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**2018 International Explosives
Safety Symposium & Exposition**

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Considerations on Analysis of Lightning Protection System Adequacy when Required Documentation is not Available

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OBJECTIVES

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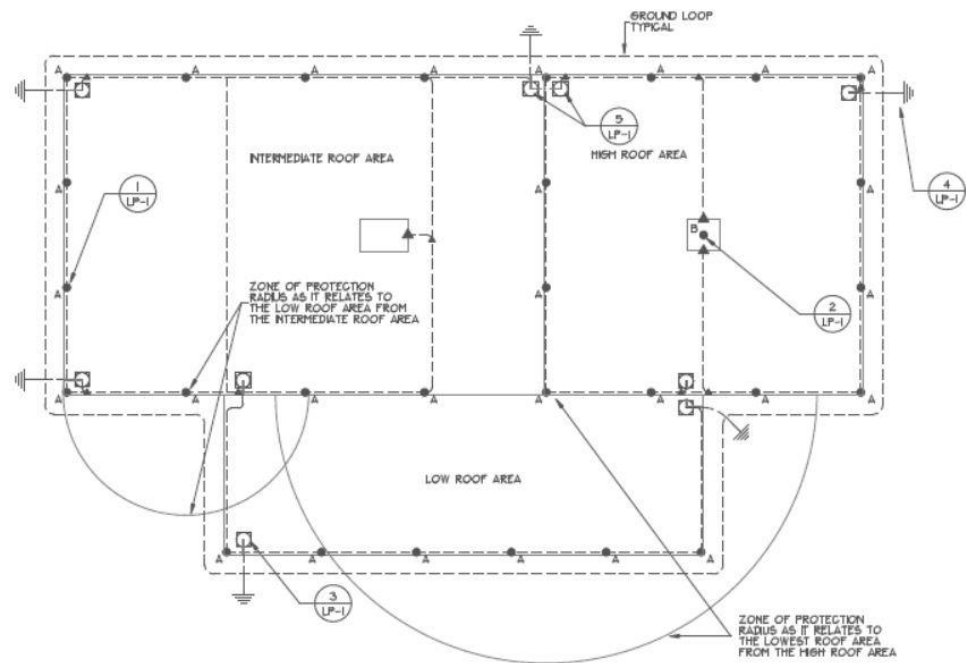
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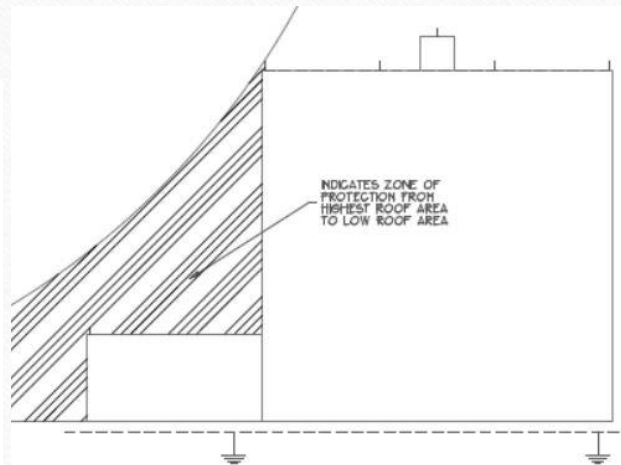
- Pre-1984 installations / Tenant facilities / As-builts not up to date
- Address methods available to assess adequacy of installed LPS
 - Define deviations to standards
 - Risk analysis of deviation
- Identification of equivalent information required
- Considerations for update to DDESB TP 26

System Evaluation Plan

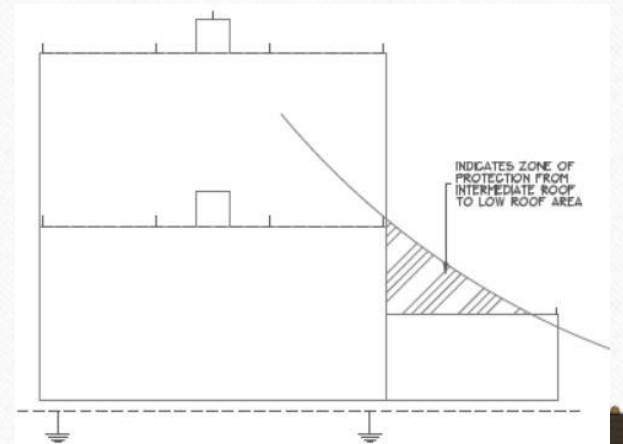
- Assess what information is available and what is missing
- Establish plan for developing information needed for site plan
- Visual Inspection
- Electrical Testing
- Documentation



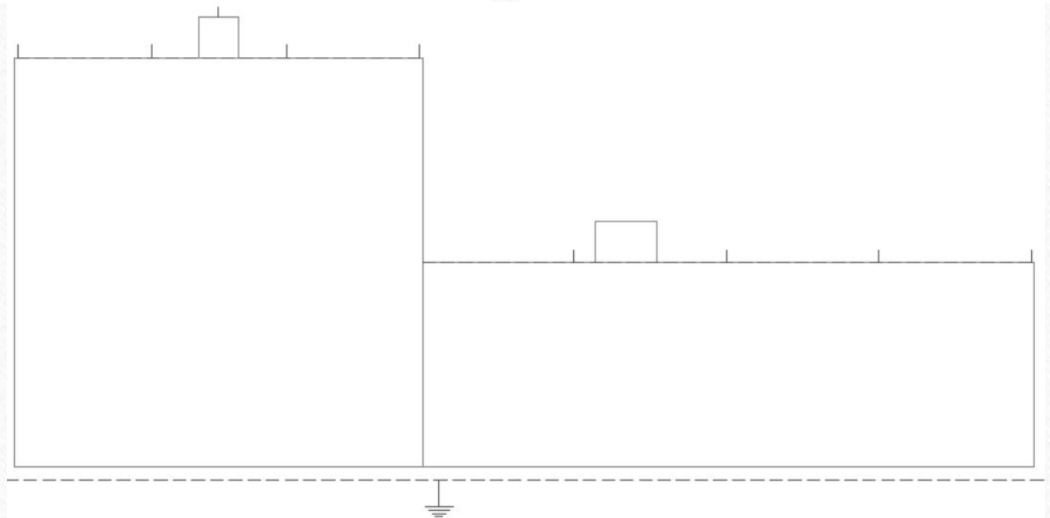
ROOF PLAN & LIGHTNING PROTECTION LAYOUT
SCALE: 1:200



EAST ELEVATION
SCALE: 1:200



WEST ELEVATION
SCALE: 1:200



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Strike Termination

- Data collection
- Support
- Zone of Protection
- Topography
- Calculations



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Zone of Protection Analysis

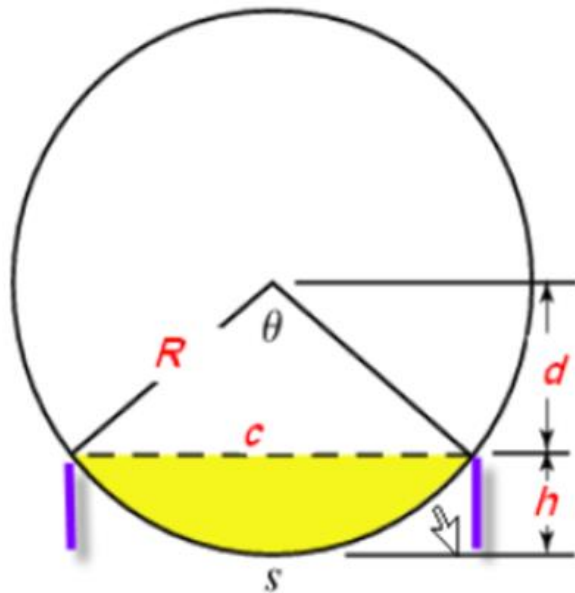
- DDESB Technical Paper No. 22 provides relationship between AT spacing and striking distance
- EGM relationship between peak current and striking distance
 - $R = 10 I^{0.65}$
- Probability that a lightning strike exceeds the calculated current
 - CIGRE + IEEE graphs (CIGRE Tech Bulletin 63)
 - IEC 62305-1 Edition 2, Table A.3

Strike Termination Efficiency

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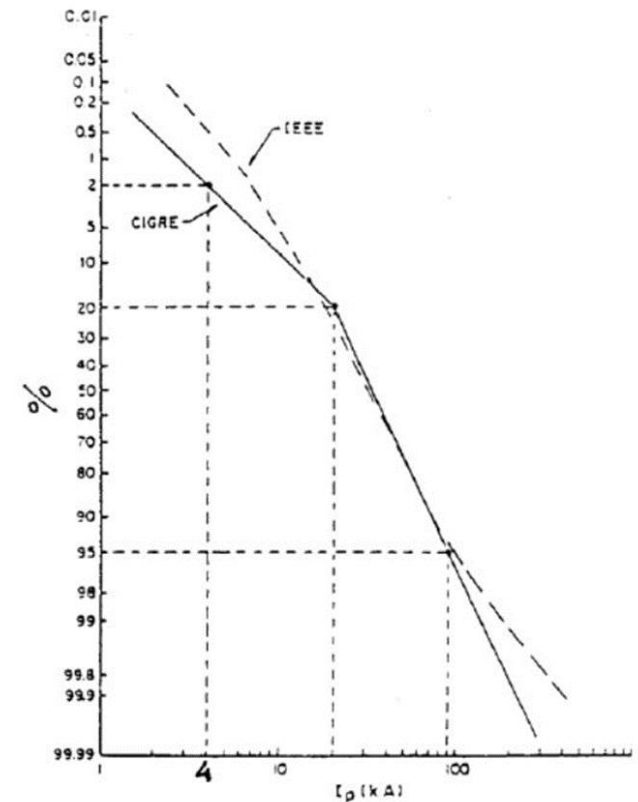
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$$c = 2\sqrt{h(2R - h)}$$

Where:

- c = the chord length or the minimum air terminal spacing
- h = the air terminal height
- $d = R - h$
- R = the radius of a circle or the zone of protection.
- s = arc segment that cannot touch the surface of the structure
- θ = acute angle so that s does not touch the surface of the structure
- Units shall be consistent, ft or m



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Down Conductors

- Document locations with spacing dimensions
- Visual if external
- Electrical if concealed

Surge Protection Documentation

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- Power
 - Type 1 or Type 2 SPDs
 - Nominal discharge current of 20kA installed at service entry
- Communications / data / signal / security
 - Maximum discharge current of 10kA installed at service entry
- Incoming lines shall enter the facility in shielded cables or metallic conduit run underground \geq 50 ft from structure

Grounding + Potential Equalization

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- Must locate and document all service entry / exit points
- Ground level potential equalization (interconnections) confirmed
 - Ground ring electrode preferred
 - Ground loop conductor acceptable
- Electrode requirements in NFPA 780
 - supplemented by service requirements



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Concrete-encased Grounding Electrodes

- Concrete-encased Electrodes without documentation or method to test to be allowed?
- Confirmation that it meets criteria
 - consists of ≥ 20 ft bare copper main-size conductor or 20 ft of $\frac{1}{2}$ " diameter steel rebar bonded together by welding, mechanical coupling, or overlapping 20 diameters and wire tying
- Test or connection point shall be provided to allow test
- Impedance test preferred to characterize quality of ground

Electrical Testing

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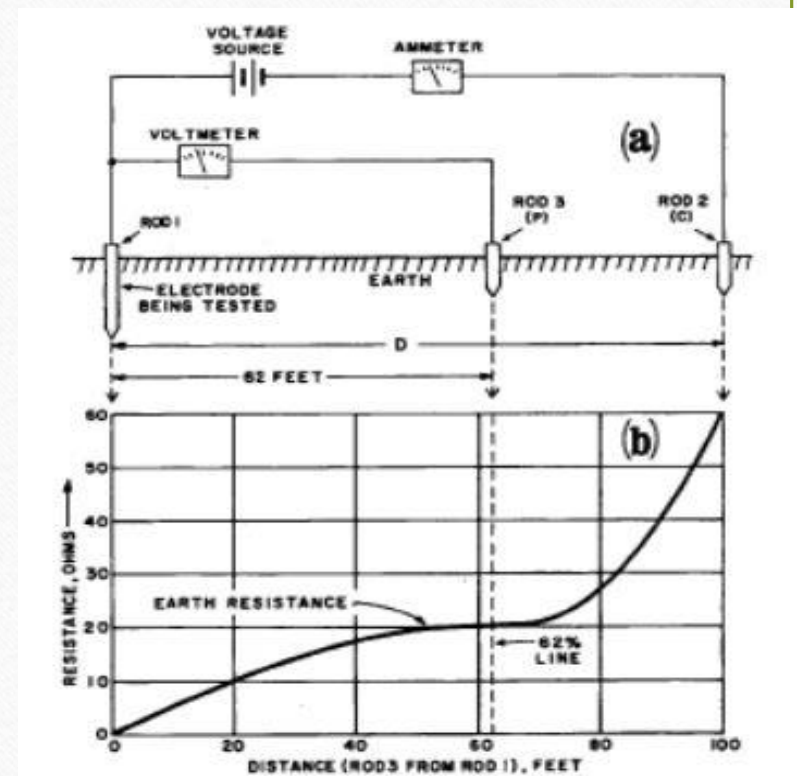
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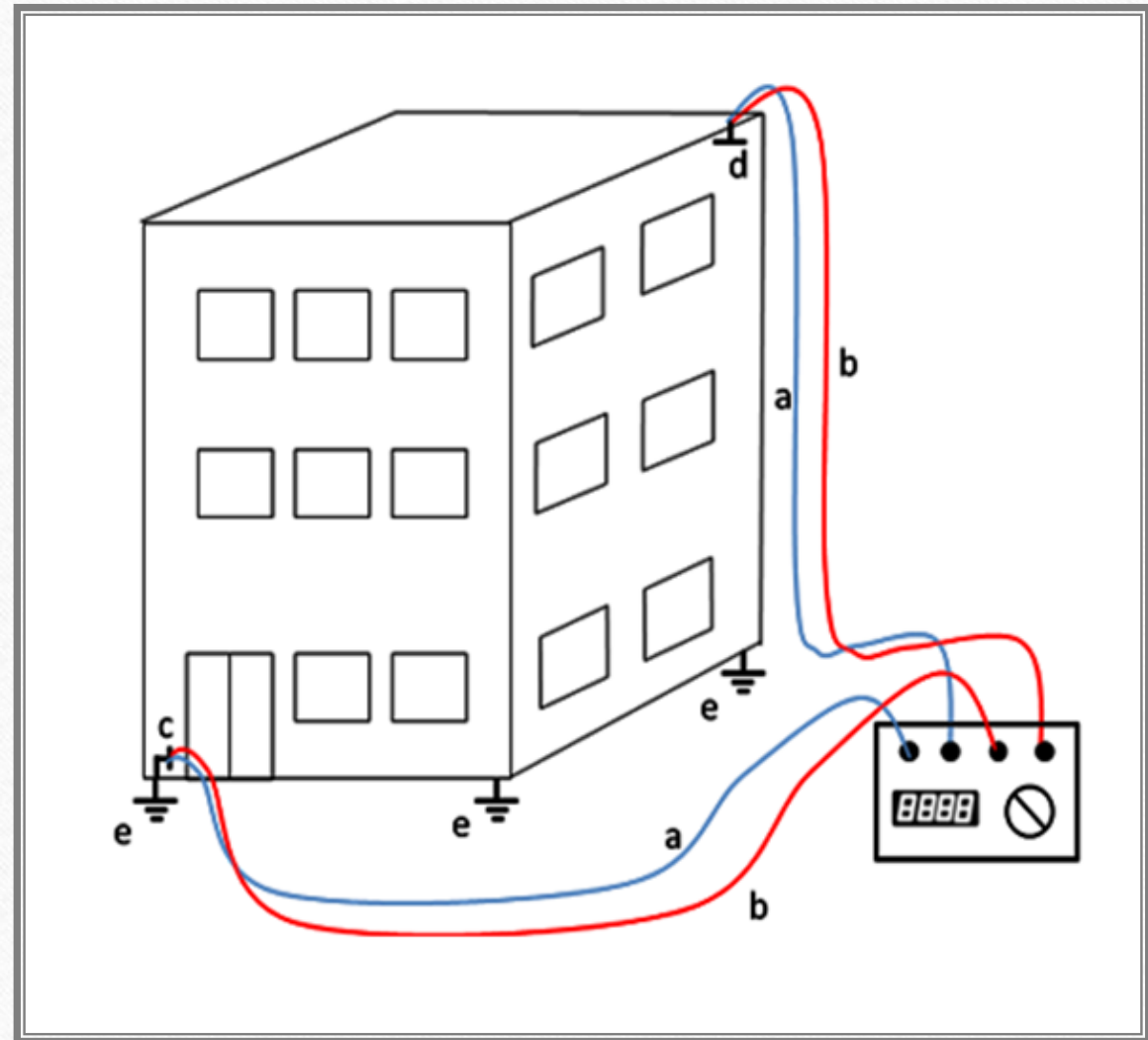
(from Biddle, Getting Down to Earth)

- Bonding testing
 - Confirmation of potential equalization
 - Continuity of concealed down conductors
- Grounding System Testing
 - 3-point Fall-of-Potential
 - Confirm S-curve for data confidence assessment
 - Possible earth resistivity testing
 - Impedance testing where justified



Test of Resistance from Air Terminal to Ground

- IEC 62305-3 guidance for testing steel reinforcing steel
- 10A test current recommended
- 200 milliohms resistance proposed
- Ground reference can be:
 - Grounding electrode
 - Equipotential Ground Bus
 - Base of down conductor



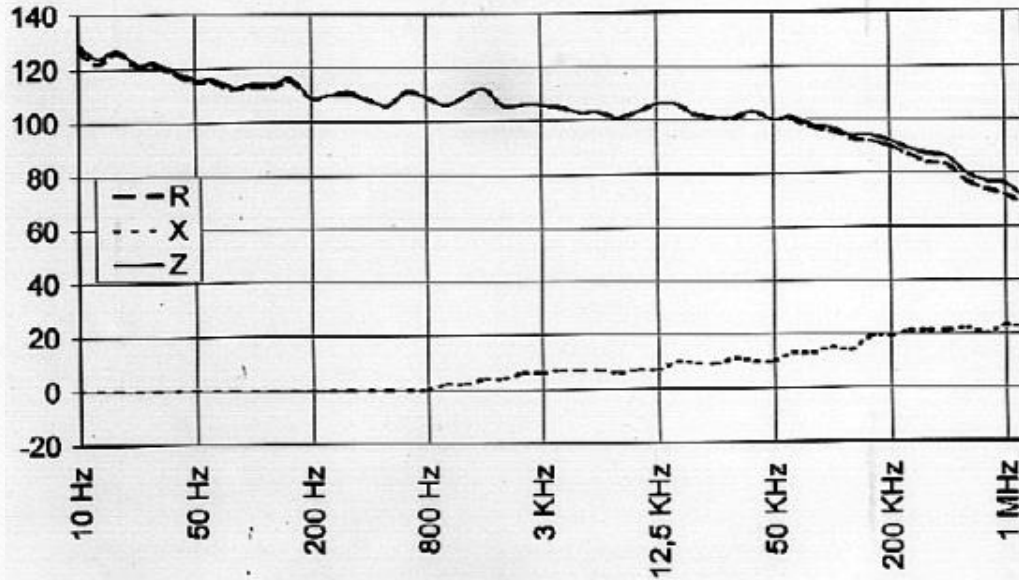
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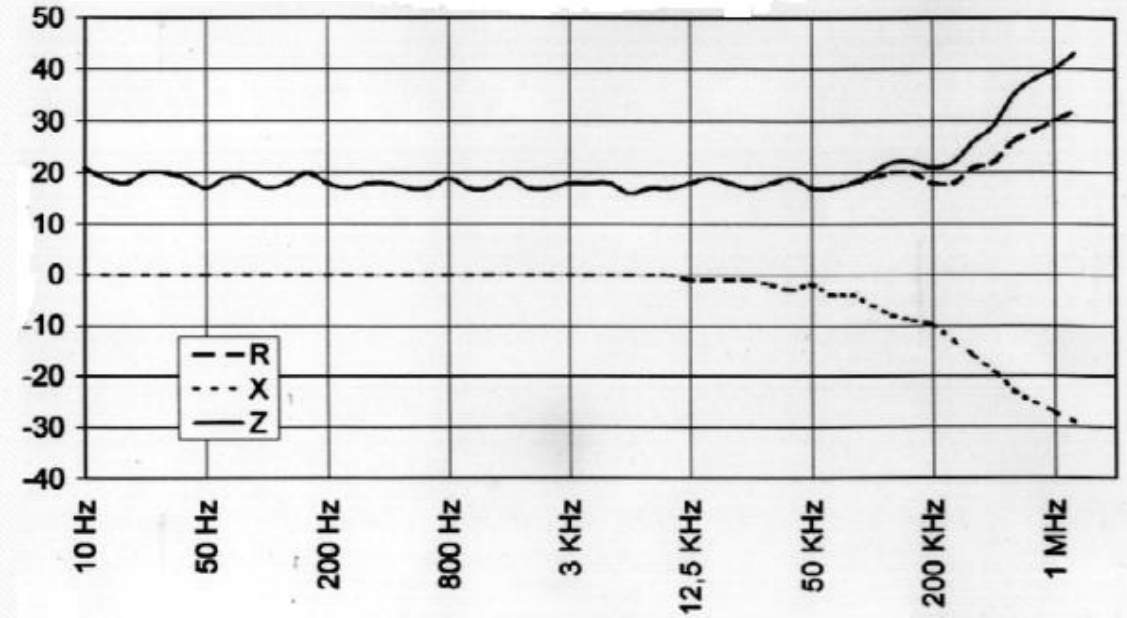
Frequency Response of Grounding Electrodes

IMPEDANCE in Ω



vertical rod in 300 Ω m

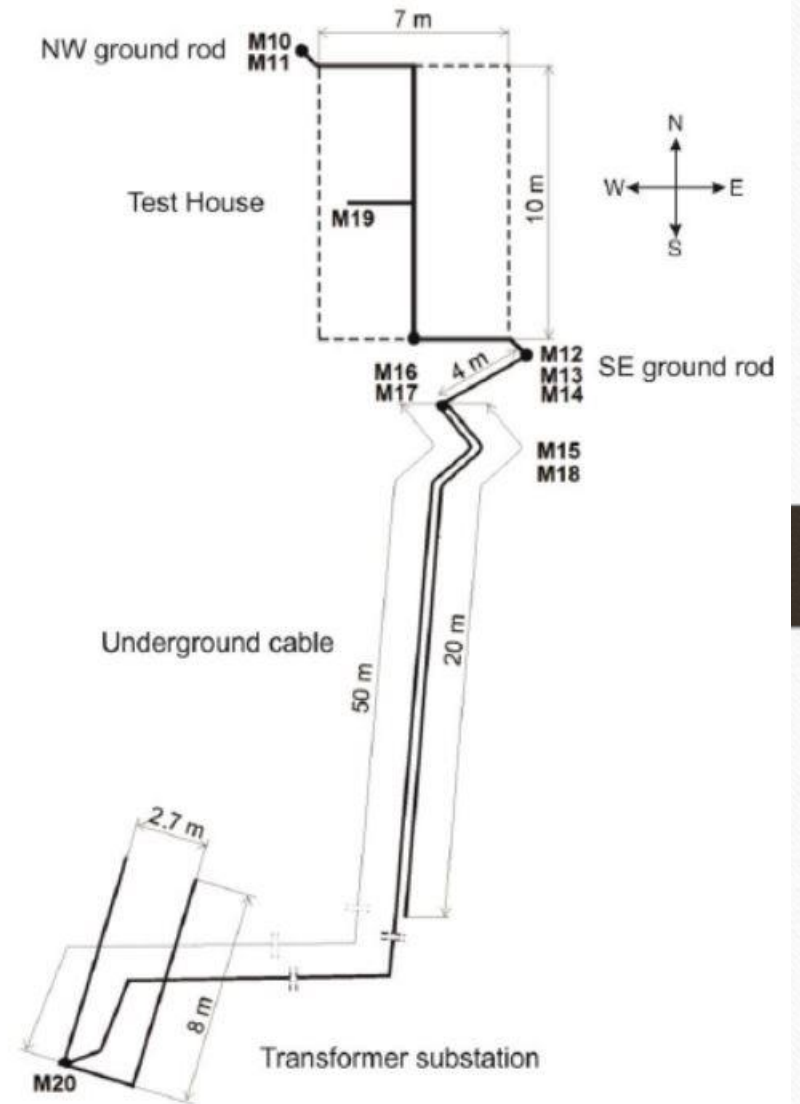
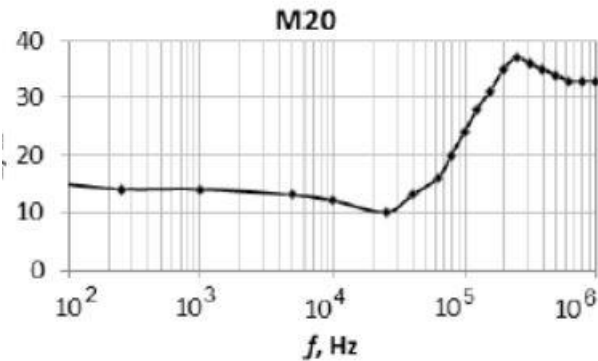
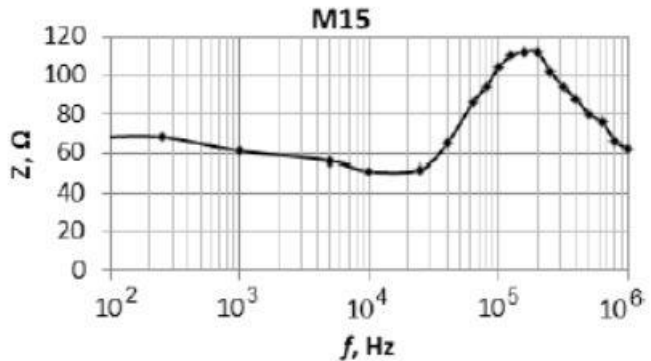
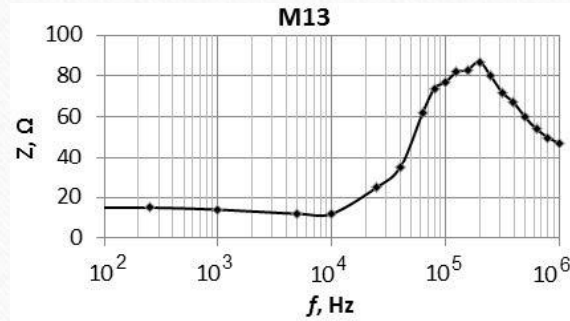
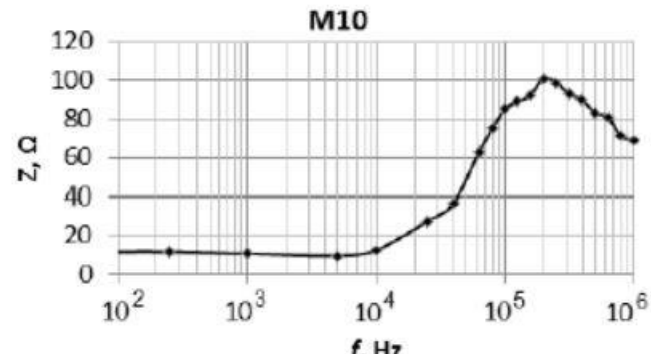
IMPEDANCE in Ω



25 m horizontal tape in 110 Ω m soil

Complex Grounding System

(from Mazlowski, et.al. ICLP 2016)



Draft Interim Guidance

- LPS visual and electrical test plans and test results to be developed
 - Testing includes bonding resistance + resistance to earth
- Goal to develop package equivalent to Service-provided drawings/sketches, photographs, contextual descriptions, and LPS test plans and test results
- Package should include zone of protection analysis based on 100-foot striking distance

Draft Interim Guidance

- Interim Guidance should address surge protection
- Details regarding removal of old system could provide valuable info in LPS redesign / modification
- Risk assessment is valuable tool in consideration of waiver for LPS or portions thereof.
 - NFPA 780 Annex or Strike-QRA assessment should be conducted to determine whether additional factors / modifications should be considered
 - Other assessments to be considered? IEC 62305-2 ?
 - Assessments must be performed by personnel trained in lightning risk assessments

Thoughts and Observations

- Consideration of IEC standard LPL I or II LPS design packages for foreign LPS designs?
 - Relevant for 1991 to present
 - No international conformity assessment program for 3rd party validation
- Critical that Service-generated packages be prepared by trained personnel knowledgeable in principles of lightning protection
- Limitations of R_{GND} test versus impedance testing to determining what is installed or adequacy to perform function
 - Measure earth resistivity as additional data quality check ?