Novel Technique for Frequency Tuning Ferrite Filled Nonlinear Transmission Lines

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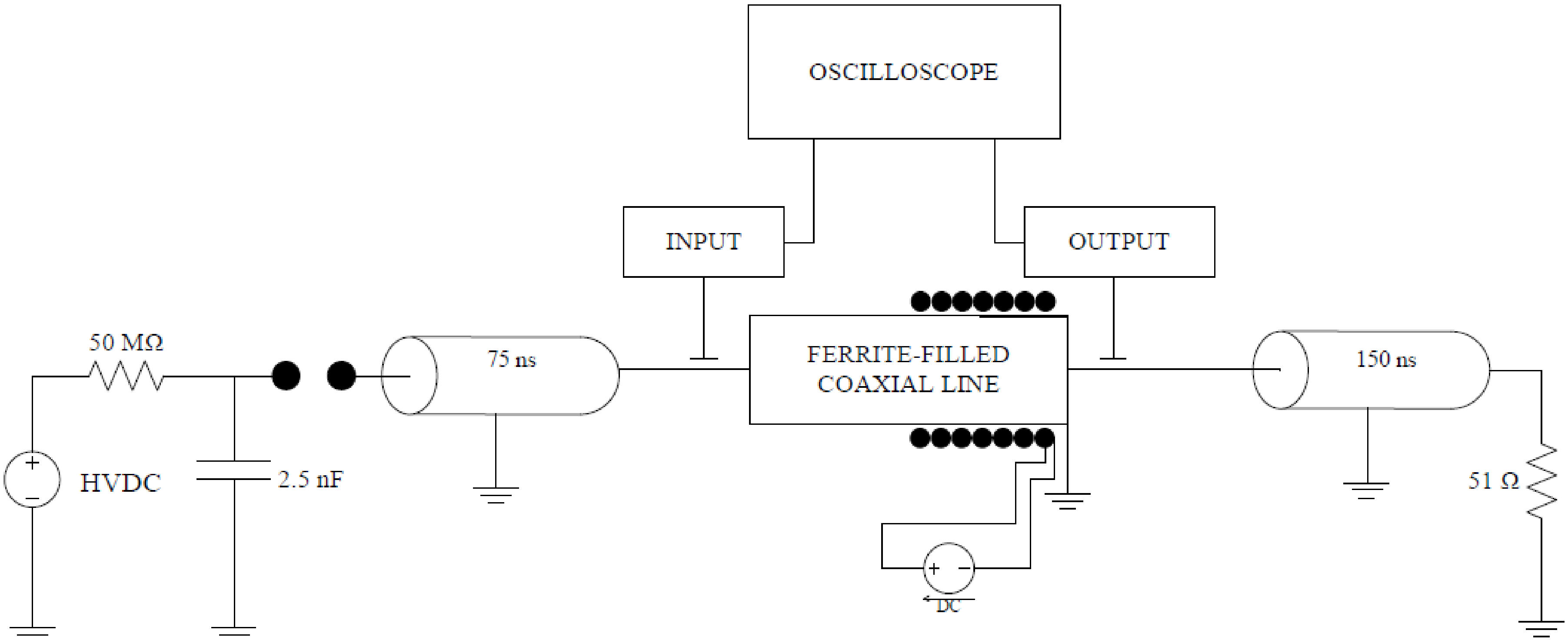
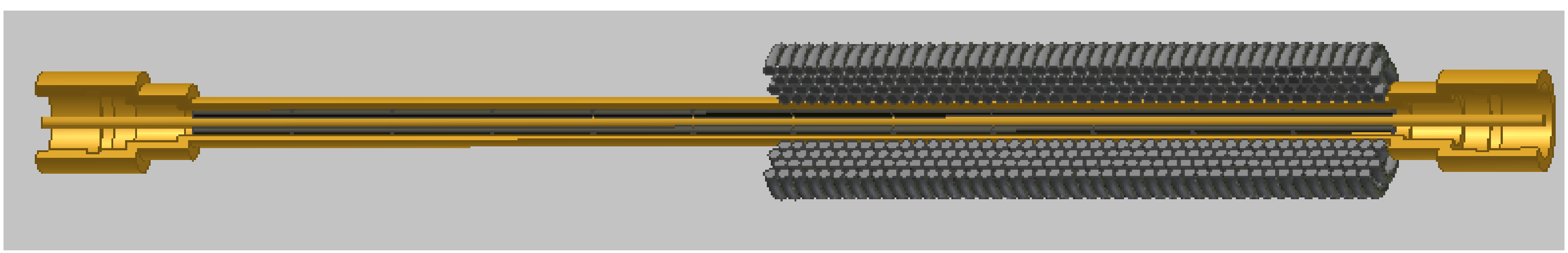
Motivation

- Utilize precessional behavior in materials with nonlinear permeability to generate microwave oscillations
- Determine dominant parameters in frequency selection
- Provide an efficient means to achieve a broad range of frequencies

Experimental Setup

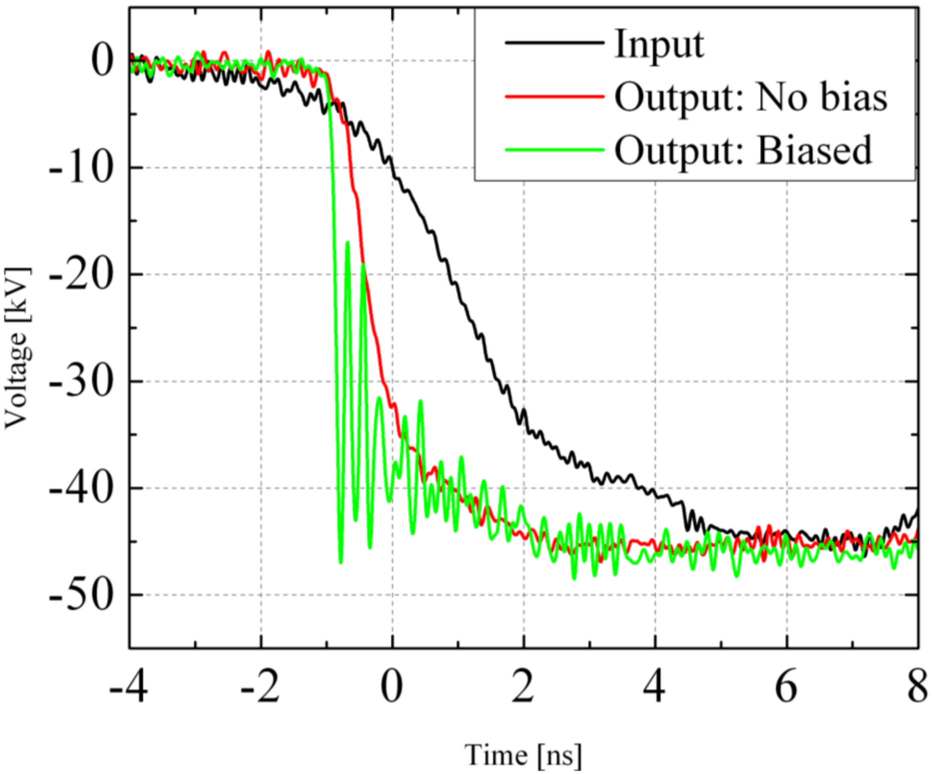




Theory of Operation

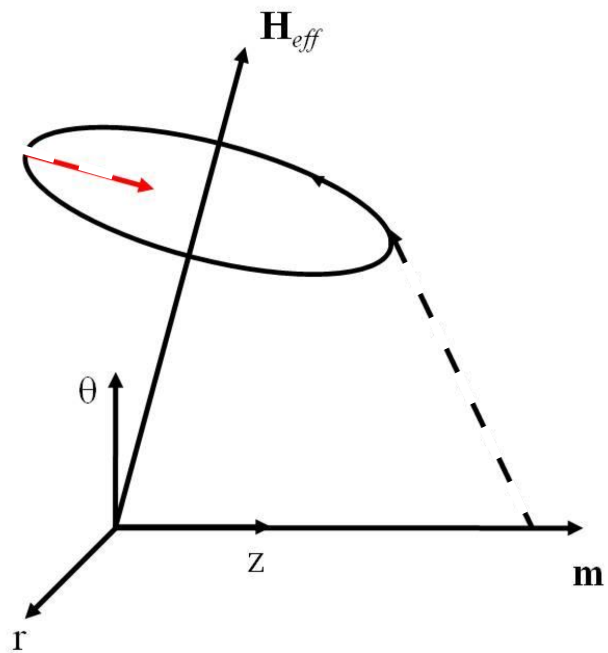
- Pulse Sharpening

$$v_p = \frac{1}{\sqrt{\mu(I)\varepsilon}}$$



- Damped Gyromagnetic Precession

$$\frac{\partial \mathbf{m}}{\partial t} = -\gamma \mathbf{m} \times \mathbf{H}_{eff} + \alpha \mathbf{m} \times \frac{\partial \mathbf{m}}{\partial t}$$



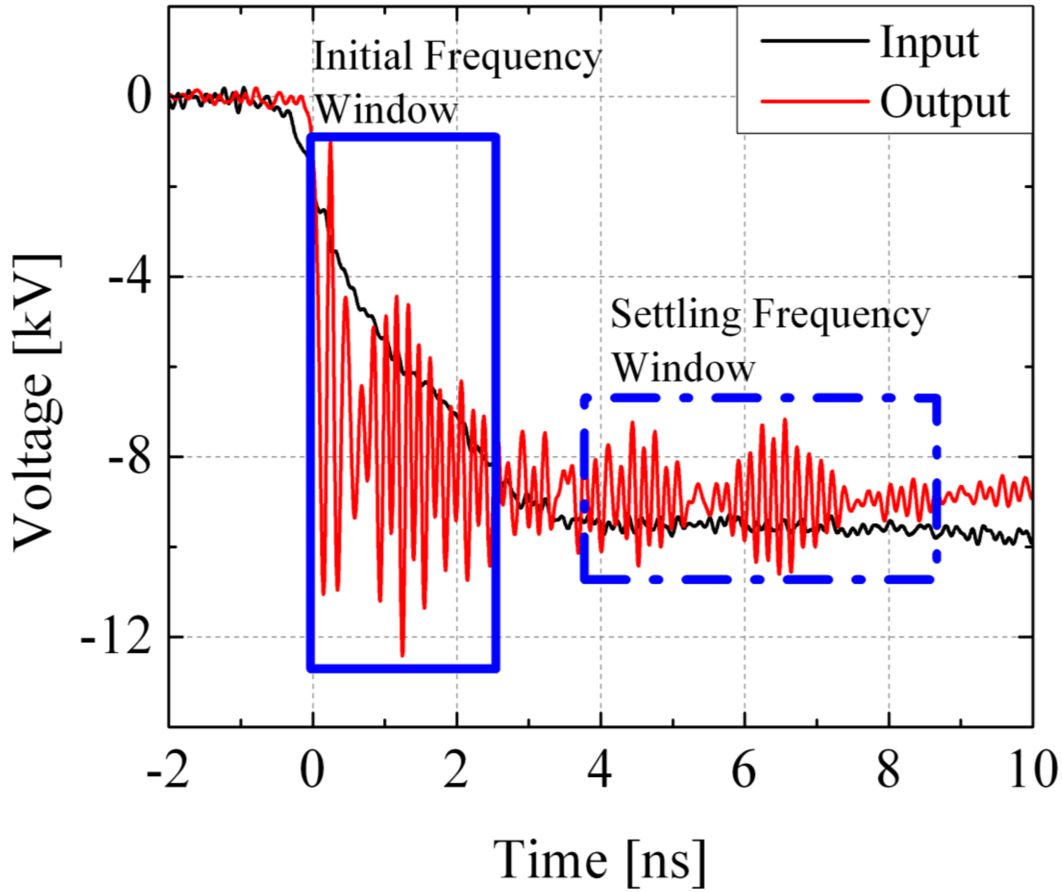
Line Details

- Ferrite
  - Ni–Zn
- Transmission Line
  - Brass (all but 2)
  - Aluminum
  - Copper
- Dielectric
  - 100 psi SF_6
- 50 Ω Impedance

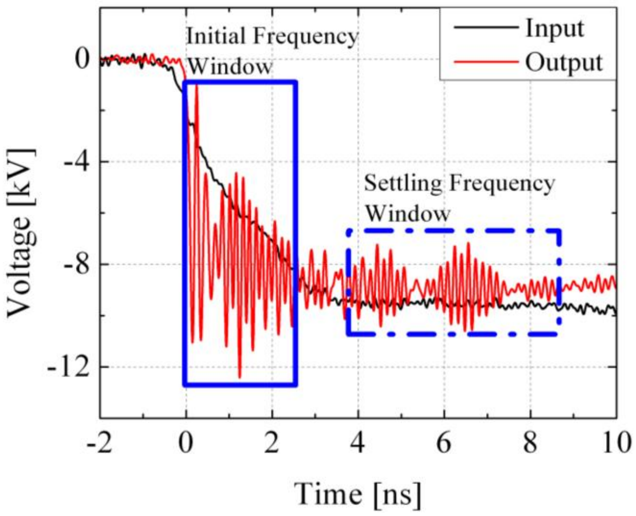
Line	Outer Conductor	Inner Ferrite	Outer Ferrite	Length
	[mm]	[mm]	[mm]	[m]
1S	2.3	0.85	1.65	1
015M	7.6	3	6	0.15
03M	7.6	3	6	0.3
1M	7.6	3	6	1
Cu and Al	7.85	3	6	0.3
03PM	9.3	3	6	0.3
1PM	9.3	3	6	1
03L	16.2	7.9	12.3	0.3
1L	16.2	7.9	12.3	1

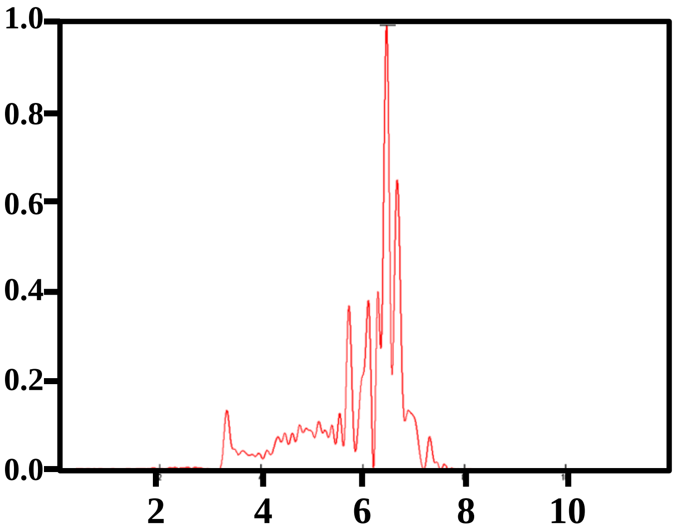
Representative Waveforms

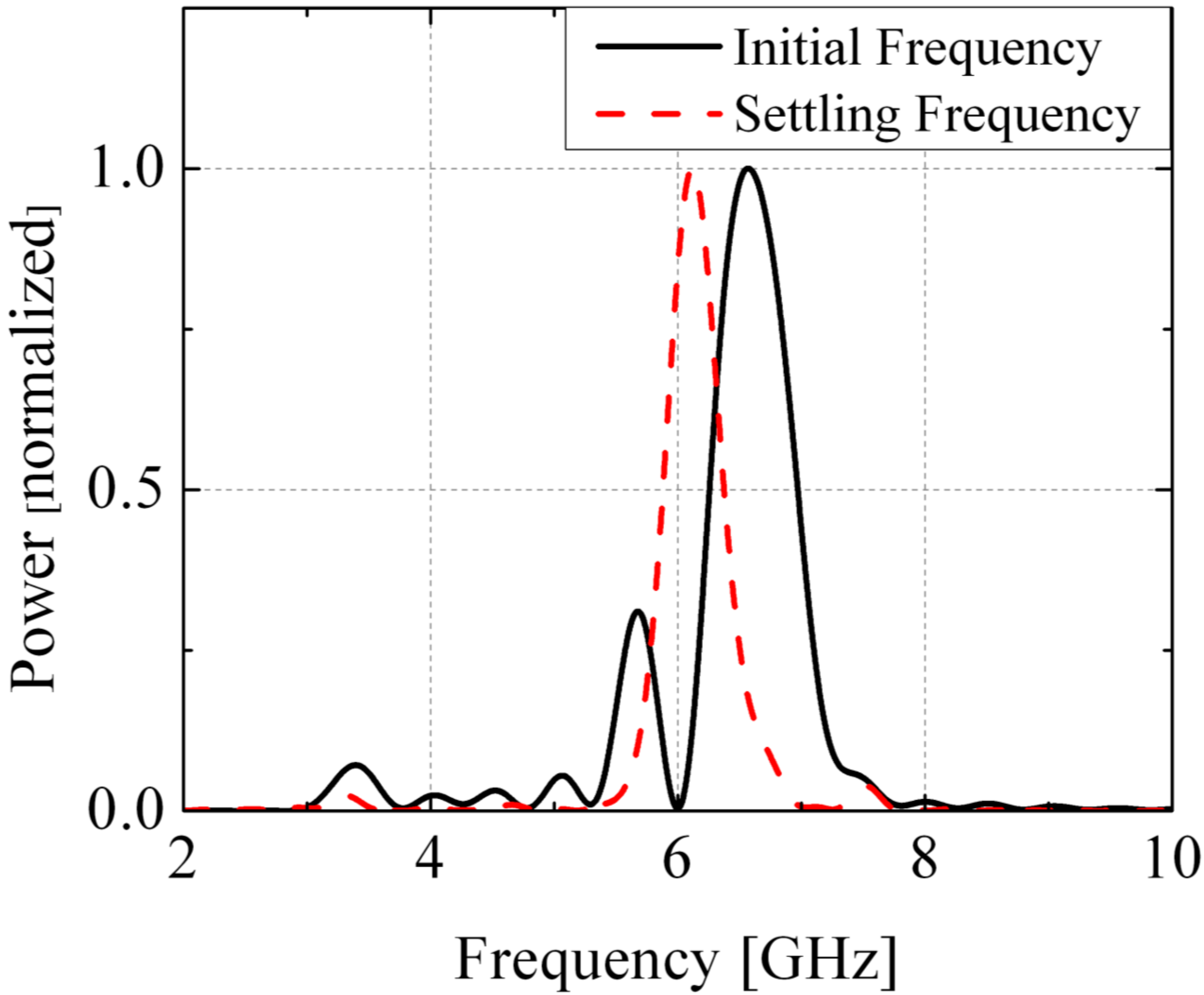
- Varying Voltages
  - Constant bias of 20 – 30 kA/m
    - 1S: 2 – 10 kV
    - ‘M’ Lines: 10 – 50 kV
    - ‘L’ Lines: 30 – 70 kV
- Varying Bias
  - Constant voltage of 10 – 50 kV
    - 0 – 70 kA/m
- Observed different initial and settling frequencies



1S Frequency Example



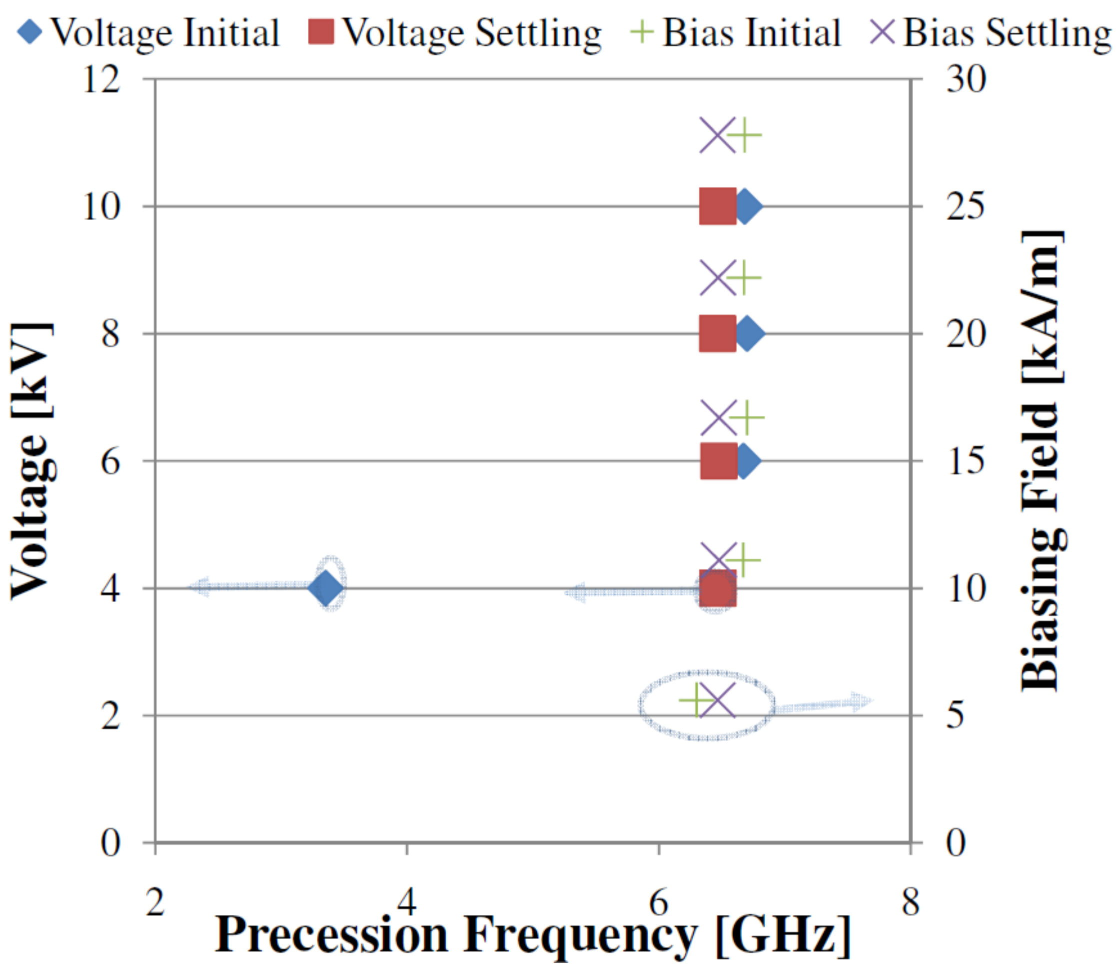




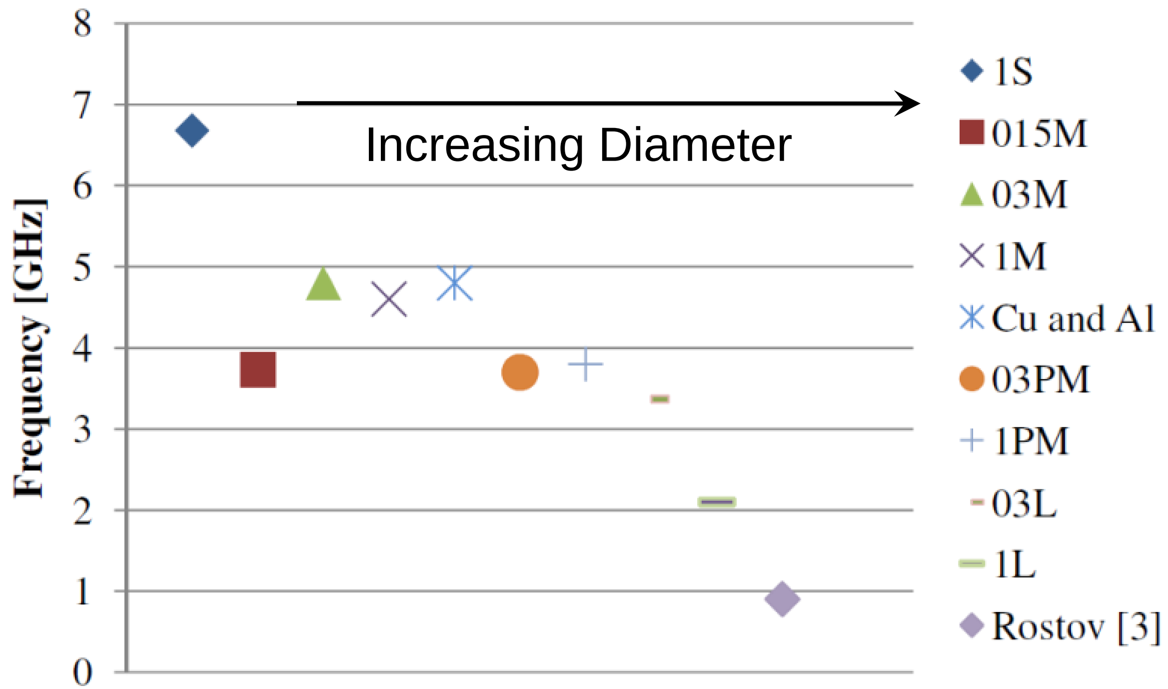
Varying Voltage and Bias on 1S

- Line 1S
- 6 – 28 kA/m (8 kV)
- 2 – 10 kV (22 kA/m)
- 6.1 – 6.4 GHz

- Why the outlier at 4 kV?
  - Lack of magnetic field strength to induce damped gyromagnetic precession

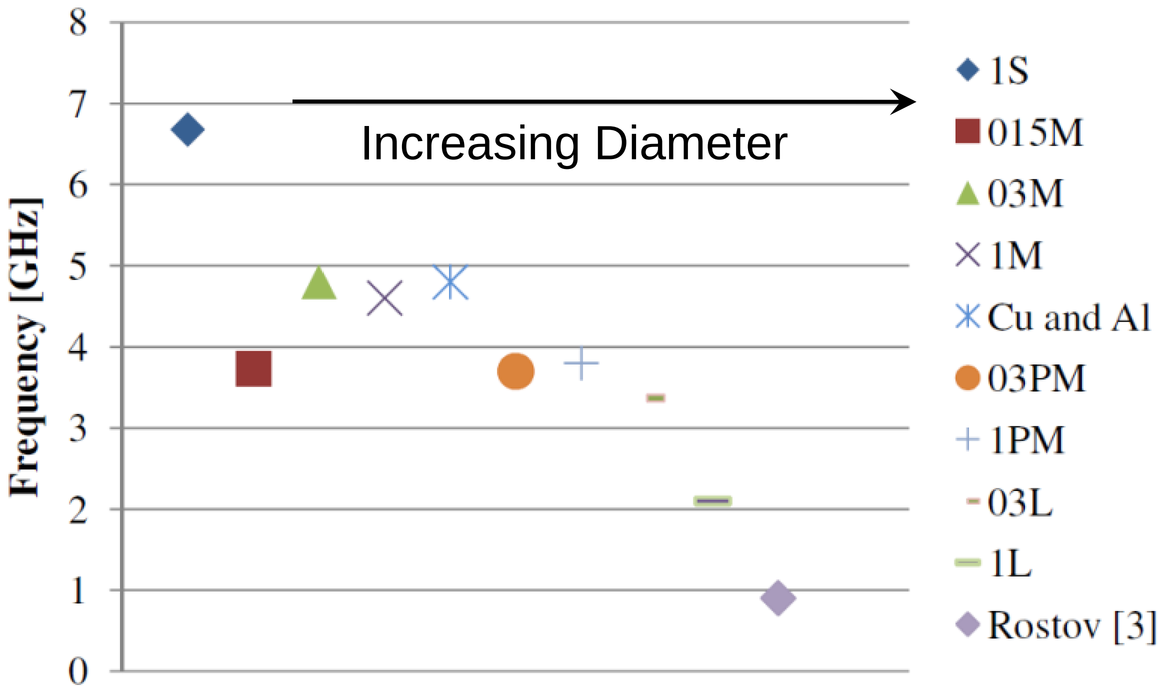


Initial Frequency Results



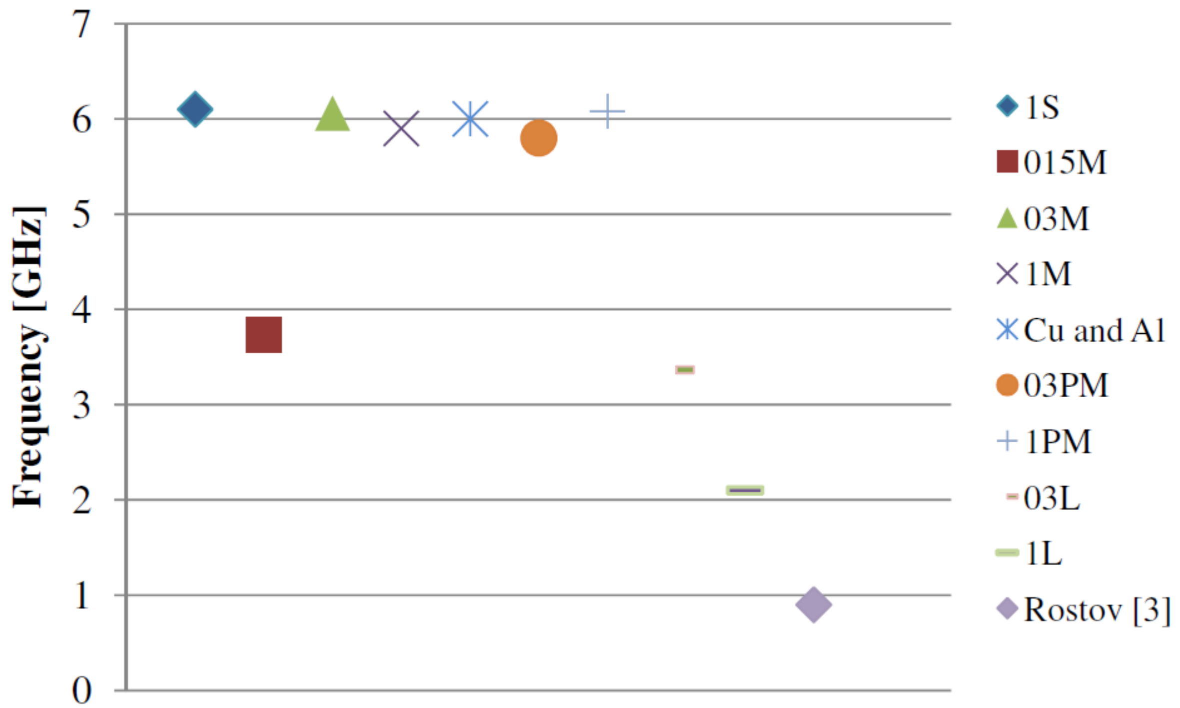
- Increased magnetic viscosity with increased ferrite size
- Increased losses with increase in ferrite size
- Lack of incident magnetic field strength to fully induce damped gyromagnetic precession

Results from Permanent Magnet Biasing



- Line 03PM: NdFeB and Ceramic magnets
  - 0 – 70 kA/m
- 10 – 50 kV
- NdFeB quickly quenched precession, thereby eliminating a settling frequency
- Ceramic yields similar results to solenoid biasing

Settling Frequency Results



- Increased losses/magnetic viscosity in larger ferrites
- Lack of incident magnetic field strength to fully stimulate precession
- 015M: too short for peak phase; therefore, precession is not fully reached

Conclusions

- Designed and tested 10 lines
- Observed frequency dependence on NLTL conductor and loaded ferrite diameters
- Clear differences between initial and settling frequencies
- Within thresholds, voltage and bias do not affect frequency