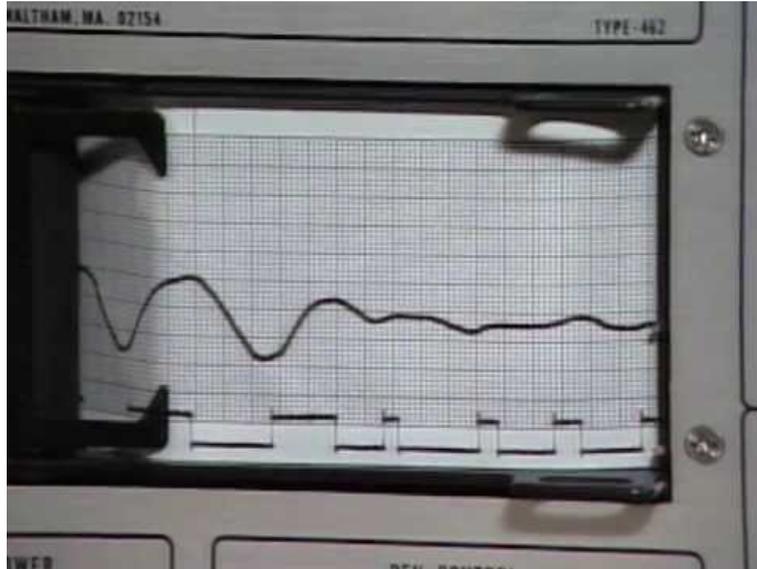# REFLECTIONS

STRIPCHART RECORDER -- we use these in the operating room; you've seen them every time there is an Earthquake

We're going to imagine a strip chart recorder watching an RF wave that we're going to send down a transmission line.   The FUTURE in our strip chart recorder is the UNSEEN stuff to the LEFT of the pen -- hasn't been written yet.   One entire wave of our RF looks like this (

Here is a wave that has been inked through 1/4 of its PERIOD (the time of one WAVELENGTH) and 3/4 of the period is in the FUTURE, going to the LEFT in time.
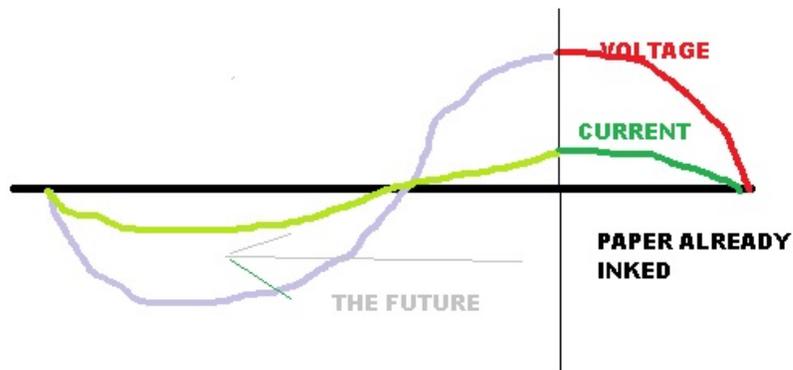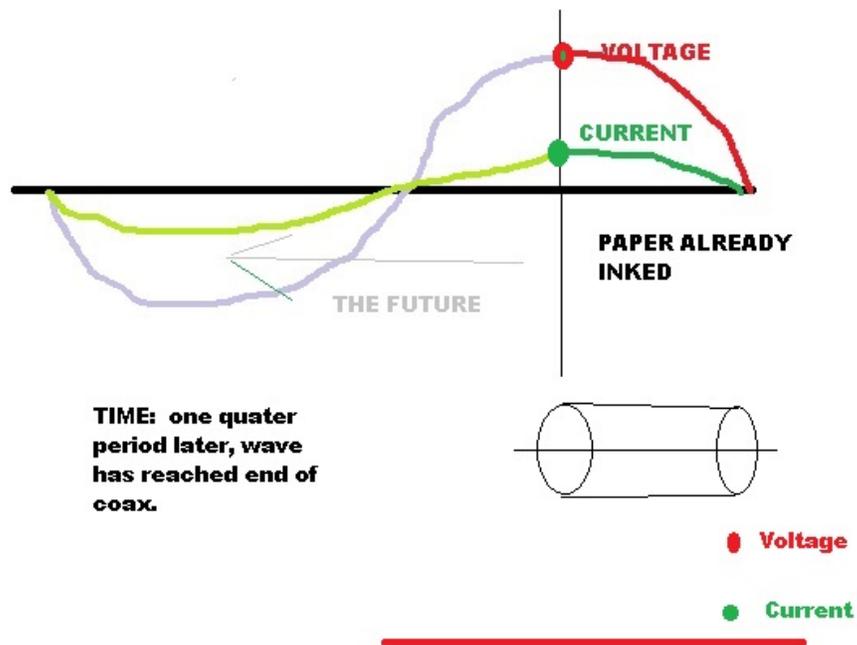

Note that we have a higher voltage than current.   Thats because this wave is being injected into a 50 ohm coax cable --- where the current will be 1/50 of the voltage (ohms law)

We are going to take the point where the vertical line is drawn, and inject that into the left side of a transmission line that is electricall 1/4 wavelngth long. The voltage and current at the inject point on the left side of the transmission line are shown

Our injection has exactly the voltage and current at our vertical line

VOLTAGE

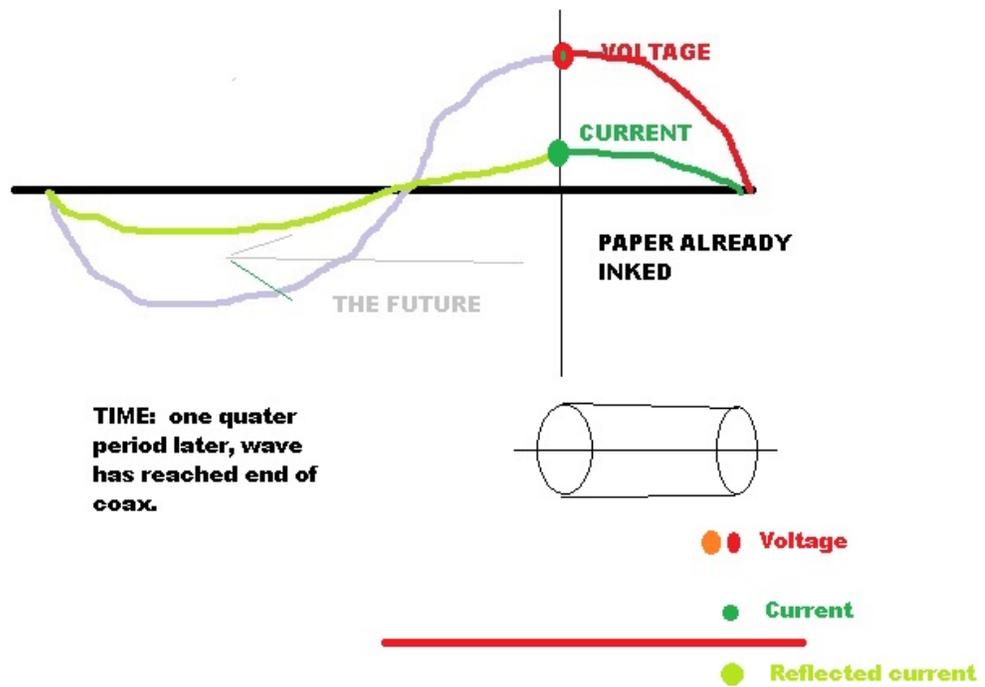CURRENT

PAPER ALREADY
INKED

THE FUTURE
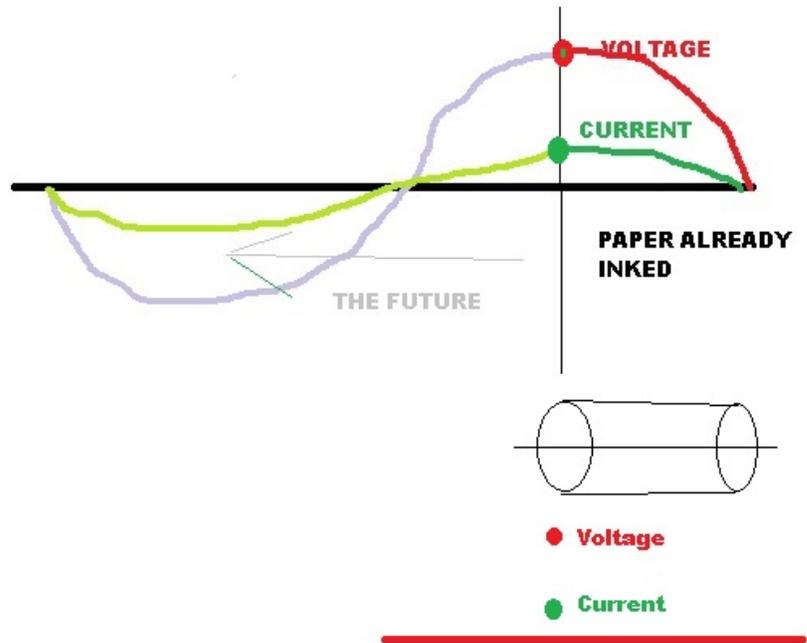
● Voltage

● Current

Now where will this voltage and current have gotten to exaclty 1/4 period later? Answer: they will have moved to the exact right end of the 1/4 wavelength long coax cable. So now, at that 1/4 period time later, we show them at the RIGHT end of the coax:

2

VOLTAGE

CURRENT

PAPER ALREADY INKED

THE FUTURE

TIME: one quater period later, wave has reached end of coax.

● Voltage

● Current

But BIG PROBLEM-- the coax is UNCONNECTED (infinite ohms) at the right side....so there is zero current flow (infinite SWR).   By Kirchoff's Current Law there can be zero total current entering the right hand end of the coax....so how do we satisfy Kirchoff's Current Law?

There is a REFLECTED WAVE that is the forward wave "bouncing" off the open circuit -- it has the same voltage, but its current is flowing the OPPOSITE DIRECTION.   We show this by putting its current as "negative".   The chart below shows both the foward voltage/current and the reverse voltage / current

VOLTAGE

CURRENT

PAPER ALREADY INKED

THE FUTURE

TIME: one quater period later, wave has reached end of coax.

● ● Voltage

● Current

● Reflected current

So, the result is that the Voltages ADD and the Currents ADD -- so the voltage at the far end is TWICE the expected voltage, and the currents CANCEL and make ZERO CURRENT (exactly as we knew it had to by Kirchoff's Current Law) --- and the impedance (V divided by I) is INFINITE (and so is the SWR).

Now.....that reflected wave takes exactly another 1/4 PERIOD to make it back to the beginning which it is still a positive voltage and a negative current......but now we are a total of 1/2 PERIOD forward future) from where we started.....and as you can see, at 1/2 period into the future, our RF Generator has moved to making maximum NEGATIVE voltage and current, so the voltages and current at the START of the coax now looks like:

4

VOLTAGE

CURRENT

PAPER ALREADY INKED

THE FUTURE

Reflected Voltage

Reflected Current

FORWARD Voltage
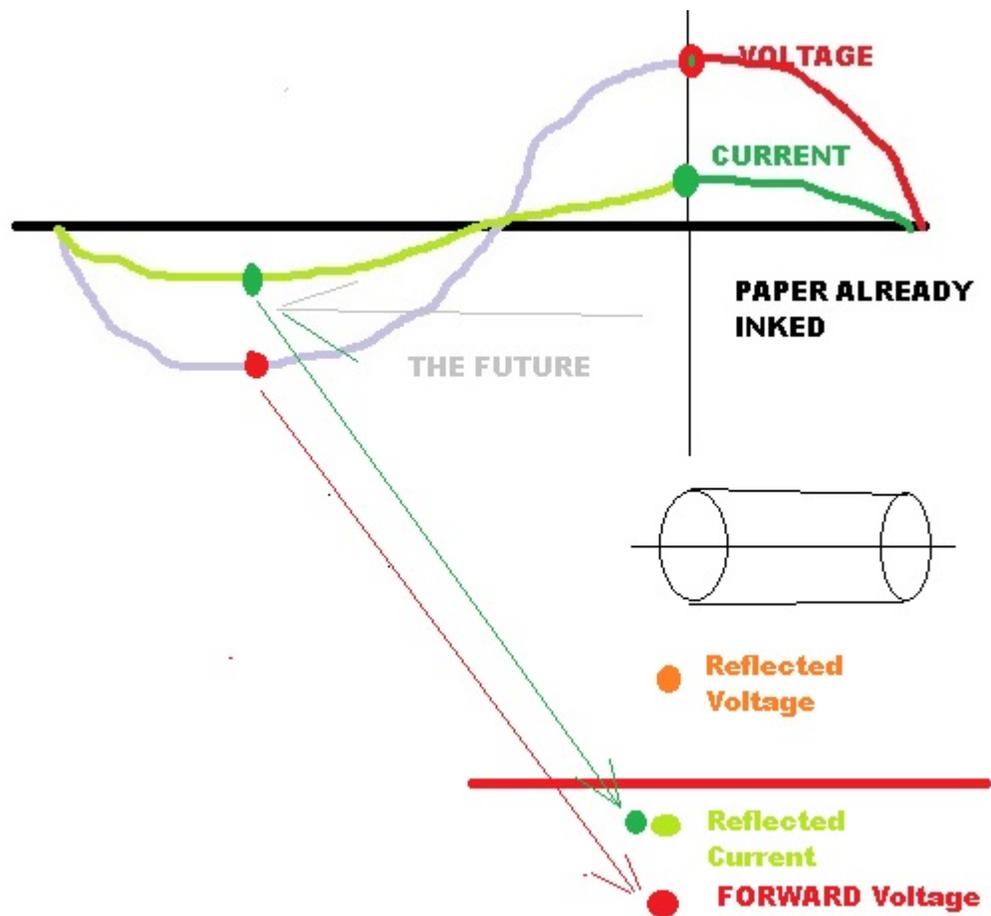
Do you see how these are going to add???

The voltages are now OPPOSITE -- so they are going to CANCEL.

The currents (both negative) are going to ADD -- double the current.

And now the input impedance of the 1/4 wave transmission line appears to be

V / I = 0 / 2*I = ZERO OHMS

So at the right side of the 1/4 wave coax connected to no antenna, we have INFINITE OHMS....

But at the input (left side) we have ZERO OHMS....

And that is what a 1/4 wave transmission line does --- it creates the GEOMETRIC INVERSE (opposite) of its output impedance.....back at the input.

if you SHORT the output, the input will look OPEN; if you OPEN the output, the input will look like a short.

For intermediate resistors....the results are simplly intermediate.

The SWR is the thing that is constant.

if you put a resistor at the output that has 150 ohms (SWR= 3)   then the input side will see an SWR of 3 but the impedance will be about 17 ohms (50/3).

Quarter wave transmission lines always invert the impedance about the point of the impedance of the transmission line.   You can make this into a nomogram so you can easily predict what will happen.

To move from one end of a 1/4 wave transmission line to the other -- just go from one side of any circle
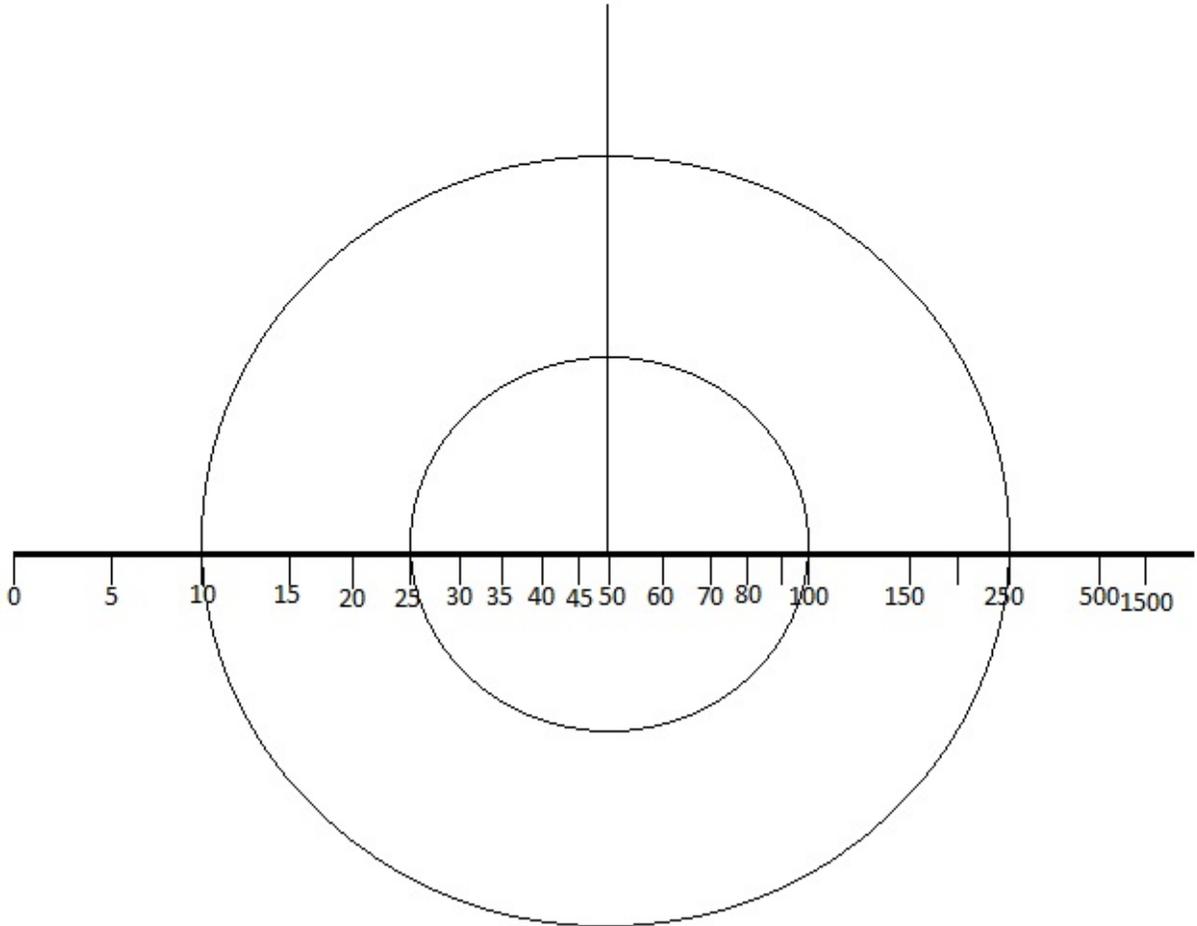
about the 50 ohm center point....to the other edge of the circle and you will be able to see what the impedance will be transformed to.   In other words -- what starts out 2 inches to the right, will end up two inches to the LEFT of 50 ohms -- and vice versa.   And we proved it with the Antenna Analyzer!