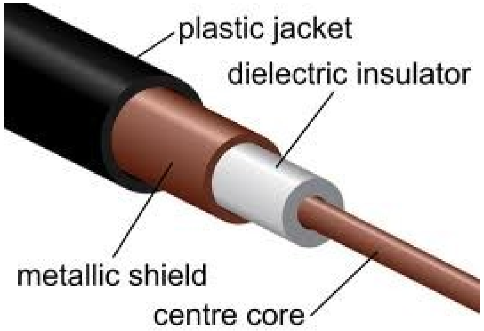
Halifax Amateur Radio Club Licensing Course

Transmission Lines

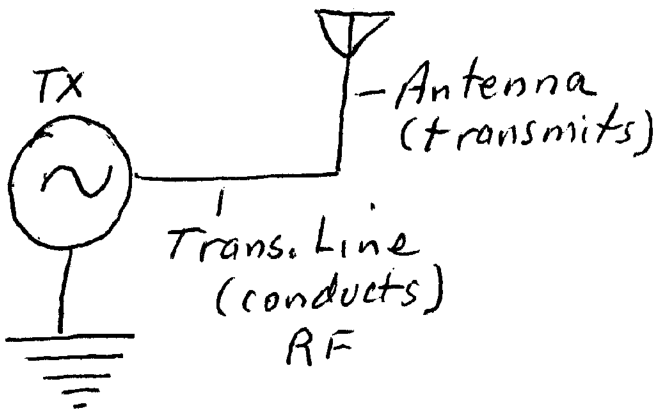
(Chapter 7)

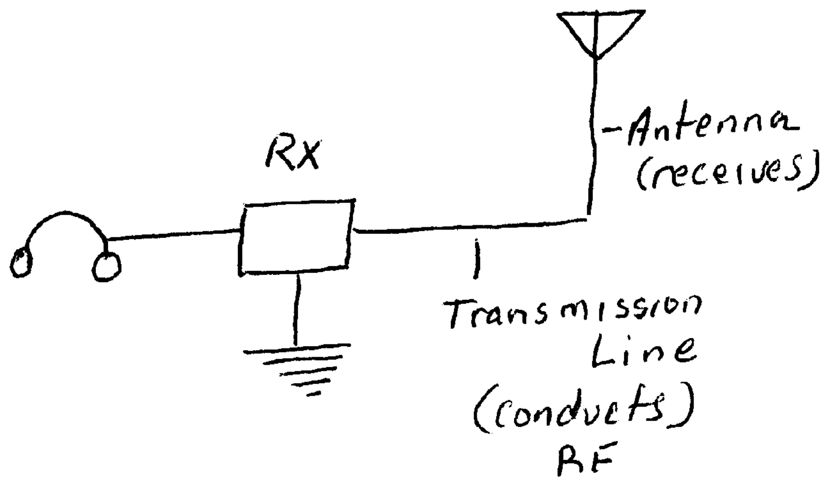


de Fred Archibald VE1FA
hfarchibald@ns.sympatico.ca

Ideal transmission line:

1. No losses
2. No radiation (TX)/no reception (RX)
3. Constant characteristics





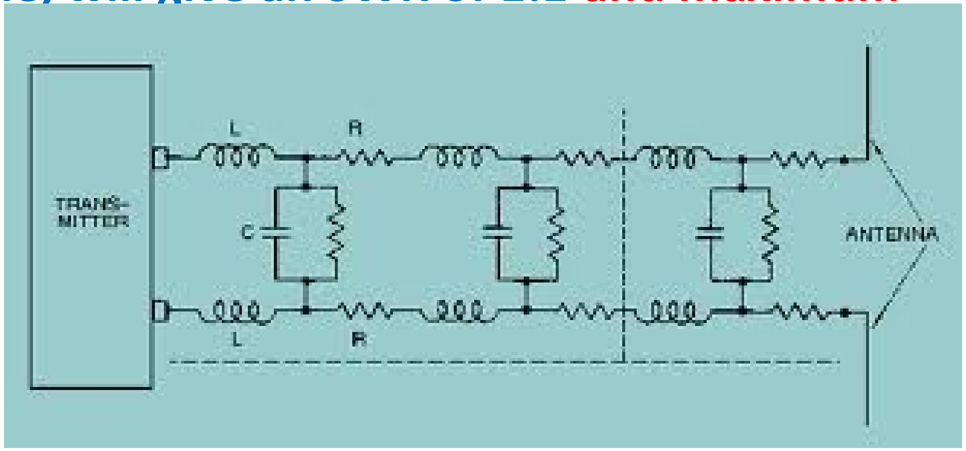
mission line has a characteristic impedance (Z0), measured in ohms (Ω)

lex sum of line's R + XL + XC

ermined by spacing, thickness of wires, and dielectric

Z0: if used to terminate the line, will give an SWR of 1:1 and maximum power transfer

distributed R + L + C



Practical result: TX/RX Zout should match trans. line Z0 , which should match antenna Z

Common trans. line Z: 50, 72, 300, 450, 600 Ω

50Ω: all amateur and most commercial radios

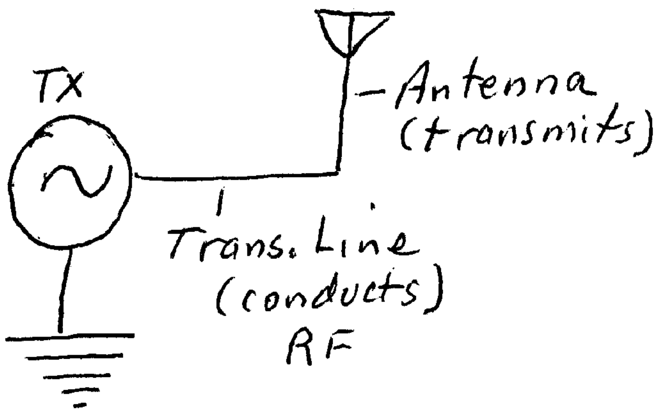
72Ω: most TV/video cellular phone radios

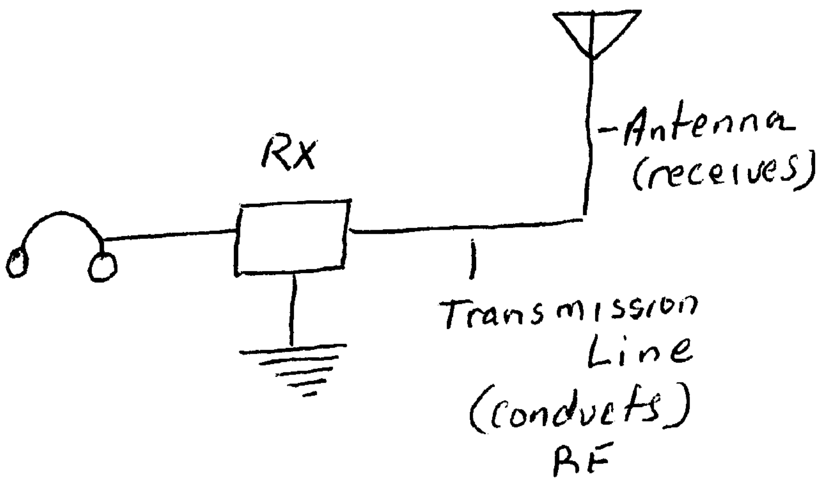
(V)SWR: (Voltage) Standing Wave Ratio

VSWR = VF + VR/VF - VR

A measure of Z mismatch or reflected RF power

If Z0 = 50Ω and ZANT = 50Ω SWR = 1:1.0
ZANT = 100Ω SWR = 1:2.0
ZANT = 25Ω SWR = 1:2.0
ZANT = 12.5Ω SWR = 1:4.0
ZANT = 500Ω SWR = 1:10

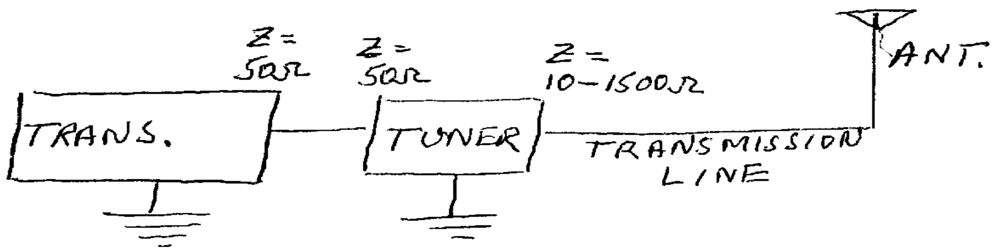




Antenna tuner: matches Z of transmission line to transmitter

It DOES NOT tune the antenna!

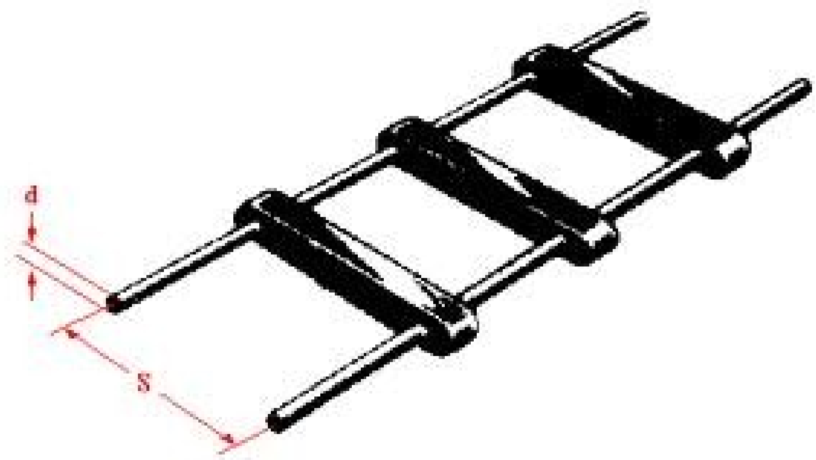
Often power/SWR meter, dummy load, balun, antenna switch included



Balanced Transmission Lines

-2 parallel wires, unshielded

-signals 180° out-of phase



Z0 = 276 log10 x 2(S/d)

S = distance between 2 wires

d = diameter of 2 wires

Advantages

-very low losses

-takes high voltage, power, SWR

-cheap

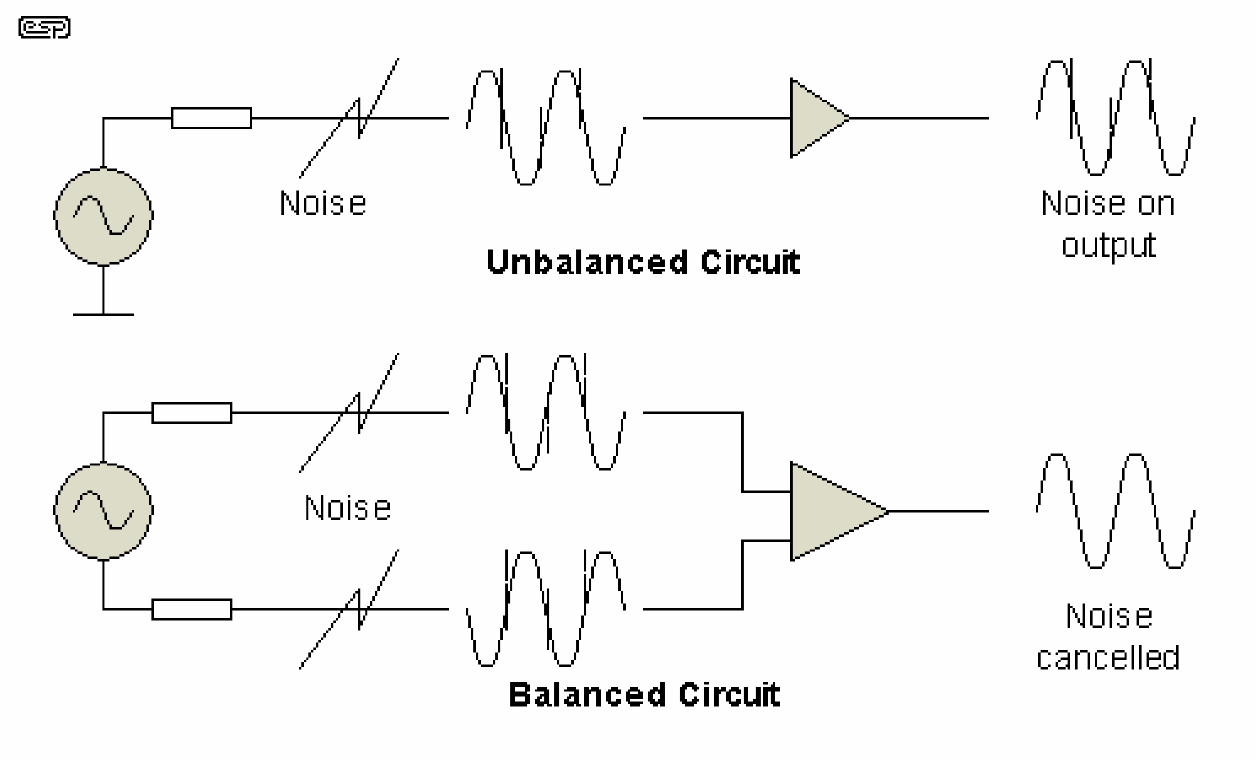
Disadvantages

-influenced by nearby metal

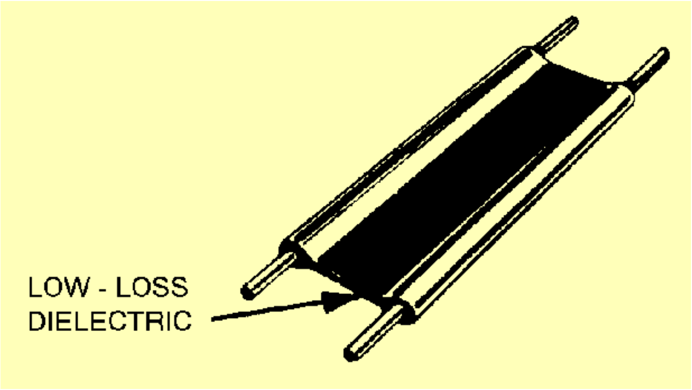
-ant. tuner must be balanced
 or have balun

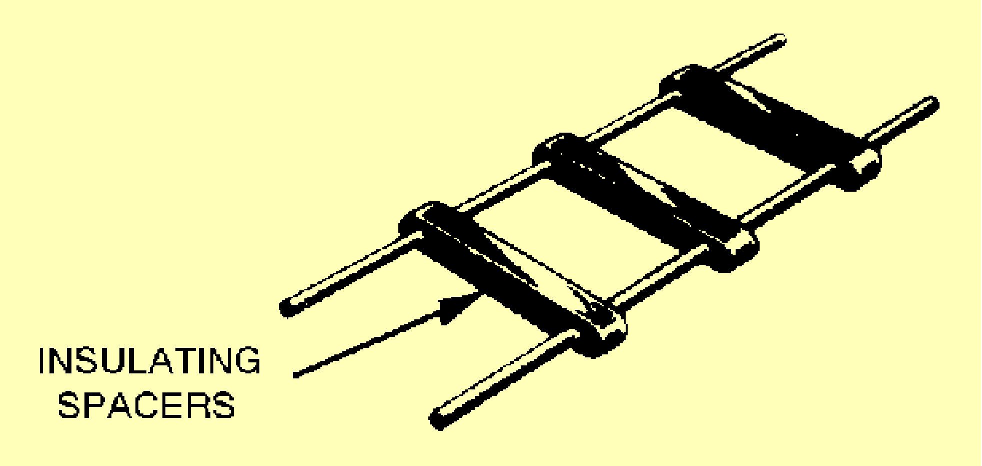
-flaps/fatigues in wind

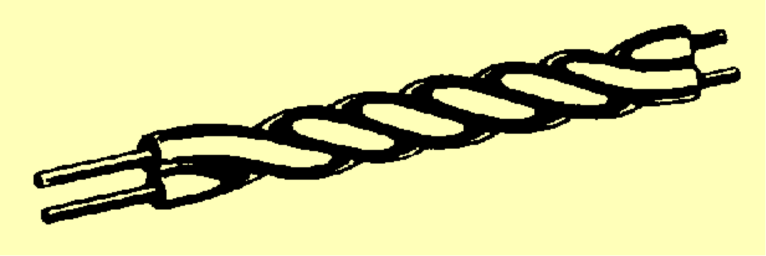
How a balanced transmission line rejects noise (and is prevented from being an antenna)!

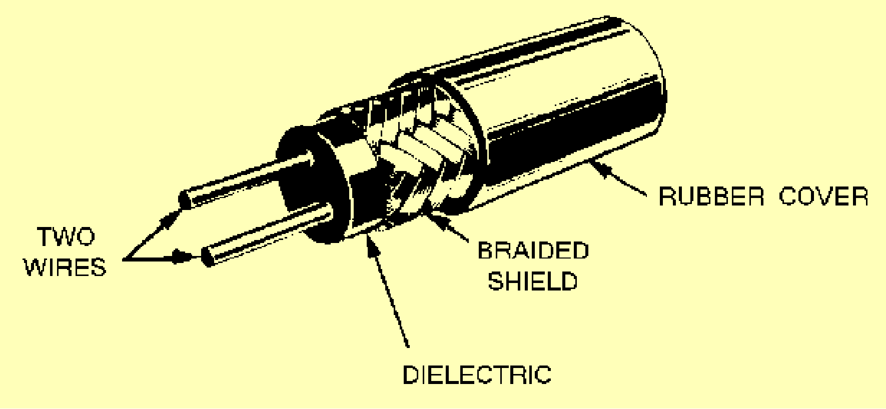


Balanced Feedline Types









Balun (Balanced: Unbalanced) transformers)

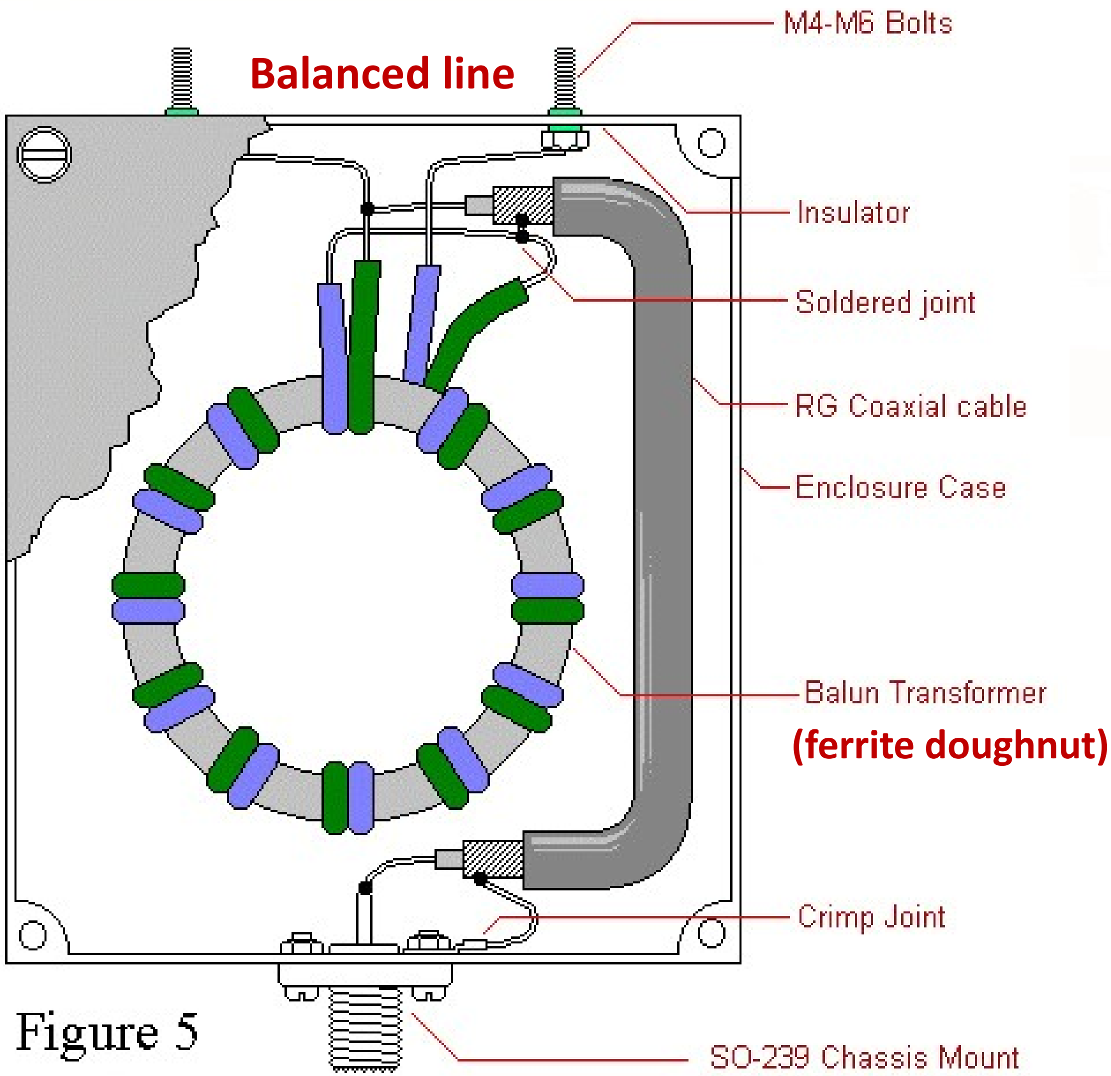
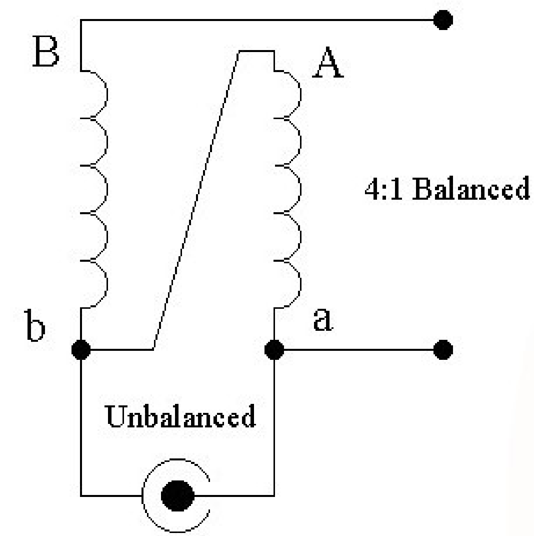


Figure 5

Unbalanced (co-ax) line

Figure 2 4:1 Balun Wiring diagram



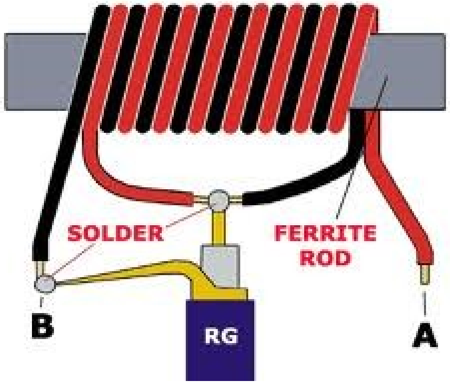
Balun may have:
-air core
-Ferrite toroidal core
-Ferrite rod core

Ferrite, powdered iron cores can saturate, overheat; air core cannot

Big core, heavy wire for high power!

Current balun: forces same current (I) in both sides of antenna or balanced line

Voltage balun: forces same voltage (E) in both sides of antenna or balanced line



Coaxial cable "choke balun"

-forces coax to be balanced

-keeps RF off <u>outside</u> of coax shield
-reduces RF in shack

-maintains antenna pattern

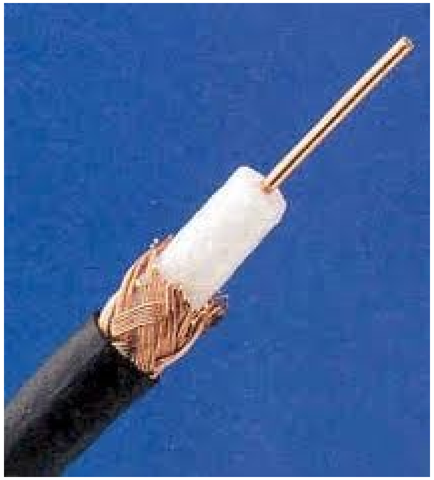
-reduces transmission + reception by co-ax

-sometimes these effects important, often not

-"scramble-wound" coil not the best

Unbalanced (Coaxial) Transmission Lines

-2 conductors on same axis
-center conductor + shield



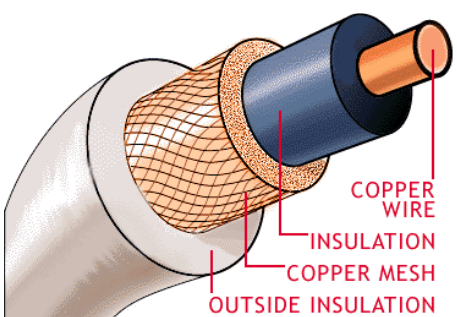
$$Z0 = 138/\sqrt{e} \times \log D/d$$

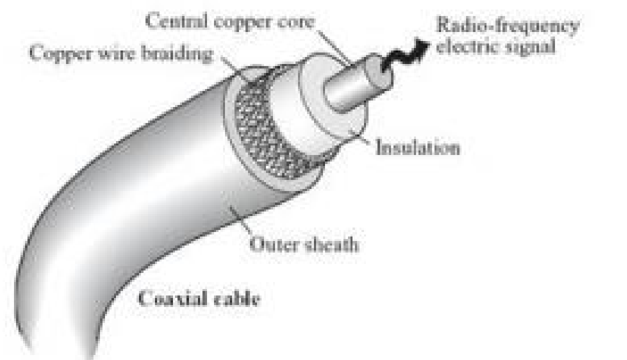
e = dielectric constant
D = outer conductor diameter
d = inner conductor diameter

Velocity factor: transmission speed in trans. line as a fraction of c
: typical 0.66, 0.82 (coax) , 0.99 (balanced line)

Advantages
Unaffected by nearby conductors
Waterproof
Easy to install

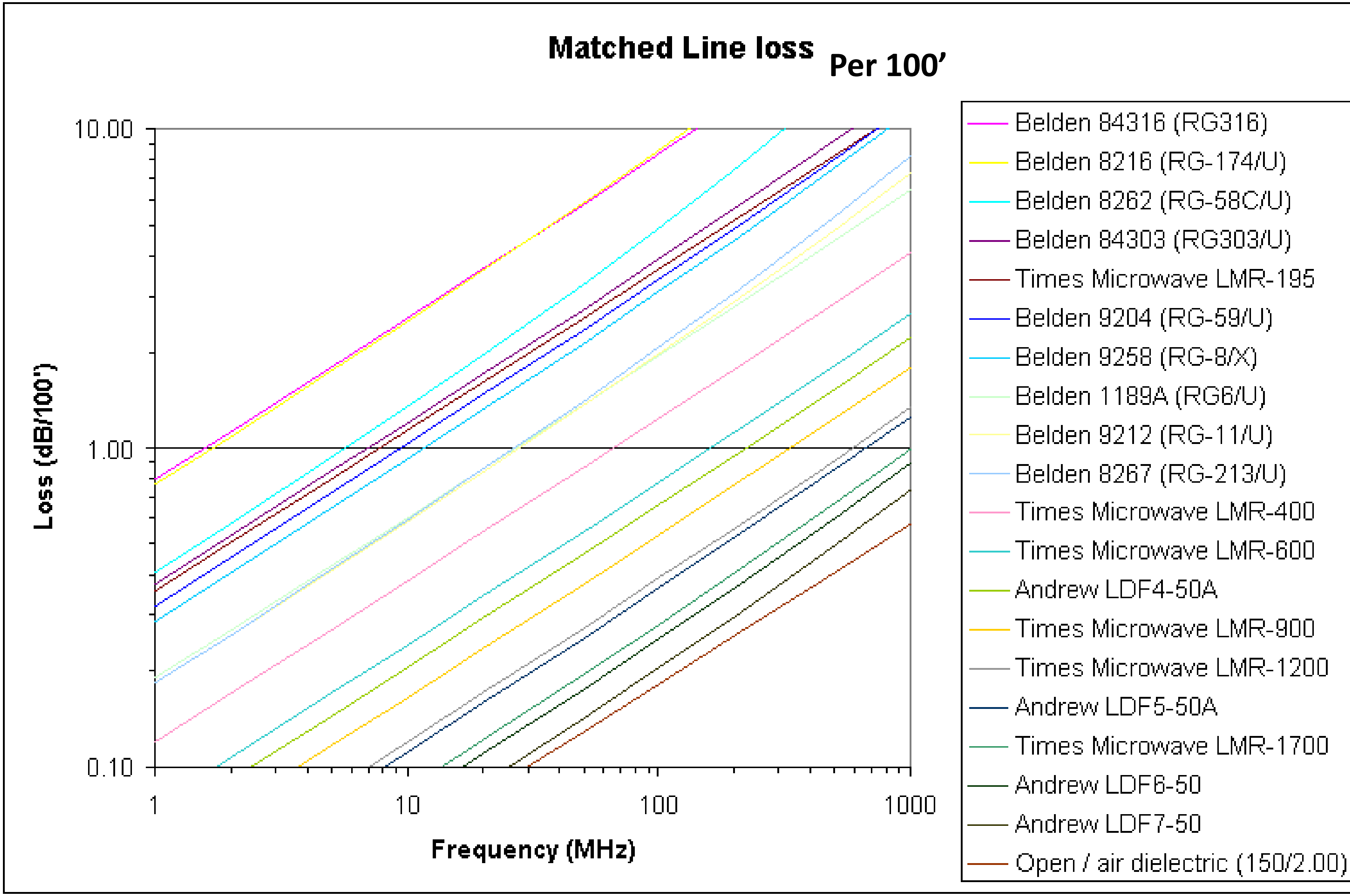
Disadvantages
More lossy than balanced
Special connectors
Ruined by water
Z matching more important


COPPER WIRE
INSULATION
COPPER MESH
OUTSIDE INSULATION


Central copper core
Copper wire braiding
Radio-frequency electric signal
Insulation
Outer sheath
Coaxial cable

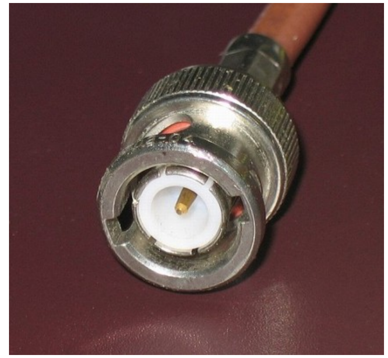
El Cheapo!

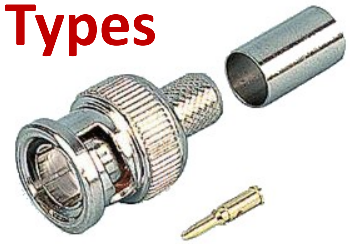
Specific cable line losses. Losses greater with any mis-match!!



Common Coaxial Connector Types

"BNC"





SO-239 =>

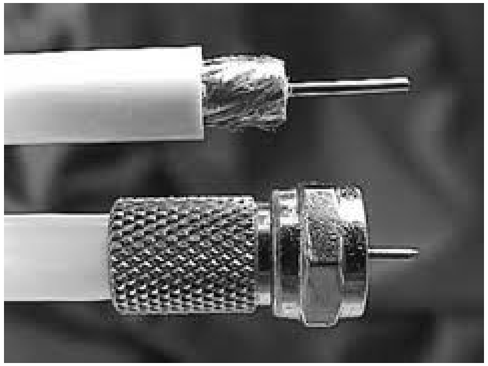
"UHF" Type

"N" Type

PL-259 =>

"UG" adaptors

The "F" connector family (usually 72Ω)



RCA connector family: now some for audio, some for RF

Halifax Amateur Radio Club Licensing Course

Antennas

(Chapter 8)

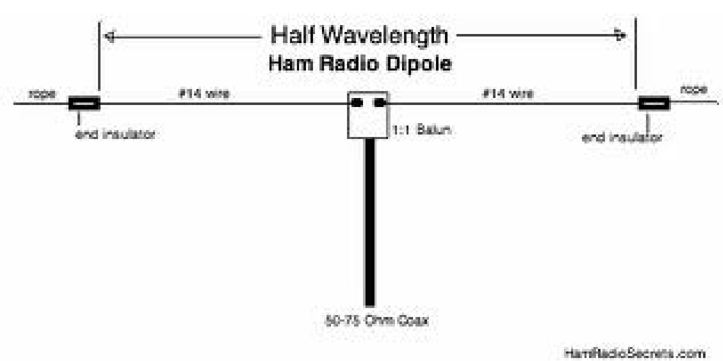
de Fred Archibald VE1FA

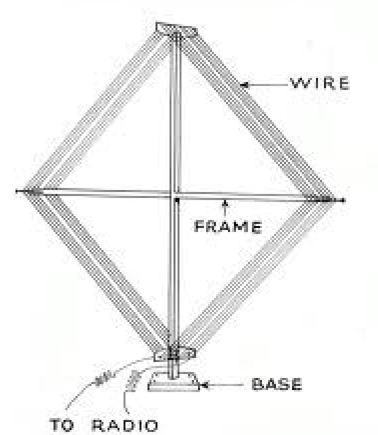
What does an antenna do??

The perfect antenna:

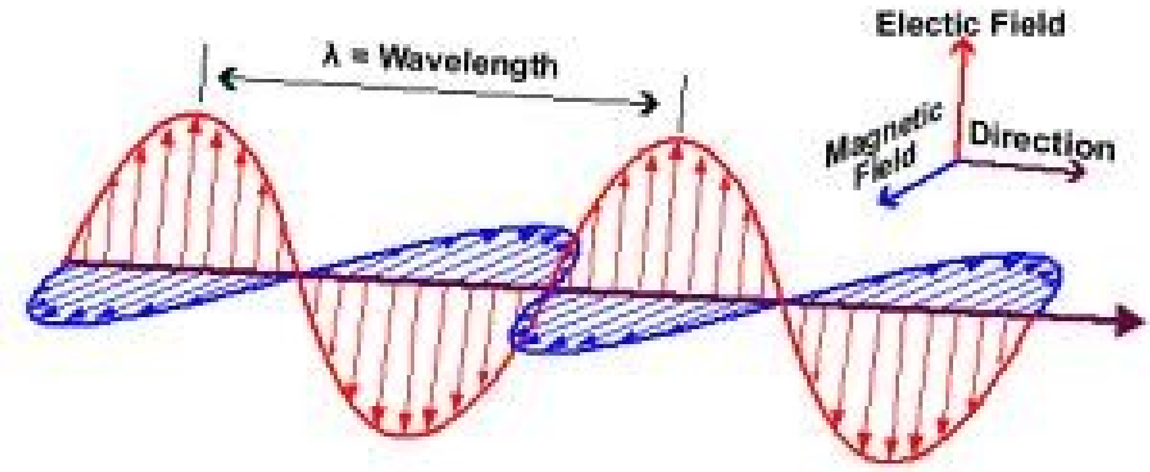
1. 100% efficient
2. Highly directional (high gain)
3. Pointable at any location
7. Poor receiver of natural radio noise
8. Cheap and easy to erect, lasts forever!

To design, set up, or most efficiently use a good radio antenna, one must understand some basic radio wave physics





Electromagnetic wave
in air/space



-Electostatic (electric) (E) field 90° from electromagnetic (magnetic) (H) field

-Both 90° from direction of travel

-Electrostatic (electric) field determines polarization

-Vertical antenna => vertically polarized RF

-Horizontal antenna => horizontally polarized RF

-If RX = TX polarization: optimal reception

- Circular polarization ?

Antenna impedance (Z): -complex combination of R + XL or XC

When antenna XL = XC , X=0, and therefore Z = R, and
antenna is resonant

Antenna most efficient at its resonant frequency.

Antenna behaves like an L+C resonant circuit

Every antenna has a resonant frequency

Antenna will have XL if applied freq > than antenna resonant freq.

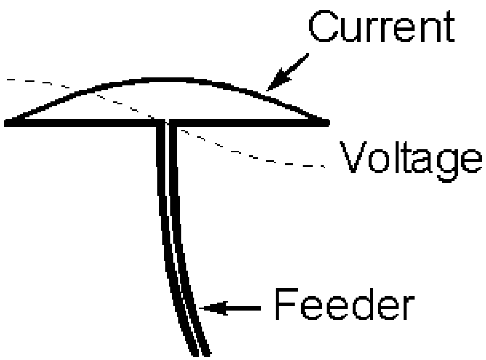
Antenna will have XC if applied freq. < than resonant freq.

Antenna properties

Feedpoint Z: often designed to be around 50 ohms

P = I2 (R + R0)

Resonant dipole antenna =>
(Z=50 Ω at resonance and 0.5λ above ground!)



Bandwidth: frequency range giving reasonable SWR (standing wave ratio)

Directivity: Gain in a particular direction, and front: back (F:B) ratio (in db)
Gain compared to theoretical isotropic radiator

Efficiency: % of RF power radiated as signal (can be 90+% to 0%)

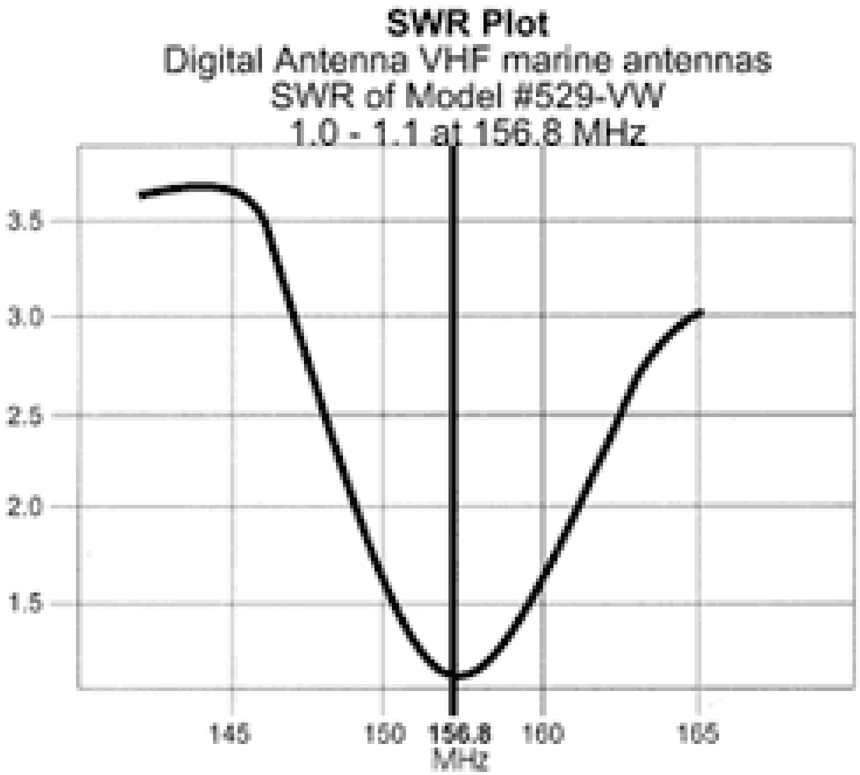
(Voltage) Standing Wave Ratio (SWR or VSWR) = Vmax/Vmin

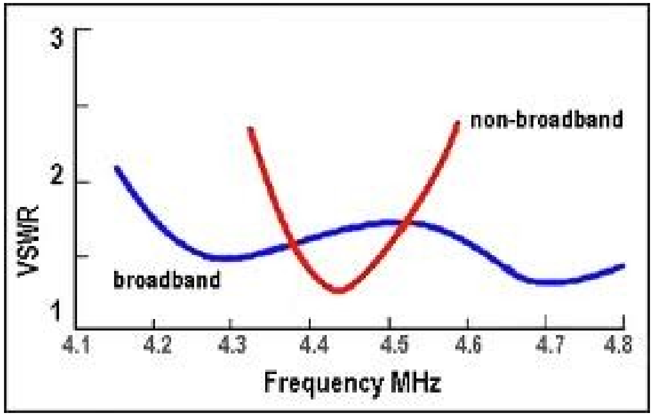
SWR=1.0: perfect Z match!

1.5: max mismatch tolerable by many modern transceivers

>1.5: need a TX to line matching device “antenna tuner”

>2.0: coaxial transmission line losses and voltages increase greatly!



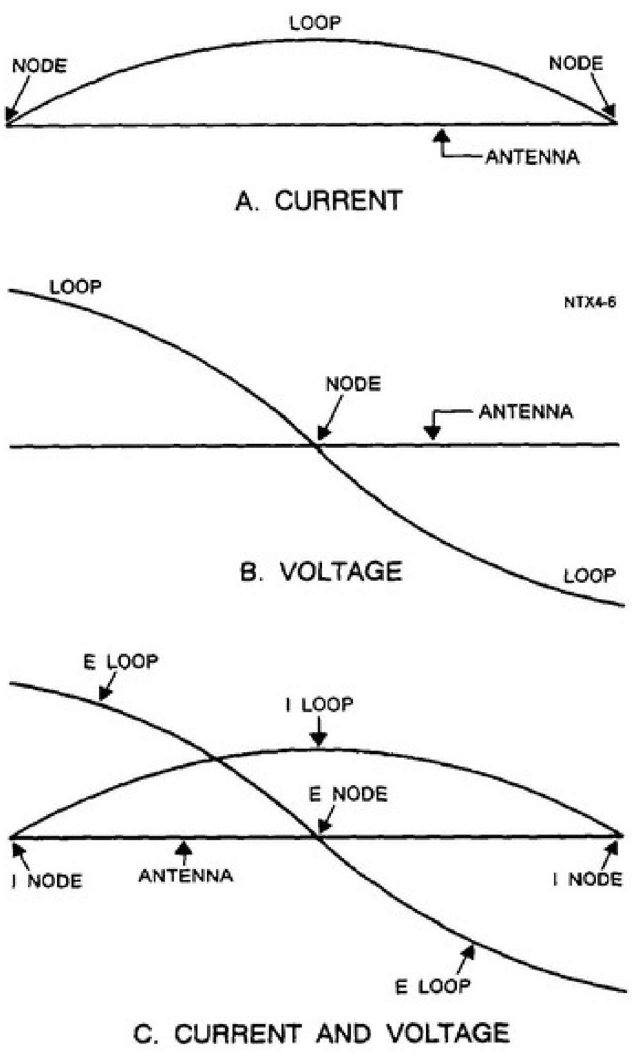


Half-Wave (λ/2) Antenna E + I Distribution at Resonance

-Changes with frequency!

-Changes with antenna dimensions!

-Why would this antenna be fed at its center??



Calculating the lengths of resonant antennas

-works for loops, verticals, dipoles, etc

-ground, nearby conductive objects will affect the exact length giving resonance

-therefore, cut long, trim to desired frequency!

$\lambda =$ c (m/s)/F (Hz) $\lambda/2$ = 492 feet/F (MHz) ...in free space

$\lambda/2$ = 468' or 143m/F (MHz) ....for dipole 0.5λ above ground*

Example: 40m dipole at 0.5λ above ground

$\lambda/2$ = 468'/7.1 MHz = 65.9' (length of 7.1 MHz dipole)

* Ground effect makes dipole seem around 5% longer

Antenna Radiation Patterns and Directivity

-All antennas directive (except isotropic)

-Directivity measured in "db gain" and Front:Back (F:B) ratio (in db)

-Effective Radiated Power (ERP)

-NEC and related programs (EZNEC, MINNEC) calculate antenna patterns

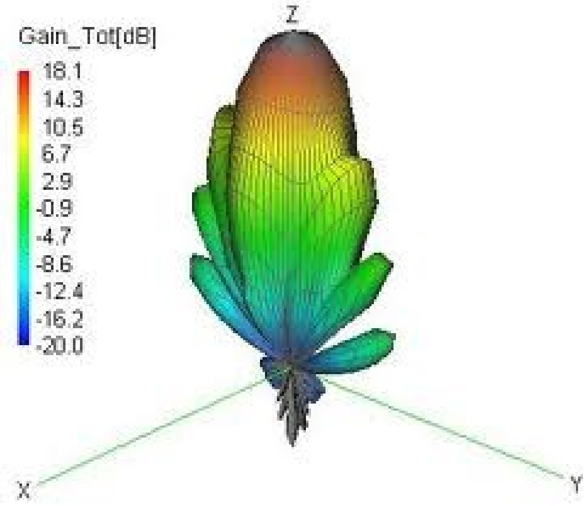
-Also known as "antenna modeling" :

-Must enter data on: height, ground conductivity, antenna design/dimensions, and frequency

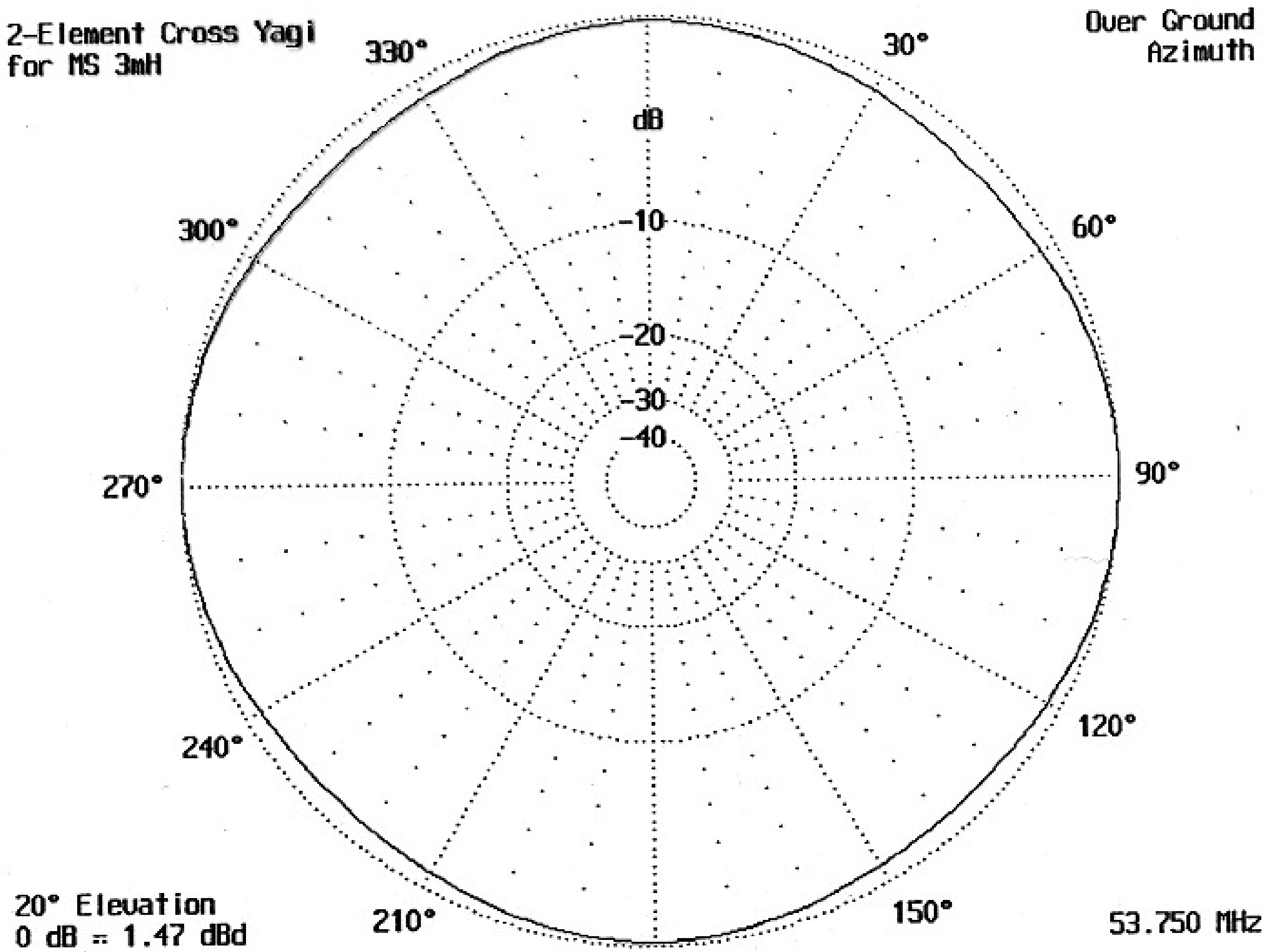
-Millions of calculations usually required!

-Must think in 3D to enter antenna to be analyzed

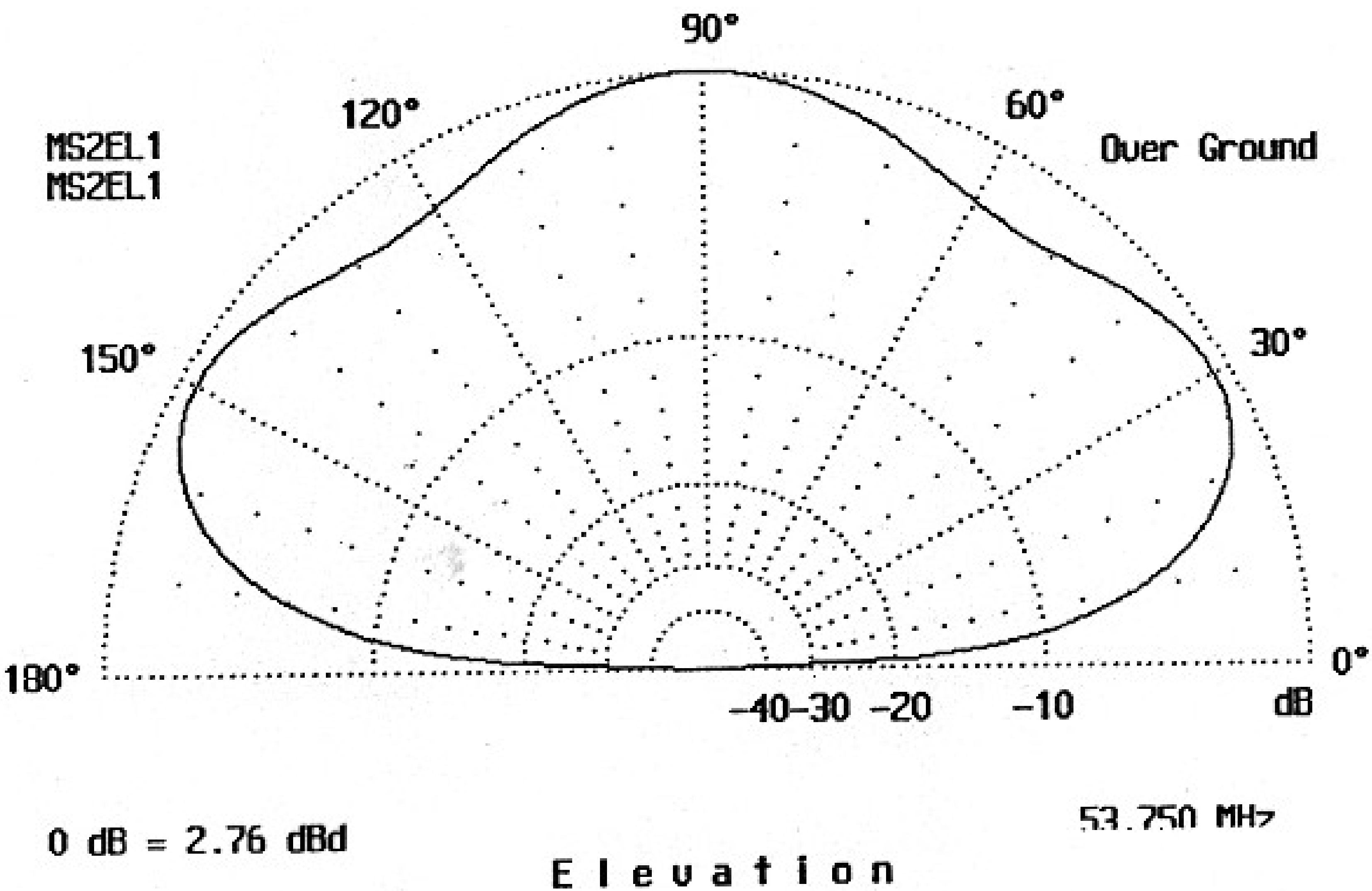
-Projections in Azimuth, Elevation, or 3-D



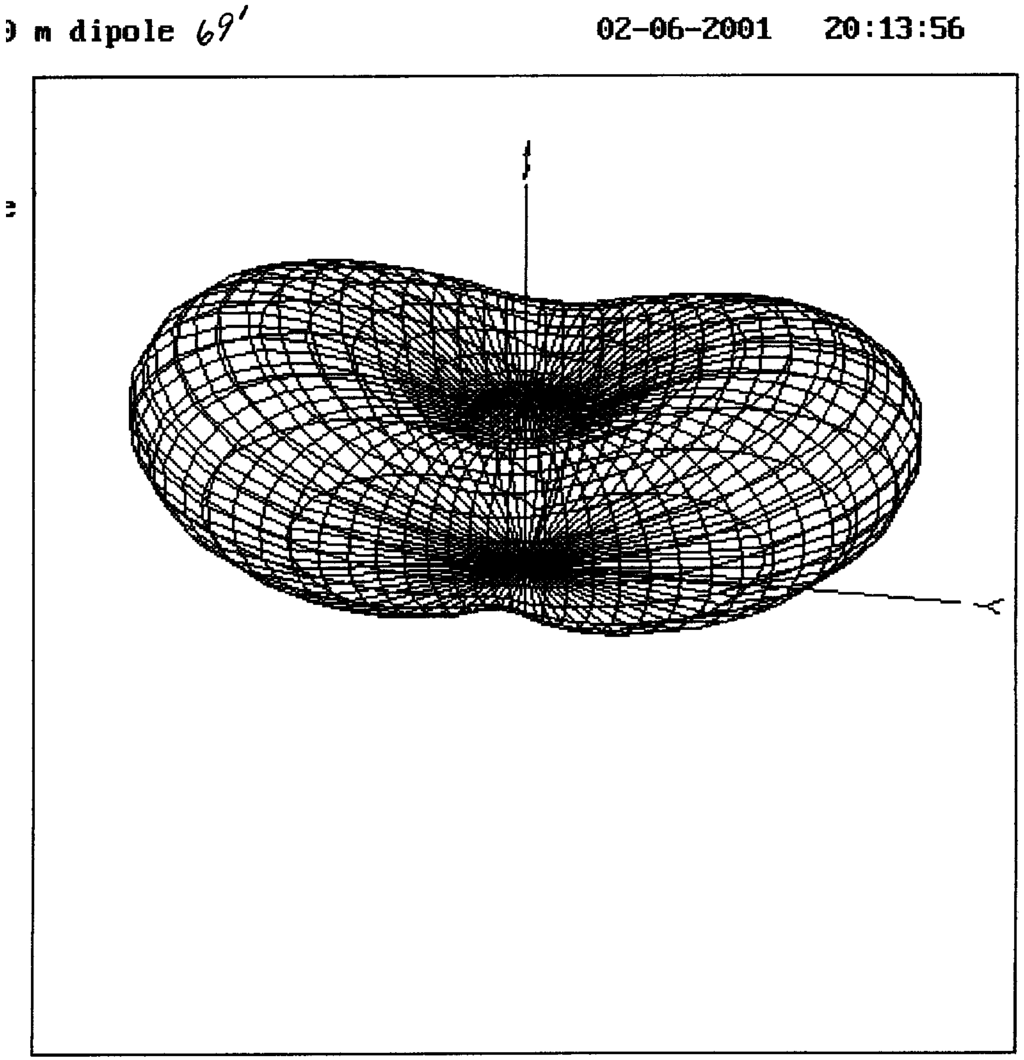
Azimuth Antenna Radiation Plot



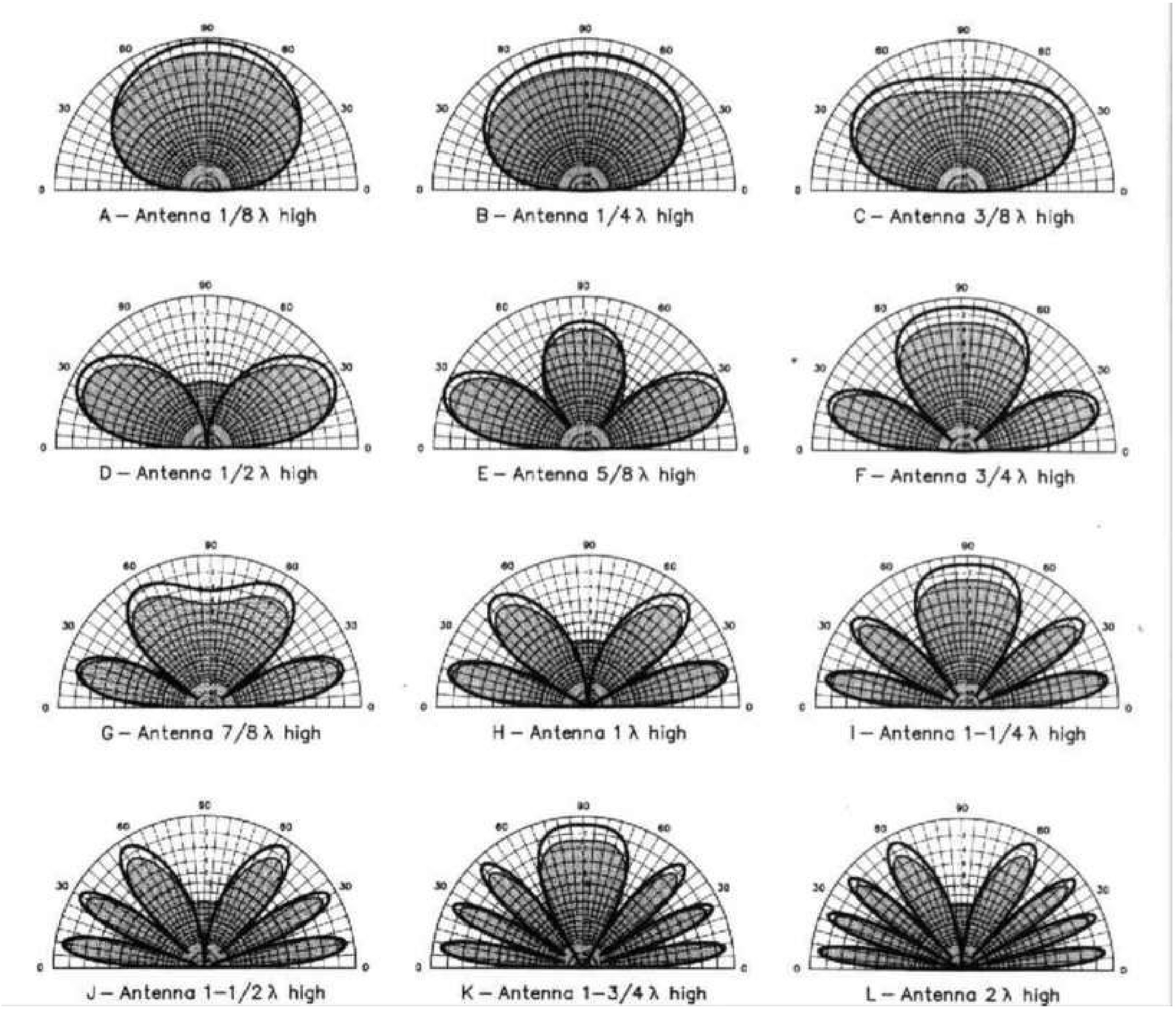
Elevation Antenna Radiation Plot



EZNEC 3D radiation model of 40m dipole at 69’

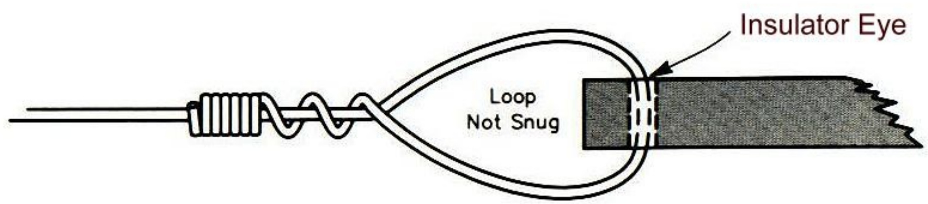


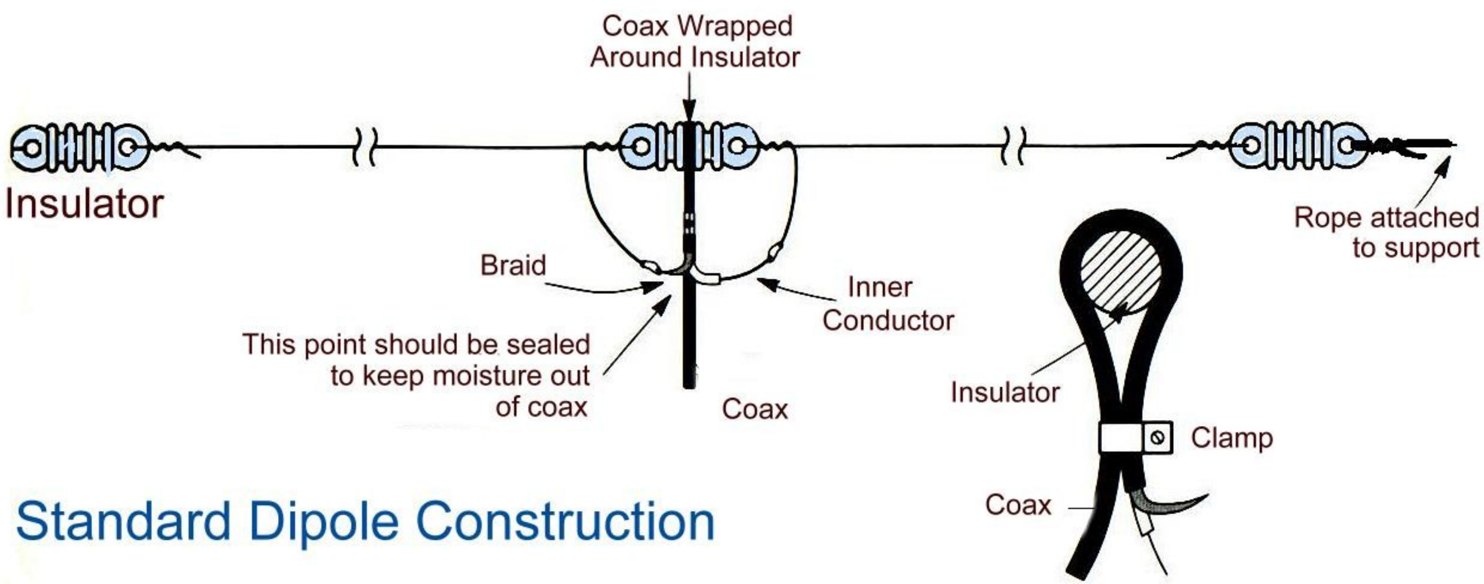
Effect of height above ground on a dipole (elevation proj.)



Broadside Dipole Gain

Takeoff angle	15°	25°	45°	90°
Dipole at	dbi	dbi	dbi	dbi
20'	-2.2	+1.8	+3.8	+5.8
35'	-0.1	+2.9	+5.6	+6.0
52' (3/8 λ)	+5.0	+7.0	+3.0	-5.0
69' (1/2 λ)	+5.5	+7.5	+4.5	-7.0
86.6' (5/8 λ)	+6.9	+7.9	-1.5	+4.9





Standard Dipole Construction

Dipole-derived antennas

(center-fed, half-wavelength long)

Dipole shortcomings:

1. Usually single band
2. Needs 2-3 supports
3. Low gain/no gain

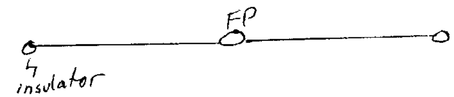
FP = feedpoint for RF

T = trap LC tuned circuit

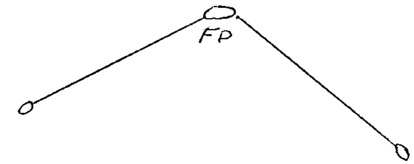
L = loading coil (makes antenna seem longer)

ATU = antenna tuning unit

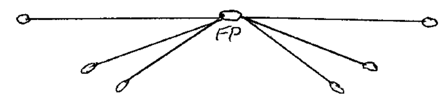
Dipole



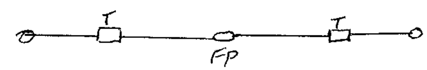
Inverted Vee dipole



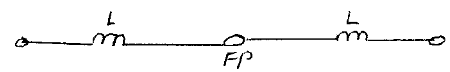
Fan or multiband dipole



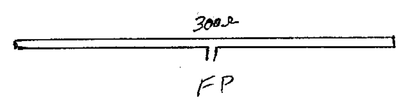
Trap dipole (2-band)



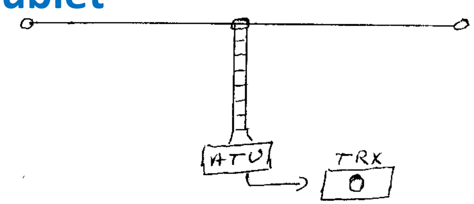
Loaded dipole



Folded dipole



Non-resonant doublet



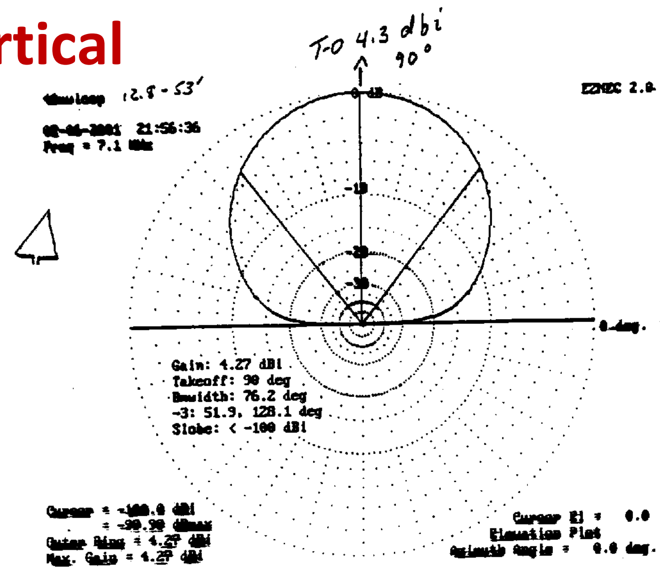
Inverted Vee dipole

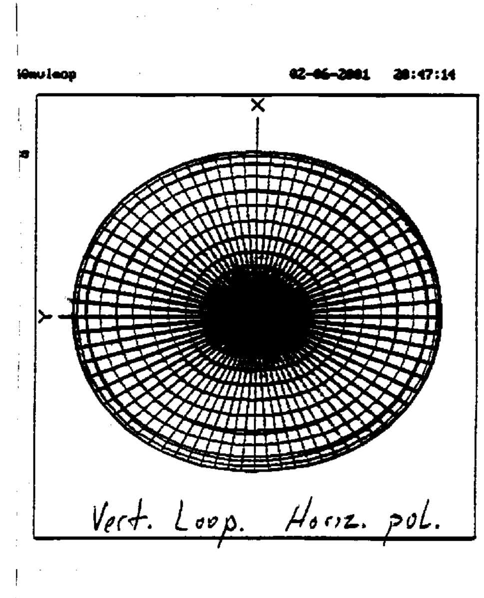
Note pulley/halyard setup: very convenient!

Note coaxial cable RF choke =>

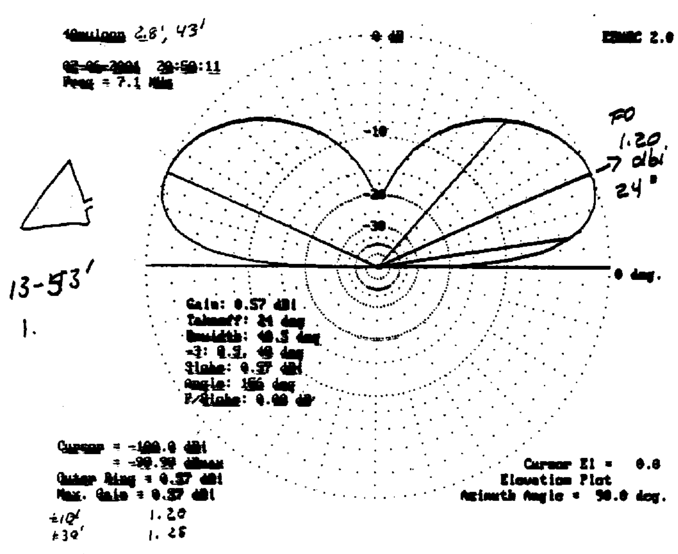
EZNEC patterns for vertical Delta loop fed at two different points

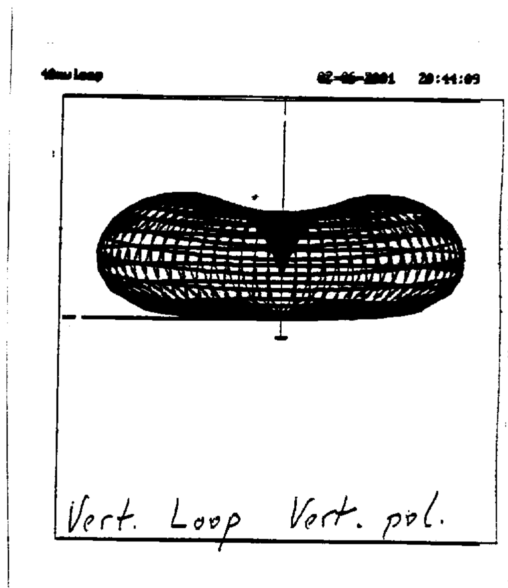
Middle bottom fed=>





1/4λ down side fed=>





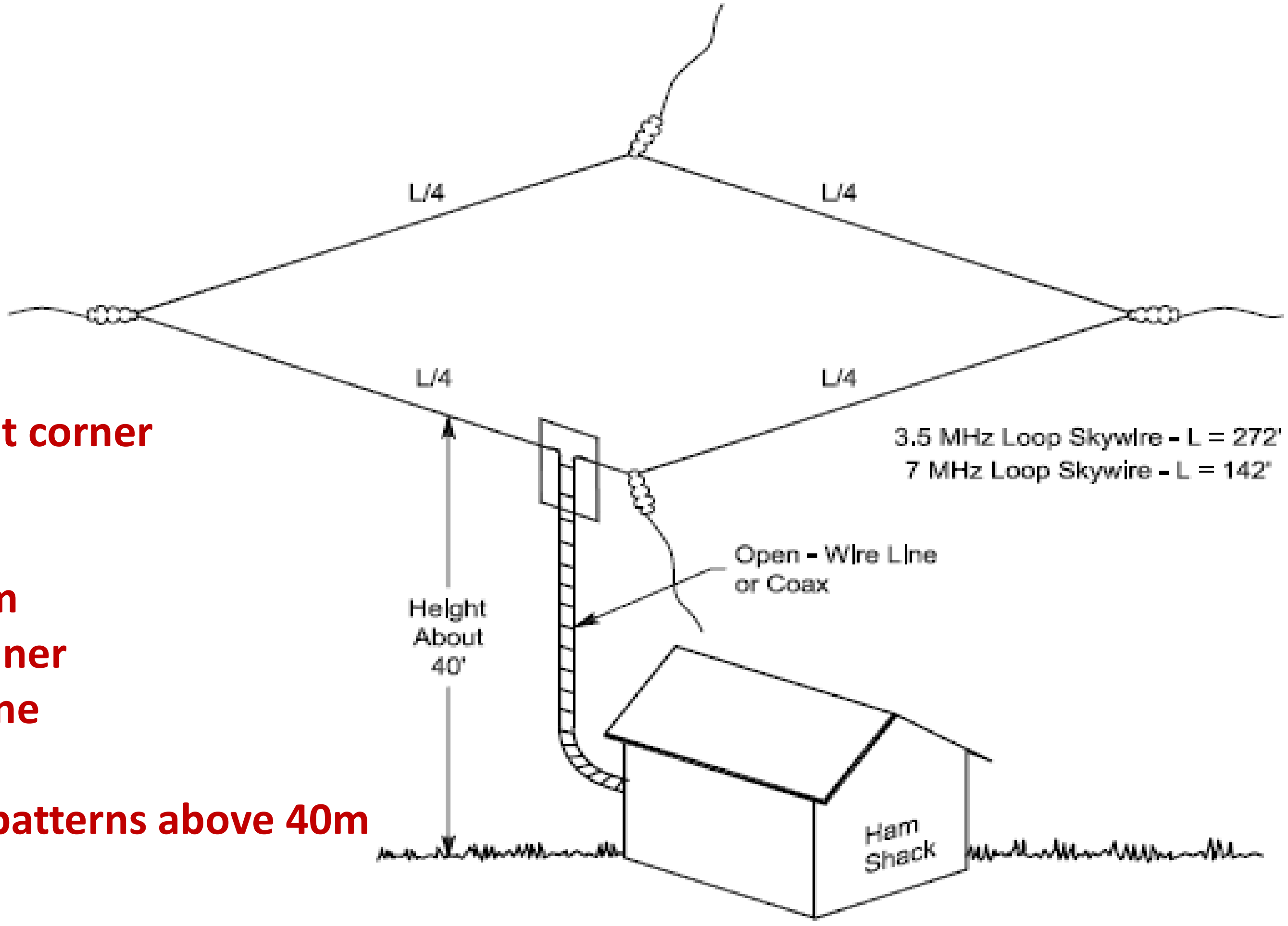
Horizontal Loop Antenna

-relatively quiet (low QRN)

-good for all frequencies above resonance

-good radiation pattern on higher bands

-requires multiple supports and room



<u>My Loop</u>

-3-sided (Delta), fed at corner

-height =52'

-circumference =486'

-good from 160m-10m

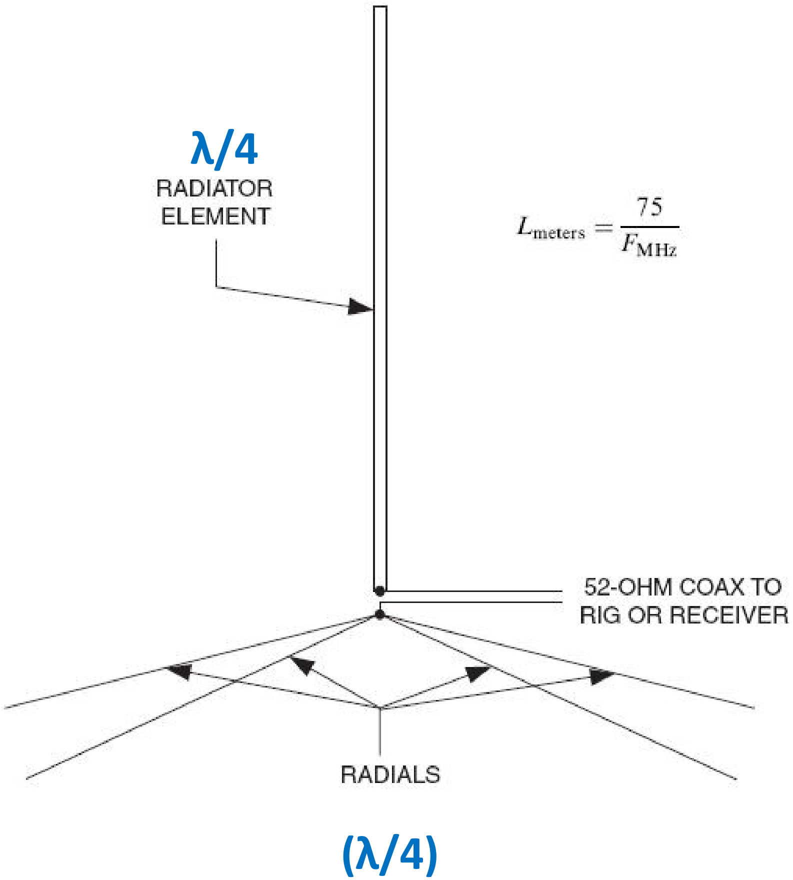
-high power balun+tuner

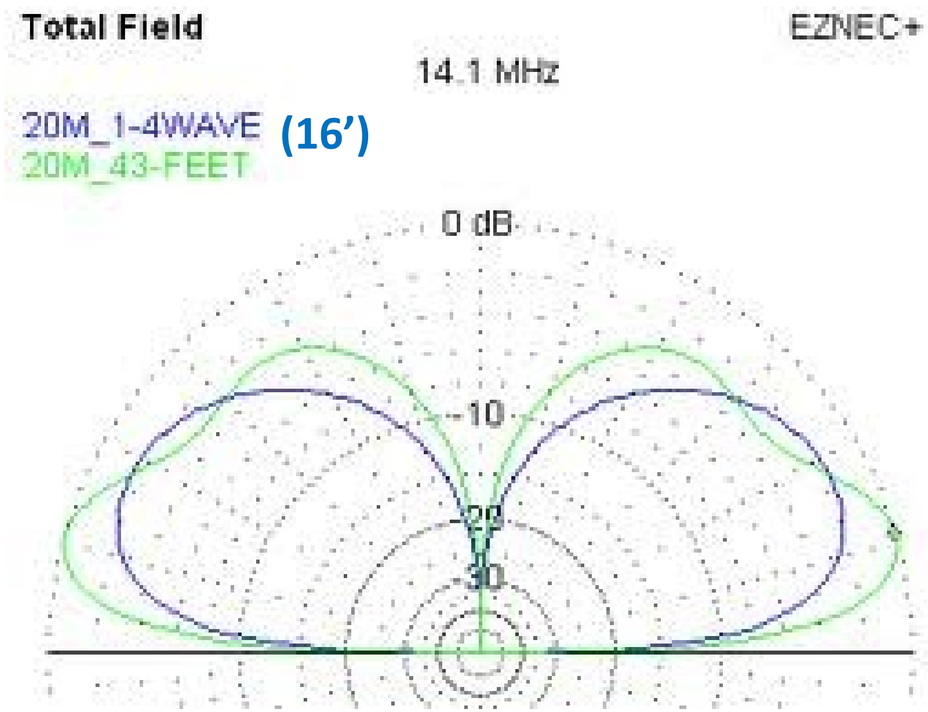
-450-ohm balanced line

-even good for LF RX

-low-angle radiation patterns above 40m

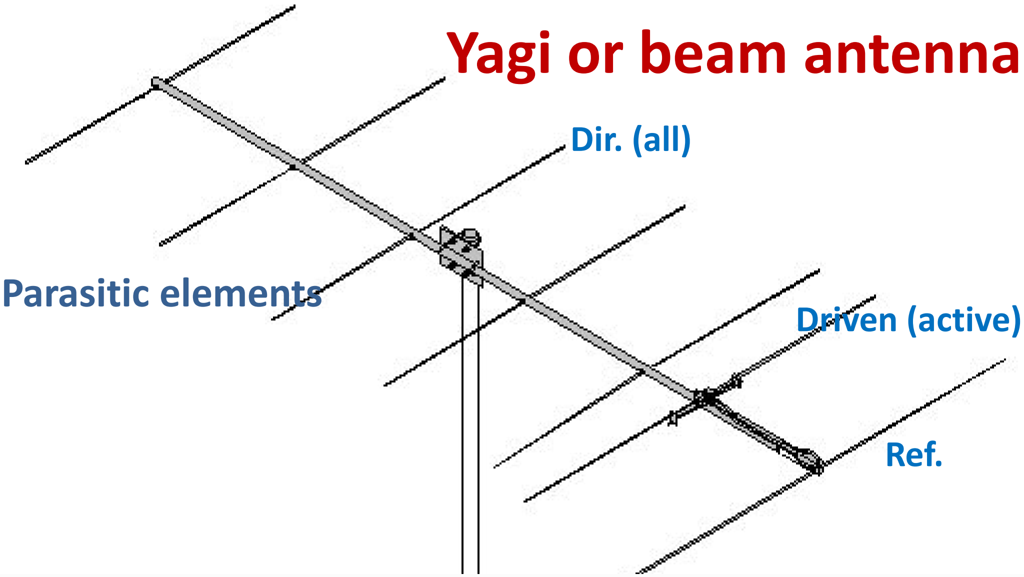
Vertical Antennas

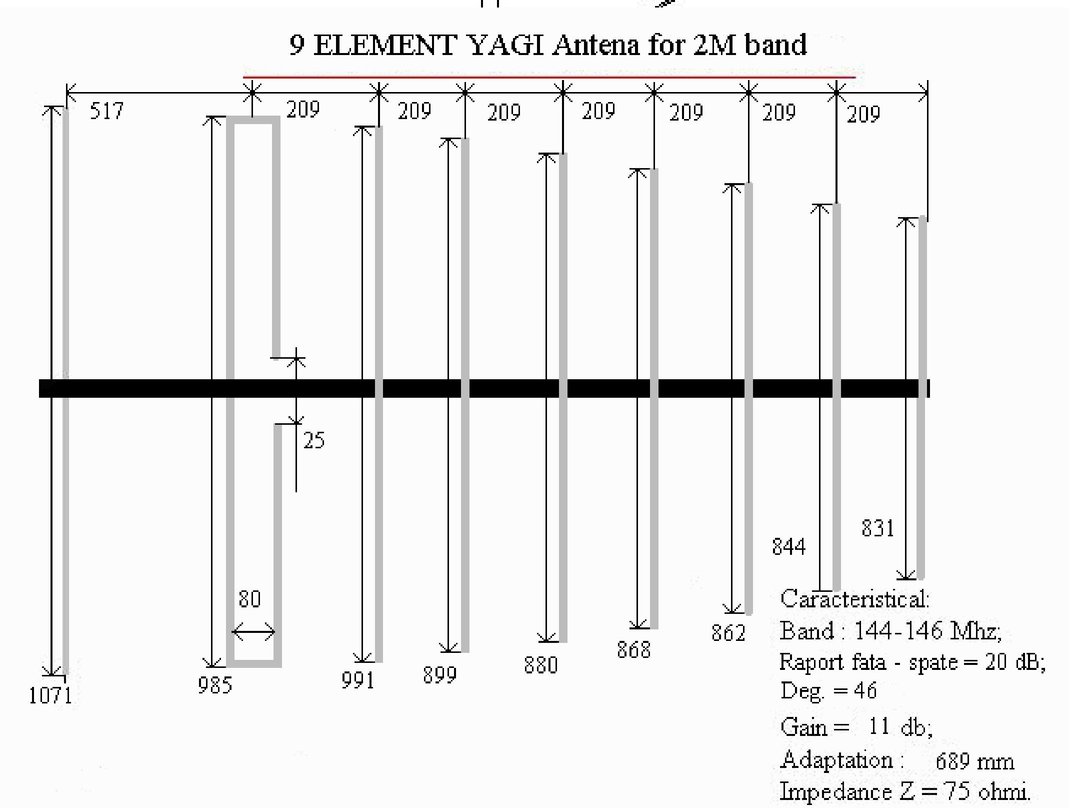




- -single band
- -low takeoff angle (good for DX!)
- -noisy
- -radials needed

Yagi or beam antenna





Hidetsugu Yagi, inventor in 1920s

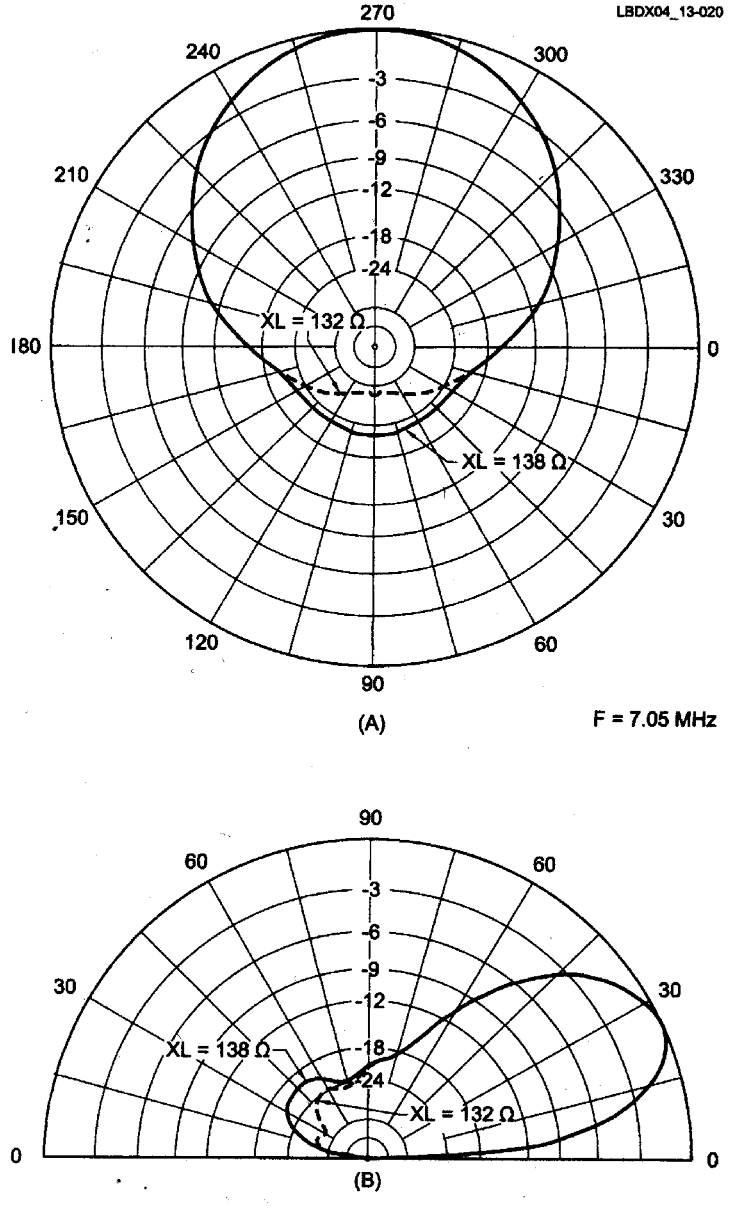
VHF, UHF: small size makes multi elements easy

Yagi azimuth pattern

Yagi
Az

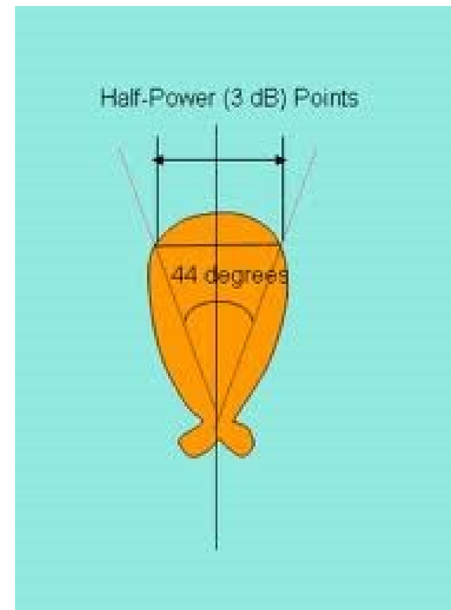
Yagi elevation pattern

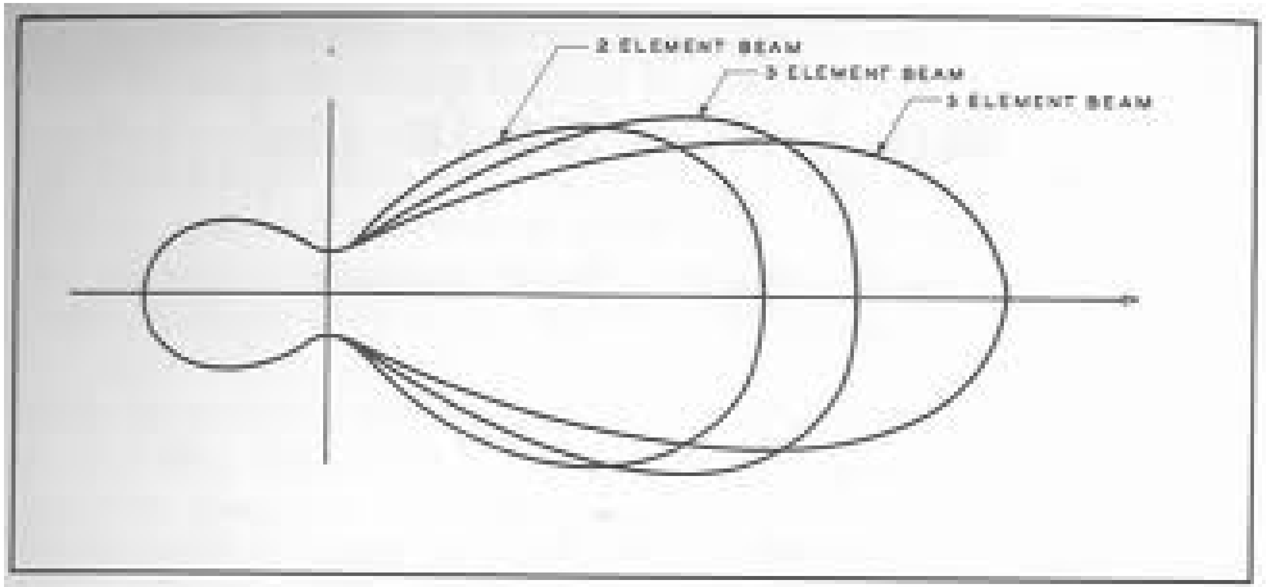
Yagi
EL

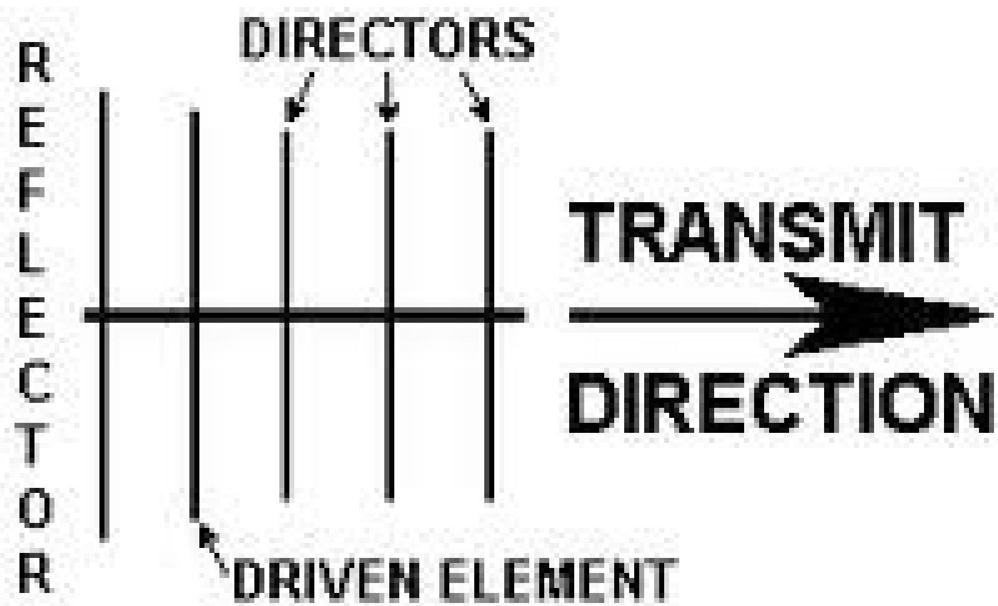


13-20—At A, horizontal radiation pattern at
neter height over average ground for the NW3Z/
3FET 40-meter Yagi. The patterns are for 7.05 MHz.
lucing the value of the loading reactance from 138
32 Ω improves the F/B performance.

Beamwidth measured at 3 db points




2 ELEMENT BEAM
ELEMENT BEAM
ELEMENT BEAM

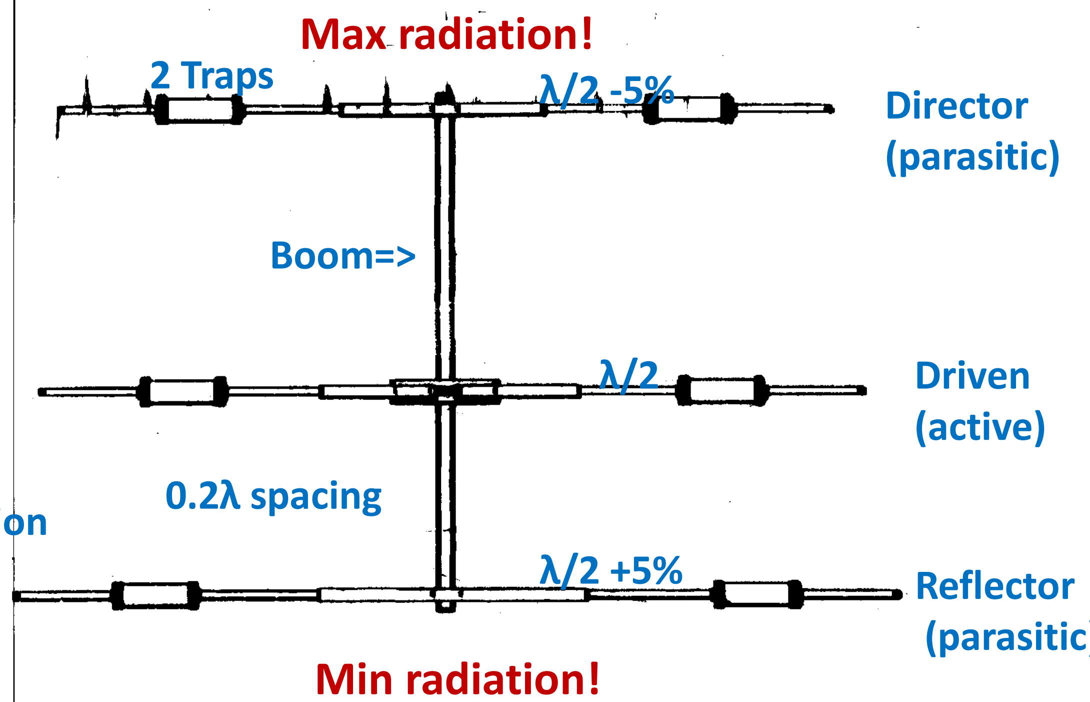

DIRECTORS
REFLECTOR
TRANSMIT
DIRECTION
DRIVEN ELEMENT

3-element 3-band yagi (Mosley CL-33)

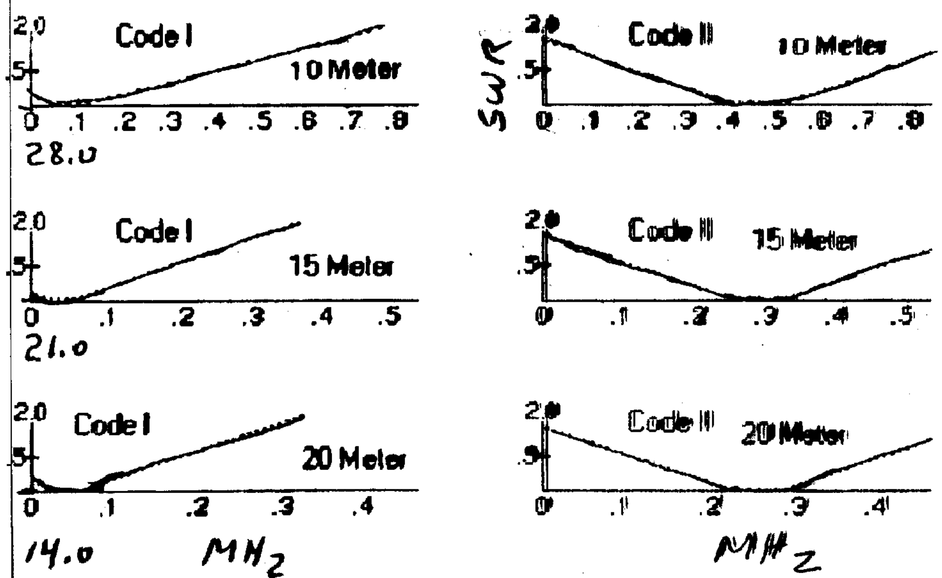
VERY popular

10-15-20meters

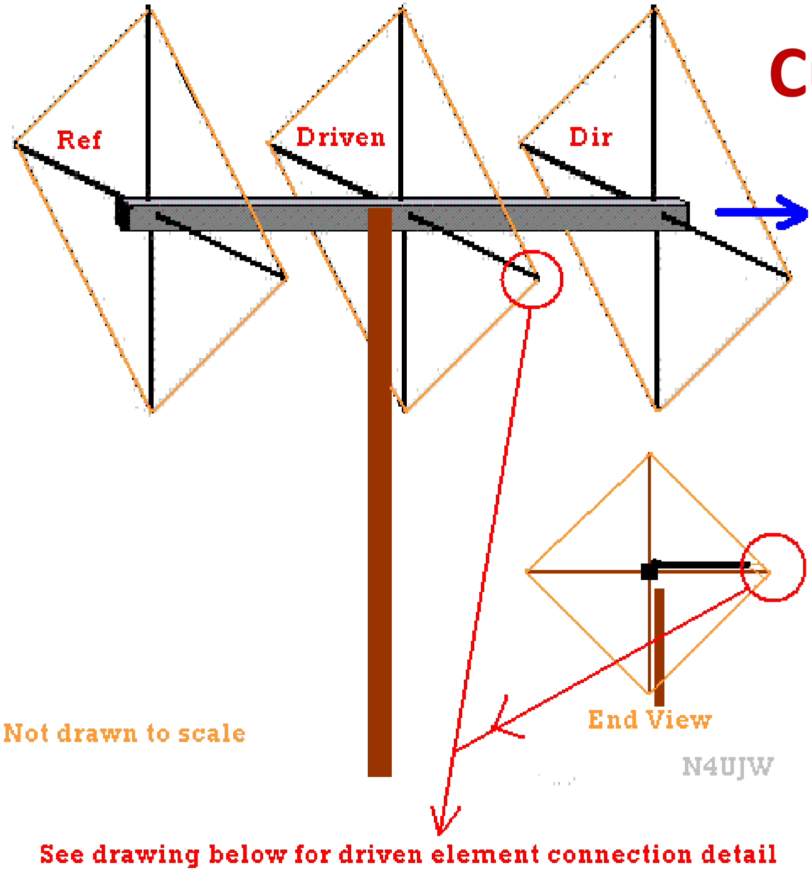
Aircraft aluminum tubing construction
Boom = 18’
Elements = 27-29’ long
Weight 40 lbs.
Front:back ratio: 20-25 db
Forward gain: **7-8.5 dbd**
9.1-10.6 dbi



SWR curves for this “Tri-bander” □



Cubical Quad Directive Antenna

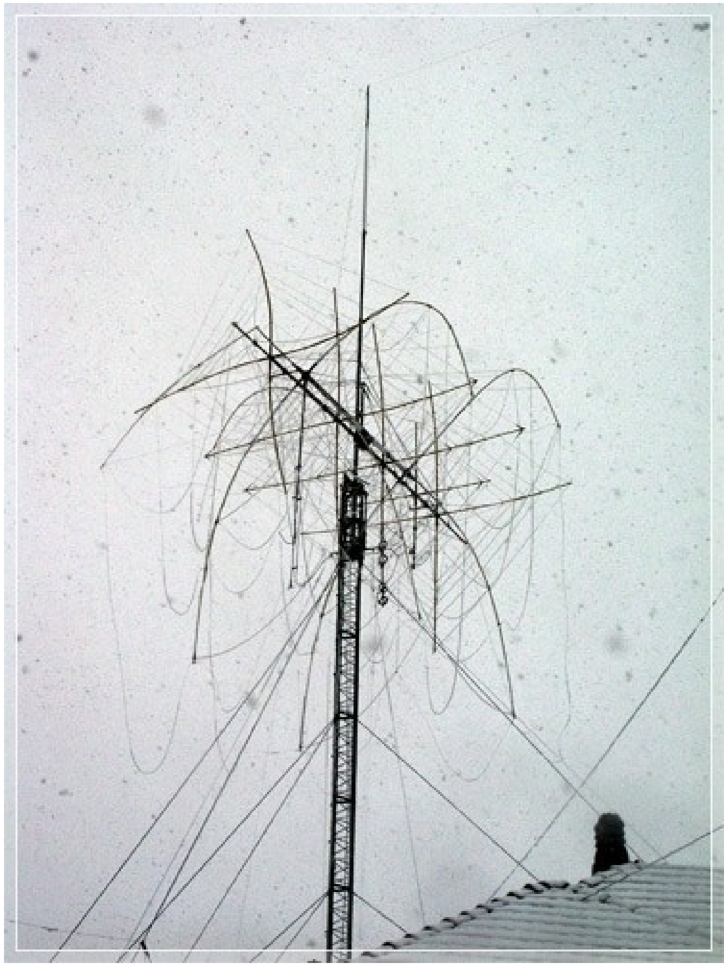


- Quiet
- Directive
- Easily multi-banded

The cubical quad…not great in wind + ice!

RR6310/A

RR6310/B



Stacked yagis after an ice storm

Improvised/expedition antennas

-Correct wire lengths dependent on operating frequency!

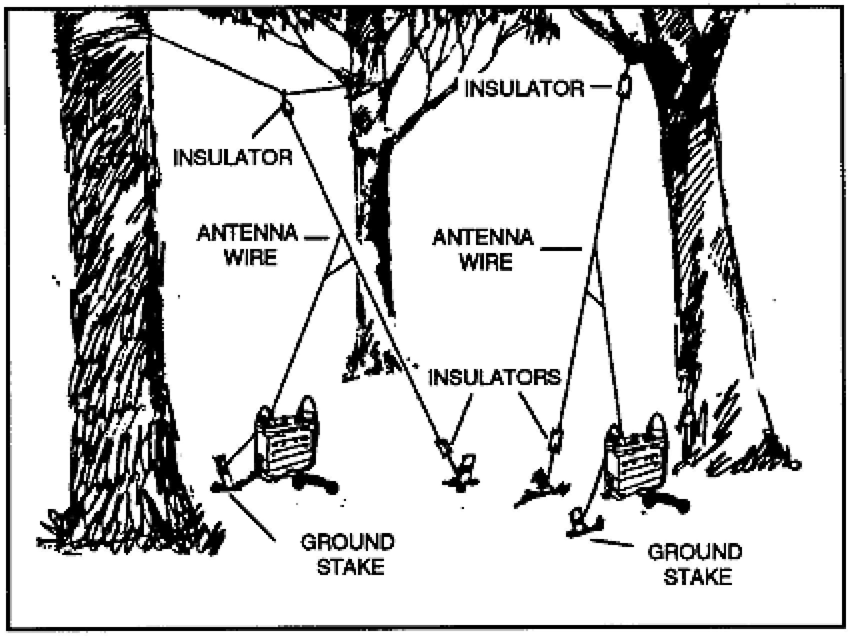


Figure 7-8. Improvised vertical half-wave antenna.

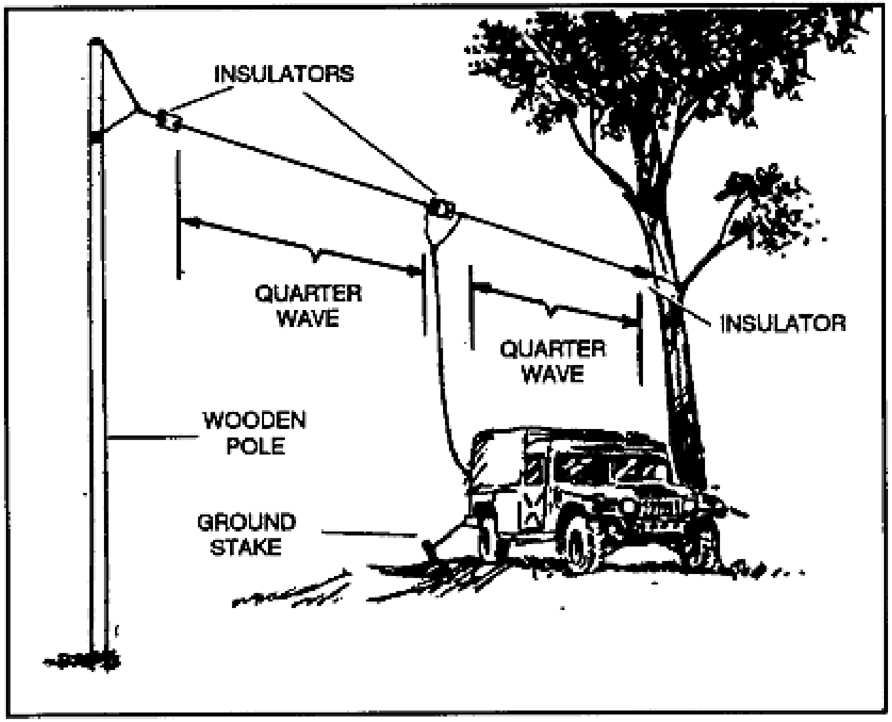


Figure 7-6. Center-fed half-wave doublet antenna.

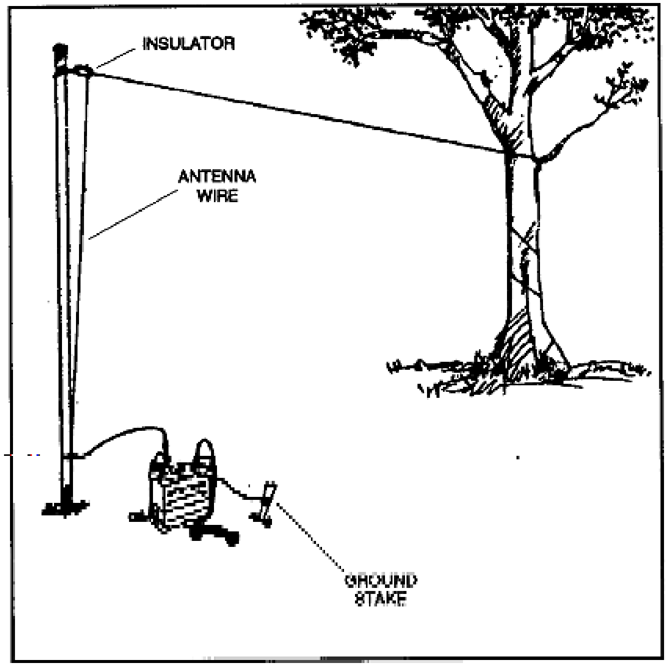
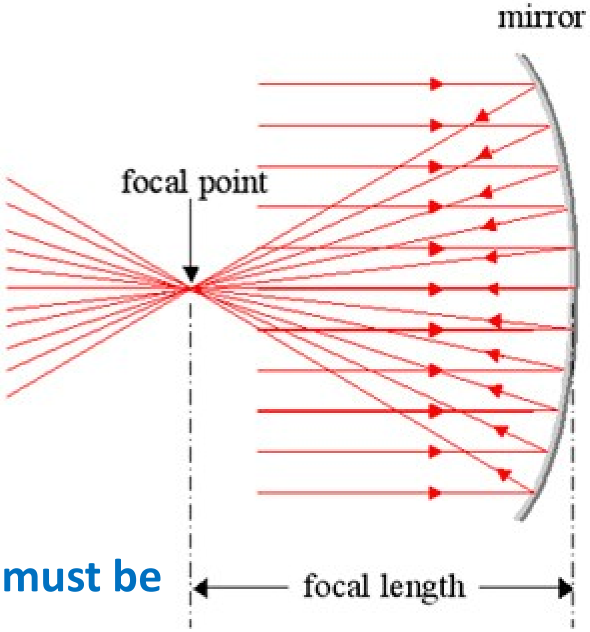


Figure 7-5. End-fed half-wave antenna.

DX-pedition antennas on 40' "TV" tower

Parabolic antennas for very high gain



-High F/B ratio

-Highly directional

-The "spotlight" of the RF spectrum

-Dipole, feedhorn, and preamplifier at focus

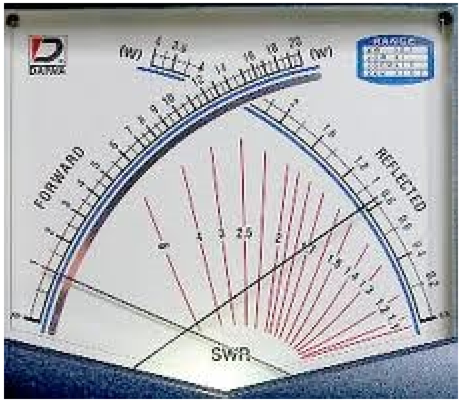
-Great for UHF => up

-The higher the freq., the more precise the parabola must be

-Mechanically very difficult for low frequencies

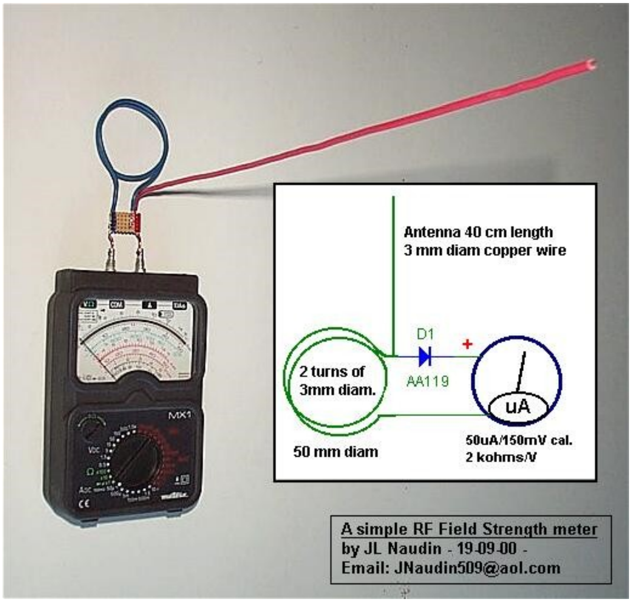
GRID PARABOLIC ANTENNA

Antenna-Related Equipment

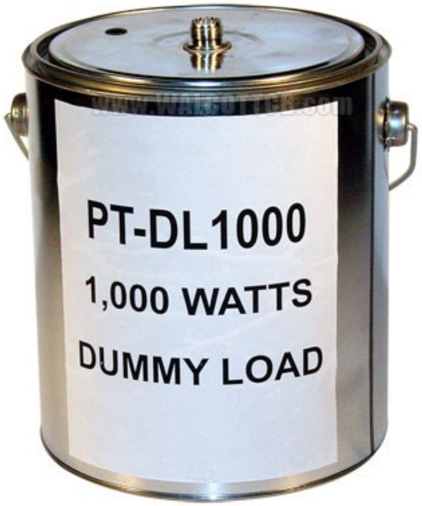


RF Power :SWR meter

Antenna/SWR analyzer



Field-strength meter



Artificial antenna
or dummy load
(pure resistance)

Antenna Safety

Climbing towers, trees, roofs

-safety belt, harness for towers

-safe equipment (quality ropes, ladders, etc)

-at least two people!

-training for tower climbing

-experience for tower put-up, tear-down

-quality tower components

Electric shock

-lightning protection for high masts, towers, aerials (good grounding, safety antenna disconnect)

AVOID POWER LINES! No wire or metallic antenna parts above, below, or near commercial power lines

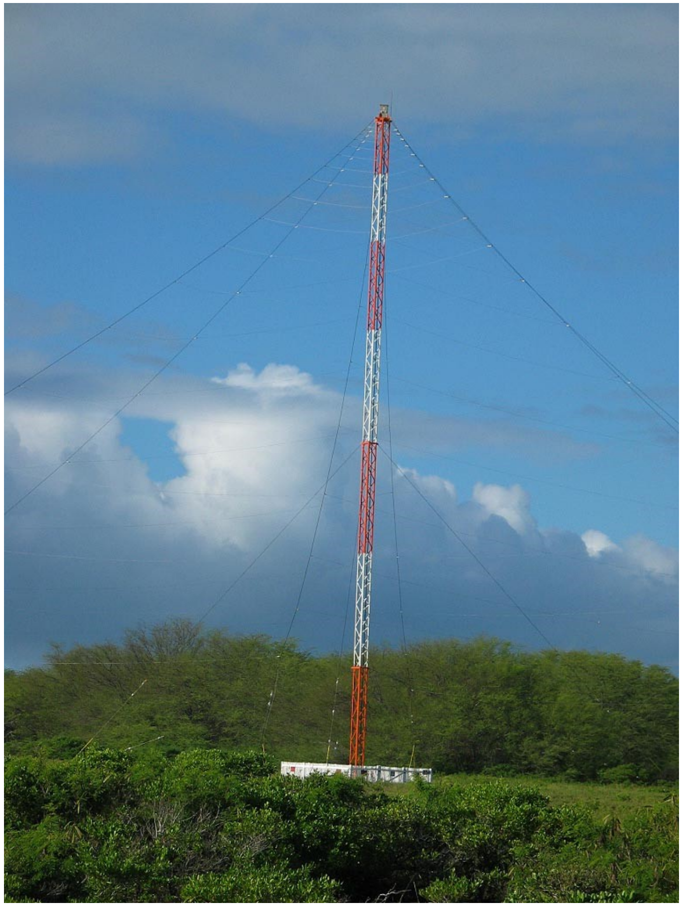
Non-ionizing radiation (RF fields):

-unclear whether any real risk to humans, but should set up station to minimize RF near radio

-also tends to minimize interference on radio

END

Of Transmission Lines and Antennas



Questions??

END

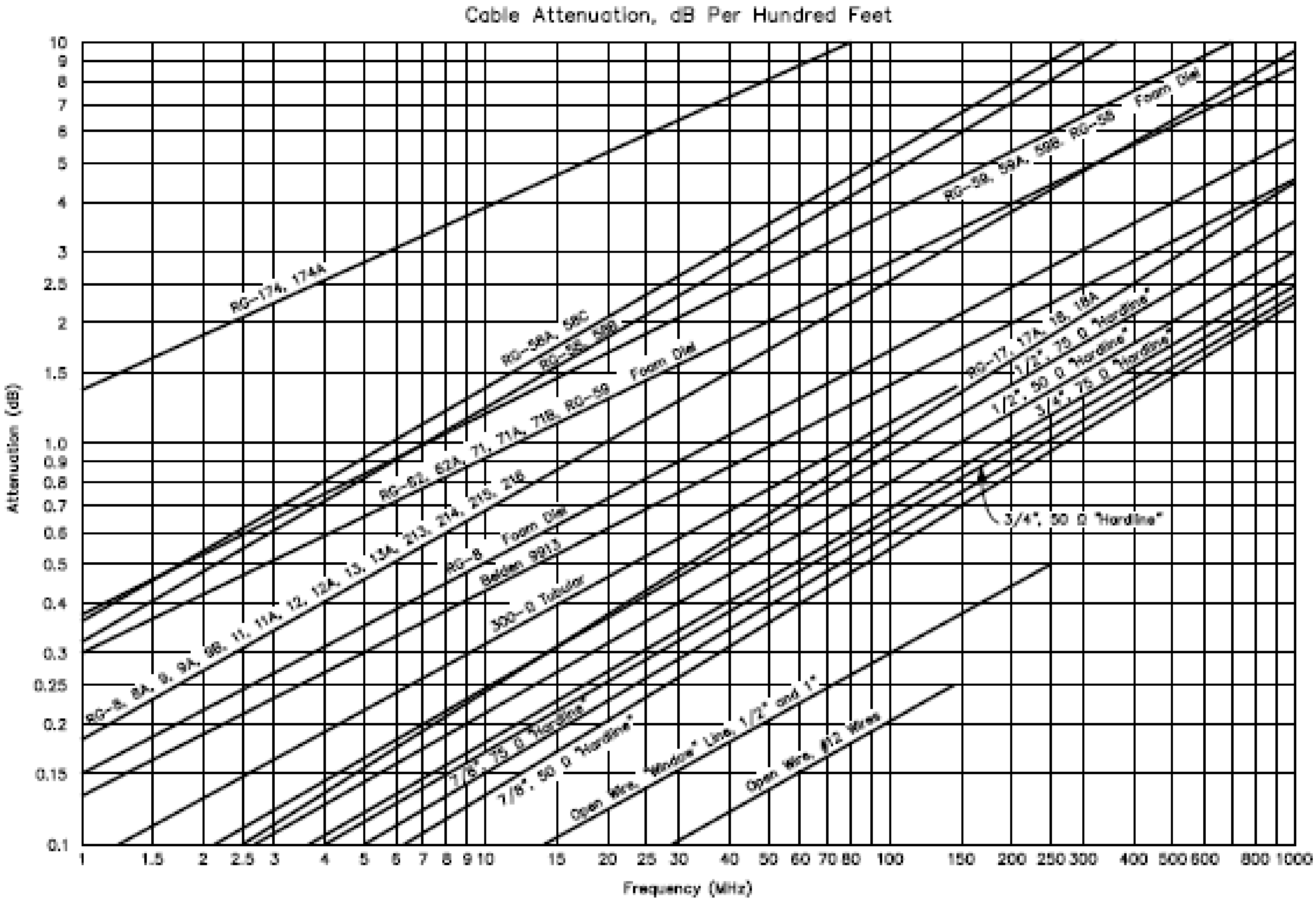
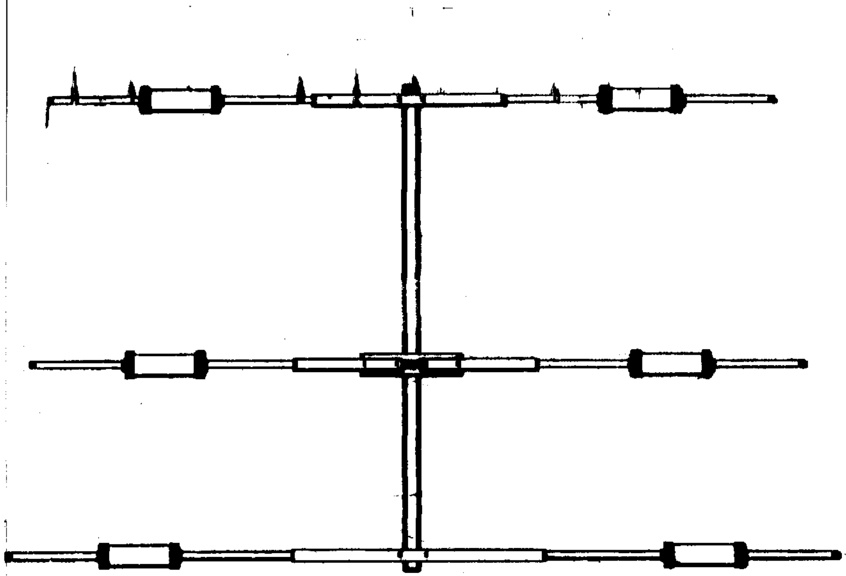
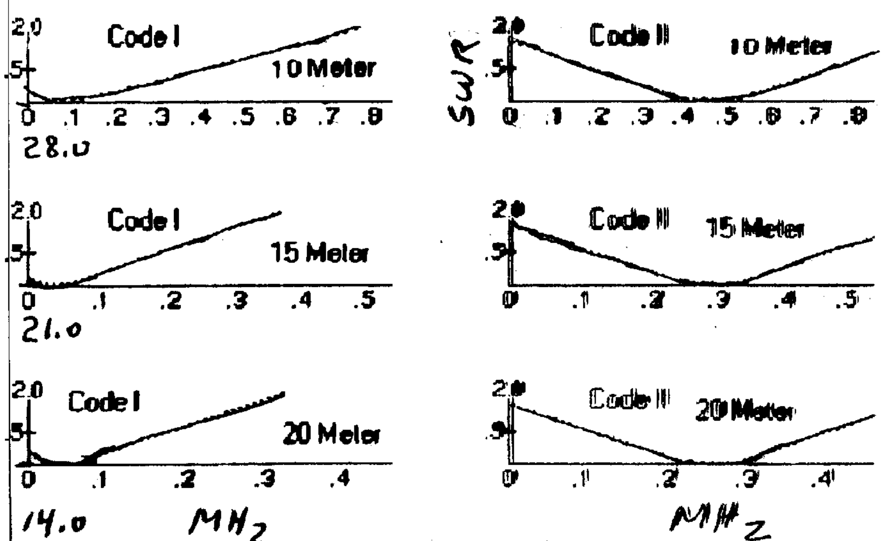


Fig 23—Nominal matched-line attenuation in decibels per 100 feet of various common transmission lines. Total attenuation is directly proportional to length. Attenuation will vary somewhat in actual cable samples, and generally increases with age in coaxial cables having a type 1 jacket. Cables grouped together in the above chart have approximately the same attenuation. Types having foam polyethylene dielectric have slightly lower loss than equivalent solid types, when not specifically shown above.





Specification and Performance Data
*CL-33-M**

Forward Gain:	10 Meter	8.5 dbd.
	15 Meter	8.1 dbd.
	20 Meter	7.3 dbd.
Front-to-Back:	10 Meter	20 db.
	15 Meter	23 db.
	20 Meter	23 db.
Power Rating:		
CW		1.8 KW
SSB		2.5 KW
SWR at resonant frequency:		1.0/1
Boom Length:		2" x .125 x 18'
Turning Radius:		16 ft.
Recommended Mast Size:		2 in.
Maximum Element Length:		27 ft.
Assembled Weight (approx.):		42 lbs.
Wind Surface Area (in sq. ft.):		6.0 ft.^{2}
Wind Load (EIA standard 80 M.P.H.):		120 lbs.
Shipping Weight (approx.):		47 lbs.
Warranty:		2 Yrs.

NEW! Mosley CL-33-WARC Kit

Convert your CL-33 to a CL-33-WARC with our "NEW" CL-33-WARC-Kit. This is an easy mod that will give you an even "Hotter" CL-33. Conversion will give the above performance!

Once your conversion is completed you can add 40 Meters with a TA-40-KR!

The Perfect Antenna

1. 100% Efficient: 100W RF AC ⇨ 100 W RF photons + 0 W heat.

2. Optimal ∢ of radiation.

3. 100% of photons focussed in beam in desired direction.

Real-World losses

Antenna resistive losses

Transmission line losses

Ground losses

Tuner losses