840...	105.6	4120...	72.77
1410...	212.6	2130...	140.8	2850...	105.2	4140...	72.42
1420...	211.1	2140...	140.1	2860...	104.8	4160...	72.07
1430...	209.7	2150...	139.5	2870...	104.5	4180...	71.73
1440...	208.2	2160...	138.8	2880...	104.1	4200...	71.39
1450...	206.8	2170...	138.1	2890...	103.7	4220...	71.05
1460...	205.4	2180...	137.5	2900...	103.4	4240...	70.71
1470...	204.0	2190...	136.9	2910...	103.0	4260...	70.38
1480...	202.6	2200...	136.3	2920...	102.7	4280...	70.05
1490...	201.2	2210...	135.6	2930...	102.3	4300...	69.73
1500...	199.9	2220...	135.1	2940...	102.0	4320...	69.40
1510...	198.6	2230...	134.4	2950...	101.6	4340...	69.08
1520...	197.2	2240...	133.8	2960...	101.3	4360...	68.77
1530...	196.0	2250...	133.3	2970...	100.9	4380...	68.45
1540...	194.7	2260...	132.7	2980...	100.6	4400...	68.14
1550...	193.4	2270...	132.1	2990...	100.3	4420...	67.83
1560...	192.2	2280...	131.5	3000...	99.94	4440...	67.53
1570...	191.0	2290...	130.9	3020...	99.28	4460...	67.22
1580...	189.8	2300...	130.4	3040...	98.62	4480...	66.91
1590...	188.6	2310...	129.8	3060...	97.98	4500...	66.63
1600...	187.4	2320...	129.2	3080...	97.34	4520...	66.33
1610...	186.2	2330...	128.7	3100...	96.72	4540...	66.04
1620...	185.1	2340...	128.1	3120...	96.10	4560...	65.75
1630...	183.9	2350...	127.6	3140...	95.48	4580...	65.46
1640...	182.8	2360...	127.0	3160...	94.88	4600...	65.18
1650...	181.7	2370...	126.5	3180...	94.28	4620...	64.90
1660...	180.6	2380...	126.0	3200...	93.69	4640...	64.62
1670...	179.5	2390...	125.4	3220...	93.11	4660...	64.34
1680...	178.5	2400...	124.9	3240...	92.54	4680...	64.06
1690...	177.4	2410...	124.4	3260...	91.97	4700...	63.79
1700...	176.4	2420...	123.9	3280...	91.41	4720...	63.52
1710...	175.3	2430...	123.4	3300...	90.86	4740...	63.25
1720...	174.3	2440...	122.9	3320...	90.31	4760...	62.99
1730...	173.3	2450...	122.4	3340...	89.77	4780...	62.72
1740...	172.3	2460...	121.9	3360...	89.23	4800...	62.46
1750...	171.3	2470...	121.4	3380...	88.70	4820...	62.20
1760...	170.4	2480...	120.9	3400...	88.18	4840...	61.95
1770...	169.4	2490...	120.4	3420...	87.67	4860...	61.69
1780...	168.4	2500...	119.9	3440...	87.16	4880...	61.44
1790...	167.5	2510...	119.5	3460...	86.65	4900...	61.19
1800...	166.6	2520...	119.0	3480...	86.16	4920...	60.94
1810...	165.6	2530...	118.5	3500...	85.66	4940...	60.69
1820...	164.7	2540...	118.0	3520...	85.18	4960...	60.45
1830...	163.8	2550...	117.6	3540...	84.70	4980...	60.20
1840...	162.9	2560...	117.1	3560...	84.22	5000...	59.96
1850...	162.1	2570...	116.7	3580...	83.75	5050...	59.37
1860...	161.2	2580...	116.2	3600...	83.28	5100...	58.79
1870...	160.3	2590...	115.8	3620...	82.82	5150...	58.22
1880...	159.5	2600...	115.3	3640...	82.37	5200...	57.66
1890...	158.6	2610...	114.9	3660...	81.92	5250...	57.11
1900...	157.8	2620...	114.4	3680...	81.47	5300...	56.75
1910...	157.0	2630...	114.0	3700...	81.03	5350...	56.04
1920...	156.2	2640...	113.6	3720...	80.60	5400...	55.52
1930...	155.3	2650...	113.1	3740...	80.17	5450...	55.01
1940...	154.5	2660...	112.7	3760...	79.74	5500...	54.51
1950...	153.8	2670...	112.3	3780...	79.32	5550...	54.02
1960...	153.0	2680...	111.9	3800...	78.90	5600...	53.54

5650...	53.07	6750...	44.42	7850...	38.19	8950...	33.50
5700...	52.60	6800...	44.09	7900...	37.95	9000...	33.31
5750...	52.14	6850...	43.77	7950...	37.71	9050...	33.13
5800...	51.69	6900...	43.45	8000...	37.48	9100...	32.95
5850...	51.25	6950...	43.14	8050...	37.25	9150...	32.77
5900...	50.82	7000...	42.83	8100...	37.02	9200...	32.59
5950...	50.39	7050...	42.53	8150...	36.79	9250...	32.41
6000...	49.97	7100...	42.23	8200...	36.56	9300...	32.24
6050...	49.56	7150...	41.93	8250...	36.34	9350...	32.07
6100...	49.15	7200...	41.64	8300...	36.12	9400...	31.90
6150...	48.75	7250...	41.35	8350...	35.91	9450...	31.73
6200...	48.36	7300...	41.07	8400...	35.69	9500...	31.56
6250...	47.97	7350...	40.79	8450...	35.48	9550...	31.39
6300...	47.59	7400...	40.52	8500...	35.27	9600...	31.23
6350...	47.22	7450...	40.24	8550...	35.07	9650...	31.07
6400...	46.85	7500...	39.98	8600...	34.86	9700...	30.91
6450...	46.48	7550...	39.71	8650...	34.66	9750...	30.75
6500...	46.13	7600...	39.45	8700...	34.46	9800...	30.59
6550...	45.77	7650...	39.19	8750...	34.27	9850...	30.44
6600...	45.43	7700...	38.94	8800...	34.07	9900...	30.28
6550...	45.00	7750...	38.69	8850...	33.88	9950...	30.13
6700...	44.75	7800...	38.44	8900...	33.69	10000...	29.98

FREQUENCY ALLOCATION TABLE

Frequency in Kilocycles	Class of Service	Frequency in Kilocycles	Class of Service
1,500– 2,000 3,500– 4,000 7,000– 8,000 14,000– 16,000 56,000– 64,000 400,000–401,000	Amateur	120– 190 235– 500 343 410 425 454 2,000–2,300	Marine, Aircraft, Point to Point
300 375	Radio Beacons and Compass	2,850– 3,500 4,000– 4,525 5,000– 5,500 5,700– 7,000 8,000– 9,050 10,000–11,000 11,400–14,000 16,000–18,100	Public Toll Service Press, Public Utilities Point to Point
550–1,500	Broadcasting		
2,750– 2,850 4,525– 5,000 5,500– 5,700 9,050–10,000 11,000–11,400	Broadcast Relay		
500–550	Distress and Life Saving		
230–235 18,100– 56,000 64,000–400,000	Educational and Experimental		
95–120 125 155 175 190 245 275 315 445 2,300– 2,750 2,850– 4,525 7,000– 9,050 11,400–14,000 16,000–18,100	Government, Army, Navy and Point to Point		

Underwriters' Regulations for Receiving Apparatus

(Sections a to j, inclusive, do not apply when antenna is installed inside of buildings.)

ANTENNA:

a. Antenna and counterpoise outside of buildings shall be kept well away from all electric light or power wires of any circuit of more than 600 volts, and from railway, trolley or feeder wires, so as to avoid the possibility of contact between the antenna or counterpoise and such wires under accidental conditions.

b. Antenna and counterpoise where placed in proximity to electric light or power wires of less than 600 volts, or signal wires, shall be constructed and installed in a strong and durable manner, and shall be located and provided with suitable clearances, as to prevent accidental contact with such wires by sagging or swinging.

c. Splices and joints in the antenna span shall be soldered unless made with approved splicing devices.

d. Light and power circuits, if used for receiving antenna, need not conform to any of the above requirements, but the devices used to connect the light and power conductors to radio receiving sets must be of an approved type.

LEAD-IN-CONDUCTORS:

e. Lead-in-conductors shall be of copper, approved copper-clad steel or other metal which will not corrode excessively, and in no case shall they be smaller than No. 14 B. & S. gauge except that bronze or copper-clad steel not less than No. 17 B. & S. gauge may be used.

f. Lead-in-conductor on the outside of buildings shall not come nearer than four (4) inches to electric light and power wires unless separated therefrom by a continuous and firmly fixed non-conductor that will maintain permanent separation. The non-conductor shall be in addition to any insulating covering on the wire.

g. Lead-in-conductors shall enter the building through a non-combustible, non-absorptive insulating bushing slanting upward toward the inside.

PROTECTIVE DEVICE:

h. Each lead-in-conductor shall be provided with an approved protective device (lightning arrester) which will operate at a voltage of five hundred (500) volts or less, properly connected and located either inside the building at some point between the entrance and the set which is convenient to a ground (see section k), or outside the building as near as practicable to the point of entrance. **The protector shall not be placed in the immediate vicinity of easily ignitable stuff, or where exposed to inflammable gases or dust or flyings of combustible materials.**

The use of an antenna grounding switch is desirable, but does not obviate the necessity for the approved protective device required under this section. The antenna grounding switch if installed shall, in its closed position, form a shunt around the protective device.

A knife switch not less than 30 amp., 250 volts, is recommended to be located between lead-in-conductor and receiving set.

j. Fuses are not required, but if used shall not be placed in the circuit from the antenna through the protective device to ground.

PROTECTIVE GROUNDING CONDUCTOR:

k. The protective grounding conductor may be bare and shall be of copper, bronze or approved copper-clad steel. The grounding conductor shall not be smaller than the lead-in-conductor, and in no case shall be smaller than No. 14 B. & S. gauge if of copper, nor smaller than No. 17 B. & S. gauge if of bronze or copper-clad steel. The grounding conductor shall be run in as straight a line as possible from the protective device to a good, permanent ground. **Preference shall be given to water piping.** Other permissible grounds are grounded steel frames of buildings or other grounded metal work in the building, and artificial grounds such as driven pipes, rods, plates, cones, etc. **Gas piping shall not be used for the ground.**

l. The grounding conductor shall be protected where exposed to mechanical injury. An approved ground clamp shall be used where the grounding conductor is connected to pipes or piping.

RECEIVING EQUIPMENT GROUNDING CONDUCTOR:

m. The grounding conductor may be run either inside or outside of the building. The protective grounding conductor and ground installed as specified in Sections k and l may be used as the operating ground. In this case the operating grounding conductor should preferably be connected to the ground terminal of the protective device.

If desired, a separate operating grounding connection and ground may be used, the grounding conductor being bare or with an insulating covering.

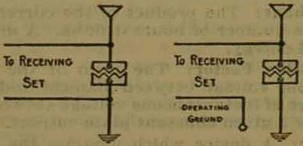
WIRES INSIDE BUILDINGS:

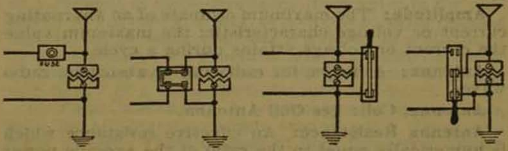
n. Wires inside buildings shall be securely fastened in a workmanlike manner and shall not come nearer than two (2) inches to any electric light or power wire not in conduit, unless separated therefrom by some continuous and firmly fixed non-conductor such as porcelain tubes or approved flexible tubing, making a permanent separation. This non-conductor shall be in addition to any regular insulating covering on the wire.

Storage battery leads shall consist of conductors having approved rubber insulation. It is recommended that the circuit from the storage battery be properly protected by fuses located as near as possible to the battery.

INSTALLATION HINTS

Required Protection for Receiving Sets





Permissible Additions

DEFINITIONS OF RADIO TERMS

Absorption Modulation: The process of varying the amplitude of a radio-frequency alternating current in accordance with any desired wave form by systematically absorbing energy from the alternating current circuit in an element of a circuit which serves as an appropriately variable resistance. For example: Using the plate circuit of a three-electrode tube as a variable resistance and varying such resistance by means of suitable voltages impressed on the grid; or, by coupling such a variable resistance to the antenna circuit of a radio transmitting set.

Admittance: The inverse of inductive reactance, *i. e.*, 1 ÷ (6.28 × frequency × inductance).

Air Condenser: A condenser having air as its dielectric, together with a minimum of solid dielectric used as mechanical support.

Alternating Current: Current which periodically reverses its direction of flow in a circuit.

Alternating Current Characteristic: The relation given by the curve obtained when the impressed emf. is plotted as abscissas against the resultant current as ordinates for alternating emf. and current.

Alternation: One-half a complete cycle; that part of a cycle during which the current flow is in one direction. See cycle.

Ampere: The unit of current. One ampere flows in a d.-c. circuit whose resistance is one ohm, when an electromotive force of one volt is present in the circuit.

Ampere-hour: The product of the current in a circuit and the number of hours it flows. A unit of work or electrical energy.

Amplification Factor: The ratio of the change of instantaneous voltage between filament and plate to a small change of instantaneous voltage between filament and grid for a given constant plate current.

Amplifier: A device which modifies the effect of a local source of power in accordance with the variations of input power, and produces an increased output power.

Amplitude: The maximum ordinate of an alternating current or voltage characteristic; the maximum value the current or voltage attains during a cycle.

Antenna: A device for radiating or absorbing radio waves.

Antenna, Coil: See Coil Antenna.

Antenna Resistance: An effective resistance which is numerically equal to the ratio of the average power dissipated in the entire antenna circuit to the square of the effective current at the point of maximum current.

Note.—Antenna Resistance includes: Radiation Resistance; Ground Resistance; Radio-frequency resistance of conductors in antenna circuit and equivalent resistance of conductors in the antenna circuit; equivalent resistance due to corona, eddy currents, insulator leakage, dielectric loss, and so on. (See Effective Height of Antenna.)

Anti-Resonance: See Parallel Resonance.

Aperiodic Circuit: An electric circuit in which a voltage impulse will produce transient current in one direction only. The word aperiodic means "without period." Free oscillations are not possible in an aperiodic circuit.

Arc Transmission: The transmission of radio messages by continuous waves produced by an electric arc.

Atmospherics: See Strays.

Atmosphere Absorption: Diminishing of the amplitude of electromagnetic radiation due to absorption of energy by the atmosphere.

Attenuation: (**Radio**)—The decrease, with distance from the radiation source, of the amplitude of the electric and magnetic components constituting an electromagnetic wave.

Audibility: (**Radio Telegraph**)—A measure of the ratio of the telephone current producing a signal in a telephone receiver to that producing a barely audible signal. (A barely audible signal is one which permits the differentiation of the dot and dash elements of the letters.)

Audio Frequencies: The frequencies corresponding to normally audible sound waves. These lie below about 10,000 cycles per second.

Autodyne Reception: See Self-Heterodyne Reception.

Band of Wave Lengths: A continuous range of wave lengths extending between two definite wave lengths.

Beat Frequency: When two currents of slightly different frequencies flow simultaneously in a circuit, the beat frequency is the difference between the two separate frequencies.

Buzzer Modulation: The process of varying the output power of a continuous-wave generator at the tonal frequency of a buzzer, either by: (a) using the buzzer as a chopper or audio-frequency interrupter in the output circuit of the generator, or a circuit suitably coupled thereto, or (b) using the buzzer element in a circuit of the continuous-wave generator which permits the ready control of the output power of the generator (*e. g.*, the grid circuit of a three-electrode tube oscillator).

By-Pass Condenser: A condenser used to provide a path for alternating current around some circuit element through which current of high frequency cannot readily pass.

Capacitive Coupling: The association of one circuit with another by means of capacity common or mutual to both.

Capacitive Reactance: That part of the impedance which is due to the presence of capacity in the circuit and which is equal to $-1 \div (6.28 \times \text{frequency} \times \text{capacity})$.

Capacity: The ratio of the quantity of electric charge in a condenser to the voltage across its terminals.

Cat-whisker: The fine wire making contact with a crystal detector.

Choke Coil: A coil possessing great inductive reactance; used for preventing the flow of high frequency currents into or out of oscillating circuits.

Chopper: A device used in transmitting circuits for modulating continuous wave signals; also known as a "tikker."

Coil Antenna: An antenna consisting of one or more complete turns of wire.

Condenser: A device having capacity, consisting of insulating material (which may be air) between two conducting plates or sets of plates.

Condenser Antenna: An antenna consisting of two capacity areas. The lower capacity area may be ground or counterpoise.

Conductance: The inverse of resistance, *i. e.*, $1 \div$ resistance.

Continuous Waves: Continuous waves (C W) are a succession of waves of constant amplitude and frequency.

Continuous Waves, Interrupted (I C W): See Interrupted Waves.

Continuous Waves, Key Modulated: Continuous waves of which the amplitude or frequency is varied by the operation of a transmitting key.

Continuous Waves, Modulated at Audio Frequency: Continuous waves of which the amplitude or frequency is varied in a periodic manner at an audible frequency.

Counterpoise: A system of wires or other conductors (not the ground) forming the lower plate of a condenser antenna.

Coupler: An apparatus which is used to transfer radio-frequency power from one circuit to another by associating together portions of these circuits. Couplers are of the same types as the types of coupling—inductive, capacitive, and resistive.

Coupling Coefficient: The ratio of the mutual or common impedance component of two circuits to the square root of the product of the total impedance components of the same kind in the two circuits. (Impedance components are either resistance, capacity, or reactance.)

Coupling, Capacitive: See Capacitive Coupling.

Current: The rate of flow of electricity in a circuit.

C. W.: Abbreviation for "continuous wave."

Cycle: A complete succession of events, during which the voltage or current in a circuit passes through all possible values. A complete set of positive and negative values of an alternating current.

Damped Alternating Current: A current passing through successive cycles of value with progressively diminishing amplitude, the average value being zero.

Decrement: The diminishing of the amplitude of successive free oscillations in an oscillatory circuit.

Decremeter: An instrument for measuring the logarithmic decrement of a circuit or of a train of logarithmically damped radio waves.

Detector: That portion of the receiving apparatus which, connected to a circuit carrying currents of radio frequency, and in conjunction with a self-contained or separate indicator, translates the radio-frequency power into a form suitable for operation of the indicator. This translation may be effected either by the conversion of the radio frequency power or by means of the control of local power. The indicator may be a telephone receiver, relaying device, tape recorder, and so on.

Dielectric: That portion of a condenser between the plates; it may be air or any non-conducting material.

Diode: A two element vacuum tube, often used as a detector or rectifier; similar to the "Fleming Valve."

Direct Coupling: Association of two radio circuits by having an inductor, a condenser, or a resistor, common to both circuits.

Direct Current: Current which flows always in the same direction in a circuit; unidirectional.

Direct-Current Characteristic: The relation given by the curve plotted between the impressed electromotive force as abscissas and the resultant current as ordinates, for direct emf. and current.

Direction Finder: A radio receiving system which permits determination of the direction of the line of travel of received radio waves.

Directive Antenna: One having the property of radiating radio waves in larger proportion along some directions than others.

Double Modulation: The process of modulating a radio-frequency alternating current successively at two lower frequencies. The intermediate frequency is usually above the range of audio frequencies. The lowest frequency is generally an audio frequency or combination of audio frequencies, as in radio telephony.

Down Lead: That portion of a transmitting or receiving antenna which serves to connect the larger portion of an antenna or the main elevated conductor to the transmitting or receiving set, or through tuning inductors or condensers to the ground connection or counterpoise system.

Duplex Signaling: The simultaneous transmission and reception of signals in both directions between two stations.

Dynatron: A three-electrode tube which depends for its action upon the liberation of electrons from an anode by electron bombardment.

Effective emf.: In a.-c. circuits, when the wave form of the voltage is sinusoidal, = 0.707×maximum voltage occuring during the cycle.

Effective Height of an Antenna: The effective height of an antenna is a height somewhat less than the measured height, upon which the absorbing and radiating qualities of an antenna depend. This lessening of the apparent height is due to the presence of surrounding objects.

Electrolyte: The active liquid in a battery or electrolytic rectifier.

Electromotive Force (emf.): Electric pressure; that force which tends to cause a current to flow. The unit of electromotive force is the volt, often referred to as the "difference of potential" between two points in the circuit.

Electron: The smallest component of matter which has been discovered. Regarded as the ultimate particle of matter, carrying a negative electric charge.

Electron Tube: See Three-Electrode Tube.

Electron Tube Rectifier: A device for rectifying an alternating current by utilizing electron flow between a hot cathode and a relatively cold anode in a vacuum.

Electrostatic Coupling: See Capacitive Coupling.

Ether: A fictitious agency existing in space by means of which electromagnetic waves are propagated.

The existence of the ether has been assumed for the purpose of aiding in the explanation of radiation phenomena.

Fading: A variation or diminution of the strength of received radio signals over prolonged, temporary or varying periods, caused by actual variation of wave intensity.

Farad: The unit of capacity. A condenser which holds one coulomb of electricity having a difference of potential of one volt between its terminals has a capacity of one farad. The microfarad, which is one-millionth of the farad is the unit generally used in radio calculations.

Feed-Back Coil: A coil designed to cause mutual action between the input and output circuits of an amplifying device, thereby increasing the amplification.

Feed-Back or Reaction Coupling (sometimes termed "Tickler" Coupling): The process by which a part of the output power of an amplifying device reacts upon the input circuit, thereby increasing the amplification.

Feed-Voltage Modulation: The peocess of varying the amplitude of a radio-frequency alternating current in accordance with any desired wave form by systematically intoducing additional power into the circuit of the radio-frequency generator in accordance with the desired wave-form variations. In the three-electrode tube this involves systematically varying the supply voltage of the plate circuit.

Filter Band Pass: A combination of electric circuits which present low attenuation to alternating currents of all frequencies between certain limiting border frequencies and comparatively high attenuation to alternating currents of all frequencies below the low limiting border frequency or above the upper limiting border frequency.

Filter High Pass: A combination of electric circuits which present high attenuation to alternating currents below a certain frequency and comparatively low attenuation to currents above that frequency.

Filter Low Pass: A combination of electric circuits which present high attenuation to alternating currents above a certain frequency and comparatively low attenuation to currents below that frequency.

Flat-Top Antenna: An antenna having horizontal conductors at the top.

Forced Alternating Current: A current having a frequency and wave form which are equal to the frequency and wave form of the impressed electromotive force.

Free Alternating Current: A damped alternating current following a transient electromagnetic disturbance in a circuit, with no external emf. acting.

Frequency: The number of complete cycles or half the number of reversals per second of direction of curreant flow of a wave, or in a circuit. The units in use are the cycle and the kilocycle (one thousand cycles).

Frequency Changer: A device delivering alternating current at a frequency which differs from the frequency of the supply current.

Full-Wave Rectifier: A rectifier so arranged as to rectify and render available all successive half cycles of an alternating current.

Fundamental of an Antenna: The lowest frequency of free alternating current in an unloaded antenna. (No series inductance or capacity.)

Fundamental Wave Length: The wave length corresponding to the lowest frequency of free alternating current which may exist in any circuit in which oscillations are possible.

Grid Leak Resistor: (Usually called a grid-leak.) A resistor connected between the filament and the grid of a three-electrode tube used in association with a condenser to give the voltage between grid and filament a certain average negative value.

Ground Wire: A conductive connection to the earth.

Group Frequency: The number of trains of damped waves or current per second.

Note.—The term "group frequency" replaces the term "spark frequency."

Harmonics: Multiples of the fundamental frequency which are often set up in a circuit; the introduction of these introduces elements into speech sounds which cause distortion. Part of the electrical energy is lost in setting up these harmonics. Harmonics which are present in the original speech sounds however must be preserved so that the quality is not altered.

Henry: The unit of inductance. One millionth of a henry, called the microhenry, is commonly used in radio calculations.

Heterodyne Reception: A method of radio reception for continuous waves, employing the principle of reaction between locally generated oscillations and incoming oscillations. See Beat Frequency.

Heterodyne, Self: See Self Heterodyne.

Hot Wire Ammeter, Expansion Type: An ammeter dependent for its indications on the change in dimensions of an element heated by a current through it.

Hydrometer: An instrument for measuring the specific gravity of electrolytes in batteries.

Inductance: A property of conductors and circuits by virtue of which opposing emf's are induced in them or in other nearby circuits, due to the magnetic fields set up by the current cutting across these circuits.

Impact Transmitter: A radio transmitting set in which the transfer of energy from the exciting to an oscillating circuit is effected during one pulse of the exciting circuit current.

Impedance: Ratio of voltage to current in an alternating-current circuit. Impedance is a factor determining the magnitude of current flow in a circuit. The greater the impedance for a given voltage the smaller the current. For series resistance and reactance it is equal to $\sqrt{(\text{Resistance})^2 + (\text{Reactance})^2}$

Impulse Emf.: An emf. the maximum value of which is large compared with its average value, the average value being taken over a time equal to the time-constant of the circuit in which the emf. is impressed.

Impulse Excitation: A method of producing free oscillations in a circuit in which the duration of the impressed voltage is short compared with the duration of the current produced.

Inductive Coupling: The association of one circuit with another by means of inductance common or mutual to both. (This term when used without modifying words is commonly used for coupling by means of mutual inductance, whereas coupling by means of self-inductance common to both circuits is called "direct inductive coupling.")

Inductive Reactance: That part of the impedance which is due to the presence of inductance in the circuit, and which is equal to 6.28 × frequency × inductance.

Input Reactance of a Three-Electrode Tube: The reactance of an electron tube to its input circuit, due to its electrode capacities. (See reactance.) The ratio of an alternating sine-wave input voltage to the portion of the resulting input current which is an alternating sine-wave current of the same frequency as the input voltage and ninety degrees out of phase with it.

Inductance: That property of an electric circuit by virtue of which a varying current induces an emf. in that circuit or in a neighboring circuit. Radio of the magnetic flux to the current producing it.

Inductor: A conductor having inductance, usually a coil of wire.

Input Resistance of a Three-Electrode Tube: That part of the resistance of the input circuit of an electron tube which is due to the presence of the tube in the circuit. The ratio of an alternating sine-wave input voltage to that portion of the resulting input current which is an alternating sine-wave current of the same frequency as the input voltage and in phase with it.

Interrupted Continuous Waves: Interrupted continuous waves (I C W) are waves obtained by the modulation at audio frequency, during signaling, of an otherwise continuous wave.

Inverted L Antenna: A flat-top antenna in which the down lead is taken from one end of the horizontal portion.

Key: A device for closing and opening transmitting circuits in the act of transmitting signals.

Kenotron: A two-element electron tube highly evacuated, generally used for rectifying alternating currents.

Lead-In: See Down Lead.

Lightning Arrester: An instrument placed in antenna circuits to furnish an easy path to ground for lightning or other extremely high voltage discharges.

Loading Coil: An inductor used to decrease the resonance frequency of an antenna or other circuit.

Logarithmic Decrement: The Napierian logarithm of the ratio of two successive current amplitudes in the same direction, for an exponentially damped alternating current. The logarithmic decrement can also be considered as a constant of a simple radio circuit, being π times the product of the resistance by the square root of the ratio of the capacity to the inductance of the circuit.

Loop Antenna: See Coil Antenna. Commonly used for a coil antenna of a single turn.

Loud Speaker: A device with or without special amplifying circuits, by means of which received sounds are made audible without the use of telephone receivers held to the ears.

Megohm: One million ohms. The unit of high resistance.

Meter: A unit of length, 39.37 inches.

Meter-Amperes: The product of the antenna current in amperes at the point of maximum current and the antenna height in meters for any radio transmitting station. It constitutes a factor for indicating the radiating strength of radio transmitting stations..

Microampere: One millionth of an ampere.

Microfarad: One millionth of a farad, a unit of capacity.

Microhm: One-millionth of an ohm.

Micromicrofarad: One-millionth of a microfarad, a convenient unit of capacity.

Microhenry: One-millionth of a henry.

Milliampere: One-thousandth of an ampere; a convenient unit in measuring small currents.

Modulation: Variation of amplitude of a radio-frequency current.

Modulation, Double: See Double Modulation.

Modulation Frequency Ratio: The ratio of modulation frequency to wave frequency.

Multiple-Tuned Antenna: An antenna with connections to ground through inductances at more than one point, the inductances being so determined that their reactances in parallel present a total reactance equal to that necessary to give the antenna the desired natural frequency.

Mutual Inductance: The inductive effect due to the proximity of two separate electrical circuits.

Ohm: The unit of resistance. The resistance of a d.-c. circuit when a current of one ampere flows under a difference of potential of one volt is one ohm.

Open Antenna: (See Condenser Antenna).

Oscillations: (In Radio Work). See Damped Alternating Current.

Output Resistance of Three-Electrode Tube: That part of the impedance of the output circuit of the tube which is due to the presence of the tube in the circuit.

Parallel Resonance: When a single lumped capacity and a single lumped inductance are connected in parallel between terminals to which an alternating emf. is applied, and the inductance or capacity or frequency is varied, the condition of parallel resonance exists when the current supplied by the source is a minimum.

Every part of every actual circuit possesses a certain amount of distributed capacity and inductance, and in practice complex arrangements of a considerable number of inductances and capacities are often used. For this reason the assumption as to a single lumped capacity and a single lumped inductance made in the above two definitions are not strictly realized in practice, and the resonance conditions attained are a combination of series resonance and parallel resonance. This is particularly true in circuits of radio frequency in which the reactances due to leads and other parts of the circuit may be appreciable factors. (See Series Resonance).

Period: The time of a complete cycle of alternating current or voltage; equal to 2 alternations.

Phase Difference: A quantity proportional to the power loss in a condenser or insulating material. Phase difference in degrees $=0.57 \times$ power factor in per cent.

Plate Condenser Antenna: A condenser antenna in which the capacity areas consist of wires or metal plates, both elevated well away from the ground.

Plate Current: The current passing between the plate and the heated cathode in a three-electrode tube.

Pliotron: A kenotron with an additional electrode called the grid, for controlling the output current.

Potentiometer: Known also as a "voltage divider." A resistance used for obtaining adjustable voltages by utilizing the voltage drop in the resistance.

Power Factor: In a.-c. circuits, the ratio of the power in watts to the volt-amperes, often expressed in per cent.

Pulsating Current: A periodic current (that is, current passing through the successive equal cycles of values), the average value of which is not zero. A pulsating current is the sum of an alternating and a direct current.

Radiation Efficiency: The radiation efficiency of an antenna at a given wave length is the ratio of power radiated to the total power delivered to the antenna.

Radiation Resistance: The ratio of the total power radiated by an antenna to the square of the effective current at the point of maximum current.

Radio Channels: A band of wave lengths or frequencies of a width sufficient to permit of its use for radio communication without the radiation of subsidiary waves of more than a certain intensity at wave lengths of frequencies outside of such band.

Radio Frequencies: (See Also Audio Frequencies.) The frequencies higher than those corresponding to normally audible sound waves.

Note.—It is not implied that radiation cannot be secured at lower frequencies, nor that radio frequencies are necessarily above the limit of audibility.

Radiogoniometer: See Direction Finder.

Reactance: That part of the impedance of a circuit due to the inductance and capacity in it. (See Impedance. Inductive reactance $= 0.00628 \times$ frequency $\times$ inductance. Capacitive reactance $= -159.3 \div$ (frequency $\times$ capacity). Frequency in kilocycles.

Rectification: Changing an alternating current into direct or pulsating current.

Rectifier: A device for rectifying alternating currents.

Regenerative Coupling: (See Feed-Back Coupling.) A receiving system designed to increase amplification in a three-electrode tube.

Resistance: The opposition offered to the flow of current in a circuit which manifests itself in the evolution of heat in the conductors.

Resistor: A device having resistance, used to introduce resistance into a circuit.

Resistive Coupling: The association of one circuit with another by means of resistance common to both.

Resonance: That condition of an a-c. circuit under which maximum current flows for a given voltage. In a series circuit there is resonance when the inductive reactance is equal to the capacitive reactance.

Rheostat: A resistor with a means for varying the resistance, to control the flow of current in the circuit in which the rheostat is connected.

Self-Inductance: A property of wires and coils, due to the magnetic lines of force created by the current in the wire, cutting back on the wires and inducing an opposing emf. in them.

Self-Heterodyne: A system of reception of continuous wave signals by the production of audio-frequency beats through the use of a device which is both a radio-frequency generator and a detector of the audio-frequency beat currents produced.

Series Resonance: When a single lumped capacity and a single lumped inductance are connected in series between terminals to which an alternating emf. is applied, and the inductance or capacity or frequency is varied, the condition of series resonance (maximum current) exists when the inductive reactance equals the capacitive reactance. (See parallel resonance.)

Signal Stray Ratio: See Strays.

Static: Static is conduction or charging current in the antenna system resulting from physical contact between the antenna and charged bodies (*e. g.*, snowflakes) or masses of gas.

Stopping Condenser: A condenser used to provide direct-current insulation, but which permits alternating current to flow in a circuit.

Strays: Electromagnetic field causing disturbances in radio reception other than those produced by radio transmitting systems or by alternating current induction from wire circuits. The term "strays" includes atmospheric disturbances and disturbances caused by electrical apparatus such as sparking commutators; sparking contacts in fire alarm apparatus. Tirrell regulators or elevator controllers; sudden current changes through arc lamps; transient or sparking grounds on power systems; electric ignition systems of internal combustion engines, or sparking at third-rail or trolley contactors. (A reduction of the effect of strays on radio reception increases the signal-stray ratio.)

T-Antenna: A flat-top antenna in which the down lead is taken from the center of the horizontal portion.

Three-Electrode Tube: A combination of a heated cathode, a relatively cold anode, and a third electrode for controlling the current flowing between the other two electrodes, the whole contained within an enclosure evacuated to a low pressure.

This device is variously known as an Audion, Audiotron, Aerotron, Electron Relay, Electron Tube, Pilotron, Triode, Oscillion, Radiotron, etc.

Tickler: See Feed-Back Coil.

Transformer: A device consisting of one coil of wire placed in proximity with another, for the purpose of coupling two circuits together by virtue of the mutual inductance between the two coils. Also used for raising or lowering alternating voltages and currents. When the voltage of a line is increased by a transformer the current is correspondingly decreased and vice-versa. The power remains the same except for losses in the transformer. In this case one coil is wound directly upon the other. The coil connected to the source of power is called the **primary** and the other coil the **secondary.**

Undamped Alternating Current: A periodic current (*i. e.*, current passing through successive equal cycles of values) with constant amplitude whose average value is zero.

Volt: See electromotive force.

Volt-Ampere: The product of the current and voltage in a circuit.

Watt: A unit of power $^1/_{746}$ of a horsepower; $^1/_{1000}$ of a kilowatt. A d.-c. circuit carrying a current of one ampere with an emf. of one volt can deliver one watt of power.

Wave Antenna: A horizontal antenna the physical length of which is approximately equal to the length of signaling waves to be received, and which is so used as to be strongly directional.

Wave-Length: The ratio of the velocity of propagation of electric waves to the frequency.

Wavemeter: An instrument for measuring frequency and wave-length.

Waves Continuous Key Modulated: (See Continuous Waves, Key Modulated).

Waves Continuous Modulated at Audio Frequency: (See Continuous Waves at Audio Frequency).

Wave-Trap: A device used with a receiving set to improve its selectivity. A commonly used type is a parallel combination of a condenser and an inductor connected in series with the antenna. (See parallel resonance).

LIST OF ABBREVIATIONS TO BE USED IN RADIO COMMUNICATION ACCORDING TO THE INTERNATIONAL RADIOTELEGRAPHIC CONVENTION

	Question	Answer or Notice
QRA	What ship or coast station is this?	This is......
QRB	What is your distance?..........	My distance is......
QRC	What is your true bearing?......	My true bearing is......degrees
QRD	Where are you bound for?.......	I am bound for......
QRF	Where are you bound from?.....	I am bound from......
QRG	What line do you belong to?.....	I belong to the......Line
QRH	What is your wave length?......	My wave length is......meters
QRJ	How many words have you to send?	I have......words to send
QRK	How do you receive me?........	I am receiving well
QRL	Are you receiving badly? Shall I send 20...................... . . . . – . for adjustment? ...	I am receiving badly. Please send 20 . . . . – . for adjustment
QRLL	Request permission to test. .min's	Permission to test granted
QRM	Are you being interfered with?	I am being interfered with
QRN	Are the atmospherics strong?.....	Atmospherics are very strong
QRO	Shall I increase power?..........	Increase power
QRP	Shall I decrease power?.........	Decrease power
QRQ	Shall I send faster?.............	Send faster
QRS	Shall I send slower?.............	Send slower
QRT	Shall I stop sending?............	Stop sending
QRU	Have you anything for me?......	I have nothing for you
QRV	Are you ready?.................	I am ready. All right now
QRW	Are you busy?.................	I am busy (or: I am busy with...) Please do not interfere
QRX	Shall I stand by?...............	Stand by. Will call when required
QRY	When will be my turn?..........	Your turn will be No.......
QRZ	Are my signals weak?...........	Your signals are weak
QSA	Are my signals strong?..........	Your signals are strong
QSB	Is my tone bad?...............	The tone is bad
	Is my spark bad?...............	The spark is bad
QSC	Is my spacing bad?.............	Your spacing is bad
QSD	What is your time?.............	My time is......
QSF	Is transmission to be in alternate order or in series?............	Transmission will be in alternate order. QSG will be in series of 5 messages. QSH will be in series of 10 messages
QSJ	What rate shall I collect for?.....	Collect......
QSK	Is the last radiogram canceled?...	The last radiogram is canceled
QSL	Did you get my receipt?.........	Please acknowledge
QSM	What is your true course?.......	My true course is......degrees
QSN	Are you in communication with land?......................	I am in communication with land
QSO	Are you in communication with any ship or station (or: with..)?	I am in communication with..... (through......)
QSP	Shall I inform......that you are calling him?................	Inform......that I am calling him
QSQ	Is......calling me?............	You are being called by......
QSR	Will you forward the radiogram?..	I will forward the radiogram
QST	Have you received the general call?	General call to all stations
QSU	Please call me when you have finished (or: at....o'clock).......	Will call when I have finished
QSV	Is public correspondence being handled?...................	Public correspondence is being handled. Please do not interfere
QSW	Shall I increase spark frequency?..	Increase your spark frequency
QSX	Shall I decrease spark frequency?.	Decrease your spark frequency
QSY	Shall I send on a wave length of ......meters?..............	Let us change to the wave length of......meters
QSZ	....	Send each word twice. I have difficulty in receiving you
QTA	....	Repeat the last radiogram
QTC	Have you anything to transmit?	I have something to transmit
QTE	What is my true bearing?.......	Your bearing is....degrees from..
QTF	What is my position?..........	Your position is........latitude ....longitude

INTERNATIONAL MORSE CODE .

For the convenience of those who may desire to master the reading of radio telegraph messages the International Morse Code is here given. This is the code used by all radio telegraph stations and is entirely distinct from that used on the wire telegraph. The latter is called the American Morse Code.

A	• —
B	— • • •
C	— • — •
D	— • •
E	•
F	• • — •
G	— — •
H	• • • •
I	• •
J	• — — —
K	— • —
L	• — • •
M	— —
N	— •
O	— — —
P	• — — •
Q	— — • —
R	• — •
S	• • •
T	—
U	• • —
V	• • • —
W	• — —
X	— • • —
Y	— • — —
Z	— — • •
Ä (German)	• — • —
Á or Å (Spanish-Scandinavian)	• — — • —
CH (German-Spanish)	— — — —
É (French)	• • — • •
Ñ (Spanish)	— — • — —
Ö (German)	— — — •
Ü (German)	• • — —
1	• — — — —
2	• • — — —
3	• • • — —
4	• • • • —
5	• • • • •
6	— • • • •
7	— — • • •
8	— — — • •
9	— — — — •
0	— — — — —

Period	• • • • • •
Semicolon	— • — • — •
Comma	• — • — • —
Colon	— — — • • •
Interrogation	• • — — • •
Exclamation point	— — • • — —
Apostrophe	• — — — — •
Hyphen	— • • • • —
Bar indicating fraction	— • • — •
Parenthesis	— • — — • —
Inverted commas	• — • • — •
Underline	• • — — • —
Double dash	— • • • —
Distress Call	• • • — — — • • •
Attention call to precede every transmission	— • — • —
General inquiry call	— • — • — — • —
From (de)	— • • •
Invitation to transmit (go ahead)	— • —
Warning—high power	— — • • — —
Question (please repeat after ......)—interrupting long messages	• • — — • •
Wait	• — • • •
Break (Bk.) (double dash)	— • • • —
Understand	• • • — •
Error	• • • • • • • •
Received (O. K.)	• — •
Position report (to precede all position messages)	— • — •
End of each message (cross)	• — • — •
Transmission finished (end of work) (conclusion of correspondence)	• • • — • —

A dash is equal in length to three dots.

The space between parts of the same letter is equal to one dot.

The space between two letters is equal in length to three dots.

The space between two words is equal in length to five dots.

TRANSMISSION FORMULAS

See Chapter 2, Page 10

Flat-top antenna to flat-top antenna

$$I_r = \frac{188}{\lambda d} (h_s) I_s \left(\frac{h_r}{R_r} \right)$$

Flat-top antenna to coil antenna

$$\frac{1184}{\lambda^2 d} (h_s) I_s \left(\frac{h_r l_r N_r}{R_r} \right)$$

Coil antenna to flat-top antenna

$$\frac{1184}{\lambda^2 d} (h_s l_s N_s) I_s \left(\frac{h_r}{R_r} \right)$$

Coil antenna to coil antenna

$$\frac{7458}{\lambda^3 d} (h_s l_s N_s) I_s \left(\frac{h_r l_r N_r}{R_r} \right)$$

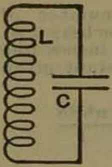
Here, I_r is the current received, I_s the current in the transmitting antenna, both in amperes; h_r, h_s are the heights of the two antennas in meters; R_r the resistance of the receiving antenna; d the distance in meters; λ the wave length in meters. In using the formulas remember that 1 meter = 3.281 feet, and 1 mile = 1609 meters, in case measurements are taken in these units.

The table below gives values of the correction factor when λ is in meters and d is in miles.

ABSORPTION FACTORS

Values of $2.718^{-0.015d}/\sqrt{\lambda}$		Frequency (kilocycles) 3000	2000	1500	1000	750	600	300
Distance		Wave-Length (Meters)						
Km.	Miles	100	150	200	300	400	500	1000
8.05	5	.962	.970	.973	.978	.982	.984	.988
16.1	10	.926	.938	.948	.957	.963	.967	.976
32.2	20	.858	.883	.897	.917	.928	.934	.942
64.4	40	.738	.780	.806	.840	.863	.872	.908
96.6	60	.633	.688	.725	.769	.803	.815	.866
128.8	80	.544	.608	.649	.705	.744	.762	.826
161	100	.467	.537	.583	.645	.692	.712	.887
322	200	.219	.288	.340	.417	.478	.506	.618
644	400	.048	.083	.116	.174	.229	.256	.384
966	600	.011	.024	.039	.072	.109	.132	.787
1288	800	.0023	.007	.013	.030	.052	.065	.147
1600	1000	.0005	.002	.0046	.013	.025	.033	.091

RADIO FORMULAS



- f, frequency, in kilocycles.
- λ, wavelength, in meters.
- C, capacity, in microfarads (μf.).
- L, inductance, in microhenries (μh.).
- R, resistance, in ohms.
- X, reactance, in ohms.
- Z, impedance, in ohms.
- E, electromotive force, in volts.
- V, potential difference or voltage, in volts.
- I, current, in amperes.
- P, power, in watts.
- ψ, phase difference of condensers, in degrees.
- φ, phase angle of alternating current circuit.

Frequency of resonance in simple circuit.

$$f = \frac{159.3}{\sqrt{LC}}, \quad \lambda = 1884\ \sqrt{LC}$$

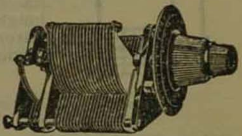
Relation between wave length and frequency

$$f = 300{,}000/\lambda, \quad \lambda = 300{,}000/f$$

Capacity of parallel-plate air condenser (plates of any shape).—N = number of plates; S = area of plate in square inches; D = distance between plates in inches.

$$C = [224.6/10^9]\ [(N-1)S/D]$$

The numerical value of 10^9 is 1,000,000,000.



Maximum capacity of variable condenser with semicular plates.—N and D as above; r_1 and r_2 = outside and inside radii respectively, of fixed plate, in inches.

$$C = \frac{353}{10^9}\ \frac{(N-1)\ (r_1^2 - r_2^2)}{D}$$

Apparent Inductance, L_a, of a Coil having capacity.—

$$L_a = L(1 + 0.0000394 f^2 CL), \quad L_a = L\left(1 + 3{,}550{,}000\ \frac{CL}{\lambda^2}\right)$$

Inductance of single-layer coil.—n = number of turns; d = diameter of coil, in inches; l = overall length = number of turns × distance between centers of adjacent wires.

$$L = 0.01\ kn^2 \frac{d^2}{l}$$

where k, for various values of the ratio of diameter to length, has the values given in table 1.

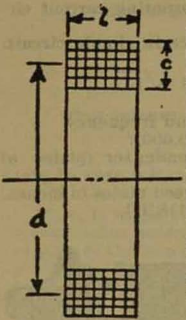
$\frac{d}{l}$	k
0.01	2.50
0.1	2.40
0.5	2.05
0.75	1.87
1.00	1.72
2.	1.32
3.	1.08
10.	0.51
100.	0.09

Frequency of Resonance of Coil.—For a single-layer coil as above with condenser of capacity C connected to it (see Fig. 1).

$$f = \frac{1593}{nd}\sqrt{\frac{1}{kC}}, \qquad \lambda = 188\, nd\sqrt{\frac{kC}{l}}$$

Inductance of multi-layer coil.—n = number of turns; d = average diameter of coil, in inches; l = length, in inches; c = depth of winding, in inches (see Fig. 3); k = constant in table 1; A = constant given below.

$$L = 0.01\,\frac{kn^2d^2}{l} \times 0.0064\,(0.693 + A)\,\frac{n^2d^2c}{l}$$



$\frac{c}{l}$	A
1	0.000
2	0.120
3	0.175
5	0.229
10	0.279
20	0.310
30	0.322

Current in receiving antenna (ordinary open type).— I_s = current in sending antenna of ordinary open type; d = distance between sending and receiving stations, in miles; R_r = resistance of receiving antenna circuit; h_s and h_r = average heights of sending and receiving antennas above ground or counterpoise, in feet.

$$I_{rs} = 3.63\frac{h_s h_r f I_s}{R_r d} \times 10^{-2} = 0.0109\,\frac{h_s h_r I_s}{R_r \lambda d}$$

Current in receiving coil antenna.—For plane of coil antenna parellel to line between sending and receiving stations, and for h_r = length of vertical side of coil antenna, in feet; l = length of horizontal side of coil antenna, in feet; N_r = number of turns of coil antenna; other symbols as in the two formulas just preceding.

$$I_{rc} = 2.32\,\frac{h_s h_r l_r N_r f^2 I_s}{R_r d} \times 10^{-13}$$

Correction factor for long distances, over about 50 miles.—Multiply any of the preceding four formulas by

$$2.718^{-0.00014d/\sqrt{f}} \quad \text{or} \quad 2.718^{-0.076d/\sqrt{\lambda}}$$

Correction factor for angle α between plane of coil antenna and line between sending and receiving stations.—Multiply any of formulas for current in receiving antenna by cosine ω.

Voltage across antenna inductance.—

$$V = 0.00628fLI = 1884\frac{LI}{\lambda}$$

Power input in sending antenna.—R_s = resistance of sending antenna circuit.

$$P_s = R_s I_s^2$$

Inductance of ordinary open type antenna (unloaded).—L_a = total inductance; L_h = inductance of horizontal portion; L_v = inductance of vertical portion.

$$L_a = (L_h + L_v)/3$$

Capacity of ordinary open type antenna (unloaded).—C_a = total capacity; C_h = capacity of horizontal portion; C_v = capacity of vertical portion.

$$C_a = C_h + C_v$$

Inductance of antenna loaded with inductance.—L_c = inductance of loading coils; other symbols as above; L = total inductance of antenna circuit.

$$L = L_a + L_c$$

Capacity of antenna with series condenser.—C_s = capacity of series condenser; C = total capacity of antenna circuit. Other symbols as above.

$$C = (C_a C_s)/(C_a + C_s)$$

Natural (fundamental) frequency of unloaded antenna.—

$$f = \frac{159.3}{\sqrt{L_a C_a}}, \lambda = 1884\sqrt{L_a C_a}$$

Frequency of antenna with loading inductance.—L_c = inductance of loading coils.

$$f = \frac{159.3}{\sqrt{(L_a + L_c)C_a}}, \lambda = 1884\sqrt{(L_a + L_c)C_a}$$

Frequency of antenna with series condenser.—C_s = capacity of series condenser.

$$f = \frac{159.3}{\sqrt{L_a \frac{C_a C_s}{C_a + C_s}}} \text{ and } \lambda = 1884\sqrt{L_a \frac{C_a C_s}{C_a + C_s}}$$

Radiation resistance of antenna.—h = height of antenna to center of capacity; h, in feet.

$$R = 16.3\, h^2 f^2 \times 10^{-10},\ R = 147\, (h^2/\lambda^2)$$

Current in a series circuit.—

$$I = \frac{E}{Z} = \frac{E}{\sqrt{R^2 + \left(0.00628fL - \frac{159.3}{fC}\right)^2}}$$

Reactance of the capacity in a circuit.—

$$X_c = -\frac{159.3}{fC} = -0.000531\frac{\lambda}{C}$$

Reactance of the inductance in a circuit.—

$$X_L = 0.00628fL = 1884(L/\lambda)$$

Reactance of a series circuit.—$X = X_c + X_L$

Impedance of a series circuit.—$Z = \sqrt{R^2 + X^2}$

Capacities in parallel.—C (total) $= C_1 + C_2 + \ldots.$

Capacities in series.—$\frac{1}{C\ (total)} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots.$

Inductances in series.—L(total) $= L_1 + L_2 + \ldots.$

Inductances in parallel.— $\frac{1}{L}$ (total) $= \frac{1}{L_1} + \frac{1}{L_2} + \ldots.$

Resistances in series.—R (total) $= R_1 + R_2 + \ldots.$

Resistances in parallel.— $\frac{1}{R}$ (total) $= \frac{1}{R_1} + \frac{1}{R_2} + \ldots.$

Ohm's law.—When the current flowing in a series circuit is not alternating or pulsating, or does not in any way vary in magnitude or direction, it is said to be direct current and the reactance X is equal to zero. This is likewise the case when a circuit containing inductance capacity and resistance is tuned or in resonance with an impressed alternating emf. The above formulas then reduce to Ohm's law, viz., $I = E/R$

Power loss in a circuit.—V = difference of potential or voltage drop between any two points in a circuit between which the power loss is to be determined.

$$P = RI^2 = V^2/R$$

Direct current resistance of a copper conductor.—Q = cross section of conductor, in square inches; l = length of conductor, in inches. ($10^{-9} = 0.000,000,001$)

$$R_c = 62\ (1/A) \times 10^{-9}$$

Direct current resistance of round copper wire.—d = diamter of wire, in inches; l = length of wire, in feet

$$R = 85.2\ (l/d^2) \times 10^{-8}$$

Phase angle of circuit.—$\tan \lambda = X/R$

Power factor.—The power factor is defined as the cosine of the phase angle, power factor $= \cos \phi = R/Z$

Condenser phase difference.—

$$\psi = 0.36rfC = 108,000\ rC/\lambda$$

Power input to a condenser.—$P = 0.0005\ fCE^2$

Power loss in condenser.—

$$P = EI\psi \text{ (small air condensers)} = EI \cos \phi$$

CAPACITY AND INDUCTANCE CALCULATIONS

Values of inductance and capacity which together will give resonance at a given frequency or wave length are shown in Fig. 9 below. These curves were constructed for the condensers commonly available, viz., 0.001 and 0.0005 μfd. It is noticed that the intersection of the broken lines drawn from the 800-meter division for the wave length and from the 415 μh division for the inductance lies in the vicinity of the curve for the 0.0005 μfd. condenser.

Variable condensers all have minimum values of capacity; that is, the capacity is not zero when the reading on the condenser dial is zero. It is assumed in this case that the minimum capacity of the 0.0005 μfd. condenser is 0.00005 μfd. The dotted line on the chart immediately shows that the lowest wave length this combination of variocoupler and condenser will tune to is 270 meters. This value can be arrived at by using the formula $\lambda = 1884\sqrt{LC}$, in which L is 415

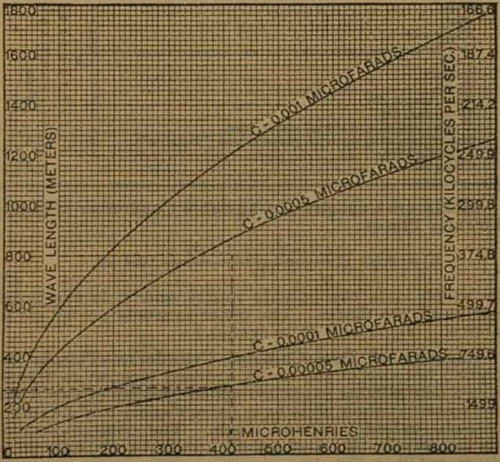


Fig. 9

μh and C is 0.00005 μf. Similar curves are drawn on the chart for the 0.001 μf condenser. These two condensers are generally known as the 23- and 43-plate condensers.

Calculation of Capacity.—For use in making computations there are given below a number of formulas for calculating the capacity of condensers of various forms. The formulas are given without any explanation as to their derivation. Where complicated factors occur, tables are given showing the values of these factors through ranges most suitable for amateur and broadcasting use.

All lengths are expressed in inches and feet, as specified, and the areas correspondingly. The capacities are given in microfarads.

Capacity of Parallel Plate Condenser.—S is the area of one plate; N, the number of plates; D, the distance between them; K, the dielectric constant of the material between the plates. S is in square inches and D in inches.

$$C = 2.246\ K \frac{S(N-1)}{D} \times 10^{-7}\ \mu f. \qquad (1)$$

Values of K (Dielectric Constant)

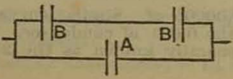
Air		1.0
Glass	4	to 10.
Mica	4	" 8
Hard rubber	2	" 4
Paraffine	2	" 3
Paper	1.5	" 3
Sulphur	3	" 4.2
Shellac	3	" 3.7
Wood, maple, dry	3	" 4.5
Wood, oak, dry	3	" 6
Molded insulating material, shellac base	4	" 7
Molded insulating material, phenolic base ("Bakelite")	5	" 7.5
Vulcanized fiber	5	" 8
Castor oil		4.7

Maximum Capacity of a Variable Condenser of Semi-Circular Plates:

$$C = 3.53\ K \frac{(N-1)\ (r_1^2 - r_2^2)}{D} + 10^{-7}\ \mu f, \qquad (2)$$

in which r_1 is the outside radius and r_2 is the inner radius of the plates. The other symbols are as given above. (r_1, r_2 and D in inches.)

Capacity of Two Co-axial Cylinders.—This is included because of the newly aroused interest in Hazeltine's neutralizing capacity, which consists of two wires separated at their ends by a narrow space and having a co-axial cylinder around them. The combination of condensers in this arrangement may be considered as represented in Fig. 10.



The capacities represented as B are the co-axial capacities, and that represented as A is the capacity between the two end surfaces of the wires.

$$C = kl \times 10^{-6}\ \mu f, \qquad (3)$$

where l is the length and k is a constant as given in the following table. r_1 and r_2 are the radii of the outer and inner cylinders.

r_1/r_2	k	r_1/r_2	k	r_1/r_2	k
1.01	142.5	1.10	14.8	2	2.04
1.02	71.3	1.2	7.75	4	1.02
1.04	36.1	1.4	14.33	6	.79
1.06	24.2	1.6	13.00	8	.68
1.08	18.4	1.8	2.40	10	.61

The values of k in the table have been calculated from

$$k = \left[(0.2416 \div \left(\log_{10} \frac{r_1}{r_0} \right) \right] \times 2.54$$

Capacity of a Long Wire Parallel to the Ground.—For a length greater than four times the height,

$$C = \frac{0.6141}{(x_1 - k_1)} \times 10^{-6}\ \mu f. \qquad (4)$$

For a length less than four times the height,

$$C = \frac{0.6141}{x_2 - k_2} \times 10^{-6}\ \mu f. \qquad (4a)$$

Values of the constants are given in the following table; h/l, l/h, l/d, and h/d are ratios between the length of the wire, the height above the ground, and the diameter of the wire. The tables are good for lengths up to about 100 feet and for wire sizes Nos. 10, 12 and 14. The values in the table below for x_1, x_2, k_1, k_2, have been computed from the expressions

$$x_1 = \log_{10} \frac{4h}{d} \quad k_1 = \log_{10} \left[\frac{1 + \sqrt{1 + \left(\frac{4h}{l} \right)^2}}{2} \right]$$

$$x_2 = \log_{10} \frac{2l}{d} \qquad k_2 = \log_{10} \left[\frac{l}{4h} + \sqrt{1 + \left(\frac{l}{4h} \right)^2} \right]$$

h/l	k_1	h/d	x_1	h/l	k_2	l/d	x_2
0.9	.444	1,600	3.806	9	.673	12,000	4.380
.8	.453	1,400	3.748	8	.627	10,000	4.301
.7	.531	1,200	3.681	7	.576	8,000	4.204
.6	.620	1,000	3.602	6	.518	6,000	4.079
.5	.656	800	3.505	5	.455	4,000	3.903
.4	.740	600	3.380	4	.382	2,000	3.602
.3	.851	400	3.204	3	.301	1,000	3.301
.2	1.02	200	2.903	2	.209	800	3.204
.1	1.31	100	2.602	1	.107	600	3.079

All measurements should be made in inches.

Capacity of a Vertical Wire.—The formula given above for the capacity of a single horizontal wire whose length is less than four times its height, omitting the k_2 in the denominator, is sometimes used to calculate the capacity of a vertical wire. It applies accurately only when h is large compared with l, and gives very rough values for a vertical single-wire antenna, the lower end of which is connected to apparatus at least several yards above the ground.

Capacity of Various Types of Antennas.—The theoretical formulas that have been evolved for the capacity of types of antenna other than the single-wire are very involved and difficult to handle. A formula has recently been derived empirically which gives the capacity of antennas of all shapes not too elongated or having the wire too widely spaced.

$$C = \left[1.22\sqrt{a} + 0.27\frac{a}{h}\right] \times 10^{-5}\ \mu f, \qquad (5)$$

in which a is the area of the top of the antenna in sq. ft. and h is the **actual** mean height above the ground in ft. For a very long antenna having a length greater than eight times its breadth, the above formula must be multiplied by the **elongation factor**

$$(1 + 0.01/b), \qquad (6)$$

where b is the breadth of the antenna in feet. This equation is accurate to about 10% for antenna tops. The capacity of the lead-ins, etc., must be estimated. The poorest agreement between the calculated and experimental values is in the case of umbrella antennas. The quantity a is the area enclosed by the bounding wires of the antenna.

The estimation of the capacity of the lead-in wires from an antenna is a very difficult matter, due to the fact that very often we do not know the length and other characteristics of the ground lead. If the apparatus happens to be located in an upper story of a building or residence and the set grounded through the water system, it can be seen what an impossible problem we have at hand. Accurate calculation of the antenna constants is possible only when a special ground lead to a pipe or plate buried in the ground is used. In this case the capacities of the antenna top and lead-in wire are calculated separately and combined by the formula for condensers in parallel, viz.,

$$C = C_h + C_v,$$

in which C_h is the capacity of the horizontal or top portion and C_v is the capacity of the vertical portion or lead-in.

The **mutual capacity** of two parallel wires is the capacity of these two wires, regarded as a single system, with respect to the earth as the other plate of the condenser. The mutual capacity is not the same as the capacity of the two wires regarded as the two plates of a condenser, and the capacity of the two-wire system is not twice the capacity of each wire by itself with respect to the earth. As a matter of fact, it is less. The normal electric field of one of the wires overlaps the normal electric field of the other. The total capacity of these two wires to earth is diminished to some extent by this overlapping.

The capacity of a two-wire antenna with respect to the earth is twice the capacity to earth of one of the wires, less the mutual capacity of the two wires. In general, although each added wire adds something to the total capacity, it adds much less than the capacity it would have alone in the same position.

The use of all these formulas will give only an approximate idea of the capacity of an antenna, as, even in the simplest cases, the presence of houses, trees and other neighboring objects, and the difficulty of allowing for the lead-in wire, makes any precise calculation impossible.

Self-Inductance of Single-Layer Coils.—Nagaoka's formula for computing the self-inductance of single-layer coils is:

$$L = 0.03948 \frac{n^2 r^2}{l} K.$$

Here n = total number of turns of wire; r = radius of the coil; l = length of the coil; K = elongation factor. If all the lengths are in centimeters, the self-inductance is given in microhenries. The nature of the elongation factor is explained as follows: Without this factor the equation is:

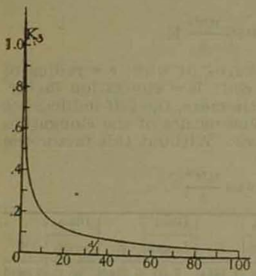
$$L = 0.03948 \frac{n^2 r^2}{l}$$

Diam./Length	K	Diam/Length	K	Diam./Length	K	Diam./Length	K	Diam./Length	K
0.00	1.0000	2.00	0.5255	4.00	0.3654	8.00	0.2366	30.0	0.0910
0.10	0.9588	2.10	.5137	4.20	.3551	8.50	.2272	35.0	.0808
0.20	.9201	2.20	.5025	4.40	.3455	9.00	.2185	40.0	.0728
0.30	.8838	2.30	.4918	4.60	.3364	9.50	.2106	45.0	.0664
0.40	.8490	2.40	.4816	4.80	.3279	10.00	.2033	50.0	.0611
0.50	0.8181	2.50	0.4719	5.00	0.2198	10.5	0.2033	60.0	0.0528
0.60	.7885	2.60	.4626	5.20	.3122	11.0	.1903	70.0	.0467
0.70	.7609	2.70	.4537	5.40	.3050	12.0	.1790	80.0	.0419
0.80	.7351	2.80	.4452	5.60	.2981	13.0	.1692	90.0	.0381
0.90	.7110	2.90	.4370	5.80	.2916	14.0	.1605	100.0	.0350
1.00	0.6884	3.00	0.4292	6.00	0.2854	15.0	0.1527	....	......
1.10	.6673	3.10	.4217	6.20	.2795	16.0	.1457	....	......
1.20	.6475	3.20	.4145	6.40	.2739	17.0	.1394	....	......
1.30	.6290	3.30	.4075	6.60	.2685	18.0	.1336	....	......
1.40	.6115	3.40	.4008	6.80	.2633	19.0	.1284	....	......
1.50	0.5950	3.50	0.3944	7.00	0.2584	20.0	0.1236	....	......
1.60	.5795	3.60	.3882	7.20	.2537	22.0	.1151	....	......
1.70	.5649	3.70	.3822	7.40	.2491	24.0	.1078	....	......
1.80	.5511	3.80	.3764	7.60	.2448	26.0	.1015	....	......
1.90	.5379	3.90	.3708	7.80	.2406	28.0	.0959	....	......

This formula assumes that when a current is passed through the coil and a magnetic field set up, all the magnetic lines of force pass through the coil from one end to the other without any of them escaping to the outside between the turns of the coil. This leakage causes a diminution of the inductance of the winding which becomes quite appreciable as the diameter of the coil increases in proportion to the length.

To correct for this leakage, we resort to multiplication by the elongation factor, K, which is a function of the ratio d/l. Nagaoka has computed values of K, which are given in the preceding table.

The graph below has been plotted from this table, and shows how the correction factor itself varies with the length and diameter. The construction of alignment charts to determine graphically the values of the inductance requires that this curve when plotted on logarithmic paper be assumed an approximate straight line. Consequently the inductance as obtained therefrom is approximate.



The table of inductances is nothing more than the solution of this formula for a great number of coils of various diameters and lengths. No approximations have been made and the values given may be considered as correct within the limitations of the slide-rule.

The method of using the table is as follows: Let us assume that we have a coil 8 cms. in diameter, 12 cms. long, and wound with No. 24 enameled wire. The self-inductance is then, from the table, 1750 microhenries. Or, let us suppose that we wish to construct a coil of No. 22 single-covered cotton wire, 10 cms. in diameter, having an inductance of 750 microhenries. The table immediately gives a length between 8 and 10 cms. long. If it is desired, a closer approximation to the length may be obtained by interpolation. Thus, the difference between the values for 8 and 10 cms. length is 1035 —722 = 313. The difference between 722 and 750 is 750 —722 = 28. There is a difference of 2 between 8 and 10. The coil must be longer than 8 cms. by the amount (28/313) × 2 = 0.0179, or the length is 8 + 0.0179 = 8.0179 cms. To find the total number of turns required, multiply the length by the value given in the column headed "turns per cm." Thus there are required in the above case 8.0179 × 12.36 = 99 turns.

Although the inductance may be determined by an exact method, there are other factors entering which complicate matters considerably. These are the distributed capacity of the winding, and the resistance which changes appreciably with the frequency.

The voltage drop between the terminals of the coil is the sum of all the drops of voltage between the turns. Any two turns of the coil have a difference of potential between them, and they act as the two plates of a condenser. This capacity is distributed in small bits throughout the length of the coil. When the frequency of the current is low, the reactance due to this capacity is large and decreases as the frequency is increased. This can be seen from the relation

$$X_c = \frac{159.3}{fC}$$

where X_c is the capacitive reactance in ohms, f is the frequency in kilocycles per second, and C is the capacity in microfarads.

These small capacities between the turns of a coil are of such importance in radio design and measurements that a coil can seldom be regarded as a pure inductance. The effect of this distributed capacity is ordinarily negligible at low frequencies, but it modifies greatly the behavior of a coil at radio frequencies. For most purposes a coil can be considered as an inductance with a small capacity in parallel with it. Investigations have shown that in ordinary coils the magnitude of this capacity does not vary with frequency. Thus a coil may in itself constitute a complete oscillating circuit even when the ends of the coil are open.

The variation of the resistance of a coil with frequency also becomes an important factor when dealing with such high frequencies, although its effect on the apparent inductance is such that it tends to neutralize the effect of distributed capacity of a coil. These points will be brought out below.

If such a coil be placed in a circuit with an e.m.f. in series, the case is one of parallel resonance, and the apparent inductance of the coil is given by

$$L_a = \frac{L(1-\omega^2LC)}{(1-\omega^2LC)^2-\omega^2R^2C^2} - \frac{R^2C}{(1-\omega^2LC)^2-\omega^2R^2C^2}$$

in which L is in henries, C in farads, and R in ohms; ω is equal to 6.28 times the frequency in cycles per second.

If the resistance is considered negligible, this may be written:

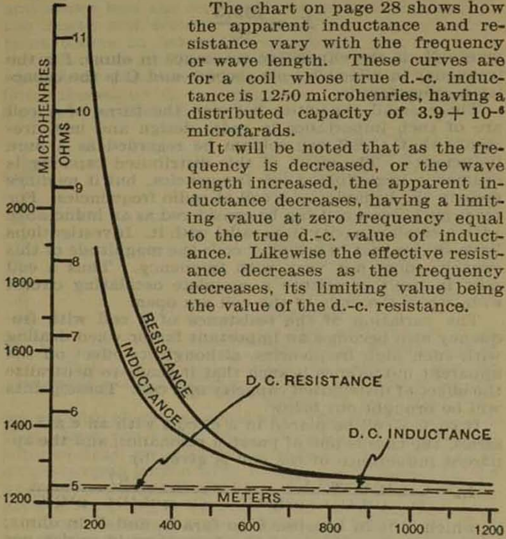
$$L_a = L(1 + 3\,9.48f^2C_0L \times 10^{-6}) = L(1 + 3550000\,\frac{C_0L}{\lambda^2}),$$

in which L_a is the apparent inductance in microhenries, L is the calculated (or measured by d-c. methods) inductance, f is the frequency in kilocycles per second' and C the capacity of the coil in microfarads.

It is thus seen that the effect of distributed capacity is to cause an increase in the inductance of the coil. The capacity itself is not calculable directly, but its value may be determined by applying these formulas to resonance methods of measurement.

The formulas also show the variation in the resistance of the coil with changes of frequency. Increases in resistance or skin effect diminish the apparent inductance of the coil.

The inductance of a coil is decreased by skin effect and increased by capacity. The two tend to neutralize each other, and, in general, Nagaoka's formula, and the table, give as good values of self-inductance as can be obtained.



The chart on page 28 shows how the apparent inductance and resistance vary with the frequency or wave length. These curves are for a coil whose true d.-c. inductance is 1250 microhenries, having a distributed capacity of $3.9 + 10^{-6}$ microfarads.

It will be noted that as the frequency is decreased, or the wave length increased, the apparent inductance decreases, having a limiting value at zero frequency equal to the true d.-c. value of inductance. Likewise the effective resistance decreases as the frequency decreases, its limiting value being the value of the d.-c. resistance.

SELF-INDUCTANCE OF SINGLE-LAYER COILS (MICROHENRIES)

Wire Size and Insulation				Diam. Mils	Turns per Inch	Turns per cm.	d=4 (cms.)						d=6 (cms.)						d=8 (cms.)					
Cotton		Silk					Length (cms.)						Length (cms.)						Length (cms.)					
Double	Single	Double	Single				4	6	8	10	12	14	4	6	8	10	12	14	4	6	8	10	12	14
20	......	......	......	42.161	23.72	9.33	38	63	90	117	149	174	73	127	185	244	304	364	115	206	302	403	507	607
......	20	......	......	37.861	26.41	10.39	45	76	108	139	172	204	88	152	221	291	364	435	138	246	361	482	607	725
......	......	20	......	36.161	27.66	10.89	50	88	123	159	196	234	100	174	253	333	415	497	157	281	413	552	695	830
22	......	......	......	35.547	28.13	11.08	53	90	127	165	203	241	104	181	262	342	428	514	163	291	427	570	717	857
......	......	......	20	34.261	29.18	11.49	57	96	136	177	218	260	112	196	281	370	460	552	175	312	457	612	770	922
......	22	......	......	31.247	31.40	12.36	66	111	157	205	251	300	129	224	325	427	531	637	202	381	529	707	890	1065
24	......	......	......	30.300	33.01	13.00	73	123	174	226	279	332	143	248	359	474	590	707	225	400	586	784	987	1180
......	......	22	......	29.547	33.85	13.33	77	129	183	238	293	448	150	260	377	497	617	740	235	420	616	822	1032	1232
......	......	......	22	27.647	36.16	14.24	88	148	209	272	334	399	172	298	431	569	705	847	269	480	702	941	1181	1415
26	......	......	......	26.140	38.25	15.05	98	165	234	304	374	446	192	332	483	636	790	950	301	535	787	1055	1320	1582
......	24	......	......	26.000	38.46	15.12	99	166	235	305	376	447	193	335	486	644	796	952	302	545	792	1057	1332	1590
......	......	24	......	24.300	41.15	16.17	114	191	271	351	431	500	221	384	559	735	912	1092	347	619	912	1215	1527	1822
28	......	......	......	22.841	43.78	17.23	129	217	306	399	489	582	250	435	632	832	1032	1245	392	701	1057	1377	1731	2071
......	......	......	24	22.401	44.65	17.55	134	225	318	412	507	605	260	452	656	867	1071	1290	408	727	1100	1429	1750	2150
......	26	......	......	21.840	45.78	18.01	140	236	334	434	535	636	273	475	690	907	1130	1355	429	765	1156	1504	1892	2257
30	......	......	......	20.225	49.45	19.48	165	277	392	510	627	747	321	557	810	1066	1325	1592	502	897	1356	1762	2225	2652
......	......	26	......	20.140	49.66	19.52	166	279	394	512	631	751	323	560	812	1070	1331	1595	506	902	1362	1770	2331	2667
......	28	......	......	18.541	53.94	21.25	196	329	467	601	742	885	380	661	935	1262	1570	1882	596	1066	1567	2087	2635	3137
......	......	......	26	18.240	54.83	21.55	202	339	430	622	767	912	393	682	990	1305	1621	1944	615	1100	1659	2156	2715	3237
......	......	28	......	16.841	59.37	23.40	237	398	564	731	900	1057	461	800	1162	1530	1900	1981	722	1287	1950	2530	3182	3805
......	30	......	......	15.925	62.81	24.70	265	445	630	817	1006	1200	515	895	1272	1707	2127	2550	807	1442	2180	2830	3562	4257
......	......	......	28	14.941	66.92	26.35	297	500	707	932	1130	1346	579	1006	1457	1947	2385	2865	907	1620	2445	3225	4000	4747
......	......	30	......	14.225	70.33	27.70	334	560	792	1015	1265	1505	647	1125	1632	2125	2670	3200	1017	1812	2737	3555	4475	5337
......	......	......	30	12.325	81.17	31.90	444	744	1052	1367	1680	2000	862	1495	2170	2857	3550	4250	1355	2410	3637	4725	4950	7100

SELF-INDUCTANCE OF SINGLE-LAYER COILS (MICROHENRIES)

Wire Size and Insulation				Diam. Mils	Turns per Inch	Turns per cm.	d=10 (cms.)						d=12 (cms.)						d=14 (cms.)					
Cotton		Silk					Length (cms.)						Length (cms.)						Length (cms.)					
Double	Single	Double	Single (enamel)				4	6	8	10	12	14	4	6	8	10	12	14	4	6	8	10	12	14
20	......	......	......	42.161	23.71	9.33	162	273	412	590	750	910	212	389	587	800	1020	1250	266	494	750	1030	1319	1625
......	20	......	......	37.861	26.41	10.39	194	296	492	707	896	1087	254	465	702	956	1220	1492	318	589	899	1230	1580	1940
......	......	20	......	36.161	27.66	10.89	221	339	564	810	1025	1245	290	532	805	1095	1397	1707	362	673	1030	1407	1806	2220
22	......	......	......	35.547	28.13	11.08	228	351	587	837	1057	1284	300	551	831	1131	1442	1762	375	697	1067	1455	1865	2292
......	......	......	20	34.261	29.18	11.49	243	377	625	897	1137	1382	322	592	891	1215	1547	1897	401	750	1142	1560	2002	2467
......	22	......	......	31.247	31.40	12.36	284	435	722	1035	1312	1595	372	682	1031	1405	1790	2192	466	865	1319	1805	2312	2845
24	......	......	......	30.300	33.01	13.00	315	482	800	1150	1455	1770	413	757	1142	1555	1982	2430	516	960	1457	2000	2562	3162
......	......	22	......	29.547	33.85	13.33	330	506	842	1206	1527	1855	433	795	1200	1632	2082	2535	442	1006	1532	2100	2687	3305
......	......	......	22	27.647	36.16	14.24	378	579	960	1380	1742	2122	496	910	1370	1867	2375	2912	621	1155	1750	2400	3070	3787
26	......	......	......	26.140	38.25	15.05	422	646	1075	1545	1950	2377	555	1015	1532	2087	2660	3262	692	1285	1962	2682	3437	4237
......	24	......	......	26.000	38.46	15.12	425	651	1081	1550	1965	2382	557	1020	1542	2095	2680	3275	697	1295	1972	2695	3462	4250
......	......	24	......	24.300	41.15	16.17	489	745	1245	1782	2255	2732	640	1170	1775	2412	3070	3650	802	1482	2267	3100	3970	4750
28	......	......	......	22.841	43.78	17.23	551	845	1407	2020	2555	3107	722	1329	2007	2732	3480	4255	905	1681	2565	3512	4500	5525
......	......	......	24	22.401	44.65	17.55	572	879	1459	2095	2650	3227	762	1380	2082	2830	3612	4425	940	1746	2662	3645	4662	5750
......	26	......	......	21.840	45.78	18.01	602	922	1534	2205	2787	3387	790	1446	2187	2980	3800	4650	987	1835	2800	3832	4787	6050
30	......	......	......	20.225	49.45	19.48	707	1082	1804	2835	3275	3982	927	1700	2565	3500	4462	5462	1159	2155	3287	4500	5775	7100
......	......	26	......	20.140	49.66	19.52	711	1087	1812	2595	3287	4000	932	1707	2580	3525	4487	5475	1167	2165	3305	4520	5787	7125
......	28	......	......	18.541	53.94	21.25	837	1282	2082	3012	3875	4712	1097	2017	2962	4145	5225	6462	1375	2555	3900	5325	6825	8400
......	......	......	26	18.240	54.83	21.55	865	1325	2205	3162	4000	4862	1132	2081	3057	4275	5462	6675	1420	2637	4017	5500	7062	8675
......	......	28	......	16.841	59.37	23.40	1015	1555	2587	3707	4695	5712	1330	2440	3687	5012	6400	7825	1665	3090	4712	6450	8275	10175
......	30	......	......	15.925	62.81	24.70	1137	1737	2895	4150	5250	6637	1487	2657	4125	5612	7162	8762	1862	3462	5375	7225	9250	11412
......	......	......	28	14.941	66.92	26.35	1275	1955	3250	4725	5900	7175	1670	3067	4662	6400	8025	9850	2091	3887	5925	8225	10375	12800
......	......	30	......	14.225	70.33	27.70	1429	2187	3637	5212	6600	8125	1875	3430	5175	7062	9000	10225	2342	4350	6625	9075	11625	14300
......	......	......	30	12.325	81.17	31.90	1900	2905	4835	6925	8775	10662	2490	4562	6887	9375	11925	14600	3120	5775	8812	12062	15437	19000

CHARACTERISTICS OF RECEIVING RADIOTRONS

TYPE	USE	A Volts	V_f Volts	I_f Amperes	"B" Volts Detector	"B" Volts Amplifier	"C" Volts	I_p Mils.	R_p Ohms	G_m Micromhos	μ
R.C.A. UX201-A	Detector Amplifier	6.0	5.0	0.25	45	45 90 135	0 4.5 9.0	1.5 2.0 2.5	18,500 12,000 11,000	460 675 725	8 ....
UV-199 & UX-199	Detector Amplifier	4.0 or 4.5	3.0	0.06	45	45 90	0 4.5	1.0 2.5	 16,500	 380	.... 6.25
WD-11 & WX-12	Detector Amplifier	1.5 or 2.0	1.1	0.25	22.5–45	45 90	0 4.5	1.5 2.5	 15,000	 400	 6
UX-200	Detector only	6.0	5.0	1.0	16.5–22.5	....	Neg. fil.	1.0	....	....	....
UX-200A	Special Detector	6.0	5.0	0.25	45	....	Neg. fil.	1.5	....	....	....
UX-240	High Mu Detector Amplifier	6.0	5.0	0.25	135 180	135 180	1.5 3.0	0.2 0.2	150,000 150,000	200 200	30 30
UX-120	Power Amplifier last Audio Stage	4 or 4.5	3.0	0.125	....	135	22.5	6.5	6,600	500	3.3
UX-112	Power Amplifier	6.0	5.0	0.5	....	90 135 157.5	6 9 10.5	2.5 6.0 8.0	8,800 5,500 4,800	890 1435 1670	7.9 7.9 8.0
UX-171	Power Amplifier last Audio Stage	6.0	5.0	0.5	....	90 135 180	16.5 27.0 40.5	10 16 20	2,500 2,200 2,000	1200 1360 1500	3.0 ....
UX-210	Power Amplifier Oscillator	6.0 8.0	6.0 7.5	1.1 1.25	....	90 135 157.5 250 350 425	4.5 9.0 10.5 18 27 35	3 4.5 6 12 18 22	9,700 8,000 7,400 5,600 5,100 5,000	775 940 1020 1330 1500 1550	7.5 7.5 7.5 7.5 7.6 7.7

CHARACTERISTICS OF CUNNINGHAM RECEIVING TUBES

TYPE	USE	A Volts	V_f Volts	I_f Amperes	"B" Volts		"C" Volts	I_p Mils.	R_p Ohms	G_m Micromhos	μ
					Detector	Amplifier					
C-11 or CX-12	Detector Amplifier	1.5	1.1	0.25	0.25	45 67.5 90	0–1.5 0–3.0 4.5	1.1 1.8 2.6	18,000 17,000 16,000	340 360 380	6.2 ....
C or CX 299	Detector Amplifier	3.0 to 4.5	3.3	0.06	22.5 to 45	45 67.5 90	0.5–1.5 1.5–3.0 4.5	1.0 1.7 2.5	19,500 16,500 15,000	320 380 415	6.25 ....
CX-220	Power Amplifier	4.5	3.3	0.125	....	90 135	16.5 22.5	3.2 7.0	7,700 6,600	428 500	3.3 ....
CX-300A	Special Detector	6.0	5.0	0.25	45	....	....	1.5	30,000	670	20
CX-301A	Detector Amplifier	6.0	5.0	0.25	45	45 67.5 90 135	0.5–1.5 1.5–3.0 4.5 9.0	0.9 1.7 2.0 2.5	18,500 14,000 12,000 11,000	460 600 710 775	8.0 ....
CX-112	Power Amplifier	6.0	5.0	0.50	....	90 135 157	6.0 9.0 10.5	2.4 5.8 7.9	8,800 5,500 4,800	890 1435 1670	8.5 ....
CX-371	Power Amplifier	6.0	5.0	0.50	....	90 135 157 180	16.0 27.0 33.0 40.0	11.0 16.0 18.0 20.0	2,500 2,200 2,150 2,100	1200 1360 1400 1430	3.0 ....
CX-310	Power Amplifier Oscillator	8.0	7.5	1.25	....	180 250 350 425	12.0 18.0 27.0 35.0	7.0 12.0 18.0 24.0	7,000 5,600 5,100 5,000	1100 1330 1500 1550	7.8 ....
CX-300	Special Detector	6.0	5.0	1.00	16–22.5	....	....	....	....	....	....

CHARACTERISTICS OF DeFOREST RECEIVING TUBES

TYPE	USE	A Volts	V_f Volts	I_f Amperes	"B" Volts Detector	"B" Volts Amplifier	"C" Volts	I_p Mils.	R_p Ohms	G_m Micromhos	μ
DeForest D-01A	General Purpose	6.0	5.0	0.25	22.5–45	67.5–135	0–9.0	....	10,000	....	....
DL4	Special R. F. Amp.	6.0	5.0	0.25	....	67.5 90	....	3.5	7,800	1150 1150	9 9
DL2	Standard Detector	6.0	5.0	0.25	16.5–45	67.5–90	....	(90) 8.5 (45) 1.0	9,500	800	7 ....
DL15	Ultra-Responsive Detector	6.0	5.0	0.25	22.5 45-	....	pos. fil.	.... 0.5	....	....	....
DL5	Audio Amplifier	6.0	5.0	0.25	....	90 135	0 3.0	3.5	12,000	800	9.5 ....
DL7	Heavy Duty Audio Amplifier	6.0	5.0	0.5	....	135	9	6.0	6,500	1100	7
DL14	"Low Mu" Power Amplifier	6.0	5.0	0.5	....	180	40.5	15	2,600	1100	3
DL9	Power Amplifier	8.0	7.5	1.6	....	350 500	30 51	25 35	 6,000	 1083	.... 6.5
DR	Half-Wave Rectifier	....	7.5	2.0	a-c. Max.	550 volts	....	Load 35	....	....	....
DL3 & DV3A	Dry-Cell Detector Amplifier	4.5	3.0	0.07	16.5–45	90	0–4.5	4	1,450	550	8

CHARACTERISTICS OF WESTERN ELECTRIC VACUUM TUBES

Courtesy of the Western Electric Company, New York City.

TYPE	FILAMENT		PLATE		Grid Voltage	Amplification Factor	Output Resistance Ohms	Mutual Conductance Micromhos
	Volts	Amperes	Voltage	Amperes				
215-A.........	1	0.25	60	0.0015	— 3	6	17,000	350
N............	1	0.25	60	0.0015	— 3	6	17,000	350
VT-5.........	1	0.25	60	0.0015	— 3	6	17,000	350
216-A.........	6	1	125	0.006	— 9	6	6,000	1,000
205-B	7	1.35	350	0.035	—20	7	3,500	2,000
VT-2.........	7	1.35	350	0.035	—20	7	3,500	2,000
203-D.........	2.5	1	60	0.0015	— 3	6.5	12,000	540
205-D.........	4.5	1.6	350	0.035	—20	7	3,500	2,000
231-D.........	3	0.6	90	0.0017	— 3	8	17,500	450

CHARACTERISTICS OF POWER RADIOTRONS

R.C.A. POWER RADIOTRONS

TYPE	Filament Voltage Volts	Filament Current Amperes	Rated Plate Voltage Volts	Rated Watts Output	Safe Continuous Anode Dissipation Wts.	Plate Current Full Load When oscillating	Average Plate Current Amperes	Amplification Constant *	Mutual Conductance Mils. per Volt **	Plate pemdance Ohms	
UV-302A XL Fil.	10	3.25	1,000	50	100	0.125	0.120 α	25	5.0	5,000	*At rated filament and plate voltages, and grid voltage noted. **At rated filament and plate voltages, and a negative grid voltage of 560. αWhen plate voltage is 1000 grid voltage is zero.
UV-211 XL Fil.	10	3.25	1,000	50	100	0.125	0.315 α	12	6.3	1,900	Excellent as a speech amplifier in a B/c transmitter. Gives a large amount of undistorted output.
UV-204-A XL Fil.	11	3.85	2,000	250	250	0.20	0.275 β	25	5.0	5,000	βWhen plate voltage is 2000 and grid voltage is zero.
UV-851 XL Fil.	11	15.5	2,000	1,000	750	0.875	1.55 β	20	23.5	850	Used extensively in B/c transmitters as an oscillator or modulator.
UV-206—Tungsten Fil.	11	14.75	15,000	1,000	350	0.10	0.055 λ	325	2.8	115,000	λ When plate voltage is 15,000 and grid voltage is zero.
UV-207—Tungsten Fil.	22	52	15,000	20,000 φ	10 kw. Max.	2	0.66 **	20	9.6	3,000	φ When operated at medium or long wave lengths in a radio-telegraph transmitter.

CHARACTERISTICS OF POWER AND RECTIFIER TUBES

DE FOREST POWER TUBES

TYPE	FILAMENT VOLTAGE VOLTS	FILAMENT CURRENT AMPERES	PLATE VOLTAGE VOLTS	PLATE CURRENT MILS.	POWER RATING WATTS	REMARKS
De Forest—P	15	6	2000	250	250 max. output 500 max. input	....
De Forest—D	7.5	2.0	500	60	30 max. input	Min. wave length 5 meters
De Forest—H	10	2.35	1500	90	150 max. input	Min. wave length 5 meters

RCA AND CUNNINGHAM RECTIFIER TUBES

TYPE	USE	V_f Volts	I_f Amperes		
CX-313	Full-Wave Rectifier	5.0	2.0	Max. a-c. voltage plate to fil. 220 R.M.S. per anode.	Max. Load 65
CX-316B	Half-Wave Rectifier	7.5	1.25	Max. a-c. 550	Max. Load 65
UX-213	Full-Wave Rectifier	5.0	2.0	R.M.S. Input Voltage 220 per plate	Rectified Current 65 mils.
UX-216B	Half-Wave Rectifier	7.5	1.25	R.M.S. Input Voltage —550 max.	Rectified Current 65 mils.

COMPARATIVE MAXIMUM UNDISTORTED POWER OUTPUT

E. T. Cunningham, Inc., Engineering Department

Type	Plate Voltage	Grid Voltage	Amp. Factor	Plate Mils.	Max. A-C. Input Voltage	Optimum Load Resistance	Max. Undistorted Power Output, Watts
C-CX 299..	90	— 4.5	6.0	2.5	3.1	15,000	0.0075
C-CX 299..	90	— 7.5	6.0	1.3	5.3	38,000	0.015
CX-301A...	90	— 4.5	8.5	2.0	3.1	12,000	0.015
CX-301A...	135	— 9.0	8.5	2.6	6.3	22,000	0.05
CX-220....	135	—22.5	3.3	7.0	16.0	7,000	0.110
CX-112....	90	— 6.0	7.9	4.0	4.2	11,000	0.04
CX-112....	135	— 9.0	8.0	6.0	6.3	6,000	0.12
CX-371....	90	—16.0	3.0	11.0	11.0	3,000	0.12
CX-371....	135	—27.0	3.0	16.0	19.0	4,000	0.35
CX-371....	157.5	—33.0	3.0	18.0	23.0	4,000	0.50
CX-371....	180	—40.5	3.0	20.0	28.0	4,000	0.65
CX-310....	180	—12.0	7.5	7.0	8.4	8,000	0.145
CX-310....	250	—18.0	7.5	12.0	13.0	12,000	0.40
C-X310....	350	—27.0	7.6	18.0	19.0	11,000	0.95
C-X310....	425	—35.0	7.7	24.0	25.0	10,000	1.54

Note: The power output given is the MAXIMUM UNDISTORTED OUTPUT for an average tube. In calculating this output, three assumptions were made: (1) That the grid is not allowed to draw current; (2) That the load impedance is adjusted to an optimum value, and (3) That the second harmonic distortion must not exceed 5 per cent.

CUNNINGHAM RADIO TUBE TEST LIMITS

E. T. Cunningham, Inc.

	C-CX 11-12	C-CX 299	CX-220	C-CX 301A	CX-112	CX-371	CX-310
I(f) (m.a.)	237–262	57–63	119–131	237–262	474–525	475–525	1190–1310
I(p) (m.a.)	1.0	0.9	4.5	C.95	5.0	12.0	18.0
Mu Min.	5.0	5.5	2.9	6.5	6.5	2.7	7.0
R(p) ohms Max.	20,000	25,000	8500	20,000	8,000	4,000	8,000
Gm Min.	300	300	400	450	1200	1200	1000
I(s) (m.a.) Min.	6.0	6.0	16.0	20.0	50.0	50.0	100
Use following voltages in reading I(f), I(p), Mu, R(p), Gm:							
E(f)	1.1	3.3	3.3	5.0	5.0	5.0	7.5
E(g)	0.0	0.0	—22.5	0.0	—9.0	—27.0	—35.0
E(p)	40.0	40.0	135.0	40.0	135.0	135.0	425.0
Use following voltages in reading Emission I(s):							
E(f)	1.1	3.3	3.3	5.0	5.0	5.0	6.0
E(p-g)	50.0	50.0	50.0	50.0	50.0	50.0	100.0

NOTE: E(p-g) indicates that the specified voltage is applied to the grid and plate connected together as an anode. The emission current is the total current flowing to both electrodes read by a milliammeter in the common lead.