Test Results With a Prototype Helical Kicker

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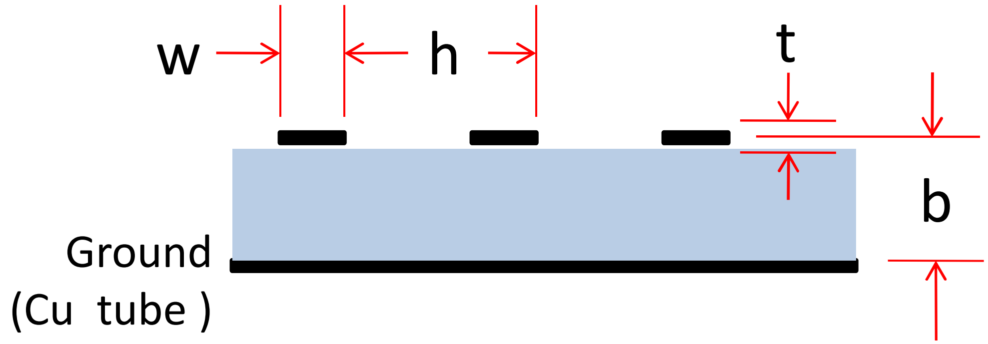
Topics

1. Test results of 200 Ω helix
2. Future effort with helix
3. Helix temperature

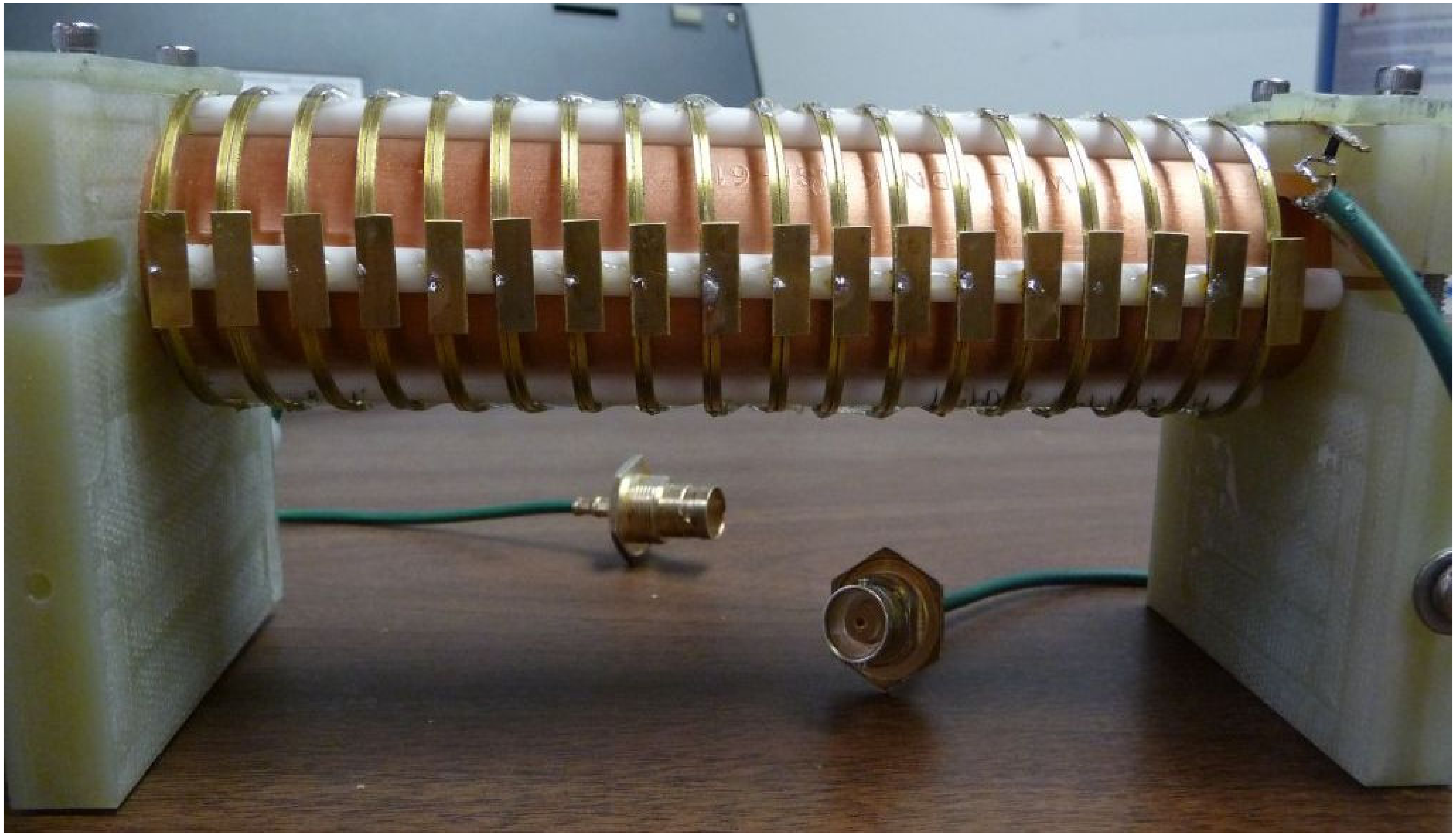
Project X meeting
May 3, 2011

Microstrip line dimensions



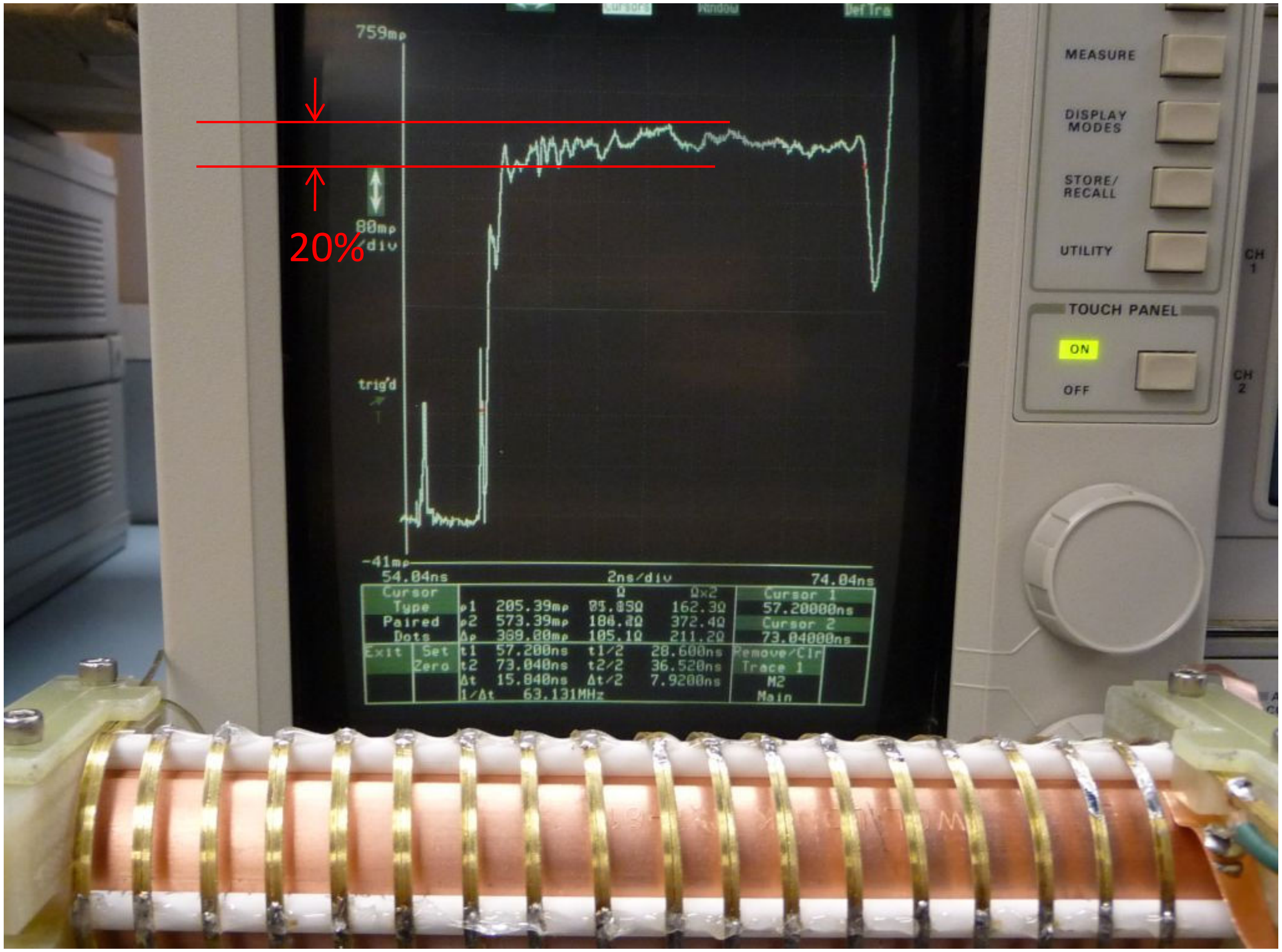
Characteristic impedance	205 ± 20 Ω (measured)
Conductor strip dimensions (w x t)	0.091 x 0.02 inch
Pitch (h)	0.333 inch
Strip height (b)	0.197 inch
Helix outer diameter	1.47 inches
Ground tube diameter	1.125 inches
helix length (18 turns)	6 inches

Helical microstrip line

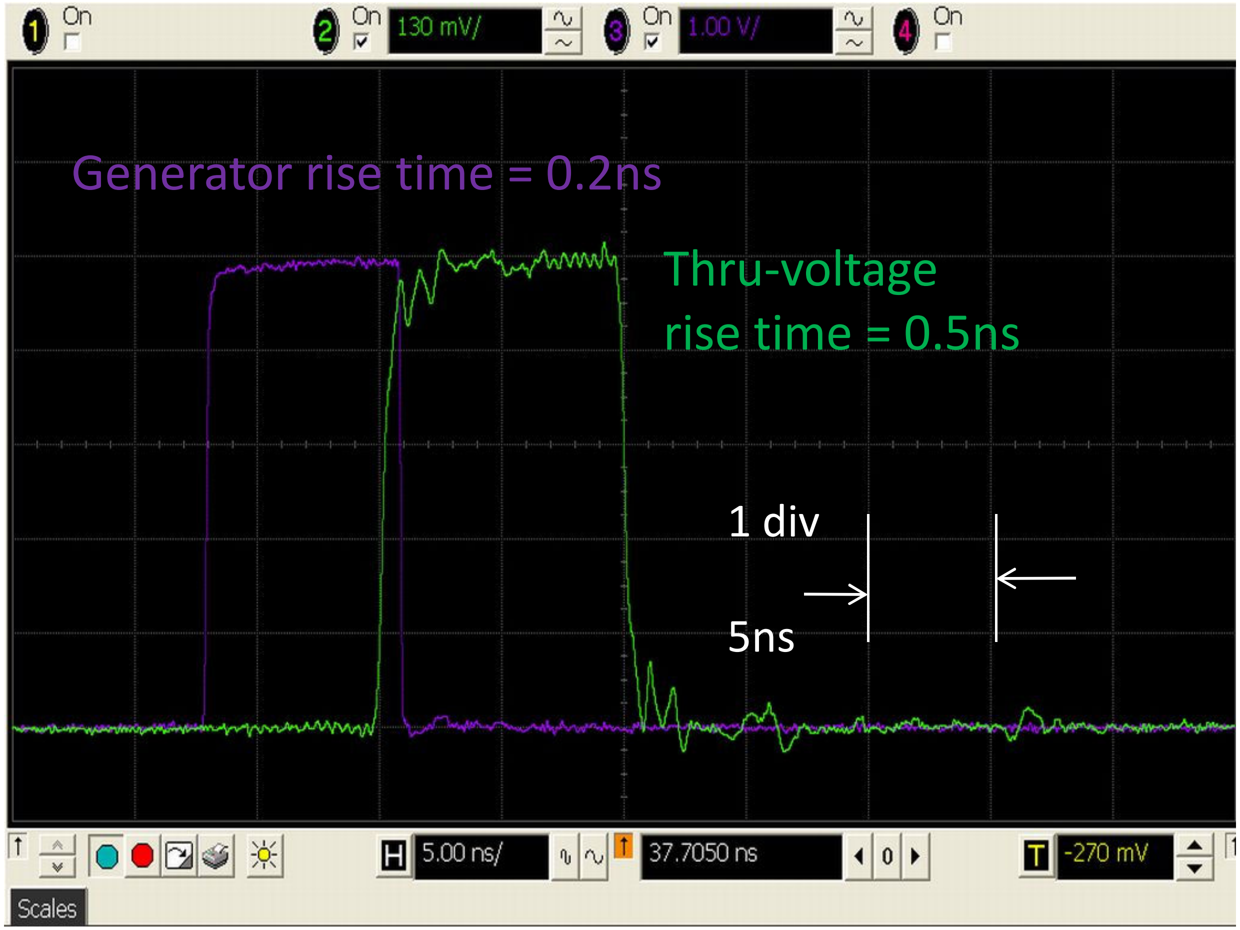


0.18 (W) x 0.50 (H) in. electrodes attached

TDR impedance measurement

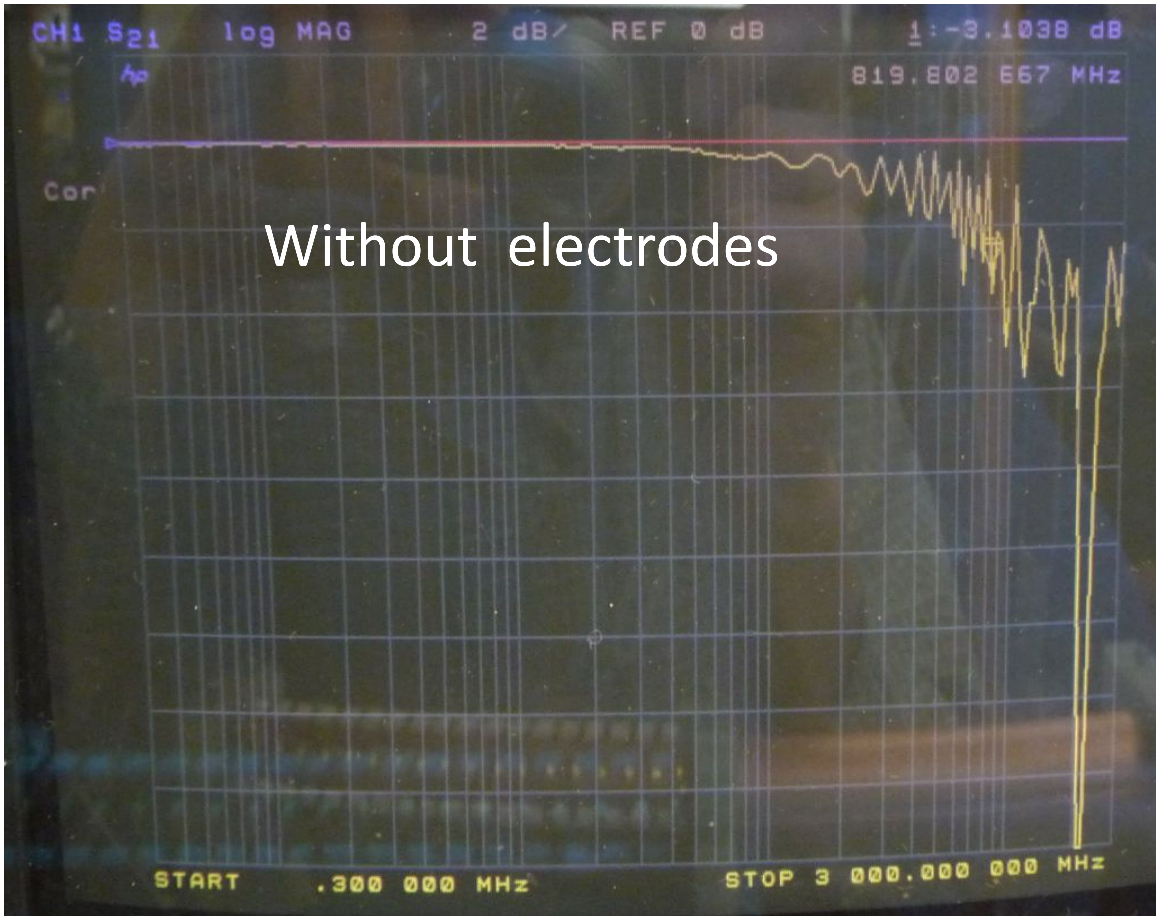


Transfer Response (TD)



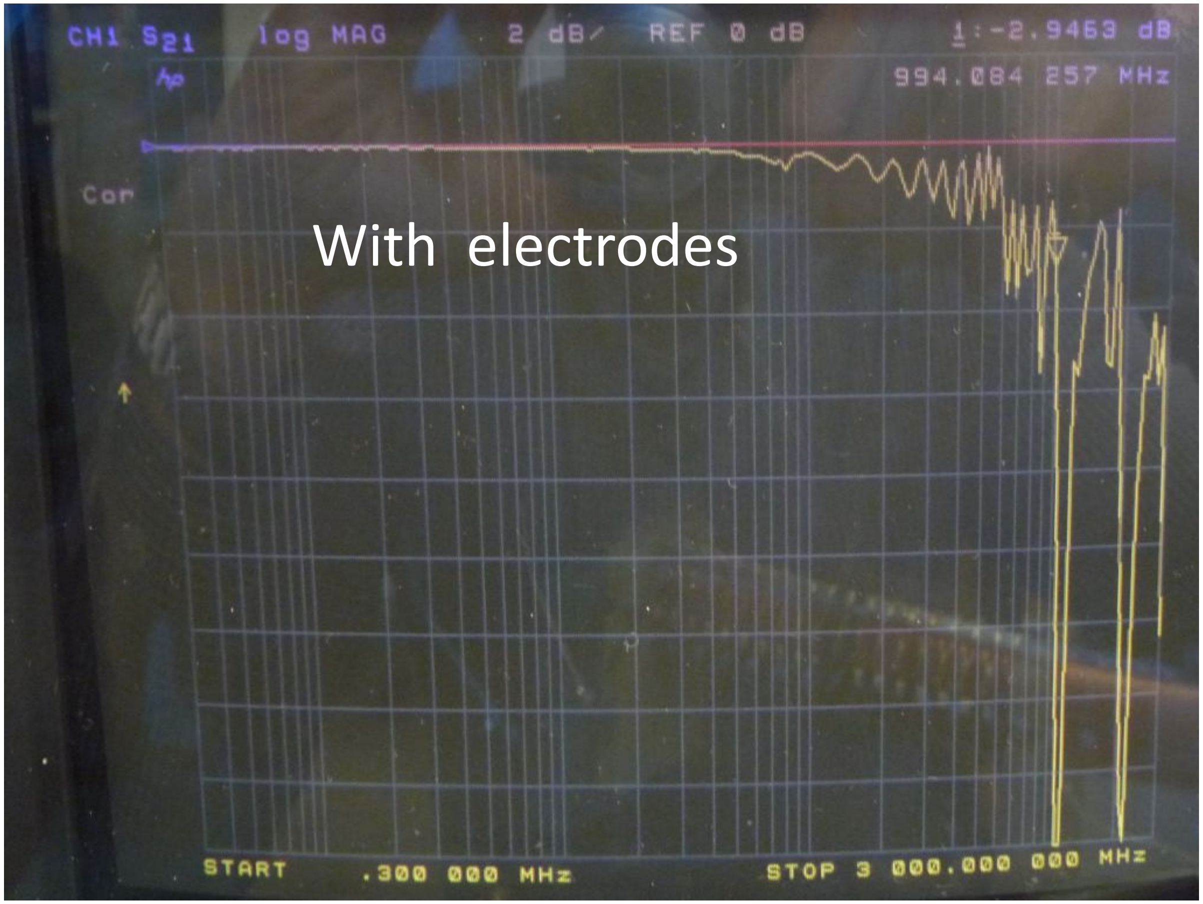
- 205 Ohm microstrip line is resistively matched to 50 Ohms, in and out
- .18 (W) x .50 (H) in. Electrodes are attached

Network analyzer response (S21)



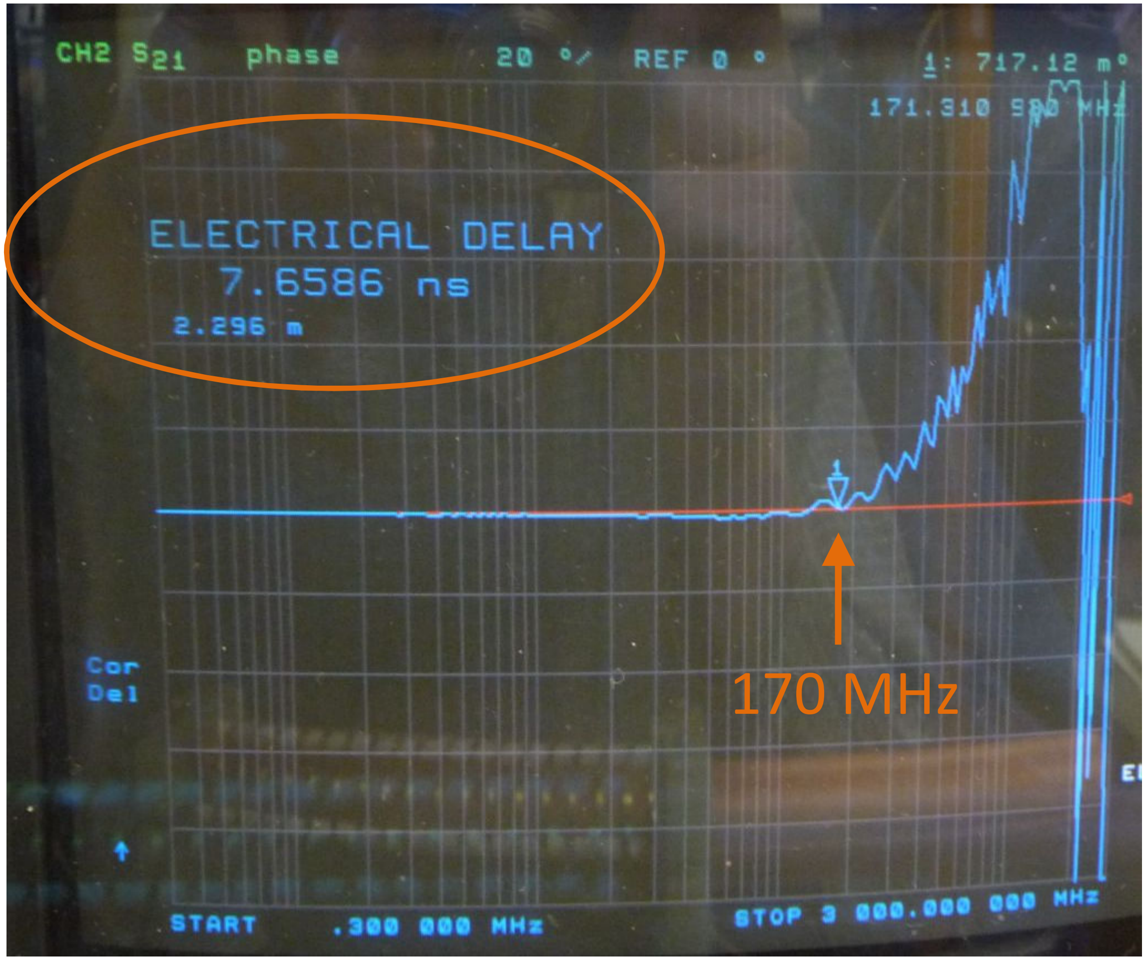
- Sweep range: .30MHz – 3GHz
- Vertical scale: 2dB/div
- Response remains below 3dB above ~800 MHz
- Matching resistor network and cable are calibrated out of the measurement

Network analyzer response (S21)



- Sweep range: .30MHz – 3GHz
- Vertical scale: 2dB/div
- Response rolloff remains below 3dB above 900 MHz
- Fixture was calibrated out

Network analyzer S21 phase response



- Sweep range: .30MHz – 3GHz
- Vertical scale: 20 deg/div
- Matching resistor network and cable are calibrated out of the measurement

Observations & Conclusions

- Prototype construction suffered from dimensional irregularities
  - Strip width varies 12% along the length
  - Pitch varies +/-10% turn-to-turn
- Resulting impedance variations are 20% along the length
  - Some ripple is due to ceramic rod supports, though
- Electrode electrical effects are only above 700 MHz
  - Each is an impedance discontinuity
  - Electrode required size seems to be small enough to be tolerable
- Dispersion effects with 6” are enough to question longer version

Design considerations

Using Valerie Lebedev's expressions from Project X Meeting, Nov. 3, 2010:

Coupling coefficient

$$K_C \approx \ln\left(\sqrt{1+(2b/h)^2}\right) \Big/ \ln\left(\frac{32b}{\pi w}\right), \qquad w << b,h$$

Dispersion

$$K_D \approx \sqrt{\varepsilon}\,\frac{\omega}{c}\left[1+8K_C{}^2\cos\left(\sqrt{\varepsilon}\,\frac{\omega l}{c}\right)\right]\sin^2\left(\sqrt{\varepsilon}\,\frac{\omega l}{2c}\right)$$

l – length of a single turn
ϵ - is dielectric permittivity

Coupling and dispersion for different 200 Ω helixes

Zo	Gnd Tube OD	b	w	h	K_C	K_D
175	.75"	.125"	.10"	.222"	.1610	.063497
205	1.125"	.177"	.090"	.333"	.1227	.063568
200	1.5625"	.177"	.090"	.441"	.0831	.063257
200	1.825"	.177"	.090"	.500"	.0676	.063116
200	2.125"	.177"	.090"	.570"	.0546	.062994

Further effort with helix microstrip line apporach

- There is no compelling reason to stay with 1.125" size helix
- Design a larger helix for less dispersion
- Choose 2.125" OD copper ground tube
  - Stock size 2" copper tube
  - Electrodes will be 1.5 cm x 1.5 cm (sufficiently small?)
- Anticipate winding full .5 m

Microstrip conductor temperature

- Copper skin depth at 80 MHz

$$\delta \approx 503\sqrt{\frac{\rho}{\mu_r f}} \approx 7.3 \text{ x } 10^{-6} \text{ (m)}$$

ρ – resistivity of copper
= $1.68\text{x}10^{-8}$ (Ω-m)
μ_r – relative permeability (=1)
f – frequency (Hz)

- Resistance in one skin depth of the strip per unit length

$$R^* = \frac{\rho}{A_X} = \frac{1.68\times10^{-8}}{7.3\times10^{-6}\bullet.09\bullet.0254} = 1.0 \ (\Omega/\text{m})$$

A_X – skin effect cross sectional area (m^2)

- Power dissipated in the microstrip

$$P^* = I^2 \bullet R^* = 1.0 \text{ (W/m)} \qquad I = \frac{400\bullet.50\,(V_{rms})}{200\,(\Omega)} = 1.0 \text{ (A)}$$

- Temperature of the conductor is derived from

$$P^* = \sigma A_S\left(T^4 - T_0^2\right)$$

σ – Stefan-Boltzmann constant
= $5.67\text{x}10^{-8}$ ($\text{W/m}^2/\text{deg}^4$)
A_S – conductor surface are = $5.58\text{x}10^{-3}$ (m^2)
T^4 – conductor temp. (K)
T_0^4 – ambient temp. (298 K)

Microstrip conductor temperature – cont.

- Conductor temperature

$$T = \left(\frac{P^*}{\sigma A_S} + T_0^4 \right)^{\frac{1}{4}} = 324\ (\mathrm{K}) = 51^\circ \mathrm{C}$$

- Compare with a 50 Ohm helix

$$T = \left(\frac{16}{\sigma A_S} + T_0^4 \right)^{\frac{1}{4}} = 492\ (\mathrm{K}) = 219^\circ \mathrm{C}$$

End