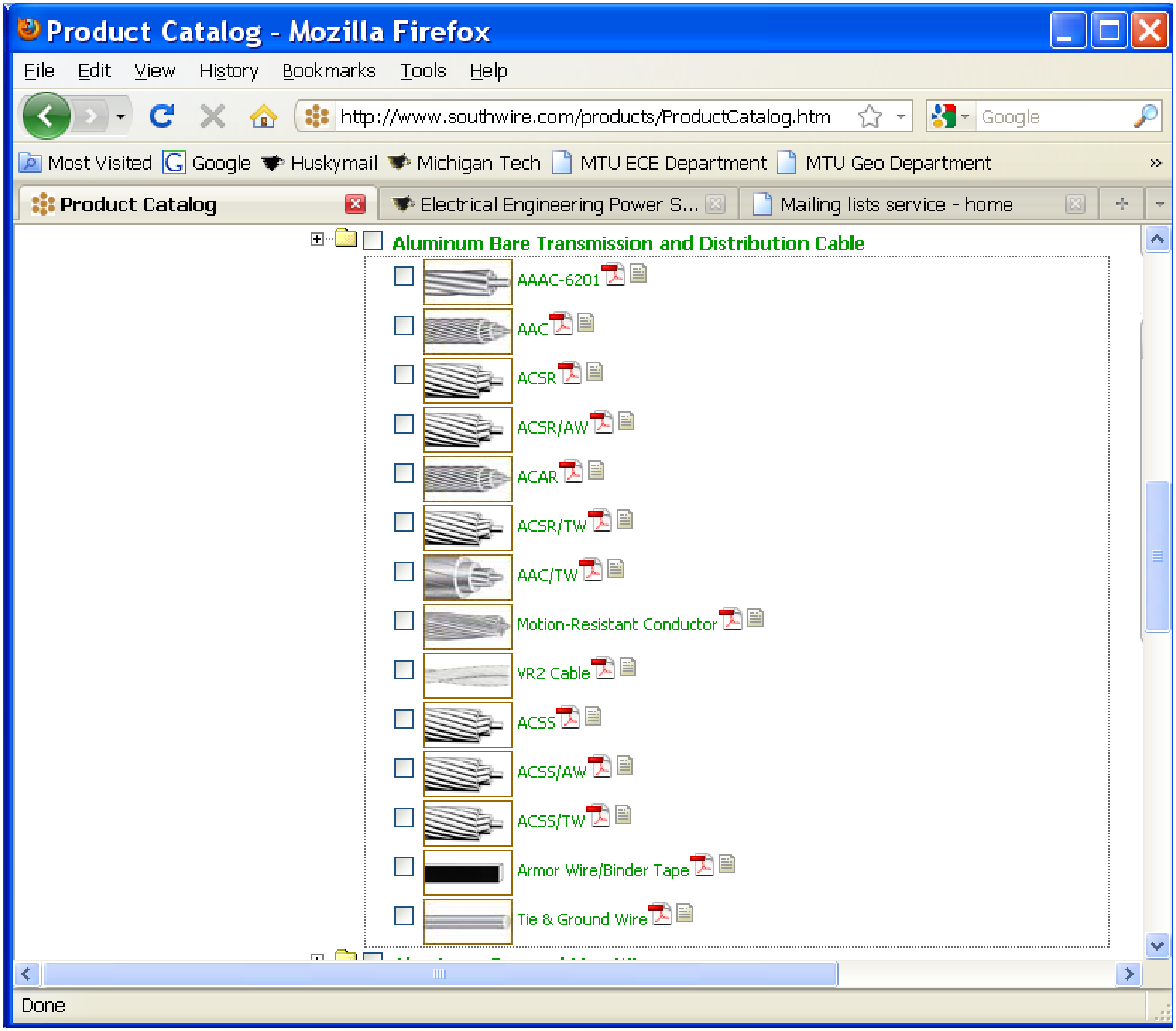
EE 5200 - Lecture 16 Mon Oct 7, 2019

Topics for Today:

- Announcements
  - Matlab to be incorporated in some of upcoming Hmwks.
  - Office: EERC 614.   Phone: 906.487.2857
  - Recommended problems from Ch.4,5 solutions posted
  - Next: Transmission Line C Parameters, Chapter 6

Chapter 4 - Series Resistance of Transmission Lines
- Conductor data (links provided on web page)
- Spiraling, effective length is about 2% longer
- Series Resistance, temperature correction

Chapter 5 - Series Inductance of Transmission Lines
- Self-inductance of a conductor
- Review of mutual inductance concepts
- Mutual inductance between 2 conductors
- Inductance matrix for group of conductors



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VR2 Cable
ACSS
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ACSS/TW
Armor Wire/Binder Tape
Tie & Ground Wire
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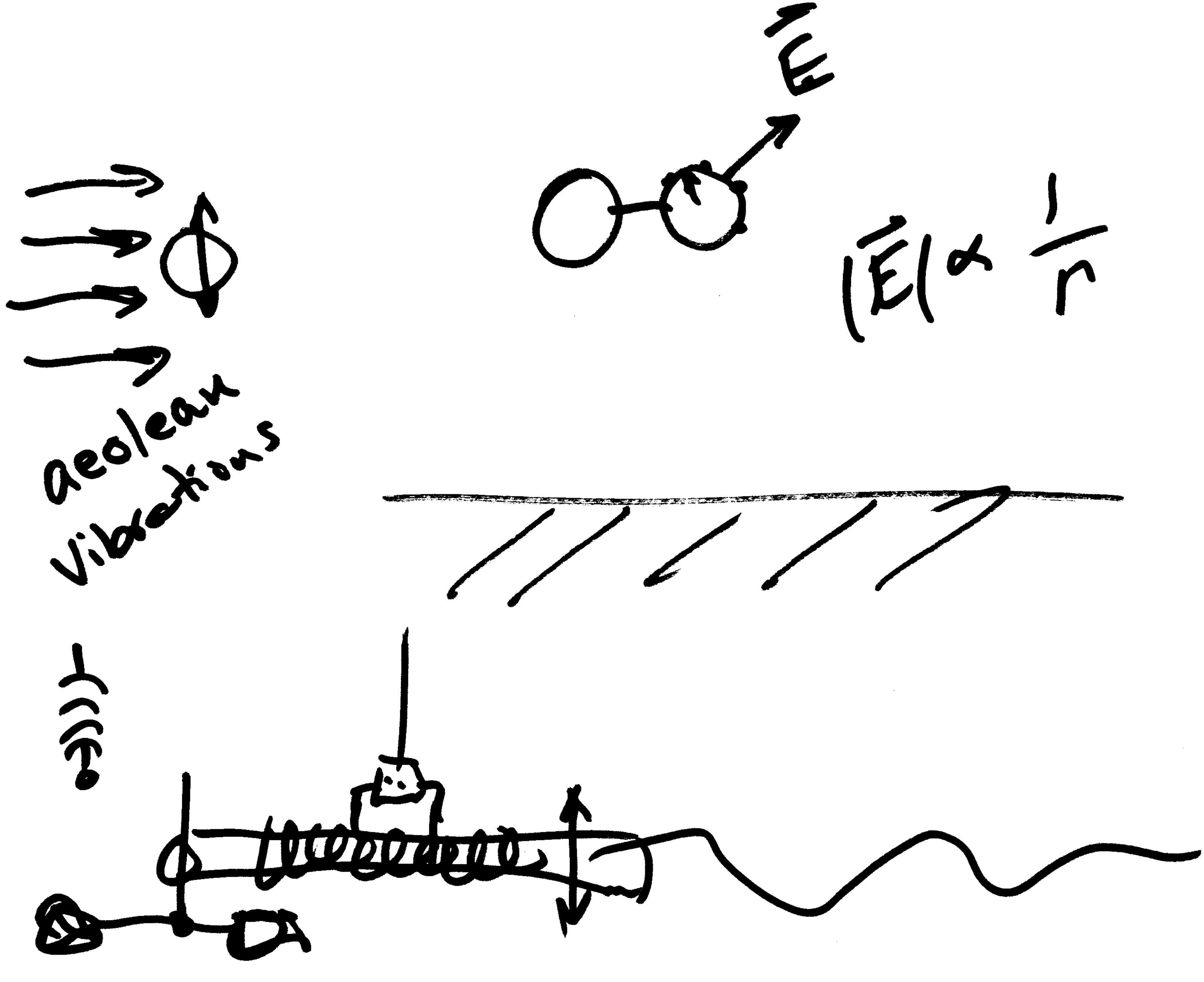

aeolean vibrations
$\vec{E}$
$|\vec{E}| \propto \frac{1}{r}$

Wind-induced oscillation (from Wikipedia)

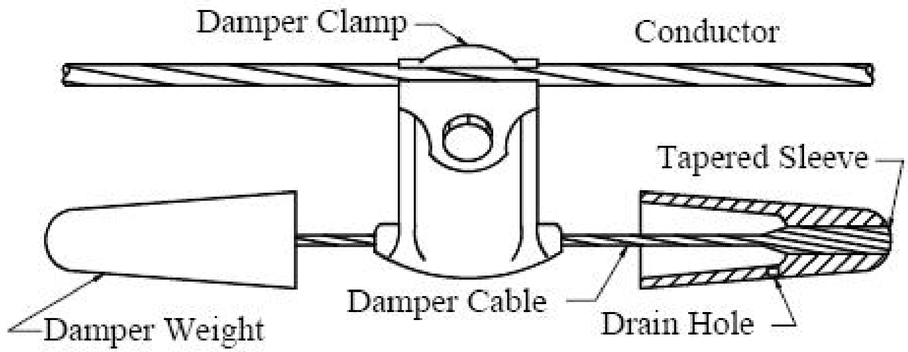
Wind can generate three major modes of oscillation in suspended cables:[4]

- Gallop has an amplitude measured in metres and a frequency range of 0.08 to 3 Hz;
- Aeolian vibration (sometimes termed flutter) has an amplitude of millimetres to centimetres and a frequency of 3 to 150 Hz;
- Wake-induced vibration has an amplitude of centimetres and a frequency of 0.15 to 10 Hz

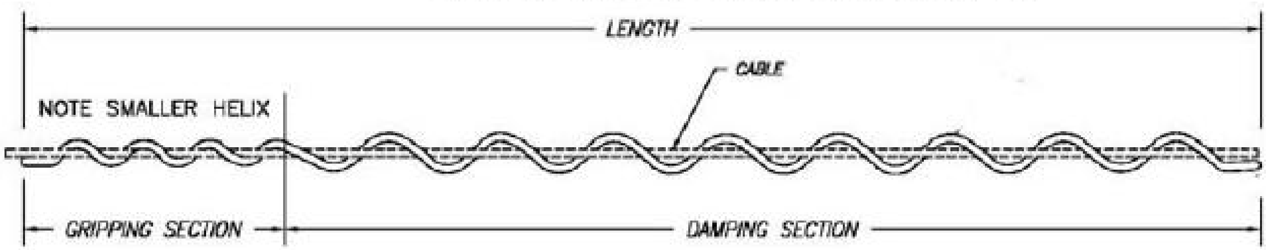
The Stockbridge damper targets oscillations due to aeolian vibration; it is less effective outside this amplitude and frequency range. Aeolian vibration occurs in the vertical plane and is caused by alternating shedding of vortices on the leeward side of the cable. A steady but moderate wind can induce a standing wave pattern on the line consisting of several wavelengths per span.[4] Aeolian vibration causes damaging stress fatigue to the cable[5] and represents the principal cause of failure of conductor strands.[4] The ends of a power line span, where it is clamped to the transmission towers, are at most risk.[5] The effect becomes more pronounced with increased cable tension,[5] as its natural self-damping is reduced.

Transmission Line Vibration Dampers -

Top: Traditional Stockbridge - 2 frequencies
Bottom: Spiral type

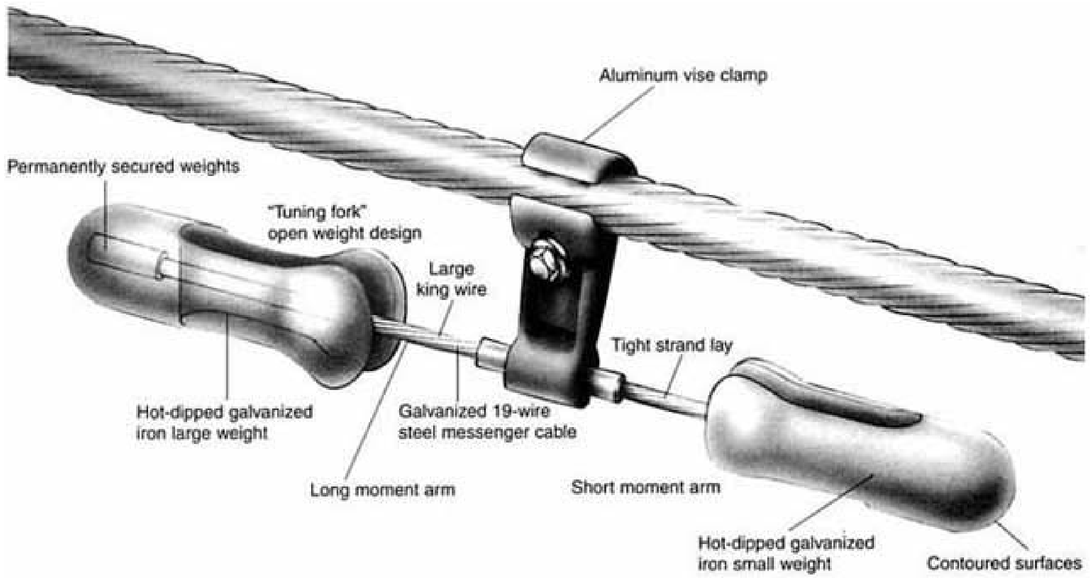


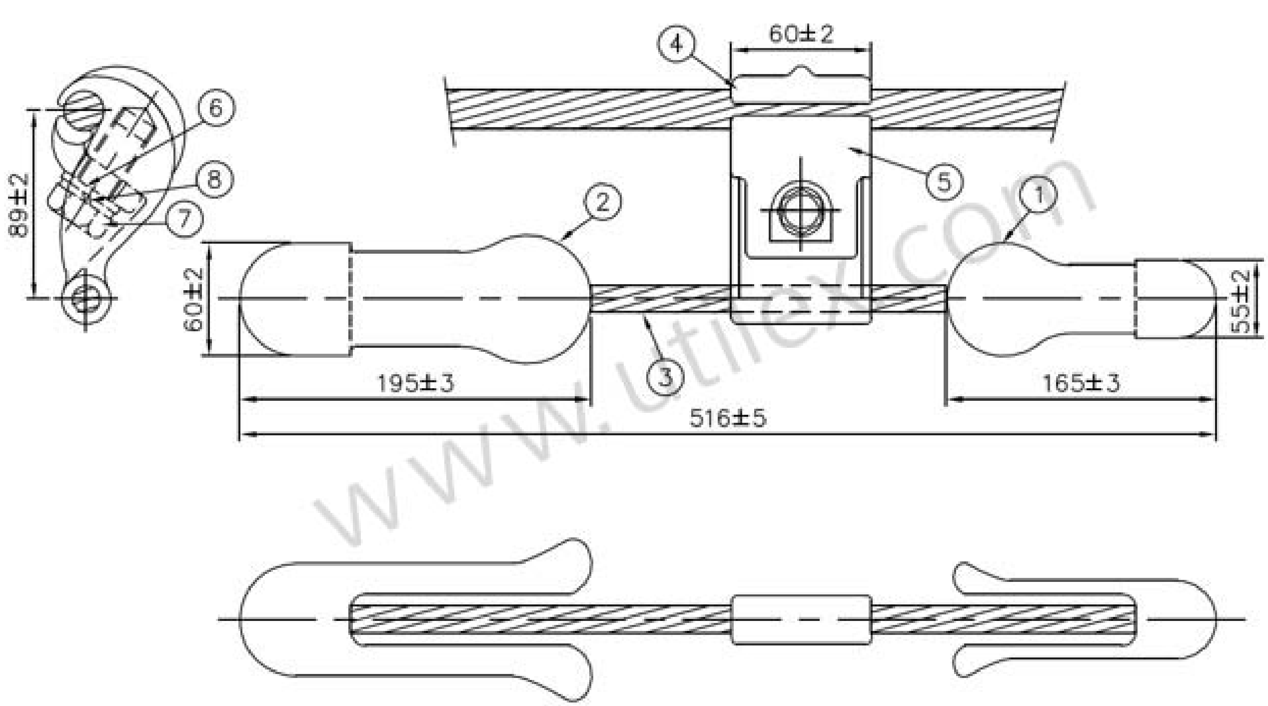
TYPICAL SUSPENSION DAMPER



SPIRAL VIBRATION DAMPER FOR SMALL CONDUCTORS

Transmission Line Vibration Damper - Four Resonant Peaks





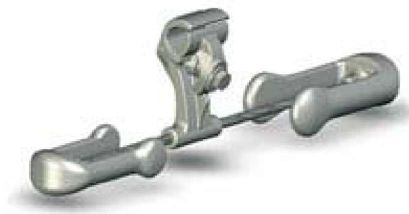
PFISTERER

Spacer Dampers, Stockbridge Dampers, Recorders and Warning Spheres

Triple Spacer Damper

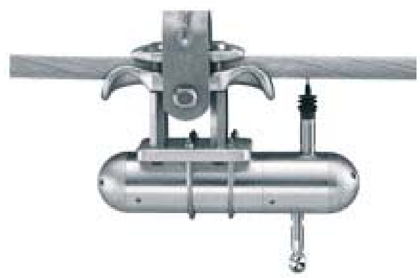
PFISTERER's spacer dampers are specifically designed and coordinated to provide damping against conductor motions caused by wind. In particular the spacer dampers control the levels of aeolian vibration and subspan oscillation within the accepted safety limits, under all service conditions and for the expected life time of the line. PFISTERER offers a complete range of spacer dampers for two, three, four and six bundles, with spacing ranges from 300 to 600 mm.

Stockbridge Damper



PFISTERER's range of stockbridge dampers is designed to dissipate energy from all types of conductors, shieldwires and OPGW cables caused by wind-induced motions. Many tests are needed to prove a successful damper design, which includes corrosion resistance, damping performance and fatigue behaviour. These tests are necessarily supplemented by electrical tests in regard to corona and RIV and are performed in PFISTERER's own laboratories.

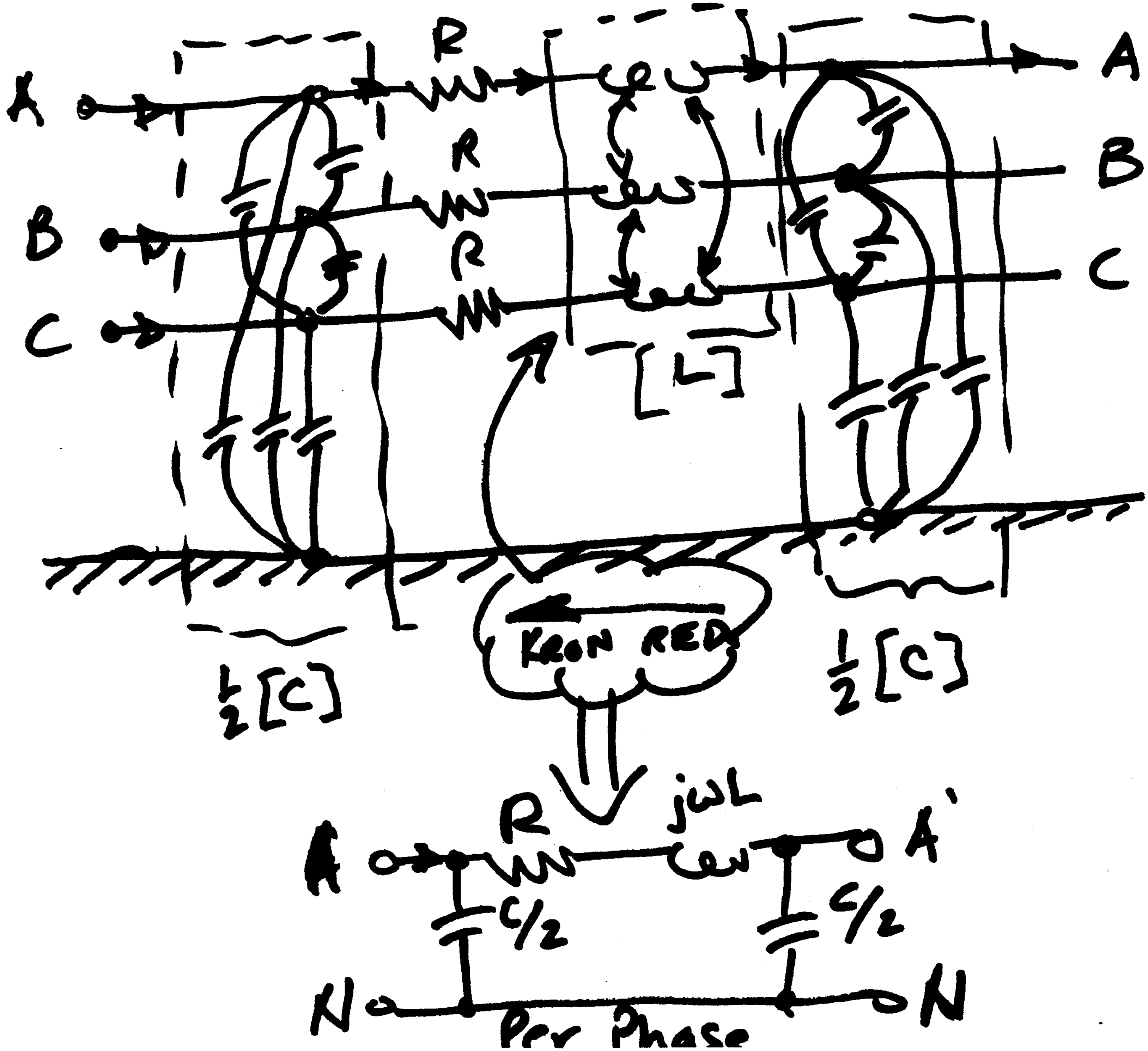
Vibration Recorder

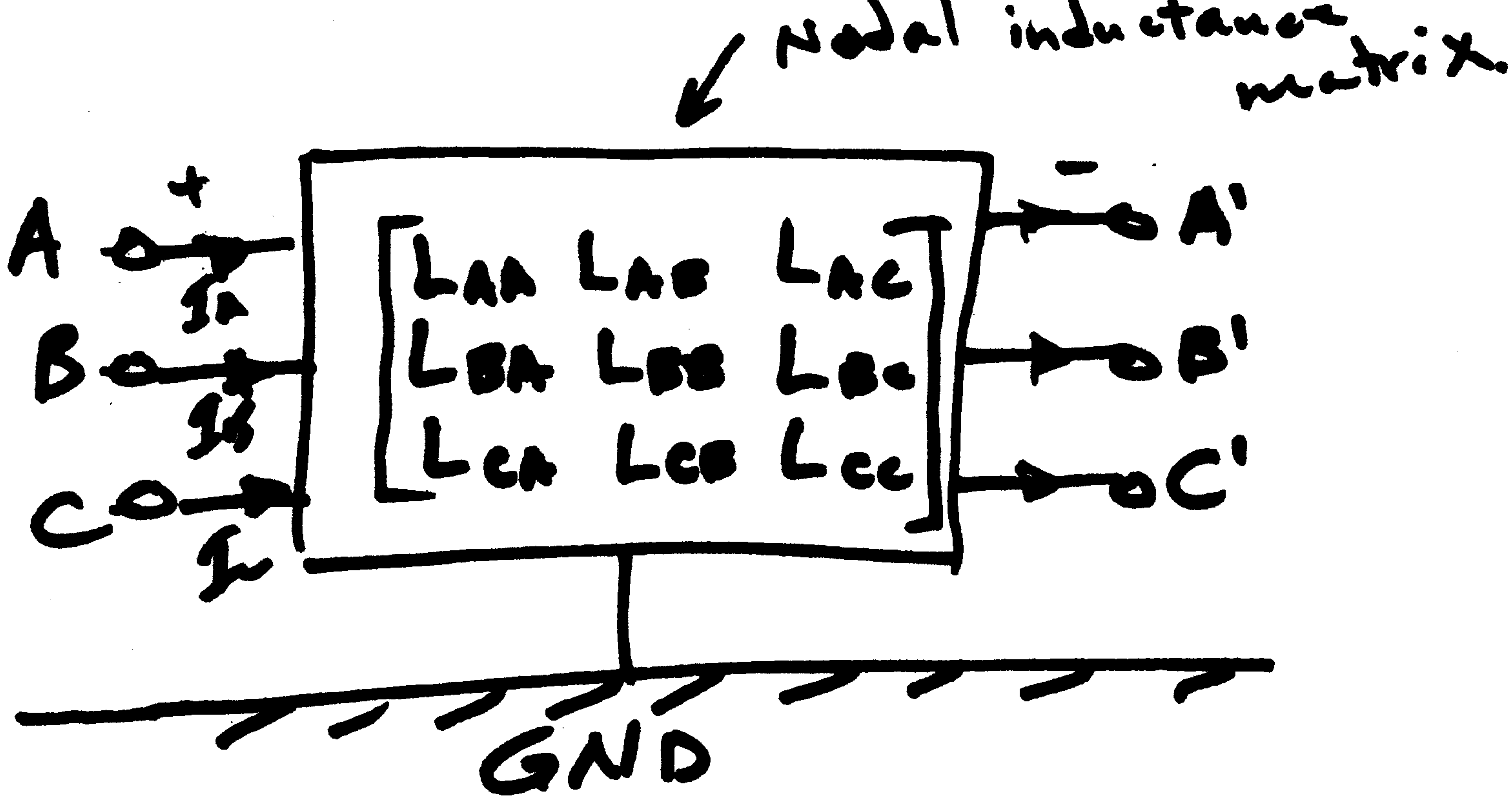


As the ultimate means of checking damping systems or to investigate the cause of conductor damages, PFISTERER offers vibration recorders. These can be used to easily measure vibrations on lines in operation. Moreover, the component of wind velocity acting perpendicularly to the line and the ambient temperature can be recorded. The conductor vibration data can be recorded and converted. By autonomous, long-term and direct measurements, an assessment of all critical line sections can be made.

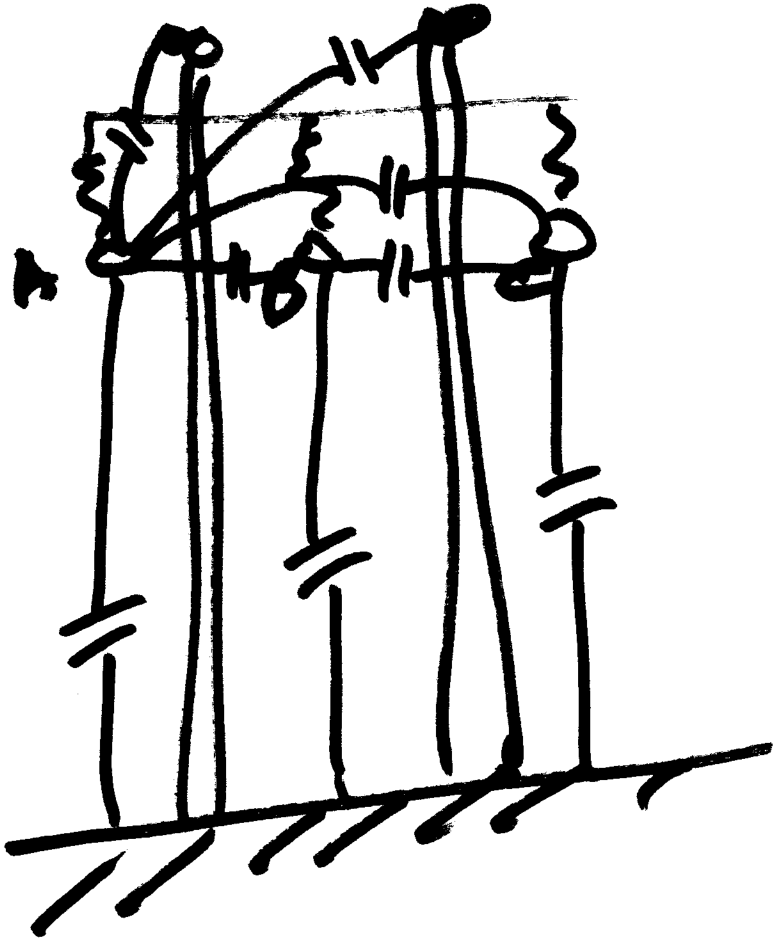
Warning Sphere

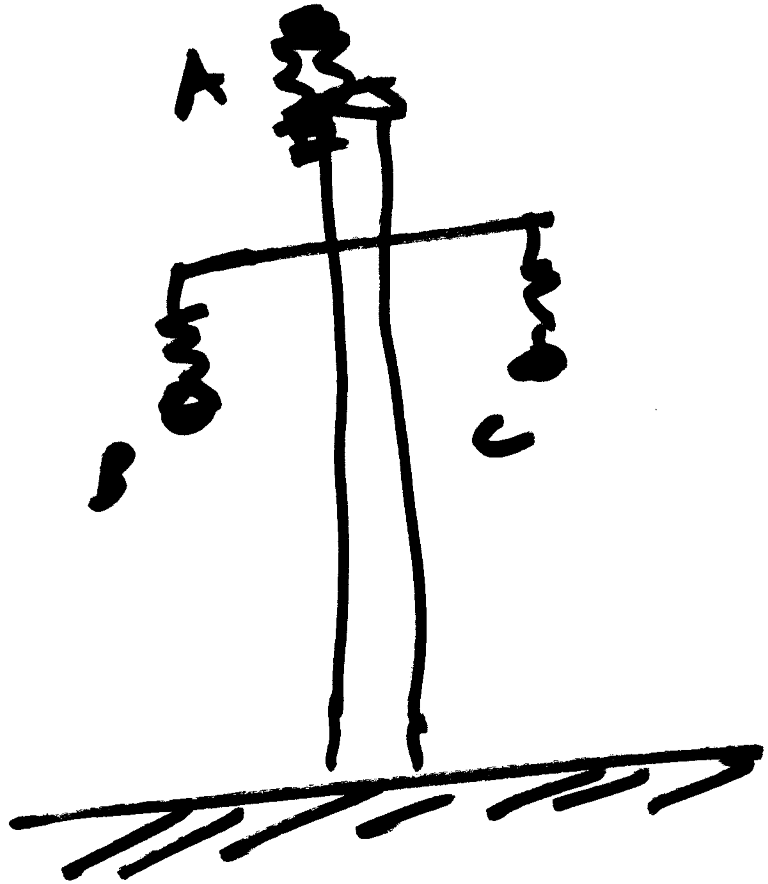
PFISTERER's warning sphere has a diameter of 600 mm and is especially manufactured to avoid the loss of colour and UV-degradation by using a special material and painting technology. Optimisations have been applied to eliminate clamp loosening and audible noise due to vibration. Installation costs can be reduced thanks to its simple installation. The sphere is available in various colours and for several conductor diameters.

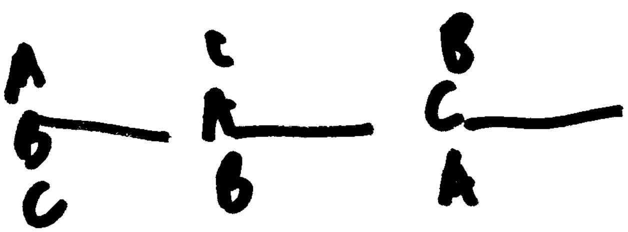

A
B
C
R
R
R
A'
B'
C'
[L]
KRON RED
½[C]
½[C]
R
jωL
A
A'
C/2
C/2
N
N
Per Phase

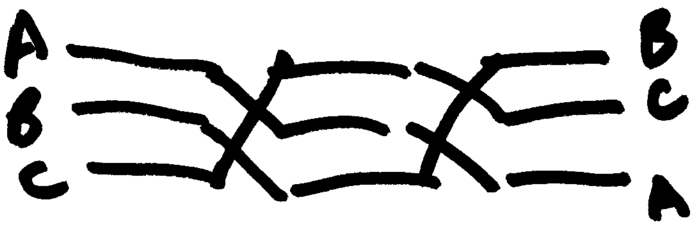


$$\begin{bmatrix} V_{A-A'} \\ V_{B-B'} \\ V_{C-C'} \end{bmatrix} = j\omega \begin{bmatrix} & & \\ & L & \\ & & \end{bmatrix} \begin{bmatrix} \tilde{I}_A \\ \tilde{I}_B \\ \tilde{I}_C \end{bmatrix}$$


A


A
B
C

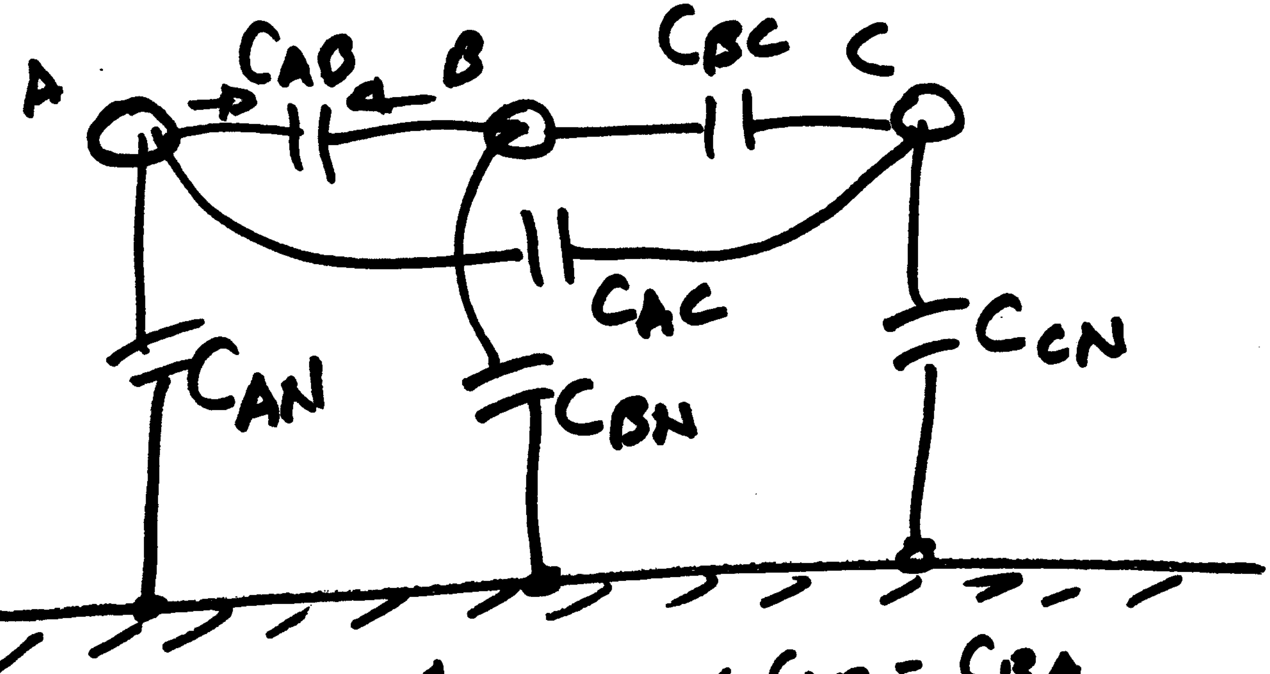

A
B
C
C
A
B
B
C
A


A
B
C
B
C
A

Cy Effects:

Note: $C_{AC} < C_{AB}, C_{BC}$

$y_{AB} = j\omega C_{AB}$



Full-Line Chg. Capacitance

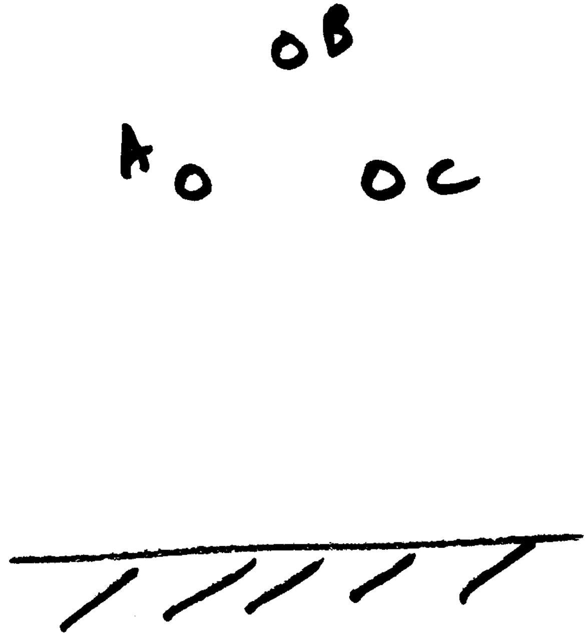
C_{AA}

$C_{AB} = C_{BA}$

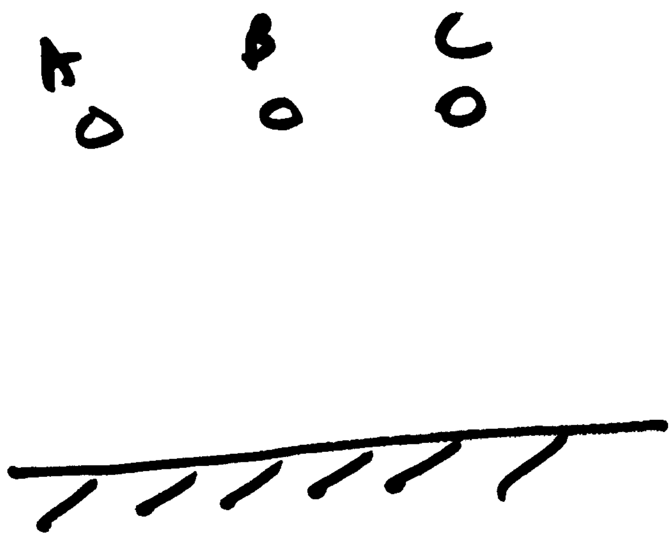
$$[C] = \begin{bmatrix} C_{AB}+C_{AC}+C_{AN} & -C_{AB} & -C_{AC} \\ -C_{BA} & C_{AB}+C_{BC}+C_{BN} & -C_{BC} \\ -C_{CA} & -C_{CB} & C_{BC}+C_{AC}+C_{CN} \end{bmatrix}$$

$$\begin{bmatrix} V_{A-A'} \\ V_{B-B'} \\ V_{C-C'} \end{bmatrix} = j\omega \begin{bmatrix} L_{AA} & L_{AB} & L_{AC} \\ L_{BA} & L_{BB} & L_{BC} \\ L_{CA} & L_{CB} & L_{CC} \end{bmatrix} \begin{bmatrix} \tilde{\underline{I}}_A \\ \tilde{\underline{I}}_B \\ \tilde{\underline{I}}_C \end{bmatrix}$$

$$+ \begin{bmatrix} R_{AA} & 0 & 0 \\ 0 & R_{BB} & 0 \\ 0 & 0 & R_{CC} \end{bmatrix} \begin{bmatrix} I_A \\ I_B \\ I_C \end{bmatrix}$$



Balanced set of
[L], [C], [R]
"Lends itself" well
to per-phase calcs.

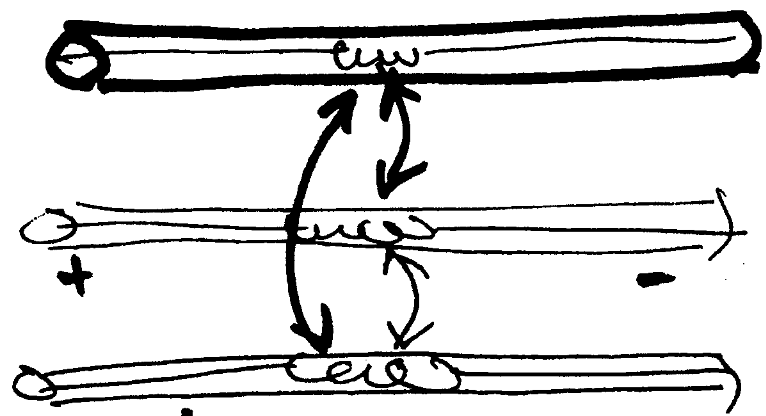


Unbalanced
[L], [C]

$$C \propto \ln \frac{r}{DEQ}$$
$$L \propto \ln \frac{DEQ}{r'}$$

Inductance

- Self
- Mutual

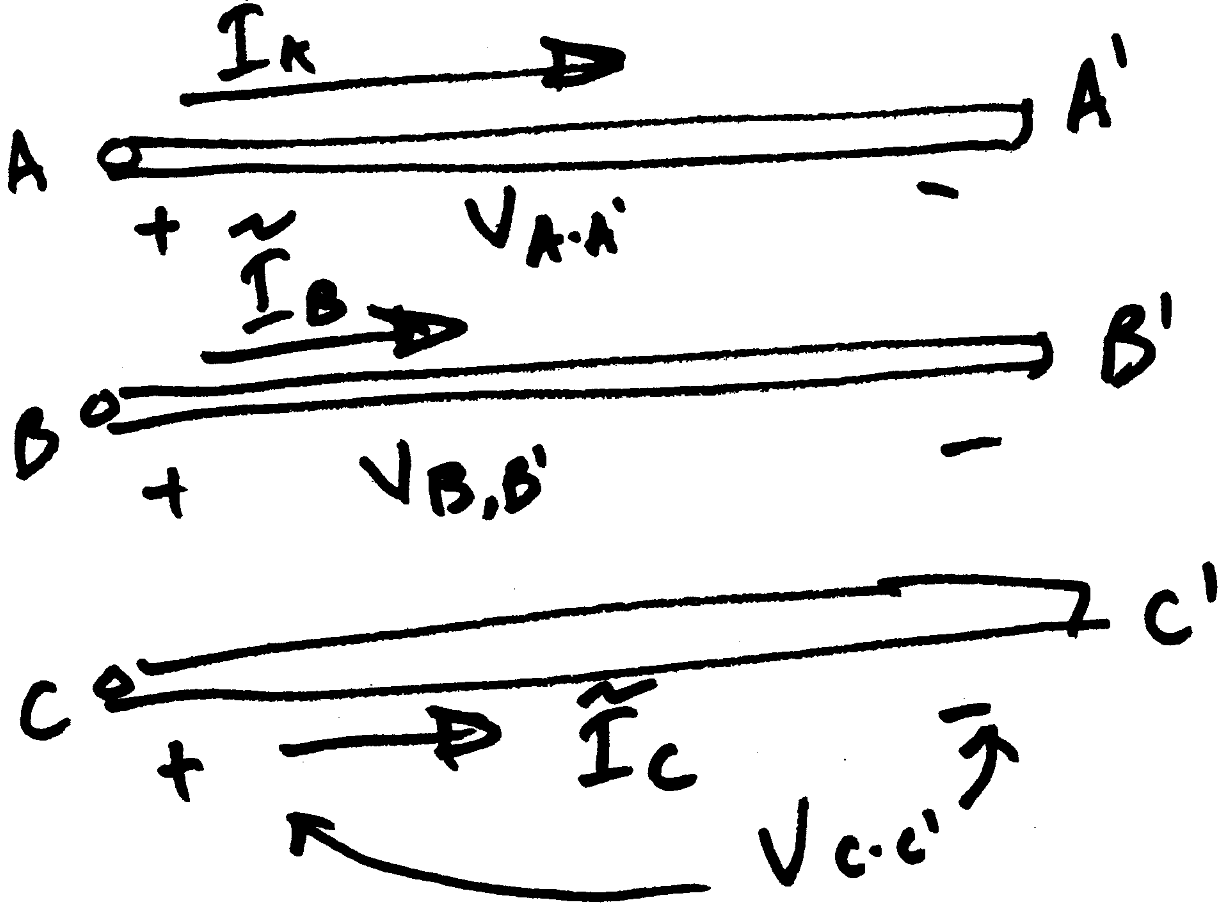


Basic E-mag

$$j\omega \begin{bmatrix} L_{11} & L_{12} & L_{13} \\ L_{21} & L_{22} & L_{23} \\ L_{31} & L_{32} & L_{33} \end{bmatrix}$$

$$\Downarrow$$

$$j\omega \begin{bmatrix} L_{00} & L_{01} & L_{02} \\ L_{10} & L_{11} & L_{12} \\ L_{20} & L_{21} & L_{22} \end{bmatrix}$$



$$\tilde{V}_{B \cdot B'} = \tilde{I}_A j\omega L_{BA} + \tilde{I}_B j\omega L_{BB} + \tilde{I}_C j\omega L_{BC}$$