Line and Antenna Sweep (LAS)
Competency Requirements

The following is a listing of each competency (topic) considered necessary to be included in a course of study towards the education of technicians performing a Line and Antenna Sweep using a frequency domain reflectometer (FDR). A full sweep for LAS for commissioning a system should be accomplished using an FDR in LMR test equipment, not depending on a Vector Network Analyzer (VNA) alone as some engineers may attempt to do. A VNA can assist with some of the listed tests, but cannot be the only piece of equipment used for Line and Antenna system FREQUENCY sweeps. Prior Radio Frequency (RF) experience, land mobile radio (LMR) experience, Cellular, or amateur radio experience along with a fundamental knowledge of antennas/transmission lines (feedlines) are recommended for a technician prior to studying the LAS competency.

A special course, fee and hands-on exam from an ETA® approved school are required pre-requisites before sitting for the knowledge exam.

Technicians seeking the ETA® Line and Antenna Sweep Technician journeyman certification (CET) must also have the basic *Associate CET (CETa)* or *General Communications Technician - Level 1*. Technicians seeking the ETA® Line and Antenna Sweep Technician stand-alone certification would be aided by having a basic education in fundamental electronics and wireless communications.

There are 11 categories of knowledge. This COMPETENCY listing is the syllabus, or identification of each individual subject, in which the technician must be knowledgeable and skilled.

1.0 INTRODUCTION TO ANTENNA SYSTEM COMMISSIONING

- 1.1. Explain the purpose of antenna system commissioning
- 1.2. Explain the benefits of antenna system commissioning
- 1.3. List the technologies available for antenna system commissioning
  - 1.3.1. Time Domain Reflectometer (TDR)
  - 1.3.2. Frequency Domain Reflectometer (FDR)
    - 1.3.2.1. Vector Network Analyzer (VNA) is a part of an LMR test equipment set as is the FDR; can be made into its own stand-alone unit, but not for full sweep verification as its own entity
    - 1.3.2.2. Compare an FDR with a stand-alone VNA
- 1.4. Describe proper safe procedures for using test equipment
- 1.5. Define a comparison of TDR and FDR
- 1.6. List system diagram requirements
  - 1.6.1. List common antenna system components
- 1.7. List antenna system commissioning documentation requirements

2.0 RADIO FREQUENCY (RF) FUNDAMENTALS

- 2.1. Explain the maximum power theorem and maximum power transfer
- 2.2. Explain impedance mismatch and its effect
- 2.3. Explain signal reflections and their effect
- 2.4. Explain how to calculate reflection coefficient
- 2.5. Explain voltage standing wave ratio (VSWR) and its cause
- 2.6. Explain standing waves
- 2.7. Describe return loss and the relationship to the primary signal
- 2.8. Compare impedance mismatch versus VSWR or return loss
- 2.9. Explain attenuation/insertion loss along with its cause and effect
- 2.10. Explain how an antenna transmits and receives an electromagnetic wave
- 2.11. Describe electromagnetic wave propagation through the atmosphere
- 2.12. Describe the antenna system components used in commercial and private radio communications systems

3.0 RADIO FREQUENCY (RF) MATHEMATICS

- 3.1. Explain Absolute values
- 3.2. Describe decibel (dB) math in unit ratios of measurable quantity (power)

3.3. Explain decibel values:
  3.3.1. dBm (decibel with reference to milliwatt, decibel per milliwatt, aka dBmW)
  3.3.2. dBc (decibel relative with carrier power)
  3.3.3. dBd (gain in decibel compared with half-wave dipole)
  3.3.4. dBi (gain in decibel compared with {hypothetical} isotropic antenna)
    3.3.4.1. 0 dBd = 2.15 dBi
3.4. Describe power ratios
3.5. Describe voltage ratios
3.6. Explain how power and voltage ratios are converted to dB values
3.7. Explain how to add and subtract decibel values
3.8. Explain how calculations can be completed by the testing unit

4.0 COAXIAL CABLE FUNDAMENTALS

4.1. Describe coaxial cable construction
4.2. Explain what determines coaxial cable impedance
  4.2.1. Explain why the standard transmission impedance is mostly at 50 ohms
4.3. Explain “Skin Effect” in a conductor
4.4. Explain a coaxial cable equivalent circuit using capacitance, inductance, and resistance features
4.5. Explain the transmission feedline coaxial cable velocity factor impacting:
  4.5.1. FDR measurements are used with coaxial transmission lines
  4.5.2. the length of a tuned coaxial stub
4.6. Explain how impedance is impacted, when coaxial cable attenuation or cable loss variates with:
  4.6.1. cable size changes
  4.6.2. frequency changes

5.0 COAXIAL CABLE (RF TRANSMISSION LINE/FEEDLINE) INSTALLATION

5.1. Describe RF transmission line hanger usage and mounting conventions (cable management)
5.2. Explain the importance of hanger spacing in relation to maintaining proper impedance
5.3. Describe RF transmission feedline grounding requirements as defined by codes and standards
  5.3.1. Describe feedline coax cable grounding kits and what purpose they serve
5.4. Describe proper grounding kits installation for good system sweep results on an FDR
5.5. Describe proper connector and ground kit weatherproofing procedures
5.6. Explain proper cabling bend radius procedure standards
  5.6.1. Describe the impact of an improper bending radius
  5.6.2. Explain how improper bend radius presents on sweep results
5.7. Describe lightning protection requirements
  5.7.1. List devices and connections used for proper lightning protection in an antenna system
  5.7.2. Explain how lightning protection devices may present on an FDR’s sweep results

6.0 RF CONNECTORS AND CONNECTORIZATION

6.1. List connector types commonly used for RF communications
  6.1.1. Differentiate between appropriate and inappropriate connectors
6.2. Explain connector specifications to codes and standards
6.3. Describe connector installation requirements
  6.3.1. List connector installation tools
  6.3.2. List cable preparation procedures
  6.3.3. Explain proper connector torque specifications
    6.3.3.1. Describe the impact improper torque has on an installation
6.4. Explain “Passive Intermodulation” and its effect*

7.0 ANTENNAS AND ANTENNA THEORY

7.1. Explain antenna theory
  7.1.1. Describe the electromagnetic field, electromagnetic waves and polarization
    7.1.1.1. e-fields (electric)
    7.1.1.2. h-fields (magnetic)
  7.1.2. Explain electromagnetic waves and polarization
7.2. List antenna specifications and how they affect the system design:
  7.2.1. frequency bandwidth

7.2.2. return loss and VSWR
7.2.3. gain
7.2.4. Beamwidth
7.2.5. beam tilt

7.3. Explain antenna types and their common specific examples/details:
7.3.1. dipole
7.3.2. isotropic
7.3.3. omni-directional
7.3.4. directional
7.3.5. quarter wave

7.4. Describe antenna wavelength (λ) and calculations
7.4.1. Recall common communication spectrum wavelengths

7.5. Explain how coaxial feedline velocity factor can affect antenna length (see 4.5)

7.6. Explain antenna radiation pattern
7.6.1. Describe common antenna radiation patterns for RF coverage

7.7. Explain antenna gain
7.7.1. Describe how to measure gain
7.7.2. Describe common gain references
7.7.2.1. Dipole
7.7.2.2. Isotropic
7.7.2.3. Quarter wave
7.7.3. Describe effective radiated power (ERP), encompassing all gains and losses

7.8. Define and explain antenna beamwidth

7.9. Explain antenna frequency bandwidth and its measurement on an FDR

7.10. Explain antenna beam tilt factors:
7.10.1. mechanical
7.10.2. electrical

7.11. Explain antenna polarization
7.11.1. Vertical
7.11.2. Horizontal
7.11.3. other

7.12. Describe antenna mounting factors
7.12.1. Explain how improper mounting affects the system

8.0 FREQUENCY DOMAIN REFLECTOMETER (FDR) TESTING

8.1. Describe adapter usage requirements

8.2. Describe calibration standards, usage and care
8.2.1. Explain why unit calibration verification must be done in a lab setting with a device of higher resolution

8.3. Explain importance of calibration and requirements
8.3.1. Describe the three-step calibration process using an open, a short, and a load
8.3.2. Explain what may cause an FDR to need recalibration

8.4. Explain phase-stable cable requirements and usage

8.5. Describe proper FDR configurations for a distance-to-fault test (DTF):
8.5.1. cable type determination
8.5.2. data points determination
8.5.3. maximum distance in relation to frequency
8.5.4. resolution

8.6. Describe how to accomplish antenna testing:
8.6.1. for return loss
8.6.2. frequency bandwidth determination

8.7. Describe attenuation or insertion loss testing of:
8.7.1. specific components measurement
8.7.2. the antenna system measurement

8.8. Differentiate between insertion loss test and return loss test

8.9. Describe how to accomplish coax cable (RF cable) testing:
8.9.1. attenuation or cable loss measurement
8.9.2. return loss or matching measurement

8.9.3. distance-to-fault (DTF) return loss measurement
8.10. Describe how to accomplish full antenna system testing:
8.10.1. return loss or matching measurement
8.10.2. distance-to-fault (DTF) measurement
8.11. Describe antenna system sweep “signatures” on an FDR

9.0 FREQUENCY DOMAIN REFLECTOMETER (FDR) TEST INTERPRETATION

9.1. Compare measured component(s) return loss values with manufacturer specifications for:
9.1.1. antenna response
9.1.2. feedline specifications
9.1.3. connector specifications
9.1.4. lightning suppressor specifications
9.1.5. other components
9.2. Explain how to calculate expected system return loss value and compare to measured value:
9.2.1. utilizing software tool(s)
9.2.2. describing knowledge of function
9.3. Explain how to compare location of component(s) on the system diagram to the measured locations on the FDR
9.3.1. Identify system components at appropriate levels
9.3.2. Identify fault locations (if any)
9.3.3. Identify possible fault causes
9.4. Antenna system sweep “signature” characteristics and their usage
9.5. Explain how to verify the antenna meets specifications

10.0 FREQUENCY DOMAIN REFLECTOMETER (FDR) OPERATION

10.1. Describe the FDR calibration process
10.2. Describe selecting test frequency range on the FDR as the first step in set-up
10.3. Explain setting markers and limit lines on the FDR and who determines that
10.4. Describe selecting test type or mode on the FDR
10.5. Describe selecting display amplitude and/or auto scale on the FDR
10.6. Describe selecting test distance range on the FDR
10.7. Describe selecting cable type on the FDR for a DTF test
10.8. Describe setting windowing or smoothing option on the FDR
10.9. Describe storing and recalling a trace on the FDR
10.10. Explain how to name a trace on the FDR
10.11. Describe setting FDR time and date
10.12. List software tools available on the FDR
10.13. Explain proper FDR sweep documentation requirements
10.13.1. Define “As Built” drawings and diagrams

11.0 FREQUENCY DOMAIN REFLECTOMETER (FDR) TROUBLESHOOTING

11.1. Describe common antenna problems
11.2. Describe common cable problems
11.3. Describe common connector problems
11.4. Describe how to compare baseline FDR sweep traces with current traces
11.5. Describe proper FDR troubleshooting resolutions

End of Line and Antenna Sweep Technician Competencies Listings (11 major categories)

Find an ETA Approved School Site: **https://www.etai.org/course_approvals.html**
Find an ETA Test Site: **https://www.etai.org/test_sites.html**

Suggested Additional Study Material and Resources:

Useful white papers can be found at the following web sites:
https://www.radiositetest.com/; https://birdrf.com/; https://www.anritsu.com/en-us/; https://txrx.com/;
Useful web sites, including additional links:
https://www.iwatsi.com/; https://www.iwa-radio.com/; https://www.electronics-notes.com/articles/radio/; https://www.fcc.gov/commercial-radio-operator-license-program; https://us-cert.cisa.gov/ncas/tips/ST04-001; https://www.tacticalrf.com/; https://www.iwceexpo.com/ & http://urgentcomm.com/; RadioReference.com Wiki Reference; http://www.rcrwireless.com/; http://www.radioresourcemag.com/; https://www.dovertrainingsolutions.com; https://www.radioclubofamerica.org/; https://www.rfglobalnet.com/;

*** PIM** Competencies - https://etai.org/comps/PIM_comps.pdf as noted in Comp. 6.4

Module 1, 2, 3, 4: Radio Antenna Systems; Thomas K. Dover & Kenneth Law; all four can be found digitally via links at https://www.dovertrainingsolutions.com; published by: Dover Telecommunication Services; 2014-2015; various pp and KB
Wiring for Wireless Sites; Ira Wiesenfeld, P.E.; ISBN 978-1401810375; Thompson Delmar Learning; 2002; pp. 260
Practical Antenna Handbook, 5E; Joseph Carr & George (Bud) W. Hippisley; ISBN 978-0071639583; McGraw-Hill/Tab Electronics; 2011; pp.784
Practical Radio Frequency Test and Measurement: A Technician's Handbook; Joseph Carr; ISBN 978-0750671613; Newnes; 1999; pp.360
Modern Electronic Communication, 9E; Jeff Beasley & Gary M. Miller; ISBN 978-0132251136; Prentice Hall; 2007; pp.992
Handbook of Radio & Wireless Technology; Sam Gibilisco; ISBN 978-0070230248; McGraw-Hill Professional; 1998/2008; pp.640
Radio and Communications Technology; Ian Poole; ISBN 978-0750656122; Newnes; 2003; pp.320
Antenna Engineering Handbook, 5E; Dr. John L. Volakis; ISBN 978-1259644696; McGraw-Hill Educ.; 2018; pp.1424
ARRL Handbook, 2022 edition; American Radio Relay League, ISBN 978-1-62595-150-2, available online from https://www.arrl.org/shop/ARRL-Handbook-2022-Softcover;

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