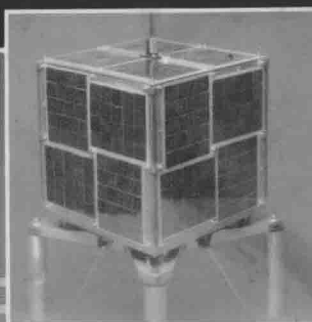


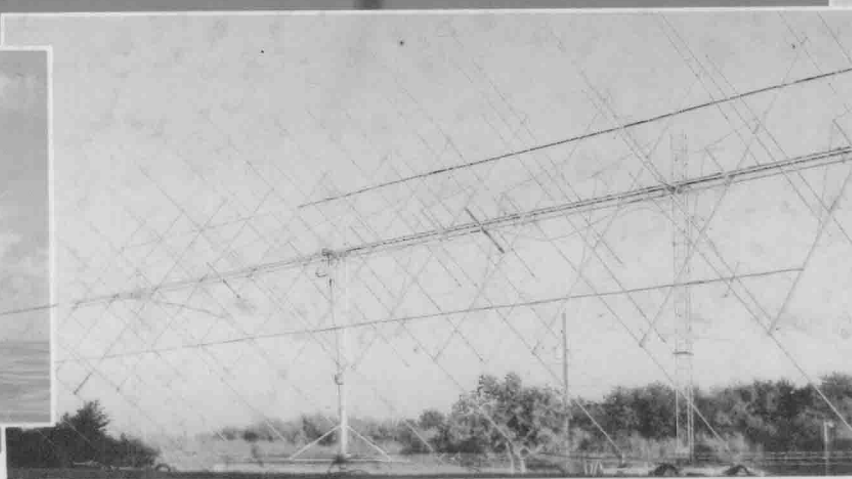
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THE 1990 ARRL HANDBOOK

FOR THE RADIO AMATEUR

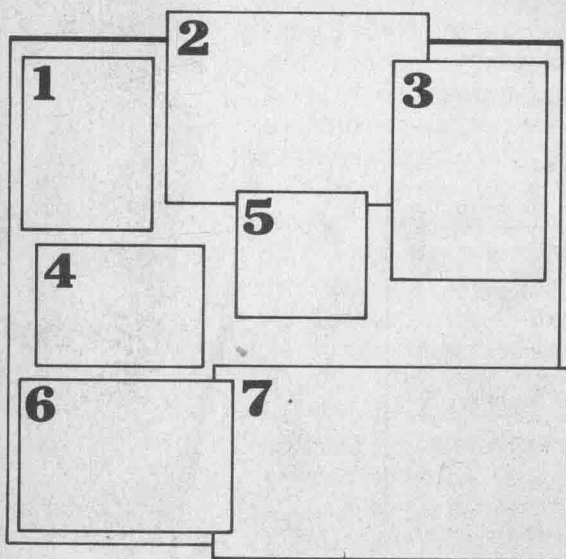


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Cover photos

Photo 1—Armond Noble, N6WR, mans the 1A station during the 1989 Field Day effort. (N6WR photo)

Photo 2—If all Field Day setups could look like this... Members of the San Jose State University ARC (W6YL) assemble their 3-element quad antenna before the start of Field Day 1988. (W6YL photo)

Photo 3—Victor Kean, K1LT, checks out the 30-foot-high 160-meter vertical used during the W8LT 1988 160-meter contest effort. The antenna is mounted at the center of the 2.5-acre aluminum-foil ground plane at the Ohio State University Radio Observatory. (K1LT photo)

Photo 4—Eight-year-old Brian Dong, KB7EWT, is shown operating the KB7FDI Novice station at the WO7F/KB7FDI 2A Field Day effort. (Brian Dong photo)

Photo 5—A sounder of six new ultra-miniature marks a new level of technological achievement in Amateur Radio. These latest-generation OSCARs measure only about an inch on a side. (Richard Chan photo)

Photo 6—Gary Fooks, K4MF, and Miguel Rodriguez, N4DNQ, used the 3-foot J-pole to get away from it all during the 1988 Field Day contest. Janner and photographer Rodriguez were taking a half-mile one-way to Key, FL. (N4DNQ photo)

Photo 7—Dave Blaschke, W5UN, built his Texas-style EME array in his back yard. The world's largest amateur 2-meter EME array features nearly 33 dBi gain, 48 17-element Yagis, and a turning radius of 152 feet. Blaschke, who lives in a Houston suburb, calls the array the "mighty big antenna," or MBA. (W5UN photo)



1990

Sixty-Seventh Edition

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Foreword

As we count down to the last decade of the 20th century, technology is changing faster than ever before. The widespread assimilation of packet radio and the promise of spread-spectrum communications and Microsats are solid reminders of our progress. This year, as it has since 1926, *The ARRL Handbook* provides up-to-date information and construction projects for beginners and advanced radio hobbyists alike.

From simple low-power transmitters and easy-to-build receivers to sophisticated amplifiers and satellite antennas, the 1990 *Handbook* has something for everyone. New additions for this year include an innovative Mode-L satellite antenna from Dick Jansson, WD4FAB, and three high-performance VHF Yagis from Steve Powlishen, K1FO.

The ARRL *Handbook* is an important part of any technical library—for Radio Amateurs and practicing engineers. We invite your comments. If you have developed a new project or have an idea on how to improve the *Handbook*, please let us know about it so we can share it with others. With your help we can continue the *Handbook's* tradition of excellence into the 21st century.

David Sumner, K1ZZ
Executive Vice President

Newington, Connecticut
October 1989

Schematic Symbols Used in Circuit Diagrams

* INSERT APPROPRIATE DESIGNATIONS A-AMMETER V-VOLTMETER mA-MILLIAMMETER etc. METERS	MOTOR OR M MOTOR	SINGLE CELL MULTICELL BATTERIES	CHASSIS EARTH GROUNDS	ASSEMBLY OR MODULE FUSE	ANTENNA MICROPHONE	HEADSET SPEAKER CRYSTAL QUARTZ HAND KEY
COMMON CONNECTIONS COAXIAL RECEPTACLE FEMALE HOT 117 V NEUT GND	CONTACTS FEM. MALE COAXIAL PLUG MALE HOT 117 V NEUT GND	CONNECTORS MULTIPLE, MOVABLE MULTIPLE, FIXED MALE CHASSIS-MOUNT HOT 117 V NEUT GND	PHONO JACK MIKE JACK PHONE JACK PHONE PLUG 234 V NEUT	SHIELDED WIRE OR COAXIAL CABLE GENERAL ENCLOSURE SHIELDING	AND GATE OR GATE INVERTER LOGIC OTHER	
NEON (AC) PILOT LAMPS	N-CHANNEL G2 G1 D S P-CHANNEL G2 G1 D S DUAL-GATE MOSFET	N-CHANNEL G D S P-CHANNEL G D S MOSFET	N-CHANNEL G D S P-CHANNEL G D S JUNCTION FET	N-CHANNEL E B2 B1 UJT	PNP C B E NPN C B E BIPOLAR	AMPLIFIER OPERATIONAL AMP OTHER LINEAR INTEGRATED CIRCUITS
AIR CORE OR FERRITE BEAD RING R F CHOKE IRON CORE ADJUSTABLE INDUCTORS	GRID PLATE DEFLECTION PLATES HEATER OR FILAMENT INDIRECTLY HEATED CATHODE COLD CATHODE GAS FILLED ELECTRON TUBE ELEMENTS	PHOTODEMISSIVE ZENER (LED) THYRISTOR (SCR) SEMICONDUCTOR DIODE / RECTIFIER TUNNEL TRIAC CAPACITIVE (VARACTOR) DIODES				
AIR CORE ADJUSTABLE INDUCTANCE ADJUSTABLE COUPLING IRON CORE WITH LINK TRANSFORMERS	TRIODE PENTODE VOLTAGE REGULATOR COMPLETE TUBES	SPST DPST SPDT RELAYS				
ELECTROLYTIC FIXED VARIABLE FEEDTHROUGH SPLIT-STATOR CAPACITORS	FIXED VARIABLE TAPPED ADJUSTABLE PRESET RESISTORS	SPST SPDT TOGGLE MULTIPOINT SWITCHES	CROSSING CONDUCTORS NOT JOINED TERMINAL CONDUCTORS JOINED WIRING			

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U.S. Customary — Metric Conversion Factors

International System of Units (SI) — Metric Units

Prefix	Symbol	Multiplication Factor
exa	E	$10^{18} = 1,000,000,000,000,000,000$
peta	P	$10^{15} = 1,000,000,000,000,000$
tera	T	$10^{12} = 1,000,000,000,000$
giga	G	$10^9 = 1,000,000,000$
mega	M	$10^6 = 1,000,000$
kilo	k	$10^3 = 1,000$
hecto	h	$10^2 = 100$
deca	da	$10^1 = 10$
(unit)		$10^0 = 1$
deci	d	$10^{-1} = 0.1$
centi	c	$10^{-2} = 0.01$
milli	m	$10^{-3} = 0.001$
micro	μ	$10^{-6} = 0.000001$
nano	n	$10^{-9} = 0.000000001$
pico	p	$10^{-12} = 0.000000000001$
femto	f	$10^{-15} = 0.000000000000001$
atto	a	$10^{-18} = 0.000000000000000001$

U.S. Customary Units

Linear Units

12 inches (in) = 1 foot (ft)
 36 inches = 3 feet = 1 yard (yd)
 1 rod = $5\frac{1}{2}$ yards = $16\frac{1}{2}$ feet
 1 statute mile = 1760 yards = 5280 feet
 1 nautical mile = 6076.11549 feet

Area

1 ft² = 144 in²
 1 yd² = 9 ft² = 1296 in²
 1 rod² = $30\frac{1}{4}$ yd²
 1 acre = 4840 yd² = 43,560 ft²
 1 acre = 160 rod²
 1 mile² = 640 acres

Volume

1 ft³ = 1728 in³
 1 yd³ = 27 ft³

Linear

1 meter (m) = 100 centimeters (cm) = 1000 millimeters (mm)

Area

1 m² = 1×10^4 cm² = 1×10^6 mm²

Volume

1 m³ = 1×10^6 cm³ = 1×10^9 mm³
 1 liter (l) = 1000 cm³ = 1×10^6 mm³

Mass

1 kilogram (kg) = 1000 grams (g)
 (Approximately the mass of 1 liter of water)
 1 metric ton (or tonne) = 1000 kg

Liquid Volume Measure

1 fluid ounce (fl oz) = 8 fluidrams = 1.804 in³
 1 pint (pt) = 16 fl oz
 1 quart (qt) = 2 pt = 32 fl oz = $57\frac{3}{4}$ in³
 1 gallon (gal) = 4 qt = 231 in³
 1 barrel = $31\frac{1}{2}$ gal

Dry Volume Measure

1 quart (qt) = 2 pints (pt) = 67.2 in³
 1 peck = 8 qt

1 bushel = 4 pecks = 2150.42 in³

Avoirdupois Weight

1 dram (dr) = 27.343 grains (gr) or (gr a)
 1 ounce (oz) = 437.5 gr
 1 pound (lb) = 16 oz = 7000 gr
 1 short ton = 2000 lb, 1 long ton = 2240 lb

Troy Weight

1 grain troy (gr t) = 1 grain avoirdupois
 1 pennyweight (dwt) or (pwt) = 24 gr t
 1 ounce troy (oz t) = 480 grains
 1 lb t = 12 oz t = 5760 grains

Apothecaries' Weight

1 grain apothecaries' (gr ap) = 1 gr t = 1 gr a
 1 dram ap (dr ap) = 60 gr
 1 oz ap = 1 oz t = 8 dr ap = 480 gr
 1 lb ap = 1 lb t = 12 oz ap = 5760 gr

Multiply →

Metric Unit = Conversion Factor × U.S. Customary Unit

← Divide

Metric Unit ÷ Conversion Factor = U.S. Customary Unit

Conversion		
Metric Unit = Factor × U.S. Unit		
(Length)		
mm	25.4	inch
cm	2.54	inch
cm	30.48	foot
m	0.3048	foot
m	0.9144	yard
km	1.609	mile
km	1.852	nautical mile
(Area)		
mm ²	645.16	inch ²
cm ²	6.4516	in ²
cm ²	929.03	ft ²
m ²	0.0929	ft ²
cm ²	8361.3	yd ²
m ²	0.83613	yd ²
m ²	4047	acre
km ²	2.59	mi ²
(Mass) (Avoirdupois Weight)		
grams	0.0648	grains
g	28.349	oz
g	453.59	lb
kg	0.45359	lb
tonne	0.907	short ton
tonne	1.016	long ton

Conversion		
Metric Unit = Factor × U.S. Unit		
(Volume)		
mm ³	16387.064	in ³
cm ³	16.387	in ³
m ³	0.028316	ft ³
m ³	0.764555	yd ³
ml	16.387	in ³
ml	29.57	fl oz
ml	473	pint
ml	946.333	quart
l	28.32	ft ³
l	0.9463	quart
l	3.785	gallon
l	1.101	dry quart
l	8.809	peck
l	35.238	bushel
(Mass) (Troy Weight)		
g	31.103	oz t
g	373.248	lb t
(Mass) (Apothecaries' Weight)		
g	3.387	dr ap
g	31.103	oz ap
g	373.248	lb ap

The Amateur's Code

The Radio Amateur is:

CONSIDERATE . . . never knowingly operates in such a way as to lessen the pleasure of others.

LOYAL . . . offers loyalty, encouragement and support to other amateurs, local clubs, and the American Radio Relay League, through which Amateur Radio in the United States is represented nationally and internationally.

PROGRESSIVE . . . with knowledge abreast of science, a well-built and efficient station and operation above reproach.

FRIENDLY . . . slow and patient operating when requested; friendly advice and counsel to the beginner; kindly assistance, cooperation and consideration for the interests of others. These are the hallmarks of the amateur spirit.

BALANCED . . . radio is an avocation, never interfering with duties owed to family, job, school, or community.

PATRIOTIC . . . station and skill always ready for service to country and community.

—The original Amateur's Code was written by Paul M. Segal, W9EEA, in 1928.—

INDEX

[Editor's Note: Except for commonly used phrases and abbreviations, topics are indexed by their noun name. Many topics are also cross-indexed, especially when noun modifiers appear (such as "voltage amplifier" and "amplifier, voltage"). For topics having extended coverage, only the first page of presentation is listed. Numerous terms and abbreviations pertaining to Amateur Radio but not contained in this index may be found in the glossaries indexed herein.]

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