PMRC May 2019

Antennas
Truths & Myths

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How would you define the term

ANTENNA ?

ANTENNA

A device made from a <u>conducting material</u> that can both transmit and receive

1) convert an AC current into an EM wave

2) convert an EM wave into an AC current

An antenna is a "transducer" (changes one form of energy to another form of energy)

True or False

The <u>electrons</u> that generate an RF wave in an antenna come from the transmitter

FALSE

The <u>electrons</u> were already in the atoms of the conducting material in the antenna itself

The electrons themselves do <u>NOT</u> travel from the transmitter to the antenna and back

The transmitter is NOT the source of the <u>electrons</u> that create the EM wave

True or False

The <u>ELECTRIC POWER</u> to generate an EM wave in an antenna comes from the transmitter, via some kind of feed line

TRUE

True or False

An antenna with a 1:1 SWR
must be a good radiator of EM waves

FALSE

A 50 ohm "dummy load" is a device that may show an SWR of 1:1 but it permits your transmitter to <u>load</u> (deliver power to) without generating any significant RF wave

A dummy load is used to "tune up" an amplifier to <u>avoid radiating RF</u>

What is inside this can

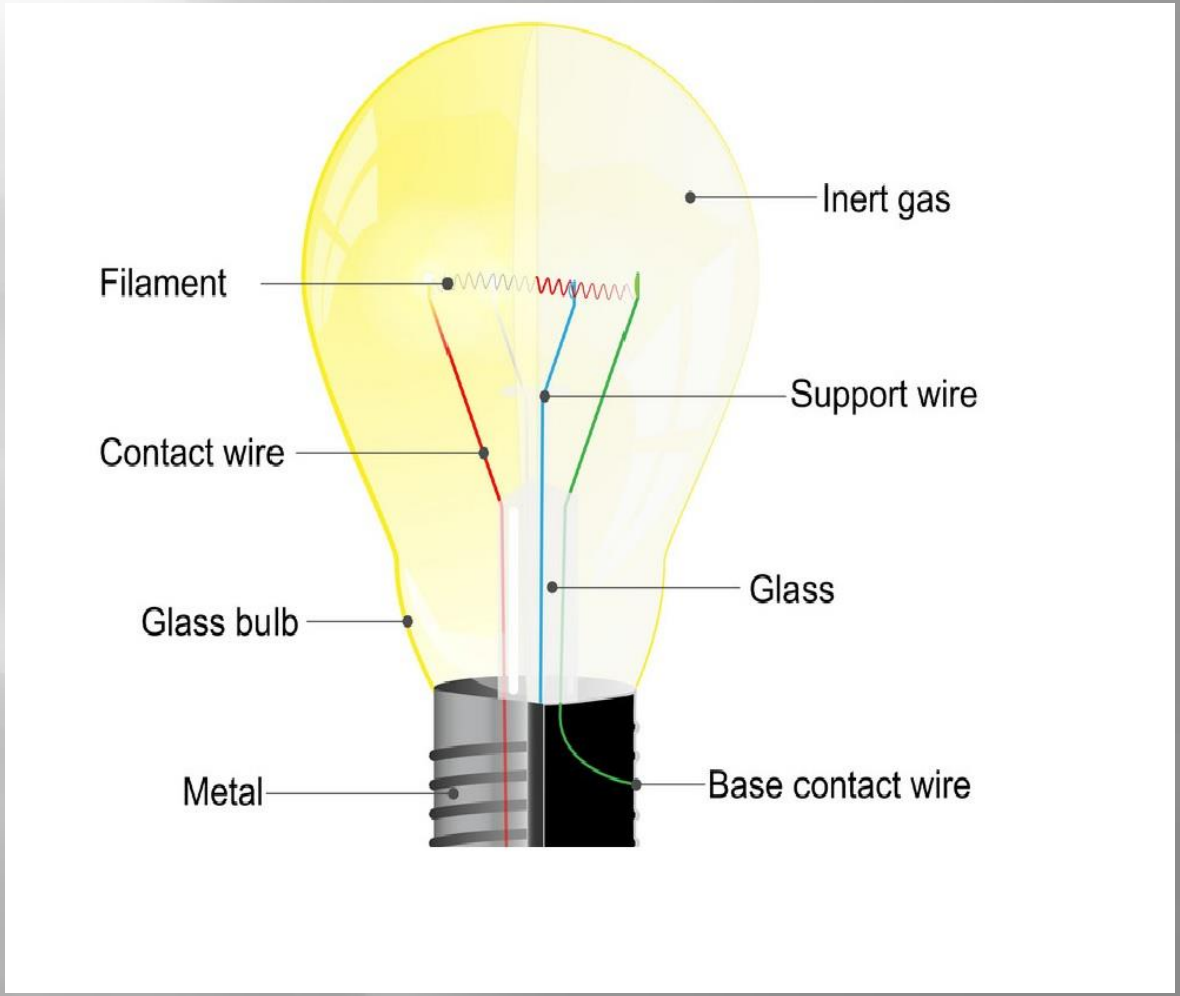
Dummy Load

Raise your hand if you <u>own</u> a dummy load

Raise your hand if you have ever <u>used</u> a dummy load to tune up your transmitter

Raise your hand if you have ever <u>taken apart</u> a commercial dummy load to see what is inside

A cheap “dummy load” ?



True or False

Every dummy load will radiate <u>some</u> RF energy?

True

I once had a 40m QSO on CW with a station in New Jersey (I lived in West Phila) using my cheap "dummy load" (**100 watt incandescent light bulb**) connected to a Heathkit DX100 with 20 ft RG58 coax

The light bulb was glowing VERY brightly when the key was down (100 W of light/heat) and ….. some EM wave

Conclusion:

Even light bulbs (and coax) can radiate <u>some</u> RF

How many <u>outdoor</u> antennas do you have at your QTH?

1

2-5

6-10

>10

Which costs more?

Your HF rig, amp and power supply

or

Your HF antennas, cables, tower, rotator, etc.

What is the SOURCE of all RADIO waves?

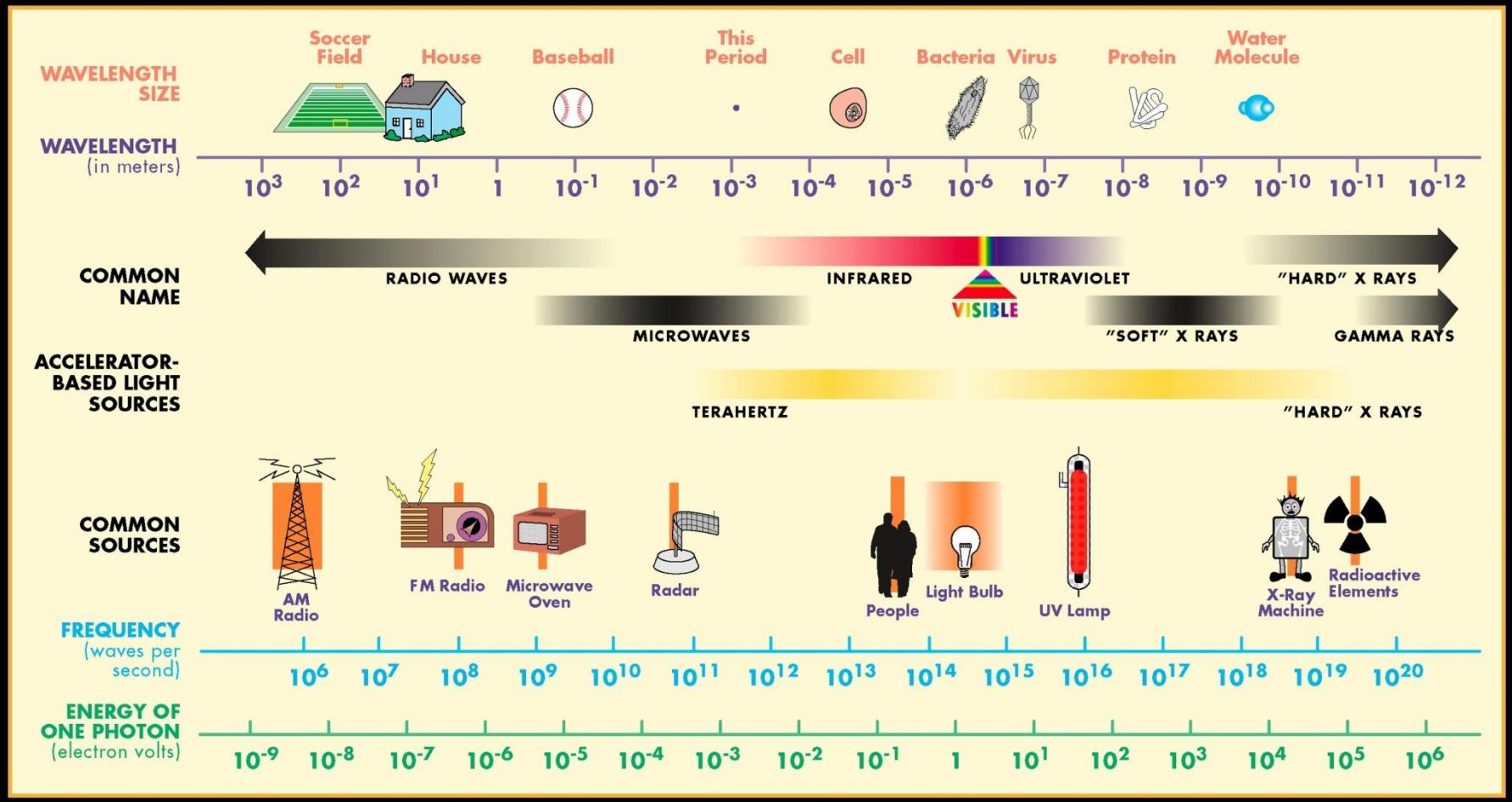
Accelerated Charged Particles:

electrons, protons, ions

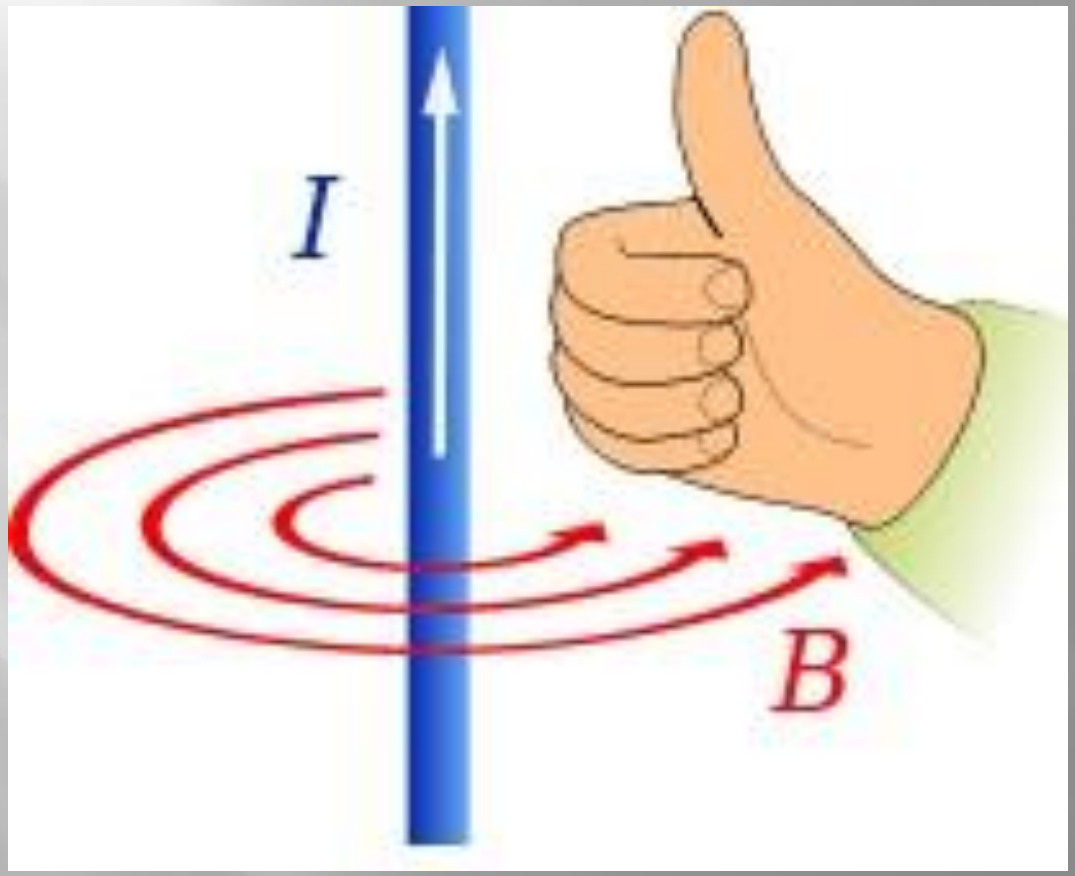
Sources of EM radiation

Type	Source
Radio	*Vibrating electrons e.g. AC current*
Microwaves	*Excited semiconductors or vibrating electrons*
Infra-red	*Electrons transitions between energy levels*
Visible	*Electrons transitions between energy levels*
Ultraviolet	*Electrons transitions between energy levels*
X Ray	*Emitted when decelerate rapidly electrons e.g. when they hit a metal target*
Gamma	*Emitted by nuclei after a nuclear reaction*

THE ELECTROMAGNETIC SPECTRUM

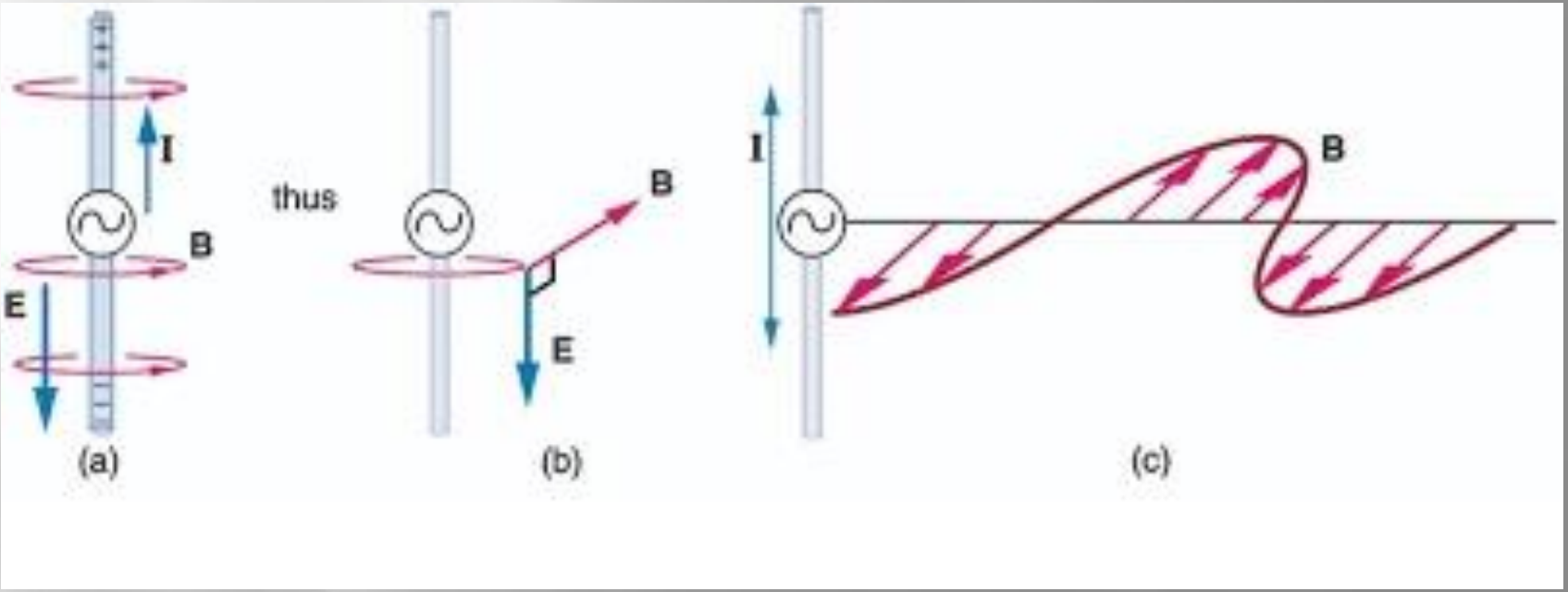


A <u>DIRECT</u> current in a wire produces a constant Magnetic Field (B) at right angles to the electric field (arrow)

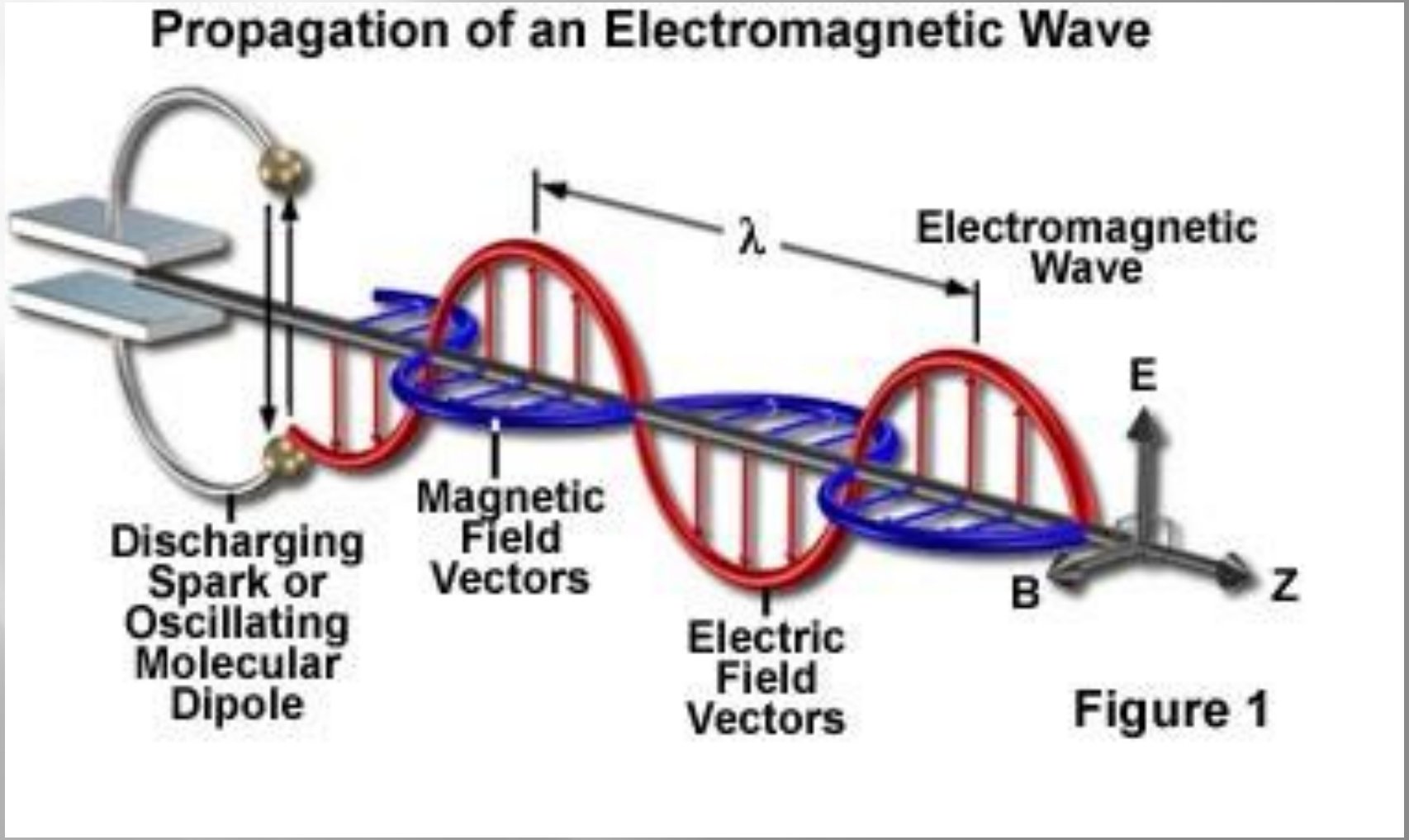


What happens to the magnetic field if the current <u>changes direction</u>

AC Currents generate <u>oscillating</u> Electric and Magnetic Fields which interact with each other to produce an EM wave



EM Wave Propagation is perpendicular to BOTH the Electric and Magnetic fields



This EM wave caused by the interaction of electric and magnetic fields was first

PREDICTED

by **<u>what scientist</u>** ?

James Maxwell (1831 – 1879)

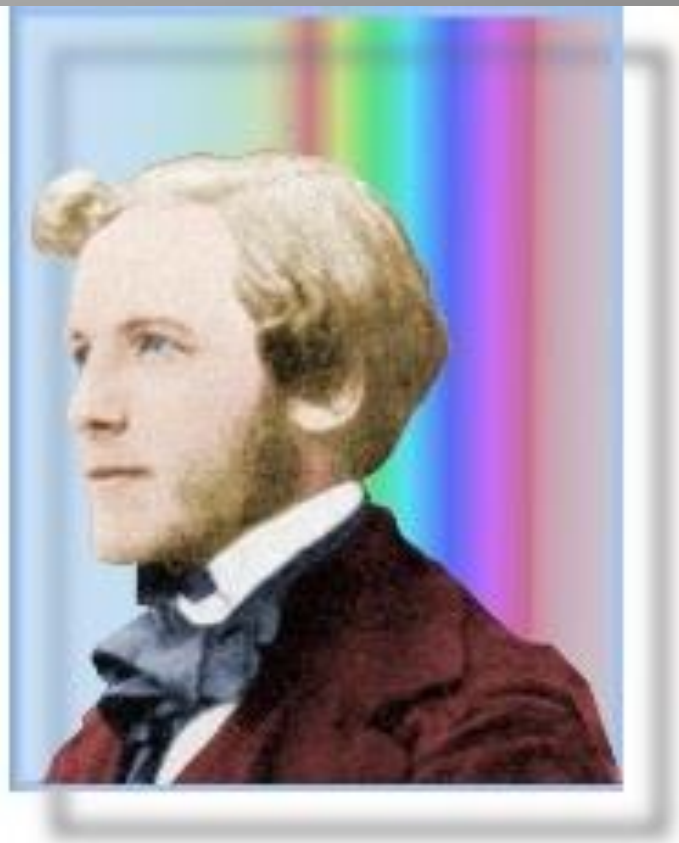
Maxwell's mathematical "proof" for the existence of EM waves

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \left(\mathbf{J} + \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t} \right)$$



Maxwell's Theory of EM Waves

Maxwell also predicted the **SPEED** of all EM waves based on fundamental electric and magnetic field properties in a vacuum

C = ~ 300 million meter / second

1861 Experimenting with spinning color wheels, Maxwell also deduced that the light receptors in the human eye are capable of seeing just three colors of light: <u>red, green, and blue</u>

True or False

Very High Frequency waves (VHF)

travel faster

than

low frequency HF waves

in a vacuum

FALSE

The **speed** of an E-M wave is determined by the electric and magnetic characteristics of the MEDIUM in which the wave travels

(and is fastest in a true vacuum)

Important

The E-M wave speed in a vacuum does NOT depend on the wave's frequency, amplitude or phase

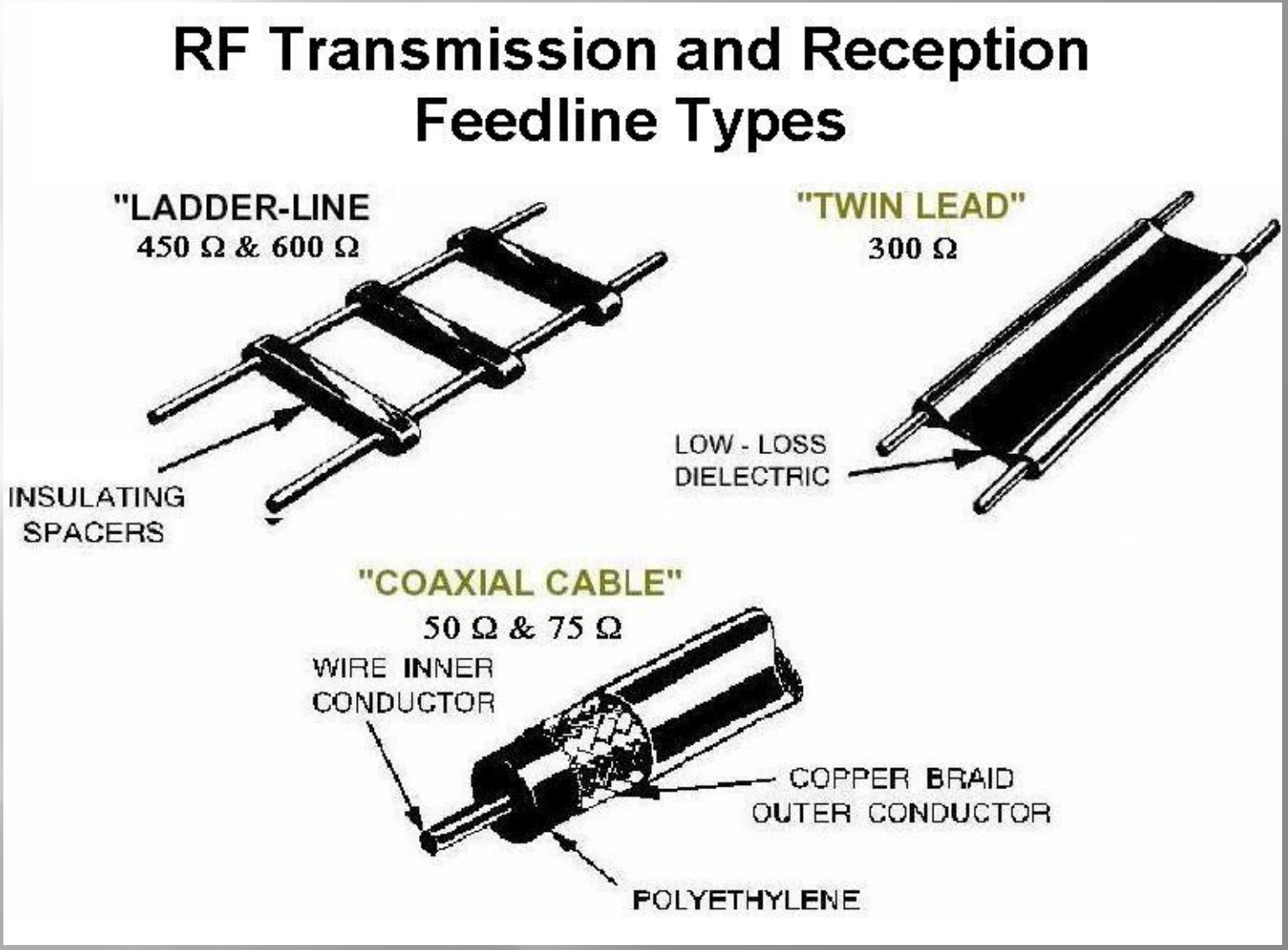
FEED LINES

True or False

The function of a "feed line" is to transfer power from the transmitter to the antenna without any significant "loss" (attenuation) and without radiating an EM wave

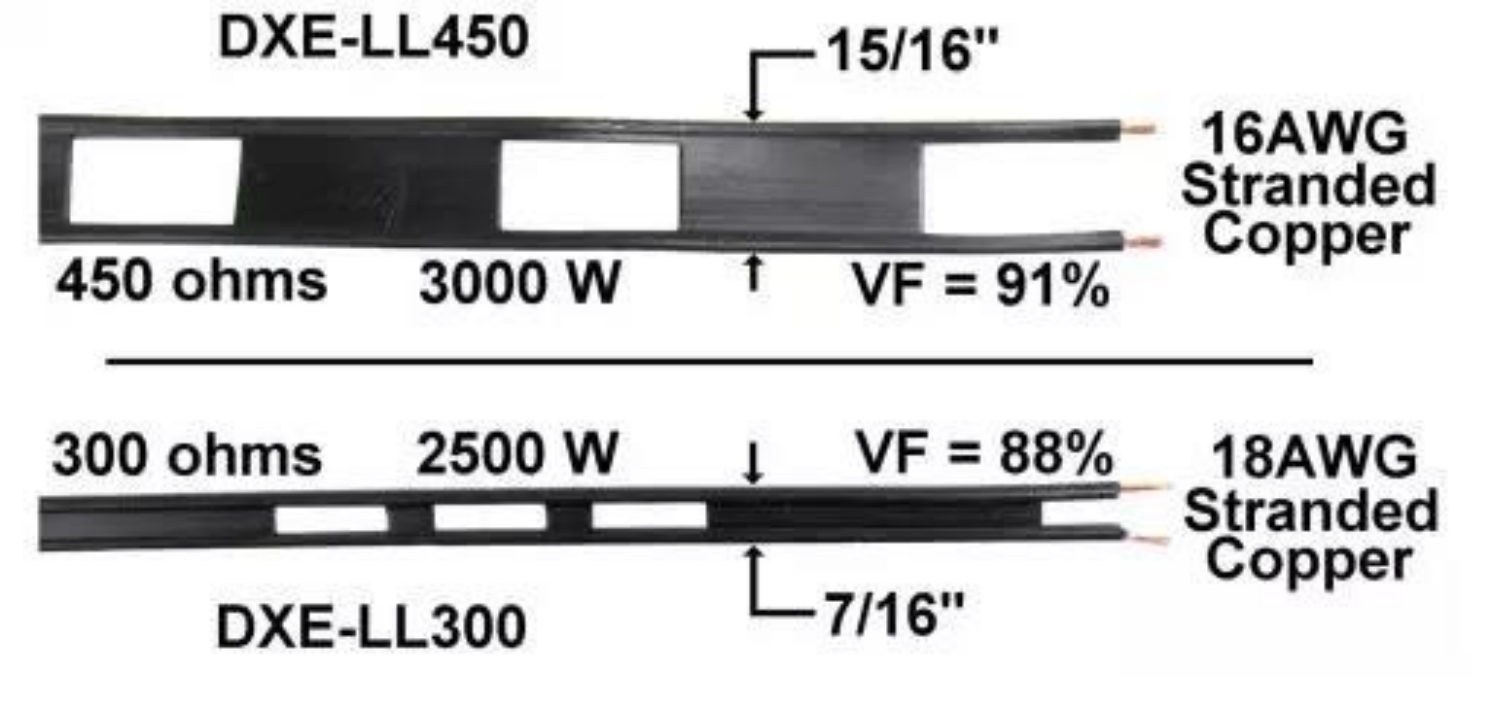
TRUE

Common Feed Lines



True or False

<u>Impedance</u> is determined by the separation of the two wires and the dielectric material

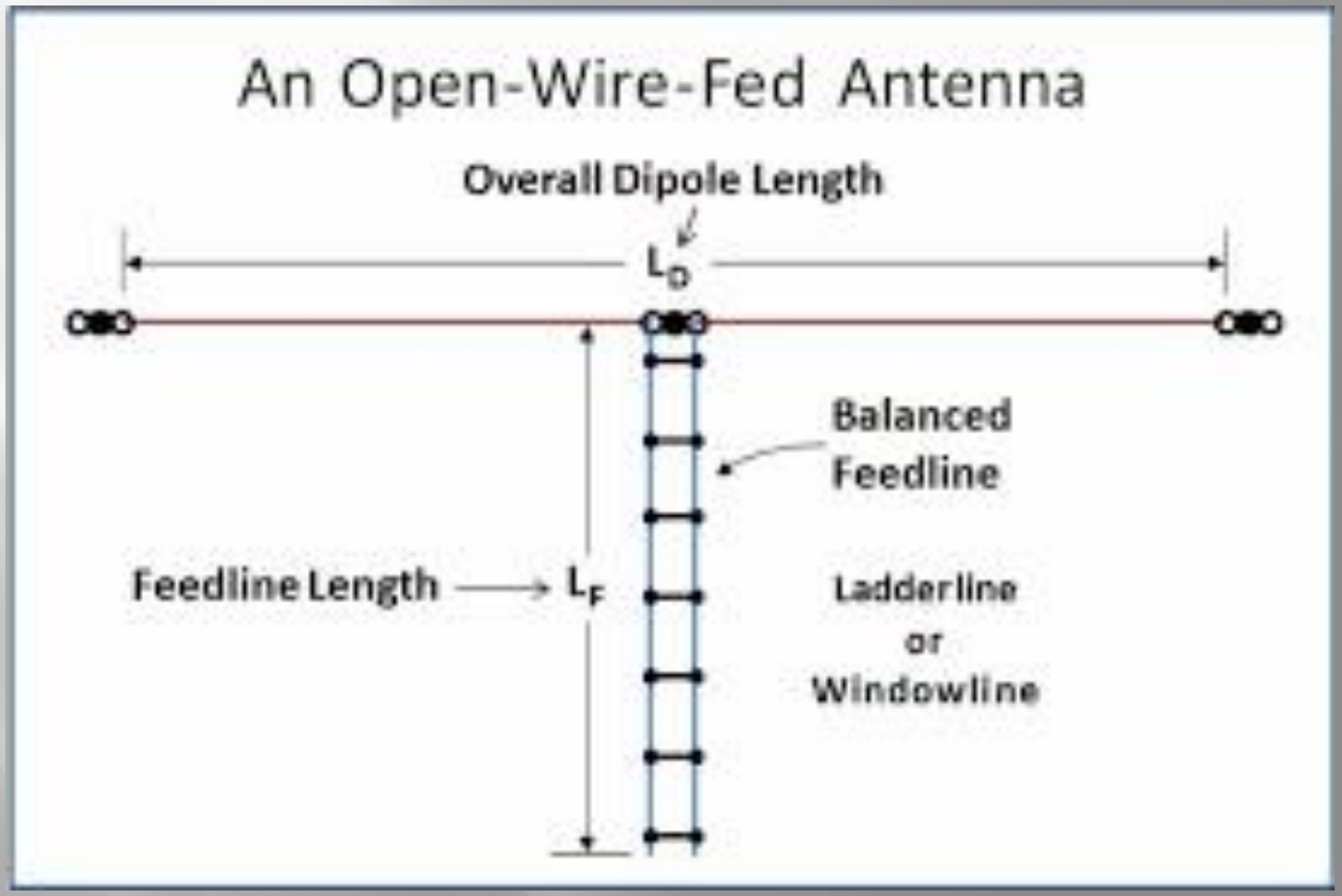


"Balanced" two-conductor feed line

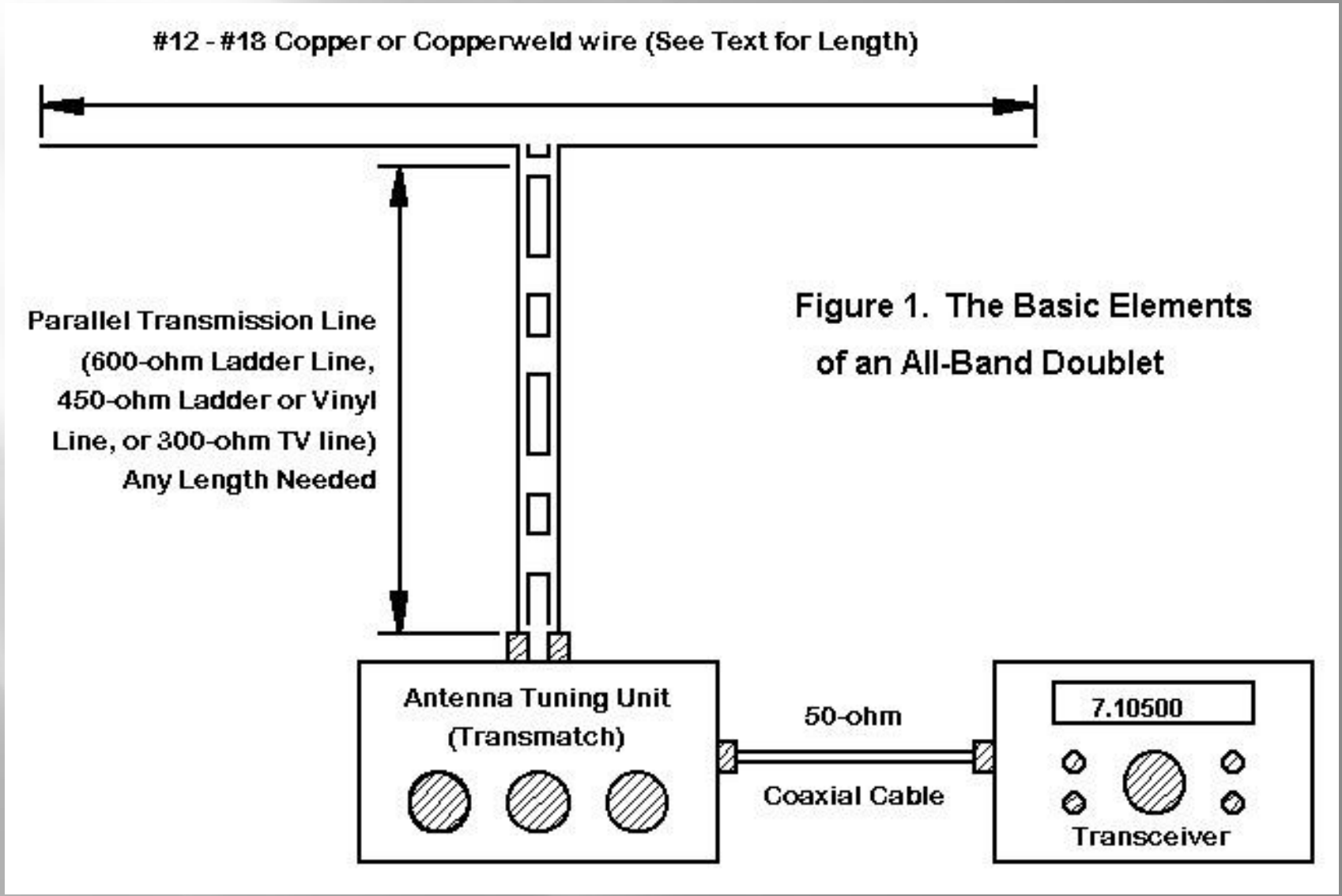
Balanced with respect to "ground"
equal current in both wires
but current is in opposite directions

True or False

Balanced half-wave dipole
fed with balanced feedline will result in
very low loss (attenuation)



TRUE, if you can convert the 450 ohm feedline to 50 ohms to match the rig's impedance



True or False

Feed lines with <u>UNEQUAL</u> currents <u>will radiate an EM wave</u>

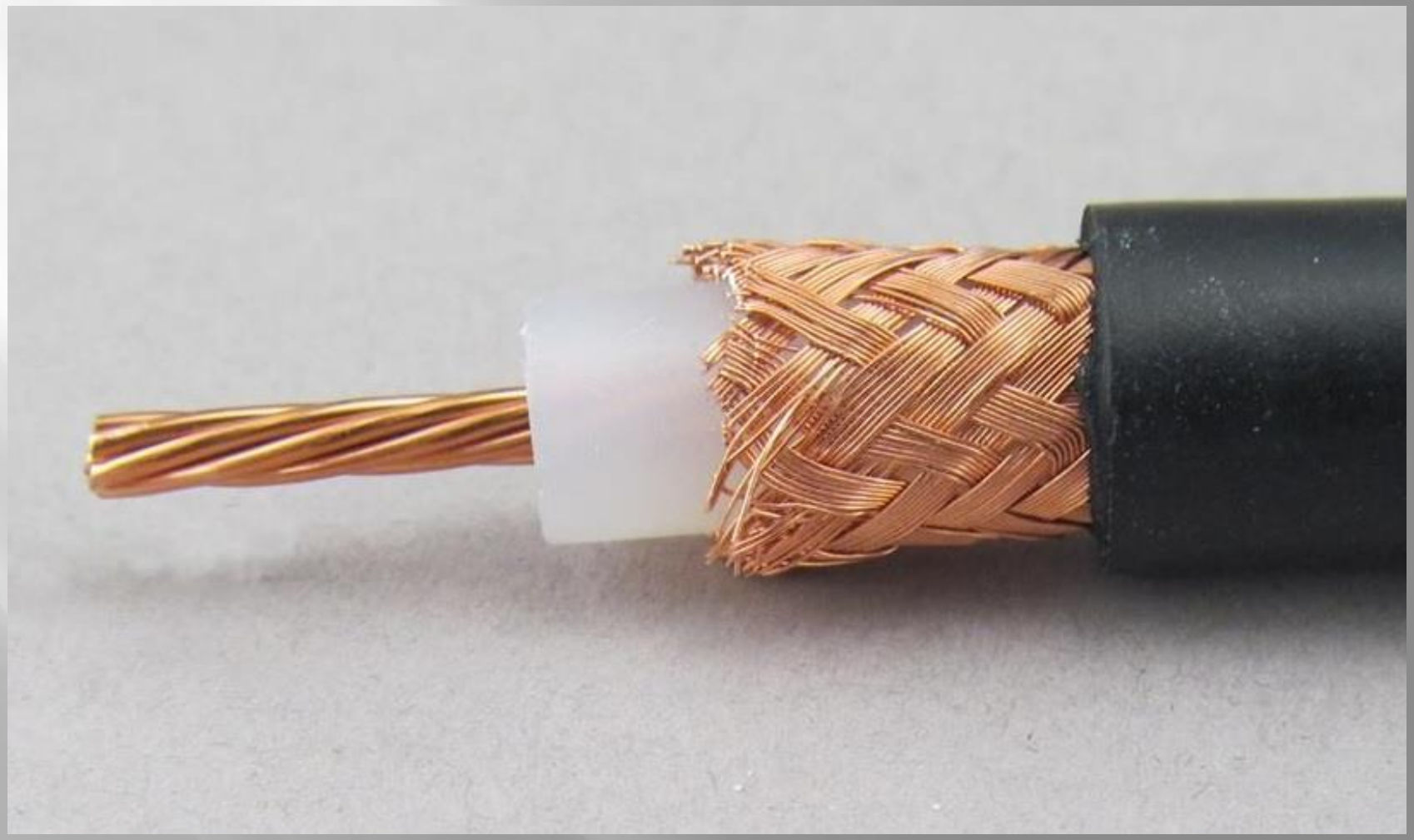
TRUE but why?

Balanced Feed Lines

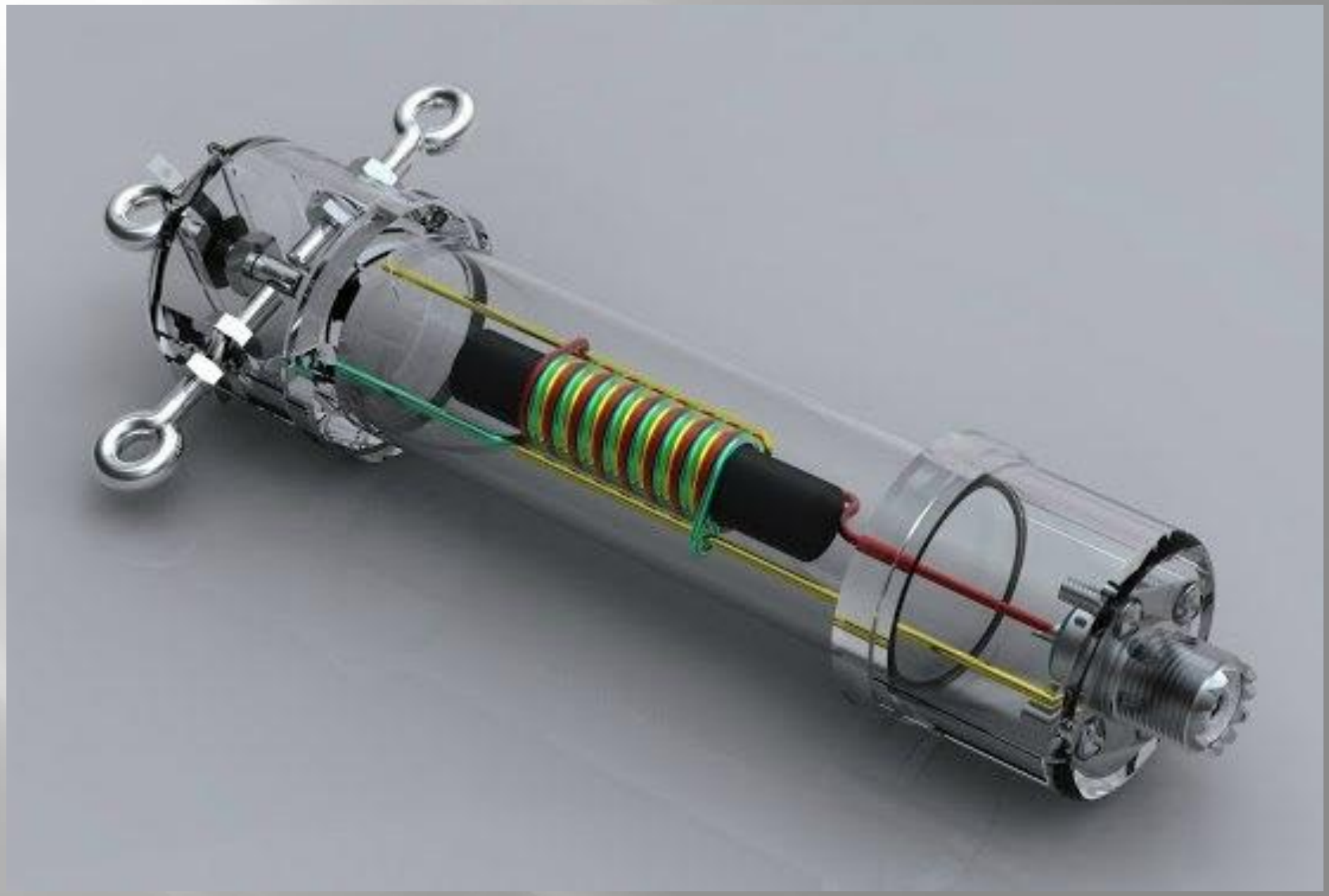
Each wire <u>does radiate</u> but the electric and magnetic fields in one wire are opposite to the fields in the other wire

so the <u>NET</u> radiation is <u>ZERO only if the wires have equal currents</u>

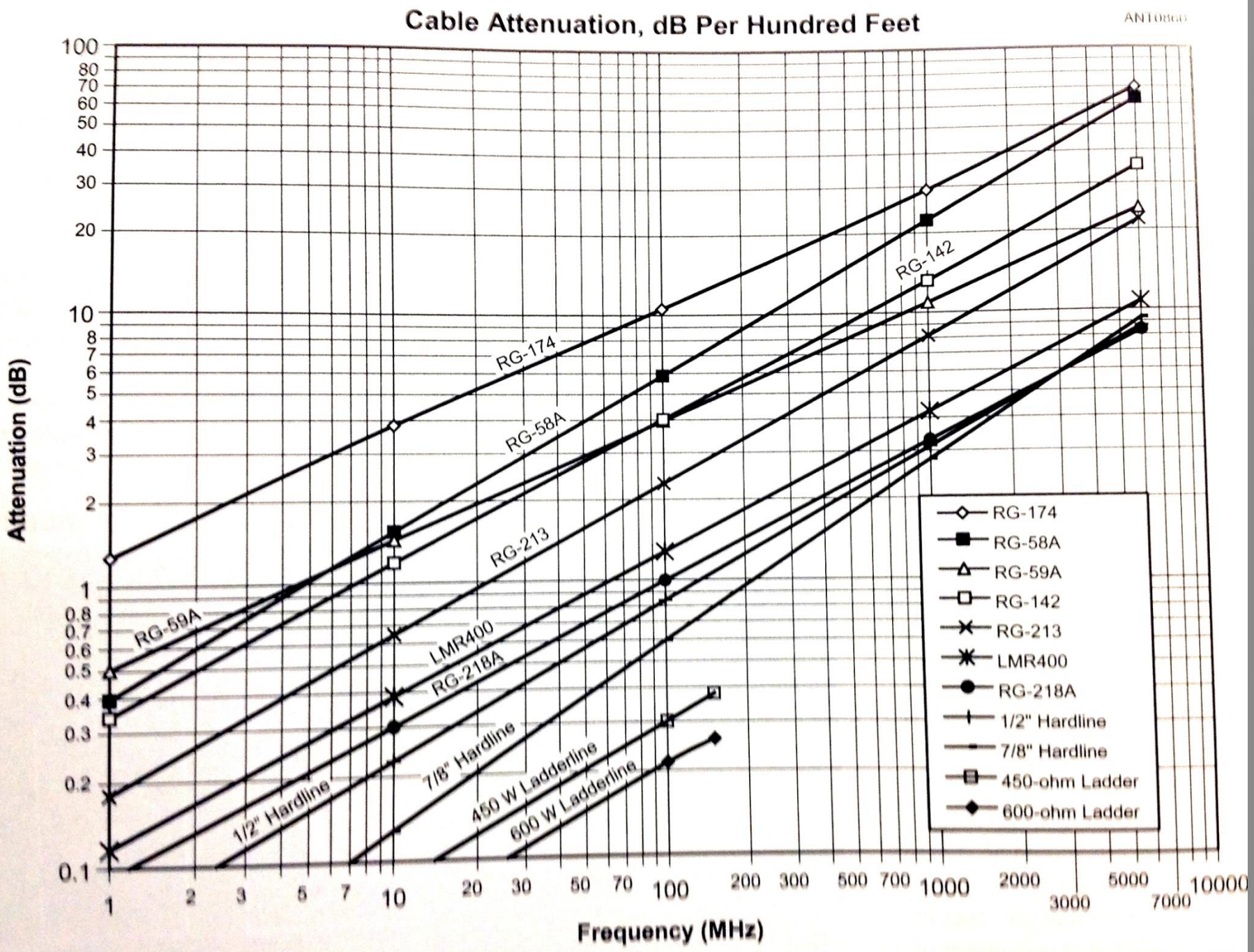
Coaxial (coax) Feed Lines are "unbalanced" (relative to grounded braid)



Why might you need this?



What do we mean by feed line cable “loss” or attenuation?


Cable Attenuation, dB Per Hundred Feet
Attenuation (dB)
Frequency (MHz)
RG-174
RG-58A
RG-59A
RG-142
RG-213
LMR400
RG-218A
1/2" Hardline
7/8" Hardline
450 W Ladderline
600 W Ladderline
RG-174
RG-58A
RG-59A
RG-142
RG-213
LMR400
RG-218A
1/2" Hardline
7/8" Hardline
450-ohm Ladder
600-ohm Ladder

"Loss" is energy converted into HEAT (not radiated)

Attenuation (loss) is measured in

Decibels (dB) per 100 ft

1 dB loss = 20% loss
2 dB loss = 37% loss
3 dB loss = 50% loss
6 dB loss = 75% loss (1 S unit)
10 dB loss = 90% loss (2 S units)

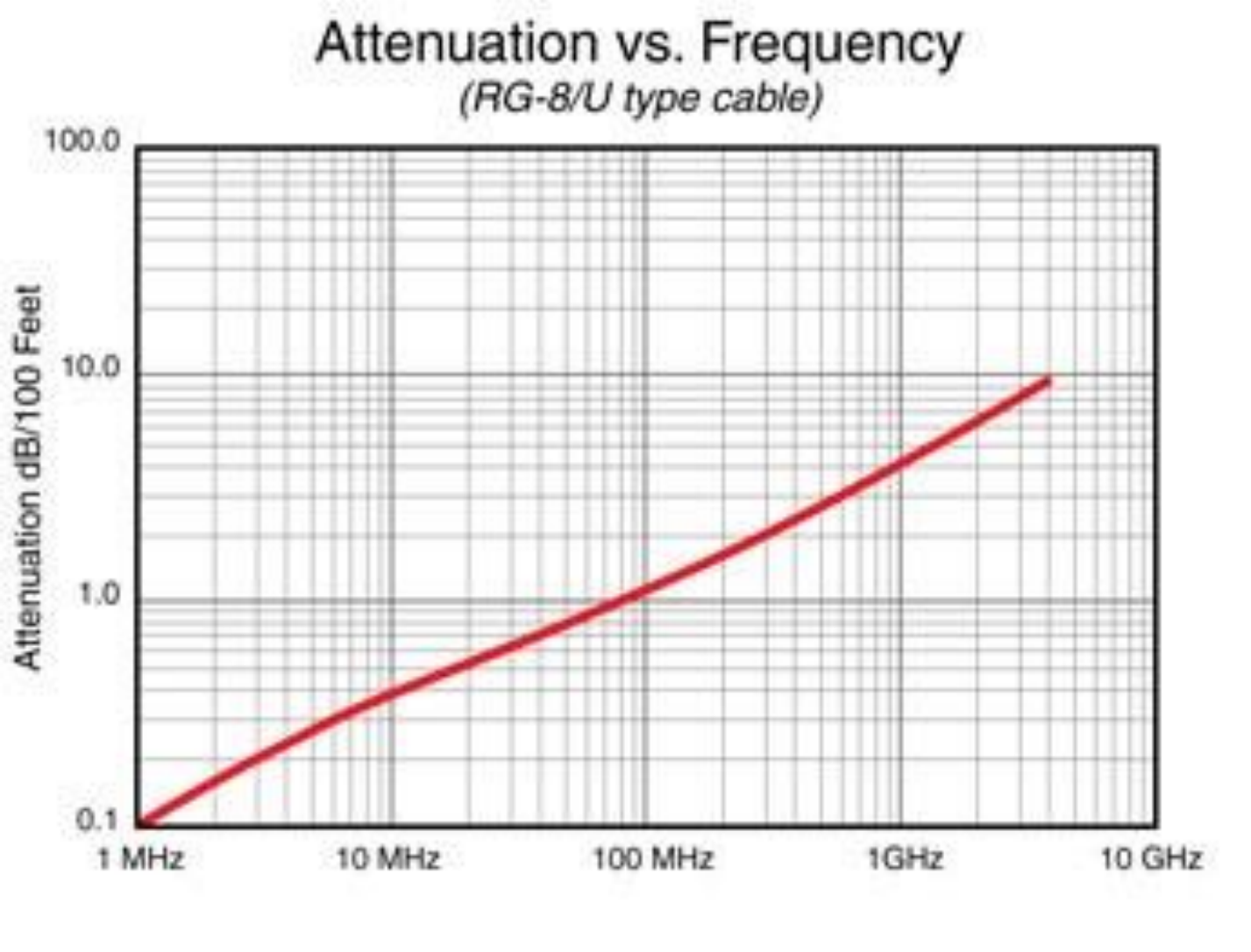
Why does RG-8U have less <u>attenuation</u> than RG-58 & RG-8X

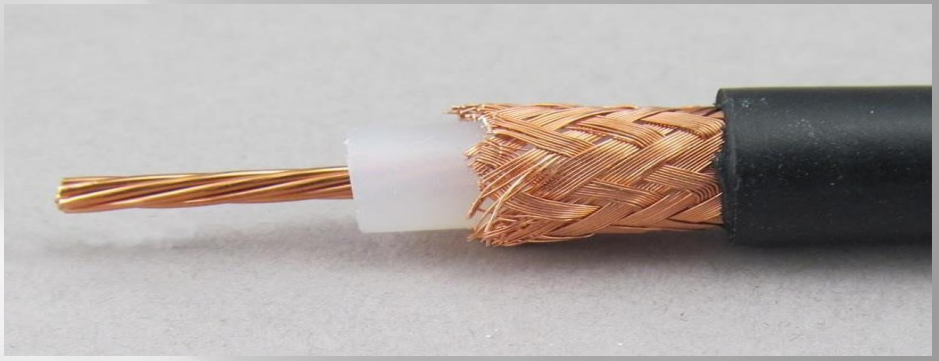
Be careful what you buy !

True or False

Feed line loss always <u>increases with frequency</u>

TRUE
but WHY?


Attenuation vs. Frequency
(RG-8/U type cable)
Attenuation dB/100 Feet
100.0
10.0
1.0
0.1
1 MHz
10 MHz
100 MHz
1GHz
10 GHz



At higher frequencies, conductors behave like a thinner wire (skin effect) and so have <u>greater resistance</u>

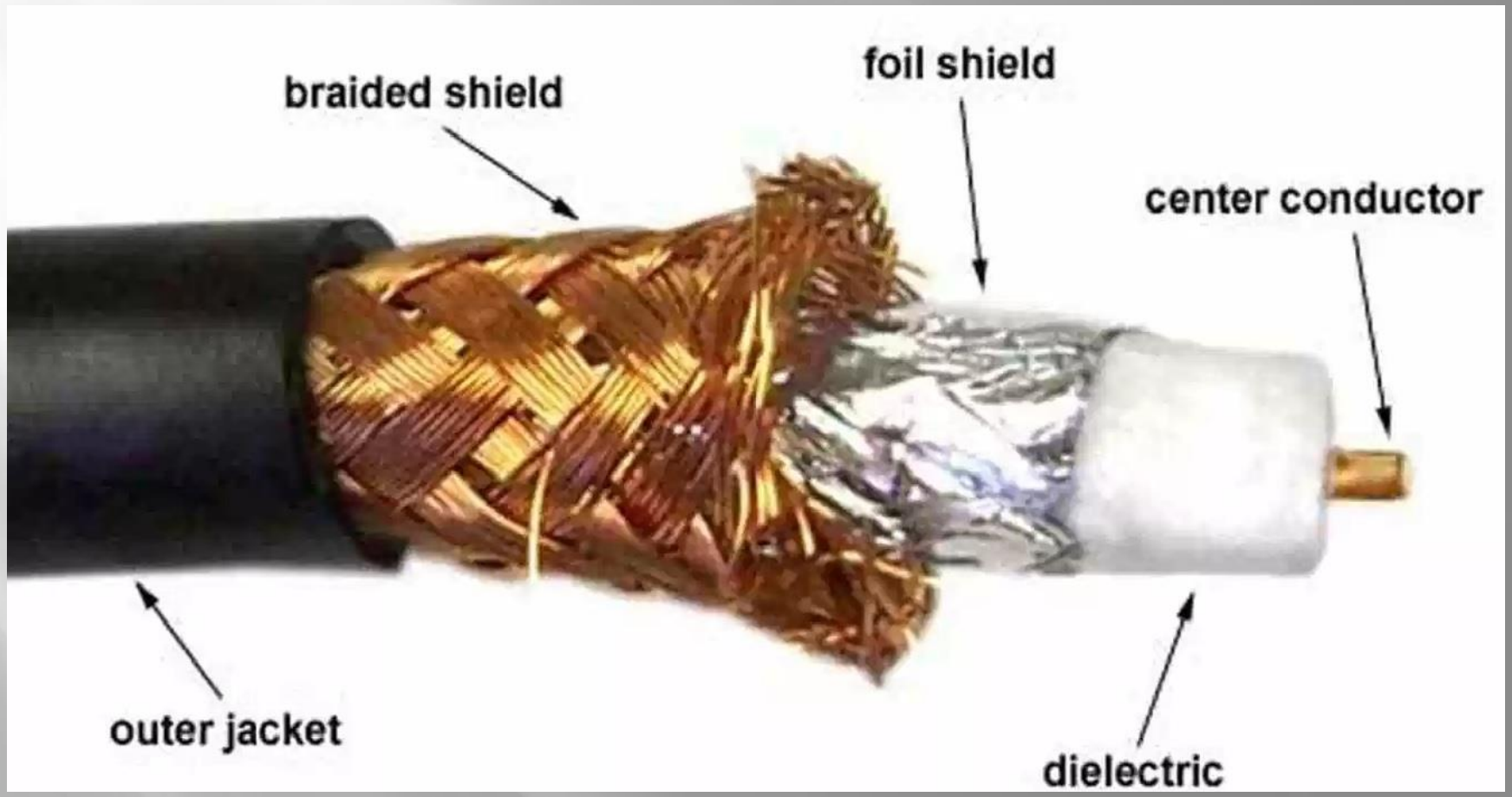
The loss inside the <u>dielectric</u> insulator increases as the frequency increases

Both kinds of losses result in **<u>HEAT</u>**

Why does “thin” coax (RG58) have more attenuation than “thick” coax like RG8

Why is ‘hardline’ a superior type of cable for UHF ?

When might you need this kind of high quality coax?



What is meant by
the term
RESONANCE?

(check with your neighbor)

time for some sound demos

Important Terms in electric circuits with an alternating current

Resistance

Reactance

Impedance

Inductive Reactance increases with frequency (magnetic fields)

Capacitive Reactance decreases with frequency (electric fields)

So at SOME frequency, might these two be equal?

Resonance

Resonance: a condition in any circuit where the inductive reactance and the capacitive reactance are <u>equal in value and opposite in sign</u>: $X_L = X_C$

Thus, the "impedance" of the circuit is that of a <u>pure resistance</u>: $Z = R$ (ohms)

WHAT DOES ALL OF THAT MEAN ?

(raise your hand if you really understand this)

Resonance Formula

Inductive reactance = Capacitive reactance

$$X_L = X_C$$

2 pi f L = 1 / (2 pi f C)

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

What is meant by the "resonant" frequency of a simple dipole antenna ?

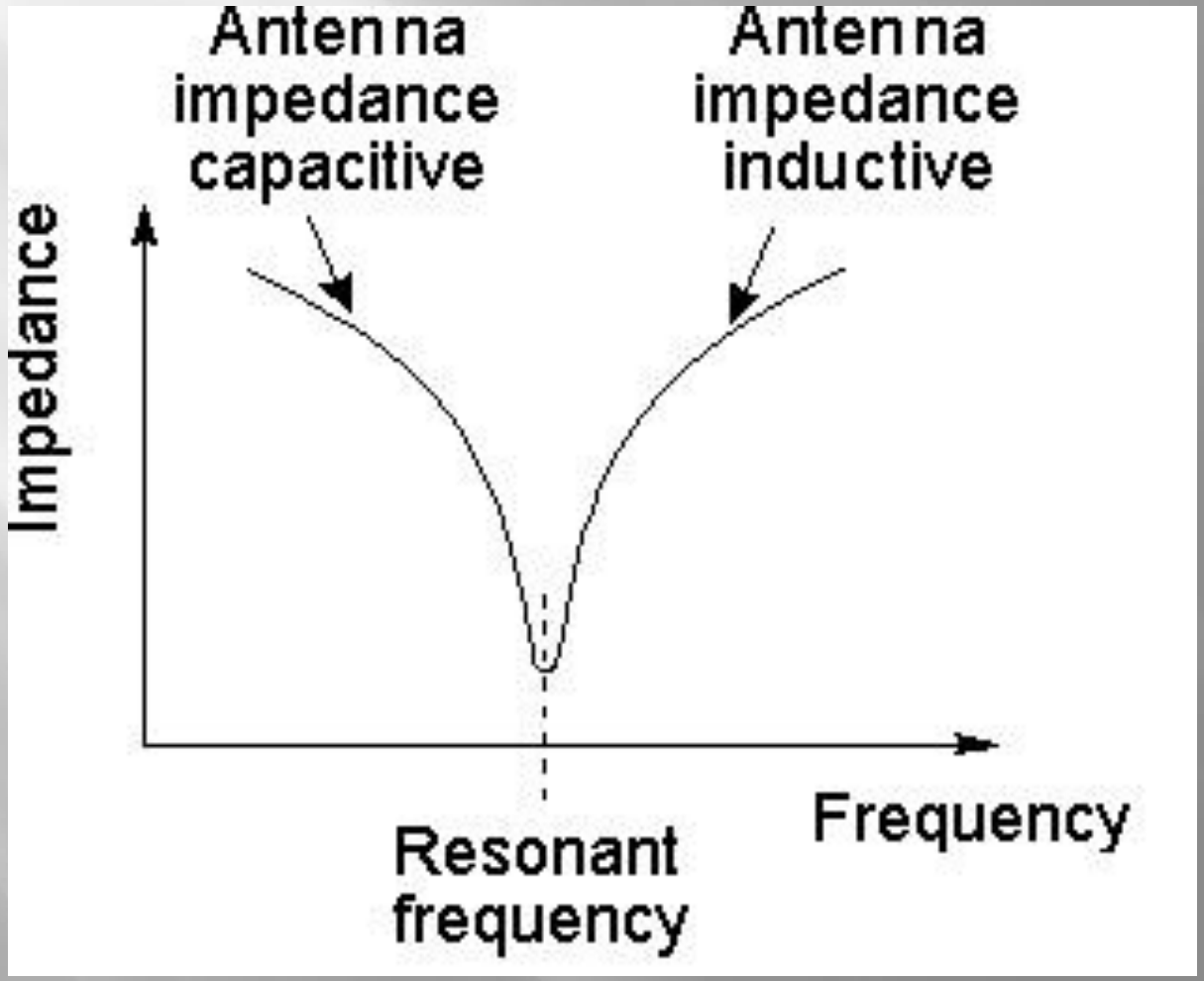
Resonance of an Antenna

At the feed point, the current and voltage are "in phase" at resonance.

The "impedance" (Z) <u>at the feed point</u> at that frequency is just a pure resistance

$$Z = V / I \quad \text{(ohms)}$$

The dipole has capacitive reactance at frequencies below resonance and inductive reactance at frequencies above resonance. At resonant frequency reactance is ZERO



True or False (tricky)

At a <u>non-resonant</u> frequency the voltage and current are no longer "in phase" and the antenna exhibits either

capacitive reactance - antenna too short
inductive reactance – antenna too long

The **impedance** of the antenna at the feed point is no longer purely resistive, and may be a poor match to 50 ohm coax

Your **SWR** may **<u>either rise or fall</u>**

What determines the "resonant frequency" of a wire dipole antenna?

Its length?
Its feed point location?
Its thickness?
Its color?
Its height above ground?

Half-Wave Dipole in space (the simplest antenna)

$$\text{Resonant length} \quad L = \frac{468}{f} \quad \text{in feet}$$

80 meters: half-wave 40 m = 120 feet

40 meters: half-wave 20 m = 65 feet

2 meters: half-wave 1 m = 38 inches

True or False

Antennas can only work well at their resonant frequency

(check you neighbor)

FALSE

Antennas can have a high efficiency as long as their "**radiation resistance**" is a significant percent of their overall resistance

A "long wire" (>100 ft) is a good HF antenna that can work well on many HF bands with a tuner in the shack (tune out the reactance)

A balanced 130 ft long center-fed antenna fed with loss low 450 ohm window line is a good overall HF antenna with a decent tuner in the shack

True or False

A Half-Wave dipole fed at the center that is $\frac{1}{2}$ wavelength above ground

has a current maximum at the center
has a voltage minimum at the center
has an impedance close to 50-70 ohms
is easy to match to common coax

TRUE

True or False

A center-fed 80m dipole 130 ft long has the

same resonant frequency

as an end-fed dipole of the same length and same height above ground

TRUE

The resonant frequency does NOT depend on where the feed line attaches to the antenna

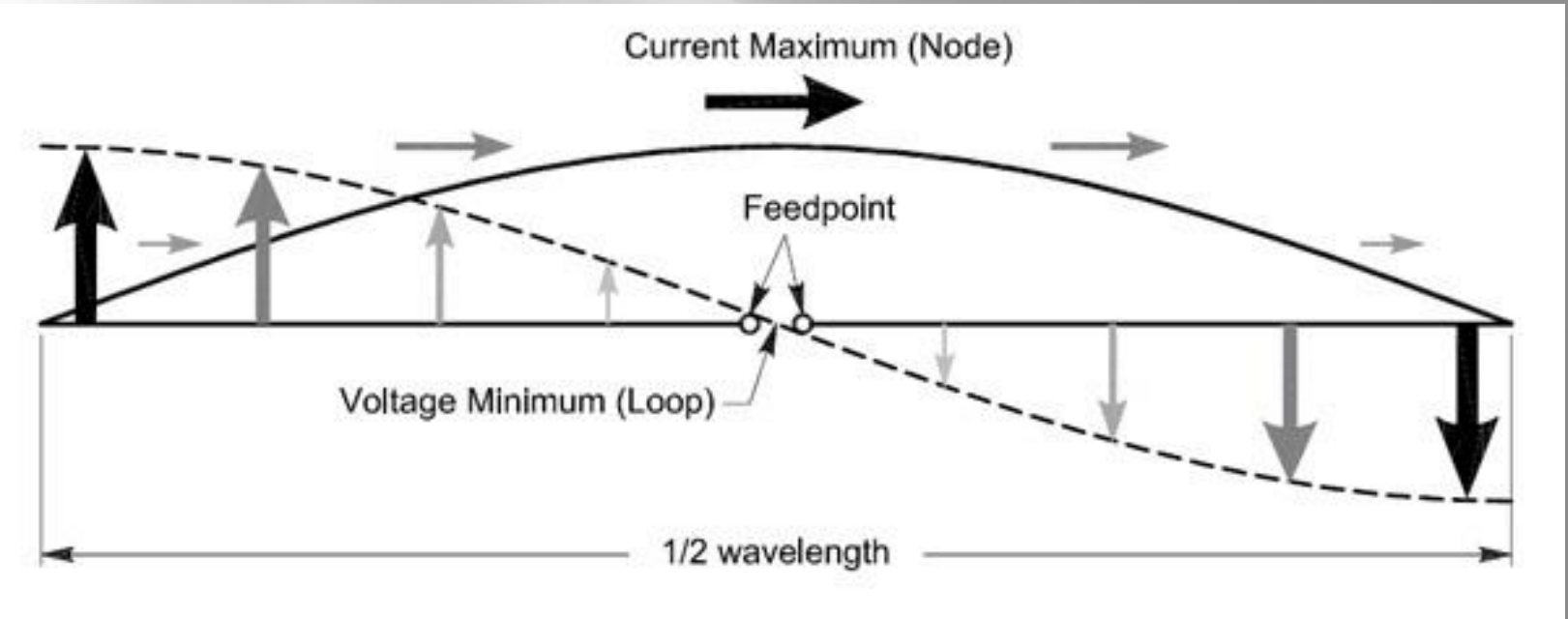
True or False

A half-wave dipole radiates mostly in the **center 50%** of the antenna and very little radiation comes off the ends of the dipole

TRUE

Radiation is maximum where current is maximum: at the <u>center</u>

Radiation is minimal at the ends



True or FALSE

The resonant frequency of a dipole depends on WHERE you attach the feed line?

FALSE

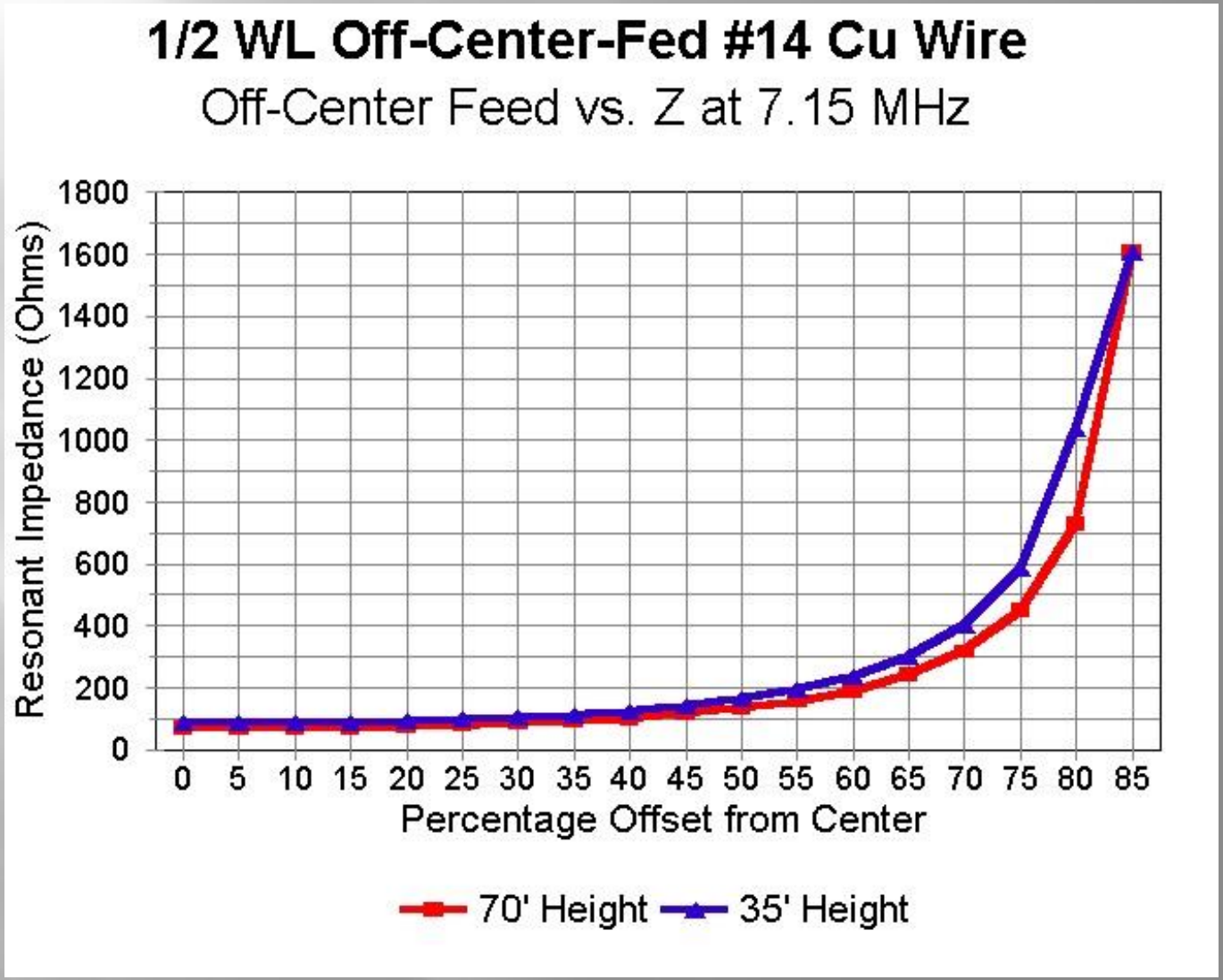
The resonant frequency
is determined by the length of the
antenna and any nearby conductors
including earth ground

True or False

The "impedance" of a half-wave dipole antenna depends on where you attach the feed line

TRUE

~50-70 ohms at center to very high values at the ends

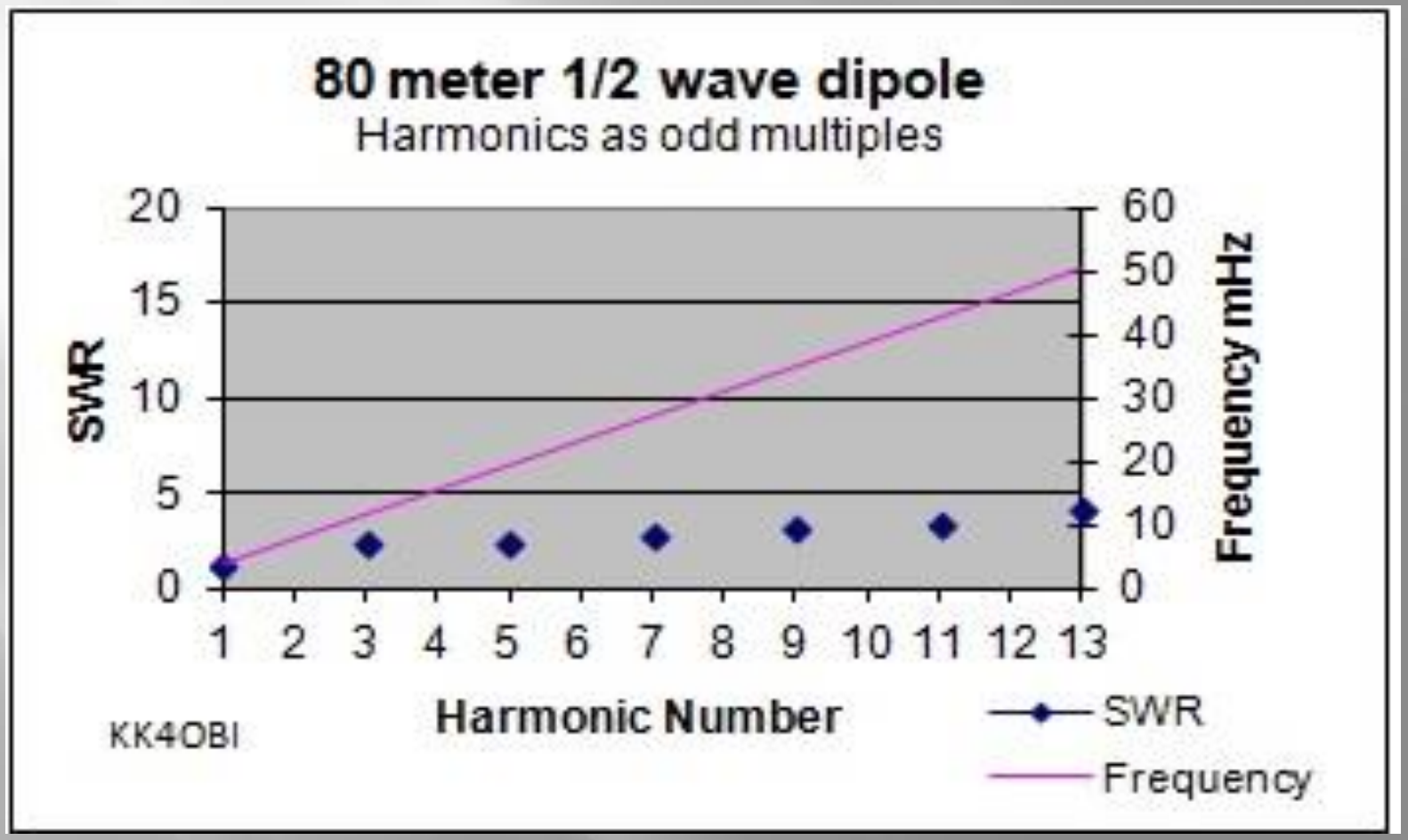


True or False

Wire antennas fed at the center will be "resonant" on the fundamental frequency f and all of the ODD harmonics: **3f, 5f, 7f**

TRUE

Dipoles fed at the center are resonant at the fundamental frequency, and at <u>ODD</u> harmonics of the fundamental frequency



Multiple Resonance Dipoles

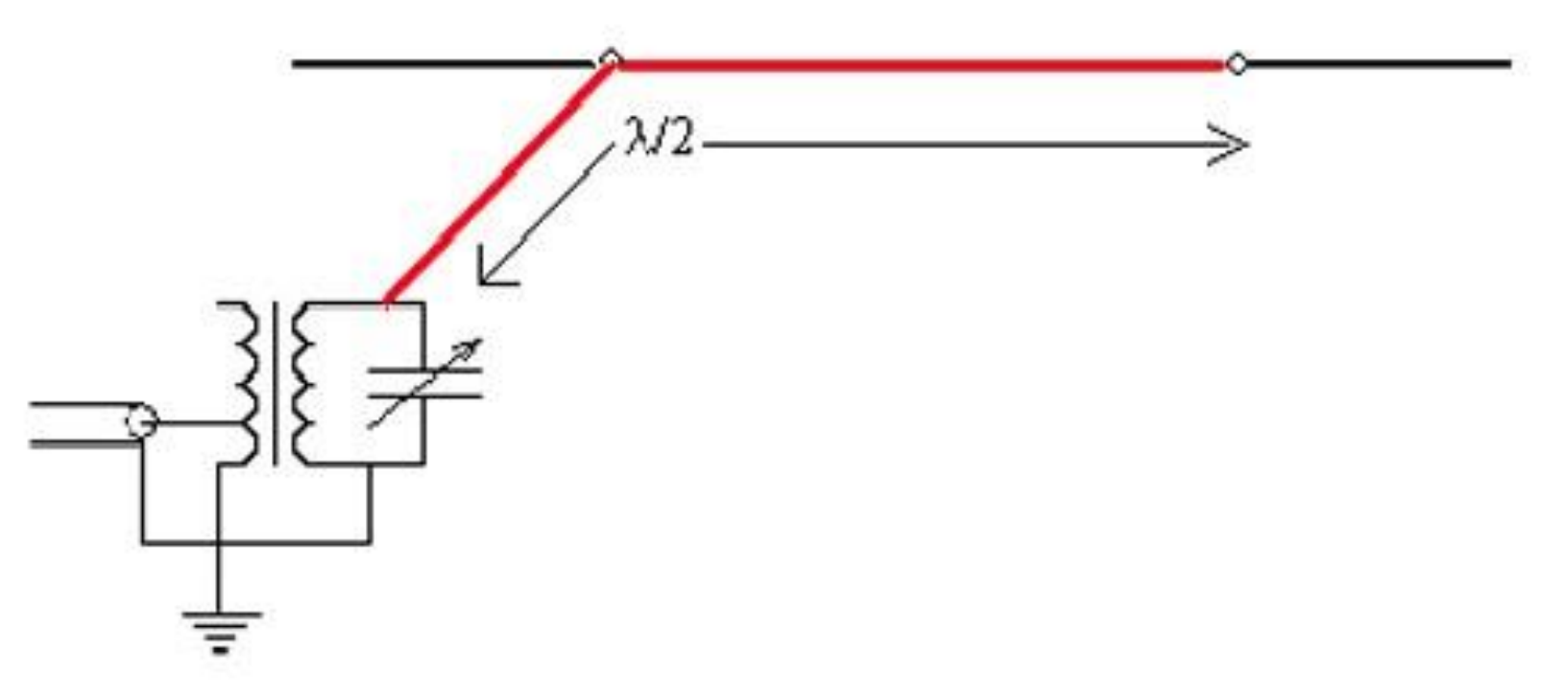
This is why a 40m ½ wave dipole (66 ft) works quite well at 15m where it behaves like a 3/2 wavelength antenna and shows an impedance close to 70 ohms

I have used a 40 meter dipole on 6 meters, where the dipole behaves like a 7/2 wavelengths long antenna

ODD multiples of ½ wave show low impedance

True or False

An **end-fed half-wave** dipole is resonant at its fundamental frequency **f** and at both the odd and even harmonics: **2f, 3f, 4f, 5f, etc.**



TRUE

True or False

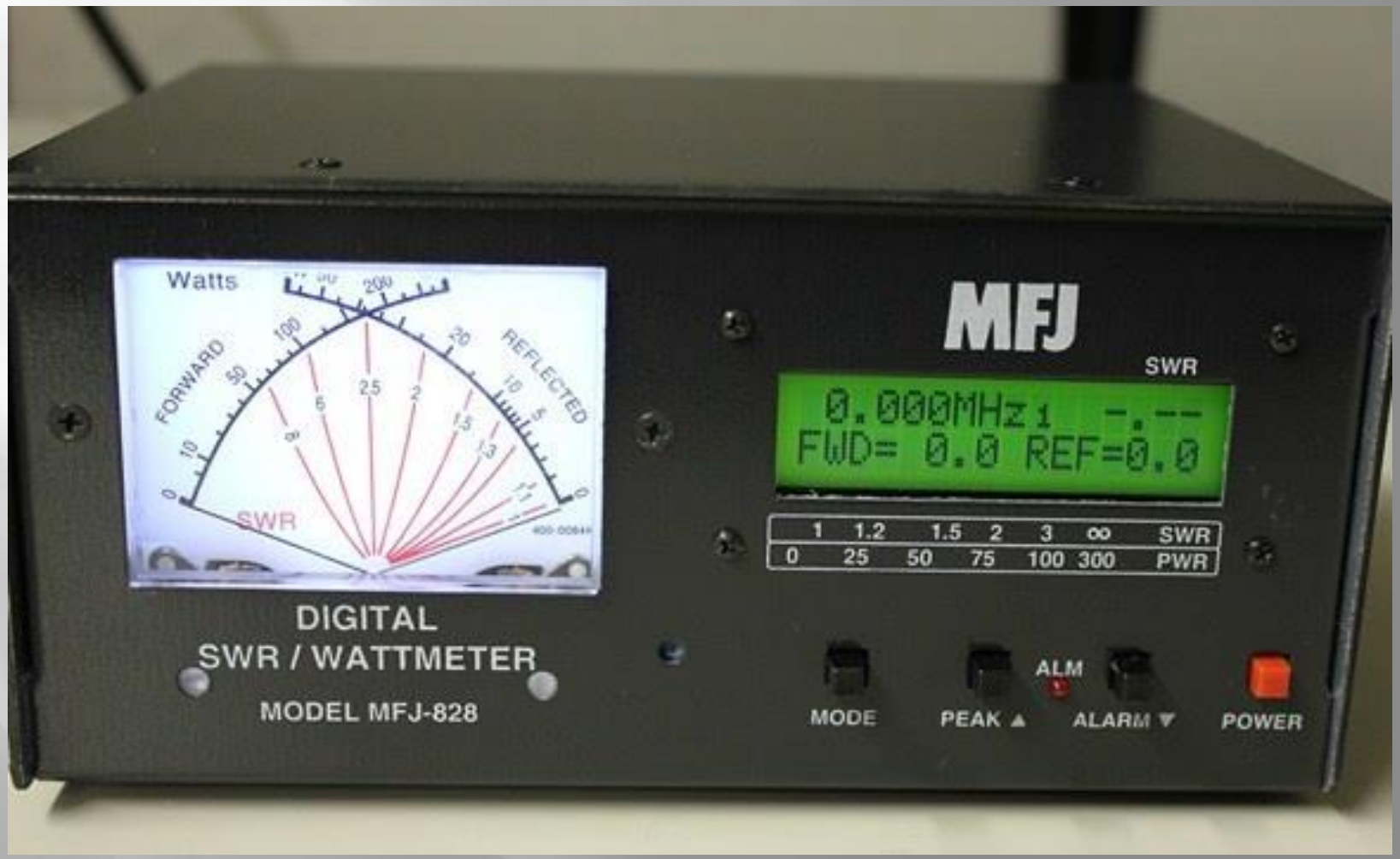
One-Quarter wave mobile antennas with a "mag mount" use the metal car body as the other half of the antenna

TRUE

unless your mag mounted antenna is a ½ wave antenna

Do you own an SWR meter?

How about a "digital display" ?



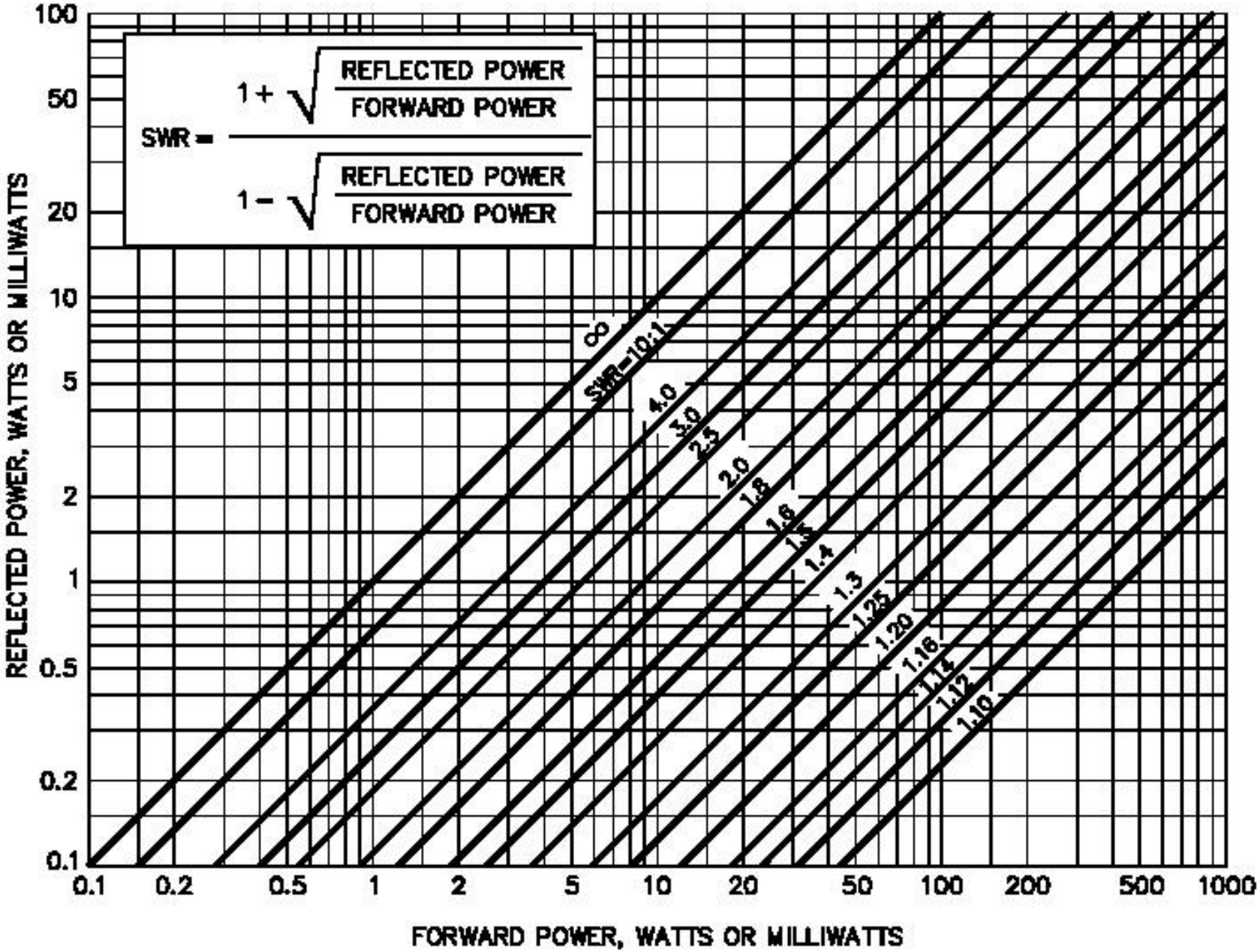
True or False

The SWR is a measure of how well the antenna accepts power delivered to it by the feedline

SWR is determined by the forward power compared to the reflected power

SWR tells you how well the feed line is matched to the antenna as a load

1:1 is a perfect SWR (zero reflected power)


SWR = (1 + √(REFLECTED POWER / FORWARD POWER)) / (1 − √(REFLECTED POWER / FORWARD POWER))
REFLECTED POWER, WATTS OR MILLIWATTS
FORWARD POWER, WATTS OR MILLIWATTS
100
50
20
10
5
2
1
0.5
0.2
0.1
0.1
0.2
0.5
1
2
5
10
20
50
100
200
500
1000
∞
SWR=10:1
4.0
3.0
2.5
2.0
1.8
1.6
1.5
1.4
1.3
1.25
1.20
1.16
1.14
1.12
1.10

Operating with a non-resonant antenna on HF

What can you do in your shack to allow your non-resonant antenna

1) to accept power from the transmitter
2) to get an acceptable SWR at the rig
3) to radiate RF from the antenna

An “antena tuner” (of course)
But do they change the SWR <u>at the antenna</u>?

This one is called an antenna “matching network”

Heathkit HF Antenna Tuner note two capacitors, 1 inductor

How do these devices allow your transmitter to “see” 50 ohms resistive?

Antenna Matching Units

They all work by providing a

"conjugate match"

at a junction using capacitors and inductors

R + jX is matched by R – jX

The reactance cancels

The IMPEDANCE the transmitter sees is a pure resistance (hopefully 50 ohms)

True or False

By providing a "conjugate match" in your shack the antenna tuner takes the reflected wave coming back from the antenna and

RE-REFLECTS

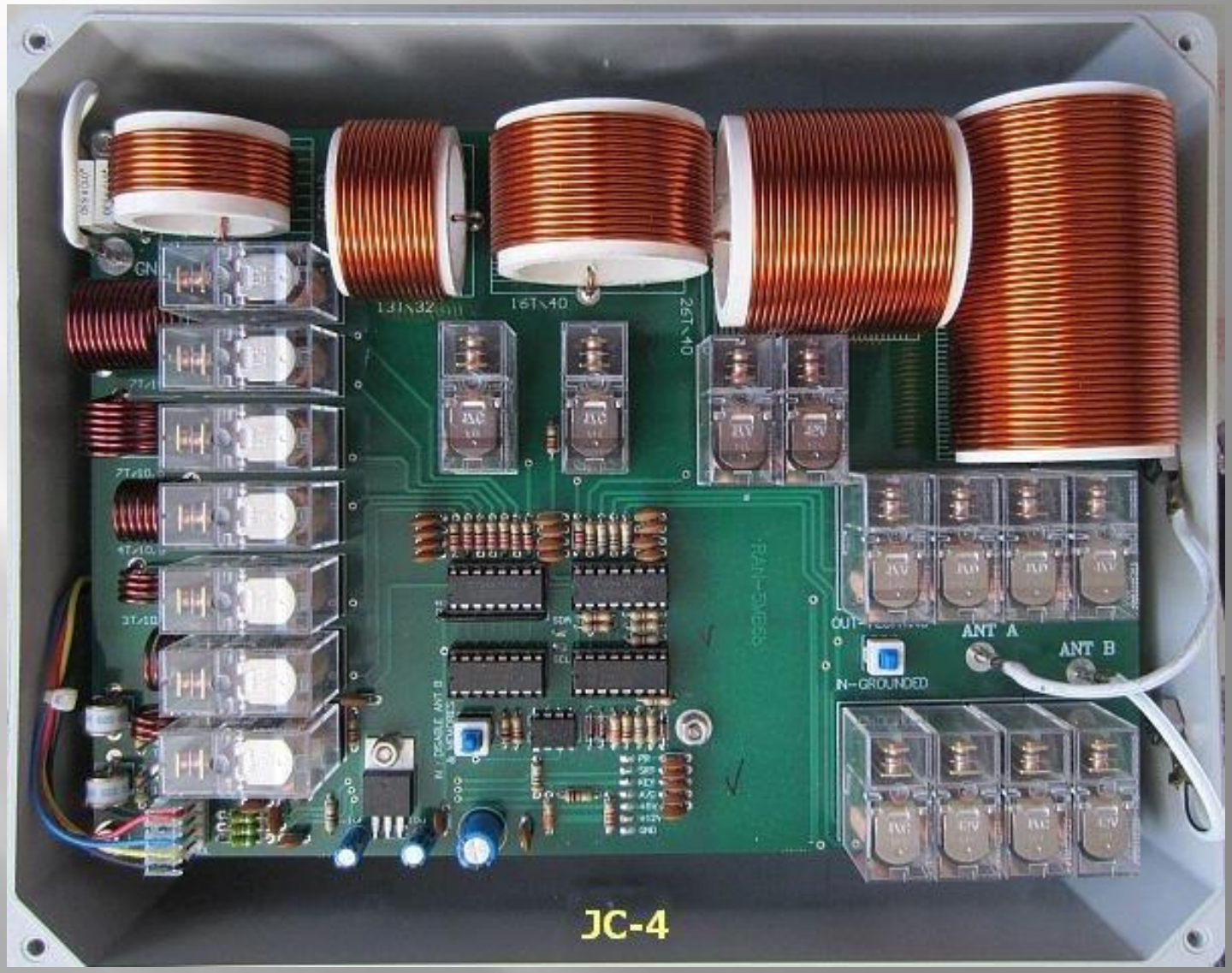
this wave back in the direction towards the antenna

TRUE

A "reflection GAIN" (at the tuner) offsets the reflection "LOSS" (at the antenna)

Additional loss in the coax due to a high SWR <u>may</u> result in some additional significant loss

Inside look at an automatically tuned antenna “tuner” (coils & capacitors)



True or False

If the line attenuation is really **ZERO dB**

then you can place an antenna tuner
either right at the antenna
or
inside the shack

It makes no difference in terms of radiated energy

TRUE

The only loss by placing an antenna “tuner” in your shack is the **additional loss** in the feed line produced by an SWR > 1:1

The antenna tuner IN YOUR SHACK does NOT alter the SWR on the feedline

The tuner simply gives your rig a 50 ohm resistive load to deliver full power

How much Loss is "OK" ?

I have a 80m dipole cut for 3800 kHz fed with 100 ft of RG213 coax (good quality)

The loss is about **<u>0.5 dB attenuation/100 ft</u>**

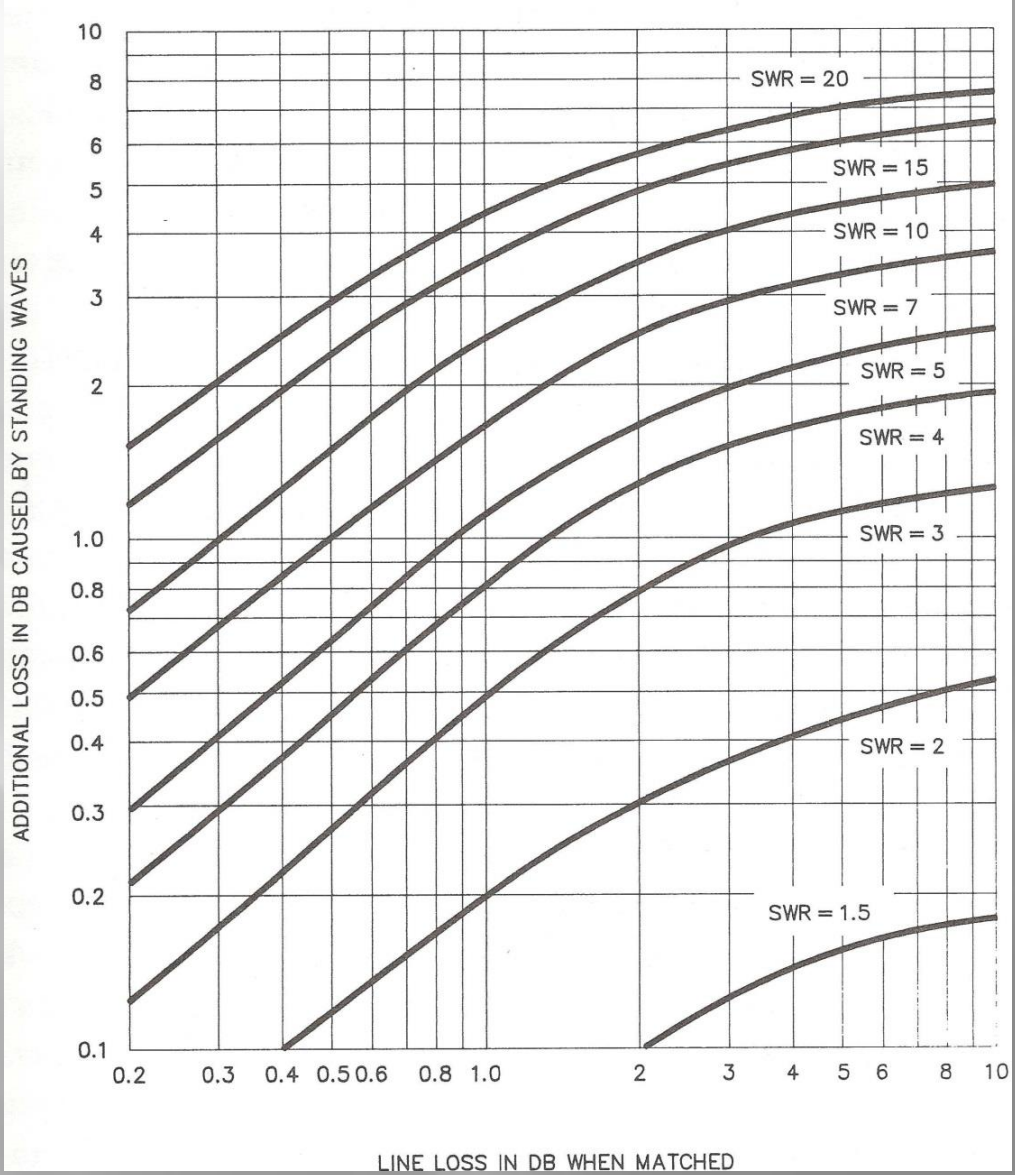
The SWR is close to 1:1 at 3800 kHz

but the SWR

Rises to 5:1 at 3500 and 3990 kHz

Can my "tuner" in the shack allow my antenna to radiate efficiently?

With a 5:1 SWR the additional loss in 100 ft of RG213 on 80m is only 1 dB (20%)



Conclusion

On 80 meters, with 100 ft of good quality coax such as LMR 400 or RG213

If your SWR meter reads 5:1 in your shack

And if you can adjust your antenna "tuner" such that the rig "sees" 50 ohms and can deliver full power to the feed line

THEN Your "extra" loss with the high

5:1 SWR is only **1 dB more** loss than if you had a 1:1 SWR on your 100 ft feed line

True or False

The **impedance** of a half-wave horizontal dipole will LOWER as you get very close to the ground

True: my 80m dipole 20 ft above ground shows an impedance of about 20 ohms

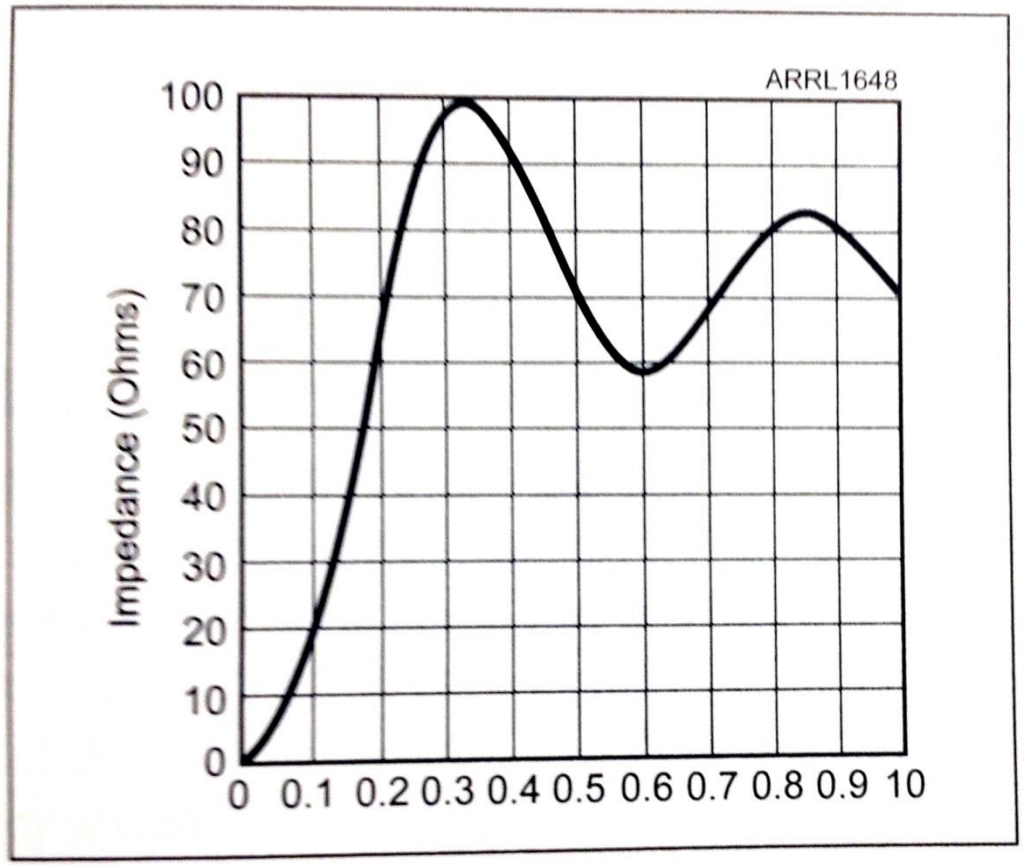


Figure 4 – A prediction of the variation of the feed point impedance of a standard half wave dipole fed at the center.

Bandwidth

What determines the
"bandwidth"
of an antenna?

Bandwidth of an Antenna

Bandwidth is often referred to as the frequency range (in kHz or MHz) yielding 2:1 SWR limits in an antenna

The bandwidth of an antenna is related to the diameter of the conductor compared to the wavelength, and to any other nearby conductors such as parasitic elements (director/reflector) in a Yagi beam or a Quad

True or False

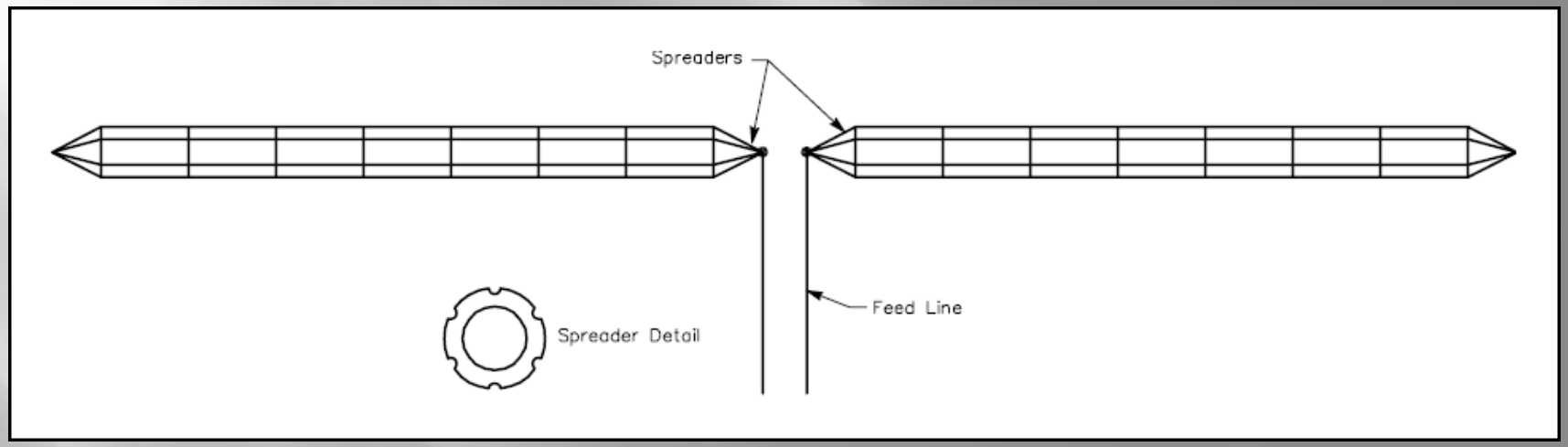
Bandwidth is <u>reduced</u> when "loading coils" or "traps" are used to shorten an antenna's physical length

"Hamsticks" and Hustler (7 ft) mobile antennas have a very narrow bandwidth on 80m and 40m due to their small length (in terms of wavelength)

Larger diameter conductors yield a wider bandwidth

Multiple conductors (wires) in a cage simulate a thicker wire and increase the "bandwidth" of a dipole antenna

This is commonly done for 80/75 meters

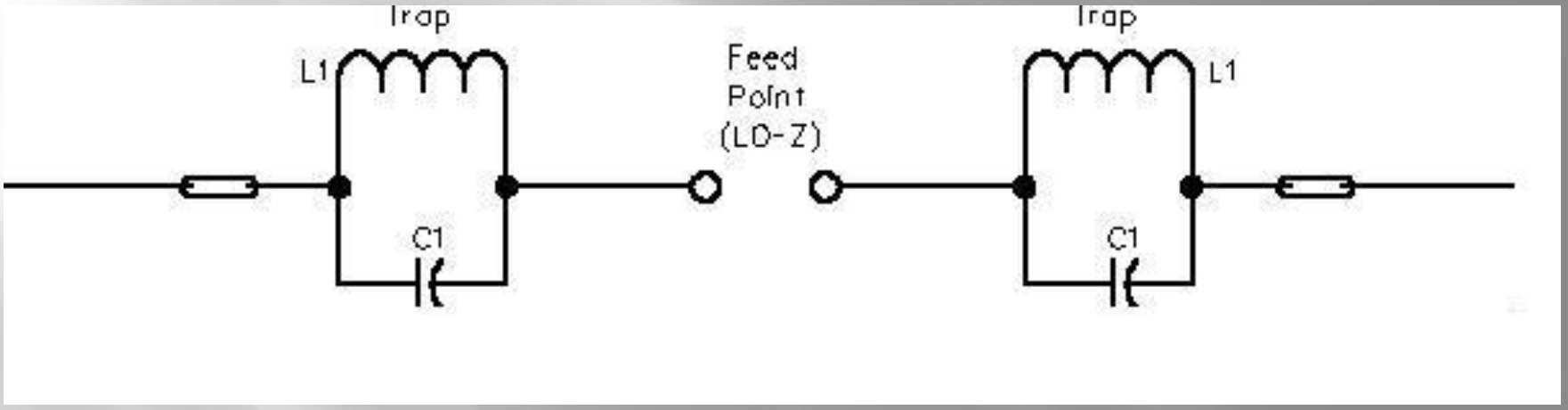


What is this device?

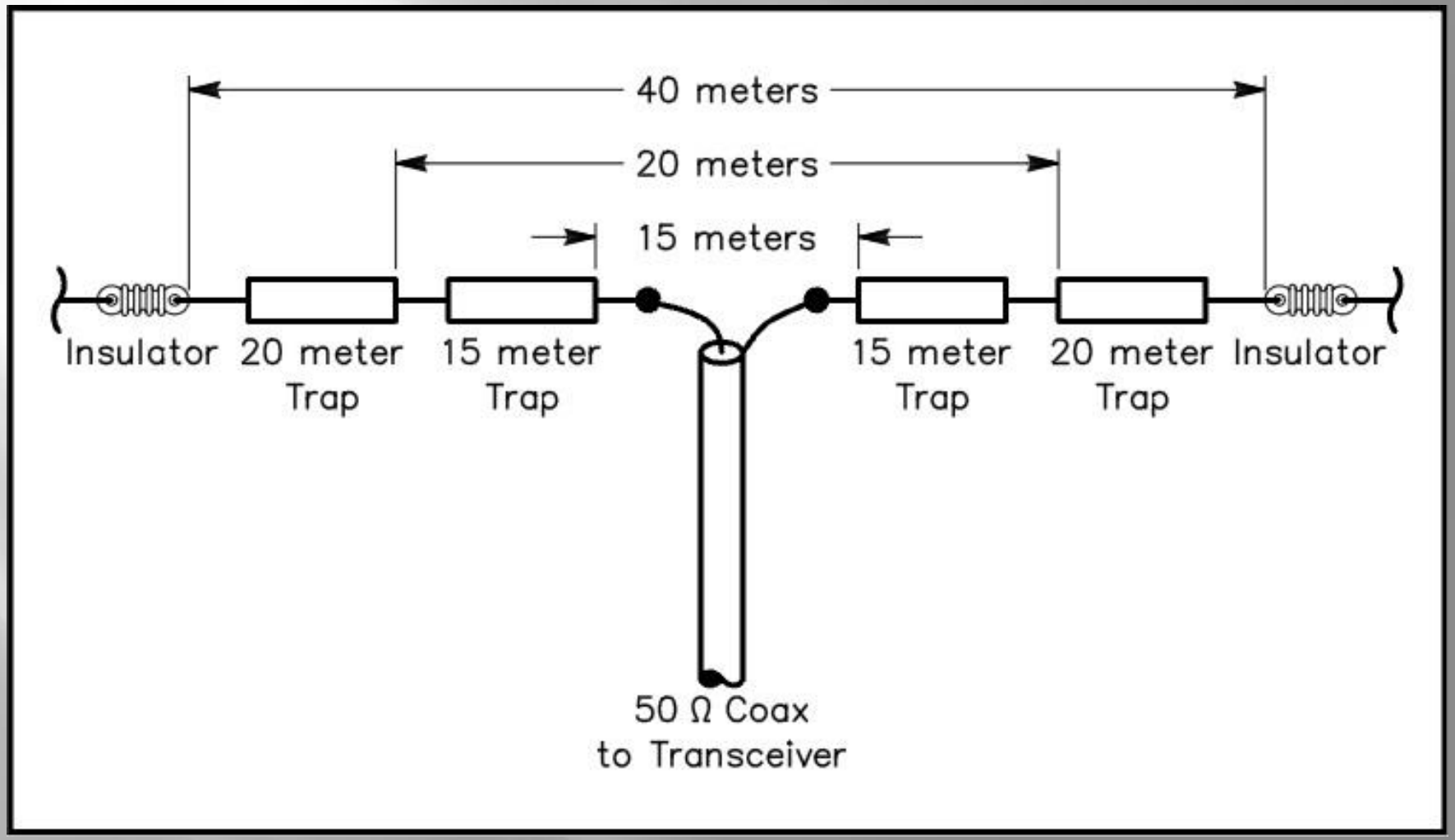
TRUE or FALSE

Traps (parallel LC circuits) can provide <u>multi-band</u> operation with one antenna?

The parallel LC circuit has a high impedance at resonance



Two traps for each band results in 3 bands in one dipole



NO TIME TO DISCUSS BEAMS, YAGI AND QUADS

THE END