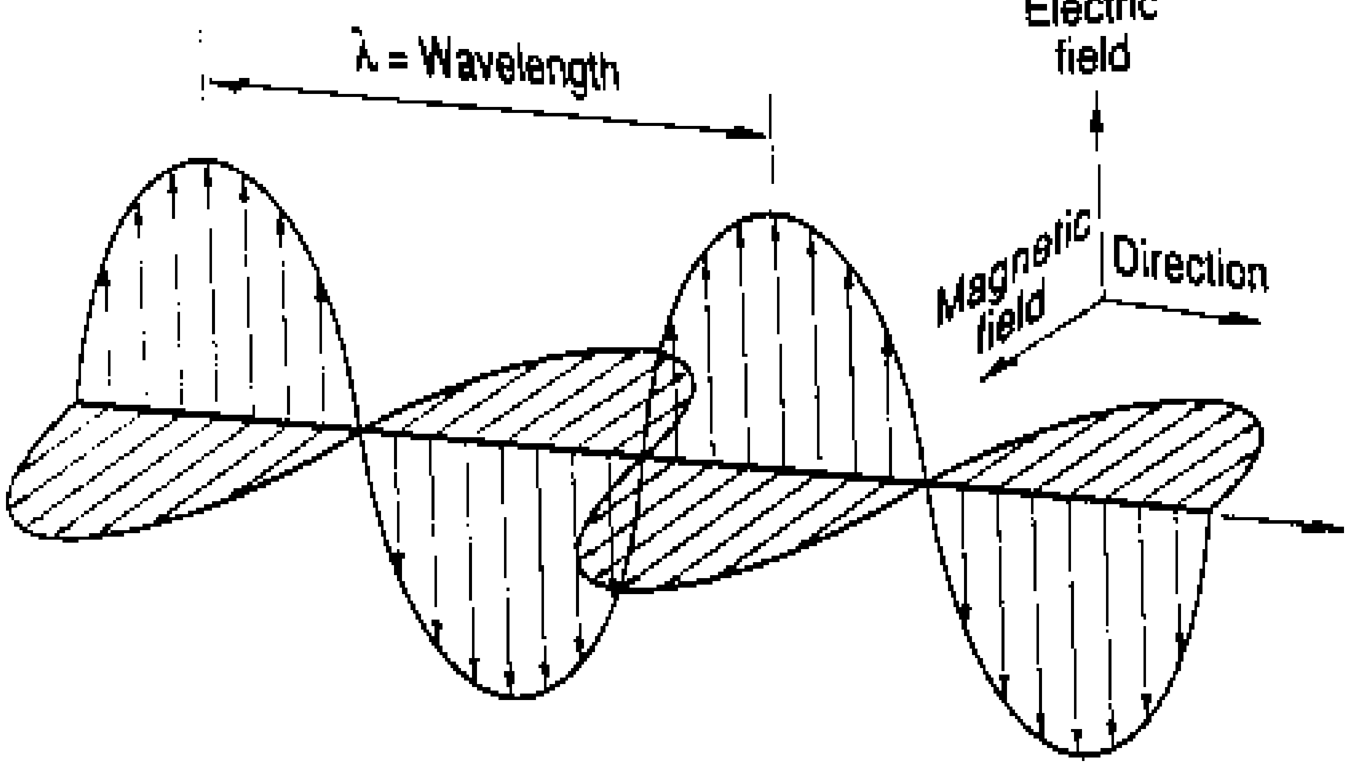
Waveguide
and
Cavity Resonator
Experiment

Electromagnetic Wave in Free Space



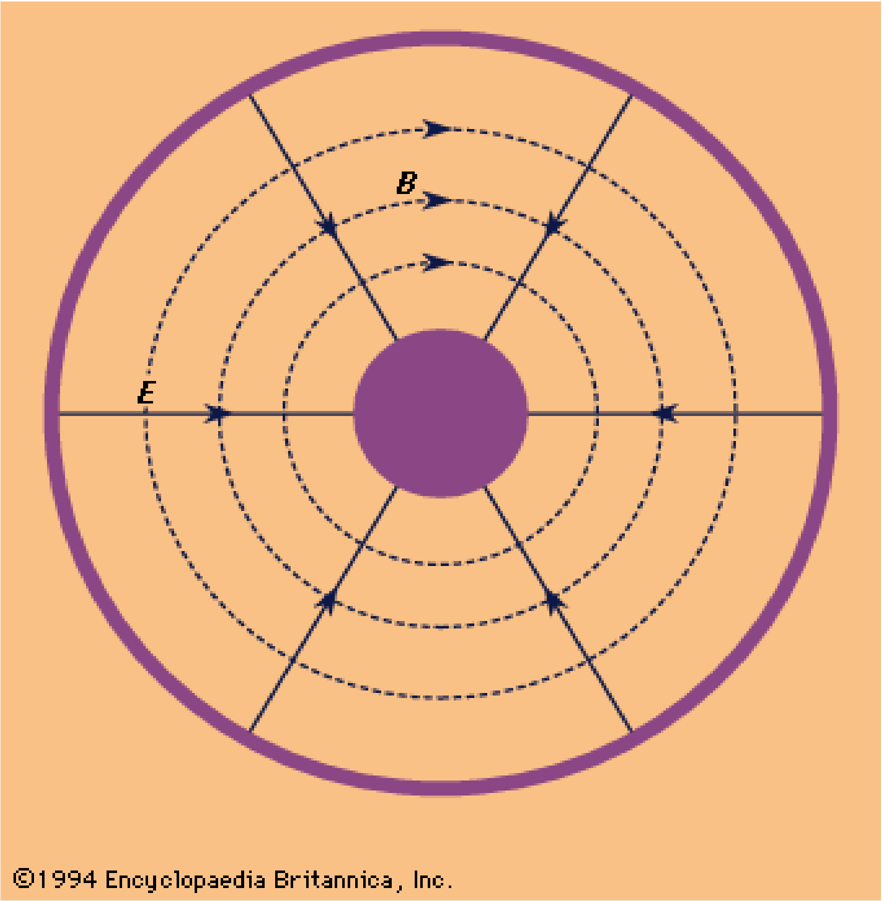
Electric and Magnetic Fields

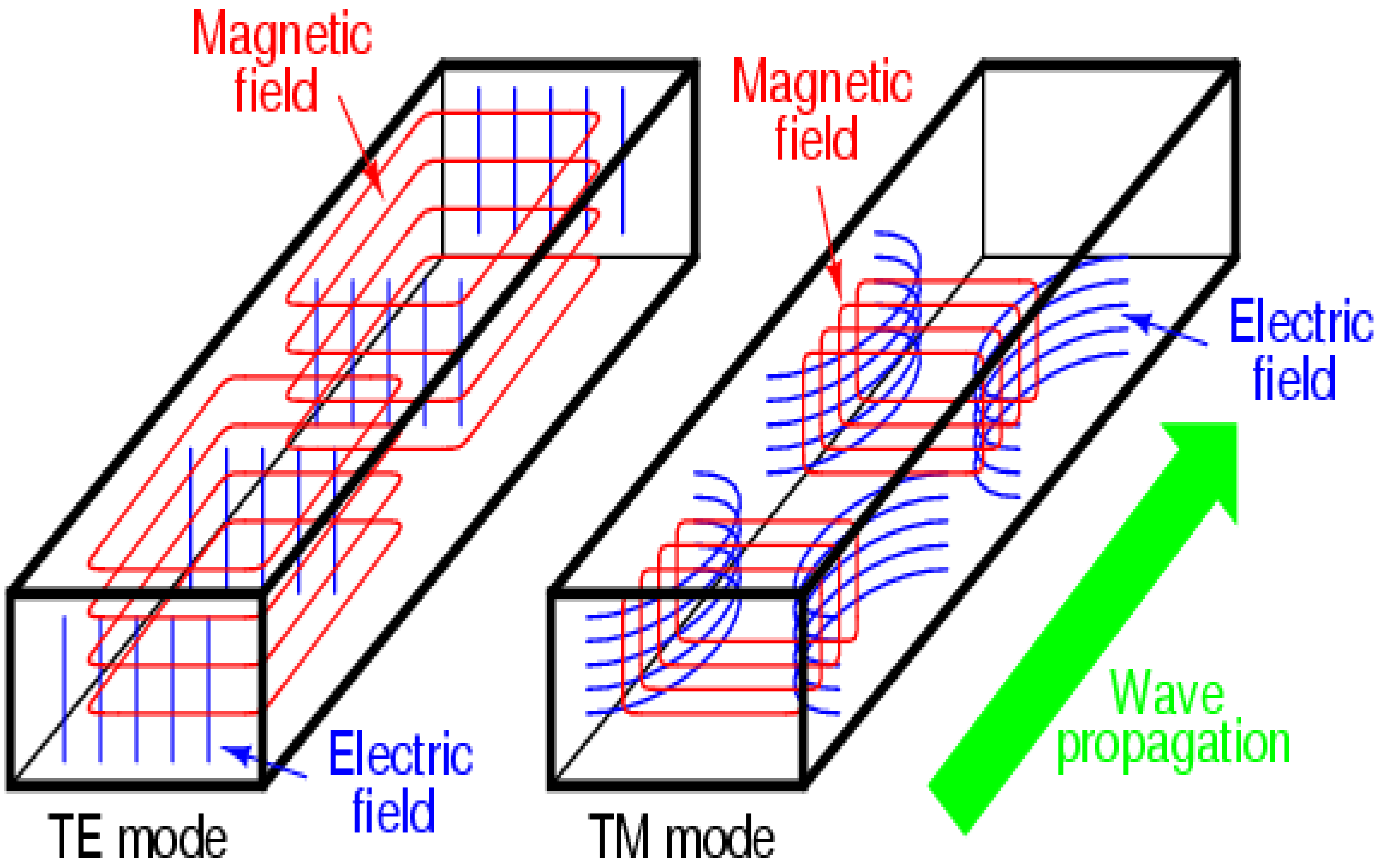
- By convention, electric fields point from plus to minus.
- Withn a wire, the electric field points in the same direction as the “current”.
- Magnetic field directions point from South to North and are at right angles to electric fields.
- Within a coax that is carrying an alternating current, portions of the wire and shield have opposite and alternating polarities that travel back and forth along the coax.

Fields

- We really don’t know what “field” is.
- We have electric, magnetic, elecromagnetic, gravitational, weak and strong nuclear, and now the Higgs field.
- Fields are suppsedly mediated by force carriers called “bosons” (photons, gravitons, gluons, W, Z, and now the Higgs boson), all in the vacuum of space.
- Fields are mathematical constructs.

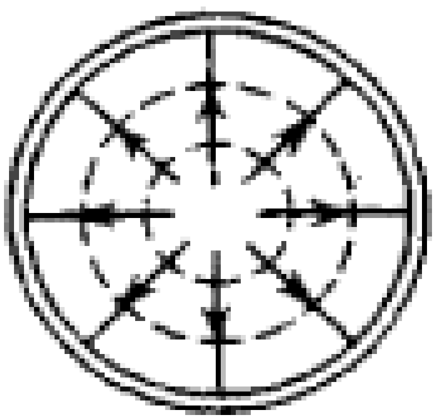
Electric and Magnetic Fields in Coax

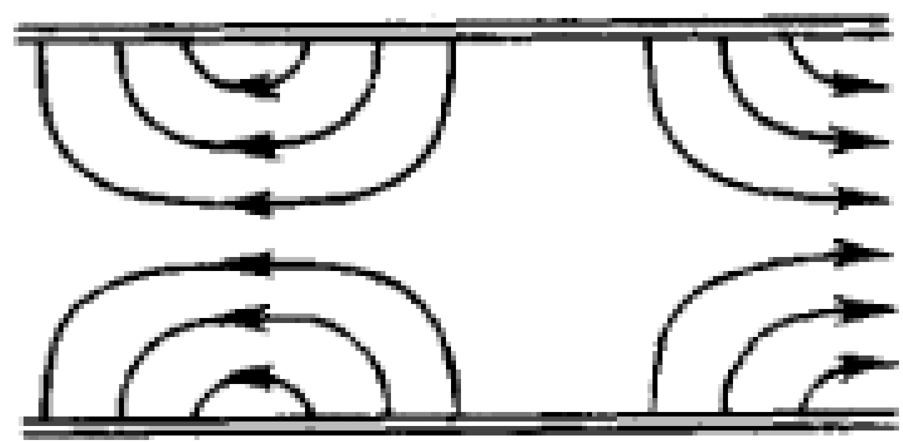


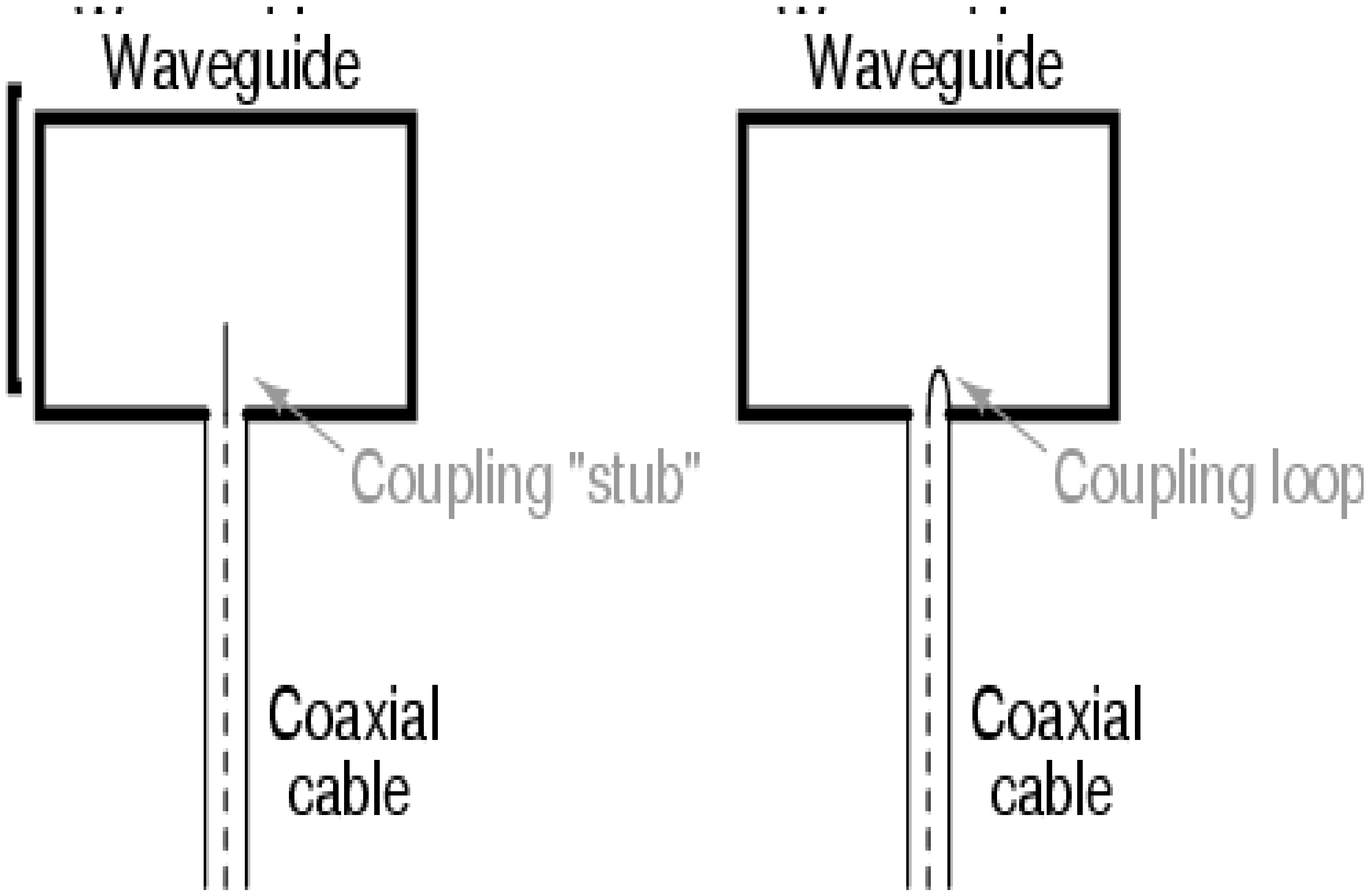


Magnetic flux lines appear as continuous loops
Electric flux lines appear with beginning and end points

Electric and Magnetic Fields in a Circular wave Guide (Dotted lines are magnetic fields)



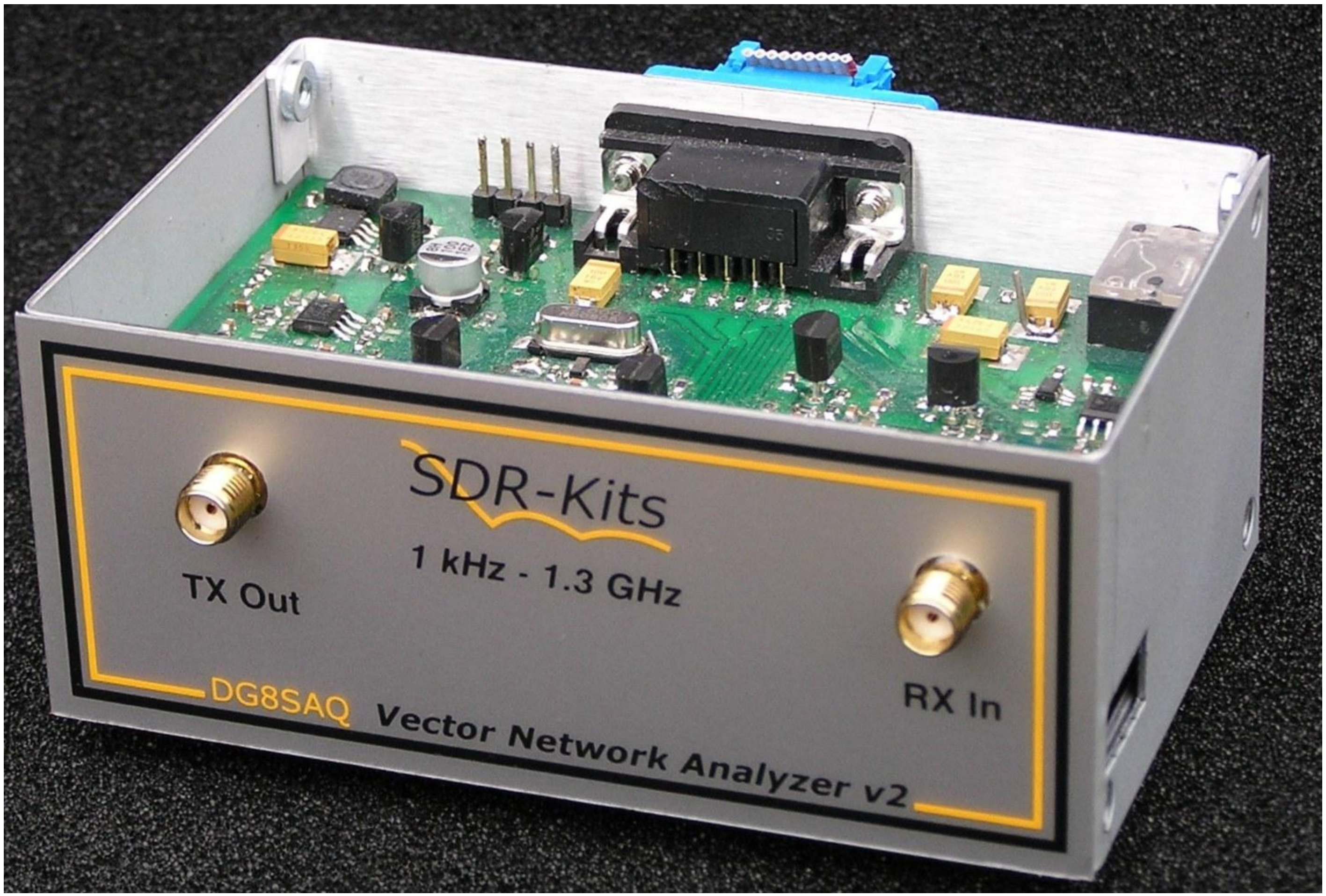


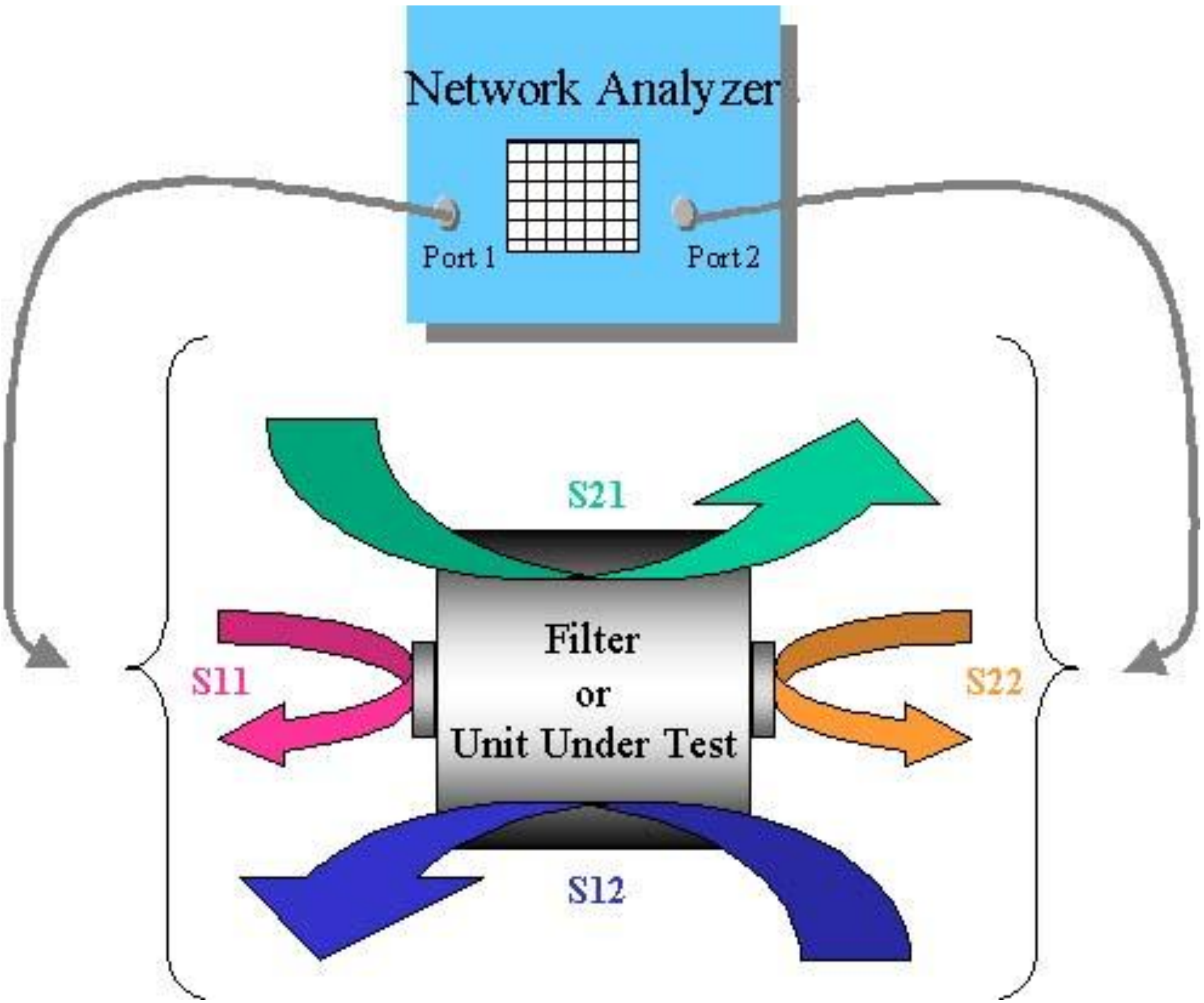

Waveguide
Coupling "stub"
Coaxial cable
Waveguide
Coupling loop
Coaxial cable

Vector Network Analyzer (VNWA)

- Inputs a frequency-sweep of known voltage and phase into the DUT (device under test).
- Measures both voltages and phases reflected from and transmitted through the DUT.
- Calculates and graphs, against frequency, the reflected and transmitted losses, in dB, from and through the DUT.
- Can also calculate and graph S-parameters, VSWR, Impedance, inductance, capitance and a dozen other parameters.

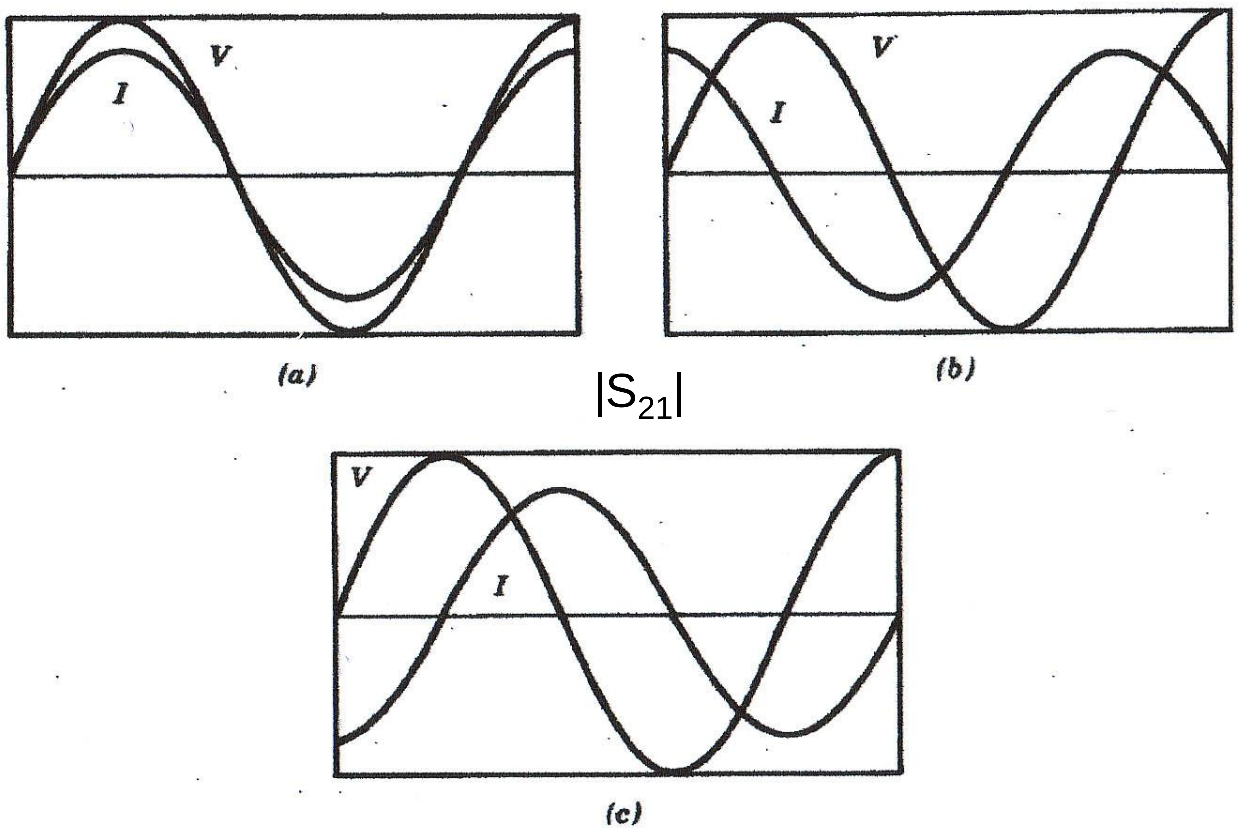
Vector Network Analyzer VNWA




Network Analyzer
Port 1
Port 2
S21
S11
Filter
or
Unit Under Test
S22
S12

Phase (ICE and ELI)

Resonant Cavities and Waveguides



$|S_{21}|$

Figure 12.1 Variations of voltage and current in simple circuit elements driven at single frequency. (*a*) Resistor. (*b*) Capacitor. (*c*) Inductor.

S_{11}

- S_{11} = Voltage Reflected / Voltage Into the Port
- Voltages include phase information and so are expressed as complex numbers. So S_{11} itself is a complex number.
- $|S_{11}|$ is the absolute value of S_{11}, calculated through complex arithmetic.
- Return Loss in dB = $-20 \times \mathrm{Log}_{10}(|S_{11}|)$
- The Network Analyzer measures S_{11} and automatically calculates and graphs the Return Loss in dB.

S_{21}

- S_{21} = Voltage out of DUT / Voltage into DUT
- Voltages include phase information, so S_{21} is a complex number.
- $|S_{21}|$ is the absolute value of S_{21}, calculated in the same way as was $|S_{11}|$.
- Transmission Loss in dB = -20 x $\text{Log}_{10}(|S_{21}|)$
- Again, note the negative sign because

  Voltage Out < Voltage In.

S_{11} dB Calculation

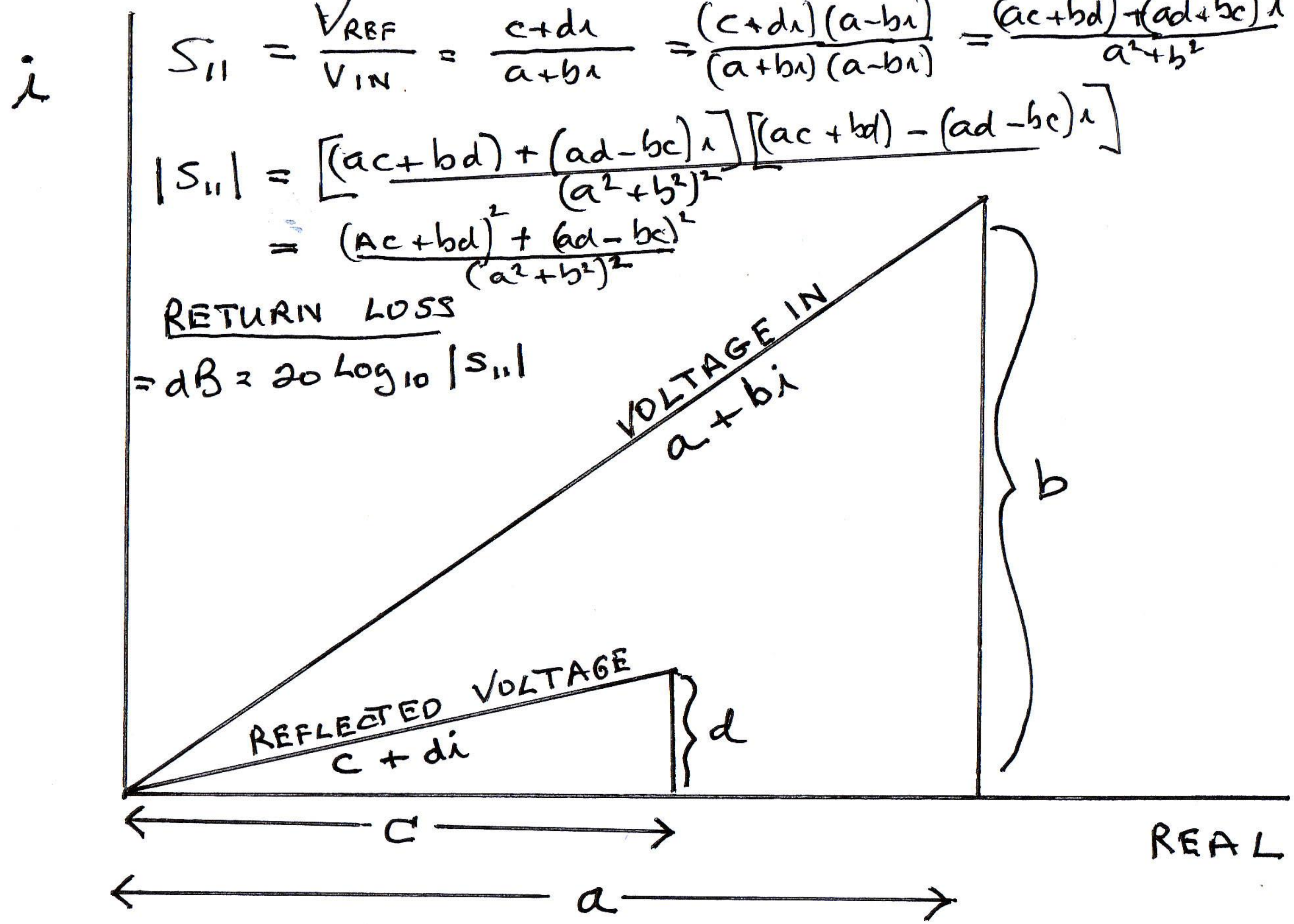
$$S_{11} = \frac{V_{REF}}{V_{IN}} = \frac{c+di}{a+bi} = \frac{(c+di)(a-bi)}{(a+bi)(a-bi)} = \frac{(ac+bd)+(ad+bc)i}{a^2+b^2}$$

$$|S_{11}| = \frac{[(ac+bd)+(ad-bc)i][(ac+bd)-(ad-bc)i]}{(a^2+b^2)^2}$$

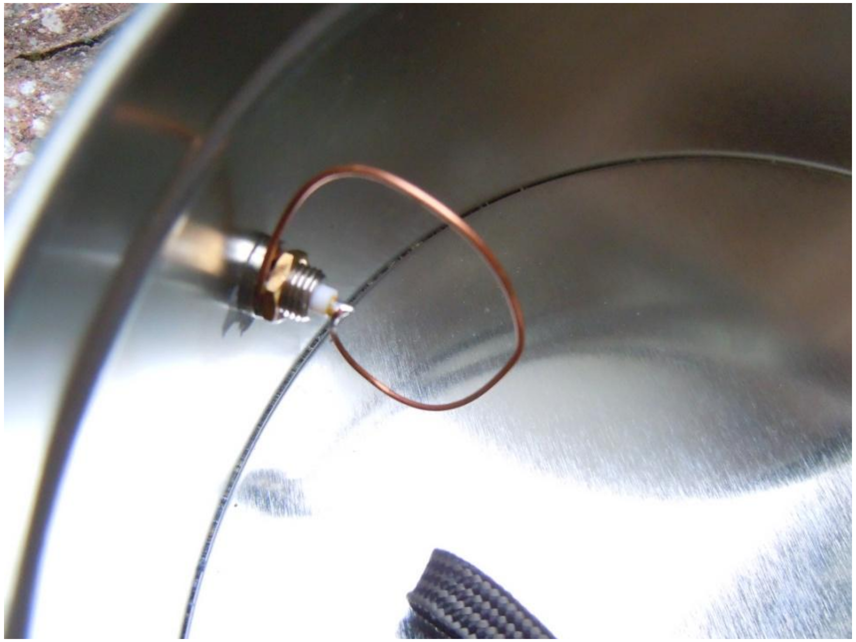
$$= \frac{(Ac+bd)^2+(ad-bc)^2}{(a^2+b^2)^2}$$

RETURN LOSS

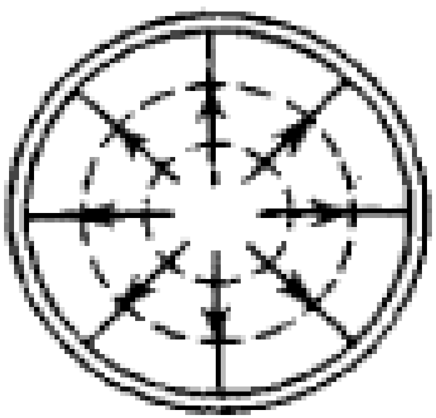
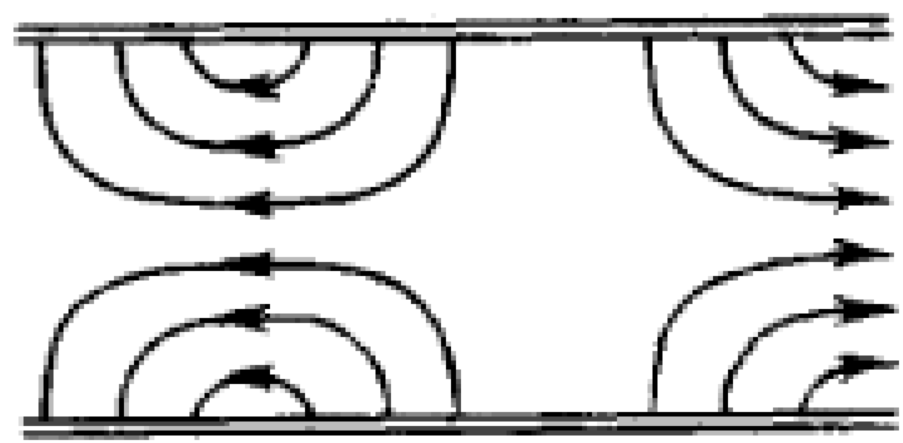
$= dB = 20 \log_{10} |S_{11}|$



Cookie Tin Cylindrical Wave Guide



Electric and Magnetic Fields in a Circular wave Guide (Dotted lines are magnetic fields)

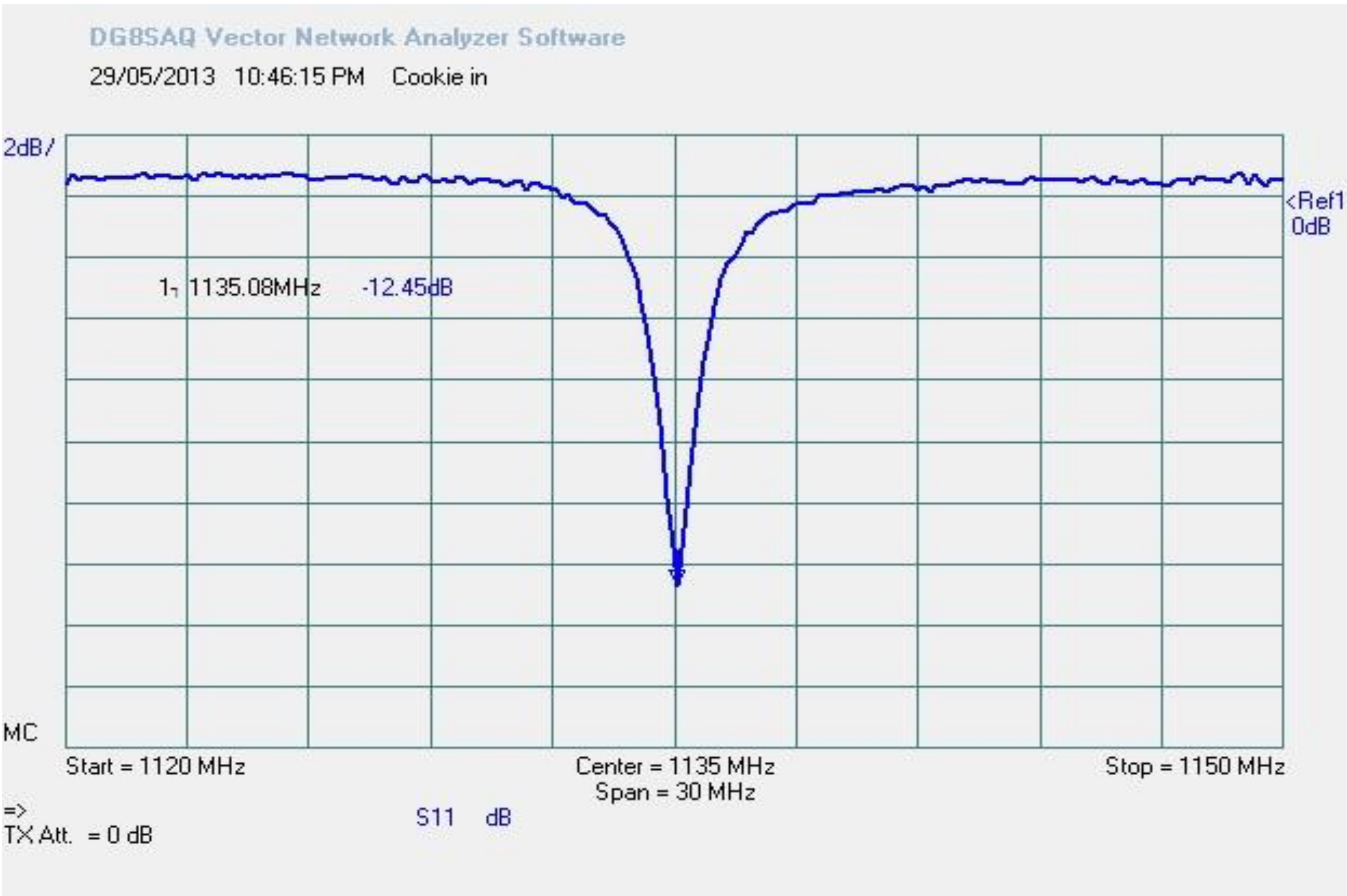
Cylindrical Waveguide TM_{01} Mode

- Resonant ∫(MHz.) = [C_0 / (2·10^6·π·r)} · $\mathbf{J_0}$
- Where $C_0 = 3 \times 10^{11}$ mm./sec (speed of light)
    - r = cylinder radius (101 mm.)
    - $\mathbf{J_0}$ = 2.4048 (Cylindrical Bessel function for TM_{01})
- ∫ calculated = 1137 MHz
- ∫ measured = 1135 MHz

Bessel Functions for TM Modes in a Cylindrical Waveguide (TM_{02}, @ 2.6 GHz., is above the 1.3 GHz. max. for the VNWA.)

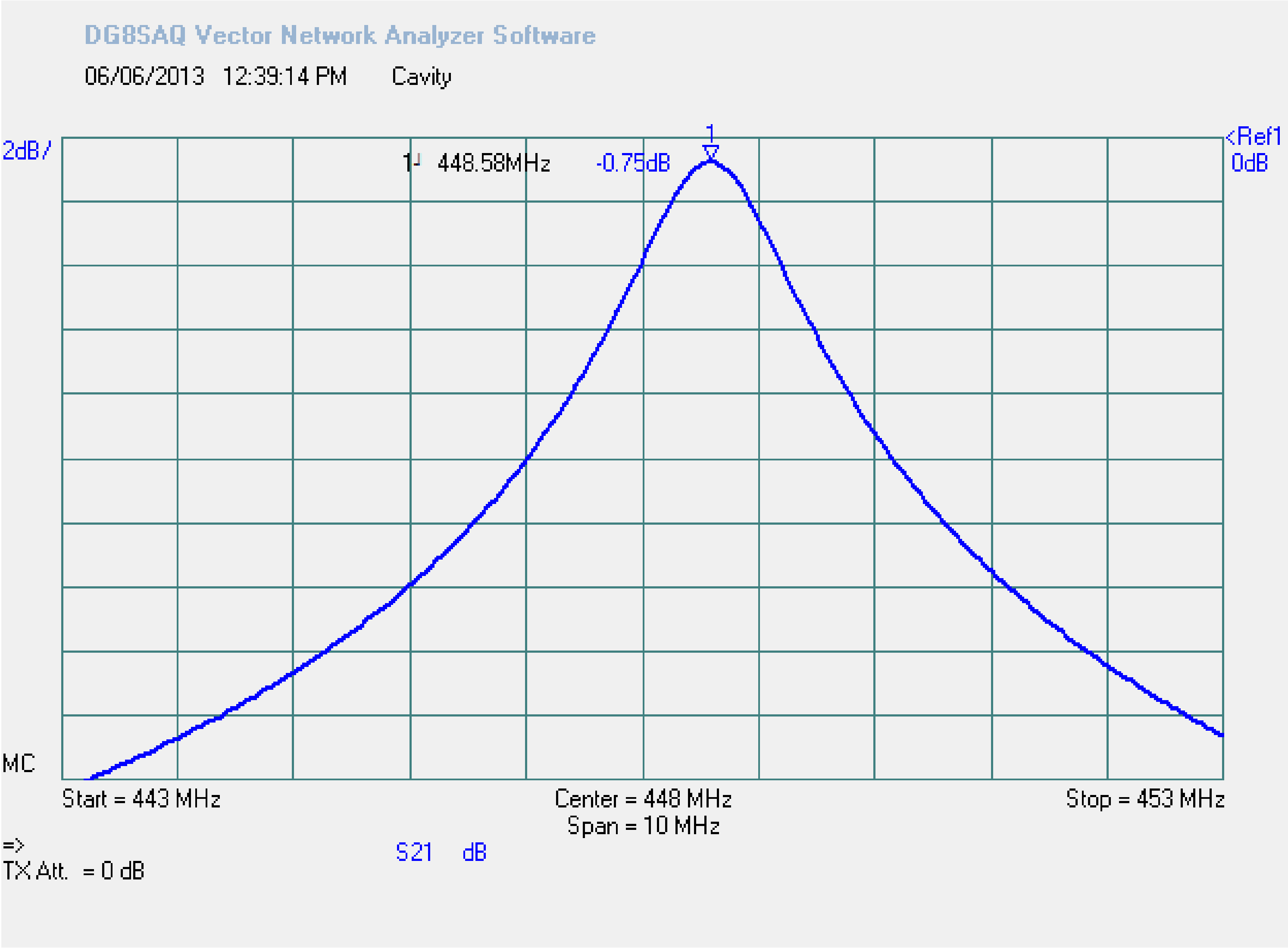
J_{01} for TM_{01}	J_{02} for TM_{02}	J_{03} for TM_{03}
2.4048	5.5201	8.6537

Return Loss
VNWA Trace: Min @ 1135.08 MHZ



448.65 MHz. Cavity

Repeater Resonant Cavity Transmission Loss



Candy Tin Resonant Cavity

Candy Tin Resonant Cavity Return Loss

Candy Tin Resonant Cavity

- Speed of light = 3×10^{11} mm./sec.
- From tip of BNC to end of tin = 304 mm.
- Calculated Resonant Frequency (MHz), if this length = one Wavelength

  $= 3 \times 10^{11} / 304 \times 10^{6} = 986.8$ MHz.
- Measured Resonant Frequency = 986.4 MHz.
- Is this a coincidence ???