CENTRAL IDAHO AMATEUR RADIO CLUB

serving our community since 1982

SWR

standing wave ratio

standing wave ratio (SWR)
is a complicated subject

calculating SWR requires
complex measurements and mathematics

this presentation is intended as an introduction
to the basic principles behind SWR as it
applies to amateur radio

the underlying principles of SWR and how it applies to RF propagation apply equally to all segments of the amateur radio spectrum as well as all types of station installations

what is SWR?

why does it matter?

how do we measure it?

some important terms

forward power

reflected power

resonant frequency

impedance

standing wave

VSWR

SWR

forward power

the power sent through a
transmission line to a load

in real-world conditions,
the transmission line and antenna do
not consume all the
forward power that reaches it

reflected power

occurs when an impedance mismatch is present in a transmission line

as the signal reaches the load, some forward power is sent back toward the signal source the presence of reflected power in a system will negatively impact the performance of the transmit capabilities

some amount of reflected power can be found in any working RF system

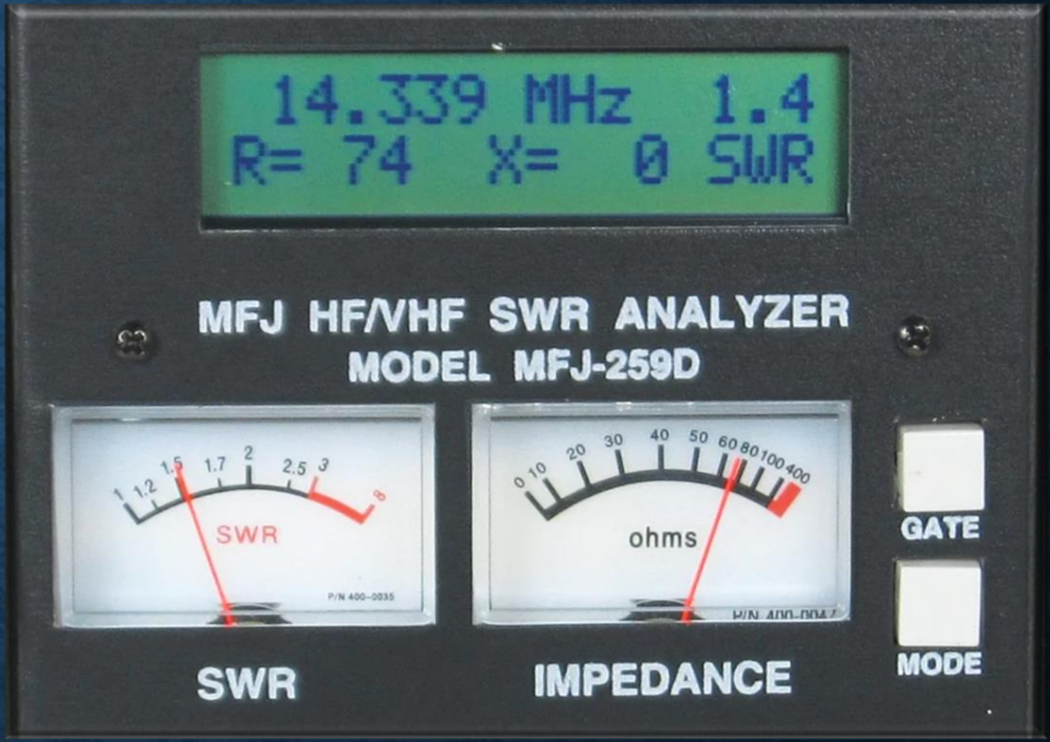
impedance (Z)

opposition to alternating
current flow

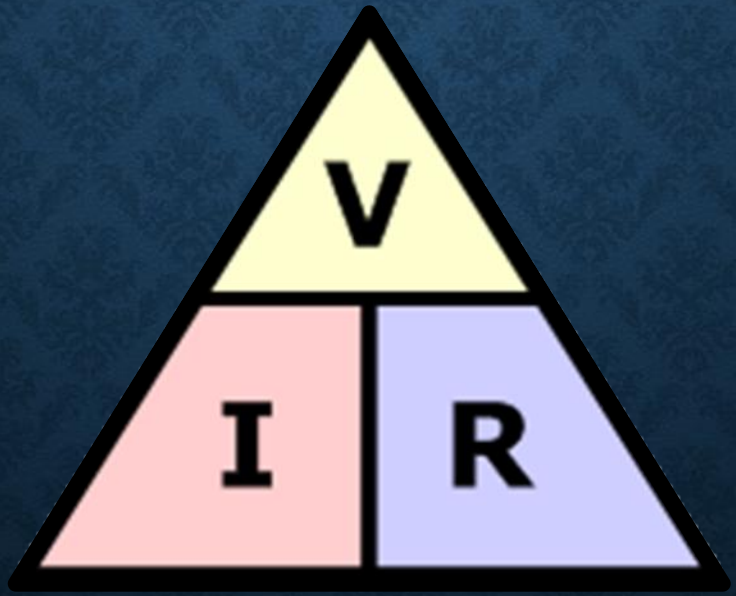
impedance and resistance
are the same principle

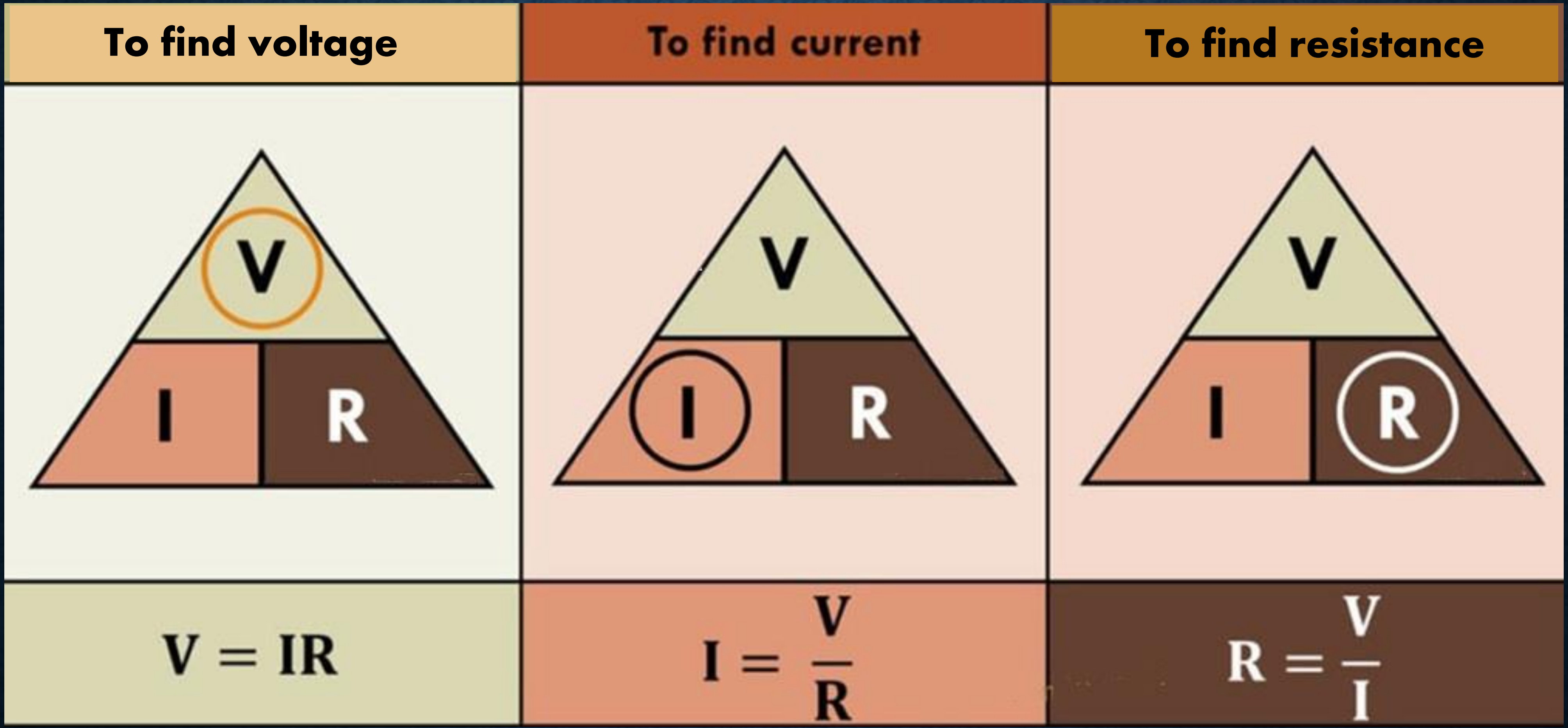
both are expressed in ohms Ω

impedance (Z)
includes both
resistance (R)
& reactance (X)



impedance & resistance are both defined as voltage across an element divided by the current





To find voltage
V
I
R
V = IR
To find current
V
I
R
I = V/R
To find resistance
V
I
R
R = V/I

in an ideal system, 100% of the signal energy is transmitted

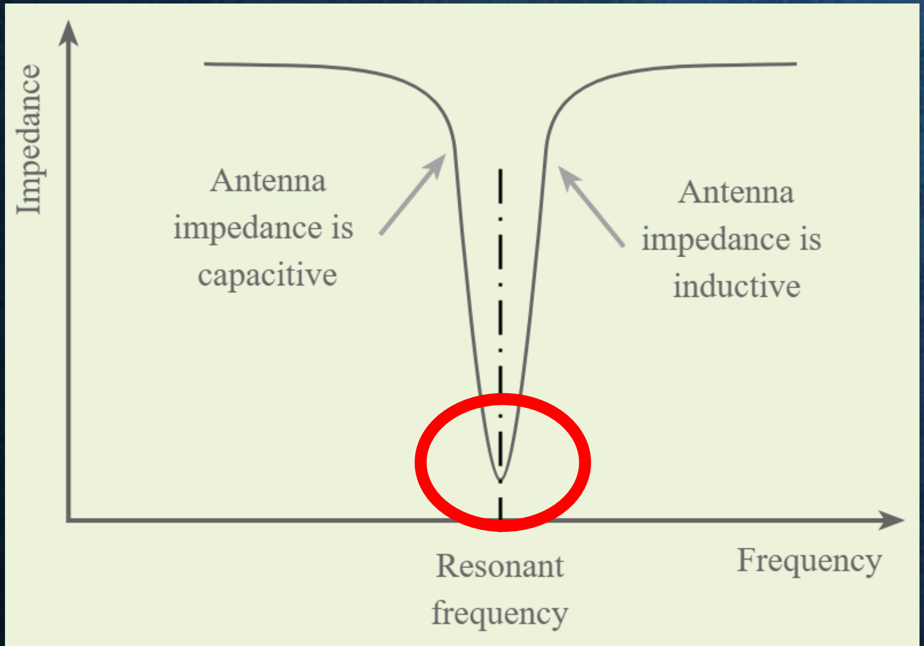
this requires an exact **impedance match** between the source, transmission line and all components in the line including the load

measuring SWR is easiest way to tell if the system impedance is acceptable ideally, an antenna is purely resistive and its reactance (X) is zero, hence the maximum amount of current flows through the antenna

the antenna is **resonant**

the exact resonant frequency of an antenna is not always the lowest SWR point shown

feedline characteristic may influence the antenna resonant point the antenna's resonant frequency occurs at the point where capacitive and inductive reactance cancel each other out



here is where reactance value

X = 0

how did we get from here…

…to here ?

we put a dummy load--which has
no RF output--on the analyzer
to make the point

a perfect SWR does
not make a perfect antenna unless there
is perfect reactance

$$X = 0$$

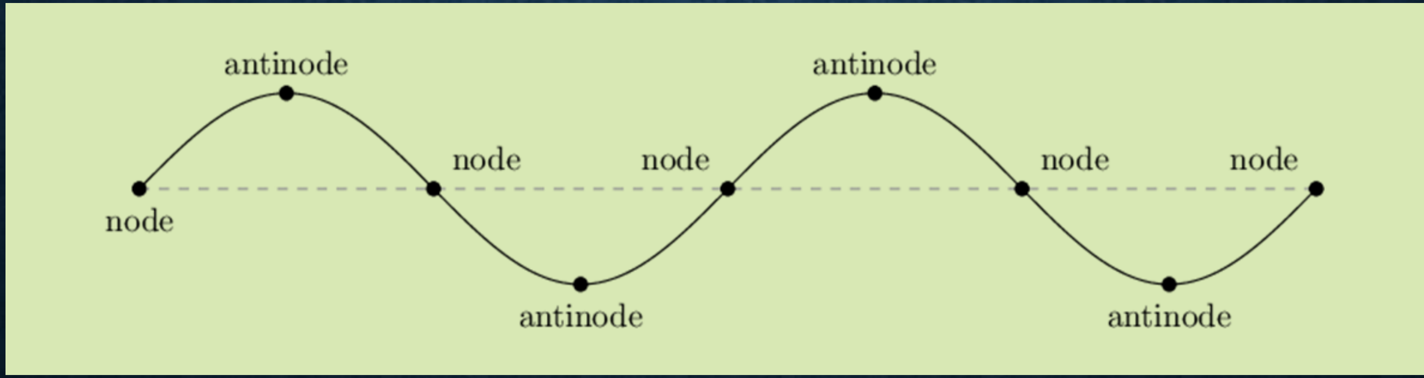
the relationship between SWR & resonant frequency will be covered in our next session on how to use an antenna analyzer

standing waves

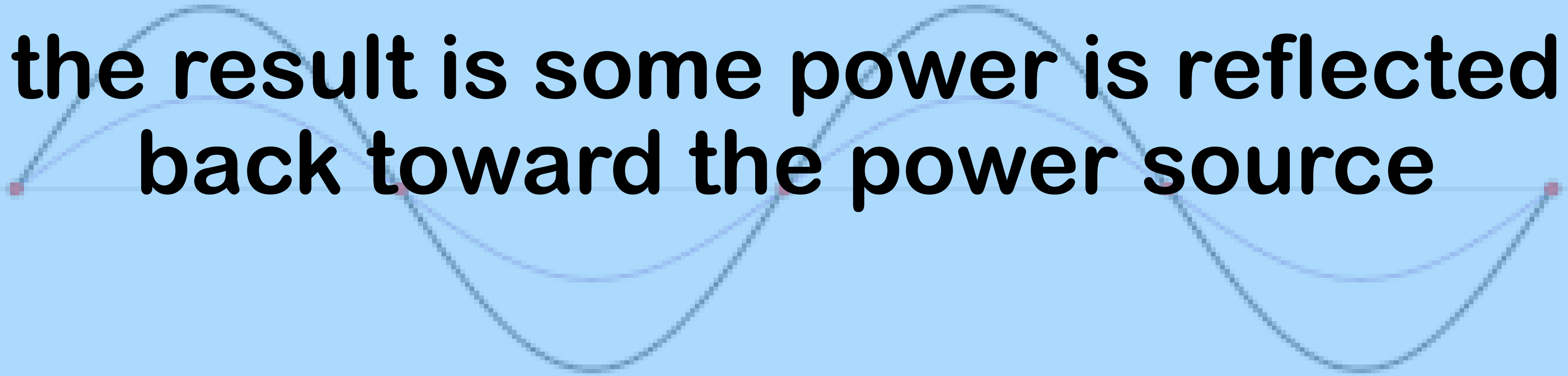
a standing wave will be found on any system where an impedance mismatch is present

these unwanted waves affect transmission efficiency and reduce the power that finally gets transmitted standing waves are so-named because theoretically, they appear on the transmission line in a fixed place

the components of standing waves are nodes and antinodes

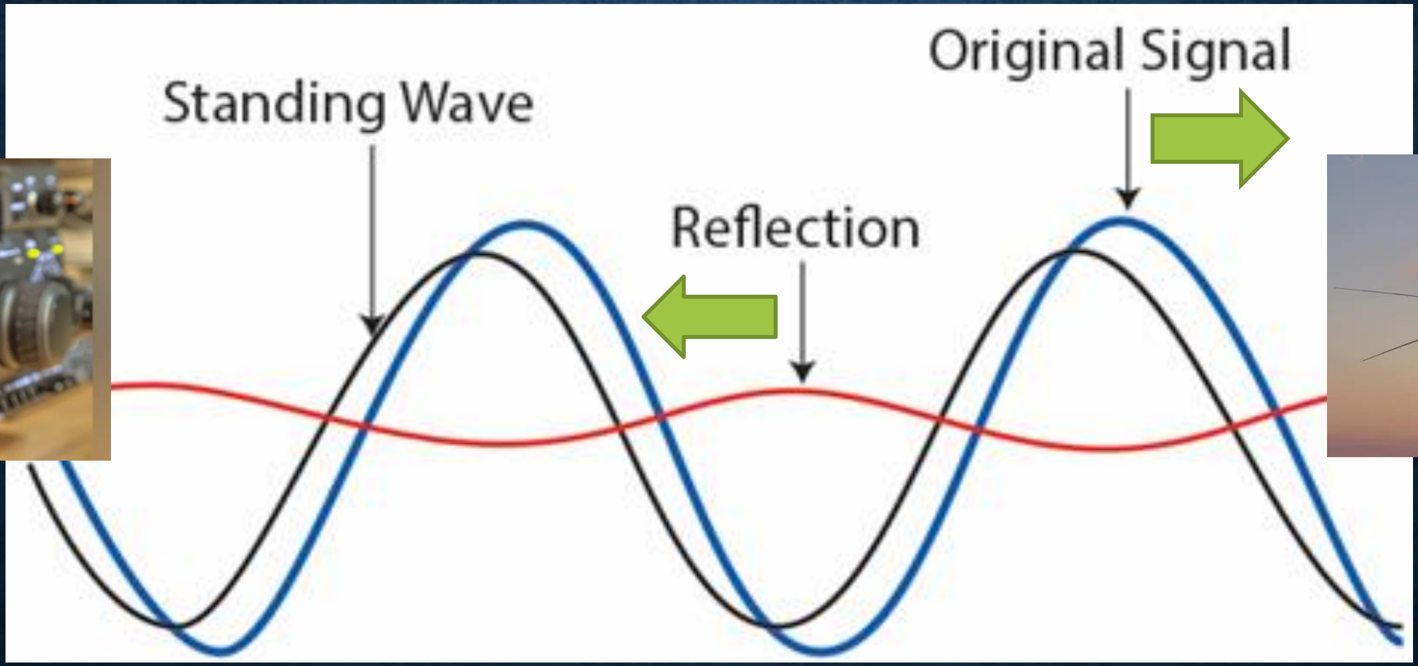


a standing wave is created when power transmitted through a line encounters a mis-match in impedance



the result is some power is reflected back toward the power source

reflected power creates standing waves and is the cause of high SWR



SWR

VSWR

what is the difference?

SWR

standing wave ratio

the measure of current & voltage standing waves combined

associated with devices used to measure transmission line efficiency

VSWR

voltage standing wave ratio

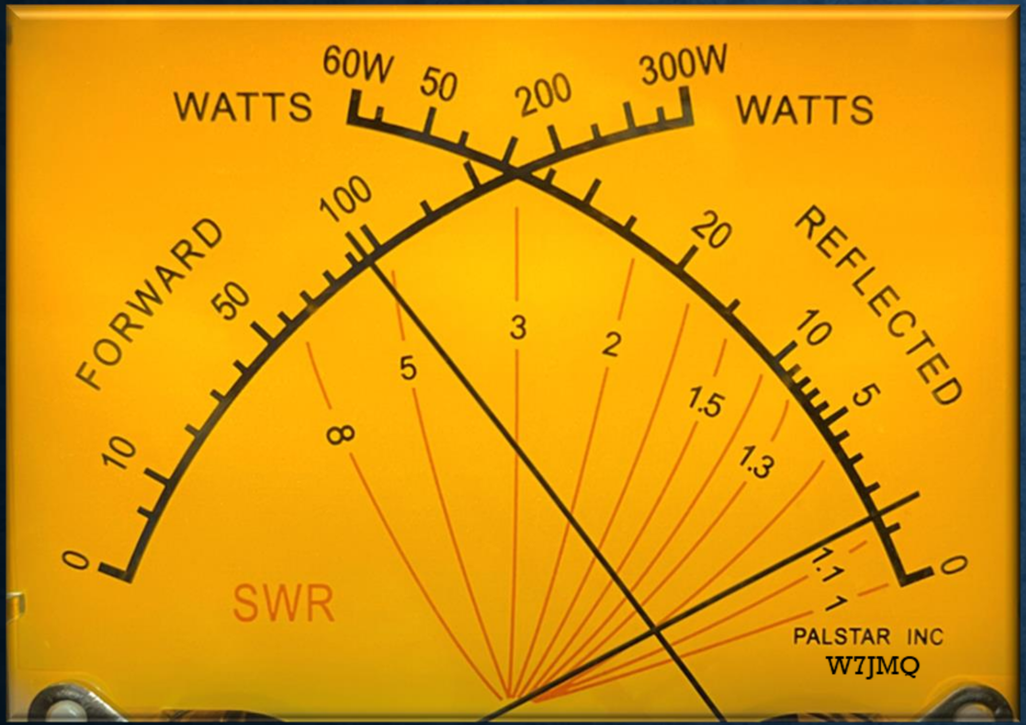
the measurment of voltage on
a standing waves

VSWR calculations are critical when designing RF systems as excessive voltages are most likely to cause component damage for our purposes, they are the same thing

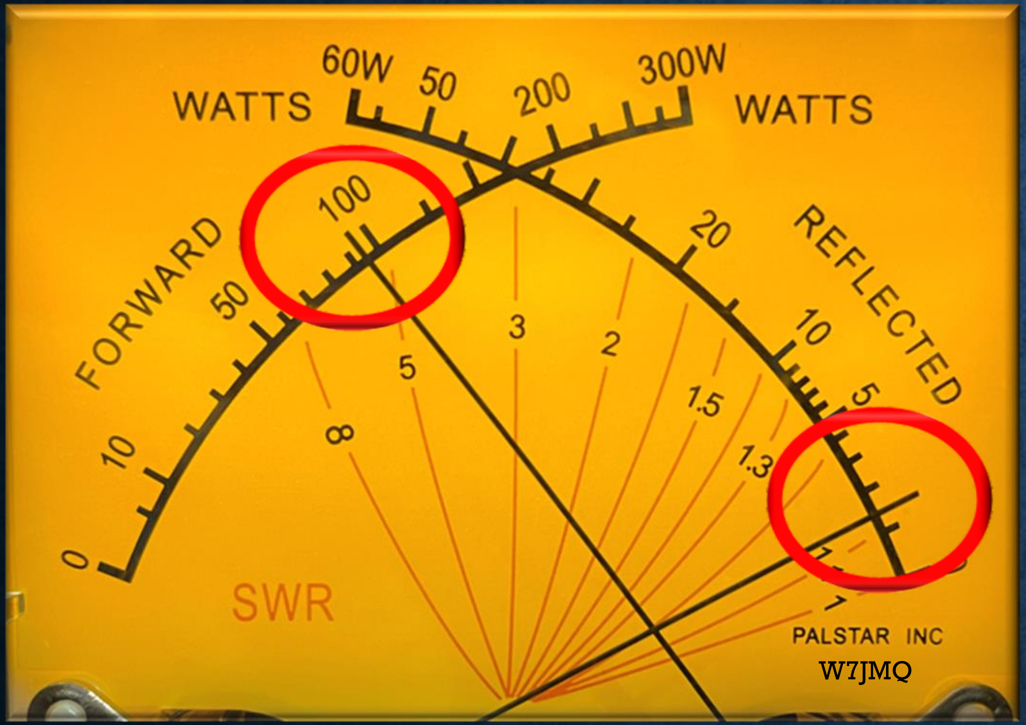
VSWR

reading SWR

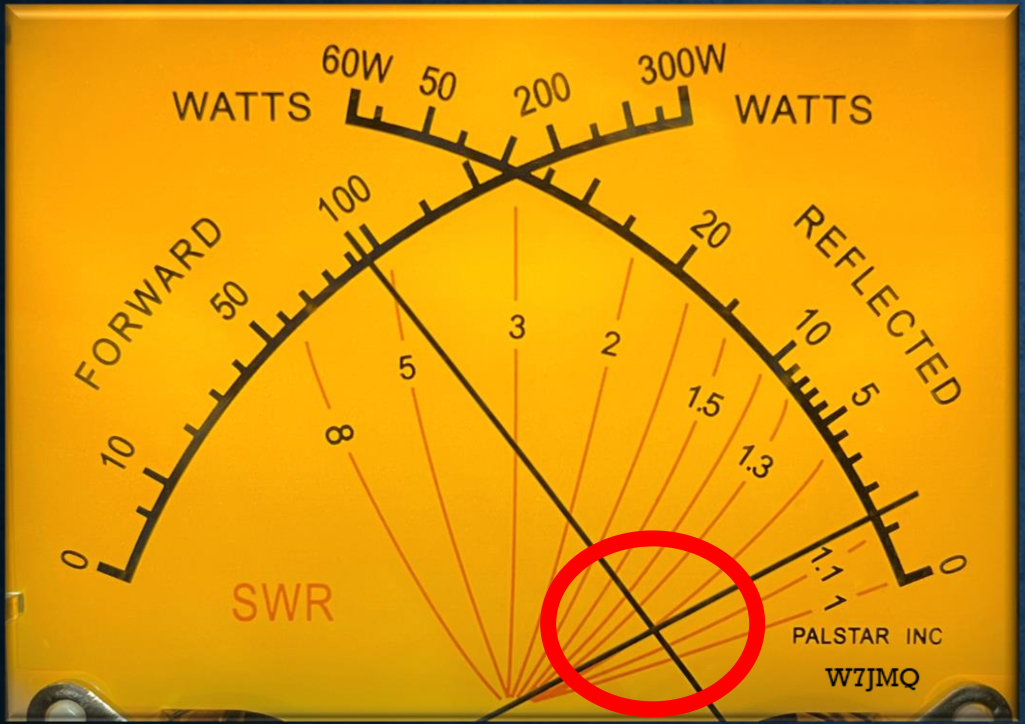
an “SWR Bridge” is an instrument inserted into a <u>powered</u> transmission line that when transmitting, will calculate the system SWR



SWR Bridge meters calculate the standing wave ratio by comparing *forward power* to *reflected power* present on a transmission line



in this instance, the meter, an “SWR Bridge”, is measuring 98 watts forward power (averaged) and 1.5 watts reflected power



the computed SWR is expressed in a ratio of

forward : reflected

where the needles cross, the SWR is shown as

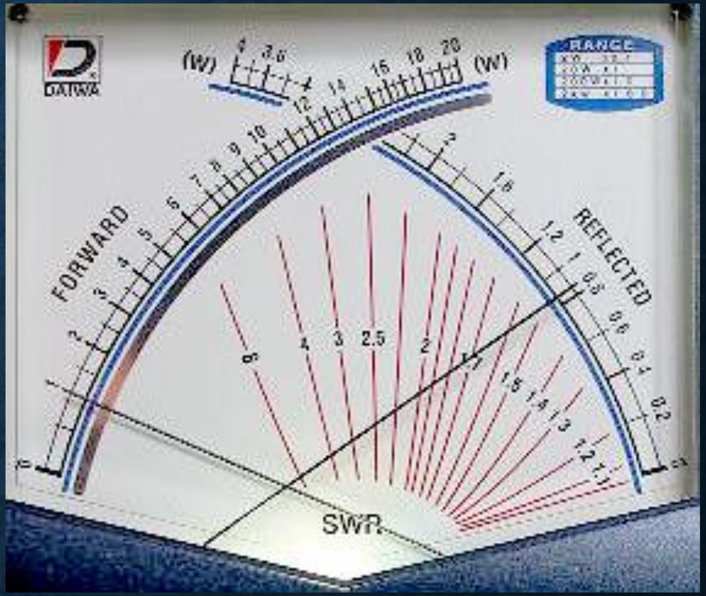
1.2 : 1

an RF transmission system operating at the highest efficiency may show a 1:1 SWR reading

not likely in the real world, as there are many factors which can increase SWR

factors that may increase SWR

- moisture & corrosion
- heat, ice, rain
- lossy cable & connections
- static electricity
- mechanical damage
- non-resonant antenna
- antenna feed point not matched to feedline



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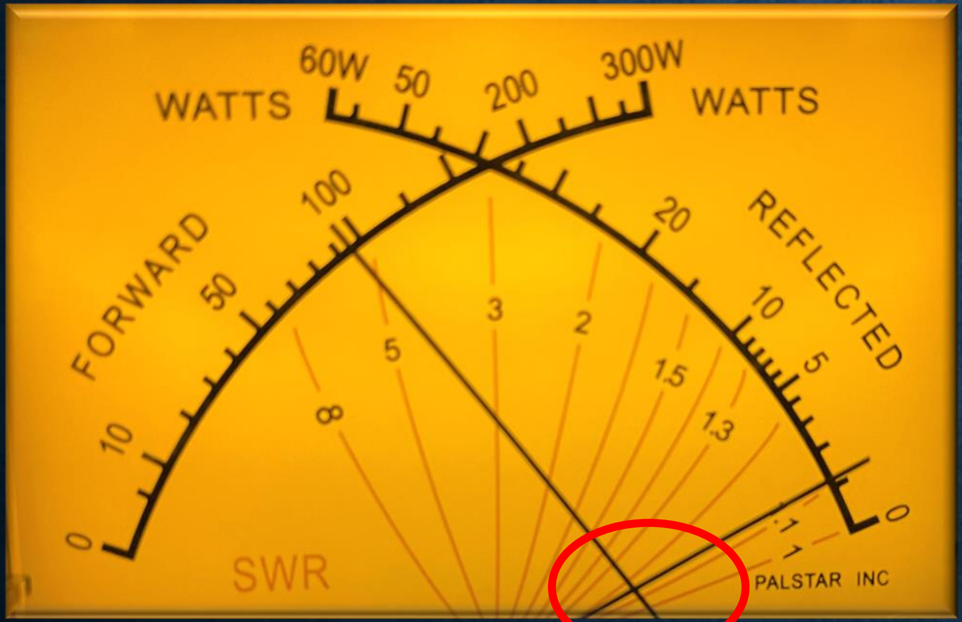
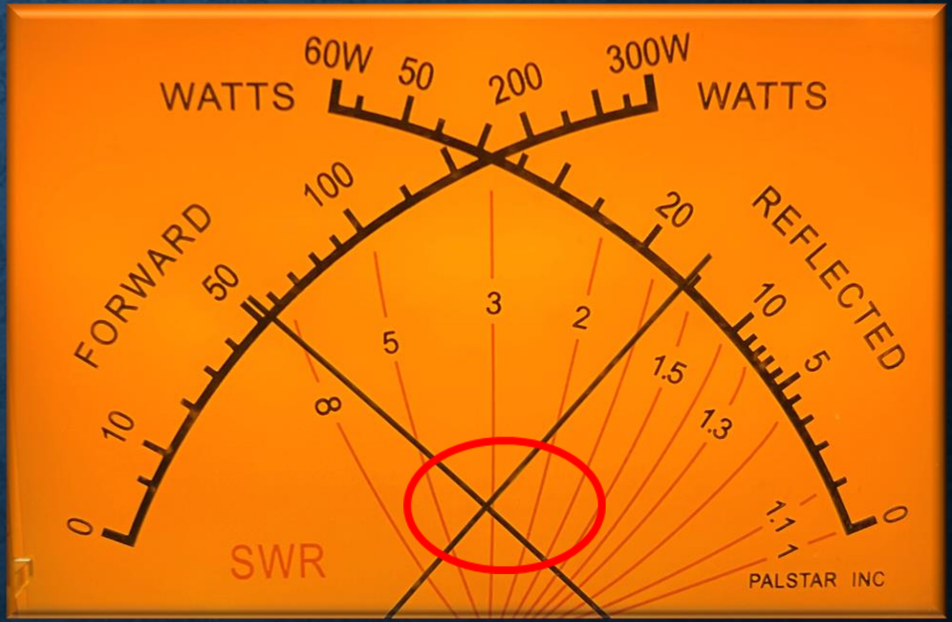
as we tune up or down from the **resonant frequency** of the antenna, the SWR will rise because the line impedance and load (antenna) are no longer matched with the transmitter

7.200 MHz
(resonant frequency)
1.2 : 1 SWR

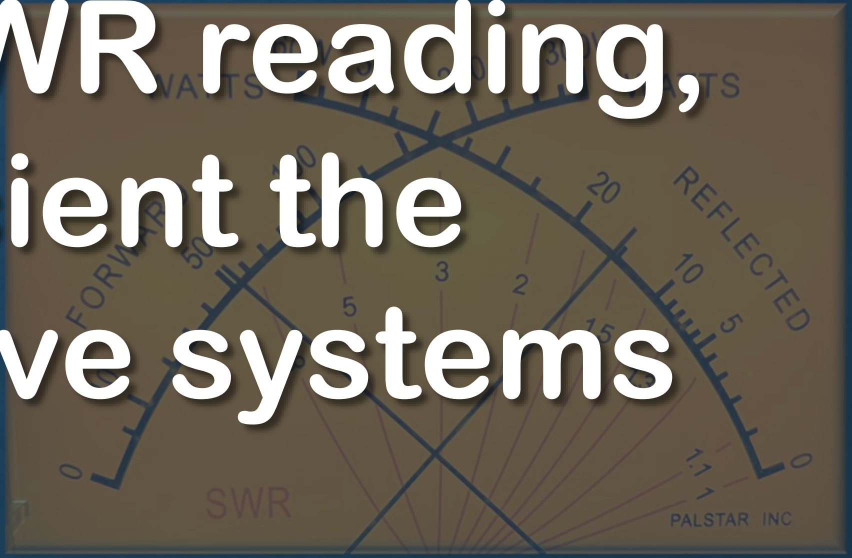


7.100 MHz
(non-resonant frequency)
3:1 SWR



7.700 MHz
(resonant frequency)

7.100 MHz



**the higher the SWR reading,
the less efficient the
transmit & receive systems**

does a 1:1 SWR mean a signal is optimal?

maybe yes & maybe no

what a 1:1 SWR reading <u>is</u> telling us is at the transmitter the line impedance is acceptable

does a high SWR really affect receive capability?

yes

an antenna will be “desensitized” when operated off the resonant point thus negatively impacting receiver performance all factors being correct:

impedance is matched throughout the system and the antenna is at its resonant frequency, no standing wave is present

SWR would be at about 1:1

when factors are incorrect:

impedance is not matched throughout the system and the antenna is not at its resonant frequency

a standing wave would be present and SWR may be high, i.e., 3:1 +

an SWR reading of 1:1 can be inaccurate for many reasons and is not necessarily an indication the system is optimal

an example is an antenna having a 3:1 SWR is fed by 80ft of RG8-X coaxial cable may show a 1:1 SWR

why?

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RG8-X cable is very “lossy” and is not efficient over a long transmission line run

the lossy characteristic causes reflected power to be transformed into heat in the cable and is thus dissipated making the SWR look lower than it is

G9A11
G9A13

the SWR Bridge at the transmitter end of the feedline does not see the dissipated reflected power and shows an SWR of 1:1

the loss in TX power at the antenna may be as high as 3+ dB which translates to about 50% or more of the signal strength

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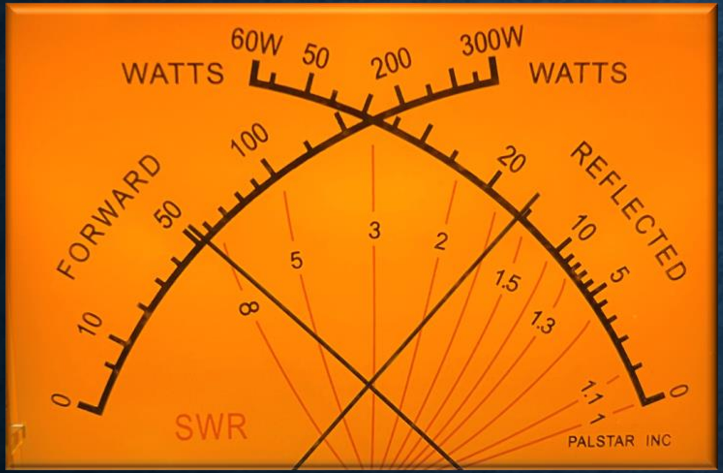
an SWR of 3:1 is typically the upper limit a modern transmitter equipped with an “antenna tuner” can handle

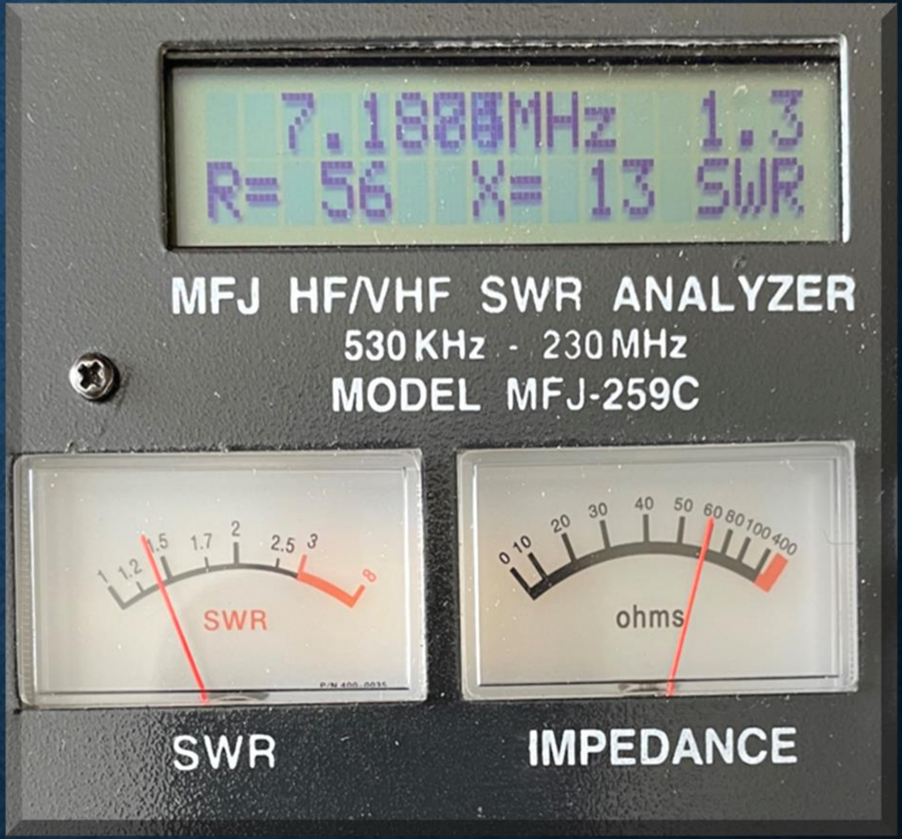


many transmitters will reduce power when a high SWR is present “antenna tuner” is a misnomer, they are <u>impedance matching networks</u> that compensate for higher SWR at the transmitter feed point

an antenna tuner does not alter characteristic impedance anywhere in the system what the antenna tuner does do is alter the line impedance at the transmitter so it does not fault or fold-back power due to a high SWR

advanced antenna analyzers can measure SWR, and can perform other important measurements

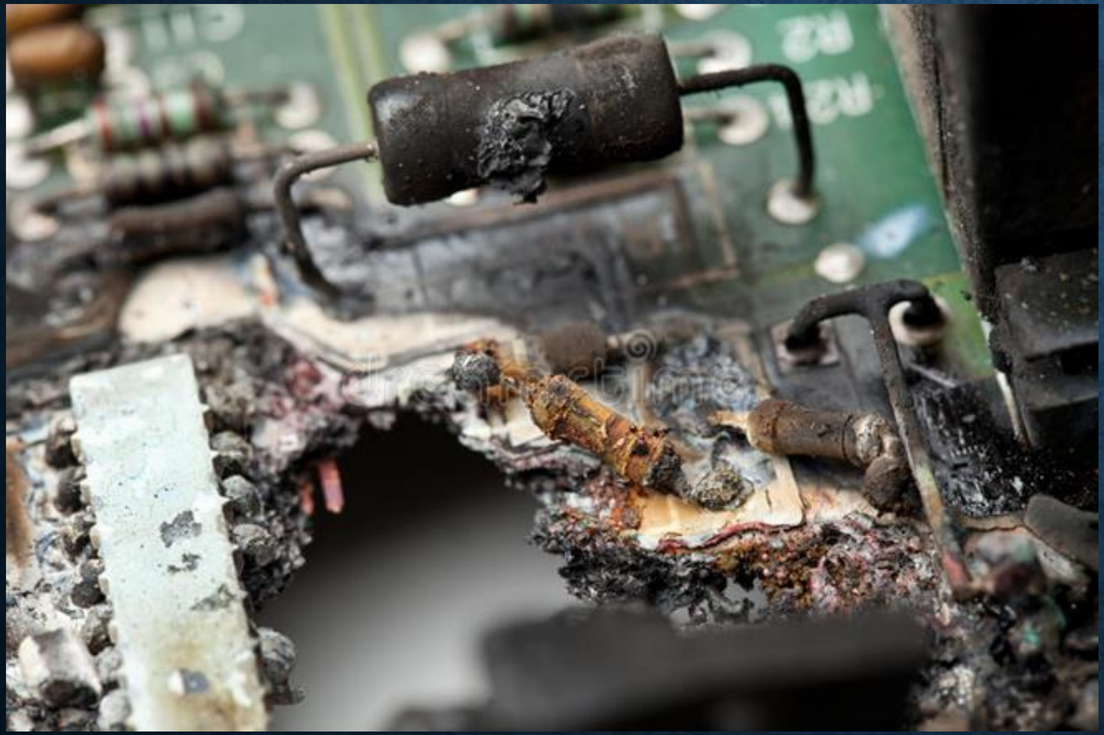
the analyzer is telling us the **frequency** at which the measurement is being taken, the **SWR**, the impedance **(R)** on the line and most important, the reactance **(X)** part of the impedance



an antenna analyzer is not an SWR Bridge

antenna analyzers are not used in a powered transmission line

and here's why



resources for further learning

https://www.youtube.com/watch?v=BpIQH6PgpeA

https://www.youtube.com/watch?v=lrOWq-2CYaw

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A. THE ANTENNA FEED POINT MUST BE AT DC GROUND POTENTIAL
B. THE FEED LINE MUST BE AN ODD NUMBER OF ELECTRICAL QUARTER WAVELENGTHS LONG
C. THE FEED LINE MUST BE AN EVEN NUMBER OF PHYSICAL HALF WAVELENGTHS LONG
D. THE ANTENNA FEED POINT IMPEDANCE MUST BE MATCHED TO THE CHARACTERISTIC IMPEDANCE OF THE FEED LINE